LOW COST ROAD SURFACING (LCS) PROJECT

LCS WORKING PAPER No 1

RATIONALE FOR THE COMPILATION OF INTERNATIONAL GUIDELINES FOR LOW-COST SUSTAINABLE ROAD SURFACING

by
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CONSULTING ENGINEERS

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THE LOW COST ROAD SURFACING INITIATIVE

The Low Cost Road Surfacing (LCS) initiative aims to provide documentation and international guidelines on the provision and maintenance of low cost road surfaces and basic access for rural communities in economically emerging and developing countries (EDCs). It is based on a research project funded principally by the British Department For International Development (DFID) under its Knowledge and Research (KaR) programme. The initiative is led by UK-based specialist consultants Intech Associates. Collaboration is being established with a number of organisations with interests or experience in the sector, including TRL Ltd, ILO/ASIST Africa and Asia-Pacific, the ILO-SIDA funded Upstream Project and Ministry of Rural Development Cambodia, WSP International, Ministry of Transport Vietnam, Greater Mekong Subregion Academic Research Network, University of the Witwatersrand RSA, The Institute of Technology of Cambodia, Chieng Mai University Thailand, and the Committee C20 (Appropriate Development) of PIARC (World Road Association). The LCS programme is being implemented over a 3 year period from 2001 to 2003.

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

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

This Working Paper is intended to inform and provoke discussion, contributions and dissemination. The LCS Project welcomes dialogue with engineers, managers, organizations, communities and individuals active or interested in the rural transport sector with the objective of the promotion of a sustainable rural access approach for EDCs.

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<u>Abbreviations</u>

EDC - economically Emerging and Developing Country
IFRTD - International Forum for Rural Transport and Development
ILO/ASIST - International Labour Office/Advisory Support Information Services & Training programme
ITC – Institute of Technology of Cambodia
KIHBT – Kenya Institute of Highway and Building Technology
KTC – Kisii Training Centre
LCS - Low Cost (Road) Surfacing
TRL - Transport Research Laboratory

RATIONALE FOR THE COMPILATION OF INTERNATIONAL GUIDELINES ON LOW-COST, LABOUR-BASED, ALTERNATIVE & SUSTAINABLE ROAD SURFACINGS

By Robert Petts, B Sc, C Eng, MICE, MIHT, MIAgrE., Principal Intech Associates.

1. BACKGROUND

This paper sets out the rationale for the development of guidelines on alternative road surfaces to be constructed and maintained using local labour and materials resources, and simple equipment techniques, where this approach is both feasible and appropriate. The guidelines will be developed over the period 2001 – 2003.

In many developing and emerging economies and regions the majority of the national public road network is unpaved. This proportion can typically be up to 90% or more. In addition, there are many un-adopted or unclassified roads and routes that also provide a vital service for the rural communities and the poor. Many of these routes are not surfaced. However, where provided, the usual constructed running surface for these roads is selected natural gravel or cementitious material such as laterite[1]. These naturally occurring materials are usually excavated from pits or quarries and hauled by trucks or tractors and trailers to be laid on the previously shaped formation or road surface, watered to achieve a suitable moisture content and compacted to form an 'all-weather' running surface.


Image 1 – Dusty Gravel Road through Community Centre

Unfortunately the agents of weather and traffic cause the laid material to be eroded and depleted. In natural gravel the binding fines, or clay materials, loose their cohesive properties through moisture loss in dry weather. They are then easily drawn out of the surfacing material by the action of pneumatic tyres. The losses are substantial in countries with long dry seasons. Intense rain also washes out the fines. Rates of gravel loss have been studied in a number of countries and empirical relationships have been established with regard to the various influential factors[2].

There are five very serious concerns to the national governments, development agencies and rural communities regarding the use of gravel road surfaces.

- *Financial and Economic Cost*

Firstly there is the financial and economic cost of the provision and on-going replacement of this gravel surface material. Gravel is a 'wasting' surface. Typically an initial gravel layer of 200mm will be laid as a road surfacing. Typically a residual gravel thickness of about 80 - 100mm is required to adequately support the traffic and protect the underlying weaker/erodible in-situ soil. This leaves the top approximately 100 – 120 mm of the initial surface to act as a 'wearing' layer. **Depending on factors of material, traffic, climate and gradient, the 100 - 120 mm wearing layer can be lost in between 1 to 10 years!** The full

1 Laterite is classified as a gravel surfacing for the purposes of this paper.
2 World Bank/PIARC HDM and TRL RTIM relationships.

cost of each periodic regravelling operation is usually between US$5,000 and US$30,000 per km depending on factors such as width and thickness of gravel layer, gravel quality, haulage distance, haul conditions, technology used, location, mineral fees, organisational arrangements etc. Typically a natural gravel running surface requires **US$500 - US$2,000 per km per year** to sustain in periodic regravelling costs alone, without considering the further routine maintenance costs such as grading/reshaping, patching and all off-carriageway operations (drainage etc.). Few developing country government agencies currently have the financial resources to sustain their designated gravel road networks. Communities also find it difficult to generate and allocate such quantities of funds or resources for road maintenance. Figure 1 illustrates the regular regravelling requirements due to loss of surface material in a typical situation. Figure 2 shows that inability to provide timely periodic maintenance of a gravel surface can quickly lead to the total loss of investment and all-weather access.

Further indirect costs are involved in the periodic regravelling operations. There is additional deterioration of other road network sections caused by the haulage of materials along them.

- *Institutional and management problems*

The second and widespread problem is the quantity of maintenance work required in routine maintenance and regravelling, and the burden on national and local road agencies and organisations. Institutional and management problems identified by the World Bank and others (e.g. RMI in Africa[3,4,5,6]) show deep seated, complex (and to date largely unsolved) problems of organising adequate maintenance of road networks in developing countries, particularly at the lower network levels. The physical, human and financial resources and motivating forces are simply not available to sustain the designated or desirable gravel road networks of many developing countries.

Despite strong economic and management arguments for asset preservation through good maintenance, there are anyway usually considerable political, commercial and social pressures to focus the limited available resources on the further development of the road network. For a road user or politician it may be difficult to accept that scarce resources should be allocated to re-gravel a visually good gravel surface nearing its critical residual thickness, which would prevent its deterioration to a condition requiring very expensive rehabilitation.

- *Inappropriate Technology*
- *Sustainable Employment*

The third serious problem is that of inappropriate technology. This is related to the fourth problem of lack of sustainable employment opportunities and the way this constrains **poverty alleviation** initiatives. Regravelling is usually carried out using imported, heavy equipment methods, which have been designed for a high-wage, low-investment-cost environment. This equipment requires considerable financial investment in a high-cost finance environment (local market finance interest rates are characteristically 25 – 60% p.a.)[7] which is typical in many EDCs. There are also very serious problems of ownership and

3 World Bank & Economic Commission for Africa, Sub-Saharan Africa Transport Program, Road Maintenance Initiative, Road Maintenance Policy Seminars, 1989.

4 Rural Roads in Sub-Saharan Africa, Lessons from World Bank Experience, John Riverson, Juan Gaviria, & Sydney Thriscutt, World Bank Technical Paper Number 141, 1991.

5 Road Deterioration in Developing Countries, Causes and Remedies, World Bank Policy Study, 1988.

6 Roads 2000, a Programme for Labour and Tractor Based Maintenance of the Classified Roads Network, paper for the RMI Road Maintenance Policy Seminar, Nairobi, Robert Petts, Intech Associates, 2 – 5 June 1992.

7 MART Working Paper No 2, Selective Experience of Training, Contracting and the Use of Intermediate Equipment for Labour-based Roadworks, Larcher & Petts, 1997.

operation of this sophisticated equipment in developing countries (see Figure 3), and common lack of appreciation of the total real costs involved. Furthermore, the local communities, small enterprises and the poor have no stake in this technology, which primarily benefits manufacturing stakeholders, large contractors, and often protected interests in the developing country. Even gravelling by tractors and trailers has a high equipment provision and operation cost component.

It is desirable to provide low initial cost, essential basic access to all rural and urban communities. This should be achieved using affordable and sustainable technologies (both in provision and maintenance). There will be a greater chance of sustainability if local resources (materials, labour and simple equipment), management, enterprises and communities can be involved in an effective way.

- *Environment*

The fifth equally important concern is with regard to the environment. There are three main issues in this respect. The first issue is that good gravel and laterite deposits are particularly limited and they are a non-replaceable resource. In many areas the local deposits are non-existent, not accessible because they are under farm land or worked out, leading to extremely expensive hauls of up to 50 km and more. This can place engineers under pressure to accept lower quality gravel from closer locations, leading to even higher rates of surface gravel loss.

The second environmental (health and social) issue is that of the dry weather dust pollution for road users and the people who are living adjacent to the road. This can lead to cleanliness and health problems, as well as damage to crops and property, and increased wear on vehicles.

The third environmental issue also has social and economic dimensions. Dust emissions can cause a severe visibility related safety hazard for road users, particularly for overtaking movements, and for pedestrians, animals and slow moving vehicles on the road.

The foregoing problems combine to make gravel an inappropriate surfacing for many road locations in developing countries and the lack of approved, appropriate and affordable alternative road surfaces is a serious impediment to ALL development activities, particularly in the rural areas. The poor and disadvantaged groups in society are particularly affected.

2. THE PROPOSED STRATEGY

Image 2 – Dressed Stone Paving under Construction

Fortunately there is a range of alternative **low-cost** surfacings which are already proven and used in various locations around the world. These methods can use **labour-based** approaches, typically generating more than 1,500 worker-days per km during construction. The local communities (particularly the **poor** and otherwise **unemployed**) would benefit considerably from their adoption in terms of **productive work creation**, **empowerment** of groups that currently are severely disadvantaged, and **local enterprise creation.** These advantages are in addition to the economic benefits to the poor communities through provision of **improved infrastructure** that would otherwise not be provided, and tackling poverty through creation of increased **social and economic opportunities** in the communities. Appropriate use of the various surfacing options would depend on local circumstances.

The labour-based techniques can create equal opportunities for female employment where properly managed and social traditions are approached sensitively with suitable consultation. The alternative surfacings are often **low maintenance** so that they would considerably ease the **financial** and (intractable) **institutional** burdens on road authorities and communities. Organisations, enterprises and community groupings with limited resources and skills could use them. The alternative surfacings would also provide considerable **environmental** benefits. They should be more **sustainable**.

There is also considerable potential to use the alternative surfacings on short particular problem sections such as through villages, weak subgrades and hill sections; effectively a 'spot improvement' or basic access approach for situations when resources are particularly constrained. Gravel is anyway not recommended for gradients of more than 6% due to severe erosion in heavy rainfall[8]. Considering the wide range of circumstances and factors, which usually vary along a road route, it is often appropriate to specify different surfaces and paving thicknesses for various sections.

Image 3 – Bamboo Reinforced Concrete Paving

Improvement options range from very low cost 'hardening' of earth road access suitable for non-motorised transport or motorcycles, up to paving suitable for very heavy truck axle loads. All of these techniques can be implemented using labour and simple equipment. Basic access can be provided and maintained in many situations for annualised funding or resourcing of much less than US$1,000 per km per year equivalent, principally using resources available within the community.

A particular constraint is that the alternative surfacing techniques are not properly documented and accessible; decision makers are usually not aware of the options, potential, requirements, cost and benefits.

Authoritative guidelines are required to enable road authorities and other interested groups in developing countries to understand the technology, issues and features of these low-cost, appropriate surfaces and enable them to be more widely adopted.

Image 4 – Hand Laid Bituminous Surface Dressing

The labour orientated road base and surfacing techniques on which the project will focus are listed and described in Figure 4.

8 Road Building in the Tropics, Dr R. S. Millard, TRL, 1993.

The project will carry out a review of the experiences with labour-based alternative road surfaces in developing countries, particularly in Africa and Asia. The countries of India, Bangladesh, Nepal and China are of particular interest due to their wider experiences with these forms of road pavement. It is intended to review experiences in Southern and Eastern Africa, Arabia, the Americas and other regions where these techniques are identified. The project will also review the experiences of pavements in Holland (brick paving) and France (stone paving) where they are still widely used despite the significantly higher wage costs now prevailing.

The issues which will be investigated on a national/regional basis will include:-

- Stage of local development (pilot/demonstration, isolated or 'mainstreamed')
- National standards, codes of practice and specifications
- Applicability/Limitations of the technique (terrain, traffic, climate, materials etc.)
- Planning and policy issues
- Affordable and sustainable standards relating to local transport needs
- Documentation on construction methods & techniques
- Methods of quality control and testing, ensuring essential technical inputs
- Resource requirements:
  - Human resources requirements - Unskilled and skilled labour components
  - Requirements for handtools and intermediate equipment
  - Materials requirements
- Productivity norms
- Typical construction and supervision costs, sample Bill of Quantities
- Maintenance requirements, arrangements, techniques and costs
- Safety Issues (workers and road users)
- Labour and employment issues
- Environmental Issues
- Socio-economic Issues
- Scope for (or constraints to) local contracting/consultancy application, and contracting issues
- Lessons for 'mainstreaming' strategy (if appropriate), with respect to demonstration, awareness creation & training etc.


Image 5 – Pavé (small stone paving) and Concrete Block Paving

The issues identified above will be investigated and draft guidelines will be prepared as a basis for peer review and limited trials to refine technical, management, socio-economic, gender, environmental, cost, resource poverty alleviation and sustainability issues. The resulting experiences will allow the guidelines to be further developed and finalised for possible dissemination through PIARC (World Road Association) which is a global, authoritative organisation representing the interests of national road authorities and other stakeholders in the road sector. PIARC has a declared policy of targeting the needs of developing countries, particularly through the work of its Committee C20 – Appropriate Development. Other dissemination paths include established links with ILO/ASIST, IFRTD, TRL, and training links with organisations such as KIHBT and KTC. There is also a network of universities and organisations active in the appropriate technology roadworks sector. These include ITC (Cambodia), Chieng Mai University (Thailand), the University of Witwatersrand (South Africa) and other interested academic institutions.

The project will liaise closely with TRL. This organisation is currently carrying out/preparing a number of research programmes which are of important and complementary relevance to this project. These include research into bitumen alternative road pavements including the use of labour-based technology (Environmentally Optimised Design), Minimising the cost of sustainable rural road access and the Labour-based Engineering Standards Programme.

Close cooperation will be established with these programmes through an International Focus Group.

The outputs from the Low Cost Surfacing (LCS) project will feed into the Transport Links website[9] established by TRL which will enable a long term exchange of research and experiences to be established, and a worldwide accessibility to the project outputs. Other effective dissemination routes e.g. NGOs will also be investigated.

Abbreviations

IFRTD - International Forum for Rural Transport and Development
ILO/ASIST - International Labour Office/Advisory Support Information Services & Training programme
ITC – Institute of Technology of Cambodia
KIHBT – Kenya Institute of Highway and Building Technology
KTC – Kisii Training Centre
LCS - Low Cost (Road) Surfacing
TRL - Transport Research Laboratory

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9 www.transport-links.org

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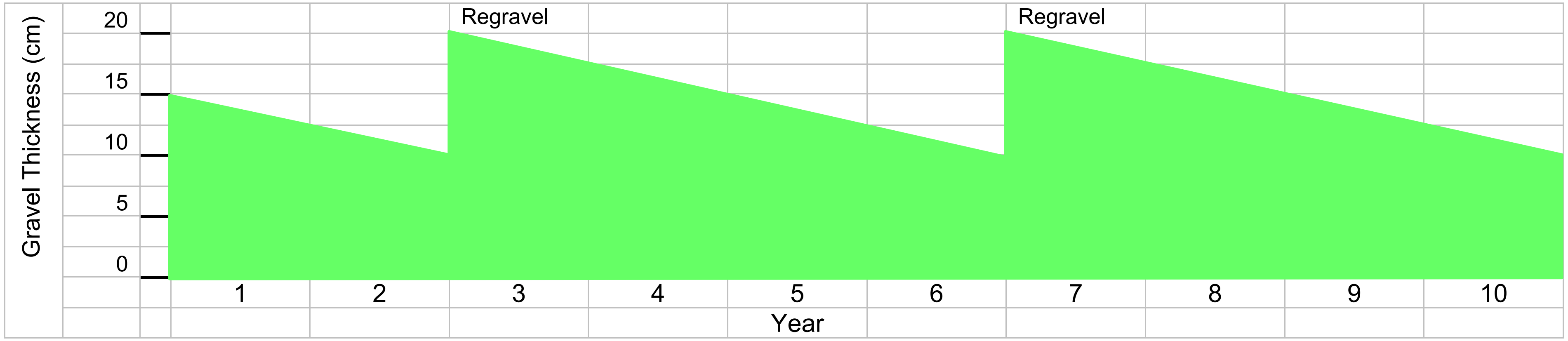
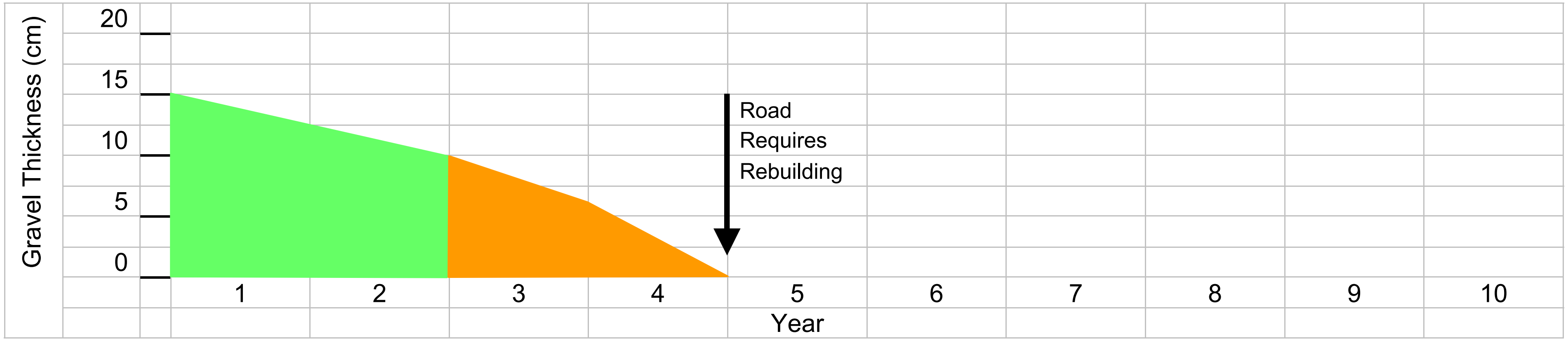
Figure 1 - GRAVEL THICKNESS **WITH** PREVENTATIVE MAINTENANCE (Including timely re-gravelling)



Sustainability of gravel surfacing is particularly dependent on timely availability of considerable financial & physical resources at frequent intervals for regravelling. Many road authorities/communities have difficulty in achieving this.

Figure 2 - GRAVEL THICKNESS **WITHOUT** PREVENTATIVE MAINTENANCE (**No** timely re-gravelling - investment is lost!)



NOTE: Based on deterioration rates predicted for lateritic gravel roads, hilly, high rainfall (2,000 mm/year) with traffic of 20 vpd by TRRL Laboratory Report 1111 and incorporated in RTIM. Use of poor quality material will cause even faster rates of gravel loss.

FIGURE 3 - PROBLEMS OFTEN ASSOCIATED WITH SOPHISTICATED IMPORTED HEAVY EQUIPMENT FOR ROADWORKS IN DEVELOPING COUNTRIES

Operational:

- Dedicated function (can only be used for one operation)
- Inter-dependence (e.g. dozer, loader, trucks, motorgrader, bowser, roller all required for gravelling – what happens when ONE link in the chain breaks down?)
- Lack of continuity of workload for plant items of dedicated function
- Usually based at locations remote from worksites – plant transporters required and long mobilization/demobilization distances involved

Technical:

- High pressure hydraulic systems
- Sophisticated mechanisms and hydraulics
- Disposable components; difficult to repair or refurbish

Local Support and Equipment Maintenance:

- Limited local market for equipment sales of each model
- Specialist repair and maintenance skills, tools and facilities required (often only available in the capital city)
- Few dealers able to provide the necessary close support
- Long spares supply lines and delivery times
- Frequent model "improvements" causing spares stocking and procurement problems and "planned" obsolescence

Cost:

- All equipment and spares imported – consuming scarce foreign exchange
- High capital and finance costs
- High costs of stocking and provision of spares

RESULT - low availability & high overall costs!

Source: Intech Associates

FIGURE 4 - SCHEDULE OF ALTERNATIVE ROAD SURFACE IMPROVEMENTS

	Road Surface Improvement Options	Description *(A roadbase option may need to be used in combination with the selected surface improvement)*
C1	Dragging Road Surface	Smoothing out minor defects on an earth or gravel road surface and redistributing loose material on the surface, using tyre or blade drag.
C2	Light Grading/Reshaping of Surface	Minor reshaping of an earth or gravel surface to restore correct camber using labour or light/heavy grading equipment.
C3	Construct Natural Gravel Surface	A layer of compacted natural gravel wearing course (typically 15 – 20cm thick)
C4	Lime Stabilization of Existing Surface	Addition of and mixing of quicklime or hydrated lime to a soil or surface material, watering and compaction to increase its strength and reduce its susceptibility to the weakening effect of increasing moisture content. This is achieved by chemical reaction of the lime with the clay particles. Mixing and compaction by light or heavy equipment.
C5	Stone Chippings Surface	A layer of single sized (typically 20mm) crushed stone chippings.
C6	Construct Hand Packed Stone Surface	A layer (typically 20 – 30cm thick) of large broken stone pieces, tightly packed and wedged in place with stone chips rammed by hand into joints, with remaining voids filled with sand. The Hand Packed Stone is normally bedded on a thin layer of sand/gravel.
C7	Construct Dressed Stone Surface	A layer (typically 15 – 20cm thick) of stone blocks cut (dressed) to a cubic shape by hand, laid by hand. Joints mortared/sealed or tightly packed and wedged with stone chips rammed into place with remaining voids filled with sand. The Dressed Stone is normally bedded on a thin layer of sand/gravel.
C8	Construct Stone Sett Surface (Pavé)	As dressed stone, however stone blocks are smaller; typically about 10cm x 10cm x 10cm with mortared joints.
C9	Construct Concrete Block Surface	A layer of concrete blocks (typically each 10cm x 20cm and 7 – 10cm thick) laid by hand on a thin (3 – 5cm) sand bed with joints also filled with sand and lightly compacted.
C10	Construct Clay Brick Surface	A layer of high quality clay bricks (typically each 10cm x 20cm and 7 – 10cm thick) laid by hand on a thin sand bed with joints also filled with sand and lightly compacted, or bedded & jointed with cement mortar.
C11	Construct Bamboo Reinforced Concrete Surface	Jointed slabs of structural quality concrete reinforced with a split bamboo rod grid. Joints with steel weight transfer dowels and bitumen seal.
C12	Construct Steel Reinforced Concrete Surface	Jointed slabs of structural quality concrete reinforced with a mild steel rod grid. Joints with steel weight transfer dowels and bitumen seal.
C13	Construct Bituminous/Tar Sand Seal Surface	A seal consisting of a hand or machine applied film of bitumen (straight run, cutback or emulsion) or road tar followed by the application of excess angular sand or fine crushed stone, lightly rolled into the bitumen/tar.
C14	Construct Ottaseal Surface	A layer consisting of a hand or machine applied film of relatively soft bitumen (usually straight run or cutback) followed by the application of graded natural gravel or crushed stone aggregate (typically 16mm downwards), rolled into the bitumen using heavy pneumatic tyred rollers.
C15	Construct Bitumen/Tar Surface Dressing Surface	A seal consisting of a hand or machine applied film of bitumen (straight run, cutback or emulsion) or road tar followed by the application of a single layer of single sized (6 – 20mm) stone chippings, lightly rolled into the bitumen/tar.
C16	Construct Bitumen Slurry Seal Surface (and "Cape" Seals)	A seal consisting of fine graded aggregates (typically 10mm downwards), water, bitumen emulsion, cement, and sometimes an additive, mixed in a concrete mixer or other machine and spread on the road surface by hand or machine. Cape seals are combinations of Surface Dressing and Slurry Seal.
C17	Construct Bituminous Premix Macadam Surface	Graded crushed stone material (typically 28mm downwards) usually derived from fresh sound quarried rock, boulders or granular material and mixed with a bituminous binder (straight run, cutback or emulsion) and laid and compacted. Material may be hand or machine mixed and laid. Compaction by light or heavy equipment.
C18	Construct Penetration Macadam Surface	Two or three layers of single size crushed stone (of decreasing nominal aggregate size, e.g. 63 mm downwards) each compacted and with bitumen (straight run, cutback or emulsion) or road tar sprayed between each stone application.
C19	Construct Water Bound Macadam Roadbase	A layer of nominal single sized (typically up to 50mm) crushed stone compacted and fully blinded with well graded fine aggregate which is watered into the voids and compacted to produce a dense stable material. Layer thickness up to twice the nominal stone size. Material may be hand or machine crushed and laid.
C20	Construct Dry Bound Macadam Roadbase	A layer of nominal single sized (typically up to 50mm) crushed stone compacted and fully blinded with angular sand or fine crushed stone material which is then vibro-compacted to produce a dense stable material. Layer thickness up to twice the nominal stone size. Material may be hand or machine crushed and laid. Suitable in areas short of water.
C21	Construct Slurry Bound Macadam Roadbase	A layer (about 7cm thick) of single size aggregate (typically 50mm) blinded with smaller aggregate (typically 25mm), plate compacted and grouted with bitumen emulsion slurry before final compaction.
C22	Construct Crushed Stone Roadbase	A layer (usually up to 20cm thick) of graded crushed stone material (typically 50mm downwards) usually derived from fresh sound quarried rock, boulders or granular material. The angular material derives its strength primarily from mechanical interlock. Material may be hand or machine crushed.
C23	Construct Mechanically Stabilised Roadbase	Addition and mixing of granular material such as crushed stone or sand to a material to increase its strength and achieve the properties required of a roadbase.
C24	• Construct Chemical or Emulsion Stabilized Roadbase	Addition and mixing of a stabilizer such as lime, cement, or ion exchange chemicals, to a material to increase its strength and achieve the properties required of a roadbase. Mixing and compaction by light or heavy equipment.
C25	• Improvement using Recycled Materials	Use of recycled road pavement materials, brick kiln waste, broken brick, demolition materials, industrial slags, etc.

C1 & C2 are maintenance/surface improvements, C3 – C18 are surface options, C19 – C25 are lower pavement layer options.