Engineering Standard

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Asphalt and Sulfur Extended Asphalt Concrete Paving

Document Responsibility: Civil Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

This Standard prescribes minimum mandatory requirements governing the design and construction of asphalt concrete paving, including use of Sulfur Extended Asphalt. This Standard does not apply to airfield pavement. Permanent airstrip design and construction details are covered in Standard Drawing AA-036257 and appropriate FAA specifications. Helipad design and construction details are covered in Standard Drawing AA-036246. This Standard does not apply to asphalt concrete paving for non-traffic areas such as lining secondary containment dikes or erosion control for slopes.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Saudi Aramco Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, Codes, and Forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-A-114	*Excavation and Backfill*
SAES-L-450	*Construction of On-Land and Near-Shore Pipelines*
SAES-L-460	*Pipeline Crossings under Roads and Railroads*
SAES-P-104	*Wiring Methods and Materials*

SAES-S-070	*Installation of Utility Piping Systems*
SAES-T-624	*Telecommunications Outside Plant - Fiber Optics*
SAES-T-911	*Telecommunication Conduit System Design*
SAES-T-928	*Telecommunication - OSP Buried Plant*

Saudi Aramco General Instruction

GI-1021.000	*Street and Road Closure: Excavation, Reinstatement, and Traffic Controls*

Saudi Aramco Product Specifications

A-970	*Paving Asphalt - Penetration Grade*
A-973	*Cutback Asphalt, MC-70*
A-974	*Cutback Asphalt, MC-250*

Saudi Aramco Best Practice

SABP-Q-010	*Mix Design and Construction of Sulfur Extended Asphalt Concrete*

3.2 Industry Codes and Standards

American Association of State Highway and Transportation Officials

AASHTO	*AASHTO Guide for Design of Pavement Structures. American Association of State Highway and Transportation Officials, 1993*
AASHTO M17	*Standard Specification for Mineral Filler for Bituminous Paving Mixtures*
AASHTO M156	*Standard Specification for Requirements for Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures*
AASHTO T49	*Standard Method of Test for Penetration of Bituminous Materials*
AASHTO T51	*Standard Method of Test for Ductility of Bituminous Materials*
AASHTO T53	*Standard Method of Test for Softening Point of Asphalt (Bitumen) and Tar in Ethylene Glycol (Ring-and-Ball)*
AASHTO T180	*Moisture-Density Relations of Soils Using a 10-lb (4.54-kg) Rammer and an 18-in. (457 mm) Drop*

AASHTO T193 *The California Bearing Ratio*

American Society for Testing and Materials

Aggregate Materials Test Methods

ASTM C88 *Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate*

ASTM C117 *Test Method for Materials Finer than 0.075 mm (No. 200) Sieve in Mineral Aggregates by Washing*

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

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

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

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

ASTM D75 *Practices for Sampling Aggregates*

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

Bituminous Materials Test Methods

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

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

ASTM D113 *Standard Test Method for Ductility of Bitumen Material*

ASTM D1559 *Test Method for Resistance to Plastic Flow of Bituminous Mixtures using Marshall Apparatus*

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

ASTM D2172	*Test Method for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures*
ASTM D2726	*Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures*
ASTM D4402	*Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperature Using Rotating Viscometer*
ASTM D6307	*Standard Test Method for Asphalt Content of Hot Mix Asphalt by the Ignition Method*

Cementitious Materials Test Methods

ASTM C5	*Standard Specification for Quicklime for Structural Purposes*
ASTM C150	*Standard Specification for Portland Cement*

Soil Materials Test Methods

ASTM D1556	*Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method*
ASTM D1557	*Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort [56,000 ft-lbf/ft³ (2,700 kN-m/m³)]*
ASTM D1883	*Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils*
ASTM D2419	*Test Method for Sand Equivalent Value of Soils and Fine Aggregate*
ASTM D2922	*Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)*
ASTM D4253	*Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table*
ASTM D4254	*Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density*
ASTM D4318	*Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*

Center for Scientific and Industrial Research (CSIR)

CR-98/077 *"Foamed Asphalt Mixes - Mix Design Procedure" Center for Scientific and Industrial Research (CSIR), Transportek Contract Report*

Ministry of Transport

MOT *General Specification for Road and Bridge Construction. Ministry of Transport, November, 1996*

4 Design of Pavement Structures

4.1 The following paragraph numbers refer to AASHTO Guide for Design of Pavement Structures, 1993, which is a part of this SAES. The text in each paragraph is an addition, modification, exception, deletion, new paragraph (whatever modification types are used) as noted:

PART II - Section 2.1.1 (Analysis Period)

(Addition) The traffic analysis period shall be twenty (20) years.

PART II - Section 2.1.2 (Traffic)

(Addition) Axle loads shall be based on a loadometer survey, truck and equipment manufacturer's technical data or the maximum axle loads allowed by the Kingdom of Saudi Arabia, Ministry of Transport (MOT). See Table 1 for maximum legal Saudi Arabia truck loads.

Table 1 – Maximum Legal Saudi Arabia Truck Loads

Steerable axle	**5,500 kg (12,100 lbs)**
Single axle	12,000 kg (26,400 lbs)
Tandem axle	18,000 kg (39,600 lbs)

PART II - Section 2.1.3 (- Reliability)

(Addition) A level of reliability of 0.8 shall be used for all Saudi Aramco Pavements

PART II - Section 2.2.1 (Serviceability)

(Addition) A Terminal Serviceability Index (P_t) of 2.5 shall be used for all Saudi Aramco pavements.

(Addition) An initial serviceability (P_0) of 4.2 shall be used for all Saudi Aramco Pavements.

PART II - Section 2.3.5 (Layer Coefficients)

(Addition) The following Structural Layer Coefficients shall be used:

Pavement Component	Coefficient per cm
Hot mix Asphalt (High Stability)	0.16
MOT Aggregate Base Course Class A – CBR 100	0.06
MOT Aggregate Base Course Class B – CBR 50	0.04
MOT Subbase, Class A or B - CBR 25	0.03
Foamed asphalt stabilized bases (alternative to aggregate base course)	Refer to Table A.1
In-situ paved roads re-cycled with foamed asphalt	Coefficient to be based on Indirect Tensile Strength (ITS) or Resilient Modulus testing

4.2 If a traffic count cannot be made, Table 2 may be used to determine the Equivalent 18 KIP loads.

Table 2

Equivalent Pavement Categories	Traffic and Load	18 KIP Loads
Residential Streets	Typical Subdivision	2 x 10E4
Access Roadways	Sedans to trucks up to 20 tons/axle	1 x 10E5
Main Highways	Sedans to trucks up to 20 tons axle	Traffic count required
Parking and Storage Lots	Sedans and small trucks	1 x 10E5
Parking and Storage Lots	Heavy Traffic (Truck Terminals, etc.)	2 x 10E6
Plant Areas, including all roads and all paved areas within the Plant fence	Occasional Heavy Loads	1 x 10E6

4.3 Where existing subgrade materials have a CBR of 5 or less, a subbase with a minimum CBR of 15 shall be provided with a minimum thickness of 20 cm. (CBR shall be as determined by ASTM D1883 at 95% compaction according to ASTM D1557 or AASHTO T180). Such subbase cannot be considered an MOT Subbase Class A or B unless it meets the requirements defined in Tables 4, 5, and 6.

If the existing subgrade has a CBR of 5 or less after using standard compaction methods, including drainage, then proven soil improvement techniques may be used. Soil improvement can increase the CBR of the subgrade or reduce the thickness of the subbase. Soil improvement techniques include geotextiles, geogrids, soil replacement, chemical treatment, and others. The subbase/ subgrade requirements need to be re-evaluated based on the soil improvement method selected. The selection and design of soil improvement techniques shall be reviewed by CSD.

4.4 Cement-stabilized base materials may be used included in pavement layer thickness calculations based on a detailed design.

Commentary Note:

Cement-stabilized base materials have proven effective in subkha areas and areas with a high water table.

4.5 If a detailed design is not performed, the minimum pavement thickness may be taken from Table 3. Minimum pavement thickness for pavements including a foamed asphalt base are shown in Table A.2. Table 3 assumes minimum subgrade/subbase CBR requirements are met.

Table 3 – Conventional Pavements

		Minimum Thickness of Combined Asphalt Base Course and Wearing Course	
Pavement Category	**Minimum Thickness of Aggregate Base Course Class A/B CM**	**With Aggregate Base Course Class B CM**	**With Aggregate Base Course Class A CM**
Residential Streets	15	8	5
Access Roadways	15	9	6
Main Highways	Traffic Count Required		
Parking and Storage Lots Sedans and Small Trucks	15	9	6
Parking and Storage Lots Heavy Traffic (Truck Terminals, etc.)	23	14	12
Plant Areas, including all roads and all paved areas within the Plant fence Occasional Heavy Loads	23	14	12

5 Specification for Asphalt and Sulfur Extended Asphalt Pavement Construction

5.1 Specification for Preparation of Subgrade Materials

General Requirements for Construction

If the rough grading has not been included in a previous contract, the subgrade shall be restored by removing all vegetation, filling all depressions, and leveling the surface.

If the contract includes rough grading and surfacing, the rough grading shall be completed as far in advance of the construction of the surfacing as feasible. Soft and unstable material that will not compact when rolled or tamped shall be removed and replaced with material approved by Saudi Aramco representative.

Unless otherwise specified, the entire subgrade shall be compacted to not less than 95% of the maximum dry density per (ASTM D1557, or AASHTO T180) while within 1.5% of the optimum moisture content or to 85% of relative density determined by ASTM D4253 and ASTM D4254. All holes, ruts, soft places, and other defects shall be corrected. In no case shall the subbase or base course be placed on soft or unstable material, or over areas that are not drained. If the subgrade is dusty or muddy, operations shall be delayed until it is in a condition satisfactory to the Saudi Aramco representative.

The subgrade shall be constructed so that after being compacted it will conform to the alignment, grade, and cross-section shown on the plans, which shall not vary by more than +6 mm as measured with a 3 m straight edge, and as required by the Project construction specification.

Where rolling of the subgrade is required, any areas which are inaccessible to a roller shall be compacted either by a mechanical or hand tamper meeting the approval of the Saudi Aramco representative.

The subgrade shall be checked and approved by the Saudi Aramco representative prior to starting construction of the subbase or base course on any portion of the work.

The subgrade shall be kept drained during the placing and compacting of the base course or subbase surface. If berms of earth are deposited along the area upon which the base or surface course is being placed, provision shall be made for surface drainage by cutting lateral ditches through the berms of earth.

The finished subgrade shall be maintained in a smooth and compacted condition until the subbase, base course, and surface course are placed.

5.2 Specification for Crushed Stone Bases and Subbases for Flexible Pavement

5.2.1 Materials

Gradation and physical properties for base and subbase materials shall conform to the requirements of Tables 4 and 5 and shall be sampled in accordance with ASTM D75.

Table 4

	Percent Passing			
	Sub-base Material Classes		Base Material Classes	
	A	B	A	B
Sieve Size	Well-graded gravel w/sand and silt	Uniform mixture of gravel and/or stone fragments w/sand, silt, and clay	Mixture of aggregate uniformly graded from coarse to fine	Uniform mixture of crushed rock or crushed gravel
2-½ inch	100	-	100	-
2 inch	90-100	100	90-100	-
1-½ inch	-	70-100	60-90	100
1 inch	-	55-85	42-77	60-100
¾ inch	-	50-80	35-70	55-85
½ inch	-	-	25-60	-
3/8 inch	-	35 - 65	-	-
No. 4	35-70	30-60	15-40	35-60
No. 10	-	20-50	10-26	25-50
No. 40	-	10-30	5-15	15-30
No. 200	0-15	5-15	2-9	8-15

Table 5

	Sub-base Material Classes		Base Material Classes	
Physical Requirements	**A**	**B**	**A**	**B**
Liquid Limit (ASTM D4318)	-	25 max	-	25 max
Plasticity Index (ASTM D4318)	-	6 max	6 max	6 max
Loss by Abrasion % (ASTM C131 or ASTM C535)	50 max	50 max	40 max	40 max
Thin and Elongated pieces, by weight (larger than 25 mm, thickness lesser than 1/5 length) per ASTM D4791	-	-	5% max	5% max
Clay Lumps & Friable Particles (ASTM C142)	-	-	3% max	3% max
Soundness Test (ASTM C88) Using Mg SO_4 Coarse Aggregate Fine Aggregate	 25 25	 25 25	 25 25	 25 25

The laboratory compacted California Bearing Ratio, per ASTM D1883 or AASHTO T193 shall conform to the requirements of Table 6.

Table 6

	Percent Passing			
	Sub-base Material Classes		Base Material Classes	
	A	B	A	B
CBR value at min. 95% compaction as per ASTM D1557	25 min.	25 min.	-	-
CBR value at min. 100% compaction as per ASTM D1557	-	-	100 min.	50 min.

5.2.2 Construction

Prior to constructing the base course, the sub-base shall be cleaned of all foreign substances. Ruts or soft, yielding spots having inadequate compaction shall be corrected.

5.2.2.1 Placing

Granular subbase and base material shall be placed in layers of uniform thickness with approved spreaders. Layer thickness shall not exceed 150 mm after compaction. Approval may be given by the Saudi Aramco Representative to greater than

150 mm thick layers, if compacting equipment can achieve acceptable degree of compaction to the full layer depth. When the base or subbase course is constructed in more than one layer, the previously constructed layers shall be cleaned of loose and foreign matter. The water content of the material shall be maintained during compaction at the optimum percentage (±1-½%) as determined by ASTM D1557 or AASHTO T180.

5.2.2.2 Compaction

While at optimum moisture (±1-½%) the subbase or base materials shall be compacted with equipment capable of obtaining the desired density to the full depth of the respective layer. The rolling shall continue until the base and subbase are compacted to not less than (100% for the base and 95% for the subbase) of the maximum laboratory dry density as determined by ASTM D1557, or AASHTO T180. In-place density shall be measured by ASTM D2922 or ASTM 1556 or other approved methods. Testing shall be conducted at a rate of one test every 2000 ft² (180 m²) of base or sub-base.

5.2.2.3 Finishing

The surface of the compacted material shall be finished by blading or with automated equipment especially designed for this purpose and rolled with a steel-wheeled roller. In no case shall thin layers of fine materials be added to the top layer of the base course in order to meet the required elevation. The surface of the completed base shall not show any deviation in excess of 6 mm when tested with a 3-meter straightedge. The completed thickness of the base shall be within ±6 mm of the thickness indicated, and the average thickness shall not be less than the design thickness.

5.3 Specification for Foamed Asphalt Stabilized Bases

The requirements for foamed asphalt stabilized bases are contained in the Appendix to this Standard.

5.4 Specification for Prime Coats and Tack Coats

5.4.1 Prime Coat

A. The prime coat shall be applied and shall consist of MC-70 or

MC-250 conforming to the requirements in MOT Table 4.01-2. A prime coat shall consist of the initial application of liquid asphalt into the surface of non-asphalt base course. Prime coat shall be tested prior to applications and every 10,000 m².

B. *Cleaning Surface:* Prior to the application of the prime coat the surface shall be cleaned of all loose dirt and other objectionable materials by means of approved mechanical sweepers or blower and or hand broom.

C. *Application:* Prime coat shall be applied only when the surface to be treated is dry, the atmospheric temperature is 16°C or above. Prime coat shall not be applied when the weather is foggy or rainy or in a sand storm. The prime coat shall be applied uniformly to the surface of the base using a pressure distributor at a rate between 0.65 and 1.75 liters per square meter and at a temperature between 50°C and 80°C for MC-70 and at a temperature between 65°C and 105°C for MC-250. The distributor truck shall be equipped with a device to accurately measure the rate of application of the prime coat.

At all times, the temperature of the MC material shall be maintained at least 10°C below the flash point of the material.

The prime coat materials shall be applied to a width of 300 mm greater on each side of the road than the specified width of the finished surface. Priming material shall be prevented from spraying on adjacent pavements.

Prime coat shall be maintained intact until it is covered by Asphalt Base course. Any area where prime coat is disturbed shall be repaired to the satisfaction of Saudi Aramco representative.

D. *Curing:* The prime coat shall be permitted to cure until the penetration into underlying surface has been approved by Saudi Aramco Representative, but at no time shall the curing period be less than 24 hours. The prime coat shall be fully set and cured before placing an asphalt mixture on the base.

5.4.2 Tack Coat

A. A tack coat shall be applied on existing bituminous or Portland cement concrete pavement to be overlaid, to the surface between layers of bituminous pavement, to bridge decks, and to vertical edges of pavement, curbs and gutters, wing walls, bridge abutments and other surfaces in contact with bituminous pavement.

B. The tack coat shall be RC-70 conforming to the requirements in MOT Table 4.01-3A. Tack coat shall be tested prior to applications and every 10,000 m².

C. *Cleaning Surface:* Prior to the application of the tack coat the surface shall be swept and cleaned until it is free from all loose dirt and any other objectionable materials.

D. *Application:* The tack coat shall be applied by means of bitumen distributor at a maximum rate of 0.25 liters per square meter or as directed by Saudi Aramco Representative. In places where the distributor bars cannot reach, tack coat shall be applied with a hand spray attached to the distributor by a hose. The tack coat shall be uniformly applied over the entire surface of the area to be covered. Tack coat shall not be placed during rainy weather, nor when the moisture on the surface to be paved would prevent proper bond, nor when the atmospheric temperature is less than 16°C, nor when the temperature of the surface on which the material is to be placed is less than 16°C.

All precautions necessary shall be taken to protect the tack coat from damage and all traffic shall be kept off the tack coat until it has been covered. If application of the surface course is delayed by more than three days, or if dirt, sand or other impurities have contaminated the tack coat, then a new tack coat shall be applied after the original one has been swept clean.

5.5 Hot Mix Asphalt Concrete Paving

5.5.1 Materials

Bituminous Paving Mixture

A. Asphalt shall be petroleum asphalt cement, penetration grade 60-70, conforming to Saudi Aramco Product Specification A-970.

B. Mineral Aggregate

1. *Gradation:* When tested according to ASTM C117 and ASTM C136 the combined mineral aggregate shall conform to the following grading:

	Percent Passing				
	Asphalt Base Course		Asphalt Wearing Course		
Sieve Size	Class A	Class B	Class A	Class B	Class C
1-½ inch	100	100	-	-	-
1 inch	75-90	100	-	-	-
¾ inch	65-80	80-100	100	100	-
½ inch	55-70	68-88	76-92	80-100	100
3/8 inch	45-60	60-80	64-79	-	80-100
No. 4	31-46	45-65	41-56	50-70	55-75
No. 10	18-33	30-50	23-37	32-47	32-47
No. 40	5-18	15-32	7-20	16-26	16-26
No.80	3-13	-	5-13	10-18	10-18
No. 200	2-9	3-10	3-8	4-10	4-10

2. *Mineral Filler:* When the combined grading of the coarse and fine aggregates is deficient in material passing the No. 200 sieve, Mineral Filler conforming to AASHTO M17 shall be added as approved by the Company Representative. Mineral Filler shall conform to the following grading:

Sieve Size	Percent Passing (By Weight)
No. 30	100
No. 50	95-100
No. 200	70-100

3. *Physical Requirement:* The combined mineral aggregates for Base Course and Wearing Course shall not consist of soft and friable materials and shall conform to the following physical requirements:

	Requirements
Sand Equivalent (ASTM D2419)	50 min.
Plasticity Index (ASTM D4318)	6 max (Base Course) 3 max (Wearing Course)
Loss by Abrasion % (ASTM C131)	40% max.
Loss by Magnesium Sulfate Soundness Test (ASTM C88) for: Coarse Aggregate Fine Aggregate	 25% max. 25% max.
Thin and elongated pieces, by weight (larger than 25 mm, thickness lesser	5% max.

C. Sulfur shall be pelletized elemental sulfur.

5.5.2 Job Mix

The Job-Mix formula shall be approved by Saudi Aramco Representative and shall combine the mineral aggregates and asphalt in such proportion as to produce a mixture conforming to the following composition limits by weight, in accordance with ASTM D2172 or ASTM D6307.

Material	Percent
Total Mineral Aggregate	93 – 96
Asphalt Binder	4 – 7

30% by weight of the bitumen (asphalt binder) in the mix shall be replaced with pelletized elemental sulfur. The maximum mixing temperature for sulfur extended asphalt mixtures is 140°C.

Exception:

Sulfur extended asphalt is not required for maintenance work within plant areas and maintenance work that includes handwork.

Commentary Note:

Mix design procedure for Sulfur Extended Asphalt is contained in Saudi Aramco Best Practice SABP-Q-010.

When tested according to the Marshall Method, the bituminous mixture shall conform to the following requirements:

	Base Course	Wearing Course
Flow (mm)	2.4 –5.0	2.4 –4.0
Stability (kg)	700 min	700 min
Loss of Marshall stability by Submerging specimens in water at 60°C for 24 hrs as compared to stability measured in accordance with ASTM D1559	25% max	25% max
Voids in total mix (percent)	3.0 – 7.0	3.0 – 5.0
Voids filled with Bitumen (percent)	60-75	70-80
Voids in mineral aggregate (VMA) (percent) ASTM D2041	Class A 13% min Class B 12% min	Class A 14% min Class B 15% min Class C 16% min

A compaction effort of 75 blows per ASTM D1559 shall be used for the mix design of all roads and parking areas. Bulk specific gravity of bituminous mixtures shall be in accordance with ASTM D2726.

Maximum Variation: Upon receiving the job-mix formula, approved by Saudi Aramco Representative, the contractor shall adjust his plant to proportion the individual aggregate, mineral filler and asphalt to produce a final mix that, when compared to the job mix formula shall be within the following limits:

	Tolerance	
Materials Sieve Size	**Base Course**	**Wearing Course**
Larger than ½ inch	± 6.0%	± 6.0%
½ inch	± 5.0%	± 6.0%
No. 4 and 3/8 inch	± 5.0%	± 5.0%
No. 10 to retained on the No. 80	± 4.0%	± 4.0%
No. 80	± 3.0%	± 3.0%
No. 200	± 1.5%	± 1.5%
Asphalt content	± 0.4%	± 0.4%

If, during production, the properties or gradation of the aggregates alter, the mix shall be redesigned and the plant readjusted.

5.5.3 Placement of Hot Mix Asphalt Concrete

A. *Weather and Temperature Limitation:* Temperature of sulfur extended asphalt mixtures shall be between 140 and 130°C when it leaves the plant. The hot mix asphalt concrete material will not be accepted unless it is covered with tarpaulins until unloaded, and unless it has a temperature of at least 115°C at the time of spreading and compaction.

Temperature of mixtures without sulfur shall be between 139°C and 163°C when it leaves the plant and at least 139°C at the time of spreading and compaction at the site.

The hot mix asphalt concrete shall be placed only when the atmospheric temperature is 4°C or above, and when the weather is not foggy or rainy and when the existing surface is free from moisture.

B. *Placement, Compaction and Thickness:* Existing pavement shall be saw-cut and tacked, and the base course shall be primed prior to placing new hot mix asphalt. Steel skid equipment shall not be used for placing hot mix asphalt until after the first layer is placed. Bituminous mixture shall be spread in a placement thickness so that after rolling, the nominal thickness of the compacted bituminous material shall not be more than 70 mm per layer. Approval may be given by the Saudi Aramco Representative to greater than 70 mm thick layers, if the contractor can prove that he can achieve the requirements by field trials, using the compacting equipment and rolling patterns that he intends to use. Trials strips shall be performed at the actual project site, and shall be removed at the Contractor expense, if the requirements were not achieved. Approval of the trial strips does not relieve the contractor from his responsibilities to meet the specifications during the actual work implementation. The compaction requirements shall be equal to or greater than 96% of the Marshall density per ASTM D1559, using material sampled at the road site. All compaction shall be completed before the temperature of the mixture drops below 90°C. The finished surface shall be free of open-textured areas of asphalt.

C. In no case shall thin layers of fine materials be added to the top of the wearing course in order to achieve the required thickness or specified tolerances.

D. Areas of asphalt which fail to meet the required tolerances / compaction shall be removed by saw cutting to the full depth of the wearing course and base course, forming parallel and perpendicular

lines to the architectural features where practical. The area for repair shall then receive an additional prime coat prior to placing asphalt materials.

E. *Protection:* Protect newly placed sections from traffic by barricades or other suitable method. After final rolling, do not permit vehicular traffic on asphalt concrete pavement until it has hardened properly.

F. Asphalt pavement shall not be in contact with pipelines that are cathodicaly protected.

5.5.4 Quality Control

All the construction and batch plants equipment requirements shall be in accordance with MOT, Section 1.08. In addition to this section the Batch Plant shall maintain a Quality Control Program which includes the following materials tests and frequencies. Tests for Saudi Aramco acceptance purposes shall be performed by a Saudi Aramco-approved independent testing lab.

1) Materials

Penetration of Asphalt Binder	1/week or 1/lot
Gradation of Fine and Coarse Aggregates	1/day or 1/lot
Specific Gravity of Aggregates	1/week
Resistance to Abrasion (LA)	1/month
Magnesium Sulphate soundness	1/month
Sand equivalent	1/month
Plasticity Index	1/month
Flat or elongated particles by weight	1/month

2) Uncompacted Asphalt Concrete

Samples for extraction, gradation and Marshall properties shall be taken daily at the following rates of production:

	Extraction/Grading	Marshall Properties
0 to 500 tons	1/200 tons	1/250 tons
501 to 800 tons	1/250 tons	1/300 tons
801 and above tons	1/300 tons	1/400 tons

3) Compacted Asphalt Concrete

Cores for density and thickness shall be taken daily from previous days production. Each core shall be legibly and permanently marked as to the location from which the core was taken, and shall be at the following rates of production:

0 to 4,000 m²	**1/600 m²**
4,000 to 20,000 m²	1/900 m²
20,000 and above m²	1/1200 m²

Core holes shall be filled with asphalt concrete material and compacted as soon as possible.

Commentary Note:

Asphalt concrete similar to the original material is recommended for filling the core holes to ensure good bonding with the existing pavement and avoid early development of potholes.

4) Equipment

All weighing scales for mineral aggregates and bitumen shall be calibrated and certified within the 6-month period before use by one of Saudi Aramco approved calibration agencies.

All temperature gauges and thermometers shall be calibrated and certified two times a year by one of Saudi Aramco approved calibration agencies.

All laboratory scales and balances, including drying ovens, shall be calibrated and certified two times a year by a Saudi Aramco approved agency.

5) Plant QC Equipment

The Batch Plant shall maintain a QC laboratory capable of performing the following basic tests:

- Gradation of fine and coarse aggregate
- Specific gravity of aggregate
- Sand Equivalent
- Plasticity Index

- Flat or elongated particles by weight
- Asphalt extraction and gradation

The Contractor's or Supplier's laboratory must provide upon request, the results of all Quality Control (QC) tests on materials and asphalt mixtures to the Saudi Aramco Representative. Saudi Aramco Representative shall be given full access to the testing laboratory facilities, the asphalt batch plant, and the job site for his inspection. All testing and production records shall be made available upon request.

The QC laboratory personnel shall comply to all reasonable requests and suggestions offered by Saudi Aramco Representative concerning test methods and testing frequency.

6) Remote Locations

In remote areas, where it is proven and verified by SAPMT and Inspection Department that a batch plant that is in full compliance with this standard is not available, an existing batch plant will be allowed with the following conditions:

A) The final product shall satisfy all requirements of this Standard.

B) Quality control shall be maintained at the batch plant and the construction site. A Saudi Aramco Approved Independent Laboratory shall be utilized to perform the required tests when there are no laboratory facilities at the batch plant.

C) The batch plant shall comply with AASHTO M156.

Commentary Note:

For road reconstruction jobs such as electrical, instrumentation, communication duct banks and pipeline road crossings, and for patching/maintenance jobs where small tonnage is required and where handwork is involved, batch plant approval is not required as long as the requirements of Paragraph 5.5.4(6)(A) are complied with.

7) Tolerances

A. *Surface Tolerance:* The surface will be tested with a four (4) meter straightedge at selected locations. The variation of the surface from the testing edge of the straightedge between any two (2) contacts with the surface shall at no point exceed four

(4) millimeters when placed on or parallel to the centerline or three (3) millimeters when placed perpendicular to the centerline of the roadway. All humps and depressions exceeding the specified tolerance shall be corrected by removing the defective work and replacing it with new material as directed by the Saudi Aramco Representative.

B. *Tolerance in Thickness:* Measurement of any core shall not be deficient by more than 10 mm or fifteen (15) percent of the design thickness whichever is less.

5.6 Polymer-Modified Hot Mix Asphalt Concrete

Commentary Note:

Sulfur extended hot mix asphalt is to be used whenever possible. Where sulfur extended asphalt paving is not used, polymer-modified hot mix asphalt concrete may be used as an option to standard non-modified hot mix asphalt concrete.

5.6.1 Material

5.6.1.1 The asphalt cement shall be modified by mixing SBS (Styrene-Butadiene-Styrene) polymer to meet the following requirements:

Property	Requirement	AASHTO	ASTM
Penetration @ 25°C	75 to 80	T49	D5
Ductility @ 25°C, cm	100 Min.	T51	D113
Ductility @ 15°C, cm	75 Min.	T51	D113
Softening point (R&B)	above 85°C	T53	D36
Dynamic Viscosity, 150°C	640 m Pa.S		D4402
Elastic Recovery	95%		

Other types of polymers may be mixed with the asphalt cement to produce a polymer-modified asphalt meeting the above requirements as approved and directed by the Company Representative.

5.6.1.2 The asphalt cement and all other materials and aggregates shall be as specified in paragraph 5.5.1.

5.6.2 Job Mix

The job mix formula shall conform to the requirements and maximum variation in paragraph 5.5.2.

5.6.3 Storage and Mixing of Polymer-Modified Asphalt

Polymer-modified asphalt shall be stored in a tank that has either mechanical agitation system or a circulation system in order to homogenize the binder prior to its use for the production of the bituminous mix. The mixing temperature for the binder shall be 170 +5°C. There are no other precautions needed for preparing mixes with the modified asphalt.

5.6.4 Placement and Quality Control

Placement, compaction, quality control and tolerances of polymer-modified hot mix asphalt concrete shall be as required in paragraphs 5.5.3 and 5.5.4 with the following exceptions:

Exceptions:

A. The polymer modified asphalt mix shall placed and compacted at a temperature determined from the viscosity-temperature relationship which is estimated to be in the range of 155 to 165°C.

B. The equipment for the compaction shall be the same as used to compact conventional mixes. The vibratory rollers are needed for thicker lifts whereas heavy tandem rollers can be used for the wearing course as break down rolling followed be pneumatic tire rollers. Aggressive rolling is needed as the viscosity of polymer binder rises sharply as compared to conventional mixes.

5.7 Joint Construction

5.7.1 Each asphalt paving layer shall be placed as continuously as possible to keep the number of joints between old and new pavements, between successive day's work, or when the mixture has become cold (less than 90°C) to a minimum.

5.7.2 Joints shall be made in such a manner as to create a continuous bond between the old and new pavement construction courses.

5.7.3 When the pavement construction involves two or more courses, successive courses shall be offset by at least 150 mm.

5.7.4 If the placing of material is discontinued or if material in place becomes cold (less than 90°C), a joint running perpendicular to the direction traveled by the paver shall be made. Before placement continues, the edge of the previously placed pavement shall be trimmed to a straight line perpendicular to the paver and cut back to expose an even vertical surface for the full thickness of the course. When placement continues,

the paver shall be positioned on the transverse joint so that sufficient hot mixture will be spread to create a joint after rolling that conforms to the required smoothness.

5.7.5 Joints that are not completed before the previously laid mixture has cooled to a temperature of 60°C shall be coated with liquid asphalt just before paving is continued.

6 Pavement Reconstruction after Trenching

6.1 Pavement reconstruction after trenching shall follow the following procedure.

6.1.1 Bedding, protection and minimum cover for pipelines and utilities shall be in accordance with SAES-L-450, SAES-L-460, SAES-P-104, SAES-S-070, SAES-T-624, SAES-T-911, SAES-T-928, and GI-1021.000.

6.1.2 Backfill material above the bedding/annulus material shall meet the requirements of SAES-A-114. Backfill materials shall be placed in lifts not exceeding 100 mm (4 in) in loose depth for hand-operated compaction. For larger compaction equipment, backfill material placed in lifts not exceeding 200 mm (8 in) in loose depth may be approved by the Saudi Aramco Representative based on a field test section using the intended compaction equipment.

6.1.3 Compaction requirements shall be as follows:

6.1.3.1 Within 0.6 m (2 ft) of the bottom elevation of the road base material, backfill shall be compacted to at least 95% of the maximum density as determined by ASTM D1557 for cohesive materials or 85% relative density for cohesionless soils as determined by ASTM D4253 and ASTM D4254.

6.1.3.2 Below 0.6 m (2 ft) of the bottom elevation of the road base material, backfill shall be compacted as follows:

6.1.3.2.1 Where the trench has been constructed through rock, backfill shall be compacted to at least 95% of the maximum density as determined by ASTM D1557 for cohesive materials or 85% relative density for cohesionless soils.

6.1.3.2.2 Where the trench has been constructed through soils (sand/marl/subkha), backfill shall be compacted to at least 90% of the maximum density as determined

by ASTM D1557 or 70% relative density for cohesionless soils.

6.1.3.3 Sand bedding/annulus materials shall be compacted to 70% relative density.

6.1.4 Base course reconstruction shall consist of the following:

6.1.4.1 Pavement and base course shall be removed to a width 375 mm or one-half the trench width, whichever is greater but limited to a maximum of 500mm, from the edge of the trench.
The excavation shall remove the base course to full depth.

6.1.4.2 One layer of bi-axial geogrid with a minimum tensile strength at 2% strain of 10 kN/m and a maximum longitudinal aperture size of 40 mm shall be placed at the sub-base or natural soil/aggregate base course interface. The geogrid shall extend to a width of 375 mm or one-half the trench width, whichever is greater, beyond both edges of the trench. Adjacent sheets of geogrid should include a 300 mm overlap.

6.1.4.3 Aggregate base material Class A or Class B shall be placed and compacted as described in paragraphs 5.2.2.1 and 5.2.2.2.

6.1.5 Asphalt concrete reconstruction shall consist of the following:

6.1.5.1 The base shall be primed and the edges of the existing pavement shall be tacked in accordance with paragraph 5.4.

6.1.5.2 Asphalt concrete materials and mix design shall be in accordance with paragraphs 5.5.1 and 5.5.2 or 5.6.

Asphalt concrete shall be placed in a minimum two lifts and compacted in accordance with paragraph 5.5.3 to a thickness equivalent to the original pavement or 100 mm, whichever is greater. Lift thicknesses may be decreased to a minimum of 25 mm if required to achieve compaction.

Revision Summary

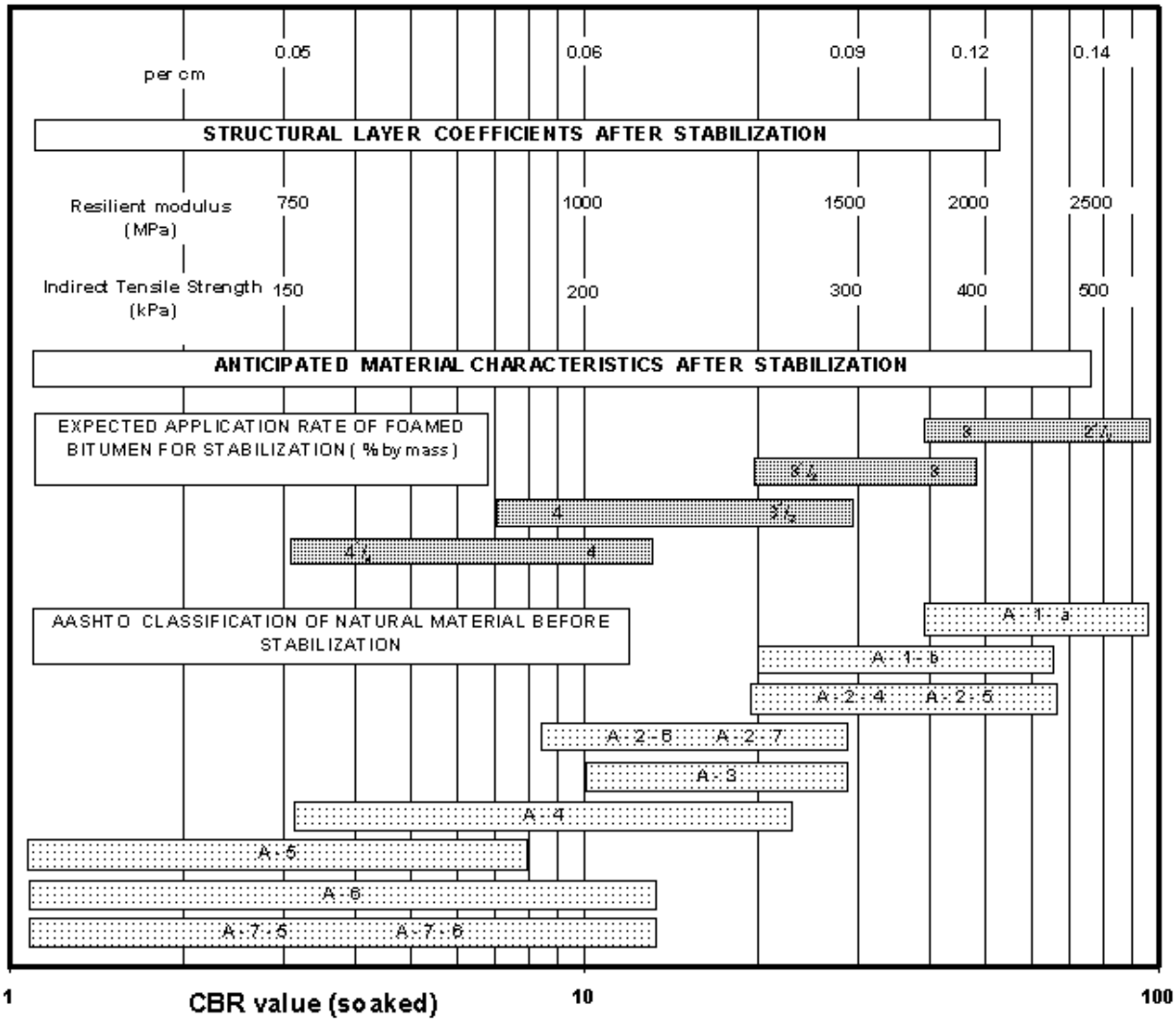
23 February 2011	Major revision.
26 November 2012	Editorial revision.

Appendix – Foamed Asphalt Stabilized Bases

A.1 Design

A.1.1 Structural layer coefficients for foamed asphalt stabilized bases are shown in Table A.1

Table A.1 – Structural Layer Coefficients for Foamed Asphalt Stabilized Material



Notes:

1. Structural layer coefficients for foamed asphalt stabilized bases shall be estimated from the material classification or CBR value. Structural layer coefficients used in design shall be verified by Indirect Tensile Strength (ITS) or Resilient Modulus values that have been determined from a mix design procedure.
2. Soaked ITS or Resilient Modulus values shall be used except as noted below.

3. Where the mean annual rainfall is less than 100 mm and the phreatic surface will not encroach to within 1000 mm of the foamed asphalt stabilized base, the soaked ITS test may be omitted and the design foamed bitumen content determined using only dry ITS values.

A.1.2 If a detailed design is not performed, the minimum pavement thickness may be taken from Table A.2. Table A.2 assumes minimum subgrade/subbase CBR requirements are met.

Table A.2 – Pavements Including Foamed Asphalt Stabilized Base Course

Pavement Category	Minimum Thickness of Foamed Asphalt Stabilized Base CM	Thickness of Asphalt Wearing Course CM
Residential Streets	10	4
Access Roadways	15	4
Main Highways	Traffic Count Required	
Parking and Storage Lots Sedans and Small Trucks	12.5	4
Parking and Storage Lots Heavy Traffic (Truck Terminals, etc.)	20	4
Plant Areas, including all roads and all paved areas within the Plant fence Occasional Heavy Loads	20	4

A.2 Specification for Foamed Asphalt Stabilized Bases

A.2.1 Materials

A.2.1.1 Stabilizing Agents

Asphalt for foaming shall be petroleum asphalt cement, penetration grade 60-70, conforming to Saudi Aramco (Ras Tanura Refinery) Product Specification A-970.

Cement shall be Ordinary Portland Cement (Type I) or Sulfate Resistant Cement (Type V), conforming to ASTM C150.

Hydrated lime shall be a slaked road lime conforming to ASTM C5.

A.2.1.2 Material to be stabilized

The material to be stabilized should as a minimum requirement satisfy the standard of Class B Subbase material, as described under

paragraph 5.2.1 above, or as specified by the Saudi Aramco Representative for the particular project.

All materials with a Placticity Index (PI) in excess of 16 shall be pretreated with hydrated lime at a nominal application rate of 3% (by weight). Hydrated lime shall be added to material with a PI in excess of 10 but less than or equal to 16 at a nominal application rate of 1.5% (by weight). Cement shall be added to all other materials at a nominal application rate of 1% (by mass).

Where required, non-plastic fine material shall be added to increase the percentage passing the 0.075 mm sieve to achieve a minimum of 5%.

A.2.2 Job Mix

Prior to construction, a mix design shall be presented to the Saudi Aramco Representative for approval for each different type of material that is to be stabilized with foamed asphalt. The mix design procedure shall be in accordance with "Foamed Asphalt Mixes – Mix Design Procedure" Center for Scientific and Industrial Research (CSIR), Transportek Contract Report CR-98/077.

A.2.3 Construction

The material to be stabilized shall either be spread as a uniform layer on top of the completed subbase, or shall be a portion of the completed subbase layer. This material shall be compacted to a density of at least 95% of the maximum dry density (as per AASHTO T180) and shall be graded to the final surface line and level requirements as defined in paragraph 5.1 above prior to stabilizing.

A.2.3.1 Stabilization

Weather and Temperature Limitations. Asphalt for foaming shall be supplied at a temperature not less than 175°C and not more than 200°C. Stabilizing work shall be undertaken only when the ambient temperature is above 15°C.

A.2.3.2 Stabilizing Equipment

i. The stabilizing equipment shall be designed and operated in such a manner as to stabilize the in-situ material to the specified depth and to construct a new base layer in a single pass. The stabilizing train shall consist of a recycling unit, an asphalt cement tanker and a water tanker (or cement slurry mixer, where required).

ii. The recycling unit shall, as a minimum, should have the following features:

iii. A minimum power capability of 600 HP.

iv. A mixing chamber of adequate size for the depth of the cut. The effective volume of the mixing chamber shall increase in relation to the depth of cut in order to accommodate additional material generated by increasing the depth of cut;

v. Two independent pumping systems and spray bars.

vi. Nozzles on each of the two spray bars at a maximum spacing of one nozzle per 160 mm width of chamber.

vii. An inspection (or test) nozzle fitted at one end of the spraybar that produces a representative sample of foamed asphalt.

viii. Computer-controlled systems to regulate the application of foamed asphalt stabilizing agent separate from water and/or slurried cement stabilizing agent, in relation to the forward speed and mass of the material being mixed.

ix An electrical heating system that is capable of maintaining the temperature of all asphalt cement flow components above 150°C.

x A single asphalt cement feed pipe between the stabilizer and the supply tanker. Circulating systems that incorporate a return pipe to the supply tanker shall not be used.

A.2.3.3 Mixing and Placing

The stabilizing train shall be set up and operated to ensure the following key requirements are met:

i. Grading of the mixed material

The forward speed of the recycling unit, rate of rotation of the milling drum and the positioning of the gradation control beam shall be set so that the in-situ subbase material is broken down to a grading that satisfies the requirements of Class B subbase described paragraph 5.2.1, Table 6.

ii. Addition of water/cement slurry and foamed asphalt stabilizing agent

The control system for the addition of water (or cement slurry where required) and foamed asphalt shall be set and carefully

monitored to ensure compliance with the requirements for compaction moisture and stabilizer content, as determined for the mix design, paragraph A.2.2.

Moisture content of the in-situ materials shall be tested not more than one week in advance of the asphalt foaming operation. A minimum of one line of samples shall be taken at 2.0 meter intervals across the road width for every 500 meters linear length, and where there is a known change in materials. Checks shall be conducted when wet weather occurs between the initial testing and work commencing.

iii. Control of cut thickness

The actual depth of cut shall be physically measured at both ends of the milling drum at least once every 100 m along the cut length.

iv. Overlap on longitudinal joints

Longitudinal joints between successive cuts shall overlap by a minimum of 50 mm to ensure complete mixing across the full width of the road.

v. Continuity of the stabilized layer

The next successive cut shall be started at least 500mm behind the previous cut to ensure continuity of the stabilized layer. There shall be no untreated material left between successive adjacent cuts nor shall any wedges of untreated material remain behind the entry point of the milling drum.

A.2.3.4 Compaction

Immediately after mixing, the stabilized material shall be compacted to 98% of the maximum dry density (as per AASHTO T180) for the full depth of the layer. Single smooth-drum or padfoot vibrating rollers with dual amplitude / frequency vibration capabilities shall be employed to effect the compaction.

Rolling shall be effected first in high-amplitude vibration mode until the lower part of the layer has been compacted, thereafter in low-amplitude mode to compact the upper part. The surface shall only be cut by grader after the high-amplitude vibration compaction has been completed and before applying the low-amplitude vibrating compaction.

A.2.3.5 Finishing

The surface of the compacted material shall be graded by skimming with a motor grader and rolled with smooth-drum and pneumatic-tired rollers accompanied by a water tanker applying a light spray of water. Such rolling shall continue until a tightly-knit surface texture has been achieved. The skimmed material shall be bladed off the road. No thin layers of fine material shall be added to the top of the layer of the foamed asphalt stabilized base course to achieve the required thickness or specified tolerances.

A.2.4 Quality Control

The contractor shall maintain a quality control program and provide the necessary competent staff and equipment to ensure adequate supervision and positive control of the works at all times. The quality control program shall include the following material tests at the stated frequencies.

A.2.4.1 Materials (sampling frequencies)

i. Asphalt cement. Penetration of asphalt cement as determined by ASTM D5 for every 20 tons or bulk tanker load.

ii. Cement. Mill certificate. In the absence of a mill certificate, quality tests as per ASTM C150 for every 20 tons.

iii. Hydrated lime. Data sheet or mill certificate. In the absence of a data sheet or mill certificate, quality tests as per ASTM C5 for every 20 tons.

A.2.4.2 Compaction control

One in-place density shall be conducted every 100 linear meters laid. Densities and moisture content shall be measured by ASTM D1556 (the sand cone method). ASTM D2922 (nuclear gauge) shall only be used where suitable adjustments are made to compensate for the presence of asphalt in the mixture.

A.2.4.3 Width of stabilized layer

The overall surface width of the stabilized layer shall be measured every 100 linear meters laid. The surface width shall not be less than that specified and shall not deviate from the horizontal alignment by more than 150 mm.

A.2.4.4 Surface regularity and thickness of stabilized layer

The surface of the completed base shall be measured every 100 linear meters. The surface shall not show any deviation in excess of 6 mm when tested with a 3 meter straightedge. The completed thickness of the base shall be within ± 6 mm of the thickness indicated, and the average thickness shall not be less than the design thickness.

A.2.4.5 Quality of stabilizing process

One 20 kg sample of mixed material shall by taken at random locations from behind the stabilizing train for each 2500 m² of surface area stabilized.

Each sample shall be sealed to retain the field moisture. Six Marshall plugs shall be made from each sample to determine the indirect tensile strength (ITS).

Three plugs shall be tested to determine the dry ITS for each sample. Where relevant, the soaked ITS shall be determined using the remaining three plugs. The average dry (and soaked, where relevant) ITS shall not be less than 85% of the ITS determined by the laboratory mix design procedure (paragraph A.2.2) for the stabilized material.

The moisture content of the material shall be adjusted in the laboratory to 70% of the optimum moisture content before manufacturing the plugs.