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5 ASPHALT WORKS

5.1 GENERAL

5.1.1 Scope

1 Materials, equipment, and construction of bituminous paving works including prime coating and tack coating.

2 Related Parts

Part 1, ... General
Part 3, ... Earthworks
Part 4, ... Unbound Pavement Materials.

5.1.2 References

1 The following standards and other documents are referred to in this Part:

ASTM C40..................Standard Test Method for Organic Impurities in Fine Aggregates for Concrete

ASTM C50..................Standard Practice for Sampling, Sample Preparation, Packing and Marking of Lime and Limestone Products

ASTM C51..................Terminology Relating to Lime and Limestone (as used by the industry)

ASTM C88 ....Standard Test Method for Soundness of Aggregates by Use of Sodium Sulphate or Magnesium Sulphate

ASTM C117................Standard Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

ASTM C127 ....Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

ASTM C128 ....Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

ASTM C131 ....Standard Test Method for Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

ASTM C136 ....Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates

ASTM C142 ....Standard Test Method for Clay Lumps and Friable Particles in Aggregates

ASTM C150................Specifications for Portland Cement

ASTM C535 ....Standard Test Method for Resistance to Degradation of Large Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

ASTM D5....................Standard Test Method for Penetration of Bituminous Materials

ASTM D6....................Standard Test Method for Loss on Heating of Oil and Asphaltic Compounds

ASTM D36..................Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)

ASTM D75 ....Standard Practice for Sampling Aggregates

ASTM D92 ....Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester

ASTM D113................Standard Test Method for Ductility of Bituminous Materials

ASTM D140 ....Standard Practice for Sampling Bituminous Materials

ASTM D242................Standard Specification for Mineral Filler for Bituminous Paving Mixtures

ASTM D402................Standard Test Method for Distillation of Cutback Asphaltic (Bituminous) Products

ASTM D546................Standard Test Method for Sieve Analysis of Mineral Filler for Bituminous Paving Mixtures

ASTM D946 ....Standard Specification for Penetration Graded Asphalt Cement for Use in Pavement Construction

ASTM D977................Standard Specification for Emulsified Asphalt

ASTM D979................Standard Practice for Sampling Bituminous Paving Mixtures

ASTM D995-95 ....Standard Specification for Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures

ASTM D1188: ....Standard Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Coated Samples

ASTM D2027..............Standard Specification for Cutback Asphalt (Medium-Curing Type)

ASTM D2041 ....Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures

ASTM D2042..............Standard Test Method for Solubility of Asphalt Materials in Trichloroethylene

ASTM D2172 ....Standard Test Methods for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures

ASTM D2419 ....Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate

ASTM D2726 ....Standard Test Method for Bulk Specific Gravity and Density of Non Absorptive Compacted Bituminous Mixtures

ASTM D2872.............. Standard Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin Film Oven Test)

ASTM D2950..............Standard Test Method for Density of Bituminous Concrete in Place by Nuclear Methods

ASTM D2995..............Standard Practice for Estimating Application Rate of Bituminous Distributors

ASTM D3319..............Standard Practice for the Accelerated Polishing of Aggregates Using the British Wheel

ASTM D3549..............Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens

ASTM D4318 ....Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

ASTM D4402 ....Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer

ASTM D4791 ....Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

ASTM D5361..............Standard Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing

ASTM D5444..............Standard Test Method for Mechanical Size Analysis of Extracted Aggregate

ASTM D5581..............Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus (6 inch-Diameter Specimen)

ASTM D5821 ....Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate

ASTM D6307..............Standard Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method

ASTM D6373..............Standard Specification for Performance Graded Asphalt Binder

ASTM D6521 ....Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)

ASTM D6648 ....Standard Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)

ASTM D6723..............Standard Test Method for Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)

ASTM D6926 ....Standard Practice for Preparation of Bituminous Specimens Using Marshall Apparatus

ASTM D6927..............Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures

ASTM D6931..............Standard Test Method for Indirect Tensile (IDT) Strength of Bituminous Mixtures

ASTM D7173 ....Standard Practice for Determining the Separation Tendency of Polymer from Polymer Modified Asphalt

ASTM D7175 ....Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer

ASTM D7405 ....Standard Test Method for Multiple Stress Creep and Recovery (MSCR) of Asphalt Binder Using a Dynamic Shear Rheometer

ASTM E11 ....Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

ASTM E274................Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire

ASTM E303................Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester

ASTM E950 ....Standard Test Method for Measuring the Longitudinal Profile of Travelled Surfaces with an Accelerometer Established Inertial Profiling Reference

ASTM E965................Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique

ASTM E1926 ....Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements

ASTM D4867………... standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures

AASHTO M82 ....Standard Specification for Cutback Asphalt (Medium-Curing Type)

AASHTO M92 ....Standard Specification for Wire-Cloth Sieves for Testing Purposes

AASHTO M140 ....Standard Specification for Emulsified Asphalt

AASHTO M208 ....Standard Specification for Cationic Emulsified Asphalt (ASTM D2397-02)

AASHTO M320 ....Standard Specification for Performance-Graded Asphalt Binder

AASHTO M332 ....Standard Specification for Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test, Single User Digital Publication

AASHTO R28.............Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)

AASHTO R35 ....Standard Practice for Superpave Volumetric Design for Hot-Mix Asphalt (HMA)

AASHTO T44 ....Standard Method of Test for Solubility of Bituminous Materials

AASHTO T48 ....Standard Method of Test for Flash and Fire Points by Cleveland Open Cup

AASHTO T240 ....Standard Method of Test for Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)

AASHTO T313 ....Standard Method of Test for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)

AASHTO T283 ....Standard Method of Test for Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage

AASHTO T314 ....Standard Method of Test for Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)

AASHTO T315 ....Standard Method of Test for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

AASHTO T316 ....Standard Method of Test for Viscosity Determination of Asphalt Binder Using Rotational Viscometer

AASHTO T350 ....Standard Method of Test for Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

AASHTO PP60...........Standard Practice for Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC)

AASHTO PP61 ....Standard Practice for Developing Dynamic Modulus Master Curves for Hot Mix Asphalt (HMA) Using the Asphalt Mixture Performance Tester (AMPT)

AASHTO TP79 ....Standard Method of Test for Determining the Dynamic Modulus and Flow Number for Hot Mix Asphalt (HMA) Using the Asphalt Mixture Performance Tester (AMPT)

BS 812-110 ....Testing aggregates Methods for determination of aggregate crushing value (ACV)

BS 1377 Part 3...........Methods of test for Soils for Civil Engineering Purposes: Chemical and electro-chemical tests

EN 12697-13..............Bituminous mixtures -Test methods - Part 13: Temperature measurement

5.1.3 Definitions

1 QS: Qatar General Organization for Standardization

2 Base Course: One or more bituminous layers beneath Wearing Course and above the unbound Road Base Layer. It usually consists of a mixture of aggregates and bituminous materials and functions as a structural portion of pavement.

3 Wearing Course: Top surface bituminous course, which resists skidding, traffic abrasion, and the disintegrating effects of climate.

4 ESAL's: Equivalent Single Axle Load.

5 NMAS: Nominal Maximum Aggregate Size.

6 Certificate: certificate issued by the concerned governmental authority or accredited third party as accredited laboratory.

5.1.4 Submittals

1 The Contractor shall submit for approval a proposed Job Mix Formula (JMF) together with all applicable design data at least one month before beginning the work. The JMF shall give a combined gradation showing a single definite percentage passing each sieve as well as a percentage of each material to be used in the mix. The JMF shall also establish the mixing and compaction temperature values and a compaction reference density. The Engineer will test samples of the materials proposed for use in order to check their quality and to check the proposed mix design. The Contractor shall report all the values obtained in the laboratory design and shall submit these together with a copy of the plotted curves resulting from the tests in an approved form to the Engineer. The Engineer may require verification of the submitted design before giving approval. The Engineer shall approve the optimum binder content based upon the design values submitted by the Contractor and shall notify the Contractor of the value. No asphalt works will be allowed to commence before the Contractor receives written approval from the Engineer for his JMF.

2 The asphalt mix design submission shall include a copy of valid calibration certificates from a calibration service agency approved by the concerned authority for the batching plant and the relevant laboratory equipment such as but not limited to balances, proving rings, and load devices.

3 Based on the Engineer request, the Contractor shall submit the pertinent certifications of materials, equipment, plants, personnel, and processes in relation to the project. Certificates must be issued by a competent authority approved by the Engineer.

4 The contractor shall submit to the Engineer for approval method statements for the following:

(a) Bituminous and asphalt materials production, storage, transportation, identification and marking procedure and traceability to source of production.

(b) Quality assurance and quality control plans for laying, compaction, and all construction activities.

(c) Quality control testing plan.

(d) Equipment and its suitability to fulfil all construction activities to the required quality.

(e) Personnel capability.

(f) Safety and environment preservation measures.

5 The Contractor shall provide the Engineer with a complete report on the origin and composition of all stone and/or gravel aggregates to be used in the work (Aggregate Resources Report). All materials shall comply with the specified requirements for the various aggregates.

6 Delivery of materials produced from commercial manufacturing process shall be accompanied by the manufacturer’s certification and test reports from local approved accredited laboratory showing the materials compliance with the specification for which it is stipulated.

7 After receiving the approval of specific sources of material the Contractor cannot change these sources without prior written approval of the Engineer.

5.1.5 Quality Assurance

1 The Contractor shall notify the Engineer of the sources of materials and the Engineer shall approve the sources. All materials shall be tested and approved before use.

2 Where the quality of material from a source of material does not comply with the designated requirements, the Contractor shall furnish material that does comply from other sources. Delivery of materials produced from commercial manufacturing processes shall be accompanied by the manufacturer's certification and test report showing that the materials comply with the designated requirements.

3 No change shall be permitted in the source of any of the materials until the technical submissions listed in the specification have been made and approved by the Engineer.

4 All processed materials shall be tested and approved before being stored at the site or incorporated in the works and may be inspected and tested at any time during the progress of their preparation and use. Questionable materials, pending laboratory testing subsequent approval shall not be unloaded and incorporated with materials previously approved and accepted.

5 It is the full responsibility of both the asphalt mixture producer and the Contractor to obtain a certificate which proves that the asphalt binder complies with the specifications. Furthermore, both the asphalt mixture producer and the Contractor shall perform all the required tests in an approved private accredited laboratory to make sure that the asphalt binder being purchased complies with the specifications.

5.2 MATERIALS

5.2.1 Unacceptable Materials

1 Materials that do not conform to the designated requirements shall be rejected and immediately removed from the site of the works unless otherwise instructed by the Engineer. No rejected material, the defects of which have been corrected, shall be used until approval has been given by the Engineer.

2 Bituminous paving courses shall consist of coarse aggregate, fine aggregate, filler material, and bitumen binder. Mixture of two different types of rocks, e.g., igneous, and sedimentary having different engineering properties shall not be permitted.

3 During execution of works, variations in the specific gravity of any individual fraction of aggregates used in the asphalt mixes by more than 1% shall cause the Engineer to request for evaluation of aggregates consistency and compliance and/or mix design validation.

5.2.2 Fine Aggregate

1 Fine aggregate is that portion of the mineral aggregate passing the 2.36mm ASTM sieve for the Marshall mix design and passing the 4.75mm sieve for the Superpave mix design.

2 Fine aggregate shall consist of crushed hard durable rock and shall be of such gradation that when combined with other aggregates in proper proportions, the resultant mixture will meet the required gradation. Fine aggregate shall be non-plastic and chemically stable.

3 The source of natural fine aggregate is considered to be the crusher site at which it is produced. Crushed fine aggregate shall be produced by crushing clean coarse aggregate and shall not be thin, flaky, or elongated. Sampling of fine aggregate shall be in accordance with ASTM D75.

4 Fine aggregate shall be clean and free from organic matter, clay, cemented particles and other extraneous or detrimental materials.

5 Unless permitted elsewhere in the contract, the aggregate type for wearing course shall be Gabbro. The aggregate type for Base Course shall be either Gabbro or Limestone.

6 The Contractor shall ensure that the sources of all fine aggregates have been approved by the Municipality concerned.

7 The specifications of fine aggregates for asphalt mixtures are listed in Table 5.1.

Table 5.1
Fine Aggregate Specifications for Marshall Mixes

Parameter	Standard	Specification Limits	Minimum Frequency
Plasticity index	ASTM D 4318	4% max. (stockpile) Non Plastic (hot bins)	- Each source - Visible change in material - 1 test every 2000m^3
Sand equivalent value	ASTM D2419	45% min.	
Soundness by magnesium sulphate	ASTM C88	18% max.	
Acid soluble chloride content	BS 1377 Part 3	0.1% max.	
Acid soluble sulphate content	BS 1377 Part 3	0.5% max.	
Clay lumps and friable particles	ASTM C142	None	
Organic Impurities	ASTM C40	No Impurities	

5.2.3 Coarse Aggregate

1 Coarse aggregate is that portion of the mineral aggregate retained on the 2.36mm ASTM sieve for the Marshall mix design and retained on the 4.75mm ASTM sieve for the Superpave mix design. Coarse aggregate shall consist of crushed natural stones and gravel. Crushed particles shall be cubic and angular in shape and shall not be thin, flaky, or elongated. The gradation shall be such that when combined with other aggregate fraction in proper proportions, the resultant mixture will meet the required gradation.

2 The source of crushed aggregate is considered to be the crushing site from which it is produced. Sampling of coarse aggregate shall be in accordance with ASTM D75.

3 Coarse aggregate shall be clean and free from organic matter, clay, cemented particles and other extraneous or detrimental material.

4 The specifications of coarse and combined aggregates for asphalt mixtures are listed in Table 5.2.

5 Unless permitted elsewhere in the contract, the aggregate type for wearing course shall be Gabbro. The aggregate type for Base Course shall be either Gabbro or Limestone.

6 If directed by the Engineer, the polished stone value (PSV) should be determined for wearing course aggregates of main lane as per ASTM D3319. The PSV shall not be less than 45.

5.2.4 Recycled Aggregate

1 Recycled aggregate produced from excavating natural ground can be used in asphalt mixtures for temporary roads and for roads, which serve agricultural areas provided that the specifications stated in Section 6 - Part 9 are complied.

Table 5.2
Coarse and Combined Aggregate Specifications for Marshall Mixes

Parameter	Standard	Specification Limits			Minimum Frequency
		Base Course (Class A)	Base Course (Class B)	Wearing Course	
One or more Fractured Faces	ASTM D5821	100% min.	100% min.	100% min.	- Each source - Visible change in material - 1 test every 2000m^3
Two or more[1] Fractured Faces	ASTM D5821	85% min.	85% min.	85% min.	
Gradation (Combined)	ASTM C136	Table 5.7, Job Mix gradation and Table 5.10 tolerances			
Flat and Elongated Particles (5:1)	ASTM D4791	15 % max.	15% max.	10 % max.	
Soundness (5 cycles by $MgSO_4$)	ASTM C88	15 % max.	15% max.	10 % max.	
Los Angeles Abrasion	ASTM C131 ASTM C535	30% max.	30% max.	25% max.	
Water absorption	ASTM C127	2.0% max.	2.0% max.	1.5% max.	
Aggregate Crushing Value (ACV)	BS 812 Part 110	25 % max.	25 % max.	20% max.	

[1]Higher values can be recommended by the Engineer based on the design ESAL.

5.2.5 Mineral Filler

1 Mineral filler when separately supplied from an external source shall consist of finely ground mineral matter in accordance with ASTM D242 such as rock dust, hydrated lime, cement or other material which can satisfy the Engineer will produce asphalt mixes of at least equal quality. It shall be free from organic substances and clay, shall be thoroughly dry and free from agglomerations, shall be non-plastic and shall meet the grading requirements shown in Table 5.3.

2 Hydrated lime shall conform to the definitions given in ASTM C51. Sampling, packaging and marking of hydrated lime shall be in accordance with ASTM C50. Storage and use of the hydrated lime shall at all times be such as to protect the material from the weather.

Table 5.3

ASTM Sieve	% Mass Passing
600 µm	100
300 µm	95 - 100
150 µm	90 – 100
75 µm	70 – 100

3 The grading of mineral filler shall be carried out in accordance with ASTM D546.

4 When cement is used as mineral filler, it shall meet the requirements of ASTM C150.

5.2.6 Asphalt Binder

1 The asphalt binder specified for use in the asphalt mixes shall be either of the following:

(a) Penetration grade 60-70: This binder type shall be graded in accordance with ASTM D946. The 60-70 binder specifications are listed in Table 5.4. Sampling shall be in accordance with ASTM D140. The 60-70 penetration graded binder is generally equivalent to PG 64-10 performance graded binder.

(b) PG 76-10: Based on the Engineer approval, the PG76-10 binder can be used in asphalt mixes. This binder type shall be a polymer-modified binder (PMB) meeting AASHTO M320 and ASTM D6373 specifications in addition to separation test criteria as listed in Table 5.5. Sampling shall be in accordance with ASTM D140.

2 Prior to the commencement of the mix design, the Contractor shall provide a certificate indicating conformance of binder with the specifications stated above. This certificate shall be obtained from an approved accredited laboratory.

3 The asphalt binder shall be prepared by the refining of petroleum and shall be uniform in character. Blending of asphalt binders from different refineries will be permitted only with the written approval of the Engineer.

Table 5.4
Specifications of Bitumen Penetration Grade 60 – 70

Parameter	**Standard**	**60 – 70 Pen**		**Minimum Frequency**
		Min.	**Max.**	
Penetration (0.1 mm) at 25°C - 100g, 5 Sec	ASTM D5	60	70	- Each source - Visible change in material - 1 test per 75t of asphalt binder per layer
Softening Point Ring & Ball Apparatus, °C	ASTM D36	46	-	
Flash Point, Cleveland Open Cup, °C	ASTM D92	230	-	- Each source - Visible change in material - 1 test per 450t of asphalt binder per layer
Ductility at 25 °C, cm	ASTM D113	100	-	
Solubility Trichloroethylene, %	ASTM D2042	99	-	
Loss on heating, %	ASTM D6	-	0.2	
Penetration of Residue of original after TFOT, %	ASTM D5	52	-	
Ductility of Residue after TFOT at 25 °C, 5cm/min, cm	ASTM D113	50	-	

Table 5.5
Specifications of Performance Graded Binders / Polymer Modified Binders (PMB)

Parameter	Standard		Specification	Minimum Frequency
	AASHTO	ASTM		
Tests on Original Binder				
Average 7 days maximum pavement design temperature, (ºC)	-	-	< 76	- Each source - Visible change in material - 1 test per 450t of asphalt binder per layer
Minimum pavement design temperature,(ºC)	-	-	>-10	
Flash Point Temperature, Minimum (ºC)	T48	D92	230	
Rotational Viscosity, Maximum 3 Pa.s, Test Temperature (ºC)	T316	D4402	135	
Dynamic Shear, G*/sinδ, Minimum, 1.00 kPa , Test Temperature (ºC) at 10 rad/s	T315	D7175	76	
Solubility, min, %	T44	D2042	99	
Separation Test: Absolute Difference[1] between G* @ 76 ºC and 10 rad/s of Top and Bottom Specimens, Maximum, %	-	D7173	20	
Requirements of the Rolling Thin Film Oven Residue (T240 / D2872)				- Each source - Visible change in material - 1 test per 450t of asphalt binder per layer
Mass Loss, Maximum, Percent	T240	D2872	1	
Dynamic Shear, G*/sinδ, Minimum, 2.20 kPa , Test Temperature (ºC) at 10 rad/s	T315	D7175	76	
Pressure Aging Vessel Residue (D6521 / R28)				
PAV Aging Temperature , (ºC)	R28	D6521	110	
Dynamic Shear, G*.sinδ, Maximum 5000 kPa , Test Temperature (ºC) at 10 rad/s	T315	D7175	37	
Creep Stiffness, S, Maximum 300 MPa and m-value, Minimum 0.300 at 60 seconds , Test Temperature (ºC)	T313	D6648	0	
Direct Tension[2], Failure Strain, Minimum, 1.0% (loading rate of 1.0 mm/min), Test Temperature(ºC)	T314	D6723	0	

1. Absolute Difference = Abs(100x(top-bottom)/top).

If the creep stiffness is below 300 MPa, the direct tension test is not required. If the creep stiffness is between 300 and 600 MPa, the direct tension failure strain requirement can be used in lieu of the creep stiffness requirement. The m-value requirement must be satisfied both cases.

4 Based on the Engineer approval, when bitumen grades PG76-10 H, V or E are specified for heavy, very heavy, and extra heavy loading, the bitumen shall meet the requirements of AASHTO M332 and will be required to indicate elastic response in percent recovery when tested in accordance with AASHTO T350 / ASTM D7405.

5 Binders modified using Crumb Rubber and other binders containing particulate materials, which are graded according to AASHTO M320 and/or AASHTO M332, shall not include particles with longest dimensions of more than 250µm. In addition, the requirements listed in Table 5.5 shall be satisfied.

5.2.7 Prime Coat

1 Liquid asphalt for use as prime coat shall be MC-70 medium curing cutback asphalt in accordance with ASTM D2027 or AASHTO M82.

2 The prime coat shall be a cutback consisting of a 60/70 penetration grade bitumen and kerosene. The residue from the distillation test, carried out to 360 °C in accordance with ASTM D402, shall be a minimum of 55 % (by volume), as determined by the difference method. Sampling shall be in accordance with ASTM D140. One sample shall be tested every 5 tons.

5.2.8 Tack Coat

1 Emulsified asphalt for use as tack coat in asphalt works may be CSS 1h or CRS-2 cationic emulsified asphalt in accordance with AASHTO M 208 or SS 1h anionic emulsified asphalt in accordance with ASTM D977 or AASHTO M140 unless otherwise designated.

2 Emulsified asphalt shall be of the slow-setting cationic or anionic type of the CSS-1h or SS-1h grades respectively and shall conform to the designated requirements. Sampling shall be in accordance with ASTM D140. One sample shall be tested every 5 tons.

5.2.9 Delivery, Storage and Handling

1 Materials shall be so stored and handled as to assure the preservation of their quality and fitness for use. Materials, even though approved before storage or handling, may again be inspected and tested before use in the Works.

2 Stored material shall be located so as to facilitate their prompt inspection. All storage locations on land not owned by the Contractor shall be restored to their original condition at the Contractor's expense.

3 Handling and stockpiling of aggregates shall at all times be such as to eliminate segregation or contamination of the various sizes and to prevent contamination of materials by dust. Stockpiles shall be kept flat and the formation of high cone-shaped piles shall not be permitted. When conveyor belts are used for stockpiling aggregates, the Engineer may require the use of baffle-chutes or perforated chimneys.

4 Where trucks are used to construct stockpiles, the stockpiles shall be constructed one layer at a time with trucks depositing their loads as close to the previous load as possible. The use of tractors or loaders to push material deposited at one location to another location in the stockpile shall not be allowed during the construction of the stockpile, and their use shall be limited to levelling the deposited material only.

5 Stockpiles of aggregate located at permanent asphalt plant sites shall be separated by bin walls and shall be constructed on asphalt or concrete floors. Stockpile locations and procedures at temporary asphalt plant sites shall be as approved by the Engineer.

6 Intermediate storage of hydrated lime and commercial mineral filler for equipment feeding the asphalt plant shall be silos of adequate size to ensure a minimum of one day's continuous operation.

5.2.10 Inspection and Control

1 For verification of weights and measures, character of materials and determination of temperatures used in the preparation of the asphalt mixes, the Engineer shall at all times have access to all portions of the mixing plant, aggregate plant, storage yards, crushers and other facilities used for producing and processing the materials of construction.

2 The Engineer shall have authority to instruct sampling and testing of any material supplied to the site from any source whatsoever in order to establish their compliance and to accept or reject as he deems necessary. Samples shall also be taken from completed work to determine compliance. The frequency of all sampling and testing shall be as designated.

3 The Contractor shall arrange for obtaining specimens of materials, asphalt mixes and samples cut from the paving courses after compaction, including the provision of necessary equipment and plant for obtaining these specimens and samples. This work shall be performed in the presence of the Engineer. The Engineer shall take possession of the samples upon their removal from the roadway unless the Contractor is authorised otherwise

4 In particular, the Contractor shall provide a portable coring machine and bits for taking 150 mm diameter full depth cores of all bituminous paving courses. The coring machine shall be available to the Engineer upon request.

5 In addition to the foregoing, if requested by the Engineer, one set of three laboratory compacted specimens and one uncompacted coated sample for each mix type and mixer plant for each day’s production, shall be delivered to approved lab. no later than 12 hours after compaction of the specimens together with the mix type and project details.

6 Upon the first erection of the batching plant and at least once every three months thereafter, the plant shall be calibrated by a calibration service organisation approved by the concerned authority.

5.3 MARSHALL MIX DESIGN

5.3.1 General

1 The types of bituminous paving mixes shall be as designated on the project drawings or in the contract documents.

2 The Engineer shall approve the asphalt mix designs and materials submitted by the Contractor.

3 The contractor shall prepare the mix design with all necessary supporting documentation which shall include the results of the Contractor’s own laboratory procedures.

4 The Contractor shall carry out a trial batching and trial laying of the particular mix design.

5 The testing and sampling of the mix design will take place for both the laboratory verification and the trial batching and laying , and shall be approved by the Engineer.

6 Based on the results of the trial batching and laying the contractor may be required to make amendments to the mix design. Providing the mix design conforms to the specification the mix shall be approved by the Engineer.

7 The approved Job Mix Formula may be amended as a result of experience in the execution and performance of the permanent asphalt works. Such an amendment may be submitted by the Contractor for the Engineer's approval in which case the Contractor shall submit full details of the proposed amendment together with such data as is necessary to support his submittal. Amendment may also be directed by the Engineer.

8 Approval by the Engineer of the Job Mix Formula or amendments thereto shall in no way relieve the Contractor of his obligations under the Contract, and the Contractor shall be responsible for the soundness of the asphalt paving mixes and the satisfactory execution and performance of the asphalt paving courses.

5.3.2 Marshall Mix Design Criteria

1 The Asphalt Institute MS-2 “Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types” shall be used in designing the bituminous mixtures using Marshall design method.

2 The recommended compacted layer thicknesses are shown in Table 5.6.

Table 5.6
Recommended Compacted Layer Thicknesses

Base Course (Class A)	**Base Course (Class B)**	**Wearing Course(WC)**
80 to 100 mm	60 to 80 mm	45 to 55 mm

3 When tested according to ASTM C136, the combined mineral aggregate shall conform to Table 5.7 for asphalt concrete mixes.

Table 5.7
Combined Aggregate Gradation for Asphalt Concrete Marshall Design Mixes

ASTM Sieve Size	**Percentage Passing (By Weight)**		
	Base Course (Class A)	**Base Course (Class B)**	**Wearing Course**
37.5 mm	100	-	-
25.0 mm	80 - 100	100	100
19.0 mm	62 - 92	80 - 100	86-100
12.5 mm	-	63 - 85	69 - 87
9.5 mm	45 - 75	57 - 77	58 - 78
4.75 mm	30 - 55	40 - 60	40 - 60
2.36 mm	20 - 40	25 - 45	25 - 45
0.850 mm	15 - 30	15 - 30	15 - 30
0.425 mm	10 - 22-	10 - 22	10 - 22
0.180 mm	6 - 15	6 - 15	6 - 15
0.075 mm	2 - 8	2 - 8	2 - 8

4 The "Laboratory Designed Mixture" for all types of bituminous coated courses shall comply with the requirements given in Table 5.8. Note that any deviation from these requirements shall be approved by the Engineer.

Table 5.8
Design Criteria for Marshall Design Mixes

Parameter	**Base Course (Class A)**	**Base Course (Class B)**	**Wearing Course**
Aggregate Properties	Tables 5.1 and 5.2		
Aggregate Grading	Table 5.7		
Number of Compaction blows at each end of specimen (see paragraph 5)	75	75	75

Binder Content (% of total mix) inclusive of tolerances	3.2 – 4.4	3.4 – 4.4	3.4 – 4.4
Stability minimum (kN)	9.5 min.	9.5 min.	11.5 min.
Flow (mm)	2 to 4	2 to 4	2 to 4
Marshall Quotient (Stability/Flow) (kN/mm)	4.75 min.	4.75 min.	4.75 min.
Voids in Mix (Air Voids) (%)	4 to 8	4.5 to 8	5 to 8
Voids in Mineral Aggregate VMA (%)	Table No.5.9		
Voids Filled with Asphalt VFA (%)	50 to 70	50 to 75	50 to 75
Voids in Marshall Specimen at 400 Blows per face at optimum binder content (%)	3.2 min.	3.4 min.	4.0 min.
Retained Stability (%)	75 min.	75 min.	75 min.
(Filler/Binder) Ratio	0.8 to 1.5	0.8 to 1.5	0.75 to 1.35

Note: Relevant ASTM standards shall be used for testing.

5 Base Course (Class B) and Wearing Course samples shall be prepared and tested using Marshall apparatus in accordance with ASTM D6926 and ASTM D6927, respectively, while Base Course (Class A) samples shall be prepared and tested in accordance with ASTM D5581. However, based on the Engineer approval, samples having aggregate sizes larger than 25mm can be prepared and tested according to ASTM D6926 and ASTM D6927 by substituting all aggregate sizes over 25mm with an equal weight of aggregate sizes in the next lower grading sizes.

6 Upon the request of the Engineer, the Tensile Strength Ratio (TSR) in accordance with ASTM D6931 (ASTM D4867) shall be obtained for the mix for quality control purposes. The TSR acceptance limits shall be determined at mix design stage and approved by the Engineer.

Table 5.9
Minimum Percent Voids in Mineral Aggregate (VMA)

Nominal Maximum Particle Size[1, 2] (mm)	Minimum VMA, Percent
9.5	16.0
12.5	15.0
19.0	14.0
25.0	13.0
37.5	12.0

[1] Standard Specification for Wire Cloth Sieves for Testing Purposes, ASTM E11 (AASHTO M92).
[2] The nominal maximum particle size larger than the first sieve to retain more than 10 percent.
[3] Interpolate minimum voids in the mineral aggregate (VMA) for design air voids values between those listed.

7 After the Job Mix Formula has been established and approved, all mixes furnished shall conform thereto within the following tolerances:

Table 5.10

Job Mix Tolerances For Field Mixtures

Description	Base Course (Class A)	Base Course (Class B)	Wearing Courses
Aggregate retained on 4.75mm sieve or larger	± 5%	± 4%	± 4%
Aggregate passing 4.75mm sieve and retained on 850µm sieve	± 4%	± 3%	± 3%
Aggregate passing 850µm sieve and retained on 75µm sieve	± 3%	± 2%	± 2%
Aggregate passing 75µm sieve	± 1.5%	± 1.0%	± 1.0%
Binder Content	± 0.3%	± 0.2%	± 0.2%

8 The 'Job Standard Mix Density' shall be obtained by making six standard Marshall specimens from samples of the approved 'Job Standard Mixture' determining the bulk specific gravity of each and comparing them with the mean value of the six. Any individual result which differs from the mean by more than 0.015 shall be rejected, and provided that not more than two results are so rejected the mean of the remaining result shall be designated the 'Job Standard Mixture Density'. The absolute density shall be considered as the theoretical specific gravity calculated in accordance with ASTM D2041.

5.3.3 Quality Control Testing

1 The Contractor shall submit a testing plan to the Engineer for approval that demonstrates how he shall prove compliance with the requirements for compaction, mix composition, level, evenness and all other requirements of Section 6. Each lot shall be approved by the Engineer before placing any subsequent asphalt concrete course. In cases where the asphalt course is laid in more than one layer, each layer shall be tested and approved before placing the subsequent asphalt concrete layer.

2 In addition to the following requirements, upon the request of the Engineer; one set of three laboratory-compacted specimens and one uncompacted coated sample for each mix type and mixer plant for each day's production shall be delivered to the approved lab.no later than 12 h after compaction of the specimens. Details of compaction date, time and temperature of mix shall be provided with the specimens together with mix type and project details.

3 The Contractor shall cut samples from each completed asphalt course during the progress of the work and before final acceptance as directed by the Engineer. The Engineer shall determine the location of the samples.

4 When testing for compaction at joints the edge of the core shall not be more than 50 mm or less than 25 mm from the joint.

5 Compacted samples shall be taken by coring in accordance with ASTM D5361, for testing by an approved accredited laboratory. The core diameter shall be 150 mm. where the Contractor fails to provide cores as required by the Engineer, the Engineer may arrange for the taking of cores on behalf of the Contractor at his cost. Samples shall be taken of the asphalt mix for the full depth of the course. A sample shall comprise a pair of adjacent cores and the average density of these shall be the density of the sample.

6 Whenever deficiencies are noted in loose mix samples or core samples, the Engineer may direct the taking of additional cores at the Contractor's expense in order to define the area of pavement involved.

7 Hot asphalt mix of the same type shall be placed and compacted in holes left by sampling. The mixture shall be compacted to the percentage compaction required for the layer using a vibrating hammer.

8 Quality control testing of the asphalt mixtures during construction shall follow the frequencies shown in Table 5.12 for Marshall Mixtures

9 Base Course (Class B) and Wearing Course samples shall be prepared and tested using Marshall apparatus in accordance with ASTM D6926 and ASTM D6927, respectively, while Base Course (Class A) samples shall be prepared and tested in accordance with ASTM D5581. However, based on the Engineer approval, samples having aggregate sizes larger than 25mm can be prepared and tested according to ASTM D6926 and ASTM D6927 by substituting all aggregate sizes over 25mm with an equal weight of aggregate sizes in the next lower grading sizes.

10 Upon the request of the Engineer, the Tensile Strength Ratio (TSR) in accordance with ASTM D6931 shall be tested for quality control purposes. The TSR acceptance limits shall be based on the mix design obtained limits approved by the Engineer.

11 If it appears from the analysis of samples of loose mix or cores that the asphalt content or aggregate gradation are beyond the permissible tolerances specified for the Job Mix Formula (established for each respective asphalt course mix) and that, such variation affects the characteristics of the asphalt mix conformity to the designated requirements is concerned, this shall be considered a major defect in the work. The portion of the asphalt course represented by these samples shall be rejected.

12 The density of the compacted mixes shall be related to the daily Marshall density determined by making minimum four Marshall specimens from samples collected from behind the paver. The density of each sample shall be determined and compared with the mean value. Any individual result, which varies from the mean by more than 0.015gm/cm^3 shall be rejected. The daily Marshall density shall not differ from the Job Mix Design Density by more than 1.0%.

13 The field density, as determined from each core sample and related to the daily Marshall Density, obtained as shown above, shall be as follows:

Table 5.11

Layer	**Relative Density (%)**

Base Course	97 – 101.8
Wearing Course	98 – 101.8

14 The finished road surface shall be inspected visually techniques and if directed by the Engineer the structural ability of the pavement in terms of layer modulus shall be assessed by using the Falling Weight Deflectometer (FWD) and Light weight Deflectometer (LWD).

15 For safety purposes the pavement surface friction shall be measured by the pendulum portable tester or locked wheel tester in accordance with ASTM E303.

Table 5.12
Quality Control Testing of the Marshall Mixtures

<table>
<tr><th>Item / Parameter</th><th>Standard</th><th>Specification Limits</th><th>Minimum Frequency</th></tr>
<tr><td>Aggregate conformance</td><td colspan="3">Sections 5.2.1, 5.2.2 and 5.2.3</td></tr>
<tr><td>Mineral Filler conformance</td><td colspan="2">Section 5.2.5</td><td>Every 300t</td></tr>
<tr><td>Prime Coat conformance</td><td colspan="3">Section 5.2.7</td></tr>
<tr><td>Tack Coat conformance</td><td colspan="3">Section 5.2.8</td></tr>
<tr><td>Asphalt Binder conformance</td><td colspan="3">Section 5.2.6</td></tr>
<tr><td>Rate of application for Prime Coat</td><td>ASTM D2995</td><td>0.45 – 0.75 kg/m^2 at 60 – 85 °C</td><td rowspan="2">- 1 per 250 m^2
- 1 every 75m per lane</td></tr>
<tr><td>Rate of application for Tack Coat</td><td>ASTM D2995</td><td>0.15 – 0.38 kg/m^2 at 10 – 60 °C</td></tr>
<tr><td>Sampling of bituminous mixtures</td><td>ASTM D979</td><td>-</td><td>Test based</td></tr>
<tr><td>Temperature of bituminous mixture (Unmodified Binders)</td><td rowspan="2">EN 12697 Part 13</td><td>• 175 °C max. mixing temperature
• 135 °C min. at paver
• 120 °C min. during rolling</td><td rowspan="2">Each truck</td></tr>
<tr><td>Temperature of bituminous mixture1 (Modified Binders)</td><td>• 175 °C max. mixing temperature
• JMF compaction temperature +15 °C min. at paver
• JMF compaction temperature min. during rolling</td></tr>
<tr><td>Daily Bulk density (See paragraph 12)</td><td>ASTM D2726[2]
ASTM D1188[3]</td><td>±1.0% of Job Standard Density</td><td>Daily</td></tr>
<tr><td>Gradation of extracted aggregates</td><td>ASTM D5444
ASTM C117</td><td>Table 5.7, Job Mix gradation and Table 5.10 tolerances</td><td rowspan="5">- Each source
- Visible change in material
- 1 test per 300t per layer for Base Course
- 1 test per 150t per layer for Wearing Course</td></tr>
<tr><td>Binder content</td><td>ASTM D2172
ASTM D6307</td><td>Job Mix value with Table 5.10 tolerances</td></tr>
<tr><td>Marshall Stability, Flow and Stability/Flow Ratio</td><td>ASTM D6927
ASTM D5581[4]</td><td>Table 5.8</td></tr>
<tr><td>Voids in mineral aggregate (VMA)</td><td rowspan="2">ASTM C127
ASTM C128
ASTM D2726[2]
ASTM D1188[3]</td><td>Table 5.9</td></tr>
<tr><td>Voids filled with asphalt (VFA)</td><td>Table 5.8</td></tr>
</table>

Item / Parameter	Standard	Specification Limits	Minimum Frequency
Voids in Mix (Air Voids) (%)	ASTM D2041 ASTM D2726[2] ASTM D1188[3]		
Voids in Marshall Specimen at 400 Blows per face at optimum binder content (%)			
(Filler/Binder) Ratio	ASTM D2172 ASTM D6307 ASTM C136		
In-place air voids	ASTM D2041 ASTM D2726[2] ASTM D1188[3]	5 – 8%	- 1 test per 600t per layer for Base Course - 1 test per 300t per layer for Wearing Course
Retained Stability (%) (Paragraph 16)	ASTM D6927 ASTM D5581[4]	75 min.	1 test per 3000t per layer
Rut Depth using Hamburg Wheel Tracker Test at 60C, wet 10,000 passes.	AASHTO T324 (mm)	12.5 max.	Each source - Visible change in material - 1 test per 10,000t per layer for Base Course 1 test per 5,000t per layer for Wearing Course
Field density (nuclear gauge)[5]	ASTM D2950	Table 5.11	At 50m intervals in alternate wheel tracks
Field density (2 cores)[5]	ASTM D5361 ASTM D2726[2] ASTM D1188[3]	Table 5.11	- 1 test per 200t per layer for Base Course - 1 test per 100t per layer for Wearing Course
Thickness	ASTM D5361 ASTM D3549	Section 5.11.1	
Evenness of surface	Section 5.11.2 & 5.11.3		

[1]Polymer manufacturer recommendation to be considered
[2]If water absorption ≤ 2%
[3]If water absorption > 2%
[4]For samples containing more than 25mm size aggregates
[5]For acceptance of in-situ compaction

16 The Retained Stability is the percentage of the average stability of 3 samples conditioned for 24 hours at 60 ± 1°C water bath and the average stability of 3 samples conditioned for 4 hours in 60 ± 1°C air bath. These two sets of samples shall be prepared at the optimum binder content by applying 75 blows and kept at ambient temperature for 17 – 20 hours and shall have similar average densities.

17 Each day the produced mixes shall be tested for checking their compliance with the approved Job Standard Mix criteria. When unsatisfactory results or changed conditions make it necessary, a new job-standard following approval of new mix design shall be established.

5.4 DENSE BITUMEN MACADAM

1 The mix properties for Dense Bitumen Macadam are listed in Table 5.13.

Table 5.13
Properties of Mix for Dense Bitumen Macadam

Parameter	Specification Limits	
	Base Course	**Wearing Course**
Number of Compaction blows at each end of specimen	75	75
Binder Content (% of total mix) inclusive of tolerances	3.2 – 4.0	3.5 – 4.1
Stability minimum (kN)	7.5	10.0
Flow (mm)	2 - 4	2 – 4
Marshall Quotient (Stability/Flow) (kN/mm), min	3.7	4.9
Voids in Mix (Air Voids) (%)	7 - 11	6 – 9
Voids in Mineral Aggregate VMA (%)	14 - 20	14 - 20
Voids Filled with Asphalt VFA (%)	47 - 60	48 - 60
Retained stability	75 min.	75 min.

2 When tested according to ASTM C136, the combined mineral aggregate shall conform to Tables 5.14, 5.15 and 5.16.

Table 5.14
Aggregate Gradation for Dense Bitumen Macadam Road Base (Unbound)

B.S Sieve (mm)	Aggregate, Crushed Rock or Gravel Percentage by mass passing
50.0 mm	100
37.5 mm	95 - 100
28.0 mm	70 - 94
14.0 mm	56 - 76
6.3 mm	44 - 60
3.35 mm	32 - 46
0.300 mm	7 - 21
0.075 mm	2 - 8

Table 5.15
Aggregate Gradation for Dense Bitumen Macadam Asphalt Base Course

B.S Sieve (mm)	Aggregate, Crushed Rock or Gravel Percentage by Mass Passing for Finished Thickness of Base Course		
	80 - 100 mm	**70 - 90 mm**	**50 - 70 mm**
50.0	100	-	-
37.5	95 - 100	100	-
28.0	70 - 94	95 - 100	100
20.0	-	71 - 95	95 - 100
14.0	56 - 76	58 - 82	65 - 85
10.0	-	-	52 - 72
6.3	44 - 60	44 - 60	39 - 55

B.S Sieve (mm)	Aggregate, Crushed Rock or Gravel Percentage by Mass Passing for Finished Thickness of Base Course		
	80 - 100 mm	70 - 90 mm	50 - 70 mm
3.35	32 - 46	32 - 46	32 - 46
0.300	7 - 21	7 - 21	7 - 21
0.075	2 - 8	2 - 8	2 - 8

Table 5.16
Aggregate Gradation for Dense Bitumen Macadam Asphalt Wearing Course

B.S Sieve (mm)	Aggregate, Crushed Rock or Gravel Percentage by Mass Passing for Finished Thickness of Wearing Course		
	50 - 60 mm	40 - 50 mm	30 - 40 mm
28.0	100	-	-
20.0	95 - 100	100	-
14.0	70 - 90	95 - 100	100
10.0	55 - 75	70 - 90	95 - 100
6.3	40 - 60	45 - 65	55 - 75
3.35	25 - 40	30 - 45	30 - 45
1.18	15 - 30	15 - 30	15 - 30
0.075	2 - 6	2 - 6	2 - 6

5.5 SUPERPAVE MIX DESIGN

1 Based on the Engineer approval, the Superpave Mix Design Method can be used to design the asphalt mixtures for Wearing Course and Base Course layers. The design of the Superpave asphalt mixtures shall follow the method outlined in AASHTO R35 and SP-2 “Asphalt Institute Superpave Mix Design Method”.

2 The contractor shall prepare the mix design with all necessary supporting documentation which shall include materials production and handling specifications, plant quality procedures, construction quality control and quality assurance procedures, quality control tests, mix acceptance criteria and performance evaluation testing program. All documentations shall be submitted to the Engineer for review and approval.

3 Based on the Engineer approval, the PG76-10 binder can be used in asphalt mixes. This binder type shall be a polymer-modified binder (PMB) meeting AASHTO M320 and ASTM D6373 specifications and the criteria listed in Table 5.5.

4 Based on the Engineer approval, when bitumen grades PG76-10 H, V or E are specified for heavy, very heavy, and extra heavy loading, the bitumen shall meet the requirements of AASHTO M332 and will be required to indicate elastic response in percent recovery when tested in accordance with AASHTO T350.

5 Based on the Engineer approval, the guidelines shown in the Appendix can be used for the mix design. Note that software (ePAVE3) shall be validated prior use.

6 The recent editions of the references shown in the Appendix are recommended to be used for preparation of mix design and quality control schemes.

7 Table 5.17 can be used as a guide for sampling and testing frequency for quality control of Superpave mixtures.

8 Performance tests shown in Table 5.18 can be used to evaluate performance of Superpave asphalt concrete mixtures.

9 Before producing bituminous concrete mixtures, the Contractor shall submit in writing to the Engineer for approval, detailed information for each mix which he proposes to furnish. The information shall include, but not be limited to the following:

(a) Copy of mix certificate approval and the mix design report.

(b) The source(s) of the aggregate for each mix as well as the pertinent test data and a written certification that the aggregates conform to all of the quality requirements.

(c) Pertinent test data on the type and properties of the aggregates, asphalt binder, modified asphalt binder, mineral filler, and chemical admixtures/asphalt modifiers to be furnished.

(d) The type and location of plant to be used for mixing each mix.

(e) Any other support data and information special to the project (e.g. technical data sheets of a polymer in case it was used).

Table 5.17
Sampling and Testing Frequency of Superpave Field Mixtures

Item / Parameter	Standard	Specification	Minimum Frequency
Aggregate Conformance	Sections 5.2.1, 5.2.2, 5.2.3 and Table 6 - Appendix		
Mineral Filler conformance	Section 5.2.5		Every 300t
Prime Coat conformance	Section 5.2.7		
Tack Coat conformance	Section 5.2.8		
Asphalt Binder conformance	Section 5.2.6		
Rate of application for Prime Coat	ASTM D2995	0.45 – 0.75 kg/m² at 60 – 85 °C	- 1 per 250 m² - 1 every 75m per lane
Rate of application for Tack Coat	ASTM D2995	0.15 – 0.38 kg/m² at 10 – 60 °C	
Sampling of bituminous mixtures	ASTM D979	-	Test based
Temperature of bituminous mixture	EN 12697 Part 13	• ±10 °C of JMF temperature in truck • Min. JMF compaction temperature +20 °C at paver • Min. JMF compaction temperature prior rolling (sec. 1.5.4 – Appendix)	Each truck
Binder content (%)	ASTM D2172 ASTM D6307	JMF value ±0.40	- Each source; - Visible change in material - 1 test per 500t per layer for Base Course - 1 test per 250t per layer for Wearing Course
Gradation of extracted aggregates	ASTM D5444	Table 9 Appendix	
Effective Specific Gravity of Aggregates (G_{se})	ASTM D6857 ASTM D2041	$G_{sb} < G_{se} < G_{sa}$	
Voids in mineral aggregate (VMA)	AASHTO T312 ASTM D6857 or ASTM D2041 (Eq. 2) ASTM D2726	±1.5	
Voids in Mix (V_a) (Min 2 Gyratory specimens at N_{des})		±1.3	
Density (% of G_{mm}) at N_{max} (Min 1 Gyratory specimens at N_{max})		Table 5 Appendix	

Item / Parameter	Standard	Specification	Minimum Frequency
Dust to binder ratio ($P_{0.075}$ / P_{be})	ASTM D6857 / ASTM D2041 ASTM D2172 / ASTM D6307 ASTM D5444	Table 5 Appendix	
Indirect tensile strength (IDT)	ASTM D6931	IDT of JMF min.	
Moisture Sensitivity (Retained IDT)	ASTM D6931 Sec. 1.5.8 Appendix	Sec. 1.5.8 Appendix	Weekly
Dynamic Modulus at 10 Hz, 45 °C, 0kPa confinement	AASHTO PP60 AASHTO TP79 Procedures A, B AASHTO PP61	Min. 1920 MPa	Every 10,000t
Flow Number (F_n) at 54.4 °C, 600kPa deviatory stress, and 0kPa confinement		Min. 740	
In-place air voids	ASTM D5361 ASTM D2726	6 – 8%	- 1 test per 200t per layer for Base Course; - 1 test per 100t per layer for Wearing Course
Thickness	ASTM D5361 ASTM D3549	Section 5.11.1	
Field density (nuclear gauge) (%G_{mm})	ASTM D2950	92 – 94%	At 50m intervals in alternate wheel tracks
Evenness of surface	Section 5.11.2 & 5.11.3		

5.6 PERFORMANCE EVALUATION OF ASPHALT CONCRETE

1 Based on the Engineer request, the asphalt mixture performance properties can be determined.

2 The performance properties of asphalt mixtures shall be measured for every asphalt concrete layer at least on the following frequencies:

(a) Prior asphalt laying on a laboratory prepared sample at the asphalt binder content specified in the JMF.

(b) Asphalt mix sampled from behind the paver every 10000t of mix.

3 The purpose of the performance testing is to allow for pavement performance evaluation and verification of pavement structural design through the AASHTO Mechanistic-Empirical Pavement Design Guide. Performance models, references, test conditions are shown in table 5.18 below:

Table 5.18

Performance Models Criteria

Performance Model	Test Reference	Test Conditions	Applications / Use
Dynamic Modulus Master Curve	AASHTO PP60, TP79 Procedure A, & PP61	100X150mm cylindrical sample under uniaxial stress, zero confining pressure and sinusoidal deviator stress	The E* is used in mechanistic analysis to evaluate the structural responses of the asphalt concrete layers

Performance Model	Test Reference	Test Conditions	Applications / Use
Rutting Model	AASHTO PP60 & TP79 Procedure B	100X150mm cylindrical sample under triaxial stress	To evaluate the rutting characteristics of the asphalt mixture in the form of a rutting model or Flow Number (FN)
Fatigue Model	AASHTO T321	64x50x380mm beam specimen is subjected to a 4-point bending with free rotation and horizontal translation at all load and reaction points	The initial flexural stiffness is measured at the 50th load cycle. Fatigue life or failure shall be defined as the number of cycles corresponding to 50% reduction in the initial stiffness.
Aging Model	ASTM D7175	Conduct asphalt binder A-VTS test in the Rheometer (DSR) to measure G* and δ in accordance with ASTM D7175 at multiple temperatures	Viscosity-temperature relationship (A-VTS) of the asphalt binder is determined in order to assess the impact of binder aging on the E* property of the asphalt mix at various stages of the pavement life

4 Modelling methods adopted by Asphalt Institute and Shell or equivalent shall be used. The contractor shall submit a proposal includes performance modelling testing and interpretation procedures to the Engineer for approval.

5.7 DELIVERY, SPREADING AND FINISHING

5.7.1 Delivery of Mixes

1 Sufficient plant capacity, haul vehicles and storage shall be provided so that adequate supplies of mixture are delivered to site to ensure that continuous paving can be achieved.

2 The dispatching of the hauling vehicles to the job site shall be so scheduled that all material delivered may be placed in daylight, unless the Engineer has approved the use of artificial light. Delivery of material shall be at a uniform rate and in an amount well within the capacity of the paving and compacting equipment.

3 All precautions shall be taken to protect the mix from the weather during transit and while waiting to discharge.

4 Hauling vehicles shall not be permitted to carry out tight turns on the laying surface.

5 The mixture at delivery to the paver shall be within 10 °C of the Job Mix Formula temperature and above an absolute minimum temperature of 135 °C. Material which has fallen below the minimum temperature of 135 °C before discharge shall be rejected and immediately removed from site. Delivery temperature shall not exceed the maximum temperature specified for mixing at the plant

6 Should a significant proportion of the mixture delivered to the paver fail to meet this requirement, or should cold lumps be found in the mixture, the Engineer shall order that paving operations be suspended until measures are taken, to the approval of the Engineer, to ensure compliance.

5.7.2 Spreading and Finishing

1 The Contractor shall prepare a paving plan and obtain approval of the Engineer to ensure adequate equipment and paving sequences.

2 Based on the approved paving plan and prior to the commencement of delivery of the mix the Contractor shall erect and maintain an approved reference guide wire for controlling the levels of the laid mix. The reference guide wire shall be supported at intervals of not more than 5m.

3 The mix shall be laid upon an approved surface and only when weather conditions are suitable and as designated. Upon arrival at the point of use, the asphalt mix shall be spread and struck off to the grade, elevation and cross-section shape intended, either over the entire width or over such partial width as may be required. If the material does not conform to the requirements, it shall not be used and shall be discarded.

4 The laid material shall be compacted as soon as rolling can be effected without causing undue displacement and while the temperature does not fall below 120 °C for unmodified asphalt mixes. Materials still uncompacted and below this temperature shall be rejected.

5 The compaction temperature for the laid polymer-modified asphalt binder mixes shall be selected based on one of the following:

(a) As specified in the JMF.

(b) As established from the trial section.

6 The Contractor shall supply accurate calibrated thermometers suitable for measuring the inner and surface temperature of the material. The material temperature shall be checked immediately before rolling and at least every 30 minutes thereafter during forward progress. A record of these temperatures shall be passed to the Engineer at the end of each day's work.

7 While paving is in progress, the output of the batching plant shall be exclusively reserved for the operations and no mixture shall be supplied to other sites or projects.

8 If during laying, the paver is repeatedly delayed because of lack of mixture or if the paver stands at one location for more than thirty minutes (for any reason), a transverse joint shall be constructed. Paving shall not recommence until the Engineer is satisfied that paving will proceed uninterrupted and until at least four loaded vehicles have arrived at the paving site.

9 The asphalt course shall be constructed to proposed levels and shall be homogeneous, providing after compaction an even surface free from undulations, rises or depressions and within the tolerances stipulated.

10 In no case shall construction of a new asphalt concrete course begin until the previously laid course has been tested and approved.

11 When the same asphalt course is to be laid in more than one layer the second layer shall be placed as soon as practicable after the first layer has been finished, rolled and cooled, and the Engineer may at his discretion request cleaning of the first layer and the application of a tack coat thereon if he so deems necessary.

12 Transverse joints in succeeding layers shall be offset at least 2 m. Longitudinal joints shall be offset at least 300 mm.

13 The use of motor grader or hand spreading of the asphalt mix shall not be permitted except in places where it is impractical to use pavers and shall be only with the specific permission of the Engineer. The asphalt mix shall comply with all conditions regarding trueness of level, thickness, and homogeneity of the mix.

14 Automatic electronic screed controls shall be required on all pavers and shall be used with a 9 m long articulated averaging beam or grade wire control as approved by the Engineer.

5.7.3 Compaction of Mixes

1 At least three rollers shall be required at all times, one self-propelled pneumatic-tire and two self-propelled steel-wheeled. As many additional rollers shall be used by the Contractor as necessary to provide specified asphalt course density and surface characteristics in an orderly, efficient and continuous manner.

2 Before beginning construction of the permanent works, unless otherwise agreed with the Engineer, the Contractor shall carry out compaction trials for each type and thickness of asphalt course to establish an approved compaction procedure which shall then be used as a minimum requirement for the compaction of the permanent works unless otherwise directed or agreed by the Engineer.

3 The compaction trials shall involve all procedures specified for the permanent works including testing as specified for the asphalt course under consideration and any equipment, processes or procedures proposed by the Contractor which are not designated. Construction of the permanent works shall not commence until a compaction procedure has been approved in writing by the Engineer. Such approval shall in no way relieve the Contractor of his responsibilities and obligations stipulated in the Contract.

4 Immediately after the asphalt mix has been spread and struck off, the surface shall be checked and any irregularities adjusted and then compacted thoroughly and uniformly by rolling.

5 To prevent adhesion of the mix to steel-wheeled rollers, the wheels shall be kept properly moistened but excess water shall not be permitted.

6 After the longitudinal joints and edges have been compacted, rolling shall start longitudinally at the sides of the road and shall gradually progress towards the centre. On super elevated sections, rolling shall begin on the low side and progress to the high side, overlapping on successive trips by at least one-half the width of tandem rollers and uniformly lapping each proceeding track. The rollers shall move at a slow but uniform speed with the drive wheels nearest the paver. The speed shall not exceed 4-5 km/h for steel-wheeled rollers or 8 km/h for Pneumatic-tire rollers. The operating speed shall be approved by the Engineer.

7 The line of rolling shall not be changed suddenly or the direction of rolling reversed suddenly. If rolling causes displacement of the material, the affected areas shall be loosened at once with hand tools and restored to the original grade of the loose material before being rerolled. Heavy equipment or rollers shall not be permitted to stand on the finished surface before it has been compacted and has thoroughly cooled.

8 When paving in a single width, the first lane placed shall be rolled in the following order:

(a) Transverse joints.

(b) Longitudinal joints.

(c) Outside edge.

(d) Initial or breakdown rolling, beginning on the low side and progressing towards the high side.

(e) Intermediate rolling.

(f) Final rolling.

1 When paving in echelon, 50 mm to 100 mm of the edge which the second paver is following shall be left unrolled. When paving in echelon the edges between the first and the second

paver shall not be exposed more than 15 minutes nor 50m by distance without being rolled. Particular attention shall be given to the construction of the transverse and longitudinal joints in all courses.

5.7.4 Transverse Joints

1 Transverse joints shall be carefully constructed and thoroughly compacted to provide a smooth riding surface. Joints shall be checked with a straightedge to assure smoothness and true alignment. Joints shall be formed with a bulkhead, such as a board, to provide a straight line and vertical face.

2 If the joint has been distorted by traffic or by other means, it shall be trimmed to line and the face shall be painted with thin coating of emulsified asphalt before the fresh material is placed against it. To obtain thorough compaction of these joints the material placed against the joint shall be tightly pushed against the vertical face with a steel-wheeled roller.

3 The roller shall be placed on the previously compacted material transversely so that not more than 150 mm of the rear rolling wheel rides on the edge of the joint. The roller shall be operated to pinch and press the mix into place at the transverse joint. The roller shall continue to roll along this line, shifting its position gradually across the joint, in 150 to 200 mm increments, until the joint has been rolled with the entire width of the roller wheel. Rolling shall be continued until a thoroughly compacted, neat joint is obtained.

5.7.5 Longitudinal Joints

1 Longitudinal joints shall be rolled directly behind the paving operations. The first lane placed shall be true to line and grade and have a vertical face. The material being placed in the abutting lane shall then be tightly pushed against the face of the previously placed lane. Rolling shall be done with a steel-wheeled roller.

2 The roller shall be shifted over onto the previously placed lane so that not more than 150 mm of the roller wheel rides on the edges of the newly laid lane. The rollers shall then be operated to pinch and press the fine material gradually across the joint. Rolling shall be continued until a thoroughly compacted, neat joint is obtained.

3 When the abutting lane is not placed in the same day, or the joint is distorted during the day's work by traffic or by other means, the edge of the lane shall be carefully trimmed to line, cleaned and painted with a thin coating of emulsified asphalt before the adjacent lane is placed.

4 The longitudinal joints in the surface course shall be along the same line as the traffic lane markers.

5.7.6 Paving Edges

1 The edges of the asphalt course shall be rolled concurrently with or immediately after rolling the longitudinal joint.

2 Care shall be exercised in consolidating the course along the entire length of the edges. Before it is compacted, the material along the unsupported edges shall be slightly elevated with hand tools. This will permit the full weight of the roller wheel to bear on the material to the extreme edges of the mat.

5.7.7 Breakdown Rolling

1 Breakdown rolling shall immediately follow the rolling of the longitudinal joints and edges. Rollers shall be operated as close to the paver as possible to obtain adequate density without causing undue displacement. In no case shall the mix temperature be allowed to drop below 120 °C before breakdown rolling.

2 If the breakdown roller is steel wheeled, it shall be operated with the drive wheel nearest the finishing machine. Pneumatic-tire rollers may be used as breakdown rollers.

5.7.8 Intermediate Rolling

1 Pneumatic-tire rollers or Steel wheeled rollers shall be used for the intermediate rolling.

2 The intermediate rolling shall follow the breakdown rolling as closely as possible and while the paving mix is still hot. Rollers shall be used continuously after the initial rolling until all of the mix placed has been thoroughly compacted. Turning of rollers on the hot paving mix which causes undue displacement shall not be permitted.

5.7.9 Finish Rolling

1 The finish rolling shall be performed with three-axle tandem rollers unless otherwise permitted by the Engineer. Finish rolling shall be accomplished while the material is still warm enough for the removal of roller marks.

2 All rolling operations shall be conducted in close sequence.

3 In places inaccessible for the operation of standard rollers as specified, compaction shall be performed by manual or mechanical tampers of such design as to give the desired density.

4 After final rolling, the smoothness, levels, crossfalls, density and thickness shall be checked and any irregularity of the surface exceeding the specified limits and any areas defective in texture, density or composition shall be corrected as directed by the Engineer, including removal and replacement as directed by the Engineer.

5.7.10 Protection of Laid Courses

1 Sections of the newly finished work shall be protected from traffic of any kind until the mix has been properly compacted and cooled. In no case shall traffic be permitted less than 24 h after completion of the asphalt course unless a shorter period is authorised by the Engineer.

5.8 COLD PLANING

1 The cold planing plant shall be to the approval of the Engineer.

2 Cold planing plant shall have sufficient power, traction and stability to maintain the required depth of cut and slope. The control of the depth of cut and the slope shall be by an automatic system based on reference wires.

3 Cold planing shall be carried out to straight crossfalls to the designated thickness. Planing shall be to a tolerance of ± 5 mm of the designated amount. The average thickness of planing achieved shall be at least the thickness designated.

4 In areas where there is severe deformation of the existing pavement, it may be necessary to vary the depth of planing.

5 Existing kerbs, gullies, manholes and other features shall not be disturbed by the planing process. This may require the use of smaller plant or removal by hand tools.

6 Any joints at the edge of planed areas shall be cut vertically and straight using asphalt saws.

7 Cold planing shall be carried out in a longitudinal direction.

8 After planing the prepared surface shall be thoroughly brushed and suction swept by mechanical means to the satisfaction of the Engineer. The surface shall be free from gouges, ridges, continuous grooves and shall have a reasonably uniform finish.

9 Cold planing shall be performed so that at the end of a day's work the termination line does not present a hazard to traffic that may use the road.

10 Any cracks noted in the pavement shall be blown clean with compressed air. The Engineer will inspect the planed surface and may instruct that further work is carried out for treating cracks in the pavement.

5.9 PRIME COAT

5.9.1 General

1 The work shall consist of furnishing and applying liquid asphalt and blotter material, if required, to a previously prepared and approved subgrade or granular base/sub-base course as designated and to the full designated width.

2 Prime coat shall not be applied when the ambient temperature is less than 13 °C nor during rain, fog, dust storms or other unsuitable weather.

5.9.2 Equipment Required

1 The equipment used by the Contractor shall include a liquid asphalt distributor as described in clause 5.17.3.

2 If the surface is covered in wind-blown dust or fine aggregate then a power broom shall be provided. The power broom shall be self-propelled and equipped with a cylindrical, rotating nylon bristle brush of not less than 760 mm in diameter and not less than 1800 mm in length. The brush shall be capable of being angled to the right and left with adjustable ground pressure. Where necessary for the proper preparation of the surface, motor graders, rollers and water trucks shall also be provided.

5.9.3 Surface Preparation

1 Immediately before applying the prime coat, all loose dirt, earth and other objectionable material shall be removed from the surface with a power broom of approved design and/or a power blower as required, and any ruts, soft spots or unacceptable irregularities in the surface shall be repaired in accordance with the instructions of the Engineer. If the Engineer so requires, the surface shall be lightly bladed and rolled immediately before the application of the prime coat, in which case brooming or blowing may not be required.

2 Priming will not be permitted when there is free water present on the surface.

5.9.4 Application

1 After preparing the road surface as above, the prime coat shall be applied by means of the distributor at the temperature and rate shown in Table 5.12. Hand-spraying of restricted, inaccessible areas is permitted, subject to the approval of the Engineer.

2 The surface of structures, kerbstones and other appurtenances adjacent to areas being treated shall be protected in such a manner as to prevent their being spattered or marred.

3 The prime coat shall usually be applied to 1/3 or 1/2 of the road width at a time. When applied in two or more lanes, there shall be a slight overlap of asphalt material along adjoining edges of the lanes. It should be noted that no overlapping is allowed at the transverse joints and that thick paper shall be used at the joint to protect the previous application and the joining application shall begin on the paper. The paper used shall be removed and satisfactorily disposed of by the Contractor after use. Care shall be taken that the application of prime coat material at the junctions of spread is not in excess of the specified amount. Excess bituminous material shall be removed from the surface.

5.9.5 Maintenance and Traffic

1 Traffic shall not be permitted on the primed surface until the asphalt material has penetrated and dried and, in the judgement of the Engineer, will not be picked up under traffic. If it becomes necessary to permit traffic before that time, but in no case sooner than 48 hours after the application of the asphalt material, blotter material shall be applied as directed by the Engineer and traffic shall be permitted to use the lanes so treated.

2 Blotter material shall be spread from trucks operated backward so that the wheels will not travel in uncovered wet asphalt material. When applying blotter material to an asphalt treated lane that adjoins a lane that has not been treated, a strip at least 200 mm wide along the adjoining edge shall be left devoid of blotter material in order to permit an overlap of asphalt material.

3 The Contractor shall maintain the primed surface in good clean condition and before the application of the next course, any surface irregularities shall be corrected and all excessive blotter material, dirt or other objectionable materials shall be removed.

5.10 TACK COAT

5.10.1 General

1 This work shall consist of furnishing and applying diluted emulsified asphalt to a previously prepared Base or Wearing courses, to provide bond for a superimposed course to the full designated width.

2 Tack coat shall not be applied when the ambient temperature is less than 13°C nor during rain, fog, dust storms or other unsuitable weather.

5.10.2 Equipment Required

1 The equipment used by the Contractor shall include liquid asphalt distributor as well as a power broom and a power blower. Power broom shall be self-propelled and equipped with a cylindrical, rotating nylon bristle Brush of not less than 760 mm in diameter and not less than 1800 mm in length. The brush shall be capable of being angled to the right and left with adjustable ground pressure. In addition, the Contractor shall supply and use efficient and approved equipment for diluting the emulsified asphalt with water.

5.10.3 Surface Preparation

1 The full width of the surface to be treated shall be cleaned with a power broom or power blower to remove dust, dirt or other objectionable materials. All faulty or unsuitable patches, excess cracks or joint filler and all surplus bituminous material shall be corrected in accordance with the instructions of the Engineer. The surface shall be dry when treated.

5.10.4 Application

1 Immediately after cleaning the surface, the tack coat shall be applied by means of the distributor at the temperature and rate directed by the Engineer. Hand spraying of restricted, inaccessible areas is permitted, subject to the approval of the Engineer.

2 The diluted emulsion shall be applied at a rate shown in Table 5.12. The Contractor shall ensure that excessive application of tack coat is avoided.

3 The surface of structures, kerbstones and other fixed objects adjacent to areas being treated shall be protected in such a manner as to prevent their being spattered or marred.

5.10.5 Maintenance and Traffic

1 After application, the surface shall be allowed to dry until it is in a proper condition of tackiness to receive the superimposed course. Tack coat shall be applied only so far in advance of the superimposed course placement as is necessary to obtain this proper condition of tackiness.

2 Until the superimposed course is placed, the Contractor shall protect the tack coat from damage.

3 If the tack coat is unavoidably damaged by rain or dust, it shall be allowed to dry, shall be cleaned again by a power broom or power blower and, if required by the Engineer, a subsequent light application of tack applied to the surface. Where, in the opinion of the Engineer, a tack coat is not necessary between layers of freshly placed courses, he may give instructions in writing to omit the tack coat. Any cleaning required in these areas shall be carried out before the application of the next course.

5.11 THICKNESS AND LEVEL

5.11.1 Thickness

1 Cores shall be taken to determine the thickness of asphalt paving courses. As determined from each core, the thickness of a paving course shall not be less than that specified by more than 5 mm in the case of a single-layered construction. Furthermore, the thickness of the Wearing course shall not be less than that specified by more than 5 mm and the total thickness of all asphalt paving courses combined shall not be less than that specified by more than 10 mm.

2 In addition, the variations in the falls to cross sections of the road shall not vary from the required value by more than 0.3 %. Any asphalt paving course containing deviations or variations exceeding these tolerances shall be corrected or removed and replaced by the Contractor, in accordance with the instructions and to the satisfaction of the Engineer.

3 Where any individual course is marginally out of tolerance on the low side, the Engineer may allow adjustment in the succeeding course to correct the overall thickness of the pavement.

4 The tolerances herein specified shall not invalidate the tolerances set forth for the evenness of surface of the asphalt paving course.

5 As directed by the Engineer the laid thickness shall be checked by cutting test pits and/or using Ground Penetrating Radar (GPR) for the determination of the structural capacity of the pavement.

5.11.2 Transverse Evenness

1 The Engineer shall test the evenness of surface for each course of the various asphalt paving courses to determine compliance.

2 The Contractor shall put at the disposal of the Engineer a 3m long straight edge and a crown template of sturdy and approved design and enough labour to assist in the checking operations. The maximum allowable differences between the pavement surface and the straight edge shall be 3mm. Transverse measurements shall be carried out every 20m of road length for each lane.

3 Any layer containing deviations or variations exceeding the tolerances specified here shall be corrected or removed and replaced in accordance with the instructions of the Engineer and to his satisfaction.

5.11.3 Evenness and Rideability

1 Smoothness is a measure of the evenness and rideability of the pavement surface. It shall be measured on the driving surface of the completed pavement for all major roads before opening to the traffic.

2 Any section containing deviations or variations exceeding the criteria specified here or by the Engineer shall be corrected or removed and replaced in accordance with the instructions of the Engineer and to his satisfaction at the Contractor’s cost.

3 The minimum length of the rectification work undertaken shall be 100m.

4 All rectified segments shall be re-tested following the completion of rectification work at no additional cost to the client.

(a) Evenness

5 The evenness of the driving surface of road pavements shall be measured with a 3m rolling straight edge along any line or lines parallel to the center line of the pavement on sections of 300m selected by the Engineer, whether or not it is constructed in shorter lengths. Sections shorter than 300m forming part of a longer pavement shall be assessed using the number of irregularities for a 300m length prorated to the nearest whole number. Where the total length of pavement is less than 300m the measurements shall be taken in 75m lengths.

6 The number of deviations (from the bottom face of the straight edge) over the length of the section greater than or equal to 4mm shall be counted. None of the measured deviations shall exceed 6mm. The evenness of the driving surface of the tested section shall be within the relevant limits given in Table 5.19.

Table 5.19
Evenness of Driving Surface

Section Length (m)	Allowed number of deviations ≥4mm
300	20
75	9

(b) Rideability

7 For major roads the International Roughness Index (IRI) shall be used to monitor the roughness and condition of the pavement surface. The acceptable IRI for ride quality shall be decided by the Engineer.

8 The rideability of the driving surface of the completed pavement shall be measured in terms of the International Roughness Index (IRI) which shall be tested with a certified and calibrated Inertial Profiler meeting the requirements of ASTM E950–Class 1.

9 The testing method shall be in accordance with ASTM E950. The IRI shall be calculated according to ASTM E1926.

10 Calibration checks on the inertial profiler shall be conducted using test methods in accordance with the manufacturer’s recommendations, at the beginning of the day of operation and at any other time the operator may suspect changes of system performance since the last calibration.

11 Calibration checks on the inertial profiler and all other quality checks shall be submitted in a method statement to the Engineer for approval.

12 The selected measuring speed shall be the posted speed and within the range recommended by the manufacturer and shall remain nearly constant during testing, not to exceed +/-5 km/h of the selected speed.

13 The profiler system shall stabilize at the test speed prior to entering the test sections. This requires bringing the profiler vehicle to the desired test speed at least 100 m prior to the beginning of the test location. Any Features along the test section such as bridges, culverts, milepost or other pertinent information shall be identified. The test shall be conducted in the paving direction.

14 The start and end point of the test section shall be automatically identified by using a photo detector. The coordinates of the test section shall be identified by using a GPS.

15 Three runs of data collection (both wheel tracks in each lane) shall be conducted. The processing of the data for IRI shall include calculating the average IRI value of the three runs for the two wheel tracks. The processed data shall be reported on 25m and 400m sub-sections calculated using the Moving Average statistical method and applying a 250mm filtering.

5.12 PAVEMENT EVALUATION TECHNIQUES

1 Pavement evaluation tests shall be carried out for the completed pavement structure at any point of the road as directed by the Engineer to assess the serviceability condition of the pavement and verify compliance with specifications.

2 Pavement evaluation methods can be grouped into two main categories, destructive and non-destructive.

3 The Contractor shall allow and provide all necessary arrangements for the execution of all pavement evaluation test required by the Engineer.

4 As directed by the Engineer the structural ability of the pavement in terms of load-deflection response and layer modulus shall be assessed by using the Falling Weight Deflectometer (FWD).

5 The pavement surface friction shall be measured based on the Engineer request using the portable pendulum tester (ASTM E303), locked wheel tester (ASTM E274) or the sand patch method (ASTM E965).

5.13 PRODUCTION OF ASPHALT CONCRETE COURSES

5.13.1 Weather Limitations

1 Production and spreading of asphalt Concrete mix shall not be permitted when the ambient temperature is less than 8 °C, nor during rain, fog, dust-storms or other unsuitable weather.

5.13.2 Equipment Required

1 The equipment required for construction of the asphalt concrete courses shall include but not be limited to the equipment mentioned in Clauses 5.3 to 5.6 of this Part, together with such miscellaneous equipment and tools as required for the satisfactory preparation and performance of the work.

2 All equipment shall be checked, calibrated and approved by the Engineer before use. The equipment shall be satisfactorily maintained and shall be used in an approved manner.

3 Adequate equipment and labour shall be used so that there is continual production and distribution of the asphalt course being constructed.

5.13.3 Survey and Preparation

1 The area to be paved shall be true to line and grade and shall have a properly prepared surface before the start of paving operations.

2 When an asphalt concrete pavement course is to be placed on top of an existing pavement, the existing pavement surface shall be prepared as designated by the Engineer.

3 Priming or tacking of surfaces to be paved shall be carried out as designated.

4 The surface of kerbs, vertical faces of existing pavements and all structures in actual contact with asphalt mixes shall be painted with a thin and complete coating of tack coat as instructed by the Engineer to provide a closely bonded, watertight joint.

5 All openings or structures in the road for water, drainage and other specified utilities shall be constructed and their positions and levels determined before the start of paving operations.

5.13.4 Heating of Asphalt Binder

1 The 60/70 penetration grade bitumen shall be heated to a temperature of between 150 to 165 degrees centigrade.

2 Bitumen of other penetration grade shall be heated to yield viscosity's in the range of 150 to 300 centistokes (175 to 150 seconds Saybolt-Furol) when delivered to the mixer, as determined from the Temperature Viscosity Chart of the product used.

3 Penetration Graded Asphalt Binders shall not be used if foaming occurs or shall it be heated above 175 °C at any time.

4 Polymer-modified binder shall be heated to a temperature specified by the supplier.

5.13.5 Heating of Mineral Aggregate

1 When using 60/70 penetration grade asphalt binder the materials shall be thoroughly dried and heated so that their temperature is 165 to 180 degrees centigrade.

2 When using asphalt binder of other penetration grade the materials shall be thoroughly dried and heated so that their temperature is within ± 8 °C of the temperature needed to satisfy the viscosity requirements of the asphalt cement.

3 The moisture content of the heated and dried materials shall not exceed 1%.

4 The quantity of materials fed through the drier shall in all cases be held to an amount which can be thoroughly dried and heated within the limits specified.

5 The heated materials shall be screened into sizes such that they may be combined into a gradation meeting the requirements of the Job Mix Formula and the hot aggregate storage bins shall be such as to minimise segregation and loss of temperature of aggregate.

6 Hot bins shall be drawn and cleaned of material at the end of each day's operation.

5.13.6 Proportioning and Mixing

1 The heated ingredients together with the mineral filler and bitumen shall be combined in such a manner so as to produce a mixture which complies with the requirements of the Job Mix Formula. Plant settings, once established, shall not be changed without the approval of the Engineer.

2 Mineral filler, in a cool dry state, shall be proportioned into the mixer either with the aggregate or after the introduction of the bitumen to avoid loss of fines that may occur in dry mixing as a result of turbulence in the mixer.

3 In batch type plants a dry mixing period of not less than four seconds shall precede the addition of the bitumen to the mix. Excess wet mixing shall be avoided. Wet mixing shall continue as long as it is necessary to obtain a thoroughly blended mix but shall not exceed 75 seconds nor be less than 30 seconds.

4 Once approved, mixing times shall not be altered unless so ordered or further approved by the Engineer.

5.14 HAULING EQUIPMENT

1 Vehicles used for the transport of aggregates or bituminous mix shall have tight, clean and smooth insulated metal bodies and shall be free from dust, screenings, petroleum oil and volatile or other mineral spirits which may affect the material being hauled. The vehicle metal bed shall, if required, be sprayed with a minimum amount of soapy water or lime solution to prevent the bituminous mix from adhering to the bed. After spraying, the truck shall be raised and thoroughly drained and no excess solution shall be permitted. Use of diesel or other solvents to spray in the truck bed is prohibited.

2 Provision shall be made for covering truck loads with canvas or other suitable material of such size that the bituminous mix is fully covered.

3 Any truck causing excessive segregation of material by its spring suspension or other contributing factors, or that shows oil leaks in detrimental amounts, or that causes undue delays, shall, upon the instruction of the Engineer, be removed from the work until such faults are corrected.

4 End dump trucks shall be equipped with chains on the tail gates for control when dumping the mix into the paving machine. Hauling trucks shall not be routed over wet or muddy access ways such that tires accumulate dirt that is deposited on the laying surface.

5 The Contractor shall provide an adequate number of trucks of such size, speed and condition to ensure orderly and continuous progress of the work all to the approval of the Engineer.

5.15 OTHER EQUIPMENT

5.15.1 Spreading and Finishing Equipment

1 The asphalt mixture shall be fed to the paver by end tipping of the truck or by means of a windrow elevator. The equipment for spreading and finishing the asphalt mixtures shall be of an approved mechanical, self-powered electronic controlled floating screed type, capable of spreading and finishing the mixture true to line, grade and required crown.

2 The pavers shall be self-propelled and equipped with hoppers and distributing screws of the reversing type to place the mixture uniformly in front of adjustable electronic controlled screeds. The pavers shall be so designed to allow a minimum paving width of 2 m, although paving in widths of less than 3 m will require the approval of the Engineer.

3 Pavers shall be equipped with such provisions and attachments to suit paving widths specified for road widening as well to as to suit paving on sloped sections. They shall be equipped with fast and efficient steering devices and shall have reverse as well as forward travelling speeds. The operational speed of the pavers shall be adjustable from 3 to 6 m/min in accordance with the instructions of the Engineer.

4 The pavers shall employ mechanical devices as equalising runners, straight edge runners, evener arms or other compensating devices to maintain trueness of grade and to confine the edges of the pavement to true lines without the use of stationary side forms. The equipment shall include blending or joint levelling devices for smoothing and adjusting longitudinal joints between lanes. The assembly shall be designed and operated in such a manner that it will place the material at the required compacted thickness.

5 Electronic screeds shall include automatic feed controls to maintain a constant level of material along the full length of the screed, automatic grade control and automatic slope control. Unless waived by the Engineer, on projects with smoothness (IRI) requirements, the paver shall carry minimum 9.0m long average beam equipped with an ultrasonic sensors capable of sensing a pavement section at several spatially separated spots. The automatic slope control shall be equipped with a proportioning manual override to enable smooth transition of changing slope rate. Automatic screed controls shall be approved by the Engineer before use.

6 Screeds shall be provided with devices for heating the screeds to the temperature required for the laying of the mixture without pulling or marring. Pavers shall also be provided with the standard attachable screed extensions. All screeds shall be of the vibrating type that permits material to be tamped into position.

7 The term "screed" includes any cutting, crowning or other physical action that is effective in producing a finished surface of the evenness and texture specified, without tearing, shoving, or gouging.

8 If, during construction, it is found that the spreading and finishing equipment in operation leaves in the pavement surface tracks or indented areas or other objectionable irregularities that are not satisfactorily corrected by scheduled operations, the use of such equipment shall be discontinued and other satisfactory spreading and finishing equipment shall be provided by the Contractor.

5.15.2 Rolling Equipment

1 Rolling equipment shall consist of vibratory steel-wheeled rollers, dead weight steel-wheeled rollers and pneumatic-tire rollers as required for proper compaction and finishing of the asphalt surface. Unless otherwise permitted, rollers shall be equipped with reversible or dual controls to allow operation both forward and backward with the operator always facing in the direction of movement.

2 Steel-wheeled rollers shall be two-axle tandem rollers or three-axle tandem rollers. These rollers shall be self-propelled and equipped with power units of not less than four cylinders and under working conditions shall develop contact pressures under the compression wheels of 45 to 65 kg/cm of width. Each two-axle roller shall have a minimum weight of 10,000 kg each and three-axle roller shall have a minimum weight of 13,000 kg. Vibrating steel-wheeled rollers shall have dual drums with a minimum weight of 7000 kg. Vibrating frequency shall be between 2000 and 3000 cycles per minute with individual controls for each tandem drum. Rollers shall be in good working condition and shall be equipped with a reversing clutch. Rollers shall be equipped with adjustable scrapers to keep the wheel surface clean and with efficient means of keeping them wet to prevent mixes from sticking. These surfaces shall have no flat areas or projections which will mark the surface of the asphalt courses. The three-axle rollers shall be equipped with a centre axle which may be operated either fixed or floating. The three-axle tandem roller shall be so constructed that when locked in a position for all treads to be in one plane, the roller wheels are held with such rigidity that, if either front or centre wheel is unsupported the other two wheels will not vary from the plane by more than 6 mm. All steel-wheeled rollers shall be in good condition and the Contractor shall furnish to the Engineer the manufacturer’s technical data for each roller and no roller shall be used except after approval of the Engineer.

3 Pneumatic-tire rollers shall be self-propelled. The rollers shall be equipped with pneumatic tires of equal size and diameter which are capable of exerting varying average contact pressure. Pneumatic-tire rollers shall be in good condition and with enough ballast space to provide uniform wheel loading as may be required. The Contractor shall furnish to the Engineer charts or tabulations showing the contact areas and contact pressures for the full range of tire inflation pressures and for the full range of tire loading for each type and size compactor tire furnished and used in pneumatic-tire rollers. The total operating weight and tire pressure may be varied by the order of the Engineer to obtain contact pressures which will result in the required asphalt course density.

5.15.3 Liquid Asphalt Distributor

1 The liquid asphalt distributor truck shall be of the pressure type with insulated tanks. The use of gravity distributors will not be permitted. The distributor shall have pneumatic tires of such width and number that the load produced on the road surface shall not exceed 100 kg/cm tire width.

2 Spray bars shall have a minimum length of 2.4 m and shall be of the full circulating type. Spray bar extensions shall also be of the full circulating type. The spray bar shall be adjustable to maintain a constant height above the surface to be treated.

3 The spray bar nozzles shall be slotted and shall be of such design so as to provide a uniform unbroken spread of asphalt material on the surface. The valves shall be operated by levers so that one or all valves may be quickly opened or closed in one operation. The distributor shall be equipped with a hose and nozzle attachment to be used for spotting areas inaccessible to the distributor. The distributor and booster tanks shall be so maintained at all times as to prevent dripping of liquid asphalt material from any part of the equipment.

4 The distributor shall be equipped with devices and charts to provide for accurate and rapid determination and control of the amount of liquid asphalt material being applied and with a tachometer of the auxiliary wheel type reading speed in m/min. The spreading equipment shall be provided with a separate power unit for the pump or a variable displacement pump driven by a hydrostatic transmission so that a uniform application of liquid asphalt material, in controlled amounts, may be made ranging from 0.15 to 5.0 kg/m^2. The distributor shall have satisfactory heating equipment and thermometers in order to provide the full range of application temperatures for the liquid asphalt material being used.

5 Before commencing the work and as required by the Engineer, the liquid asphalt distributor shall be checked and calibrated such that the rate of transverse spread or longitudinal spread shall not vary more than 10 % from the required rate of application.

APPENDIX

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1 APPENDIX - ASPHALT WORKS

1.1 DEFINITIONS

1 **Superpave**: Is an abbreviation of **Su**perior **Per**forming Asphalt **Pave**ment. Superpave system consist the following steps:

(a) Performance-Based Asphalt Binder Grading System

(b) Performance-Based Specifications of Materials & HMA.

(c) Test methods and practices for material selection & mix design.

(d) Performance prediction of HMA.

2 **Asphalt Binder Content (P_b):** the percent by weight of asphalt binder in the total mixture.

3 **Initial Trial Asphalt Binder (P_{bi})**: the percent by weight of the asphalt binder in the total mixture for each trial blend in the selection of the Design Aggregate Structure (DAS).

4 **Bulk Specific Gravity ($G_{1, 2,}$ to $_n$; … G_{sb}, G_{mb})**: the ratio of the weight in air of a unit volume of a permeable material (including both permeable and impermeable voids connected to the surface of the aggregate particle) at a stated temperature relative to the weight in air of an equal volume of gas-free distilled water at the stated temperature. This definition generally applies to individual aggregate stockpiles (G_I through G_n), the blended aggregate (G_{sb}, AASHTO T84, T85 and T100) or the compacted mix (G_{mb}, AASHTO T166 or T275).

5 **Effective Binder Content (P_{be})**: the volume of the asphalt binder that is not absorbed into the aggregate but remains in the mixture to coat the aggregate particles.

6 **Effective Specific Gravity (G_{se})**: the ratio of the weight in air of a unit volume of a permeable material (excluding voids permeable to binder) at a stated temperature relative to the weight in air of an equal volume of gas-free distilled water at the stated temperature.

7 **Maximum Specific Gravity (G_{mm}):** the ratio of the weight of a given volume of voidless (Va=0) loose HMA at a stated temperature (usually 77 °F (25°C)) to a weight of an equal volume of gas-free distilled water at the same temperature (AASHTO T209).

8 **Voids in Mineral Aggregate (VMA):** It is the total space between the aggregate particles in the compacted paving mixture which includes 1) the air voids (Va) and 2) the effective binder volume . The VMA is defined as the volume of void space between the aggregate particles before adding the binder. Note: mineral aggregate is the aggregate which does not include any or organic material but it is the material that consists of minerals and compounds such as calcium, silicon, etc ….

9 **Air Voids (V_a):** The total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as percent of the bulk volume of the compacted paving mixture.

10 **Voids Filled with Asphalt (VFA):** the percentage portion of the volume of intergranular void space between the aggregate particles (i.e. VMA) that is occupied by the effective asphalt binder volume. It is expressed as the ratio of ($VMA-V_a$) to the VMA.

11 **Volume of Absorbed Binder (V_{ba}):** the volume of binder absorbed into the aggregate (equal to the difference in aggregate volume when calculate with the bulk specific gravity and effective specific gravity).

12 **Dust to Binder Ratio ($P0.075/P_{be}$):** ratio by weight of the percentage of the aggregate passing the 0.075 mm sieve (P_{200}) to the effective binder content (P_{be}).

13 **Standard Axle**: is 8.2 ton (18,000 lb) single axle with dual wheels; the center to center distance of dual wheels is 34.29 cm (13.5 in); the tire pressure is 0.517 MPa (75 psi).

14 **ESAL's**: is an abbreviation of Equivalent Single Axle Load. The equivalency factor is the number of repetition of the standard axle required to induce the same damage as the given axle. AASHTO Road Test has shown that an equivalent number of the standard axle can represent the damaging effect of the passage of an axle of any mass. This means that the ESAL is the number of applications of the standard axle that is equivalent in the damage to the pavement to an axle of any mass. The relationship is non-linear and is a fourth degree. For example, one application of a 16.2 ton single axle (36,000 lb twice as the standard axel) was found to cause damage equal to approximately sixteen applications of the standard axle; or one application of a 16.2 tons axle were required to cause the same damage or reduction in the pavement serviceability as sixteen applications of the standard axle. Also, one application of a 5.47 ton single axle (12,000 lb two thirds of the standard axel) was found to cause damage equal to approximately 0.2 applications of the standard axle; or five applications of a 5.47 tons axle were required to cause the same damage or reduction in the pavement serviceability as one applications of the standard axle.

15 **Standard Sieves**: Superpave standard sieve sizes are 50.0, 37.5, 25.0, 19.0, 12.5, 9.5, 4.75, 2.36, 1.18, 0.6, 0.3, 0.15 and 0.075 mm

16 **Maximum Aggregate Size (MS):** one standard size larger than the nominal maximum aggregate size (This definition applies only to Superpave mix design.)

17 **Nominal maximum aggregate size (NMAS):** one standard size larger than the first sieve that retains more than 10 percent of the aggregate (this definition applies only to Superpave mix design).

18 **N_{ini}, N_{des} and N_{max}:** These are the number of gyrations of the gyratory compactor at three compaction levels simulating the construction traffic for N_{ini}, the design traffic for N_{des} and the maximum anticipated densification by the highest traffic for N_{max}

19 **Design Aggregate Structure (DAS):** the aggregate blend meeting all Superpave requirements.

20 **Design Asphalt Content (DAC):** the percent by weight of the asphalt binder in the total mix selected at 4.0 % air voids in the mix meeting all Superpave requirements.

21 **ePAVE3:** is a user-friendly menu driven Excel program for the Superpave mix design system. It is a decision making program that includes all the computations, requirements and comparisons to design hot mix asphalt for a given project. ePAVE3 includes Superpave requirements based on the latest (to date) Asphalt Institute Superpave Mix Design – Superpave Series No. 2 (SP-2), third Edition 2001 and last edition of AASTO 2005 including M323 specification "Standard Practice for Designing Superpave HMA", and R35.

22 **Polymer:** An organic substance that is originated from petroleum gases. It is the product of a complicated chemical process. The word “polymer” originally consists of two words “poly” which means numerous and “meros” which means parts; therefore, polymer means the substance with many parts. Polymers can be either copolymers or homopolymers. The most common polymers that are used to modify the asphalt binder for road applications are either “Elastomers” such as SBS or “Plastomers” such as EVA and Polyethylene.

23 **Neat and Polymer Modified Binder (PMB):** neat binder is a black or dark brown material produced from refining of petroleum oil in petroleum refineries. The polymer modified binder is a neat binder that has been modified by the addition of polymers. The purpose of blending polymer and other chemical substances is to improve the neat binder Rheological properties to achieve the Performance Grade (PG) requirements of Superpave grading system. This process is complicated and involves accurate control of the process parameters such as mixing mechanism, temperature, time, concentration and blending details

1.2 INTRODUCTION

1 This guide, which is based on ref. 1, should be considered as a guide to assist Engineers, consultants and contractors to design Hot-Mix Asphalt (HMA) using Superpave system. It is the contractor full responsibility to select the applicable parameters for his project in liaison with the Engineer. This system was developed using the last editions of the Asphalt institute “Superpave Mix Design”, 2001, and AASHTO, 2005.

1.3 SUPERPAVE DESIGN PARAMETERS

1 Before starting any HMA design using Superpave system for any project, the mixture and materials specifications and requirement must be identified. Superpave mix design system requires three parameters in order to design a mix. These Parameters are:

(a) Expected traffic volume in the project.

(b) Nominal Maximum Aggregate Size (NMAS).

(c) Location of the project.

2 The contract documents shall specify and define the design parameters for the project. A brief description of the basic design parameters is given in the following sections.

1.3.2 Traffic

1 In Superpave, Traffic is defined as the total anticipated project level equivalent single axle load (ESALs) on the design lane for a period of 20 years. To simplify the design process, traffic class designations for each ESALs that appears in the Superpave system is specified herein. If the contract documents do not specify the ESALs applicable to the project, the Engineer can use the information provided in Table 1 to select the traffic classes needed to establish Superpave criteria.

Table 1
ESAL and Traffic Designation

Class Designation		ESALs Range	Applications
VL	Very Light	Less than 300,000	Agricultural roads with light traffic , local and city streets without trucks
L	Light	300,000 to 3 million	Agriculture, Feeder and collector roads
M	Medium	3 million to 10 million	Main roads and city streets
H	Heavy	10 million to 30 million	Highways and Expressway
VH	Very Heavy	More than 30 million	Heavily trafficked highways, industrial areas ...

1.3.3 Nominal Maximum Aggregate Size (NMAS)

1 Six Nominal Maximum Aggregate Sizes (NMAS) are identified in the Superpave system; these are 37.5, 25.0, 19.0, 12.5, 9.5 and, 4.75 mm as specified in Table 2.

Table 2
SUAERPAVE Standard NMAS mixtures

Nominal Maximum Size (NMAS)	**Maximum Size (MS)**
37.5 mm	50.0 mm
25.0 mm	37.5 mm
19.0 mm	25.0 mm
12.5 mm	19.0 mm
9.5 mm	12.5 mm
4.75 mm	9.5 mm

2 The selection of design NMAS for a specific layer is based on the general rule that the NMAS does not exceed half to one-third (1/2 to 1/3) the layer thickness. If the contract documents do not specify the NMAS for the project, the Engineer can use the above criteria and the information provided in Table 3 to select the NMAS of the project.

Table3
Recommended NMAS for Different Layer Types

Layer	**Recommended NMAS**
Sand Mix	4.75 mm
Wearing coarse	9.5 or 12.5 or 19.0 mm
Base coarse	25.0 or 37.5 mm

1.4 SELECTION OF HMA PROPERTIES & REQUIREMENTS

1 Based on the specified design parameters (Traffic in ESAL, NMAS, geographic location of the project and location of required layer to be designed), the mixture properties and requirements can be selected. These properties include compaction level, which can be identified from Table 4 and the properties of HMA, which can be identified from Table 5.

Table 4
Superpave Gyratory Compactive Effort (SGCE)

Traffic (ESAL, million)	**Gyrations**		
	N_{ini}	**N_{des}**	**N_{max}**
VL (< 0.3)	6	50	75
L (0.3 to 3)	7	75	115
M to H (3 to < 30)	8	100	160

VH (≥ 30)	9	125	205

Table 5
Superpave Criteria for the Mixture Design

Criteria			Traffic Class Designation (or ESAL, million)				
			VL	**L**	**M**	**H**	**VH**
Required Density (% Gmm)	$N_{initial}$		≤ 91.5	≤ 90.5	≤ 89.0		
	N_{design}		96.0				
	N_{max}		≤ 98.0				
Voids in the Mineral Aggregate (VMA %min) **Important Note:** mixtures with VMA greater than 2.0% above the minimum should be avoided.	Nominal Maximum Size, mm	37.5	11.0 %				
		25.0	12.0 %				
		19.0	13.0 %				
		12.5	14.0 %				
		9.5	15.0 %				
		4.75	16.0%				
Voids Filled with Asphalt, %		37.5	64-80	64-78	64-75		
		25.0	67-80	65-78	65-75		
		19.0	70-80	65-78	65-75		
		12.5	70-80	65-78	65-75		
		9.5	70-80	65-78	65-75		
		4.75	70-80	65-78	65-75		
Dust Proportion (DP) Ratio, if gradation line is above the PCS			For all NMAS DP = 0.6 - 1.2, for NMAS 4.75 DP = 0.9 - 2.0				
Dust Proportion (DP) Ratio, if gradation line is below the PCS.			0.8 – 1.6				
Average Indirect Tensile Strength of the Dry Set in the Moisture Sensitivity Evaluation, kPa			Report				

1.5 OVERVIEW OF SUPERPAVE MIX DESIGN PROCESS

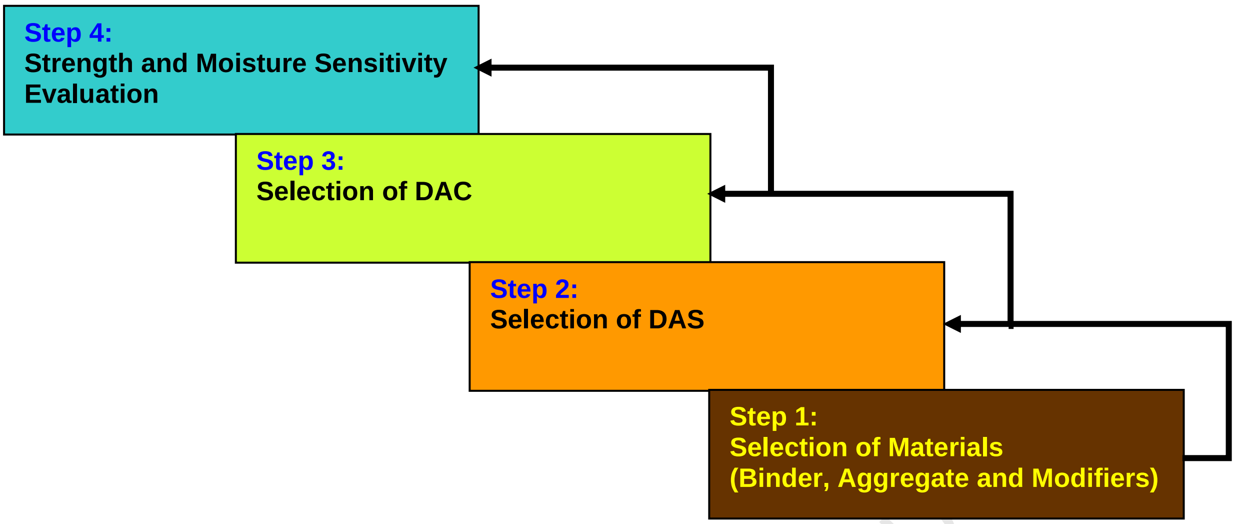
1 According to SP-2 and AASHTO R 35, there are four major steps in the volumetric mix design process. These steps consist of

(a) Material Selection, (Type of binder and aggregate).

(b) Selection of Design Aggregate Structure (DAS).

(c) Selection of Design Asphalt Content (DAC).

(d) Evaluation of Strength and Moisture Sensitivity of the Mix.



2 ePAVE3 program should be used to assist in the preparation of the mix design and obtain the mix deign report summarizing the computations and test results. ePAVE3 mix design report shall be submitted to the Engineer for approval.

1.5.2 Step1: Selection of Materials

1 This process includes the selection of the asphalt binder PG (ABPG) and the aggregates that meet all Superpave criteria.

2 The selection of ABPG necessitates an understanding of the climatic condition (e.g., temperature) in which the pavement will be constructed and operated. This includes both the average seven-day maximum high temperature and the single-day minimum low temperature for the last twenty years and the latitude for that particular geographic location.

3 To account for traffic volume and speed or both, adjustments should be made to the selected ABPG using AASHTO M332.

4 The requirements of the aggregate are selected based on the anticipated traffic and position of the layer within the pavement. The quality criteria for Superpave aggregates are summarized in Table 6. In order to be used in Superpave mixtures, the aggregate blends must meet two sets of criteria known as source properties and consensus properties. Source property requirements apply to each aggregate stockpile, but consensus properties apply to the combined blend of multiple stockpiles. **The consensus properties are mandatory for all Superpave aggregate blends while; source properties are left to the contracts**.

(a) Consensus Properties (Superpave Requirements):

i.	Coarse Aggregate Angularity, (CAA)	ASTM D5821
ii.	Fine Aggregate Angularity, (FAA)	AASHTO T304-Method A
iii.	Flat and Elongated Particles (F&E)	ASTM D4791
iv.	Sand Equivalent, (SE)	AASHTO T176

(b) Source Properties (QCS Requirements):

QCS General Specifications, source properties are considered specific to the geology of a particular region and the experience with local materials.

i.	Toughness	AASHTO T96
ii.	Soundness	AASHTO T104
iii.	Clay lumps & friable particles	AASHTO T112
iv.	Others.	

Table 6
Superpave Criteria for Aggregate Consensus Properties

Traffic Class Designation (or ESAL, million)					Layer Depth, mm	Property
VH(>30)	**H(10to<30)**	**M (3 to<10)**	**L (0.3 to 3)**	**VL (< 0.3)**		
100/100	95/90	85/80	75/-	55/-	≤ 100 mm	CAA, % min.
100/100	80/75	60/-	50/-	-/-	> 100 mm	
45	45	45	40	-	≤ 100 mm	FAA, % min.
45	40	40	40	-	> 100 mm	
50	45	45	40	40	SE, % min	
10	10	10	10	-	F&E, % max	
Note: CAA values (X/Y) denotes that X% of the coarse aggregate has one fractured face and Y% has two or more fractured faces						

1.5.3 Step2: Selection of a Design Aggregate Structure (DAS)

1 Once a group of aggregates has been identified, these aggregates are combined at different percentages to produce at least three distinct blends conforming to Superpave gradation requirements presented in Table 7 according to designed NMAS.

Table 7
Aggregate Gradation Requirements – Control Points

Sieve Size	Nominal Maximum Aggregate Size, mm - Control Point (Percent Passing)											
	37.5 mm		25.0 mm		19.0 mm		12.5 mm		9.5 mm		4.75 mm	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
50.0 mm	100	-	-	-	-	-	-	-	-	-	-	-
37.5 mm	90	100	100	-	-	-	-	-	-	-	-	-
25.0 mm	-	90	90	100	100	-	-	-	-	-	-	-
19.0 mm	-	-	-	90	90	100	100	-	-	-	-	-
12.5 mm	-	-	-	-	-	90	90	100	100	-	100	-
9.5 mm	-	-	-	-	-	-	-	90	90	100	95	100
4.75 mm	-	-	-	-	-	-	-	-	-	90	90	100
2.36 mm	15	41	19	45	23	49	28	58	32	67	-	-
1.18	-	-	-	-	-	-	-	-	-	-	30	60
0.075 mm	0	6	1	7	2	8	2	10	2	10	6	12

2 Primary Control Sieve (PCS) shown in Table 8 can be used to determine if the nominated blend is fine or coarse gradation. If the gradation line passes below the PCS, it is considered as coarse graded and it is considered fine gradation if the line passes above the PCS.

Table 8
Gradation Classification - PCS Control Points

9.5mm	12.5mm	19mm	25mm	37.5 mm	**Nominal Maximum Size**
2.36mm	2.36mm	4.75mm	4.75mm	9.5mm	**Primary Control Sieve Size**
47%	39%	47%	40%	47%	**%Passing PCS**

3 Typically, three blends are developed ranging from the coarse to the fine side of the Superpave control points for a given nominal maximum size (*note: control points and PCS differ for different NMAS*). After selecting a blend (i.e. from the three trial blends), the aggregate consensuses properties must be confirmed to meeting Superpave criteria by actual testing.

4 The most difficult part of designing an aggregate structure is the creation of the VMA necessary to meet the volumetric criteria. The procedure is typically a trial and error process; however, there are some general guidelines that will assist in obtaining the VMA. The following recommendations may be tried to increase VMA:

(a) Move the gradation away from the maximum density line;

(b) Use highly angular particles;

(c) Use particles with a rough surface texture;

(d) Reduce the percent of natural sand and use more percent of the crushed sand;

(e) Reduce the amount of P200 used in the HMA; and

(f) Use S-shaped gradation curve.

5 A good design aggregate structure is one that is economical and meets Superpave volumetric criteria.

1.5.4 Work Instructions of Step 2 Selection of DAS

1 To select the design aggregate structure, do the following:

(a) Obtain representative hot bin specimens from the plant.

(b) Determine the consensus properties, water absorption, bulk and apparent specific gravities for each aggregate fraction.

(c) Grade the specimens using Superpave standard sieve set.

(d) Input the values from two and three into ePAVE3 or combine manually. to develop three blends that meet the Superpave criteria (i.e. within the control points for the design NMAS)

(e) Estimate the initial trial asphalt binder content using ePAVE3 or by using formulas presented in ASSHTO R35.

(f) For unmodified asphalt binders, determine the mixing and compacting temperature for the proposed asphalt binder as follows:

(i) Measure the rotational viscosity using AASHTO T316 or ASTM D4402 at 135 C and 165 C.

(ii) Input the measured viscosities into ePAVE3. ePAVE3 will generate the viscosity-temperature relationship.

(iii) From the graph, determine:

2 The mixing temperature at a rotational viscosity of 0.17 ± 0.02 Pa.s.

3 The compaction temperature at a rotational viscosity of 0.28 ± 0.03 Pa.s.

(g) For modified asphalt binders, determine the mixing and compaction temperature in accordance with one of the methods presented in NCHRP 648.

(h) Prepare enough hot mix to make two 150 mm (or 100 mm) gyratory specimens and two specimens to measure the Maximum Specific Gravity (G_{mm}) for each blend at the estimated initial trial asphalt content.

Note: small specimen size of 100 mm is used for mixes having NMAS of 19.0 mm or below.

(i) Leave the mix in the oven for two hours at the compaction temperature then compact two 150.0 mm (or 100 mm) specimens for each blend using the Superpave Gyratory Compactor (SGC) to N_{des} according to AASHTO T312 (minimum number of specimens is six).

(j) For the specimens that were compacted to N_{des}, measure the bulk specific gravity (G_{mb}), and obtain the specimen height at N_{ini} and N_{des} from the gyratory compactor that is automatically recording the specimen height for each gyration.

(k) Measure the Maximum Specific Gravity (G_{mm}) for two specimens for each blend according to ASSHTO T209.

(l) Input the measured values into ePAVE3. ePAVE3 will perform the computations, display results, and check them against the criteria of the project.

(m) Check the results given by ePAVE3 for the three blends and select the most conforming blend as the DAS; in case none of the three blends meets Superpave criteria, repeat the design by developing additional aggregate blends from the same source ; if the criteria is not met change the sources.

2 Preparation of the binder and aggregate mixtures for the gyratory compactor (SGC) should be timed such that a minimum of 20 minutes is allowed between batches. Batched specimens should be conditioned in a closed draft oven for a minimum of 2 hours ± 5 minutes prior to compacting them in the SGC. Refer to AASHTO R30 for more details. The short time oven aging is performed to permit time for the aggregate to absorb the binder. All specimens including those for SGC and maximum specific gravity tests, should be cured the same amount of time.

1.5.5 Step 3: Selection of the Design Asphalt Content

1 The selected aggregate blend (DAS) will then be mixed with four different proportions of the binder as follows:

(a) Estimated asphalt binder content corrected to give 4.0% air voids.

(b) Estimated asphalt binder content corrected to give 4.0% air voids minus 0.5 %.

(c) Estimated asphalt binder content corrected to give 4.0% air voids plus 0.5 %.

(d) Estimated asphalt binder content corrected to give 4.0% air voids plus 1.0 %.

2 A sufficient amount of the proposed aggregate blend will need to be prepared to permit two specimens to be compacted in the SGC according to Superpave system for gyrations equal (Ndes), and the maximum specific gravity to be determined at each of the four binder contents.

3 Preparation of the binder and aggregate mixtures for the SGC specimens should be timed such that a minimum of 20 minutes is allowed between batches. Batched specimens should be conditioned in a closed draft oven for a minimum of 2 hours ± 5 minutes prior to compacting them in the SGC. Refer to AASHTO R30 for more details. The short time oven aging is performed to permit time for the aggregate to absorb the binder. All specimens including those for SGC and maximum specific gravity tests, should be cured the same amount of time.

4 The procedure used for design in the laboratory will need to closely match the field conditions at the time of construction. Failure to consistently test the materials at the same time interval may result in a highly erratic all specific gravity values and possibly failure to achieve the required VMA. After the necessary testing has been accomplished, the calculation of the volumetric parameters can begin. The averaged results of the various volumetric calculations need to be plotted relative to the corresponding binder content. The design binder content is selected as that which satisfies the specified volumetric criteria at 4 percent air voids (refer to AASHTO R35 for more details).

1.5.6 Work Instruction of Step 3- Selection of DAC

1 To select the deign asphalt content, do the following:

(a) After selecting the most conforming blend (DAS) from step 2, prepare enough hot mix to make two 150 mm (or 100 mm) gyratory specimen and two specimens to measure the Maximum Specific Gravity (Gmm) for four trial mixes using DAS of the selected blend and four asphalt binder levels as specified in item (5.5.4) herein.

(b) Compact two 150.0 mm (or 100 mm) specimens for each mix using the Superpave Gyratory compactor to N_{des} according to AASHTO T312 (total number of specimens are eight)

(c) For the specimens that were compacted to N_{des}, measure the bulk specific gravity (G_{mb}), and obtain the specimen height at Nini and N_{des} from the gyratory compactor that is automatically recording the specimen height for each gyration.

(d) Input the measured values into ePAVE3. The program will perform all calculations, produce the results and compare the results with required mix design properties for the project.

(e) ePAVE3 will generate the design curves, these are:

(i) % air voids vs. asphalt content.

(ii) % VMA vs. asphalt content.

(iii) % VFA vs. asphalt content.

(iv) % G_{mm} at N_{ini} vs. asphalt content.

(f) From the percentage, air voids vs. asphalt content curve determine the design asphalt content (DAC) which corresponds to 4.0 % air voids.

(g) Use the %VMA vs. asphalt content, %VFA vs. asphalt content % and %G_{mm} vs. asphalt content graphs to obtain the VMA, FVA and the % G_{mm} @ N_{ini} values at the design asphalt content.

(h) Input the DAC, %VMA, %VFA % and G_{mm} @ N_{ini} into the appropriate cells in ePAVE3. ePAVE3 will perform the computations, display results, and check them against the criteria of the project.

(i) If the mix properties at the design asphalt content conform to the Superpave criteria then go to the N_{max} verification; if not then analyze, evaluate and modify the design as needed until the mix properties at the design asphalt content (DAC) conform to the criteria.

1.5.7 N_{max} and N_{des} Verification

1 After conforming to Superpave criteria, then do the N_{max} verification as follows:

(a) Prepare enough hot mix at the selected gradation from (DAS) step 2 and the selected design asphalt content (DAC) from step 3, to compact two 150 mm (or 100 mm) specimens and two G_{mm} specimens.

(b) Compact the specimens to N_{max} using the gyratory compactor according to AASHTO T312.

(c) Measure the G_{mb} at N_{max} for the two specimens that were prepared using SGC and measure the G_{mm}.

(d) Input the values into ePAVE3, which will perform the computations, provide the results, and compare them with the Superpave criteria.

(e) Check the results of ePAVE3, if acceptable then the design is concluded if not then redesign the mix.

2 After conforming that the mix properties at N_{max} meet Superpave criteria, then do the N_{des} verification as follows:

(a) Prepare enough hot mix at the selected gradation from (DAS) step 2 and the selected design asphalt content (DAC) from step 3, to compact two 150 mm (or 100 mm) specimens and two G_{mm} specimens.

(b) Compact the specimens to N_{des} using the gyratory compactor according to AASHTO T312.

(c) Measure the G_{mb} at N_{des} for the two specimens that were prepared using SGC and use the G_{mm} from the previous step. Obtain the specimen height at N_{des} and N_{ini} from the gyratory compactor that is automatically recording the specimen height for each gyration.

(d) Input the values into ePAVE3, which will perform the computations, provide the results, and compare them with the Superpave criteria.

(e) Check the results of ePAVE3, if acceptable then the design is concluded if not then redesign the mix.

1.5.8 Step 4: Evaluation of the Strength and the Moisture Sensitivity of the Mixture

1 The identification of the combination of a design aggregate structure and design binder content is now complete. The mixture now needs to demonstrate that it is capable of resisting the moisture induced damage. This evaluation is performed in accordance with AASHTO T283.

2 Moisture sensitivity evaluation requires that a total of six specimens consisting of the proposed aggregate blend and binder at the design binder content, be prepared and compacted to approximately 7 ± 0.5% air voids. This group of specimens is divided into two subsets with three of the specimens being identified as the control specimens and the other three being identified as conditioned specimens.

3 At the end of the conditioning period all of the specimens are loaded to failure in indirect tension. Report the average Indirect Tensile Strength (IDT) of the dry subset in the mix design report (see Table 5); and if the ratio of the average strength of the conditioned subset to the control subset (retained strength) is more than or equal to 80% , then the mixture passes the test. If the retained strength is less than 80%, then the mixture fails. The retained strength can be increased by substituting part of the material finer than 0.075 mm by mineral admixtures or by using chemical anti-stripping agents. Prepare another six (6) specimens and test them as previously described. If this procedure does not improve the retained strength to more than 80%, then the design process should be repeated using different source.

1.5.9 Work Instructions of Step 4 Evaluation of Strength and the Moisture Sensitivity

1 To check the Strength and the moisture sensitivity of the designed mix, do the following:

(a) Prepare enough hot mix to make six 150 mm (or 100 mm) gyratory compactor specimens using the selected gradation (DAS) and the design asphalt content (DAC).

(b) Use the N_{max} verification densification data to identify the number of gyrations required to achieve 7.0 ± 0.5% % air voids (i.e. %G_{mm} = 92.5 to 93.5 %).

(c) Compact six 150.0 mm (or 100 mm) specimens using the Superpave Gyratory Compactor according to AASHTO T312 compactor (total number of specimens are six) to a number of gyrations that will provide approximately 7.0 ± 0.5 % air voids.

(d) Use ASSHTO T283 to test the six specimens.

(e) Input the measured values into ePAVE3. ePAVE3 will perform the computations and provide the results and compare them with the Superpave criteria

(f) Check the results given by ePAVE3. Report the average IDT of the Dry group in the mix design report (see Table 5). If the ratio of the average IDT of the conditioned subset to the control subset is 80% or more, then the mixture passes the test if not consider redesigning the mix and use some additives.

1.6 JOB MIX DESIGN PROPOSAL

1 A proposed Job Mix Formula (JMF) shall be formulated by the Contractor and submitted to the Engineer for approval. The JMF shall be prepared by the Contractor in precise compliance with Superpave system. The Contractor shall select his sources of aggregate and bituminous material and, after sufficient quantities have been stockpiled or are available for use, obtain representative specimens of the materials and test to determine if they conform to the requirements of the specifications.

2 Before producing bituminous concrete mixtures, the Contractor shall submit in writing to the Engineer, detailed information for each mix which he proposes to furnish. The information shall include, but not be limited to the following:

(a) Copy of mix certificate

(b) The source(s) of the aggregate for each mix.

(c) Pertinent test data and a written certification that the aggregates conform to all of the quality requirements specified herein and in section 5.2.

(d) Type of Asphalt modifier intended to be used in the project. The Asphalt binder modifier shall be an approved modifier; along with the Certificate of Conformity of the modified asphalt binder to the required grade according to the Superpave Performance Based Grading System.

(e) Pertinent test data on the type and properties of the asphalt binder, modified asphalt binder, mineral filler, and chemical admixtures/asphalt modifiers to be furnished.

(f) Superpave mix design report in ePAVE3 format.

(g) The type and location of plant to be used for mixing each mix.

(h) Type of Asphalt modifier intended to be used in the project. The Asphalt binder modifier shall be an approved modifier; along with the Certificate of Conformity of the modified asphalt binder to the required grade according to the Superpave Performance Based Grading System.

(i) Pertinent test data on the type and properties of the asphalt binder, modified asphalt binder, mineral filler, and chemical admixtures/asphalt modifiers to be furnished.

(j) Superpave mix design report in ePAVE3 format.

(k) The type and location of plant to be used for mixing each mix.

(l) The proposed beginning date for producing bituminous concrete mixtures.

(m) Any other support data and information special to the project (e.g. technical data sheets of a polymer in case it was used).

3 The Engineer shall be provided access to the materials sampling and testing operations at all times.

4 At the same time that the above information is provided, the Engineer shall obtain one hundred (100) kilogram specimens of each individual aggregate size, eight (8) liters of bituminous material and, when used, sufficient quantities of the mineral filler and the chemical admixture/asphalt modifier to complete two (2) proposed mix design checks, all representing the materials which the Contractor proposes to furnish. The final job mix formula shall be made by using hot-bins aggregate.

1.6.2 Acceptance of Job Mix Formula

1 The Engineer shall review the JMF to determine that it contains all required information. If it does not contain all required information, it shall be returned within seven (7) days to the Contractor for further action and resubmission by the Contractor.

2 If the proposed JMF contains all required information but fails to meet all of the requirements specified, it shall not be accepted by the Engineer and will be returned to the Contractor within fourteen (14) days. The Contractor shall prepare and submit to the Engineer a new JMF conforming to the requirements specified and propose a new date for beginning production of the bituminous mixtures.

3 When the Engineer is satisfied that the JMF proposed by the Contractor conforms to all the requirements of the specifications, he shall order the Contractor to construct a minimum of two hundred (200) meter long field test strip; but not exceeding one day's production. The test strip is used for three purposes:

(a) To check the contractor ability to ***produce*** the approved mix within tolerances.

(b) To check the contractor ability to ***construct and compact*** the mix to satisfy job specifications.

(c) To check the riding quality according to project specifications.

4 The Engineer shall evaluate the test strip as to its constructability and compactability and the mix for conformance to the laboratory tested JMF within the tolerances listed in Table 9. Five (5) specimens shall be obtained from the test strip and tested.

5 If the Engineer is not satisfied with the results of the test strip, he shall state his objections in writing and request a revised JMF and a new test strip.

6 When the Engineer is satisfied that the JMF proposed by the Contractor conforms to all requirements of the specifications and the test strip results are acceptable, he will issue written acceptance to the Contractor to begin producing the proposed mixes. Production of bituminous concrete mixtures shall not begin until the Engineer has given written acceptance of the Job Mix Formula.

7 Acceptance of the JMF by the Engineer does not relieve the Contractor of his obligation to produce bituminous concrete mixtures conforming to all specified requirements.

1.6.3 Construction Quality Control:

1 Testing to control the quality of bituminous concrete mixtures produced shall be the responsibility of the Contractor.

2 For each class of bituminous concrete produced and each day's production, the Contractor shall perform one (1) complete Superpave analysis at N_{des} including gradation and asphalt binder content, air voids, %VMA, %VFA, DP ratio, Indirect tensile strength on a specimen obtained from the discharge gate or hauling vehicle. In addition, the Contractor shall evaluate on a weekly basis the strength and moisture sensitivity of the mix from a specimen obtained from the discharge gate or hauling vehicle.

3 No mixture conditioning is required when conducting quality control or quality assurance testing on plant-produced mixture.

Table 9
Superpave Job Mix Formula Tolerances for HMA Plant Mix

Mix Composition Property	Tolerance Limit
Asphalt Binder Content (P_b)	±0.40
Gradation Passing 4.75 mm and Larger Sieves	±5
Gradation Passing 2.36mm to 150µm Sieve	±4
Gradation Passing 75µm Sieve	±1.2
Air Voids (V_a)	±1.3
Voids in Mineral Aggregate (VMA)	±1.5
Field Density	92 to 94 (%G_{mm})

1.7 REFERENCES

1) Hot Asphalt Mix Design System Using Superpave System Detailed in Asphalt Institute SP-2 and the AASHTO 2005 Standards – MOT – Saudi Arabia, 2006.
2) AASHTO M323: Standard Specification for Superpave Volumetric Mix Design.
3) (NCHRP) Report 567: Volumetric Requirements for Superpave Mix Design.
4) (NCHRP) Report 409: Quality Control and Acceptance of Superpave-Designed Hot Mix Asphalt.
5) (NCHRP) Report 539: Aggregate Properties and the Performance of Superpave-Designed Hot-Mix Asphalt.
6) (NCHRP) Report 513: Simple Performance Tester for Superpave Mix Design.
7) (NCHRP) Report 648: Mixing and Compaction Temperatures of Asphalt Binders in Hot-Mix Asphalt.
8) AASHTO T320: Standard Method of Test for Determining the Permanent Shear Strain and Stiffness of Asphalt Mixtures Using the Superpave Shear Tester (SST).
9) AASHTO T321: Standard Method of Test for Determining the Fatigue Life of Compacted Hot-Mix Asphalt (HMA) Subjected to Repeated Flexural Bending.
10) AASHTO T322: Standard Method of Test for Determining the Creep Compliance and Strength of Hot-Mix Asphalt (HMA) Using the Indirect Tensile Test Device.
11) AASHTO T340: Standard Method of Test for Determining the Rutting Susceptibility of Hot Mix Asphalt (APA) Using the Asphalt Pavement Analyzer (APA).

END OF PART