Intech Associates
CONSULTING ENGINEERS

IN ASSOCIATION WITH

Transport Development Strategy Institute

SUPPORTED BY

DFID Department for International Development

MINISTRY OF TRANSPORT VIETNAM

Rural Transport Project 2

RRST GUIDELINES

RURAL ROAD PAVEMENT CONSTRUCTION

RRST OPTIONS

Included within SEACAP 1

July 2007

FOREWORD

These Guidelines have been prepared as an assignment by Intech-TRL under the South East Asia Community Access Programme (SEACAP) funded by DFID under support for the Vietnam Ministry of Transport second Rural Transport Program (RT2).

The Guidelines synthesize the knowledge and experience developed under the Rural Road Surfacing Research (RRSR); including the Rural Road Surfacing Trials (RRST) and Rural Road Gravel Assessment Programme (RRGAP), as well as from other sources.

The RRST construction trials have confirmed the need for clear and informative guidelines to aid both the contractors and supervisors of construction of the range of rural pavement options. A wide range of technical pavement-layer specifications have been developed, applied and refined in both RRST programmes. These supervision and construction guidelines synthesize the accumulated substantial experience and knowledge and provide guidance on the range of trialed paving techniques, including:

- Explanation of key issues within the specifications
- A series of clear and concise step by step guides on construction
- Key supervision issues
- Advice on supervision procedures
- Advice on in situ and laboratory control testing
- Advice on quality control

This document is an output from projects funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of the DFID.

ACKNOWLEDGEMENTS

The success and achievements of the SEACAP 1 project are due to the contributions and commitment of a large number of persons over an extend period of time. Firstly the vision and belief of Peter O'Neill and Simon Lucas of DFID in the development of the SEACAP concept and support for this particular (the first) SEACAP project is acknowledged. The local support and commitment of the Ministry of Transport and the Steering Committee chaired by Dr Nguyen Van Nhan and secretary Mr Tran Tien Son has been a vital facilitating framework for the research and dissemination work. Hoang Cong Quy (Head of RTU), Tran Quoc Thang (PMU18), Dr Nguyen Manh Hung (ITST South), Dr Vu Duc Chinh (Director, Road Laboratory 1), and the provincial administrations in the twelve RRST provinces provided invaluable cooperation and contributions to the programme. The local contractors and consultants cooperated to develop knowledge and apply and improve the various paving techniques. Strong support was also provided by Mr. Simon Ellis (Task Team Leader) and Ms. Tran Thi Minh Phuong (Operations Officer) of the World Bank. David Salter, the SEACAP Programme Manager, provided invaluable facilitation, guidance and programme support.

The sustained efforts of the Project team of Robert Petts, Dr Jasper Cook, Pham Gia Tuan, Bach The Dzung, Le Duc Tho, Ms Nguyen Quynh Lan, Nick Elsworth, Trevor Bradbury, Dr Doan Minh Tam (ITST), Ta Van Giang (ITST), Ung Viet Trung (ITST), Le Minh Duc (ITST), Dr Doan Thi Phin (TDSI), Ms Pham Kim Hanh (TDSI), Heng Kackada (Intech Cambodia), and the ITST Field Engineers also ensured the delivery of a professional and appropriate series of project outcomes.

RURAL ROAD PAVEMENT CONSTRUCTION AND SUPERVISION GUIDELINES

TABLE OF CONTENTS

APPENDICES

ABBREVIATIONS

ADT	Average Daily Traffic
ARRB	Australian Road Research Board
ASEAN	Association of South East Asian Nations
Bmb	Bamboo
BRC	Bamboo Reinforced Concrete
CAFEO	Conference of ASEAN Federation of Engineering Organisations
CBR	California Bearing Ratio
CSIR	Council for Scientific and Industrial Research (South Africa)
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development
DST	Department of Science and Technology, Ministry of Transport
EDCs	Economically emerging and Developing Countries
esa	equivalent standard axles
FHWA	Federal Highways Association (US)
FM	Fines Modulus
FWD	Falling Weight Deflectometer
GMSARN	Greater Mekong Subregion Academic and Research Network
HDM4	Highway Development and Management Model
HQ	Headquarters
IFG	International Focus Group
ILO	International Labour Organisation
IRI	International Roughness Index
ITST	Institute of Transport Science and Technology
Km	kilometre
LCS	Low Cost Surfacing
m	metre
mm	millimetre
MERLIN	**M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation
MoT	Ministry of Transport
OM	Operations Manual
PDoT	Provincial Department of Transport
PIARC	World Road Association
PMU	Project Management Unit
PPC	Provincial Peoples Committee
PPMU	Provincial Project Management Unit
QA	Quality Assurance
RITST	Research Institute of Transportation Science & Technology
RRGAP	Rural Road Gravel Assessment Programme
RRST	Rural Road Surfacing Trials
RTU	Rural Transport Unit
RT2	Rural Transport 2nd Project
SEACAP	South East Asia Community Access Programme
SOE	State Owned Enterprise
TG	Technical Guidelines
TRL	Transport Research Laboratory
VOCs	Vehicle Operating Costs
VPD	Vehicles per day
WAN	Wide Area Network
WLC	Whole Life Costs

1 INTRODUCTION

1.1 Background

Since 1998 DFID and World Bank have funded with the Ministry of Transport (MoT) two Rural Transport Projects (RT1 and RT2) in Vietnam and are in the process of initiating a third (RT3), In addition, since 2003 cooperation between the MoT, World Bank and DFID has resulted in the implementation of a significant Rural Road Surfacing Research (RRSR) programme The aim of the RRSR programme is to establish a range of sustainable road surfaces that better use local resources, minimising Whole-life-Costs and supporting the Vietnam Government's poverty alleviation and road maintenance policies.

The technical assistance work of the RRSR has been undertaken by Intech-TRL in conjunction with their local partners ITST. The various technical aspects of the RRSR are co-ordinated by a Ministry of Transport Steering Committee under the direction of the Department of Science and Technology (DST). The main element of the RRSR programme so far has been two Rural Road Surfacing Trial programmes (RRST-I and RRST-II) in which a range of alternative options have been identified, designed and incorporated into an extensive trials programme involving the construction so far of 41 trial roads in 12 provinces in five regions throughout Vietnam with varied physical characteristics.

The programme has included not only the stabilisation of local soils by lime, cement and bitumen emulsion but also more innovative options for Vietnam such as bamboo reinforced concrete, fired clay brick, concrete brick and cobble or dressed stone surfacing. An important aspect of the trials design has been the incorporation of control sections constructed using existing standard Vietnamese rural road options such as unsealed gravel or hot bitumen sealed water-bound macadam.

The RRST studies comprised two main phases. MoT, World Bank and DfID agreed an allocation of US$600,000 for the works costs of the first trials phase (RRST-I) in the provinces of:-

Region	***Province***	***Construction Budget***
Mekong Delta:	Tien Giang	US$150,000
	Dong Thap	US$175,000
Central Coastal:	Thua Thien Hue	US$150,000
	Da Nang	US$125,000

Construction of this initial research phase of trials was largely completed in 2005. The second phase (RRST-II) of longer length demonstration trials was completed in June 2006, with the construction budgets:-

Region	***Province***	***Construction Budget***
Central Highlands:	Gia Lai	US$500,000
	Dak Lak	US$400,000
	Dak Nong	US$400,000
Red River Delta:	Hung Yen	US$400,000
	Ninh Binh	US$700,000
Northern Highlands:	Tuyen Quang	US$500,000
	Ha Tinh	US$500,000
	Quang Binh	US$500,000

As part of its mainstreaming and dissemination objectives, the RRSR programme has produced a significant body of technical documentation. Included in this is a series of Technical Specifications relating to the construction of the RRST pavement options, to which this Construction Guideline is closely related.

1.2 Guideline Structure

Following this introduction (Chapter 1), the document outlines the objectives of the guideline, and its intended target audience (Chapter 2) and summarises the pavement options (Chapter 3). The main body of the document then comprises a series of technical chapters (Chapters 4-8) relating directly to specific RRST pavement options and their specifications, grouped as follows:

- Surface seals
- Stabilised bases and sub-bases
- Non stabilised bases and sub-bases
- Block pavement options
- Cement Concrete pavements

A final chapter (Chapter 9) deals with key shoulder construction issues, which influence the integrity and performance of the actual road pavements.

Following these main chapters the document contains three important appendices. The first contains a series of illustrated guides to key construction issues for the RRDST pavement options. The second highlights some fundamental issues relating to site supervision and construction quality control, whilst the third contains a series of standard site forms developed and used during the RRST construction phases.

2 GUIDELINE APPLICATION

2.1 Guideline Objectives

The SEACAP 1 Final Report identified a number of Rural Road Construction aspects that were recommended to be addressed to improve the performance of the sector and improve value-for-money for the considerable volumes of public funds invested. These included guidance for contractors and site supervisors and improved quality assurance and testing regimes. In particular the following issues were emphasised:

1. Clear training and guidance is required for both for contractors and site supervisors using some of the new trialled options in wider general application of the techniques.
2. Small scale contractors are generally not used to following technical specifications closely and may require a combination of easy-to-follow guidelines and initial close supervision.
3. There appeared to be a general initial resistance to new procedures, with many contractors, especially in RRST-II, tending to use locally established practice as default procedures without reference to contract specifications.
4. Some new option procedures are likely to be best controlled by a tightly overseen method specification approach. This is particularly true of operations where control testing may involve significant delays, e.g. concrete surfaces and lime or cement stabilisation.
5. 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.
6. 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.

The above issues highlighted the need for appropriate training and guidelines on construction and construction supervision to improve the effectiveness and efficiency of the considerable investments planned for the Vietnam rural road sector. In addition, there was also an appreciation that other rural road sector stakeholders, such as PDoT administrators, consultants or Donors, would also benefit from general guidance on construction issues related to the new surfacing and paving options.

Simplified guidelines or handbooks on the important features, precautions and requirements for each surface or paving layer type were seen as an important aid for both technical and non-technical personnel involved with the planning, approval, design, construction and supervision of rural roads.

This document therefore aims to fulfil the above needs by supplying a technical accompaniment to the RRST Technical Specifications for pavements and pavement surfacing, that:

1. Provides clear descriptions of the pavement and surfacing options,
2. Highlights key materials issues,
3. Highlights key procedures issues,
4. Illustrates examples of key activities,
5. Emphasises key supervision issues,
6. Provides useful standard forms for site use.

2.2 Guideline Users

This guideline has been drafted with the aim of being useful to a range of practitioners within the Vietnam rural road sector. It may also serve as a model within a wider regional context. The principal users of the guideline are likely to be:

Contractors: This document serves as a guide to good practice in constructing a range of rural road pavement and surface options as contractually defined in the RRST Technical Specifications. It expands upon the contract related definitions within the specifications and gives contractors a wider appreciation of the engineering principles behind the various options.

Local Consultants/PDoTs: The document provides a useful summary of the resources and expertise required for each of the RRST options. It can therefore make a valuable contribution towards the selection of pavement options appropriate to the governing road environments.

Supervisors: This document provides a guide to key issues that must be addressed regarding construction Quality Control. Key issues are highlighted with respect to control and approval of construction materials and construction procedures. A selection of standard site forms is also provided.

Infrastructure Managers/Development and Donor Agencies: This document provides useful back ground information on the resources required to effectively manage the design and construction of a range of rural road pavements. It can provide a valuable check list on activities that should be undertaken to ensure the value for money is achieved for public or donor funding.

Students: The document provides a detailed introduction to students on the new and innovative approaches to constructing rural transport infrastructure in a more cost-effective and sustainable way, making the best use of the local resources available.

3 RRST PAVEMENT AND SURFACING SPECIFICATIONS

The RRST programmes trialled a wide range of flexible, block, rigid and unsealed pavement options. Various pavement layer options were frequently combined to produce a representative matrix of rural paving options appropriate to differing Vietnamese road environments.

Original draft technical specifications were produced and approved by the MoT for trial construction purposes options. These have subsequently been reviewed by Intech-TRL in the light of the experiences gained during the trials construction, as well as taking into account the valuable comments received from the contractors and PDoT/PPMUs. The revised specifications, as listed in Table 3.1 and contained within the SEACAP 1 Final Report (Appendix L) form the basis for this guideline.

Reference	Specification
RRST 1-01	Bituminous Emulsion – Surface Dressing Chip seal
RRST 1-02	Bituminous Emulsion – Sand Seal
RRST 2-01	Gravel Sub-Base/Base
RRST 2-02	Lime Stabilised Sub-Base/Base
RRST 2-03	Cement Stabilised Sub-Base/Base
RRST 2-04	Emulsion Stabilised Sub-Base/Base
RRST 2-05	Armoured Gravel Roadbase
RRST 2-06	Sand Sub-Base
RRST 2-07	Quarry-Run Sub-Base
RRST 2-08	Graded Crushed Stone Sub-Base/Base
RRST 2-09	Sand Bedding Layer
RRST 2-10	Dry Bound Macadam Sub-Base/Base
RRST 3-01	Fired Clay Brick Pavement – Unmortared Joints
RRST 3-02	Fired Clay Brick Pavement – Mortared Joints
RRST 3-03	Cement Brick Pavement – Mortared Joints
RRST 3-04	Cobble Stone Paved Surface
RRST 3-05	Mortared Dressed Stone
RRST 4-01	Bamboo Reinforced Concrete
RRST 4-02	Steel Reinforced Concrete
RRST 4-03	Non-Reinforced Concrete

Table 3.1: RRST Pavement Specifications

4 BITUMINOUS EMULSION SURFACE SEALS

4.1 Bituminous Emulsion

4.1.1 Description

Bitumen emulsion is usually prepared by a supplier using an emulsifying plant and contains penetration grade bitumen dispersed in water. When the emulsion is used and exposed to air, the water in the emulsion evaporates or separates from the bitumen during a process of 'breaking' (and changing from brown to black in colour). This leaves the residual bitumen in place to adhere to the road-base and aggregate. Emulsion provides safer works operations than normal bitumen by avoiding the need to heat to a high temperature, and it is not flammable. For application using labour-based methods, bitumen emulsion is the preferred material to be used as the most suitable form of bitumen.

Emulsions are classified as:-

- Anionic, where the particles of bitumen are negatively charged, or
- Cationic, where the particles of bitumen are positively charged.

Use of emulsions should be compatible with the conditions and environment of the application.

Rapid setting emulsion (RS) grades are the best suited to surface dressing work to achieve rapid development of the bond between the bitumen and the other materials.

4.1.2 Key Issues

Bitumen Emulsion

- Bitumen emulsion should be from an established supplier able to provide the documentation to demonstrate compliance with the specifications.
- Documentation should be inspected to ensure it complies with the current Vietnam standard (22TCN 250-98).
- Emulsion shall be used within 3 months of manufacture and regularly agitated (rolled if stored in drums) during storage to prevent premature separation of the components.

4.2 Bituminous Emulsion Stone Chip Seal: Specification RRST 101

4.2.1 Description

Surface Dressing consists of supply and application of a seal of bituminous binder material over the previously prepared road base. The seal is immediately covered with single sized stone aggregate chippings. The chippings completely cover the seal and are lightly rolled into the seal to form an interlocking mosaic. When one application of bituminous material and aggregate is placed it is termed as Single Bituminous Surface Dressing (SBSD). When two applications of bituminous material and aggregate are placed it is termed as Double

SBSD: Spreading of stone chips

Bituminous Surface Dressing (DBSD). The surface dressing acts as a waterproof seal and running surface.

This treatment may also be used as a maintenance activity on an existing asphalt or surface dressed road to seal minor cracks and extend the life of the surface, if the existing surface has not deformed (more than 20mm under a 2m straight edge[1]).

Key issues with respect to RRST 101 are listed below and illustrated in Appendix A1.

4.2.2 Key Issues: Material Selection

Aggregate

The main qualities for sealing aggregate can be summarised as follows:

- Resistance to slow crushing
- Resistance to rapid loading or impact
- Resistance to stripping, or to have the ability to maintain adhesion with the binder
- Durability or the resistance to in-service weathering.
- Hardness or resistance to abrasion or attrition
- Resistance to polishing
- Good chip surfacing has a micro-texture that is generally skid resistant

Basic rocks (e.g. basalt) are considered to have better adhesion properties than acidic rocks (e.g. granite). The comparatively poor performance of acid (e.g. granitic) rocks may not only be related to the high silica content but to the occurrence of feldspar crystals, Experience has indicated, for example, that aggregate from a coarse granite with large feldspar inclusions is likely to encounter bitumen adhesion difficulties. Quartzites are also regarded as having poor bitumen adhesion properties. Material cleanliness or freedom from dust is also a key factor. Limits of less that 1% dust <75 microns can be difficult to obtain by screening alone and washing of the aggregate may be required.

Effective checking of grading, shape and cleanliness of potential aggregate is essential. If the source has not been previously successfully used for surfacing aggregate then a stripping test programme is strongly recommended.

4.2.3 Key Issues: Construction and Supervision

1. The road-base or existing surface should be checked for the correct shape and cross fall.
2. Bitumen emulsion work should not be carried out in wet weather, on wet surfaces, or when rain is expected before the emulsion will break.
3. Surfacing aggregates should be stored on site in clean dry areas adjacent to the road.
4. Prior to priming, the surface must be clean and free from dust, or loose material, which should be removed by brooming.
5. Aggregate chippings should be placed along the side of the road in heaps ready to apply as soon as the seal emulsion is in place.
6. Where necessary the aggregate should be screened on site.
7. Bitumen emulsion must be evenly applied by spray bar, hand lance or hand watering can application. The actual rate of spread should be regularly checked.

[1] Greater deformation would indicate pavement structural problems that should suggest more extensive remedial work is required.

8. Immediately after the application of bitumen emulsion, the stone chipping application should be made by hand from the adjacent stockpiled heaps.
9. The surface must then lightly rolled immediately with an approved 1 -3 tonne roller with NO vibration.
10. Excess aggregate shall be left in place to be bedded in or displaced by the traffic.
11. The completed surface dressing shall be allowed to dry out and cure before opening to traffic, which should take one or two days depending on weather conditions.
12. The final surface should be quality inspected.

4.2.4 Key Issues: Site Testing

The visual inspections should be made to check compliance with the drawings and specifications; for example regarding adequate surface preparation, and the size, type and cleanliness of the aggregate. Regular testing of the rate of spread of emulsion/residual bitumen will help to ensure the required construction quality.

4.3 Bituminous Emulsion Sand Seal: Specification RRST 102

4.3.1 Description

Spreading of sand on emulsion

A sand seal consists of supply and application of a seal of bituminous binder material over the previously prepared road base. The seal is immediately covered with sand or fine aggregate chippings. The sand/fine aggregate completely covers the seal and is lightly rolled into the seal to form a weather proof matrix and running surface suitable for light vehicular traffic. It is therefore suitable for application in areas with poor access to hard stone sources.

A sand seal may be used either to provide an additional layer of protection on a chip seal already laid, or as a single sealing to a block pavement; although the latter usage should only be considered after assessment of the likely adhesion between the block surface and bitumen..

This treatment may also be used as a maintenance activity on existing asphalt or surface dressed road to seal minor cracks and extend the life of the surface, if the existing surface has not deformed (more than 20mm under a 2m straight edge[2]).

4.3.2 Key Issues: Materials

Sand

This may be either appropriate natural sand or fine sand-sized aggregate that has been machine crushed or hand broken and then screened. Processed aggregate must be derived from fresh un-weathered material which can be either quarried rock or natural

[2] Greater deformation would indicate pavement structural problems that should suggest more extensive remedial work is required.

granular material such as gravel, cobbles or boulders. The sand must be clean, free from organic matter, with a clay content of not more than 2%.

The maximum aggregate size is specified as 6mm, with no more than 15% of material finer than 0.15mm.

Effective checking of grading, shape and cleanliness of potential aggregate is essential.

4.3.3 Key Issues: Construction and Supervision

1. The road-base or existing surface should be checked for the correct shape and cross fall.
2. Bitumen emulsion work should not be carried out in wet weather, on wet surfaces, or when rain is expected before the emulsion will break.
3. Surfacing sand should be stored on site in clean dry areas adjacent to the road.
4. Prior to priming the surface must be clean and free from dust, or loose material, which should be removed by brooming.
5. Sand must be placed along the side of the road in heaps ready to apply as soon as the seal emulsion is in place.
6. Where necessary the sand should be screened on site.
7. Bitumen emulsion must be evenly applied by spray bar, hand lance or hand watering can. The actual rate of spread should be regularly checked.
8. Immediately after the application of bitumen emulsion, the sand application should be made by hand from the adjacent stockpiled heaps.
9. The surface must then be lightly rolled immediately with an approved 1 -3 tonne roller with NO vibration.
10. Excess sand/fine material shall be left in place to be bedded in or displaced by the traffic.
11. The completed surface dressing shall be allowed to dry out and cure before opening to traffic, which should take one or two days depending on weather conditions.
12. The final surface should be quality inspected.

4.3.4 Key Issues: Site Testing

The visual inspections should be made to check compliance with the drawings and specifications; for example regarding adequate surface preparation, and the size, type and cleanliness of the sand. Regular testing of the rate of spread of emulsion/residual bitumen will help to ensure the required construction quality.

5 STABILISED BASE AND SUB-BASE

5.1 Stabilisation Options

5.1.1 General

When the only economically available natural materials contain a considerable quantity of high plasticity fine material and/or a relatively high proportion of weak particles, it may become impractical or even impossible to produce a satisfactory base or sub-base from the untreated material. In such cases locally available materials may be effectively improved by treatment with an additive such as cement, lime, bitumen or a proprietary chemical.

The stabilisation of natural materials can involve a variety of materials and procedures, including the use of specialised equipment. The RRST procedures described in this document are concerned only with the in situ mixing of the following stabilisers, using locally available agricultural equipment.

- Hydrated Lime: Specification RRST 202
- Portland Cement: Specification RRST 203
- Bitumen Emulsion: Specification RRST 204

Stabilisation is carried out primarily to increase strength and bearing capacity, although other benefits can be achieved such as:

- To control volume or strength variability when moisture content changes.
- To increase the resistance to erosion, weathering or traffic usage.
- To reduce the permeability of the stabilised soil.

Many natural materials can be stabilised to make them suitable for road pavements but this process is only economical when the cost of overcoming a deficiency in one material is less than the cost of importing another which is satisfactory without stabilisation.

5.1.2 Stabiliser Selection

Selection of the appropriate stabiliser is a key initial issue and the principal factor to be considered when selecting the most suitable method of treatment is the type and geotechnical nature of the material to be treated. Figure 5.1 provides initial guidance on the selection of appropriate methods of treatment for natural materials based on their grading and plasticity characteristics. The usual range of suitability for applying the various types of stabilisation is defined by the percentage of material passing the 0.075 mm sieve and the plasticity index (PI) of the soil.

In general terms it would be expected that clay soils would be more suitable for lime stabilisation and more sandy materials would be suited to cement or emulsion stabilisation

Other factors to be taken into account are:

- Climatic conditions
- Requirements of the stabilised material
- The capabilities and experience of the construction personnel
- The availability of specialist construction plant
- The availability of testing facilities for investigation and subsequent quality control
- Relative costs

Climatic factors can significantly influence the choice of treatment selected and may affect the practicality of construction. In wetter areas where the moisture content of pavement materials is high, it is important to ensure that the wet strength of the treated material is adequate and that susceptibility to moisture variations is low. Climatic conditions and the pavement environment will also influence the resistance of stabilised materials to carbonation.

Type of Stabilisation	**Soil Properties**					
	More than 25% passing the 0.075 mm sieve			Less than 25% passing the 0.075mm sieve		
	PI < 10	10<PI<20	PI > 20	PI < 6 PP < 60	PI < 10	PI > 10
Cement	S	S	M	S	S	S
Lime	M	S	S	X	M	S
Bitumen/Emulsion	M	M	X	S	S	X

Key

PI: Plasticity Index PP: Plasticity Product (PI x % passing 0.075mm)

S: Suitable M Marginally Effective

X: Not Suitable

Table 5.1: Guide to the type of stabilisation likely to be effective

5.1.3 Special Testing Procedures

Laboratory strength testing on the proposed materials during the design phase of any rural road works must indicate the percentages of stabiliser required for effective modification of the natural materials. This testing must be repeated on the actually identified project material sources as soon as they are confirmed at contract stage.

Whilst the CBR test is generally the norm for testing base and sub-base materials it is preferable in some case to use unconfined compression tests (UCS), particularly for cement stabilised materials wherever possible. This is because the nature and strength behaviour of the stabilised material is very different to the crushed rock material that defines the CBR test.

Neither CBR nor UCS control testing is appropriate for bitumen emulsion stabilised materials. This is discussed further in section 5.4.3, below.

As the increase of strength of stabilised materials occurs over relatively long periods of time, samples are generally cured for 7, 14 or 28 days prior to testing. A seven-day curing period, although arbitrary, is often chosen as a convenient reference for cement treated materials, whilst a longer twenty-eight day period is chosen for lime treated materials to take into account their slower strength gain. In high rainfall and high water table environments of Vietnam a 7 day soaking period should also be incorporated into any control testing on cement or lime stabilised materials to provide an early indication whether there is cause for concern.

5.1.4 Construction Plant

The following essential plant should be available and in good proven working order on site:

- Single axle tractor rotovator or 2-axle tractor driven rotovator with blades capable of mixing to a loose material depth of 20 cm or more.
- A minimum 3 tonne vibrating roller; equivalent pneumatic tyred rollers are also recommended by some authorities, although these were not trialled under the RRST programme.

5.2 Lime Stabilised Sub-Base/Base; Specification RRST 202

5.2.1 Description

Lime is commonly used world-wide to improve the engineering properties of certain appropriate in situ or imported soils materials. The chemical is normally used in its hydrated or slaked form (calcium hydroxide), and is most often applied where soils have a high plasticity. In the context of Vietnamese rural roads, hydrated lime improvement or stabilisation of local soils for road-base, sub-base, or shoulders may be used as a viable alternative to the importation of higher grade road building materials.

When lime is added to a plastic material, it first flocculates the clay and substantially reduces the plasticity. The removal of water and the increase in Plastic Limit cause a substantial and rapid increase in the strength and traffickability of the material.

Typically 3 to 8 percent stabiliser is necessary to gain a significant increase in the compressive and tensile strengths. The gain in strength with lime stabilisation is slower than that for cement and a much longer time is therefore available for mixing and compaction. The reduction of plasticity and increase in strength is time dependent during the initial weeks and the production of cementitious compounds can continue for 1 or more years, the strength developed will be influenced by the materials and the environment. The elastic modulus varies similarly to the strength and continues to increase over time.

5.2.2 Key Issues: Materials

Lime

Lime to be used in the stabilisation should be in its powdered hydrated form [Ca(OH)2] complying with Transport Sector Standard 22TCN81-84 in general and Specification RRST 202 in particular.

Adequate checks should be made on the chemical analysis reports for each source of lime indicating the amount of "available lime".

Natural Materials

It is essential to check the grading and plasticity of the proposed sources of natural material, both prior to construction and during its progress. These properties should not vary to any significant extent from the material on which the stabilisation mix designs were based. If there is any significant variation, then a new mix design testing programme is recommended.

Stabilised Materials

Testing of stabilised material should comprise the following:

- Strength and index testing of laboratory mixed lime stabilised material from the designated natural material source prior to construction.
- Strength and index testing of on-site mixed materials during construction.

California Bearing Ratio (CBR) Test is normally the strength test procedure adopted for lime stabilised materials. This testing should be undertaken on materials at the specified degree of compaction. The curing period for lime-stabilised materials is 21 days of moist cure followed by 7 days of soaking.

5.2.3 Key Issues: Construction and Supervision

1. Imported local soil must be placed on a previously prepared and approved sub-grade or sub-base to a loose thickness sufficient to achieve the final compacted thickness. The in situ soil may be used if it is of suitable characteristics and shaped to the required cross section.
2. Stabilisation work should not be carried out in wet weather, on wet surfaces, or when rain is expected before the completed work can be covered and protected.
3. Ensure that the base or sub-base layers are placed over the full required width, including the shoulders if these are being constructed in a combined procedure.
4. The soil to be treated must be processed by breaking up and pre-mixing using approved single axle tractor rotovators or 2-axle tractor driven rotovators. Hard soil must be loosened initially by hand tools or scarifying equipment.
5. Ensure that particles over 5mm do not exceed 25% and those over 10mm do not exceed 10% by weight.
6. After breakdown the material must be shaped and the layer tamp sealed with a single pass by a roller.
7. Bags of lime should be accurately spaced at equal intervals along the section to be treated so as to provide the specified rate of application.
8. The bags should be opened and the lime spread by hand tools in transverse rows over the full width to be treated.
9. Uniform distribution of the lime over the entire surface should be attained by levelling off the lime rows by hand rakes and/or screeds.
10. Immediately after the lime has been spread, it must be mixed by rotavator with the loose soil for the full depth of treatment.
11. The target soil moisture content should generally be just below the standard optimum content.

12. Addition of water to achieve the target design moisture content should only be carried out after an initial dry mixing phase. Ensure there is satisfactory moisture distribution over the full depth, width and length of the section being treated.
13. Prevent any portion of the work from getting excessively wet after the lime has been added.
14. Mixing must be continued until a thorough and uniform mix of the soil and lime has been achieved over the full width, length and depth of the material being treated, which must be homogeneous and of uniform appearance throughout.
15. Ensure there is no disturbance of any previously compacted layer.
16. After mixing has been satisfactorily completed the layer must be shaped and then tamped for 1-2 passes using the roller with vibration switched OFF. Compaction with vibration switched ON should then be completed as per the specification.
17. The exact number of passes, (generally in the region of 6-8) should be determined from compaction–density testing undertaken on the initial pilot section.
18. Final compaction and shaping must be completed within 24 hours of mixing, before the initial hardening of the stabilised soil.
19. The finished layer must be cured for a period of 28 days.
20. Traffic or any other equipment, other than that involved in the curing process, must not be allowed onto the treated material for the first seven days after compaction.
21. In the case of a 2-layer construction the second layer construction may be carried out immediately after compaction of the first layer is completed.
22. In the cases where the sub-base or road base is not to be emulsion sealed, a layer of sand, 40 to 50mm thick, must be spread over the treated material and kept damp by regular watering in intervals not exceeding 24 hours in dry weather.

5.2.4 Key Issues: Site Testing

On-site testing should be a combination on in-situ sand replacement density and DCP testing.

The DCP test may be used as an immediate guide to compaction and as the control on quality once a relationship has been established between density-moisture condition and DCP-CBR for the particular materials concerned. This relationship should be established during short pilot sections at the start of the road construction for each material type/source.

5.3 Cement Stabilised Sub-Base/Base; Specification RRST 2.03

5.3.1 Description

Cement is commonly used worldwide to improve the engineering properties of certain appropriate in situ or imported soils materials. In the context of Vietnamese rural roads, cement improvement or stabilisation of local soils for road-base, sub-base or shoulders may be used as an economically viable alternative to the importation of higher-grade road building materials.

Although cement can be used to stabilise most soils it is most commonly employed in sandy materials and is generally not effective in soils with a high organic content or those with high clay content.

Addition of cement results in a reduction in plasticity and swell, and an increase in strength and bearing capacity. The cement content determines whether the characteristics of the mixture are dominated by the properties of the original soil (grain interlock) or by the hydration products (cemented matrix). As the proportion of cement in the mixture increases, so the strength increases. Strength also increases with time. During the first one or two days after construction this increase is rapid. Thereafter, the rate slows down although strength gain continues provided the layer is well cured.

Typically 3 to 6 percent of cement has been used in the RRST project to effectively stabilise sandy soils. The choice of cement content will depend on the strength required and the nature of the material to be stabilised.

5.3.2 *Key Issues: Materials*

Cement

Portland or other kinds of cement used for stabilisation should be checked to ensure it meets the requirements defined in the following:

- Chemical Testing Methods: TCVN 140-64
- Mechanic Testing Methods: TCVN 140-64

Adequate checks should be made on the chemical analysis reports for each source of cement; in general, cement grade 300 or better may be used for soil stabilisation. Site checks should be made to ensure the cement, as delivered, is of the agreed type and from the agreed source, and that it is not “old stock” that has been affected by moisture.

Natural Materials

It is essential to check the grading and plasticity of the proposed sources of natural material, both prior to construction and during its progress. These properties should not vary to any significant extent from the material on which the stabilisation mix designs were based. If there is any significant variation then a new mix design testing programme is recommended.

Stabilised Materials

Testing of stabilised material should comprise the following:

- Strength and index testing of laboratory mixed cement stabilised material from the designated natural material source prior to construction.
- Strength and index testing of on-site mixed materials during construction.

Uniaxial Compressive Strength (UCS) testing is normally the strength test procedure adopted for cement stabilised materials. This testing should be undertaken on materials at the specified degree of compaction. A 7 day curing period can be adopted, followed by 7 day soaking, for cement-stabilised materials. Comparisons can be made between UCS and CBR using the following correlation

$$\text{UCS (MPa)} = 0.00468 \times \text{CBR (Ref: SADC Guidelines)}$$

5.3.3 *Key Issues: Construction and Supervision*

1. Imported soil, usually sandy, must be placed on a previously prepared and approved sub-grade or sub-base to a loose thickness sufficient to achieve the final compacted thickness.

The in situ soil may be used if it is of suitable characteristics and shaped to the required cross section.

2. Stabilisation work should not be carried out in wet weather, on wet surfaces, or when rain is expected before the completed work can be covered and protected.
3. Ensure that the base or sub-base layers are placed over the full required width, including the shoulders if these are being constructed in a combined procedure.
4. The soil to be treated must be processed by breaking up and pre-mixing using approved single axle tractor rotovators or 2-axle tractor driven rotovators. Hard soil must be loosened initially by hand tools or scarifying equipment.
5. Ensure that particles over 5mm do not exceed 25% and those over 10mm do not exceed 10% by weight.
6. After breakdown the material must be shaped and the layer tamp sealed with a single pass by a roller.
7. Bags of cement should be accurately spaced at equal intervals along the section to be treated so as to provide the specified rate of application.
8. The bags should be opened and the cement spread by hand tools in transverse rows over the full width to be treated.
9. Uniform distribution of the cement over the entire surface should be attained by levelling off the cement rows by hand rakes and/or screeds.
10. Immediately after the cement has been spread, it must be mixed by rotavator with the loose soil for the full depth of treatment.
11. The target soil moisture content should generally be just below the standard optimum content.
12. Addition of water to achieve the target design moisture content should only be carried out after an initial dry mixing phase. Ensure there is satisfactory moisture distribution over the full depth, width and length of the section being treated.
13. Prevent any portion of the work from getting excessively wet after the cement has been added.
14. Mixing must be continued until a thorough and uniform mix of the soil and cement has been achieved over the full width, length and depth of the material being treated, which must homogeneous and of uniform appearance throughout.
15. Ensure there is no disturbance of any previously compacted layer.
16. After mixing has been satisfactorily completed the layer must be shaped and then tamped for 1-2 passes using the approved vibrating roller with vibration switched OFF. Compaction with vibration switched ON should then be completed as per the specification.
17. The exact number of passes, (generally in the region of 6-8) should be determined from compaction–density testing undertaken on an initial pilot section.
18. Final compaction and shaping must be completed within 6 hours of mixing, before hardening of the stabilised soil.
19. The finished layer must be cured for a period of 7 days.
20. Traffic or any other equipment, other than that involved in the curing process, must not be allowed onto the treated material for the first seven days after compaction.
23. In the case of a 2-layer construction the second layer construction may be carried out immediately after compaction of the first layer is completed.

24. In the cases where the sub-base or road base is not to be emulsion sealed, a layer of sand, 40 to 50mm thick, must be spread over the treated material and kept damp by regular watering in intervals not exceeding 24 hours in dry weather.

5.3.4 Key Issues: Site Testing

On-site testing should be a combination on in-situ sand replacement density and DCP testing.

The DCP test may be used as an immediate guide to compaction and as the control on quality once a relationship has been established between density-moisture condition and DCP-CBR for the particular materials concerned. This relationship should be established during short pilot sections at the start of the road construction for each material type/source..

5.4 Emulsion Stabilised Sand for Sub-Base; Specification RRST 2.04

5.4.1 Description


On-site mixing of emulsion with sand

The action of bitumen or bitumen emulsion mixed with certain soils is as a binder, a water repellent, reducing dimensional changes, erosion and loss of strength associated with wetting-up of soils. The water in the emulsion evaporates or separates from the emulsion during a process of 'breaking' (and changing from brown to black in colour), leaving the residual bitumen in place to bind the host material. Bitumen emulsion contains penetration grade bitumen dispersed in water. Stabilisation with bitumen emulsion, a suspension of bitumen particles in water, is an effective method of achieving good dispersion of bitumen in materials with low plasticity characteristics (PI< 6%). Materials with higher plasticity characteristics may be pre-treated with lime, but this will tend to be prohibitively expensive in the case of low volume sealed roads.

Bitumen emulsion is most successfully used with granular soils, where it can result in the improvement of the following properties: flexibility (crack resistance); resistance to weakening by moisture (water proofing) and deceased permeability; and increased cohesion and hence durability.

Bitumen emulsion stabilisation of gravelly to silty sands may sometimes be a viable alternative to cement treatment, particularly in cases when bitumen is favourably priced with respect to cement. It may also be favoured in situations where resistance to cracking is required. In the context of Vietnamese rural roads, bitumen emulsion stabilisation of local soils for road-base, sub-base or shoulders may be used as an economically viable alternative to the importation of higher-grade road building materials.

The strength of bitumen treated materials is usually assessed in terms of Marshall Stability or Hubbard-Field stability at 60 degrees centigrade.

5.4.2 Key Issues: Materials

Bitumen Emulsion

Use of emulsions should be compatible with the nature, conditions and environment of the materials being stabilised. Slow setting ANIONIC or CATIONIC emulsion (SS) grades are to be used for soil stabilisation rather than medium (MS) or rapid setting (RS) types, which are unsuitable.

Bitumen emulsion should be from an established supplier able to provide the documentation to demonstrate compliance with the specifications.

Documentation should be inspected to ensure it complies with the current Vietnam standard (22TCN 250-98).

Emulsion shall be used within 3 months of manufacture and regularly agitated (rolled if stored in drums) during storage to prevent premature separation of the components.

Natural Materials

It is essential to check the grading and plasticity of the proposed sources of natural material, both prior to construction and during it progress. These properties should not vary to any significant extent from the material on which the stabilisation mix designs were based. If there is any significant variation then a new mix design testing programme is recommended.

Stabilised Materials

Standard strength testing of emulsion stabilised materials by CBR or Unconfined Compressive Strength (UCS) methods is not a valid option. Correlation with design calculations can be undertaken by using Marshall Stability testing procedures on site-mixed samples.

5.4.3 Key Issues: Construction and Supervision

This procedure has only undergone limited trials in Vietnam and construction and supervision procedures are still to be fully evolved. The following notes represent the current knowledge and may require some modification in the light of continuing experience.

1. Imported soil, usually sandy, must be placed on a previously prepared and approved sub-grade or sub-base to a loose thickness sufficient to achieve the final compacted thickness. The in situ soil may be used if it is of suitable characteristics and shaped to the required cross section.
2. Stabilisation work should not be carried out in wet weather, on wet surfaces, or when rain is expected before the completed work can be covered and protected.
3. Ensure that the base or sub-base layers are placed over the full required width, including the shoulders if these are being constructed in a combined procedure.
4. The soil to be treated must be processed by breaking up and pre-mixing using approved single axle tractor rotovators or 2-axle tractor driven rotovators. Hard soil must be loosened initially by hand tools or scarifying equipment.
5. Ensure that particles over 5mm do not exceed 25% and those over 10mm do not exceed 10% by weight.
6. After breakdown the material must be shaped and the layer tamp sealed with a single pass by a roller.
7. The target soil moisture content should generally be just below the standard optimum content. Ensure there is satisfactory moisture distribution over the full depth, width and length of the section being treated.
8. It is recommended that for labour based operations the required amounts of bitumen emulsion should be added to short 10-25m lengths of pavement at a time and then thoroughly mixed with the approved rotovator assisted by hand raking.

9. Consideration should be given to diluting the emulsion in hot dry conditions in order to achieve adequate mixing in sand materials.
10. Mixing must be continued until a thorough and uniform mix of the soil and emulsion has been achieved over the full width, length and depth of the material being treated, which must be homogeneous and of uniform appearance throughout.
11. It is recommended that a small percentage of the emulsion be retained for final topping up of patches that become apparently deficient in emulsion during mixing.
12. Ensure there is no disturbance of any previously compacted layer.
13. After mixing has been satisfactorily completed the layer must be shaped and then tamped for 1-2 passes using the roller with vibration switched OFF. Compaction with vibration switched ON should then be completed as per the specification.
14. The exact number of passes, (generally in the region of 6-8) should be determined from compaction–density testing undertaken on an initial pilot section.
15. Final compaction and shaping must be completed within 6 hours of mixing, before hardening of the stabilised soil.
16. The finished layer must be cured for a period of 7 days.
17. Traffic or any other equipment, other than that involved in the curing process, must not be allowed onto the treated material for the first seven days after compaction.
18. In the case of a 2-layer construction the second layer construction may be carried out immediately after compaction of the first layer is completed.
19. In the cases where the sub-base or road base is not to be emulsion sealed, a layer of sand, 40 to 50mm thick, must be spread over the treated material and kept damp by regular watering in intervals not exceeding 24 hours in dry weather.

5.4.4 Key Issues: Site Testing

The process is essentially a method specification and in situ testing techniques such as DCP or sand replacement density require careful correlation. The DCP-CBR standard correlations are in particular reported as not being suitable for bitumen emulsion stabilised materials. Visual assessment of the quality of the finished product allied to a close observation of the key procedures and material specifications is therefore essential.

6 NON-STABILISED BASE AND SUB-BASE OPTIONS

6.1 Non Stabilisation Options

Some materials can be used in their natural or mechanically processed state to provide sub-bases and road bases of adequate quality and characteristics. The principal requirements relate to strength, durability, plasticity and moisture susceptibility. Where these materials are available within reasonable haul distances, they are often the cheapest construction solution.

6.2 Armoured Gravel Road-Base; Specification RRST 205

6.2.1 Description

This activity can be used in the circumstances where an existing gravel/laterite surface is to be upgraded to a sealed surface, or for a completely new pavement construction. The intention is the cost-effective use of suitable locally available natural gravels, and to improve them sufficiently to accept a thin bituminous surfacing.

This activity has two components: an initial component of natural gravel laid to camber, watered and compacted in two layers, followed by a topping or armouring (usually 50-75mm thick) of crushed/broken stone aggregate laid to camber, watered and compacted. The first component may consist of an existing gravel/laterite road surface, scarified and with material added if necessary to achieve the required shaped and compacted thickness.

The surface seal would be applied to the road base as a separate specification item using specification RRST 101 and RRST 102.

6.2.2 Key Issues: Materials

Stone armouring

This is crushed fresh material that may include, quarried rock, natural granular material such as rocks, gravel or boulders.

The materials source should be sampled and tested to ensure it is capable of providing a consistent supply of rock materials that comply with the specified grading, strength, and shape criteria.

Additional 5mm down screenings or natural sand may be required as a blinding material where the crushed rock grading is deficient in fines. These should be sampled, tested and quality monitored at the same time as principal crushed rock material.

Natural Gravel

For the purposes of the construction of rural road sub-base the target for acceptable quarry run material will be to meet the established requirements for naturally occurring gravel used for the same purpose as defined in Tables 1 and 2 in 22 TCN 304-03.

The materials must comply with specified grading and plasticity criteria as well as compacted strength and particular care must be taken in ensuring the removal of oversize material. The selected material must comply with the overall guideline that the nominal stone size must not exceed the 50% of the specified final armouring thickness.

6.2.3 Key Issues: Construction and Supervision

Natural Gravel

1. Ensure that any deformations, ruts, soft spots or other defects in the formation have been corrected to the satisfaction of the Engineer.
2. Secure lateral support for the layer shall be in place prior to the construction of the gravel base layer.
3. After ensuring appropriate amounts of gravel are unloaded, spreading and compaction should start immediately. If labour-based methods are a construction option, the workers should use special spreading rakes, appropriate hand tools or hoes to spread the material evenly onto the sub-grade. Work should progress from the centre line towards the shoulder, and material should be spread from one side of the centre line at a time. Oversize pieces of rock should be removed or crushed, if possible, using sledge hammers
4. If the material is in a dry condition then water should be added prior to compaction. Make sure that there is a sufficient supply of water, to maintain close to optimal moisture content in the gravel during compaction.
5. Compaction should be carried out along the road line starting at the shoulder of the road and gradually working towards the centre line, ensuring an adequate overlap between passes.
6. The first passes of the vibrating roller should be done without vibration in order to avoid that the roller getting "bogged down" in loose material.
7. Water should be added as necessary to facilitate compaction. Make sure that the camber of the road is always maintained for both the base layers as well as the gravel layer.
8. Component layer thickness tolerances are -5 mm to +15 mm.

Stone armouring

1. The aggregate shall be spread uniformly upon the prepared laterite layer in quantities such as to comply with the specified final compacted thickness.
2. Ensure that any segregation of the dumped material is countered by reworking it by labourers with hand tools.
3. Immediately following the spreading of aggregate, it is to be first rolled dry with the aid of an approved vibratory roller. The rolling shall begin from edges with roller running forward and backward, parallel to the centreline of the road until the layer has been firmly compacted.
4. Rolling should continue until the material matrix is thoroughly keyed and stone movement ahead of the roller in no longer visible. Light sprinkling of water may be required to assist compaction.

5. Ensure that the rolled surface is checked transversely and longitudinally with templates and if the irregularities exceed 12 mm from the required plane, then the surface should be loosened and aggregate added or removed before rolling again.
6. Ensure that blinding materials are not used make up depressions.
7. After the dry rolling, blinding material should be swept by hand brooms evenly into any voids evident on the surface. The surface should then be copiously sprinkled with water, swept and rolled with the approved vibratory roller.
8. The sprinkling, sweeping, and rolling operations shall be continued, with additional screenings applied if necessary, until the coarse aggregate has been thoroughly keyed, well bonded and firmly set in its full depth and a grout of screening and water is seen squeezing out ahead of the roller.
9. Care shall be taken to see that the underlying natural gravel layer does not get damaged due to the addition of excessive water during construction.
10. After final compaction of the road base, the road shall be allowed to dry overnight. Next morning ‘hungry’ spots shall be filled with screening materials as directed by the Supervising Engineer, lightly sprinkling water if necessary and rolled.
11. Once the surface has been satisfactorily completed, it should then be sealed in accordance with the Engineering Drawings and the appropriate specification.

6.2.4 Key Issues: Site Testing

Gravel Layer

On-site testing should be a combination on in-situ sand replacement density and DCP testing.

The DCP test may be used as an immediate guide to compaction and as the control on quality once a relationship has been established between density-moisture condition and DCP-CBR for the particular materials concerned. This relationship should be established during short pilot sections at the start of the road construction.

Crushed Rock Armouring

DCP testing may be effective in this material and testing may be limited to sand replacement densities, with allowance being made for the thinness of the layer.

Particular attention should be paid to monitoring and checking the final thickness of the armouring layer.

6.3 Sand for Sub-Base; Specification RRST 206

6.3.1 Description

There are some areas in Vietnam where abundant sources of sand are readily, available, notably the Red River Delta, parts of the Mekong Delta and the central coastal belt. Some of these sands can be suitable as unstabilised rural road sub-bases. The selected sand must however, have grading characteristics that are compatible with being cost-effectively compacted to achieve desired in situ strengths,.


Pumped sand sub-base; Mekong Delta

Sands that fail to meet the required grading and compaction criteria may be considered for cement stabilisation – see the previous section 5.0.

6.3.2 Key Issues: Materials

Sand for sub-base should be tested and inspected to ensure that it:

1. Complies with any target grading that is specified.
2. Has a Sand Equivalent Value (SEV) of greater than 70.
3. Is clean sand free from clay coating, organic debris and other deleterious materials.

The sand source should be capable of producing a material with consistent engineering properties throughout the construction period. If the sand source has no previous history of use as a compacted material then consideration should to undertaking short test compaction trials before final source approvals are given.

6.3.3 Key Issues: Construction and Supervision

1. Ensure that any deformations, ruts, soft spots or other defects in the formation have been corrected to the satisfaction of the Engineer.
2. Secure lateral support for the sub-base shall be in place prior to the construction of the sand sub-base layer.
3. After ensuring appropriate amounts of sand are unloaded, spreading should start as soon as possible If labour-based methods are a construction option, the workers should use special spreading rakes, appropriate hand tools or hoes to spread the material evenly onto the sub-grade. Work should progress from the centre line towards the shoulder, and the material should be spread from one side of the centre line at a time.
4. If the sand is hydraulically pumped to its point of placement, as could be the case in Delta regions, ensure that appropriate measures are in place to drain off excess water prior to compaction.
5. If the sand is in a dry condition then water should be added prior to compaction. Make sure that there is sufficient supply of water, to maintain optimal moisture content in the sand during compaction.
6. The maximum spread thickness of each layer should not exceed the loose thickness defined in the specification and as appropriate to the compaction plant available.
7. Compaction should be carried out in a series of continuous operations covering the full width and length of the layer concerned using the vibrating roller that has been approved by the engineer.
8. Compaction should be carried out along the road line starting at the shoulder of the road and gradually working towards the centre line, ensuring an adequate overlap between passes.
9. The first passes of the vibrating roller should be done without vibration in order to avoid that the roller getting "bogged down" in the loose material.
10. Water should be added as necessary to facilitate compaction. Make sure that the camber of the road is always maintained.
11. Ensure by inspection that the sand material is on completion of compaction, well closed, free from movement under the compaction plant and free from compaction planes, ridges, cracks or loose material.
12. All extraneous matter, loose, segregated or otherwise defective areas must be removed and made good with new material to the full thickness of the layer.

13. Ensure that the component layer thickness complies with the specified tolerances (-5 mm to +15 mm) and that the final shape confirms with the Drawings; this must be checked with a camber board, or straight edge, spirit level and tape.

6.3.4 Key Issues: Site Testing

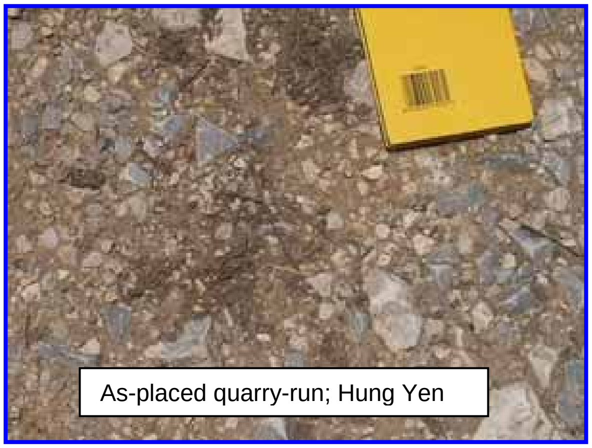
On-site testing should be a combination on in-situ sand replacement density and DCP testing.

The DCP test may be used as an immediate guide to compaction and as the control on quality once a relationship has been established between density-moisture condition and DCP-CBR for the particular materials concerned. This relationship should be established during short pilot sections at the start of the road construction.

6.4 Quarry Run for Sub-Base; Specification RRST 207

6.4.1 Description

Then term "Quarry Run" is used as a general term to cover naturally occurring rock and weathered rock materials excavated from a quarry or borrow area and delivered to site without processing, apart from any required selection or screening for the removal of oversize boulders or cobbles.



As-placed quarry-run; Hung Yen

In areas where hard rock quarries have been developed primarily for aggregate production, the use of quarry run in rural road construction provides a use for materials that may otherwise be considers as waste for dumping. Provided they are acceptable, this use of these materials, therefore, brings with it an environmental advantage.

6.4.2 Key Issues: Materials

This type of material is by its nature highly variable and care should be taken in initially assessing the suitability of the source; in addition and equally importantly supervision resources must be available to ensure the continued consistency of its properties throughout the contract. Even if they meet specified criteria, any materials with excessive variation within the acceptable envelopes should be rejected due to the consequent problems caused in compaction control.

For the purposes of the construction of rural road sub-base the target for acceptable quarry run material will be to meet the established requirements for naturally occurring gravel used for the same purpose as defined in Tables 1 and 2 in 22 TCN 304-03.

The materials must comply with specified grading and plasticity criteria as well as compacted strength and particular care must be taken in ensuring the removal of oversize material.

6.4.3 Key Issues: Construction and Supervision

1. Ensure that any deformations, ruts, soft spots or other defects in the formation have been corrected to the satisfaction of the Engineer.

2. Secure lateral support for the sub-base shall be in place prior to the construction of the sand sub-base layer.

3. After ensuring appropriate amounts of quarry run are unloaded, spreading and compaction should start immediately. If labour-based methods are a construction option, the workers should use special spreading rakes, appropriate hand tools or hoes to spread the material evenly onto the sub-grade. Work should progress from the centre line towards the shoulder, and material should be spread from one side of the centre line at a time. Oversize pieces of rock should be removed or crushed, if possible, using sledge hammers.
4. If the material is in a dry condition then water should be added prior to compaction. Make sure that there is a sufficient supply of water, to maintain close to optimal moisture content in the quarry run during compaction.
5. An inspection should be made of the laid out material prior to compaction to identify and remove any oversize.
6. Compaction should be carried out along the road line starting at the shoulder of the road and gradually working towards the centre line, ensuring an adequate overlap between passes.
7. The first passes of the vibrating roller should be done without vibration in order to avoid that the roller getting "bogged down" in loose material.
8. Water should be added as necessary to facilitate compaction. Make sure that the camber of the road is always maintained for both the base layers as well as the gravel layer.
9. Component layer thickness tolerances are -5 mm to +15 mm.

6.4.4 Key Issues: Site Testing

On-site testing should be a combination on in-situ sand replacement density and DCP testing. Care should be taken with this potentially variable material in ensuring that appropriate MDD values are used for in situ density assessment.

The DCP test may be used as an immediate guide to compaction and as the control on quality once a relationship has been established between density-moisture condition and DCP-CBR for the particular materials concerned. This relationship should be established during short pilot sections at the start of the road construction.

6.5 Graded Crushed Stone for Sub-Base; Specification RRST 2.08

6.5.1 Description

This is not generally used as an option for rural roads due to the requirement for graded aggregate size processing and the consequent cost. It is however a potential sub-base and base alternative to stone macadam in areas where adequate supplies of quarried and processed rock are readily and cheaply available.

6.5.2 Key Issues: Materials

The materials source should be sampled and tested to ensure it is capable of providing a consistent supply of crushed aggregate materials that complies with the specified grading, strength, and shape criteria.

6.5.3 Key Issues: Construction and Supervision

1. The aggregate shall be spread uniformly upon the prepared sub-grade in quantities such as to comply with the specified final compacted thickness.
2. Ensure that any segregation of the dumped material is countered by reworking it by labourers with hand tools.

3. Immediately following the spreading of aggregate, it is to be first rolled dry with the aid of an approved vibratory roller. The rolling shall begin from the road edges with roller running forward and backward, parallel to the centreline of the road until the layer has been firmly compacted.
4. Rolling should continue until the material matrix is thoroughly keyed and stone movement ahead of the roller in no longer visible. Light sprinkling of water may be required to assist compaction.
5. Ensure that the rolled surface is checked transversely and longitudinally with templates and if the irregularities exceed 12 mm from the required plane, then the surface should be loosened and aggregate added or removed before rolling again.
6. Ensure that blinding materials are not used make up depressions.
7. After the dry rolling, blinding material should be swept by hand brooms evenly into any voids evident on the surface. The surface should then be copiously sprinkled with water, swept and rolled with the approved vibratory roller.
8. The sprinkling, sweeping, and rolling operations shall be continued, with additional screenings applied if necessary, until the coarse aggregate has been thoroughly keyed, well bonded and firmly set in its full depth and a grout of screening and water is seen squeezing out ahead of the roller.
9. Care shall be taken to see that the underlying layer does not get damaged due to the addition of excessive water during construction.
10. After final compaction of the road base, the road shall be allowed to dry overnight. Next morning 'hungry' spots shall be filled with screening materials as directed by the Supervising Engineer, lightly sprinkling water if necessary and rolled.
11. Once the surface has been satisfactorily completed it should then be sealed in accordance with the Engineering Drawings and the appropriate specifications.

6.5.4 Key Issues: Site Testing

The process is essentially a method specification and DCP testing may be effective in this material and testing may be limited to sand replacement densities, with allowance being made for the thinness of the layer.

In situ testing techniques such as DCP or sand replacement density are largely ineffective. Visual assessment of the quality of the finished product allied to a close observation of the key procedures and material specifications is therefore essential.

6.6 Sand Bedding Layer; Specification RRST 209

6.6.1 Description

Sand beds beneath selected pavement surfacings act as a bedding-in and load transfer layer for the overlying construction. In some cases they act additionally as a drainage medium. Sand layers are required as a bedding medium beneath the following RRST surfacings:

- Dressed stone setts — Specification 305
- Cobble stones — Specification 304
- Fired clay bricks — Specification 301,302
- Cement bricks — Specification 303
- Bamboo reinforced concrete — Specification 401
- Steel reinforced concrete — Specification 402

- Non-Reinforced concrete Specification 403

6.6.2 Key Issues: Materials

Sand for sub-base should be tested and inspected to ensure that it:

1. Is clean sand free from clay coating, organic debris and other deleterious materials.
2. Has a Sand Equivalent Value (SEV) of greater than 70.
3. Complies with the target grading that is specified.

The sand source should be capable of producing a material with consistent engineering properties throughout the construction period.

6.6.3 Key Issues: Construction and Supervision

Compacting sand bedding layer

1. Ensure that any deformations, ruts, soft spots or other defects in underlying layer have been corrected to the satisfaction of the Engineer.
2. Sand materials should be dumped on the prepared formation in such a manner as to allow for continuity of operations over the length of the formation.
3. Traffic must be prevented from crossing the works until the bedding sand and any covering layer have been completed and/or cured ready for traffic.
4. Spreading of the sand material should be by manual methods to slightly above the screed levels. The sand will then be lightly compacted with one pass of either a 60kg plate compactor or a 1000kg vibrating roller.
5. Screeding boards will be used to remove the excess sand and level it to the correct profile giving a final thickness of 50mm.

6.6.4 Key Issues: Site Testing

No site testing is required for this procedure.

Visual inspection of the materials and finished layer is required.

6.7 Dry Bound Macadam Base/Sub-Base; Specification RRST 2.10

6.7.1 Description

Spreading of DBM fine aggregate

A Macadam layer essentially consists of a stone skeleton of single sized coarse aggregate in which the voids are filled with another finer material. The stone skeleton, because of its single size large material will contain considerable voids, but will have the potential for high shear strength. If confined properly, a crucial requirement for macadam base courses, the stone skeleton forms the "backbone" of the macadam and is largely responsible for the strength of the constructed layer. The material used to fill the voids provides lateral stability to the stone skeleton but adds little bearing capacity. This structure also drains well.

Two types of Macadam pavement are already in common use in Vietnam; they are Penetration Macadam (where hot bitumen is used as a filler) and Waterbound Macadam (WBM) where the aggregate fines are washed or slushed into the coarse skeleton with water. In common practice in Vietnam, a composite WBM practice has evolved which comprises the use of intermediate stone sizes.

Dry-bound macadam is a similar technique to the original WBM, however instead of water and deadweight compaction being used to assist with the introduction and consolidation of fine material, a vibrating roller is used. Dry-bound macadam can be appropriate where the sub-grade is weak and sensitive to water soaking, or in areas where water is difficult or expensive to obtain.

The water bound or dry-bound macadam process involves laying single-sized crushed/broken stone of either 37.5 mm or 50mm nominal size with finer, cohesionless material laid on top and vibrated into the voids, without the use of water. The development of small vibrating rollers has made the use of this technique attractive for rural road works in some locations. Dry-bound macadam is built up in layers of thickness equivalent to about twice the nominal stone size, until the required overall layer thickness is achieved.

Dry-bound macadam can be made with stones crushed by hand or equipment, and can therefore be suitable for local employment generating purposes. Labour breaking and laying of stone can also be used in remote areas with access difficulties for crushing equipment or heavy plant.

6.7.2 Key Issues: Materials

The materials source should be sampled and tested to ensure it is capable of providing a consistent supply of coarse and fine materials that comply with the specified grading, strength, and shape criteria.

From the visual assessment viewpoint it should be noted that the coarse material should have a virtually single size distribution.

The 5mm down fine material should be a well graded non plastic material. This material is normally crushed rock material although the use of suitably graded natural sand may be permitted.

6.7.3 Key Issues: Construction and Supervision

1. Ensure that any deformations, ruts, soft spots or other defects in the underlying layer have been corrected to the satisfaction of the Engineer.
2. Secure lateral support for the sub-base should be in place prior to the construction of the macadam sub-base or road base layer.
3. The coarse aggregate should be placed first. After ensuring appropriate amounts of the stone are unloaded spreading should be commenced with special rakes or hoes to spread the material evenly onto sub-grade or sub-base and to initially set the material in a level surface. High, poorly positioned or oversize individual stones should be accommodated by breaking or seating by hand with a club or lump hammer prior to initial machine compaction. Suitable eye protection should be worn by the labour using the hammer.
4. Compaction to lock in of the coarse aggregate should then be undertaken with 8 or 12Tonne static rollers. Rolling should always be progressing towards the higher side: if the road cross section is cambered, rolling starts at the sides and progresses towards the centre; if super-elevated, it should start at the low side and progresses upwards.
5. Rolling should continue until no movement of the coarse aggregate is visible under the rollers and the material is effectively keyed in.

6. The well graded fine aggregate, should then be spread onto the keyed-in coarse aggregate layer by hand using shovels and rakes (or by mechanical chip-spreader). The thickness of the loose filler placed in one application should not exceed 25 mm and should be evenly distributed.
7. Compaction should then be carried out in a series of continuous operations covering the full width and length of the layer concerned using a minimum 3000kg vibrating roller that has been approved by the engineer.
8. The process of successive applications of fine aggregate and vibratory compaction is continued until the layer is choked with fine aggregate. The blinding fines may need to be lightly watered for dry-bound macadam to assist in the process. However, care is necessary in this operation to ensure that any water sensitive plastic materials in the sub-base or sub-grade do not become saturated.
9. Any loose material remaining is brushed off and final compaction carried out. The sequence is then repeated until the design thickness is achieved.
10. .The dry-bound macadam should, on completion of compaction, be well closed, free from movement under the compaction plant and free from compaction planes, ridges, cracks or loose material. All extraneous matter, loose, segregated or otherwise defective areas should be removed and made good with new material to the full thickness of the layer.

Component layer thickness should be checked to ensure that it is within the specified tolerances.

6.7.4 Key Issues: Site Testing

The process is essentially a method specification and in situ testing techniques such as DCP or sand replacement density are largely ineffective. Visual assessment of the quality of the finished product allied to a close observation of the key procedures and material specifications is therefore essential.

7 BLOCK PAVEMENTS

7.1 Fired Clay Brick Pavement; Specifications RRST 301 and RRST 302

7.1.1 Description

Fired Clay Bricks are the product of firing moulded blocks of sandy, silty clay. They are commonly used in low cost road pavement construction in areas that suffer from a deficiency of natural gravel or rock materials. They are suited to labour based or small contractor/community based construction and maintenance. Good quality fired clay bricks can be produced in small or large scale production kilns, using wood, coal or agricultural waste, or other suitable fuel.

Bricks placed in herring-bone pattern

This surfacing consists of placing a layer of bricks usually laid on their longer edge, within mortar bedded and jointed edge restraints or kerbs on each side of the pavement. The kerbs are usually also of brick, although other materials such as concrete or dressed stone units are sometimes used. The edge restraint is an essential feature of incremental block paving techniques, and must be constructed in advance of the main paving.

The bricks are normally laid in a herring bone pattern to assist load transfer between individual bricks, or other approved pattern indicated on the Engineering Drawings.

In Specification RRST 301 the bricks are laid on sand bedding layer (Specification RRST 209) and the joints between the bricks are in-filled with suitable sand; whilst in Specification RRST 3.02 the bricks are laid on a thin layer of cement mortar in and the joints between the bricks are in-filled with cement mortar.

A seal may be specified to be used to waterproof the finished surface as a separate operation (RRST102).

Un-mortared brick paving is not suitable for locations subject to flooding. Un-sealed brick paving is not suitable to locations with medium to high rainfall (more than about 1000mm/year) or on moisture susceptible sub-grades or sub-bases.

7.1.2 Key Issues: Materials

The characteristics and quality of the bricks produced is determined by the suitability of the raw material for brick making and the quality of the manufacturing process.

The raw material for brick manufacture should ideally be a sandy clayey silt or silty clay of low to medium plasticity. The material should be uniform and comprise a relatively high proportion of silica (quartz) minerals. It must also be free from significant quantities of deleterious materials such as combustible vegetable matter, mica minerals and salts.

Although specifications RRST 301 and 302 define brick dimensions as 200mm x 100mm x 70mm these may be varied at the Engineer's discretion, depending on local practice in brick production, provided a brick layer thickness of 100mm is retained.

It is essential that "Engineering Quality" bricks are use in the construction of road pavements and a Vietnamese Standard crushing strength of 20MPa is recommended. Bricks below this strength have been shown to provide inadequate resistance to traffic impact, and are likely to break or wear rapidly or irregularly. Experience has indicated that attention may need to be directed at ensuring that locally produced bricks not only attain the required strength and that this quality is maintained throughout the pavement construction.

Small scale brick manufacturing is sometimes aimed at the local housing construction market, which may not require engineering quality bricks, which can be more expensive to produce. More attention is required to kiln design, and the production process, particularly 'burn' period firing temperature, to produce engineering quality bricks.

7.1.3 Key Issues: Construction and Supervision- RRST 301

1. Ensure that any deformations, ruts, soft spots or other defects in the underlying layer have been corrected to the satisfaction of the Engineer.
2. Setting out pegs and string lines must be used to ensure that the final shape of the brick layer confirms with the specification.
3. The pavement edge bricks or kerbs should be placed first to the correct final level. They must be, bedded and jointed with cement mortar to act as a level and alignment guide for laying the rest of the paving (Figure 7.1). The beginning and end of the pavement section should also be reinforced similar to the pavement edge.
4. After the pavement edge is satisfactorily completed and has gained sufficient strength, the sand for the bedding layer can be spread and then lightly compacted to level and shape. Allowance should be made for the additional consolidation that will occur under the final compaction (see item 7.)
5. The bricks can then be laid on edge (100mm depth) over the previously compacted bedding layer within the edge restraints. The bricks should be laid in the herring bone or other approved pattern.
6. Joint spacing between bricks should be between 5 and 10mm.
7. Joints between bricks are then filled by sand, which is first spread over the placed bricks, and then brushed in without disturbing them. The laid paving can then be compacted with a vibrating plate compactor to properly bed the bricks and key the joint sand securely between the bricks. Joints should be refilled as necessary to achieve full joints and satisfactory interlock between the bricks.
8. The final surface should be quality inspected and crossfalls checked with a camber board, or straight edge, spirit level and tape.

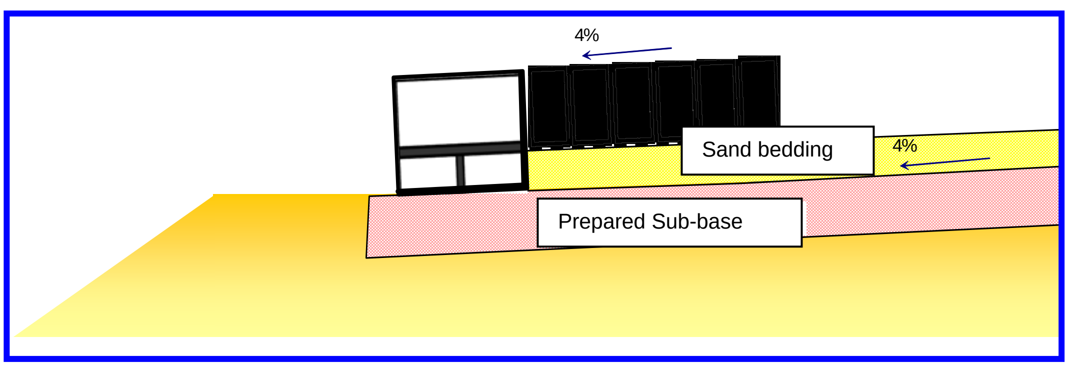


Figure 7.1: Detail at Edge of Brick Pavement

7.1.4 Key Issues: Construction and Supervision- RRST 302

The construction procedure of brick pavement with mortared joints is largely the same as un-mortared except that cement mortar is used instead of sand for bedding and joint filling. Other key issues are as follows:

1. Additional care should be taken to ensure that the final shape of the brick layer complies with the Drawings; once bricks have been laid and filled with mortar it is difficult to make corrections.
2. Bricks should be lightly tapped into the correct level position with a mason's hammer to ensure that there is no void beneath each laid brick.
3. Joint filling can either follow closely on behind the brick placement or it can be undertaken in small areas at a time. However the time between mixing and laying cement mortar must not exceed the initial setting time; which although dependant on type of cement, amount of water used and weather condition will be around 90 minutes.
4. Joint infill should be finished level with the top face of the bricks so as to provide a smooth finished surface. Any excess mortar must be removed.
5. After the mortar has set, the mortared brick paving will be cured for a period of 7 days by keeping the surface damp with water, retained for example using a sand blanket. After 7 days the surface may be fully opened to traffic.

7.1.5 Key Issues: Site Testing

No specific site testing would normally be required for this procedure other than to physically check on the brick dimensions and appearance. The general strength of the bricks may be estimated by knocking two bricks together sharply; there should be a resultant ringing tone. If obviously sub-standard bricks are then suspected, then brick samples should be submitted for laboratory testing. Any obviously sub-standard or badly shaped bricks should be removed from the site.

Pavement dimensions and crossfall should also be checked at regular intervals.

7.2 Concrete Brick Pavement; Specifications RRST 303

7.2.1 Description

Concrete brick paving is a well-established technique used in many countries for applications from light pedestrian traffic to rural roads to very heavy vehicle loading, for example in port and container handling areas. The success of the technique is based on the proven ability of individual concrete bricks to effectively disperse load to adjacent bricks through the sand joints. Concrete brick pavements have good load spreading properties, especially on low strength sub-grades.

Placed concrete bricks prior to sealing

Concrete brick paving has been adapted successfully as a viable alternative to gravel or unsealed macadam on low volume rural roads, especially for high rainfall or steep terrain road environments. The concrete bricks are re-usable if road base failure occurs (the bricks are merely taken up, cleaned and reused after the road-base/foundation has been repaired). The technique is suitable for small scale local concrete brick production and laying by contractors or community groups.

The activity defined in Specification RRST 303 comprises 70mm thick rectangular concrete bricks being laid in a herringbone or other approved pattern to camber within confining edge-kerbs on each side of the pavement. They are compacted into place, with sand brushed-in at the joints. The kerbs are usually also of concrete brick or larger units, although other materials such as brick or dressed stone units are sometimes used. The edge restraint is an essential feature of incremental block paving techniques, and must be constructed in advance of the main paving.

A seal may be specified to be used to waterproof the finished surface as a separate operation; for example RRST 102, sand emulsion seal.

This activity is also associated with a sand bedding layer (RRST 209).

Un-mortared concrete brick paving is not suitable for locations subject to flooding. Un-sealed concrete brick paving is not suitable to locations with medium to high rainfall (more than about 1000mm/year) or on moisture susceptible sub-grades or sub-bases.

7.2.2 Key Issues: Materials

The specification RRST 303 defines concrete bricks as having being 200x100x70mm thick; being composed of concrete with a maximum aggregate size is 6mm. Other brick dimensions should only be allowed if they are formally approved by the Design Engineer.

It is essential that bricks of the required strength are used in the construction of road pavements and a crushing strength of 25MPa is recommended. Bricks below this strength have been shown to provide inadequate resistance to traffic impact, and are likely to break or wear rapidly or irregularly. Experience has indicated that attention may need to be directed at ensuring that locally produced bricks not only attain the required strength but that this quality is maintained throughout the pavement construction.

The bricks should be inspected to ensure that they are regular in shape and texture with sharp edges and parallel faces, although they may have a bevel on the top edges.

7.2.3 Key Issues: Construction and Supervision

1. Ensure that any deformations, ruts, soft spots or other defects in the underlying layer have been corrected to the satisfaction of the Engineer.
2. Setting out pegs and string lines must be used to ensure that the final shape of the brick layer confirms with the specification.
3. The pavement edge bricks or kerbs should be placed first to the correct final level. They must be, bedded and jointed with cement mortar to act as a level and alignment guide for laying the rest of the paving. The beginning and end of the pavement section should also be reinforced similar to the pavement edge.
4. After the pavement edge is satisfactorily complete and has gained sufficient strength, the sand for the bedding layer can be spread and then lightly compacted to level and shape. Allowance should be made for the additional consolidation that will occur under the final compaction (see item 7).
5. The concrete bricks can then be laid on their bottom face (70mm depth) over the previously compacted bedding layer within the edge restraints. The bricks should be laid in a herring bone or other approved pattern.
6. Joint spacing between bricks should be between 5 and 10mm.
7. Joints between bricks are then filled by sand, which is first spread over the placed bricks, and then brushed in without disturbing them. The laid paving can then be compacted with a vibrating plate compactor to properly bed the bricks and key the joint

sand securely between the bricks. Joints should be refilled as necessary to achieve full joints and satisfactory interlock between the bricks.

8. The final surface should be quality inspected and crossfalls checked with a camber board, or straight edge, spirit level and tape.

7.2.4 Key Issues: Site Testing

No specific site testing would normally be required for this procedure other than to physically check on the brick dimensions and appearance. Any obviously sub-standard bricks should be removed from the site.

Pavement dimensions and crossfall should also be checked at regular intervals.

7.3 Cobble Stone Pavement; Specifications RRST 304

7.3.1 Description

As-built cobble stone pavement; Ninh Binh

Cobble stone surfacing is a historically well-established technique that has been adapted successfully as a robust low maintenance alternative to gravel or unsealed macadam on low volume rural roads where there is a good local supply of suitable stone. Cobble stone surfaces have good load spreading properties and the surfacing material is re-usable if road foundation failure occurs (the cobble stones are merely taken up, cleaned and reused after the roadbase/foundation has been repaired).

The technique is suitable for small scale commune-based quarrying and production, especially where local skills in stone excavation and production are established in the locality.

This activity comprises roughly cubic selected cobble stones of 100-150mm size being laid to camber between edge restraints and compacted into a sand bedding layer (RRST 209).Cobble Stone Paving is one of a number of road surface improvement or paving options that use natural stone and are suitable for construction using labour and simple equipment.

This paving option does not require the use of high-cost equipment, therefore a high proportion of the costs may be spent in, and benefit, the local community.

7.3.2 Key Issues: Materials

Cobble Stones

The cobble stones should be a strong, homogenous, isotropic rock, free from significant discontinuities such as cavities, joints, faults and bedding planes. Rocks such as fresh granite, basalt and crystalline limestone have proven to be suitable materials. Quartzite rock is not suitable, nor is any rock that polishes or develops a slippery surface, or erodes under traffic.

Rock for cobble stone should be tested to ensure it meets the specified requirements;

- Uniaxial compressive strength >75MPa
- Los Angeles Abrasion value: <25%
- Sodium Sulphate Soundness <10% loss

Cobble stones should be roughly cubic in shape with a thickness in the range 100-150mm. The individual cobble stones should have at least one face that is reasonably flat and suitable to be the upper surface.

Joint Infill

The material infilling the spaces between the cobble stones should be a loose, dry natural or crushed stone material with a particle size distribution equivalent to a well graded coarse sand to fine gravel. It must be clean and free from clay coating, organic debris and other deleterious materials.

7.3.3 Key Issues: Construction and Supervision

1. Ensure that any deformations, ruts, soft spots or other defects in the underlying layer have been corrected to the satisfaction of the Engineer.
2. Setting out pegs and string lines must be used to ensure that the final shape of the cobble stone layer confirms with the specification.
3. Mortared pavement edge stones or kerbs shall be placed first to the correct lines and levels to act as a strong edge restraint and as a level and alignment guide for laying of the rest of the paving. The beginning and end of the pavement section should also be reinforced similar to the pavement edge.
4. After the pavement edge is satisfactorily complete and has gained sufficient strength, the sand for the bedding layer can be spread and then lightly compacted to its level and shape. Allowance should be made for the additional settlement that will occur under the final compaction (see item 10).
5. The cobble stones can then placed on the previously compacted bedding layer within the edge restraints. All cobble stones will be placed with the smoothest face uppermost.
6. Each stone should be lightly tapped into position with a mason's hammer, to ensure initial bedding.
7. The cobbles should be placed in an approved pattern with the longest dimension across the road.
8. Joint spacing between cobbles should be between 5 and 10mm.
9. Joints between cobbles are then infilled with the specified sand-gravel material, which is first spread over the placed cobble stones, and then brushed in.
10. When a suitable area of cobbles and infilled joints is laid, it should be consolidated with a small vibrating roller or plate compactor. Additional infill materials should then be brushed into the surface as required.
11. A final rolling is then carried out by a minimum 1 Tonne vibrating roller with 6-8 passes per point. Light and even sprinkling of water may be used to aid the consolidation of the sand-gravel within the joints.
12. The final surface should be quality inspected and crossfalls checked with a camber board, or straight edge, spirit level and tape.

7.3.4 Key Issues: Site Testing

No specific site testing would normally be required for this procedure other than to physically check on the cobble dimensions and appearance. Any obviously sub-standard cobbles should be removed from the site.

Pavement dimensions and crossfall should also be checked at regular intervals.

7.4 Mortared Dressed Stone Pavement; Specifications RRST 305

7.4.1 Description

Dressed stone surfacing is an historically well-established technique that has been adapted successfully as a robust alternative to gravel or unsealed macadam on low volume rural roads where there is a good local supply of suitable stone. Dressed stone surfaces have good load spreading properties, especially on low strength sub-grades. The surfacing material is re-usable if road foundation failure occurs (the stones are merely taken up, cleaned and reused after the roadbase/foundation has been repaired).

Stone setts; Hue

The technique is suitable for small scale commune-based quarrying and production, especially where local skills in stone cutting and dressing are established in the locality.

This activity comprises 200mm thick stone setts being laid to camber between edge restraints and compacted into a sand bedding layer (Specification RRST 209), followed by cement mortaring of the joints.

7.4.2 Key Issues: Materials

Dressed Stones

The individual dressed stones should be a strong, homogenous, isotropic rock, free from significant discontinuities such as cavities, joints, faults and bedding planes. Rocks such as fresh granite and crystalline limestone have proven to be suitable materials, particularly those with an inherent stress condition that promotes natural breakage following a right-angled joint pattern. These characteristics will facilitate the quarrying by manual methods.

Rock for dressed stones should be tested to ensure it meets the specified requirements;

- Uniaxial compressive strength >75MPa
- Los Angeles Abrasion value: <25%
- Sodium Sulphate Soundness <10% loss

The specification RRST 304 defines the dressed stones as being 300mm x 200mm x 100mm in size, however other similar dimensions may approved by the Engineer depending on local availability and practice.

The dressed stones should be inspected to ensure that they are regular and uniform in shape and texture with sharp square edges and parallel faces. They must also be free from flaws and discontinuities with a reasonably smooth top surface.

Joint Infill

The material infilling the spaces between the dressed stones should be a loose, dry natural or crushed stone material with a particle size distribution equivalent to a well graded coarse sand to fine gravel. It must be clean and from clay coating, organic debris and other deleterious materials

Mortar

RRST 304 describes the cement mortar for joints as being Grade 75 (fine sand).

7.4.3 Key Issues: Construction and Supervision

1. Ensure that any deformations, ruts, soft spots or other defects in the underlying layer have been corrected to the satisfaction of the Engineer.
2. Setting out pegs and string lines must be used to ensure that the final shape of the dressed stone layer confirms with the specification.
3. Mortared pavement edge stones or kerbs shall be placed first to act as a level and alignment guide for the laying of the rest of the paving. The beginning and end of the pavement section should also be reinforced similar to the pavement edge.
4. After the pavement edge is satisfactorily complete and has gained sufficient strength, the laying of the individual dressed stones can continue by bedding each stone on cement mortar and after taping each stone into place with a masons hammer, the joints should be also filled to within about 30mm of the top surface with cement mortar.

5. The dressed stones should be placed in an approved staggered pattern with the longest dimension across the road. Alternate stones at the pavement edge will be half size to allow joints in the paving to be staggered in adjacent rows.
6. Joint spacing between the dressed stones should be between 5 and 10mm.
7. When a small area of dressed stones is in place and before the cement mortar has set (depending on conditions but usually within 90 minutes of mixing) they can be consolidated in position with a small hand-operated plate compactor.
8. The joints should then be completed by filling and consolidating to within 10mm of the surface with cement mortar, and finished smoothly. The joints should be finished smoothly and just below the top of the dressed stones to facilitate surface drainage.
9. The final surface should be quality inspected and crossfalls checked with a camber board, or straight edge, spirit level and tape.

7.4.4 Key Issues: Site Testing

No specific site testing would normally be required for this procedure other than to physically check on the dressed stone dimensions and appearance. Any obviously sub-standard stones should be removed from the site.

Pavement dimensions and crossfall should also be checked at regular intervals.

8 CEMENT CONCRETE PAVEMENTS

8.1 General Descriptions


On-site concrete batch mixer

Cement concrete slab pavements are widely used to provide a high strength, durable road surface with very low maintenance requirements. They are suitable for any traffic loading from bicycles to high flows of heavy trucks. To achieve the potential performance it is necessary to ensure some basic technical requirements, principally relating to preparation works, quality and curing of the concrete. It is also necessary to properly construct the necessary joints to ensure that they perform as designed.

Cement concrete slab pavements tend to be the most expensive of surface construction options, however in Whole Life Cost terms they can be cheaper than other surfaces due to long life, savings in maintenance organisation and works costs, and Vehicle Operating Costs; these factors can outweigh the high initial construction costs.

Three types of cement concrete slab pavement are proven and in use with various characteristics:-

- Bamboo reinforced concrete pavement – the bamboo primarily provides resistance to shrinkage cracking while the concrete is gaining strength and provides a minor contribution to pavement strength.
- Steel reinforced concrete pavement – the steel reinforcement provides resistance to shrinkage cracking while the concrete is gaining strength and provides a contribution to pavement strength.
- Non-reinforced concrete pavement – there is no reinforcement, except for load transfer at joints, and performance depends particularly on good construction quality and avoidance of overloading by heavy vehicles.

The highest risk to concrete slab pavements is probably from impact loading from heavy vehicles at the construction joints, when vehicles move onto the edge of the pavement, and at the first and last slabs in a section of paving (where there is no load transfer arrangement to adjoining surfacing). Particular attention is necessary to ensure smooth surface transition at these locations.

8.2 Key General Issues: Materials

The concrete materials for all the three RRST options are required to comply with current Vietnam Standards applicable to crushed stone aggregate for rural roads (TCVN 1771: 1987; TCVN 1772:1987).

In addition to the above however the RRST specifications require that **no uncrushed rounded coarse natural aggregate should be approved** for use as coarse aggregate. Particular note should be taken of this in areas where local rounded alluvial gravels are in plentiful supply and have up to now been approved for use by local authorities.

Cement must also comply with current Vietnam regulations. Particular note should be taken of the age of any proposed cement. Supervision should include site checks to ensure the cement, as actually delivered, is of the agreed type and from the agreed source, and that it is not "old stock" and that it has been affected by moisture.

There are clear requirements in the RRST specifications as to the quality of water permitted for use in concrete mixes and supervision must ensure that these are be adhered to.

All materials proposed for use must be sampled and tested as per the Standards and Specifications.

Prior to construction concrete cubes for approval testing must be made using the actually proposed materials, including the water sources. During construction, cubes must be made from concrete taken from the actual on site batching process.

8.3 Key General Issues: Construction and Supervision

Cement concrete pavements are a high cost investment and justify particular attention to a number of quality control aspects to ensure that the expected high performance is achieved. Particular attention should be paid to:

1. The preparation of the surface on which the concrete slab is laid.
2. The correct levels, rigidity, strength and integrity of the formwork to ensure that it will resist the placing and compaction/tamping forces when the concrete is laid.
3. The correct formation of joints and placement of the load transfer dowels
4. No construction joints are to be permitted within a slab. If the concrete mixer breaks down during pouring and no replacement is immediately available, the supervisor may allow completion of the slab using manual mixing methods provided that a clean surface is available, that mix proportions are carefully controlled and that thorough mixing is ensured before placing of the concrete
5. The arrangements for storing the materials, mixing, transporting and placing of the concrete, so that formwork or reinforcement is not disturbed/displaced.
6. Over-watering is a common practice with contractor's personnel to make the concrete easier to mix and place. However this weakens the concrete and substantially increases the risk that it will crack on drying out. The surface quality will also be reduced and it will be likely to deteriorate under traffic. THE SUPERVISOR SHALL PAY CLOSE ATTENTION TO THE WATER PROPORTIONS AND SHALL ARRANGE SLUMP TESTS TO ENSURE AN ACCEPTABLE WATER CONTENT IS ACHIEVED.
7. Suitable grooving of the finished concrete surface provides good skid resistance and improved safety for the road users.
8. As soon as the concrete is placed and set, the curing should commence and be continued for a period of 7 days. This ensures that as the concrete gains strength there is sufficient moisture present for this process. This also reduces the risk of shrinkage cracking.

8.4 Bamboo Reinforced Pavement; Specifications RRST 401

8.4.1 Description

Reinforced cement concrete is a form of rigid pavement designed to spread the applied load due to traffic through a slab effect. It is therefore ideal for construction on weak sub-grades, and on routes liable to seasonal flooding. The normal basic materials in the typical reinforced pavement slab are Portland cement concrete, reinforcing steel, load transfer devices (between slabs), and joint sealing materials. However, bamboo has great potential as an alternative for steel reinforcement because it has good tensile strength, it is replenishable, very cost effective and very little mechanisation is needed to prepare it for use.

Regional experience with bamboo reinforced concrete (BRC) has indicated that it is a durable strong pavement with an estimated life span of over 20 years. It can be constructed by small-scale local contractors or communities with the minimum of equipment. The pavement requires minimal routine maintenance for the shoulders and occasional re-filling of the slab expansion joints with bitumen. Despite relatively high initial costs, the whole life costs of bamboo reinforced concrete pavement make it an attractive option in some areas, such those prone to flooding or at risk from high erosion.

Concrete compaction with vibrating poker

8.4.2 Key Issues: Materials

Section 8.2 outlines the general requirements fopr concrete materials

Bamboo should comply with the specified criteria. The proposed bamboo should be inspected for suitability in its cuts lengths prior manufacture of the reinforcement mesh. In addition the storage history of the proposed bamboo should be checked to ensure it complies with the seasoning requirements.

The bamboo reinforcement grids should be closely inspected to ensure the:

- The adequate dimensions of the culms
- The spacing of the culms in the mesh
- The adequate overlap of any joined culms.

Steel for dowel bars must be accompanied by suitable certification as to their suitability.

8.4.3 Key Issues: Construction and Supervision

1. Ensure that any deformations, ruts, soft spots or other defects in the underlying layer have been corrected to the satisfaction of the Engineer.
2. A layer of thin relatively impermeable textile should be placed over the previously approved sand bedding layer. If this not done then the sand bedding layer should be in soaked condition immediately prior to concrete placement to prevent water being drawn from the mix into the bedding layer.
3. Ensure that all formwork is constructed to be mortar tight and rigid enough to retain the specified shape and position during placing and compaction of the concrete.
4. The bamboo mesh should have been all previously prepared on a suitable plane surface and properly stored close to the road site.
5. Care should be taken to vary the basal and distal ends of the bamboo splints when fabricating the bamboo mesh. This ensures that a uniform area of reinforcement would be obtained throughout the area of the pavement.

6. The bamboo reinforcement should be placed at the top 1/3 of the concrete slab, with a cover of 50mm from the pavement surface. The mesh grid is to have dimensions of 200mmx200mm, as detailed on the Engineering Drawings.
7. Prior to placing the concrete, all formwork and reinforcement should be thoroughly inspected and passed by the Engineer's Representative. All wood chips, dust, sand, construction debris and any other deleterious material must be removed from the formwork and reinforcement prior to placing the concrete.
8. All formwork should be well secured and free from defects or gaps, and able to resist the tamping forces. The top edge of the formwork should be within ± 2mm of the required finished road levels.
9. The reinforcement meshes should be placed on temporary wooden spacers or permanent concrete blocks to ensure the desired 50mm cover to the reinforcement. The wooden blocks must be removed as pouring of concrete progressed. If concrete spacers are used, they should have same strength as the concrete pavement.
10. Contraction joints of 10mm width are required at 5m intervals in the pavement, so to relieve tensile stresses, and expansion joints at 250m intervals. All joints are be provided with load transfer steel dowels of 14 mm diameter mild steel reinforcing bars of 500mm length, placed at 250mm centres.
11. At expansion joints the dowel bar should be anchored into the concrete at one end and the other end coated with bitumen and fitted into a PVC sleeve. The PVC tube is omitted at contraction joints.
12. Ensure that all formwork is wetted so that it is damp when the concrete is poured. Pools of excess water must not be allowed to form in the base of the formwork.
13. All concrete should be mixed on site in small capacity batch mixers complying with the appropriate Vietnamese Standards. Mixers with a capacity less than one bag of cement should not be used and no mixer should be charged in excess of its rated capacity.
14. Proportions of aggregates should be measured using weighing apparatus or batching boxes.
15. Wheelbarrows should be used to transfer concrete from mixing plant to pavement site. Ensure that neither formwork nor reinforcement is disturbed during transfer of concrete to pouring site. Temporary planking walkways should be provided to allow concrete to be transported to the pouring location.
16. Once the concrete had been placed uniformly within the forms, compaction should be carried out using a mechanical poker vibrator. Care should be taken to ensure a good bond between layers of fresh concrete placed separately by vibrating the two layers together until a satisfactorily homogenous cross section is obtained.
17. No concrete should be compacted after initial setting had proceeded. All concrete should be compacted until no air bubbles appear on the surface of the fresh concrete.
18. Care should be taken not to touch the formwork or embedded reinforcement with the vibrator since this would result in concrete having begun initial setting being exposed to re-vibration and also have a detrimental effect on the bond between the concrete matrix and the reinforcement.
19. After placement and compaction, the camber should be shaped in the fresh concrete to lines and levels detailed in the Engineering Drawings using a wooden profile board.
20. In order to improve the skid-resistance of the surface transverse grooves should be etched in the fresh concrete surface utilising an appropriate rake.
21. Formwork should not be removed for 24 hours, although a longer period may be recommended.

22. The concrete should be cured by spreading sand or sacking over the surface of the pavement and repeatedly wetting the materials for a period of at least 7 days. The Engineer may direct a longer curing period depending on local circumstances.
23. All joints should be filled and sealed with a mixture of sand and bitumen, with a reservoir of bitumen provided at the top of each joint.
24. No traffic should be allowed on the pavement until a period of 7 days has elapsed. Suitable temporary diversions should be made for continued flow of normal traffic.
25. The final surface should be quality inspected.

8.4.4 Key Issues: Site Testing

It is essential that concrete slump tests are undertaken as specified in order to identify sub-standard mixing procedures.

Pavement dimensions and crossfall should also be checked at regular intervals

8.5 Steel Reinforced Pavement; Specifications RRST 402

8.5.1 Description

Reinforced cement concrete is a form of rigid pavement designed to spread the applied load due to traffic through a slab effect. It is therefore ideal for construction on weak sub-grades, and on routes liable to seasonal flooding. The normal basic materials in the typical reinforced pavement slab are Portland cement concrete, reinforcing steel, load transfer devices (between slabs), and joint sealing materials. The pavement requires minimal routine maintenance for the shoulders and occasional re-filling of the slab expansion joints with bitumen.

The main function of the nominal reinforcing steel in rigid pavements is to resist the formation of shrinkage cracks. Basic provision of reinforcing steel is not considered to add significant structural benefit, although its presence near the top surface of the concrete will improve the resistance to development of tensile stress cracking. Despite relatively high initial costs, the whole life costs of steel reinforced concrete pavement can be lower than gravel/laterite pavement in some circumstances.

8.5.2 Key Issues: Materials

Section 8.2 outlines the general requirements for concrete materials

Steel for dowel bars and the reinforcement mesh or grids must be accompanied by suitable certification as to their source and suitability. The steel reinforcement grids should be inspected prior use.

8.5.3 Key Issues: Construction and Supervision

1. Ensure that any deformations, ruts, soft spots or other defects in the underlying layer have been corrected to the satisfaction of the Engineer.
2. A layer of thin relatively impermeable textile should be placed over the previously approved sand bedding layer. If this not done then the sand bedding layer should be in soaked condition immediately prior to concrete placement to prevent water being drawn from the mix into the bedding layer.
3. Ensure that all formwork is constructed to be mortar tight and rigid enough to retain the specified shape and position during placing and compaction of the concrete.

4. The steel mesh should have been all previously prepared on a suitable plane surface and properly stored close to the road site. It can either be from pre-formed mesh or a grid fabricated on site with wire binding.
5. The steel reinforcement should be placed at the top 1/3 of the concrete slab, with a cover of 50mm from the pavement surface. The mesh grid is to have dimensions of 200mmx200mm, or as detailed on the Engineering Drawings.
6. Prior to placing the concrete, all formwork and reinforcement should be thoroughly inspected and passed by the Engineer's Representative. All wood chips, dust, sand, construction debris and any other deleterious material must be removed from the formwork and reinforcement prior to placing the concrete.
7. All formwork should be well secured and free from defects or gaps, and able to resist the tamping forces. The top edge of the formwork should be within ± 2mm of the required finished road levels.
8. The reinforcement meshes should be placed on temporary wooden spacers or permanent concrete blocks to ensure the desired 50mm cover to the reinforcement. The wooden blocks must be removed as pouring of concrete progressed. If concrete spacers are used, they should have same strength as the concrete pavement.
9. Contraction joints of 10mm width are required at 5m intervals in the pavement, so to relieve tensile stresses, and expansion joints at 250m intervals. All joints are be provided with load transfer steel dowels of 14 mm diameter mild steel reinforcing bars of 500mm length, placed at 250mm centres.
10. At expansion joints the dowel bar should be anchored into the concrete at one end and the other end coated with bitumen and fitted into a PVC sleeve. The PVC tube is omitted at contraction joints.
11. Ensure that all formwork is wetted so that it is damp when the concrete is poured. Pools of excess water must not be allowed to form in the base of the formwork.
12. All concrete should be mixed on site in small capacity batch mixers complying with the appropriate Vietnamese Standards. Mixers with a capacity less than one bag of cement should not be used and no mixer should be charged in excess of its rated capacity.
13. Proportions of aggregates should be measured using weighing apparatus or batching boxes.
14. Wheelbarrows should be used to transfer concrete from mixing plant to pavement site. Ensure that neither formwork nor reinforcement is disturbed during transfer of concrete to pouring site. Temporary planking walkways should be provided to allow concrete to be transported to the pouring location.
15. Once the concrete had been placed uniformly within the forms, compaction should be carried out using a mechanical poker vibrator. Care should be taken to ensure a good bond between layers of fresh concrete placed separately by vibrating the two layers together until a satisfactorily homogenous cross section is obtained.
16. No concrete should be compacted after initial setting had proceeded. All concrete should be compacted until no air bubbles appear on the surface of the fresh concrete.
17. Care should be taken not to touch the formwork or embedded reinforcement with the vibrator since this would result in concrete having begun initial setting being exposed to re-vibration and also have a detrimental effect on the bond between the concrete matrix and the reinforcement.
18. After placement and compaction, the camber should be shaped in the fresh concrete to lines and levels detailed in the Engineering Drawings using a wooden profile board.

19. In order to improve the skid-resistance of the surface transverse grooves should be etched in the fresh concrete surface utilising an appropriate rake.
20. Formwork should not be removed for 24 hours, although a longer period may be recommended.
21. The concrete should be cured by spreading sand or sacking over the surface of the pavement and repeatedly wetting the materials for a period of at least 7 days. The Engineer may direct a longer curing period depending on local circumstances.
22. All joints should be filled and sealed with a mixture of sand and bitumen, with a reservoir of bitumen provided at the top of each joint.
23. No traffic should be allowed on the pavement until a period of 7 days has elapsed. Suitable temporary diversions should be made for continued flow of normal traffic
24. The final surface should be quality inspected.

8.5.4 Key Issues: Site Testing

It is essential that concrete slump tests are undertaken as specified in order to identify sub-standard mixing procedures.

Pavement dimensions and crossfall should also be checked at regular intervals.

8.6 Non-Reinforced Pavement; Specifications RRST 4.03

8.6.1 Description

Non-reinforced cement concrete is a form of rigid pavement designed to spread the applied load due to traffic through a slab effect. It is therefore ideal for construction on weak sub-grades, and on routes liable to seasonal flooding. The normal basic materials in the typical non-reinforced pavement slab are Portland cement, load transfer devices (between slabs), and joint sealing materials. The pavement requires minimal routine maintenance for the shoulders and occasional re-filling of the slab expansion joints with bitumen.

Despite relatively high initial costs, the whole life costs of non-reinforced concrete pavement can be lower than gravel/laterite pavement in some circumstances.

8.6.2 Key Issues: Materials

Section 8.2 outlines the general requirements for concrete materials

Steel for dowel bars must be accompanied by suitable certification as to their source and suitability.

8.6.3 Key Issues: Construction and Supervision

1. Ensure that any deformations, ruts, soft spots or other defects in the underlying layer have been corrected to the satisfaction of the Engineer.
2. A layer of thin relatively impermeable textile should be placed over the previously approved sand bedding layer. If this not done then the sand bedding layer should be in soaked condition immediately prior to concrete placement to prevent water being drawn from the mix into the bedding layer.
3. Ensure that all formwork is constructed to be mortar tight and rigid enough to retain the specified shape and position during placing and compaction of the concrete.
4. Prior to placing the concrete, all formwork and reinforcement should be thoroughly inspected and passed by the Engineer's Representative. All wood chips, dust, sand,

construction debris and any other deleterious material must be removed from the formwork and reinforcement prior to placing the concrete.

5. All formwork should be well secured and free from defects or gaps, and able to resist the tamping forces. The top edge of the formwork should be within ± 2mm of the required finished road levels.
6. Contraction joints of 10mm width are required at 5m intervals in the pavement, so to relieve tensile stresses, and expansion joints at 250m intervals. All joints are be provided with load transfer steel dowels of 14 mm diameter mild steel reinforcing bars of 500mm length, placed at 250mm centres.
7. At expansion joints the dowel bar should be anchored into the concrete at one end and the other end coated with bitumen and fitted into a PVC sleeve. The PVC tube is omitted at contraction joints.
8. Ensure that all formwork is wetted so that it is damp when the concrete is poured. Pools of excess water must not be allowed to form in the base of the formwork.
9. All concrete should be mixed on site in small capacity batch mixers complying with the appropriate Vietnamese Standards. Mixers with a capacity less than one bag of cement should not be used and no mixer should be charged in excess of its rated capacity.
10. Proportions of aggregates should be measured using weighing apparatus or batching boxes.
11. Wheelbarrows should be used to transfer concrete from mixing plant to pavement site. Ensure that formwork is not disturbed during transfer of concrete to pouring site. Temporary planking walkways should be provided to allow concrete to be transported to the pouring location.
12. Once the concrete had been placed uniformly within the forms, compaction should be carried out using a mechanical poker vibrator. Care should be taken to ensure a good bond between layers of fresh concrete placed separately by vibrating the two layers together until a satisfactorily homogenous cross section is obtained.
13. No concrete should be compacted after initial setting had proceeded. All concrete should be compacted until no air bubbles appear on the surface of the fresh concrete.
14. Care should be taken not to touch the formwork with the vibrator.
15. After placement and compaction, the camber should be shaped in the fresh concrete to lines and levels detailed in the Engineering Drawings using a wooden profile board.
16. In order to improve the skid-resistance of the surface transverse grooves should be etched in the fresh concrete surface utilising an appropriate rake.
17. Formwork should not be removed for 24 hours, although a longer period may be recommended.
18. The concrete should be cured by spreading sand or sacking over the surface of the pavement and repeatedly wetting the materials for a period of at least 7 days. The Engineer may direct a longer curing period depending on local circumstances.
19. All joints should be filled and sealed with a mixture of sand and bitumen, with a reservoir of bitumen provided at the top of each joint.
20. No traffic should be allowed on the pavement until a period of 7 days has elapsed. Suitable temporary diversions should be made for continued flow of normal traffic.
21. The final surface should be quality inspected.

8.6.4 Key Issues: Site Testing

It is essential that concrete slump tests are undertaken as specified in order to identify sub-standard mixing procedures.

Pavement dimensions and crossfall should also be checked at regular intervals.

9 SHOULDERS

9.1 General

9.1.1 Description

The shoulders form an essential and integral part of the constructed road works. The shoulders provide lateral support for the road pavement layers, as well as a safe area for occasional vehicle and pedestrian passage. It is important that the shoulder is well constructed to provide these functions, and will not deteriorate too quickly due to the effects of occasional traffic and weather. Shoulders should be constructed so that they do not allow water to be trapped over moisture susceptible sub-grades or in lower pavement layers, and the surface should not be porous to allow rainwater to easily penetrate the pavement layers. The principal requirements are therefore adequate strength and to be impervious to standing or runoff water. The shoulders should not be easily erodible.

Shoulders should be constructed to fall away from the edge of the road pavement at a fall of 5% or as shown on the Drawings.

9.1.2 Key Issues: Materials

Natural gravel/laterite, quarry run or crushed stone are suitable materials for shoulder construction. In situ or imported material may also be stabilised to produce required specification. However, some materials may need to be laid and blinded with fine material to reduce water penetration. In some cases it is justifiable to seal the shoulders with a bituminous chip or sand seal.

9.1.3 Key Issues: Construction and Supervision

1. Imported local soil must be placed on a previously prepared and approved formation to a loose thickness sufficient to achieve the final compacted thickness. The in situ soil may be used if it is of suitable characteristics and shaped to the required levels and cross section.
2. If the shoulder material is to be processed, this should be carried out according to the Specification requirements.
3. The material should be watered if necessary to achieve the target soil moisture content.
4. The layer should be shaped and then tamped for 1-2 passes using the roller with vibration switched OFF, Compaction with vibration switched ON should then be completed as per the specification or as directed by the Engineer. Alternatively, if permitted by the Engineer, compaction may be carried out by vibrating plate compactor.

9.1.4 Key Issues: Site Testing

The visual inspections should be made to check compliance with the drawings and specifications; for example regarding use of suitable material, adequate compaction, shape and crossfall.

10 REFERENCE DOCUMENTATION

10.1 General

Because of differences in climate, soils, materials, sub-grade conditions, water table and flood conditions, construction practices, quality assurance regime, vehicles types and loading, funding and road maintenance regime between countries, and even regions within countries, it is necessary to take due care in transfer of experiences from one country to another.

The guidance provided in this document is specifically developed for application in the range of Vietnamese conditions, based primarily on an extensive programme of local trials in 12 varied provinces of Vietnam. However some contributory knowledge has been derived from experiences of the project team in other environments and some of the following international and regional documentation.

Conversely, it is probable that the Vietnam specific guidelines may be taken and adapted for application elsewhere. However, care must be taken to appreciate and take into account different environmental and other circumstances that may justify changes or refinement of these guidelines. There is no substitute for local development and experience, and even trials. These Guidelines can provide a framework of issues to be considered.

The following documentation may also assist in this respect.

10.2 Vietnam

1. Ministry Of Transport (MoT- VN), Rural road design standards 22TCN 210-92, Vietnam, 1992.
2. MoT- VN, Construction guidelines of sub-base, base and pavement, Vietnam, .
3. MoT- VN, Construction technical specifications of bitumen emulsion seal/ macadam & crushed stone graded, Vietnam,.
4. MoT- VN,Technical specifications of inorganic stabilized soil 22TCN 81-84, Vietnam, 1984.
5. MoT- VN, Construction technical specifications of hot bitumen seal 22TCN 09-77, Vietnam, 1977.
6. MoT- VN, Construction technical specifications of natural gravel pavement 22TCN 304-03, Vietnam, 2003.
7. Cook J R, and Petts R C, Rural Road Gravel Assessment Programme (RRGAP), Vietnam, Module 4 Final Report, July 2005.
8. WSP, Report on Contracting Constraints in the Rural Roadworks Sector, Vietnam, 2002.
9. WSP, Rural Road Surfacing Studies, Phase 1 Final Report, March 2003.

10.3 Regional and International

1. ARRB. Sealed Local Roads Manual, 1995
2. Austroads, Guide to stabilisation in roadworks, 1998.
3. Azam M, Fayadh S, Gleeson F & Petts R C, LCS Working Paper No 7, Bamboo Reinforced Concrete Pavement, Road Construction In Cambodia June 2002,
4. Beusch A, Hartmann P, Petts R C & Winkelmann P, Low Cost Road Construction in Indonesia, Labour-based Road projects in Manggarai District, Volumes 1 & 2, 1997.
5. BRE, Brickmaking in Developing Countries, 1979.
6. CIDB. Labour based technology and methods for employment intensive construction. Best Practice Guideline 1, 2004
7. Cook J R, Gourley C & Elsworth N, Guidelines on the Selection and Use of Construction Materials in Developing Countries. DFID Knowledge and Research report, R6989. TRL Ltd, 2001
8. CRRI, Low Volume Roads, Construction & Maintenance, A Working Manual, India, 1996.
9. CSIR, Guidelines for the Selection, Design and Construction of Waterbound Macadam Base Layers, March 2001.
10. CSIR, Structural Design of Segmental Block Pavements for Southern Africa, J M Clifford, 1984.
11. Cundill M A, The MERLIN road roughness machine: User Guide, 1996.
12. Gleeson F, LCS Working Paper No 13, Report On Puok Market Trials Construction, Siem Reap, Cambodia, April 2003,
13. Gourley C S, Greening P A K Jones D & Petts R C , LCS Working Paper No 12, Paving The Way For Rural Development & Poverty Reduction, September 2002,
14. Gourley C.S and Greening P A K. Performance of low-volume sealed roads: results and recommendations from studies in southern Africa. TRL Collaborative Research Programme on Highway Engineering Materials in the SADC Region, 1999.
15. 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.
16. Hitch LS & Russell R, Sand - bitumen for road base: an examination of five methods of measuring stability. TRL Report LR 717, 1975
17. ILO, Stone paving blocks, quarrying cutting and dressing, Training Element and Technical guide for SPWP Workers Booklet No 8, 1992.
18. Indian Roads Congress, Recommended Practice for Bituminous Penetration Macadam (Full Grout), 1978.
19. Indian Roads Congress, Standard Specification and Code of Practice for Water Bound Macadam (2^{nd} revision), 1988.
20. Intech Associates – TRL, Rural Road Surfacing Research, Cambodia and Vietnam, 2002 – 2006.
21. Intech Associates, Low cost surfacing research, KaR 7782, 2000 – 2004.
22. Intech Associates, Proceedings of Contracting Development Workshops, Zimbabwe, 1997-9.

23. Intech Associates, *Roads 2000* Pilot project and investigations, Kenya, 1990 – 1996.
24. 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.
25. 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.
26. Lebo J & Schelling D, Design and Appraisal of Rural Transport Infrastructure, Ensuring basic access for rural communities, World Bank Technical Paper No 496, 2001.
27. Miles, Derek., MART Working Paper No.1, Towards Guidelines For Labour-Based Contracting, A framework document, MART and ILO, 1995.
28. Millard R S, TRL, 1993, Road Building in the Tropics.
29. Parry J D, Hewitt N C & Jones T, TRL, Concrete pavement trials in Zimbabwe, 1993.
30. Petts R C, LCS Working Paper No 1, Rationale For The Compilation Of International Guidelines On Low-Cost, Labour-Based, Alternative & Sustainable Road Surfacings 2nd edition, March 2002.
31. 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.
32. SABITA, Black-top roads for reconstruction and development, Instructor Training Module, 1994.
33. SABITA, Methods and Procedures, Labour enhanced construction for bituminous surfacings, 1994.
34. SADC, Guideline for Low-Volume Sealed Roads, 2003
35. Sharp K G & Armstrong J P, Interlocking Concrete Block Pavements, 1985.
36. TRL ORN 18, A Guide to the Pavement Evaluation and Maintenance of Bitumen-Surfaced Roads in Tropical and Sub-Tropical Countries, 1999.
37. TRL, Deflection measurements and road strengthening, 1986.
38. TRL, Introduction to soil stabilisation, 1987.
39. TRL, Overseas Road Note 31 (4th Edition) A Guide to the Structural Design of Bitumen Surfaced Roads in Tropical and Sub-Tropical Countries, 1993.

RRST GUIDELINES

RURAL ROAD PAVEMENTCONSTRUCTION

Appendix A
Illustration of Construction Procedures

RRST GUIDELINES

RURAL ROAD PAVEMENT CONSTRUCTION

APPENDIX A1
Bitumen Emulsion Seals

A1.1 Bituminous Emulsion Chip Seal; RRST 101

The road-base or existing surface should be visually checked for compliance with the Specification and by templates, levels or survey equipment for the correct shape and cross fall.

Surfacing aggregates should be stored on site in clean dry areas adjacent to the road. As- delivered materials should be checked for specification compliance. Where it is necessary to temporarily store material on the roadway, ensure that care is taken to minimise the extent of this and provide a suitable hazard warning for road users.

Prior to priming the surface must be clean and free from dust and loose material which should be removed by brooming.

Aggregate chippings must be placed along the side of the road in heaps ready to apply as soon as the seal emulsion is in place. Where necessary the aggregate should be screened on site.

Bitumen emulsion may applied by spray bar, hand lance or by hand water-can application. Application rates should be checked by site supervisors.

Immediately after the application of bitumen emulsion, the stone chipping application should be made by hand from the adjacent stockpiled heaps. Application rates should be checked by site supervisors.

The surface must then be lightly rolled immediately with an approved roller with NO vibration. Excess aggregate shall be left in place to be bedded in or displaced by the traffic.

The final surface should be quality inspected.

A1.2. Bituminous Emulsion Sand Seal: RRST 102

A similar general approach to emulsion chip seal but using natural sand or fine sand-sized aggregate that has been machine crushed or hand broken and then screened.

Immediately after the application of bitumen emulsion, the sand application should be made by hand from the adjacent stockpiled heaps.

Experience indicates that spreading sand in small panels at a time is both easier to control and achieves abetter overall results

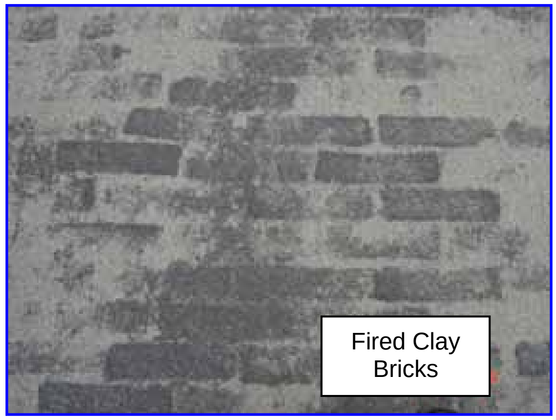
The surface must then lightly rolled immediately with an approved 1-3 tonne roller with NO vibration.

Excess sand/fine material shall be left in place to be bedded in or displaced by the traffic.

Sand sealing may be specified as a waterproofing to concrete block or fired clay brick pavements.

Concrete Blocks

Procedures are similar to those for a sand seal on top of an emulsion chip seal.



Fired Clay Bricks

RRST GUIDELINES

RURAL ROAD PAVEMENT CONSTRUCTION

APPENDIX A2
Stabilised Sub-Base; Base

A2.1 Stabilisation with Slaked Lime; RRST 202

Approved local soil should be placed on a previously prepared and approved sub-base or formation. The break up of clayey clods and pre-mixing of the in-situ or imported soil to be treated is essential in order to ensure a homogenous material for stabilisation.

Bags of lime should be accurately spaced at equal intervals so as to provide the specified rate of application. This spacing should be cross-checked.

After breaking open the bags the lime should be uniformly spread using hand tools on top of the layer to be stabilised.

Lime should meet the specified grading specifications. On site removal of coarse material may be required. Lime that has already been affected by water and is excessively lumpy must be rejected.

Immediately after the lime has been spread, it shall be mixed with the loose soil for the full depth of treatment by an approved rotovating machine.

After initial mixing it will normally be necessary to add and mix in water in order to achieve the target design moisture condition and hence acceptable compaction and strength.

After mixing has been satisfactorily completed the layer must be shaped and then tamped for 1-2 passes using the roller with vibration switched OFF. Compaction with vibration switched ON should then be completed according to the specification.

Layer compaction must be completed within 24 hours of the mixing of the lime with natural soil.

A2.2 Stabilisation with Cement; RRST 203

This procedure is broadly similar to that of lime stabilisation except that mixing, shaping and compaction must be completed within 6 hours of spreading the cement.

Pre-mixing of the sandy soil to be treated may be required if it is not homogenous.

Bags of cement should be accurately spaced at equal intervals so as to provide the specified rate of application. This spacing should be cross-checked. Cement that has already been affected by water and is excessively lumpy must be rejected.

After breaking open the bags the cement should be uniformly spread using hand tools on top of the layer to be stabilised.

Immediately after the cement has been spread, it shall be mixed with the loose soil for the full depth of treatment by an approved rotovating machine.

Mechanical mixing may be aided by manual raking.

It will normally be necessary to add and mix in water in order to achieve the target design moisture condition and hence acceptable compaction and strength.

After mixing has been satisfactorily completed the layer must be shaped and then tamped for 1-2 passes using the roller with vibration switched OFF.

Following initial tamping the compaction with vibration switched ON should then be completed according top the specification. Areas with apparent surface defects may be required to be scarified and re-compacted.

A2.3 Stabilisation with Bitumen Emulsion; RRST 204

Approved sandy soil should be placed on a previously prepared and approved sub-base or formation. Pre-treatment of the sandy soil may be required to break up or remove any lumps.

The target soil moisture content should generally be just below the standard optimum content. Ensure there is satisfactory moisture distribution over the full depth, width and length of the section being treated.

The un-stabilised soil should be dampened if necessary to achieve this, and mixed to ensure uniform dispersion of the moisture through the unstabilised material.

In hot conditions dampening of sandy soil should immediately precede mixing.

.

Consideration should be given to diluting the emulsion in hot dry conditions in order to achieve adequate mixing in sand materials.

It is recommended that for labour based spreading operations the required amounts of bitumen emulsion should be added to short 10-15m lengths of pavement at a time;

Bitumen emulsion can then be uniformly spread on top of the layer.

Initial raking by hand tools can be employed to aid a uniform spread of the emulsion.

It is recommended that a small percentage of the emulsion be retained for final topping up of patches that become apparently deficient in emulsion both prior to and during mixing.

Mixing of lengths evenly spread with emulsion should be done only with approved rotovating equipment.

Mixing must be continued until a thorough and uniform mix of the soil and emulsion has been achieved over the full width, length and depth of the material being treated, which must be homogeneous and of uniform appearance throughout.

After mixing has been satisfactorily completed the layer must be shaped and then tamped for 1-2 passes using the roller with vibration switched OFF. Compaction with vibration switched ON should then be completed.

RRST GUIDELINES

RURAL ROAD PAVEMENT CONSTRUCTION

APPENDIX A3
Non-Stabilised Sub-Base/Base Procedures

General

Appendix A3 is concerned with illustrating aspects relating to the construction of non-stabilised sub-base and base pavement layers. The materials used in these procedures are essentially naturally occurring or processed granular materials and vary from well graded clayey lateritic gravels to coarse aggregate in nature.

Section A3.1 of this appendix illustrates key points in the general procedure for the construction of granular materials for the sub-base or base of rural roads in Vietnam. Subsequent sections A3.2 to A3.6 highlight variations in the general procedure for specific materials (eg Quarry Run) or particular RRST options such as Dry Bound Macadam.

A3.1 Granular Sub-Base and Base

Ensure that any deformations, ruts, soft spots or other defects in the underlying layers have been corrected and that the layer has been laid to the correct shape and strength condition.

Ensure that the specified materials are delivered to site and unloaded in the appropriate amounts taking into account the compacted thickness of the layer to be constructed and the bulking factor of the particular materials being used.

Secure lateral support for the sub-base should be in place prior to the construction of the sub-base or road base layer.

Ensure that any segregation of the material during dumping or spreading is remedied by reworking to the appropriate grading and that any oversized material removed or broken by labourers with hand tools.

The rolling shall begin from the road edges with roller running forward and backward, parallel to the centreline of the road until the layer has been firmly compacted.

Rolling should continue until the material matrix is thoroughly keyed and stone movement ahead of the roller in no longer visible.

After initial compaction of the road base, 'hungry' spots shall be filled with screening materials as directed by the Supervising Engineer, lightly sprinkling water if necessary and re-rolled.

Once the surface has been completed it should be carefully inspected before approving construction of any overlying layers or seals.

A3.2: Armoured Gravel Roadbase; RRST205

This activity has two components: an initial component of natural gravel laid to camber, watered and compacted in two layers, followed by a topping or armouring (usually 50-75mm thick) of crushed/broken stone aggregate laid to camber, watered and compacted.

The approved natural gravel should be delivered and laid out in the standard approved manner.

Either manually using hand tools;

Or with the assistance of available approved mechanical plant.

The natural gravel is compacted and shaped in the approved normal manner.

Make sure that there is a sufficient supply of water, to maintain close to optimal moisture content in the gravel during compaction.

The approved aggregate armouring is then spread uniformly over the natural gravel surface.

Following the spreading of aggregate, ensure that it is first rolled dry with the aid of an approved vibratory roller. The rolling shall begin from the edges of the pavement and work towards the centre of the road, with the roller running forward and backward, parallel to the centreline of the road until the layer has been firmly compacted. On super-elevated sections the rolling should start at the low side and work towards the high side.

Rolling should continue until the material matrix is thoroughly keyed and stone movement ahead of the roller in no longer visible. Light sprinkling of water may be required to assist compaction.

A3.3 Sand Sub-base (Hydraulically Pumped) RRST 206

In some projects it is possible that sand may be transported by barge or boat and then hydraulically pumped to its point of placement, as could be the case in the Mekong or Red River Delta regions.

The sand can be pumped directly onto the approved sub-grade between previously prepared shoulder restraints.

The sand is in an oversaturated condition and it is necessary to ensure that appropriate measures are in place to drain off excess water prior to compaction.

Once the sand is fully drained the layer is shaped and compacted in the normal manner.

A3.4 Quarry Run for Sub-Base; RRST 207

Quarry Run is by its nature highly variable and the principal issue with this procedure is consistency of material quality.

Initially assessing the suitability of the source to produce acceptable material is crucial. Even if the source meets specified criteria, any materials with excessive variation within the acceptable envelopes should be rejected due to the consequent problems caused in compaction control.

Supervision resources must be available to ensure the continued consistency the as-delivered material throughout the contract.

It may be necessary to counter variability in as-delivered by material be removing oversize and/or some reworking with hand tools.

A3.5 Dry Bound Macadam Base/Sub-Base; Specification RRST 210

Lateral confinement is a crucial requirement for macadam sub-base and base courses. The stone skeleton forms the "backbone" of the macadam and is largely responsible for the strength of the constructed layer.

The coarse aggregate should be placed first. After ensuring appropriate amounts of the stone are unloaded, spreading should be commenced with special rakes or hoes to spread the material evenly onto sub-grade or sub-base, and to initially set the material in a plane surface. High, poorly positioned or oversize individual stones should be accommodated by breaking or seating by hand with a club or lump hammer prior to initial machine compaction.

Compaction to lock in of the coarse aggregate should then be undertaken with 8 or 12Tonne static rollers. Rolling should always progress towards the higher side: if the road cross section is cambered, rolling starts at the sides and progresses towards the centre; if super-elevated, it should start at the low side and progresses upwards.

The well graded fine aggregate, should then be spread onto the keyed-in coarse aggregate layer by hand, using shovels and rakes (or by mechanical chip-spreader).

The thickness of the loose filler placed in one application should not exceed 25 mm and should be evenly distributed.

Compaction should then be carried out in a series of continuous operations covering the full width and length of the layer concerned using an approved vibrating roller.

The process of successive applications of fine aggregate and vibratory compaction is continued until the layer is choked with fine aggregate. The blinding fines may need to be lightly watered for dry-bound macadam to assist in the process.

RRST GUIDELINES

RURAL ROAD PAVEMENT CONSTRUCTION

APPENDIX A4
Block Pavements

A4.1 Fired Clay Brick Pavement; RRST 301 (Emulsion sand seal and sand joints)

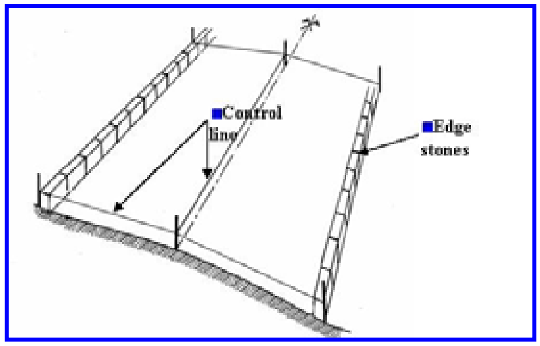
Delivered bricks shall be stacked on or adjacent to the prepared formation in such a manner as to allow for continuity of operations.

The pavement edge bricks or kerbs should be placed first to the correct final level. They must be, bedded and jointed with cement mortar to act as a level and alignment guide for laying the rest of the paving as well as a secure firm edge restraint.

No progress should be allowed on the main area of brick surface until the pavement edge is satisfactorily completed.

After the pavement edge is satisfactorily completed and has gained sufficient strength, the sand for the bedding layer can be spread and then lightly compacted to level and shape.

The bricks can then be laid on edge (100mm depth) using string lines as a guide, over the previously compacted bedding layer within the edge restraints.



The bricks should be laid in the herring bone or other approved pattern.

Ensure an even abutment of the bricks against the edge constraints; with any gaps at the edge to be later in-filled with cement mortar.

Joint spacing between bricks should be between 5 and 10mm.

Joints between bricks are then filled by sand, which is first carefully spread over the placed bricks, and then brushed in without disturbing them.

The laid paving can then be compacted with a vibrating plate compactor to properly bed the bricks and key the joint sand securely between the bricks.

Joints should be refilled as necessary and re-compacted to achieve full joints and satisfactory interlock between the bricks.

A seal is likely be specified in order to waterproof the finished surface as a separate operation (RRST102).

A4.2 Fired Clay Brick Pavement; RRST 302 (Mortared joints)

Similar procedures to RRST 301; the principal difference is that cement mortar is used instead of sand for bedding-in and joint filling.

Joint infill should be finished level with the top face of the bricks so as to provide a smooth finished surface. Any excess mortar must be removed.

A4.3 Concrete Brick Pavement; RRST 303

The kerbs are usually of concrete brick or larger units, although cast in situ concrete is also acceptable.

As in all block paving options the edge restraint is an essential feature and must be constructed in advance of the main paving.

After the pavement edge is satisfactorily complete and has gained sufficient strength, the sand for the bedding layer can be spread and then lightly compacted to level and shape.

The concrete bricks can then be laid on their bottom face (70mm depth) using string lines as a guide, on the previously compacted bedding layer within the edge restraints.

Joint spacing between bricks should be between 5 and 10mm.

The bricks should be laid in a herring bone or other approved pattern.

Joints between bricks are then filled by sand, which is first carefully spread over the placed bricks, and then brushed in without disturbing them.

Joints should be refilled as necessary to achieve full joints and satisfactory interlock between the bricks. If laid bricks are laid to a herring bone pattern, edge gaps should be in-filled by cement mortar.

A bitumen or bitumen emulsion sand seal (RRST 102) is likely to be specified as a waterproofing procedure.

A4.4 Cobble Stone Pavement; RRST 304

Mortared pavement edge stones must be placed first to the correct lines and levels to act as a strong edge restraint and as a level and alignment guide for laying of the rest of the paving.

After the pavement edge is satisfactorily complete and has gained sufficient strength, the sand for the bedding layer can be spread and then lightly compacted to its level and shape.

Cobble stones can then be taken from small adjacent stockpiles to be placed on the previously compacted bedding layer within the edge restraints.

All cobble stones should be examined and then placed with the smoothest face uppermost.

Each stone should be lightly tapped into position with a mason's hammer, to ensure initial bedding.

The cobbles should be placed in an approved pattern, with joint spacing between the cobbles of between 5 and 10mm.

Joints between cobbles are then infilled with the specified sand-gravel material, which should be a loose, dry natural or crushed stone material with a particle size distribution equivalent to a well graded coarse sand to fine gravel.

The specified sand-gravel material is first spread over the placed cobble stones, and then brushed in.

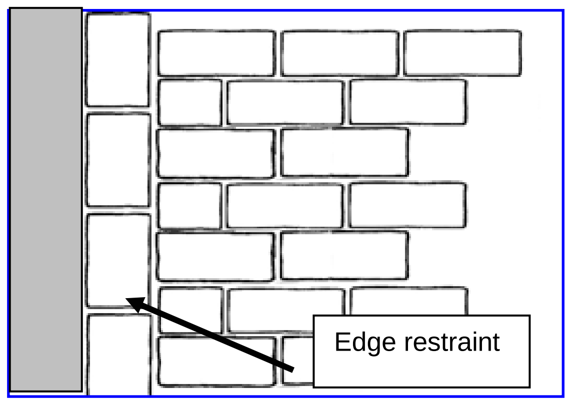
When a suitable area of cobbles and infilled joints is laid, it should be consolidated with a small vibrating roller or plate compactor. Additional infill materials should then be brushed into the surface as required.

A final rolling is then carried out by a minimum1 Tonne vibrating roller with 6-8 passes per point. Light and even sprinkling of water may be used to aid the consolidation of the sand-gravel within the joints.

A4.5 Mortared Dressed Stone Pavement; RRST 305

A similar procedure to RRST 304, but using mortared dressed stone blocks; in this case manually extracted from fresh granite exploiting natural stress patterns within the rock mass.

The dressed stones should be placed in an approved staggered pattern with the longest dimension across the road. Alternate stones at the pavement edge will be half size to allow joints in the paving to be staggered in adjacent rows.



As with other block paving options, the stone blocks should be placed with already established edge restraints.

Joint spacing between the dressed stones should be between 5 and 10mm. The joints should be also filled to within about 30mm of the top surface with cement mortar.

Edge restraints formed by mortared stone blocks with long axis parallel to the road.

When a small area of dressed stones is in place and before the cement mortar has set they can be consolidated in position with a small hand-operated plate compactor.

The joints should then be completed by filling and consolidating to within 10mm of the surface with cement mortar, and finished smoothly.

RRST GUIDELINES

RURAL ROAD PAVEMENT CONSTRUCTION

APPENDIX A5 Concrete Pavements

This appendix provides key illustrations for RRST concrete roads in general

A5.1 RRST Concrete Pavements: General Considerations
RRST 401; RRST 402; RRST 403

Attention should be paid to the preparation of the sand bedding surface on which the concrete slab is laid. This should be compacted and formed to the specified shape.

A layer of thin relatively impermeable membrane should be placed over the previously approved sand bedding layer. If this not done then the sand bedding layer should be in soaked condition immediately prior to concrete placement to prevent water being drawn from the mix into the bedding layer.

Ensure that all formwork is constructed to be mortar tight and rigid enough to retain the specified shape and position during placing and compaction of the concrete.

All concrete should be mixed on site in small rated capacity batch mixers complying with the appropriate Vietnamese Standards. Mixers with a capacity less than one bag of cement should not be used and no mixer should be charged in excess of its rated capacity.

Wheelbarrows should be used to transfer concrete from mixing plant to the pavement site. Ensure that neither formwork nor reinforcement is disturbed during transfer of concrete to pouring site. Temporary planking walkways should be provided to allow concrete to be transported to the pouring location.

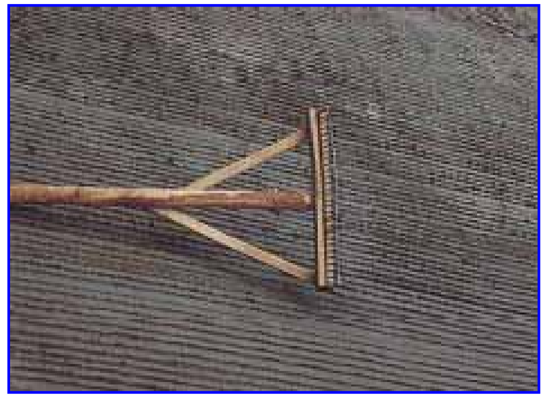
The control of the water-cement ratio in the concrete mix is crucial. **Over-watering should not be tolerated;** it is however common practice with contractors' personnel to attempt this in order to make the concrete easier to mix and place. However this weakens the concrete and substantially increases the risk that it will crack on drying out.

Regular slump testing is an essential control on water content.

In some circumstances construction of half-width concrete slabs may be permitted with the agreement of the Engineer. Longitudinal joints should have a load transferring dowel and sealing arrangement similar to that of transverse contraction joints. In low volume roads (Commune Class B) it may be permissible to use bevelled formwork to produce a "tongue in groove" load transferring arrangement for longitudinal joints in place of dowels.

After placement and compaction, the camber should be shaped in the fresh concrete to lines and levels detailed in the Engineering Drawings using a wooden profile board.

Suitable grooving of the finished concrete surface provides good skid resistance and improved safety for the road users.



As soon as the concrete is placed and set, the curing should commence either by spreading sand or sacking over the surface of the pavement and repeatedly wetting the materials for a period of at least 7 days.

All joints should be filled and sealed with a mixture of sand and bitumen, with a reservoir of bitumen provided at the top of each joint.

A5.2 Bamboo Reinforced Concrete Pavement; RRST 401

The proposed bamboo should be inspected for suitability in its cuts lengths prior manufacture of the reinforcement mesh. It must be sound and have been properly cured.

The bamboo mesh grid is to have dimensions of 200mmx200mm, with splints measuring 25mm in width on average. Bamboo should be placed with its concave face upwards.

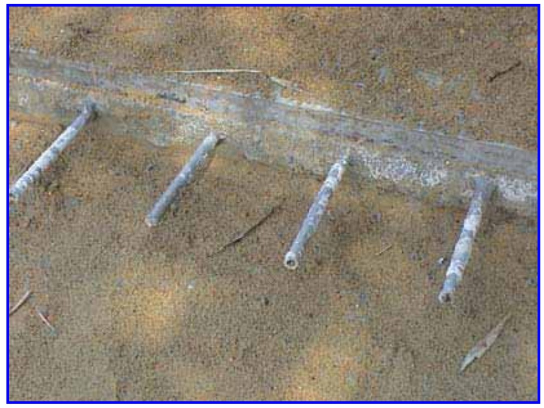
The bamboo reinforcement grids should be closely inspected to ensure the:

- The adequate dimensions of the culms
- The spacing of the culms in the mesh
- The adequate overlap of any joined culms.

The bamboo reinforcement should be placed at the top 1/3 of the concrete slab, with a cover of 50mm from the pavement surface.

The reinforcement meshes should be placed on temporary spacers or permanent concrete blocks to ensure the minimum 50mm cover to the reinforcement. The temporary spacers must be removed as pouring of concrete progressed. If concrete spacers are used, they should have same strength as the concrete pavement.

Contraction joints of 10mm width are required at 5m intervals in the pavement, so to relieve tensile stresses, and expansion joints at 250m intervals. All joints should be provided with load transfer steel dowels of 14 mm diameter mild steel reinforcing bars of 500mm length, placed at 250mm centres.



Once the concrete had been placed uniformly within the forms, compaction should be carried out using a mechanical poker vibrator. Care should be taken to ensure a good bond between layers of fresh concrete placed separately by vibrating the two layers together until a satisfactorily homogenous cross section is obtained. Pours within slabs should be continuous.

Vibrating plate compactors may be used to aid in the compaction of the concrete but only in conjunction with the specified vibrating poker.

RRST GUIDELINES
RURAL ROAD PAVEMENT CONSTRUCTION

APPENDIX B

Key Supervision Activities

B1 Natural Construction Material Approvals

Material approvals should be normally undertaken in two distinct phases.

- General approval of source materials
- Approval of materials as delivered to site

The final Quality Assurance assessments of As Built roads also include elements of material approval; as illustrated in Section B5 below.

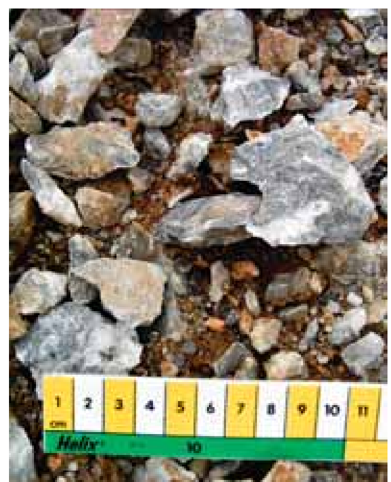
Visually check, material at source for general approval. Sample for approval testing

The likely variability of the source should be assessed. This is of particular importance with respect to hill gravel or laterite sources where no processing is involved. Sampling must be realistically representative of the material being won. Take samples from stockpiles or already excavated material rather from borrow pit faces

If the material is being processed then assess the capability of the plant to consistently produce satisfactory material in sufficient quantities.

Samples should be large enough to meet the required testing standards

Examine material as delivered to site and sample and test as required. As-delivered material must be as per agreed specification.



Visual checks of as–delivered material can a give good indication of whether or not it meets sized and shape specifications

As delivered materials that do not meet agreed specifications should not be approved even if the original source has been approved.

As-delivered materials must be sampled and tested.

B2 Construction Plant Approval

Many of the RRST specifications require specific plant to use in the construction procedures. Use of inappropriate plant, or plant in poor condition, should not be approved.

Renovators proposed for use in stabilisation options should be checked for their general acceptability and condition.

Details such as blade depth must also be checked.

Some RRST procedures specify light vibrating rollers. Inappropriate plant should not be approved

Example: This large vibrating roller is **not suitable** for the use to which it was put in completing a DBM layer on a 3.5m rural road.

Example; **Appropriate use** of light vibrating plant in cement stabilisation procedure.

Example; Inappropriate use of a static roller to roll fines into DBM.

Example: Appropriate use of static roller to lock-in coarse aggregate for DBM.

Example; Light grader **suitable** for rural roads spreading and shaping.

Example: Inappropriate use of heavy trucks to deliver materials along the RRST road being constructed.

B3 Construction Procedures Supervision

It is essential that the correct procedures are followed in constructing RRST options; otherwise this can lead to early pavement deterioration and even road failure. The following are some examples of poor construction practice that should not be approved by supervising engineers.

Construction of narrow shoulders on unprotected embankment; this is likely to lead to erosion and edge failure.

Bamboo reinforcement not placed as specified and subsequently exposed at the pavement surface.

Poor supervision of concrete mix; mix is too wet.

Poorly finished and cracked joint area in concrete pavement with insufficient seal as a reservoir.

Poor application procedure for bitumen emulsion.

Insufficient bitumen applied to seal resulting in rapidly deteriorating surfaces.

Bitumen or bitumen emulsion application rates should always be checked.

Oversize aggregate being laid in DBM, leading to poor compaction and subsequent deterioration.

Poorly compacted and weak sub-base can lead to pavement deterioration. Example: deep ruts and failure in locally constructed brick pavement.

Poor quality bricks being laid prior to edge restraints and with insufficient gaps between bricks. Any one of these three actions should lead to non-approval of the construction.

Insufficient gaps between bricks does not allow sand in to establish a locked pavement

RRST GUIDELINES
RURAL ROAD PAVEMENT CONSTRUCTION

Appendix C

Standard Supervision Forms

DAILY SUPERVISOR FORM

Road

Date

Supervisor

Rainfall
Sunshine
Temperature

Work Done

Chainage		Work Type	Amount	Labour	Hours	Plant	Hours
From	To						

Materials

From	To	Material Type	Use for	Source	Comments on materials

QA

Testing		Sampling Ref.	Lab Tests Assigned	In situ Testing Ref.	Comments on Testing
From	To				

Measurement		Thickness	Crossfall	Comments
From	To			

Addiornal Comments

Signature

Lab test code		**Material sign**	
1. Graded	9. LosAngeles abration value	CSA: Coarse Aggregate	SA: Sand
2. Plastic index	10. Water Absorption	FSA: Fine Aggregate	CL: Clay
3. Particle size distribution (pass sieve)	11. Aggregate shape	C: Cement concrete	B: Bitumen
4. Particle size distribution (hydrometer)	12. Cement	DRS: Dressed Stone	EA: Earth
5. Moisture Content	13. Organic content	CBS: Coble Stone	Br: Brick
6. Unconfined Compression strength	14. Sand Equivalent Value	BE: Bitumen Emulsion	
7. Standard Compaction	15. Strip	NG: Natural gravel	
8. California Bearing Ratio	16. Sulfate Content	CR: Crushed stone graded	

Site Photograph Inventory

Date	Chainage		Surface Type	Work Type	Photogragh	Note
	From	To				

Road Construction Quality Assessment Site Form

Province: Trial Road Name**:**
Date**:** Inspector:

Chainage		Ref No	Trial Option	Carriageway Condition	Shoulder Condition	Road Geometry	Inspection Pit Quality Assessment
From	To						

Comment & Conclusion

Signed Date

Road Construction Quality Assessment Site Form Notes

Aspect	**Code**	**Assessment**
Carriageway	A	No quality problems identified
	B	Slight problem – some action may be required
	C	Major problem. Completion/repair in guarantee period
Shoulder	A	No quality problems identified
	B	Slight problem – some action may be required
	C	Major problem. Completion/repair in guarantee period
Road Geometry	A	Geometry acceptable
	B	Slight problem – some action may be required
	C	Major problem. Completion/repair in guarantee period
Inspection Pit	A	No quality problems identified
	B	Slight problem – some action may be required
	C	Major problem. Completion/repair in guarantee period

Road Construction Data Assessment Form

Province: Trial Road Name:
Date: Cross checked by :

Chainage		Ref No	Trial Option	Site Testing Results		Lab Testing Results		Daily Work Sheets
From	To			Results Received	Layer Quality	Results Received	Material Quality	

<u>Comment & Conclusion</u>

Signed Date:

Road Construction Data Assessment Form Notes

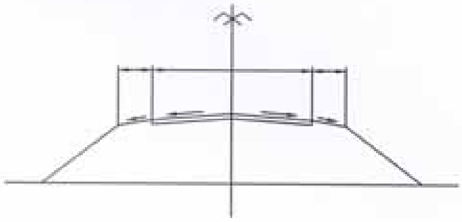
Aspect	**Code**	**Assessment**
Lab. Test		
Material quality	A	Satisfactory
	B	Some unsatisfactory criteria
	C	Unsatisfactory
Results received	A	Full data as required
	B	Insufficient data but not considered significant
	C	Significant data missing
Site test		
Quality	A	Satisfactory
	B	Some local weak areas
	C	Unsatisfactory
Results received	A	Full data as required
	B	Insufficient data but not considered significant
	C	Significant data missing
Daily worksheet	A	Full data as required
	B	Insufficient data but not considered significant
	C	Significant data missing

Field Quality Assurance Data Collection Form

PROVINCE: . . . .

Road name: . . . .

Chainage: Km +
Pavement Option: . . . .

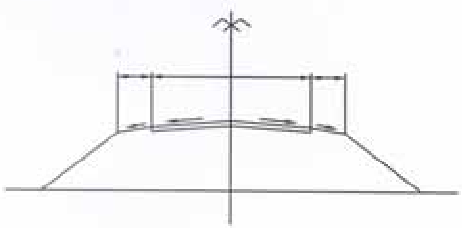


Carriageway: . . . .

Shoulders: . . . .

Inspection pit:
- Pavement: . . . .
- Base: . . . .
- Sub-base: . . . .

Chainage: Km +
Pavement Option: . . . .

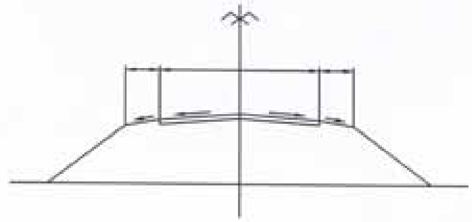


Carriageway: . . . .

Shoulders: . . . .

Inspection pit:
- Pavement: . . . .
- Base: . . . .
- Sub-base: . . . .

Chainage: Km +
Pavement Option: . . . .

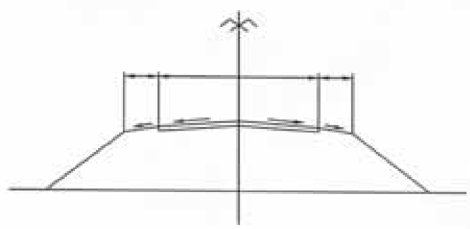


Carriageway: . . . .

Shoulders: . . . .

Inspection pit:
- Pavement: . . . .
- Base: . . . .
- Sub-base: . . . .

Chainage: Km +
Pavement Option: . . . .



Carriageway: . . . .

Shoulders: . . . .

Inspection pit:
- Pavement: . . . .
- Base: . . . .
- Sub-base: . . . .