# APPROPRIATE SURFACE SEALING FOR SUSTAINABLE LOW VOLUME RURAL ROADS IN VIETNAM

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## ABSTRACT

The UK Department for International Development (DfID) and World Bank co-funded research into appropriate Low Volume Rural Road (LVRR) pavement and surfacing options is underway in Vietnam under the South East Asia Community Access Programme (SEACAP). Previously there has been a sector concentration on the provision of unsealed gravel roads, which, although relatively cheap to construct, are often unsustainable in the high rainfall; steep gradient or flood prone, environments prevalent in Vietnam.

The SEACAP 1 project involved the construction of LVRR trial roads in a representative selection of road environments in a number of provinces with diverse characteristics. A wide range of sub-base, base and surfacing options were trialled including bitumen emulsion, stone chip and sand seals. Standard local hot bitumen seals and unsealed options have been constructed as control sections. Construction was completed between June 2005 and July 2007 and representative lengths selected for long term condition monitoring. Initial performance information is now becoming available and this, together with the construction cost and construction quality assessment data, is allowing the development of practical Performance, Whole Life Cost and Technology Option Selection models.

This paper summarises the outcomes of SEACAP 1 to date with particular focus on the use of the bitumen emulsion seals in comparison with the local hot bitumen and unsealed options.

## INTRODUCTION

### Background

In Vietnam the rural communities and their Government face many challenges in achieving national development and reducing rural poverty. Improving rural access and developing rural road networks are national priorities. The provision of sustainable, value-for-money, all season, all weather access for rural communities promotes growth and gives people opportunity to access economic, health and social opportunity. Rural roads are of vital importance to rural communities for their economic and social wellbeing and reduction of poverty. The rural poor do not have motor cars. However they need reliable access for bicycles, motorcycle, locally made vehicles and the other simple means of transport they rely on. As take-up of economic opportunity arises from access provision, a more diverse vehicular fleet will emerge. Table 1 shows the variation in rural traffic patterns from typical provinces in Vietnam. The essential challenge for engineers and road managers is how to provide and maintain this rural access for the types of traffic in use, on a sustainable basis with the limited available resources.

Tropical rainfall patterns lead to frequent floods and mean that the traditional, low-cost earth or gravel roads are at high risk of damage resulting in reduced or even complete loss of access. Other local factors such as difficult terrain, poor foundation conditions, or scarcity of good road building materials can compound these problems. Nevertheless under recently completed rural road access programmes, unsealed gravel roads were still seen by donors and road engineers as the optimum solution in Vietnam. However, this view has been coming under increasing criticism both from Vietnamese rural road practitioners and the rural communities themselves.

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**Table 1: Typical Vietnam Rural Road Traffic Data**

| | | 24 hour Traffic | | | |
|---|---|---|---|---|---|
| | **Province: Road** | **Motor vehicle/day** | **Motorcycle/day** | **Cycle/day** | **ADT** |
| Mekong Delta | Dong Thap: Tan Thuan Tay | 0 | 1718 | 1085 | 226 |
| | Tien Giang: My Phuoc Tay | 2 | 1110 | 646 | 143 |
| Central Coastal | Da Nang: Binh Ky | 16 | 443 | 113 | 50 |
| | Hue: Thong Nhat | 24 | 694 | 706 | 105 |
| Central Highlands | Gia Lai: Ia Pnol | 101 | 134 | 1064 | 67 |
| | Dak Lak: Cu Ne | 176 | 1150 | 106 | 120 |
| | Dak Lak: Buon Ho | 277 | 469 | 56 | 50 |
| Red River Delta | Hung Yen: Nhat Quang | 130 | 176 | 229 | 29 |
| | Hung Yen: Tan Hung | 272 | 140 | 154 | 22 |
| | Ninh Binh: Yen Trach | 152 | 1760 | 2029 | 278 |
| | Ninh Binh: Thu Trung | 168 | 2069 | 2123 | 313 |
| Northern Highlands | Tuyen Quang: Lang Quan | 101 | 907 | 1025 | 142 |
| | Tuyen Quang: Thang Quan | 20 | 266 | 726 | 63 |
| | Tuyen Quang: Y la | 148 | 1249 | 1304 | 190 |
| | Quang Binh: Cam Lien | 31 | 540 | 305 | 69 |
| | Ha Tinh: Thach Minh | 67 | 572 | 776 | 96 |

Note: ADT (average daily traffic) calculated from factoring of all traffic types, as follows

| | | |
|---|---|---|
| Trucks>5t GW: 5.0 | Trucks <5tGW: 2.5 | Local tractor/trucks: 1.0 |
| Cars: 0.8 | Motorcycles: 0.1 | Cycles:0.01 |

Gravel road surfaces are justified in many developing countries using unrealistically low construction and maintenance cost norms that are unsustainable not only in terms of provision of an adequate quality wearing surface, but also with regard to the likelihood and true cost of provision of their necessary maintenance. Maintenance is an essential and integral part of the yearly working life of these roads, far more so than for comparative sealed surfaces. This maintenance liability for gravel roads requires an adequate, dependable, and timely flow of funds, as well as a managerially and technically capable organization or private sector arrangement to implement the maintenance on an on-going basis. This is rarely found in a developing country. The unfortunate result is that often community access is temporarily improved by the provision of a gravel road access, only for the road to steadily deteriorate back to poor earth standard through absence of adequate maintenance. This can have serious negative consequences for poor rural communities.

## Vietnam Rural Road Rural Surfacing Research

In response to the increasing recognition that gravel surfacing was not a universal solution for rural roads in Vietnam, the Ministry of Transport (MoT) in 2002 requested studies of alternative surfaces for rural roads as part of the World Bank-funded Rural Transport Programme 2 (RTP2). These studies became known as the Rural Road Surfacing Research (RRSR) initiative, through which the Rural Road Surfacing Trials (RRST) and the complementary Rural Road Gravel

Assessment Programme (RRGAP) were carried out. This research programme and its extensions were subsequently incorporated into the DfID-funded South East Asia Community Access Programme (SEACAP).

SEACAP is a growth targeted transport initiative facilitating the improvement of sustainable access to rural communities, centred on Vietnam, Cambodia and Lao. The aim of this programme is to influence funders to provide low-cost, maintainable, locally owned access to rural communities through adoption of local materials and training local people in evidence based sustainable techniques. To do this, the programme provides funding for applied research, its dissemination to implementing agencies and support to help them adopt improved techniques in rural access including innovative techniques in road surfaces and stabilisation of slopes.

The research and dissemination activities of the RRSR were carried out under the co-ordination of the Ministry of Transport RRSR Steering Committee. An international consultant (Intech-TRL) provided the technical assistance for the various RRSR components, primarily in conjunction with the Vietnamese Institute of Transport Science and Technology (ITST).

# RRSR TRIALS IN VIETNAM

## Trials Objectives

The aim of the RRSR programme was to establish a range of sustainable road surfaces and paving technologies as alternatives to unsealed gravel that would improve overall rural access while making better use of local resources, minimise whole-life-costs and support the Vietnam Government's poverty alleviation and road maintenance policies. The Intech-TRL project team designed, costed and drew up specifications for monitoring and control sections on 41 trial roads in 12 provinces based on the following guiding principles:

- Designs should be appropriate to the traffic, climatic and terrain environments.
- Local construction materials should be used where possible.
- Maintenance requirements must be sensibly in line with local community resources.
- Construction techniques should be suitable for small contractors and local employment.

The technical outputs of the trials project were defined as:-

- Recommended revisions to the Vietnam Rural Road Construction and Maintenance Standards,
- Revised Guidelines on the selection of Rural Road Surfacing for Provincial Authorities.

## The Trials Programme

The RRST studies contained two main phases of trial construction between 2004 and 2006 with a total construction cost of US$4,400,000 which together comprised over 140 km of trial and associated roads from which a representative 107 sections of between 80m to 200m length have been selected for ongoing performance and whole-life-cost monitoring. Key aspects of the two phases are as follows:

**RRST-I.** The RRST programme was concentrated on 4 roads in the Mekong Delta and the Central Coastal area. Short lengths (100-200m) of different pavement options appropriate to the province were constructed on each trial road under the close instruction and supervision of the specialist consultants.. Each trial road had in addition short lengths (100m) of control sections of unsealed or penetration macadam sealed road.

**RRST-II** The RRST-II programme was undertaken in a wider set of physical environments in the Northern Highlands, Central Highlands and the Red River Delta as an extension of the RRST-I programme. It involved much longer lengths of trial and control section, from 500m to more the 2 km and was seen as an important step in the roll out and mainstreaming of sustainable and appropriate rural surfacing solutions. Supervision was undertaken by local consultants with Intech-TRL taking an overall Quality Assurance and strategic guidance role.

The RRST programmes included not only the stabilisation of local soils by lime, cement and bitumen emulsion but also more innovative options for Vietnam such as concrete brick, clay brick cobble stone and stone setts surfacing. Figure 1 summarises the various pavement and surfacing options that were combined in trial matrices suitable to the requirements of each of the 12 participating provinces.

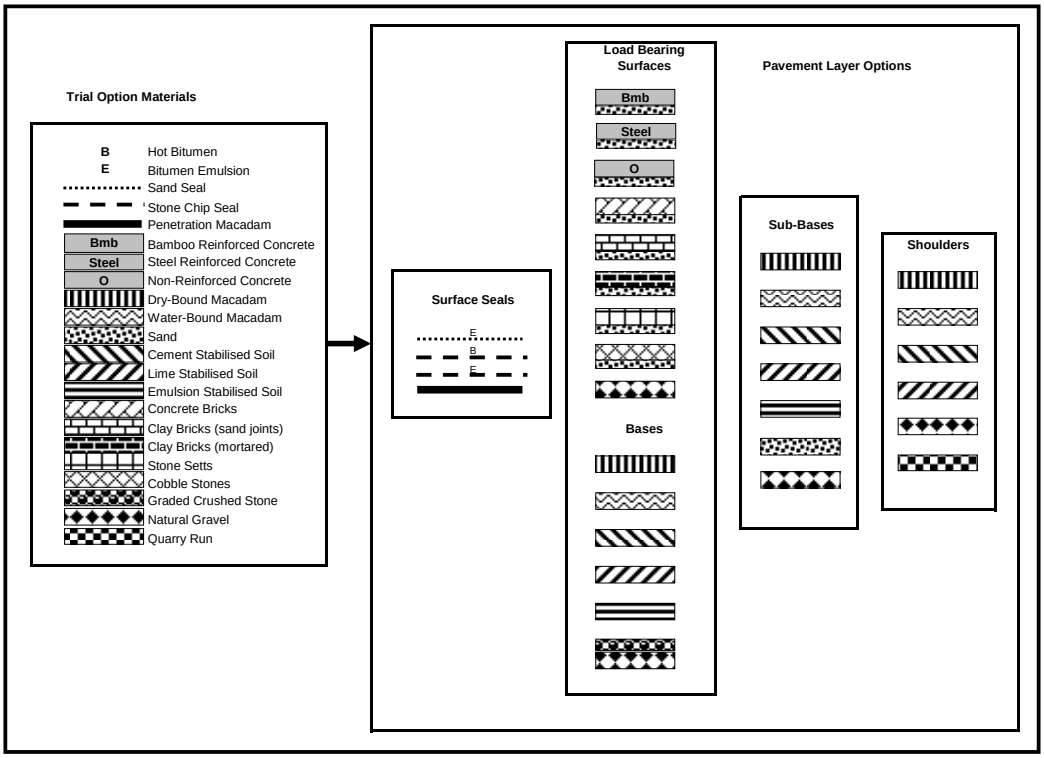


***Figure 1: RRST trial layer options***

## Selection of Seals

The use of bitumen emulsion sealed surface options in comparison with hot bitumen was a key aspect of both RRST programmes.They concentrated on the trialling of bitumen emulsions seals as an alternative to the use of hot bitumen for a number of reasons:

- Application suitable for labour oriented methods because of low health and safety risks
- Suitable for commune based maintenance operations
- Better site control on small rural contracts on application compared with hot bitumen.

The RRST programmes therefore trialled and are currently monitoring the following bitumen emulsion sealed sections

- Double stone chip seals (DBEST); 23 trial sections

- Single stone chip overlain with sand seal (SBEST+ESS); 8 trial sections
- Single sand seal (ESS); 8 trial sections.

For comparison a number of standard Vietnamese options were also constructed and are being monitored

- Hot bitumen double stone chip seal (DBST), 18 trial control sections
- Hot bitumen penetration macadam (PenMac), 7 trial control sections
- Hot bitumen triple stone chip seal (TBST); 2 trial control sections.

**Table 2 Summary details of the seals used on the RRST programmes**

| Seal | Description | Use |
|---|---|---|
| DBEST and SBEST | Rapid setting cationic emulsion with 60% residual 40/90 bitumen placed at ambient temperature; for two layers at 2.8 litre/$m^2$ and 1.8 litre/ $m^2$ with 14mm and 6 mm nominal aggregate.<br>SBEST single layer placed at 2.8 litres/ $m^2$ with 14mm aggregate. | Over bases and sub-bases of dry or wet bound macadam; cement or lime stabilised local soils; or natural gravel. |
| ESS | Rapid setting cationic emulsion with 60% residual 40/90 bitumen placed at ambient temperature at 1.6-1.8 litre/$m^2$ followed by sand/fine aggregate with max size 6mm and less than 15% <0.15mm at 6-7 litre/$m^2$. | On top of SBEST or as a single seal to fired clay brick or concrete blocks. |
| DBST | 60/70 pen bitumen; $160^0$ C at placement; 1st layer @1.8 kg/$m^2$, 2nd @1.2 kg/$m^2$. Two layers 10/16mm then 5/10mm aggregate @ 14-16 and 10-12 litres/$m^2$ respectively. | Over wet bound macadam bases and sub-bases of local specification. |
| TBST | 60/70 pen bitumen; $160^0$ C at placement; 1st layer @1.9 kg/$m^2$, 2nd @1.5 kg/$m^2$, 3rd @1.1kg/m2 Three layers 16/20 then 10/16mm then 5/10mm aggregate @ 18-20, 14-16 and 9-11 litres/$m^2$ respectively. | Over wet bound macadam bases and sub-bases of local specification. |
| PenMac | 40/90 pen bitumen; $120^0$ C at placement in 2 applications @ 5-6kg/m2 and 2-3kg/m2. 1st application on 50-70mm crushed stone the 2nd on 10-20mm chippings finally a 3rd layer of 5-10mm chippings at 13-15 litres/$m^2$ laid over surface. | Over wet bound macadam road-base of local specification. |

Bitumen emulsion aggregate and binder spread rates were in line with current TRL documentation (TRL 2003; TRL 2000), while local options involving hot bitumen followed existing Vietnamese standards.

One or two provinces favoured the construction of a what was termed a hot bitumen triple chip seal; apparently used in an attempt to counter both poor local stone materials and variable construction quality. In general, the use of various forms of PenMac has been the standard alternative to unsealed gravel in rural road programmes in Vietnam.

# TRIAL OUTCOMES

## Construction Issues

The successful construction of the trials demonstrated to local contractors and consultants, as well as provincial authorities, the potential for using the new surfacing and paving options as alternatives to gravel in future rural infrastructure programmes. In addition, some valuable lessons were learnt with regard to modifying specifications and construction procedures. With respect to the construction of sealed options in particular the following key points were noted.

The emulsions used on site, containing around 60 per cent bitumen, could be readily sprayed by hand lance or applied by manual methods at ambient temperature. In contrast the application of hot bitumen was more problematical and in most cases little or no temperature control was evident in the local procedures.

However, some difficulty was experienced with the use of bitumen emulsion, particularly with sand seals, on gradients and steep cambers. The tendency for the emulsion to 'run off' the road surface caused problems in keeping the bitumen in place until some evaporation of water had taken place before aggregate cover was applied. There were evident bedding problems for sand and stone chip seals on rural roads where the traffic was predominantly bicycles or motorbikes. The adverse impact of rainfall on the attempted construction of emulsion seals, as with any bituminous material, highlighted the need for restricted application during the rainy season.

Despite an initial resistance from most contractors, after using what was for them a new emulsion sealing procedure, they agreed on the usefulness and potential of emulsion once they had gained experience and confidence with the techniques.

There appears to be a significant lack of awareness of the importance of Quality Assessment in the rural road sector and a consequent lack of a quality control ethic. Hence the role of site supervisors in controlling the contractors' procedures and material usage is not yet generally accepted in the rural road sector in Vietnam. Current practice appears to be concerned largely with observation and reporting of progress rather than technical control. This aspect was particularly evident in some of the more remote and locally supervised sites in RRST-II where the QA as-built surveys revealed very poor control on surfacing aggregate size and shape. For at least the near future, this problem needs to be taken into consideration in selecting an appropriate technology.

In some provinces, for example those in the Central Highlands, the preponderance of basaltic bedrock allied to the limited aggregate production facilities led to difficulties in obtaining satisfactory shape characteristics to the surfacing aggregate. Similarly the only available sand for ESS was in some areas outside the normal specifications. However, given that one of the key aspects of rural road construction is the use of local materials it is necessary to look at means of modifying the specifications and designs in order to use them effectively.

## Costs

The comparative construction costs for typical bitumen and bitumen seals are shown in Table 3 together with other relevant costs for comparison. This table indicates the similarity of cost between the hot bitumen and bitumen emulsion seals, with the lower cost of emulsion in the Mekong area reflecting the location of production plants in the South. It also demonstrates the apparent and misleading attractiveness of unsealed gravel as a rural road option based solely on construction costs of poor quality gravel with no account taken of sustainability or whole life costs.

**Table 3: Typical Construction Costs RRST-I and RRST-II**

| | DBEST Cost/m2 | DBST Cost/m2 | DBEST over Waterbound Macadam Cost/km | PenMac over Waterbound Macadam Cost/km | Gravel Cost/km |
|---|---|---|---|---|---|
| Northen Highlands | $2.18 | $2.50 | $18,590 | | |
| Central Coast | $2.63 | $2.26 | $21,220 | $26,900 | $2,800 |
| Red River Delta | $3.27 | $4.06 | $24,900 | | |
| Mekong Delta | $1.69 | | $24,400 | $29,700 | $6,955 |
| Central Highlands | $2.57 | | $29,400 | $44,700 | $3,200 |
| Costs in US$<br>Cost/km calculated on a 3.5m wide carriageway | | | | | |

A cost model has been developed as part of the RRSR project, to facilitate the assessment of whole life costs for the rural roads. Due to a lack of reliable data this model does not currently include vehicle operating costs (VOCs) and hence may be more reasonably considered to be a Whole Life Asset Cost Model. Initial analysis of unsealed road options based on this model demonstrates that potential maintenance costs in some areas of Vietnam can exceed construction costs in a relatively short life assessment period of eight years; in some situations by a factor in excess of 2.

In such cases the use of alternative sealed options such as DBEST over dry-bound or wet-bound macadam becomes economically preferable without even considering sustainability issues such as the lack of essential maintenance programmes or the lack of appropriate re-gravelling resources. When additional likely VOC savings for the more durable surfaces are estimated and included, the case for the adoption of the alternative surfaces and paving techniques becomes difficult to disregard.

## Seal Performance

Monitoring of the condition of the selected trial and control sections and their deterioration over time is an integral part of the overall RRST programme. As-Built condition surveys served as the base line for the trials monitoring surveys, which have been carried out at roughly 6-monthly intervals since June 2005 and August 2006 for RRST-I and RRST-II respectively. Specific procedures were drawn up based on Overseas Road Note 18 (TRL 1999) but modified for local conditions.

As might be expected, few firm trends have as yet become apparent in the performance of the trial seals, particularly for RRST-II. However based on a preliminary analysis of the RRST-I data the following interim conclusions may be drawn:

- Only localised minor aggregate loss has occurred from SBEST+ESS seals on one contract and surface texture of the SBEST+ESS has generally become smoother with time on the very low volume trials in the Mekong Delta; Table 4.

**Table 4 Typical visual monitoring results from the Mekong Delta**

| Section | Aggregate Loss | | Surface Texture | | Description |
|---|---|---|---|---|---|
| | Jun 05 | March 07 | Jun 05 | March 07 | |
| DT05 | 0 | 0.07 | 2.00 | 2.61 | SBEST+ESS over lime stabilised base-sub-base |
| DT06 | 0 | 0.71 | 2.00 | 2.8 | SBEST+ESS over dry bound macadam |
| DT07 | 0 | 2.03 | 3.00 | 3.00 | PenMac over water bound macadam |
| TG05 | 0 | 0.00 | 3.00 | 2.70 | SBEST+ESS over lime stabilised base-sub-base |
| TG06 | 0 | 0.00 | 3.00 | 2.00 | SBEST+ESS over dry bound macadam |
| TG07 | 0 | 1.00 | 3.0o | 2.00 | PenMac over water bound macadam |
| Notes: Visual assessment figures based on the average of conditions from 5m blocks of surface.<br>For aggregate loss 0=none; 1= 0-50% loss; 2= >50% loss<br>For surface texture 1= smooth ; 2 = slightly coarse and 3= coarse. | | | | | |

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- SBEST +ESS on dry bound macadam has performed as well as PenMac surfacing, with cracking in seals on lime stabilised bases associated with the roadbase problems rather than the seals themselves.
- Single ESS on clay bricks is showing signs of wear and cracking
- Single ESS on concrete blocks has developed significant cracks
- So far there is no substantial difference in the performance of hot bitumen and bitumen emulsion seals.

**Table 5 Summary of the principle advantages and disadvantages of the trialled seals in the light of the construction observations and current monitoring data**

| Description | Principal Advantages | Principal Concerns |
|---|---|---|
| Sand bitumen emulsion<br>ESS | Suitable for labour based methods because of low health and safety risks. Hence suitable for commune based maintenance operations.<br>Suitable for low volume traffic roads in areas deficient in stone aggregate but with plentiful supplies of suitable sand. . | Best performance with the application of a second sand seal after 5-6 months road use, in order to provide a more durable surface. Application procedures not suitable for steep gradients. Not suitable for areas prone to tropical storm floods.<br>Procedures not well known by local contractors; requires good site control. Sand seal on brick options show a tendency to strip and crack at brick joints.<br>Potential difficulties in obtaining small quantities of emulsion for local maintenance. |
| Double and single stone chip bitumen emulsion<br>SBEST<br>DBEST | Suitable for labour based methods because of low health and safety risks. Hence suitable for commune based maintenance operations. | Care required in matching emulsion application rates to actually available stone sizes and aggregate shape. Procedures not well known by local contractors; requires good site control.<br>Potential difficulties in obtaining small quantities of emulsion for local maintenance. |
| Double stone chip hot bitumen<br>DBST | Well known and established procedure in Vietnam. | Generally currently very poor site control on bitumen application temperature, which affects durability.<br>Significant health and safety hazard. |
| Triple stone chip hot bitumen<br>TBST | Locally developed procedure. | Excessive use of bitumen in what is effectively similar to a semi-penetration macadam in composition and thickness. Care required in matching application rates to actually available stone sizes and shape.<br>Generally currently very poor site control on bitumen application temperature.<br>Significant health and safety hazard. |
| Penetration macadam<br>PenMAc | Well known and established procedure in Vietnam.<br>Low initial maintenance if well constructed. | Does not use either locally available materials or local labour. Health hazard issues as regards hot bitumen. Difficult to control quality.<br>The use of bitumen at 7kg/m2 means that this option carries a high cost penalty. |

# SEALED SURFACES IN LOW VOLUME RURAL ROADS

## Justification for use

The Vietnam Rural Road Gravel Assessment Programme (Cook and Petts, 2005) identified serious constraints to the use of gravel 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 indicate that around 58**%** of the surveyed sites are suffering unsustainable deterioration, while 28% are losing material at twice the assessed sustainable rate of 20mm/year.

Rainfall in Vietnam tends to be concentrated within a 5-6 month rainy season and in some coastal provinces the impact of tropical storms in producing intense and highly erosive rainfall events is significant, Table 6.

**Table 6 Representative rainfall data from Vietnam**

| | | Rainfall (mm) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Maximum Daily | | | | | | Annual |
| | Location | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Avge |
| Red River | Ninh Binh | 293 | 184 | 151 | 188 | 96 | 180 | 1633 |
| Red River | Hung yen | 92 | 100 | 89 | 114 | 72 | 103 | 1356 |
| N.Highlands | Ha Tinh | 169 | 205 | 302 | 164 | 166 | 289 | 2187 |
| N.Highlands | Quang Binh | 156 | 204 | 125 | 248 | 130 | 177 | 1899 |
| N.Highlands | Tuyen Quang | 156 | 172 | 179 | 110 | 131 | 87 | 1763 |
| Mekong | Dong Thap | 148 | 72 | 112 | 76 | 109 | 64 | 1508 |
| Mekong | Tien Giang | 82 | 74 | 43 | 53 | 273 | 110 | 1394 |
| C. Highlands | Gia Lai -Pleiku | 109 | 96 | 159 | 120 | 139 | 115 | 2157 |
| C. Highlands | Dak Nong | 119 | 184 | 83 | 124 | 56 | 129 | 2736 |
| C. Highlands | Dak Lak | 264 | 184 | 83 | 124 | 56 | 129 | 1939 |
| C. Coastal | Hue | 354 | 201 | 360 | 197 | 683 | 311 | 3003 |
| C. Coastal | Da Nang | 140 | 185 | 157 | 136 | 211 | 293 | 2155 |

In such an environment the range of trialed sealed surface and paving options provides appropriate, economical and sustainable alternatives to natural gravel in the Vietnam rural road sector. Suitability will depend on local circumstances, as solutions applicable to the Mekong Delta, for example, will be different from those appropriate for say the Northern or Central Highlands. These alternatives, involving the appropriate use of locally available materials, may be constructed by small local enterprises using low-capital, labour based and light equipment methods. Communities themselves could also use some of the techniques to improve their own access. Sealed surface options should have lower (and more manageable) maintenance requirements than gravel, not only in terms of cost but also by reducing the need for (imported) heavy equipment to transport and compact. In addition a number of other strategic issues and objectives are also satisfied:

- Improved sustainability,
- Durability in the expected traffic and environmental conditions,
- Use of locally available or produced materials,
- Techniques with low capital investment (limited or simple equipment requirements), and manageable by local contractors,
- Use of local labour and skills,

- Socially and environmentally acceptable use of materials.

Further, important paid employment opportunities for both women and men are generated by the use of these local resource based methods, both in the construction and maintenance of the roads and in the processing of the local materials. Maintenance operations are simplified and are both technically feasible and more affordable using largely labour and light equipment orientated methods. These kinds of operations are more suitable for the communities themselves or small local contracting enterprises.

## The Use of Seals within Environmentally Optimised Design

There are frequently significant budget constraints on the development of rural infrastructure and local authorities have to balance available resources with the demands of constructing sustainable low volume rural roads. Recent international and regional research has highlighted the usefulness of applying the principles of Environmentally Optimised Design (EOD) to selection, design and construction of pavement and surfacing options for low volume rural roads.

In essence EOD in this context can be described as utilising the available resources of budget and materials in the most cost-effective manner to counter the sometime variable factors of traffic, terrain, materials and sub-grade that may exist along an alignment. EOD may be considered as spectrum of solutions for improving or creating low volume rural access – from dealing with individual critical areas on a road link (Spot Improvement) to providing a total whole rural link design (Variable Longitudinal Design).

Variable Longitudinal Design applies the principle of adapting designs to suit variable road environments along an individual road alignment. This results in selecting different pavement/surfacing options in response to different impacting factors along an alignment and hence a more focussed use of limited construction resources.

Spot Improvement involves the appropriate improvement of specifically identified road sections either in actual need of upgrade or deemed to be at high risk of failure, and allows the appropriate application of limited resources to be targeted at key areas on existing earth or gravel road links to improve access throughout the year.

Sealed surfaces can offer a rational and cost-effective alternative within the EOD framework. They can be used on the more demanding sections of an alignment and allow sections of unsealed cheaper road to be constructed where road environment factors are more favourable. Bitumen emulsion options, with their greater suitability for local small contractor or labour based usage are particularly attractive in this regard.

## Research into practice

Prior to the RRSR, the Vietnam rural roads were very largely constructed with unsealed gravel surfaces. While initial construction was cheap, it became increasingly clear that the maintenance requirement for these roads was beyond the capacity of the MoT and it's Provincial Departments of Transport (PDoT).

The RRSR has yielded two key outcomes.

- First, the use of unimproved natural gravel as a universal rural road surfacing material has been proved to be unsustainable in over 60% of the situations in Vietnam.

- Second, there are alternative and cost effective pavement options involving the use of emulsion seal that are far more sustainable that can be used instead of gravel. This has led to a substantial change in the technical approaches used by the MoT on rural roads

and the outcomes of the RRSR will now be incorporated into the third World Bank funded RTP project (USD 150M), as well as other investment programmes in Vietnam.

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### BIOGRAPHY

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