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KERAJAAN MALAYSIA
JABATAN KERJA RAYA MALAYSIA

STANDARD SPECIFICATION FOR ROAD WORKS

Section 4: Flexible Pavement

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FOREWORD

As practices in road construction change over time, it is imperative for Jabatan Kerja Raya (JKR) to continuously update and improve their standard specifications. These new specifications are not only aimed at keeping abreast with current technologies but also to help in improving the quality of constructed product. In unison, these new specifications have a significant positive impact on the construction industry especially with the incorporation of new products and technologies.

Standard Specification for Road Works is an essential component in the road infrastructure construction industry. This specification provides an improved guidance in the material selection and the production of good quality workmanship and products, based on current best practices. The purpose of this standard specification is to establish uniformity in road works to be used by road designers, road authorities, manufacturers and suppliers of road related products.

This document "Section 4: Flexible Pavement" is a part of a series of improved specifications in the Standard Specification for Road Works. The compilation of this document was carried out through many discussions by the technical committee members. Additionally it was vetted through by a group of independent consultants and presented at various workshops. Feedbacks and comments received were carefully considered and incorporated in the specification where appropriate.

Standard Specification for Road Works - Section 4: Flexible Pavement consists of two (2) parts namely "Standard Specification" and "Specialty Mix and Surface Treatment". The part on "Specialty Mix and Surface Treatment" is entirely new.

ACKNOWLEDGEMENT

This **Standard Specification For Road Works Section 4: Flexible Pavement** has been prepared by a technical committee consisting of engineers mainly from Cawangan Jalan, Jabatan Kerja Raya. The members of the committee involved in preparing this Standard Specification For Road Works - Section 4: Flexible Pavement are:-

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The Committee would also like to thank other JKR personnels and individuals who have contributed towards the successful completion of this specification.

SECTION 4 – FLEXIBLE PAVEMENT

4.14 SURFACE TREATMENT 3 - CRACK SEALING

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SECTION 4 – FLEXIBLE PAVEMENT

SECTION 4 - FLEXIBLE PAVEMENT

4.1 UNPAVED ROADS

4.1.1 Drainage Layer

4.1.1.1 Description

This work shall consist of furnishing, placing, compacting and shaping drainage layer on a prepared and accepted subgrade in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O.

4.1.1.2 Materials

Coarse aggregate shall be screened crushed hard rock and fine aggregate shall be screened quarry dust or sand. The aggregate shall be well graded and lie within the limits as shown in Table 4.1.1.

TABLE 4.1.1: GRADATION LIMITS FOR DRAINAGE LAYER

BS Sieve Size (mm)	Percentage Passing by Weight
75.0	100
37.5	75 - 100
20.0	60 - 90
10.0	25 - 75
5.0	10 - 45
2.00	0 - 20
1.18	0 - 10

4.1.1.3 Construction Methods

Not withstanding any earlier approval of finished subgrade, the surface of the subgrade shall be, on completion of compaction and immediately before placing drainage layer, well closed and free from movement under the compaction plant and from ridges, cracks, loose material, pot holes, ruts or other defects. Any damage to or deterioration of the subgrade shall be made good in accordance with Section 2 of this Specification.

The material shall be transported, laid and compacted at a moisture content within the range +1% to -2% of the optimum moisture content determined in compliance with BS 5835 and without drying out or segregation.

The drainage layer shall be placed and compacted to the required width and thickness as shown on the Drawings, in one single layer.

The material shall be spread and lightly compacted with tracked spreading plant or other approved equipment with consideration given to the protection of the subgrade.

4.1.2 Sub-Base

4.1.2.1 Description

This work shall consist of furnishing, placing, compacting and shaping sub-base material on a prepared and accepted subgrade in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O.

4.1.2.2 Materials

Sub-base shall be a natural or artificial mixture of locally available materials such as sand, gravel, crushed aggregate etc, free from organic matter, clay lumps and other deleterious materials. It shall be well graded and conform to Table 4.1.2 and the following quality requirements;

TABLE 4.1.2: GRADATION LIMITS FOR SUB-BASE

BS Sieve Size (mm)	Percentage Passing by Weight
75.0	100
37.5	85 - 100
20.0	65 - 100
10.0	45 - 100
5.0	25 - 85
0.600	8 - 45
0.075	0 - 10
The particle size shall be determined by the washing and sieving method of BS 1377.	

i. The CBR of the sub-base shall not be less than 30% or as shown on the Drawings when compacted to 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5 kg rammer method, soaked for 4 days under a surcharge of 4.5 kg). This shall involve carrying out a series of CBR tests at various dry densities, using the field moisture content. The field density shall then be measured at a number of points using the sand replacement method and the CBR deduced from the mean of the field density measurements.

ii. If more than 10% of the material is retained on the BS 20.0 mm sieve, the whole material can be assumed without test to have a CBR value of 30% or more.

iii. The plasticity index when tested in accordance with BS 1377 shall be not more than 12.

iv. The 10% fines value when tested in accordance with MS 30 shall be not less than 30 kN.

v. The sand equivalent of aggregate fraction passing the No. 4 (4.75 mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

4.1.2.3 Construction Methods

Prior to placing any sub-base material, the underlying subgrade (particularly the top 300 mm of the subgrade) shall have been shaped and compacted in accordance with the provisions of Sub-Section 2.2.7 or Sub-Section 4.1.1 as appropriate. Not withstanding any earlier approval of finished subgrade, the surface of the subgrade shall be, on completion of compaction and immediately before placing sub-base layer, well closed and free from movement under the compaction plant and from ridges, cracks, loose material, potholes, ruts or other defects. Any damage to or deterioration of the subgrade shall be made good in accordance with Section 2 of this Specification.

Sub-base material shall be transported, laid and compacted at a moisture content within the range +1% to -2% of the optimum moisture content without drying out or segregation.

Sub-base material shall be placed over the full width of the formation to the required thickness as shown on the Drawings or directed by the S.O. in one layer or more, each layer not exceeding 200 mm compacted thickness. Where two or more layers are required, they shall be of approximately equal thickness and none shall be less than 100 mm compacted thickness.

Each layer of sub-base shall be processed as necessary to bring its moisture content to a uniform level throughout the material suitable for compaction, and shall then be compacted using suitable compaction equipment approved by the S.O. to not less than 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5 kg rammer method). Compaction shall be carried out in a longitudinal direction along the roadbed, and shall generally begin at the outer edge and progress uniformly towards the crown on each side in such a manner that each section receives equal compactive effort, all to the satisfaction of the S.O.

All loose, segregated or other defective areas shall be removed to the full thickness of the layer, and new sub-base material laid and compacted.

The sub-base shall be finished in a neat and workmanlike manner, and shall have an average thickness over any 100 metre length not less than the required thickness. The top surface of the sub-base shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances as specified in Sub-Section 4.5.2.

4.1.3 Gravel Surfacing

4.1.3.1 Description

This work shall consist of furnishing, placing, compacting and shaping gravel surfacing material on a prepared and accepted subgrade or sub-base in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O.

4.1.3.2 Materials

Gravel surfacing material shall be a natural or prepared soil-aggregate mixture comprising gravel and sand size particles together with a small proportion of plastic fines, and shall be essentially free from vegetative and other organic matter, expansive clay minerals and lumps of clay. The material shall conform to the following physical and mechanical quality requirements;

i. The liquid limit when tested in accordance with BS 1377 shall be not more than 35%.

ii. The plasticity index when tested in accordance with BS 1377 shall be in the range 4 to 10.

iii. The aggregate crushing value when tested in accordance with MS 30 shall be not more than 35%.

iv. The gradation shall conform to one of the envelopes as shown in Table 4.1.3 with the fraction passing the BS 75 um sieve not greater than 2/3 of the fraction passing the BS 425 um sieve.

v. The sand equivalent of aggregate fraction passing the No. 4 (4.75 mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

TABLE 4.1.3: GRADATION LIMITS FOR GRAVEL SURFACING

BS Sieve Size (mm)	Percentage Passing by Weight			
	A	B	C	D
37.5	100	100	100	100
12.5	45-75	55-85	60-100	-
4.75	30-60	35-65	50-85	55-90
2.00	20-45	25-50	40-70	40-70
0.425	15-30	15-30	25-45	20-50
0.075	8-20	8-20	8-20	8-25
The particle size shall be determined by the washing and sieving method of BS 1377.				

Material with a maximum particle size of 37.5 mm, while otherwise not conforming to the gradation specification but satisfying the other requirements, shall be acceptable provided that it shall have a CBR value of 30% or more when compacted to 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5 kg rammer method, soaked for 4 days under a surcharge of 4.5 kg).

4.1.3.3 Construction Methods

Prior to placing any gravel surfacing material, the underlying subgrade or sub-base shall have been shaped and compacted in accordance with the provisions of Sub-Section 2.2.7 or Sub-Section 4.1.2 as appropriate. Notwithstanding any earlier approval of finished sub-base, the surface of the sub-base shall be, on completion of compaction and immediately before placing gravel surfacing material, well closed and free from movement under the compaction plant and from ridges, cracks, loose material, pot holes, ruts or other defects. Any damage to or deterioration of the subgrade shall be made good in accordance with Section 2 of this Specification.

Gravel surfacing shall be placed to the required width and thickness as shown on the Drawings or directed by the S.O. in one layer or more, each layer not exceeding 200 mm compacted thickness. Where two or more layers are required, they shall be of approximately equal thickness and none shall be less than 100 mm compacted thickness.

Spreading of the material shall be carried out by motor grader or other approved mechanical plant.

Each layer of gravel surfacing shall be processed as necessary to bring its moisture content to a uniform level throughout the material suitable for compaction, and shall then be compacted using suitable compaction equipment approved by the S.O. to not less than 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5 kg rammer method). Compaction shall be carried out in a longitudinal direction along the carriageway, and shall generally begin at the outer edge and progress uniformly towards the centre on each side, except on super elevated curves where rolling shall begin at the lower edge and progress uniformly towards the higher edge. In all cases compaction shall be carried out in such a manner that each section receives equal compactive effort, all to the satisfaction of the S.O.

Throughout the placement, adjustment of moisture content and compaction of gravel surfacing material, care shall be taken to maintain a uniform gradation of the material and prevent segregation.

All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer, and new material laid and compacted.

4.2 PAVED ROADS

Unbound Pavement Courses

4.2.1 Drainage Layer

4.2.1.1 Description

This work shall consist of furnishing, placing, compacting and shaping drainage layer on a prepared and accepted subgrade in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O.

4.2.1.2 Materials

Coarse aggregate shall be screened crushed hard rock and fine aggregate shall be screened quarry dust or sand. The aggregate shall be well graded and lie within the limits as shown in Table 4.2.1

TABLE 4.2.1 GRADATION LIMITS FOR DRAINAGE LAYER

B.S. Sieve Size (mm)	Percentage Passing by Weight
75.0	100
37.5	75 - 100
20.0	60 - 90
10.0	25 - 75
5.0	10 - 45
2.00	0 - 20
1.18	0 - 10

4.2.1.3 Construction Methods

Not withstanding any earlier approval of finished subgrade, the surface of the subgrade shall be, on completion of compaction and immediately before placing drainage layer, well closed and free from movement under the compaction plant and from ridges, cracks, loose material, pot holes, ruts or other defects. Any damage to or deterioration of the subgrade shall be made good in accordance with Section 2 of this Specification.

The material shall be transported, laid and compacted at a moisture content within the range +1% to -2% of the optimum moisture content determined in compliance with BS 5835 and without drying out or segregation.

The drainage layer shall be placed and compacted to the required width and thickness as shown on the Drawings, in one single layer.

The material shall be spread and lightly compacted with tracked spreading plant or other approved equipment with consideration given to the protection of the subgrade.

4.2.2 Sub-Base

4.2.2.1 Description

This work shall consist of furnishing, placing, compacting and shaping sub-base material on a prepared and accepted subgrade in accordance with this Specification

The gravel surfacing shall be finished in a neat and workman like manner; its width shall be everywhere at least as specified or shown on the Drawings on both sides of the centre-line, and its average thickness over any 100 metre length shall be not less than the required thickness and its minimum thickness at any point shall be not less than the required thickness minus 20 mm. The top surface of the gravel surfacing shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances as specified for 'roadbase' in Sub-Section 4.5.2.

and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O.

4.2.2.2 Materials

Sub-base shall be a natural or artificial mixture of locally available materials such as sand, gravel, crushed aggregate etc, free from organic matter, clay lumps and other deleterious materials. It shall be well graded and conform to Table 4.2.2 and the following quality requirements;

TABLE 4.2.2: GRADATION LIMITS FOR SUB-BASE

BS Sieve Size (mm)	Percentage Passing by Weight
75.0	100
37.5	85 - 100
20.0	65 - 100
10.0	45 - 100
5.0	25 - 85
0.600	8 - 45
0.075	0 - 10
The particle size shall be determined by the washing and sieving method of BS 1377.	

i. The CBR of the sub-base shall not be less than 30% or as shown on the Drawings when compacted to 95% of the maximum dry density determined in the B.S. 1377 Compaction Test (4.5 kg rammer method) and soaked for 4 days under a surcharge of 4.5 kg. This shall involve carrying out a series of CBR tests at various dry densities, using the field moisture content. The field density must then be measured at a number of points using the sand replacement method and the CBR deduced from the mean of the field density measurements.

If more than 10% of the material is retained on the BS 20.0 mm sieve, the whole material can be assumed without test to have a CBR value of 30% or more.

ii. The plasticity index when tested in accordance with BS 1377 shall be not more than 12.

iii. The 10% fines value when tested in accordance with MS 30 shall be not less than 30 kN.

iv. The sand equivalent of aggregate fraction passing the No. 4 (4.75 mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

4.2.2.3 Construction Methods

Prior to placing any sub-base material, the underlying subgrade (particularly the top 300 mm of the subgrade) shall have been shaped and compacted in accordance with the provisions of Sub-Section 2.2.7 or Sub-Section 4.2.1 as appropriate. Not withstanding any earlier approval of finished subgrade, the surface of the subgrade shall be, on completion of compaction and immediately before placing sub-base layer, well closed and free from movement under the compaction plant and from ridges, cracks, loose material, potholes, ruts or other defects. Any damage to or deterioration of the subgrade shall be made good in accordance with Section 2 of this Specification.

Sub-base material shall be transported, laid and compacted at a moisture content within the range +1% to -2% of the optimum moisture content without drying out or segregation.

Sub-base material shall be placed over the full width of the formation to the required thickness as shown on the Drawings or directed by the S.O. in one layer or more, each layer not exceeding 200 mm compacted thickness. Where two or more layers are required, they shall be of approximately equal thickness and none shall be less than 100 mm compacted thickness.

Each layer of sub-base shall be processed as necessary to bring its moisture content to a uniform level throughout the material suitable for compaction, and shall then be compacted using suitable compaction equipment approved by the S.O. to not less than 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5 kg rammer method). Compaction shall be carried out in a longitudinal direction along the roadbed, and shall generally begin at the outer edge and progress uniformly towards the crown on each side in such a manner that each section receives equal compactive effort, all to the satisfaction of the S.O.

All loose, segregated or other defective areas shall be removed to the full thickness of the layer, and new sub-base material laid and compacted.

The sub-base shall be finished in a neat and workmanlike manner, and shall have an average thickness over any 100 metre length not less than the required thickness. The top surface of the sub-base shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances as specified in Sub-Section 4.5.2.

4.2.3 Crushed Aggregate Roadbase

4.2.3.1 Description

This work shall consist of furnishing, placing, compacting and shaping crushed aggregate roadbase material on a prepared and accepted subgrade or sub-base in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as directed by the S.O.

4.2.3.2 Materials

Crushed aggregate roadbase material shall be crushed rock, crushed gravel or a mixture of crushed rock and gravel, which shall be hard, durable, clean and essentially free from clay and other deleterious materials.

The material shall conform to the following physical and mechanical quality requirements;

i. The plasticity index when tested in accordance with BS 1377 shall be not more than 6.

ii. The aggregate crushing value when tested in accordance with MS 30 shall be not more than 25%.

iii. The flakiness index when tested in accordance with MS 30 shall be not more than 25%.

iv. The weighted average loss of weight in the magnesium sulfate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 18%.

v. The material shall have a CBR value of not less than 80% when compacted to 95% of the maximum dry density determined in the B.S. 1377 Compaction Test (4.5 kg rammer method) and soaked for 4 days under a surcharge of 4.5 kg;

vi. The sand equivalent of aggregate fraction passing the No. 4 (4.75 mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

vii. The gradation shall comply with the envelope as shown in Table 4.2.3

TABLE 4.2.3: GRADATION LIMITS FOR CRUSHED AGGREGATE ROADBASE

B.S. Sieve Size (mm)	Pereentage Passing by Weight
50.0	100
37.5	85 - 100
28.0	70 - 100
20.0	60 - 90
10.0	40 - 65
5.0	30 - 55
2.00	20 - 40
0.425	10 - 25
0.075	2 - 10
The particle size shall be determined by the washing and sieving method of BS 1377.	

4.2.3.3 Construction Methods

Prior to placing any crushed aggregate roadbase material, the subbase shall have been constructed in accordance with the provisions of Section 4.2.2.3.

Crushed aggregate roadbase shall be placed to the required width and thickness as shown on the Drawings or directed by the S.O. in one layer or more, each layer not exceeding 200 mm compacted thickness.

Where two or more layers are required, each layer shall be of approximately equal thickness and none shall be less than 100 mm compacted thickness.

The material shall be spread using a motor grader of sufficient capacity or other approved mechanical spreader, at the optimum moisture content ±1%.

Compaction shall be carried out using suitable approved equipment, in a longitudinal direction, and begin at the lower edges and progress towards the crown, or in the case of superelevation towards the upper edge, in such a manner that each section receives equal compactive effort, sufficient to produce a density of not less than 95% of the dry maximum density as determined by BS 1377: Test 13.

Throughout the placing, adjustment of moisture content and compaction of crushed aggregate roadbase material, care shall be taken to maintain a uniform gradation of the material and prevent its separation into coarse and fine parts, all to the satisfaction of the S.O.

The crushed aggregate roadbase width shall be everywhere at least that specified or shown on the Drawings on both sides of the centre-line; and its average thickness over any 100 metre length shall be not less than the required thickness.

The surface of the roadbase shall on completion of compaction and immediately before placing bituminous surfacing be well closed and free from movement under the compaction plant and from ridges, cracks, loose material, pot holes, ruts other defects.

All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer, and new material laid and compacted. The addition of fine material will not be permitted.

The surface shall be to the required level and grade and comply with the tolerances as specified in Sub-Section 4.5.2.

4.2.4 Wet-Mix Roadbase

4.2.4.1 Description

This works shall consist of furnishing, placing, compacting wet-mix roadbase on a prepared and accepted sub-base in accordance with this Specification and the lines and levels as shown on the Drawings and/or as directed by the S.O.

4.2.4.2 Materials

Aggregate for wet-mix roadbase shall be crushed rock, crushed gravel or a mixture of crushed rock and gravel, which shall be hard, durable, clean and essentially free from clay and other deleterious materials.

The aggregate shall conform to the following physical and mechanical quality requirements:-

i. The flakiness index when tested in accordance with MS 30 shall be not more than 25%.

ii. The aggregate crushing value when tested in accordance with MS 30 shall be not more than 25%.

iii. The weighted average loss of weight in the magnesium sulfate soundness test (5 cycles) when tested in accordance with ASSHTO Test Method T 104 shall be not more than 18%.

iv. The sand equivalent of aggregate fraction passing the No. 4 (4.75 mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

v. The gradation shall comply with the limits shown in Table 4.2.4.

TABLE 4.2.4: GRADATION LIMIT FOR WET-MIX ROADBASE

B.S. Sieve Size (mm)	Percentage by Weight Passing
50.0	100
37.5	95 - 100
20.0	60 - 80
10.0	40 - 60
5.0	25 - 40
2.36	15 - 30
0.060	8 - 22
0.075	0 - 8
The particle size shall be determined by the washing and sieving method of BS 1377.	

4.2.4.3 Construction Methods

Not withstanding any earlier approval of finished sub-base, prior to placing wet-mix roadbase material, any damage to or deterioration of the sub-base shall be made good in accordance with Sub-Section 4.2.2.

Wet-mix roadbase material shall be placed to the required width and thickness as shown on the Drawings or as directed by the S.O. in one layer or more, each layer not exceeding 200 mm compacted thickness. Where two or more layers are required, they shall be of approximately equal thickness and none shall be less than 100 mm compacted thickness.

The material shall be laid using a paving machine at a moisture content $\pm$0.5% of the optimum which shall be maintained during the compaction operation.

Compaction shall be carried out using suitable approved equipment in a longitudinal direction, and begin at the lower edges and progress towards the crown, or in the case of superelevation towards the upper edge, in such a manner that each section receives equal compactive effort, sufficient to produce a density of not less than 95% of the maximum dry density as determined by BS 1377: Test 13.

Throughout the placing, and compaction of wet-mix roadbase material, care shall be taken to maintain a uniform gradation of the material and prevent its separation into coarse and fine parts.

All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer, and new wet-mix roadbase material laid and compacted, the addition of fine aggregate only shall not be permitted.

The wet-mix roadbase width shall be everywhere at least that specified or shown on the Drawings on both sides of the centre-line.

The average thickness measured over any 100 m length shall be not less than shown on the Drawings or specified and the minimum thickness measured at any one point shall be not less than 20 mm of the thickness shown or specified.

The surface of the wet-mix roadbase shall, on completion of compaction and immediately before placing bituminous surfacing, be well closed and free from movement under the compaction plant and from ridges, cracks, loose material, pot holes, ruts or other defects.

The surface shall be to the required level and grade and comply with the tolerances specified in Sub-Section 4.5.2.

Bound Pavement Courses

4.2.5 Bituminous Roadbase

4.2.5.1 Description

This work shall consist of furnishing, placing, shaping and compacting bituminous roadbase on a bitumen primed pavement course.

The work shall be carried out to the lines, levels, grades, dimensions and cross-section as shown on the Drawings and/or as directed by the S.O.

4.2.5.2 Materials

The materials for bituminous roadbase shall conform to the physical and mechanical quality requirements as specified in Sub-Section 4.3.3.2.

The gradation of the combined coarse and fine aggregates and mineral filler, shall conform to the appropriate envelope shown in Table 4.2.5.

TABLE 4.2.5: GRADATION LIMITS FOR ASPHALTIC CONCRETE

Mix Type	Bituminous Roadbase
Mix Designation	AC 28
BS Sieve Size (mm)	Percentage Passing by Weight
28.0	100
20.0	72 - 90
14.0	58 - 76
10.0	48 - 64
5.0	30 - 46
3.35	24 - 40
1.18	14 - 28
0.425	8 - 20
0.150	4 - 10
0.075	3 - 7

4.2.5.3 Mix Design

The design for the bituminous roadbase mixture shall be carried out in accordance with Sub-Section 4.3.3.3.

4.2.5.4 Equipment

The equipment shall all as specified in Sub-Section 4.3.3.4.

4.2.5.5 Construction Methods

All the provisions of Sub-Section 4.3.3.5 for the construction of asphaltic concrete pavement courses shall apply as appropriate to the construction of bituminous roadbase.

The bituminous roadbase shall be finished in a neat and workmanlike manner; its width shall be everywhere at least that specified or shown on the Drawings on both sides of the centre-line; and its average thickness over any 100 metre length shall be not less that the required thickness. The top surface of bituminous roadbase shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances as specified for 'binder course' in Sub-Section 4.5.2.

4.2.6 Cement-Treated Base

4.2.6.1 Description

This work shall consist of furnishing, placing, shaping and compacting cement-treated base course on a bitumen primed pavement course. Cement-treated base material shall compose of mineral aggregate and ordinary Portland cement uniformly blended and mixed with water in the plant. The mixed material shall be spread, shaped and compacted in accordance with this Specification and in conformity to the lines, grades, dimensions and typical cross-sections as shown on the Drawings. This pavement course shall be built in a series of parallel lanes that may reduce longitudinal and transverse joints to a minimum.

4.2.6.2 Materials

(a) Water

Water shall be clean, clear and free from injurious of sewage, oil, acid, strong alkalis or vegetable matter and it shall be free from clay or silt. If the water is of questionable quality, it shall be tested in accordance with the requirements of MS 28.

(b) Cement

Cement shall be ordinary Portland cement, and shall comply with the requirements of MS 522.

Manufacturers' certificates of test shall in general be accepted as proof of soundness, but the S.O. may require additional tests to be carried out on any cement which appears to have deteriorated through age, damage to containers, improper storage or for any other reason.

The S.O. may, without tests being made, order that any bag of cement, a portion of the contents of which has hardened, or which appears to be defective in any other way, to be removed from the site.

The cement shall be transported to the site in covered vehicles adequately protected against the entrance of water. It shall be stored in a weather-proof cement store to the approval of the S.O. and shall be taken for use in the works in the order of its delivery into the store.

Where cement is delivered in bulk containers, additional arrangements shall be made for bulk storage to the approval of the S.O., or the Contractor may use his bulk container lorries for storage at his own expense.

(c) Aggregate

The source of aggregate to be used shall be the one approved by the S.O. The aggregate shall be selected crushed materials meeting the gradation requirements given in Table 4.2.5. The material shall be free of roots, sod and weeds. The crushed aggregate shall consist of hard, durable particles of accepted quality, free from an excess of flat, elongated, soft or disintegrated pieces or objectionable matter. The method used in producing the aggregate shall be such that the finished product shall be as consistent as practicable. All stones and rocks of inferior quality shall be removed.

The gradation in Table 4.2.6 represents the limits which shall determine suitability of aggregate for use from the sources of supply. The final gradation decided on, within the limits designated in Table 4.2.6, shall be well graded from coarse to fine and shall not vary from the low limit on one sieve to the high limit on adjacent sieves, or vice versa. The portion of the base aggregate, including any blended material, passing the BS 425 um sieve shall have a plasticity index of not more than 6 when tested in accordance with BS 1377.

The aggregate shall have the Los Angeles abrasion value of not more than 45% when tested in accordance with ASTM C 131 and the aggregate crushing value of not more than 40% when tested in accordance with MS 30.

All aggregate samples required for testing shall be furnished by the Contractor at his own expense. Sampling shall be done in accordance with ASTM D 75. No aggregate shall be used in the production of cement-treated base mixtures without prior approval by the S.O.

TABLE 4.2.6: GRADATION LIMITS FOR CEMENT-TREATED BASE

BS Sieve Size (mm)	Percentage by Weight Passing
50.0	100
37.5	90 - 100
20.0	70 - 90
10.0	45 - 70
5.0	35 - 65
0.600	15 - 30
0.075	5 -15

(d) Bituminous Prime Coat

The bituminous prime coat material shall be slow-setting, cationic bitumen emulsion of grade SS-1K conforming to MS 161. The bitumen emulsion shall be sprayed at ambient temperature at a spray rate of 1.5 to 2.0 l/m^2 to underlying pavement course. The exact amount shall be specified by the S.O. The S.O. may require trial areas to be carried out in order to determine the exact amount of the bituminous prime coat to be used.

4.2.6.3 Laboratory Tests And Cement Content

(a) Laboratory Tests for Job Mix Design

At least thirty days prior to the time the Contractor is expected to begin placement of cement-treated base (CTB) course, he shall submit to the S.O. for approval a job mix design. The job mix design shall be submitted with certified laboratory reports showing material compliance, strength requirements and required laboratory tests. After approval of the job mix design, no substitution of materials or proportions shall be made without approval of a new mix design submitted by the Contractor in accordance with this Specification and approved by the S.O.

The CTB specimens shall develop a minimum characteristic compressive strength of 5 MPa in seven days and 10 MPa in 28 days when tested in accordance with BS 1924. The specimens shall also develop a flexural strength of not less than 2 MPa in 28 days when tested in accordance to BS 1924. The strength specified are Characteristic Strengths based on at least 6 tests.

(b) Cementitious Material Content

The quantity of ordinary Portland cement to be used with the aggregate and water shall be determined from tests of materials submitted by the Contractor for the job mix design and shall not be less than 80 kg/m^3. The cost of the cement shall be absorbed in cost per cubic metre for the cement-treated base course.

4.2.6.4 Construction Methods

(a) Weather Limitations

The cement-treated base shall not be mixed or placed when the weather is rainy.

(b) Preparing Underlying Course

Prior to placing cement-treated base course, the sub-base shall have been constructed in accordance with the provisions of Sub-Section 4.2.2.

(c) Mixing

The aggregate shall be proportioned and mixed with cement and water in a mixing plant. The location of the mixing plant shall be such that the mixture can be placed within the time stipulated in the specification. The plant shall be equipped with feeding and metering devices which will introduce the cement, aggregate and water into the mixer in the quantities as specified. Mixing shall continue until a thorough and uniform mixture has been obtained.

The aggregate storage bins on the mixing plant shall be provided with approved 'scalper' screens to eliminate the possibility of oversize or other objectionable materials from entering the bins.

The water shall be proportioned by weight or volume, and a means shall be provided for the S.O. to verify the amount of water per batch or the rate of flow for continuous mixing. The discharge of the water into the mixer shall not be started before part of the aggregate is placed into the mixer. The inside of the mixer shall be kept free from any hardened mix.

The cement shall be added in such a manner that it is uniformly distributed throughout the aggregate during the mixing operation.

The mixing plant shall be either batch mixing or continuous mixing type of adequate capacity and proper verifiable controls.

(d) Test Section

Prior to full production, the Contractor shall prepare a quantity of the cement-treated base according to the job mix design. The amount of mixture shall be sufficient to construct a test section of 30 metres long and 2 spreader widths placed in two sections and shall be of the same depth specified for the construction of the course which it represents. The underlying grade or pavement structure upon which the test section is to be constructed shall be the same as the remainder of the course represented by the test section. The equipment used in construction of the test section shall be of the same type and weight to be used on the remainder of the course represented by the test section.

In no case shall the plant-produced mix be considered acceptable if the mix properties or field densities of the test section do not meet the requirements of the mix design criteria.

If the test section should prove to be unsatisfactory, the necessary adjustments to the mix design, plant operation, and/or rolling procedures shall be made. Additional test sections, as required, shall be constructed and evaluated for conformance to this Specification. When test sections do not conform to this Specification, the sections shall be removed and replaced at the Contractor's own expense. A marginal quality test section that has been placed in an area of little or no traffic may be left in place. If a second test section also does not meet this Specification, both sections shall be removed at the Contractor's own expense. Full production shall not begin without the S.O.'s approval. There shall be no separate payment for test sections.

(e) Placing

The mixture shall be transported to the job site in suitable vehicles and shall be deposited on the moistened underlying layer in uniform layers by means of approved mechanical spreaders. Not more than 60 minutes shall elapse between the start of mixing and the start of compaction of the cement-treated base mixture on the prepared underlying layer.

The cement-treated base course shall be placed in successive horizontal layers not to exceed 250 mm in compacted depth. Prior to the placement of each successive layer, the surface of the preceding layer shall be moistened, when in the opinion of the S.O., the surface is too dry to provide proper bond.

The cement-treated base material shall be spread by a spreader box, self-propelled spreading machine or other methods approved by the S.O. If spreader boxes or other spreading machines are used that do not spread the material the full width of the lane or the width being placed in one construction operation, a sufficient number of them shall be provided and operated in staggered formation to obtain a full-width spreading. If in the opinion of the S.O., full-width construction is undesirable because of inadequate equipment, operating difficulties or climatic conditions, the cement-treated base course shall be constructed in partial widths. If the time elapsing between the placing of adjacent partial widths exceeds 30 minutes, a construction joint satisfactory to the S.O. shall be provided.

The equipment and methods employed in spreading the cement-treated base material shall ensure accuracy and uniformity of depth and width. If conditions arise where uniformity in spreading cannot be obtained, the S.O. may require additional equipment or modification in spreading procedure to obtain satisfactory results. Spreading equipment shall be not more than 10 metres nor less than 3 metres in width.

(f) Compaction

Immediately upon completion of the spreading operations, the mixtures shall be thoroughly compacted. The number, type and weight of rollers shall be sufficient to compact the mixture to the required density.

The field density of the compacted mixture shall be at least 98 percent of the maximum density of laboratory specimens prepared from samples of the cement-treated base material taken from the material in place. The specimens shall be compacted and tested in accordance with ASTM D 1557 Method D. The in-place field density shall be determined in accordance with ASTM D 1556 and ASTM D 2167. Any mixture that has not been compacted shall not be left undisturbed for more than 30 minutes. The moisture content of the mixture at the start of compaction shall not be below nor more than 2 percentage points above the optimum moisture content. The optimum moisture content shall be determined in accordance with ASTM D 558 and shall be less than that amount which will cause the mixture to become unstable during compaction and finishing.

(g) Pre-cracking

The cement-treated base course shall be pre-cracked. For sections identified to be pre-cracked, the time between placements of successive layers shall be at least 4 hours. Each layer shall be kerfed (not cut) to a depth of at least one-third of that layer with a suitable equipment. The resultant width shall not exceed 10 mm and shall be filled with a bituminous emulsion conforming to the requirements of MS 161 diluted with water at a ratio of 1:2 or as agreed by the S.O. The layers shall be water-cured except for the top layer, where curing compound shall be used. The pre-cracking shall be done in 3m x 3m panels unless specified otherwise by the S.O.

(h) Layer Thickness

The maximum depth of a compacted layer shall be 250 mm, except where the total depth of the compacted base course is required to be greater than 150 mm, no layer shall be in excess of 200 mm or less than 100 mm when compacted. In multilayer construction, the surface of the compacted material shall be kept moist until covered with the next layer. Successive layers shall be placed and compacted so that the required total depth of the base course is completed the same day.

(i) Finishing

The completed base course shall conform to the required lines, grades and cross-sections. If necessary, the surface shall be lightly scarified to eliminate any imprints by the compacting or shaping equipment. The surface shall then be re-compacted to the required density.

The compaction and finishing operations shall be completed within 2 hours of the time water is added to the mixture and shall produce a smooth, dense surface that is free of surface checking, ridges or loose materials.

(j) Surface Tolerance

The finished surface shall not vary by more than 10 mm when tested with a 3 metre straight edge applied parallel with or at right angles to the centerline of the stabilised area. Any deviation in excess of this amount shall be corrected at the Contractor's own expense.

(k) Construction Joints

At the end of each day's construction, a transverse construction joint shall be formed by a header or by cutting back into the compacted material to form a true vertical face free of loose material.

Longitudinal joints shall be formed by cutting back into the compacted material to form a true vertical edge.

The curing seal shall be maintained and protected for 7 days.

Finished portions of the base course that are used by the equipment in the construction of an adjoining section shall be protected to prevent damage to the completed work.

(l) Protecting and Curing

The completed cement-treated base course shall be cured with a bitumen emulsion applied as soon as possible and in no case later than 4 hours after completion of the finishing operations. The surface of the base course shall be kept moist until the curing compound material is applied.

The curing compound specified shall be uniformly applied to the surface of the completed cement-treated base course with approved heating and distributing equipment and give complete coverage without excessive runoff. At the time the bituminous material is applied, the surface shall be dense free of all loose and extraneous material and shall contain sufficient moisture to prevent penetration of curing compound. Water shall be applied in sufficient quantity to fill the surface voids immediately before the bituminous curing compound is applied.

If there is a need for construction equipment of other traffic to use the bituminous covered surface before the bituminous material has dried sufficiently to prevent pick-up, sufficient granular cover shall be applied before such use.

The curing material shall be maintained and applied as needed by the Contractor during the 7-day protection period so that the entire treated base course will be covered effectively during this period.

(m) Strength Testing

To ensure that the strength requirements of the cement-treated base are met, a minimum of six compressive strength test on 150mm x 150mm x 150mm cubes and one flexural strength on 100mm x 100mm x 600mm beams, as specified in BS 1924, shall be determined of the cement-treated base course for every 1,000 m^2 of material placed. A minimum of one set of test per day shall be performed if less than 1,000 m^2 is placed. The compressive and flexural strengths shall be determined on seven-day laboratory specimens. Material for the laboratory specimens shall be sampled at the same area the density test is carried out, on the day the material is placed. Three (3) laboratory cubes and beams shall be produced and from each set of three (3) cubes and beams, two (2) shall be tested for compressive and flexural strengths at seven (7) days with one spare cube and beam being held in reserve to replace any obviously defective cube or beam that may develop.

4.3 BITUMINOUS PAVEMENT COURSES

4.3.1 Bituminous Prime Coat

4.3.1.1 Description

This work shall consist of the careful and thorough cleaning of the surface of a prepared and accepted unbound roadbase and cement-treated base (CTB), and the furnishing and application to the cleaned roadbase and CTB surface of a bituminous prime coat, all in accordance with this Specification and the lines, dimensions and cross sections as shown on the Drawings and/or as directed by the S.O.

4.3.1.2 Materials

The material shall be cut-back bitumen of grade MC-70 conforming to the requirements of MS 159 (refer Table 4.3.1) or slow-setting cationic bitumen emulsion of grade SS-1K conforming to the requirements of MS 161 (refer Table 4.3.2) or other materials as approved by the S.O.

TABLE 4.3.1 MS 159 REQUIREMENTS FOR CUT-BACK BITUMEN MC-70

Properties	Min	Max	Test Methods (or technically identical with)
Kinematic viscosity at 60 °C, cSt	70	140	ASTM D2170
Flash Point (Tag Open-Cup), °C	38	-	ASTM D1310
Distillation test:			ASTM D402
Distillate, percent by volume of total distillate:			
225 °C	-	20	
260 °C	20	60	
316 °C	65	90	
Residue from distillation to 360 °C, percent volume by difference	55	-	
Tests on residue from distillation:			
Penetration at 25 °C, 100g, 5 sec.	120	250	ASTM D402/ASTM D5
Ductility at 25 °C, cm	100	-	ASTM D402/ASTM D113
Solubility in trichlorethylene, percent, mass	99	-	ASTM D402/ASTM D2040
Water, percent, volume	-	0.2	ASTM D95

TABLE 4.3.2 MS 161 REQUIREMENTS FOR BITUMEN EMULSION SS-1K

Properties	Unit	Grade SS-1K	Test Methods (or technically identical with)
Tests on emulsion:			
Saybolt Furol viscosity at 25 °C, minimum maximum	sec.	 20 100	ASTM D244
Storage stability test, 24 h, maximum	% difference	1	ASTM D244
Sieve test, maximum	%	0.10	ASTM D244
Cement mixing test, maximum.	%	2	ASTM D244
Residue from distillation, minimum	% mass	57	ASTM D244
Tests on residue from distillation:			
Penetration at 25 °C,100g, 5 sec. minimum maximum	0.1 mm	 60 200	ASTM D5
Solubility in trichlorethylene, Minimum	% mass	97.5	ASTM D2042

The S.O. shall receive a copy of the test results for each delivery of cut-back bitumen, bitumen emulsion or other materials employed in the Works.

4.3.1.3 Equipment

The Contractor shall provide the plant and the equipment necessary for the execution of the work in accordance with this Specification. Details of this equipment including manufacturer, model type, capacity, etc shall be forwarded to the S.O. for his approval before the plant or equipment is mobilised.

(a) Mechanical Power Broom

The power broom is to be of the self propelled suction type capable of removing all loose particles and dust from the surface to receive the bituminous prime coat, or a self propelled power broom fitted with an air blower with a delivery pressure of 0.7 N/mm^2.

(b) Pressure Distributor for Bituminous Material

The distributor shall be a purpose built model of recognised manufacture and shall be approved by the S.O. It shall conform to the requirements described hereunder.

The distributor shall have a suitable capacity and shall be equipped with a gas or oil fired heating system capable of heating a full charge of bituminous material to 180 °C. The heating system shall be such that overheating of the bituminous prime coat will not occur and shall be of a type in which flames from the burner do not come into direct contact with the casing of the tank containing the bituminous prime coat. The tank shall be insulated in such a manner that when filled with bituminous prime coat at 180 °C and not heated, the drop in temperature shall be less than 3 °C per hour. A

thermometer shall be provided to measure continuously the temperature of the bituminous prime coat in the tank and shall be so arranged that the highest temperature in the tank is measured. The tank shall be fitted with an accurately calibrated dipstick or contents gauge, and the pipe for filling the tank shall be fitted with an easily replaceable filter.

The distributor shall run on pneumatic tyred wheels of such width and number that the load produced on the road surface when the vehicle is fully charged shall not exceed 12 kg/mm of tyre width. The vehicle shall be equipped with a 'fifth wheel' tacheometer system to accurately measure its forward speed during spraying operations.

The distributor shall be equipped with a full circulation type spray bar with nozzles from which the bituminous prime coat is sprayed on to the road surface uniformly over the full spraying width. The spraying width shall be variable in increments of not more than 100 mm up to a maximum of 5.0 metres. The spraying pump shall be driven by a separate power unit and shall be equipped with an accurate pressure gauge and an accurate flow rate gauge or meter. On the suction side the pump shall be fitted with an easily replaceable filter. The spray bar and pump shall be so designed that bituminous prime coat at even temperature and uniform pressure may be sprayed uniformly over the spraying width at controlled rates in the range 0.25 to 8.0 litres/sq.m at normal distributor operating speeds, such that deviation from the prescribed rate of application shall not exceed 10%.

The distributor shall be equipped with a hand spraying system.

The meters for the 'fifth wheel' tachometer system and the bituminous prime coat pumping flow rate, pumping pressure and temperature shall be located in such a manner that the vehicle driver can easily read them while operating the distributor. The spray bar shall be controlled by a second operator riding at the rear of the vehicle in such a position that all the discharge sprays are in his good view.

All measuring equipment on the distributor shall have been recently calibrated and accurate, and satisfactory records of the calibrations shall be submitted to the S.O. If in the course of the work the rates of application of bituminous prime coat are found to be inaccurate, the distributor shall be withdrawn from the Works and recalibrated to the satisfaction of the S.O. before being returned to service.

The S.O. may require such performance tests as he considers necessary to check that the distributor is operating satisfactorily. As directed by the S.O., the Contractor shall make the distributor and its equipment available for such tests and shall supply all necessary assistance, materials, tools, testing apparatus, etc., all at the Contractor's own expense.

(c) Storage and Heating Facilities for Bituminous Prime Coat

Tanks for storage of bituminous prime coat shall have a capacity suited to the proposed rate of utilisation of the material and the method and frequency of its delivery to the Works, all to the satisfaction of the S.O. The bituminous prime coat storage tanks and barrel decanters shall be equipped with indirect heat transfer oil heating, to raise the bituminous prime coat to the specified temperature, without over heating.

4.3.1.4 Construction Methods

(a) General Conditions

Bituminous prime coat work shall only be carried out in dry and warm weather when the surface to be treated is essentially dry.

(b) Surface Preparation and Cleaning

Prior to applying the bituminous prime coat, the unbound aggregate roadbase shall have been shaped and compacted in accordance with the provisions of this Specification. Notwithstanding any earlier approval of finished roadbase, any damage to or deterioration of the roadbase shall be made good to the satisfaction of the S.O. before bituminous prime coat is applied.

Immediately prior to applying the bituminous prime coat, the full width of the surface to be treated shall be swept using a power broom followed by a compressed air blower and, if necessary, scraped using hand tools to remove all dirt, dust and other objectionable materials, all to the satisfaction of the S.O.

(c) Application of Bituminous Prime Coat

The bituminous prime coat shall be sprayed on to the cleaned roadbase surface by means of a pressure distributor. Any areas inaccessible to the distributor spray bar shall be treated using the distributor's hand spraying system. The rate or rates of application shall be as directed by the S.O. based on the results of test applications, but shall usually be in the range 0.5 to 1.0 litre/sq.m. The temperature of cut-back bitumen MC-70 shall be maintained in the range 50 °C to 70 °C during spraying operations.

For the bitumen emulsion SS-1K, the spraying temperature shall be in the range 25 °C to 45 °C. After the bitumen emulsion "breaks", sand or quarry dust shall be lightly spread over the primed surface. The covered surface shall be left undisturbed to cure for a period of 24 hours after which the surface can be swept clear of the sand or quarry dust before construction of the overlying pavement course.

If necessary, in order to prevent the bituminous prime coat from flowing on the sprayed surface, the preseribed prime coat shall be applied in two separate spraying operations. Where the condition of the treated surface indicates that it is necessary, bituminous prime coat additional to that prescribed shall be applied as the S.O. shall direct.

Bituminous prime coat shall be distributed uniformly over the surface to be treated without streaking; the quantities applied shall not deviate by more than 10% from those prescribed. Areas with insufficient bituminous prime coat shall be resprayed as necessary to make up the deficiency, all to the satisfaction of the S.O.

The surfaces of structures, road furniture and trees adjacent to the areas being sprayed shall be protected in such a manner as to prevent their being spattered or marred by bituminous prime coat. Bituminous prime coat shall not be discharged into road drains, gutters, etc.

(d) Curing and Opening to Traffic

Bituminous prime coat shall normally be left undisturbed for at least 24 hours after application and shall not be opened to traffic until, in the opinion of the S.O., it has penetrated the roadbase and cured sufficiently such that it will not be picked up by the wheels of vehicles.

The Contractor shall maintain the bituminous prime coat, all to the satisfaction of the S.O., until the overlying pavement course is constructed, which shall not be within 24 hours after the application of the bituminous prime coat nor within such longer period as is required, in the opinion of the S.O., for the prime coat to achieve maximum penetration of the roadbase and become fully cured.

4.3.2 Bituminous Tack Coat

4.3.2.1 Description

This work shall consist of the careful and thorough cleaning of the surface of a prepared and accepted bituminous or bitumen primed pavement course, and the furnishing and application to the cleaned surface of a bituminous tack coat prior to the construction of an overlying bituminous pavement course, all in accordance with this Specification and the lines, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O.

4.3.2.2 Materials

Bituminous tack coat material shall be rapid-setting cationic bitumen emulsion of grade RS-1K conforming to the requirements of MS 161.

4.3.2.3 Equipment

The equipment shall be as specified in Sub-Section 4.3.1.3.

4.3.2.4 Construction Methods

(a) General Conditions

Bituminous tack coat shall only be applied on to a clean and dry surface of bituminous or bitumen primed pavement course.

Bituminous tack coat shall only be applied as far in advance of the construction of the overlying bituminous pavement course as is necessary to achieve a satisfactory degree of tackiness before the overlying material is placed, all to the satisfaction of the S.O.

(b) Surface Preparation and Cleaning

Prior to applying bituminous tack coat, the surface to be treated shall have been prepared in accordance with the appropriate Sections of this Specification. Notwithstanding any earlier approval of this surface, any damage to it or deterioration of it shall be made good before bituminous tack coat is applied.

Immediately prior to applying bituminous tack coat, the full width of the surface to be treated shall be swept using a power broom followed by a compressed air blower, and if necessary, scraped using hand tools, to remove all dirt, dust and other objectionable materials, all to the satisfaction of the S.O.

(c) Application of Bituminous Tack Coat

The bituminous tack coat shall be sprayed on to the clean and dry surface of bituminous or bitumen primed pavement course by means of a pressure distributor. Any areas inaccessible to the distributor spray bar shall be treated using the distributor's hand spraying system. The rate or rates of application shall be as directed by the S.O. based on the results of test applications, but shall usually be in the range 0.25 to 0.55 litres/sq.m. The temperature of the bituminous tack coat shall be maintained in the range 25 °C to 45 °C during spraying operations.

Bituminous tack coat shall be distributed uniformly over the surface to be treated without streaking; the quantities applied shall not deviate by more than 10% from those prescribed. Areas with bituminous tack coat in excess of these limits shall have the excess removed at the Contractor's expense, and areas with insufficient bituminous tack coat shall be resprayed as necessary to make up the deficiency, all to the satisfaction of the S.O.

The surfaces of structures, road furniture and trees adjacent to the areas being sprayed shall be protected in such a manner as to prevent their being spattered or marred by bituminous tack coat. Bituminous tack coat shall not be discharged into road drains, gutters, etc.

Traffic shall be kept off the bituminous tack coat at all times, and the Contractor shall maintain the bituminous tack coat, all to the satisfaction of the S.O., until the overlying pavement course is constructed.

4.3.3 Asphaltic Concrete

4.3.3.1 Description

This work shall consist of furnishing, placing, shaping and compacting asphaltic concrete binder course and/or wearing course on a prepared and accepted bituminous or bitumen primed pavement course, and shall include the careful and thorough cleaning of surfaces which are to be covered prior to the application of bituminous prime coat and tack coat. The work shall be carried out all in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O.

4.3.3.2 Materials

(a) Aggregates

Aggregates for asphaltic concrete shall be a mixture of coarse and fine aggregates, and mineral filler. The individual aggregate shall be of sizes suitable for blending to produce the required gradation of the combined aggregate, all to the satisfaction of the S.O.

Coarse Aggregate

Coarse aggregate shall be screened crushed hard rock, angular in shape and free from dust, clay, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The Los Angeles abrasion value when tested in accordance with ASTM C 131 shall be not more than 25%.

ii. The weighted average loss of weight in the magnesium sulfate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 18%.

iii. The flakiness index when tested in accordance with MS 30 shall be not more than 25%.

iv. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

v. The polished stone value when tested in accordance with MS 30 shall be not less than 40 (only applicable to aggregates for wearing course).

Fine Aggregate

Fine aggregate shall be clean screened quarry dust. Other types of fine aggregate may be used subject to the approval of the S.O. Fine aggregate shall be non-plastic and free from clay, loam, aggregation of material, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

ii. The fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.

iii. The Methylene Blue value when tested in accordance with Ohio Department of Transportation Standard Test Method shall be not more than 10 mg/g.

iv. The weighted average loss of weight in the magnesium sulphate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 20%.

v. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

Notwithstanding compliance with the requirements of this Specification, limestone aggregates shall not be permitted for use in wearing course.

The gradation of the combined coarse and fine aggregates, together with mineral filler, shall conform to the appropriate envelope shown in Table 4.3.3.

TABLE 4.3.3 GRADATION LIMITS FOR ASPHALTIC CONCRETE

Mix Type	Wearing Course	Wearing Course	Binder Course
Mix Designation	AC 10	AC 14	AC 28
BS Sieve Size (mm)	Percentage Passing by Weight		
28.0			100
20.0		100	72 - 90
14.0	100	90 - 100	58 - 76
10.0	90 - 100	76 - 86	48 - 64
5.0	58 - 72	50 - 62	30 - 46
3.35	48 - 64	40 - 54	24 - 40
1.18	22 - 40	18 - 34	14 - 28
0.425	12 - 26	12 - 24	8 - 20
0.150	6 - 14	6 - 14	4 - 10
0.075	4 - 8	4 - 8	3 - 7

For each type of mix required in the Works, the Contractor shall propose a laboratory design mix gradation which shall consist of a single definite percentage passing for each sieve size in the above Table and shall produce a smooth curve within the appropriate gradation envelope. This job laboratory design mix gradation, with the allowable tolerances for a single test as specified in Sub-Section 4.3.3.3 (c), shall then become the job standard mix or job mix formula.

(b) Mineral Filler

Mineral filler shall be incorporated as part of the combined aggregate gradation. It shall be of finely divided mineral matter of hydrated lime (calcium hydroxide). At the time of mixing with bitumen, the hydrated lime shall be sufficiently dry to flow freely and shall be essentially free from agglomerations. Not less than 70% by weight shall pass the BS 75 um sieve. The total amount of hydrated lime as mineral filler shall be limited such that the ratio of the combined coarse aggregate, fine aggregate and mineral filler of the final gradation passing 75 um sieve to bitumen, by weight, shall be in the range of 0.6 to 1.2. As a guide, the total amount of hydrated lime shall be approximately 2% by weight of the combined aggregates. The hydrated lime shall also be treated as an anti-stripping agent.

If hydrated lime is not available, ordinary Portland cement shall be used as an

alternative, subject to approval by the S.O.

(c) Bituminous Material

Bituminous binder for asphaltic concrete shall be bitumen of penetration grade 60-70 or 80-100 which conforms to MS 124, or polymer modified binder. The use of polymer modified binder in asphaltic concrete shall conform to Sub-Section 4.11 of this Specification.

4.3.3.3 Mix Design

(a) Job Mix Formulae

The Contractor shall propose a job mix formula for each type of mix required in the Works. In order to obtain optimum quality of the mixes, the job mix formula for each type of mix shall be prepared on the basis of testing several laboratory design mix aggregate gradations within the limits set in Table 4.3.3 at an appropriate range of bitumen content. As a guide to the testing range of bitumen content, the design bitumen content will usually be in the range given in Table 4.3.4.

Each combination of laboratory design mix aggregate gradation and bitumen content shall be subject to the Marshall test procedure and volumetric analysis as follows;

i. Preparation of laboratory specimens for the standard stability and flow test in accordance with ASTM D 1559 using 75-blow/face compaction standard,

ii. Determination of the bulk specific gravity of the specimens in accordance with ASTM D 2726,

iii. Determination of the stability and flow values in accordance with ASTM D 1559,

iv. Analysis of the specific gravity and air voids parameters to determine the percentage air voids in the compacted aggregate, the percentage air voids in the compacted aggregate filled with bitumen and the percentage air voids in the compacted mix.

For each laboratory design mix gradation, four specimens shall be prepared for each bitumen content within the range given in Table 4.3.4 (see Note 1) at increments of 0.5 percent, in accordance with ASTM D 1559 using 75 blows/face compaction standard. All bitumen contents shall be in percentage by weight of the total mix.

As soon as the freshly compacted specimens have cooled to room temperature, the bulk specific gravity of each test specimen shall be determined in accordance with ASTM D 2726.

The stability and flow value of each test specimen shall then be determined in accordance with ASTM D 1559.

After the completion of the stability and flow test, specific gravity and voids analysis shall be carried out for each test specimen to determine the percentage air voids in the compacted aggregate filled with bitumen (VFB) and the percentage air voids in the compacted mix (VIM).

Values which are obviously erratic shall be discarded before averaging. Where two or more specimens in any group of four are so rejected, four more specimens shall be prepared and tested.

The average values of bulk specific gravity, stability, flow, VFB and VIM obtained above shall be plotted separately against the bitumen content and a smooth curve drawn through the plotted values.

The mean optimum bitumen content shall be determined by averaging five optimum bitumen contents so determined as follows;

i. Peak of curve taken from the stability graph (see Note 2),

ii. Flow equals to 2 mm from the flow graph,

iii. Peak of curve taken from the bulk specific gravity graph (see Note 3),

iv. VFB equals to 75% for wearing course and 70% for binder course from the VFB graph,

v. VIM equals to 4.0% for wearing course and 5.0% for binder course from the VIM graph.

The individual test values at the mean optimum bitumen content shall then be read from the plotted smooth curves and shall comply with the design parameters given in Table 4.3.5

If all the values comply with Table 4.3.5, the mixture with the mean optimum bitumen content shall be used in plant trials.

If any of the values does not comply with Table 4.3.5, the mix design procedure shall be repeated using different laboratory design mix aggregate gradation until all the design parameters are satisfied.

Note:

1. The range of bitumen content shall be extended if necessary to ensure that the curves of stability and bulk specific gravity have their peak within the range selected.

2. Where the stability curve exhibits more than one peak, the bitumen content chosen for the determination of the mean optimum bitumen content shall be the one which satisfies the voids requirements better. It is sometimes necessary where no peak stability is obtained, to prepare and test supplementary specimens at intervals of 0.25% bitumen content on either side of the expected optimum.

3. With highly absorptive aggregate, some difficulty in determining peak bulk specific gravity may occur. In such cases, the bitumen content at which the increase in bulk specific gravity shows a marked falling off shall be adopted.

TABLE 4.3.4: DESIGN BITUMEN CONTENTS

AC 10 - Wearing Course	5.0 - 7.0%
AC 14 - Wearing Course	4.0 - 6.0 %
AC 28 - Binder Course	3.5 - 5.5%

TABLE 4.3.5: TEST AND ANALYSIS PARAMETERS

Parameter	Wearing Course	Binder Course
Stability, S	> 8000 N	> 8000 N
Flow, F	2.0 - 4.0 mm	2.0 - 4.0 mm
Stiffness, S/F	> 2000 N/mm	> 2000 N/mm
Air voids in mix (VIM)	3.0 - 5.0%	3.0 - 7.0%
Voids in aggregate filled with bitumen (VFB)	70 - 80%	65 - 75%

(b) Plant Trials

After having received the S.O. preliminary approval of his proposed job mix formula, the Contractor shall arrange to mix, lay and compact asphaltic concrete conforming to the proposed formula for each type of mix required in the Works. A minimum of 20 tonnes of each mix shall be placed in trial areas to demonstrate to the satisfaction of the S.O. that the mixing, laying and compacting equipment conforms to the requirements of this Specification, and that the proposed mix is satisfactory. The trial areas shall not be part of the Contract Works but shall be provided by the Contractor at his own expense. The proposed trial area shall be approved by the S.O.

As directed by the S.O., comprehensive sampling and testing of each class of mix shall be carried out to check for satisfactory compliance with its job mix formula, and for a satisfactory degree of compaction. In order to demonstrate to the satisfaction of the S.O. that mixing, laying and compacting equipment conform to the requirements of the specification, and that the proposed mix is satisfactory, the following observations and tests shall be carried out;

i. Record the type and weight of rollers. Check the tyre pressure of the pneumatic tyre roller (shall comply with Sub-Section 4.3.3.4 (e)).

ii. Record the type of paver (shall comply with Sub-Section 4.3.3.4 (d)).

iii. Check that the trial area is suitable (not on soft ground, uneven surface or part of the Contract Works).

iv. Take samples of the mix, one set from each lorry load, and carry out the following tests;
   - Binder content and aggregate grading (shall conform to the precise aggregate gradation and bitumen content as determined from the mix design and within the tolerances set forth in Table 4.3.6.
   - Preparation of Marshall specimens.
     - Bulk specific gravity.
     - Volumetric properties (shall comply with Table 4.3.5).
     - Marshall stability and flow (shall comply with Table 4.3.5).

v. Record temperatures of mix on the lorry, at plant and site (shall not exceed 163 °C at any time and shall be not less than 130 °C (increased by 10 °C for penetration grade 60-70 bitumen) immediately before unloading into the paver hopper).

vi. Record laying (uncompacted) thickness.

vii. Check texture of paved surface before rolling (there shall be no substantial blemishes and irregularities).

viii. Record temperatures of mix immediately before rolling starts (rolling temperatures). The temperature of mix at the commencement of rolling shall be not less than 120 °C (increased by 10 °C for penetration grade 60-70 bitumen). Rolling shall not be continued when the mix has cooled to 80 °C and lower.

ix Record rolling pattern.

x. Check texture of compacted surface.

xi. Take core samples after the laid material has sufficiently hardened (at least three samples from each lorry load).

xii. Measure compacted thickness and density of the core samples (shall comply with Sub-Section 4.3.3.5 (i) and (j)).

If the composition of the mix does not conform to the precise aggregate gradation and bitumen content as determined in the mix design procedure as described in Sub-Section 4.3.3.3 (a) and within the tolerances set forth in Table 4.3.6, and/or the Marshall specimens do not comply with any of the properties set forth in Table 4.3.4 the mix design procedure shall be repeated using different aggregate gradation and the plant trial shall be repeated.

If the texture of the paved and/or compacted surface are not satisfactory, and/or the compacted thickness and/or density are inadequate, the plant trial shall be repeated using different paver and/or roller(s).

Upon satisfaction by the S.O., the Contractor shall be required to produce a full report of the plant trials and this document shall be used in full scale production in the Works.

(c) Compliance with the Job Mix Formula

The S.O. final approval of the job mix formula shall bind the Contractor to produce asphaltic concrete mixes conforming to the precise gradation and bitumen content specified in the formula within the tolerances set forth in Table 4.3.6.

Modifications to the job mix formula shall only be made with the approval of the S.O. Should the S.O. at any time have reasons to believe that the asphaltic concrete mixes and methods of mixing and laying are different from those approved, he shall so advise the Contractor and instruct that asphaltic concrete works be discontinued pending proper mix design and plant trials.

TABLE 4.3.6: TOLERANCES FOR ASPHALTIC CONCRETE MIXES

Parameter	Permissible Variation % by Weight of Total Mix
Bitumen content	± 0.2 %
Fractions of combined aggregate passing 5.0 mm and larger sieves	± 5.0 %
Fractions of combined aggregate passing 3.35 mm and 1.18 mm sieves	± 4.0 %
Fractions of combined aggregate passing 425 um and 150 um sieves	± 3.0 %
Fractions of combined aggregate passing 75 um sieve	± 2.0 %

4.3.3.4 Equipment

The Contractor shall provide all the plant and equipment necessary for executing the work in accordance with this Specification and shall furnish the S.O. with such details of particular items of equipment, e.g. manufacturer, model type, capacity, weight, operating features, etc., as the S.O. shall require.

(a) Road Cleaning Equipment

Immediately prior to applying bituminous tack coat, the full width of the surface to be treated shall be swept using a power broom followed by a compressed air blower, and if necessary, scraped using hand tools, to remove all dirt, dust and other objectionable materials, all to the satisfaction of the S.O.

(b) Asphalt Mixing Plant

The asphalt plant shall be either a batch plant or a drum mix plant or a continuous mix plant of recognized manufacture and shall be approved by the S.O. It shall conform to the requirements deseribed hereunder.

The mixing plant shall have a capacity suited to the Works and sufficient to enable the paver to operate more or less continuously when paving at normal speeds at the required thicknesses. The plant shall be to designed as to enable consistent production of asphaltic concrete mixes within the tolerances prescribed in this Specification, all to the satisfaction of the S.O.

Mixes produced and delivered shall have actual tonnages of aggregates, filler and bitumen components recorded. The temperature of the mix leaving the plant shall be recorded for each batch or every 15 minutes. Where the control system incorporates a computer and a printer capable of printing the information, copies of the printouts shall be provided to the S.O. for quality assurance.

Tanks for storage of bitumen shall have a capacity suited to the proposed rate of utilizations of the material and the method and frequency of its delivery to the Works, all to the satisfaction of the S.O. The tanks shall be provided with means of measuring the volume of their contents at all times and of drawing off samples of the

contents. The bitumen feeding system shall provide for continuous circulation of hot binder through the system and back into the feed tank. The end of the return line discharging into the feed tank shall always be kept submerged in the bitumen in the tank in order to prevent oxidation of the returning hot binder. The storage tanks, and where necessary barred decanters, and all elements of the bitumen feeding system shall be equipped with heating system or insulating jackets as necessary to provide for effective and positive control of the temperature of the bitumen at all times up to the temperature required for utilizations. The method of heating shall be such that neither flames nor the products of combustion shall come into direct contact with the bitumen or the casing of its immediate container, and such that no portion of the bitumen shall be subject to overheating.

Calibration of the plant to an accuracy of $\pm$ 1% error must be carried out before the production of the trial mixes. This calibration is to test the integrity of all the weighing system of the storage bins and bitumen hopper.

Calibration is also required for the feeders to match the production capacity. Once the calibration is set and mixes production commence, calibration procedures shall be repeated every 30,000 tonnes or one month whichever is earlier.

i) Batch Plants

The plants shall be provided with accurate mechanical means for uniformly feeding the aggregate into the dryer so that uniform production and temperature of the heated aggregate will be obtained. A separate feed bin with an adjustable gate opening shall be provided for each aggregate to be included in the combined aggregate for the mix; normally four bins will be required. The feed bins and gates shall be constructed and equipped that they shall be readily accessible for calibrating at all times, and shall provide for a continuous and uniform flow of each aggregate required in the mix.

The plant shall have a rotary drum dryer of satisfactory design for drying and heating the combined aggregate so that its temperature will be at the required level at the time it is mixed with the bitumen. The burner shall be so designed that complete combustion of the fuel will be obtained, and the aggregate will remain clean and not become coated with soot or oil.

The plant shall be equipped with four (or more) screens, the smallest of which shall generally be not more than 3.2 mm. The screens shall have a normal capacity slightly in excess of the maximum output of the mixing plant. The screens shall be readily accessible for inspection.

The plant shall include four (or more) storage bins for screened aggregates, each with a capacity of not less than twice the pugmill dead load capacity. The bins shall be arranged so as to provide separate dry storage for each screened fraction of the aggregate. Each bin shall be provided with an overflow pipe of such size and location as to prevent any backing up of material into other bins. Each bin shall be so constructed that representative aggregate samples can be readily obtained, and shall have means for observing the aggregate level. Separate dry storage shall be provided for mineral filler, and the plant shall be satisfactorily equipped to feed filler into the mixer.

Accurate means of weighing by load cells shall be provided for weighing the aggregates and filler and also for weighing the bitumen required for each batch of mix.

Suitable means shall be provided for maintaining the prescribed temperature of the bitumen in the pipelines, weigh bucket of flow meter, and spray bars.

An armoured thermometer with a range of 30 °C to 200 °C shall be fitted in the bitumen feed line at a suitable location near the discharge valve at the mixer unit. Suitable dial-scale mercury actuated thermometer, electric pyrometers or other thermometer instruments shall be fitted at the discharge chute of the dryer and in each hot aggregate storage bin to indicate the temperature of the heated aggregate.

The plant shall be equipped with adequate and safe stairways to the mixing platform and sampling location and guarded ladders and cat-walks shall provide access to all other positions as necessary for proper operation, inspection and maintenance of the plant, all to the satisfaction of the SO. All gear, pulley, chains, sprockets and other dangerous moving parts shall be property guarded and proteeted. Ample and unobstructed space shall be provided on the mixing platform, and elear and unobstrueted passage shall be maintained at all times in and around the truck loading area, whieh shall, be kept free from drippings from the mixer.

Eaeh storage bin for screened aggregate shall be provided with a bottom outlet gate so constructed as to prevent leakage when elosed. These gates shall have a quiek and complete closing action. The plant shall be equipped with a weigh box or hopper for accurately weighing out aggregate from each of the screened aggregate storage bins. The weigh box or hopper shall be suspended from its scale's lever mechanism and shall be sufficiently large to holds a full batch equal to the pugmill capacity without hand raking of the aggregate. The discharge gate shall be so constructed as to allow rapid and complete emptying of the weigh box or hopper into the mixer, and prevent leakage when closed.

The plant shall be equipped with a binder weigh bucket which shall be charged through a fast acting non-dip valve in the binder feed pipe located directly over the bucket. The bucket shall be suspended from its scale's lever mechanism and shall have a capacity sufficient to weigh out binder up to 20% of the weight of the pugmill dead load capacity. The bucket shall have a discharge mechanism which shall provide for rapid and complete emptying of the bucket in a thin uniform sheet or multiple sprays over the full length and width of the mixer. The discharged shall not leak or drip when closed.

The batch mixer shall be a suitable twin-shaft pugmill, with a capacity of at least 500 kg of asphaltie concrete, capable of producing a thoroughly homogeneous mixture. The clearanee of the paddle blades from all fixed and moving parts of the mixer shall be not more than 20 mm. If the pugmill is not enclosed, it shall be equipped with a dust hood to prevent loss of fines from the mixture. The discharge gate shall be so constructed as to allow rapid and complete emptying of the mixer, and prevent leakage of any mix constituent when closed.

The mixer shall be equipped with an accurate time lock system for controlling the operations of a complete mixing cycle. It shall lock the aggregate weigh box or hopper gate after charging the mixer with aggregate, until the closing of the mixer gate at the completion of the mixing cycle; it shall lock the binder weigh bucket discharge mechanism during the dry mixing and wet mixing period. The dry mixing period is defined as the interval of time between the opening of the aggregate weigh box of hopper gate and the start of discharging the binder weigh bucket. The wet mixing period is defined as the interval of time between the start of discharging the binder weigh bucket and the opening of the mixer gate. The dry and wet mixing periods shall both be adjustable in increments of not more than 5 seconds from zero to not more than 60 seconds total for dry and wet mixing.

The filler silo shall have suitable a screw conveyor system to discharge into the pugmill.

The control system for the plant shall be housed in a weather proof cabin with windows to view the plant operations. Control in the cabin shall have the capability to accurately batch the aggregates, filler and bitumen for the mix, transfer to the pugmill mixer and control the mixing time. The temperature of the heated aggregates, filler and bitumen shall also be displayed in this cabin and adjusted to meet the Specification when required.

ii) Drum Mix Plants

The cold material feeder unit shall consist of not less than 5 bins with suitable heaped capacity appropriate for the plant. Each bin shall be equipped with a variable speed weighing belt feeder (driven by variable speed electric motor fitter with a tachometer) with a load cell for accurate weight measurement of each type of aggregate used in the mix in equivalent dry tonnes per hour. The cold feed system shall incorporate a device for moisture compensation capable of producing an accurate and continuous blend of the individual aggregate sizes from the cold feed compartment. The cold feed system shall also be equipped with a scalping screen of screed size of not more than 50mm to discard any oversized aggregates before entering the dryer drum.

The drum mixer shall have flight designs to accomplish the proper transfer of heat from the exhaust gases of the burner to the aggregates and to blend the aggregates and bitumen together adequately. The flight, at the upper end of the drum, shall be able to direct the aggregate into the drum beyond the tip of the flame, thereafter the subsequent flight shall be efficient to lift and tumble the aggregates with the cumulation of a veil of aggregates across the whole cross-sectional area near the mid-point of the length of drum where the aggregate temperature shall have been raised to dew point. This veil of aggregates shall be sufficiently complete and dense to maximise heat transfer and to screen the bitumen from the direct flame to minimise hardening and oxidation of the bitumen during the mixing process. The downstream mixing flight designs shall complete the heat transfer process and raise the mix temperature to the desired level for discharge. The length to diameter ratio of the drum shall be appropriately designed to obtain more complete heat transfer; to enable the bitumen to be injected in an inert atmosphere where proper coating/adhesion onto aggregates can take place without severe oxidation or hardening of bitumen and effective mixing and sufficient designed mix temperatures are achieved. The drum shall be inclined, oil-fired and suitably and sufficiently insulated.

The control system of a drum mixer shall be automatically computer controlled with a fully independent manual back-up system. The system shall be such that the operator is able to view the operation of the whole plant and of the individual component stations. All relevant information of the plant operation and the progress of the tonnage of mix tonnage produced and mix design information shall be made available. The control system shall possess a Quality Assurance package to act as an audit tool (when required to be used) whereby the information on Plant Monitor, Progress Monitor, and Mix Temperatures can be made available at pre-set, variable time intervals.

Freshly mixed material shall be collected and delivered to be stored in a surge silo through a proper conveyor system.

Note: Continuous Mix Plant' has been left out due to its uncommon use today.

(c) Tip-Truck

The Contractor shall provide a suitable number of tip-trucks of a type approved by the S.O. for transporting asphaltic concrete from the mixing plant to the paving sites. The trucks shall have trays with smooth, flat beds and sides, and shall have load capacities of not less than 5 tonnes. Prior to loading, the inside of each truck tray shall be lightly and evenly coated with a soap or detergent solution, or such other liquid as the S.O. shall approve, to prevent adhesion of the asphaltic concrete. The trucks shall be equipped with covers of canvas or other suitable material to protect the asphaltic concrete.

(d) Asphalt Paver

The asphalt paver shall be of recognized manufacture and shall be approved by the S.O. It shall conform to the requirements described hereunder.

The paver shall be self-propelled and capable of reverse as well as forward travel. It shall be equipped with a hopper at the front designed to receive the paving mix from tip-trucks, and shall have a mechanical distribution system for spreading the mix evenly and without segregation over the surface to be paved in front of a screeding and compacting unit which shall be equipped with a suitable heating device. The screeding and compacting mechanism shall be capable of confining the edges of the material being laid without the use of stationary side forms, shall be adjustable to strike off the mixture to the thickness and cross-section shape required, and shall be controlled by an automatic levelling device to produce an even carpet of bituminous mixture with a uniform surface texture free from indentations, ridges, tear marks or other irregularities. The paver shall be capable of laying the bituminous mixture in paving widths in the range 2.5 to 3.75 m and of finishing the pavement layer true to the required lines, grades, levels, dimensions and cross-sections, subject to compaction by rolling, all to the satisfaction of the S.O.

(e) Rollers

A pneumatic tyred roller and two steel wheeled tandem rollers shall be provided. However, a three wheeled steel roller may be substituted for one of the tandem rollers if the S.O. shall so approve. All rollers shall be of recognised manufacture and shall be approved by the S.O.

i) Pneumatic Tyred Roller

The pneumatic tyred roller shall be self-propelled and capable of being reversed without backlash; it shall be equipped with power steering and dual controls allowing operation from either the left or right side.

The roller shall have nine wheels equipped with smooth treaded tyres all of the same size and construction, and capable of operating at inflation pressures of up to 0.9 N/mm^2. Five wheels shall be on the driven axle and four on the steering axle, all equally spaced on both axles and arranged so that the tyres on the steering axle track midway between those on the driven axle with a small overlap. The roller shall be equipped with water tanks, sprinkler systems and pads of coconut matting to keep all tyres evenly wetted during operation.

The roller shall be equipped with means of adjusting its total weight by ballasting so that the load per wheel can be varied in the range 1.0 to 2.0 tonnes. In operation, the ballasted weight and the tyre inflation pressure shall be adjusted to meet the requirements of each particular operation. Each tyre shall be kept inflated at the specified pressure such that the pressure difference between any two tyres shall not exceed 0.04 N/mm^2. Means shall

be provided for checking and adjusting tyre pressures at all times at the place of the works.

The Contractor shall provide the S.O. with a calibration chart for the roller showing the relationship between the quantity or depth of ballast and total weight, and also a chart showing the relationship between wheel load, tyre inflation pressure and contact pressure.

ii) Steel Wheeled Tandem Roller

The steel wheeled tandem roller shall be self-propelled and capable of being reversed without backlash; they shall be equipped with power steering and dual controls allowing operation from either the left or right side. The roller shall be equipped with water tanks, sprinkler systems and scraper blades to keep all wheels evenly wetted and clean during operation.

Each steel wheeled tandem roller shall be ballasted so that its total operating weight is in the range 8 to 10 tonnes and its driven roll (or rolls) shall exert a rolling force of not less than 3.5 tonnes/metre of roll width. The Contractor shall provide the S.O. with a calibration chart for each roller showing the relationships between the quantity or depth of ballast and total weight and rolling force.

4.3.3.5 Construction Methods

(a) General Conditions

Asphaltic concrete paving work shall only be carried out in dry weather when the surface to be covered is clean and dry, and has received a bituminous tack coat which shall have achieved a satisfactory degree of tackiness, all to the satisfaction of the S.O. All laying, rolling and finishing works shall be carried out during daylight hours, unless the Contractor shall have provided suitable flood-lighting for the job site, to the satisfaction of the S.O.

The S.O. may order the discontinuation of work on account of adverse weather, unsatisfactory condition of materials, equipment or surface to be paved, or such other conditions as he or she shall consider detrimental to the work.

(b) Surface Preparation and Cleaning

Prior to constructing an asphaltic concrete pavement layer, the surface to be covered shall have been prepared in accordance with the appropriate Sections of this Specification. Notwithstanding any earlier approval of this surface, any damage to or deterioration of it shall be made good before asphaltic concrete paving work is commenced.

If the surface to be covered is to be provided with a bituminous tack coat, then this shall be applied all in accordance with the provisions of Sub-Section 4.3.2.

(c) Aggregate Handling and Heating

Each aggregate to be used in the asphaltic concrete mixes shall be stored in a separate stockpile near the mixing plant. Stockpiles of sand and other fine aggregates shall be kept dry using waterproof covers and other means as necessary. In placing the aggregates in the stockpiles and loading them into the mixing plant's cold aggregate feed bins, care shall be taken to prevent segregation or uncontrolled combination of materials of different gradation. Segregated or contaminated materials shall be rescreened or rejected for use in the Works and removed from the mixing plant site.

The aggregates shall be fed into the dryer at a uniform rate proportioned in accordance with the appropriate job mix formula. The rate of feed for each aggregate shall be maintained within 10% of the rate prescribed, and the total rate of feed shall be such that the plant's screens shall never be overloaded.

The aggregates shall be dried and heated so that when delivered to the mixer they shall be at a temperature in the range 150 °C to 170 °C.

Immediately after heating, the aggregates shall be screened into four (or more) fractions which shall be separately stored in the hot aggregate storage bins in readiness for mixing.

Mineral filler cum anti-stripping agent to be used in the mix shall be stored separately and kept completely dry. Its rate of feed into the plant shall be accurately controlled by weight or volumetric measurement, all to the satisfaction of the S.O.

(d) Heating of Bitumen

The bitumen shall be heated so that when delivered to the mixer it shall be at a temperature in the range 140 °C to 160 °C.

(e) Mixing Asphaltic Concrete

The mixing plant shall be so coordinated and operated as to consistently produce asphaltic concrete mixes within the tolerances prescribed in this Specification, all to the satisfaction of the S.O.

i) Mixing in Batch Plants

For each batch the screened hot aggregates shall be weighed out into the aggregate weigh hopper in accordance with the proportions prescribed in the appropriate job mix formula; the sequence of weighing out shall commence with the largest sized aggregate and progress down to the fines, unless the S.O. shall otherwise approve. Mineral filler shall be weighed out into the filler weigh hopper, where this is provided, or added last to the aggregate weigh hopper, in accordance with the job mix formula proportions.

The hot binder shall be weighed out into the binder weigh bucket in accordance with the proportions prescribed in the job mix formula.

The hot aggregates and filler shall be discharged into the pugmill and mixed dry for the dry mixing time prescribed in the job mix formula, which shall usually be in the range five to 10 seconds. The hot binder shall then be added and wet mixing performed for the wet mixing time prescribed in the job mix formula; this shall be sufficient so that all particles of aggregate are uniformly coated with bitumen, and shall usually be 45 seconds or less for dense graded mixtures.

The volume oblades just break out of the mixture at the height of their action.

After the completion of wet mixing, each batch of asphaltic concrete shall be discharged from the pugmill either into a storage hopper or directly into a truck for hauling to the paving site. Care shall be taken that no segregation of the mix occurs.

ii) Mixing in Drum Mix Plants

The screened hot aggregates and filler shall be fed continuously from their storage bins in accordance with the proportions prescribed in the appropriate

job mix formula, combined in the plant, and fed continuously into the mixer. The hot binder shall be sprayed on to the combined aggregate as it enters the pugmill at the rate required to achieve the bitumen content prescribed in the job mix formula. The materials shall then be carried through the pugmill and in the process be thoroughly mixed by the action of the paddles and discharged over the dam into the storage hopper. The mixing time shall be sufficient so that all particles of aggregate are uniformly coated with bitumen, and shall usually be 45 seconds or less for dense graded mixtures.

The plant shall be so adjusted as to maintain the level of mixture in the pugmill such that the tips of the paddle blades just break out of the mixture at the height of their action.

(f) Transportation of Asphaltic Concrete

Asphaltic concrete shall be transported from the mixing plant to the site of the paving works in loads of not less than 5 tonnes using tip-trucks as specified in Sub-Section 4.3.3.4 (c). Except where asphaltic concrete is to be hand laid, it shall be discharged directly into the paver hopper, as required, from the tip-trucks. Care shall be taken in the truck loading, hauling and unloading operations to prevent segregation of the mix. During transportation, the asphaltic concrete shall be protected from contamination by water, dust, dirt and other deleterious materials.

The temperature of asphaltic concrete immediately before unloading from the truck either into the paver hopper or on to the road for hand spreading shall be not less than 130 °C (increased by 10 °C for penetration grade 60-70 bitumen). Any load which has cooled below the specified temperature in the truck shall be rejected for use in the Works and removed from the Site of the Works.

(g) Laying Asphaltic Concrete

The sequence of laying operations shall be planned in advance by the Contractor and approved by the S.O. Generally each paving layer shall have a compacted thickness of not less than twice the nominal maximum aggregate size of the mixture, and not more than 100 mm. Where applicable, e.g. on superelevated sections and on carriageways with cross-slope in one direction only, laying shall commence along the lower side of the carriageway and progress to the higher side. Laying shall not be carried out in a downhill direction along any section of road.

As far as is practicable, laying shall be carried out using a paver approved by the S.O. Hand-casting of bituminous mix on to the machine finished surface shall be kept to the practicable minimum necessary for correcting blemishes and irregularities. In any areas inaccessible to the paver, laying shall be carried out by hand methods using rakes, lutes and other hand tools, all to the satisfaction of the S.O. All laying of bituminous mix shall be such that after compaction by rolling the specified course or layer thickness and surface profile shall be achieved. Care shall be taken to achieve a uniform surface texture free from indentations, ridges, tear marks or other irregularities, and to prevent segregation of the mix.

At the commencement of initial rolling the temperature of asphaltic concrete shall be not less than 120 °C (increased by 10 °C for penetration grade 60-70 bitumen). Material which has cooled below the specified temperature before laying shall not be used and shall be removed from the Site of the Works. The Contractor shall provide accurate thermometers at the paving site at all times, and shall check the temperature of asphaltic concrete in the paver hopper at regular intervals and before laying restarts after each interruption of the paving operation.

As far as is practicable, the paver shall be operated continuously and the supply of bituminous mix shall be regulated so as to enable continuous paving. Transverse

joints in a paving lane shall be kept to a practicable minimum, and intermittent stopping and restarting of the paver shall be avoided as far as is practicable.

Care shall be taken that no bituminous mix is placed on expansion joints at bridges, inspection covers for utilities ducts, drainage and sewerage manholes and the like, and that catchpits, drainage openings through kerbs, etc., remain properly open and serviceable. During laying operations, such areas and openings shall be protected by suitably shaped and secured boards or other materials approved by the S.O., and compaction of mix in the immediately surrounding or adjacent areas shall be completed by hand methods, all to the satisfaction of the S.O. Alternatively, bituminous mix shall be laid and compacted by hand methods as necessary around surfacing discontinuities of these types, all to the satisfaction of the S.O.

(h) Construction Joints

Existing bituminous surfacing which new bituminous mix is to adjoin shall be cut back to present a straight, vertical edge not less than 25 mm deep and a smooth transition section not less than 500 mm long against which to lay the new material. The specified thickness of the new surfacing shall be built up gradually from the vertical joint to avoid any bumps or ridges across the carriageway.

Where longitudinal or transverse joints are required in a layer of bituminous mix under construction, the material first laid and compacted shall be cut back to a vertical face for the full thickness of the layer on a line satisfactory to the S.O. before the adjacent area is paved.

At all construction joints, a thin uniform coating of bitumen emulsion of grade RS-1K shall be brushed on to the vertically cut joint faces some 10 to 15 minutes before laying the next section of bituminous mix commences to ensure good bonding. Also, all contact surfaces of kerbs, gutters, manholes, catchpits, etc. shall be similarly treated with a coating of bitumen emulsion before bituminous mix is placed against them.

Construction joints in a layer of bituminous mix shall be offset from those in any immediately underlying bituminous layer by at least 100 mm for longitudinal joints and at least 500 mm, for transverse joints.

Construction joints shall not be permitted along wheelpaths.

(i) Compaction of Asphaltic Concrete.

For each layer of asphaltic concrete, compaction by rolling shall commence as soon after laying as the material will support the rollers without undue displacement; nevertheless the temperature of asphaltic concrete at the commencement of rolling shall be not less than 120 °C (increased by 10 °C for penetration grade 60-70 bitumen). Rolling shall not be continued when the temperature of asphaltic concrete has decreased to 80 °C or lower.

In any areas inaccessible to the rollers, proper compaction shall be carried out using vibrating plate compactors, hand tampers or other suitable means, all to the satisfaction of the S.O.

Initial (or breakdown) rolling shall be carried out with an approved steel wheeled tandem roller or three wheeled steel roller. The principal heavy rolling shall be carried out with an approved pneumatic tyred roller immediately following the initial rolling; the pneumatic tyred roller shall be ballasted to an operating weight of not less than 15 tonnes and its tyre inflation pressure shall be not less than 0.7 N/mm^2. The final rolling shall be carried out with an approved steel wheeled tandem roller and shall serve to eliminate minor surface irregularities left by the pneumatic tyred roller.

All rollers shall operate in a longitudinal direction along the carriageway with their driven wheels towards the paver. Rolling shall generally commence at the lower edge of the paved width and progress uniformly to the higher edge, except that where there is a longitudinal construction joint at the higher edge, this shall be rolled first ahead of the normal pattern of rolling. Generally, successive roller passes shall overlap by half the width of the roller, and the points at which the roller is reversed shall be staggered. However, when operating on gradients in excess of 4%, the breakdown roller shall not pass over any previously unrolled mix when operating in the downhill direction.

In all cases, compaction shall be carried out in such a manner that each section receives equal compactive effort, all to the satisfaction of the S.O.

The steel wheeled rollers shall operate at speeds of not more than 5 km/h and the pneumatic tyred rollers shall operate at speeds of not more than 8 km/h. No roller or heavy vehicle shall be allowed to stand on newly laid bituminous mix before compaction has been completed and the material has thoroughly cooled and set. Rolling shall be carried out to achieve the appropriate requirement as shown in Table 4.3.7.

TABLE 4.3.7: REQUIREMENTS OF COMPACTED DENSITY FOR ASPHALTIC CONCRETE

Type of Pavement Layer	Required Compacted Density
Wearing course	98 - 100% Marshall density
Binder course	95 - 100% Marshall density

Care shall be taken to prevent over-compaction of asphaltic concrete.

Within 24 hours of laying and compacting the bituminous mix, the Contractor shall cut core samples of not less than 100 mm nominal diameter at locations selected by the S.O. The rate of sampling shall be one sample per 500 m^2 of mix laid, but not less than two samples for the work completed in each paving session. These core samples shall be used by the S.O. to determine the thickness of the compacted layer of mix and the compacted density of the material in accordance with either ASTM Test Method D 1188 or ASTM Test Method D 2726, whichever is applicable.

(j) Finished Asphaltic Concrete

Asphaltic concrete binder and wearing courses shall be finished in a neat and workmanlike manner; their widths shall be everywhere at least those specified or shown on the Drawings on both sides of the centre-line; the average thickness over any 100-metre length shall be not less than the required thickness, and the minimum thickness at any point shall be not less than the required thickness minus 5 mm.

The top surface of asphaltic concrete binder and wearing courses shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances specified in Sub-Section 4.5.

(k) Opening to Traffic

Asphaltic concrete shall not be opened to traffic until compaction has been completed and the material has thoroughly cooled and set in the opinion of the S.O. This will usually be not less than four hours after the commencement of rolling. Where it is necessary to allow earlier use of the finished surface to facilitate the movement of traffic, vehicles may be allowed to run on the work after rolling has been completed, provided that speeds are restricted to 30 km/h or less and sharp turning movements are prohibited.

4.4 SHOULDERS

4.4.1 Description

This work shall consist of furnishing, compacting and shaping earth, gravel or paved shoulder material on a prepared and accepted sub-base or subgrade, all in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O.

4.4.2 Materials

4.4.2.1 Paved Shoulders

The bituminous surfacing and underlying pavement courses shall be constructed as described in the appropriate Sections of this Specification.

4.4.2.2 Gravel Shoulders

Gravel shoulder material shall conform to the requirements for gravel surfacing material set forth in Sub-Section 4.1.3.

4.4.2.3 Earth Shoulders

Earth shoulder material shall be suitable material as described in Sub-Section 2.2.1.

4.4.3 Construction Methods

Shoulders shall be constructed in stages or in one operation as directed or approved by the S.O., but in no instance shall a shoulder be built up to a level higher than that part of the abutting carriageway structure which has been completed and accepted.

Prior to placing any shoulder material, the underlying sub-base or subgrade shall have been shaped and compacted in accordance with the provisions of Sub-Sections 4.1.2.3 and 2.2.7 respectively, and the abutting carriageway structure course or courses shall likewise have been shaped and compacted in accordance with the provisions of the appropriate Sub-Sections of this Specification. Notwithstanding any earlier approval of the underlying and abutting pavement courses, any damage to or deterioration of these underlying and abutting pavement courses shall be made good to the satisfaction of the S.O. before shoulder construction proceeds.

Shoulders shall be placed to the required width and thickness as shown on the Drawings or as directed by the S.O. in one layer or more, each layer not exceeding 200 mm compacted thickness at the point of maximum thickness. Where two or more layers are required, they shall be of approximately equal shape and thickness, and none shall be less than 100 mm compacted thickness at the point of maximum thickness.

Each layer of shoulder material shall be processed as necessary to bring its moisture content to a uniform level throughout the material suitable for compaction, and shall then be compacted using suitable compaction equipment approved by the S.O. to not less than 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5 kg rammer method). Compaction shall be carried out in a longitudinal direction along the shoulder and shall generally begin at the outer edge and progress uniformly towards the carriageway, except on super-elevated curves where rolling shall begin at lower edge and progress uniformly towards the higher edge. In all cases, compaction shall be carried out in such a manner that each section receives compactive effort appropriate to its thickness, all to the satisfaction of the S.O.

Throughout the placing, adjustment of moisture content and compaction of shoulder material, care shall be taken to maintain a uniform gradation of the material and prevent its separation into coarse and separate parts, all to the satisfaction of the S.O.

Where shown on the Drawings or directed by the S.O., earth shoulders shall be turfed in accordance with Sub-Section 2.2.8.2.

Shoulders shall be finished in a neat and workmanlike manner. The total width of carriageway and shoulder shall be everywhere at least that specified or shown on the Drawings on both sides of the centre-line. The top surface of each shoulder shall have the required shape, super-elevation, levels and grades, shall be everywhere within 10 mm of the required plane, and shall provide a flush joint with the carriageway surface and shall be uniformly free draining away from the carriageway, all to the satisfaction of the S.O.

4.5 HORIZONTAL ALIGNMENT, SURFACE LEVELS AND SURFACE REGULARITY OF PAVEMENT COURSES

4.5.1 Horizontal Alignment

The horizontal alignment shall be determined from the centre-line of the pavement surface shown on the Drawings. The edges of the pavement as constructed and all other parallel construction lines shall be correct within a tolerance of + 50 mm and minus 0 mm from the centre-line, except for kerbs, channel blocks and edge lines which shall be laid with a smooth alignment within a tolerance of + 25 mm and minus 0 mm from the centre-line.

4.5.2 Surface Levels of Pavement Courses

The design levels of pavement courses shall be calculated from the vertical profile, crossfall and pavement course thicknesses shown on the Drawings. The level of any point on the constructed surface of a pavement course shall be the design level subject to the appropriate tolerances given in Table 4.5.1.

TABLE 4.5.1: TOLERANCES IN SURFACE LEVELS OF PAVEMENT COURSES

Pavement Course	Tolerance
Wearing Course	± 5 mm
Binder Course	± 5 mm
Roadbase	+ 0 mm to - 20 mm
Sub-base	+ 10 mm to - 20 mm

The combination of permitted tolerances in the levels of different pavement courses shall not result in a pavement thickness less than that shown on the Drawings. Each pavement course shall have an average thickness not less than that shown on the Drawings.

4.5.3 Surface Regularity

4.5.3.1 Description

Riding quality on a road surface is positively correlated with roughness of the surface. Low roughness corresponds to good riding quality and vice versa. Roughness of a pavement surface is brought about by uneven settlement, short and long wave undulations, rutting, wide cracking and other surface defects such as potholes, delamination etc..

The International Roughness Index (IRI) is used internationally to measure the degree of roughness of a pavement surface. It is representative of the vertical motions induced in moving vehicles for the frequency bandwidth which affects both the response of the vehicle and the comfort perceived by the occupants

The IRI describes a scale of roughness which is zero for a true planar surface, increasing to about 6 m/km for moderately rough paved roads, 12 m/km for

extremely rough paved roads with potholes and patches, and up to about 20 m/km for extremely rough unpaved roads.

4.5.3.2 Measurement of IRI

The regularity of the completed pavement surface shall be measured before traffic is allowed on it and is measured in terms of its lane IRI. Lane IRI shall be measured using the ARRB Walking Profiler (WP) following the procedures as outlined in AUSTROADS PAT 01:2001 **(Appendix 1)**

Other types of equipment may be used to measure lane IRI provided that the output from the equipment correlate strongly with the output from WP ($R^2 > 0.95$).

4.5.3.3 Acceptance criteria

The Contractor shall make available lane IRI values for the whole road length as well as for each 100 meter section of the completed pavement surface.

The lane IRI measured for the whole road length and each 100 meter section shall be less than 2.0 m/km.

4.5.3.4 Rectification work for non-compliance

In case of non-compliance, the Contractor shall carry out rectification works on any part of the completed pavement surface so that the lane IRI values for the whole road length and for each 100 meter section are less than 2.0 m/km.

SPECIALTY MIX 1 - POROUS ASPHALT

POROUS ASPHALT

Porous asphalt is a special-purpose wearing course. It is produced using open-graded aggregate mixed with polymer modified binder and contains a relatively high air voids after compaction. The design and in-place air voids shall be in the range of 20 to 25 percent to ensure drainability.

It offers the following benefits;

i. Improved skid resistance at high speeds, especially during wet weather.
ii. Reduced hydroplaning effects.
iii. Reduced splash and spray.
iv. Reduced headlight reflection and glare on wet pavement surface.
v. Reduced rolling tyre noise levels.

Porous asphalt shall be laid on impermeable and relatively even bituminous surface with adequate cross fall. A minimum cross fall of a 2.5 percent is recommended. Existing cracks and depression shall be sealed and patched prior to application of porous asphalt.

A minimum thickness of 50 mm is essential to provide adequate drainage within the porous asphalt layer.

Porous asphalt shall be compacted using static steel wheel tandem roller only. Vibratory rollers are not permitted because they lead to excessive compaction and the possibility of aggregate crushing. Pneumatic tyre rollers are not permitted because they knead and close the surface, affection the drainability of porous asphalt. They also cause stripping of aggregates that stick to their tyres. Three wheel rollers are also not permitted because they leave roller marks that can be difficult to remove.

Porous asphalt shall not be laid in areas where;

i. The pavement structural strength is sub-standard.
ii. There is considerable traction due to sudden acceleration, braking and turning like at major junctions.
iii. There are tight radius curves, loops of radius less than 75 meters.
iv. The gradient exceeds 10 percent.
v. Excessive deposits of debris, oil and fuel may be experienced.
vi. Free drainage cannot be accommodated along the road shoulder.
vii. Length of roads less that 100 meters because of spray carry-over from adjacent surfacing.
viii. There is high flexibility like on bridges.
ix. Frequent excavation by statutory undertakers may occur.
x. Traffic level exceeds 4000 commercial vehicles per lane per day at opening.
xi. Slow moving traffic are expected as there is no beneficial reduction in spray or noise levels achieved at speeds below 40 km/h.

Porous asphalt is a non-structural layer. Therefore, it shall not be applied on pavement which are experiencing structural deficiency.

4.6 SPECIALTY MIX 1- POROUS ASPHALT

4.6.1 Description

This work shall consist of furnishing, placing, shaping and compacting porous asphalt as a wearing course on an existing, impermeable and accepted bituminous pavement course. This Specification shall be read in conjunction with Sub-Section 4.3.3 of the Standard Specification for Road Works of JKR (JKR/SPJ/2008). All requirements in the Sub-Section 4.3.3 shall apply unless stated otherwise in this Specification.

Porous asphalt is a special-purpose wearing course. It is produced using open-graded aggregate mixed with polymer-modified binders and contains a relatively high and interconnected air voids after compaction. It offers the following benefits;

i. Improved skid resistance at high speeds, especially during wet weather.

ii. Reduced hydroplaning effects.

iii. Reduced splash and spray.

iv. Reduced headlight reflection and glare on wet pavement surface.

v. Reduced rolling tyre noise levels.

4.6.2 Materials

4.6.2.1 Coarse Aggregate

Coarse aggregate shall be screened crushed hard rock, angular in shape and free from dust, clay, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The loss by abrasion and impact in the Los Angeles machine when tested in accordance with ASTM C 131 shall be not more than 25%.

ii. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 18%.

iii. The flakiness index when tested in accordance with MS 30 shall be not more than 25%.

iv. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

v. The polished stone value when tested in accordance with MS 30 shall be not less than 40.

Notwithstanding compliance with the aforementioned requirements, crushed or uncrushed limestone and gravel shall not be permitted.

4.6.2.2 Fine Aggregate

Fine aggregate shall be screened quarry fines. They shall be non-plastic and free from clay, loam, aggregations of material, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

ii. The fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.

iii. The Methylene Blue value when tested in accordance with Ohio Department of Transportation Standard Test Method shall be not more than 10 mg/g.

iv. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 20%.

v. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

4.6.2.3 Mineral Filler

Mineral filler shall be incorporated as part of the combined aggregate gradation. It shall be of finely divided mineral matter of hydrated lime (calcium hydroxide). At the time of mixing with bitumen, the hydrated lime shall be sufficiently dry to flow freely and shall be essentially free from agglomerations. Not less than 70% by weight shall pass the BS 75 μm sieve. If hydrated lime is not available, ordinary Portland cement shall be used as an alternative, subject to approval by the S.O. The amount of mineral filler to be added shall be not less than 2% by weight of the combined aggregates. However, the amount shall be limited to not more than 2% if hydrated lime is used.

4.6.2.4 Bituminous Binder

The bituminous binder for use with porous asphalt shall be of performance grade PG 76 or higher in compliance with AASHTO Standard M320-02.

(a) Polymer Modified Binder

The performance grade PG 76 or higher shall be achieved by incorporating an appropriate quantity of polymer additives to conventional bitumen which shall be penetration grade 70-100 conforming to MS 124. The polymer shall be non-carcinogenic. The Contractor shall submit material safety data sheet of the proposed polymer modified binder. The properties of the polymer modified binder (PMB) shall be as given in Table 4.6.1.

TABLE 4.6.1: PROPERTIES OF POLYMER MODIFIED BINDER

TEST	REQUIREMENT	TEST SPECIFICATION
PMB prior to Rolling Thin Film Oven Test (RTFOT)		
Viscosity, max. 3 Pa.s, test temperature °C	135 (see Note 1)	ASTM D 4402
Dynamic shear, G*/sin δ minimum 1.00 kPa, 10 rad/s, test temperature °C	76	AASHTO T 315
Penetration, 100 g, 5 s, 25 °C, 0.1 mm	Report (see Note 2)	ASTM D 5
Ring and ball softening point, minimum, °C	60	ASTM D 36
Flash point, minimum, °C	230	AASTHO T 48
Moisture sensitivity test, minimum, %	80	AASHTO T 283
Emission of toxic gases, maximum, mg/m^3	15	
PMB after RTFOT (AASHTO T 240 or ASTM D 2872)		
Mass loss, maximum, %	1.00	AASHTO T 240 or ASTM D 2872
Dynamic shear, G*/sin δ minimum 2.20 kPa, 10 rad/s, test temperature °C	76	AASHTO T 315

Notes:

1. The requirement may be waived at the discretion of the S.O. if the supplier warrants that the polymer modified binder can be adequately pumped and mixed at the temperatures that meet all applicable safety standards.

2. The penetration value will be taken as the reference for consistency check on the production.

(b) Determination of Mixing and Compaction Temperatures

A viscosity-temperature relationship shall be established, using suitable rheometer, for the modified bitumen. The temperatures to which the modified bitumen must be heated to produce a viscosity of 0.2 – 0.5 Pa.s shall be the mixing temperatures. The temperatures to which the modified bitumen must be heated to produce a viscosity of 5 – 30 Pa.s shall be the compaction temperatures.

(c) Storage of Polymer Modified Binder

The Contractor shall provide a polymer modified binder storage system capable of delivering modified bitumen to the asphalt mixing plant. The storage system should be located close to the asphalt mixing plant and it should include distribution and circulation pipes that are properly insulated to prevent rapid temperature drop.

The storage tank shall have suitable mechanical agitator and be connected through delivery pipes and back-circulation pipes. Suitable orifices shall be provided at

convenient points in the storage system for taking samples. Sampling shall be done in accordance with MS 539.

4.6.2.5 Bituminous Tack Coat

Tack coat shall be modified bitumen emulsion (eg. Neomed) or conventional bitumen emulsion of grade RS-3K (the latter shall comply with MS 161). Spraying shall be carried out using a suitable sprayer capable of providing uniform spray at a rate of 0.5 to 1.0 litre/m^2.

(a) Composition

The composition of tack coat material shall be as given in Table 4.6.2.

TABLE 4.6.2: COMPOSITION OF TACK COAT MATERIAL

Tack Coat	Water, % mass	Bitumen, % mass	Latex, % mass
RS-3K	35	65	0
Neomed or equivalent	35 – 41	60 – 65	2 – 4

(b) Properties

The properties of Neomed or equivalent modified bitumen emulsion shall comply with the requirements as given in Table 4.6.3.

TABLE 4.6.3: PROPERTIES OF MODIFIED BITUMEN EMULSION

Property	Requirement	Test Specification
Percentage retained on 850 µm sieve	max 10	ASTM D 244
Saybolt Furol viscosity at 50 °C	min 100, max 400	ASTM D 244
Penetration on residue at 25 °C, 100 g, 5 s, 0.01 mm	45 – 70	ASTM D 244 & ASTM D 5
Ring and ball softening point on residue, °C	45 – 60	ASTM D 244 & ASTM D 36

4.6.3 Gradation of Combined Aggregates

The gradation of the combined coarse and fine aggregates, together with at least 2% mineral filler, shall conform to the appropriate envelope as given in Table 4.6.4.

TABLE 4.6.4: GRADATION LIMITS OF COMBINED AGGREGATES

BS Sieve Size, mm	Percentage Passing, by weight	
	Grading A	Grading B
20.0	-	100
14.0	100	85 - 100
10.0	95 - 100	55 - 75
5.0	30 - 50	10 - 25
2.36	5 - 15	5 - 10
0.075	2 - 5	2 - 4

4.6.4 **Mix Design**

With high air voids and open-graded aggregates, high binder contents are essential to ensure mix integrity, increase resistance to oxidation and raveling, and improve durability. The quantity of binder shall be carefully balanced such that it is not deemed too excessive to cause binder drain-down during production, transport and laying, and neither it is deemed too little to adversely affect durability.

4.6.4.1 Laboratory Compacted Specimens

Porous asphalt mixes shall be compacted in the laboratory by using the Marshall method, in accordance with ASTM D 1559. The specimens shall then be used for further analysis as described hereof.

Because of the limited compactive effort applied in the field on porous asphalt mixes, the number of blows per face shall be 50.

4.6.4.2 Air Voids Requirements

The design and in-place air voids shall be in the range of 18 to 25 percent.

4.6.4.3 Binder Drain-Down Test

Binder drain-down test shall be carried out in accordance with the test method as specified in Appendix 1. A sample of porous asphalt shall be placed in an oven for 3 hours at an anticipated mix production temperature in a wire basket fabricated using standard 6.3 mm sieve cloth. Any binder drain-down from the asphalt shall be collected in a pan. The binder drain-down shall be not more than 0.3% by weight of the total mix.

4.6.4.4 Cantabro Test

Cantabro test shall be carried out in accordance with the procedure as given in **Appendix 2.** Three Marshall specimens shall be simultaneously subjected to 300 revolutions in the Los Angeles drum, minus the steel balls, at 25 °C. The average loss of mass shall be not more than 15%.

4.6.4.5 Determination of Design Binder Content

Using a selected design aggregate gradation that comply with Table 4.18, prepare nine laboratory mixes at each binder content in the range 4.0 – 6.0%, in increments of 0.5%.

For each binder content, conduct binder drain-down test on the first three laboratory mixes at the anticipated production temperature.

For each binder content, determine theoretical maximum specific gravity on the next three laboratory mixes in accordance with ASTM D 2041.

Use the remaining laboratory mixes to fabricate three Marshall specimens at each binder content. Apply 50 blows per side at the anticipated compaction temperature at site.

Determine the air voids of the Marshall specimens in accordance with ASTM D 3023.

Using the same Marshall specimens, conduct Cantabro test in accordance with the test method as given in Appendix 2.

The lower limit of the design binder content shall be determined in accordance with the following two criteria;

i. Average loss of mass in the Cantabro test shall be not more than 15%.

ii. Average air voids shall be not more than 25%.

The upper limit of the design binder content shall be determined in accordance with the following two criteria;

i. Average binder drain-down shall be not more than 0.3%.

ii. Average air voids shall be not less than 18%.

Note that the binder drain-down test shall be used to adjust the mixing temperature of porous asphalt and/or the viscosity of the binder.

Take the mean of the lower limit and upper limit of the design binder content as determined from the Cantabro test and binder drain down test respectively as the initial design binder content. Use this value to check for air voids and make adjustment where necessary such that the air voids is between 18% and 25% but the design binder content shall be within the lower limit and upper limit.

The binder content that meets all the above criteria shall be recommended as the design binder content.

The aggregate gradation selected and the design binder content recommended shall be proposed to the S.O. as the job mix formula.

4.6.4.6 Trial Lay

After having received the S.O.'s preliminary approval of the proposed job mix formula, the Contractor shall arrange to mix, lay and compact the porous asphalt mix. A minimum of 20 tons shall be placed in trial areas to demonstrate to the satisfaction of the S.O. that the mix is satisfactory and the mixing, laying and compacting equipment conforms to the requirement of this specification. The trial areas shall not be part of the Contract Works but shall be provided by the Contractor at his own expense. They shall be approved by the S.O.

As directed by the S.O., comprehensive sampling and testing of the porous asphalt mix shall be carried out to check for satisfactory compliance with the job mix formula and satisfactory degree of compaction. The observations and tests to be carried out shall be, but not restrieted to, as follows;

i. Check that the trial site is suitable.

ii. Record the type and weight of roller.

iii. Record the type of paver.

iv. Carry out the following tests on the mix specimen;
- Binder content and aggregate grading (ASTM D 2172/BS 598, ASTM C 136).
- Theoretical maximum specific gravity (ASTM D 2041).
- Preparation of Marshall specimens (ASTM D 1559).
- Bulk specific gravity of Marshall specimens (ASTM 3203).
- Caleulation of air voids (ASTM D 3203).

v. Record temperatures of mix on the tipper lorry, at plant and site.

vi. Record laying temperatures.

vii. Record laying thickness.

viii. Observe the surface texture of mix laid behind paver.

ix. Record rolling temperatures i.e. immediately before rolling starts.

x. Record rolling pattern.

xi. Observe the surface texture of eompacted mix.

xii. Take at least three core samples from each lorry load after the mix has sufficiently hardened.

xiii. Record compacted thickness, density and air voids of the core samples.

xiv Check drainability of the compacted surfaeing (refer to Sub-Section 4.6.6.5)

xv. Check at least one longitudinal joint to ensure that the joint is satisfactorily constructed.

4.6.4.7 Complianee with Job Mix Formula

The S.O.'s final approval of the job mix formula shall bind the Contractor to furnish the porous asphalt mix meeting the precise aggregate gradation and binder content specified in the formula within the tolerances set forth in Table 4.6.5.

TABLE 4.6.5: TOLERANCES FOR POROUS ASPHALT

Parameter	**Permissible Variation,** % by weight of total mix
Bitumen.	+/- 0.2%
Fractions of combined aggregate passing 5.00 mm and larger sieves.	+/- 5.0%
Fractions of combined aggregate passing 2.36 mm sieve.	+/- 4.0%
Fraction of combined aggregate passing 75 μm sieve.	+/- 2.0%

4.6.5 Sampling and Testing of Porous Asphalt

Frequency of sampling and testing shall be not less than that shown in Tables 4.6.6 and 4.6.7. Table 4.6.6 provides for two levels of minimum frequency. The reduced frequency may only be adopted if the test results consistently conform to the requirements. Where a non-conformance occurs in any test, the frequency of sampling and testing for that particular property shall be increased to the normal level until conforming results have been obtained on five consecutive lots.

TABLE 4.6.6: FREQUENCY OF SAMPLING AND TESTING OF POROUS ASPHALT

Test	Normal Minimum Frequency	Reduced Minimum Frequency
Aggregate gradation	One test per 300 tons of asphalt plant production.	One test per 500 tons asphalt plant production.
Binder content	One test per 300 tons of asphalt plant production.	One test per 500 tons of asphalt plant production.
Maximum specific gravity and air voids	One test per 300 tons of asphalt plant production.	One test per 500 tons of asphalt plant production.
Temperature	Each loaded truck.	Each loaded truck.

TABLE 4.6.7: FREQUENCY OF SAMPLING AND TESTING OF COMPONENT MATERIALS

Test	Minimum Frequency
Los Angeles abrasion	Monthly
Water absorption	Monthly
Flakiness index of coarse aggregate	Monthly
Magnesium sulfate soundness	Monthly
Polymer modified binder	Certification of each delivery

4.6.6 Construction Method

4.6.6.1 Pavement Preparation

Porous asphalt shall be laid only on structurally sound pavement with minimal cracks, ruts and depressions.

A strong, durable bond of porous asphalt to the underlying pavement surface is essential.

A thick tack coat is essential to ensure;

i. A good bonding of the relatively small surface area of contact of the open-graded porous asphalt to the underlying pavement surface.

ii. A good resistance to damage induced by residual moisture which may be trapped at the bottom of the porous asphalt layer.

iii. Effective sealing of cracks and other surface deficiencies which may be present in the existing pavement surface, thus providing an impervious underlying surface.

Porous asphalt shall not be used to restore poor road profile.

Existing pavement surface shall be regulated with dense continuously graded asphalt to remove depression which may trap and hold water under porous asphalt layer.

4.6.6.2 Laying

Porous asphalt shall be laid only on impermeable and plane pavement surface with adequate cross fall. A minimum cross fall of 2.5 percent is recommended.

Porous asphalt shall be laid by machine and compacted within three hours of mixing.

Laying shall commence on the low side of the carriageway.

A minimum thickness of 50 mm is essential to provide adequate drainage within the porous asphalt layer.

Hand casting shall be kept to minimum.

Porous asphalt shall not be laid directly over an existing concrete pavement because the difficulty in establishing an adequate bond. However, it shall be preceded with a layer of dense bituminous mix on the existing concrete pavement to assist bonding.

When the rehabilitation of a deteriorated concrete pavement includes bituminous mixes overlay, porous asphalt shall be used as the final wearing course.

Porous asphalt shall not be laid in areas where;

i. The pavement structural strength is sub-standard.

ii. There is considerable traction due to sudden acceleration, braking and turning like at major junctions.

iii. There are tight radius curves, loops of radii less than 75 meters.

iv. The gradient exceeds 10 percent.

v. Excessive deposits of debris, oil and fuel may be experienced.

vi. Free drainage cannot be aecommodated along the road shoulders.

vii. Length of roads less than 100 meters because of spray carry-over from adjacent surfacing.

viii. There is high flexibility like on bridges.

ix. Frequent excavations by statutory undertakers may occur.

x. Traffic levels exceed 4000 commercial vehicles per lane per day at opening.

xi. There is a 40 km/h speed limit because there is no beneficial reduction in spray or noise levels achieved at low speeds.

4.6.6.3 Compaction

Porous asphalt shall be compacted using static steel wheel tandem rollers only.

Vibratory rollers are not permitted because they lead to excessive compaction and the possibility of aggregate crushing.

Pneumatic tyre rollers are not permitted because they knead and close the surface, affecting the drainability of porous asphalt. They also cause stripping of aggregates that stick to their tyres.

Three wheel rollers are also not permitted because they leave roller marks that can be difficult to remove.

Compaction by rolling shall commence as soon after laying as the material will support the rollers without undue displacement; nevertheless the temperature of the porous asphalt at the commencement of rolling shall be not less than 110 °C.

In any areas inaccessible to the rollers, proper compaction shall be carried out using vibrating plate compactors, hand tampers or other suitable means, all to the satisfaction of the S.O.

The steel wheel tandem rollers shall operate in a longitudinal direction along the carriageway with their driven wheels towards the paver. Rolling shall generally commence at the lower edge of the paved width and progress uniformly to the higher edge, except that where there is a longitudinal construction joint at the higher edge, this shall be rolled first ahead of the normal pattern of rolling. Generally, successive roller passes shall overlap by half the width of the roller, and the points at which the roller is reversed shall be staggered. However, when operating on gradients in excess of 4%, the breakdown roller shall not pass over any previously unrolled mix when operating in the downhill direction.

In all cases, compaction shall be carried out in such a manner that each section receives equal compactive effort, all to the satisfaction of the S.O.

The rollers shall operate at speeds of not more than 5 km/h. No roller or heavy vehicle shall be allowed to stand on newly laid bituminous mix before compaction has been completed and the material has thoroughly cooled and set. Rolling pattern shall be in accordance with trial lay carried out earlier and shall give field density not less than 97% of the laboratory mix design density.

The porous asphalt layer shall be finished in a neat and workmanlike manner; their widths shall be everywhere at least those specified or shown on the Drawings on both sides of the centre-line; the average thickness over any 100-metre length shall be not less than the required thickness, and the minimum thickness at any point shall be not less than the required thickness minus 5 mm.

Care shall be taken to prevent over-compaction of porous asphalt.

Within 24 hours of laying and compacting the bituminous mix, the Contractor shall cut core samples of not less than 100 mm nominal diameter at locations selected by the S.O. The rate of sampling shall be one sample per 500 m^2 of mix laid, but not less than two samples for the work completed in each paving session. These core samples shall be used by the S.O. to determine the thickness of the compacted layer of mix and the compacted density of the material in accordance with either ASTM Test Method D 1188 or ASTM Test Method D 2726, whichever is applicable.

4.6.6.4 Joint Construction

The formation of all joints shall be made in such a manner as to ensure a continuous bond between old and new sections of the course. All joints shall present the same texture, density, and smoothness as other sections of the course

Cold longitudinal joints shall not be cut as the inherent rough texture of the mixture will readily provide good bonding along the joints. Cutting the joints may incur damages to the mixture along the joints as the aggregate gradation of mixture is of open-graded nature. Application of tack coat along the joints is deemed unnecessary as it may clog the voids along the joints and impede the flow of water across the joints.

4.6.6.5 Shaping Edges

While the surface is being compacted and finished, the Contractor shall carefully trim the outside edges of the pavement to the proper alignment.

Edges so formed shall be beveled while still hot and compacted.

4.6.6.6 Drainability

Being the principle benefit of porous asphalt, the drainability shall be sufficient to allow satisfactory drainage of rain water during heavy rainfall. The drainability of porous asphalt wearing course having a minimum thickness of 50 mm shall be not less than 10 litres/minute through a discharge area of 54 cm^2 immediately after construction.

4.6.6.7 Finished Porous Asphalt

Porous Asphalt wearing courses shall be finished in a neat and workmanlike manner; their widths shall be everywhere at least those specified or shown on the Drawings on both sides of the centre-line; the average thickness over any 100-metre length shall be not less than the required thickness, and the minimum thickness at any point shall be not less than the required thickness minus 5 mm.

The top surface of a wearing course shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances specified in Sub-Section 4.5.

The International Roughness Index (IRI) value of the finished wearing course surface shall be carried out as described in Sub-Section 4.5 and shall be not more than 2.0 m/km.

4.6.6.8 Opening to Traffic

Porous asphalt shall not be opened to traffic until compaction has been completed and the material has thoroughly cooled. This will usually be not less than 4 hours after the commencement of rolling.

SPECIALTY MIX 2 -
STONE MASTIC ASPHALT

STONE MASTIC ASPHALT (SMA)

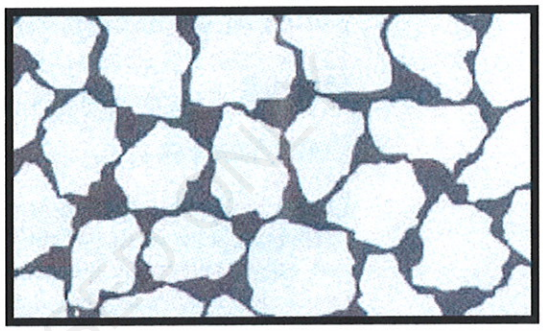
Stone Mastic Asphalt (SMA) originated in Germany in the 1970's to provide maximum resistance to rutting caused by the studded tyres on European roads. SMA is a dense, gap graded hot mix asphalt with a large proportion of coarse aggregate (>65%) and a rich bitumen filler mastic. SMA is characterized by its high coarse aggregate content which forms a stone skeleton structure. The voids of the structural matrix are filled with high viscosity bituminous mastic.

Typically, SMA mixes have polymer modified bitumen contents that range between 5.5 – 7.5%. The polymer modified bitumen may be further stabilised using cellulose fibres to prevent excessive binder draindown. Additionally, the presence of the fibres enhances the durability of the SMA mix by allowing the use of higher bitumen content.

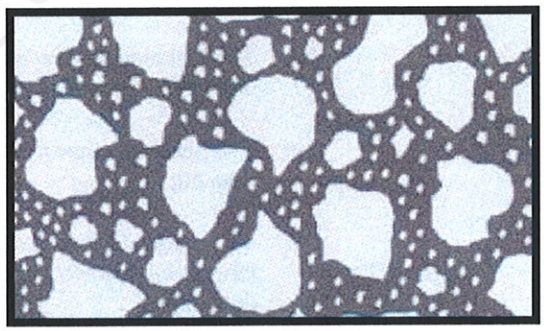
SMA is able to provide durable surfacing and exhibit high resistance to rutting due to heavy axle loads. This type of surfacing also offers improved texture depth, in the range of 0.7 – 1.0mm, thus providing good skid resistance.

This mix is recommended to be used in high stress areas such as climbing lanes or where excessive axle loads are expected.

SMA however does not provide permanent solution to diesel spillage problem. Due to its relatively high cost compared to the conventional asphalt, it should not be used indiscriminately.



Aggregate composition of SMA



Aggregate composition of dense graded asphalt

SPECIALTY MIX 2 - STONE MASTIC ASPHALT

4.7.1 Description

This work shall consist of furnishing, placing, shaping and compacting stone mastic asphalt as a wearing course. This specification shall be read in conjunction with the main Standard Specification for Road Works of JKR (JKR/SPJ/2008). All requirements in the JKR/SPJ/2008 shall apply unless stated otherwise in this specification.

Stone mastic asphalt or SMA is a polymer modified hot bituminous mixture with a large proportion of coarse aggregate and rich bitumen-filler mastic. Generally, SMA comprises approximately over 65% coarse aggregate and a minimum of 8% filler content as per Table 4.7.2. The coarse aggregate, through point to point contact, forms a high skeleton with good internal friction and aggregate interlock to resist load-induced shear. It provides durable surface that is resistant to cracking and rutting.

4.7.2 Materials

4.7.2.1 Coarse Aggregate

Coarse aggregate shall be screened crushed hard rock and retained on 5.0 mm sieve opening angular in shape and free from dust, clay, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The loss by abrasion and impact in the Los Angeles machine when tested in accordance with ASTM C 131 shall be not more than 25%,

ii. The flakiness index when tested in accordance with MS 30 shall be not more than 25%,

iii. The polished stone value when tested in accordance with MS 30 shall be not less than 40,

iv. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 18%,

v The water absorption when tested in accordance with MS 30 shall be not more than 2%.

Notwithstanding compliance with the aforementioned requirements, crushed or uncrushed limestone and gravel shall not be permitted.

4.7.2.2 Fine Aggregate

Fine aggregate shall be screened quarry fines. They shall be non-plastic and free from clay, loam, aggregations of material, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 20%.

ii. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

iii. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

iv. The fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.

v. The Methylene Blue value when tested in accordance with Ohio Department of Transportation; Standard Test Method shall be not more than 10m mg/g.

4.7.2.3 Mineral Filler

Mineral filler shall be added as part of the combined aggregate gradation. Limestone dust, hydrated lime or ordinary portland cement shall be used as filler. The material shall pass 75 μm sieve by not less than 70% by weight. The amount of filler to be added shall be not less than 8% by weight of the combined aggregates, where if cement is used it shall not exceed 2% by weigh of the combined aggregates.

4.7.2.4 Bituminous Binder

The bituminous binder for use with Stone Mastic Asphalt shall be of performance grade PG76 or higher in compliance with AASHTO Standard M320-02.

(a) Polymer-Modified Binder

The performance grade PG76 or higher shall be achieved by incorporating an appropriate quantity of polymer additives to conventional bitumen which shall be penetration grade 80/100 conforming to M.S.124. The polymer shall be non- carcinogenic. The contractor shall submit Material Safety Data Sheet on the proposed PMB. The properties of the polymer modified binder shall be as given in Table 4.7.1.

(b) Determination of Mixing and Compaction Temperature

A viscosity-temperature relationship shall be established, using suitable rheometer, for the polymer modified binder. The temperatures to which the polymer modified binder must be heated to produce a viscosity of 0.2 – 0.5 Pa.s shall be the mixing temperatures. The temperatures to which the polymer modified binder must be heated to produce a viscosity of 5 – 30 Pa.s shall be the compacting temperatures.

(c) Storage of Polymer Modified Binder (PMB)

The Contractor shall provide a PMB storage system capable of delivering modified bitumen to the asphalt mixing plant. The storage system should be located close to the asphalt mixing plant and it should include distribution and circulation pipes that are properly insulated to prevent rapid temperature drop.

The storage tank shall have suitable mechanical agitator and be connected through delivery pipes and back-circulation pipes. Suitable orifices shall be provided at convenient points in the storage system for taking samples. Sampling shall be done in accordance with MS 539.

TABLE 4.7.1: PROPERTIES OF POLYMER-MODIFIED BINDER

TESTS	REQUIREMENT	TEST SPECIFICATION
PMB prior to Rolling Thin Film Oven test		
Viscosity, max. 3 Pa.s, test temperature C.	135 (see Note 1)	ASTM D 4402
Dynamic shear, G/sin δ min. 1.00 kPa, 10 rad/s, test temperature C.	76	AASHTO T 315
Penetration, 100 g, 5 s, 25 C, 0.1 mm.	Report (see Note 2)	ASTM D 5
Ring and Ball softening point, min. C.	60	ASTM D 36
Flash Point, min °C	230	AASTHO T 48
Moisture sensitivity test, greater than (%)	80	AASHTO T283
PMB after Rolling Thin Film Oven test (AASHTO T 240) or ASTM D 2872		
Mass loss, max %.	1.00	AASHTO T 240 or ASTM D 2872
Dynamic shear, G/sin δ min. 2.20 kPa, 10 rad/s, test temperature C.	76	AASHTO T 315

Notes:

1. The requirement may be waived at the discretion of the S.O. if the supplier warrants that the polymer-modified binder can be adequately pumped and mixed at the temperatures that meet all applicable safety standards.

2. The penetration value will be taken as the reference for consistency check on the production.

(d) Resistance to Fuel Spillage

The polymer modified bitumen shall be tested for its resistance to fuel spillage. Three Marshall specimens shall be fabricated at optimum binder content and kept immersed in Octane-97 petrol for 24hours. The average loss of weight before and after the immersion shall not be more than 4%, based on an average of 3 tests.

4.7.2.5 Stabilising Agent

The PMB serves both as property enhancer and stabilising agent. However, other stabilizers, in the form of organic loose cellulose fibre or bitumen pre-coated pelletized cellulose fiber, may also serve as stabilizing agent and incorporated into SMA mix to prevent undue draining during transportation and bleeding during its service life. Dosage rates for organic stabilising agent is 0.3% by weight of the total mix. Allowable tolerances of fibre dosage shall be ± 10% of the required fiber weight. The selected loose cellulose fibres should meet the properties described in Table 4.7.2 while the properties of bitumen pre-coated pelletized cellulose fibre shall meet the properties described Table 4.7.3.

TABLE 4.7.2: PROPERTIES OF CELLULOSE FIBER

MESH SCREEN ANALYSIS	
Fiber Length	6 mm (0.25") (Maximum)
Passing 850 µm (No. 20) ASTM sieve	85% (± 10%)
Passing 425 µm (No. 40) ASTM sieve	65% (± 10%)
Passing 106 µm (No. 140) ASTM sieve	30% (± 10%)
OTHER PROPERTIES	
Ash content	10% (± 5%) non – volatiles
pH	7.5 (± 1.0)
Oil Absorption, %	5.0 (± 1.0)
Moisture content	< 5% (by weight)

Notes:

1. Mesh Screen Analysis
   This test is performed using standard 850, 425, 106 µm (No. 20, 40, 140) sieves, nylon brushed and a shaker. A representative 10 gram sample of fiber is sieved, using a shaker and two nylon brushes on each screen. The amount retained on each sieve is weighed and the percentage passing calculated. Repeatability of this method is suspect and needs to be verified.

2. Ash Content
   A representative 2 - 3 gram sample of fiber is placed in a tarred crucible and heated between 595° C (1100° and 1200° F) for not less than two hours. The crucible and ash are cooled in a desiccator and reweighed.

3. pH Test
   Five grains of fiber is added to 100 ml of distilled water, stirred and let sit for 30 minutes. The pH is determined with a probe calibrated with pH 7.0 buffer.

4. Oil Absorption Test
   Five grams of fiber is accurately weighed and suspended in an excess of mineral spirits for not less than five minutes to ensure total saturation. It is then placed in a screen mesh strainer (approximately 0.5 square millimeter hole size) and shaken on a wrist action shaker for ten minutes (approximately 1 - 1/4 motion at 240 shakes/minute). The shake mass is then transferred without touching, to a tarred container and weighed. Results are reported as the amount (number of times its own weight) the fibers are able to absorb.

5. Moisture Content
   Ten grams of fiber is weighed and placed in 121° C (250 ° F) forced air oven for two hours. The sample is then reweighed immediately upon removal from the oven.

TABLE 4.7.3 : PROPERTIES OF BITUMEN PRECOATED PELLETIZED CELLULOSE FIBRE

Properties	Requirement
Bulk density (g/L)	470 – 540
Fine material, vibration sieve (%) < 3500 µm	Max.5
Abrasion, vibration sieve (%) <3500 µm	Max. 6
Fiber content after extraction (%)	85-90

Notes:

1. Bulk density
   A standard 1000ml measuring cup is used. Without any pressure the sample is filled smoothly to the top of measuring cup. The filled measuring cup is then weighed. The bulk density is calculated by weight of filled measuring cup over weight of empty measuring cup.

2. Fine material.
   A 100g of sample is weighed and placed into a 3.55mm sieve. The sieve is then vibrated by using vibrating sieve machine for 2 min @ amplitude 2. Fine material is determined by weighing the residue after sieve in percentage.

3. Abrasion test
   A 100g of sample is weighed and placed into a standard abrasion tester and strain it for 6 seconds. After strained, the sample is discharged and placed into a 3.55mm sieve. The sieve is then vibrated by using vibrating sieve machine for 2 min@amplitude 2. Abrasion value is determined by weighing the residue after sieve in percentage.

4. Fibre content after extraction.
   A 6-10g of sample is weighed and placed into a glass fiber or pure cellulose extraction thimble. The timble with sample is then placed vertically in an extractor. Naphta or toluene extracting agent is used and extraction is continued until the extracting agent become colorless. The thimble is taken out and dried in an oven at 105 ^{0}C for minimum 2 hrs. Let the thimble cooled down to room temperature in a dessicator and weighed. Fiber content after extraction is calculated by weight of dried thimble minus weight of empty thimble and divide by of sample.

4.7.2.6 Bituminous Tack Coat

A thin tack coat of asphalt emulsion RS-1K of similar material conforming to MS 161 shall be applied to ensured uniform and complete adhere of the overlay.

4.7.3 Gradation Of Combined Aggregate

The gradation of the combined coarse aggregate, fine aggregate and mineral filler shall conform to the appropriate envelope as given in Table 4.7.4.

TABLE 4.7.4 : GRADATION LIMITS OF COMBINED AGGREGATES

ASTM Sieve	Percentage by weight Passing Sieve	
	SMA14	SMA 20
Sieve size (mm)		
19.0	100	100
12.5	100	85 – 95
9.5	72 - 83	65 – 75
4.75	25 - 38	20 – 28
2.36	16 - 24	16 – 24
0.600	12 - 16	12 – 16
0.300	12 - 15	12 – 15
0.075	8 - 10	8 – 10

4.7.4 Mix Design

4.7.4.1 Laboratory Compacted Specimen

The Contractor shall propose a job mix formulae required in the Works. In order to obtain optimum quality of the mixtures, the job mix formulae for the mix shall be prepared on the basis of testing several laboratory design mix gradations within the limits set in Table 4.74 at an appropriate range of bitumen content. As a guide, the design bitumen content will usually be in the range of 5 – 7%.

Each combination of laboratory design mix aggregate gradation and bitumen content shall be subject to the Marshall test procedure and volumetric analysis as follows;

i. Preparation of laboratory specimens for the standard stability and flow test in accordance with ASTM D 1559 using 50 blows/face compaction standard,

ii. Determination of the bulk specific gravity of the specimens in accordance with ASTM D 2726,

iii. Determination of the stability and flow values in accordance with ASTM D 1559,

iv. Analysis of the specific gravity and air voids parameters to determine the percentage air voids in the compacted aggregate, the percentage air voids in the compacted aggregate filled with bitumen and the percentage air voids in the compacted mix.

For the proposed design mix gradation, four specimens shall be prepared for each bitumen content within the range of 5 – 7% (see Note 1) at increments of 0.5 percent, in accordance with ASTM D 1559 using 50 blows/face compaction standard. All bitumen content shall be in percentage by weight of the total mix.

As soon as the freshly compacted specimens have cooled to room temperature, the bulk specific gravity of each test specimen shall be determined in accordance with ASTM D 2726.

The stability and flow value of each test specimen shall then be determined in accordance with ASTM D 1559.

After the completion of the stability and flow test, specific gravity and voids analysis shall be carried out for each test specimen to determine the percentage air voids in mineral aggregate (VMA) and the percentage air voids in the compacted mix (VIM).

Values which are obviously erratic shall be discarded before averaging. Where two or more specimens in any group of four are so rejected, four more specimens shall be prepared and tested.

The average values of bulk specific gravity, stability, flow, VFB and VMA obtained above shall be plotted separately against the bitumen content and a smooth curve drawn through the plotted values.

The mean optimum bitumen content shall be determined by averaging four optimum bitumen contents so determined as follows;

i. Peak of curve taken from the stability graph (see Note 2),

ii. Flow equals to 3 mm from the flow graph,

iii. Peak of curve taken from the bulk specific gravity graph (see Note 3),

iv. VIM equals to 3.5% from the VIM graph.

The individual test values (Stability, Flow, VMA and VIM) at the mean optimum bitumen content shall then be read from the plotted smooth curves and shall comply with the design parameters given in Table 4.7.5

If all the values comply with Table 4.7.5, the mixture with the mean optimum bitumen content shall be used in plant trials.

If any of the values does not comply with Table 4.7.5 the mix design procedure shall be repeated using a different laboratory design mix aggregate gradation until all design parameters are satisfied.

Note:

1. The range of bitumen content shall be extended if necessary to ensure that the curves of stability and bulk specific gravity have their peak within the range selected.

2. Where the stability curve exhibits more than one peak, the bitumen content chosen for the determination of the mean optimum bitumen content shall be the one which satisfies the voids requirements better. It is sometimes necessary, where no peak stability is obtained, to prepare and test supplementary specimens at of 0.25% bitumen content on either side of the expected optimum.

3. With highly absorptive aggregate, some difficulty in determining peak bulk specific gravity may occur. In such cases, the bitumen content at which the increase in bulk specific gravity shows a marked falling off shall be adopted.

TABLE 4.7.5 SMA MIX REQUIREMENTS

VIM (MS-2)	3 – 5%
VMA (MS-2)	Min 17% .
Stability	Min 6200 N
Flow	2 – 4 mm
Draindown (Appendix 4)	Max 0.3%

4.7.4.2 Binder drain-down Test

Binder drain-down test shall be conducted on three laboratory mix at the mean optimum binder content to ascertain that the binder draining property of the mix is satisfactory.

Binder drain-down test shall be carried out in accordance with procedures in Appendix 4. The samples shall be placed in an oven for 3 hour at an anticipated mix production temperature in a wire basket fabricated using standard 6.3 mm sieve cloth. Any binder drain down from the asphalt shall be collected in a pan. The binder drain-down shall be not more than 0.3% by weight of the total mix. **(See Appendix 4).**

If the average binder drain-down exceeds 0.3%, the mix design procedure shall be repeated using a different laboratory design mix aggregate gradation until all design parameters are satisfied. Alternatively, stabilizing agents shall be added to reduce binder drainage.

4.7.4.3 Determination of Optimum Binder Content

The binder content that meet the criteria in Table 4.7.5 and satisfy the binder drain-down test requirement shall be selected as the optimum binder content. The aggregate gradation selected and the optimum binder content determined shall be proposed to the S.O. as the Job Mix Formulae.

4.7.4.4 Trial Lay

After having received the S.O.'s preliminary approval of the proposed job mix formulae, the Contractor shall arrange to mix, lay and compact the stone mastic asphalt mix. A minimum of 20 tons shall be placed in trial areas to demonstrate to the satisfaction of the S.O. that the mix is satisfactory and the mixing, laying and compacting equipment

conforms to the requirement of this specification. The trial areas shall not be part of the Contract Works but shall be provided by the Contractor at his own expense. They shall be approved by the S.O.

As directed by the S.O., comprehensive sampling and testing of the stone mastic asphalt mix shall be carried out to check for satisfactory compliance with the job mix formulae and satisfactory degree of compaction. The observations and tests to be carried out shall be, but not restricted to, as follows;

i. Check that the trial site is suitable.

ii. Record the type and weight of rollers.

iii. Record the type of paver.

iv. Carry out the following tests on the loose mix specimen;
- Binder content and aggregate grading (ASTM D 2172/BS 598, ASTM C 136)
- Theoretical maximum specific gravity (ASTM D 2041).
- Preparation of Marshall specimens (ASTM D 1559).
- Bulk specific gravity of Marshall specimens (ASTM 3203)
- Calculation of air voids (ASTM 3203).

v. Record temperatures of mix on the tipper lorry, at plant and site.

vi. Record laying temperatures.

vii. Record laying thickness.

viii. Observe the surface texture of mix laid behind paver.

ix. Record rolling temperatures i.e. immediately before rolling starts.

x. Record rolling pattern.

xi. Observe the surface texture of compacted mix.

xii. For each lorry load, take at least three core samples after the mix has been laid, compacted and sufficiently hardened.

xiii. Record compacted thickness, density and air voids of the core samples.

xiv. Check at least one longitudinal joint to ensure that the joint is satisfactorily constructed.

4.7.4.5 Compliance with Job Mix Formulae

The S.O.'s final approval of the job mix formulae shall bind the Contractor to furnish the Stone Mastic Asphalt meeting the precise aggregate gradation and binder content specified in the formulae within the tolerances set forth in Table 4.7.6

TABLE 4.7.6: TOLERANCES FOR STONE MASTIC ASPHALT

Parameter	Permissible Variation, % by weight of total mix
Bitumen	+/- 0.3%
Fractions of combined aggregate passing 5.00 mm and larger sieves.	+/- 5.0%
Fractions of combined aggregate passing 2.36 mm sieve.	+/- 4.0%
Fraction of combined aggregate passing 75 µm sieve.	+/- 2.0%

4.7.5 Equipment

4.7.5.1 SMA Mixing Plant

Plants used for the preparation of the SMA mixture shall conform to AASHTO M 156 and the following;

(a) Handling Mineral Filler

Adequate dry storage shall be provided for the mineral filler and provisions shall be made for proportioning the filler into the mixture uniformly and in the desired quantities. Mineral filler in a batch plant will be added directly into the mixture uniformly and in the desired quantities. Mineral filler in a batch plant will be added directly into the weigh hopper. In a drum plant mineral filler will be added directly into the drum mixer. Special attention is directed to providing appropriate equipment for accurately proportioning the relative large amounts of mineral filler required for an SMA mixture.

(b) Fiber Addition

Adequate dry storage shall be provided for the fiber additive, and provisions shall be made for proportioning fiber into the mixture uniformly and in the desired quantities.

Mixing in Batch Plant Fiber shall be added through a separate inlet directly into the weigh hopper the puginill. The addition of fiber should be timed to occur during the hot aggregate charging the hopper. Adequate dry mixing time is required to ensure proper blending of the aggregate and fiber stabiliser. Dry mixing time shall be increased 5 to 15 second. Wet mixing time shall be increased at least 5 seconds for cellulose fibers and up to 5 seconds for mineral fibers to ensure adequate blending with the PMA.

Mixing inDrum Mix Plant In a drum mix plant fiber shall be added into the drum mixer to ensure complete blending of the fiber into the mix. For this purpose, when adding loose fiber a separate fiber feeding system shall be utilised that can accurately and uniformly introduce fiber into the drum at such a rate as not to limit the normal production of mix through the drum. At no time shall there be any evidence of fiber in the baghouse or returned/wasted baghouse fines.

(c) Hot-Mixture Storage

When the hot mixture is not to be hauled immediately to the project and placed, suitable bins shall be provided. Such bins shall be either surge bins to balance production capacity with hauling and placing capacity or storage bins which are heated and insulated and which have a controlled atmosphere around the mixture. The holding time shall be within limitations imposed by the S.O., based on laboratory tests of the stored mixture. In no case will SMA mixture be kept in storage overnight or for the next days paving.

4.7.5.2 Hauling Equipment

Hauling equipment should be of a type normally used for the transport of dense grade asphalt hot mix. Truck beds shall be covered and insulated if necessary, so that the mixture may be delivered on the road at the specified temperature.

4.7.5.3 Pavers

Pavers shall be of a type normally used for the placement of asphaltic concrete. They shall be self-contained, power-propelled units provided with an adjustable activated screed, heated and capable of spreading and finishing courses of asphalt plant mix material in lane widths applicable to the specified typical section and thickness shown on the plans.

The paver shall be capable of being operated at forward speeds consistent with satisfactory placement and compaction of the mixture. The paver shall be capable of striking a smooth finish of uniform texture.

4.7.6 Construction Method

4.7.6.1 Surface Preparation

i. Immediately before placing the SMA mixture, the surface shall be cleaned of loose or deleterious material by brooming or other approved means.

ii. A thin tack coat of asphalt emulsion RS-1K or similar material conforming to (JKR/SPJ/2008) shall be applied to ensure uniform and complete adhere of the overlay.

iii. Where the existing surface is distorted, a leveling course of Hot Mix Asphalt shall be required to restore proper cross-section prior to construction of the overlay.

4.7.6.2 Weather Limitations

The SMA mixture shall be placed on a dry clean surface when the atmospheric temperature in the shade and of the roadbed is above 25°C and rising and the mix conforms to the applicable requirements shown under "Laying".

4.7.6.3 Control Of Asphalt Mixture

The SMA mixture furnished by the Contractor shall conform to the job-mix formulae, within the allowable deviations as shown in Table 4.7.6.

4.7.6.4 Laying

The mixture when delivered to the paver shall have a temperature of around 150° C. The mixture temperature shall be measured in the truck just prior to dumping into the spreader.

The mixture shall be spread and struck off to the established grade and elevation with asphalt layers. Placing speed will be adjusted so that sufficient time is allowed for compaction operations and to provide continuity.

4.7.6.5 Compaction

Immediately after the mixture has been spread and struck off, it shall be thoroughly and uniformly compacted by rolling.

i. Due to the nature of SMA mixture the surface shall be rolled immediately. Rolling shall be accomplished with steel wheel rollers of a minimum weight of 8 tonnes. Pneumatic tire rollers and vibratory rollers shall not be used on SMA. Rolling procedures should be adjusted to provide the specified pavement density. Rollers shall move at a uniform spec not to exceed 5 km/h with the drive roller nearest the paver. Rolling shall be continued until all roller marks are eliminated and the minimum density has been obtained but not after the mat has cooled to 116° C or lower. The Contractor shall monitor density during the compaction process by use of density gauges to assure that the minimum required compaction is being obtained.

ii. To prevent adhesion of the mixture to the rollers, it shall be necessary to keep the wheels properly moistened with water mixed very small quantities of detergent or other approved material.

iii. The pavement should be compacted to at least 94% of maximum theoretical density.

iv. Once sufficient in place density has been achieved rolling operations should cease as over rolling may cause migration of PMA and filler to the compacted pavement surface.

4.7.6.6 Finished Stone Mastic Asphalt

Stone Mastic Asphalt wearing courses shall be finished in a neat and workmanlike manner; their widths shall be everywhere at least those specified or shown on the Drawings on both sides of the centre-line; the average thickness over any 100-metre length shall be not less than the required thickness, and the minimum thickness at any point shall be not less than the required thickness minus 5 mm.

The top surface of a wearing course shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances specified in Sub-Section 4.5.

The International Roughness Index (IRI) value of the finished wearing course surface shall be carried out as described in Sub-Section 4.5 and shall be not more than 2.0 m/km.

4.7.6.7 Opening To Traffic

Traffic should not be placed on the newly compacted surface until the mat has cooled to 60°C or lower.

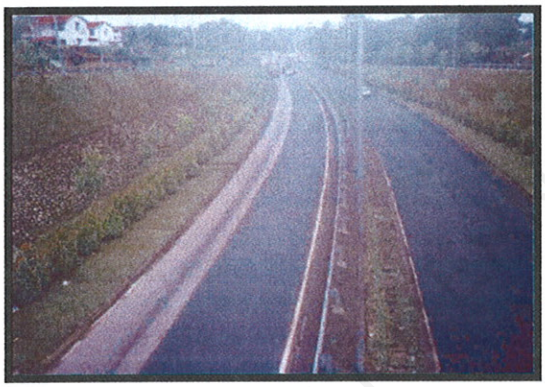
SPECIALTY MIX 3 -
GAP GRADED ASPHALT

GAP GRADED ASPHALT

Gap Graded Polymer Asphalt is used by many developed countries. It is a wearing course containing polymer modified bitumen and made up of 100 percent crushed aggregates. Essentially, the Gap Graded aggregate gradation skip a number of sieve sizes resulting in better stone to stone contact that enhance mechanical interlocking and increase mix stiffness. The stiff polymer modified bitumen improves mix stability at high bitumen content.

This polymer modified wearing course is used to increase durability, strength and safety aspects of the riding surface in dry or wet driving. The mix is suitable to solve cracking and deformation problem high skid resistance standard. It offers high texture in the range of 0.8-1.2mm.

The mix is recommended to be used in highly stressed areas such as climbing lanes or where there is a high volume of heavy vehicles. It is also suitable to be laid on roads that require high skid resistance. Gap graded asphalt however does not provide permanent solution to diesel spillage problem. Due to its higher cost compared to the conventional asphalt, its use should be limited to high volume roads only. When used on roads with sharp corners, ravelling may develop after some time.



4.8 SPECIALTY MIX 3 - GAP GRADED ASPHALT

4.8.1 Description

This work shall consist of furnishing, placing, shaping and compacting gap graded asphalt as a wearing course on an existing, impermeable and accepted bituminous pavement course. This Specification shall be read in conjunction with Sub-Section 4.3.3 of the main Standard Specification for Road Works of JKR (JKR/SPJ/2008). All requirements in the Sub-Section 4.3.3 shall apply unless stated otherwise in this Specification.

The gap graded asphalt is a wearing course containing polymer modified bitumen and made up of 100 percent crushed aggregates. This modified wearing course is used to increase durability, strength and safety aspects of the riding surface in dry or wet driving conditions.

4.8.2 Materials

4.8.2.1 Coarse Aggregate

Coarse aggregate shall be screened crushed hard rock, retained on 5.0 mm sieve, angular in shape and free from dust, clay, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The loss by abrasion and impact in the Los Angeles machine when tested in accordance with ASTM C 131 shall be not more than 25%.

ii. The flakiness index when tested in accordance with MS 30 shall be not more than 25%.

iii. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 18%.

iv. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

v. The polished stone value when tested in accordance with MS 30 shall be not less than 40.

Notwithstanding compliance with the aforementioned requirements, crushed or uncrushed limestone and gravel shall not be permitted.

4.8.2.2 Fine Aggregate

Fine aggregate shall be screened quarry fines. They shall be non-plastic and free from clay, loam, aggregations of material, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

ii. The fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.

iii. The Methylene Blue value when tested in accordance with Ohio Department Of Transportation; Standard Test Method shall be not more than 10 mg/g.

iv. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 20%.

v. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

4.8.2.3 Mineral Filler

Mineral filler shall be incorporated as part of the combined aggregate gradation. It shall be of finely divided mineral matter of hydrated lime (calcium hydroxide). At the time of mixing with bitumen, the hydrated lime shall be sufficiently dry to flow freely and shall be essentially free from agglomerations. Not less than 70% by weight shall pass the BS 75 um sieve. The total amount of hydrated lime as mineral filler shall be limited such that the ratio of the combined coarse aggregate, fine aggregate and mineral filler of the final gradation passing 75 um sieve to bitumen, by weight, shall be in the range of 0.6 to 1.2. As a guide, the total amount of hydrated lime shall be approximately 2% by weight of the combined aggregates. The hydrated lime shall also be treated as an anti-stripping agent.

If hydrated lime is not available, ordinary Portland cement shall be used as an alternative, subject to approval by the S.O.

4.8.2.4 Bituminous Binder

The bituminous binder for use with gap graded asphalt shall be of performance grade PG 76 or higher in compliance with AASHTO Standard M320-02.

(a) Polymer Modified Binder

The performance grade PG 76 or higher shall be achieved by incorporating an appropriate quantity of polymer additives to conventional bitumen which shall be penetration grade 80 – 100 conforming to MS 124. The polymer shall be non-carcinogenic. The contractor shall submit Material Safety Data Sheet on the proposed polymer modified binder. The properties of the polymer modified binder (PMB) shall be as given in Table 4.8.1.

(b) Determination of Mixing and Compaction Temperature

A viscosity-temperature relationship shall be established, using suitable rheometer, for the modified bitumen. The temperatures to which the modified bitumen must be heated to produce a viscosity of 0.2 – 0.5 Pa.s shall be the mixing temperatures. The temperatures to which the modified bitumen must be heated to produce a viscosity of 5 – 30 Pa.s shall be the compacting temperatures.

(c) Storage of Polymer Modified Binder (PMB)

The Contractor shall provide a PMB storage system capable of delivering modified bitumen to the asphalt mixing plant. The storage system should be located close to the

asphalt mixing plant and it should include distribution and circulation pipes that are properly insulated to prevent rapid temperature drop.

The storage tank shall have suitable mechanical agitator and be connected through delivery pipes and baek-circulation pipes. Suitable orifices shall be provided at convenient points in the storage system for taking samples. Sampling shall be done in accordance with MS 539.

TABLE 4.8.I: PROPERTIES OF POLYMER MODIFIED BINDER

TESTS	REQUIREMENT	TEST SPECIFICATION
PMB prior to Rolling Thin Film Oven Test		
Viscosity, max. 3 Pa.s, test temperature C.	135 (see Note 1)	ASTM D 4402
Dynamic shear, G/sin δ min. 1.00 kPa, 10 rad/s, test temperature C.	76	AASHTO T 315
Penetration, 100 g, 5 s, 25 C, 0.1 mm.	Report (see Note 2)	ASTM D 5
Ring and Ball softening point, min. C.	60	ASTM D 36
Flash Point	230	AASHTO T48
Moisture Sensitivity Test,min	80%	AASHTO T283
PMB after Rolling Thin Film Oven (AASHTO T 240 or ASTM D 2872)		
Mass loss, max %.	1.00	AASHTO T 240 or ASTM D 2872
Dynamic shear, G/sin δ min. 2.20 kPa, 10 rad/s, test temperature C.	76	AASHTO T 315

Notes:

1. The requirement may be waived at the discretion of the S.O. if the supplier warrants that the polymer-modified binder can be adequately pumped and mixed at the temperatures that meet all applicable safety standards.

2. The penetration value will be taken as the reference for consistency check on the production.

(d) Resistance to Fuel Spillage

The polymer modified bitumen shall be tested for its resistance to fuel spillage. Three Marshall specimens shall be fabricated at optimum binder content and kept immersed in Octane-97 petrol for 24hours. The average loss of weight before and after the immersion shall not be more than 4%, based on an average of 3 tests.

(e) Bituminous Tack Coat

A thin tack coat of bitumen emulsion RS-1K or similar material conforming to MS 161 shall be applied to ensure uniform and complete adherenee of the overlay.

4.8.3 Gradation Of Combined Aggregates

The gradation of the combined coarse and fine aggregates, together with 2% mineral filler shall conform to the appropriate envelope as given in Table 4.8.2.

TABLE 4.8.2: AGGREGATE GRADATION FOR GPA WEARING COURSE

ASTM Sieve size	Percentage by Weight Passing Sieves	
Size	GPA I (layer thickness < 50mm)	GPA II (layer thickness > 50mm)
25.0 mm	-	100
20.0 mm	100	76 - 100
14.0 mm	-	64 - 89
12.5 mm	85 - 100	-
10.0 mm	-	56 - 81
8.0 mm	65 - 85	-
4.0 mm	40 - 65	41 - 55
2.00 mm	20 - 40	16 - 31
600 μm	-	12 - 16
300 μm	10 - 20	6 - 10
75 μm	3 - 10	3 - 7
Bitumen Content (%)	5 - 7%	5 - 7%

4.8.4 Mix Design

4.8.4.1 Job Mix Formulae

The Contractor shall propose a job mix formula required in the Works. In order to obtain optimum quality of the mixtures, the job mix formula for the mix shall be prepared on the basis of testing several laboratory design mix gradations within the limits set in Table 4.30 at an appropriate range of bitumen content. As a guide, the design bitumen content will usually be in the range of 5 – 7%.

Each combination of laboratory design mix aggregate gradation and bitumen content shall be subject to the Marshall test procedure and volumetric analysis as follows;

i. Preparation of laboratory specimens for the standard stability and flow test in accordance with ASTM D 1559 using 75 blows/face compaction standard.

ii. Determination of the bulk specific gravity of the specimens in accordance with ASTM D 2726.

iii. Determination of the stability and flow values in accordance with ASTM D 1559.

iv. Analysis of the specific gravity and air voids parameters to determine the percentage air voids in the compacted aggregate, the percentage air voids in the compacted aggregate filled with bitumen and the percentage air voids in the compacted mix.

For the proposed design mix gradation, four specimens shall be prepared for each bitumen content within the range of 5 – 7% (see Note 1) at increments of 0.5 percent, in accordance with ASTM D 1559 using 75 blows/face compaction standard. All bitumen content shall be in percentage by weight of the total mix.

As soon as the freshly compacted specimens have cooled to room temperature, the bulk specific gravity of each test specimen shall be determined in accordance with ASTM D 2726.

The stability and flow value of each test specimen shall then be determined in accordance with ASTM D 1559.

After the completion of the stability and flow test, specific gravity and voids analysis shall be carried out for each test specimen to determine the percentage air voids in mineral aggregate (VMA) and the percentage air voids in the compacted mix (VIM).

Values which are obviously erratic shall be discarded before averaging. Where two or more specimens in any group of four are so rejected, four more specimens shall be prepared and tested.

The average values of bulk specific gravity, stability, flow, VFB and VMA obtained above shall be plotted separately against the bitumen content and smooth curves drawn through the plotted values.

The mean optimum bitumen content shall be determined by averaging four optimum bitumen contents so determined as follows;

i. Peak of curve taken from the stability graph (see Note 2).

ii. Flow equals to 2 mm from the flow graph.

iii. Peak of curve taken from the bulk specific gravity graph (see Note 3).

iv. VIM equals to 4% from the VIM graph.

The individual test values (Stability, Flow, VMA and VIM) at the mean optimum bitumen content shall then be read from the plotted smooth curves and shall comply with the design parameters given in Table 4.8.3.

If all the values comply with Table 4.8.3, the mixture with the mean optimum bitumen content shall be used in plant trials.
If any of the values does not comply with Table 4.8.3, the mix design procedure shall be repeated using a different laboratory design mix aggregate gradation until all design parameters are satisfied.

Notes

1. The range of bitumen content shall be extended if necessary to ensure that the curves of stability and bulk specific gravity have their peak within the range selected.

2. Where the stability curve exhibits more than one peak, the bitumen content chosen for the determination of the mean optimum bitumen content shall be the one which satisfies the voids

requirements better. It is sometimes necessary, where no peak stability is obtained, to prepare and test supplementary specimens at intervals of 0.25% bitumen content on either side of the expected optimum.

3. With highly absorptive aggregate, some difficulty in determining peak bulk specific gravity may occur. In such cases, the bitumen content at which the increase in bulk specific gravity shows a marked falling off shall be adopted.

TABLE 4.8.3: DESIGN PROPERTIES

Marshall Properties	Specification limit
Marshall Stability	> 6200 N
Marshall Flow	2 – 4 mm
Stiffness	> 1550 N/mm
Voids in mix	3 - 5 %
Voids filled with bitumen	76 - 82 %

4.8.4.2 Determination of Optimum Binder Content

The binder content that meet the criteria in Table 4.8.3 shall be selected as the optimum binder content. The aggregate gradation selected and the optimum binder content determined shall be proposed to the S.O. as the job mix formula.

4.8.4.3 Trial Lay

After having received the S.O.'s preliminary approval of the proposed job mix formula, the Contractor shall arrange to mix, lay and compact the gap graded asphalt mix. A minimum of 20 tons shall be placed in trial areas to demonstrate to the satisfaction of the S.O. that the mix is satisfactory and the mixing, laying and compacting equipment conforms to the requirement of this specification. The trial areas shall not be part of the Contract Works but shall be provided by the Contractor at his own expense. They shall be approved by the S.O.

As directed by the S.O., comprehensive sampling and testing of the gap graded asphalt mix shall be carried out to check for satisfactory compliance with the job mix formula and satisfactory degree of compaction. The observations and tests to be carried out shall be, but not restricted to, as follows;

i. Check that the trial site is suitable.

ii. Record the type and weight of rollers.

iii. Record the type of paver.

iv. Carry out the following tests on the loose mix specimen;
- Binder content and aggregate grading (ASTM D 2172/BS 598, ASTM C 136).
- Theoretical maximum specific gravity (ASTM D 2041).
- Preparation of Marshall specimens (ASTM D 1559).
- Bulk specific gravity (ASTM 2726).
- Air voids (ASTM 3203).

v. Record temperatures of mix on the tipper lorry, at plant and site.

vi. Record laying temperatures.

vii. Record laying thickness.

viii. Observe the surface texture of mix laid behind paver.

ix. Record rolling temperatures i.e. immediately before rolling starts.

x. Record rolling pattern.

xi. Observe the surface texture of compacted mix.

xii. For each lorry load, take at least three core samples after the mix has been laid, compacted and sufficiently hardened.

xiii. Record compacted thickness, density and air voids of the core samples.

xiv. Check at least one longitudinal joint to ensure that the joint is satisfactorily constructed.

4.8.4.4 Compliance with Job Mix Formula

The S.O.'s final approval of the job mix formula shall bind the Contractor to furnish the Gap Graded Asphalt meeting the precise aggregate gradation and binder content specified in the formula within the tolerances set forth in Table 4.8.4.

TABLE 4.8.4: TOLERANCES FOR GAP GRADED ASPHALT

Parameter	Permissible Variation, % by weight of total mix
Bitumen	+/- 0.2%
Fractions of combined aggregate passing 5.00 mm and larger sieves.	+/- 5.0%
Fractions of combined aggregate passing 2.36 mm sieve.	+/- 4.0%
Fraction of combined aggregate passing 75 μm sieve.	+/- 2.0%
Void content in the total mixture	+/- 1.0%

4.8.5 Equipment

4.8.5.1 Asphalt Mixing Plant

i. Mixing plants shall be suitable for the job and of sufficient capacity in accordance with the specifications as laid down in ASTM D 915.

ii. The S.O. or his authorized representative shall have access, at all times, to all parts of the mixing plant for checking the adequacy of equipment, for the preparation of the mixtures.

iii. The temperature of the bituminous material delivered to the mixer shall be sufficient to provide a suitable viscosity for adequate coating of the aggregate particles, but shall not exceed the applicable maximum temperature set forth in bitumen clause.

iv. The aggregate for the mixture shall be dried and heated to the temperature designated by the job formulae within the job tolerance specified. The maximum temperature and rate of heating shall be such that no permanent damage occurs to the aggregates.

v. The aggregates and the bituminous material shall be measured or gauged and introduced into the mixer in the amount specified by the job mix formulae.

vi. The combined materials shall be mixed until a complete and uniform coating of the particles and a thorough distribution of the bituminous material throughout the aggregate are secured. Wet mixing time shall be as short as practically feasible to prevent excessive aging in the plant.

4.8.5.2 Hauling Equipment

Trucks used for hauling bituminous mixtures shall have suitably treated beds to prevent the mixture from adhering to them. When necessary the mixture shall be protected to ensure delivery to the site at the specified temperature.

4.8.5.3 Pavers

Bituminous pavers shall be self-contained, power-propelled units with an activated screed or strike-off assembly, heated if necessary, and shall be capable of spreading and finishing courses of bituminous plant-mix material which will meet the specified thickness, smoothness, and grade.

4.8.5.4 Rollers

Rollers shall be 4 - 11 tons, steel wheel, tandem or equivalent.

4.8.6 Construction Method

4.8.6.1 Surface Preparation

Immediately before placing the bituminous mixture, the underlying course shall be cleared of all loose or deleterious material with power blowers, power brooms, or hand brooms as directed. Tack coat shall then be applied as specified.

4.8.6.2 Weather Limitations

The bituminous mixture shall not be placed on a wet surface.

4.8.6.3 Laying

i. Deliveries shall be so scheduled so that it is compatible with the speed of spreading and rolling.

ii. Hauling over freshly placed material shall not be permitted until the material has been compacted, as specified, and allowed to cool to atmospheric temperature.

iii. The mix shall be placed at a temperature of not less than 150 °C. Prior to the beginning of the compaction, the temperature shall not be less than 120 °C.

iv. Upon arrival, the mixture shall be spread to the full width by an approved bituminous paver. It shall be struck off in a uniform layer of such depth that, when the work is completed, it shall have the required thickness and shall conform to the grade and contour indicated. The speed of the paver shall be regulated to eliminate; pulling and tearing of the bituminous mat.

v. Unless otherwise directed, placing shall begin along the center line of areas to be paved on a crowned section or on the high side of areas with a one-way slope. The mixture shall be placed in consecutive adjacent strips having a minimum width of, 3 m, except where edge lanes require strips less than 3 m to complete the area.

vi. The longitudinal joint in one layer shall offset that in the layer immediately below; by at least 3 m.

vii. Transverse joints in one layer shall be offset by at least 60 cm from transverse joints in the previous layer. Transverse joints in adjacent lanes shall be offset a minimum of 3 m.

viii. The mixture may be spread, raked and luted by hand tools on areas (irregularities or unavoidable obstacle) where application of equipment for spreading and finishing is found to be impractical.

4.8.6.4 Compaction

i. Rolling of the mixture shall begin as soon after spreading as it will bear the roller without undue displacement or hairline cracking.

ii. Over-compaction shall be avoided.

iii. The compaction temperature shall be at 120 – 150 °C.

iv. Rolling shall be accomplished using the plant as approved by the S.O. during trial lay.

v. Once sufficient in place density has been achieved rolling operations should cease as over rolling may cause migration of PMA and filler to the compacted pavement surface.

vi. The pavement should be compacted to at least 98% of Marshall density.

4.8.6.5 Joints

i. The formation of all joints shall be made in such a manner as to ensure a continuous bond between old and new sections of the course. All joints shall present the same texture, density, and smoothness as other sections of the course

ii. Cold longitudinal joints shall be cut back by sawing or kerbing over their full length to expose a clean, sound surface for the full depth of the course. All contact surfaces shall be given a tack coat of bituminous material prior to placing any fresh mixture against the joint. The tack coat shall be applied uniformly on the cut joint surface using hand brush.

4.8.6.6 Shaping Edges

i. While the surface is being compacted and finished, the Contractor shall carefully trim the outside edges of the pavement to the proper alignment.

ii. Edges so formed shall be beveled while still hot and compacted.

4.8.6.7 Finished Gap Graded Asphalt

Gap Graded Asphalt wearing courses shall be finished in a neat and workmanlike manner; their widths shall be everywhere at least those specified or shown on the Drawings on both sides of the centre-line; the average thickness over any 100-metre length shall be not less than the required thickness, and the minimum thickness at any point shall be not less than the required thickness minus 5 mm.

The top surface of a wearing shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances specified in Sub-Section 4.5.

The International Roughness Index (IRI) value of the finished wearing course surface shall be carried out as described in Sub-Section 4.5 and shall be not more than 2.0 m/km.

4.8.6.8 Opening to Traffic

Traffic should not be placed on the newly compacted surface until the mat has cooled to 60 °C or lower.

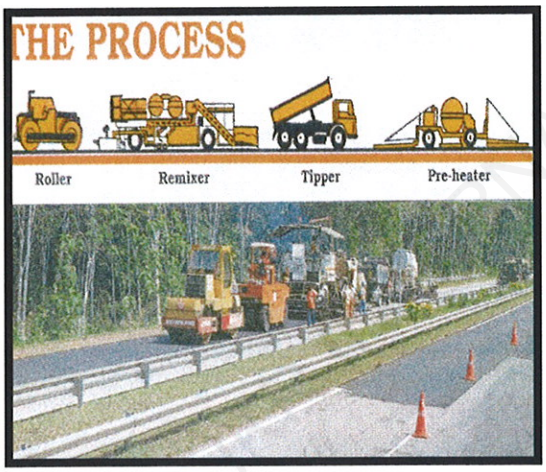
SPECIALTY MIX 4 -
HOT IN-PLACE RECYCLING

HOT IN-PLACE RECYCLING

Hot In-Place Recycling (HIPR) is generally used to address functional pavement failures such as bleeding, ravelling, surface cracking and undulation. HIPR is a rehabilitation technique that involves heating, scarifying, mixing, levelling and compacting the existing bituminous surface. This technique also includes blending the scarified material with fresh bituminous mix, bitumen rejuvenating agent and if necessary, virgin bitumen.

HIPR technique is an economical and practical solution for the rehabilitation of surface distresses by reducing the haul of materials, usage of fresh aggregates and bituminous mix. This technique restores the ride quality and surface condition of structurally sound pavements. In urban areas, it maintains kerb heights for safety and drainage purposes. It also addresses deteriorated pavement surfacing whereby cracks propagation are mitigated, ruts and depression are filled, shoves and bumps are levelled. In addition, cross-fall and crowns are also reinstated and utilities manhole covers need not be raised.

Since the effective recycling depth is limited to 60mm only, HIPR shall not be used to address pavement failures that are related to the base and subgrade layers. Localised subgrade and/or base failures shall be treated prior to the use of this technique. Proper site selection is therefore of paramount importance for the success of this technique.



4.9 SPECIALTY MIX 4 HOT IN-PLACE RECYCLING

4.9.1 Description

This work shall consist of repair of surface failures, surface cracks and general rehabilitation of the pavement surface using the Hot In-Place Recycling process, which includes heating, scarifying, mixing, levelling and compacting the existing bituminous surface to the levels, grades, thickness and cross-sections as shown in the Drawings or as instructed by the S.O. This process shall also include blending the scarified material with an asphalt rejuvenating agent and if necessary, bitumen and fresh bituminous mix all as specified and as instructed by the S.O. Areas with subgrade and/or base failures shall be treated prior to the use of this technique.

4.9.2 Materials

Recycled asphalt mixture is the combined reclaimed and fresh bituminous material obtained after the remixing process in the field.

4.9.2.1 Recycled Asphalt Mixture

Fresh bituminous mix where necessary shall be added. The properties of the recycled asphalt shall meet the requirements below.

(a) Coarse Aggregate For Fresh Bituminous Mix

Coarse aggregate shall be screened crushed hard rock, retained on 5.0 mm sieve, angular in shape and free from dust, clay, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The loss by abrasion and impact in the Los Angeles machine when tested in accordance with ASTM C 131 shall be not more than 25%,

ii. The aggregate crushing value when tested in accordance with BS 812 shall be not more than 25%, (for remixing with additional thickness and remixing and new overlay only)

iii. The flakiness index when tested in accordance with MS 30 shall be not more than 25%,

iv. The polished stone value when tested in accordance with MS 30 shall be not less than 40,

v. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 18%. If sodium sulphalte is used as the test medium, the weighted average weight loss of weight shall not be more than 12%.

vi The water absorption when tested in accordance with MS 30 shall be not more than 2%.

Notwithstanding compliance with the aforementioned requirements, crushed or uncrushed limestone and gravel shall not be permitted.

(b) Fine Aggregate For Fresh Bituminous Mix

Fine aggregate shall be screened quarry fines. They shall be non-plastic and free from clay, loam, aggregations of material, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 20%.

ii. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

iii. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

iv. The fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.

vi. The Methylene Blue value when tested in accordance with Ohio Department of Transportation Standard Test Method shall be not more than 10 mg/g.

(c) Aggregate Properties for Existing Pavement

The properties of the aggregate in the existing bituminous mix shall not deviate by more than 20% from values specified in Clause 4.9.2.1(a) and 4.9.2.1.(b)

(d) Binder

Fresh bituminous binder shall be 80-100 and 50-70 penetration grade bitumen conforming to M.S. 124. The penetration of the bitumen recovered from the recycled asphalt, after laying, shall be within the range of 50 to 70.

4.9.2.2 Marshall Properties For Fresh Bituminous Mix

The fresh bituminous mix to be used for all recycled asphalt shall conform to Table 4.9.1

4.9.2.3 Rejuvenating Agent

The rejuvenating agents used consist of hydrocarbon compounds or liquid bitumen type and shall have the physical properties so that when added to the existing bituminous mix, the blended binder shall be within the requirements of Clause 4.9.2.2.

The rejuvenating agent shall not be carcinogenic and the contractor shall provide relevant technical information and material safety data sheet of the proposed type of rejuvenating agent to be used for approval by the S.O.

4.9.3 Mix Design

Prior to starting hot in-place recycling operations, the Contractor shall furnish the S.O. with a proposed mix design. The proposed mix design shall be based on samples obtained by the Contractor, and shall include the following elements:

i. The bitumen content of the existing pavement to be recycled.

ii The penetration at 25°C and softening point of the recovered binder obtained from the existing pavement to be recycled.

iii. Aggregate gradation of the existing pavement to be recycled.

iv. Type and amount of rejuvenating agent recommended.

v. The penetration at 25°C and softening point of the binder recovered from the recycled mixture (includes binder from the existing pavement to be recycled, fresh binder, and rejuvenating agent).

vi. Aggregate gradation of the blended mix (includes aggregates in the existing pavement to be recycled combined with the newly added aggregates), which shall conform to the envelope given in Table 4.9.1

vii. Marshall properties on the proposed blended mix shall conform to Table 4.9.2

Table 4.9.1: Aggregate Gradation for Blended Mix

Mix design	Type 1	Type 2
B.S. Sieve	**% Passing By Weight**	
37.5	-	
28.0	-	100
20.0	100	76 - 100
14.0	80 - 95	64 - 89
10.0	68 - 90	56 - 81
5.0	52 - 72	46 - 71
3.35	45 - 62	32 - 58
1.18	30 - 45	20 - 42
0.425	17 - 30	12 - 28
0.150	7 - 16	6 - 16
0.075	4 - 10	4 - 8
Target Bitumen Content	5.0 – 7.0 %	4.5 – 6.5%
Air Voids	3.0 – 5.0 %	3.0 – 5.0%

4.9.3.1 Selection Criteria for Existing Pavement

HIPR is used to repair pavement that suffers surface failures only such as ravelling, stripping and low skid resistance. HIPR shall not be used on pavement which contains geotextile, geogrid, tar and cutback bitumen.

4.9.3.2 Treatment of Existing Pavement

Areas with base and/or subgrade failures shall be reconstructed accordingly from the subgrade/base up to the wearing course. The recycling process shall continue over this area, unless the reconstructed length is greater than 5 metres lane-length.

4.9.4 Job Mix Formulae

The contractor shall carry out a trial lay of Hot In-Place Recycling over a section of at least 150 metres length. Job mix formulae for the blended mix shall be established

from the trial lay and the gradation shall conform to the appropriate envelope selected in the mix design process.
The Marshall properties of blended mix shall conform to requirement as stated in Table 4.9.2 below.

Table 4.9.2: Marshall Properties

Parameter	< 2 million ESA	> 2 million ESA
Stability S	> 500 kg	> 700 kg
Flow F	> 2.0 kg	> 2.0 kg
Stiffness S/F	> 250 kg/mm	> 350 kg/mm
Air voids in mix	3.0% - 5.0%	3.0% - 5.0%
Voids in aggregate filled with bitumen	75% - 85%	75% - 85%

4.9.5. Equipment

4.9.5.1 General

In general, the recycling machine shall not operate on more than one lane width of carriageway and shall be capable of performing the in-situ recycling in a single pass. Where liquid petroleum gas or an equivalent is used, all the necessary safety devices shall be fitted and approved by the Department of Occupational Safety and Health (DOSH) prior to commencement of any works. The Contractor must submit a certificate from the manufacturer of the recycling machine, certifying that the machine is fit for use (mechanically in working condition) prior to commencement of the works.

4.9.5.2 Safety Measures

The contractor shall ensure that all necessary safety measures are taken prior to the commencement of work, in particular the gas tanks of the preheaters and remixers and the transfer of gas from the transporter to the tanks. In the event of any gas leakages, the contractor shall ensure that the necessary emergency procedures are taken so that the safety of its personnel and surrounding areas is not compromised.

4.9.5.3 Catalogues and relevant information on machine

The Contractor shall provide catalogues, relevant technical information and data pertaining to the proposed recycling machine to be used.

4.9.5.4 Hot In Place Recycling System

The proposed hot in place recycling system shall consist and be capable of the following:

i. A road heater of the indirect heating type machine capable of high heating efficiency for providing a suitable temperature gradient. The heating mechanism shall be capable of heating the bituminous surface to a temperature so as to allow for scarifying the parent material to the prescribed depths without breaking the aggregate particles, charring the existing bituminous material and producing undesirable pollutants. In any case, the heating mechanism shall be so equipped that the application would

be executed in an enclosed or shielded hood. The depth of heat penetration should not be less than the intended depth to be recycled.

ii. Scarifiers capable of uniformly loosening the bituminous pavement to the depth specified and equipped with separate automatic height adjustments in order to clear existing manholes and other obstructions.

iii. A collecting system capable of collecting the heated and scarified material for remixing, and distributing over the widths being processed and finishing so as to produce a uniform cross-section.

iv. A system for adding and uniformly blending a rejuvenating agent and/or bitumen to the reclaimed mix during remixing and levelling operations. The application rate for the added material shall be synchronized with the machine speed to provide uniform application.

v. A mixer unit to uniformly mix fresh bituminous material with the reclaimed mix and distributing the blended mixture over the width that is being processed.

vi. A screed to spread the blended mixture in the prescribed widths and thickness. These shall be equivalent in performance to screw spreaders and screeds of conventional asphalt spreaders/finishers.

4.9.6 Construction methods

4.9.6.1 General

Prior to commencement of work, the contractor shall survey the site for any obstruction or services that may be affected or damaged by this process and inform the S.O. for further instructions. Hot in-place recycling shall not be carried out over areas with obstruction or services that may be damaged by the process. The contractor shall replace and make good any damaged services and facilities due to the work at this own expense.

4.9.6.2 Surface preparation and cleaning

The existing pavement surface to be recycled shall be free of any loose and deleterious material such as silt, dirt and other debris that might interfere with the heating process. These shall be removed by grading, blowing, brooming or other methods approved by the S.O. prior to the heating and scarifying process. The contractor shall ensure that all other obstructions are protected.

4.9.6.3 Heating, Scarifying, Mixing and Placing Processes

The pavement surface shall be evenly heated to a temperature of not less than 120°C at the scarified depth behind the screed and not more than 180°C, with a continuously moving radiant heater to allow the pavement to be scarified without breaking the coarse aggregate in the bituminous mixture. The heating operation shall be applied under an enclosed hood extending at least 100 mm beyond the width of scarification on both sides. Heating shall be controlled to ensure uniform heat penetration without causing differential softening of the pavement surface. Charring of the bitumen shall not be allowed. Any charred areas, shall be removed from the site and replaced immediately with fresh asphalt before the scarifying process is carried out. Similarly, existing thermoplastic line marking material shall be removed before the scarifying process is carried out.

The heated pavement shall be immediately scarified by carbide tipped teeth, set on less than 25 mm centers, mounted in multiple racks or on a rotating mandrel, controlled by the machine operator. The scarifying equipment shall be able to cut a

plane through the pavement that is within 20 mm of the alignment of the grade and slope of the finished pavement. Where appropriate, liquid bitumen, rejuvenating agent or new asphalt mix shall be added during the remixing process, before the mix is paved.

4.9.6.4 Remixing

(a) Remixing Process (For Normal Reshaping and Reprofiling)

Where remixing is specified by the S.O., the existing pavement shall be heated and scarified to the specified depth. Rejuvenating agent and additional asphaltic concrete material shall be added to the reclaimed mix and compacted all in a single pass. The purpose of the additional material is to reprofile existing ruts, to restore binder properties and to correct aggregate gradation.

(b) Remixing with Additional Thickness

Where remixing to a specified overlay thickness is required for strengthening and restoring the original pavement, the existing bituminous pavement layer shall be heated and scarified to a predetermined depth. Rejuvenating agent and additional asphaltic concrete material shall be added to achieve the specified thickness and required material composition. The whole process of heating, scarification and addition of rejuvenating agent and binder, paving and compaction shall be executed in a single pass.

(c) Remixing and New Overlay

Where a new overlay of asphaltic concrete is required on top of the remixed layer, the process of remixing, as described in Sub-Section 6.4.1 above shall be carried out and in addition to that, a new asphaltic concrete overlay of a specified thickness as approved by the S.O. shall be simultaneously paved on top of the newly remixed pavement. Both layers shall be compacted at the same time, provided that the combined thickness does not exceed 100mm.

4.9.7 Laying and Compaction

The recycled layer shall achieve a compacted density of not less than 98% of Marshall density.

4.9.8 Joints

When a pass is adjacent to a previously placed mat, the heating shall extend at least 100mm into the adjacent mat to enable a hot-on-hot longitudinal joint to be constructed.

4.9.9 Finished HIPR Surface

The completed HIPR surface shall be finished in a neat and workmanlike manner, with recycling and paving widths conforming to those specified or shown in the Drawings. The average thickness over any 100metre length shall be not less than the specified thickness, and the minimum thickness at any point shall be not less than the specified thickness minus 5 mm.

4.9.9.1 Regularity of Completed Pavement Surface

(a) Description

Riding quality on a road surface is positively correlated with roughness of the surface. Low roughness corresponds to good riding quality and vice versa. Roughness of a pavement surface is brought about by uneven settlement, short and

long wave undulations, rutting, wide cracking and other surface defects such as potholes, delamination etc..

The International Roughness Index (IRI) is used internationally to measure the degree of roughness of a pavement surface. It is representative of the vertical motions induced in moving vehicles for the frequency bandwidth which affects both the response of the vehicle and the comfort perceived by the occupants

The IRI describes a scale of roughness which is zero for a true planar surface, increasing to about 6 m/km for moderately rough paved roads, 12 m/km for extremely rough paved roads with potholes and patches, and up to about 20 m/km for extremely rough unpaved roads.

(b) Measurement of IRI

The regularity of the completed pavement surface is measured in terms of its lane IRI. Lane IRI shall be measured using the ARRB Walking Profiler (WP) following the procedures as outlined in **Appendix 1.**

Other types of equipment such as high speed profiler may be used to measure lane IRI provided that the output from the equipment correlate strongly with the output from WP (R^2>0.95).

(c) Acceptance Criteria

The Contractor shall make available lane IRI values for the whole road length as well as for each 100m length of the completed pavement surface.

The lane IRI measured for the whole road length and each 100 meter section for HIPR treatment involving remixing with additional thickness and remixing and new overlay shall be less than 2.0m/km.

The lane IRI measured for the whole road length and each 100 meter section for HIPR treatment involving only remixing process shall be less than 2.5m/km.

(d) Rectification Work for Non-Compliance

In case of non-compliance, the contractor shall carry out rectification works on any part of the completed pavement surface so that the lane IRI values for the whole road length and for each 100 meter section are less than 2.0m/km.

(e) Quality Control of Finished HIPR Surface

Mix samples shall be taken after the placing of the blended mixture at the frequency of one sample per 500 metre length of lane or a minimum of once per working day, whichever is the greater. The mix sample shall be checked for bitumen content, penetration and softening point of the recovered binder and aggregate grading.

Core samples shall be taken from the finished asphalt layer at a frequency of one core per 250 metre per lane length or a minimum of three cores, whichever is the greater. Core samples shall be checked for the thickness of the recycled layer and its compacted density.

4.9.10 Opening to Traffic

The pavement shall not be opened to traffic until compaction has been completed and the material has thoroughly cooled and set in the opinion of the S.O. This will usually be not less than 4 hours after the commencement of rolling.

SPECIALTY MIX 5 -
COLD IN-PLACE RECYCLING

COLD IN PLACE RECYCLING

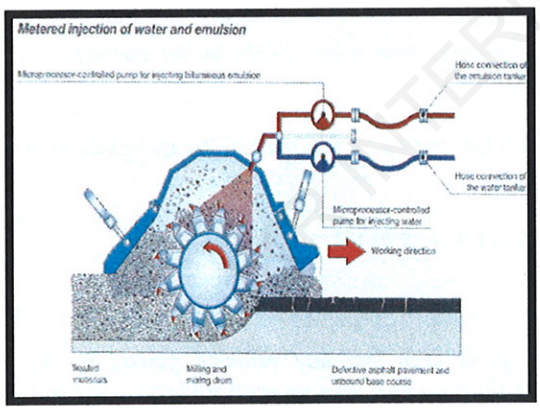
Cold in-place recycling (CIPR) is a structural pavement rehabilitation technique. It re-uses the existing pavement materials. This technique involves scarifying, stabilising and re-laying the recycled materials with minimal off-site hauling or mixing.

CIPR involves the processing and stabilising of the existing pavement layers without heating to produce a rejuvenated pavement layer. There are many types of stabilising agents that can be used in CIPR but the most common are bitumen emulsion, foamed bitumen, lime, Portland Cement and fly ash. Stabilising agents can be injected directly into the recycler mixing chamber while the scarifying operation is carried out, ensuring excellent mixing of the stabilizing agent with the scarified materials. Where required, the scarified materials may be modified by the addition of fresh aggregates and/or bitumen.

The main advantages of CIPR technique include conservation of materials and energy, full utilisation of local materials, minimise use of new materials, reduction of traffic disruption, improved pavement strength, and lower capital costs.

CIPR is applied to older pavements that are structurally deficient and no longer are candidates for a simple overlay. Most pavement distresses, such as fatigue cracking, transverse thermal cracking, reflective cracking can be successfully corrected using cold in place pavement recycling technique. Generally, CIPR technique costs lower than full reconstruction method.

CIPR should not be used to rehabilitate pavement that has failed due to poor embankment or foundation support. Normally, a surfacing layer is required on top of the recycled pavement layer



4.10 SPECIALTY MIX 5 - COLD IN-PLACE RECYCLING

4.10.1 Description

This work shall include all activities in connection with the construction of a new pavement layer using the cold in-place recycling process to recycle material from the pavement layers of an existing road. The work shall inelude;

i. breaking down and recovering material of an existing pavement using a purpose-built recycling machine;

ii. where required, modifying the characteristics of the recovered material by the addition of imported material;

iii. the provision and application of stabilising agents and water; and

iv. mixing, placing, compacting and shaping the recycled material to achieve a new pavement layer.

New pavement layers shall conform to the lines, grades, thickness and typical cross-sections shown on the Drawings and/or described in detailed pavement design report and/or as required by the S.O.

4.10.2 Materials

4.10.2.1 Existing Pavement Material

Investigations carried out, together with the results of tests conducted on representative samples of materials in the existing pavement structure, shall be detailed in pavement design report and/or issued separately by the S.O. As a minimum, these shall include;

i. a description of the pavement structures that is/are likely to be encountered when cold in-place recycling;

ii. anticipated grading, plasticity and other relevant properties of the materials to be recycled from the pavement layers;

iii. n-situ moisture contents measured at the time of investigation;

iv. structural and mix designs.

These information shall be supplied in good faith but any reliance placed by the Contractor on these information shall be at his own risk, and he shall undertake his own separate testing programme to determine the conditions prevailing at the time of construction.

Any significant deviation in the physical or mechanical properties of the material recovered by recycling that are indicative of changes in the existing pavement shall be immediately reported to the S.O. The Contractor shall take whatever action he deems necessary to ensure that the new pavement layer produced in the cold in-place recycling process complies with the design requirements, unless otherwise directed by the S.O.

4.10.2.2 Imported Pavement Material

Natural material (sand, gravel, etc), crushed stone products (graded products, crusher dust, etc) and/or salvaged Recycled Asphalt Pavements (RAP) from other sites may be required to be mixed with the recycled material for the purposes of;

i. altering the grading of the recycled material; and/or

ii. supplementing the volume of the recycled material (e.g. for shape correction);

iii. improving the structural properties of the pavements.

The specific requirements for imported materials shall be detailed out in pavement design report and/or as directed by the S.O.

4.10.2.3 Stabilising Agents

(a) General

All stabilising agents shall be of the quality and type specified, and the Contractor shall provide documentary evidence to this effect when required by the S.O. Any stabilising agent that is not satisfactory shall be rejected.

(b) Cement

Cement used in the cold in-place recycling process shall be ordinary Portland cement complying with MS 522.

The use of any other class or type of cement shall only be considered if the Contractor can demonstrate that it will provide a cost benefit without any technical detriment to the Works, subject always to the written approval from the S.O.

(c) Bitumen Emulsion

Bitumen emulsion used in the cold in-place recycling process shall be of slow-setting type complying with the requirements of MS 161 and as shown in Table 4.10.1.

TABLE 4.10.1: LIMITS FOR BITUMEN EMULSION (SLOW-SETTING)

	Parameter	Minimum	Maximum
i.	Viscosity, Saybolt Furol at 25° C (sec):	20	100
ii.	Settlement, 5 days (%):	0	5
iii.	Storage stability test, 24hr (%):	0	1
iv.	Sieve test (%):	0	0.1
v.	Cement mixing test (%):	0	2.0
vi.	Distillation for oil, by volume of bitumen emulsion (%):	0	5
vii.	Distillation for residue (%):	60	
viii.	Penetration for residue (%):	60	200
ix.	Ductility of residue, 25° C, 5cm/min (cm)	40	
x.	Solubility in trichloroethylene (%)	97.5	
xi.	Particle charge test	Positive	

The use of any other class or type of bitumen emulsion shall only be considered if the Contractor can demonstrate that it will provide a cost benefit without any technical detriment to the Works, subject always to the written approval from the S.O.

(d) Bitumen for Foaming

Bitumen used for foaming in the cold in-place recycling process shall be of penetration grade 80/100 complying with MS 124, and free of any anti-foaming agent. The foamed bitumen shall be produced at a temperature range of between 160 °C – 180 °C and at the designed water content. The bitumen shall have the following foaming properties;

i. Expansion ratio[1]: minimum 8 times

ii. Half life[2]: minimum 8 seconds

The use of any other class or type of bitumen for foaming shall only be considered if the Contractor can demonstrate that it will provide a cost benefit without any technical detriment to the Works, subject always to the written approval of the S.O.

(e) Water

Water used in the cold in-place recycling process shall be potable, clean and free of harmful matter.

4.10.3 Mix Design

4.10.3.1 General

Details regarding materials to be used, application rates of stabilising agent, type and application rate of any required additives, any specific pre-treatment requirements and the compacted thickness of the recycled stabilised layer shall be determined in advance of the Work.

Laboratory tests on materials sampled from the existing pavement and/or borrow areas shall be carried out to determine the basic properties of the recycled pavement material prior to addition of stabilising agent. Samples taken from the existing pavement material shall be representative of the material that will be recycled for the particular section.

The preliminary laboratory testing shall form the basis for determining the feasibility of cold in-place recycling and indicating the most appropriate method.

For sections determined as feasible for cold in-place recycling, further laboratory tests shall then be undertaken to determine the following key parameters;

i. the volume of any additional material to be imported from specific borrow areas;

ii. the type and optimal application rate of the stabilising agent;

iii. the amount and type of any required additives.

The additional laboratory tests shall be as specified in Sub-Section 4.10.5 for each of the stabilising agents to which this Specification apply.

[1] Maximum volume of foam/original volume of bitumen
[2] Time taken for the foam volume to reduce to half its maximum volume

4.10.3.2 Preliminary Laboratory Testing

Testing of the existing pavement material shall be undertaken and shall conform to the following physical and mechanical quality requirements;

i. the plasticity index shall be not more than 6 for unbound material;

ii. the aggregate crushing value when tested in accordance with MS 30 shall be not more than 25%;

iii. the flakiness index when tested in accordance with MS 30 shall be not more than 25%;

iv. the material shall have a CBR value of not less than 80% when compacted to 95% of the maximum dry density determined in the BS 1377 Compaction Test (4.5kg rammer method) and soaked for 4 days under a surcharge of 4.5kg;

v. the gradation shall comply with the envelope shown in Table 4.10.2.

TABLE 4.10.2: GRADATION LIMITS FOR RECYCLED LAYER MATERIAL

Sieve size	Cumulative % passing
50.0 mm	100
37.5 mm	85 – 100
20.0 mm	60 – 100
10.0 mm	40 – 90
5.0 mm	30 – 75
2.36 mm	20 – 60
425 µm	10 – 45
75 µm	2 – 20

Compliance with the conformance requirements of Sub-Section 4.10.3.3 shall not be deemed as acceptance for its use in cold in-place recycling. It shall be regarded as indicating potential suitability.

Non-compliance with the conformance requirements of Sub-Section 4.10.3.3 shall not be deemed as non-acceptance for its use in cold in-place recycling. It shall be regarded as indicating deficiencies that require attention to render it potentially suitable.

Where the existing pavement material is deemed potentially suitable for cold in-place recycling, the Contractor shall provide the S.O. with recommendations of proposed stabilisation type and additional material/ treatment required. Such additional material/ treatment shall be used to correct any deficiencies in the properties of the existing pavement material that would otherwise render it unsuitable for stabilisation.

Subject to no objection by the S.O. to the recommendations, the Contractor shall undertake detailed testing as specified in Sub-Section 4.10.5.

4.10.3.3 Compliance Requirements for Recycled Layer Materials

(a) General Requirements

The following sub-sections set out the specific compliance requirements for the recycled pavement layer. The Contractor shall provide the S.O. with the results of all tests together with his proposals for the mix and pavement designs for each section of the road. The minimum length of any one section shall be 500m. After review, the S.O. shall either accept such proposals, in writing, or describe his concerns and suggest that specific changes be made.

The untreated material shall comprise existing pavement layer material and any other additional material/treatment required as recommended in Sub-Section 4.10.4, and its physical and chemical composition shall be representative of the material expected on site immediately prior to the addition of stabilising agent.

The stabilising agent shall be in conformance with the requirements of Sub-Section 4.10.2.3 and shall be applied such that the resulting material shall be representative of the recycled material expected on site.

Laboratory tests on stabilised material shall be undertaken to determine the application rate of the stabilising agent. Specimens shall be prepared at the optimum fluid content for the particular stabilising agent based on and derived from the optimum moisture content of the untreated material determined in the AASHTO T 180 (modified moisture density relationship) or BS 812 /BS 1924.

Modification of the specimen moisture content to attain the appropriate optimum fluid content for the particular stabilising agent shall be in accordance with current best practice and the Contractor's own experience.

(b) Cement Stabilisation

The compliance requirements for cement stabilised cold-in-place recycled layer material requirements are given in Table 4.10.3.

TABLE 4.10.3: REQUIREMENTS FOR CEMENT STABILISED COLD IN-PLACE RECYCLED LAYER MATERIAL

Parameter			Requirement
Unconfined Compression Test (UCS), in accordance with B.S. 1881, part 116. 7-day strength, moist curing @ 25°C, height/width 1:1	Minimum 97% of Modified AASHTO density	Range (MPa) (minimum and maximum limits)	2 – 5
Indirect tensile test (ITS) on 150mm diameter briquette cured as for UCS specimens, in accordance with AASHTO T-198	Minimum 97% of Modified AASHTO density	Minimum (MPa)	0.2
Maximum cement content by weight			5%

The job mix stabilising agent content shall be determined from the testing and submitted to the S.O., together with all other details of the mix for quality control purposes, including target moisture content and density.

(c) Bitumen Emulsion Treatment

The compliance requirements for bitumen emulsion treated cold-in-place recycled layer material are given in Table 4.10.4.

TABLE 4.10.4: REQUIREMENTS FOR BITUMEN EMULSION STABILISED COLD IN-PLACE RECYCLED LAYER MATERIAL

Parameter		Minimum Strength (MPa)
Unconfined Compression Test (UCS), in accordance with B.S. 1881, part 116. 7-day strength, moist curing @ 25°C, height/width 1:1	Minimum 97% of Modified AASHTO density*	0.7
Indirect tensile test (ITS) on 100mm diameter briquette cured at 40°C for 72 hours, in accordance with AASHTO T-198	Marshall compaction (75 blows per side)	0.2
Indirect tensile test (ITS) on cured briquettes, soaked for 24 hours as above	Marshall compaction (75 blows per side)	0.15
Maximum added cement content by weight		2%

** Density determined at optimum fluid content for the mixture at the relevant compactive effort.*

The job mix stabilising agent content shall be determined from the testing and submitted to the S.O. together with all other details of the mix for quality control purposes, including target fluid content and density.

(d) Foamed Bitumen Stabilisation

The compliance requirements for foamed bitumen stabilised cold-in-place recycled layer material are given in Table 4.10.5. The classification is based on the indirect tensile strength test (ITS).

TABLE 4.10.5: REQUIREMENTS FOR FOAMED BITUMEN STABILISED COLD IN-PLACE RECYCLED LAYER MATERIAL

Parameter		Minimum Strength (MPa)
Unconfined Compression Test (UCS), in accordance with B.S. 1881, part 116. 7-day strength, moist curing @ 25°C, height/width 1:1	Minimum 97% of Modified AASHTO density*	0.7
Indirect tensile test (ITS) on 100mm diameter briquette cured at 40°C for 72 hours, in aecordance with AASHTO T-198	Marshall compaction (75 blows per side)	0.2
Indirect tensile test (ITS) on cured briquettes, soaked for 24 hours as above	Marshall compaction (75 blows per side)	0.15
Maximum added cement content by weight		2%

** Density determined at optimum moisture content for the mixture at the relevant compactive effort.*

The job mix stabilising agent content shall be determined from the testing and submitted to the S.O., together with all other details of the mix for quality control purposes, including target moisture content and density.

4.10.3.4 Trial Sections

Trial (pilot) section construction shall be undertaken on each contract section for which the layer and/or material design requirements are expected to change. Each accepted trial section shall demonstrate compliance with the specification requirements to the satisfaction of the S.O., prior to cold-in place recycling continuing on the section. As a minimum, the following details shall be included;

i. Gradation of the recycled material;

ii. Compaction requirements including type of roller and rolling pattern to be employed to achieve the required density;

iii. Strength of the recycled layer material in terms of UCS and ITS as specified in Table 4.10.8;

iv. Recycling depth and compacted thickness of new recycled layer material as specified in detailed pavement design report;

v. In-situ moisture content in order to determine the application rate of water to achieve the OMC;

vi. Percentage by weight of the stabilising agent used as specified in Table 4.10.8, and

vii. Speed of advance of the recycler machine as specified in Table 4.10.8.

The trial section shall have a minimum 150m length at the proposed laying width. Quality control sampling and testing frequency shall be at least double that specified for normal job production as directed by the S.O.

If the trial lay results are within the permissible tolerance, then the trial lay results shall be designated as Job Standard Mix (JSM).

Trial sections deemed to comply with the specification requirements shall be accepted as part of the permanent works and the Contractor shall be permitted to proceed on the specific section.

For trial sections deemed as non-compliance with the specification requirements, the Contractor shall submit a work proposal for making good such sections for approval by the S.O. Trial sub-sections made good and subsequently approved as being in compliance with the specification requirements shall be paid for at the same nominal rate as the normal job for the particular section of work.

4.10.4 Equipment

4.10.4.1 General

All equipment shall be supplied and operated in such a manner as to recycle the in situ pavement to the specified depth and construct a new pavement layer, all in accordance with the requirements of the specifications. All equipment deployed on the site shall be of adequate rated capacity and in good working order. Obsolete, poorly maintained or dilapidated equipment shall not be allowed on site.

The minimum compliance requirements for the equipment to be used for cold in-place recycling are given in the following sub-sections. The Contractor shall provide the S.O. with details and technical specifications of the equipment at least two weeks in advance of the first proposed usage.

4.10.4.2 Equipment for Cold In-Place Recycling

Cold in-place recycling shall be carried out using a modified milling machine or a purpose-built recycling machine to;

i. add the required amounts of water and stabilising agents;

ii. mix all ingredients together to achieve a uniform consistency; and

iii. place the reconstituted material within the excavation created by the initial milling.

Unless specified in the detailed pavement design report or directed by the S.O., all the operations described above shall be effected simultaneously in a single pass of the machine.

Unless otherwise specifically permitted within the contract documents, the modified milling machine or recycler to be used for cold in-place recycling shall meet the following minimum requirements;

i. It shall be factory-built by a manufacturer having a demonstrable rack record and manufacturing history in the particular type of equipment.

ii. The milling drum shall have a minimum cut width of 2 metres with the capability of changing the speed of rotation.

iii. A level control system that maintains the depth of milling within a tolerance of ± 10 millimetres of the required depth during continuous operation.

iv. The milling drum shall rotate within an enclosed chamber inside which water and stabilising agents are added to the recovered material at the rate required to achieve compliance with the specified laboratory design mixture during continuous operation.

v. All spray systems fitted to the recycler shall be controlled by micro-processor to regulate the flow rate with the speed of advance of the machine. All spray systems shall also have the ability to allow variable widths of application.

vi. It shall have sufficient power to mix the recycled material together with all additives to produce a uniform homogenous reconstituted material during continuous operation.

All ancillary equipment for supplying water, stabilising agents and other additives to the recycler during operation shall be in accordance with the recycler manufacturer's recommendations.

4.10.4.3 Additional Requirements when Stabilising with Cement

Where the cement stabilising agent is not applied directly on the surface of the road prior to recycling, the recycler shall be fed with cement slurry that is produced in a separate mobile mixing unit pushed ahead of the recycler. Such a mixing unit shall be equipped as follows;

i. It shall have the capability to supply the cement slurry at the required rate to comply with the mix design during continuous operation.

ii. It shall be capable of regulating the application rate of cement slurry in accordance with the speed of advance of the recycler and volume of material during continuous operation.

iii. It shall provide uniform mixture of the cement slurry to the recycler to produce a homogenous recycled mixture.

iv. There shall be a method for monitoring cement usage during operation that can be validated by simple physical measurement for control purposes.

4.10.4.4 Additional Requirements when Stabilising with Bitumen Emulsion

In addition to the requirements specified in 4.10.4.2, the recycler shall be equipped as follows;

i. It shall have the capability to supply the bitumen emulsion at the required rate to comply with the mix design during continuous operation.

ii. It shall be capable of regulating the application rate of bitumen emulsion in accordance with speed of advance of the recycler and volume of material during continuous operation.

iii. It shall provide uniform application of the bitumen emulsion to the reconstituted pavement material to produce a homogenous mixture.

iv. There shall be a method for monitoring bitumen emulsion application during operation that ean be validated by simple physical measurement for control purposes.

4.10.4.5 Additional Requirements when Stabilising with Foamed Bitumen

In addition to the requirements specified in 4.10.4.2, the recycler shall be equipped as follows;

i. It shall have the capability to supply the foamed bitumen at the required rate to comply with the mix design during continuous operation.

ii. It shall be capable of regulating the application rate of foamed bitumen in accordance with speed of advance of the recycler and volume of material during continuous operation.

iii. It shall provide uniform application of the foamed bitumen to the reconstituted pavement material to produce a homogenous mixture.

iv. There shall be a method for monitoring bitumen application during operation that can be validated by simple physical measurement for control purposes.

v. It shall be equipped with temperature and pressure gauges for monitoring purposes prior to foaming.

vi. There shall be a means to provide a representative sample of foamed bitumen at any stage during normal operation.

4.10.5 Construction Method

4.10.5.1 General

(a) Surface Preparation

Prior to commencement of cold in-place recycling, the surface of the existing section to be recycled shall;

i. be cleared of all foreign matter and standing water from the entire width of cut and to a minimum of one metre to either side;

ii. be accurately marked showing the proposed cut lines.

(b) Production Plan

Prior to commencement of cold in-place recycling, the Contractor shall prepare a production plan detailing the proposed day's work, which shall include the following;

i. an annotated sketch showing the overall layout of the existing section intended for recycling during the day showing the proposed cut pattern, sequence of cut and overlap dimensions between cuts;

ii. the estimated time required for proposed day's production;

iii. the amount and type of stabilising agents to be applied to each cut;

iv. the proposed control testing programme;

v. any other information relevant to the intended work.

(c) Weather Limitations

No cold in-place recycling work shall be undertaken during wet conditions or in such other conditions that may result in the work quality being negatively compromised, unless otherwise directed by the S.O.

(d) Equipment, Materials and Material Delivery

The Contractor shall ensure that all logistical requirements for unhindered production of the day's proposed work are prepared prior to commencement of the Work.

All equipment for the cold in-place recycling process, from milling to final compaction and finishing, shall be on site and in good working condition, as described in Sub-Section 4.10.4.

All materials required for the day's production, including stabilising agents and any additional material, shall be available.

All ancillary equipment for the delivery of stabilising agents and any additional material to the site shall be available as required and in good working condition.

Specific equipment checks to be undertaken prior to the start of each production run shall include;

i. All supply pipes, chambers and jets for supply of stabilising agent, water, or other additives, are free of blockage and primed;

ii. Sufficient quantities of stabilising agent, water, or other additives, are available in their supply equipment for unhindered continuous production during the run;

iii. Bitumen temperature (where foamed bitumen is applied) is correct;

iv. All equipment settings are correct and gauges and monitoring equipment are functioning;

v. Equipment operators and crew are ready, and equipped as appropriate to undertake their tasks and fulfill their responsibilities.

(e) Time Limitations

The maximum permissible time between mixing the recycled material with any stabilising agent and final compaction of the placed material is given in Table 4.10.6.

TABLE 4.10.6: MAXIMUM TIMES BETWEEN MIXING AND FINAL COMPACTION

Stabilising agent	Time Limit (hours)
Cement	3
Bitumen emulsion	6
Foamed bitumen	12

(f) Application Quantities of Stabilising Agents, and any additional materials

The Contractor shall record the area of application and quantity of stabilising agent and any additional materials used per run, and shall keep these records for at least 12 months after completion of the project.

(g) Others

The Contractor shall undertake the cold in-place recycling process with due diligence and shall instigate immediate corrective measures in the event of any other occurrence or event that may lead to a sub-standard end product.

4.10.5.2 Laying

The mixed material shall be continuously placed back in the excavation created by milling as the recycler advances. The recycler shall be equipped to place mixed material to the thickness and uniformity required to achieve the design properties of the layer after trimming and final compaction, in accordance with the design and specifications.

The Contractor shall provide necessary ancillary equipment and resources to ensure that deficiencies in thickness or uniformity of the re-placed layer material can be corrected immediately, and prior to initial compaction.

4.10.5.3 Compaction

(a) Initial Compaction

The recycled layer shall be initially compacted immediately, or as soon as any deficiencies are made good in accordance with Sub-Section 4.10.5 above. Initial compaction shall be undertaken by a smooth-drum or pad foot vibrating roller, operating on high-amplitude vibration. The static mass of the roller shall be selected in accordance with Table 4.10.7.

TABLE 4.10.7: MINIMUM STATIC ROLLER MASS

Thickness of compacted layer	Minimum static mass of roller (tonne)
< 150mm	12
150mm to 200mm	15
200mm to 250mm	19
> 250mm	24

Note: The operating speed of the primary roller shall never exceed 3km/hr and rolling shall be applied over the full width of each cut.

(b) Trimming and Final Compaction

After primary rolling has been completed, a grader shall be used if required to cut the final surface levels. Grader work shall be limited to the minimum necessary to achieve the required final surface shape, evenness and texture. Skimmed material shall be removed and under no account compacted into the trimmed layer.

Final compaction shall commence as soon as possible after trimming. Final compaction comprises secondary rolling, to achieve the specified density, and finishing. Secondary rolling shall be undertaken using a smooth-drum vibrating roller (nominal 12 tonne static mass) operating on low-amplitude vibration. Any additional moisture required maintaining workability and achieving the specified density requirements shall be applied by spraying the surface with multiple light applications from a water tanker.

Finishing shall be undertaken with a pneumatic-tyred roller to achieve a close-knit surface appearance. For bitumen emulsion and foamed bitumen treated layer materials additional water shall be sprayed on to the surface and rolled whilst wet to achieve this finish.

For cement stabilised layer materials, water shall be sprayed regularly using full-width spray bar fitted with fine nozzles to prevent the surface from drying out and for curing purposes. Alternatively, if early opening to traffic is required, a rapid setting bitumen emulsion curing membrane with a minimum spray rate of 0.6 litre/m^2, or such other curing membrane as otherwise approved by the S.O., shall be applied immediately after finishing operations.

4.10.5.4 Joints

Two types of joint can be required during the cold in-place recycling process longitudinal (between adjacent cut sections), transverse construction/operational joints); formed transverse (in cement stabilised layers). Joints shall be constructed to avoid built-in weakness using best practice techniques, and in accordance with the following;

(a) Longitudinal Joints

Longitudinal joints between adjacent cuts shall overlap by at least 100mm to ensure complete treatment across the full width of the road. Guidelines marked on the road surface for each cut shall be checked to ensure that only the first cut is the same width as the milling drum. All successive cut widths into existing original material shall be less than the drum width by at least 100mm.

(b) Transverse Joints

Transverse joints, created at the start and end of each cut and each time the recycling process stops, shall be formed to ensure that there is continuity of treatment across the resulting joint. The overlap shall be at least 1.5m or equal to the diameter of the milling drum.

4.10.5.5 Protection and Maintenance

The Contractor shall protect and maintain the completed layer until the next pavement layer or surfacing is applied.

Curing agents or a temporary surfacing in the forms of sand blinding, surface dressing, slurry seal or other method as approved in the contractor's work plan shall be applied after finishing as required. The treatment shall be appropriate to the cold in-place

recycled material type, and the time and trafficking levels prior to application of the next pavement layer.

Minimum curing time of 72 hours shall be allowed for cement stabilised layer prior to overlaying of hot mix over the treated layer. For foamed and bitumen emulsion stabilised layers a minimum curing period of 48 hours shall be allowed. The Contractor shall overlay with hot mix immediately, after the minimum curing time has been achieved.

The Contractor shall undertake necessary maintenance activities to ensure that the curing agent or temporary surfacing remains intact and protects the cold in-place recycled pavement layer against deterioration prior to application of the next pavement layer. The contractor shall also make good any damage to the stabilised surface at his own cost by using approved method prior to laying of the hot mix.

4.10.5.6 Quality of Materials and Workmanship

The general quality control requirements applicable to cold in-place recycling that shall be complied with during normal operation are given in Table 4.10.8.

Tolerances on horizontal alignment, surface levels and surfaee regularity for the cold in-place recyeled layers shall conform to the following requirements;

(a) Horizontal Alignment

The horizontal alignment shall be determined from the centre-line of the pavement surface shown on the Drawings. The edges of the pavement as constructed and all other parallel construction lines shall be correct within a tolerance of + 50mm and minus 0 mm from the centre-line, except for kerbs, channel blocks and edge lines which shall be laid with a smooth alignment within a tolerance of + 25mm and minus 0mm from the centre-line.

(b) Surface Levels of Pavement Courses

The design levels of pavement courses shall be calculated from the vertical profile, cross fall and pavement course thickness shown on the Drawings. The level of any point on the constructed surface of a pavement course shall be the design level subject to the appropriate tolerances given in Table 4.10.9.

(c) Surface Regularity of Recycled Layer

The transverse regularity of completed recycled surface shall be measured with a 3m straight-edge and no depression shall exceed 10mm.

Any individual irregularity measured with the rolling straight-edge, or 3m straight-edge, laid parallel to the road centre-line shall not exceed 10mm.

TABLE 4.10.8: GENERAL QUALITY CONTROL REQUIREMENTS FOR COLD IN-PLACE RECYCLING

Parameter	Test Method	Frequency	Acceptance
Field compaction (Density)	B.S. 1377 Sand Replacement Method	One test per 500m^2 and at least one test per daily operation	95% for natural gravel/crushed aggregates; 97% for mixture of crushed aggregates and RAP; 98% for RAP of JSM
Stabilising agent application rate	Consumption records reconciled with theoretical usage.	Every completed section and daily	± 10% of target rate
Unconfined Compression Strength (UCS)	As defined in Table 1.4, 1.5 or 1.6 for the particular stabilising agent	One test per 2000m^2 and at least one test per daily operation, each test comprising four (4) specimens	No result less than the minimum required strength for the particular stabilising agent. For cement stabilised layer no result shall fall outside specified range.
Indirect Tensile Strength (ITS)	As defined in Table 1.4, 1.5 or 1.6 for the particular stabilising agent	One test per 2000m^2 and at least one test per daily operation, each test comprising four (4) specimens	No result less than the minimum required strength.
Depth of recycling	Physical measurement of cutting depth relative to final surface elevation	At least two tests per 50m linear progress	±10mm of target depth
Thickness of new recycled layer	Small inspection holes cut through completed layer	One test per 250m of completed layer	±10mm of specified layer thickness
Moisture content	B.S 1377: Part 2 1990	At least once each 500m length of cut	+20% of the Optimum Moisture Content (OMC) determined from AASHTO test T180.
Speed of advance	Manufacturer's advisory note.	At least once each 250m length of cut.	5m/min - 12m/min.

TABLE 4.10.9: TOLERANCES IN SURFACE LEVELS OF PAVEMENT COURSES

Pavement Course	Tolerance
Wearing Course	+/- 5 mm
Binder Course	+/- 5 mm
Roadbase	+ 0 mm - 20 mm
Sub-base	+ 10 mm - 20 mm

The combination of permitted tolerances in the levels of different pavement courses shall not result in a pavement thickness less than that shown on the Drawings. Each pavement course shall have an average thickness not less than that shown on the Drawings.

SPECIALTY MIX 6 -
POLYMER MODIFIED ASPHALTIC CONCRETE

4.11 SPECIALTY MIX 6 - POLYMER MODIFIED ASPHALTIC CONCRETE

4.11.1 Description

This work shall consist of furnishing, placing, shaping and compacting polymer modified asphaltic concrete wearing course and/or binder course on a prepared and accepted bituminous or bitumen primed pavement course, and shall include careful and thorough cleaning of surfaces which are to be covered prior to the application of bituminous tack coat and/or prime coat. The work shall be carried out all in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O.

Polymer modified asphaltic concrete is a mixture of continuously graded aggregate and polymer modified binder. The binder is produced by incorporating an appropriate quantity of synthetic polymer to conventional bitumen. Polymer modified asphaltic concrete offers the following benefits;

i) Improved resistance to rutting.
ii) Improved resistance to fatigue cracking.
iii) Improved resistance to cracking due to binder hardening.
iv) Improved adhesion of binder to aggregates.

4.11.2 Materials

(a) Aggregate

Aggregate for polymer modified asphaltic concrete shall be a mixture of coarse and fine aggregates, and mineral filler. The individual aggregate shall be of sizes suitable for blending to produce the required gradation of the combined aggregate, all to the satisfaction of the S.O.

Coarse aggregate shall be screened crushed hard rock, angular in shape and free from dust, clay, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The Los Angeles Abrasion Value when tested in accordance with ASTM C 131 shall be not more than 25%.

ii. The weighted average loss of weight in the magnesium sulphate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 18%.

iii. The flakiness index when tested in accordance with MS 30 shall be not more than 25%.

iv. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

v. The polished stone value when tested in accordance with MS 30 shall be not less than 40 (for wearing course only).

Fine aggregate shall be clean screened quarry dusts. Other types of fine aggregate may be used subject to the approval of the S.O. Fine aggregate shall be non-plastic and free from clay, loam, aggregation of material, vegetative and other organic matter, and other

POLYMER MODIFIED ASPHALITIC CONCRETE

Polymer modified asphaltic concrete is an option to prolong the life or enhance the performance of bituminous pavement layers. It is a mixture of continuously graded aggregate and polymer modified binder. The binder is produced by incorporating an appropriate quantity of synthetic polymer to conventional bitumen. Polymer modified asphaltic concrete offers the following benifits;

i. Improved resistance to runting.
ii. Improved resistance to fatigue cracking.
iii. Improved resistance to craking due to binder hardening.
iv. Improved adhesion of binder to aggregate.

Polymer modified binder shall be of performance grade PG 76 or higher in compliance with AASHTO Standard M320-02. This premium grade binder shall be produced by pre-blending conventional bitumen with an appropriate quantity of synthetic polymer.

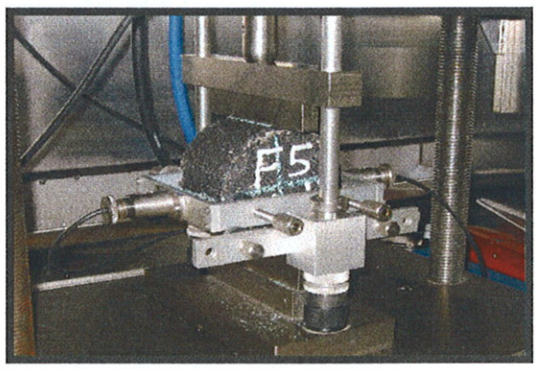
The polymer shall be either a plastomer such as low-density polyethylene (LDPE) abd ethylene vinyl acetate (EVA) or an elastomer such as styrene butadiene styrene (SBS) and styrene butadiene rubber (SBR), or a combination of both. However, the types of polymer shall be used provided that the specified propeties of the resulted binder and asphaltic concrete mix are complied.

Polymer shall be pre-blended with conventional bitumen before mixing plant. it shall either be a high-shear blending equipment system provided whereby polymer modified binder can be manufactured on site, or polymer modified binder obtained from an approved source. In either case, a binder storage tank equipped with suitable mechanical agitator shall be provided close to the asphalt mixing plant. Continuous agitation during prolonged storage is essential to prevent separation of the binder.

In carrying out mix design for polymer modified asphaltic concrete, additional testing are essential and there includes resilient modulus and dynamic creep.

This mix is recommended for use in high stress areas such as climbing lanes or where excessive axle loads are expected.

Due to relatively high cost compared to conventional asphaltic concrete, it should not be used indiscriminately.



deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

ii. The fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.

iii. The Methylene Blue value when tested in accordance with Ohio Department of Transportation Standard Test Method shall be not more than 10 mg/g.

iv. The weighted average loss of weight in the magnesium sulphate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 20%.

v. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

Notwithstanding compliance with the requirements of this Specification, limestone aggregate shall not be permitted for use in wearing course.

The gradation of the combined coarse and fine aggregates and mineral filler, shall conform to the appropriate envelope shown in Table 4.11.1.

For each type of mix required in the Works, the Contractor shall propose a laboratory design mix gradation which shall consist of a single definite percentage passing for each sieve size in Table 4.11.1 and shall produce a smooth curve within the appropriate gradation envelope. This job laboratory design mix gradation, with the allowable tolerances for a single test as specified in Sub-Section 4.11.3 (a), shall then become the job mix formula.

(b) Mineral Filler

Mineral filler shall be incorporated as part of the combined aggregate gradation. It shall be of finely divided mineral matter of hydrated lime (calcium hydroxide). At the time of mixing with bitumen, the hydrated lime shall be sufficiently dry to flow freely and shall be essentially free from agglomerations. Not less than 70% by weight shall pass the BS 75 um sieve. The total amount of hydrated lime as mineral filler shall be limited such that the ratio of the combined coarse aggregate, fine aggregate and mineral filler of the final gradation passing 75 um sieve to bitumen, by weight, shall be in the range of 0.6 to 1.2. As a guide, the total amount of hydrated lime shall be approximately 2% by weight of the combined aggregates. The hydrated lime shall also be treated as an anti-stripping agent.

If hydrated lime is not available, ordinary Portland cement shall be used as an alternative, subject to approval by the S.O.

TABLE 4.11.1: COMBINED AGGREGATE GRADATION

Mix Type	Wearing Course	Wearing Course	Binder Course
Mix Designation	AC 10	AC 14	AC 28
BS Sieve Size, mm	Percentage Passing (by weight)		
28.0			100
20.0		100	72 – 90
14.0	100	90 – 100	58 – 76
10.0	90 – 100	76 – 86	48 – 64
5.0	58 – 72	50 – 62	30 – 46
3.35	48 – 64	40 – 54	24 – 40
1.18	22 – 40	18 – 34	14 – 28
0.425	12 – 26	12 – 24	8 – 20
0.150	6 – 14	6 – 14	4 – 10
0.075	4 – 8	4 – 8	3 – 7

(c) Polymer Modified Binder

Polymer modified binder shall be of performance grade PG 76 or higher in compliance with AASHTO Standard M320-02. This premium grade binder shall be produced by pre-blending conventional bitumen, which shall conform to MS 124, with an appropriate quantity of synthetic polymer.

A polymer is a large molecule that is made up of many small molecules or monomers. There are naturally occurring polymer and synthetic polymer.

Naturally occurring polymer can be organic or mineral substances such as hair, rubber, diamond and sulphur. Even bitumen can be regarded as a polymer because of the long-chain nature of some of the organic molecules that are the constituent parts of bitumen.

Synthetic polymer shall be manufactured in a chemical process to combine particular molecules in a way that would not occur naturally and shall be non-carcinogenic. There are two types of polymer which are described as follows;

i) Plastomer, or Polyolefin.

A plastomer will generally stiffen the binder to increase its high temperature performance. For bituminous mixture used as surfacing course, this results in greater resistance to rutting and deformation. For intermediate and base courses, this results in an increased strength of the pavement structures.

Some examples of plastomer are low-density polyethylene (LDPE) and ethylene vinyl acetate (EVA).

ii) Elastomer, or Block Copolymer.

An elastomer will generally both stiffen and increase the flexibility or stretchiness of the binder, improving both high and low temperature performance. An elastomeric binder will rebound after being stretched, thus the bituminous mixture is able to recover from the stresses that occur under heavy loadings.

Some examples of elastomer are styrene butadiene styrene (SBS) and styrene butadiene rubber (SBR).

Either type of the polymer or a combination of both types of polymer shall be used in the production of the polymer modified binder. However, other types of polymer shall also be used provided that the properties of the resulted binder and mix are complied.

When added to bitumen, the polymer does not chemically combine or change the chemical nature of the bitumen but it dissolves into certain component fractions of the bitumen, spreading out its long chain polymer molecules to create an inter-connecting matrix of the polymer throughout the bitumen. It is this matrix of the long chain polymer molecules that modifies the physical properties of the bitumen.

The properties of the polymer modified binder (PMB) shall be as given in Table 4.11.2.

TABLE 4.11.2 - PROPERTIES OF POLYMER MODIFIED BINDER

TEST	REQUIREMENT	TEST SPECIFICATION
PMB prior to Rolling Thin Film Oven Test (RTFOT)		
Viscosity, max. 3 Pa.s, test temperature °C	135 (see Note 1)	ASTM D 4402
Dynamic shear, G*/sin δ min. 1.00 kPa, 10 rad/s, test temperature °C	76	AASHTO T 315
Penetration, 100 g, 5 s, 25 C, 0.1 mm	Report (see Note 2)	ASTM D 5
Ring & ball softening point, min. °C	60	ASTM D 36
Flash point, min °C	230	AASTHO T 48
Moisture sensitivity test, min. %	80	AASHTO T 283
Emission of toxic gases, max. mg/m^3	15	
PMB after RTFOT (AASHTO T 240 or ASTM D 2872)		
Mass loss, max. %	1.00	AASHTO T 240 or ASTM D 2872
Dynamic shear, G*/sin δ min. 2.20 kPa, 10 rad/s, test temperature °C	76	AASHTO T 315

Note:

1. The requirement shall be waived at the discretion of the S.O. if the supplier warrants that the polymer modified binder can be adequately pumped and mixed at the temperatures that meet all applicable safety standards.

2. The penetration value shall be taken as the reference for consistency check on the production.

Polymer shall be pre-blended with conventional bitumen before mixing with the aggregate in the asphalt mixing plant. The Contractor shall either provide a high-shear blending equipment system close to the asphalt mixing plant whereby polymer modified binder can be manufactured on site, or shall obtain polymer modified binder from an approved source. In either case, the Contractor shall provide a binder storage tank equipped with a suitable mechanical agitator close to the asphalt mixing plant. This tank shall also include distribution and circulation pipes that are properly insulated or heated. Continuous agitation of the binder during prolonged storage is essential to prevent separation. A suitable orifice shall be provided at a convenient point in the storage tank system for taking samples. Samples shall be taken after prolonged storage or at any other circumstances deemed necessary by the S.O. and tested for the

properties as shown in Table 4.11.2 above at an approved laboratory. Sampling shall be done in accordance with MS 539.

A viscosity-temperature relationship shall be established, using suitable rheometer, for the polymer modified binder. The temperatures to which the polymer modified binder must be heated to produce a viscosity of 0.2 – 0.5 Pa.s shall be the mixing temperatures. The temperatures to which the polymer modified binder must be heated to produce a viscosity of 5 – 30 Pa.s shall be the compaction temperatures.

4.11.3 Mix Design

(a) Job Mix Formulae

Stage 1

The Contractor shall propose a job mix formula for each type of mix required in the Works. In order to obtain optimum quality of the mixtures, the job mix formula for each type of mix shall be prepared on the basis of testing several laboratory design mix gradations within the limits set in Table 4.11.1 at an appropriate range of polymer modified binder content. As a guide to the testing range of the binder content, the design binder content will usually be in the range given in Table 4.11.3.

Each combination of laboratory design mix aggregate gradation and binder content shall be subject to the Marshall test procedure and volumetric analysis as follows;

i. Preparation of laboratory specimens for the standard stability and flow test in accordance with ASTM D 1559 using 75-blows/face compaction standard at compaction temperature as determined from the above viscosity-temperature relationship,

ii. Determination of the bulk specific gravity of the specimens in accordance with ASTM D 2726,

iii. Determination of the stability and flow values in accordance with ASTM D 1559,

iv. Analysis of the specific gravity and air voids parameters to determine the percentage air voids in the compacted aggregate, the percentage air voids in the compacted aggregate filled with the binder and the percentage air voids in the compacted mix.

For each laboratory design mix gradation, four specimens shall be prepared for each binder content within the range given in Table 4.11.3 (see Note 1) at increments of 0.5 percent, in accordance with ASTM D 1559 using 75 blows/face compaction standard. All binder content shall be in percentage by weight of the total mix.

As soon as the freshly compacted specimens have cooled to room temperature, the bulk specific gravity of each test specimen shall be determined in accordance with ASTM D 2726.

The stability and flow value of each test specimen shall then be determined in accordance with ASTM D 1559.

After the completion of the stability and flow test, specific gravity and voids analysis shall be carried out for each test specimen to determine the percentage air voids in the

compacted aggregate filled with binder (VFB) and the percentage air voids in the compacted mix (VIM).

Values which are obviously erratic shall be discarded before averaging. Where two or more specimens in any group of four are so rejected, four more specimens shall be prepared and tested.

The mean values of bulk specific gravity, stability, flow, VFB and VIM obtained above shall be plotted separately against the binder content and a smooth curve drawn through the plotted values.

The mean optimum binder content shall be determined by averaging five optimum binder contents so determined as follows;

i. Peak of curve taken from the stability graph (see Note 2),

ii Flow equals to 2 mm from the flow graph,

iii. Peak of curve taken from the bulk specific gravity graph (see Note 3),

iv. VFB equals to 75% for wearing course and 70% for binder course from the VFB graph,

v. VIM equals to 4.0% for wearing course and 5.0% for binder course from the VIM graph.

The individual test values at the mean optimum binder content shall then be read from the plotted smooth curves and shall comply with the design parameters given in Table 4.11.4.

If all the values comply with Table 4.11.4, the mixture with that mean optimum binder content shall be used in Stage 2 below.

If any of the values does not comply with Table 4.11.4, the mix design procedure shall be repeated using a different aggregate gradation until all design parameters are satisfied.

Note:

1. The range of binder content shall be extended if necessary to ensure that the curves of stability and bulk specific gravity have their peak within the range selected.

2. Where the stability curve exhibits more than one peak, the binder content chosen for the determination of the mean optimum binder content shall be the one which satisfies the voids requirements better. It is sometimes necessary where no peak stability is obtained, to prepare and test supplementary specimens at intervals of 0.25% binder content on either side of the expected optimum.

3. With highly absorptive aggregate, some difficulty in determining peak bulk specific gravity may occur. In such cases, the binder content at which the increase in bulk specific gravity shows a marked falling off shall be adopted.

TABLE 4.11.3: RANGE OF DESIGN BINDER CONTENTS

AC 10 – Wearing Course	5.5 – 7.5 %
AC 14 – Wearing Course	4.5 – 6.5%
AC 28 – Binder Course	4.0 – 6.0%

TABLE 4.11.4: TEST AND ANALYSIS PARAMETERS FOR POLYMER MODIFIED ASPHALTIC CONCRETE

Parameter	Wearing Course	Binder Course
Stability, S	> 13000 N	> 13000 N
Flow, F	2.0 - 5.0 mm	2.0 - 5.0 mm
Stiffness, S/F	> 2600 N/mm	> 2600 N/mm
Air voids in mix (VIM)	3.0 - 5.0%	3.0 - 7.0%
Voids in aggregate filled with bitumen (VFB)	70 - 80%	65 - 75%

Stage 2

From the mean optimum binder content established in Stage 1, five values of binder content shall be selected (one below and three above that mean optimum binder content). For each of these binder content, test specimens shall be prepared using the same aggregate gradation and compaction effort as established in Stage 1.

The job mix formula shall be the mix which satisfies the following properties;

i) Indirect tension test for resilient modulus (ASTM D 4123)

Total resilient modulus	> 2500 MPa
Test temperature	25 °C
Applied load	20 N/mm of specimen thickness (max. 1500 N)
Loading frequency	1 Hz
Loading time	0.1 s
Rest period	0.9 s
Rise time	70 ms
Poisson's ratio	0.35
No. of preconditioning pulses	50
No. of test pulses	5
Rotation of specimen	90°

Report mean value of total resilient modulus (E_{RT}) from two alignments (rotation). Disregard test result if E_{RT} values for the same test specimen differ by more than 10% from the mean value.

ii) Dynamic, unconfined, compressive creep test (EN 12697-25)

Dynamic creep modulus	> 75 MPa
Slope at steady state	< 0.25

Specimen end treatment Silicone based lubricant + graphite dust

Pre-conditioning;	
Test temperature	40 °C
Applied axial stress	150 kPa
Loading frequency	0.5 Hz
Loading time	0.2 s
Rest period	1.8 s
No. of load cycles	30

Testing;	
Test temperature	40 °C
Applied axial stress	300 kPa
Loading frequency	0.5 Hz
Loading time	0.2 s
Rest period	1.8 s
No. of load cycles	3600

Report dynamic creep modulus and slope at steady state, the latter shall be log strain divided by log load cycle between 2000 and 3600 load cycles.

The mean values of total resilient modulus, dynamic creep modulus and slope at steady state shall be plotted separately against the binder content and a smooth curve drawn through the plotted values.

The new mean optimum binder content shall be determined by averaging three optimum binder contents as follows;

i. Peak of curve taken from the total resilient modulus graph,
ii. Peak of curve taken from the dynamic creep modulus graph,
iii. Peak of curve taken from the slope at steady state graph.

The individual test values at the mean optimum binder content shall then be read from the plotted smooth curves and shall comply with respective design parameters.

If all the values comply with respective design parameters, the mixture with that binder content shall be considered as the job mix formula.

(b) Plant Trials

After having received the S.O. preliminary approval of his proposed job mix formula, the Contractor shall arrange to mix, lay and compact polymer modified asphaltic concrete conforming to the proposed formula for each type of mix required in the Works. A minimum of 20 tonnes of the mix shall be placed in trial areas to demonstrate to the satisfaction of the S.O. that the mixing, laying and compacting equipment conforms to the requirements of this Specification, and that the proposed mix is satisfactory. The trial

areas shall not be part of the Contract Works but shall be provided by the Contractor at his own expense. The proposed trial area shall be approved by the S.O.

As directed by the S.O., comprehensive sampling and testing of the mix shall be carried out to check for satisfactory compliance with its job mix formula, and for a satisfactory degree of compaction. In order to demonstrate to the satisfaction of the S.O. that mixing, laying and compacting equipment conform to the requirements of the specification, and that the proposed mix is satisfactory, the following observations and tests shall be carried out.

i. Record the type and weight of rollers. Check the tyre pressure of the pneumatic tyre roller (shall comply with Sub-Section 4.11.4 (e)).

ii. Record the type of paver (shall comply with Sub-Section 4.11.4 (d)).

iii. Check that the trial area is suitable (not on soft ground, uneven surface or part of the Contract Works).

iv. Take sample of the mix and carry out the following tests;

- Binder content and aggregate grading (shall conform to the precise aggregate gradation and bitumen content as determined from the mix design and within the tolerances set forth in Table 4.11.5)
- Preparation of Marshall specimens.
- Bulk specific gravity of Marshall specimens.
- Volumetric properties of Marshall specimens (shall comply with Table 4.11.4).
- Marshall stability and flow (shall comply with Table 4.11.4).
- Resilient modulus.
- Dynamic creep.

v. Record temperatures of mix on the lorry, at plant and site (shall not exceed 180 °C at any time and shall be not less than 145 °C immediately before unloading into the paver hopper).

vi. Record laying (uncompacted) thickness.

vii. Check texture of paved surface before rolling (there shall be no substantial blemishes and irregularities).

viii. Record temperatures immediately before rolling starts (rolling temperatures)

ix. Record rolling pattern.

x. Check texture of compacted surface.

xi. Cut core samples after the laid material has sufficiently hardened (at least three samples from each lorry load).

xii. Record compacted thickness and density from core samples (shall comply with Sub-Section 4.11.5 (i) and (j).

If the composition of the mix does not conform to the precise aggregate gradation and bitumen content as determined in the mix design procedure as deseribed in Sub-Section

4.11.3 and within the tolerances set forth in Table 4.11.5, and/or the Marshall specimens do not comply with any of the properties set forth in Table 4.11.4 as well as resilient modulus, creep modulus and slope at steady state in Stage 2 of the mix design, the mix design procedure shall be repeated.

If the texture of the paved and/or compacted surface are not satisfactory, and/or the compacted thickness and/or density are inadequate, the plant trial shall be repeated using different paver and/or roller(s).

Upon satisfaction by the S.O., the Contractor shall be required to produce a full report of the plant trial and this document shall be used in full scale production in the Works.

(c) Compliance with the Job Mix Formula

The S.O. final approval of the job mix formula shall bind the Contractor to produce polymer modified asphaltic concrete mixes conforming to the precise gradation and binder content specified in the formula within the tolerances set forth in Table 4.11.5 and using polymer modified binder that consistently comply with the properties as specified in Table 4.11.2.

Modifications to the job mix formula shall only be made with the approval of the S.O. Should the S.O. at any time have reasons to believe that the materials and methods of mixing and laying are different from those approved, he shall so advise the Contractor and instruct that polymer modified asphaltic concrete works be discontinued pending further plant trials and testing.

TABLE 4.11.5: TOLERANCES FOR POLYMER MODIFIED ASPHALTIC CONCRETE

Parameter	Permissible Variation % By Weight of Total Mix
Binder content	± 0.2 %
Fractions of combined aggregate passing 5.0 mm and larger sieves	± 5.0 %
Fractions of combined aggregate passing 3.35 mm and 1.18 mm sieves	± 4.0 %
Fractions of combined aggregate passing 425 um and 150 um sieves	± 3.0 %
Fractions of combined aggregate passing 75 um sieve	± 2.0 %

4.11.4 Equipment

The Contractor shall provide all the plant and equipment necessary for executing the work in accordance with this Specification and shall furnish the S.O. with such details of particular items of equipment, e.g. manufacturer, model type, capacity, weight, operating features, etc., as the S.O. shall require.

(a) Road Cleaning Equipment

Immediately prior to applying bituminous tack coat, the full width of the surface to be treated shall be swept using a power broom followed by a compressed air blower, and if necessary, scraped using hand tools, to remove all dirt, dust and other objectionable material, all to the satisfaction of the S.O.

(b) Asphalt Mixing Plant

The asphalt plant shall be either a batch plant or a drum mix plant of recognized manufacture and shall be approved by the S.O. It shall conform to the requirements described hereunder.

The mixing plant shall have a capacity suited to the Works and sufficient to enable the paver to operate more or less continuously when paving at normal speeds at the required thicknesses. The plant shall be so designed as to enable consistent production of polymer modified asphaltic concrete mixes within the tolerances prescribed in this Specification, all to the satisfaction of the S.O.

Mixes produced and delivered shall have actual tonnages of aggregates, filler and binder components recorded. The temperature of the mix leaving the plant shall be recorded for each batch or every 15 minutes. Where the control system incorporates a computer and a printer capable of printing the information, copies of the printouts shall be provided to the S.O. for quality assurance.

Tanks for storage of binder shall have a capacity suited to the proposed rate of utilizations of the material and the method and frequency of its delivery to the Works, all to the satisfaction of the S.O. The tanks shall be provided with means of measuring the volume of their contents at all times and of drawing off samples of the contents. The binder feeding system shall provide for continuous circulation of hot binder through the system and back into the feed tank. The end of the return line discharging into the feed tank shall always be kept submerged in the binder in the tank in order to prevent oxidation of the returning hot binder. The storage tanks, and where necessary barred decanters, and all elements of the binder feeding system shall be equipped with heating system or insulating jackets as necessary to provide for effective and positive control of the temperature of the binder at all times up to the temperature required for utilizations. The method of heating shall be such that neither flames nor the products of combustion shall come into direct contact with the binder or the casing of its immediate container, and such that no portion of the binder shall be subject to overheating.

Calibration of the plant to an accuracy of $\pm$ 1% error must be carried out before the production of the trial mixes. This calibration is to test the integrity of all the weighing system of the storage bins and binder hopper.

Calibration is also required for the feeders to match the production capacity. Once the calibration is set and mixes production commence, calibration procedures shall be repeated every 30,000 tonnes or one month whichever is earlier.

i) Batch Plants

The plants shall be provided with accurate mechanical means for uniformly feeding the aggregate into the dryer so that uniform production and temperature of the heated aggregate will be obtained. A separate feed bin with an adjustable gate opening shall be provided for each aggregate to be included in the combined aggregate for the mix; normally four bins will be required. The feed bins and gates shall be constructed and equipped that they shall be readily accessible for calibrating at all times, and shall provide for a continuous and uniform flow of each aggregate required in the mix.

The plant shall have a rotary drum dryer of satisfactory design for drying and heating the combined aggregate so that its temperature will be at the required level at the time it is mixed with the bitumen. The burner shall be so designed that complete combustion of the fuel will be obtained, and the aggregate will remain clean and not become coated with soot or oil.

The plant shall be equipped with four (or more) screens, the smallest of which shall generally be not more than 3.2 mm. The screens shall have a normal capacity slightly in excess of the maximum output of the mixing plant. The screens shall be readily accessible for inspection.

The plant shall include four (or more) storage bins for screened aggregates, each with a capacity of not less than twice the pugmill dead load capacity. The bins shall be arranged so as to provide separate dry storage for each screened fraction of the aggregate. Each bin shall be provided with an overflow pipe of such size and location as to prevent any backing up of material into other bins. Each bin shall be so constructed that representative aggregate samples can be readily obtained, and shall have means for observing the aggregate level. Separate dry storage shall be provided for mineral filler, and the plant shall be satisfactorily equipped to feed filler into the mixer.

Accurate means of weighing by load cells shall be provided for weighing the aggregates and filler and also for weighing the bitumen required for each batch of mix.

Suitable means shall be provided for maintaining the prescribed temperature of the bitumen in the pipelines, weigh bucket of flow meter, and spray bars.

An armoured thermometer with a range of 30 °C to 200 °C shall be fitted in the bitumen feed line at a suitable location near the discharge valve at the mixer unit. Suitable dial-scale mercury actuated thermometer, electric pyrometers or other thermometer instruments shall be fitted at the discharge chute of the dryer and in each hot aggregate storage bin to indicate the temperature of the heated aggregate.

The plant shall be equipped with adequate and safe stairways to the mixing platform and sampling location and guarded ladders and cat-walks shall provide access to all other positions as necessary for proper operation, inspection and maintenance of the plant, all to the satisfaction of the S.O. All gear, pulley, chains, sprockets and other dangerous moving parts shall be property guarded and protected. Ample and unobstructed space shall be provided on the mixing platform, and clear and unobstructed passage shall be maintained at all times in and around the truck loading area, which shall, be kept free from drippings from the mixer.

Each storage bin for screened aggregate shall be provided with a bottom outlet gate so constructed as to prevent leakage when closed. These gates shall have a quick and complete closing action. The plant shall be equipped with a weigh box or hopper for accurately weighing out aggregate from each of the screened aggregate storage bins. The

weigh box or hopper shall be suspended from its scale's lever mechanism and shall be sufficiently large to holds a full batch equal to the pugmill capacity without hand raking of the aggregate. The discharge gate shall be so constructed as to allow rapid and complete emptying of the weigh box or hopper into the mixer, and prevent leakage when closed.

The plant shall be equipped with a binder weigh bucket which shall be charged through a fast acting non-dip valve in the binder feed pipe located directly over the bucket. The bucket shall be suspended from its scale's lever mechanism and shall have a capacity sufficient to weigh out binder up to 20% of the weight of the pugmill dead load capacity. The bucket shall have a discharge mechanism which shall provide for rapid and complete emptying of the bucket in a thin uniform sheet or multiple sprays over the full length and width of the mixer. The discharged shall not leak or drip when closed.

The batch mixer shall be a suitable twin-shaft pugmill, with a capacity of at least 500 kg of asphaltic concrete, capable of producing a thoroughly homogeneous mixture. The clearance of the paddle blades from all fixed and moving parts of the mixer shall be not more than 20mm. If the pugmill is not enclosed, it shall be equipped with a dust hood to prevent loss of fines from the mixture. The discharge gate shall be so constructed as to allow rapid and complete emptying of the mixer, and prevent leakage of any mix constituent when closed.

The mixer shall be equipped with an accurate time lock system for controlling the operations of a complete mixing cycle. It shall lock the aggregate weigh box or hopper gate after charging the mixer with aggregate, until the closing of the mixer gate at the completion of the mixing cycle; it shall lock the binder weigh bucket discharge mechanism during the dry mixing and wet mixing period. The dry mixing period is defined as the interval of time between the opening of the aggregate weigh box of hopper gate and the start of discharging the binder weigh bucket. The wet mixing period is defined as the interval of time between the start of discharging the binder weigh bucket and the opening of the mixer gate. The dry and wet mixing periods shall both be adjustable in increments of not more than 5 seconds from zero to not more than 60 seconds total for dry and wet mixing.

The filler silo shall have suitable a screw conveyor system to discharge into the pugmill.

The control system for the plant shall be housed in a weather proof cabin with windows to view the plant operations. Control in the cabin shall have the capability to accurately batch the aggregates, filler and bitumen for the mix, transfer to the pugmill mixer and control the mixing time. The temperature of the heated aggregates, filler and bitumen shall also be displayed in this cabin and adjusted to meet the Specifications when required.

ii) Drum Mix Plants

The cold material feeder unit shall consist of not less than 5 bins with suitable heaped capacity appropriate for the plant. Each bin shall be equipped with a variable speed weighing belt feeder (driven by variable speed electric motor fitter with a tachometer) with a load cell for accurate weight measurement of each type of aggregate used in the mix in equivalent dry tonnes per hour. The cold feed system shall incorporate a device for moisture compensation capable of producing an accurate and continuous blend of the individual aggregate sizes from the cold feed compartment. The cold feed system shall also be equipped with a scalping screen of screed size of not more than 50mm to discard any oversized aggregates before entering the dryer drum.

The drum mixer shall have flight designs to accomplish the proper transfer of heat from the exhaust gases of the burner to the aggregates and to blend the aggregates and bitumen together adequately. The flight, at the upper end of the drum, must be able to direct the aggregate into the drum beyond the tip of the flame, thereafter the subsequent flight must be efficient to lift and tumble the aggregates with the cumulation of a veil of aggregates across the whole cross-sectional area near the mid-point of the length of drum where the aggregate temperature must have been raised to dew point. This veil of aggregates must be sufficiently complete and dense to maximise heat transfer and to screen the bitumen from the direct flame to minimise hardening and oxidation of the bitumen during the mixing process. The downstream mixing flight designs must complete the heat transfer process and raise the mix temperature to the desired level for discharge. The length to diameter ratio of the drum must be appropriately designed to obtain more complete heat transfer; to enable the bitumen to be injected in an inert atmosphere where proper coating/adhesion onto aggregates can take place without severe oxidation or hardening of bitumen and effective mixing and sufficient designed mix temperatures are achieved. The drum must be inclined, oil-fired and suitably and sufficiently insulated.

The control system of a drum mixer must be automatically computer controlled with a fully independent manual back-up system. The system must enable the operator to view the operation of the whole plant and of the individual component stations. All relevant information of the plant operation and the progress of the tonnage of mix tonnage produced and mix design information must be made availed. The control system should possess a Quality Assurance package to act as an audit tool (when required to be used) whereby the information on Plant-Monitor, Progress Monitor, and Mix Temperature can be made availed at pre-set, variable time intervals.

Freshly mixed material shall be collected and delivered to be stored in a surge silo through a proper conveyor system.

(c) Tip-Trucks

The Contractor shall provide a suitable number of tip-trucks of a type approved by the S.O. for transporting polymer modified asphaltic concrete from the mixing plant to the paving sites. The trucks shall have trays with smooth, flat beds and sides, and shall have load capacities of not less than 5 tonnes. Prior to loading, the inside of each truck tray shall be lightly and evenly coated with a soap or detergent solution, or such other liquid as the S.O. shall approve, to prevent adhesion of the polymer modified asphaltic concrete. The trucks shall be equipped with covers of canvas or other suitable material to protect the polymer modified asphaltic concrete.

(d) Asphalt Paver

The asphalt paver shall be of recognized manufacture and shall be approved by the S.O. It shall conform to the requirements described hereunder.

The paver shall be self-propelled and capable of reverse as well as forward travel. It shall be equipped with a hopper at the front designed to receive the paving mix from tip-trucks, and shall have a mechanical distribution system for spreading the mix evenly and without segregation over the surface to be paved in front of a screeding and compacting unit which shall be equipped with a suitable heating device. The screeding and compacting mechanism shall be capable of confining the edges of the material being laid without the use of stationary side forms, shall be adjustable to strike off the mixture to the thickness and cross-section shape required, and shall be controlled by an automatic leveling device to produce an even carpet of bituminous mixture with a uniform surface texture free from indentations, ridges, tear marks or other irregularities. The paver shall be capable of laying the bituminous mixture in paving widths in the range 2.5 to 3.75 m and of

finishing the pavement layer true to the required lines, grades, levels, dimensions and cross-sections, subject to compaction by rolling, all to the satisfaction of the S.O.

(e) Rollers

A pneumatic tyred roller and two steel wheeled tandem rollers shall be provided. All rollers shall be of recognised manufacture and shall be approved by the S.O. They shall conform to the requirements described hereunder.

Pneumatic Tyred Roller

Pneumatic tyred roller shall be self-propelled and capable of being reversed without backlash; it shall be equipped with power steering and dual controls allowing operation from either the left or right side.

The roller shall have nine wheels equipped with smooth tyres all of the same size and construction. Five wheels shall be on the driven axle and four on the steering axle, all equally spaced on both axles and arranged so that the tyres on the steering axle track midway between those on the driven axle with a small overlap. The roller shall be ballasted to an operating weight of not less than 15 tonnes with a tyre inflation pressure of not less than 0.7 N/sq.mm.

The Contractor shall provide the S.O. with a calibration chart for the roller showing the relationship between the quantity or depth of ballast and total weight, and also a chart showing the relationship between wheel load, tyre inflation pressure and contact pressure.

Steel Wheeled Tandem Roller

Steel wheeled tandem rollers shall be self-propelled and capable of being reversed without backlash; they shall be equipped with power steering and dual controls allowing operation from either the left or right side. They shall be equipped with water tanks, sprinkler systems and scraper blades to keep all wheels evenly wetted and clean during operation.

Steel wheeled tandem rollers shall be ballasted so that their total operating weight are in the range 8 to 10 tonnes and their driven roll (or rolls) shall exert a rolling force of not less than 3.5 tonnes/metre of roll width. The Contractor shall provide the S.O. with a calibration chart for each roller showing the relationships between the quantity or depth of ballast and total weight and rolling force.

4.11.5 Construction Methods

(a) General Conditions

Polymer modified asphaltic concrete paving work shall only be carried out in dry weather when the surface to be covered is clean and dry, and has received a bituminous tack coat which shall have achieved a satisfactory degree of tackiness, all to the satisfaction of the S.O. All laying, rolling and finishing work shall be carried out during daylight hours, unless the Contractor shall have provided suitable flood-lighting for the job site, to the satisfaction of the S.O.

The S.O. may order the discontinuation of work on account of adverse weather, unsatisfactory condition of materials, equipment or surface to be paved, or such other conditions as he or she shall consider detrimental to the work.

(b) Surface Preparation and Cleaning

Prior to constructing a polymer modified asphaltic concrete pavement layer, the surface to be covered shall have been prepared in accordance with the appropriate Sections of this Specification. Notwithstanding any earlier approval of this surface, any damage to or deterioration of it shall be made good before polymer modified asphaltic concrete paving work is commenced.

If the surface to be covered is to be provided with a bituminous tack coat, then this shall be applied all in accordance with the provisions of Sub-Section 4.3.2.

(c) Aggregate Handling and Heating

Each aggregate to be used in the polymer modified asphaltic concrete mixes shall be stored in a separate stockpile near the mixing plant. Stockpiles of sand and other fine aggregates shall be kept dry using waterproof covers and other means as necessary. In placing the aggregates in the stockpiles and loading them into the mixing plant's cold aggregate feed bins, care shall be taken to prevent segregation or uncontrolled combination of materials of different gradation. Segregated or contaminated materials shall be rescreened or rejected for use in the Works and removed from the mixing plant site.

The aggregates shall be fed into the dryer at a uniform rate proportioned in accordance with the appropriate job mix formula. The rate of feed for each aggregate shall be maintained within 10% of the rate prescribed, and the total rate of feed shall be such that the plant's screens shall never be overloaded.

The aggregates shall be dried and heated so that when delivered to the mixer they shall be at a temperature in the range 160 °C to 180 °C.

Immediately after heating, the aggregates shall be screened into four (or more) fractions which shall be separately stored in the hot aggregate storage bins in readiness for mixing.

Mineral filler cum anti- stripping agent to be used in the mix shall be stored separately and kept completely dry. Its rate of feed into the plant shall be accurately controlled by weight or volumetric measurement, all to the satisfaction of the S.O.

(d) Heating Polymer Modified Binder

The polymer modified binder shall be heated so that when delivered to the mixer it shall be at a temperature in the range 150 °C to 170 °C.

(e) Mixing Polymer Modifed Asphaltic Concrete

The mixing plant shall be so coordinated and operated as to consistently produce polymer modified asphaltic concrete mixes within the tolerances prescribed in this Specification, all to the satisfaction of the S.O.

i) Mixing in Batch Plants

For each batch the screened hot aggregates shall be weighed out into the aggregate weigh hopper in accordance with the proportions prescribed in the appropriate job mix formula; the sequence of weighing out shall commence with the largest sized aggregate and progress down to the fines, unless the S.O. shall otherwise approve. Mineral filler shall be weighed out into the filler weigh hopper, where this is provided, or added last to the aggregate weigh hopper, in accordance with the job mix formula proportions.

The hot binder shall be weighed out into the binder weigh bucket in accordance with the proportions prescribed in the job mix formula.

The hot aggregates and filler shall be discharged into the pugmill and mixed dry for the dry mixing time prescribed in the job mix formula, which shall usually be in the range five to 10 seconds. The hot binder shall then be added and wet mixing performed for the wet mixing time prescribed in the job mix formula; this shall be sufficient so that all particles of aggregate are uniformly coated with bitumen, and shall usually be 45 seconds or less for dense graded mixtures.

The volume of each batch shall be such that the tips of the pugmill paddle blades just break out of the mixture at the height of their action.

After the completion of wet mixing, each batch of polymer modified asphaltic concrete shall be discharged from the pugmill either into a storage hopper or directly into a truck for hauling to the paving site. Care shall be taken that no segregation of the mix occurs.

ii) Mixing in Drum Mix Plants

The screened hot aggregates and filler shall be fed continuously from their storage bins in accordance with the proportions prescribed in the appropriate job mix formula, combined in the plant, and fed continuously into the mixer. The hot binder shall be sprayed on to the combined aggregate as it enters the pugmill at the rate required to achieve the bitumen content prescribed in the job mix formula. The materials shall then be carried through the pugmill and in the process be thoroughly mixed by the action of the paddles and discharged over the dam into the storage hopper. The mixing time shall be sufficient so that all particles of aggregate are uniformly coated with bitumen, and shall usually be 45 seconds or less for dense graded mixtures.

The plant shall be so adjusted as to maintain the level of mixture in the pugmill such that the tips of the paddle blades just break out of the mixture at the height of their action.

(f) Transporting Polymer Modified Asphaltic Concrete

Polymer modified asphaltic concrete shall be transported from the mixing plant to the site of the paving works in loads of not less than 5 tonnes using tip-trucks as specified in Sub-Section 4.11.4 (c). Except where polymer modified asphaltic concrete is to be hand laid, it shall be discharged directly into the paver hopper, as required, from the tip-trucks. Care shall be taken in the truck loading, hauling and unloading operations to prevent segregation of the mix. During transportation, the polymer modified asphaltic concrete shall be protected from contamination by water, dust, dirt and other deleterious materials.

The temperature of polymer modified asphaltic concrete immediately before unloading from the truck either into the paver hopper or on to the road for hand spreading shall be not less than 150 °C. Any load which has cooled below the specified temperature in the truck shall be rejected for use in the Works and removed from the Site of the Works.

(g) Laying Polymer Modified Asphaltic Concrete

The sequence of laying operations shall be planned in advance by the Contractor and approved by the S.O. Generally each paving layer shall have a compacted thickness of not less than twice the nominal maximum aggregate size of the mixture, and not more than 100 mm. Where applicable, e.g. on superelevated sections and on carriageways with cross-slope in one direction only, laying shall commence along the lower side of the

carriageway and progress to the higher side. Laying shall not be carried out in a downhill direction along any section of road.

As far as is practicable, laying shall be carried out using a paver approved by the S.O. Hand-casting of bituminous mix on to the machine finished surface shall be kept to the practicable minimum necessary for correcting blemishes and irregularities. In any areas inaccessible to the paver, laying shall be carried out by hand methods using rakes, lutes and other hand tools, all to the satisfaction of the S.O. All laying of bituminous mix shall be such that after compaction by rolling the specified course or layer thickness and surface profile shall be achieved. Care shall be taken to achieve a uniform surface texture free from indentations, ridges, tear marks or other irregularities, and to prevent segregation of the mix.

At the commencement of initial rolling, the temperature of polymer modified asphaltic concrete shall be as determined form the viscosity-temperature relationship. Material which has cooled below the specified temperature before laying shall not be used and shall be removed from the Site of the Works. The Contractor shall provide accurate thermometers at the paving site at all times, and shall check the temperature of asphaltic concrete in the paver hopper at regular intervals and before laying restarts after each interruption of the paving operation.

As far as is practicable, the paver shall be operated continuously and the supply of bituminous mix shall be regulated so as to enable continuous paving. Transverse joints in a paving lane shall be kept to a practicable minimum, and intermittent stopping and restarting of the paver shall be avoided as far as is practicable.

Care shall be taken that no bituminous mix is placed on expansion joints at bridges, inspection covers for utilities ducts, drainage and sewerage manholes and the like, and that catchpits, drainage openings through kerbs, etc., remain properly open and serviceable. During laying operations, such areas and openings shall be protected by suitably shaped and secured boards or other materials approved by the S.O., and compaction of mix in the immediately surrounding or adjacent areas shall be completed by hand methods, all to the satisfaction of the S.O. Alternatively, bituminous mix shall be laid and compacted by hand methods as necessary around surfacing discontinuities of these types, all to the satisfaction of the S.O.

(h) Construction Joints

Existing bituminous surfacing which new bituminous mix is to adjoin shall be cut back to present a straight, vertical edge not less than 25 mm deep and a smooth transition section not less than 500 mm long against which to lay the new material. The specified thickness of the new surfacing shall be built up gradually from the vertical joint to avoid any bumps or ridges across the carriageway.

Where longitudinal or transverse joints are required in a layer of bituminous mix under construction, the material first laid and compacted shall be cut back to a vertical face for the full thickness of the layer on a line satisfactory to the S.O. before the adjacent area is paved.

At all construction joints, a thin uniform coating of bitumen emulsion of grade RS-1K shall be brushed on to the vertically cut joint faces some 10 to 15 minutes before laying the next section of bituminous mix commences to ensure good bonding. Also, all contact surfaces of kerbs, gutters, manholes, catchpits, etc. shall be similarly treated with a coating of bitumen emulsion before bituminous mix is placed against them.

Construction joints in a layer of bituminous mix shall be offset from those in any immediately underlying bituminous layer by at least 100 mm for longitudinal joints and at least 500 mm, for transverse joints.

Construction joints shall not be permitted along wheelpaths.

(i) Compacting of Polymer Modified Asphaltic Concrete

For each layer of polymer modified asphaltic concrete, compaction by rolling shall commence at temperature as determined from the viscosity-temperature relationship during the mix design process.

In any areas inaccessible to the rollers, proper compaction shall be carried out using vibrating plate compactors, hand tampers or other suitable means, all to the satisfaction of the S.O.

Initial (or breakdown) rolling shall be carried out with an approved steel wheeled tandem roller. The principal heavy rolling shall be carried out with an approved pneumatic tyred roller immediately following the initial rolling; the pneumatic tyred roller shall be ballasted to an operating weight of not less than 15 tonnes and its tyre inflation pressure shall be not less than 0.7 N/mm^2. The final rolling shall be carried out with an approved steel wheeled tandem roller and shall serve to eliminate minor surface irregularities left by the pneumatic tyred roller.

All rollers shall operate in a longitudinal direction along the carriageway with their driven wheels towards the paver. Rolling shall generally commence at the lower edge of the paved width and progress uniformly to the higher edge, except that where there is a longitudinal construction joint at the higher edge, this shall be rolled first ahead of the normal pattern of rolling. Generally, successive roller passes shall overlap by half the width of the roller, and the points at which the roller is reversed shall be staggered. However, when operating on gradients in excess of 4%, the breakdown roller shall not pass over any previously unrolled mix when operating in the downhill direction.

In all cases, compaction shall be carried out in such a manner that each section receives equal compactive effort, all to the satisfaction of the S.O.

The steel wheeled rollers shall operate at speeds of not more than 5 km/h and the pneumatic tyred rollers shall operate at speeds of not more than 8 km/h. No roller or heavy vehicle shall be allowed to stand on newly laid bituminous mix before compaction has been completed and the material has thoroughly cooled and set. Rolling shall continue as long as is necessary to achieve the appropriate requirement as shown in Table 4.11.6.

TABLE 4.11.6: REQUIREMENTS OF COMPACTED DENSITY FOR POLYMER MODIFIED ASPHALTIC CONCRETE

Type of Pavement Layer	Required Compacted Density
Wearing course	98 - 100% of Marshall density
Binder course	95 - 100% of Marshall density

Care shall be taken to prevent over-compaction of polymer modified asphaltic concrete.

Within 24 hours of laying and compacting the bituminous mix, the Contractor shall cut core samples of not less than 100 mm nominal diameter at locations selected by the S.O. The rate of sampling shall be one sample per 500 m^2 of mix laid, but not less than two samples for the work completed in each paving session. These core samples shall be used by the S.O. to determine the compacted thickness and density of the material in accordance with ASTM Test Method D 2726.

(j) Finished Polymer Modified Asphaltic Concrete

Polymer modified asphaltic concrete binder and wearing courses shall be finished in a neat and workmanlike manner; their widths shall be everywhere at least those specified or shown on the Drawings on both sides of the centre-line; the average thickness over any 100-metre length shall be not less than the required thickness, and the minimum thickness at any point shall be not less than the required thickness minus 5 mm.

The top surface of a wearing or binder course shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances specified in Sub-Section 4.5.

The International Roughness Index (IRI) value of the finished wearing course surface shall be carried out as described in Sub-Section 4.5 and shall be not more than 2.0 m/km.

(k) Opening to Traffic

Polymer modified asphaltic concrete shall not be opened to traffic until compaction has been completed and the material has thoroughly cooled and set in the opinion of the S.O. This will usually be not less than four hours after the commencement of rolling. Where it is necessary to allow earlier use of the finished surface to facilitate the movement of traffic, vehicles may be allowed to run on the work after rolling has been completed, provided that speeds are restricted to 30 km/h or less and sharp turning movements are prohibited.

SURFACE TREATMENT 1 - CHIP SEAL

CHIP SEAL

Chip Seal is an application of a binder in the form of an emulsion or bitumen, followed by an application of single-size aggregate. It is used to correct functional pavement distresses only such as bleeding, polishing, ravelling etc. Chip Seal is a three-stage process; after the existing surfacing has been prepared by patching, cracks are filled by spraying binder, followed by application of single size aggregates. The final operation is several passes of pneumatic tyre roller. The road is usually opened to traffic after sweeping excess aggregates or may be immediately opened to slow moving traffic.

Chip Seal is used to restore skid resistance, provide water proofing layer and retard binder hardening.

Polymer modified emulsion or bitumen can be used to mitigate reflection cracking. Chip Seal is an economical surface treatment designed to protect and prolong the pavement life.

Chip Seal on aged but structurally sound pavement surfacing will help to prolong the pavement functional condition. Chip Seal can be used on new bituminous surfacing to increase skid resistance.

Chip Seal shall not be applied on pavements suffering from structural deficiency. To minimise windscreen breakages due to flying aggregates, rolling shall be completed before the emulsion breaks to ensure adequate embedment of aggregates into the binder.

4.12 SURFACE TREATMENT 1 - CHIP SEAL

4.12.1 Description

This work shall consist of furnishing, placing and shaping chip seal surfacing as a wearing course. This specification shall be read in conjunction with Sub-Section 4.3 of the Standard Specification for Road Works of JKR (JKR/SPJ/2008). All requirements in the Sub-Section 4.3 shall apply unless stated otherwise in this Specification.

Chip sealing (also known as surface dressing) is a thin surfacing course that involves sequential application of bitumen and chipping, either singly or in layers. It is primarily applied to restore the surface characteristics of an aged surface such as surface texture and skid resistance. It can also be applied on new pavements to provide more durable surface. Pavements with structural failures should be treated prior to chip sealing work.

4.12.2 Materials

4.12.2.1 Coarse Aggregate

Coarse aggregate shall be screened crushed hard rock, retained on 5.0 mm sieve, angular in shape and free from dust, clay, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The loss by abrasion and impact in the Los Angeles machine when tested in accordance with ASTM C 131 shall be not more than 25%.

ii. The flakiness index when tested in accordance with MS 30 shall be not more than 25%.

iii. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 18%.

iv. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

v. The polished stone value when tested in accordance with MS 30 shall be not less than 40.

Notwithstanding compliance with the aforementioned requirements, crushed or uncrushed limestone and gravel shall not be permitted.

4.12.2.2 Fine Aggregate

Fine aggregate shall be screened quarry dust. They shall be non-plastic and free from clay, loam, aggregations of material, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 20%.

ii. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

iii. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

iv. The fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.

v. The Methylene Blue value when tested in accordance with Ohio Department of Transportation; Standard Test Method shall be not more than 10 mg/g.

4.12.2.3 Bituminous Binder

(a) Conventional Bitumen

Conventional bitumen used for binder shall be penetration grade 80-100. Prior to the commencement of the chip sealing works, the Contractor shall provide to the S.O. test results from a sample of conventional bitumen which shall comply with MS 124. During executing the Works, the Contractor shall obtain manufacturer's compliance certificates for the bitumen from which the material delivered to site is sourced.

(b) Polymer Modified Bitumen

Polymer modified bitumen shall be a mixture of penetration grade 80-100 bitumen and 8% of minus 40 mesh size scrap rubber additive, or otherwise approved by S.O.

The Contractor shall provide manufacturer's certification of polymer properties which shall conform with the following Production Control Properties;

Minimum 20% Torsional Recovery at 25 °C when tested in accordance with Austroads Modified Binder Test, MBT 22:1995 (**Appendix 5**)

(c) Bitumen Emulsion

Bitumen emulsion shall be RS-3K conforming to MS 161. The Contractor shall provide manufacturer's test results showing compliance of the batch from which the material to be incorporated into the Works is sourced.

Rubber/polymer modified emulsion shall be approved by the S.O. The emulsion shall be anionic or cationic, as appropriate to the source rock, and shall have a minimum bitumen content of 60%. The spraying temperature of the emulsion shall be between 25 and 45 °C and it shall be utilised within 90 days of manufacture.

(d) Cutter and Flux

Kerosene shall be used as cutter while diesel as flux.

(e) Precoat and Adhesion Agent

Precoat shall conform to the following blend;

Bitumen residue (by volume)	50%
Kerosene (by volume)	49%
Adhesion agent (by volume)	1%

Adhesion agent shall be Wetfix N422 or equivalent.

4.12.2.4 Gradation of Combined Aggregate

Checks on the gradation of combined aggregate shall be undertaken each week to ensure compliance with Table 4.12.1. Test results for any aggregate intended for incorporation into the Works from other than previously approved sources shall be provided.

Subsequent testing of any materials for which compliance certificates have already been provided shall be undertaken at the expense of the S.O.

TABLE 4.12.1: GRADATION LIMIT OF COMBINED AGGREGATE

	PERCENTAGE %		
Sieve (mm)	14 mm	10 mm	6 mm
25.0	-	-	-
20.0	100	-	-
14.0	85 - 100	100	-
10.0	0 - 20	85 - 100	100
6.3	-	0 - 20	85 - 100
4.75	0 - 5	0 - 10	0 - 25
2.36	0 - 2	0 - 2	0 - 10

4.12.2.5 Plant, Equipment and Personnel

The Contractor shall supply all plant, equipment and personnel necessary for the competent execution of the Works.

(a) Personnel

The Contractor shall ensure that sprayer driver and operator are skilled and trained with an understanding of sprayer calibration and an appreciation of the requirements of the Works. The Contractor shall also ensure relevant personnel understand the types and quantities of the various materials and mixtures to be used.

(b) Pressure Distributor for Bituminous Materials

The Contractor shall provide documentation to show that the binder distributor has undergone initial calibration, and that it satisfies the requirements of a transverse distribution test wherein the variation in output between adjacent 100mm wide sections is within plus/minus 15% of the average over the full spray bar width, excluding the external 250mm of each end of the spray bar.

The distributor shall have suitable controls to maintain constant speed in the range of 5 - 10 km/h as recorded on a reliable speedometer fitted to the fifth wheel. The distributor shall be fitted with heating elements capable of heating the binder to at least 200 °C and shall be capable of spraying the binder uniformly at this temperature.

(c) Storage and Heating Facilities for Bituminous Materials

The Contractor shall provide on-site heating tank to store excess bituminous binder. The tank shall be so equipped as to enable stored binder to be sufficiently heated to enable the binder to be pumped, and it shall have agitation facilities to ensure homogeneity of blended binders.

The tank shall be fitted with temperature controls to ensure that the binder temperature does not exceed spraying temperatures.

(d) Aggregate Spreading Equipment

The Contractor shall use mechanical spreader of a type capable of spreading aggregate uniformly over the full width of the area being treated, and having suitable controls to allow adjustment of the application rate during the spreading operation.

Sufficient tipping trucks shall be provided to enable full coverage of each sprayed area.

Any bituminous material adhering to tyres which might cause pick-up of cover aggregate shall be cleaned. Any vehicles which leak fuels shall be removed from the Works site.

(e) Pneumatic Tyre Roller

Pneumatic tyre roller shall be self-propelled, equipped with power steering and dual controls allowing operation from either left or right side and capable of being reversed without backlash. The roller shall have nine wheels fitted with smooth tyres of the same size and constriction, capable of being inflated to pressures up to 0.6 N/mm2.

Any bituminous material adhering to tyres which might cause pick-up of cover aggregate shall be cleaned. Any rollers which leak fuels shall be removed from the Works site.

(f) Power Broom

The Contractor shall provide a rotary power broom of a type specifically designed for removing material from road surfaces.

4.12.2.6 Traffic Control

All temporary traffic controls shall comply with the requirements of Arahan Teknik (Jalan) 2C/85. Traffic control plan shall be submitted for approval by S.O. at least 48 hours prior to commencement of the Works.

The Contractor shall set out all traffic control devices and position traffic control personnel prior to establishing plants on the road.

Traffic control shall be maintained at all times to ensure the safety of traffic through and around the Works.

4.12.2.7 Treatment of Existing Surface

(a) Description

Prior to the construction of chip seal, failed areas in the existing pavement shall be treated to provide a sound surface for chip sealing works. All materials used for this purpose shall comply with requirements of Sub-Sections 4.2 and 4.3.

(b) Pothole Repairs

The Contractor shall inspect the site, locate and mark out damaged pavement. Damaged portions shall be removed to expose the roadbase and the excavated materials shall be disposed to a suitable site. The roadbase shall be reshaped and recompacted.

(b) Pothole Repairs

The Contractor shall inspect the site, locate and mark out damaged pavement. Damaged portions shall be removed to expose the roadbase and the excavated materials shall be disposed to a suitable site. The roadbase shall be reshaped and recompacted.

For prime coat prior to placing binder course, cut-back bitumen of grade MC-70 conforming to MS 159 or bitumen emulsion of grade SS-1K conforming to MS 161 shall be used. Application rate shall be between 0.5 and 1.0 litre/m^2.

For tack coat prior to placing wearing course, bitumen emulsion of grade RS-1K conforming to MS 161 shall be used. Application rate shall be between 0.25 and 0.55 litre/m^2.

Potholes in excess of 80mm depth shall be patched using asphaltic concrete AC 28, compacted flush with the existing level. Potholes less than 80mm depth shall be patched using asphaltic concrete AC 14, compacted flush with the existing level.

(c) Surface Failure Repairs

The site shall be inspected to locate and mark areas with surface failures. Surface failures shall be milled off to a depth of 50mm or 100mm as appropriate, and the debris shall be removed from site. Milling shall be carried out in the longitudinal direction and a uniform milling depth in the transverse direction shall be maintained. Prior to overlaying milled-off surface, all debris and granular materials shall be removed. Bituminous tack coat shall be applied to the surface before overlaying.

Bitumen emulsion of grade RS-1K shall be used for tack coat on milled-off surface. Application rate shall be between 0.25 to 0.55 litre/m^2.

Prepared milled-off surface shall be overlaid with 50mm or 100mm thickness of AC 14 as appropriate.

(d) Pavement Reconstruction

Areas to be reconstructed shall be located and marked out, and the extent of such treatment shall be proposed to the S.O.

Upon the S.O.'s approval, damaged areas shall be excavated and removed to a depth deemed necessary for the treatment, but not exceeding 1m deep from the existing surface. Excavated materials shall be disposed to a suitable site, and the exposed subgrade shall be scarified and recompacted.

Excavated areas shall be filled with sub-base and roadbase materials conforming to the requirements of Sub-Section 4.2. Each layer shall be reshaped and recompacted to the required density. Where the treatment requires substitution of good materials to a depth deeper than 1m, such requirement shall be notified to the S.O. who shall then issue instructions for the necessary actions.

The thickness of sub-base and roadbase to be reconstructed shall normally match the thickness found in the existing road. However, the compacted thickness of sub-base and roadbase shall not be less than 100mm and 300mm respectively.

For prime coat, cut-back bitumen of grade MC-70 conforming to MS 159 or bitumen emulsion of grade SS-1K conforming to MS 161 shall be used at application rate between 0.5 and 1.0 litre/m^2.

For tack coat, bitumen emulsion of grade RS-1K conforming to MS 161 shall be used at application rate between 0.25 and 0.55 litre/m^2.

Prepared roadbase shall be overlaid with asphaltic conerete AC 28, flushed with the existing pavement level. The compacted thickness of AC 28 shall normally match the thickness found in the existing pavement However, it shall not be less than 100mm.

(e) Regulation with Leveling Course

Pavement areas which need regulating or overlaying shall be located and marked, and the amount of bituminous mix necessary for this work shall be surveyed and estimated. Upon the S.O.'s approval, these areas shall be prepared to receive regulating or overlay course. All debris and loose materials shall be removed before applying tack coat. Surface irregularities shall be regulated to restore crossfall profile.

Bitumen emulsion of grade RS-1K shall be used as tack coat on milled-off surface. Application rate shall be between 0.25 and 0.55 litre/m^2.

Asphaltic concrete AC 14 shall be used for regulating and overlay courses in excess of 40mm thickness and asphaltic concrete AC 10 for courses with less than 40mm thick.

(f) Crack Sealing

Areas for crack sealing shall be located and marked, and all detritus, vegetation and moisture from within and adjacent to the cracks shall be removed.

Rubberised bituminous product shall be applied into the cracks by means of a hand lance or other appropriate equipment. Avoid excessive application of the bitumen.

The treated areas shall be excluded form traffies until the crack sealing material has 'set up' and there is no likelihood of the material adhering to vehicle tyres. Crusher fines or similar shall be applied when necessary to prevent 'pick-up'.

4.12.3 Surface Preparation

The pavement surface shall be swept to remove loose stones, dust, dirt and foreign matter immediately before spraying.

For unkerbed roads, sweeping shall be extended by 0.5 m clear of the area to be sealed.

Adherent patches of foreign material and water shall be removed prior to applying the binder.

All pavement markers and adjacent fixtures and properties shall be protected from contamination by bitumen.

4.12.4 Setting Out

The Contractor shall mark out by string line or paint where necessary and this shall include pavement widening.

4.12.5 Stockpile Sites

A separate site for each aggregate size shall be provided. Allow 5 metres between adjacent sites.

The sites shall be well drained and on hard ground. Every precaution shall be taken to prevent dust from coating precoated chippings to such a degree as would prevent the precoated chippings from adhering to hot binder. Access roads to stockpile sites shall be maintained.

Sites under trees, telephone lines, overhead transmission lines or where overhead clearance is less than 6 metres shall be avoided.

All vegetation to 5 metres beyond stockpile boundary shall be cleared. Any non-conforming aggregate shall be removed from site.

Every precaution shall be taken to ensure that the aggregate remains dry.

4.12.6 Precoating Aggregate

A uniform film of precoating material to the aggregate shall be applied at an application rate of between 8 and 12 litres/m^3.

Aggregate which has been excessively precoated to the extent that it forms lumps shall be rejected.

Aggregate which has been insufficiently precoated shall be resprayed to achieve a uniform black coating to the aggregate.

4.12.7 Spraying of Binder

4.12.7.1 Preparation

The S.O. shall be informed at least 48 hours of the intention to spray bitumen.

Trial run shall be undertaken to confirm the calibration of the Pressure Distributor.

4.12.7.2 Weather Conditions

Spraying shall commence only when pavement temperature is in excess of 20 °C, or has been in excess of 15 °C for at least one hour.

Cease spraying if rain threatens, or in windy or dusty conditions. Protect the work in the event of an adverse change in weather by closing the affected section of road or by rigidly controlling traffic speed.

4.12.7.3 Preparing the Sprayer

The mixture in the sprayer shall be circulated.

The horizontal and vertical alignment and the cleanliness of the spray bar and its extensions shall be checked. Determine the appropriate number of nozzles for the width to be sprayed. Ensure the end nozzles fitted are the correct type and the nozzles are not chocked at all time.

The alignment and setting of the nozzle shall be checked to ensure that the fans of material from intermediate nozzles are parallel and at an angle of 30 degrees to the center line of the spray bar. Ensure that the fans from the end nozzles are parallel to each other and at an angle of 45 degrees to the center line of the spray bar.

The height of the spray bar shall be set so that the lower faces of the nozzles are 250mm above the pavement when the sprayer is full.

Shielding shall be provided when necessary to prevent spraying material on the kerb, or to counter any wind effects which would compromise uniform spraying.

The guide rod shall be positioned to conform to the setting out and edges of spray. Check by making a dummy run.

Protection sheeting shall be provided at end nozzles to protect traveling vehicles from being smeared.

4.12.7.4 Preparing the Sprayer Run

The volume and temperature of the sprayer contents shall be recorded while it is on level ground. The length of sprayer run shall be determined from the available quantity in the sprayer and the application rate. For chip sealing works, the Contractor shall ensure that the area to be sprayed is not greater than the area that can be covered by aggregate in the loaded trucks.

Each spray run shall start on a protective strip of paper placed on the pavement. The paper shall be wide enough to ensure the pavement is protected for the full width of spray. Place sufficient protective paper to protect road fixtures.

Whenever the sprayer is stationary on the road pavement, paper shall be placed on the pavement as masking around areas to be sprayed and beneath time spray bar.

4.12.7.5 Sprayer Run

Uniform spraying speed shall be attained before spraying commences.

Avoid an excess or defieiency of material due to faulty overlap at longitudinal joints when spraying a road in part widths.

Overlap shall be 300mm with an intermediate nozzle. End nozzles shall not be used on an overlap.

Spraying shall be stopped before the level of material in the tank falls to a level which reduces the full discharge of the pump.

Remove and dispose of all cut-on/off paper.

Clean off any sprayed material from road fixtures.

4.12.7.6 Application Rates

Polymer modified bitumen shall be applied within the following parameters;

1.50 - 1.70 litres/m^2
1.30 - 1.50 litres/m^2
1.10 - 1.30 litres/m^2

4.12.7.7 Hand Spraying

Work shall be planned in advance to minimize the requirement for the use of a hand sprayer. Any strips of pavement not adequately covered with sprayed material shall be sprayed later with the hand attachment.

4.12.7.8 Heating and Storage of Binder.

Bituminous materials shall not be heated to spraying temperatures too soon in advance of requirements. Avoid heating the bitumen in quantities excess to requirements and holding the bitumen beyond 10 hours at spraying temperatures. The bitumen shall be stored or held at temperatures below minimum spraying temperature. It shall be heated to spraying temperatures but shall not exceed maximum.

The bitumen shall be removed from the site where;

i. Stored/held beyond 48 hours at temperatures exceeding 120 °C.

ii. Heated to above 190 °C for straight run bitumen or above the maximum recommended temperatures specified by the polymer manufacturer.

4.12.7.9 Spraying Temperatures

Unmodified bitumen shall be sprayed within the range 150 to 180 °C whereas polymer modified bitumen shall be sprayed within the range 180 to 200 °C.

4.12.8 Application of Aggregate

4.12.8.1 Application Rates

Aggregate application rates shall be maintained within the following parameters;

Nominal 14mm aggregate	12 - 18 kg/m^2
Nominal 10mm aggregate	8 - 12 kg/m^2
Nominal 6mm aggregate	5 - 8 kg/m^2

Spread the aggregate evenly and uniformly over the sprayed surfaee.

Avoid placing aggregate more that one stone deep.

Use a mechanical spreader.

Re-run or hand cover bare or insufficiently covered places after the first spreading.

4.12.8.2 Rolling of Chippings

The treated surface shall be rolled with self-propelled rubber tyre rollers with a minimum tyre pressure of 600 kPa and a minimum wheel load of 1 tonne.

After initial slow pass, the roller speed shall be between 10 and 25 km/h.

Rolling shall conform to the following minimum requirements;

i. Entire area to receive one roller pass immediately after covering.

ii. 25% of rolling requirement to be completed within 20 minutes of covering.

iii. Minimum of 50% of rolling requirement to be completed on the same day as covering next day after covering.

Minimum rolling requirement: Eight (8) complete roller passes.

For two coat treatments when the second coat is to be applied immediately, the total rolling on the first coat shall be double that specified.

Rolling shall be done in daylight hours only. Sweep the surface after rolling. Ensure a uniform distribution of aggregate.

Drag broom shall be adjusted to distribute surplus aggregate, but not to dislodge embedded aggregate. Ensure aggregate on the final surface is uniformly distributed, and firmly held by the binder.

4.12.9 Traffic

Prohibit traffic;

i. from new work until at least 100% of rolling has taken place.

ii. from adjacent strip of roadway during spraying.

All loose aggregate shall be removed from the new work.

4.12.10 Waste Material

All waste materials shall be removed from the site and disposed.

4.12.11 Conformance

Any work on which the binder is applied at less than 90%, or more than 115% of the design application rate shall be rectified at the Contractor's own expense.

4.12.12 Measurement and Payment

4.12.12.1 Binder Application

Measured in square metres of area coated for each of the following application rates;

i. 1.50 - 1.70 litres/m^2
ii. 1.30 - 1.50 litres/m^2
iii. 1.10 - 1.30 litres/m^2

Payment shall be made for the total area sprayed, as recorded on binder application sheets.

4.12.12.2 Aggregate Application

Measured in square metres for each of the following;-

Nominal 14mm aggregate
Nominal 10mm aggregate
Nominal 6mm aggregate

Areas for each aggregate size shall be determined from records of binder application.

4.12.12.3 Precoat Applied to Aggregate

Not measured for payment purposes.

Measured in square metres for.mark, clean and seal with crack filler material.

SURFACE TREATMENT 2 - MICRO-SURFACING

MICRO-SURFACING

Micro-Surfacing is a modified version of slurry seal and was introduced in Canada in early 1990s. Micro-Surfacing consists of a mixture of polymer modified bitumen emulsion, selected mineral aggregate, mineral filler, water and other additives such as cement and latex, properly proportioned, mixed and spread on existing bituminous surfacing.

Micro-Surfacing is used to restore the surface characteristics of pavement or to preserve pavement surfacing. This surfacing mixture can be designed to correct rutting, improve skid resistance, seal surface cracks, protect pavement surfacing against hardening, and improve surface texturing. With relatively short curing time of about one hour, it minimises disruption to traffic.

Micro-Surfacing may be used on low and high traffic roads to fill ruts, improve skid resistance and riding quality and arrest ravelling. This system is well suited as preventive maintenance treatments to extend the life of sound pavements.

Micro-Surfacing is a thin surface treatment, thus it is not appropriate to resolve pavement structural deficiencies. This mixture shall not be used on pavement surfacing having major and active cracks.

4.13 SURFACE TREATMENT 2 - MICRO-SURFACING

4.13.1 Description

This work shall consist of furnishing, placing and shaping Micro-Surfacing as a wearing course. This Specification shall be read in conjunction with Sub-Section 4.3.3 of the Standard Specification for Road Works of JKR (JKR/SPJ/2008). All requirements in the Sub-Section 4.3.3 shall apply unless stated otherwise in this Specification.

Micro-Surfacing shall consist of a mixture of quick setting polymer modified asphalt emulsion, selected mineral aggregate, mineral filler, water and other additives, properly proportioned, mixed and spread on a paved surface in accordance with this Specification and/or as directed by the S.O. The mix shall be able to accept traffic after a short period of time, typically 60 minutes after laying, depending on site conditions.

4.13.2 Materials

4.13.2.1 Coarse Aggregate

Coarse aggregate shall be screened crushed hard rock, retained on 5.0 mm sieve, angular in shape and free from dust, clay, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The loss by abrasion and impact in the Los Angeles machine when tested in accordance with ASTM C 131 shall be not more than 25%.

ii. The flakiness index when tested in accordance with MS 30 shall be not more than 25%.

iii. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 18%.

iv. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

v. The polished stone value when tested in accordance with MS 30 shall be not less than 40.

Notwithstanding compliance with the aforementioned requirements, crushed or uncrushed limestone and gravel shall not be permitted.

4.13.2.2 Fine Aggregate

Fine aggregate shall be screened quarry dust. They shall be non-plastic and free from clay, loam, aggregations of material, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The weighted average loss of weight in the magnesium sulfate soundness test (five cycles) when tested in accordance with AASHTO T 104 shall be not more than 20%.

ii. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

iii. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

iv. The fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.

v. The Methylene Blue value when tested in accordance with Ohio Department of Transportation; Standard Test Method shall be not more than 10 mg/g.

4.13.2.3 Mineral Filler

Mineral filler shall be added as part of the combined aggregate gradation. Ordinary Portland cement that is free of lumps shall be used. The material shall pass 75 μm sieve by not less than 70% by weight and the amount of filler that need to be incorporated shall be determined by a laboratory mix design.

4.13.2.4 Binder

(a) Bitumen Emulsion

The emulsion shall be of a quick-set polymer-modified type. The polymer material shall be milled into the emulsifier solution prior to the emulsification process.

The polymer shall be Styrene Butadiene Rubber (SBR) or natural rubber latex.

When tested, the emulsion and residual bitumen shall meet the following requirements in Table 4.13.1.

TABLE 4.13.1: PROPERTIES OF EMULSION AND RESIDUAL BITUMEN

TEST	DESCRIPTION	SPECIFICATION
RESIDUAL BITUMEN		
ASTM D 36	Softening Point (°C, Ring & Ball)	54 °C minimum
ASTM D 5	Penetration at 25 °C	40 - 90
EMULSION		
ASTM D 244	Viscosity @ 25 °C SSF, seconds	15 - 50
ASTM D 244	Particle Charge Test	Positive
ASTM D 244	Water Content	40% maximum
ASTM D 244	Residue on 850μm	0.1% maximum

(b) Water

The water shall be free of harmful salts and contaminants.

(c) Quick-Setting Additives

Quick-setting additives shall be added to provide the quick-set properties of the mixture. They shall be included as part of the mix design and be compatible with other components of the mix.

4.13.3 Gradation of Combined Aggregates

The aggregate gradation shall be within the limits as specified in Table 4.13.2.

TABLE 4.13.2: AGGREGATE GRADATION

ASTM Sieve Size (mm)	% Passing by Weight	Tolerance (%)
8.0	90 - 100	± 5
4.75	60 - 74	± 5
3.35	45 - 58	± 4
2.0	36 - 50	± 4
1.0	23 - 38	± 4
0.710	20 - 33	± 3
0.090	5 - 12	± 3

4.13.4 Mix Design

Compatibility of the aggregate, polymer modified bitumen emulsion, mineral filler and additives shall be verified by the mix design. The mix design shall be made of combined aggregate gradation as shown in Table 4.13.2. The mix properties shall comply with requirements in Table 4.13.3.

TABLE 4.13.3: TEST REQUIREMENTS

DESCRIPTION	SPECIFICATION	TEST
Cohesion; @ 30 minutes @ 60 minutes	 12 kg-cm min. 20 kg-cm min.	ISSA TB-139
Wet track abrasion loss (One hour soak)	75 g/ft^2 (800 g/m^2) max.	ISSA TB-100
Mix time @ 25 °C	40 - 120 sec.	ISSA TB-113

The component materials used in the mix design shall be within the following limits;

TABLE 4.13.4: LIMITS OF COMPONENT MATERIALS

Binder content (%)	5.5 to 8.0 by weight of combined aggregates.
Mineral filler	0 – 2% by weight of combined aggregates.
Quick-setting additive	As required.
Water	As required to produce proper mix consistency.

4.13.5 Equipment

All equipment, tools and machines used in the performance of this work shall be maintained in satisfactory working condition at all times to ensure a high quality product.

The material shall be mixed by a self-propelled micro-surfacing mixing machine which shall be a continuous flow mixing unit able to accurately deliver and proportion the aggregates, emulsified bitumen, mineral filler, additive and water to a revolving multi-blade double shafted mixer and discharge the mixed product on a continuous flow basis. The machine shall have sufficient storage capacity for the aggregates, emulsified bitumen, mineral filler, additive and water to maintain an adequate supply to the proportioning controls.

4.13.5.1 Proportioning Devices

Individual volume or weight controls for proportioning each material to be added to the mix (i.e. aggregate, mineral filler, emulsified asphalt, additive and water) shall be provided and properly marked.

These devices are usually revolution counters or similar devices and are used in material calibration and determining the materials output at any time.

4.13.5.2 Machine Calibration

Each mixing unit to be used in performance of the work shall be calibrated prior to construction. The documentation shall include the individual calibration of each material at various settings, which can be related to the machine metering devices.

4.13.5.3 Spreading Equipment

The mixture shall be spread uniformly by means of a conventional augured surfacing spreader box attached to the mixer and equipped with paddles to agitate and spread the material evenly throughout the box. A front seal shall be provided to insure no loss of the mixture at the road contact point. The rear metal seal shall act as final strike-off and shall be adjustable. The spreader box shall have suitable means provided to side shift the box to compensate for variations in the pavement geometry.

4.13.5.4 Auxiliary Equipment

Suitable surface preparations equipment, traffic control equipment hand tools and any other support equipment shall be provided as necessary to perform the work.

4.13.6 Surface Preparations

The area to be surfaced with micro-surfacing shall be thoroughly cleaned of vegetation, loose material, silt spots and other objectionable material. Water used in pre-wetting the surface shall be applied by the mixing machine immediately ahead of the spreader box at a rate to dampen the surface without any free flowing water allowed. Manholes and other service entrance shall be protected from the micro-surfacing by a suitable method. Area with base and/or subgrade failures shall be reconstructed accordingly from the subgrade/base up to the wearing course.

4.13.7 Application

The surface may be pre-wetted by fogging ahead of the spreader box. The micro-surfacing shall be of the desired consistency upon leaving the mixer. A sufficient amount of material shall be carried in all parts of the spreader box at all times so that a complete coverage is obtained.

4.13.7.1 Unsuitable Weather

Work shall stop during the period of heavy rain or when there is standing water on the surface.

4.13.7.2 Thickness and Spreading Rate

The micro-surfacing mixture shall be of proper consistency at all times so as to provide the application rate required by the surface condition. The application shall be undertaken in two layers, with an initial regulating layer followed by a uniform wearing course carpet giving a total combined thickness for both the layers between 10 - 12 mm in thickness. The recommended spreading rate for the micro-surfacing using the 0 - 8 mm aggregate gradation shall be between 18 - 25 kg/m^2 for two layers.

4.13.7.3 Joints

No excessive build-up, uncovered areas, or unsightly appearance shall be permitted on longitudinal or transverse joints. The contractor shall provide suitable width spreading equipment to produce a minimum number of longitudinal joints throughout the project.

4.13.7.4 Mix Stability

The Micro-Surfacing shall possess sufficient stability so that premature breaking of the material in the spreader box does not occur. The mixture shall be homogeneous during and following mixing and spreading.

4.13.7.5 Hand Work

Areas that cannot be reached with the mixing machine shall be surfaced using hand squeegees to provide complete and uniform coverage. If necessary, the area to be hand worked shall be lightly dampened prior to mix placement.

4.13.8 Site Control

Throughout mixing periods, the mix proportions shall be rigidly controlled and the weight of all materials incorporated there shall be recorded. The quantity of bitumen emulsion used and the rate spread of the mixed material in terms of kilograms of aggregates per square metre shall also be recorded for each load of aggregates.

4.13.8.1 Test Requirements

Whenever spreading is taking place, the tests prescribed in the Table 4.12.5 shall be carried out. A copy of the results for each of the tests and for each recorded rate of spread shall be given to the S.O.

TABLE 4.12.5: AGGREGATE GRADATION

Test	Frequency
Binder content in cured mix	2 samples / machine load
Grading of samples of aggregates	2 samples / machine load

4.13.8.2 Finished Surface

The finished Micro-Surfacing shall be of uniform surface texture and appearance throughout the work, without variations within the lane width, or from lane to lane and shall be free from holes, streaks and surface irregularities. Any Micro-Surfacing, which does not comply with the clause, or is non-uniform in surface texture or appearance, shall be made good by replacement of fresh material. Any surface which shows continual material loss, or extension non-adherence to the substrate shall be made good by removal and replacement of fresh material.

4.13.8.3 Trafficking Time

The process shall be such that the laid material may be opened to traffic within typically sixty (60) minutes.

4.13.8.4 Protection of Newly Laid Surface

Traffic shall be kept off newly treated surfaces until material is deemed to have set, and traffic speeds shall be kept to a minimum until the surface does not experience detrimental effects.

4.13.8.5 Skid Resistance

The skid resistance value of the completed material on carriageway shall have a minimum average value of 46 (corrected to 35 °C) as measured by the SRT pendulum device or equivalent for a number of tests to be agreed by the S.O. and the Contractor, depending on the size and type of site involved.

4.13.8.6 Remedial Measures

The Contractor shall carry out appropriate remedial works on failed Micro-Surfacing works, the type and extend of which shall be at the discretion of the S.O.

SURFACE TREATMENT 3 - CRACK SEALING

CRACK SEALING

Crack sealing is a preventive road maintainance technique whereby cracks in the road surfacing are sealed to prevent water from infiltrating into the underlying pavement layers. The water, once in the pavement structure, can cause early failure of road pavement in a number of ways;

i. It can stripping of the bitumen from the aggregates, decreasing strength of the bituminous mixture.
ii. Forces from passing traffic will exert hydraulic pressure in the water trapped inside the cracks. The pressure will then be transmitted to the sound areas and break them open.
iii. It can weaken the road base and sub base and eventually the subgrade. This will result in increased deflections and accelerating deterioration of the surface due to development of more and wider cracks, depressions and potholes. This will ultimately lead to failure and the need reconstruction.

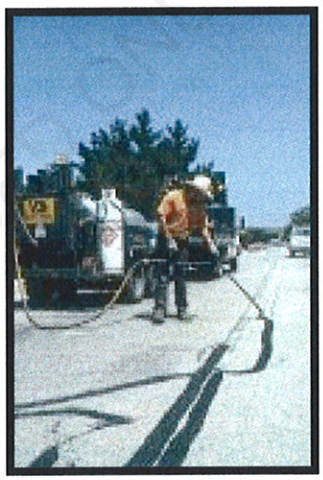
There are many crack sealing material in the market, each with distinct characteristics. The principal material types are;

i. Cold-applied polymer modified bitumen emulsion,
ii. Hot-applied polymer modified bitumen, and
iii. Chemically cured thermosetting materials.

The best candidates for crack sealing are relatively new pavement that are begining to from cracks, with crack width greater than 3 mm.

Crack sealing is not recommended on crocodile cracks, high-density multiple cracks and other types of crack which are due to structural damage.

Prior to crack sealing, the cracks must be free of all dirt, dust, debris, moisture and other foreign materials. The crack sealant shall have a clean, dry bonding surface. This shall be accomplished with compressed air and a simple blow pipe. The area to be sealed shall be kept clean and dry until all sealing operations are completed.



In a crack sealing operation, appropriate crack sealant is either poured or sprayed into the crack. The surface is then blinded with sand and finished with a rubber squeegee.

4.14 SURFACE TREATMENT 3 - CRACK SEALING

4.14.1 Description

This work shall consist of furnishing and placing specialised crack sealing materials above or into cracks in the road surfacing to prevent the intrusion of water and incompressible materials into the cracks.

4.14.2 Materials

The crack sealing material shall be able to fill and/or seal the cracks to prevent water and incompressible materials entering the pavement at the surface. The material shall be selected on the basis of the key properties that it has in order to be efficiently placed and perform satisfactorily. Some of the more desirable properties are as follows;

i. Short preparation time.

ii. Quick and easy to place (good workability).

iii. Short curing time.

iv. Adhesiveness.

v. Cohesiveness.

vi. Resistance to softening and flow.

vii. Flexibility.

viii. Elasticity.

ix. Resistance to ageing and weathering.

x. Resistance to abrasion by traffic.

There are many crack sealing materials in the market, each with distinct characteristics. The principal material families and types are as follows;

i. Cold-applied thermoplastic bituminous materials.
   - Bitumen emulsion.
   - Polymer modified bitumen emulsion.

ii. Hot-applied thermoplastic bituminous materials.
   - Penetration grade bitumen.
   - Polymer modified bitumen.

iii. Chemically cured thermosetting materials.
   - Self-leveling silicone.

The desirable properties of these different types of crack sealing materials are shown in Table 4.14.1.

TABLE 4.14.1: CRACK SEALING MATERIAL TYPES AND PROPERTIES

Property	Material Type				
	Emulsion	Bitumen	Polymer Modified Emulsion	Polymer Modified Bitumen	Self-Leveling Silicone
Short preparation	*		*		**
Good workability	*	**	*	**	
Short curing time		**		**	*
Adhesiveness	**	**	*	*	*
Cohesiveness				*	*
Resistance to softening			*	*	**
Flexibility			*	*	**
Elasticity			*	*	**
Resistance to aging				*	**
Resistance to abrasion				**	

* Applicable ** Very applicable

Bitumen emulsion and penetration grade bitumen possess little, if any, flexibility and highly susceptible to temperature. Hence, their use is limited in crack filling for non-working cracks. Similarly, since fiber particles provide minimal elasticity to bitumen and do not significantly affect temperature susceptibility, fiberised bitumen is most appropriate for non-working cracks.

Three materials excluded from the list above are cutback bitumen, mineral-filled (granite dust, limestone dust etc) bitumen and sand-bitumen mixes. Cutback bitumen is rarely used because of environmental hazards, whereas mineral-filled bitumen is not cost-effective. Sand-bitumen mixes are considered to be crack repair (partial-depth patching, spot patching etc.) materials.

4.14.2.1 Polymer Modified Emulsion

Polymer modified emulsion shall be a mixture of bitumen emulsion conforming to MS 161 and appropriate quantity of polymer additive. The resultant mixture shall have the properties as given in Table 4.14.2.

TABLE 4.14.2: PROPERTIES OF POLYMER MODIFIED EMULSION

Property	Requirement	Test Specification
Percentage retained on 850 µm sieve	max 10	ASTM D 244
Saybolt Furol viscosity at 50 °C	min 100, max 400	ASTM D 244
Penetration on residue at 25 °C, 100 g, 5 s	45 – 70	ASTM D 244 & ASTM D 5
Ring and ball softening point on residue	45 – 60 °C	ASTM D 244 & ASTM D 36

4.14.2.2 Polymer Modified Bitumen

Polymer modified bitumen (PMB) shall be a mixture of penetration grade bitumen conforming to MS 124 and appropriate quantity of polymer additive. The polymer shall be non-carcinogenic. The resultant mixture shall be of performance grade PG 70 or higher in compliance with AASHTO Standard M320-02.

The properties of the polymer modified bitumen shall be as given in Table 4.14.3.

TABLE 4.14.3: PROPERTIES OF POLYMER MODIFIED BITUMEN

TEST	REQUIREMENT	TEST SPECIFICATION
PMB prior to Rolling Thin Film Oven Test (RTFOT)		
Viscosity, max. 3 Pa.s, test temperature °C	135 (see Note 1)	ASTM D 4402
Dynamic shear, G/sin δ min. 1.00 kPa, 10 rad/s, test temperature °C	70	AASHTO T 315
Penetration, 100 g, 5 s, 25 C, 0.1 mm.	Report (see Note 2)	ASTM D 5
Ring and ball softening point, min. °C.	55	ASTM D 36
Flash point, min °C	230	AASTHO T 48
Moisture sensitivity test, min. %	80	AASHTO T 283
Emission of toxic gases, max. mg/m^3	15	
PMB after RTFOT (AASHTO T 240 or ASTM D 2872)		
Mass loss, max. %.	1.00	AASHTO T 240 or ASTM D 2872
Dynamic shear, G/sin δ min. 2.20 kPa, 10 rad/s, test temperature °C	70	AASHTO T 315

Notes:

1. The requirement may be waived at the discretion of the S.O. if the supplier warrants that the polymer-modified binder can be adequately pumped and mixed at the temperatures that meet all applicable safety standards.

2. The penetration value shall be taken as the reference for consistency check on the production.

4.14.2.3 Self-Leveling Silicone

Self-leveling silicone shall conform to ASTM D 5893 with specifications as given in Table 4.13.4.

TABLE 4.13.4: SELF-LEVELING SILICONE SPECIFICATIONS

Test	Test Method	ASTM D 5893 Test Criteria*
Extrusion Rate, ml/min	ASTM C 1183	50
Tensile stress at 150% strain (23°C), kPa	ASTM D 412(C)	310
Rheological properties	ASTM D 2202	Type 1, smooth
Tack-Free Time, h	ASTM C 679	5
Bond (-29°C, 100% extension, immersed, non-immersed, oven-aged)	ASTM D 5893	Pass
Hardness (-29°C, type A2)	ASTM C 661	25
Hardness (23°C, type A2)	ASTM C 661	30
Flow	ASTM D 5893	No flow
Ultimate elongation, %	ASTM D 412(C)	600
Accelerated weathering	ASTM C 793	Pass
Resilience, %	ASTM D 5893	75

* Based on 21-day cure time.

4.14.3 Application Methods

Sealing of individual cracks is often regarded as being tedious and time consuming. However, when done correctly, it often provides the most effective treatment in terms of waterproofing and extending the pavement life.

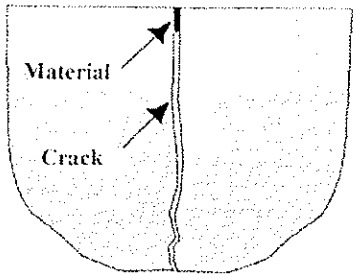
Crack sealing materials shall be placed in cracks in four different configurations as described below.

4.14.3.1 Configurations

(a) Flush Fill

In a flush fill configuration, the crack sealing material shall be simply placed into the existing, uncut crack and excess material is struck off. Figure 1 illustrates the flush fill configuration.

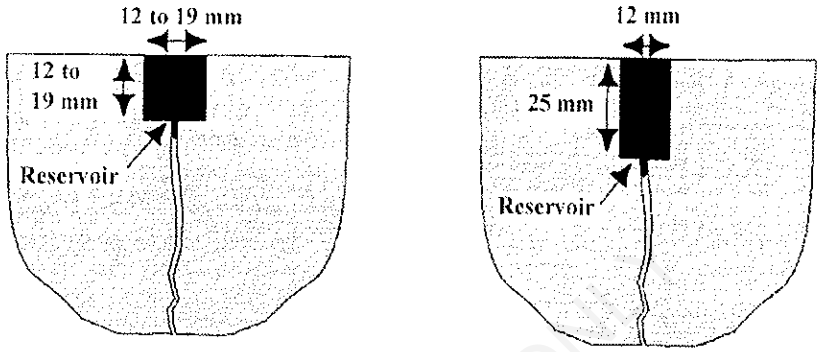
FIGURE 1 – FLUSH FILL



(b) Reservoir

In a reservoir configuration, the crack sealing material shall be placed only within the confines of a cut crack. The material shall be placed either flush with or slightly below the pavement surface. Figure 2 illustrates the reservoir configuration.

FIGURE 2 – RESERVOIR



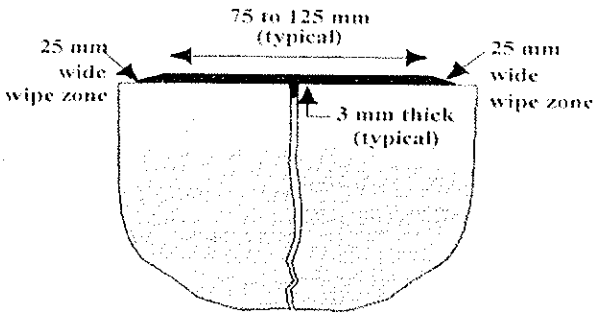
Standard Reservoir-and-Flush **Deep Reservoir-and-Flush**

(c) Overband

In an overband configuration, the crack sealing material shall be placed into and over an uncut crack. The material shall be shaped into a band over the crack by using a rubber blade squeegee or a sealing shoe that flattens the material over the crack which assists in establishing a hot bond for the band. If not, the unshaped material may continue to flow and level out after being applied and the bonds occurring as a result of this self-leveling are relatively weak because the material will have decreased in temperature. Figure 3 illustrates the overband configuration.

Overband configuration is most appropriate for cracks having a considerable amount of edge deterioration (more than 10% of crack length) because the overband simultaneously fills and covers the deteriorated segments in the same pass.

FIGURE 3 – OVERBAND

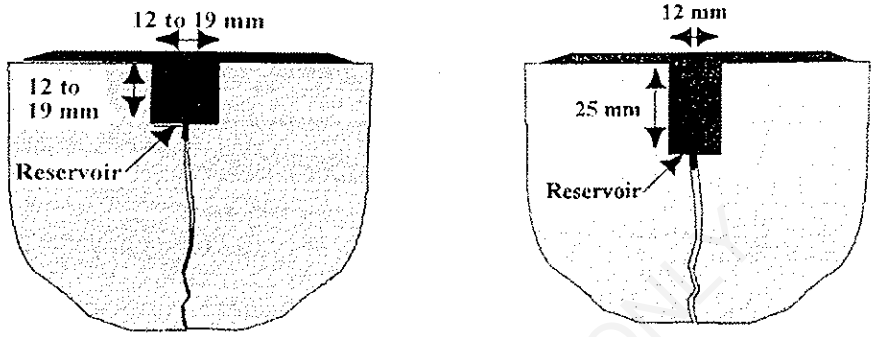


Simple Band-Aid

(d) Combination (reservoir and overband)

In a combination configuration, the crack sealing material shall be placed into and over a cut crack. A squeegee shall be used to shape the material into a band that is centred over the crack reservoir. Figure 4 illustrates the combination configuration.

FIGURE 4 – COMBINATION (RESERVOIR AND OVERBAND)



Standard Recessed Band-Aid **Deep Recessed Band-Aid**

For long term crack sealing performance, configurations (c) and (d) shall be considered.

4.14.3.2 Selection of Crack

The S.O. shall designate the location of the cracks to be sealed. Crocodile cracks, high-density multiple cracks and other types of crack which are due to structural damage shall not be treated with crack sealing. The best candidates for crack sealing are relatively new pavements that are beginning to form cracks, with crack width greater than 3 mm but less than 20 mm. Cracks with crack width greater than 20 mm and are not due to structural damage shall be cut and patched.

4.14.3.3 Preparation of Crack

Cracks shall be prepared to receive sealants. The better the preparation, the better the chance that the sealant will last and perform. Cracks shall be free of all dirt, dust, debris, moisture and other foreign materials. These materials are likely to be encountered particularly if cracks are cut. The sealant shall have a clean, dry bonding surface. The area to be sealed shall be kept clean and dry until all sealing operations are completed.

Crack preparation shall be accomplished with compressed air and a simple blow pipe. This technique works well when the dirt is dry and packed hard. If the cracks are filled with wet dirt, the dirt needs to be removed and the crack must be completely dried. An air compressor or a hot air lance generating temperatures in excess of 1370 °C is the best tool.

Results from the SHRP study showed there is a 40% greater chance of crack sealant success if cracks are cut prior to sealing. Cutting a reservoir above the cracks allows adequate crack sealant expansion and contraction. The reservoir also ensures that the proper amount of crack sealant penetrates the crack. An operator passes the pavement cutter over the crack and cuts a reservoir into the crack. Once the cutting is complete, compressed air (hot or cold) or engine-powered steel wire brush shall be used to remove the dust created by the cutting operation.

Table 4.14.5 lists the types of equipment commonly used for cutting and cleaning/drying cracks.

TABLE 4.14.5: CRACK CUTTING AND CLEARING/DRYING EQUIPMENT

Operation	Type of Equipment	Recommendations
Crack cutting.	Vertical-spindle router.	Use only with sharp carbide-tipped or diamond router bits.
	Rotary-impact router.	Use only with sharp carbide-tipped router bits.
	Random crack saw.	Use only on fairly straight cracks. Diamond-blade saw, 200 mm maximum diameter.
Crack cleaning and drying.	Blower (backpack or power-driven).	Not recommended. Insufficient blast velocity (75 to 110 m/s).
	Air compressor.	Equipped with oil and moisture filters. Pressure – 690 kPa minimum. Flow – 0.07 m^3/s minimum. Velocity – 990 m/s minimum.
	Hot-air lance.	Velocity – 610 m/s minimum. Temperature – 1370 C minimum. No direct flame on pavement.
	Sandblaster.	Nor recommended. Environmental and health concerns.
	Wire brush.	Do not use with worn brushes. Not recommended for cleaning previously treated cracks as there is a tendency to smear material.

(a) Cutting of Crack

Crack cutting shall be carried out by using a high production machine that follows cracks well and produces minimal spalls or fractures, otherwise it may inflict additional damage on the pavement.

The vertical-spindle router is the least damaging and most maneuverable pavement cutting machine though its cutting rate is quite low.

The rotary-impact router is much more productive than the vertical-spindle router. However, it may cause considerable more damage, depending on the type of cutting bit used. Carbide router bits are highly recommended over steel router bits.

The random crack saw with 150 to 200 mm diameter diamond blades can follow meandering cracks moderately well. Although its cutting rate is not nearly as high as the rotary-impact router, it provides a more rectangular reservoir with smoother walls and a higher percentage of aggregate surface area.

(b) Cleaning and Drying of Crack

Crack cleaning and drying are perhaps the most important aspeet of crack sealing and filling operations because a high percentage of failures are adhesion failures that result from dirty or moist craek channels.
The four primary procedures used in cleaning and drying crack channels are described in the following sections.

i) Air blasting

Air blasting shall be done with either one of the following equipment;

- Portable backpack or power-driven blowers.
- High-pressure air compressors with hoses and wands.

Backpack and power-driven blowers deliver high volumes or air at low pressures. As a result, blast velocity is generally limited to between 75 and 110 m/s which is undesirable. The advantages of these blowers are they require only one worker and provide good mobility.

High-pressure air compressors which can deliver a minimum blast pressure of 690 kPa, blast flow of 0.07 m^3/s and blast velocity of 990 m/s are more effective in cleaning cracks. They are recommended to be equipped with oil and moisture filtering systems as the introduction of oil or moisture to the crack channel can seriously inhibit bonding of the crack sealing material to the sidewall.

As high-pressure air blasting provides no heat and very little drying, it shall only be performed when the pavement and crack channel are completely dry.

High-pressure air blasting shall be conducted in two steps;

1. First pass, made along the crack, shall dislodge loose dirt and debris from the crack channel (and surrounding pavement if overband configuration is to be applied). The wand shall be held no less than 50 mm above the crack channel.

2. Second pass shall completely remove all the dislodged particles from the pavement surface. The wand shall be held further away from the pavement surface to make use of a larger blast area.

High-pressure air blasting shall be conducted immediately ahead of the sealing material application. The greater the time interval between these two operations, the more likely dust and debris will resettle into the crack channel.

ii) Hot Air blasting

Hot air blasting shall be performed with a hot compressed-air lance connected to a compressed-air unit. The extreme heat it delivers to a crack provides two benefits;

i. Crack moisture is quickly dissipated, thereby improving the bonding of the sealing material.

ii. Heated crack surface can enhance bonding of hot-applied sealing materials if the material application operation follows closely behind the hot air blasting operation.

Minimum requirements for hot air blasting unit shall be a 1370 °C heat capacity and a 610 m/s blast velocity.

Hot air blasting shall be conducted in two steps;

i. First pass, made along the crack, shall clean and heat the crack sidewalls (and surrounding pavement if overband configuration is to be

applied). The heat lance shall be held approximately 50 mm above the crack channel. Proper heating is manifested by a slightly darkened colour; burning is apparent by a black colour and a very gritty texture.

ii. Second pass shall completely remove all the dislodged particles from the pavement surface. The heat lance shall be held further away from the pavement surface to make use of a larger blast area.

Hot air blasting shall be conducted immediately ahead of the sealing material application. This will limit the amount of dust and debris blown into the cleaned crack channel, maximise crack warmth for enhanced bonding and minimise moisture condensation into the crack channel.

iii) Sandblasting

Due to environmental and health hazards, sandblasting is not recommended.

iv) Wire brushing

Cut cracks shall be cleaned by using mechanical, power-driven wire brushes in conjunction with air blasting (hot or cold). Depending on the brush and bristle characteristics, this combination is quite effective at removing debris lodged in the crack. Brush attachment shall contain bristles which are flexible enough to allow penetration into the crack channel, yet rigid enough to remove dirt and debris.

Notwithstanding the use of the cleaning and drying procedures as described above, if the equipment is unable to remove dirt, debris and any form of loose fragments, they shall be removed manually with hand tools.

4.14.3.4 Application of Crack Sealing Material

(a) Cold-applied thermoplastic bituminous materials

Bitumen emulsion materials shall be applied in various ways. They shall be loaded into distributors for partially heated application or kept in drums for unheated application. Distributors shall be equipped with pressure or gravity hoses for wand application. Hand-held or wheeled pour pots shall be used to apply heated or unheated bitumen emulsion to the cracks. The emulsion shall be applied at ambient temperature or shall be partially heated to between 52 and 66 °C.

(b) Hot-applied thermoplastic bituminous materials

Unmodified bitumen shall be heated and placed using bitumen distributors or direct-heating kettles. These units typically burn propane gas for heat and the heat is applied directly to the melting vat containing the bitumen.

For modified bitumen, the direct-heat system is not recommended as it can cause uneven heating or overheating of the material, particularly when no agitation devices are available. The modified bitumen shall be heated and mixed in indirect-heat, agitator-type kettles. These units burn either propane or diesel fuel, and the resulting heat is applied to a transfer-oil that surrounds a double-jacketed melting vat containing the treatment material. They shall be equipped with agitation devices.

(c) Chemically cured thermosetting materials

Silicone pumps shall be capable of being directly attached to the original material container, typically a 19-litre or 208-litre drum. Pumps and applicators shall provide the sealing material to the crack at a minimum flow rate of 0.03 litre/second. Teflon-lined application hoses and seals are recommended because they are able to prevent silicone from curing in the pump or hose.

4.14.3.5 Material Finishing and Shaping

Material finishing and shaping shall be accomplished in two ways;

i. Various sizes of dish-shaped attachments shall be connected to the end of the application wand for one-step application, finishing and shaping.

ii. Industrial rubber squeegees shall be used behind the material applicator to provide the desired shape.

The one-step method requires one less worker but often does not provide as much control in finishing as the squeegee method especially for overband configurations.

Prior to installation, the finishing and shaping tool shall be tested to ensure that the desired configuration is achieved.

Dish attachment to the application wand shall be of proper size and aligned to facilitate application.

Squeegees shall be properly molded into a 'U' or 'V' shape so that the sealing material can be concentrated over the crack. If the strike-off is to be flush, the rubber insert shall be flat. If overband configuration is required, the rubber insert shall be cut to the desired dimensions. The depth of the cut shall be a little larger than the desired thickness of the overband because some thickness will be lost as a result of the squeegee being pushed forward and slightly downward. The squeegee shall be operated closely behind the application wand. However, if the sealing material is runny enough to sink into the crack or flow underneath the mold provided by the squeegee, a little distance shall be kept to allow for material cooling.

4.14.3.6 Opening to Traffic

Traffic shall not be allowed on the crack sealing material until it has cured and the possibility of tracking no longer exists. However, if the S.O. so decides that it is necessary to allow traffic to pass over the material before adequate curing, clean sand, quarry dust or other approved materials shall be spread by using shovels over the sealed cracks. These materials shall be applied immediately after finishing and shaping so that they can stick to the sealing material and serve as temporary covers. They shall be applied in a thin layer and shall fully cover the exposed sealing material.

SURFACE TREATMENT 4 - COLOURED SURFACING

COLOURED SURFACING

Coloured surfacing is a treatment with specific colour on the wearing course and may be used to differentiate the various elements. It may be used to improve traffic flow and traffic safety. It is a resin-based surfacing with anti skidding properties. It consists of a layer of epoxy and polyurethane mixture topped with fine aggregate. This surfacing has to achieve a suitable level of surface friction but its primary function is to retain an appropriate level of colouration for a certain minimum period.

Coloured surfacing provides a clear definition between areas of the road elements that are allocated for specific use with benefits that include:

- Improved delineation and definition of road space;
- Increased compliance with the traffic rules;
- Increased awareness of other road users;
- Reduction in traffic collisions and;
- Improved road safety.

The presence of anti-skid properties inherent in the fine aggregates significantly reduces skidding related accidents. This coloured surfacing is primarily used for demarcation on various road elements and special markings. Examples of these are pedestrian crossings, exit ramps, motorcycle lanes, gore areas and special markings such as on-pavement speed limit sign.

The use of coloured surfacing does not improve night time visibility unless it is enhanced with white or yellow foreground colour road markings to provide the necessary visual contrast.

Correct colouration is achieved with the right amount of pigment for the coloured resin and this must be checked against a standard colour requirement. It is also necessary to incorporate suitable quality pigment to ensure the specified colour is maintained for the specified period. Quality pigment is more resistant to ultra violet light and has slow rate of fading.

The application of coloured surfacing should be delayed for at least 28 days for newly paved surface due to the relatively fresh bitumen coating of the aggregates. This would cause poor adhesion between the coloured surfacing material and the pavement surface which may result in cracking and peeling of the material.

4.15 SURFACE TREATMENT 4 - COLOURED SURFACING

4.15.1 Description

This work shall consist of furnishing, placing, shaping and compacting coloured mixture as a wearing course on an existing, impermeable and accepted bituminous or concrete pavement course. This Specification shall be read in conjunction with Sub-Section 4.3.3 of the Standard Specification for Road Works of JKR (JKR/SPJ/2008-S4). All requirements in the Sub-Section 4.3.3 shall apply unless stated otherwise in this Specification.

This Specification describes resin-based coloured surfacing system.

Resin-based coloured surfacing system (RCSS) is a range of flexible pigmented polyurethane binder, specially formulated to provide a durable anti-slip screed on the surface of an existing, impermeable and accepted bituminous or concrete pavement course when mixed with aggregates.

RCSS comprises three layers of applications. A modified epoxy basecoat and an intermediate layer of aliphatic polyurethane, both filled with aggregates, followed by a final layer of aliphatic polyurethane topcoat.

Basecoat is a solvent free high flexibility epoxy binder filled with aggregates. Topcoat and the intermediate layer are high flexibility polyurethane coating with excellent ultra-violet and abrasion resistance.

4.15.2. Materials

The RCSS epoxy and polyurethane materials shall be prepared in three basic components; Part A - resin base, Part B – hardener, and Part C - aggregates.

(a) Epoxy Basecoat

The Epoxy Basecoat shall be a solvent free bisphenol-A type epoxy resin cross-linked with a highly flexible modified cycloaliphatic amine hardener.

(b) Fine Aggregate

Fine aggregate shall be clean screened quarry dust. Other types of fine aggregate may be used subject to the approval of the S.O. Fine aggregate shall be non-plastic and free from clay, loam, aggregation of material, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The fine aggregate size shall be between 40 - 60 mesh.
ii. The fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.
iii. The Methylene Blue value when tested in accordance with Ohio Department of Transportation Standard Test Method shall be not more than 10 mg/g,
iv. The weighted average loss of weight in the magnesium sulfate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 20%.
iv. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

Notwithstanding compliance with the aforementioned requirements, limestone aggregate

shall not be permitted for use in resin-based coloured surfacing system.

(c) The Polyurethane Topcoat

The Polyurethane intermediate layer and topcoat shall be a pigmented Aliphatic Polyester Polyurethane with high flexibility, abrasion resistance, chemical resistance and excellent resistance against ultra-violet (UV) radiation.

(d) Colour Pigments

Colour pigments used for coloured resins shall be of good quality and highly resistant to UV light with slow rate of fading. Prior approval from the S.O. shall be obtained for use of colour pigments.

The amount of pigments that shall be added to the resin is extremely important to provide effective colouration. The Contractor shall add adequate amount of pigments to produce the required colour of the surfacing material to the satisfaction of the S.O.

4.15.3 Properties

(a) Physical Properties

Compressive Strength (BS 6319:Part 2:1983).....75 N/mm^2
Flexural Strength (BS 6319:Part 3:1990)..... 25 N/mm^2
Skid Resistance Value (BS 8204:Part 3:1993)..... 60
Abrasion Resistance (BS 8204:Part 2:2002)..... 9000 cycles
Shrinkage Coefficient of Thermal Expansion (ASTM C 531).. <1%

Curing time;
Pedestrian traffic..... 2 hours
Vehicular traffic..... 12 hours

(b) Chemical Properties

RCSS shall be resistant to petrol, diesel, lubricant brake fluid and battery water.

(c) Weathering Properties

RCSS shall not crack upon subjecting to natural weathering. The surfacing system shall not easily fade or change colour upon exposure to UV radiation.

4.15.4 Applications

Installation of RCSS shall be carried out only by approved installers who has undergone application trainings and certified as qualified applicator by the manufacturer.

RCSS shall be suitable for use as high friction coloured surfacing on highways with surface texture depths of between 0.5 mm to 2.0 mm.

Installation of the surfacing system shall be carried out only when the road surface temperature is between 10 °C to 50 °C.

For newly paved surface, the application of RCSS shall not be earlier than 28 days after the completion of the pavement wearing course due to the presence of relatively fresh bitumen coating the aggregates.

(a) Surface Preparation

All imperfections on the road surface which are deemed not acceptable to the installer shall be reinstated with appropriate materials approved by the manufacturer.

The road surface shall be clean, dry and free from loose aggregates, oil, grease and other loose matters which are likely to impair the adhesion of the system to the road surface.

Installation shall not be carried out if the road surface temperature is outside the range of 10 °C and 50 °C.

(b) Basecoat Application

The pre-weighed component B shall be poured into the container of the pre-weighed component A.

The components shall be mixed until homogeneous, using a high torque, slow speed electrical or mechanical stirrer.

The mixed epoxy binder shall be applied by using roller brush onto the prepared surface at a minimum coverage rate which will vary according to the texture and porosity of the surface but shall not be less than 1.20 kg/m^2.

After the binder is applied, fine aggregates shall be broadcast over the binder and shall be evenly spread out using a broom or squeegee.

After the binder is sufficiently cured (between 2 - 4 hours), the excess fine aggregates shall be removed by industrial vacuum machine or other suitable means before the application of the intermediate layer

(c) Intermediate Coat Application

The pre-weighed component B shall be poured into the container of the pre-weighed component A.

The components shall be mixed until homogeneous, using a high torque, low speed electrical or mechanical stirrer.

The mixed polyurethane coating shall be applied over the hardened surface of the epoxy screed using a paint roller at a minimum coverage rate of not less than 3.5 m^2 per litre.

After the binder is applied, fine aggregate shall be broadcast over the binder and shall be evenly spread out using a broom or squeegee.

After the binder is sufficiently cured (between 2 - 4 hours), the excess aggregate shall be removed by industrial vacuum machine or other suitable means.

(d) Topcoat Application

The pre-weighed component B shall be poured into the container of the pre-weighed component A.

The components shall be mixed until homogeneous, using a high torque, low speed electrical or mechanical stirrer.

The mixed polyurethane coating shall be applied over the hardened surface of the epoxy screed using a paint roller.

4.15.5 Precautions

(a) Cleaning

Primer and coloured mixture shall be removed from tools and equipment with suitable solvent immediately after use. Hardened material shall only be removed mechanically.

(b) Limitation

The coloured surfacing shall not be applied on to surfaces known to suffer or are likely to suffer from rising damp conditions. The surfacing material shall not be laid on wet surfaces and on diesel damaged bituminous surfaces

(c) Health and Safety

Coloured surfacing primer shall not come in contact with the skin and eyes, or be swallowed. Ensure adequate ventilation and avoid inhalation of vapours. Wear suitable protective clothing, gloves and eye protection. When working in confined areas, suitable respiratory protective equipment shall be used. The use of barrier creams provides additional skin protection. In case of contact with skin, rinse with plenty of clean water. Do not use solvent. In case of contact with eyes, rinse immediately with plenty of clean water and seek medical attention immediately. Do not induce vomiting.

(d) Fire

Resin-based coloured surfacing and primer are non-flammable. Most solvents are flammable. Keep away from sources of ignition. No smoking. In the event of fire, extinguish with $C0_2$ or foam. Do not use a water jet.

(e) Disposal

Spillages of component products shall be absorbed on to earth, sand or other inert material and transferred to a suitable vessel. Disposal of such spillages or empty packaging shall be in accordance with local waste disposal regulations

4.15.6 Maintenance and Repair

Should the coloured surfacing be damaged or become debonded from the substrate, it shall be repaired by cutting the damaged area back to firmly bonded material, cleaning the damaged area using compressed air or industrial vacuum, masking the perimeter and reinstate to the original specification.

APPENDIX 1

APPENDIX 1

AUSTROADS PAVEMENT TEST

Determination of the International Roughness Index (IRI)
Using ARRB TR. Walking Profiler

Preface

This test method was prepared by a Working Group of the AUSTROADS Pavement Reference Group.

Foreword

This test method defines the procedure for measuring the International Roughness Index (IRI) of pavement surfaces using the ARRB TR Walking Profiler.

Definitions

(a) The IRI (International Roughness Index)

The IRI is the roughness index determined by applying a mathematical model (referred to as a quarter-car model) which has the dynamic response of a simulated response-type road roughness measuring vehicle along a single wheel-path of measured road profile. The IRI is expressed in terms of accumulated vertical displacement of the simulated suspension in metres per measured kilometre (m/km). IRI can be reported in different ways, as follows:

- Single Track IRI
  The IRI based on a quarter car model run over a single track of longitudinal profile.

- Lane IRI
  This is a composite IRI value representing the roughness of a road lane section. It is determined by averaging two individual, Single Track IRI values obtained separately in each wheel-path of a lane (at 0.75 metres either side of the lane mid-track).

(b) NAASRA Roughness

The NAASRA Roughness is determined by applying a mathematical model (referred to as a half-car model and having the dynamic response of a standard vehicle) to two longitudinal profiles measured simultaneously. NAASRA Roughness is expressed in counts per kilometre (c/km).

Note: An *approximate* value of NAASRA Roughness can be calculated from measured IRI as follows:

NAASRA Roughness = -1.3 + 26.5(IRI) c/km.

(c) A Surface Profile of a line on a surface is the representation of the vertical locations of points on the line against their horizontal distances along the line from a specified starting point.

(d) Grade is the rate of longitudinal rise or fall of the surface with respect to the horizontal distance, expressed as a ratio or a percentage. The longitudinal grade of the pavement surface to be measured shall not exceed 1 in 6.

(e) Road Roughness is a measure of the riding quality of pavement in response to longitudinal profile.

(f) Absolute Offset is the machine-specific average output value between forward and reverse offset.

(g) Absolute Slope is the machine specific average value between forward and reverse slope.

Test Method

1.0 Scope

This test method defines the procedure for measuring the International Roughness Index (IRI) of pavement surfaces using the ARRB TR Walking Profiler. This device is pushed over the pavement surface by an operator at a slow walking pace.

It is assumed that the reader is familiar with the Walking Profiler Instruction Manual published by ARRB Transport Research and/or has a copy available for reference.

2.0 Referenced Documents

The following documents are referred to in this test method:

ARRB Transport Research (1996) – *Walking Profiler Instruction Manual,* Model APR1, February 1996 (Published: ARRB Transport Research Ltd., Vermont South, Victoria 3133).

3.0 Apparatus

(a) A manually operated walking profiler fitted with a lap-top computer and measuring beam which enables the collection and presentation of pavement surface profile and roughness information. The profiler shall be calibrated in accordance with the procedure specified in the manufacturer's Instruction Manual reproduced as Appendix 1a of this test method.

(b) Calibrated Smart Level or other similar device which can measure pavement grade or slope to an accuracy of ± 1 % of grade.

(c) Paint, crayon or similar for marking reference points along the intended survey path.

Note: The use of a chalked string line facilitates the marking of the survey path.

(d) Ruler or tape measure, graduated in millimetres, for establishing reference marks along the intended survey path. The ruler or tape measure used shall be accurate to at least ± 5 mm.

(e) Broom for sweeping the survey surface.

(f) Thermometer, suitable for the measurement of temperatures within the range 0 – 100 °C readable to at least 1 °C and having an accuracy of ± 1 °C.

Note: A digital thermometer with a sensor remote from the display is recommended. This will enable the probe to be secured under the cowling while the display is mounted near the lap-top computer.

4.0 Procedure

4.1 Pre-Operation Set-Up

(a) Ensure the profiler battery and the lap-top computer internal battery are fully charged and all leads are correctly connected and secured on the walking profiler and computer.

(b) Clean the foot pads of the measuring beam by lightly brushing.

(c) Ensure that the tyres, on the profiler wheels, and other components are free from the build up of deposits of road-making materials (eg. bitumen, cements etc.) by cleaning with a mild solvent or brushing.

(d) Ensure that the power to the machine is switched on at least 20 minutes prior to any use of the walking profiler.

4.2 Operating Conditions

Do not operate the walking profiler in ambient temperatures outside the temperature range of 0 to 45 °C or on road surface temperatures exceeding 75 °C.

4.3 Field Offset Trim

(a) Switch on the power to the walking profiler and wait at least 20 minutes before performing the field offset trim procedure.

(b) Perform the field offset trim immediately prior to use of the walking profiler for the IRI survey. If, during performance of the IRI survey, the air temperature within the cowling changes by more than 10°C from the temperature recorded when the most recent field offset trim was performed, then another field offset trim shall be performed.

(c) Record the temperature within the profiler cowling, then perform the field offset trim in accordance with the manufacturer's Instruction Manual (the procedure is reproduced as Appendix 1b to this Test Method). If necessary repeat the procedure until a successful run is obtained.

4.4 IRI Surveys

4.4.1 Single Track IRI Survey

(a) Define the length of the test section to be surveyed, which should have a length exceeding 100 metres. Select the wheel-path or other tracking line upon which the single track survey is to be performed.

Note: The IRI result is applicable for runs greater than or equal to 100 m in length.

(b) Check that the longitudinal grade of the test section does not exceed 1 in 6. If the grade is greater abandon the test.

(c) Mark the starting point of the line of survey with a cross as indicated in the Instruction Manual and mark the transverse position survey line every 3 to 5 metres along its length to facilitate accurate tracking of the machine. Ensure the line to be surveyed is free from all loose material.

Note: For inexperienced operators the tracking line may best be marked by use of a chalked string line.

(d) Record the time and the temperature, within the profiler cowling. Conduct the survey in the direction of lane traffic flow in accordance with the manufacturer's Instruction Manual and within the operational speed range. Note: Care should be taken to minimise the deviations from the survey line, with even greater care required as the transverse cross-slope of the site increases. If, during the survey, the centre line of the machine beam is permitted to deviate from this line by greater than ± 100 mm, repeat the run.

(e) Display and then record the Single Track IRI value calculated by the lap top computer for the surveyed section.

4.4.2 Lane IRI Survey

(a) Define the length of the test section to be surveyed, which should have a length exceeding 100 metres. Unless otherwise stipulated, the tracking lines shall be located 0.75 metres either side of the centre of the lane to be surveyed. Note: The IRI is accurate for runs greater than or equal to 100 m in length.

(b) Check that the longitudinal grade of the test section does not exceed 1 in 6. If the grade is greater abandon the test.

(c) Mark the starting points for each line of survey as in the instructions in the manufacturer's Instruction Manual, such that both starting points are coincident at the same road chainage location. Ensure that each line of survey is free from all loose material.

(d) Record the time and the temperature within the profiler cowling, then conduct the first survey in the direction of lane traffic flow in accordance with the manufacturer's Instruction Manual and within the operational speed range.

(e) Display and record the single track IRI value (IRI^1) calculated by the lap top computer for the first completed line of survey.

(f) Record the time and the temperature, within the profiler cowling, then conduct the second survey in the direction of lane traffic flow in accordance with the manufacturer's Instruction Manual and within the operational speed range.

(g) Record the IRI value (IRI^2) calculated for the second line of survey.

5.0 Calculations

When a Lane IRI Survey has been carried out by the completion of two single lane surveys, one in the inner wheel-path and the other in the outer wheel-path, calculate the Lane IRI using the following equation:

$$\text{Lane IRI} = \tfrac{1}{2} (IRI^1 + IRI^2)$$

Where IRI^1 = The result of the first Single Lane IRI as computed by the on-board lap-top computer and

IRI^2 = The result of the second Single Lane IRI as computed by the on-board lap-top computer.

6.0 Reporting

Report the following:

(a) The start and end chainage of the test section for which either Single Track IRI or Lane IRI was determined.

(b) The Single Track IRI and the transverse location of each completed line of survey which exceeds 100 metres in length.

(c) Where appropriate the Lane IRI for the test section.

If required, the following may also be reported for each 100 metre long sub-section of the test section:

i. The start and end chainage of each sub-section,

ii. The Single Track IRI and the transverse location of each completed line of survey within each sub-section,

iii. The Lane IRI for each sub-section.

Note:

1. When the length of the test section is not exactly divisible by 100 metres then one sub-section of length between 100 to 200 meters shall be included.

2. The average of the Lane IRI values from sequential sub-sections will equal the overall test section Lane IRI only if the length of all the sub-sections is identical.

APPENDIX 1a

Calibration Procedure

1a.1 Calibration Frequency

The following calibration procedure shall be performed at least once every six months or if a satisfactory field offset trim cannot be achieved. This procedure is specific to calibration of the ARRB TR Walking Profiler.

1a.2 Apparatus

(a) Stainless steel calibration surface plate with minimum dimensions of at least 320 mm long, 75 mm wide and 25 mm high. The top surface of the plate shall be machined plane with an out-of-flatness not exceeding 0.1 mm. The bottom of the plate shall be fitted with three adjustable legs to enable adjustment, for level, of the top surface.

(b) Stainless steel step block conforming to the following dimensions:

i. Width 74.0 $\pm$ 1.0 mm,
ii. Length 74.0 $\pm$ 1.0 mm,
iii. Height 25.0 $\pm$ 0.1 mm.

with the two large faces parallel to within 0.1 mm.

(c) Bulls eye spirit level.

(d) A small paint brush for cleaning the calibration plate and block

1a.3 Calibration Procedure

Laboratory Offset and Slope Calibration

(a) Stabilise the temperature of the measuring beam and profiler by placing the walking profiler, with the beam attached, in a clean, temperature controlled environment for at least twelve hours prior to commencement of the calibration. The cowl should be left in position during the conditioning period to prevent accidental damage to or dirt contamination of the mechanism and measuring foot.

(b) Remove the cowl and ensure there is sufficient room beside the walking profiler to carry out the calibration procedure.

(c) Set the Test/Survey selector switch, on the walking profiler, to the TEST position.

(d) Place the calibration surface plate on the ground beside the walking profiler, immediately adjacent too and with the long side parallel to the measuring foot. Place the bulls eye level on top of the surface plate and establish a level surface by adjusting the legs.

(e) Undo the two (2) M4 hexagon head screws which secure the accelerometer cable clamp. Check that the 6 foot pads, on the measuring beam, are clean.

(f) Clean the top of the surface plate by lightly brushing with the paint brush. Disengage the rear pick up arm cones and remove the measuring beam from the walking profiler. Place the

measuring beam on top of the surface plate in the forward position ie as it was removed from the walking profiler. Do not lift the measuring beam by the accelerometer or the resilient mounting plate. Ensure the accelerometer cable is not pulling or twisting on the accelerometer at any time throughout the calibration process.

(g) Gently lift the measuring beam ends, one at a time and gently tap each end on the surface plate as necessary to position it correctly. Check to ensure there is no overhang of the measuring beam, at either end on the surface plate.

(h) Activate the calibration menu and then follow the prompts from the computer. Continue the calibration, through forward offset to reverse offset, forward slope and reverse slope as directed by the computer prompts. The calibration is complete when the absolute offset lies between –300 mV and +300 mV, and the absolute slope lies between – 2900 m V and – 3100 mV.

(i) Replace the measuring beam in the walking profiler and reposition the accelerometer cable clamp. Ensure the cable is free to move without pulling tight or snagging any other leads when the walking profiler is in use and confirm the correct operation of the entire machine before field use by performing an offset calibration check.

APPENDIX 1b

Field Offset Trim Procedure

1b.1 Introduction

The field offset trim procedure is undertaken to initialise the walking profiler for the ambient conditions, particularly temperature, under which an IRI survey will be conducted. A field offset trim should be carried out each time the walking profiler is used, to make full allowance for local variables.

Prior to any use of the walking profiler, including the field offset trim procedure, the power to the machine must have been switched on for at least twenty (20) minutes.

The field offset trim procedure should be carried out on a 20 metre portion of the section to be surveyed, that portion being as level and smooth as possible and free of any loose material.

The field offset trim procedure is carried out under the direction of the on-board computer system discussed in the Manufacturer's Instruction Manual. It is assumed that the reader is familiar with that Manual and/or has a copy available for reference.

1b.2 Apparatus

As listed in Section 3 of the Test Method.

1b.3 Field Offset Trim Procedure

(a) Set up the walking profiler in the intended working situation, switch on the power and wait at least 20 minutes before performing the field offset trim procedure.

(b) Select a section approximately 20 metres long, and as level and smooth as possible, of the pavement to be measured, and sweep it clear of all loose debris.

(c) Using a chalked string line or similar, mark a straight line along the selected section of pavement, to be the path of the field offset trim run.

(d) At one end of the chosen path, rule a chalk line about 0.7 metres long in the direction of the intended walking profiler run, then approximately bisect this line at right angles with another chalk line, again about 0.7 metres long. This cross will mark both the beginning and the end of the field offset trim run.

(e) Press the <F10> key on the on-board computer to activate the main menu, select *Calibration* using the horizontal arrow key, and press <Enter> to display the vertical selection panel.

(f) Use the vertical arrow keys to select *Field Offset Trim*, then press <Enter>.

(g) Ensure that the machine is in the staged condition as defined in the Manufacturer's Instruction Manual. Manoeuvre the walking profiler on its back wheels to position it over the chalked cross such that the arrow markings on the machine align with the lines on the pavement (see Figure 2 of *Quick Guide to Conducting a Precision Survey* in the Manufacturer's Instruction Manual).

(h) Press <Enter> to start data logging for the field offset trim run.

(i) Squeeze the staging release bar to the push handle, then push the machine forward in a straight line for at least 20 metres and stop in the staged condition by letting go of the staging release bar and gently pushing until the mechanism locks.

(j) Press <H> (for half-way) to mark the end of the outward phase.

(k) Mark the pavement with chalk directly below each of the arrow markings on the machine, then remove the machine and join opposite chalk marks on the pavement with two ruled lines, one in the direction of the walking profiler run, the other at right angles (see Figure 4 of *Quick Guide to Conducting a Precision Survey* in the Manufacturer's Instruction Manual). The intersection of these two lines marks the position of the front foot of the walking profiler at the last placement of the measuring beam, and is the precise end of the survey.

(l) Turn the machine to face it back toward the starting point of the run and position it over the cross drawn on the pavement in (k), using the procedure described in (g).

(m) Press <Enter> to continue the field offset trim run, then push the machine back along the same line, finishing the run by staging it precisely over the starting cross. ***If the finishing position is more than 5 mm horizontally from precisely over the starting cross, the procedure must be repeated from point*** **(e).**

(n) Press <F> (for finish) to indicate the end of the field offset trim run. The software then automatically calculates the new offset correction and incorporates it into the processing system. The new value will be displayed and a message will indicate that the process was successful and prompt the operator to press <Enter> to return to the main menu.

(o) Check that there are no particles adhering to the footpads after completing the field offset trim procedure. ***If there are any present, the offset correction may be in error and the procedure should be repeated.***

APPENDIX 2

APPENDIX 2

BINDER DRAIN-DOWN TEST PROCEDURE

1.0 Scope

This test method covers the determination of the amount of binder drain-down in an uncompacted porous asphalt sample when the sample is held at elevated temperatures comparable to those encountered during the production, storage, transport and placement of the mixture.

The values stated in gram-millimeter units are to be regarded as the standard.

This Standard may involve hazardous materials, operations and equipment. This Standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this Standard to establish appropriate safety and health practices and determines the applicability of regulatory limitations prior to use.

2.0 Reference Documents

AASHTO Standards T245 Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus and M92 Standard Specification for Wire Cloth Sieve for Testing Purposes.

3.0 Binder Drain-Down

For the purpose of this test method, binder drain-down is considered to be that portion of the bituminous mixture which separates itself from the sample as a whole and is deposited outside the wire basket during the test. (Note, any noticeable aggregate particles that are deposited outside the basket should be added back into the mixture and not counted as binder drain-down. Alternatively the test should be re-run).

4.0 Summary of Method

A sample of the porous asphalt mixture of mass 1.1 kg is prepared in the laboratory or obtained from field production. The sample is placed in a wire basket that is positioned on a pre-weighed paper plate. The sample, basket and plate are placed in a forced air oven for one hour at a pre-selected temperature. At the end of three hours, the basket containing the sample is removed from the oven along with the paper plate and the paper plate is weighed to determine the amount of binder drain-down that occurred.

5.0 Significance and Use

Test method can be used to determine whether the amount of binder drain-down measured for a given porous asphalt mixture is within acceptable levels. It also provides an evaluation of the binder drain-down potential of a porous asphalt mixture produced in the field.

6.0 Apparatus

(a) Oven capable of maintaining the temperature in a range from 120 – 200 °C. The oven should maintain the set temperature to within ± 2 °C (± 3.6 °F).

(b) Paper plates of appropriate size. The paper plates shall be of appropriate durability to withstand the oven temperatures.

(c) Standard cylindrical shaped basket constructed using standard 6.3mm (0.25inch) sieve cloth as specified AASHTO M92.

(d) Spatulas, trowels, mixer and bowls as needed.

(e) Balance accurate to 0.1 gram.

7.0 Prepared Samples

7.1 Laboratory Prepared Samples

7.1.1 For each mixture, the binder drain-down characteristics should be determined at the anticipated plant production temperature. Duplicate samples should be tested.

7.1.2 Dry the aggregate to constant mass and sieve it into appropriate size fractions as indicated in AASHTO T 245, Section 3.2.

7.1.3 Determine the anticipated plant production temperature or select a mixing temperature in accordance with AASHTO T 245, Section 7.3.1. The supplier's recommendations should be sought when using modified bitumen.

7.1.4 Weigh into separate pans for each test sample the amount of each size fraction required to produce complete bituminous mixture samples having a mass of 1200 grams. The aggregate fractions shall be combined such that the resulting aggregate blond has the same gradations as the job mix formula. Place the aggregate samples in an oven and heat to a temperature not to exceed the mixing temperature established in 7.1.3 by more than approximately 28 °C (50 °F).

7.1.5 Heat the PMA to the temperature established in item 7.1.3.

7.1.6 Place the heated aggregate in the mixing bowl. Add any stabiliser (Note 1) as directed by the supplier and thoroughly mix the dry components. Form a crater in the aggregate blend and add the required amount of asphalt. The amount of asphalt shall be such that the final sample has the same asphalt content as the job-mix-formula. At this point, the temperature of the aggregate and PMA shall be within the limits of the mixing temperature established in 7.1.3. Using a spatula (if mixing by hand) or a mixer, mix the aggregate and binder quickly, until the aggregate is thoroughly coated.

Note 1 - Some types of stabilisers such as fibers or some polymers must be added directly to the aggregate prior to mixing with the binder. Other types must be added directly to the binder prior to blending with the aggregate.

7.2 Plant Produced Samples

7.2.1 For plant produced samples, duplicate samples should be tested at the plant production temperature.

7.2.2 Samples may be obtained during plant production by sampling the mixture at the tricks prior to the mixture leaving the plant. Samples obtained during actual production should be reduced to the proper test sample size by the quartering method.

8.0 Procedure

8.1 Transfer the laboratory produced or plant produced uncompacted porous asphalt mixture sample to a tarred wire basket described in 6(C). Place the entire sample in the wire

basket. Do not consolidate or otherwise disturb the sample after transfer to the basket. Determine the mass of the sample to the nearest 0.1 gram.

8.2 Determine and record the mass of a paper plate to the nearest 0.1 gram. Place the basket on the paper and place the assembly into the oven at the temperature as determined in 7.1.3 for 3 hours ± 1 minute.

8.3 After the sample has been in the oven for 3 hours, remove the basket and paper plate. Determine and record the mass of the paper plate to the nearest 0.1 gram.

9.0 Calculations

9.1 Calculate the percent of mixture which drained by subtracting the initial paper plate mass from the final paper plate mass and divide this by the initial total sample mass. Multiply the result by 100 to obtain a percentage.

10.0 Report

10.1 Report the average percent binder drain-down at the test temperature.

APPENDIX 3

APPENDIX 3

CANTABRO TEST PROCEDURE

1.0 Scope

Cantabro test shall be done on the proposed mix to measure its resistance to stone loss at high frequency. The test procedures and apparatus are described below;

2.0 Apparatus

2.1 Marshall Compactor - see description in ASTM D 1559.

2.2 Loss Angeles Drum - see description in ASTM C 131.

2.3 Thermometers: to measure the temperatures of the aggregate, binder and bituminous mix, metal thermometers with a scale up to 200 °C and accuracy of 3 °C are used. To measure the temperature at which the test is carried out, a thermometer with a scale from 0-50 °C and an accuracy of 0.5 °C is used.

2.4 Balances: a balance with a capacity of 2 kg and an accuracy of 0.1 g to weight the samples and another with a capacity of 5 kg and an accuracy of 1 g to prepare the mixes.

2.5 General materials: tray, pots, spatulas, asbestos gloves, curved scoops, filter paper rings etc.

3.0 Procedure

The different aggregate fractions which make up the mix are dried in a stove at 105-110 °C until constant weight is reached. At the proposed optimum binder content, four Marshall specimens are manufactured with 50 blows on each side at adequate temperature (see Note 1). The relative density and void percentage can be determined as soon as they have cooled to ambient temperature. The procedure to determine the density and void percentage shall be based on geometric procedures.

The specimens are dried at ambient temperature for 2 days. Before testing the specimens, they are kept at test temperature, 25 °C, for at least six hours. After the specimens have been kept for the required time, weigh it (M_0), then place immediately into the Los Angeles drum without abrasion loads (balls). The drum is turned at a velocity between 188 and 208 rad/s and submitted to 300 revolutions. This is repeated for the four specimens.

Weigh the specimen after test (M_1). For each specimen, the stone loss or attrition resistance is computed;

$$L = (M_0 - M_1)/(M_0) \times 100$$

The average stone loss (L) is reported and shall be not more than 15%.

Note 1: Mixing temperatures are usually 130 °C for pure bitumen and 170 °C for polymer modified bitumen.

APPENDIX 4

APPENDIX 4

SMA ASPHALT DRAINDOWN TEST PROCEDURE

1.0 Scope

1.1 This test method covers the determination of the amount of draindown in an uncompacted SMA mixture sample when the sample is held at elevated temperatures comparable to those encountered during the production, storage, transport and placement of the mixture.

1.2 The values stated in gram-milimeter units are to be regarded as the standard.

1.3 This standard may involve hazardous materials, operations and equipment. This standard does not purpose address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determines the applicability of regulatory limitations prior to use.

2.0 Reference Documents

AASHTO Standards T245 Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus and M92 Standard Specification for Wire Cloth Sieve for Testing Purposes.

3.0 Draindown

For the purpose of this test method, draindown is considered to be that portion of the PMA which separates itself from the sample as a whole and is deposited outside the wire basket during the test. (Note, any noticeable aggregate particles that are deposited outside the basket should be added back into the mixture and not counted as draindown. Alternatively the test should be rerun).

4.0 Summary of Method

A sample of the SMA mixture to be tested is prepared in the laboratory or obtained from field production. The sample is placed inn a wire basket that is positioned on a pre-weighed paper plate. The sample, basket and plate are placed in a forced air oven for three hour at a pre-selected temperature. At the end of three hours, the basket containing the sample is removed from the oven along with the paper plate and the paper plate is weighed to determine the amount of draindown that occurred.

5.0 Significance and Use

Test method can be used to determine whether the amount of draindown measured for a given SMA mixture is within acceptable levels. It also provides an evaluation of the draindown potential of a SMA mixture produced in the field.

6.0 Apparatus

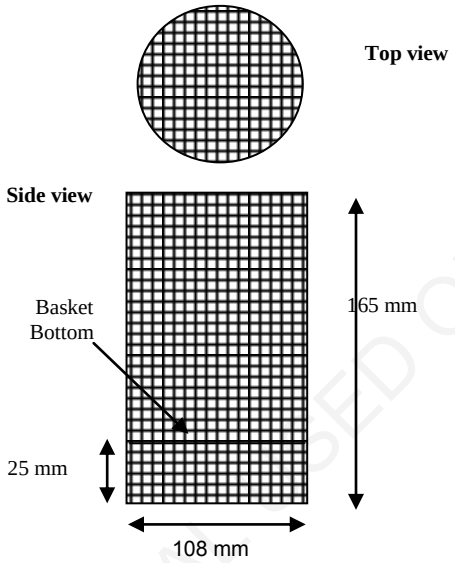
6.1 Oven capable of maintaining the temperature in a range from 120 - 200° C. The oven should maintain the set temperature to within $\pm 02^0$ C.

6.2 Paper plates of appropriate size. The paper plates used be of appropriate durability to withstand the oven temperatures.

6.3 Standard cylindrical shaped basket meeting the dimensions shown in Figure 1. The basket shall be constructed using standard 6.3mm (0.25inch) sieve cloth as specified AASHTO M92.

6.4 Spatulas, trowels, mixer and bowls as needed.

6.5 Balance accurate to 0.1 gram.



7.0 Sample Preparation

7.1 Laboratory Prepared Sample

7.1.1 For each mixture tested the draindown characteristics should be determined at the anticipated plant production temperature. Duplicate samples should be tested.

7.1.2 Dry the aggregate to constant mass and sieve it into appropriate size fractions as indicated in AASHTO T 245 section 3.2.

7.1.3 Determine the anticipated plant production temperature or select a mixing temperature in accordance with AASHTO T 245, Section 7.3.1. The PMA supplier's recommendations should be sought when using modified bitumen.

7.1.4 Weigh into separate pans for each test sample the amount of each size fraction required to produce complete SMA mixture samples having a mass of 1200 grams. The aggregate fractions shall be combined such that the resulting aggregate blond has the same gradations as the job mix formula. Place the aggregate samples in an oven and heat to a temperature not to exceed the mixing temperature established in 7.1.3 by more than approximately 28 °C (50 °F).

7.1.5 Heat the PMA to the temperature established in 7.1.3.

7.1.6 Place the heated aggregate in the mixing bowl. Add any stabiliser (Note 1) as directed by the supplier and thoroughly mix the dry components. Form a crater in the aggregate blend

and add the required amount of asphalt. The amount of asphalt shall be such that the final sample has the same asphalt content as the jab-mix-formula. At this point, the temperature of the aggregate and PMA shall be within the limits of the mixing temperature established in 7.1.3. Using a spatula (if mixing by hand) or a mixer, mix the aggregate (and stabiliser) and PMA quickly, until the aggregate is thoroughly coated.

Note : - Some types of stabilisers such as fibers or some polymers must be added directly to the aggregate prior to mixing with the PMA Other types must be added directly to the PMA prior to blending with the aggregate.

7.2 Plant Produced Sample

7.2.1 For plant produced samples, duplicate samples should be tested at the plant production temperature.

7.2.2 Samples may be obtained during plant production by sampling the mixture at the trucks prior to the mixture leaving the plant. Samples obtained during actual production should be reduced to the proper test sample size by the quartering method.

8.0 Procedure

8.1 Transfer the laboratory produced or plant produced uncompacted SMA mixture sample to a tarred wire basket described in 6.3. Place the entire sample in the wire basket. Do not consolidate or otherwise disturb the sample after transfer to the basket. Determine the mass of the sample to the nearest 0.1 gram.

8.2 Determine and record the mass of a paper plate to the nearest 0.1 gram. Place the basket on the paper and place the assembly into the oven at the temperature as determined in 7.1.3 for 3 hours ± 1 minute.

8.3 After the sample has been in the oven for 3 hours, remove the basket and paper plate. Determine and record the mass of the paper plate to the nearest 0.1 gram.

9.*0 Calculations*

9.1 Calculate the percent of mixture which drained by subtracting the initial paper plate mass from the final paper plate mass and divide this by the initial total sample mass. Multiply the result by 100 to obtain a percentage.

10. Report

10.1 Report the average percent drainage at the test temperature.

APPENDIX 5

APPENDIX 5

AUSTROADS MODIFIED BINDER TEST MBT 22:1995

Torsional Recovery of Polymer Modified Binders

Foreword

Polymer modified binders (PMBs) are thought to provide benefits due to their increased elastic behaviour. A simple means of determining the elastic properties of a PMB is to measure its Torsional Recovery. The Torsional Recovery test is simple and can be readily utilised for routine quality control purposes.

Method

1.0 Scope

This test method sets out the procedure for the determination of Torsional Recovery of polymer modified binders using a simple bolt and cup assembly.

2.0 Referenced Documents

The following documents are referred to in this test method:

AS/NZS 2341	Methods of testing bitumen and related roadmaking products 2341.12 Method 12: Determination of penetration
ASTM E1	Standard specification for ASTM thermometers
AUSTROADS	
MBT 01:	Method of sampling polymer modified binders, polymers and scrap rubber
MBT 02:	Protocol for handling polymer modified binders in the laboratory

3.0 Principle

The Torsional Recovery apparatus operates by manually rotating an aluminium bolt, previously embedded in a cup of modified binder, through an angle of 180 degrees and measuring the extent of recovery of the original applied rotation. The initial 180 degree twist is applied with a spanner over a 10 second period. The recovery after 30 seconds is reported.

4.0 Apparatus

(a) **Bolt assembly** - a cylindrical headed aluminium bolt assembly, with a total mass of 45 $\pm$ 5 g. The bolt has a cylindrical head with a diameter of 28.6 mm and a thickness of 9.52 mm. The threaded shank of the bolt is 44.5 mm long. A metal "spider", with three radial pins and two nuts, can be used to centre the assembly. A pointer is required for angle measurements in the absence of the spider.

(b) **Sample tin** - sample tin of 80 - 85 ml capacity and internal diameter 51-52 mm. A penetration can, as defined in AS2341.12, is suitable.

(c) **Angle measuring device** - angle measuring device and sample clamp assembly for clamping the sample/bolt assembly and determining the initial and recovered angle. The recommended device provides a scale, of 80 mm radius and graduated in degrees around at least half its circumference, and a clamp capable of holding the sample cup within 3 mm of its center and without deforming the cup by more than 3 mm in any direction.

(d) **Water bath** - capable of operating at 25 ± 0.5 °C, fitted with an appropriate thermometer.

Note: A suitable thermometer is an IP 39 C, or ASTM 90C, as specified in ASTM E 1.

(e) **Forced convection oven** - capable of operating in the range 60 °C to 200 °C, with a set point accuracy of ± 5 °C.

(t) **Stop-watch**

(g) **Spanner** - to suit the bolt assembly.

5.0 Procedure

5.1 General

PMBs are complex mixtures of polymers and a variety of petroleum products. If handled in accordance with the directions of the suppliers, there should be no significant risk. The hazard of burns with PMBs is greater than with standard bitumens, due to the (normally) higher handling temperatures. It is recommended that notices, describing the action to be taken in the event of bitumen or PMB burns, should be displayed in the laboratory in the areas where bitumen and PMBs are handled. A suitable warning could be as follows:

WARNING: HOT BITUMEN & PMBs CAN CAUSE SEVERE BURNS

The following precautions should be taken when handling bitumen, or PMBs;

(a) Eye protection, such ask safety glasses and/or face shields, shall be worn when handling hot bitumen or PMBs.

(b) Heat-resistant gloves, with close-filling cuffs, and other suitable protective clothing, shall be worn when handling hot bitumen or PMBs.

(c) There shall be no smoking while handling hot bitumen or PMBs.

(d) While the material is still cold, loosen the lid of the sample container (invert the can and warm the lid, if necessary), or punch a hole in the lid.

(e) Examine the cold sample for the presence of water. If water is thought to be present, drain most of it out, or blow with clean compressed air to evaporate the free water.

5.2 Sample Preparation

Samples for testing shall be provided in accordance with MBT 01 and MBT 02.

5.3 Measurements

(a) Assemble the bolt, spider and nuts to position the surface of the bolt head 8 ± 2 mm below the top of the sample cup.

(b) Preheat the assembly and cup to 180 °C.

(c) Pour the modified binder into the cup assembly, until it begins to form a meniscus on the top surface of the bolt.

(d) Allow the assembly to cool for one hour by leaving it to stand at room temperature (25 ± 3 °C). Adjust the assembly height to keep the top surface of the bolt flush with the sample surface.

(e) Place the assembly into the 25 °C water bath and allow it to stabilise for one hour (see Note 1).

Note 1: The test should be conducted in an air conditioned laboratory at 25 ± 3 °C. Alternatively, the test can be conducted within the water bath.

(f) Adjust the spider to a position 7 ± 2 mm above the rim and return the assembly to the bath.

(g) Place the sample assembly on the base-plate and fit the pointer to the 180 degree position without disturbing the sample.

(h) Using the spanner, turn the bolt moving the pointer from the 180 degrees position to the zero position using a steady motion for 10 seconds (see Note 2).

Note 2: The rate at which the torque is applied to the sample is critical for reproducible results. The objective is to apply 180 degrees of rotation in 10 seconds. A scale marked from zero (0 degree) to 10 (180 degrees) will help with this task.

(i) Release the bolt when the pointer reaches the zero position and commence timing.

(j) Record the recovered angle after 30 seconds as A.

6.0 Calculation

The Torsional Recovery is given by the following equation;

Torsional Recovery, %= 100 A/180
where A = recovered angle, in degrees.

7.0 Report

Report the Torsional Recovery as the mean of two results, together with the Temperature of the test and the Recovery Time.

JKR/SPJ/2008-S4
JKR 20403 0003 07

KERAJAAN MALAYSIA
JABATAN KERJA RAYA MALAYSIA

STANDARD SPECIFICATION FOR ROAD WORKS

SPJ SECTION 4: FLEXIBLE PAVEMENT

ADDENDUM NO.1: BITUMEN PENETRATION GRADE 60-70

ADDENDUM NO.2: CLAUSE 4.16 NATURAL RUBBER MODIFIEDASPHALT
CLAUSE 4.17 CRUMB RUBBER MODIFIED ASPHALT

KETUA PENGARAH KERJA RAYA
JABATAN KERJA RAYA MALAYSIA
JALAN SULTAN SALAHUDDIN,
50582 KUALA LUMPUR.

Addendum No. 1

SAKPKR BIL. 1/2017 BERTARIKH 7 FEBRUARI 2017

ARAHAN PENGGUNAAN BITUMEN PENETRATION GRADE 60 – 70 DALAM KERJA PENURAPAN JALAN

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Rujukan: JKR.KPKR:121.010/05 Jld. 7(5)
Tarikh: 7 Februari 2017

Semua Pengarah Kanan / Pengarah Cawangan Ibu Pejabat JKR
Semua Pengarah Kerja Raya Negeri
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Pengarah JKR Unit Khas
Pengarah JKR KESEDAR
Semua Jurutera Daerah

SURAT ARAHAN KPKR BIL. 1/2017

ARAHAN PENGGUNAAN BITUMEN *PENETRATION GRADE* 60 – 70 DALAM KERJA PENURAPAN JALAN

1.0 TUJUAN

Surat Arahan ini bertujuan untuk menetapkan satu (1) gred bitumen sahaja digunakan iaitu bitumen *penetration grade* 60 – 70 dalam kerja penurapan jalan. Sehubungan itu, penggunaan bitumen *penetration grade* 80 – 100 tidak lagi dibenarkan.

Rujukan: JKR.KPKR:121.010/05 Jld. 7(5)
Tarikh: 7 Februari 2017

2.0 LATAR BELAKANG

2.1 Spesifikasi Piawaian Jalan JKR/SPJ/2008-S4 (SPJ) klausa 4.3.3.2 (c) menetapkan bahawa *bituminous binder* bagi *asphaltic concrete* seharusnya bitumen *penetration grade* 60 – 70 atau 80 – 100 atau *polymer modified binder*.

2.2 Bagi penggunaan bitumen konvensional, terdapat dua (2) pilihan iaitu *bitumen penetration grade* 60 – 70 atau 80 – 100, di mana gred 60 – 70 mempunyai nilai kepekatan yang lebih tinggi berbanding gred 80 – 100. Sehubungan itu bagi *asphalt* yang mengunakan bitumen *penetration grade* 60 - 70, SPJ telah menetapkan suhu pembancuhan *asphalt* di kuari, serta suhu penurapan dan pemadatan *asphalt* di tapak ditingkatkan sehingga 10 °C berbanding suhu jika bitumen *penetration grade* 80 – 100 digunakan.

2.3 Kajian di luar negara menunjukkan *asphalt* yang dibancuh dengan bitumen *penetration grade* 60 – 70 dapat meningkatkan keupayaan turapan dalam menampung beban trafik sehingga 21% dan memanjangkan jangka hayat turapan sehingga 18% berbanding bitumen *penetration grade* 80 – 100.

3.0 PENETAPAN PENGGUNAAN BITUMEN *PENETRATION GRADE* 60–70

3.1 Bagi memastikan penggunaan bitumen yang seragam sama ada jalan utama dengan beban trafik yang tinggi atau jalan luar bandar dengan beban trafik yang lebih rendah dan sama ada *asphalt* digunakan sebagai

binder course atau *wearing course*, hanya satu (1) gred bitumen sahaja seharusnya digunakan. Gred bitumen itu ialah bitumen *penetration grade* 60 – 70.

3.2 Bitumen *penetration grade* 60 – 70 seharusnya mematuhi spesifikasi terkini *Malaysian Standard MS 124 'Specification for penetration grade of bitumen for use in pavement construction.'*

3.3 *Asphalt* menggunakan bitumen *penetration grade* 60 – 70 seharusnya mematuhi Spesifikasi Piawaian Jalan (SPJ) yang terkini.

4.0 KUAT KUASA

4.1 Surat Arahan ini berkuat kuasa mulai **1 Mei 2017**. Tarikh ini ditetapkan dengan mengambil kira masa secukupnya yang diperlukan oleh syarikat-syarikat pengeluar bitumen di negara ini bagi membuat perubahan yang sewajarnya ke atas cara pemprosesan minyak mentah di loji penapis bagi menghasilkan bitumen *penetration grade* 60 – 70.

Sekian, terima kasih.

'BERKHIDMAT UNTUK NEGARA'

DATO' SRI Ir. Dr. ROSLAN BIN MD TAHA

Rujukan: JKR.KPKR:121.010/05 Jld. 7(5)
Tarikh: 7 Februari 2017

s.k.

- Ketua Setiausaha, Kementerian Kerja Raya
- Timbalan Ketua Pengarah Kerja Raya (Sektor Infra)
- Timbalan Ketua Pengarah Kerja Raya (Sektor Bangunan)
- Timbalan Ketua Pengarah Kerja Raya (Sektor Pakar)
- Pengarah Cawangan Dasar dan Pengurusan Korporat

Addendum No. 2

SAKPKR BIL. 11/2019 BERTARIKH 7 MAC 2019

ADDITIONAL OF:

CLAUSE 4.16 NATURAL RUBBER MODIFIED ASPHALT
CLAUSE 4.17 CRUMB RUBBER MODIFIED ASPHALT

ACKNOWLEDGEMENT

This specification on Rubber Modified Asphalt has been prepared by a committee consisting of engineers and specialists from Centre of Excellence for Engineering and Technology (CREaTE), Cawangan Senggara Fasiliti Jalan (CSFJ) and Cawangan Jalan (CJ), Public Works Department (PWD) Malaysia, and industrial players; their cooperation is greatly acknowledged.

The members of the comittee involved in preparing the **Standard Specification for Road Works - Section 4.16: Natural Rubber Modified Asphalt** are:-

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The committee would also like to thank all other individuals who had contributed towards the successful completion of this specification.

RUBBER MODIFIED ASPHALT

PAGE

4.17 CRUMB RUBBER MODIFIED ASPHALT

4.16 NATURAL RUBBER MODIFIED ASPHALT

4.16.1 DESCRIPTION

This work shall consist of furnishing, placing, shaping and compacting natural rubber modified asphalt (hereinafter referred to as asphaltic concrete) wearing course on a prepared and accepted bituminous pavement course, and shall include careful and thorough cleaning of surfaces which are to be covered prior to the application of bituminous tack coat. The work shall be carried out all in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections as shown on the Drawings and/or as required by the S.O.

Natural rubber modified asphaltic concrete is a mixture of continuously graded aggregate and natural rubber modified binder. The binder is produced by incorporating an appropriate quantity of natural rubber into the conventional bitumen.

4.16.2 MATERIALS

a) Aggregates

Aggregates for natural rubber modified asphaltic concrete shall be a mixture of coarse and fine aggregates, and mineral filler. The individual aggregate shall be of sizes suitable for blending to produce the required gradation of the combined aggregates, all to the satisfaction of the S.O.

Coarse aggregates shall be screened crushed hard rock, angular in shape and free from dust, clay, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i) the Los Angeles abrasion value when tested in accordance with ASTM C 131 shall be not more than 25%.

ii) the weighted average loss of weight in the magnesium sulfate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 18%.

iii) the flakiness index when tested in accordance with MS 30 shall be not more than 25%.

iv) the water absorption when tested in accordance with MS 30 shall be not more than 2%.

v) the polished stone value when tested in accordance with MS 30 shall be not less than 40.

Fine aggregates shall be clean screened quarry dusts. Other types of fine aggregate may be used subject to the approval of the S.O. Fine aggregates shall be non-plastic and free from clay, loam, aggregation of material, vegetative and other organic matter, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i) the sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

ii) the fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.

iii) the Methylene Blue value when tested in accordance with Ohio Department of Transportation Standard Test Method shall be not more than 10 mg/g.

iv) the weighted average loss of weight in the magnesium sulfate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 20%.

v) the water absorption when tested in accordance with MS 30 shall be not more than 2%.

Notwithstanding compliance with the requirements of this Specification, limestone aggregates shall not be permitted.

The gradation of the combined coarse and fine aggregates and mineral filler, shall conform to the appropriate envelope shown in Table 1.

Table 1 *Combined aggregate gradation for asphaltic concrete*

Mix Designation	**AC 10**	**AC 14**
BS Sieve Size, mm	**Percentage Passing (by weight)**	
28.0	-	-
20.0	-	100
14.0	100	90 – 100
10.0	90 – 100	76 – 86
5.0	58 – 72	50 – 62
3.35	48 – 64	40 – 54
1.18	22 – 40	18 – 34
0.425	12 – 26	12 – 24
0.150	6 – 14	6 – 14
0.075	4 – 8	4 – 8

For each type of mix required in the Works, the Contractor shall propose a laboratory design mix gradation which shall consist of a single definite percentage passing for each sieve size in Table 1 and shall produce a smooth curve within the appropriate gradation envelope. This job laboratory design mix gradation, with the allowable tolerances for a single test as specified in sub-section 4.16.5 (c), shall then become the job standard mix or job mix formula.

b) Mineral Filler

Mineral filler shall be incorporated as part of the combined aggregate gradation. It shall be hydrated lime (calcium hydroxide). At the time of mixing with bitumen, it shall be sufficiently dry to flow freely and shall be essentially free from agglomerations. Not less than 70% by weight shall pass the BS 75 µm sieve. The total amount of mineral

filler shall be approximately 2% by weight of the combined coarse and fine aggregates. The mineral filler shall also be treated as an anti-stripping agent.

If hydrated lime is not available, ordinary Portland cement shall be used as an alternative, subject to approval by the S.O.

c) Natural Rubber Modified Binder

Natural rubber modified binder shall be of performance grade PG 76 or higher in compliance with AASHTO Standard M320-02. This premium grade binder shall be produced by pre-blending conventional bitumen, penetration grade 60 - 70 which shall conform to MS 124, with an appropriate quantity of natural rubber.

4.16.3 NATURAL RUBBER

Natural rubber shall be the material extracted from rubber trees. It shall be either in the form of natural rubber latex or dry natural rubber.

a) Natural Rubber Latex

Natural rubber latex is a sticky, milky colloid obtained by tapping rubber trees. The latex is collected before it coagulates and transferred into air-tight containers with sieving for ammoniation. The ammoniation is necessary to preserve the latex in a colloidal state for longer periods of time. Natural rubber latex shall be either centrifuged latex which has a minimum rubber content of 60% or evaporated latex which has a higher rubber content.

b) Dry Natural Rubber

Dry natural rubber is natural rubber latex that has dried. After tapping the rubber trees, the latex will drip for usually about four hours into a cup and will stop as the latex coagulates naturally on the tapping cut. After the liquid latex is collected from the cup, some trees will continue to drip and this leads to a small amount of 'cup lump' which is collected at the next tapping. The latex that coagulates on the tapping cut is also collected as 'tree lace'. Rubber collected by smallholders and coagulated by any means is called 'smallholders' lump'. Latex that drips onto the ground is collected too as 'earth scrap'. The following paragraphs describe the four types of dry natural rubber;

i) Cup Lump

Cup lump is the coagulated latex found in the collection cup when the tapper next visits the tree to tap it again. It arises from latex clinging to the wall of the cup after the liquid latex was last collected, and from late-dripping latex before the latex coagulates on the cut, or from latex which is purposely left to coagulate in the cup and collected on the following day. It is of higher purity and of greater value than the other three types.

ii) Tree Lace

Tree lace is the latex that has coagulated on the tapping cut that the tapper peels off the previous cut before making a new cut. It usually has higher

copper and manganese contents than cup lump. Both copper and manganese are pro-oxidants and can lower the physical properties of the natural rubber.

iii) Smallholders' Lump

Smallholders' lump is produced by smallholders who collect rubber from trees far away from the nearest factory. As it is often impossible to preserve the latex sufficiently to get it to the factory that processes latex in time for it to be used to make high quality products, and as the latex would anyway have coagulated by the time it reaches the factory, the smallholder will coagulate it by any means available, in any container like small buckets. Often the latex is coagulated in holes in the ground, which are usually lined with plastic sheeting. Acidic materials and fermented fruit juices are used to coagulate the latex, a form of assisted biological coagulation. Little care is taken to exclude leaves, barks etc. from the lumps that are formed.

iv) Earth Scrap

Earth scrap is the latex that gathers around the base of the tree. It arises from latex overflowing from the cut and running down the bark of the tree, from rain flooding a collection cup containing latex, and from spillage from tappers buckets during collection. It contains soil and other contaminants, and has variable rubber content, depending on the amount of contaminants mixed with it. Earth scrap is collected by the field workers two or three times a year and will be cleaned to recover the rubber. However, the product is of very low quality.

Of the four types of dry natural rubber described above, only cup lump shall be allowed to be used as additive to bitumen. However, of the two forms of natural rubber described above, latex is the most effective additive to bitumen. Whether natural rubber latex or dry natural rubber cup lump is used as additive to bitumen, the modified binder shall comply with performance grade PG 76 or higher in compliance with AASHTO Standard M320-02.

c) Properties of Natural Rubber

Natural Rubber Latex

Natural rubber latex shall be a sticky, milky colloid obtained from rubber trees. Initially when collected after tapping the rubber tree, the latex usually contains 30% dry rubber and 70% water. It shall be collected before it coagulates and shall then be transferred into air-tight containers with sieving for ammoniation whereby an ammonia solution shall be used to preserve the latex in a colloidal state for longer periods of time. The latex shall then be processed into high quality latex concentrate by centrifugation or evaporation. The dry rubber content of the latex shall be not less than 60%. The latex shall be of low ammonia with a maximum ammonia content of 0.3%. The complete requirements for the natural rubber latex are shown in Table 2.

Table 2 *Properties of natural rubber latex*

Characteristic	Requirement	Test Specification
Total solid content, % by mass, min.	61.5	ISO 124
Dry rubber content, % by mass, min.	60.0	ISO 126
Coagulum content, % by mass, max.	0.03	ISO 706
Ammonia content, % by mass, max.	0.3	ISO 125
Mechanical stability time (MST) @ 55% TSC, seconds, min.	650	ISO 35

The Contractor shall submit full technical details of the natural rubber latex and obtain the S.O.'s approval of the material prior to the commencement of works.

Natural Rubber Cup Lump

Natural rubber cup lump, for use as bitumen additive, shall be produced through stringent quality control of the raw cup lump collected from the plantations. The production shall involve cleaning, size reduction via wet pre-breaker, creeper and shredder, and drying. The requirements for the processed natural rubber cup lump are shown in Table 3.

Table 3 *Properties of natural rubber cup lump*

Characteristic	Requirement	Test Specification
Dirt retained on 44 aperture, % by mass, max.	0.16	ISO 249
Ash content, % by mass, max.	1.00	ISO 247
Nitrogen content, % by mass, max.	0.60	ISO 1656
Volatile matter content, % by mass, max.	0.80	ISO 248-1
Wallace rapid plasticity (Po), min.	30	ISO 2007
Plasticity retention index (PRI), %, min.	40	ISO 2930

The Contractor shall submit full technical details of the processed natural rubber cup lump and obtain the S.O.'s approval of the material prior to the commencement of works.

4.16.4 PREPARATION OF NATURAL RUBBER MODIFIED BINDER

Natural rubber shall be pre-blended with conventional bitumen before mixing with the aggregate in the asphalt mixing plant. The Contractor shall either provide a blending equipment system or tank close to the asphalt mixing plant whereby natural rubber modified binder can be manufactured on site, or shall obtain natural rubber modified binder from an approved source which is referred to as terminal blend. The terminal blend shall be transported in a well insulated tanker, and transferred into a binder storage tank at the asphalt mixing plant as described below. In either case, the Contractor shall provide a binder storage tank equipped with a suitable mechanical agitator close to the asphalt mixing plant. This tank shall also include distribution and circulation pipes that are properly insulated or heated. Continuous agitation of the binder during prolonged storage is essential to prevent separation. A suitable sampling point shall be provided at a convenient point in the storage tank system for taking samples. Samples shall be taken after prolonged storage or at any other

circumstances deemed necessary by the S.O. and tested for the properties as shown in Table 5 at an approved laboratory. Sampling shall be done in accordance with MS 539.

The blending equipment system or tank shall be of adequate capacity which will allow for at least 50% increase in volume when natural rubber, in particular natural rubber latex, is added. It shall be fitted with piping inside for heating with hot oil that are capable of raising the temperature of the bitumen to a maximum of 200℃. The tank shall be insulated with a minimum of 75 mm thick rockwool and aluminium cladding. The tank shall also be equipped with a mechanical agitator, either a paddle wheel type which will sweep the natural rubber down through the depth of the tank or a propeller type stirrer which will create a vortex, drawing the natural rubber down into the body of the bitumen. Either type of agitator shall be able to produce a homogenous bitumen – natural rubber blend.

a) Blending Natural Rubber Latex into Bitumen

Natural rubber latex has a water content of up to 40% which will cause foaming, irrespective of whether it is first added to cold bitumen which is then heated, or whether it is added to bitumen already heated to above the boiling point of water.

Bitumen shall be heated to a temperature of 150 – 170℃. Natural rubber latex shall be added gradually into the blending equipment system or tank, through a pump and spray or through a sprinkler system or poured manually, at an appropriate rate so as not to cause excessive foaming. Whichever method is used, the natural rubber latex shall fall gently onto the surface of the bitumen and not splash into the bitumen. It shall be allowed to float on the bitumen surface for about 20 seconds to allow its constituent water to evaporate (flash off) before being drawn into the bitumen by the mechanical agitator. It should not float on the surface for a longer period as, once the water has evaporated, coagulation will start and a lumpy mixture result. When the intensity of foaming has been gauged, the remainder of the natural rubber latex shall be added as fast as seems desirable to ensure that the foaming is not too great for the capacity of the blending tank, and agitated vigorously into the bitumen. As long as the latex is added slowly and the degree of foaming assessed, there will be no danger of the bitumen foaming over. Alternatively, anti-foaming agent shall be used as approved by the S.O..

Stirring shall be continued for a minimum period of 20 minutes after complete addition of the natural rubber latex. After blending is complete, the natural rubber modified binder shall be allowed to cool to below 120℃ but with continuous stirring unless it is to be used immediately. After storage, the binder shall be heated to a temperature of 150 – 170℃ before use.

b) Blending Dry Natural Rubber into Bitumen

Bitumen shall be heated to a temperature of 150 – 170℃. Dry natural rubber shall be dispersed over the surface of the bitumen in a thin layer. It is then drawn into the bitumen by the mechanical agitator. Further dry natural rubber shall be added when the previous thin layer has been drawn down away from the surface.

c) Completion of Blending

Blending shall be deemed to be complete when a small drop of natural rubber modified binder from the tank, placed on an impervious surface, shows only a few specks of rubber which are soft enough to be spread into the binder by a knife or spatula. If the rubber particles still preserve their entity and cannot be rubbed away into the binder, blending is considered incomplete and further heating and agitation are necessary.

d) Storage of Natural Rubber Modified Binder

The natural rubber molecule consists of a very long chain of many isoprene units which can be broken into several smaller ones by various processes; the natural rubber is said to be degraded or broken down chemically. Heating is one of the processes which lead to degradation of natural rubber. It degrades with time at high temperatures. It is recommended that the effective rubber content should not be allowed to drop below about half of the original rubber content added to ensure that the extent of degradation of the natural rubber modified binder will not significantly affect the properties of the asphaltic concrete. Therefore, it is recommended that the binder after blending is complete shall not be stored at elevated temperatures for longer than the periods shown in Table 4 as given in Road Research Laboratory Road Note 36. The total storage time allowable at different temperatures shall be calculated as follows; after storage at one temperature, the allowable storage time at any subsequent temperature shall be reduced by the following ratio;

$$\frac{\text{Time at first temperature}}{\text{Time allowable at first temperature}}$$

Table 4 *Allowable storage time for natural rubber modified binder*

Temperature (°C)	**Storage Time (hours)**
200	1
180	3
160	12
140	48
120 or below[1]	7 days
Ambient	Indefinitely

e) Application of Natural Rubber Modified Binder

At the time of application, the rubber additive shall be thoroughly dissolved in and dispersed uniformly throughout the bitumen without any coagulation of the rubber particles or the presence of undissolved lumps.

The properties of the natural rubber modified binder shall be as given in Table 5.

[1] *Above ambient temperatures.*

***Table 5** Properties of natural rubber modified binder*

Test	Requirement	Test Specification
Natural rubber modified binder prior to rolling thin film oven test (RTFOT)		
[3]Viscosity, max. 3 Pa.s, test temperature ℃	135[2]	ASTM D 4402
[3]Dynamic shear, G*/sin δ min. 1.00 kPa, 10 rad/s, test temperature ℃	76	AASHTO T 315
[4]Penetration, 100 g, 5 s, 25 ℃, 0.1 mm	Report[5]	ASTM D 5
[4]Ring and ball softening point, min. ℃	Report[5]	ASTM D 36
[4]Flash point, min. ℃	230	AASTHO T 48
Natural rubber modified binder after RTFOT (AASHTO T 240) or ASTM D 2872		
[3]Mass loss, max. %	1.00	AASHTO T 240 or ASTM D 2872
[3]Dynamic shear, G*/sin δ min. 2.20 kPa, 10 rad/s, test temperature ℃	76	AASHTO T 315

A viscosity-temperature relationship shall be established, using suitable rheometer, for the natural rubber modified binder. The temperatures to which the natural rubber modified binder must be heated to produce a viscosity of 0.2 Pa.S shall be the mixing temperatures. The temperatures to which the natural rubber modified binder must be heated to produce a viscosity of 2 – 20 Pa.S shall be the compaction temperatures.

4.16.5 MIX DESIGN

a) Job Mix Formula

The Contractor shall propose a job mix formula for each type of mix required in the Works. In order to obtain optimum quality of the mixtures, the job mix formula for each type of mix shall be prepared on the basis of testing several laboratory design mix gradations within the limits set in Table 1 at an appropriate range of natural rubber modified binder content. As a guide to the testing range of the binder content, the design binder content will usually be in the range given in Table 6.

***Table 6** Range of design binder contents*

AC 10 - Wearing Course	5.5 – 7.5%
AC 14 - Wearing Course	4.5 – 6.5%

[2] *The requirement may be waived at the discretion of the S.O. if the supplier warrants that the natural rubber modified binder can be adequately pumped and mixed at the temperatures that meet all applicable safety standards.*
[3] *These tests shall be carried out as and when required by the S.O. but shall be not less than one test per 30 tons of binder produced or at least once per project if the total quantity of binder produced is less than 30 tons. The binder samples shall be taken immediately prior to the production of asphalt. Test frequency may be reduced if test results consistently conform to the requirements.*
[4] *These tests shall be carried out minimum once for each blending process for quality control purposes during blending at the asphalt mixing plant or terminal blending.*
[5] *The penetration and softening point values shall be taken as reference for consistency check on the production.*

Each combination of laboratory design mix aggregate gradation and binder content shall be subject to the Marshall test procedure and volumetric analysis as follows;

i) Preparation of Marshall specimens for the standard stability and flow test in accordance with ASTM D 1559 using 75-blows/face compaction standard at compaction temperature as determined from the above viscosity-temperature relationship,

ii) Determination of the bulk specific gravity of the specimens in accordance with ASTM D 2726,

iii) Determination of the stability and flow of the specimens in accordance with ASTM D 1559,

iv) Analysis of the specific gravity and air voids parameters to determine the percentage air voids in the compacted aggregate, the percentage air voids in the compacted aggregate filled with the binder and the percentage air voids in the compacted mix.

For each laboratory design mix gradation, four Marshall specimens shall be prepared for each binder content within the range given in Table 6[6] at increments of 0.5 percent, in accordance with ASTM D 1559 using 75 blows/face compaction standard. All binder contents shall be in percentage by weight of the total mix.

As soon as the freshly compacted Marshall specimens have cooled to room temperature, the bulk specific gravity of each specimen shall be determined in accordance with ASTM D 2726.
The stability and flow value of each specimen shall then be determined in accordance with ASTM D 1559.

After the completion of the stability and flow test, specific gravity and voids analysis shall be carried out for each specimen to determine the percentage air voids in the compacted aggregate filled with binder (VFB) and the percentage air voids in the compacted mix (VIM).

Values which are obviously erratic shall be discarded before averaging. Where two or more specimens in any group of four are so rejected, four more specimens shall be prepared and tested.

The mean values of bulk specific gravity, stability, flow, VFB and VIM obtained above shall be plotted separately against the binder content and a smooth curve drawn through the plotted values.

The mean optimum binder content shall be determined by averaging five optimum binder contents so determined as follows;

i) Peak of curve taken from the stability graph[7],
ii) Flow equals to 3.5 mm from the flow graph,

[6] *The range of binder content shall be extended if necessary to ensure that the curves of stability and bulk specific gravity have their peak within the range selected.*
[7] *Where the stability curve exhibits more than one peak, the binder content chosen for the determination of the mean optimum binder content shall be the one which satisfies the voids requirements better. It is sometimes necessary where no peak stability is obtained, to prepare and test supplementary specimens at intervals of 0.25% binder content on either side of the expected optimum.*

iii) Peak of curve taken from the bulk specific gravity graph[8],
iv) VFB equals to 75.0% from the VFB graph, and
v) VIM equals to 4.0% from the VIM graph.

The individual test values at the mean optimum binder content shall then be read from the plotted smooth curves and shall comply with the design parameters given in Table 7.

If any of the values does not comply with Table 7, the mix design procedure shall be repeated using a different aggregate gradation until all design parameters are satisfied.

Table 7 *Test and analysis parameters for natural rubber modified asphaltic concrete*

Parameter	Requirement
Stability (S)	> 13,000 N
Flow (F)	2.0 – 5.0 mm
Stiffness (S/F)	> 2,600 N/mm
Voids in mix (VIM)	3.0 – 5.0%
Voids in aggregate filled with bitumen (VFB)	70 – 80%

Additional eight Marshall specimens shall be prepared using the same aggregate gradation and compaction effort, with the mean optimum binder content established during the mix design stage. Four of these specimens shall be tested for resilient modulus and another four specimens for dynamic, unconfined, compressive creep as described below;

i) Indirect tensile test for resilient modulus (ASTM D 4123)

Total resilient modulus	> 3,000 MPa
Test temperature	25℃
Applied load (max. 1,500 N)	20 N/mm of specimen thickness
Loading frequency	1 Hz
Loading time	0.1 s
Rest period	0.9 s
Rise time	70 ms
Poisson's ratio	0.35
No. of preconditioning pulses	50
No. of test pulses	5
Rotation of specimen	90°

Report mean value of total resilient modulus (E_{RT}) from two alignments (rotation). Disregard test result if E_{RT} values for the same test specimen differ by more than 10% from the mean value.

[8] *With highly absorptive aggregates, some difficulty in determining peak bulk specific gravity may occur. In such cases, the binder content at which the increase in bulk specific gravity shows a marked falling off shall be adopted.*

ii) Dynamic, unconfined, compressive creep test (EN 12697-25)

Dynamic creep modulus	> 75 MPa
Slope at steady state	< 0.25
Pre-conditioning;	
Test temperature	40℃
Applied axial stress	150 kPa
Loading frequency	0.5 Hz
Loading time	0.2 s
Rest period	1.8 s
No. of load cycles	30
Testing;	
Test temperature	40℃
Applied axial stress	300 kPa
Loading frequency	0.5 Hz
Loading time	0.2 s
Rest period	1.8 s
No. of load cycles	3,600

Report dynamic creep modulus and slope at steady state, the latter shall be log strain divided by log load cycles between 2,000 and 3,600 load cycles.

b) Plant Trials

After having received the S.O. preliminary approval of his proposed job mix formula, the Contractor shall arrange to mix, lay and compact natural rubber modified asphaltic concrete conforming to the proposed formula for each type of mix required in the Works. A minimum of 20 tons of the mix shall be placed in trial areas to demonstrate to the satisfaction of the S.O. that the mixing, laying and compacting equipment conforms to the requirements of this Specification, and that the proposed mix is satisfactory. The trial areas shall not be part of the Contract Works but shall be provided by the Contractor at his own expense. The proposed trial area shall be approved by the S.O..

As directed by the S.O., comprehensive sampling and testing of the mix shall be carried out to check for satisfactory compliance with its job mix formula, and for a satisfactory degree of compaction. In order to demonstrate to the satisfaction of the S.O. that mixing, laying and compacting equipment conform to the requirements of the specification, and that the proposed mix is satisfactory, the following observations and tests shall be carried out.

i) Record the type and weight of rollers. Check the tyre pressure of the pneumatic tyre roller (shall comply with sub-section 4.16.6 (g)).

ii) Record the type of paver (shall comply with sub-section 4.16.6 (f)).

iii) Check that the trial area is suitable (not on soft ground, uneven surface or actual contract site).

iv) Take sample of the mix and carry out the following tests;

- Binder content and aggregate grading (shall comply with sub-section 4.16.5 (c)).
- Preparation of Marshall specimens.
- Bulk specific gravity of Marshall specimens.
- Volumetric properties of Marshall specimens (shall comply with Table 7).
- Marshall stability and flow (shall comply with Table 7).
- Resilient modulus.
- Dynamic, unconfined, compressive creep.

v) Record temperatures of mix on the lorry, at plant and site (shall not exceed 180℃ at any time and shall be not less than 150℃ immediately before unloading into the paver hopper).

vi) Record laying (uncompacted) thickness.

vii) Check texture of paved surface before rolling (there shall be no substantial blemishes and irregularities).

viii) Record temperatures immediately before rolling starts (rolling temperatures)

ix) Record rolling pattern.

x) Check texture of compacted surface.

xi) Cut core samples after the laid material has sufficiently hardened (at least three samples from each lorry load).

xii) Record compacted thickness and density from core samples (shall comply with sub-section 4.16.7 (i)).

As a result of the plant trials, the S.O. may require amendments to the job mix formula, further tests and analysis, and additional plant trials.

Upon satisfaction by the S.O., the Contractor shall be required to produce a full report of the plant trial and this document shall be used in full scale production in the Works.

c) Compliance with the Job Mix Formula

The S.O. final approval of the job mix formula shall bind the Contractor to produce natural rubber modified asphaltic concrete mixes conforming to the precise gradation and binder content specified in the formula within the tolerances set forth in Table 8 and using natural rubber modified binder that consistently comply with the properties as specified in Table 5.

Modifications to the job mix formula shall only be made with the approval of the S.O. Should the S.O. at any time have reasons to believe that the materials and methods of mixing and laying are different from those approved, he shall so advise the Contractor and may instruct that natural rubber modified asphaltic concrete works be discontinued pending further plant trials and testing.

Table 8 *Tolerances for natural rubber modified asphaltic concrete*

Parameter	Permissible Variation % By Weight of Total Mix
Binder content	± 0.2 %
Fractions of combined aggregates passing 5.0 mm and larger sieves	± 5.0 %
Fractions of combined aggregates passing 3.35 mm and 1.18 mm sieves	± 4.0 %
Fractions of combined aggregates passing 425 μm and 150 μm sieves	± 3.0 %
Fractions of combined aggregates passing 75 μm sieve	± 2.0 %

d) Sampling and Testing of Natural Rubber Modified Asphaltic Concrete

Frequency of sampling and testing shall be not less than that shown in Table 9. It provides for two levels of minimum frequency. The reduced frequency may only be adopted if the test results consistently conform to the requirements.

Table 9 *Frequency of sampling and testing of natural rubber modified asphaltic concrete*

Test	Normal Minimum Frequency	Reduced Minimum Frequency
Binder content, aggregate gradation, stability, flow, VIM and VFB	One test per 200 tons asphalt plant production.	One test per 300 tons asphalt plant production.
Resilient modulus and dynamic, unconfined, compressive creep	These tests shall be carried out as and when required by the S.O. but shall be not less than one test per 1,000 tons of asphalt produced or at least once per project if the quantity of asphalt produced is less than 1,000 tons. Test frequency may be reduced if test results consistently conform to the requirements.	
Temperature	Each loaded tip-truck.	Each loaded tip-truck.

4.16.6 EQUIPMENT

The Contractor shall provide all the plant and equipment necessary for executing the work in accordance with this Specification and shall furnish the S.O. with such details of particular items of equipment, e.g. manufacturer, model type, capacity, weight, operating features, etc., as the S.O. shall require.

a) Road Cleaning Equipment

Immediately prior to applying bituminous tack coat, the full width of the surface to be treated shall be swept using a power broom followed by a compressed air blower, and if necessary, scraped using hand tools, to remove all dirt, dust and other objectionable material, all to the satisfaction of the S.O.

b) Asphalt Mixing Plant

The asphalt plant shall be either a batch plant or a drum mix plant of recognised manufacturer and shall be approved by the S.O. It shall conform to the requirements described hereunder.

The mixing plant shall have a capacity suited to the Works and sufficient to enable the paver to operate more or less continuously when paving at normal speeds at the required thicknesses. The plant shall be designed so as to enable consistent production of natural rubber modified asphaltic concrete mixes within the tolerances prescribed in this Specification, all to the satisfaction of the S.O.

Mixes produced and delivered shall have actual tonnages of aggregates, filler and binder components recorded. The temperature of the mix leaving the plant shall be recorded for each batch or every 15 minutes. Where the control system incorporates a computer and a printer capable of printing the information, copies of the printouts shall be provided to the S.O. for quality assurance.

Tanks for storage of binder shall have a capacity suited to the proposed rate of utilizations of the material and the method and frequency of its delivery to the Works, all to the satisfaction of the S.O. The tanks shall be provided with means of measuring the volume of their contents at all times and of drawing off samples of the contents. The binder feeding system shall provide for continuous circulation of hot binder through the system and back into the feed tank. The end of the return line discharging into the feed tank shall always be kept submerged in the binder in the tank in order to prevent oxidation of the returning hot binder. The storage tanks, and where necessary barred decanters, and all elements of the binder feeding system shall be equipped with heating system or insulating jackets as necessary to provide for effective and positive control of the temperature of the binder at all times up to the temperature required for utilizations. The method of heating shall be such that neither flames nor the products of combustion shall come into direct contact with the binder or the casing of its immediate container, and such that no portion of the binder shall be subject to overheating.

Calibration of the plant load cells to an accuracy of $\pm$ 1% error must be carried out before the production of the trial mixes. This calibration is to test the integrity of all the weighing system of the aggregate bins, filler hoppers and binder hopper.

Temperature-measuring equipment, such as thermometers or electrical thermocouples, providing temperature measurements of plant processes and materials, shall also be calibrated accordingly.

Calibration is also required for the feeders to match the production capacity. Once the calibration is set and mixes production commence, calibration procedures shall be repeated every 30,000 tons or one month whichever is earlier.

c) Batch Plant

The plant shall be provided with accurate mechanical means for uniformly feeding the aggregate into the dryer so that uniform production and temperature of the heated aggregate will be obtained. A separate feed bin with an adjustable gate opening shall be provided for each aggregate to be included in the combined aggregate for the mix; normally four bins will be required. The feed bins and gates shall be constructed and equipped that they shall be readily accessible for calibrating at all times, and shall provide for a continuous and uniform flow of each aggregate required in the mix.

The plant shall have a rotary drum dryer of satisfactory design for drying and heating the combined aggregate so that its temperature will be at the required level at the time it is mixed with the bitumen. The burner shall be so designed that complete combustion of the fuel will be obtained, and the aggregate will remain clean and not become coated with soot or oil.

The plant shall be equipped with four (or more) screens, the smallest of which shall generally be not more than 3.2 mm. The screens shall have a normal capacity slightly in excess of the maximum output of the mixing plant. The screens shall be readily accessible for inspection.

The plant shall include four (or more) storage bins for screened aggregates, each with a capacity of not less than twice the pugmill dead load capacity. The bins shall be arranged so as to provide separate dry storage for each screened fraction of the aggregate. Each bin shall be provided with an overflow pipe of such size and location as to prevent any backing up of material into other bins. Each bin shall be so constructed that representative aggregate samples can be readily obtained, and shall have means for observing the aggregate level. Separate dry storage shall be provided for mineral filler, and the plant shall be satisfactorily equipped to feed filler into the mixer.

Accurate means of weighing by load cells shall be provided for weighing the aggregates and filler and also for weighing the bitumen required for each batch of mix.

Suitable means shall be provided for maintaining the prescribed temperature of the bitumen in the pipelines, weigh bucket of flow meter, and spray bars.

An armoured thermometer with a range of 30℃ to 200℃ shall be fitted in the bitumen feed line at a suitable location near the discharge valve at the mixer unit. Suitable dial-scale mercury actuated thermometer, electric pyrometers or other thermometer instruments shall be fitted at the discharge chute of the dryer and in each hot aggregate storage bin to indicate the temperature of the heated aggregate.

The plant shall be equipped with adequate and safe stairways to the mixing platform and sampling location and guarded ladders and cat-walks shall provide access to all other positions as necessary for proper operation, inspection and maintenance of the plant, all to the satisfaction of the S.O. All gear, pulley, chains, sprockets and other dangerous moving parts shall be property guarded and protected. Ample and unobstructed space shall be provided on the mixing platform, and clear and unobstructed passage shall be maintained at all times in and around the truck loading area, which shall, be kept free from drippings from the mixer.

Each storage bin for screened aggregate shall be provided with a bottom outlet gate so constructed as to prevent leakage when closed. These gates shall have a quick and complete closing action. The plant shall be equipped with a weigh box or hopper for accurately weighing out aggregate from each of the screened aggregate storage bins.

The weigh box or hopper shall be suspended from its scale's lever mechanism and shall be sufficiently large to holds a full batch equal to the pugmill capacity without hand raking of the aggregate. The discharge gate shall be so constructed as to allow rapid and complete emptying of the weigh box or hopper into the mixer, and prevent leakage when closed.

The plant shall be equipped with a binder weigh bucket which shall be charged through a fast acting non-dip valve in the binder feed pipe located directly over the bucket. The bucket shall be suspended from its scale's lever mechanism and shall have a capacity sufficient to weigh out binder up to 20% of the weight of the pugmill dead load capacity. The bucket shall have a discharge mechanism which shall provide for rapid and complete emptying of the bucket in a thin uniform sheet or multiple sprays over the full length and width of the mixer. The discharged shall not leak or drip when closed.

The batch mixer shall be a suitable twin-shaft pugmill, with a capacity of at least 500 kg of asphaltic concrete, capable of producing a thoroughly homogeneous mixture. The clearance of the paddle blades from all fixed and moving parts of the mixer shall be not more than 20 mm. If the pugmill is not enclosed, it shall be equipped with a dust hood to prevent loss of fines from the mixture. The discharge gate shall be so constructed as to allow rapid and complete emptying of the mixer, and prevent leakage of any mix constituent when closed.

The mixer shall be equipped with an accurate time lock system for controlling the operations of a complete mixing cycle. It shall lock the aggregate weigh box or hopper gate after charging the mixer with aggregate, until the closing of the mixer gate at the completion of the mixing cycle; it shall lock the binder weigh bucket discharge mechanism during the dry mixing and wet mixing period. The dry mixing period is defined as the interval of time between the opening of the aggregate weigh box of hopper gate and the start of discharging the binder weigh bucket. The wet mixing period is defined as the interval of time between the start of discharging the binder weigh bucket and the opening of the mixer gate. The dry and wet mixing periods shall both be adjustable in increments of not more than 5 seconds from zero to not more than 60 seconds total for dry and wet mixing.

The filler silo shall have suitable a screw conveyor system to discharge into the pugmill.

The control system for the plant shall be housed in a weather proof cabin with windows to view the plant operations. Control in the cabin shall have the capability to accurately batch the aggregates, filler and bitumen for the mix, transfer to the pugmill mixer and control the mixing time. The temperature of the heated aggregates, filler and bitumen shall also be displayed in this cabin and adjusted to meet the Specifications when required.

d) Drum Mix Plant

The cold material feeder unit shall consist of not less than 5 bins with suitable heaped capacity appropriate for the plant. Each bin shall be equipped with a variable speed weighing belt feeder (driven by variable speed electric motor fitter with a tachometer) with a load cell for accurate weight measurement of each type of aggregate used in the mix in equivalent dry tons per hour. The cold feed system shall incorporate a device for moisture compensation capable of producing an accurate and continuous blend of the individual aggregate sizes from the cold feed compartment. The cold feed system

shall also be equipped with a scalping screen of screed size of not more than 50 mm to discard any oversized aggregates before entering the dryer drum.

The drum mixer shall have flight designs to accomplish the proper transfer of heat from the exhaust gases of the burner to the aggregates and to blend the aggregates and bitumen together adequately. The flight, at the upper end of the drum, shall be able to direct the aggregate into the drum beyond the tip of the flame, thereafter the subsequent flight shall be efficient to lift and tumble the aggregates with the cumulation of a veil of aggregates across the whole cross-sectional area near the mid-point of the length of drum where the aggregate temperature shall have been raised to dew point. This veil of aggregates shall be sufficiently complete and dense to maximise heat transfer and to screen the bitumen from the direct flame to minimise hardening and oxidation of the bitumen during the mixing process. The downstream mixing flight designs shall complete the heat transfer process and raise the mix temperature to the desired level for discharge. The length to diameter ratio of the drum shall be appropriately designed to obtain more complete heat transfer; to enable the bitumen to be injected in an inert atmosphere where proper coating/adhesion onto aggregates can take place without severe oxidation or hardening of bitumen and effective mixing and sufficient designed mix temperatures are achieved. The drum shall be inclined, oil-fired and suitably and sufficiently insulated.

The control system of a drum mixer must be automatically computer controlled with a fully independent manual back-up system. The system shall be such that the operator able to view the operation of the whole plant and of the individual component stations. All relevant information of the plant operation and the progress of the tonnage of mix produced and mix design information shall be made available. The control system shall be possess a Quality Assurance package to act as an audit tool (when required to be used) whereby the information on Plant Monitor, Progress Monitor and Mix Temperature shall be made available at pre-set, variable time intervals.
Freshly mixed material shall be collected and delivered to be stored in a surge silo through a proper conveyor system.

e) Tip-Trucks

The Contractor shall provide a suitable number of tip-trucks of a type approved by the S.O. for transporting natural rubber modified asphaltic concrete from the mixing plant to the paving sites. The trucks shall have trays with smooth, flat beds and sides, and shall have load capacities of not less than 5 tons. Prior to loading, the inside of each truck tray shall be lightly and evenly coated with a soap or detergent solution, or such other liquid as the S.O. shall approve, to prevent adhesion of the natural rubber modified asphaltic concrete. The trucks shall be equipped with covers of canvas or other suitable material to protect the natural rubber modified asphaltic concrete.

f) Asphalt Paver

The asphalt paver shall be of recognised manufacturer and shall be approved by the S.O. It shall conform to the requirements described hereunder.

The paver shall be self-propelled and capable of reverse as well as forward travel. It shall be equipped with a hopper at the front designed to receive the paving mix from tip-trucks, and shall have a mechanical distribution system for spreading the mix evenly and without segregation over the surface to be paved in front of a screeding and

compacting unit which shall be equipped with a suitable heating device. The screeding and compacting mechanism shall be capable of confining the edges of the material being laid without the use of stationary side forms, shall be adjustable to strike off the mixture to the thickness and cross-section shape required, and shall be controlled by an automatic levelling device to produce an even carpet of bituminous mixture with a uniform surface texture free from indentations, ridges, tear marks or other irregularities. The paver shall be capable of laying the bituminous mixture in paving widths in the range 2.5 to 3.75 m and of finishing the pavement layer true to the required lines, grades, levels, dimensions and cross-sections, subject to compaction by rolling, all to the satisfaction of the S.O.

g) Rollers

A pneumatic-tyred roller and two steel-wheeled tandem rollers shall be provided. All rollers shall be of recognised manufacture and shall be approved by the S.O. They shall conform to the requirements described hereunder.

Pneumatic-Tyred Roller

Pneumatic-tyred roller shall be self-propelled and capable of being reversed without backlash; it shall be equipped with power steering and dual controls allowing operation from either the left or right side.

The roller shall have nine wheels equipped with smooth tyres all of the same size and construction. Five wheels shall be on the driven axle and four on the steering axle, all equally spaced on both axles and arranged so that the tyres on the steering axle track midway between those on the driven axle with a small overlap. The roller shall be ballasted to an operating weight of not less than 15 tons with a tyre inflation pressure of not less than 0.7 N/mm^2.

The Contractor shall provide the S.O. with a calibration chart for the roller showing the relationship between the quantity or depth of ballast and total weight, and also a chart showing the relationship between wheel load, tyre inflation pressure and contact pressure.

Pneumatic-tyred rollers shall be equipped with water tanks, sprinkler systems and scraper blades to keep all wheels evenly wetted and clean during operation. Soap or detergent solution, or such other liquid as the S.O. shall approve, shall be used to prevent the asphalt from sticking to the roller tyres.

Steel-Wheeled Tandem Rollers

Steel-wheeled tandem rollers shall be self-propelled and capable of being reversed without backlash; they shall be equipped with power steering and dual controls allowing operation from either the left or right side. They also shall be equipped with water tanks, sprinkler systems and scraper blades to keep all wheels evenly wetted and clean during operation. Soap or detergent solution, or such other liquid as the S.O. shall approve, shall be used to prevent the asphalt from sticking to the roller tyres.

Steel-wheeled tandem rollers shall be ballasted so that their total operating weight are in the range 8 to 10 tons and their driven roll (or rolls) shall exert a rolling force of not less than 3.5 tons/meter of roll width. The Contractor shall provide the S.O. with a

calibration chart for each roller showing the relationships between the quantity or depth of ballast and total weight and rolling force.

4.16.7 CONSTRUCTION METHODS

a) General Conditions

Natural rubber modified asphaltic concrete paving work shall only be carried out in dry weather when the surface to be covered is clean and dry, and has received a bituminous tack coat which shall have achieved a satisfactory degree of tackiness, all to the satisfaction of the S.O. All laying, rolling and finishing work shall be carried out during daylight hours, unless the Contractor shall have provided suitable flood-lighting for the job site, to the satisfaction of the S.O.
The S.O. may order the discontinuation of work on account of adverse weather, unsatisfactory condition of materials, equipment or surface to be paved, or such other conditions as he or she shall consider detrimental to the work.

b) Surface Preparation and Cleaning

Prior to constructing a natural rubber modified asphaltic concrete pavement layer, the surface to be covered shall have been prepared in accordance with the appropriate Sections of this Specification. Notwithstanding any earlier approval of this surface, any damage to or deterioration of it shall be made good before natural rubber modified asphaltic concrete paving work is commenced.

If the surface to be covered is to be provided with a bituminous tack coat, then this shall be applied all in accordance with the provisions of sub-section 4.3.2 in JKR/SPJ/2008-S4.

c) Aggregate Handling and Heating

Each aggregate to be used in the natural rubber modified asphaltic concrete mixes shall be stored in a separate stockpile near the mixing plant. Stockpiles of sand and other fine aggregates shall be kept dry using waterproof covers and other means as necessary. In placing the aggregates in the stockpiles and loading them into the mixing plant's cold aggregate feed bins, care shall be taken to prevent segregation or uncontrolled combination of materials of different gradation. Segregated or contaminated materials shall be rescreened or rejected for use in the Works and removed from the mixing plant site.

The aggregates shall be fed into the dryer at a uniform rate proportioned in accordance with the appropriate job mix formula. The rate of feed for each aggregate shall be maintained within 10% of the rate prescribed, and the total rate of feed shall be such that the plant's screens shall never be overloaded.

The aggregates shall be dried and heated so that when delivered to the mixer they shall be at a temperature in the range of 160℃ to 180℃.

Immediately after heating, the aggregates shall be screened into four (or more) fractions which shall be separately stored in the hot aggregate storage bins in readiness for mixing.

Mineral filler cum anti- stripping agent to be used in the mix shall be stored separately and kept completely dry. Its rate of feed into the plant shall be accurately controlled by weight or volumetric measurement, all to the satisfaction of the S.O.

d) Heating Natural Rubber Modified Binder

The natural rubber modified binder shall be heated so that when delivered to the mixer it shall be at a temperature in the range of 150℃ to 170℃.

e) Mixing Natural Rubber Modified Asphaltic Concrete

The mixing plant shall be so coordinated and operated as to consistently produce natural rubber modified asphaltic concrete mixes within the tolerances prescribed in this Specification, all to the satisfaction of the S.O.

Mixing in Batch Plants

For each batch the screened hot aggregates shall be weighed out into the aggregate weigh hopper in accordance with the proportions prescribed in the appropriate job mix formula; the sequence of weighing out shall commence with the largest sized aggregate and progress down to the fines, unless the S.O. shall otherwise approve. Mineral filler shall be weighed out into the filler weigh hopper, where this is provided, or added last to the aggregate weigh hopper, in accordance with the job mix formula proportions.

The hot binder shall be weighed out into the binder weigh bucket in accordance with the proportions prescribed in the job mix formula.

The hot aggregates and filler shall be discharged into the pugmill and mixed dry for the dry mixing time prescribed in the job mix formula, which shall usually be in the range five to 10 seconds. The hot binder shall then be added and wet mixing performed for the wet mixing time prescribed in the job mix formula; this shall be sufficient so that all particles of aggregate are uniformly coated with bitumen, and shall usually be 45 seconds or less for dense graded mixtures.

The volume of each batch shall be such that the tips of the pugmill paddle blades just break out of the mixture at the height of their action.

After the completion of wet mixing, each batch of natural rubber modified asphaltic concrete shall be discharged from the pugmill either into a storage hopper or directly into a truck for hauling to the paving site. Care shall be taken that no segregation of the mix occurs.

Mixing in Continuous Mix Plants

The screened hot aggregates and filler shall be fed continuously from their storage bins in accordance with the proportions prescribed in the appropriate job mix formula, combined in the plant, and fed continuously into the mixer. The hot binder shall be sprayed on to the combined aggregate as it enters the pugmill at the rate required to achieve the bitumen content prescribed in the job mix formula. The materials shall then be carried through the pugmill and in the process be thoroughly mixed by the action of the paddles and discharged over the dam into the storage hopper. The mixing time shall

be as prescribed in the job mix formula; this shall be sufficient so that all particles of aggregate are uniformly coated with the natural rubber modified binder, and shall usually be 45 seconds or less for dense graded mixtures.

The plant shall be so adjusted as to maintain the level of mixture in the pugmill such that the tips of the paddle blades just break out of the mixture at the height of their action.

f) Transporting Natural Rubber Modified Asphaltic Concrete

Natural rubber modified asphaltic concrete shall be transported from the mixing plant to the site of the paving works in loads of not less than 5 tons using tip-trucks as specified in sub-section 4.2.4.4 (c) of JKR/SPJ/2008-S4. Except where natural rubber modified asphaltic concrete is to be hand laid, it shall be discharged directly into the paver hopper, as required, from the tip-trucks. Care shall be taken in the truck loading, hauling and unloading operations to prevent segregation of the mix. During transportation, the natural rubber modified asphaltic concrete shall be protected from contamination by water, dust, dirt and other deleterious materials.

The temperature of natural rubber modified asphaltic concrete immediately before unloading from the truck either into the paver hopper or on to the road for hand spreading shall be not less than 150℃. Any load which has cooled below the specified temperature in the truck shall be rejected for use in the Works and removed from the Site of the Works.

g) Laying Natural Rubber Modified Asphaltic Concrete

The sequence of laying operations shall be planned in advance by the Contractor and approved by the S.O. Generally each paving layer shall have a compacted thickness of not less than twice the nominal maximum aggregate size of the mixture, and not more than 100 mm. Where applicable, e.g. on superelevated sections and on carriageways with cross-slope in one direction only, laying shall commence along the lower side of the carriageway and progress to the higher side. Laying shall not be carried out in a downhill direction along any section of road.

As far as is practicable, laying shall be carried out using a paver approved by the S.O. Hand-casting of bituminous mix on to the machine finished surface shall be kept to the practicable minimum necessary for correcting blemishes and irregularities. In any areas inaccessible to the paver, laying shall be carried out by hand methods using rakes, lutes and other hand tools, all to the satisfaction of the S.O. All laying of bituminous mix shall be such that after compaction by rolling the specified course or layer thickness and surface profile shall be achieved. Care shall be taken to achieve a uniform surface texture free from indentations, ridges, tear marks or other irregularities, and to prevent segregation of the mix.

At the commencement of initial rolling, the temperature of natural rubber modified asphaltic concrete shall be as determined form the viscosity-temperature relationship. Material which has cooled below the specified temperature before laying shall not be used and shall be removed from the Site of the Works. The Contractor shall provide accurate thermometers at the paving site at all times, and shall check the temperature

of asphaltic concrete in the paver hopper at regular intervals and before laying restarts after each interruption of the paving operation.

As far as is practicable, the paver shall be operated continuously and the supply of bituminous mix shall be regulated so as to enable continuous paving. Transverse joints in a paving lane shall be kept to a practicable minimum, and intermittent stopping and restarting of the paver shall be avoided as far as is practicable.

Care shall be taken that no bituminous mix is placed on expansion joints at bridges, inspection covers for utilities ducts, drainage and sewerage manholes and the like, and that catchpits, drainage openings through kerbs, etc., remain properly open and serviceable. During laying operations, such areas and openings shall be protected by suitably shaped and secured boards or other materials approved by the S.O., and compaction of mix in the immediately surrounding or adjacent areas shall be completed by hand methods, all to the satisfaction of the S.O. Alternatively, bituminous mix shall be laid and compacted by hand methods as necessary around surfacing discontinuities of these types, all to the satisfaction of the S.O.

h) Construction Joints

Existing bituminous surfacing which new bituminous mix is to adjoin shall be cut back to present a straight, vertical edge not less than 25 mm deep and a smooth transition section not less than 500 mm long against which to lay the new material. The specified thickness of the new surfacing shall be built up gradually from the vertical joint to avoid any bumps or ridges across the carriageway.

Where longitudinal or transverse joints are required in a layer of bituminous mix under construction, the material first laid and compacted shall be cut back to a vertical face for the full thickness of the layer on a line satisfactory to the S.O. before the adjacent area is paved.
At all construction joints, a thin uniform coating of bitumen emulsion of grade RS-1K shall be brushed on to the vertically cut joint faces some 10 to 15 minutes before laying the next section of bituminous mix commences to ensure good bonding. Also, all contact surfaces of kerbs, gutters, manholes, catchpits, etc. shall be similarly treated with a coating of bitumen emulsion before bituminous mix is placed against them.

Construction joints in a layer of bituminous mix shall be offset from those in any immediately underlying bituminous layer by at least 100 mm for longitudinal joints and at least 500 mm, for transverse joints.

Construction joints shall not be permitted along wheelpaths.

i) Compacting Natural Rubber Modified Asphaltic Concrete

For each layer of natural rubber modified asphaltic concrete, compaction by rolling shall commence at temperature as determined from the viscosity-temperature relationship during the mix design process.

In any areas inaccessible to the rollers, proper compaction shall be carried out using vibrating plate compactors, hand tampers or other suitable means, all to the satisfaction of the S.O.

Initial (or breakdown) rolling shall be carried out with an approved steel wheeled tandem roller. The principal heavy rolling shall be carried out with an approved pneumatic tyred roller immediately following the initial rolling; the pneumatic tyred roller shall be ballasted to an operating weight of not less than 15 tons and its tyre inflation pressure shall be not less than 0.7 N/mm^2. The final rolling shall be carried out with an approved steel wheeled tandem roller and shall serve to eliminate minor surface irregularities left by the pneumatic tyred roller.

All rollers shall operate in a longitudinal direction along the carriageway with their driven wheels towards the paver. Rolling shall generally commence at the lower edge of the paved width and progress uniformly to the higher edge, except that where there is a longitudinal construction joint at the higher edge, this shall be rolled first ahead of the normal pattern of rolling. Generally, successive roller passes shall overlap by half the width of the roller, and the points at which the roller is reversed shall be staggered. However, when operating on gradients in excess of 4%, the breakdown roller shall not pass over any previously unrolled mix when operating in the downhill direction.

In all cases, compaction shall be carried out in such a manner that each section receives equal compactive effort, all to the satisfaction of the S.O.

The steel wheeled rollers shall operate at speeds of not more than 5 km/h and the pneumatic tyred rollers shall operate at speeds of not more than 8 km/h. No roller or heavy vehicle shall be allowed to stand on newly laid bituminous mix before compaction has been completed and the material has thoroughly cooled and set. Rolling shall continue as long as is necessary to achieve the appropriate requirement as shown in Table 10.

Table 10 *Compacted density for natural rubber modified asphaltic concrete*

Type of Pavement Layer	Required Compacted Density
Wearing course	98 – 100% of Marshall density

Care shall be taken to prevent over-compaction of natural rubber modified asphaltic concrete.

Within 24 hours of laying and compacting the bituminous mix, the Contractor shall cut core samples of not less than 100 mm nominal diameter at locations selected by the S.O. The rate of sampling shall be one sample per 500 m^2 of mix laid, but not less than two samples for the work completed in each paving session. These core samples shall be used by the S.O. to determine the compacted thickness and density of the material in accordance with ASTM Test Method D 2726.

j) Finished Natural Rubber Modified Asphaltic Concrete

Natural rubber modified asphaltic concrete wearing courses shall be finished in a neat and workmanlike manner; their widths shall be everywhere at least those specified or shown on the Drawings on both sides of the centre-line; the average thickness over any

100-metre length shall be not less than the required thickness, and the minimum thickness at any point shall be not less than the required thickness minus 5 mm.

The top surface of a wearing or binder course shall have the required shape, superelevation, levels and grades, and shall be everywhere within the tolerances specified in sub-section 4.5 of JKR/SPJ/2008-S4.

The International Roughness Index (IRI) value of the finished wearing course surface shall be carried out as described in sub-section 4.5.3 of JKR/SPJ/2008-S4 of this specification and shall be not more than 2.0 m/km.

k) Opening to Traffic

Natural rubber modified asphaltic concrete shall not be opened to traffic until compaction has been completed and the material has thoroughly cooled and set in the opinion of the S.O. This will usually be not less than four hours after the commencement of rolling. Where it is necessary to allow earlier use of the finished surface to facilitate the movement of traffic, vehicles may be allowed to run on the work after rolling has been completed, provided that speeds are restricted to 30 km/h or less and sharp turning movements are prohibited.

4.17 CRUMB RUBBER MODIFIED ASPHALT

4.17.1 DESCRIPTION

This Specification provides information on the design, production and use of crumb rubber modified asphalt (CRMA).

Crumb rubber modified asphalt is a mixture of aggregates and crumb rubber modified binder (CRMB).

CRMB is a blend of hot bituminous binder and crumb rubber manufactured from reclaimed tyre rubber which are produced from tyres with a typical outside diameter greater than 660 mm and less than 1,520 mm used on commercial vehicles such as lorries and busses.

This Specification focuses on CRMB (asphalt-rubber) in ASTM D 8, which defines asphalt-rubber as "a blend of asphalt cement, reclaimed tyre rubber, and certain additives in which the rubber component is at least 15 percent by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles".

The CRMB is formulated and reacted at elevated temperatures and under high agitation to promote physical interaction of the bituminous binder and reclaimed tyre rubber constituents, and to keep the rubber particles suspended in the blend. The CRMB contains visible particles of reclaimed tyre rubber.

The application of CRMB as described in this Specification is for crumb rubber - stone mastic asphalt (CR-SMA), crumb rubber - gap graded asphalt (CR-GGA), crumb rubber - open graded friction course (CR-OGFC) and crumb rubber - stress absorbing membrane interlayer (CR-SAMI).

4.17.2 MATERIALS

a) Aggregates

Aggregates for CRMA shall be a combination of coarse and fine aggregates, and mineral filler. The individual aggregate shall be of sizes suitable for blending to produce the required gradation of the combined aggregates, all to the satisfaction of the S.O.

Coarse aggregates shall be screened crushed hard rocks, angular in shape and free from dust, clay, vegetative and other organic matters, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The Los Angeles abrasion value when tested in accordance with ASTM C 131 shall be not more than 25%.

ii. The weighted average loss of weight in the magnesium sulfate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 18%.

iii. The flakiness index when tested in accordance with MS 30 shall be not more than 25%.

iv. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

v. The polished stone value when tested in accordance with MS 30 shall be not less than 40 (for wearing course only).

Fine aggregates shall be clean screened quarry dust. Other types of fine aggregate may be used subject to the approval of the S.O. Fine aggregates shall be non-plastic and free from clay, loam, aggregation of materials, vegetative and other organic matters, and other deleterious substances. They shall conform to the following physical and mechanical quality requirements;

i. The sand equivalent of aggregate fraction passing the No. 4 (4.75mm) sieve when tested in accordance with ASTM D 2419 shall be not less than 45%.

ii. The fine aggregate angularity when tested in accordance with ASTM C 1252 shall be not less than 45%.

iii. The Methylene Blue value when tested in accordance with Ohio Department of Transportation Standard Test Method shall be not more than 10 mg/g.

iv. The weighted average loss of weight in the magnesium sulfate soundness test (5 cycles) when tested in accordance with AASHTO Test Method T 104 shall be not more than 20%.

v. The water absorption when tested in accordance with MS 30 shall be not more than 2%.

Notwithstanding compliance with the requirements of this Specification, limestone aggregates shall not be permitted for use in wearing course.

The gradation of the combined coarse and fine aggregates, and mineral filler, shall conform to the appropriate envelopes shown in Table 1.

Table 1 *Combined Aggregate Gradation for CRMA Mixtures*

Mix Designation	**CR-SMA**	**CR-GGA**	**CR-OGFC**	**CR-SAMI**
BS Sieve Size, mm	**Percentage Passing (by weight)**			
20.0	100	100	100	100
14.0	85 – 100	85 – 100	85 – 100	75 – 100
10.0	50 – 75	50 – 70	45 – 80	0 – 15
5.0	20 – 35	18 – 35	3 – 30	-
2.36	15 – 25	8 – 20	0 – 15	0 – 5
0.6	8 – 20	-	-	-
0.3	6 – 15	-	-	-
0.075	5 – 10	0 – 7	0 – 4	0 – 2

For CR-SMA, CR-GGA and CR-OGFC, the Contractor shall propose a laboratory design mix gradation which shall consist of a single definite percentage passing for each sieve size in Table 1 and shall produce a smooth curve within the appropriate gradation envelope. This job laboratory design

mix gradation, with the allowable tolerances for a single test as specified in Table 6 (for CR-SMA, CR-GGA) and Table 7 (for CR-OGFC), shall then become the job mix formula.

b) Mineral Filler

Mineral filler shall be incorporated as part of the combined aggregate gradation (except CR-SAMI) and shall be hydrated lime (calcium hydroxide). At the time of mixing with CRMA, it shall be sufficiently dry to flow freely and shall be essentially free from agglomerations. The quantity which pass the BS 0.075 mm sieve shall not be less than 75% by total weight of the hydrated lime.

If hydrated lime is not available, ordinary Portland cement shall be used as an alternative, subject to approval of the S.O.

The mineral filler shall also be treated as an anti-stripping agent.

c) Crumb Rubber Modified Binder (CRMB)

CRMB shall be of performance grade PG 76 or higher in compliance with AASHTO Standard M320-02. This premium grade binder shall be produced by pre-blending conventional bituminous binder of penetration grade 60 – 70 which shall conform to MS 124, with an appropriate quantity of crumb rubber.

Crumb Rubber

Crumb rubber shall be obtained by grinding reclaimed rubber tyres from heavy commercial vehicles to mesh sizes 20 to 40 (0.8 to 0.4 mm) because in general they contain higher proportion of natural rubber as compared to tyres from cars, pickups and small lorries which are made of styrene-butadiene synthetic rubber (SBR) or polybutadiene synthetic rubber.

Crumb rubber shall be either buffed crumb or whole tyre crumb.

i. **Buffed crumb**[1] shall be produced from worn tyres when the tyres are submitted for retreading. Rubber material shall be first removed from the tread in the form of 'buffing' or rasping. These buffing shall undergo ambient grinding process and shall be sieved to produce crumbs of various particle sizes. Since they are removed from the tyre tread, buffed crumb comprise high quality, abrasion resistant rubber material free from tyre reinforcement fabric or steel.

ii. **Whole tyre crumb rubber** shall be produced from reclaimed rubber tyres by ambient grinding process. The whole tyres shall be cut into large pieces and then shredded into chips about 3 to 5 mm in size. These chips shall be subsequently passed through a coarse mill or cutter, before being sent through fine grinding mills and screens.

[1] *When buffed crumb are used, contamination with excessive fibers, metals or minerals is generally negligible.*

Fiber content

The fiber content shall be less than 0.5% by weight. Fiber content shall be determined by weighing fiber agglomerations which are formed during the gradation test procedures. Rubber particles shall be removed from the fiber agglomerations before weighing.

Moisture content

The moisture content shall be less than 0.75% by weight after drying to constant mass at 60 ℃.

Mineral contaminants

The mineral contaminants shall not be greater than 0.25% by weight as determined by sedimentation analysis of a 100 g crumb rubber sample in a one-litre glass beaker filled with water.

Metal contaminants

The rubber shall contain no visible metal particles as indicated by thorough stirring of a 100 g crumb rubber sample with a magnet.

Chemical composition

The chemical composition of crumb rubber derived from different types and/or parts of tyres are shown in Table 2. For use as bituminous binder modifier, crumb rubber derived from different sources shall be mixed to obtain a satisfactory composition. After selecting and evaluating crumb rubber from a single or from multiple sources, the chemical composition shall remain the same throughout the project.

Table 2 *Chemical Composition of Crumb Rubber*

Test Parameter	Specification
Acetone Extract (%)	< 22
Rubber Hydrocarbon (%)	42 – 65
Carbon Black Content (%)	28 – 38
Natural Rubber Content (%)	> 30
Ash Content (%)	< 8.0

Source

Crumb rubber from more than one source may be used to ensure satisfactory compliance with gradation and compositional requirements. Whichever source or sources are used, they and their proportion shall remain the same as submitted to the S.O. and approved for the project. If the source of crumb rubber need to be changed, all relevant information shall be submitted to the S.O. and the new material shall not be used until approved by the S.O.

Packaging and labelling

Crumb rubber shall be supplied in reusable bulk containers or in weather (moisture) resistant disposable bags. If crumb rubber dosage is not controlled through a hopper equipped with accurate load cells (and connected through a screw feeder with the blending tank), the weight of bags containing crumb rubber shall be accurate to ± 2.0%. Stacking of crumb rubber containers and bags shall be minimised to avoid excessive consolidation of crumb rubber.

Each crumb rubber container or bag shall be labelled with the manufacturer's designation for the rubber, including the specific type and grade of rubber, the nominal rubber weight (per container or bag), the manufacturer's lot number designation and date, and any other information deemed pertinent by the crumb rubber supplier.

4.17.3 PREPARATION OF CRUMB RUBBER MODIFIED BINDER (CRMB)

a) Blending Equipment

The Contractor shall provide a blending equipment system located at the asphalt mixing plant.

The blending equipment shall have suitable heating system to raise the temperature of CRMB blend to its optimum blending temperature which shall be 170 to 190 ^{o}C. The blending equipment system, including its distribution and circulation pipes, shall be properly insulated to prevent rapid temperature drop during blending and discharging to the asphalt mixing plant. Suitable storage tank(s) that matches the capacity of the blending equipment and complete with suitable mechanical agitators shall be provided and the tank(s) shall be connected through the distribution and circulation pipes.

The blending equipment system shall be capable of producing CRMB with consistent required properties.

Alternatively, the CRMB shall be obtained from the supplier(s) approved by the S.O., hereafter referred to as terminal blend which is described in sub-section 4.17.3 (b).

b) Blending Process

CRMB shall be produced by blending hot bituminous binder with crumb rubber. The bituminous binder shall be penetration grade 60 – 70 and shall be heated to about 170 to 190 ^{o}C.

The crumb rubber shall be added to the hot bituminous binder and thoroughly mixed. The dosage of crumb rubber shall be at least 15% by weight of the bituminous binder. Other additives may also be incorporated into the blended bituminous binder and crumb rubber. Examples of such additive are natural rubber, extender oil and anti-stripping agent.

During heating and mixing of the bituminous binder and crumb rubber, the rubber particles will swell and softens as it reacts with the binder. This reaction is influenced by the blending temperature, the time the temperature remains

elevated, the type and amount of mechanical mixing, the size and texture of the crumb rubber, and the aromatic component of the binder. The crumb rubber absorbs aromatic oils and light fractions (small volatile or active molecules) from the binder and releases some of the similar oils used in the rubber production into the binder.
The resulting CRMB blend shall then be pumped into storage tank(s) where it shall be kept at a minimum temperature of 170 ºC for a period of 45 to 60 minutes to allow for further swelling of the crumb rubber.

Terminal Blend

Terminal blend is a mixture of bituminous binder and crumb rubber, which is finely ground to sizes less than 40 mesh. It shall be essentially produced elsewhere outside the asphalt mixing plant, hereafter referred to as the 'terminal', by using a wet process. The binder shall be heated in a tank to an elevated temperature and crumb rubber shall be introduced into the tank and digested into the binder using a high shear process. During this process, samples shall be taken and tested for solubility in accordance to ASTM D 2042 to ensure the crumb rubber has been completely digested. The solubility of the terminal blend after completion of blending shall be not less than 97.5%.

After completion of the blending, the terminal blend shall be transported in well insulated tankers, and transferred into storage tanks at the asphalt mixing plant as described above. The terminal blend may be held in the storage tanks for a maximum period of 3 days without agitation as the crumb rubber is considered completely digested into the binder. However, if the storage period exceed 3 days, proper agitation shall be provided.

The primary difference between terminal blend and the CRMB produced at the asphalt mixing plant (field blend) is the amount of crumb rubber used in the binder (terminal blend less than 10%; field blend at least 15%). However, the crumb rubber content in the terminal blend can be increased to 15 – 20% or more.

c) Formulation

The Contractor shall provide a blend formulation to the S.O. for approval at least 10 days before paving works is scheduled to commence. The blend formulation shall consist of the following information;

i. Bituminous binder
   - Source
   - Grade

ii. Crumb rubber
   - Source
   - Percentage by total weight of bituminous binder

d) Completion of Blending

The blending process shall be deemed to be complete when a small drop of CRMB from the blending system, placed on an impervious surface, shows only

a few specks of rubber which are soft enough to be spread into the CRMB by a knife or spatula. If the rubber particles still preserve their entity and cannot be rubbed away into the CRMB, blending is deemed incomplete, thus further heating and agitation are required.

e) Sampling of CRMB

The S.O. may, as and when required, instruct the Contractor to sample the CRMB from the blending system and send them for testing. Sampling points shall be provided at convenient points in the blending system. Sampling shall be done in accordance with MS 539. The Contractor shall bear all charges related to the testing as specified in Table 3.

f) Storage of CRMB

The Contractor shall provide a storage system capable of delivering the modified binder to the asphalt mixing plant. The storage system shall be located close to the asphalt mixing plant and it shall include distribution and circulation pipes that are properly insulated to prevent rapid temperature drop.

The storage tank shall have suitable mechanical agitator and be connected through delivery pipes and back-circulation pipes. Suitable sampling points shall be provided at convenient points in the storage system for taking samples. Sampling shall be done in accordance with MS 539.

The CRMB shall be used within 24 hours. If storage is necessary due to inevitable reasons, the binder shall be cooled to 145 – 155 ^{o}C and the storage time shall be limited to 3 days. During storage, the binder shall be continuously agitated.

If prolonged storage (more than 3 days) is unavoidable, the CRMB shall be tested for compliance as specified in Table 3. If non-compliance occurs, the CRMB shall be modified by adding more crumb rubber until the CRMB complies with the requirement.

g) Application of CRMB

At the time of application, the crumb rubber shall be dispersed uniformly throughout the bituminous binder. The properties of the CRMB, whether it is blended close to the asphalt mixing plant or produce by terminal blending, shall be as given in Table 3.

***Table 3** Properties of CRMB*

Test	Requirement	Test Specification
CRMB prior to rolling thin film oven test (RTFOT)		
[3]Viscosity, test temperature 177 °C, Pa.s	1.5 – 4.0[2]	ASTM D 4402
[3]Dynamic shear, G*/sin δ min. 1.00 kPa, 10 rad/s, test temperature °C	76	AASHTO T 315
[4]Penetration, 100 g, 5 s, 25 °C, x 0.1 mm, min.	25[5]	ASTM D 5
[4]Ring and ball softening point, °C, min.	60	ASTM D 36
[4]Flash point, °C, min.	240	AASTHO T 48
CRMB after RTFOT (AASHTO T 240) or ASTM D 2872		
[3]Mass loss, %, max.	1.00	AASHTO T 240 or ASTM D 2872
[3]Dynamic shear, G*/sin δ min. 2.20 kPa, 10 rad/s, test temperature °C	76	AASHTO T 315

4.17.4 CRUMB RUBBER - STONE MASTIC ASPHALT (CR-SMA) AND CRUMB RUBBER - GAP GRADED ASPHALT (CR-GGA)

a) Mix Design

Job Mix Formula

The Contractor shall propose a job mix formula required for the Works. In order to obtain optimum quality of the mixtures, the job mix formula shall be prepared on the basis of testing several laboratory design mix gradations within the limits as shown in Table 1 at an appropriate range of CRMB content. As a guide, the designed CRMB content for CR-SMA and CR-GGA will usually be in the range given in Table 4.

***Table 4** Range of Design Binder Contents*

Type of Asphalt Mixture	Design Binder Content
CR-SMA	5% – 7%
CR-GGA	6% – 8%

Each combination of laboratory design mix aggregate gradation and CRMB content shall be subject to the Marshall test procedure and volumetric analysis as follows;

[2] *The requirement may be waived at the discretion of the S.O. if the Contractor warrants that the CRMB can be adequately pumped and mixed at the temperatures that meet all applicable safety standards.*

[3] *These tests shall be carried out as and when required by the S.O. but shall be not less than one test per 30 tons of CRMB produced or at least once per project if the total quantity of CRMB produced is less than 30 tons. The CRMB samples shall be taken immediately prior to the production of CR-SMA or CR-GGA. Test frequency may be reduced if test results consistently conform to the requirements.*

[4] *These tests shall be carried out minimum once for each blending process for quality control purposes during blending at the asphalt mixing plant or terminal blending.*

[5] *The penetration and softening point values shall be taken as reference for consistency check on the production.*

i. Preparation of laboratory specimens for the standard stability and flow test in accordance with ASTM D 1559 using 75 blows/face compaction standard,

ii. Determination of the bulk density of the specimens in accordance with ASTM D 2726,

iii. Determination of the stability and flow values in accordance with ASTM D 1559,

iv. Analysis of the density and air voids parameters to determine the percentage air voids in the compacted aggregates, the percentage air voids in the compacted aggregates filled with CRMB and the percentage air voids in the compacted mix.

For the proposed design mix gradation, 4 specimens shall be prepared for each CRMB content within the range of Table 4[6] at increments of 0.5%, in accordance with ASTM D 1559 using 75 blows/face compaction standard. All CRMB content shall be in percentage by weight of the total mix. Prior to mixing with aggregates, the CRMB shall be heated to a temperature of 160 to 175 ^{o}C.

As soon as the freshly compacted specimens have cooled to room temperature, the bulk density of each test specimen shall be determined in accordance with ASTM D 2726.

The stability and flow value of each test specimen shall then be determined in accordance with ASTM D 1559.

After the completion of the stability and flow test, density and voids analysis shall be carried out for each test specimen to determine the percentage air voids in mineral aggregate (VMA) and the percentage air voids in the compacted mix (VIM).

Any erratic values shall be discarded before averaging. When 2 or more specimens in any group of 4 are so rejected, 4 more specimens shall be prepared and tested.

The average values of bulk density, stability, flow and VIM obtained above shall be plotted separately against the bitumen content and a smooth curve drawn through the plotted values.

The mean optimum CRMB content shall be determined by averaging 4 optimum CRMB contents so determined as follows;

i. Peak of curve taken from the stability graph[7],

ii. Flow equals to 3.5 mm from the flow graph,

[6] *The range of binder content shall be extended, if necessary, to ensure that the curves of stability and bulk density have their peak within the range selected.*

[7] *Where the stability curve exhibits more than one peak, the bitumen content chosen for the determination of the mean optimum bitumen content shall be the one which satisfies the voids requirements better. It is sometimes necessary, where no peak stability is obtained, to prepare and test supplementary specimens at intervals of 0.25% bitumen content on either side of the expected optimum.*

iii. Peak of curve taken from the bulk density graph[8],

iv. VIM equals to 4.5% (for CR-SMA) and 5.5% (for CR-GGA) from the VIM graph.

The individual test values (stability, flow and VIM) at the mean optimum CRMB content shall then be read from the plotted smooth curves and shall comply with the design parameters given in Table 5.

If all the values comply with Table 5, the mixture with the mean optimum CRMB content shall be used in plant trials. Otherwise, the mix design procedure shall be repeated using a different laboratory design mix aggregate gradation until all design parameters are satisfied.

Table 5 *CR-SMA and CR-GGA Requirements*

Test	Requirement	
	CR-SMA	**CR-GGA**
VIM	3 – 6%	4.5 – 6.5%
Stability	min. 6,000 N	min. 6,000 N
Flow	2.0 – 5.0 mm	2.0 – 5.0 mm
Binder drain-down	max. 0.2%	max. 0.2%
[9]Semi-Circular Bend, critical strain energy release rate, J_c, test temperature 25 ^oC, aged	min. 0.5 kJ/m^2	min. 0.5 kJ/m^2
[9]Hamburg Wheel-Tracking, rut depth @ 20,000 no. of passes, test temperature 50 ^oC	max. 12.5 mm	max. 12.5 mm

Binder Drain-Down Test

Binder drain-down test shall be conducted on 3 samples at mean optimum CRMB content to ascertain that the binder draining property of the mix is satisfactory.

Binder drain-down test shall be carried out in accordance with the test method as specified in Appendix A. A sample of CR-SMA and CR-GGA shall be placed in an oven for 3 hours at the anticipated asphalt mixing temperature in a wire basket fabricated using standard 6.3 mm sieve cloth. Any binder drain-down from the asphalt shall be collected in a pan. The binder drain-down shall be not more than 0.2% by weight of the total mix.

If the average binder drain-down exceeds 0.2%, the mix design procedure shall be repeated using a different laboratory design mix aggregate gradation until all design parameters are satisfied.

Alternatively, this test shall be carried out in accordance to the Schellenberg method. A sample of CR-SMA and CR-GGA (1 kg) shall be placed in 800 ml glass beaker in an oven at 170 ^oC for 1 hour. The beaker shall then be taken out from the oven and turned upside down to pour out the sample. Then, the beaker shall be weighed to get the mass of the binder which remain inside the beaker.

[8] *With highly absorptive aggregate, some difficulty in determining peak bulk density may occur. In such cases, the bitumen content at which the increase in bulk density shows a marked falling off shall be adopted.*

[9] *These tests shall be carried out once for each source (asphalt mixing plant) of CR-SMA or CR-GGA. Refer to Appendixes D and E for test procedures.*

The binder drain-down shall be calculated as a percentage loss of mass to the initial mass of sample (1 kg). The complete procedure of the test method is given in Appendix B.

Determination of Optimum Binder Content

The binder content that meet the criteria in Table 4 and satisfy the binder drain-down test requirement shall be selected as the optimum binder content. The aggregate gradation selected and the optimum binder content determined shall be proposed to the S.O. as the job mix formula.

Mixing and Compaction Temperatures

As a guide, the mixing temperature for CR-SMA and CR-GGA will usually be between 175 to 185 ºC. If higher than 195 ºC, the asphalt mixtures shall be disposed. The CR-SMA and CR-GGA mixtures shall be compacted immediately after laying and the compaction process shall be completed at temperature higher than 110 ºC. The mixing, laying and compaction temperature shall be determined during trial lay.

Trial Lay

After having received the S.O.'s preliminary approval of the proposed job mix formula, the Contractor shall arrange to mix, lay and compact the CR-SMA and CR-GGA mixtures. A minimum of 50 tons shall be placed at the job site to demonstrate to the satisfaction of the S.O. that the mixtures is satisfactory and the mixing, laying and compacting equipment conforms to the requirement of this specification.

As directed by the S.O., comprehensive sampling and testing of the CR-SMA and CR-GGA mixtures shall be carried out to check for satisfactory compliance with the job mix formula. If the asphalt mixture used in the trial lay complies with the job mix formula as well as compacted thickness and density requirements, the trial section shall be accepted as part of the Contract Works. Otherwise, the trial section shall not be considered as part of the Contract Works and shall be removed by the Contractor at his own expense.

The observations and tests to be carried out during trial lay shall be, but not restricted to the following;

i. Select a suitable location for the trial lay within the job site.

ii. Record the types and weight of roller.

iii. Record the type of paver.

iv. Carry out the following tests on the asphalt mixture;
   - Binder content and aggregate grading (ASTM D 2172/BS 598, ASTM C 136).
   - Theoretical maximum density (ASTM D 2041).
   - Preparation of Marshall specimens (ASTM D 1559).

- Bulk density of Marshall specimens (ASTM 3203).
- Calculation of air voids (ASTM D 3203).

v. Record temperatures of asphalt mixture on the tipper lorry, at plant and site.

vi. Record laying temperatures.

vii. Record laying thickness.

viii. Observe the surface texture of mixture laid behind paver.

ix. Record rolling temperatures i.e. immediately before rolling starts.

x. Record rolling pattern.

xi. Observe the surface texture of compacted mixture.

xii. Take at least 3 core samples from each tipper lorry load after the mixture has sufficiently hardened.

xiii. Record compacted thickness, density and air voids of the core samples.

xiv. Check at least one longitudinal joint to ensure that the joint is satisfactorily constructed.

Compliance with Job Mix Formula

The S.O.'s final approval of the job mix formula shall bind the Contractor to furnish the CR-SMA and CR-GGA mixtures meeting the precise aggregate gradation and CRMB content specified in the formula and within the tolerances set forth in Table 6.

Table 6 *Tolerances for CR-SMA and CR-GGA*

Parameter	**Permissible Variation** (% by weight of total mix)
CRMB content	± 0.3% **x CR**
Fractions of combined aggregate passing 5.00 mm and larger sieves	± 5.0%
Fractions of combined aggregate passing 2.36 mm sieve	± 4.0%
Fractions of combined aggregate passing 0.6 mm and 0.3 sieves	± 3.0%
Fraction of combined aggregate passing 0.075 mm sieve	± 2.0%

Note: ***CR*** *is the percentage of crumb rubber (by weight of the bituminous binder) blended with the binder. It shall be applicable to the lower limit only as there are discrepancies between the actual and the measured binder contents when tested in accordance to ASTM D 2172 due to the following causes;*

a) Most of the crumb rubber with mesh sizes 20 to 40 (0.8 - 0.4 mm) remains on the filter paper, and

b) A small amount of the binder remains in the extracted aggregate.

The upper limit shall be CRMB content as specified in the formula + 0.3%.

b) Construction Equipment

Mixing Plant

The contractor shall provide all the plant and equipment necessary for executing the work in accordance with this Specification and shall furnish the S.O. with such details of items of equipment, e.g. manufacturer, model type, capacity, weight, operating features etc.

The asphalt plant shall be either a batch plant or a drum mix plant or a continuous mix plant of a recognized manufacture and shall be approved by the S.O. It shall conform to the requirements described hereunder.

The mixing plant shall have a capacity suited to the Works and shall be sufficient to enable the paver operate more or less continuously when paving at normal speeds at the required thickness. The plant shall be designed so as to enable consistent production of asphalt mixtures within the tolerances prescribed in this Specification, all to the satisfaction of the S.O.

The plant shall also comply with the following requirements;

i. Handling mineral filler:
Adequate dry storage shall be provided for the mineral filler and provisions shall be made for proportioning the filler into the mixture uniformly in the desired quantities. Mineral filler in a batch plant will be added directly into the mixture uniformly in the desired quantities. Mineral filler in a batch plant will be added directly into the weigh hopper. In a drum plant mineral filler will be added directly into the drum mixer. Special attention is directed to providing appropriate equipment for accurately proportioning the relative large amounts of mineral filler required for CR-SMA mixture. Two separate silos shall be provided, one to keep the mineral filler (i.e. limestone powder) and another one to keep cement or hydrated lime.

ii. Hot-mixture storage:
When the hot mixture is not to be hauled immediately to the project and placed, suitable bins shall be provided. Such bins shall be either surge bins to balance production capacity with hauling and placing capacity or storage bins which are heated and insulated and which have a controlled atmosphere around the mixture. The holding time shall be within limitations imposed by the S.O., based on laboratory tests of the stored mixture. CR-SMA and CR-GGA mixtures shall not be stored overnight for paving on the next day.

Hauling Equipment

Hauling equipment should be of a type normally used for the transport of asphalt mixtures. Tipper lorry beds shall be covered and insulated if necessary, so that the mixture may be delivered on the road at the specified temperature.

Paver

The paver shall be of a type normally used for the placement of asphaltic

concrete. It shall be self-contained, power-propelled units provided with an adjustable activated screed, heated and capable of spreading and finishing courses of asphalt plant mix material in lane widths applicable to the specified typical section and thickness shown on the plans.

The paver shall be capable of being operated at forward speeds consistent with satisfactory placement and compaction of the mixture. The paver shall be capable of striking a smooth finish of uniform texture.

Steel Wheel Tandem Roller

The steel wheeled tandem roller shall be self-propelled and capable of being reversed without backlash; they shall be equipped with power steering and dual controls allowing operation from either the left or right side. The roller shall be equipped with water tanks, sprinkler systems and scraper blades to keep all wheels evenly wetted and clean during operation.

Each steel wheeled tandem roller shall be ballasted so that its total operating weight is in the range 8 to 10 tons and its driven roll(s) shall exert a rolling force of not less than 3.5 tons/m of roll width.

c) Construction Method

Surface Preparation

i. Immediately before placing the CR-SMA and CR-GGA mixtures, the surface shall be cleaned of loose or deleterious material by brooming or other approved means.

ii. A thin tack coat of bitumen emulsion RS-1K or similar material conforming to MS 161 shall be applied to ensure uniform and complete adherence of the overlay.

iii. Where the existing surface is non-uniform, a leveling course of asphaltic concrete shall be required to restore proper cross-section prior to construction of the overlay.

Weather Limitations

The CR-SMA and CR-GGA mixtures shall be placed on a dry clean surface when the atmospheric and the road surface temperatures are above 20 ^{o}C and the mixtures conforms to the applicable requirements as described in sub-section 4.17.4 (c).

Control of Asphalt Mixture

The CR-SMA and CR-GGA mixtures furnished by the Contractor shall conform to the job mix formula, within the allowable tolerances as shown in Table 5.

Laying

The temperature of asphalt mixture when delivered to the paver shall be greater than 160 ^{o}C, measured in the tipper lorry immediately prior to dumping into the paver hopper. If the temperature drops to 140 ^{o}C or below, the asphalt mixture shall be rejected.

The asphalt mixture shall be spread and struck off to the established grade and elevation with asphalt layers. Placing speed will be adjusted so that sufficient time is allowed for compaction operations and to provide continuity.

Compaction

Immediately after the asphalt mixture has been spread and struck off, it shall be thoroughly and uniformly compacted by rolling.

i. Due to the nature of CR-SMA and CR-GGA mixtures, the surface shall be rolled immediately. Rolling shall be accomplished with steel wheel tandem rollers of minimum weight of 8 tons. Pneumatic tyred rollers shall not be used. Rolling procedures shall be adjusted to provide the specified pavement density. Rollers shall move at a uniform speed not to exceed 5 km/h with the drive roller nearest the paver. Rolling shall be continued until all roller marks are eliminated and the minimum density has been obtained but not after the layer has cooled to 110 ^{o}C or lower. The Contractor shall monitor density during the compaction process by using density gauges or approved rolling pattern to ensure that the minimum required compaction is obtained.

ii. To prevent adhesion of the mixture to the rollers, it shall be necessary to keep the wheels properly moistened with water mixed very small quantities of detergent or other approved material.

iii. The pavement shall be compacted to minimum 94% of theoretical maximum density which shall be determined using the Rice method as described in ASTM D 2041 or minimum 98% of Marshall density.

Opening to Traffic

Traffic shall not be allowed on the newly compacted surface until compaction has been completed and the material has thoroughly cooled to 60 ^{o}C or lower. As a guide, this will usually be not less than 4 hours after the commencement of rolling. Where it is necessary to allow earlier use of the finished surface to facilitate the movement of traffic, vehicles may be allowed to run on the pavement after rolling has been completed, provided that speeds are restricted to 30 km/h or less and sharp turning movements are prohibited.

4.17.5 CRUMB RUBBER - OPEN GRADED FRICTION COURSE (CR-OGFC)

a) Mix Design

With high air voids and open-graded aggregates, high binder contents are essential to ensure mix integrity, increase resistance to oxidation and raveling, and improve durability. The quantity of binder shall be carefully balanced such that it is not deemed too excessive to cause binder drain-down during production, transport and laying, and neither is deemed too little to adversely affect durability.

Laboratory Compacted Specimens

CR-OGFC mixtures shall be compacted in the laboratory by using the Marshall method in accordance with ASTM D 1559. The specimens shall then be used for further analysis as described hereof.

Because of the limited compactive effort applied in the field on CR-OGFC mixture, the number of blows per face shall be 50.

Air Voids Requirements

The design and in-place air voids shall be in the range of 18 to 25%.

Binder Drain-Down Test

Binder drain-down test shall be conducted on 3 samples at mean optimum CRMB content to ascertain that the binder draining property of the mix is satisfactory.

Binder drain-down test shall be carried out in accordance with the test method as specified in Appendix A. A sample of CR-OGFC shall be placed in an oven for 3 hours at the anticipated asphalt mixing temperature in a wire basket fabricated using standard 6.3 mm sieve cloth. Any binder drain-down from the asphalt shall be collected in a pan and shall be not more than 0.2% by weight of the total mix.

If the average binder drain-down exceeds 0.2%, the mix design procedure shall be repeated using a different laboratory design mix aggregate gradation until all design parameters are satisfied.

Cantabro Test

Cantabro test shall be carried out in accordance with the procedure as given in Appendix C. 3 Marshall specimens shall be simultaneously subjected to 300 revolutions in the Los Angeles drum, without the steel balls, at 25 ^{o}C. The average loss of mass shall be not more than 15%.

Determination of Design Binder Content

Using a selected design aggregate gradation that comply with Table 1, prepare 9 laboratory mixtures at each binder content in the range 8 to 10%, in increments of 0.5%.

For each binder content, conduct binder drain-down test on the first 3 laboratory mixtures at the anticipated production temperature.

For each binder content, determine theoretical maximum density on the next 3 laboratory mixtures in accordance with ASTM D 2041.

Use the remaining laboratory mixtures to fabricate 3 Marshall specimens at each binder content. Apply 50 blows per side at the anticipated compaction temperature at site.

Determine the air voids of the Marshall specimens in accordance with ASTM D 3023.

Using the same Marshall specimens, conduct Cantabro test in accordance with the test method as given in Appendix C.

The lower limit of the design binder content shall be determined in accordance with the following two criteria;

i. Average loss of mass in the Cantabro test shall be not more than 15%.

ii. Average air voids shall be not more than 25%.

The upper limit of the design binder content shall be determined in accordance with the following two criteria;

i. Average binder drain-down shall be not more than 0.2%.

ii. Average air voids shall be not less than 18%.

Take the mean of the lower limit and upper limit of the design binder content as determined from the Cantabro test and binder drain-down test respectively as the initial design binder content. Use this value to check for air voids and make adjustment where necessary such that the air voids are between 18 to 25% but the design binder content shall be within the lower limit and upper limit.

The binder content that meets all the above criteria shall be recommended as the design binder content.

The aggregate gradation selected and the design binder content recommended shall be proposed to the S.O. as the job mix formula.

Trial Lay

After having received the S.O.'s preliminary approval of the proposed job mix formula, the Contractor shall arrange to mix, lay and compact the CR-OGFC mixture. A minimum of 50 tons shall be placed at the job site to demonstrate to the satisfaction of the S.O. that the mix is satisfactory and the mixing, laying

and compacting equipment conforms to the requirement of this specification. As directed by the S.O., comprehensive sampling and testing of the CR-OGFC mixture shall be carried out to check for satisfactory compliance with the job mix formula. If the asphalt mixture used in the trial lay comply with the job mix formula as well as compacted thickness and density requirements, the trial section shall be accepted as part of the Contract Works. Otherwise, the trial section shall not be considered as part of the Contract Works and shall be removed by the Contractor at his own expense.

The observations and tests to be carried out during trial lay shall be, but not restricted to the following;

i. Select a suitable location for the trial lay within the job site.

ii. Record the types and weight of roller.

iii. Record the type of paver.

iv. Carry out the following tests on the asphalt mixture;
   - Binder content and aggregate grading (ASTM D 2172/BS 598, ASTM C 136).
   - Theoretical maximum density (ASTM D 2041).
   - Preparation of Marshall specimens (ASTM D 1559).
   - Bulk density of Marshall specimens (ASTM 3203).
   - Calculation of air voids (ASTM D 3203).

v. Record temperatures of asphalt mixture on the tipper lorry, at plant and site.

vi. Record laying temperatures.

vii. Record laying thickness.

viii. Observe the surface texture of mix laid behind paver.

ix. Record rolling temperatures i.e. immediately before rolling starts.

x. Record rolling pattern.

xi. Observe the surface texture of compacted mix.

xii. Take at least 3 core samples from each tipper lorry load after the mix has sufficiently hardened.

xiii. Record compacted thickness, density and air voids of the core samples.

xiv. Check permeability of the compacted surfacing (refer to sub-section 4.17.5 (c)).

xv. Check at least one longitudinal joint to ensure that the joint is satisfactorily constructed.

Compliance with Job Mix Formula

The S.O.'s final approval of the job mix formula shall bind the Contractor to furnish the CR-OGFC meeting the precise aggregate gradation and CRMB content specified in the formula within the tolerances set forth in Table 7.

Table 7 *Tolerances for CR-OGFC*

Parameter	Permissible Variation (% by weight of total mix)
CRMB content	± 0.3% **x CR**
Fractions of combined aggregate passing 5.00 mm and larger sieves	± 5.0%
Fractions of combined aggregate passing 2.36 mm sieve	± 4.0%
Fraction of combined aggregate passing 0.075 mm sieve	± 2.0%

*Note: Refer to Table 6 with regards to **CR**.*

b) Sampling and Testing of CR-OGFC

Frequency of sampling and testing shall be not less than that shown in Table 8 which provides for two levels of minimum frequency. The reduced frequency may only be adopted as instructed by the S.O. if the test results consistently conform to the requirements.

Table 8 *Frequency of Sampling and Testing of CR-OGFC*

Test	Normal Minimum Frequency	Reduced Minimum Frequency
Aggregate gradation	One test per 300 tons of asphalt plant production.	One test per 500 tons asphalt plant production.
CRMB content	One test per 300 tons of asphalt plant production.	One test per 500 tons of asphalt plant production.
Binder drain-down	One test per 300 tons of asphalt plant production.	One test per 500 tons of asphalt plant production.
Temperature	Each loaded tipper lorry.	Each loaded tipper lorry.

c) Construction Method

Pavement Preparation

CR-OGFC shall be laid only on structurally sound pavement with minimal cracks, ruts and depressions.
A strong, durable bond of CR-OGFC to the underlying pavement surface is essential.
A thick tack coat is essential to ensure;

i. A good bonding of the relatively small surface area of contact of the open-graded CR-OGFC to the underlying pavement surface.

ii. A good resistance to damage induced by residual moisture which may be trapped at the bottom of the porous asphalt layer.

iii. Effective sealing of cracks and other surface deficiencies which may be present in the existing pavement surface, thus providing an impervious underlying surface.

CR-OGFC shall not be used to restore poor road profile.

Existing pavement surface shall be regulated with dense continuously graded asphalt mixture to remove depression which may trap and hold water under CR-OGFC layer.

Laying

CR-OGFC shall be laid only on impermeable and plane pavement surface with adequate cross fall. A minimum cross fall of 2.5% shall be provided.

CR-OGFC shall be laid by machine and compacted within 3 hours of mixing.

Laying shall commence on the low side of the carriageway.

CR-OGFC shall be laid to a minimum and maximum thickness of 25 mm and 40 mm respectively.

Hand casting shall be kept to minimum.

CR-OGFC shall not be laid directly over an existing concrete pavement because the difficulty in establishing an adequate bond. However, it shall be preceded with a layer of dense graded bituminous mixture on the existing concrete pavement to assist bonding.

When the rehabilitation of a deteriorated concrete pavement includes bituminous mixture overlay, CR-OGFC shall be used as the final wearing course.

CR-OGFC shall not be laid in areas where;

i. The pavement structural strength is sub-standard.

ii. There is considerable traction due to sudden acceleration, braking and turning like at major junctions.

iii. There are tight radius curves, loops of radius less than 75 m.

iv. The gradient exceeds 10%.

v. Excessive deposits of debris, oil and fuel may be experienced.

vi. Free drainage cannot be accommodated along the road shoulders.

vii. Length of roads less than 100 m because of spray carry-over from adjacent surfacing.

viii. There is high flexibility like on bridges.

ix. Frequent excavations by statutory undertakers may occur.

x. Traffic levels exceed 4,000 commercial vehicles per lane per day at opening.

xi. There is a 40 km/h speed limit because there is no beneficial reduction in spray or noise levels achieved at low speeds.

Compaction

CR-OGFC shall be compacted using static steel wheel tandem rollers only.

Vibratory rollers are not permitted because they lead to excessive compaction and the possibility of aggregate crushing.

Pneumatic tyred rollers are not permitted because they knead and close the surface, affecting the permeability of CR-OGFC. They also cause stripping of aggregates that stick to their tyres.

3 wheel steel rollers are not permitted because they leave roller marks that can be difficult to remove.

Compaction by rolling shall commence as soon after laying as the material will support the rollers without undue displacement; nevertheless, the temperature of the CR-OGFC at the commencement of rolling shall be not less than 110 ^{o}C.

In any areas inaccessible to the rollers, proper compaction shall be carried out using vibrating plate compactors, hand tampers or other suitable means, all to the satisfaction of the S.O.

The steel wheel tandem rollers shall operate in a longitudinal direction along the carriageway with their driven wheels towards the paver. Rolling shall generally commence at the lower edge of the paved width and progress uniformly to the higher edge, except that where there is a longitudinal construction joint at the higher edge, this shall be rolled first ahead of the normal pattern of rolling. Generally, successive roller passes shall overlap by quarter of the roller width, and the points at which the roller is reversed shall be staggered. However, when operating on gradients in excess of 4%, the breakdown roller shall not pass over any previously unrolled mix when operating in the downhill direction.

In all cases, compaction shall be carried out in such a manner that each section receives equal compactive effort, all to the satisfaction of the S.O.
The rollers shall operate at speeds of not more than 5 km/h. No roller or heavy vehicle shall be allowed to stand on newly laid bituminous mix before compaction has been completed and the material has thoroughly cooled and set. Rolling pattern shall be in accordance with trial lay carried out earlier and shall give field density not less than 97% of Marshall density.

The CR-OGFC layer shall be finished in a neat and workmanlike manner; their widths shall be everywhere at least those specified or shown on the Drawings on both sides of the centre-line; the average thickness over any 100 m length shall be not less than the required thickness, and the minimum thickness at any point shall be not less than the required thickness minus 5 mm.

Care shall be taken to prevent over-compaction of CR-OGFC.

Within 24 hours of laying and compacting the bituminous mixture, the Contractor shall cut core samples of not less than 100 mm nominal diameter at locations selected by the S.O. The rate of sampling shall be one sample per 500 m^2 of mixture laid, but not less than 2 samples for the work completed in each paving session. These core samples shall be used by the S.O. to determine the thickness of the compacted layer of mixture and the compacted density of the material in accordance with either ASTM D 1188 or ASTM D 6857.

Joint Construction

The formation of all joints shall be made in such a manner as to ensure a continuous bond between old and new sections of the course. All joints shall present the same texture, density, and smoothness as other sections of the course

Cold longitudinal joints shall not be cut as the inherent rough texture of the mixture will readily provide good bonding along the joints. Cutting the joints may incur damages to the mixture along the joints as the aggregate gradation of mixture is of open-graded nature. Application of tack coat along the joints is deemed unnecessary as it may clog the voids along the joints and impede the flow of water across the joints.

Shaping Edges

While the surface is being compacted and finished, the Contractor shall carefully trim the outside edges of the pavement to the proper alignment.

Edges so formed shall be beveled while still hot and compacted.

Permeability

Being the principle benefit of CR-OGFC, the permeability shall be sufficient to allow satisfactory drainage of rain water during heavy rainfall. The permeability of CR-OGFC wearing course having a minimum thickness of 25 mm shall be not less than 900 ml per 15 seconds immediately after construction if tested in accordance to the test procedure as described in Appendix F.

Opening to Traffic

Traffic shall not be allowed on the newly compacted surface until the layer has cooled to 60 ^oC or lower.

4.17.6 CRUMB RUBBER - STRESS ABSORBING MEMBRANE INTERLAYER (CR-SAMI)

Crumb rubber - stress absorbing membrane interlayer (CR-SAMI) is a pavement layer constructed by spraying CRMB on the surface of the existing pavement and then spreading and rolling in aggregate chipping prior to overlaying with asphalt mixture. The main function of the CR-SAMI is to retard propagation of cracks from the existing pavement into the new overlay.

a) Equipment

CRMB Distributor

The distributor shall be equipped with an internal heating device capable of heating the material evenly up to 220 °C; an internal mixing unit capable of maintaining a proper mixture of bituminous binder and crumb rubber; have adequate pump capacity to maintain a high rate of circulation in the tank and to spray the CRMB; have adequate pressure devices and suitable manifolds to provide constant positive cut-off to prevent dripping from the nozzles. The distributor shall be equipped with an electronically controlled computerised compensation unit for controlling application rates at various width and speed changes. The application unit shall have electronic controls and a digital read out installed and operated from the inside of the cab of the distributor. The distribution bar on the distributor shall be fully circulating. Any distributor that produces a streaked or irregular distribution of the material shall be promptly repaired or removed from the site.

Distributor equipment shall include a tachometer, pressure gauges, volume measuring devices, and a thermometer for reading temperature of tank contents. Controls for spray bar shall be located in cab of truck, for controlling width and rate of spray of product. It shall be so constructed that uniform applications may be made at the specified rate per m^2 with a tolerance of ± 0.2 kg/m^2.

Aggregate Spreader

The aggregate spreader shall be hydrostatically driven and self-propelled. It shall be equipped with a hydraulically controlled variable adjustable head that is capable of spreading aggregate in widths from 1.5 to 5.5 m. The spreader shall be mounted on pneumatic tyres, and shall spread the aggregate on the road surface in a manner that ensures that the tyres do not contact the road surface until after the aggregate has been applied. The unit shall be equipped with an electronic radar type sensor used to measure ground speed and will automatically adjust the aggregate application rate depending on width of application and the speed of chip spreader. It shall have the ability to apply aggregate on any gradient from 0 - 6%. The spreader shall be equipped with an integral hopper with a minimum capacity of 5 tons of aggregate which shall be filled by trucks in a manner which ensures that the truck tyres never come in contact with the road surface until the aggregate has been properly applied. To maintain constant aggregate application, a self-locking truck hitch will permit towing of aggregate trucks without stopping the chip spreader. It shall be capable of maintaining positive engagement over irregular terrain.

Pneumatic-Tyred Roller

A minimum of 2 self-propelled, multiple wheel, pneumatic-tyred rollers shall be used, both shall weigh a minimum of 15 tons, and shall have a total compacting width of at least 1.5 m.

b) Construction Method

Surface Preparation

Defects on the existing pavement surface such as potholes and depressions shall be patched or regulated accordingly. The surface shall then be thoroughly cleaned by sweeping with power broom and/or air blower prior to application of CRMB and aggregate chipping.

Seasonal and Weather Limitations

Construction shall proceed only when the atmospheric temperature is at least 20 °C. No water shall be present on the road surface.

Application of CRMB

The CRMB shall be applied at a temperature in the range between 180 to 200 ^{o}C and at a rate of 2.0 to 2.6 kg/m^2.

Longitudinal joints shall be parallel to centrelines. Where any construction joint occurs, the edges shall be broomed back and blended so there are no gaps and the elevations are the same, and free from ridges and depressions. Longitudinal joints shall be overlapped by 100 mm.

During application, adequate provision shall be made to prevent marring and discoloration of adjacent pavements, structures, vehicles, foliage or personal properties.

The CRMB distributor shall be operated at constant speed to ensure the homogeneity during the spraying process. Over-spray shall be avoided and partial-miss shall be made good manually.

Construction equipment or other vehicles shall not drive on the CRMB layer before aggregates are applied.

Application of Aggregate

The application of aggregate shall follow as close as possible behind the application of the CRMB which shall not be spread further in advance of the aggregate spread than can be immediately covered. The aggregate shall be spread uniformly by a self-propelled spreader at a rate ranging from 12 to 16 kg/m^2 which shall be determined from a trial section. During construction, the aggregate shall fully cover the CRMB area and no loose aggregate shall be allowed. Any deficient areas shall be covered with additional aggregate manually.

Compaction

A minimum of 2 pneumatic-tyred rollers, each with operating weight of at least 15 tons, shall be used for aggregate embedment into the CRMB. Rolling shall commence immediately after spreading the aggregate. There shall be at least 3 passes (a pass being 1 movement of a roller in either direction) by the roller to embed the aggregate particles firmly into the CRMB. Each pass shall overlap at least 1/3 of the wheel width.

Compaction sequence shall be from the lower side to the crown.

Sweeping

When all the aggregate has been firmly embedded into the CRMB and the pavement has cooled, all loose aggregate shall be swept or removed manually. This shall be done at a time in a manner, which will not displace any embedded aggregate or damage the CRMB. The aggregate removed shall be disposed from the site.

Preparation for Overlay

Tack coat, using RS-1K bituminous emulsion, shall be applied at 0.25 to 0.5 l/m^2 before overlay is carried out.

Opening to Traffic

CR-SAMI layer construction shall be immediately followed by overlay. No traffic is allowed between these processes. Where it is necessary to allow earlier use of the finished CR-SAMI to facilitate the movement of traffic, vehicles shall only be allowed at least 3 hours after the CR-SAMI construction, provided that speeds are restricted to 25 km/h or less and sharp turning movements are prohibited.

Appendix A - Binder Drain-Down Test

1.0 Scope

This test method covers the determination of the amount of binder drain-down in an un-compacted asphalt mixture sample when the sample is held at elevated temperatures comparable to those encountered during the production, storage, transport and placement of the mixture.

2.0 Reference Documents

AASHTO Standards T 245 Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus and M 92 Standard Specification for Wire Cloth Sieve for Testing Purposes.

3.0 Binder Drain-Down

For the purpose of this test method, binder drain-down is considered to be that portion of the bituminous mixture which separates itself from the sample as a whole and is deposited outside the wire basket during the test.[10]

4.0 Summary of Method

A sample of the asphalt mixture of mass 1.1 kg is prepared in the laboratory or obtained from field production. The sample is placed in a wire basket that is positioned on a pre-weighed paper plate. The sample, basket and plate are placed in a forced air oven for one hour at a pre-selected temperature. At the end of 3 hours, the basket containing the sample is removed from the oven along with the paper plate and the paper plate is weighed to determine the amount of binder drain-down that occurred.

5.0 Significance and Use

Test method can be used to determine whether the amount of binder drain-down measured for a given asphalt mixture is within acceptable levels. It also provides an evaluation of the binder drain-down potential of asphalt mixture produced in the field.

[10] *Any noticeable aggregate particles that are deposited outside the basket shall be added back into the mixture and not counted as binder drain-down. Alternatively the test shall be repeated.*

6.0 Apparatus

i. Oven capable of maintaining the temperature in a range from 1200 – 1750 ºC. The oven shall maintain the set temperature to within ± 2 ºC.
ii. Paper plates of appropriate size. The paper plates shall be of appropriate durability to withstand the oven temperatures.
iii. Standard cylindrical shaped basket meeting the dimensions shown in Figure 1. The basket shall be constructed using standard 6.3 mm sieve cloth as specified AASHTO M 92.
iv. Spatulas, trowels, mixer and bowls as needed.
v. Balance accurate to 0.1 g.

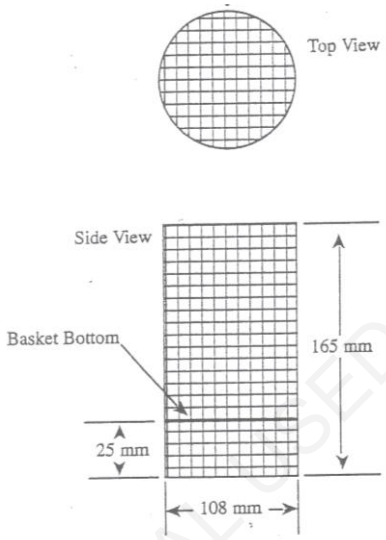


FIGURE 1 – Wire basket assembly

7.0 Prepared Samples

7.1 Laboratory Prepared Samples

i. For each mixture, the binder drain-down characteristics shall be determined at the anticipated plant production temperature. Duplicate samples shall be tested.

ii. Dry the aggregate to constant mass and sieve it into appropriate size fractions as indicated in AASHTO T 245, Section 3.2.

iii. Determine the anticipated plant production temperature or select a mixing temperature in accordance with AASHTO T 245, Section 7.3.1. The supplier's recommendations shall be sought when using modified bitumen.

iv. Weigh into separate pans for each test sample the amount of each size fraction required to produce complete bituminous mixture samples having a mass of 1,200 g. The aggregate fractions shall be combined such that the resulting aggregate blend has the same gradations as the job mix formula. Place the aggregate samples in an oven and heat to a temperature not to exceed the mixing temperature established in (iii) by more than approximately 28 ºC.

v. Heat the asphalt mixture to the temperature established in item (iii).

vi. Place the heated aggregate in the mixing bowl. Form a crater in the aggregate blend and add the required amount of asphalt. The amount of asphalt shall be such that the final sample has the same binder content as the job mix formula. At this point,

the temperature of the aggregate and asphalt mixture shall be within the limits of the mixing temperature established in (iii). Using a spatula (if mixing by hand) or a mixer, mix the aggregate and binder quickly, until the aggregate is thoroughly coated.

7.2 Plant Produced Samples

For plant produced samples, duplicate samples shall be tested at the plant production temperature.

Samples shall be obtained during plant production by sampling asphalt mixtures from tipper lorries prior to the mixtures leaving the plant. Samples obtained during actual production shall be reduced to the proper test sample size by the quartering method.

8.0 Procedure

i. Transfer the laboratory produced or plant produced un-compacted open graded friction course mixture sample to a tarred wire basket described in 6.0 (iii). Place the entire sample in the wire basket. Do not consolidate or otherwise disturb the sample after transfer to the basket. Determine the mass of the sample to the nearest 0.1 g.

ii. Determine and record the mass of a paper plate to the nearest 0.1 g. Place the basket on the paper and place the assembly into the oven at the temperature as determined in 7.1 (iii) for 3 hours ± 1 minute.

iii. After the sample has been in the oven for 3 hours, remove the basket and paper plate. Determine and record the mass of the paper plate to the nearest 0.1 g.

9.0 Calculations

Calculate the percent of mixture which drained by subtracting the initial paper plate mass from the final paper plate mass and divide this by the initial total sample mass. Multiply the result by 100 to obtain a percentage.

10.0 Report

Report the average percent binder drain-down at the test temperature.

Appendix B - Schellenberg Binder Drainage Test

1.0 Scope

This method is to determine the free asphalt quantity of asphalt binder separated from asphalt mixtures at the condition of high temperature and used to inspection of maximum binder content of crumb rubber - stone mastic asphalt (CR-SMA), crumb rubber - gap graded asphalt (CR-GGA) and crumb rubber - open graded friction course (CR-OGFC).

2.0 Apparatus and Materials

i. 800 ml beaker
ii. Oven
iii. Small-size asphalt mixtures mixer
iv. Glass plate
v. Balance: with a sensibility not greater than 0.1 g
vi. Others: hand shovel, cotton yarn, etc.

3.0 Test Procedure

i. Prepare 3 duplicate asphalt samples which comply with the job mix formula. Each sample shall be 1 kg.
ii. Clean the 800 ml beaker, dry it and weigh the beaker mass m_0 to an accuracy of 0.1 g.
iii. Pour 1 kg of the mixture into the beaker, and weigh the total mass of the beaker and the mixture to an accuracy of 0.1 g.
iv. Cover the beaker with a glass plate, put the beaker into a 170 ± 2 ºC oven, if it is the CR-SMA, the temperature shall be 185 ºC for 60 ± 1 minutes.
v. Take the beaker out without any impact or vibration, put the mixture downwards on the glass plate, weigh the total mass m_2 of the beaker, binder attached on the beaker, fine aggregate and mastic to an accuracy of 0.1 g.

For construction quality inspection, samples shall be obtained during plant production by sampling asphalt mixtures from tipper lorries prior to the mixtures leaving the plant. Samples obtained during actual production shall be reduced to the proper test sample size by the quartering method.

4.0 Calculation

The drainage mass loss of the asphalt shall be calculated according to *Equation 1*.

$$\Delta m = \frac{m_2 - m_0}{m_1 - m_0} \times 100 \qquad \textit{(Equation 1)}$$

where:

m_0 = The beaker mass (g);

m_1 = The total mass of beaker and asphalt mixtures for test use (g);

m_2 = The total mass of beaker, asphalt binder attached on the beaker, fine aggregate, and mastic (g);

Δm = The drainage mass loss of the asphalt (%).

5.0 Report

The test shall be carried out on at least 3 samples and the average value shall be taken as the test result.

Appendix C - Cantabro Test

1.0 Scope

Cantabro test shall be done on the proposed mix to measure its resistance to stone loss at high frequency. The test procedures and apparatus are described below;

2.0 Apparatus

i. Marshall Compactor - see description in ASTM D 1559.
ii. Loss Angeles Drum - see description in ASTM C 131.
iii. Thermometers: to measure the temperatures of the aggregate, binder and bituminous mix, metal thermometers with a scale up to 200 ^{o}C and accuracy of 3 ^{o}C are used. To measure the temperature at which the test is carried out, a thermometer with a scale from 0 to 50 ^{o}C and an accuracy of 0.5 ^{o}C is used.
iv. Balances: a balance with a capacity of 2 kg to an accuracy of 0.1 g to weight the samples and another with a capacity of 5 kg to an accuracy of 1 g to prepare the mixes.
v. General materials: tray, pots, spatulas, asbestos gloves, curved scoops, filter paper rings etc.

3.0 Procedure

The different aggregate fractions which make up the mix are dried in a stove at 105 – 110 ^{o}C until constant weight is reached. At the proposed optimum binder content, 4 Marshall specimens are manufactured with 50 blows on each side at adequate temperature[11]. The relative density and void percentage shall be determined as soon as they have cooled to ambient temperature. The procedure to determine the density and void percentage shall be based on geometric procedures.

The specimens shall be dried at ambient temperature for 2 days. Before testing the specimens, they shall be kept at test temperature, 25 ^{o}C, for at least six hours. After the specimens have been kept for the required time, weigh it (M_0), then place immediately into the Los Angeles drum without abrasion loads (balls). The drum shall be turned at a velocity between 188 and 208 rad/s and submitted to 300 revolutions. This shall be repeated for the 4 specimens.

Weigh the specimen after test (M_1). For each specimen, the stone loss or attrition resistance is computed;

$$L = \frac{M_0 - M_1}{M_0} x\ 100\% \qquad \textit{(Equation 2)}$$

The average stone loss (L) is reported and shall be not more than 15%.

[11] *Mixing temperatures are usually 130 ^{o}C for conventional binder and 170 ^{o}C for CRMB.*

Appendix D - Semi-Circular Bend (SCB) Test

1.0 Scope

This test method covers the procedures for preparation, testing, and measurement of asphalt mixture cracking resistance at Long Term Pavement Performance (LTPP) database intermediate temperatures using semi-circular bend (SCB) geometry laboratory prepared or pavement core asphalt mix samples tested monotonically. The SCB sample is a half-disk with a notch cut parallel to the loading and vertical axis. The test method describes the determination of the critical strain energy release rate, J_c, and other parameters determined from the load-displacement curve. These parameters can be used to rank the resistance of asphalt mixtures to cracking.

2.0 Summary of Test Method

A semi-circular specimen is loaded monotonically until fracture failure occurs under at constant rate of deformation in a three-point bending load configuration. The load and deformation are continuously recorded and are used to compute the critical strain energy release rate, J_c. High J_c values are desirable for fracture-resistant mixtures. A J_c value ranging from 0.5 to 0.60 kJ/m^2 is typically recommended to ensure adequate fracture resistance of the mixture.

This test procedure considers the elasto-plastic/viscoelastic relationship of asphalt mixtures and fracture mechanics (Mull, et al., 2006, Anderson 2005 and suggested by Wu et al., 2005).

3.0 Apparatus

i. Load Test System:
A load test system consisting of an axial loading device, environmental chamber, and control and data acquisition system. The test system shall meet the minimum requirements specified in Table 9.
- Axial Loading Device – The load apparatus shall be capable of maintaining a constant cross-head deformation rate of 0.5 mm/min.
- Environmental Chamber – A chamber capable of maintaining 60.3 ºC of the climatic intermediate temperature calculated in Equation 3.
- Control and Data Acquisition System – The system shall include a data acquisition system comprising analog to digital conversion or digital input, or both, for storage and analysis on a computer. The system shall be capable of measuring and recording 3 signals during the test including load, displacement, and chamber temperature 10 Hz. The minimum resolution of the measurements is provided in Table 9.

Table 9 *SCB Test System Minimum Requirements*

Measurement	Range	Accuracy
Load Measurement and Control	0 to 10 kN	± 1%
Displacement Measurement and Control	0 to 30 mm	± 0.5%
Temperature Measurement and Control Range	5 to 35 ºC	± 0.3 ºC

ii. Measurement Devices:
- Load Measuring Device – The load measuring device shall consist of an electronic load cell, designed for placement between the load platen and piston, with the minimum capacity and sensitivity stated in Table 9. The load cell shall be calibrated in accordance with ASTM Standards E4.
- Axial Deformations – Axial deformations shall be measured with linear variable differential transformers (LVDT) or other devices capable of measuring displacement within the range and tolerance provided in Table 9. The LVDT shall be calibrated in accordance with Practice ASTM Standards E3029, Class B.
- Temperature – Chamber temperature shall be measured with Resistance Temperature Detectors (RTD) or other suitable devices accurate to within ± 0.3 ^{o}C.

iii. Gyratory Compactor – A gyratory compactor and associated equipment for preparing laboratory specimens in accordance with ASTM Test Method D6925 shall be used.

iv. Saw – The saw shall be capable of producing three different notch sizes ranging from 0 to 50 mm. The width of the saw blade shall be < 3.5 mm.

v. Test Fixture—The loading frame shall consist of a loading rod and 2 sample support rods. The schematic of the test apparatus is shown in Figure 2. The diameters of the loading and supports rods shall be 25 mm and the anvil span shall be 127 mm.

vi. Reaction Surface Treatment—Polytetrafluoroethylene (PTFE) strips are used to reduce friction between the specimen and the lower two support rollers.

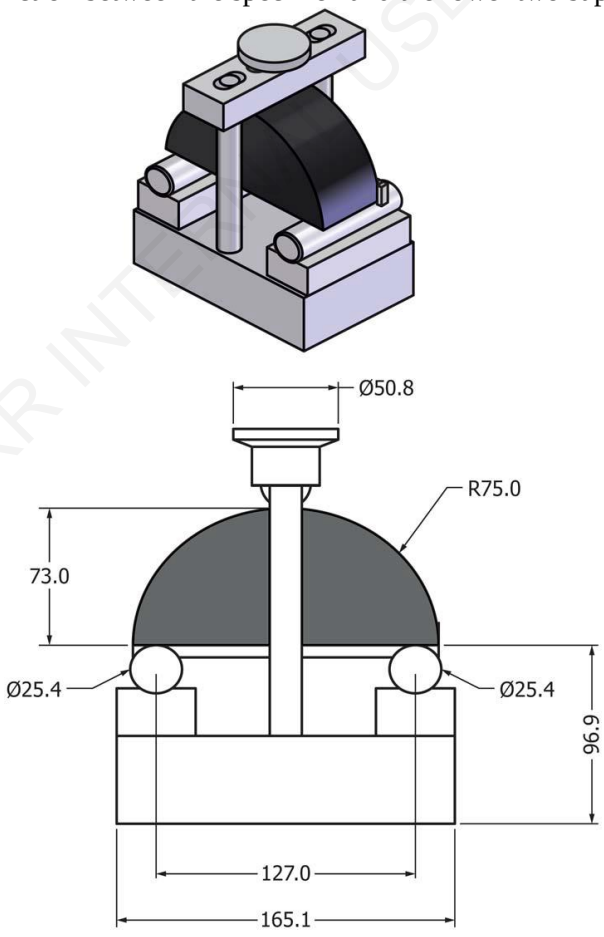


Figure 2 *Shop Drawing of SCB Test Fixture*

4.0 Sampling, Test Specimens, and Test Units

Semi-circular bend testing may be performed on field cores or laboratory prepared test specimens.

4.1 Laboratory-compacted asphalt mixture samples:

i. Specimen Size – The test specimens shall be 150 mm in diameter by 120 mm thick.

ii. Air Void Content – Prepare a minimum of 3 gyratory test specimens at the target air void content using the Superpave Gyratory Compactor (SGC) according to ASTM Test Method D6925 at the target air void content ± 0.5%. The typical air void target for the test specimens is 7.0 %.

iii. The semi-circular shaped specimens are prepared by first cutting a 150 mm diameter by 120 mm thick specimen into 2 equal circular samples 57 mm thick. These samples are cut along its central axis into 2 equal circular samples. The height (radius) of the 2 halves shall be within 1 mm of each other.[12]

4.2 Samples Cored from Asphalt Pavement:

i. Roadway cores can be used if pavement thickness is between 38 to 60 mm. Cores shall be taken full depth so that no prying action is needed to extract the cores from the pavement.

ii. Care shall be taken to avoid stress or damage to the interface during coring, handling, and transportation. The cores shall be trimmed such that only a single layer is tested.

iii. Roadway core specimens shall be approximately 150 mm diameter with all surface of the perimeter perpendicular to the surface of the core within 6 mm. If the thickness of the core being tested is greater than 57 mm, it shall be trimmed with a wet masonry saw to a height of 57 mm.

iv. The semi-circular shaped specimens are prepared by slicing the 150 mm diameter specimen prepared in 7.2.3 along its central axis into 2 equal circular samples. The height (radius) of the 2 halves shall be within 1 mm of each other.

Notching – A straight vertical notch is cut along the symmetrical axis of each semi-circular specimen. The location of the notch shall be in the center of the specimen within 0.3 mm. The three nominal notch depths are 25 mm, 32 mm, and 38 mm. The notch depth tolerance is ± 1.0 mm. The width of the notch shall be <3.5 mm.[13]

Aging – Laboratory-prepared test specimens shall be long term temperature-conditioned in according to AASHTO R30. Roadway cores need not be aged prior to testing.[14]

A minimum of 4 specimens shall be tested at each of the following notch depths: 25 mm, 32 mm, and 38 mm.

[12] *Some practitioners believe that the test should be conducted on specimens with 2 cut faces. If this approach is used, increase the compacted sample height by approximately 15 ± 5 mm such that the semi-circular shaped specimens with 2 cut faces have a final thickness of 57 ± 1 mm.*

[13] *Ruggedness testing between 4 laboratories has shown the J_c for split samples to have a within laboratory COV of 9.9 % for specimens with notch widths between 1.3 mm and 3.4 mm. The specimens should be symmetrical about the cut notch.*

[14] *A loose mix aging method is under development that may be able to achieve the AASHTO R30 level of aging in 12 to 24 h, NCHRP 9-54 Long Term Aging of Asphalt Mixtures for Performance Testing and Prediction. The long term temperature aging is needed to account for binder source, RAP, RAS and rejuvenators on mix performance (Reinke, et al., 2009, 2015, Cooper, et al. 2014, 2015).*

5.0 Procedure

i. Inspect the fixture to ensure all contact surfaces are clean and free of debris. Place the PTFE tape or pads to reduce friction caused by interactions between the specimen and testing fixture during loading. Depending on fixture geometry the PTFE pads can be placed either:
   - between the specimen and the bottom support rollers or,
   - with the specimen resting on the support rollers between the rollers and the base of the text fixture.

ii. Load the specimen in the fixture, ensuring the specimen is centered and making uniform contact (level) on the support rollers (as shown in Figure 3).

iii. Set the environmental chamber temperature and allow it to stabilize to the test temperature 60.3 °C. A dummy specimen with a temperature sensor mounted to its center can be monitored to determine when the specimen reaches the test temperature 60.3 °C. In the absence of a dummy specimen, the specimens should be placed in the environmental chamber set at the test temperature for a minimum of 2 ± 0.5 h to reach the required temperature equilibrium.

iv. Select test temperature based on the climatic intermediate temperature performance grade temperature as defined in AASHTO M320 or M332 and provided below in *Equation 3*:

$$PG\ IT = \frac{PG\ HT + PG\ LT}{2} + 4 \qquad \textit{(Equation 3)}$$

where:

$PG\ IT$ = Intermediate performance grade temperature (°C),
$PG\ HT$ = Climatic high performance grade temperature, and
$PG\ LT$ = Climatic low performance grade temperature.

v. After temperature equilibrium is reached, apply a preload of 45 ± 10 N for a maximum duration of 30 s to specimen to ensure the sample is seated properly. After ensuring the sample is level, release the load.

vi. Begin to apply load to specimen in displacement control at a rate of 0.5 mm/min ensuring that time, force, and displacement are measured and recorded at a sampling rate of 10 Hz. Test may be terminated when the applied load decreases to 25% of the peak load.

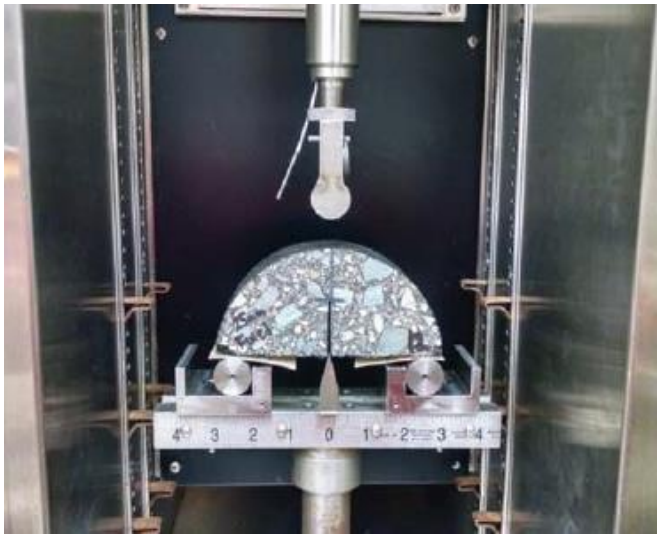
6.0 Calculation or Interpretation of Results

The critical value of *J*-integral (J_c) is determined using Equation 4:

$$J_c = \frac{-1}{b}\left(\frac{dU}{da}\right) \qquad \textit{(Equation 4)}$$

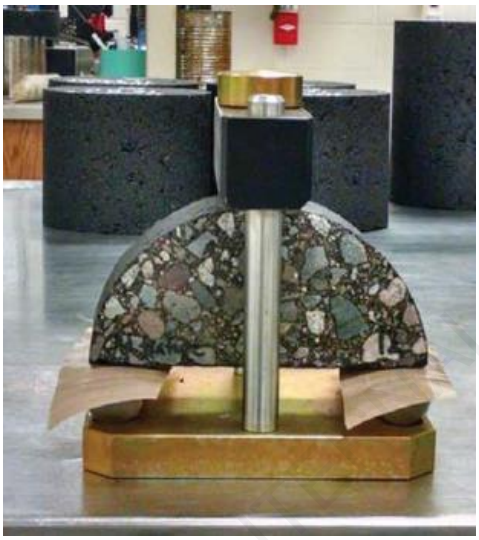
where:

J_c = critical strain energy release rate (kJ/m^2),
b = sample thickness (m),
a = notch depth (m),
U = strain energy to failure (kJ), and
dU/da = change of strain energy with notch depth (kJ/m).

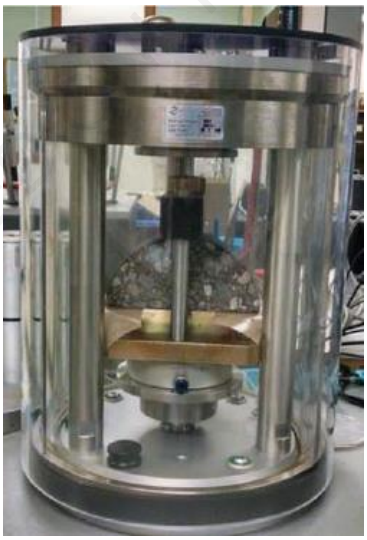


(a)

(b)



(c) Sample placed in Marshall fixture



(d) Fixture in AMPT

Figure 3 *Examples of SCB Test Fixtures for a Universal Testing Machine (a and b) and a Marshall Press (c) or AMPT (d)*

Appendix E - Hamburg Wheel-Tracking Test

1.0 Scope

This test method describes a procedure for testing the rutting and moisture-susceptibility of asphalt mixture pavement samples in the Hamburg Wheel-Tracking Device.

The method describes the testing of submerged, compacted asphalt mixture in a reciprocating rolling-wheel device. This test provides information about the rate of permanent deformation from a moving, concentrated load. A laboratory compactor has been designed to prepare slab specimens. Also, the Superpave Gyratory Compactor (SGC) has been designed to compact specimens in the laboratory. Alternatively, field cores having a diameter of 150 mm, 250 mm, or 300 mm, or saw-cut slab specimens may be tested.

The test method is used to determine the premature failure susceptibility of asphalt mixture due to weakness in the aggregate structure, inadequate binder stiffness, or moisture damage. This test method measures the rut depth and number of passes to failure.

The potential for moisture damage effects are evaluated since the specimens are submerged in temperature-controlled water during loading.

2.0 Referenced Documents

AASHTO Standards:

i. R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
ii. T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
iii. T 168, Sampling Bituminous Paving Mixtures
iv. T 209, Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)
v. T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
vi. T 312, Preparing and Determining the Density of Asphalt Mixture (HMA) Specimens by Means of the Superpave Gyratory Compactor

3.0 Summary of Method

A laboratory-compacted specimen of asphalt mixture, a saw-cut slab specimen, or a core taken from a compacted pavement is repetitively loaded using a reciprocating steel wheel. The specimen is submerged in a temperature-controlled water bath of 40 to 50 ºC or a temperature specified for the binder being used. The deformation of the specimen, caused by the wheel loading, is measured.

The impression is plotted as a function of the number of wheel passes. An abrupt increase in the rate of deformation may coincide with stripping of the asphalt binder from the aggregate in the asphalt mixture specimen.

4.0 Apparatus

i. *Hamburg Wheel-Tracking Device* – An electrically powered machine capable of moving a 203.2 diameter, 47 mm wide steel wheel over a test specimen. The load on the wheel is 705 ± 4.5 N. The wheel reciprocates over the specimen, with the position varying sinusoidally over time. The wheel shall make 52 ± 2 passes across the specimen per minute. The maximum speed of the wheel shall be approximately 0.305 m/s and will be reached at the midpoint of the specimen.

ii. *Temperature Control System* – A water bath capable of controlling the temperature within ± 1.0 ^{o}C over a range of 25 to 70 ^{o}C. This bath shall have a mechanical circulating system to stabilize the temperature within the specimen tank.

iii. *Impression Measurement System* – A linear variable differential transducer (LVDT) device capable of measuring the depth of the impression of the wheel within 0.15 mm, over a minimum range of 0 to 20 mm. The system shall be mounted and capable of measuring the depth of the impression at different intervals across the width of the wheel's path on the test specimen. The impression shall be measured at least every 400 passes of the wheel. This system must be capable of measuring rut depth without stopping the wheel. This measurement must be referenced to the number of wheel passes.

iv. *Wheel Pass Counter* – A non-contacting solenoid that counts each wheel pass over the specimen. The signal from this counter shall be coupled to the wheel impression measurement, allowing for the rut depth to be expressed as a function of the wheel passes.

v. *Slab Specimen Mounting System* – A stainless steel tray that can be mounted rigidly to the machine. This mounting system must restrict shifting of the specimen to within 0.5 mm during testing. The mounting system shall suspend the specimen, allowing for free circulation of the water bath on all sides. The mounting system shall be designed to provide a minimum of 20 mm of free circulating water on all sides of the specimen.

vi. *Cylindrical Specimen Mounting System* – A stainless steel tray that can be mounted rigidly to the machine. This mounting system must restrict shifting of the specimen to within 0.5 mm during testing. The mounting system shall include 2 high-density polyethylene molds (as shown in Figures 4 and 5) placed in a stainless steel tray to secure the specimen. The stainless steel tray is suspended in the machine, allowing for free circulation of the water bath on all sides. The mounting system shall be designed to provide a minimum of 20 mm of free circulating water on all sides of the specimen.

vii. *Linear Kneading Compactor* – A hydraulic powered unit used to compact asphalt mixtures into rectangular slabs. The mixture is placed in a mold and compacted through a series of vertically aligned steel plates that compress the asphalt mixture into a flat slab of predetermined thickness and density.

viii. Balance of 12000 g capacity, accurate to 0.1 g.

ix. Ovens for heating aggregate and asphalt binders.

x. Superpave Gyratory Compactor (SGC) and molds conforming to T 312.

xi. Bowls, spoon, spatula, etc.

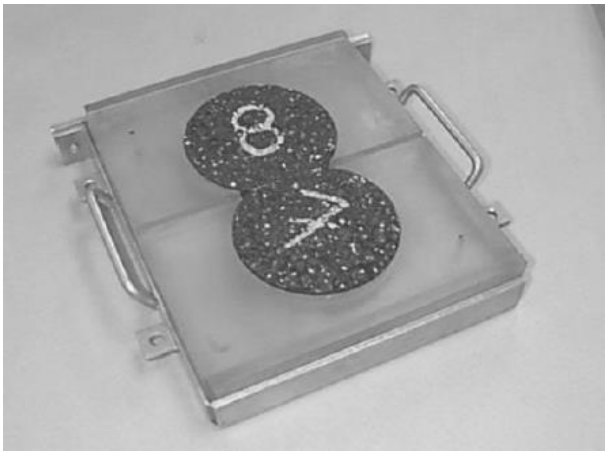
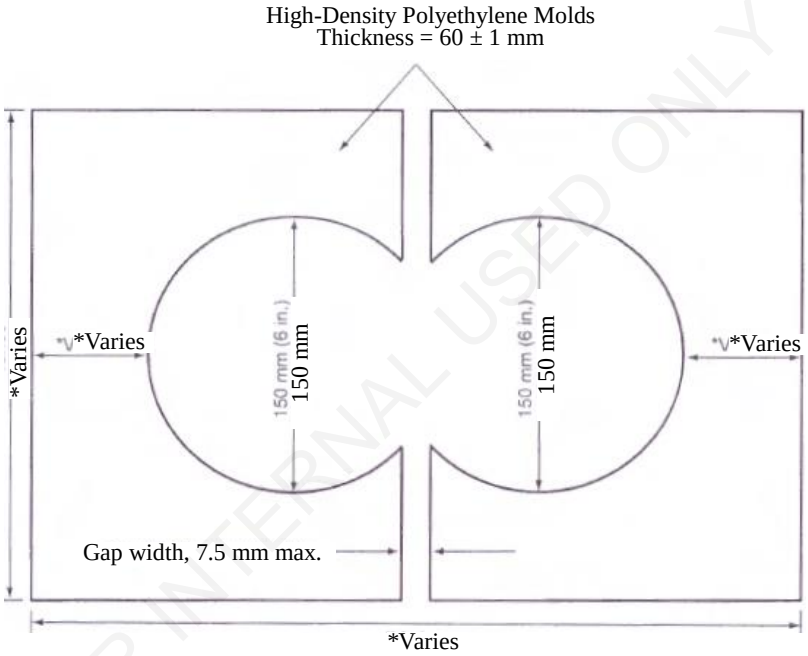


Figure 4 *Cylindrical specimen mounting system*



**Dimension may vary depends on manufacturer.*

Figure 5 *Schematic of Cylindrical Specimen Mounting System*

3.0 Specimen Preparation

2 test specimens shall be prepared for each test. Specimens may either be slab specimens or cylinders.

3.1 Laboratory-Produced Asphalt Mixture:

i. Mixture proportions are batched in accordance with the desired job mix formula.

ii. The temperature to which the asphalt binder must be heated to achieve a viscosity of 170 ± 20 cSt shall be the mixing temperature. For modified asphalt binders, use the mixing temperature recommended by the binder manufacturer.

iii. Dry-mix the aggregates and mineral admixture (if used) first; then add the correct percentage of asphalt binder. Mix the materials until all aggregates thoroughly coated. (Wet-mix the aggregates if a lime slurry or other wet material are used).

iv. Test samples shall be conditioned at the appropriate compaction temperature in accordance with the short-term conditioning procedure for mechanical properties in R 30.

v. The temperature to which the asphalt binder must be heated to achieve a viscosity of 280 ± 30 cSt shall be the compaction temperature. For modified asphalt binders, use the compaction temperature recommended by the binder manufacturer.

vi. Specimens compacted in the laboratory shall be either compacted slab specimens or SGC cylindrical specimens.

- Compacted Slab Specimens:
  Material shall be compacted into slab specimens using a Linear Kneading Compactor (or equivalent) and shall be 320 mm long and 260 mm wide. A slab specimen thickness of 38 mm to 100 mm can be used. The slab specimen thickness shall be at least twice the nominal maximum aggregate size. Compacted slab specimen shall be cooled at room temperature on a clean, flat surface until the specimen is cool to the touch.

- SGC Cylindrical Specimens:
  Material shall be compacted into specimens using an SGC according to T 312. A specimen thickness shall be at least twice the nominal maximum aggregate size. Two 150 mm diameter specimens are needed. Compacted specimens shall be cooled at room temperature on a clean, flat surface until the specimen is cool to the touch.

3.2 Field-Produced Asphalt Mixture – Loose Mix:

i. Obtain a sample of asphalt mixture in accordance with T 168.

ii. Specimens compacted in the laboratory shall be either compacted slab specimens or SGC cylindrical specimens as specify in 3.1 (vi).

3.3 Field-Produced Asphalt Mixture – Field Compacted (Core/Slab Specimen):

i. Cutting Field Cores or Field Slab Specimens – Field cores or field slab specimens shall consist of wet saw-cut compacted specimens taken from asphalt mixture pavements. Field cores shall be 300 mm, 250 mm, or 150 mm in diameter. Field slab specimens shall be wet saw-cut to approximately 260 mm wide by 320 mm long. A slab specimen thickness is typically 38, but may be adjusted to fit the specimen mounting system by wet saw-cutting. Field cores shall also be cut according to 3.4 (ii).[15]

ii. Cutting SGC Cylindrical Specimens and Field Cores – Cut specimens using a wet saw after a minimum of 24 hr from the time of compaction. Saw the specimens along a secant line (or chord) such that when joined together in the molds, there is no space between the cut edges. The amount of material sawed from the SGC cylindrical specimens may vary to achieve a gap width no greater than 7.5 mm between the molds.

[15] *Care should be taken to load the sample so it is level to the surface of the mold. The sample must be trimmed if it is too tall or shimmed up if it is too short (supporting with plaster if needed). The down pressure from the wheel is calibrated to be 705 N (158 lb) at the center, level to the top of the mold position. Even a small change in elevation will change the down pressure significantly.*

4.0 Determining Air Void Content

i. Determine the bulk specific gravity of the specimens in accordance with T 166.
ii. Determine the maximum specific gravity of the mixture in accordance with T 209.
iii. Determine the air void content of the specimens in accordance with T 269. It is recommended for laboratory-compacted specimens, that the target air void content be 7.0 ± 1.0%. Field specimens may be tested at the air void content at which they are obtained.

5.0 Procedure

i. Slab and Large Field Core Specimen Mounting:
Use Plaster-of-Paris to rigidly mount the 300 mm, 250 mm, or slab specimens in the mounting trays. Mix the plaster at approximately a 1:1 ratio of plaster to water. Pour the plaster to a height equal to that of the specimen so that the air space between the specimen and the sides of the mounting tray is filled. The slab specimen shall be in direct contact with the mounting tray; however, plaster may flow underneath the specimen. The plaster underneath the specimen shall not exceed 2 mm. Allow the plaster at least 1 h to set. If using other mounting material is used, it should be able to withstand 890 N of load without cracking.
ii. SGC Cylindrical and Field Core Specimen Mounting:
Place the high-density polyethylene molds in the mounting tray. Insert the cut specimens in the molds. Shim the molds in the mounting tray as necessary. Secure the molds into the mounting tray by thightening the bolts of the edge plate 'hand tight'.
iii. Place the mounting tray(s) with the test specimens into the device and secure by tightening the bolts 'hand tight'.
iv. Turn the testing device and computer on.
v. Start the software used to communicate with the testing device.
vi. Enter the pertinent project information and testing configuration requirements.
    a) Select the test temperature based on the applicable specifications.
    b) Select the maximum allowable rut depth based on the applicable specifications.
    c) Select the maximum number of passes based on the applicable specifications.
    d) Enter a start delay of 30 min to precondition the test specimens. The temperature of the specimens in the mounting tray shall be the test temperature selected in 5.0 (vi)(a) upon completion of this preconditioning period.
vii. Proceed to 5.0 (viii) to operate the testing device in "Auto" mode. Proceed to 5.0 (ix) to operate the testing device in "Manual" mode.[16]
viii. Performing the Test in Auto Mode:
    - Adjust the height of the LVDT to a location as per manufacturer's recommendations.[17]
    - Lower the wheels onto the edge of the test specimens such that a majority of the wheel is in contact with high-density polyethylene molds in the mounting tray.

[16] *Perform the test in "Auto" mode for testing devices manufactured in the United States later than 1998, where software will automatically open and close the valves to fill and drain the water bath. Devices made available to the United States prior to 1998 do not have this option and must be operated manually.*

[17] *The LVDT for each steel wheel is automatically zeroed at the start of the test. The software will display a zero at the start of the test.*

- Start the test by selecting the "Start" button of the testing device software.[18]
- The wheel-tracking device shall shut off when 20,000 passes have occurred or when the test has achieved the maximum impression depth established in 5.0 (vi)(b). The testing device software automatically saves the test data file.
- Raise the wheel(s) and remove the specimen mounting tray(s) and rutted specimens.
- Proceed to 5.0 (x).

ix. Performing the Test in Manual Mode:

- Close the drain valve(s) and fill the water bath of the wheel-tracking device with water until the float device(s) raises to a horizontal position.[19]
- Precondition the test specimens in the water bath for 30 min after the water has reached the selected test temperature.
- Lower the wheels onto the specimens after the test specimens have preconditioned at the selected test temperature for 30 min. For machines that start automatically after the selected preconditioning time, it is allowable to lower the wheels before the preconditioning cycle. The wheel shall not be in contact with the specimen for more than 5 min prior to starting the wheel.
- Ensure the micro-control unit's LVDT reads between 10 mm and 18 mm. Adjust the LVDT height to obtain this reading. Loosen the 2 screws on the LVDT mount and slide the LVDT up or down to the desired height. Tighten the screws.
- Start the test.
- The wheel-tracking device will disengage when 20,000 passes have occurred. The devise will also disengage if the average LVDT displacement (read from the micro-control unit, not the screen) is 40.90 mm or greater for an individual specimen. Note that the screen readout subtracts the initial LVDT reading from the total displacement.
- Open the valve(s) beneath the tanks and drain the water bath. Raise the wheel(s) and remove the specimen mounting tray(s) and rutted specimens.

x. Clean the water bath, heating coils, wheels, and temperature probe with water and scouring pads or per the manufacturer's recommendations. Use a wet-dry vacuum to remove particles that have settled to the bottom of the baths. Clean the filter element and spacers after every test or as per the manufacturer's recommendations. Do not use solvents to clean the water bath.

xi. Turn the wheels after each test, so the same section of the wheel surface is not in contact with the test specimen from test to test. This rotation will provide for even wear over the entire wheel. The test should operate with a smooth movement across the test specimen.

[18] *The start delay time or preconditioning time will start after the water heats to the test temperature selected in 5.0 (vi)(a).*

[19] *Adjust the amount of hot and cold water if necessary, as the water temperature may vary.*

6.0 Calculation

Plot the rut depth versus number of passes for each test. A typical plot of the output produced by the Hamburg Wheel-Tracking Device is shown in Figure 6. From this plot, obtain the following values:

- slope and intercept of the first steady-state portion of the curve, and
- slope and intercept of the second steady-state portion of the curve.

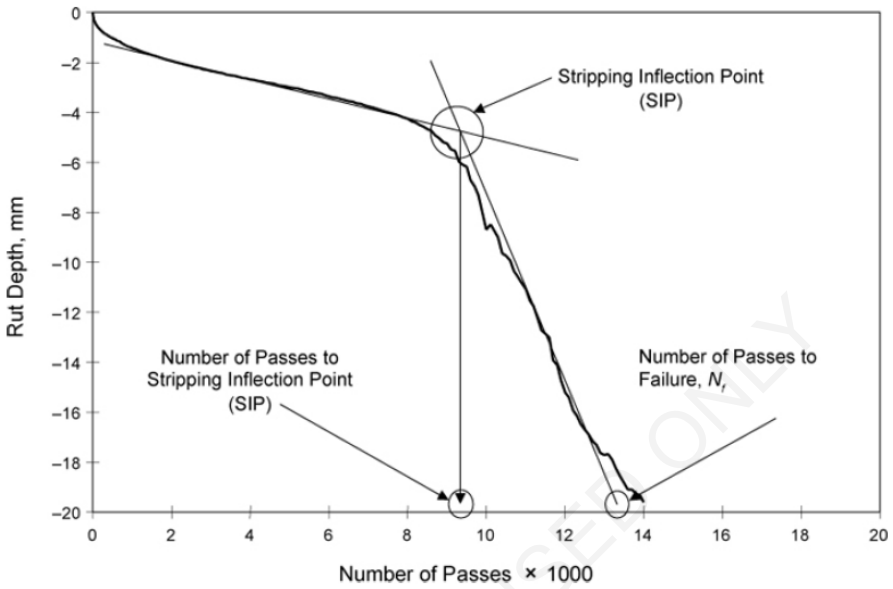


***Figure 6** Hamburg Curve with Test Parameters*

Calculate the following test parameters, all expressed in "Passes."

$$Stripping\ inflection\ point\ (SIP) = \frac{intercept\ (second\ portion) - intercept(first\ portion)}{slope\ (first\ portion) - slope\ (second\ portion)} \qquad \textit{(Equation 5)}$$

where:

Failure rut depth is the specified maximum allowable rut depth for the test.

7.0 Report

The report shall include the following parameters:

i. Asphalt mixture production (field or lab);
ii. Compaction method (slab or SGC cylindrical specimen);
iii. Number of passes at maximum impression;
iv. Maximum impression;
v. Test temperature;
vi. Specimen(s) air voids;
vii. Type and amount of anti-stripping additive used;
viii. Creep slope;
ix. Strip slope; and
x. Stripping inflection point.

Appendix F – Water Permeability Test of Asphalt Mixtures

1 Scope

This method is applicable to determinate the permeability coefficient of asphalt mixtures specimen prepared by rolling and to inspect asphalt pavement in field.

2.0 Apparatus and Materials

i. Pavement water permeameter: It's shape and dimension are shown as Figure 7; the measuring cylinder filled with water at the upper part is made of clear organic glass with a volume of 600 ml with graduation; at 100 ml and 500 ml, there are thick mark lines; the base is connected with the lower part through a ø 10 mm tubule with a valve in the middle. The measuring cylinder is coupled through the support and for the opening below the base, inside diameter is 150 mm and outside diameter is 220 mm. The apparatus is attached by 2 stainless steel rings, 5 kg for each and the inside diameter is 160 mm.
ii. Measuring cylinder and large funnel.
iii. Stopwatch.
iv. Sealing material: water-proof putty, putty or plasticine.
v. Others: water, chalk, plastic ring, scraper, broom, etc.

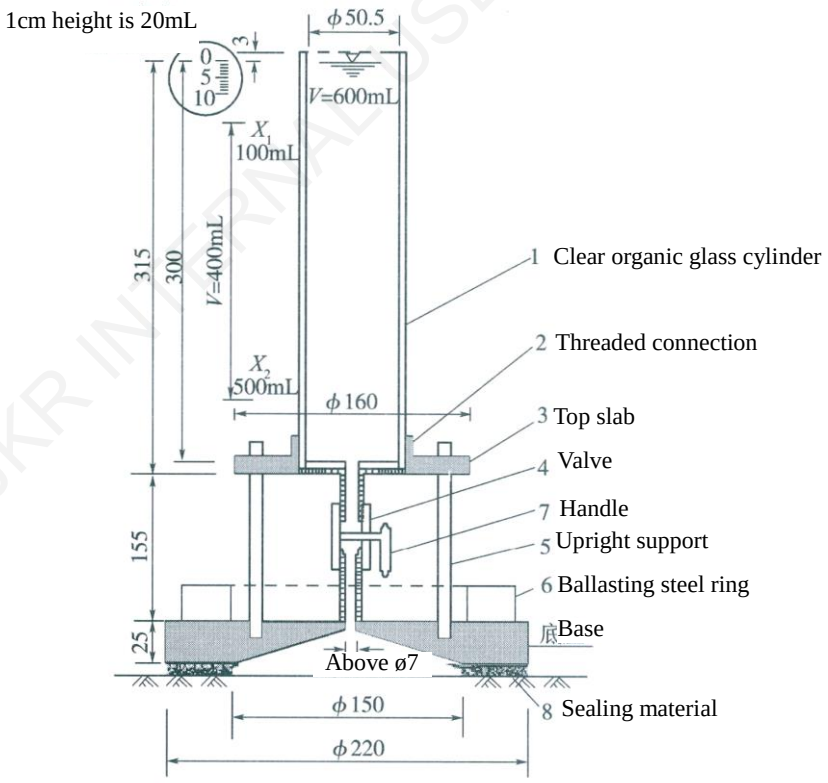


Figure 7 *Water Permeameter (Dimension Unit: mm)*

3.0 Procedure

i. Assemble and install pavement water permeameter.

ii. Prepare asphalt mixtures specimen according to preparation method of asphalt mixtures specimen (rolling method) of this specification, extracted from mold after being cooled down to the specified time and remove the paper on the surface at preparation of the specimen.

ii. Place specimen on a stable plane and plastic ring at the measuring points at the center of the specimen, draw 2 circles with a chalk along the inner side and outer side of the plastic ring and the part between the outer ring and the inner ring is the sealing area required to be sealed with sealing material.

iii. Make a sealing treatment to the annular seal area with sealing material and notice not to make the sealing material into the inner circle; if the sealing material enters by accident, tear it away with scraper. Pile the strip sealing material which is twisted into thumb shape at the center of the annular seal area and pile it into a circle.

iv. Erect the specimen at left and right sides with suitable cushion block or wood block. Place a water receptor below the specimen. Place the water permeameter on the measuring points of the specimen and superpose the water permeameter center to the ring center as much as possible, then press the water permeameter slightly on the surface of the strip sealing material and add the counterweight in case of pressure water outflowing from the part between the base and the specimen.

v. Close the valve, fill the measuring cylinder with water, then open the valve to make the water in the measuring cylinder flow downwards to remove the air in the bottom of the water permeameter; when the water surface in the measuring cylinder falls down slowly, press the water permeameter slightly with both hands to discharge all the bubbles at the bottom of the water permeameter. Close the valve and fill the measuring cylinder with water again.

vi. Open the valve and start the stopwatch immediately when the water surface falls to 100 ml and read and record the graduation of mesuring cylinder at an interval of 60 s until the water surface falls to 500 ml. In the test, if the water permeates from the parts between the base and the sealing material, it means the sealing between the base and pavement is poor and resealing is required. When the water surface falls at a slow rate, stop after the seepage amount is determined for 3 min; when the water surface falls at a fast rate and reaches 500 ml within 3 min, record the time when the water surface reaches 500 ml; if the water surface remains unchanged after falling at a certain height, it means to be basically watertight or watertight ultimately which shall be indicated in the report.

vii. 3 specimens made of the same materials shall be used to determine the permeability coefficient in accordance with the procedure above and take the average value as the test result.

4.0 Calculation

Permeability coefficient of asphalt mixtures specimen shall be calculated according to Formula (*Equation 6*), subject to the time required by the water surface from 100 ml to 500 ml; if the water penetration time is overlong, the water amount passed in 3 min may be adopted for calculation.

$$C_w = \frac{V_2 - V_1}{t_2 - t_1} \times 60 \qquad \textit{(Equation 6)}$$

Where:

C_w = The pavement permeability coefficient (ml/min);

V_1 = The water amount at the first timing (ml), 100 ml usually;

V_2 = The water amount at the second timing (ml), 500 ml usually;

t_1 = The time at the first timing (s);

t_2 = The time at the second timing (s).

5.0 Report

Report the permeability coefficient of each specimen point by point and the average value of 3 specimens. If the specimen is watertight, it shall be indicated in the report.