Intech Associates
CONSULTING ENGINEERS

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SEACAP PROGRAMME

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SEACAP 8
CAMBODIA Low Cost Surfacing Phase 2

FINAL REPORT

Volume 2
Appendices B & C

July 2006

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Our Ref: 0370/VA4

Your Ref: SEACAP 8

21 October 2006

Attention Excellency Suos Kong
Secretary of State
Ministry of Rural Development
Chairman SEACAP Steering Committee
Phnom Penh, Cambodia.

Dear Excellency Suos Kong,

RE: SEACAP 8 FINAL REPORT, VOLUME 2 (APPENDICES B & C)

Please find attached a copy of the Final Report, Volume 2 for the Low Cost Surfacing, Phase 2 (SEACAP 8), incorporating the comments received on the initial draft document.

We hope that some of the recommendations of this report will be able to be applied in Rural Road design and construction practices and taken up by future programmes and initiatives.

We would like to thank everybody involved with the Puok Trials and SEACAP 8 over the years of research and investigations for their support and contributions.

Yours sincerely

Robert Petts
Project Manager

cc Excellency Suos Kong, Secretary of State, Ministry of Rural Development, Chairman SEACAP Steering Committee
H.E. Lim Sidenine, MPWT, Vice Chairman SEACAP Steering Committee
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CAMBODIA LOW COST SURFACING TRIALS PHASE 2 COMPLETION REPORT

Volume 2

First Edition: July 2006

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FOREWORD

These draft Specifications have been specifically developed for rural road contract applications where local resource based methods are to be encouraged in support of Government poverty reduction initiatives. This in effect means that the use of local labour (Labour Based Appropriate Technology – LBAT) and contractors are actively encouraged through the policies of the client authority and the appropriate design and wording of the Contract documentation.

The draft Specifications have been written with the appreciation of the difficulty in obtaining reliable materials strength and testing services in remote rural road locations. The use of the Dynamic Cone Penetrometer (DCP) is promoted due to its low cost and simplicity of use, and furthermore it's in-built checking characteristics. However the nature of construction materials is such that the measured strength can vary substantially with moisture and soaking conditions. It is recommended that the moisture-strength relationships are determined at the beginning of the contract for the principal sources and types of material. Thereafter the DCP may be used as a swift and convenient way to monitor materials quality, identifying locations where more detailed investigations may be justified.

The compaction requirements of the Specifications are based on "method specifications". It is recommended that short trial sections are constructed at the start of the Contract to confirm the number of passes required with the equipment available to achieve the requirements of the Specifications, unless the material source has a proven compaction history.

Axle loading on rural roads has become an issue of widespread concern in Cambodia. Overloaded trucks on some routes can inflict considerable damage and substantially accelerate the wastage of road investments. It is necessary to engineer the road design with full appreciation of the risk of high axle loading. Where reference is made to axle loading conditions in the Specifications; Light loading conditions refer to locations where there is little or no possibility of use by vehicles loaded to more than 6 tonnes per axle. Medium loading conditions refer to locations where there is little or no possibility of use by vehicles loaded to more than 12 tonnes per axle. Heavy loading refers to routes that could be used for haulage of aggregates by standard or strengthened heavy duty highway trucks and use by other heavy vehicles. Routes that may be subjected to heavy axle loading (>12 tonnes per axle) require careful consideration and specific attention to pavement design that may necessitate the application of higher specifications for the materials than recommended in this document. This would be particularly relevant for the upper pavement layers. In general terms Hand Packed Stone, Dressed Stone and Bamboo Reinforced Concrete Pavement are the only road bases/surfaces contained in this document that are recommended as suitable to withstand Heavy axle loading conditions, with appropriate pavement and drainage design.

DRAFT SPECIFICATION 1

1. EARTH WORKS AND SUBGRADE

1.1 DESCRIPTION

The operation comprises the excavation of borrow material, hauling, spreading and compaction of the material on the embankment fill to lines, levels and dimensions as shown on the Engineering Drawings and as directed by the Engineer. The Contractor shall take the necessary action if required and directed by the Engineer to avoid any erosion or other damages in connection with the excavation or fill operations.

1.2 MATERIALS

Materials for the embankment shall consist of suitable materials excavated from the roadway excavations, channel excavations or structural excavations and from the approved borrow pits. Material from borrow pits shall only be used where the Contractor has demonstrated and the Engineer has agreed that there is an inadequate quantity of suitable material from the scheduled excavations.

The Embankment shall be constructed of materials with a CBR value not lower than the design values stated in these Specifications or on the Drawings.

These CBR values of embankment shall be for samples compacted to 90% of the maximum dry density determined by AASHTO T180. All test samples shall be soaked, in accordance with the requirements of AASHTO T193. Materials with a CBR value less than 3% shall not be considered suitable for Embankment.

The term “subgrade” shall refer to the top layer of the earthworks immediately underlying the pavement structure at formation level, and shall be 200mm thick or such greater thickness as may be defined in the drawings. Subgrade shall be compacted to 95% of maximum dry density. The provisions of these Specifications applicable to “embankment” shall generally apply to subgrade in addition to those provisions especially applicable to subgrade.

Embankment materials for subgrade classified as selected materials shall be constructed to the thicknesses and levels shown on the Drawings and shall consist of naturally occurring soil aggregate free of topsoil and all other organic matter. The soil aggregate shall consist of sound durable particles which do not breakdown under compaction or repeated wetting/drying cycles. All particles greater then 50 mm shall be screened or hand-picked and removed at source or from the working layer.

The subgrade material shall have a Liquid Limit, as determined by AASHTO T 89, of not greater than 40 percent and a plasticity index, as determined by AASHTO T 90, of not greater than 20 percent. The fraction passing the 0.075 mm sieve shall be more than 10 percent but not greater than 30 percent. In addition the material shall have a CBR of not less than 7 percent or minimum designed subgrade strength measured after a 4-day soak on a laboratory mix compacted to 95 percent of the maximum dry density in a moisture range of 3 percent as determined in AASHTO T-180.’

1.3 CONSTRUCTION METHODS

All borrow material locations shall be authorised in writing by the Engineer. Such authorisation shall only be granted if the excavation of side drains or other roadway

excavations does not yield sufficient fill. The Contractor shall obtain the prior permission of the Engineer before developing any borrow area including the widening of cuts or drains. Should there be insufficient suitable material adjacent to the road to complete the earthworks construction the Engineer shall instruct the Contractor to open a borrow pit and to transport the material by suitable approved means. Any such borrow pit shall be operated in such a way as to cause the minimum of environmental damage to the location and nuisance to the public. The Contractor shall conduct all negotiations with the land owner/occupier, preparing and signing the legal agreements, making payments (if any) and giving proper notice to enter upon the land and obtaining all the necessary consents. The Contractor shall provide copies of all relevant documentation to the Engineer for approval before starting borrow excavation.

The Works shall be carried out using appropriate hand tools and equipment. Embankments and fills shall be constructed in layers approximately parallel to the finished grade of the road bed. During construction, a smooth grade having an adequate crown shall be maintained at all times to provide drainage. The fill layers shall not exceed a thickness of 150mm after compaction, consisting of materials free from roots, sods or other deleterious material.

The Contractor shall establish sufficient setting out pins, pegs, markers and profile boards to ensure that the final shape of the earthworks conforms with the Drawings, and to allow checking thereof.

Where fill (side fill) is being carried out to widen an existing embankment or repair erosion of an embankment batter, the new fill material shall be fully keyed into the old fill by means of benching which shall be in steps each not less than 300 mm high. Steps shall be cut in advance of the filling.

The side slopes of embankments and side fills shall be trimmed to line and compacted sufficiently to prevent the formation of erosion gullies.

In areas where the formation (top of subgrade) is in cut, then the excavations shall be trimmed to the required shape and levels and the surface compacted. If the subgrade in the area of cut does not meet the requirements of this clause, it shall be removed by the Contractor and disposed of in such a way as to cause the minimum of environmental damage to the location and nuisance to the public.

1.4 CONSTRUCTION EQUIPMENT

In the absence of site testing facilities the Engineer shall instruct the Contractor on the method of compaction with the available plant. In general this will be in the range for vibrating rollers, of:

(a) Where the final road surface is earth, gravel or other unsealed surface:

Weight	Number of Passes (Earthworks)
700 kg	8 per point
1,000 kg	6 per point

(b) Where the final road surface is to be sealed or paved:

Weight	Number of Passes (Earthworks)
3,000 kg	6 per point

Compaction shall be carried out from the edges of the embankment or side fills towards the centre and the material shall be as close as reasonably possible to the Optimum Moisture Content for the compaction effort. The Contractor shall use a water bowser to achieve this state and shall allow time for material which is too wet to dry to the same state before attempting to compact. If site testing is available the earthworks shall be compacted to not less than 90% MDD AASHTO Modified Proctor for embankment and 95% MDD for subgrade. The compacted layer shall be approved by the Engineer before the Contractor can commence the fill of a new layer.

Areas of final drainage excavation or fill and other restricted areas of earthworks that are impractical to compact by equipment shall be compacted by hand using hand rammers or plate compactors.

The type and condition of the compaction and watering equipment shall be approved by the Engineer.

1.5 MEASUREMENT

The unit of measurement is cubic metres (m^3) solid measure. Measurements and levels shall be taken on the finished embankment surface (subgrade level) and the earthwork quantities will be calculated from the before and after level surveys.

Payment for earth and selected material will be at the Contract unit price regardless of the source of material and regardless of whether the excavation of the material has been paid for under another item or not.

The rates shall include the supply, placing, mixing, watering, compaction and shaping as specified and shown on the Drawings.

The payment items shall be as follows:

Item Reference	Description	Unit of Measurement
1a	Embankment fill	Cubic metre compacted
1b	Subgrade	Cubic metre compacted

In some locations it may be justified to make specific additional provisions in the Bills of Quantities for the following items. This should be determined from the pre-construction detailed survey:-

Item Reference	Description	Unit of Measurement
1c	Excavation in rock	Cubic metre in-situ
1d	Excavation of soft spots and organic material, disposal and fill with suitable material	Cubic metre in-situ

1.6 LABORATORY & SITE TESTING

The Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum, and the Engineer shall have the authority to have these tests at more frequent intervals where quality of a material or work is in doubt.

Materials from each source should be submitted to the Engineer for approval in advance of the commencement of work.

Where testing facilities are not conveniently available, the Contractor shall submit samples to the Engineer for approval.

The Contractor shall carry out in-situ density tests on completed layers to ensure the compaction densities required by the Specifications are obtained. The test equipment and method used shall be approved by the Engineer.

Visual inspections will be made to check compliance with the Drawings and Specifications.

The Engineer may undertake Dynamic Cone Penetrometer (DCP) tests on the completed embankment earthworks as a guide to check the standard of material and compaction. Further testing will be undertaken during, or on completion, of the embankment construction if the Engineer considers the fill may not be up to the required standard. Any sub-standard fill is to be removed and replaced with approved fill material compacted up to the required standard and this fill has to be approved by the Engineer before the filling operation continues. If sub-standard fill has been covered by further fill layers, these have to be removed to allow the sub-standard fill to be replaced. All replacement of sub-standard fill will be at the cost of the Contractor. The in-situ strength (CBR) measurements by DCP of the completed embankment and subgrade layers shall be interpreted by the Engineer with consideration of the differences in moisture condition to the requirements measured by 4 day soaked laboratory test method.

A level survey will be carried out on the completed embankment earthworks (at sub-grade level) at 100 metre intervals in the design cross-section positions, to confirm that the as-built finished levels comply with the design. If the earthworks do not comply, additional earthworks may be required as directed by the Engineer with any remedial or additional work (such as benching) being at the Contractor's cost. The level information will also be used for the calculation of earthwork quantities.

The Table following indicates the recommended test and frequency requirements for the embankment and subgrade works.

TEST	DESIGNATION	SAMPLING AND TESTING FREQUENCY (1)	COMPLIANT CONDITIONS	
			Embankment	Subgrade
Atterberg Limits	AASHTO T-89 and T-90	3 per source plus 1 per 500 m	NA	PI < 20%
Sieve Analysis	AASHTO T-88		NA	Percentage of passed 0.075mm sieve < 25%
CBR	AASHTO T-193	3 per source plus 1 per 1,000 m	4 days soaked CBR > 3%	4 days soaked CBR>10% (2)
Moisture-Density relation	AASHTO T-180	1 per 500 m		
Field Density by Sand-Cone	AASHTO T-191	5 per 500 m	Dry density > 90% of MDD, Moisture ±2%	Dry density > 95% MDD, Moisture ±2%

(1) more frequently if material character changes significantly

(2) or minimum designed subgrade as per specified in the engineering drawing

NA : Not Applicable

MDD: Maximum Dry Density

> : greater or higher than

DRAFT SPECIFICATION 2

2. GRAVEL SHOULDER

2.1 DESCRIPTION

This work will comprise providing, laying and compacting approved shoulder gravel material to lines, levels and dimensions as shown on the Engineering Drawings and as directed by the Engineer.

2.2 MATERIALS

The road shoulder shall be constructed from naturally occurring gravels, crushed rock or stabilised gravel from sources approved by the Engineer according to the requirements of this specification.

The gravel or laterite shall be well-graded material and have a low clay content suitable for use as a durable all weather road surfacing material. The aggregate should not be friable or break down under the action of traffic.

The naturally occurring gravel shall comply with the following conditions:

Particle distribution

SIEVE SIZE	PERCENTAGE PASSING BY (MASS)		
(mm)	37.5mm	20mm	10mm
50	100	-	-
37.5	80-100	100	-
20	60-80	80-100	100
10	45-65	55-80	80-100
5	30-50	40-60	50-70
2.36	20-40	30-50	35-50
0.425	10-25	12-27	12-30
0.075	5-15	5-15	5-15

Material passing the 0.425 mm sieve,

- Liquid Limit shall not exceed 35%,
- Plasticity Index in the range 8-20%

Strength: In situ CBR of not less than 30%

2.3 CONSTRUCTION METHODS

Prior to laying the gravel shoulder, the Contractor shall correct any deformations, ruts, soft spots or other defects in the formation to the satisfaction of the Engineer whose approval shall be obtained before gravel shoulder works commence. All

drainage works necessary to keep the road formation and pavement layers free of standing water should be completed.

The Contractor shall establish sufficient setting out pins, pegs and string lines to ensure that the final shape of the shoulder conforms with the Drawings, which shall be checked with a camber board, or straight edge, spirit level and tape. Any depressions in the surface shall be re-scarified and sufficient new material added to attain the correct shape.

Material for the construction of the shoulder shall be dumped on the prepared formation in such a manner as to allow for continuity of operations over the length of the formation and to cause least inconvenience and danger to traffic.

Spreading of the material shall be by manual methods and shall be in such a manner as to allow the free flow of traffic through the works. The spreading shall be in layers to form the final compacted thickness shown on the drawings.

Compaction shall be carried out in a series of continuous operations covering the full width and length of the shoulder layer.

Water should be added as necessary to facilitate compaction. The in-situ strength of the completed gravel shoulder layer shall be not less than CBR 30 as measured by the Dynamic Cone Penetrometer (DCP) method.

The gravel material shall, 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 shall be removed and made good with new material to the full thickness of the layer.

Roadbase drainage: Sub-base and shoulders will usually be impervious and therefore drainage arrangements are normally required to drain any moisture that may enter the roadbase layer. If such drainage or inverted filter drains are to be constructed, they shall be built and finished in advance of the roadbase construction. Drainage shall be constructed according to the Specifications and Drawings.

2.4 CONSTRUCTION EQUIPMENT

The minimum compactive effort per rolling per constructed layer shall be in the range of:

Vibrating Roller Minimum Weight	Number of Passes
1,000 kg	6 per point

Where narrow width prevents the use of rollers the shoulders shall be compacted by hand using hand rammers or plate compactors.

The type and condition of the compaction equipment shall be approved by the Engineer.

2.5 MEASUREMENT

Construction of road shoulders shall be measured by the cubic metres of placed, and compacted material on the shoulder. The quantity of work will be calculated by multiplication of the actual thickness implemented by the width and approved length of the road shoulder.

The rates shall include the supply, placing, mixing, watering, compaction, shaping, and curing as specified and shown on the Drawings.

The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including supplying the materials, and providing all labour, tools, equipment, incidentals necessary, overheads and profit.

The payment item shall be:

Item Reference	Description	Unit of Measurement
2	Gravel Shoulders	Cubic metre compacted

2.6 LABORATORY & SITE TESTING

The Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum, and the Engineer shall have the authority to have these tests at more frequent intervals where quality of a material or work is in doubt.

Materials from each source should be submitted to the Engineer for approval in advance of the commencement of work.

Where testing facilities are not conveniently available, the Contractor shall submit samples to the Engineer for approval.

Visual inspections will be made to check compliance with the Drawings and Specifications.

DCP tests shall be undertaken on the completed works of gravel shoulder. The testing frequency rate shall be at least one test per shoulder every 1km. Further testing will be undertaken during, or on completion, of the works if the Engineer considers the material used may not be up to the required standard. Any sub-standard works are to be removed and replaced to the required standard at the cost of the Contractor. The in-situ strength of CBR by DCP of the completed gravel surfacing, subgrade or shoulder not less than 30%.

Shallow inspection pits shall be excavated through the completed gravel shoulder every km and are to be properly reinstated, all as directed by the Engineer. Layer thickness tolerances should be in a range of -5 mm to +15 mm.

The following table is the recommended test and frequency and requirements of gravel material for Gravel Shoulder.

TEST	DESIGNATION	SAMPLING AND TESTING FREQUENCY (1)	COMPLIANT CONDITIONS	
Atterberg Limits	AASHTO T-89 and T-90	3 per source plus 1 per 1,000 m	For material passing 0.425 mm sieve	LL < 35%
				PI < 20%
Sieve Analysis	AASHTO T-88	3 per source plus 1 per 1,000 m	Referred to Sub-Clause D.2.2	
CBR	DCP	1 per km each shoulder	CBR>30%	

(1) more frequently if material character changes)

> : is greater or higher than

DRAFT SPECIFICATION 3

3. GRAVEL SUB-BASE

3.1 DESCRIPTION

The sub-base is an important load-spreading layer in the completed pavement. It enables traffic stresses to be reduced to acceptable levels in the sub-grade; it acts as a working platform for the construction of the upper pavement layers and as a separation layer between sub-grade and roadbase. Under special circumstances it may also act as a filter or as a drainage layer. In wet climatic conditions, the most stringent requirements are dictated by the need to support construction traffic.

The work comprises providing, laying and compacting approved gravel to lines, levels and dimensions as shown on the Engineering Drawings and as directed by the Engineer.

3.2 MATERIALS

This pavement layer shall be constructed from naturally occurring gravels, crushed rock or stabilised gravel from sources approved by the Engineer according to the requirements of this specification.

The gravel or laterite shall be well-graded material. The Sub-base gravel shall comply with the following conditions:

Particle distribution

SIEVE SIZE	PERCENTAGE PASSING BY (MASS)		
(mm)	37.5mm	20mm	10mm
50	100	-	-
37.5	80-100	100	-
20	60-80	80-100	100
10	45-65	55-80	80-100
5	30-50	40-60	50-70
2.36	20-40	30-50	35-50
0.425	10-25	12-27	12-30
0.075	5-15	5-15	5-15

Material passing the 0.425 mm sieve,

- Liquid Limit shall not exceed 35%,
- Plasticity Index in the range 8-20%

Strength: Soaked CBR of not less than 30%

3.3 CONSTRUCTION METHODS

Prior to laying the sub-base, the Contractor shall correct any deformations, ruts, soft spots or other defects in the formation to the satisfaction of the Engineer whose approval shall be obtained before gravel sub-base works commence. All drainage works necessary to keep the road formation and pavement layers free of standing water should be completed.

The Contractor shall establish sufficient setting out pins, pegs and string lines to ensure that the final shape of each pavement layer complies with the Drawings, which shall be checked with a camber board, or straight edge, spirit level and tape. Any depressions in the surface shall be re-scarified and sufficient new material added to attain the correct shape.

Material for the construction of the sub-base shall be dumped on the prepared formation in such a manner as to allow for continuity of operations over the length of the formation and to cause least inconvenience and danger to traffic.

Spreading of the material shall be by manual or equipment methods and shall be in such a manner as to allow the free flow of traffic through the works. The spreading shall be in layers not exceeding 150 mm loose thickness to form the final compacted thickness shown on the drawings.

Compaction shall be carried out in a series of continuous operations covering the full width and length of the layer concerned. Water should be added as necessary to facilitate compaction. The in-situ strength of the completed gravel layers shall be not less than CBR 30 as measured by the AASHTO 4 day soaked method.

The gravel material shall, 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 shall be removed and made good with new material to the full thickness of the layer.

Tolerance of layer thickness should be in the range of -5 mm to +15 mm.

3.4 CONSTRUCTION EQUIPMENT

The minimum compactive effort per rolling per constructed layer shall be in the range,

Vibrating Roller Minimum Weight	Number of Passes
1,000 kg	6 per point

The type and condition of the compaction and watering equipment shall be approved by the Engineer.

3.5 MEASUREMENT

The unit of measurement shall be cubic metres (m^3) of placed and compacted material. The quantity for which payment shall be made shall be the product of the instructed average width, the instructed compacted thickness and the measured length along the centre line of the road.

The rates shall include the supply, placing, spreading, shaping, watering and compaction as specified and shown on the Drawings.

The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including supplying the materials, and providing all labour, tools, equipment, incidentals necessary, overheads and profit.

The payment item shall be:

Item Reference	Description	Unit of Measurement
3	Gravel Sub-Base	Cubic metre compacted

3.6 LABORATORY & SITE TESTING

The Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum, and the Engineer shall have the authority to have these tests at more frequent intervals where quality of a material or work is in doubt.

Materials from each source should be submitted to the Engineer for approval in advance of the commencement of work.

Where testing facilities are not conveniently available, the Contractor shall submit samples to the Engineer for approval.

The Contractor shall carry out in-situ density tests on completed sub-base layers to ensure the compaction densities required by the Specifications are obtained. The test equipment and method used shall be approved by the Engineer.

Visual inspections will be made to check compliance with the Drawings and Specifications.

The Engineer may undertake DCP tests on the completed works of gravel sub-base as a guide to check the standard of material and strength. Further testing will be undertaken during, or on completion, of the works if the Engineer considers the material used may not be up to the required standard. All replacement of sub-standard sub-base material will be at the cost of the Contractor. The in-situ strength (CBR) measurements by DCP of the completed sub-base layer shall be interpreted by the Engineer with consideration of the differences in moisture condition to the requirements measured by 4 day soaked laboratory test method.

A level survey shall be carried out on the completed works at 100 metre intervals in the design cross-section positions, to confirm that the as-built finished levels comply with the design. If the work does not comply, corrective work may be required as directed by the Engineer with any remedial or additional work being at the Contractor's cost. The level information will also be used for the calculation of works quantities.

Shallow inspection pits shall be excavated through the completed gravel sub-base on the centre-line and 0.5 metres from each edge of the sub-base every 100m and are to be properly reinstated, all as directed by the Engineer. Layer thickness tolerances should be in a range of -5 mm to +15 mm.

The following table is the recommended test and frequency and requirements of material for Gravel Sub-base.

TEST	DESIGNATION	SAMPLING AND TESTING FREQUENCY (1)	COMPLIANT CONDITIONS	
Atterberg Limits	AASHTO T-89 and T-90	3 per source plus 1 per 500 m	For material passing 0.425 mm sieve	LL < 35%
				PI < 20%
Sieve Analysis	AASHTO T-88	3 per source plus 1 per 500 m	Referred to Sub-Clause D.2.2	
CBR	AASHTO T-193	3 per source plus 1 per 1,000 m	4 days Soaked CBR>30% (2)	
Moisture-Density relation	AASHTO T-180	1 per 1,000 m		
Field Density by Sand-Cone	AASHTO T-191	5 per 1,000 m	Dry density > 95% MDD, Moisture ±2%	
Los Angeles Abrasion	AASHTO T-96	3 per source plus 1 per 1,000 m	Coarse particles	LA <50%

(1) more frequently if material character changes)

(2) or minimum designed sub-base as specified in the engineering drawings

NA : Not Applicable

MDD: Maximum Dry Density

> : is greater or higher than

DRAFT SPECIFICATION 4

4. SAND-AGGREGATE ROADBASE

4.1 DESCRIPTION

Sand-Aggregate roadbase consists of a layer of broken or crushed single size or poorly graded stones of size up to 25mm mixed with finer aggregates or sand. This technique allows a designer to use poorly graded stone aggregates that for example may be produced by small mobile crushing machines or from a labour operation stone quarry. Sand or crusher dust is used to fill voids of coarse aggregate and a dense layer can be achieved with appropriate mixing proportions and compaction. This type of roadbase may be suitable for light (axle load < 6t) to medium (axle load < 12t) axle loading situations.

4.2 MATERIALS.

Sand-Aggregate roadbase consists of a uniform mixture of poorly graded crushed or broken stone aggregate with natural occurring sand or crusher dust from a stone quarry.

Stone aggregate

This shall be machine crushed or hand broken fresh material that may include, quarried rock, natural granular material such as rocks, gravel or boulders. The material shall be preferably well graded but gap-graded or single sized can also be accepted with this technique.

The crushed/broken material shall comply with the following requirements:

- Water absorption shall not exceed 2%.
- Los Angeles Abrasion (LAA) value not more than 35 or as directed by the Engineer.
- Each particle shall have at least one broken face. Particles shall be angular and not rounded in appearance.

Sand

These should be clean, non-plastic, angular, well graded, natural sand or crushed stone passing the 5.0mm sieve:-

- Plasticity Index of binding materials shall be not more than 6.
- Fineness Modulus of sand fraction shall not be less than 1.80 and shall be free from deleterious materials.

The following table is the recommended grading of the Sand-Aggregate mixture:

Sieve Size (mm)	Percent by Weight Passing
50	100
38	90-100
20	60-90
10	40-70
4.8	30-35
2.4	20-45
0.60	10-30
0.30	10-25
0.075	5-15

Mixing proportion

The percentage of sand to be added for the mixture depends on the grading and especially the voids content of the stone aggregate. Experiences have shown that the proportion of sand to be added to the mixture typically varies from 20% to 35% by volume of the total. This mixing proportion can be determined by size analysis of the stone aggregate and sand in such away to obtain a combined grading within the above recommended grading envelope.

However in the absence of suitable laboratory or testing facilities the amount of sand to be added can be easily and cheaply determined from a simple test by filling aggregate into a container with known volume. The container is then shaken to simulate compaction and water is then filled into the container. The volume of water added to fill the container is considered to be equivalent to the voids contained in the aggregates. The amount of sand to be added should be 10% to 20% more than the voids of the stone aggregate measured by this method.

4.3 CONSTRUCTION METHODS

Prior to laying the sand-aggregate material, the Contractor shall correct any deformations, ruts, soft spots or other defects in the formation or sub-base to the satisfaction of the Engineer whose approval shall be obtained before sand-aggregate roadbase works commence. All drainage works necessary to keep the road formation and pavement layers free of standing water should be completed.

The Contractor shall establish sufficient setting out pins, pegs and string lines to ensure that the final shape of each pavement layer complies with the Drawings, which shall be checked with a camber board, or straight edge, spirit level and tape. Any depressions in the surface shall be re-worked and sufficient new material added to attain the correct shape.

The sand-aggregate process involves screening and mixing of the materials to achieve the specified grading that shall be carried out in a stockyard. The materials shall be mixed thoroughly and uniformly to form a homogeneous mass. During mixing water is to be added to keep the mixed material moist to prevent segregation.

If the specified roadbase thickness is more than 150mm, the mixed roadbase materials shall be spread in two equal layers so that the compacted thickness of each layer shall combine to conform to the thickness shown on the Drawings and specifications.

During spreading water shall be added as necessary so that, at the time of compaction the moisture content is within $\pm$ 5% of the OMC. On completion of

spreading and watering the surface shall be shaped, and compacted using approved compaction equipment and procedures.

It is recommended to compact sand-aggregate roadbase by a vibrating roller of minimum weight 3 tonnes. Rolling shall begin at the outer edge towards the centre of the road with the wheels overlapping the shoulder. After initial compaction and the roadbase layer becomes firm, the roller will be transferred to the opposite side of the road and operation will be repeated. After both edges are rolled to a firm condition, the roller will be gradually moved towards the centre by over lapping 150 mm of the rolled width until the mix has attain the required density.

The roadbase shall be compacted to a density of not less than 98% of the MDD. The surface shall be well closed free of compaction planes, roller marks or loose and segregated pockets.

The in-situ strength of the completed sand-aggregate macadam layers shall be not less than CBR 55 (light axle loading) or 80 (medium axle loading) as measured by the Dynamic Cone Penetrometer (DCP) method or insitu CBR method.

Tolerance of layer thickness should be in the range of -5 mm to +15 mm.

4.4 CONSTRUCTION EQUIPMENT

The minimum compactive effort per rolling per constructed layer shall be in the range,

Vibrating Roller Minimum Weight	Number of Passes
3,000 kg	6-8 per point

The type and condition of the compaction and watering equipment shall be approved by the Engineer.

4.5 MEASUREMENT

The unit of measurement shall be cubic metres (m^3) of placed and compacted material. The quantity for which payment shall be made shall be the product of the instructed average width, thickness and the measured length along the centre line of the road.

The rates shall include the supply, placing, spreading, shaping, watering and compaction as specified and shown on the Drawings.

The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including supplying the materials, and providing all labour, tools, equipment, incidentals necessary, overheads and profit.

The payment item shall be:

Item Reference	Description	Unit of Measurement
4	Sand-aggregate roadbase	Cubic metre compacted

4.6 LABORATORY & SITE TESTING

The Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum, and the Engineer shall have the authority to have these tests at more frequent intervals where quality of a material or work is in doubt.

Materials from each source should be submitted to the Engineer for approval in advance of the commencement of work.

Where testing facilities are not conveniently available, the Contractor shall submit samples to the Engineer for approval.

Visual inspections will be made to check compliance with the drawings and specifications.

Shallow inspection pits shall be excavated through the completed roadbase on centre line and 0.5 metres from each edge of the road base every 0.5 km and are to be properly reinstated all as directed by the Engineer. Tolerance of layer thickness must be in range of -5 mm to +15 mm.

The in-situ strength of the completed sand-aggregate roadbase layer shall be measured by the Dynamic Cone Penetrometer (DCP) method or insitu CBR method.

The following table is the recommended test and frequency and requirements for the sand-aggregate roadbase.

TEST	DESIGNATION	SAMPLING AND TESTINGFREQUENCY (1)	COMPLIANT CONDITIONS
Sieve Analysis (Mixed material)	AASHTO T-27	3 per Source plus 1 per 500 m^3	Referred to Sub-Clause 4.2
Atterberg Limits	AASHTO T-89 and T-90	3 per Source	PI<6% LL<20%
Modified Proctor	AASHTO T-180	3 per Source	
CBR (for axle load conditions)	DCP	3 per 500m	CBR>55% (light) CBR>80% (medium)
Los Angeles Abrasion	AASHTO T-96	3 per Source plus 1 per 500 m^3	< 25%
Sodium Sulphate Soundness	AASHTO T-104	3 per Source plus	< 10% loss
Moisture- Density relation	AASHTO T-180	1 per 1,000 m^3	

(1) more frequently if material character changes)

> : greater or higher than

DRAFT SPECIFICATION 5

5. WATER-BOUND MACADAM ROADBASE

5.1 DESCRIPTION

Macadam is a paving technique developed by a Scottish Engineer called John McAdam at the beginning of the 19th century, using broken stones of various sizes combined together and placed in layers. Various developments of this technique are used today.

Water-bound macadam consists of a layer of broken or crushed stones of size up to 50mm, with finer, cohesionless material laid on top and washed into the voids and compacted with a vibrating roller. The development of small vibrating rollers has made the use of this technique attractive for rural road works in some locations where suitable hard stone is available. Water-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.

Water-bound macadam can be made with stones crushed by hand or equipment, and can therefore be suitable for 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.

Due to the introduction of substantial quantities of water in the construction process, the technique may not be suitable in locations with water supply constraints, or on subgrades that are weak or particularly moisture susceptible.

This type of roadbase may be suitable for light (axle load < 6t) to medium (axle load < 12t) axle loading situations.

Other types of macadam (penetration-macadam, bitumen-macadam, tar-macadam) involve introduction of a binder to improve performance.

5.2 MATERIALS

Each layer of water-bound macadam shall consist of a crushed or broken stone layer and a separate application of Blinding Fines.

Stone

This shall be machine crushed or hand broken fresh material that may be obtained from quarried rock, natural granular material such as rocks, gravel or boulders. The material shall be single sized, separated by screening. After crushing/breaking, the material should be angular in shape with a flakiness index (British Standard 812, Part 105, 1990) of less than 35 percent.

The crushed/broken material shall comply with the following requirements:

- Water absorption shall not exceed 2%.
- Los Angeles Abrasion (LAA) value not more than 35 or as directed by the Engineer.
- Flakiness Index shall be less than 35%.

The crushed/broken stone materials shall conform to one of the following grading limits:

BS Test Sieve (mm)	Percentage by mass of total aggregate passing test sieve			
	M1	M2	M3	M4
75	100	100	100	-
50	85 – 100	85 – 100	85 – 100	100
37.5	35 – 70	0 – 30	0 – 50	85 – 100
28	0 – 15	0 – 5	0 – 10	0 – 40
20	0 - 10	-	-	0 - 5

The grading of M2 and M4 correspond with nominal 50mm and 37.5mm single-sized road stones (British Standard 63 (1987)) and are appropriate for use with mechanically crushed aggregate. M1 and M3 are broader specification. M1 can be used for hand-broken stone but if screens are available, M2, M3 and M4 are preferred.

Blinding Fines

These should be clean, non-plastic, angular, well graded, crushed stone or natural sand passing the 5.0mm sieve:-

- Plasticity Index of binding materials shall be not more than 6.
- Fineness Modulus of sand fraction shall not be less than 1.80 and shall be free from deleterious materials.

5.3 CONSTRUCTION METHODS

Prior to laying the water-bound macadam, the Contractor shall correct any deformations, ruts, soft spots or other defects in the formation or sub-base to the satisfaction of the Engineer whose approval shall be obtained before water-bound macadam works commence. All drainage works necessary to keep the road formation and pavement layers free of standing water should be completed.

The Contractor shall establish sufficient setting out pins, pegs and string lines to ensure that the final shape of each pavement layer complies with the Drawings, which shall be checked with a camber board, or straight edge, spirit level and tape. Any depressions in the surface shall be re-worked and sufficient new material added to attain the correct shape.

The water-bound macadam process involves laying single-sized crushed/broken stone of either 37.5 mm or 50mm nominal size in a series of layers to achieve the design thickness. The compacted thickness of each layer should not exceed twice the nominal stone size. Each layer of coarse aggregate shall be shaped and compacted with a static roller, and then the well graded fine aggregate, passing the 5.0mm sieve, spread onto the surface, washed into the voids by the application of water, and rolled with a vibrating roller to produce a dense layer.

Compaction shall be carried out in a series of continuous operations covering the full width and length of the layer concerned.

Any loose material remaining should be brushed off and final compaction carried out. The sequence is then repeated until the design thickness is achieved. To aid the entry of the fines, the grading of the 37.5 mm nominal size stone should be towards the coarse end of the recommended range. Economy in the production process can be obtained if layers consisting of 50 mm nominal size stone and layers of 37.5 mm nominal size stone are both used to allow the required total thickness to be obtained more precisely and to make better overall use of the crushed stone production.

The blinding fines are watered into the larger aggregates in the construction 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. The compacted thickness of each layer should not exceed twice the maximum size of the stone.

The water-bound macadam shall, 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 shall be removed and made good with new material to the full thickness of the layer.

The in-situ strength of the completed water-bound macadam layers shall be not less than CBR 55 (light axle loading) or 80 (medium axle loading) as measured by the insitu CBR method.

Tolerance of layer thickness should be in the range of -5 mm to +15 mm.

5.4 CONSTRUCTION EQUIPMENT

The minimum compactive effort per rolling per constructed layer shall be in the range:

Vibrating Roller Minimum Weight	Number of Passes
3,000 kg	6-8 per point

The type and condition of the compaction and watering equipment shall be approved by the Engineer.

5.5 MEASUREMENT

The unit of measurement shall be cubic metres (m^3) of placed and compacted material. The quantity for which payment shall be made shall be the product of the instructed average width, thickness and the measured length along the centre line of the road.

The rates shall include the supply, placing, spreading, shaping, watering and compaction as specified and shown on the Drawings.

The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including supplying the materials, and providing all labour, tools, equipment, incidentals necessary, overheads and profit.

The payment item shall be:

Item Reference	Description	Unit Of Measurement
5	Water-bound macadam roadbase	Cubic metre compacted

5.6 LABORATORY & SITE TESTING

The Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum, and the Engineer shall have the authority to have these tests at more frequent intervals where quality of a material or work is in doubt.

Materials from each source should be submitted to the Engineer for approval in advance of the commencement of work.

Where testing facilities are not conveniently available, the Contractor shall submit samples to the Engineer for approval.

Visual inspections will be made to check compliance with the drawings and specifications.

Shallow inspection pits shall be excavated through the completed roadbase on centre line and 0.5 metres from each edge of the road base every 0.5 km and are to be properly reinstated all as directed by the Engineer. Tolerance of layer thickness must be in range of -5 mm to +15 mm.

The in-situ strength of the completed water-bound macadam layer shall be not less than CBR 55 as measured by the insitu CBR method.

The following table is the recommended test and frequency and requirements for water-bound macadam roadbase.

TEST	DESIGNATION	SAMPLING AND TESTING FREQUENCY (1)	COMPLIANT CONDITIONS
Sieve Analysis	AASHTO T-27	3 per Source plus 1 per 500 m^3	
Atterberg Limits	AASHTO T-89 and T-90	3 per Source	PI<6% LL<20%
Modified Proctor	AASHTO T-180	3 per Source	
CBR (for axle load conditions)	AASHTO T-193	3 per Source	CBR>55% (light) CBR>80% (medium)
Los Angeles Abrasion	AASHTO T-96	3 per Source plus 1 per 500 m^3	< 25%
Sodium Sulphate Soundness	AASHTO T-104	3 per Source plus	< 10% loss
Moisture-Density relation	AASHTO T-180	1 per 1,000 m^3	

(1) more frequently if material character changes)

> : greater or higher than

DRAFT SPECIFICATION 6

6. ARMOURED GRAVEL ROADBASE

6.1 DESCRIPTION

This technique can be used in the circumstances where an existing gravel/laterite surface is to be upgraded to a bituminous sealed surface, or for a completely new roadbase. The intention is the cost-effective use of suitable natural gravels where they occur close to the road site, and to improve them sufficiently to accept a thin bituminous surfacing. This activity has two components: an initial component of (typically 180mm compacted, unless otherwise stated in the Drawings or Bill of Quantities) laterite/gravel laid to camber, watered and compacted in two layers, followed by a (typically 70mm compacted) topping or armouring of crushed/broken stone aggregate laid to camber, watered and compacted. The first component may consist of the existing gravel/laterite road surface, scarified and with material added if necessary to achieve the required shaped and compacted thickness.

The work comprises providing, laying and compacting approved gravel and armouring materials to lines, levels and dimensions as shown on the Engineering Drawings and as directed by the Engineer. This type of roadbase may be suitable for light (axle load < 6t) to medium (axle load < 12t) axle loading situations.

A surface seal would be applied to the roadbase as a separate specification item.

6.2 MATERIALS

A) Gravel/Laterite Layers

The pavement layer(s) shall be constructed from naturally occurring gravels, crushed rock or stabilised gravel from sources approved by the Engineer according to the requirements of Specification No 3 for gravel sub-base.

B) Aggregate Armouring Layer

This is crushed fresh material that may be obtained from, quarried rock, or natural granular material such as rocks, gravel or boulders. The materials shall be separated by screening and then recombined to produce the required particle distribution if necessary. After crushing, the material should be angular in shape with a flakiness index of less than 35 percent. If the material resulting from crushing the stones does not have a sufficient amount of fines, sand should be added and blended.

The layer crushed material shall comply with the following requirements:

- Water absorption shall not exceed 2%.
- Los Angeles Abrasion (LAA) value not more than 35 or as directed by the Engineer.
- Flakiness Index shall not be greater than 35%.
- Plasticity Index of binding materials shall not more than 6.

- Fineness Modulus of sand fraction shall not be less than 1.80 and shall be free from deleterious materials.
- The maximum particle size shall be no more than 50% of the final specified thickness of the aggregate armouring layer.

The materials shall be well graded and conform to the following grading limits:

Sieve size	*Passing the sieve (% by mass)*
	Nominal maximum particle size (mm)
	37.5
50	*100*
37.5	*80-100*
20	*60-90*
10	*40-70*
5	*30-55*
2.36	*20-45*
0.425	*8-30*
0.075	*5-15*

The in-situ strength of the completed aggregate armouring layer shall be not less than CBR 55 (light axle loading) or 80 (medium axle loading) as measured by the DCP method.

6.3 CONSTRUCTION METHODS

Prior to laying the roadbase, the Contractor shall correct any deformations, ruts, soft spots or other defects in the formation or sub-base all to the satisfaction of the Engineer whose approval shall be obtained before armoured gravel roadbase works commence. All drainage works necessary to keep the road formation and pavement layers free of standing water should be completed.

The Contractor shall establish sufficient setting out pins, pegs and string lines to ensure that the final shape of each pavement layer complies with the Drawings, which shall be checked with a camber board, or straight edge, spirit level and tape. Any depressions in the surface shall be re-scarified and sufficient new material added to attain the correct shape.

A) Gravel/Laterite Layers

Material for the construction of pavement layer(s) shall be dumped on the prepared formation in such a manner as to allow for continuity of operations over the length of the formation and to cause least inconvenience and danger to traffic.

Spreading of the material shall be by manual or equipment methods and shall be in such a manner as to allow the free flow of traffic through the works. The spreading

shall be in layers not exceeding 150 mm loose thickness to form the final compacted thickness shown on the drawings.

Water should be added as necessary to facilitate compaction.

The in-situ strength of the completed gravel layers shall be not less than CBR 30 as measured by the AASHTO 4 day soaked method.

The gravel/laterite material shall, 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 shall be removed and made good with new material to the full thickness of the layer.

Tolerance of layer thickness should be in the range of -5 mm to +15 mm.

B) Aggregate Armouring Layer

This work shall consist of the supply, mixing, placing, shaping and compaction of an aggregate armouring layer composed of a broken stone aggregate mechanically interlocked by watering, rolling and bonded together with screening, binding materials where necessary to the Specifications and to the lines, levels, dimensions and cross-falls shown on the Drawings or as directed by the Engineer.

Spreading of Aggregate:

The broken aggregate shall be spread uniformly upon the prepared laterite layer in such quantities that the thickness of un-compacted layer is about 30% greater than the required final thickness. The loose layer is expected to be consolidated to about 66-75% thickness by compaction. Any segregation of the dumped material shall be reworked by labourers with hand tools. The surface of the aggregate shall be carefully finished with the aid of templates and levelling of all high or low spots by removing or adding aggregates as may be the case. The irregularities are much easier to correct in loose layer than later. The relationship between the loose thickness and compacted thickness shall be determined from field trials and used in controlling the loose thickness at the time of spreading the mixed materials.

Dry rolling:

Immediately following the spreading of aggregate, it is to be first rolled dry with the aid of a (minimum) 1,000kg twin drum 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. Rolling shall continue until the material matrix is thoroughly keyed and stone creeping ahead of the roller in no longer visible. Light sprinkling of water may be required to assist compaction. Rolling should not be done if the sub-base or subgrade is soft or yielding. The rolled surface shall be checked transversely and longitudinally with templates and if the irregularities exceed 12 mm from the required plane, the surface should be loosened and aggregate added or removed before rolling again. In no case shall the use of screenings be permitted to make up depressions.

Watering and Wet rolling:

After the dry rolling, the surface shall be copiously sprinkled with water, swept and rolled with a (minimum) 1,000kg twin drum vibratory roller. Hand brooms shall be

used to sweep the wet screenings into voids and distribute them evenly. 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.

Care shall be taken to see that the roadbase, sub-base or sub grade does not become damaged due to the addition of excessive water during construction.

Curing of the roadbase:

After final compaction of the roadbase, the road shall be allowed to dry overnight. Next morning hungry spots shall be filled with screening materials as directed by the Engineer, lightly sprinkling water if necessary and rolled. No traffic shall be allowed on the road until the roadbase has set.

6.4 CONSTRUCTION EQUIPMENT

The minimum compactive effort per rolling per constructed layer shall be in the range:

Vibrating Roller Minimum Weight	Number of Passes
1,000 kg	6-8 per point

The type and condition of the compaction and watering equipment shall be approved by the Engineer.

6.5 MEASUREMENT

The unit of measurement shall be cubic metres (m^3) of placed and compacted material. The gravel/laterite layer and the armouring layer should be paid separately. The quantity for which payment shall be made shall be the product of the instructed average width, thickness and the measured length along the centre line of the road.

The rates shall include the supply, placing, spreading, shaping, watering and compaction as specified and shown on the Drawings.

The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including supplying the materials, and providing all labour, tools, equipment, incidentals necessary, overheads and profit.

The payment item shall be:

Item Reference	Description	Unit Of Measurement
6a	Gravel/Laterite layer	Cubic metre compacted
6b	Aggregate armouring layer	Cubic metre compacted

6.6 LABORATORY & SITE TESTING

General

The Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum, and the Engineer shall have the authority to have these tests at more frequent intervals where quality of a material or work is in doubt.

The gravel/laterite layer should be tested in accordance with Specification 3. The following requirements relate to the aggregate armouring layer.

TEST	DESIGNATION	SAMPLING AND TESTING FREQUENCY (1)	COMPLIANT CONDITIONS
Sieve Analysis	AASHTO T-27	3 per Source plus 1 per 500 m^3	
Atterberg Limits	AASHTO T-89 and T-90	3 per Source	PI<6% LL<20%
Modified Proctor	AASHTO T-180	3 per Source	
CBR (for axle load conditions)	AASHTO T-193	3 per Source	CBR>55% (light) CBR>80% (medium)
Los Angeles Abrasion	AASHTO T-96	3 per Source plus 1 per 500 m^3	< 25%
Sodium Sulphate Soundness	AASHTO T-104	3 per Source plus	< 10% loss
Moisture-Density relation	AASHTO T-180	1 per 1,000 m^3	

(1) more frequently if material character changes)

> : greater or higher than

Laboratory Testing

Materials from each source should be submitted to the Engineer for approval in advance of the commencement of work.

Where testing facilities are not conveniently available, the Contractor shall submit samples to the Engineer for approval.

Site Testing

Visual inspections will be made to check compliance with the drawings and specifications.

Shallow inspection pits shall be excavated through the completed roadbase on centre line and 0.5 metres from each edge of the road base every 0.5 km and are to be properly reinstated, all as directed by the Engineer. Tolerance of Component layer thickness should be in range of -5 mm to +15 mm.

The in-situ strength of the completed gravel/laterite layers shall be not less than CBR 30 as measured by the Dynamic Cone Penetrometer (DCP) method.

The in-situ strength of the completed aggregate armouring layer shall be not less than CBR 55 as measured by the Dynamic Cone Penetrometer (DCP) method.

DRAFT SPECIFICATION 7

7. HAND-PACKED STONE ROADBASE

7.1 DESCRIPTION

Hand-Packed Stone Roadbase is one of a number of roadbase options that use natural stone and are suitable for construction using labour and simple equipment. Other options are Water Bound Macadam (WBM), Dry Bound Macadam, Crushed Stone Macadam, Telford Paving, Cobble Stone paving, Stone Setts or Pavé and Dressed Stone.

This work shall consist of the supply materials, labour, tools and equipment to construct Hand-Packed Stone Roadbase in accordance with these specifications and to the lines, levels and grades, dimensions and cross-sections shown on the Drawings and as required by Engineer.

Hand-Packed Stone Roadbase consists of a layer of roughly cubic shaped or selected stones of about 100 - 150mm in size, laid tightly packed together on a bed of loose sand or fine aggregate of 50mm to 60mm in thickness. The larger stones are wedged in place with smaller stone chips rammed by hand into the joints using hammers and steel rods.

Coarse Sand or fine crushed aggregate is brushed into the remaining spaces between the stones. When a sufficient area of stones is placed, the layer is watered and compacted with a vibrating or non-vibrating roller. Additional filler is brushed into the surface if necessary.

Hand-packed stone can be used as a road base or as a final surfacing. It can be used as part of a stage construction strategy where resources are not immediately available to provide a sealed bitumen surface finish.

The technique is suitable for small scale commune-based quarrying and production.

7.2 MATERIALS

Stone

The parent material for the broken stone pieces should be a strong, homogenous, isotropic rock, free from significant discontinuities such as cavities, joints, faults and fine bedding planes. It should be in a fresh condition free from deleterious inclusions, and not susceptible to weathering, degradation or significant strength deterioration on exposure. Experience indicates that igneous rocks such as fresh granite and basalt can be suitable materials. Some other rocks are suitable and approval of these is at the discretion of the Engineer.

The rock should have the following mechanical properties:

- ❑ Uni-axial compressive strength >75MPa
- ❑ Los Angeles Abrasion value <25%
- ❑ Sodium Sulphate Soundness <10% loss

The stones shall be free from vegetation, soft particles and excess clay or any other substance, which is considered deleterious.

The individual large stones shall be approximately 100 to 150mm in size (or other dimensions approved by the Engineer) and shall be roughly cubic shape with uniform texture. Ratios between dimensions of each stone shall be in range of 0.7 to 1.

Machine crushed or hand broken stones compliant to the above requirement are suitable for the construction of hand-packed stone road base. However, the stone from hand broken quarry operations is usually more appropriate and performs better than machine crushed because it usually has better characteristics which provide improved interlocking between stones.

Bedding Material (Cushion)

The bedding layer beneath the Hand Packed Stone acts as a cushion and load transfer layer for the overlying construction. Coarse sand or fine crushed aggregate from the stone quarry may be used as bedding layer.

Bedding material shall be clean sharp sand or quarry-crushed-dust free from clay coating, organic debris and other deleterious materials and with a Sand Equivalent Value (SEV) of greater than 70.

The following is the recommended target grading envelope:

Sieve Designation	Percentage by weight passing square mesh sieves
10 mm	100
2.00 mm	55-100
0.425 mm	30-70
0.075 mm	0-10

Joints filling and blinding material

Material used to fill the voids between the large and small wedging stones shall be non-plastic, angular, well graded, crushed stone or natural sand which shall have:

- Fineness Modulus of sand fraction shall not be less than 1.80 and shall be free from deleterious materials.
- Fraction passing 75 micron sieve shall not exceed 10%

Blinding or Joint filling material shall be clean, free from clay coating, organic debris and other deleterious. The following is the recommended target grading envelope:

Sieve Designation	Percentage by weight passing square mesh sieves
25 mm	100
10 mm	60-100
2.00 mm	40-70
0.425 mm	25-45
0.075 mm	0-10

7.3 CONSTRUCTION METHODS

Preparation of foundation: Prior to laying the hand-packed stone roadbase, the Contractor shall correct any deformations, ruts, soft spots or other defects in the formation or sub-base all to the satisfaction of the Engineer whose approval shall be obtained before roadbase works commence. All drainage works necessary to keep the road formation and pavement layers free of standing water should be completed.

The Contractor shall establish sufficient setting out pins, pegs and string lines to ensure that the final shape of each pavement layer complies with the Drawings, which shall be checked with a camber board, or straight edge, spirit level and tape. Any depressions in the surface shall be re-scarified and sufficient new material added to attain the correct shape.

Shoulders construction: Side shoulders shall be constructed in advance to a thickness corresponding to the compacted layer of the hand-packed stone roadbase as indicate in the Engineering Drawings. The shoulders material and construction method shall conform to the Specification for Gravel Shoulder (Specification No 2). After the shoulders are ready, their inside edges shall be trimmed vertical and the included area shall be cleaned. Arrangement for drainage of the roadbase layer (through the shoulder) should be completed before construction of the bedding layer.

Bedding layer: Coarse sand or crusher dust shall be spread uniformly upon the prepared sub base in such quantities that the thickness of the compacted layer is 50 – 60mm. The loose layer should be consolidated to about 85% of Maximum Density. The relationship between the loose thickness and compacted thickness shall be determined from field trials and used in controlling the loose thickness at the time of spreading the materials. Immediately following the spreading of bedding material, it should be rolled dry with the aid of a 0.8 to 1.0 tonne roller. The rolling shall begin from the edges with the roller running forward and backward, parallel to the centre line of the road until the layer has been lightly compacted.

Placing and Packing Stones: Before placing the stones, guiding string lines shall be placed using metal pegs made of reinforcement steel to indicate the finished layer level. The peg interval shall be 5 metres. Lines shall be placed longitudinally and along the cross section of the road, and diagonally, to indicate the desired camber. Stones shall be placed from the edges of the road towards the centreline. Largest stones shall be used along the edge of the pavement. These larger stones will act as kerbs which will restrain the rest of the stone paving of the carriageway and prevent undesired side movement or damage to the shoulders. Selected large stone shall be

laid first, and then followed by the rest of the carriageway to achieve this restraining effect. To aid construction it is advisable to also place a row of stones along the centre line, before placing the rest of the stones. Individual stones shall be laid to have contact to each other but each stone must bed into the sand or fine aggregate cushion without any support from the adjacent stones. Each stone must be tapped firmly into the final position with a hammer. The residual thickness of the bedding layer underneath the stone blocks should not be less than 30mm. After laying of a sufficient area of stones, the large voids between the stones shall be filled with smaller broken stones packed in with a hammer and steel rod. A Camber board should be used to assure an even and regular top surface both longitudinally and across the section during the laying and packing operation.

Joints filling and blinding: After laying and packing the stones, the pavement should be checked to ensure that each stone is firmly packed, and then remaining voids shall be infilled with fine graded aggregate. A thin layer of filling materials shall be spread over the surface of hand-packed stones layer followed by primary compaction. An 800kg to 1 tonne vibrated roller is suitable for this primary compaction with 6-8 passes per point. Water shall only be added to facilitate compaction after 3-4 passes of vibrated compaction. Water is used 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. Vibration helps move the fill material into the voids between the larger stones. A heavier compactor of 8 to 10 tonnes deadweight (minimum 3 tonnes vibrating) is recommended for final compaction with minimum 5 passes per point. Compaction shall start from the edge into the centreline of the pavement. On superelevated sections the compaction should proceed from the lower side. For sections with longitudinal gradient, compaction shall follow direction of the gradient (from lower toward higher points). Any areas of loose material after compaction shall be re-constructed.

Finishing and curing: After final compaction of hand-pack stone road-base, the road shall be allowed to dry out for a period of at least 24 hours. After initial laying, hand-packed stone road-base may not be totally stable and small areas of looseness may develop. These shall be reworked to the satisfaction of the Engineer. A minimum curing period of 10 days is required and any identified weak spots shall be corrected within this period before laying any surfacing. Hand packed stone may be opened to traffic after one or two days drying. A temporary layer of about 10 mm thick of suitable granular filling material should be spread on the pavement surface before opening the road to traffic with restricted to moderate speed. The excess material shall be cleaned from the roadbase and disposed of by the Contractor prior to any further rectification works and surfacing. This temporary covering and measures should be included in the Contractor's rate for the work.

7.4 CONSTRUCTION EQUIPMENT

The minimum compactive effort per rolling per constructed layer shall be in the range:

	Minimum Weight	Number of Passes
For primary compaction	1,000 kg vibrating	6-8 per point
For final compaction	3,000 kg vibrating	6-8 per point

The type and condition of the compaction equipment shall be approved by the Engineer.

7.5 MEASUREMENT

The unit of measurement shall be cubic metres (m^3) of placed and compacted material, including the bedding layer. The quantity for which payment shall be made shall be the product of the instructed average width, thickness and the measured length along the centre line of the road.

The rates shall include the supply, placing, spreading, shaping, watering and compaction as specified and shown on the Drawings.

The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including supplying the materials, and providing all labour, tools, equipment, incidentals necessary, overheads and profit.

The payment item shall be:

Item Reference	Description	Unit of Measurement
7	Hand-packed road-base	Cubic metre compacted including bedding layer

7.6 LABORATORY & SITE TESTING

The Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum, and the Engineer shall have the authority to have these tests undertaken at more frequent intervals, where quality of a material or work is in doubt.

Materials from each source should be submitted to the Engineer for approval in advance of the commencement of work.

Where testing facilities are not conveniently available, the Contractor shall submit samples to the Engineer for approval.

The following table is a recommendation for testing and frequency:

TEST	DESIGNATION	SAMPLING AND TESTING FREQUENCY (1)	COMPLIANT CONDITIONS
Sieve Analysis	AASHTO T-27	3 per Source plus 1 per 500 m^3	
Los Angeles Abrasion	AASHTO T-96	3 per Source plus 1 per 500 m^3	< 25%
Sodium Sulphate Soundness	AASHTO T-104	3 per Source plus	< 10% loss
Uni-axial compressive strength		> 75 Mpa	
Fractured faces	Visual	3 per Source plus as required based on visual observation (more frequently if material character changes)	

(1) more frequently if material character changes)

> : greater or higher than

Visual inspections shall be made to check compliance with the drawings and specifications, and dimensional regularity of stones.

Maximum clearance to a 2 metre straight edge laid at any orientation across the finished pavement to be 10mm.

Shallow inspection pits shall be excavated through the completed roadbase on centre line and 0.5 metres from each edge of the road base every 1.0 km and to be properly reinstated all as directed by the Engineer. Layer thickness tolerances should be -5 mm to +15 mm.

A pavement layer quality and specification compliance inspection will be undertaken on all completed sections of the stone paving layer by the Engineer's Representative prior to acceptance of the Works.

DRAFT SPECIFICATION 8

8. DRESSED STONE SURFACING WITH/WITHOUT SEALED JOINTS

8.1 DESCRIPTION

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

This technique comprises 200mm (or other size as specified on the Drawings, in recognition of the availability of dressed stone pieces) thick dressed stone blocks being laid to camber between edge constraints and compacted into a sand bedding layer (Specification Clause 42), followed by sand, sand-cement or sand-bitumen filling of the block joints.

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.

Dressed stone can be used as a road base or as a final surfacing. It can be used as part of a stage construction strategy where resources are not immediately available to provide a smooth sealed bitumen surface finish.

8.2 MATERIALS

Stone Blocks

The parent material for the stone blocks should be a strong, homogenous, isotropic rock, free from significant discontinuities such as cavities, joints, faults and bedding planes. It should be in a fresh condition free from deleterious inclusions, and not susceptible to weathering, degradation or significant strength deterioration on exposure. Experience indicates that igneous rocks such as fresh granite and basalt can be particularly suitable materials.

The rock should have the following mechanical properties:

- ❑ Uni-axial compressive strength >75MPa
- ❑ Los Angeles Abrasion value <25%
- ❑ Sodium Sulphate Soundness <10% loss

The stone blocks shall be 150-200mm thick and between 100mm and 300mm in plan size (or other dimensions approved by the Engineer in recognition of the dressed stones available) and shall be regular and uniform in shape and texture with sharp square edges and parallel faces. The specified depth dimension of the blocks shall not vary by more than 20mm between individual blocks. The blocks shall be free from flaws and discontinuities. The top (surface) face shall be chiselled, split or cut

reasonably smooth. The distance between a 30cm straight edge placed across any orientation on the top face and the sett top surface must not be more than 3mm; this criteria applies to any point on the face more than 20mm from the edge of the block.

Sand for bedding and joint filling

Sand for cushion (bedding), sand-cement joints or bitumen emulsion sand-seal-joints and should be clean, non-plastic, angular, well graded, natural sand or crushed stone passing the 5.0mm sieve:-

- Plasticity Index of binding materials shall be not more than 6
- Fineness Modulus of sand fraction shall not be less than 1.80 and shall be free from deleterious materials.

Bitumen emulsion for joint filling

To improve water proofing of the surface, one option is for the joints between the stone blocks to be filled to within 5mm of the surface with bitumen emulsion sand-seal. The type of bitumen emulsion should be Cationic Slow Setting bitumen emulsion (CSS).

Cement for joint filling

To improve both pavement strength and water proofing of the surface, one option is for the joints between the stone blocks to be filled completely within sand-cement mortar. Ordinary Portland Cement should be used for this purpose.

8.3 CONSTRUCTION METHODS

Prior to laying the dressed stone, the Contractor shall correct any deformations, ruts, soft spots or other defects in the formation or sub-base all to the satisfaction of the Engineer whose approval shall be obtained before roadbase works commence. All drainage works necessary to keep the road formation and pavement layers free of standing water should be completed.

The Contractor shall establish sufficient setting out pins, pegs and string lines to ensure that the final shape of each pavement layer conforms with the Drawings, which shall be checked with a camber board, or straight edge, spirit level and tape. Any depressions in the surface shall be re-scarified and sufficient new material added to attain the correct shape.

The stone blocks should be laid on a previously prepared sand bedding layer of 30 – 50 mm thickness. The sand shall be laid and spread on the previously prepared formation or sub-base and lightly compacted, by hand tamping or pedestrian roller with no vibration.

The pavement edge stones or kerbs shall be placed first to act as a level and alignment guide for the rest of the paving. These edge blocks are to be bedded and joint mortared in place using a sand-cement mortar mix of 4 part sand to 1 part cement by volume. Just sufficient water should be added to the mortar mix to achieve a stiff and stable bedding. All other blocks shall be placed 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 (stretcher bond). Blocks should be sorted and laid according sizes so that each lateral row of blocks consists of a consistent width of stone block.

Each stone block shall be lightly tapped into position with a mason's hammer, to ensure initial bedding into the sand. Joints between blocks should be a nominal 10mm wide and completely filled with sand, with an excess to allow for consolidation during compaction.

When an area of blocks has been placed, they should be consolidated in position by dry compaction with a pedestrian vibrating roller. After a few pass of dry compaction, water can be applied to facilitate compaction. If a sand-cement or sand-emulsion joint seal is specified, the sand joints should then be cleaned out to a depth of 30mm and filled to within 5mm of the finished surface with sand-cement (4:1) mortar or bitumen emulsion–sand seal and finished smoothly.

Excess surface sand should be swept up and removed.

Delivered stone blocks shall be stacked on, or adjacent to, the prepared formation in such a manner as to allow for continuity of operations, avoid damage to the stones and to cause least inconvenience and danger to traffic.

All extraneous matter or damaged stone blocks shall be removed and made good with new material to the full thickness of the layer.

Where sand-cement jointing is specified, the dressed stone paving shall be covered with straw, sacking or other moisture retention medium and kept moist for a period of 4 days.

The dressed stone paving may be opened to traffic 7 days after the completion of the jointing work.

8.4 CONSTRUCTION EQUIPMENT

The minimum compactive effort for the rolling of the placed dressed stone shall be in the range:

Vibrating Roller Minimum Weight	Number of Passes
1,000 kg	6-8 per point

The type and condition of the compaction equipment shall be approved by the Engineer.

8.5 MEASUREMENT

Dressed stone surfacing shall be measured by the square metres of placed and jointed stone layer on the road. The quantity of work will be calculated by measurement of the width and approved length of the road, measured along the centre line of the road.

The payment and thickness of the dressed stone paving will include the sand bedding layer as specified.

The rates shall include the supply, bedding, placing, tamping and joint filling with sand, cement, or bitumen emulsion of the dressed stone surfacing including kerb constraints, as specified and shown on the Drawings.

The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including

supplying the materials, and providing all labour, tools, equipment, incidentals necessary, overheads and profit.

The payment item shall be:

Item Reference	Description	Unit Of Measurement
7a	180/190/200/210/220/230 mm (1) Dressed Stone Surfacing, sand jointed	Square metre
7b	180/190/200/210/220/230 mm (1) Dressed Stone Surfacing, sand-cement jointed	Square metre
7c	180/190/200/210/220/230 mm (1) Dressed Stone Surfacing, sand-emulsion jointed	Square metre
(1) Thickness to be specified to include the sand bedding layer.		

8.6 LABORATORY & SITE TESTING

General

The Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum, and the Engineer shall have the authority to have these tests undertaken at more frequent intervals, where quality of a material or work is in doubt.

Materials from each source should be submitted to the Engineer for approval in advance of the commencement of work.

Laboratory Testing

TYPE OF TEST	DESIGNATION	SAMPLING AND TESTING FREQUENCY (1)	COMPLIANT CONDITIONS
Sieve Analysis (sand)	AASHTO T-27	3 per Source plus 1 per 500 m^3	
Los Angeles Abrasion	AASHTO T-96	3 per Source plus 1 per 500 m^3	< 25%
Sodium Sulphate Soundness	AASHTO T-104	3 per Source plus	< 10% loss
Uni-axial compressive strength		> 75 Mpa	
Dressed faces	Visual	3 per Source plus as required based on visual observation. (more frequently if material character changes)	

(1) more frequently if material character changes)
> : greater or higher than

Site Testing

Visual Inspection of operations.

Dimensional regularity of stones. Tolerance on dressed stone block thickness variation ±15mm. Upper face of individual blocks maximum 3mm surface depression from a 30cm straight edge laid across the face at any point more than 20mm from the edge of the block. Maximum clearance to a 2 metre straight edge laid at any orientation across the finished pavement to be 10mm at any point more than 20mm from the edge of the sett.

A pavement layer quality and specification compliance inspection will be undertaken on all completed sections of the dressed stone paving layer by the Engineer's Representative prior to acceptance of the Works.

DRAFT SPECIFICATION 9

9. BAMBOO REINFORCED CONCRETE PAVEMENT

9.1 DESCRIPTION

Reinforced cement concrete is a well established form of rigid road pavement designed to spread the applied load due to traffic through a slab effect, and avoid overstressing of the road foundations. It is therefore ideal for construction on weak subgrades, and on routes liable to seasonal flooding. It is also particularly suitable for locations where heavy or overloaded trucks are expected to be used, for example on quarry access routes. 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 the steel slab reinforcement because it has good tensile strength, it is replenishable, very cost effective and very little mechanisation is needed to prepare it for use.

Asian and Pacific 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 road 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 can be lower than gravel/laterite pavement in some circumstances.

9.2 MATERIALS

Bamboo

Only adult bamboo of age 3 or 4 years growth should be used. The most positive method to determine the age of the culm (stalk) during growth is to put a mark on all culms each year at the same place. If in a certain situation culms are ripe after four years then all culms with four marks can be cut.

Harvesting should be done in the dry season, because then the bamboo culms have lower moisture content. During the rainy season no felling should occur.

Usually bamboo culms are cut with a sharp machete, but for heavier culms a pruning saw or an axe can be used. Bamboo can be divided into two types: the clump type and the running type. In the clump type bamboo grows in clumps of 50 or 100 culms and in the running type the culms are evenly distributed over the area.

In the clump type the old mature culms will be found in the centre with the young ones at the circumference. An entrance to the centre has to be made which results in a horseshoe pattern. Culms should be cut 20 – 30 cm above ground level in order not to damage the roots and just above a node in order to avoid water collection with subsequent rot.

In the running type, bamboo culms can be cut at ground level, because the roots remain protected in the ground.

Splints (i.e. split culms) are generally more desirable than whole culms for the reinforcement of concrete. Larger culms should be split into splints approximately 20 - 25mm wide and at least 10mm thick.

Bamboo should be cut, allowed to dry and season for a minimum of 4 weeks and up to 6 weeks before use.

The storage of bamboo requires special care. The ground must be clean, free of refuse of all kind and free of termites. Bamboo should be stored under cover to protect it from rain and clear of the ground (20 or 30cm). Good ventilation and frequent inspection are necessary. Fresh bamboo, standing vertically will dry in less than four weeks; a horizontal position doubles this time. Bamboo should be well supported when it is stored in order to prevent excessive warping of the culms.

The bamboo for reinforcement shall be in a split form (splints), produced after proper seasoning. The Engineer may specify treatment to prevent decay and minimise its capacity to absorb water.

Bamboo splitting should be undertaken by separating the base with a sharp blade and then pulling a blunt blade through the culm, thus producing nearly straight section splints with continuous fibres. Bamboo splints shall be reasonably straight with a width not exceeding 20-25mm.

Concrete

Concrete shall be Class 20 and have a minimum compressive strength of 20Mpa (28 days) with a mix proportion of 1:2:4 (cement: sand: aggregate), with a water/cement ratio of 0.45. The use of low water-cement ratios (e.g. 0.45), higher cement contents, plasticiser and high early-strength cement is beneficial in minimising the risk of cracks.

Concrete shall otherwise be constructed to the requirements of Specifications Clause 5.1 of the Construction Specifications published by the Ministry of Public Works and Transport (MPW&T).

Load Transfer Dowels

Load transfer dowels shall be provided at each joint between slabs. They shall be made with 14 mm diameter mild steel reinforcing bars, 500mm in length. The steel shall comply with Construction Specification of the MPW&T Clause 5.2 for reinforcement.

9.3 CONSTRUCTION METHODS

Bamboo Reinforced Concrete (BRC) pavement shall be constructed on a previously prepared sand bedding layer that has been examined and accepted by the Engineer's Representative. This layer accommodates the movements in the concrete slabs due to temperature variations in service. The sand shall be laid loose, spread and lightly compacted to the required thickness prior to the construction of the BRC slabs. To prevent excessive loss of moisture from the fresh concrete to the bedding sand a polythene membrane may be used between the bedding sand and the concrete slab.

Reinforcement

Bamboo mesh should be placed at the top 1/3 of the concrete slab, with a cover of 50mm from the pavement surface. The bamboo mesh grid is to have dimensions of 200mmx200mm, with splints measuring 25mm in width on average, as detailed on the Engineering Drawings. Each intersection of the bamboo grid is to be secured with binding wire. The reinforcing grid is to be positioned on, and secured to, solid brick or concrete spacers to ensure the correct height.

Bamboo should be placed with its concave face upwards. The basal and distal ends of the bamboo must be alternated in the mesh so that a uniform reinforcing area is obtained along the length and breadth of the slab. Minimum concrete cover on the bamboo reinforcement at any point is 50mm.

Precautions should be taken to counter the tendency of the bamboo mesh to float during casting by ensuring a low water-cement ratio.

Bamboo reinforcements may be spliced, either by providing an overlap of 16 times the splint width, or using suitable mechanical devices. Splices should be staggered and not located at sections of high stress.

Joints

Partial depth Contraction joints of 10mm width are to be provided at 5m intervals in the pavement, to relieve tensile stresses. Full depth Expansion joints of 10mm width are to be provided at 25m intervals. All joints are to be filled and sealed with a mixture of sand and bitumen, with a reservoir of bitumen provided at the top of each joint. All joints are be provided with load transfer steel dowels.

14mm diameter mild steel reinforcing bars of 500mm length are to be placed at 250mm centres at all expansion and contraction joints.

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 to omitted at contraction joints.

On wide roads where the pavement will be cast in two or more widths, the contraction joint reinforcement shall also be installed in the longitudinal construction joints.

Concrete

All concrete shall be mixed on site in small capacity batch mixers complying with the appropriate Cambodian MPW&T Standards. Mixers with a capacity less than one bag of cement shall not be used and no mixer shall be charged in excess of its rated capacity. Cement shall be fresh and stored in a clean dry location. Aggregates shall be stored separately in a clean area. Proportions of aggregates shall be measured using weighing apparatus or batching boxes. Water should be fresh not brackish (total salt content <30,000mg/litre) and not contaminated by industrial or other waste. Water proportions shall be determined using containers of known volume.

All formwork shall be made from steel or sound timber and be well secured and free from defects or gaps, and able to resist the tamping forces. The top edge of the formwork shall be within ± 2mm of the required finished road levels. Prior to placing the concrete, all formwork and reinforcement shall be thoroughly inspected and passed by the Engineer's Representative. All wood chips, dust, sand, construction debris and any other deleterious material shall be removed from the formwork and reinforcement prior to placing the concrete. All formwork shall be wetted to ensure it is damp when the concrete was poured. Care should be taken during this operation

such that pools of excess water did not form in the base of the formwork and also that the bamboo mesh is not wetted.

Temporary planking walkways shall be provided to allow the concrete to be barrowed to the location of placement without disturbing the reinforcement mesh.

Once the concrete had been placed uniformly within the forms, compaction shall 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.

No concrete shall be compacted after initial setting had proceeded. All concrete shall be compacted until no air bubbles appear on the surface of the fresh concrete. Care shall 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. It could also have a detrimental effect on the bond between the concrete matrix and the bamboo reinforcement.

After placement and compaction, the camber shall be shaped in the fresh concrete to lines and levels detailed in the Engineering Drawings. In order to improve the skid-resistance of the surface and to shorten the vehicles' breaking distance, transverse grooves shall be etched in the fresh concrete surface utilising an appropriate rake or grooving device.

To minimise the effects of early evaporation in direct sunlight and to provide comfort for workers, it is recommended to use a portable canopy to cover the area of the slab being placed.

After the concrete has set, it shall 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. No traffic shall be allowed on the pavement until a period of 14 days has elapsed. Suitable temporary diversions should be made for continued flow of normal traffic.

The first and last slabs of the BRC pavement will be subject to extraordinary impact loading as vehicles traverse from the adjacent paving to the BRCP without the benefit of load transfer dowels. These slabs therefore require additional reinforcement and it is recommended that a steel grid of 10mm plain mild steel reinforcement at 200mm centres (either mesh or wire tied individual rods) is used only for these end slabs.

9.4 CONSTRUCTION EQUIPMENT

The following equipment, apparatus and special handtools shall be used:

- ❑ Formwork (steel or sound timber)
- ❑ Concrete mixer of at least 250 litre capacity
- ❑ Batching boxes or weighing apparatus
- ❑ Wheelbarrows
- ❑ Vibrating poker powered by electricity or portable generator
- ❑ Tamping screed
- ❑ Portable sun protection canopy if casting in direct sunlight
- ❑ Grooving rake

9.5 MEASUREMENT

The unit of measurement shall be square metres (m^2) of constructed bamboo reinforced concrete. The quantity for which payment shall be made shall be the product of the instructed average width and the measured length along the centre line of the road.

The rates shall include the supply, placing, spreading, shaping, watering, compaction and curing as specified and shown on the Drawings.

The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including supplying the materials, and providing all labour, tools, equipment, incidentals, temporary and protection arrangements necessary, overheads and profit.

The payment item shall be:

Item Reference	Description	Unit Of Measurement
11a	50mm Sand Bedding layer	Square metre
11b	150mm Bamboo Reinforced Concrete	Square metre

9.6 LABORATORY & SITE TESTING

General

The Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum. The Engineer shall have the authority to have these tests conducted at more frequent intervals where quality of a material or work is in doubt.

Laboratory Testing

TYPE OF TEST	FREQUENCY OF TEST
Sieve Analysis (bedding sand)	3 per Source plus 1 per 500 m^3
Concrete Particle Size Distribution	One per 1km (more frequently if material character changes)
Concrete cube strength	One set of 3 cubes to be crushed at 7 days and one set of 3 cubes to be crushed at 28 days for mix design per materials source. One set of 3 cubes to be crushed at 7 days and one set of 3 cubes to be crushed at 28 days per 500m of pavement.

Site Testing

Visual inspections will be made to check compliance with the drawings and specifications:

- bedding sand
- bamboo mesh
- dowels
- formwork
- aggregate
- water
- concrete placing and finish

A Slump Test will be carried out on every concrete batching shift, or as directed by the Engineer. The slump shall be 60 - 80mm to allow for moisture losses into the sand bedding. If a separation membrane is use the slump should be 40 - 60mm. Concrete exceeding this criteria will be rejected. The Engineer may vary this requirement due to local materials and conditions.

A pavement layer quality and specification compliance inspection will be undertaken on all completed sections of the BRC pavement by the Engineers Representative prior to acceptance of the Works.

APPENDIX C

WHOLE LIFE COST ANALYSIS TECHNOLOGY OPTIONS

Table C.1: Technology Choices for Road Construction Operations

OPERATION	LABOUR-BASED APPROPRIATE TECHNOLOGY (LBAT) METHOD	MACHINE-BASED (MB) METHOD
Quarry preparation: vegetation and topsoil removal, and reinstatement	Labour and hand tools	Dozer and excavator
Quarry excavation	Labour and hand tools most suitable for gravels, weaker/jointed and weathered rock. Solid rock requires hand drills, plugs and feathers	Excavator for weaker/jointed rock. Pneumatic hammer and drills + dynamite for solid rock material
Quarry loading	Labour and hand tools	Excavator or loader
Produce concrete kerb	Labour, hand tools, small mixer and moulds	Mould equipment and concrete mixer
Produce stone kerb	Labour and hand tools	Not suitable
Produce burnt clay brick kerb	Labour and small scale kiln	Mechanised brick production system
Lay kerb	Labour and hand tools	Concrete kerbs can be laid by special machine
Produce dressed stone or setts for surfacing	Labour and hand tools	Not suitable
Produce stone for hand packed stone roadbase or surfacing	Labour and hand tools	Excavator and stone crushing plant
Produce stone material for WBM roadbase	Labour and hand tools (option of mobile crushing machine)	Excavator and stone crushing plant
Produce stone aggregate for well graded aggregate roadbase	Not suitable	Excavator and stone crushing plant
Produce stone aggregates for bituminous surface treatment	Labour, hand tools and mobile crushing machine	Excavator and stone crushing plant
Produce stone aggregates for concrete pavement and structures	Labour, hand tools	Excavator and stone crushing plant
Clear site of grass and light bush	Labour and hand tools	Dozer, grader, excavator
Grubbing and removal of stumps and roots	Labour and hand tools	Dozer, grader, excavator
Setting out horizontal and vertical alignment	Labour and Hand tools	Qualified staff, Levelling instruments
Material haulage to site	Animal cart or locally made truck for short distances	Conventional truck
On site excavation	Labour and hand tools	Excavator
Materials moving on site	Labour and hand tools (suitable for short hauled distance)	Dozer, excavator, grader, tractor with trailer, truck
Spreading of material	Labour and hand tools	Grader, dozer
Watering	Labour and hand tools	Water tanker, tractor with water bowser
Compaction	Labour and tools, pedestrian roller	Compactors
Preparation of existing surface (scarifying, shaping)	Labour, hand tools	Dozer, grader, excavator
Excavation of side drainage,	Labour and hand tools	Excavator
Construction of subgrade filter drain	Labour and hand tools	Not suitable
Construction of scour checks, mitre and catch water drains	Labour and hand tools	Usually not suitable
Construction gravel (laterite) subbase, gravel surfacing or shoulder	Labour, hand tools and small compactor	Grader, compactor and watering machine
Construction of hand packed stone road based or surfacing	Labour, hand tools and small compactor	Not suitable

OPERATION	LABOUR-BASED APPROPRIATE TECHNOLOGY (LBAT) METHOD	MACHINE-BASED (MB) METHOD
Construction of bituminous surface dressing	Labour, hand tools and pedestrian roller	Bitumen distributor, stone chipping spreader and compactor
Construction of Telford WBM	Labour, hand tools and roller	Not suitable
Construction of WBM	Labour, hand tools and roller	Not suitable
Construction concrete pavement	Labour, hand tools, concrete mixer and concrete vibrator	Concrete paver
Construction of concrete or brick side drains	Labour and hand tools	Not suitable
Construction of concrete structures	Labour, hand tools and concrete mixer	Substantially LBAT with cranage
Construction of masonry, brick or timber structures	Labour, hand tools and concrete mixer	Not suitable
Turfing	Labour and hand tools	Not suitable
Tree planting	Labour and hand tools	Not suitable
Install road furniture	Labour and hand tools	Not suitable
Road markings	Labour and hand tools	Marking machine