Indian Roads Congress

International Seminar on "Innovations in Construction and Maintenance of Flexible Pavements" to be held at Agra from 1st to 4th September 2006

Theme- IV Construction and Maintenance of Low Volume Roads

TITLE: Rural Road Surfacing Research for Sustainable Access and Poverty Reduction in South East Asia

AUTHORS: Robert Petts, BSc CEng MICE MIHT MIAgrE, Intech Associates (UK)
Dr Jasper Cook, MSc CGeol, MIHT, FGS, TRL Ltd (UK)
Pham Gia Tuan, BSc, Intech-TRL (Hanoi, Vietnam)
Bach The Dzung, BSc, Intech-TRL (Hanoi, Vietnam)
Heng Kackada, BSc MSc, Intech Cambodia

ADDRESS FOR COMMUNICATION:

Robert Petts, Regional Manager, Intech-TRL
Suite 1314
49 Hai Ba Trung Street
Hanoi, Vietnam
e-mail:- rob@intech-consult.demon.co.uk

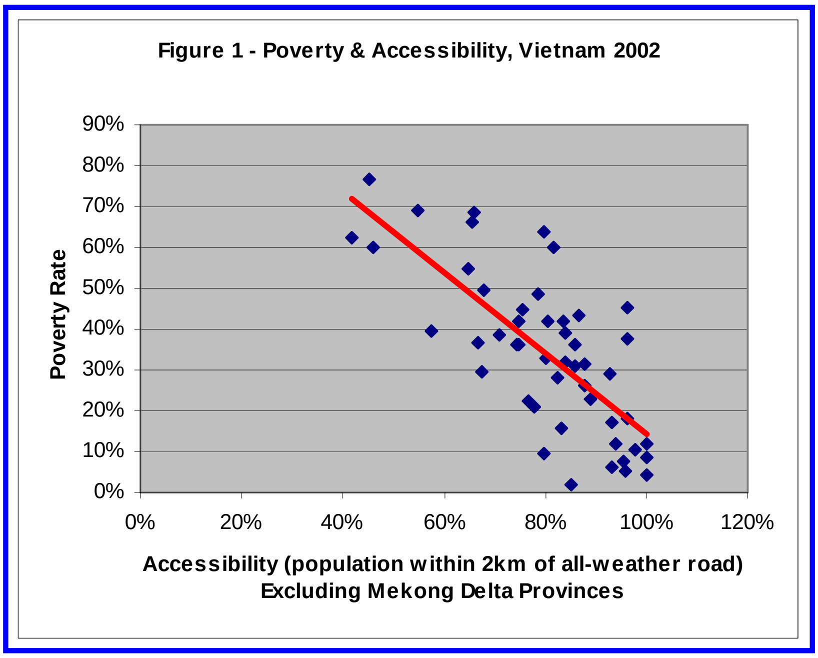
ABSTRACT

The lack of year round access to many rural communities is a serious constraint to social and economic development, and poverty reduction. Poor access limits the effectiveness of agricultural, commercial, educational and health initiatives though unreliable travel and high unit transport costs for crops, goods, services and people. Previous rural transport initiatives have usually concentrated on the provision of gravel roads for all year rural access. However, documented experiences have shown that these roads, although relatively cheap to construct, are often an unachievable maintenance burden for many rural communities and road authorities, and are rarely maintained in a serviceable condition. There are also real concerns regarding the unsustainable consumption of limited natural gravel resources.

The paper describes recent DFID and World Bank funded research on alternatives to gravel roads in Vietnam and Cambodia. A substantial range of proven, low-cost, rural road paving options is available and many of these have been trialed in over 150 road sections constructed in South East Asia. These paving options are suitable for construction and maintenance by Small and Medium Enterprises (SMEs). The paper also reviews the alternative surfacing options. Most of these paving options require little capital investment in equipment, use labour-based techniques and can optimize the use of local materials resources. They can utilize locally made or available simple equipment, thus promoting local manufacturing and appropriate equipment ownership. For many of these techniques overhead costs could be reduced and a higher proportion of the costs could be recycled in the local community. The maintenance burden of these alternatives is usually lower than for gravel roads, and whole life costs can be cheaper than the provision of a gravel surface. Poverty reduction would be facilitated both through the involvement of the local community in the works, and improved, more sustainable access.

1. BACKGROUND – THE CHALLENGE

In many developing countries, the main road network carries about 80 to 90 per cent of passenger and freight transport and it is, therefore, of key importance to the national economy. Main road networks are understandably given high priority in the allocation of investment and maintenance funds in recognition of their economic importance. Conversely, rural roads may make up over 80 per cent of the road network length, but are given lower priority in the allocation of funding because they carry much lower volumes of motorised traffic. Despite this, these rural roads are of vital importance to rural communities for their economic and social wellbeing and reduction of poverty. There is an established link between poverty and poor access (example Figure 1).



Source: Vietnam 2002 Living Standards Survey

The rural poor do not have motor cars. However they need reliable access for affordable transport or services (both motorised and non-motorised) such as bicycles, motorcycles, animal carts, minibuses, buses, whether owned or hired. Even if a vehicle ride is too expensive for them, they will still depend on the transporters that bring the medicine and teachers to the village, or carry crops. The essential challenge for engineers and road managers is therefore how to provide and maintain this rural access for the types of traffic currently in use, on a sustainable basis with the limited resources available.

Unsealed rural roads with earth and gravel/laterite surfaces comprise the greater proportion of the length of public roads in rural areas in developing regions[1]. Globally, they account for almost 60 per cent of the main road network, or about 1.2 million kilometres. In addition, there exists an estimated 5 to 6 million kilometres of designated minor roads and motorable tracks, and an extensive network of undesignated tracks and paths, probably several times the extent of the designated network[2].

Engineers have traditionally relied on the use of natural gravel/laterite as a rural road surface, due to its initial low costs and simplicity of use. However recent research[3] confirms the serious problems relating to maintenance and sustainability of such surfaces in many situations common in South East Asia. This experience is valid for certain combinations of conditions in other regions. There are also health and environmental concerns regarding the widespread use of gravel.

---

1 Vietnam has a road network of approximately 210,000 km, of which over 100,000 km are to earth standard.
2 Paving the way for rural development & poverty reduction, Gourley, Greening Jones & Petts, CAFEO 20, 2002.
3 Rural Road Gravel Performance Assessment investigations in Vietnam, SEACAP 4, by Intech-TRL (Ref. 1)

2. THE LIMITATIONS OF GRAVEL

The word gravel is used within this document to denote any naturally occurring granular material, including laterite gravel, used as a road surfacing material. The experiences also apply in many circumstances to (often more expensive) graded crushed rock aggregate. Gravel is a 'wasting' surface. Material is lost from the surface of the road due to the action of traffic and rainfall. Natural gravel should only be used for rural road surface applications in situations where certain conditions are fulfilled. In general, **gravel should not be used where**:-

- **Gravel quality is poor** – Gravel should comply with grading and plasticity requirements, and not break down under traffic, otherwise it will be lost from the surface at a high rate. Natural gravel quality varies substantially within each pit location and with depth. Great care is essential to ensure that only suitable material is selected, and that mixing of marginal/unsuitable material is avoided,
- **Compaction & thickness cannot be assured** – uncompacted surface gravel will be less durable. Supervision arrangements should ensure that the full specified compacted thickness is placed,
- **Haul distances are long** – if haul distances are longer than 10km, then other surface types may be cheaper in whole life cost terms. Hauling gravel for construction and periodic maintenance can cause damage or further maintenance liabilities to the haul routes,
- **Rainfall is very high** – Gravel loss is related to rainfall and may be excessive with intense storms or where annual precipitation is greater than 2,000mm,
- **There are dry season dust problems** – long dry seasons can allow the binding fines to be removed from the surface by traffic or wind. This is particularly problematic where communities live beside the road or their crops and property are regularly coated in dust. Inhalation of road dust is unhealthy and there are also visibility-safety issues,
- **Traffic levels are high** – gravel loss is related to traffic flows. It is unlikely that a gravel surface will be cost-effective at traffic flows of more than 200 motor (2 or more axles) vehicles per day.
- **There are Longitudinal Gradients** – Gravel should not be used in low rainfall situations (< 1,000mm/year) on longitudinal road gradients of more than 6%. In medium rainfall areas (1,000 – 2,000 mm/year) gravel loss by erosion will be high on gradients of more than 4%.
- **Adequate maintenance cannot be provided** – Gravel is a high maintenance surface requiring both routine reshaping/grading and expensive periodic re-gravelling. Neither are achieved to adequate levels in many Emerging and Developing nations due to funding and operational constraints [4, 5] .
- **Sub-grade is weak or soaked (flood risk) –** Weak subgrades (in-situ foundations) require additional thickness of residual gravel to prevent traffic 'punching through' to the subgrade. Flooding can seriously damage gravel surfaces,

  or,
- **Gravel deposits are limited/environmentally sensitive** – Gravel is a natural and finite resource, usually occurring in limited quantities. Once deposits are used up, subsequent periodic re-gravelling will involve longer hauls and higher maintenance costs.

---

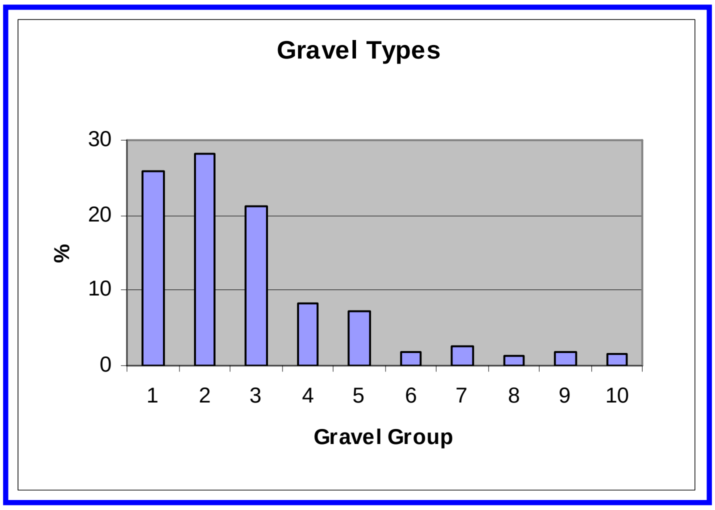
4 In Cambodia it is estimated that a gravel rural road typically requires about US$1,600 per km per year for maintenance. These resources are simply not available on a national network basis - Rural Road Investment, Maintenance and Sustainability, A Case Study on the Experience in the Cambodian Province of Battambang, D Johnston and D Salter, ILO, May 2001.

5 Roads 2000, a programme for labour and tractor based maintenance of the classified road network, paper for the RMI road maintenance policy seminar, Nairobi 2 – 5, Petts June 1992

Even in simple combinations of some of the above factors, gravel can be lost from the road surface at rates of more than 3cm per year, leading to the need to re-gravel at very frequent intervals[6]. The funding and resources are usually not available to achieve this and the road will invariably deteriorate and revert to an earth surface.

3 RECENT RESEARCH IN VIETNAM

Intech-TRL have recently completed, as part of SEACAP[7], a condition survey of a representative selection of unsealed and gravel rural roads in Vietnam. This Rural Road Gravel Assessment Programme (RRGAP) survey, which included in situ and laboratory testing of the road materials, has been conducted on 269 roads and 766 cross sections constructed with a variety of materials (Figure 2), in rainfall environments of between 850 and 3,000mm/year.



1	Laterite Gravel
2	Hill Gravel
3	Graded Crushed Rock
4	Non-Graded Crushed rock
5	Alluvial Gravel
6	Gravel + Soil Mix
7	Weathered Rock
8	Hand Packed stone
9	Quarry Waste
10	Other

Figure 2 – RRGAP Range of Materials Employed as Unsealed Road Surfaces

Analysis of the results has been finalised[8]. Issues identified relating to the general use of gravel materials on rural roads include the following:

1. Gravel material loss from the road surface is highly variable (Figure 3), with material type, drainage, sub-grade condition, gradient and rainfall being key factors. Many gravel roads have typically 80-90% of the road in fair to good condition after only a year or two of service, with some sections (10-20% of the length) in poor condition. This suggests a need to consider a spot improvement, or composite construction approach, in which at-risk or difficult sections are given a higher quality, more durable surface.
2. Many of the materials are not within widely accepted specification parameters. Hence a need to consider a design and quality assurance approach that specifies appropriate local materials rather than a blanket overall specification. Also a pragmatic approach is required to materials selection and approval, particularly in a remote location, constrained-resource environment, lacking good testing facilities and arrangements.

---

[6] Required regravelling frequencies of 3 years or less are reported in some locations.
[7] SEACAP – South East Asia Community Access Programme, funded by DFID, World Bank and ADB.
[8] Cook & Petts, Rural Road Gravel Assessment Programme (RRGAP),Vietnam, Module 4 Final Report, July 2005.

3. 75% of the surveyed roads have received no effective maintenance at all since construction. This emphasises the need either to construct road surfaces that are robust enough to withstand a low maintenance regime, or to put in place effective road maintenance arrangements that are not hampered by local funding or operational constraints, or skill and resource shortages. A coherent design and maintenance strategy is required, that recognises life cycle costs and the realities of maintenance capacity. It should be appreciated that effective maintenance regimes usually take decades, rather than years, to develop.
4. Two provinces outside of the RRGAP programme with very high rainfall (>3500mm/year) immediately overlaid the donor-sponsored gravel surfaces at their own cost, usually with concrete or bitumen penetration macadam. Besides the need for better surface selection procedures, this suggests the possibility of a staged construction approach to some rural roads, in which an initial unsealed surface may be overlain at a later date with an appropriate seal. However, indications are that a gravel wearing course would not usually be suitable for this approach unless sealing was guaranteed to be undertaken within a short period, or certainly before the onset of the first rainy season in high rainfall areas.

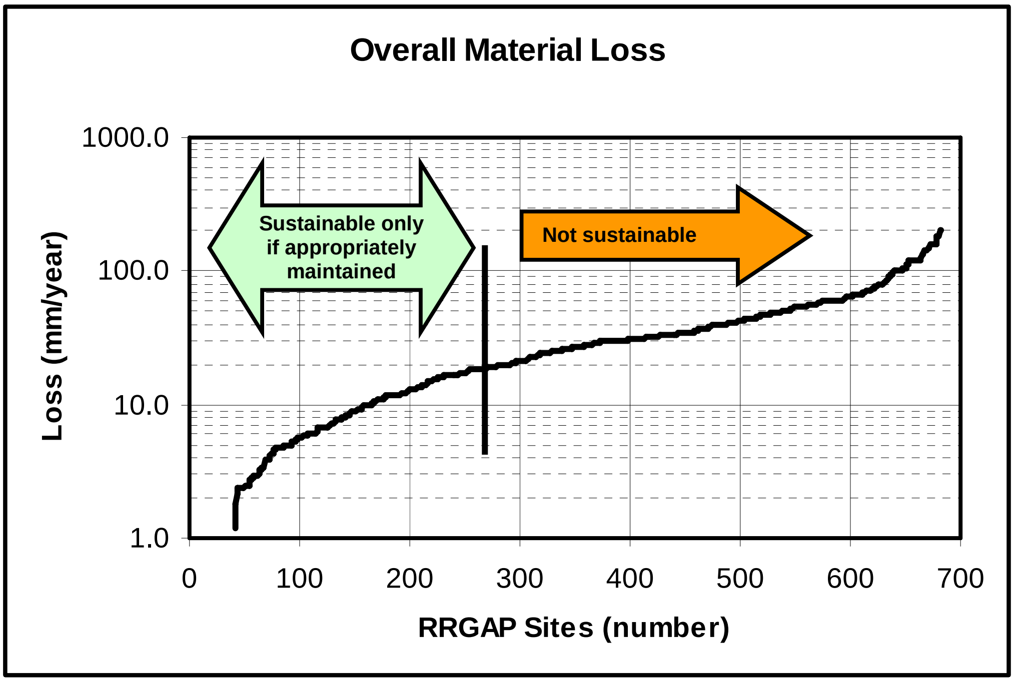


Figure 3 – Adjusted Apparent Material Loss Summary

Median	26 mm/yr
%>20mm/yr	58
%>40mm/yr	29

The results of the research have been published in July 2005. However it is clear that extensive awareness creation and training initiatives will be required to improve knowledge and decision making for policy makers, managers, engineers, contractors and communities regarding the challenges and constraints of the use of gravel and unsealed surfaces on rural roads. This paper supports that strategy.

4 PREVIOUS 'RULES OF THUMB'

Previous sector 'Rules of Thumb' indicated that gravel could be suitable for roads with traffic flows of between 50 and 200 motor vehicles per day (vpd). These guidelines suggested that earth roads would be suitable for traffic flows up to 50 vpd. However, such guidelines are extremely misleading, as some soils are totally inappropriate to support any traffic flows whatsoever. Furthermore, the criteria listed previously demonstrate that even gravel should never be considered for some combinations of conditions. Furthermore, research in Southern Africa has shown that low cost bituminous seals can be justified at flows of only 70 motor vehicles per day[9,10]. It is likely that full and realistic whole life costing of surface options will show that natural gravel is **NOT** the most cost-effective surface in most situations. It is necessary to be more rigorous in evaluating the options for rural and access road surfacing. Long hauls, high rainfall, high traffic, poor material, steep gradients, flooding, poor construction practices, lack of maintenance capacity and other extremes of condition will exclude gravel from being the most appropriate surface in many circumstances.

Figure 6 shows the guidelines for gravel rural road surface selection produced for the Ministry of Transport, Vietnam, based on the gravel road performance research.

Figure 4 - ENGINEERED NATURAL SURFACES: Maintainable using simple locally made equipment

3. THE PROVEN ALTERNATIVES TO GRAVEL

Fortunately there is a range of proven alternatives to natural gravel. Some of these have similar initial construction costs to gravel in certain circumstances. Most have better whole life cost[11] attributes and lower maintenance liabilities.

Poor people often rely on non-motorised transport, motorcycles and simple trucks for their transport needs. On many soils, an engineered earth road is sufficient to provide basic access for these vehicle types, provided that specific, limited location constraints, such as watercourse crossings and steep gradients are adequately engineered with spot improvements. The camber and drainage must of course be maintained using appropriate, low cost techniques. Engineered Natural Surfaces therefore have enormous scope to improve access at very low costs for poor rural communities.

9 Performance of low-volume sealed roads: Results and recommendations from studies in southern Africa. TRL Project Report PR/OSC/167/99. Transport Research Laboratory, Crowthorne, Berkshire, UK, CS Gourley and PAK Greening, November 1999.

10 New approaches for the provision of low volume sealed roads. 20th Annual South African Transport Conference. Pretoria, South Africa, PAK Greening and CS Gourley, July 2001.

11 Whole Life Costs – discounted total construction and maintenance costs through the nominal life of the road.

Engineers need to give greater attention to improving these basic access routes which often constitute more than 50% of the rural networks in developing countries. Low cost construction and maintenance techniques using local labour and simple equipment have an important role to play. These techniques are particularly suitable for implementation by small enterprises or communities. They use the locally available labour and have negligible capital requirements. Such Engineered Natural Surfaces (ENS) can be provided for less than US$2,000 per km in many situations, including the necessary low cost drainage measures. Low cost grading of ENS can be achieved for as little as US$25 per km of grading using simple locally made equipment (Figure 4).

However in some circumstances the in-situ soils are just too weak to support any traffic in the wet, and must be covered. For these situations, there is a range of alternative surfacing and paving options already proven in various countries that could provide appropriate, economical and sustainable alternatives to natural gravel in developing countries. Suitability will depend on local circumstances. These alternatives, involving the appropriate use of locally available materials, may be cheaper in whole-life-cost terms. Many can be carried out by small and medium enterprises using low-capital, labour based and light equipment methods.

Communities themselves could use some of the techniques to improve their own access. The alternative surfaces should have lower (and more manageable) maintenance requirements than gravel, not only in terms of cost but also by reducing the need for (imported/expensive) heavy equipment to transport and compact. Their environmental impact could be substantially less.

Figure 5

The rural road surfacing options are summarised in Figure 7. These are all proven surfacing techniques. Guidelines on the use of these alternative surfaces and pavement layers have been compiled and successfully implemented in a number of countries. Similar documents are currently being compiled for South East Asia by Intech Associates-TRL, based on research work in Cambodia, Vietnam and elsewhere.

4. SUITABILITY FOR SMALL & MEDIUM ENTERPRISES (SMEs)

The rural transport sector in many developing countries is characterized by the dominance of large construction enterprises using capital intensive methods for construction and maintenance works. These contractors have high overhead costs and their mobilization to the rural areas is expensive. Small and Medium Enterprises (SMEs) are generally poorly developed and have limited opportunities to penetrate the market.

However, if encouraged, SMEs would be particularly well suited to carrying out rural road construction of the alternative surfacing options due to:

- Possibility to be based in the rural areas with low mobilization costs,
- Low capital and set-up requirements,
- Inter-sector flexibility; possibility to provide services to a range of sectors and clients,
- Good market entry point for small entrepreneurs,
- Possibility to use affordable simple equipment, either owned or hired,
- Possibility to use local labour skills such as carpentry and masonry,
- Less pressures for corrupt practices, as they are part of the local community,
- Less opportunities for HIV-Aids infections due to less labour imported into the community,
- More of the costs recycled into the local community in employment of local labour, local tools production, local transport, local materials and profits,
- Construction skills developed in the local community which can be utilized for maintenance and other activities,
- Low overhead costs.

However, investigations have shown that these enterprises often suffer from a number of constraints that prevent them from establishing, surviving and delivering low cost infrastructure services to the rural communities. These constraints include:-

- Barriers, bureaucracy or costs of establishing SMEs,
- Inadequate Government policy framework to support the SME sector for rural roads,
- Insufficient public awareness of the potential benefits of SME rural roadworks implementation, lack of public access to works and contract cost data,
- Lack of appropriate contract documentation, pre-qualification & bidding procedures, standards and specifications, financial and performance audit, dispute resolution for small scale works, in place,
- Contract pre-qualification too demanding, for example 3 years previous experience of similar work,
- Contracting procedures and requirements usually (unnecessarily) demand heavy equipment holdings,
- Lack of access to capital or credit for equipment purchase or cashflow,

- Lack of opportunities to hire equipment,
- Poor contractors' capacity in costing and planning works,
- Inadequate access to low cost training, documentation and guidelines on small scale roadworks,
- Contract technical solutions are usually restricted to gravel and macadam surfaces,
- Lack of sustainable local funding for small rural road works contracts and maintenance,
- Lack of market and sustainable workload for SMEs,
- Lack of representation of SMEs (e.g. business association),
- Late and/or non-transparent payments for locally funded work,
- Corruption in award and payment for work.

The national sector stakeholders must cooperate to overcome or minimise these constraints, drawing where possible on the experiences and support of overseas partners and the knowledge and experiences of sector experts.

5. REDUCING THE MAINTENANCE BURDEN

Gravel road surfaces are justified in many developing countries using unrealistically low construction and maintenance cost norms that are inappropriate not only in terms of provision of an adequate quality initial surface, but also with regard to the likelihood and true cost of provision of the necessary maintenance environment to sustain a gravel surface. Routine maintenance is a fundamental and integral part of the yearly working life of these roads, much more so than for comparative sealed surfaces, and it is misleading to ignore the real cost of this work in budget assessments. These surfaces not only require the routine maintenance of other surfaces such as patching and off-road drainage clearing, but regular grading of the surface is necessary. This is required to reshape the surface to effectively shed the rainwater to the side of the road and prevent softening and defects formation caused by standing water. Normally, a camber of between 3% and 7% should be maintained. The grading activity is required to be carried out usually on a basis of 1 – 6 times a year depending on local conditions. This liability requires a well organised <u>and</u> funded routine maintenance organization. This is rarely found in a developing country.

Routine maintenance is a very challenging logistical requirement for gravel roads, however the periodic re-gravelling requirement is the specific burden that usually makes gravel roads an unaffordable and unsustainable surface option in many circumstances. The rates of gravel loss found in even many low rainfall environments cannot be replenished by the road authorities, due to lack of sufficient recurrent funding and resources (logistical and material). Inevitably many gravel roads revert to poor earth standard through lack of, or delayed, re-gravelling.

Whole life costing of the construction and maintenance of a gravel road and feasible alternatives will often show the gravel to be unsuitable in many circumstances. This will be particularly true where the capacity to provide effective and timely maintenance (or lack of it) is realistically evaluated and built into the costing process. The evident common cycle of constructing gravel roads and re-constructing them later through delayed or inadequate maintenance is a very high cost and unsustainable approach, and an irresponsible waste of scarce resources.

Whole life costing should be carried out based on local costing and surface performance evidence. Transferring experiences from other physical, climatic and operational environments needs to be carried out with care, making due adjustments for local conditions.

6. CONCLUSIONS

A range of proven, low-cost, rural road paving options exist as an alternative to the use of problematic natural gravel as a road surface. The low cost paving options usually have a number of economic, social, health and environmental advantages over gravel. These alternative paving techniques are suitable for construction and maintenance by Small and Medium Enterprises (SMEs). Most of these paving options require little capital investment, use local resource based techniques and can optimize the use of local materials.

The alternative surfaces often have lower maintenance requirements and lower whole life costs than gravel surfaces (depending on a range of local factors). Wider adoption of these alternative surfaces would reduce the overall network maintenance funding and works burden.

However there are a range of constraints that currently prevent these technical and operational approaches from being widely used in developing countries. Initiatives are required to be taken by governments, road authorities, contractors' associations and donor agencies to tackle these constraints to "mainstream" the rural road surface alternatives and to develop a vibrant market for rural infrastructure works. This will enable SMEs to establish and survive to deliver appropriate low cost road infrastructure solutions to the rural communities. This would provide an important improvement in the prospects for social and economic development, and rural poverty reduction.

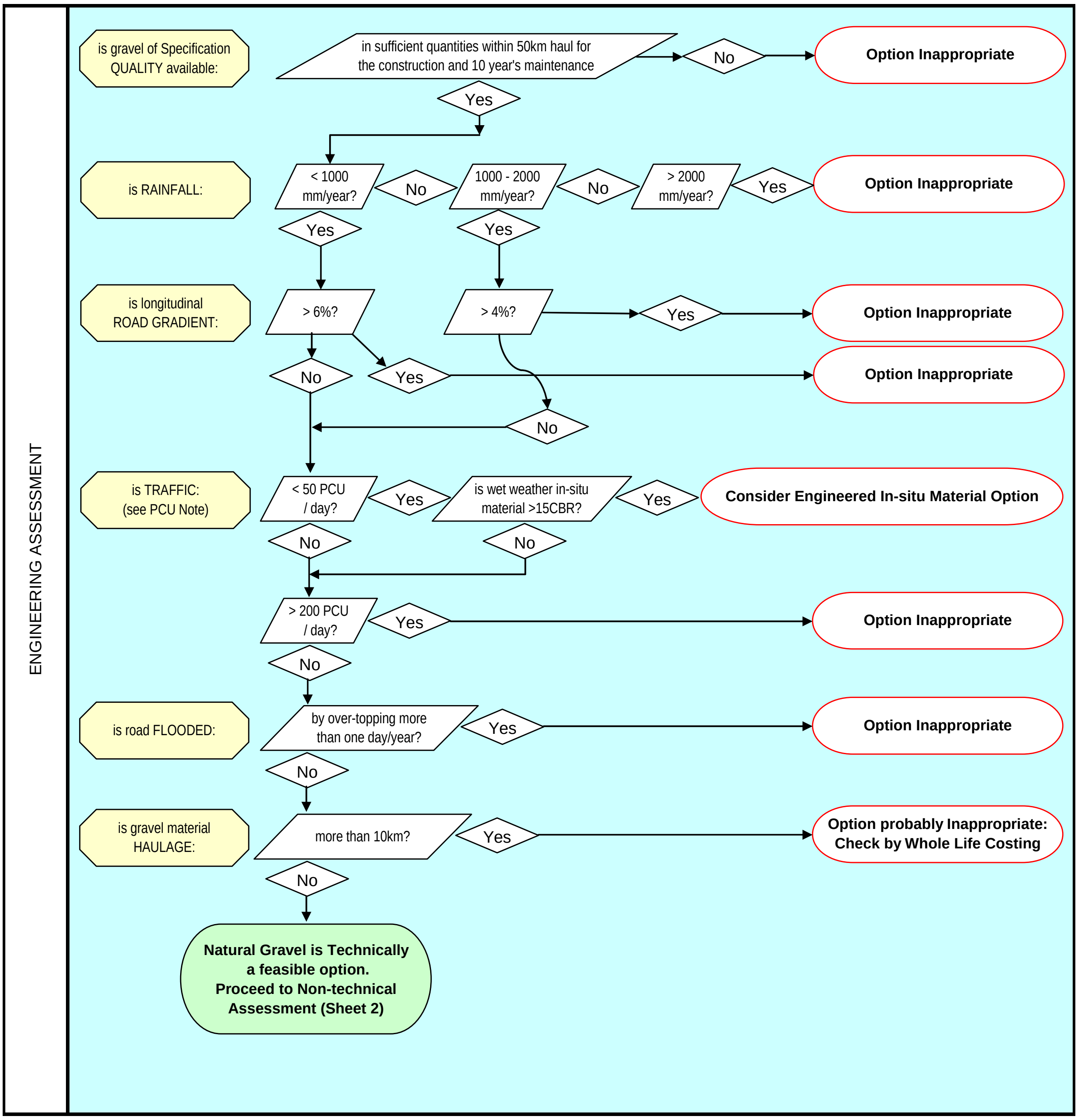
SELECTED REFERENCES

1. Cook J.R. & Petts R.C. -TRL, Rural Road Gravel Assessment Programme (RRGAP), Vietnam, Module 4 Final Report, July 2005.
2. Gleeson, Fergus. Low Cost Surface (LCS) Options Trials, Conclusion of Construction Phase, Intech Associates, 2002.
3. Gourley, G. S. and Greening, P.A. K.,Performance of low-volume sealed roads: Results and recommendations from studies in southern Africa. TRL Project Report PR/OSC/167/99. Transport Research Laboratory, Crowthorne, Berkshire, UK, November 1999.
4. Gourley, Greening, Jones & Petts, Paving the way for rural development & poverty reduction, CAFEO 20, 2002.
5. Government of Vietnam, Living Standards Survey, 2002.
6. Greening P. A. K. and Gourley, G. S.,New approaches for the provision of low volume sealed roads. 20th Annual South African Transport Conference. Pretoria, South Africa, July 2001.
7. Intech Associates, *Roads 2000* Pilot project and investigations, Kenya, 1990 – 1996.
8. Intech Associates, Proceedings of Contracting Development Workshops, Zimbabwe, 1997-9.
9. Intech Associates, Low cost surfacing research, KaR 7782, 2000 – 2004.
10. Intech Associates – TRL, Rural Road Surfacing Research, Vietnam, 2002 – 2006.
11. Johnston, D. and Salter, D., Rural Road Investment, Maintenance and Sustainability, A Case Study on the Experience in the Cambodian Province of Battambang, , May 2001.
12. Larcher, Paul. Miles, Derek. & Petts, Robert., MART Working Paper No 5, Workshop Report, Intermediate Equipment for Labour-Based Roadworks, Accra, Ghana, 19 & 20 April 1996.
13. Lebo J and Schelling D, Design and Appraisal of Rural Transport Infrastructure. Ensuring basic access for rural communities. World Bank Technical Paper No. 496, 2001.
14. Miles, Derek., MART Working Paper No.1, Towards Guidelines For Labour-Based Contracting, A framework document, MART and ILO, 1995.
15. Petts, Robert, Roads 2000, a programme for labour and tractor based maintenance of the classified road network, paper for the RMI road maintenance policy seminar, Nairobi 2 – 5 June 1992.
16. Petts, Robert., Low Cost Surfacing, Working Paper No 1 - Rationale for the compilation of international guidelines on low-cost, labour-based, alternative & sustainable road surfacings, March 2002.
17. PIARC, 1994, International Road Maintenance Handbook.
18. WSP, Report on Contracting Constraints in the Rural Roadworks Sector, Vietnam, 2002.

Figure 6

Decision Flow Chart for the Consideration of Natural Gravel as a Rural Road Surface Option

SHEET 1 - Engineering Assessment



NOTES: PCU = Passenger Car Unit (other vehicle types to be converted from traffic surveys and maximum predicted daily flows for next 3 years).
CBR = California Bearing Ratio - Strength in situ measured by DCP, or to be decided by visual assessment
DCP = Dynamic Cone Penetrometer
Engineered Insitu Material = Earth Road Standard with maintained camber and effective drainage system

Intech Associates CONSULTING ENGINEERS

TRL

Figure 7

RURAL ROAD SURFACING GUIDELINES

Using Local Resource Based Methods

Focusing on the use of local labour, materials, enterprises and the community themselves.

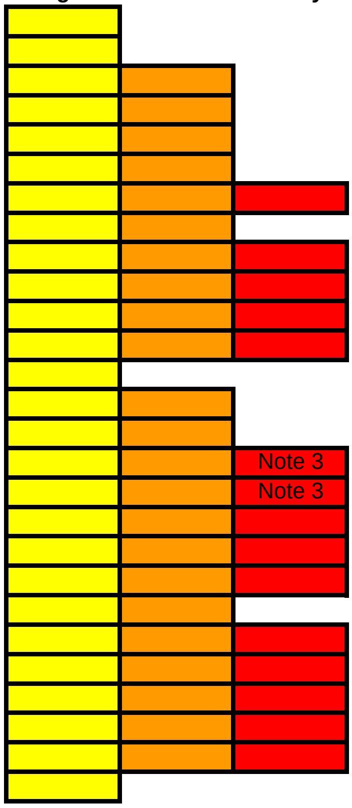
Broad suitability guidelines are indicative only - dependant on site conditions and environment.

SUITABILITY FOR TRAFFIC

As a Road Surface

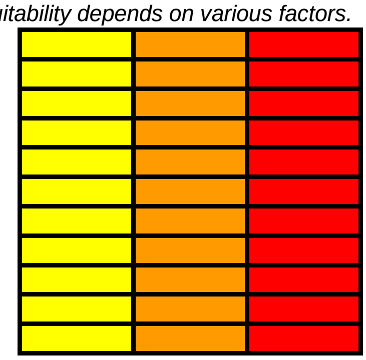
Light Medium Heavy

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



Application suitability depends on various factors.

Number	Type of Roadbase or Subbase
1	**Soil Stabilisation**
2	**Natural Gravel / Laterite**
3	**Water Bound Macadam**
4	**Dry Bound Macadam**
5	**Crushed Stone Macadam**
6	**Hand Packed Stone**
7	**Telford Paving**
8	**Slurry Bound Macadam**
9	**Sand Aggregate**
10	**Armoured Laterite**
11	**Pulverised Fuel Ash**



Traffic

Light: Mainly non-motorised, motorbikes & less than 25 motor vehicles per day, with few medium/heavy vehicles

Medium: Up to 100 motor vehicles per day including up to 20 medium (10t) goods vehicles

Heavy: Accessible by all vehicle types including heavy and overloaded trucks

Notes

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