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FEDERAL HIGHWAY ADMINISTRATION

Long-Term Pavement Performance Division

SPECIFIC PAVEMENT STUDIES
CONSTRUCTION GUIDELINES FOR EXPERIMENT SPS-1
STRATEGIC STUDY OF STRUCTURAL FACTORS FOR FLEXIBLE PAVEMENTS

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INTRODUCTION

This report describes the guidelines for the construction of test sections for the Specific Pavement Studies' SPS-1 experiment, Strategic Study of Structural Factors for Flexible Pavements. These guidelines were originally developed by the Strategic Highway Research Program (SHRP) in cooperation with state and provincial highway agency personnel participating in various meetings, including a construction guidelines review meeting held in Atlanta, Georgia, September 10-12, 1990. The recommendations of the participants and comments by other highway agency personnel were incorporated in the guidelines. These guidelines will help participating highway agencies develop acceptable construction plans for test sections for this experiment. This revised report is a product of several years experience of the RCOC staffs and participating agencies in developing contract documents for constructing SPS experiment sites. The revisions incorporate the recommendations of the SPS-1 and SPS-2 Construction Guidelines Workshop held in St. Paul Minnesota, April 1993.

The SPS-1 experiment, Strategic Study of Structural Factors for Flexible Pavements, requires the construction of multiple test sections with similar design details and materials at each of sixteen sites distributed in the four climatic regions. The experimental design and construction considerations for this experiment are described in the SHRP document, "Specific Pavement Studies: Experimental Design and Research Plan for Experiment SPS-1, Strategic Study of Structural Factors for Flexible Pavements," February 1990. The SPS-1 experiment has been developed as a coordinated national experiment to address the needs of the highway community at large. Therefore, it is important to control construction uniformity at all test sites to reduce the influence of construction variability on test results. Consequently, the construction guidelines outlined in this report must be followed by all participating highway agencies to accomplish the desired objectives of the experiment.

OBJECTIVE

The objective of this document is to provide guidelines for preparing and constructing SPS-1 test sections to maximize uniformity of these procedures across all projects. More specifically, the objectives are:

To review the major construction features of the different test sections.

- To describe the details of the different experimental levels of the test sections.
- To provide specifications for subgrade preparation, base course materials, permeable drainage layers, filter fabrics, and asphalt concrete used in the experiment.
- To provide specifications on typical cross section design, details of the drainage system, pavement layers, and shoulders.
- To describe the general construction operations and as-built requirements.

It is strongly recommended that direct discussions between the RCOC, the participating agency, and contractor(s) be held periodically throughout the preconstruction and construction phases of the project. This interaction is critically important for developing the necessary understanding, by the participants, of the objectives of the experiment and the need for cooperation in adhering as much as possible to the requirements outlined in this report. It is suggested that RCOC attendance and limited participation is needed in the pre-bid conference, pre-construction conferences and such other coordination activities as are scheduled by the agency.

EXPERIMENTAL DESIGN

The combinations of experimental factors, project sites and test sections for SPS-1 are illustrated in the experimental design shown in Table 1. The pavement structure factor levels shown along the left side of Table 1 result in 24 different pavement structures. The experiment design calls for 12 test sections to be constructed at each project site. With two projects located within each combination of moisture, temperature, and subgrade, a total of 16 projects are required.

Each column in Table 1 is designated with a letter code (J-Y) to differentiate between project sites. Pavement test sections are assigned a two digit test section number. The test sections are numbered consecutively at each test site (either 01 through 12 or 13 through 24). It should be noted that the test sections do not have to be constructed in the sequence of the test section numbers. The numbering scheme is used to provide a unique number for each type of section in the experiment and to help identify the data pertaining to each section.

Each participating agency must construct at least one of the sets of test sections specified with a letter code (J through Y) in Table 1. FHWA-LTPP Division will consult with and advise the participating highway agency of the specific experimental set that should be built to best satisfy the requirements of the experiment.

Table 1. Experiment design

PAVEMENT STRUCTURE COMBINATIONS				FACTORS FOR MOISTURE, TEMPERATURE, SUBGRADE TYPE, AND LOCATION															
				WET								DRY							
				Freeze				No Freeze				Freeze				No Freeze			
				Fine		Coarse		Fine		Coarse		Fine		Coarse		Fine		Coarse	
Drainage	Base Type	Total Base Thick	Surface Thick	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
NO	DGAB	8"	4"		K13		M13		O13		Q13		S13		U13		W13		Y13
			7"	J1		L1		N1		P1		R1		T1		V1		X1	
		12"	4"	J2		L2		N2		P2		R2		T2		V2		X2	
			7"		K14		M14		O14		Q14		S14		U14		W14		Y14
	ATB	8"	4"	J3		L3		N3		P3		R3		T3		V3		X3	
			7"		K15		M15		O15		Q15		S15		U15		W15		Y15
		12"	4"		K16		M16		O16		Q16		S16		U16		W16		Y16
			7"	J4		L4		N4		P4		R4		T4		V4		X4	
	ATB / 4" DGAB	8"	4"	J5		L5		N5		P5		R5		T5		V5		X5	
			7"		K17		M17		O17		Q17		S17		U17		W17		Y17
		12"	4"		K18		M18		O18		Q18		S18		U18		W18		Y18
			7"	J6		L6		N6		P6		R6		T6		V6		X6	
YES	4" PATB / DGAB	8"	4"	J7		L7		N7		P7		R7		T7		V7		X7	
			7"		K19		M19		O19		Q19		S19		U19		W19		Y19
		12"	4"		K20		M20		O20		Q20		S20		U20		W20		Y20
			7"	J8		L8		N8		P8		R8		T8		V8		X8	
		16"	4"		K21		M21		O21		Q21		S21		U21		W21		Y21
			7"	J9		L9		N9		P9		R9		T9		V9		X9	
	ATB / 4" PATB	8"	4"		K22		M22		O22		Q22		S22		U22		W22		Y22
			7"	J10		L10		N10		P10		R10		T10		V10		X10	
		12"	4"	J11		L11		N11		P11		R11		T11		V11		X11	
			7"		K23		M23		O23		Q23		S23		U23		W23		Y23
		16"	4"	J12		L12		N12		P12		R12		T12		V12		X12	
			7"		K24		M24		O24		Q24		S24		U24		W24		Y24

BASE CODES:

DGAB -	Dense graded untreated aggregate base
ATB -	Dense graded asphalt cement treated base
PATB -	102 mm (4") thick open graded permeable asphalt cement treated drainage layer
4" DGAB -	102 mm (4") thick dense graded untreated aggregate base layer beneath asphalt treated base

SI conversion: 4" = 102 mm; 7" = 178 mm; 8" = 204 mm; 12" = 305 mm; 16" = 407 mm

Ideally, the two complemetary sites having the same soil-climate category (e.g. J, K or N, O) should be constructed in different states and/or provinces. However, it is acceptable that these two sites, i.e. all 24 test sections, may be constucted within the same project.

TEST SECTIONS

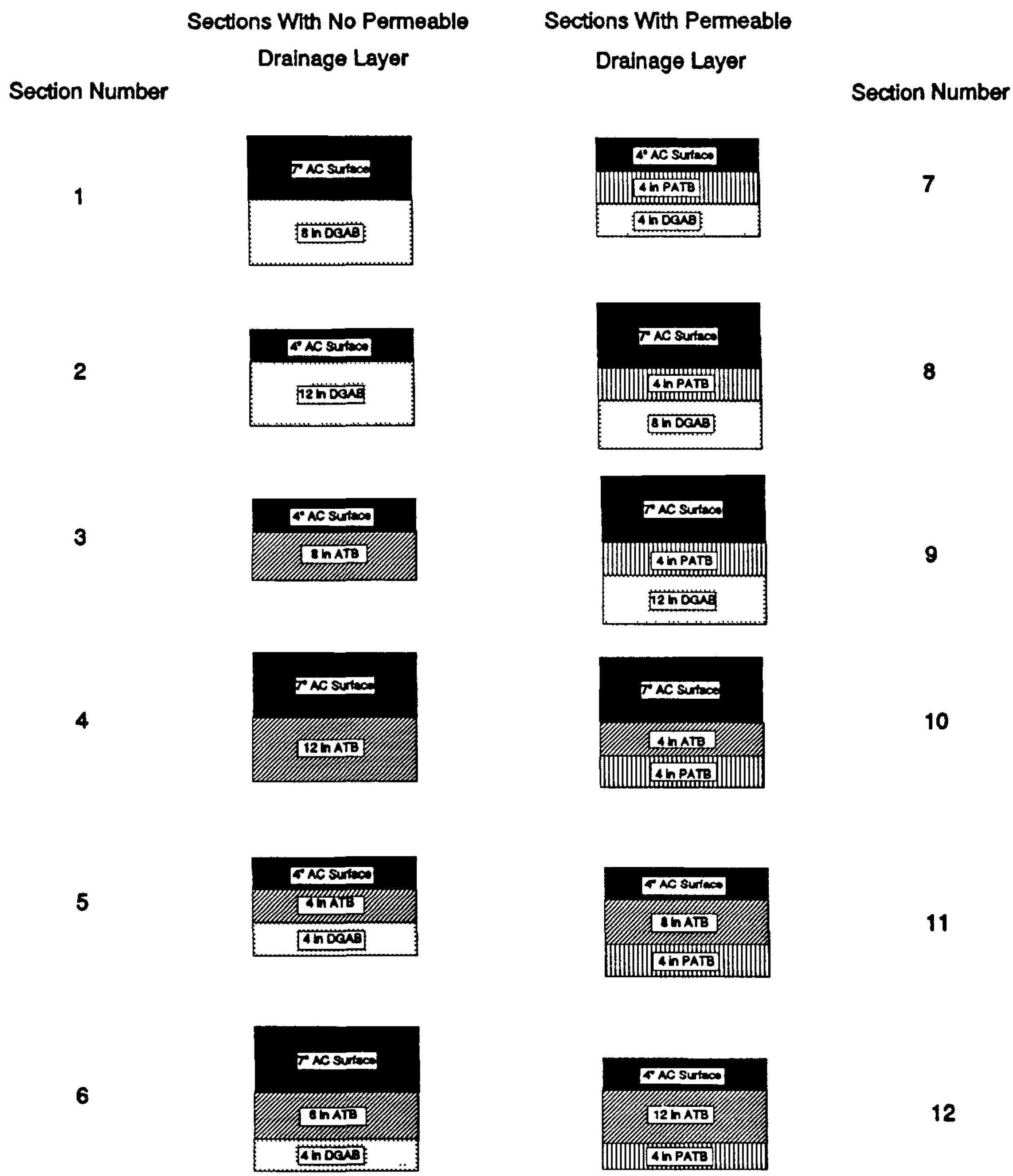
The combinations of pavement layer materials and thicknesses required for the different test sections are illustrated in Figures 1 and 2 for the two complementary sites required for each soil-climate combination.

Pavement cross sections for each test section are presented in Appendix A for illustrative purposes. The details of the cross-sections at a site may be altered within the limits provided in these guidelines to accommodate site-specific conditions.

Each test section must be constructed as uniformly as practical over a minimum length of 183 m (600 feet) (preferably 213 m (approximately 700 feet)) to allow 152.5 m (500 feet) for monitoring and at least 15.25 m (50 feet) at each end for post-construction material sampling. Figure 3 illustrates the suggested layout of a single test section within a project site.

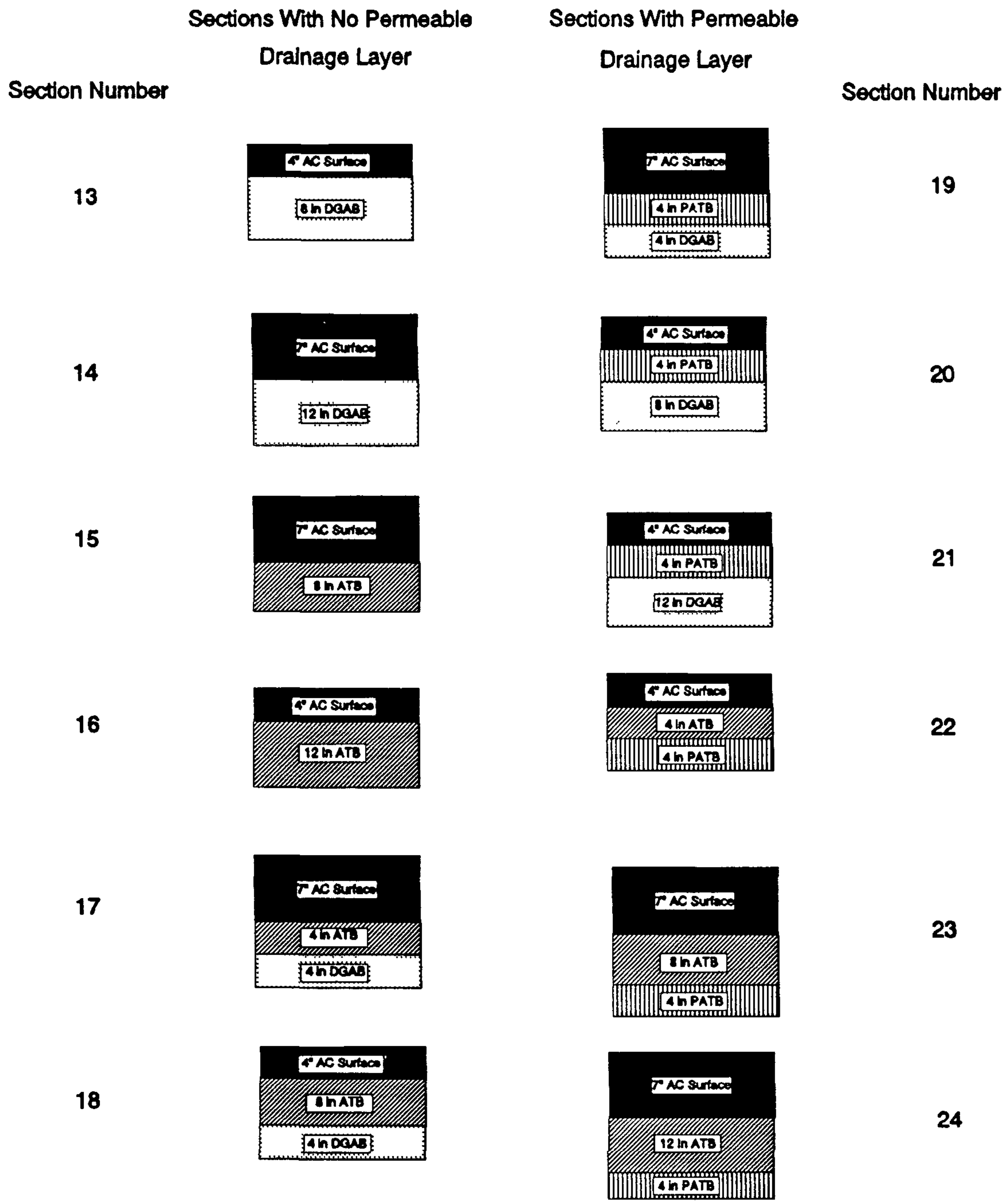
The sequence of the test sections at each site should be arranged to accommodate site-specific conditions and allow construction expediency. Items that should be considered in ordering the test sections at a particular project site include the following:

- Future rehabilitation needs - Placement of test sections with similar life expectancies adjacent to each other to facilitate future rehabilitation activities.
- Base material - Placement of test sections with similar base material adjacent to each other to minimize haul distances and to optimize plant runs of processed material.
- Drainage provisions - Placement of test sections with in-pavement drainage layers adjacent to each other to minimize transitions between drained and undrained pavement sections.
- Transitions - Placement of test sections with similar thicknesses or materials adjacent to each other to minimize the distance needed between sections to accommodate changes in thickness and material type. In addition, transitions should be long enough to accommodate resurfacing of failed sections while minimizing grade problems.



SI Conversion: 4" = 102 mm; 7" = 178 mm; 8" = 203 mm; 12" = 305 mm

Figure 1. Layer Combinations for Test Sections 1 Through 12



SI Conversion: 4" = 102 mm; 7" = 178 mm; 8" = 203 mm; 12" = 305 mm

Figure 2. Layer Combinations for Test Sections 13 Through 24

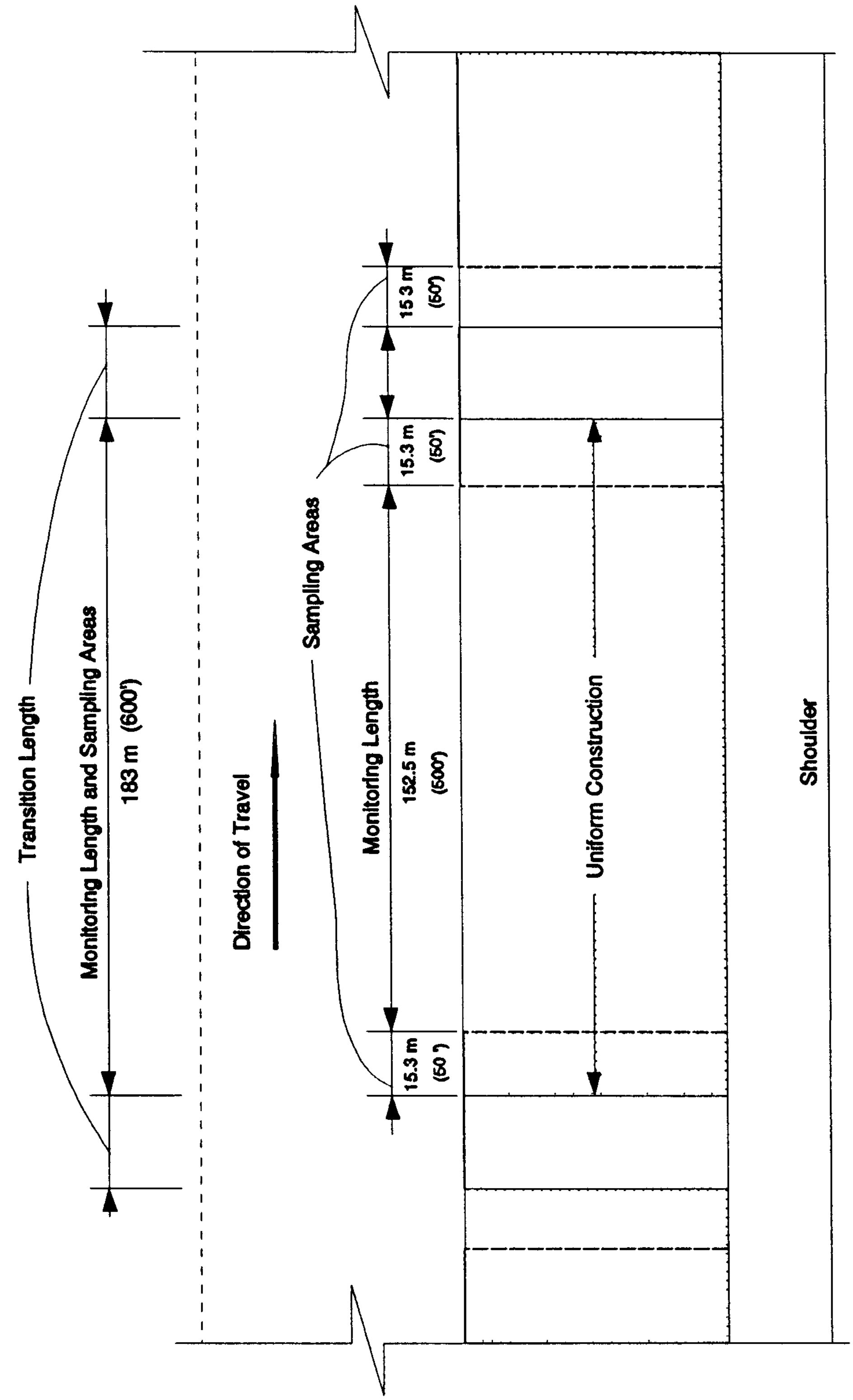


Figure 3. Suggested Test Section Layout

Figure 4 illustrates a test site layout in which test sections are ordered with consideration to life expectancy. In this layout, test sections with anticipated lowest expected life are located downstream. In addition, test sections with anticipated similar approximate life expectancy are ordered such that sections with similar base type materials and surface thicknesses are located adjacent to each other. As those test sections with lowest expected life are likely to deteriorate more rapidly than other test sections, their downstream location would reduce the potential influence of traffic on other test sections. Also, early rehabilitation of these sections, if required, should not affect the other test sections.

Figure 5 illustrates an alternative test site layout in which test sections are ordered with consideration to base material type, base structure and surface thicknesses. The intent is to minimize the number of transitions between base types. With this type of layout, plans should be made to facilitate early rehabilitation of those test sections with an expected short service life. For example, a 3.66 m (12 foot) inside shoulder may be constructed to allow traffic movement during rehabilitation construction. Also, distances between test sections for transition could be increased to allow for future overlay tapering. Design of transitions between test sections must consider changes in material types and thicknesses as well as differences in pavement drainage and longitudinal profile.

PREPARATION AND COMPACTION OF SUBGRADE

Ideally, the test sections should be located in shallow fills. However, if it is not possible to locate a test section in a shallow fill, then the entire length of a test section should be located in a cut or fill section. Also, cut-fill transitions or side hill fills should not be located within a test section. In addition, rock cut sections should be avoided unless all test sections are located within the cut.

Subgrade soils shall be prepared according to the following requirements:

- The subgrade soil shall be tested according to AASHTO T99, Method D to determine the moisture-density relationship.
- Fill material shall be compacted to a minimum of 95% of AASHTO T99 density for the top 305 mm (12 inches). Expansive soils shall be compacted to a minimum of 90% of AASHTO T99 for the top 305 mm (12 inches).
- Moisture content of the compacted subgrade soil should be in the range of 85% to 120% of the optimum moisture content.

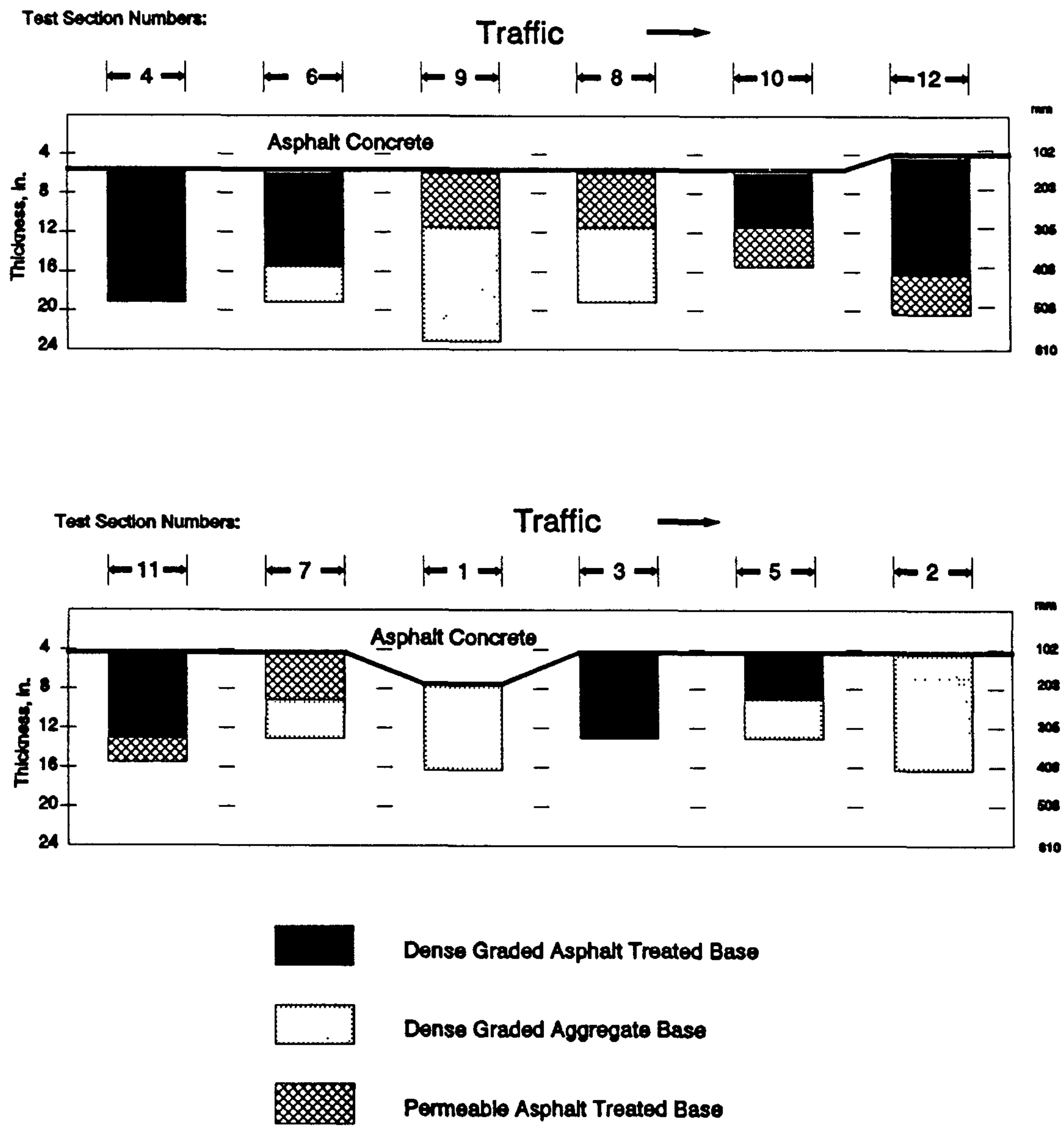


Figure 4. Test Section Ordering with Consideration to Service Life Expectancy

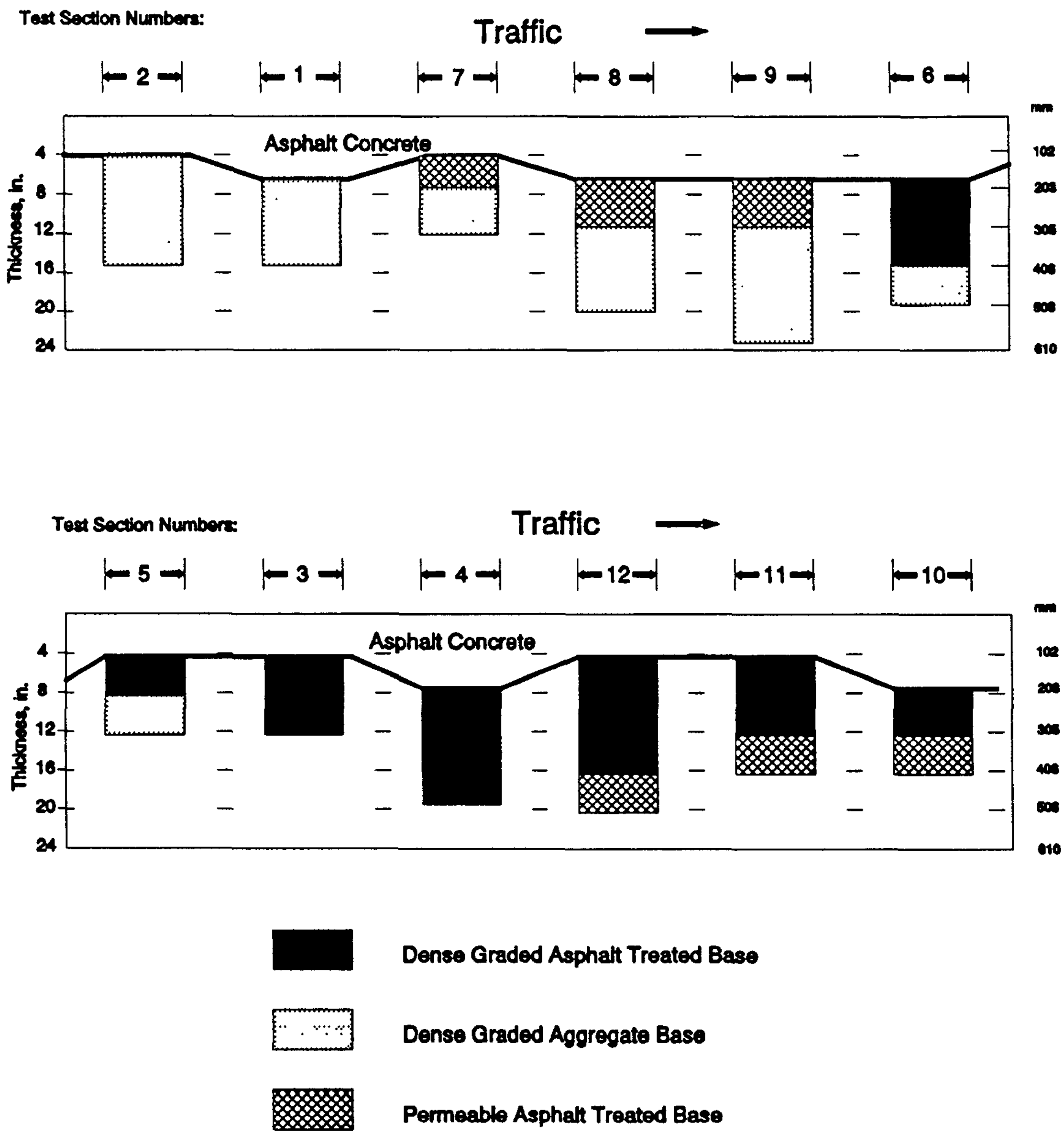


Figure 5. Test Section Ordering with Consideration to Base Material Type

- Sections built as part of a reconstruction project shall have the upper 305 mm (12 inches) of subgrade compacted to the appropriate specification.
- Subgrade shall be compacted for the width of the travel lanes plus the width of the inside and outside shoulders except where sections are built as part of reconstruction of an existing pavement. In this case, reconstruction must extend a minimum of 914 mm (3 feet) outside the edge of the travel lanes to allow proper preparation of the subgrade and base course.
- Where sections are constructed on newly placed fill material, the thickness of the fill should be as uniform as possible along the test section.
- Proof rolling should be performed to verify the uniformity of support and to identify unstable areas which might require remedial construction (undercutting and replacement). Geotextile reinforcement shall not be used to stabilize the subgrade.
- Surface irregularities shall not exceed 6 mm (1/4 inch) between two points longitudinally or transversely using a 3.05 m (10 foot) straightedge.
- Finished subgrade elevations shall not vary from design more than 12 mm (0.04 feet) based on a rod and level survey readings taken at a minimum of 5 locations (edge, outer wheel path, midlane, inner wheel path, and inside edge of lane) at longitudinal intervals no greater than 15.25 m (50 feet). Locations for survey measurements are illustrated in Figure 6.
- Modifiers, lime, portland cement etc., can be added to provide a stable working platform to facilitate construction. The use of modifiers shall be limited to materials and quantities which will alter the index properties of the subgrade (e.g. reduce the plasticity index) without unduly increasing the strength of the subgrade in the pavement structure. Working platforms consisting of thin asphalt concrete layers placed directly on subgrade are not permitted.

Note: The working platform is considered a pavement layer, therefore, sampling and testing, in addition to that required for the subgrade, must be planned and performed.

BASE LAYERS

Base materials included in this experiment are divided into two categories: undrained and drained base structures. The drained and undrained designations do not refer to external pavement drainage features such as cross-slope and ditches. Undrained base structures refer to relatively impermeable dense graded base layers consisting of dense graded aggregate base and/or asphalt treated base. The drained base structures refer to a

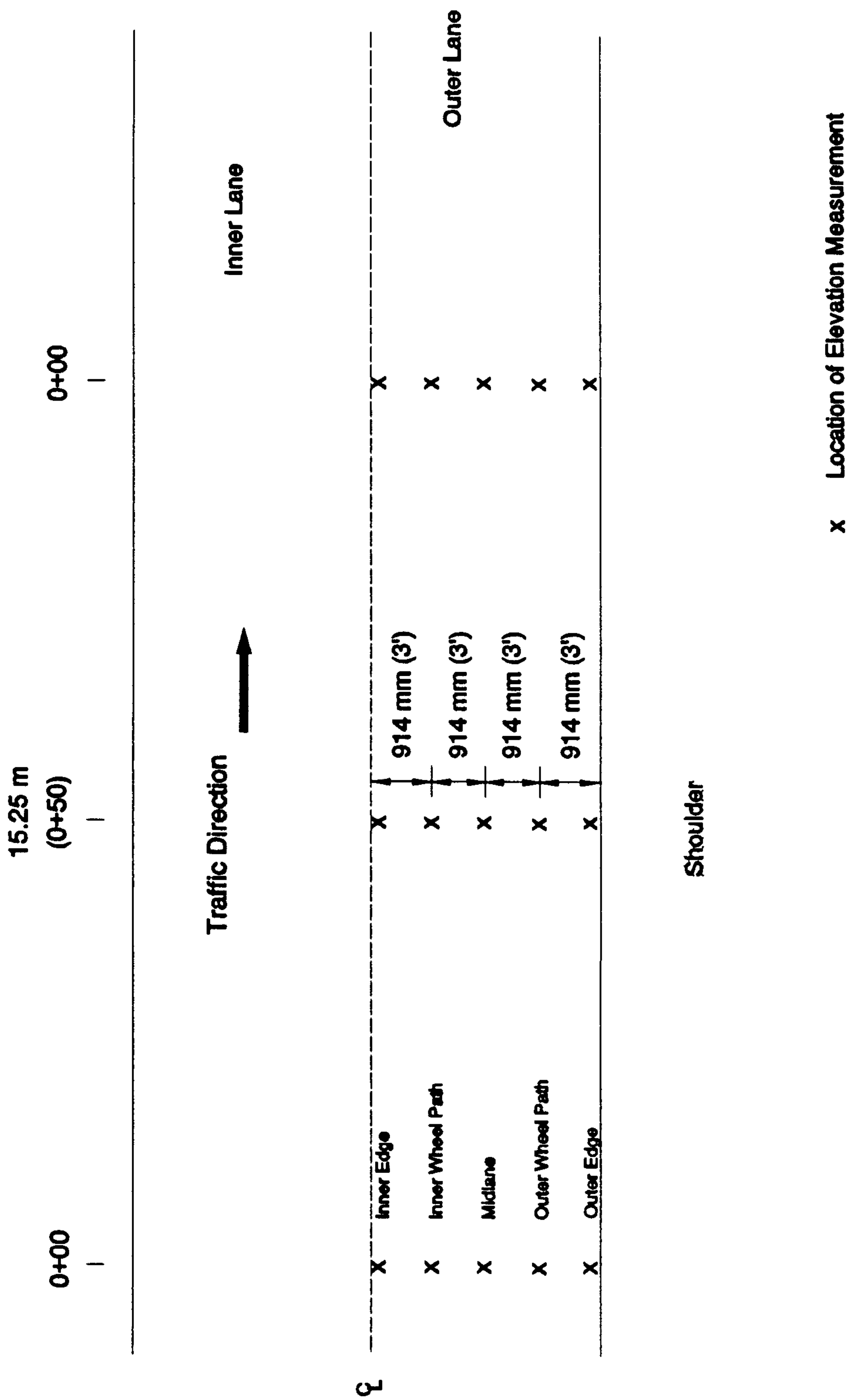


Figure 6. Elevation Measurement Locations

system which consists of a permeable asphalt treated base drainage layer and edge drains.

Undrained Base Structures

Test Sections 1 through 6 and 13 through 18 are constructed with undrained base structures that incorporate untreated dense graded aggregate bases. Filter fabrics and longitudinal edge drains shall not be used on these sections.

Dense Graded Aggregate Base

The dense graded aggregate base (DGAB) is an untreated, crushed material. Requirements and construction guidelines for this aggregate material are presented in the following sections.

Aggregate Requirements. The quality and gradation criteria for selection of the aggregate required in the construction in the dense graded aggregate base (DGAB) shall be as follows:

- The base material must consist of a high quality crushed stone, crushed gravel or crushed slag.
- The base aggregate shall consist of a minimum of 50% of material retained on the No. 4 sieve. Of the particles retained on the 8 mm (3/8 inch) sieve at least 75% shall have 2 or more fracture faces.
- A 38 mm (1.5 inch) top size aggregate is preferred, however, the maximum top size normally specified by the state agency, if less than 38 mm (1.5 inch), shall be used.
- The final aggregate mixture must be dense graded.
- The fraction passing No.200 sieve shall be less than 60% of the fraction passing the No. 30 sieve and not more than 10% of the total sample.
- The fraction passing No. 40 sieve shall have a liquid limit not greater than 25 and plasticity index not greater than 4.
- Aggregate tested with L.A. Abrasion which shows loss of more than 50% at 500 revolutions shall not be used.
- No additives, other than water, are allowed in the dense graded aggregate base.

Construction Requirements. The base course shall be prepared to grade according to the participating agency's practice and the following requirements:

- No segregation or degradation of materials should occur during laydown and compaction.
- Lift thickness must not be greater than 152 mm (6 inches) compacted.
- Maximum dry density and optimum moisture content shall be determined by AASHTO T180 method D.
- The DGAB course must be compacted to an average of not less than 95% of AASHTO T180 density.
- The DGAB shall be compacted for the width of the travel lanes plus the width of the inside and outside shoulders except in cases where sections are built as part of reconstruction of an existing pavement. In this case, reconstruction must extend a minimum of 914 mm (3 feet) outside the edge of the travel lanes to allow proper preparation of the subgrade and base course.
- In-place density for purposes of construction quality control shall be measured and recorded prior to application of an asphalt cement prime coat, if used.
- A low viscosity asphalt cement shall be used to prime the surface of the DGAB in test sections where permeable asphalt treated base is to be placed on the DGAB. Application and curing will be performed according to the techniques practiced by the agency. A prime coat may also be applied to the DGAB surface in other test sections.
- Surface irregularities shall not exceed 6 mm (1/4 inch) between two points longitudinally or transversely using a 3.05 m (10-foot) straightedge.
- Final DGAB elevations shall not vary from design more than 12 mm (0.04 feet) based on a rod and level survey conducted taking readings at a minimum of 5 locations (edge, outer wheel path, midlane, inner wheel path, and inside edge of lane) at longitudinal intervals no greater than 15.25 m (50 feet). Locations for survey measurements are illustrated in Figure 6.

Asphalt Treated Base

Material and construction requirements for the dense graded asphalt treated base (ATB) are presented in the following sections.

Material Requirements. The aggregate requirements for ATB shall be the same as those for the DGAB. The ATB shall be a dense graded, hot laid, central plant mix, asphalt treated material. It shall be produced in conformance to the participating highway agency specifications, except as modified per these guidelines.

- Asphalt emulsions are not allowed in the mixture.

- Additives such as lime, if commonly used by the participating agency, are allowed in the ATB mixtures. Experimental additives or modifiers should not be used in the test sections, but may be used in supplemental test sections.
- No recycled asphalt concrete materials shall be used in the ATB.
- The mixture should be designed to the equivalent of the following minimum mix design specifications:

	Hveem (std)	Marshall (std 102 mm (4") dia.)	
Swell (Max.)	0.7 mm (0.030 in.)	Compaction blow	50
Stabilometer Value (Min)	35	Flow	2 mm - 5 mm (0.08 - 0.20 in)
Moisture Vapor Susceptibility	25	Stability	4.4 kN (1000 lb)
Air Void	3 - 5%	Air Void	3 - 5%

NOTE: The 38 mm (1.5 inch) top-size aggregate for the ATB exceeds the size limit for standard size Marshall and Hveem mix design procedures. Some agencies use the 152 mm (6-inch) Marshall procedure for mixtures with aggregates larger than 25 mm (1-inch) and design to the following criteria:

Compaction Hammer Weight	10.2 kg (22.5 lbs)
Specimen Dimensions	152 mm diameter by 95 mm height (6-inch diameter by 3.75 inch height)
Approximate Weight	4050 g
Compaction blows	75
Flow	3 mm - 7.6 mm (0.12 - 0.30 inch)
Stability	10 kN (2250 lb)
Air Void	3 - 5%

Construction Requirements. Placement requirements for the ATB shall be equivalent to that used for HMAC surface courses and shall also include the following:

- Low viscosity asphalt shall be used to tack the ATB before placement of the surface course in accordance with agency procedures.
- A track mounted paver shall be required only when placing ATB directly on a permeable asphalt treated layer.

- A maximum lift thickness of 152 mm (6 inches) (compacted) is recommended for the first lift of ATB with subsequent lifts not to exceed 102 mm (4 inches) each, compacted.
- Compaction of the first lift shall be at least 90% of Maximum Theoretical Density. Subsequent lifts shall be compacted to an average of 92% of Maximum Theoretical Density. In-place density measurements for construction quality control shall be recorded.
- Surface irregularities shall not exceed 6 mm (1/4 inch) between two points longitudinally or transversely using a 3.05 m (10-foot) straightedge.
- Final ATB elevations shall not vary from design more than 12 mm (0.04 feet) based on a rod and level survey conducted taking readings at a minimum of 5 locations (edge, outer wheel path, midlane, inner wheel path, and inside edge of lane) at longitudinal intervals no greater than 15.25 m (50 feet). Locations for survey measurements are illustrated in Figure 6. (It is suggested that elevation measurements may be included as a staking item in the construction contract.)
- The objective of elevation control and minimizing surface irregularities is to ensure layer thickness within 6 mm (1/4 inch) of the thickness required in the experiment design.

Drained Base Structures

Test sections 7 through 12 and 19 through 24 are constructed with drained base structures that incorporate a permeable asphalt treated base layer (PATB) and edge drains to permit water to be drained out of the pavement structure. The PATB is constructed in combination with the DGAB materials previously described.

Permeable Asphalt Treated Base

The Permeable Asphalt Treated Base (PATB) serves as a drainage layer in the pavement structure. Material and construction requirements for the PATB are presented in the following.

Material Requirements. The PATB material shall meet the following requirements:

- PATB shall be an open graded, hot laid, central plant mixed, asphalt base material.
- The use of asphalt cement emulsion in the mix is prohibited.

- An AASHTO No. 57 size stone, or such other gradation used by an agency as a highly permeable drainage material in pavement structures, shall be used. It is required that this gradation have no more than 2 percent passing the No. 200 sieve, as shown in the gradation guidelines in Table 2. The aggregate shall consist of crushed material having more than 90% with at least one fracture face.
- The mix shall be designed with a target asphalt cement content of 2 to 2.5 percent.
- Additives or modifiers may be used to reduce stripping of asphalt if such use represents the participating agency's practice. Experimental additives or modifiers shall not be used in the test sections.
- Asphalt grade and type used in the PATB layer may be the same as the asphalt used in the surface HMAC course. Experience on early SPS-1 projects indicated good placement experience when using AC-30 for the PATB mix.
- No recycled asphalt concrete shall be permitted in the PATB.

Construction Requirements. Construction requirements for the PATB include the following:

- A static steel wheel roller shall be used to compact the permeable base applying 14.6 kN to 29.1 kN per meter (0.5 to 1.0 tons per foot) of roller width.
- No portion of the PATB layer shall be day-lighted.
- Appreciable amounts of distortion shall be avoided on the permeable base.
- A roller may be used immediately in front of the paver to dress up the permeable base if required.
- A track mounted paver is strongly recommended for operation on the permeable base. It has been the experience on early projects in this experiment that the PATB may be sufficiently stable, after cooling or with the use of stiffer asphalt grades or modifiers, to allow wheeled pavers and construction trucks to operate on the PATB surface. However, sharp turning movements do cause significant distortion and should be avoided.
- Other than the paver and roller, no other equipment or vehicles should be allowed to operate or park on the travel lane or outside shoulder portion of the permeable base. Limited operation of equipment on the inside lane may be permitted. The use of side-dump delivery for layers constructed on the PATB should be encouraged to minimize damage to the PATB layer. However, limited construction traffic (with reduced loads) may be allowed provided the contractor is cautioned that excessive shoving and tearing of the PATB surface will be cause for prohibiting traffic. This requirement is intended to prevent damage to the

PATB layer which would affect layer thicknesses in subsequent layers and also to prevent damage to the drainage properties of the finished PATB layer.

- Transverse interceptor drains, as illustrated in Figure 7, shall be installed on the down slope end of the permeable base layers. They shall be placed in the transition zone between drained and undrained base structure test sections. They should be placed at least 30.5 m (100 feet) past the end of the 152.5 m (500 feet) monitoring section, or in the center of transitions which are shorter than 30.5 m (100 feet).

Filter Fabrics

Filter fabric (or geotextiles) shall be used, in sections where the PATB layer is placed directly above the subgrade, (Sections 10, 11, 12, 22, 23, and 24) to prevent the clogging of the permeable layer due to the migration of fine material from the subgrade. The requirements for the filter fabrics used in the test sections conform to recommendations of AASHTO-ABC-ARBTA Task Force 25.

Material Requirements

- Nonwoven or woven geotextile materials which conform to recommendations for Class B drainage applications where installation stresses are low will be used in edge drains. Fabric used where PATB is constructed as the first layer on the subgrade and for the transverse interceptor drains shall meet Class A requirements. The following are the physical requirements on an average per roll basis sampled in accordance with ASTM D4354 shall be met:

Property	Minimum Value		Test Method
	Class A	Class B	
Grab Strength, N (lbs)	800 (180)	355 (80)	ASTM D 4632
Puncture Strength, N (lbs)	355 (80)	111 (25)	ASTM D 3787
Trapezoid Tear, N (lbs)	222 (50)	111 (25)	ASTM D 4533
Burst Strength, kPa (lb/in^2)	2000 (290)	896 (130)	ASTM D 3786
Permeability $k_{fabric} > k_{soil}$			ASTM D 4491
Apparent Opening Size			ASTM D 4751
1. Soil with ≤50% passing No. 200 sieve.	AOS < 0.6mm > #30 US std. sieve		
2. Soil with >50% passing No. 200 sieve.	AOS < 0.3mm > #50 US std. sieve		

Table 2. Recommended Gradation for PATB

Sieve	Percent Passing
38 mm (1 1/2 inch)	100
25 mm (1 inch)	95-100
13 mm (1/2 inch)	25-60
No. 4	0-10
No. 8	0-5
No. 200	0-2

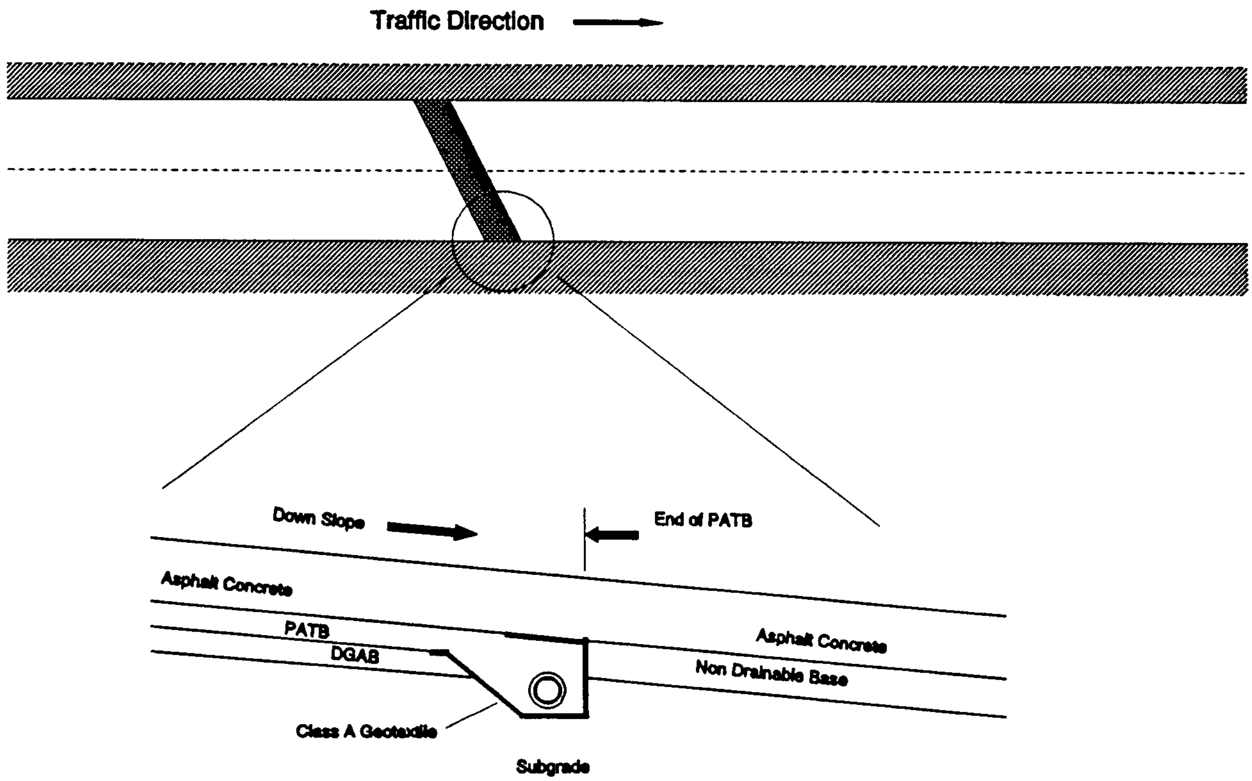


Figure 7. Transverse Interceptor Drain

Construction Requirements

- For sections with PATB placed on subgrade, filter fabrics shall be installed directly on the subgrade beneath the PATB layer and extend around the outside edge drain trench across the travel lanes and around the inside edge drain trench. For sections with PATB placed on DGAB the filter fabric must extend around each edge drain and wrap around the outer edge of the PATB layer, but does not need to extend under the full width of the pavement. In either case, the fabric must wrap around the edges of the PATB layer for a minimum of 610 mm (2 feet). The fabric must be heat resistant within the range of temperatures expected during placement of the PATB.
- Filter fabrics must be installed according to manufacturer's specifications and as shown in the typical drawings.
- Exposure of geotextiles to the elements between laydown and cover shall not exceed 14 days and manufacturer's specifications.
- Any filter fabric which is ripped or torn during the construction process shall be replaced or repaired with a patch which extends 914 mm (3 feet) beyond the perimeter of the tear or damage.
- Geotextile shall be overlapped a minimum of 610 mm (2 feet) at all longitudinal and transverse geotextile joints. Joints may be sewn if required by agency practice.

Edge Drains

Edge drains shall be installed in the shoulders of those pavement sections constructed with a PATB (Sections 7 through 12 and 19 through 24) to collect the water from the permeable base.

- Both inside and outside edge drains shall be constructed for crowned pavements. However, only one edge drain will be required for pavements with cross-slope.
- The edge drains shall be located no closer than 914 mm (3 feet) from the edge of the travel lane (inner and/or outer) for new construction and reconstruction (inlays).
- The edge drains shall run continuous throughout each of the 183 m (600 foot) minimum length permeable base test sections.
- The PATB is recommended as backfill in the edge drain trench, however, other approved open graded material may be used.

- Collector pipes shall be a minimum 76 mm (3-inch) diameter slotted plastic pipe and outlet pipes shall be a minimum 76 mm (3-inch) diameter unslotted rigid plastic pipe. Pipes must be capable of withstanding the temperature of the PATB without damage if PATB is used as backfill.
- Transverse collector subdrains shall be located in transition zones between drained and undrained sections where a longitudinal slope exists. The drain should be installed at an acute angle relative to the downslope direction.
- Drainage pipes should be sized for the expected flows determined as part of design. Discharge outlet pipes should be located at maximum intervals of 76.2 m (250 feet) and rodent protected. Outlets must be at least 152 mm (6 inches) above the expected 10 year flow elevation of the collector ditches to prevent backflow into the drainage system.

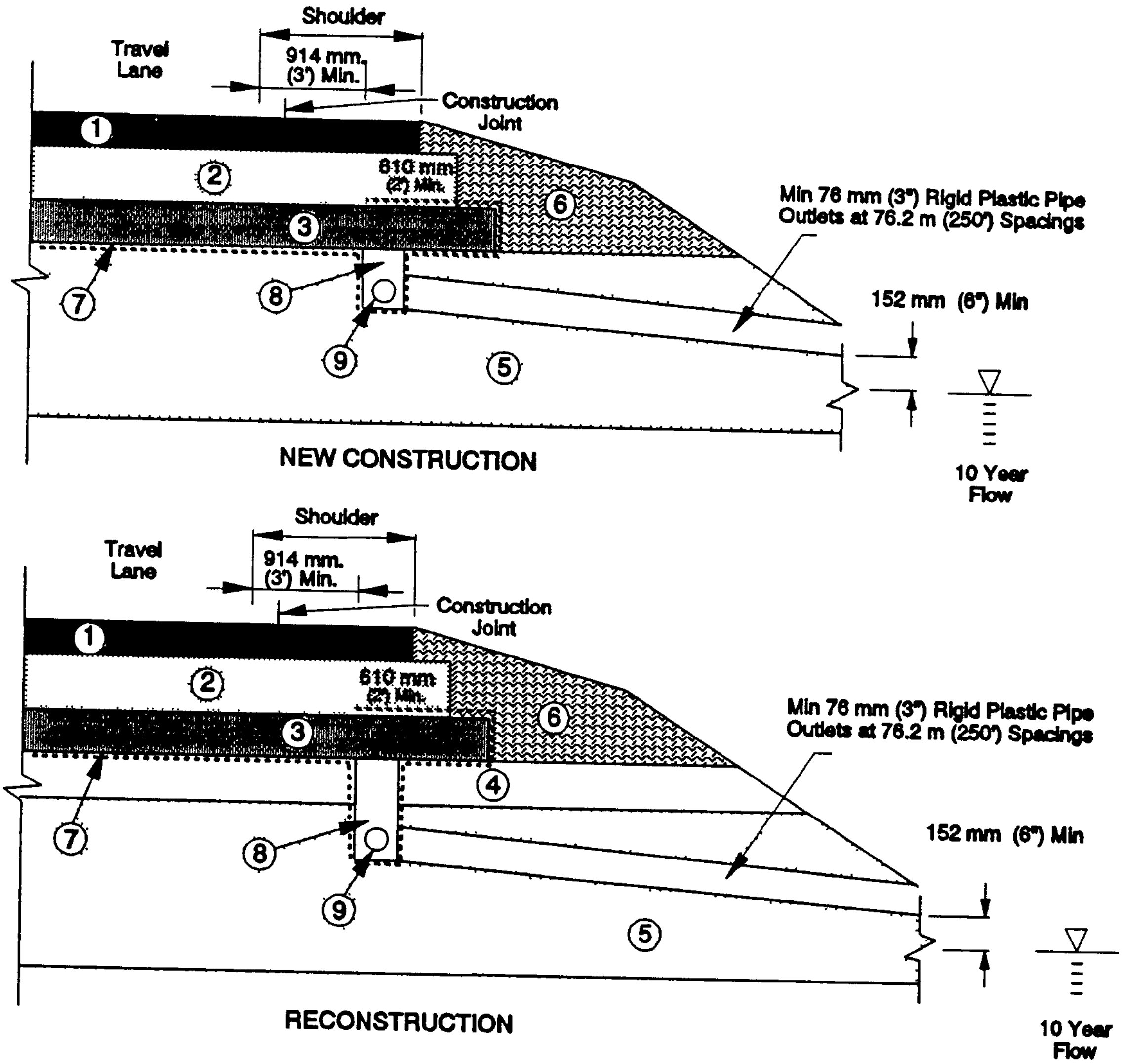
Figures 8 and 9 present typical details of the design of the edge drains. The depth and width of the edge drain may be altered depending on site conditions to conform to participating agency practice.

SHOULDERS

Shoulders in new construction shall have the full pavement structure across their width and shall be a minimum of four feet wide. For reconstruction sections, the new pavement structure shall extend a minimum of 914mm (3 feet) outside the edge of the travel lanes, with shoulders partially reconstructed to grade. If possible, all shoulders shall be paved full width with the surface course to eliminate longitudinal edge joints. If full width paving cannot be achieved, the paving shall be performed so that the edge joint occurs a minimum of one foot outside the edge of the travel lane. Curb and gutters, if used, must be placed a minimum of 1.83 m (6 feet) from the edge of the travel lane.

ASPHALT CONCRETE MIX DESIGN

It is not practical or feasible to specify either the same mix, mix design, or even mix design method for all test locations. To promote uniformity across test sites, design of the asphaltic concrete mixes shall be performed in compliance with the guidelines contained in the FHWA Technical Advisory T5040.27, "Asphalt Concrete Mix Design and Field Control," March 10, 1988 with the mix design criteria conforming to the Asphalt Institute Manual, MS-2, "Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types," 1988. A copy of the T5040.27 guidelines are reproduced in Appendix B of this report.

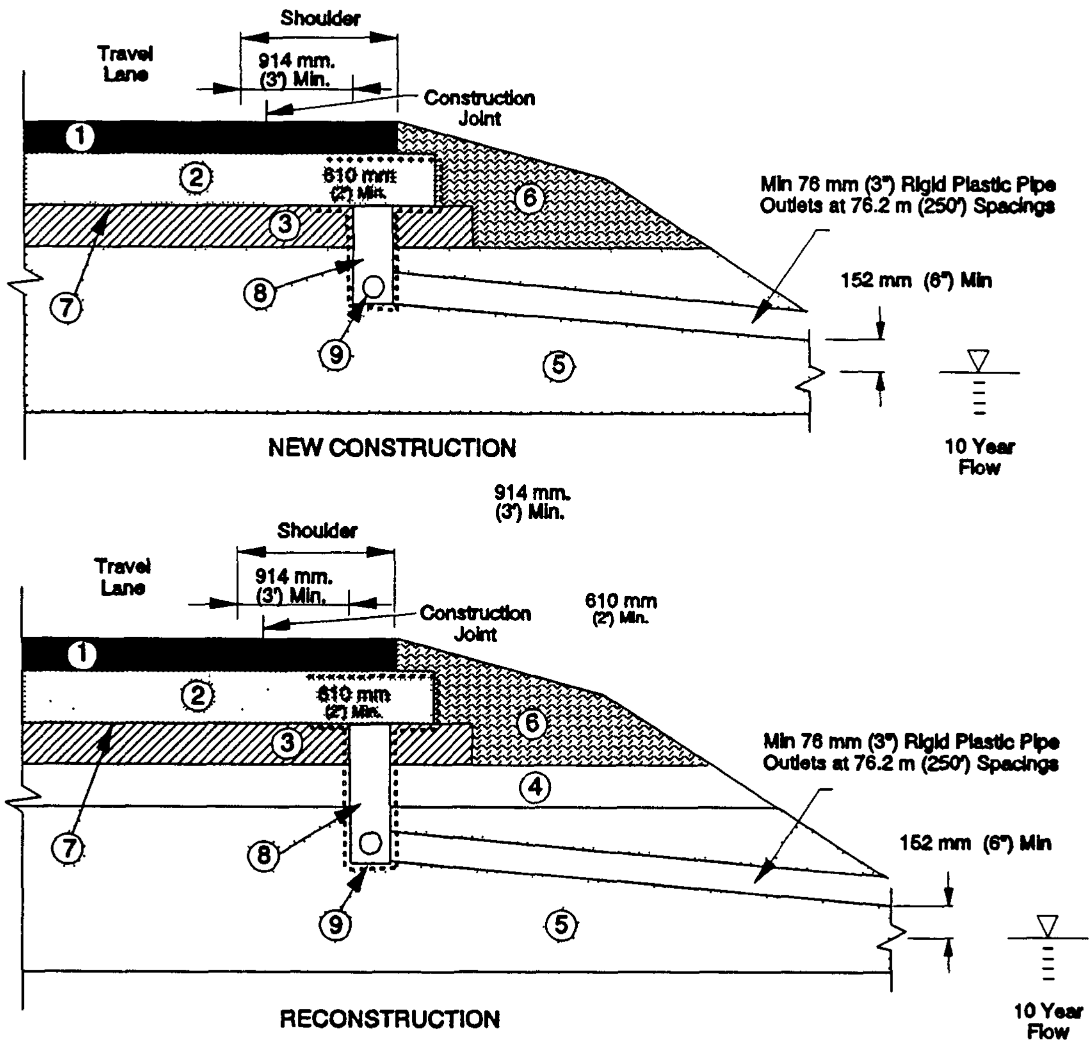


LEGEND

1. Asphalt Concrete Surface
2. Dense Graded Asphalt Treated Base
3. 102 mm (4") Permeable Asphalt Treated Base
4. Recompacted Subgrade
5. Subgrade
6. Fill Material
7. Class A Geotextile
8. Permeable Backfill
9. 76 mm (3") Slotted Plastic Pipe

Note: Longitudinal Construction Joint must be min 305 mm (1') outside Travel Lane.

Figure 8. Edge Drain Detail for Test Sections with PATB Placed Directly on Subgrade



LEGEND

1. Asphalt Concrete Surface
2. 102 mm (4") Permeable Asphalt Treated Base
3. 102 mm (4") Dense Graded Aggregate Base
4. Recompacted Subgrade
5. Subgrade
6. Fill Material
7. Asphalt Prime Coat
8. Permeable Backfill
9. 76 mm (3") Slotted Plastic Pipe

...... Class B Geotextile

Note: Longitudinal Construction Joint must be min 305 mm (1') outside Travel Lane.

Figure 9. Edge Drain Detail for Test Sections Placed over DGAB

In accordance with the FHWA Technical Advisory and the Asphalt Institute Manual, the asphalt concrete surface mixtures shall be designed to the following equivalent specifications:

Marshall (standard 100 mm (4-inch))	
Compaction blows	75
Stability (Minimum)	8 kN (1,800 lbs)
Flow	2 mm - 4 mm (0.08 - 0.14 in)
Hveem (standard)	
Stability (Minimum)	37
Swell (Maximum)	0.7 mm (0.03 in.)
Air Voids	3 - 5%

Agencies using non-standard Hveem or Marshall mix design procedures, should design mixes to achieve design indices equivalent to those obtained using these standard procedures.

The asphalt concrete shall employ all new materials which have not been used in previous construction. Recycled asphalt pavement materials are not permitted on test sections for this experiment.

Aggregates

Aggregates used in the mix shall be new aggregates of the highest quality available to the agency. These aggregates shall conform to the following guidelines:

- A minimum of 60% crushed coarse aggregate (retained on #4 sieve) with two fractured faces.
- A minimum sand equivalent test of 45 as obtained following AASHTO T176.
- A dense aggregate gradation.

Asphalt Cement

The asphalt grade and characteristics should be selected by the agency based on normal practice. Asphalt cements with low temperature susceptibility (Penetration-Viscosity Number; PVN $\geq$ -0.5) are recommended.

Additives

Additives, such as lime, which are routinely used by an agency are permitted in the mix design. The use of modifiers, such as polymers or crumb rubber, or experimental additives is discouraged for mixtures used in the test sections, but may be used in supplemental test sections.

CONSTRUCTION OPERATIONS

Construction operations shall be performed in compliance with the guidelines presented in the FHWA Technical Advisory T5040.27 and the high quality construction practice employed by the participating agency. Adequate attention shall be given to details and control of mix plant, hauling, placement, and compaction operations must be maintained on the test sections to prevent construction practices which are known to result in limited performance. In addition, care should be taken to ensure that construction of the test sections is performed in a manner consistent with normal highway construction practice.

The following construction related guidelines shall be followed:

- Lift thicknesses shall be limited to a maximum depth of 102 mm (4 inches).
- Longitudinal joints shall be staggered between successive lifts to avoid vertical joints.
- If a distinct surface course HMAC mix is used, its thickness shall be the same on all test sections at the test site.
- The asphalt concrete mix shall be placed only after the contractor has satisfactorily demonstrated proper placement and compaction procedures on non-test section locations.
- Longitudinal joints shall be located between adjacent lanes, not within travel lanes.
- The compacted thickness of any single layer should be a minimum of 38 mm (1.5 inches). This is to permit laboratory resilient modulus testing on recovered cores in accordance with test protocol P07.
- All transverse construction joints shall be placed outside the test sections, e.g. within the transitions between test sections.
- The as-compacted thickness of the asphalt concrete (surface plus binder course) in the test sections shall be constructed to within ± 6 mm (1/4 inch) of the values specified in the experiment design (i.e. 102 mm (4") & 178 mm (7")).

- The finished surface of the pavement should be smooth and provide an excellent ride level. As a target, the as-constructed surface should have a pro-rated profile index of less than 158 mm per 1000 m (10 inches per mile) as measured by a California type Profilograph and evaluated following California Test 526. Profile correction by milling is not permitted.

TRANSITIONS

The 183 m (600 foot) overall length of each test section includes an area 152.5 m (500 feet) for monitoring and areas 15.25 m (50 feet) long before and after the monitoring section for materials sampling. The distance between these 183 m (600 foot) long test sections must be sufficient to allow changes in materials and thicknesses during construction. This distance is required to accommodate changes in thickness and materials type in a manner that will reduce the influence on the properties of the finished pavement. A suggested minimum transition length of 30.5 m (100 feet) is recommended between different test sections to provide sufficient production in order to develop consistency after changes in materials and thicknesses.

SPECIAL CONSIDERATIONS

The time from grading of a untreated layer to the placing of the treated layer or surface layer shall be minimized. If the surface is exposed to rain, the layer shall be allowed to dry to the design optimum moisture content and recompacted to specified density. Preparation of the roadway embankment and subgrade may be accomplished in the previous construction season. However, the remaining construction, base courses and surface, shall be completed within a single season.

Surface friction courses may be used on the test sections if required by the participating agency. In this case, the thickness of the friction course should be limited to 19 mm (0.75 inch), and should not be considered as part of the asphalt concrete thickness specified for the test section.

DEVIATIONS FROM GUIDELINES

An agency that desires to participate in the SPS-1 experiment but finds it necessary to deviate from some of the guidelines described in the report should review these deviations with the LTPP Regional Office or LTPP Division. LTPP will assess the implications of these deviations on the study objectives. If the implications of the non-compliance appear minimal, the deviations will be accepted, otherwise LTPP Division will suggest alternatives for consideration by the participating agency.

APPENDIX A - PAVEMENT SECTIONS

Examples of pavement cross sections are presented in the appendix to illustrate the specific details required for the test sections. Deviations from these typical sections are permitted within the limits outlined in this document to accommodate specific site conditions and participating agency practice. The depicted pavement structure is two lanes of a four lane divided highway structure with a crowned cross section. The pavement structures required for the test sections consist of combinations of plant mix asphalt treated base, dense graded aggregate base, a permeable asphalt treated base, and a hot mixed asphalt concrete surface layer. The cross sections are referenced to the test sections numbers listed in Table 1. Figures A1 through A12 illustrate cross sections of the test sections incorporating different base materials and thickness.

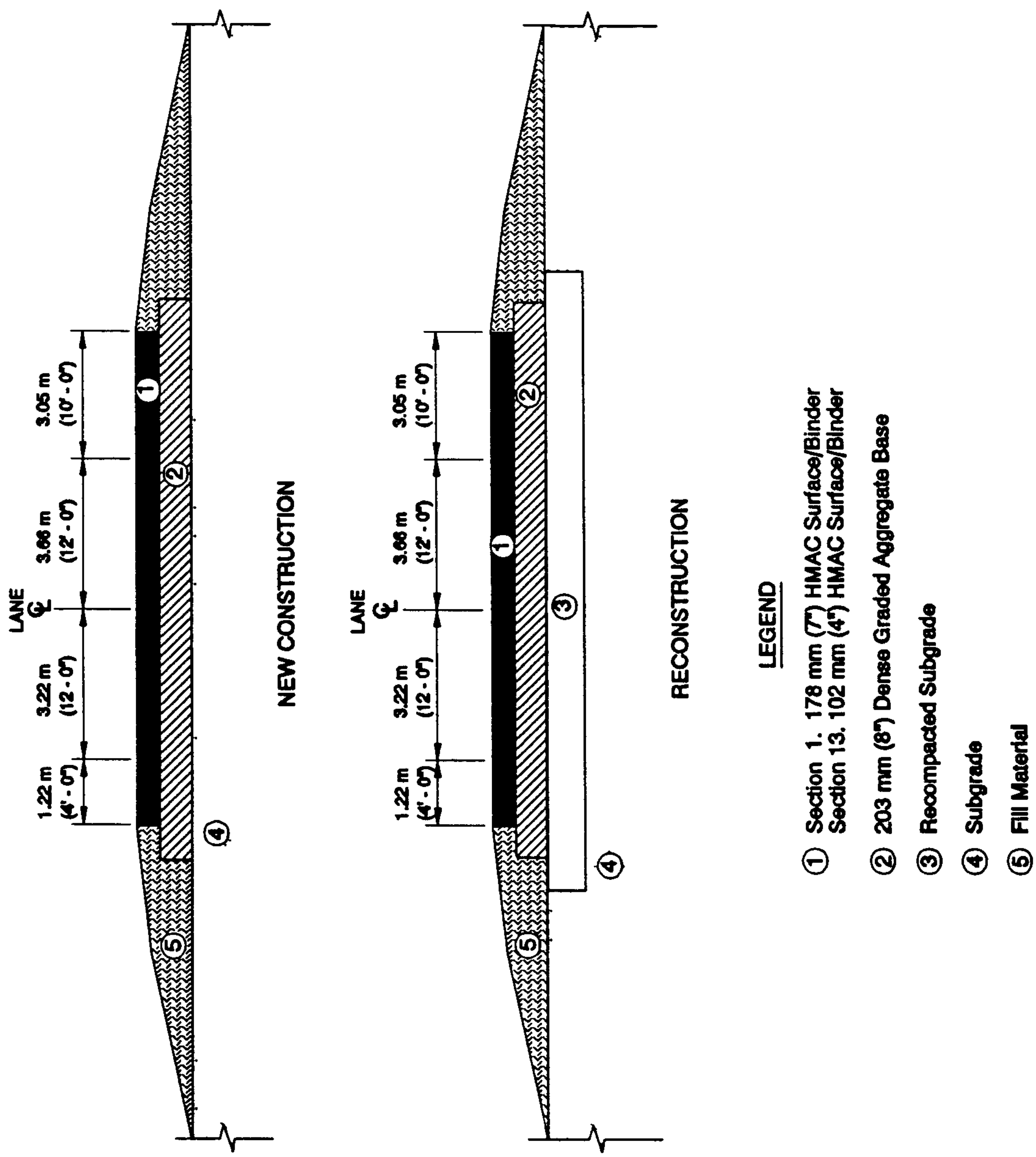


Figure A - 1. Test Sections 1 and 13 (with 203 mm (8") DGAB).

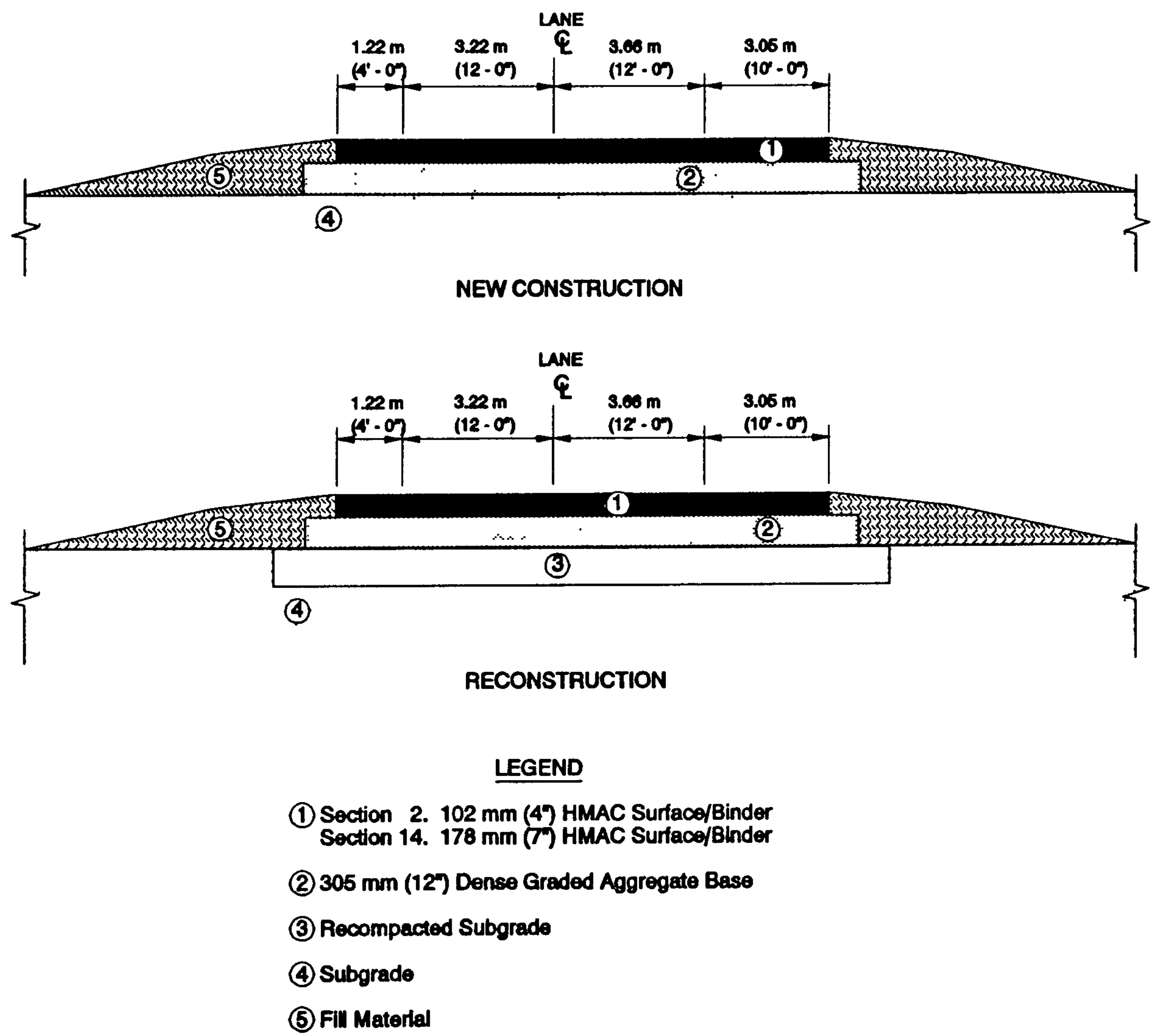


Figure A - 2. Test Sections 2 and 14 (with 305 mm (12") DGAB).

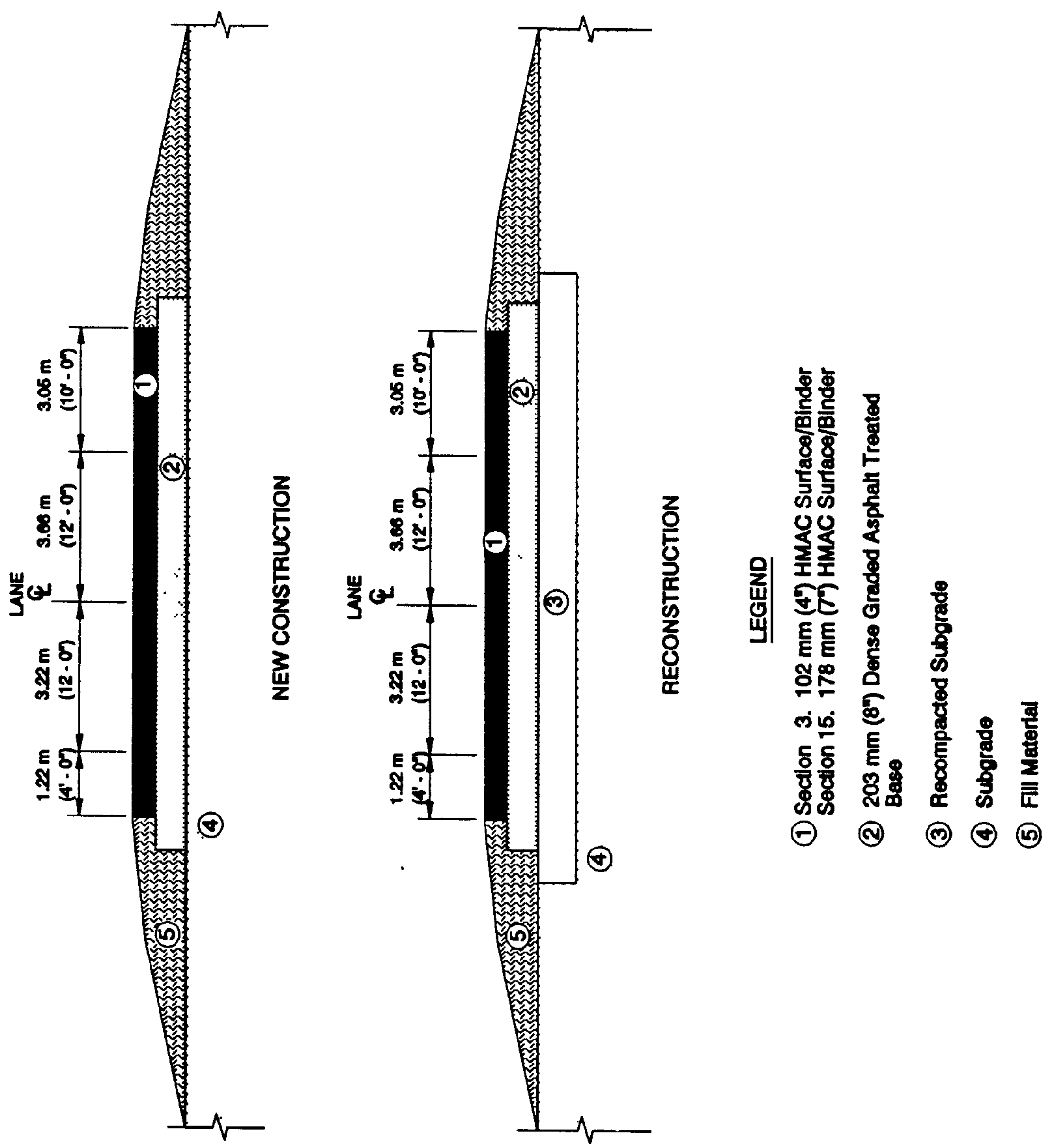
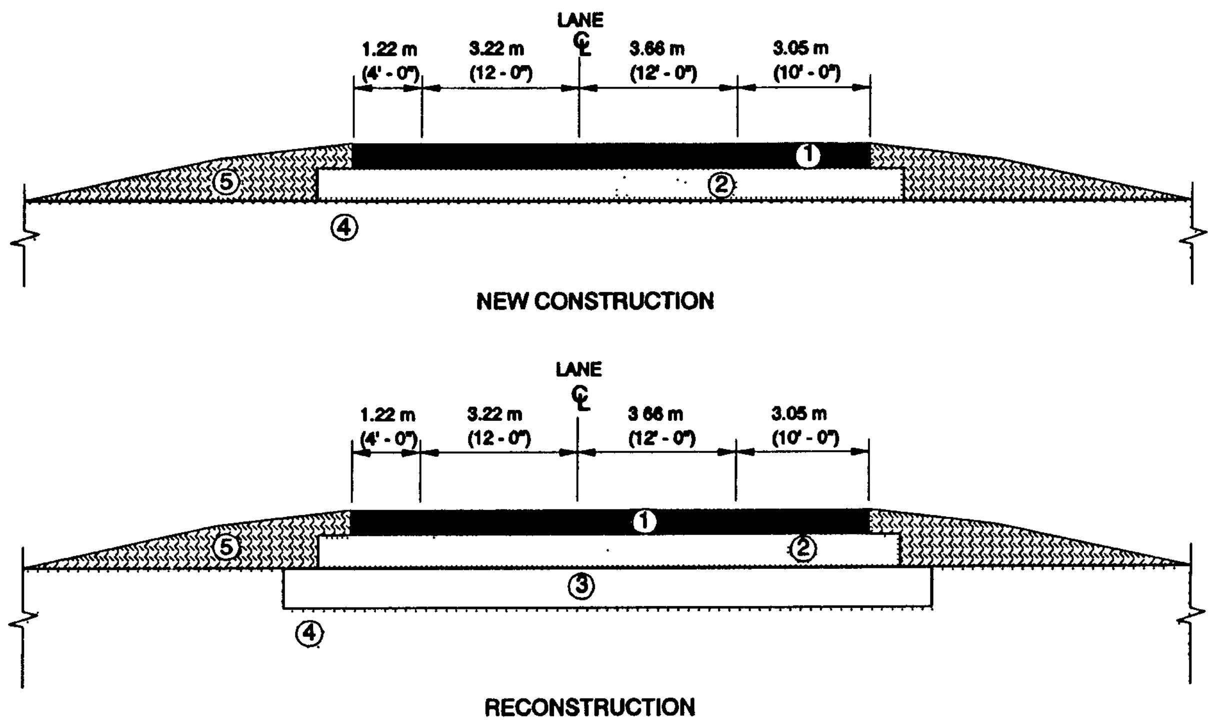


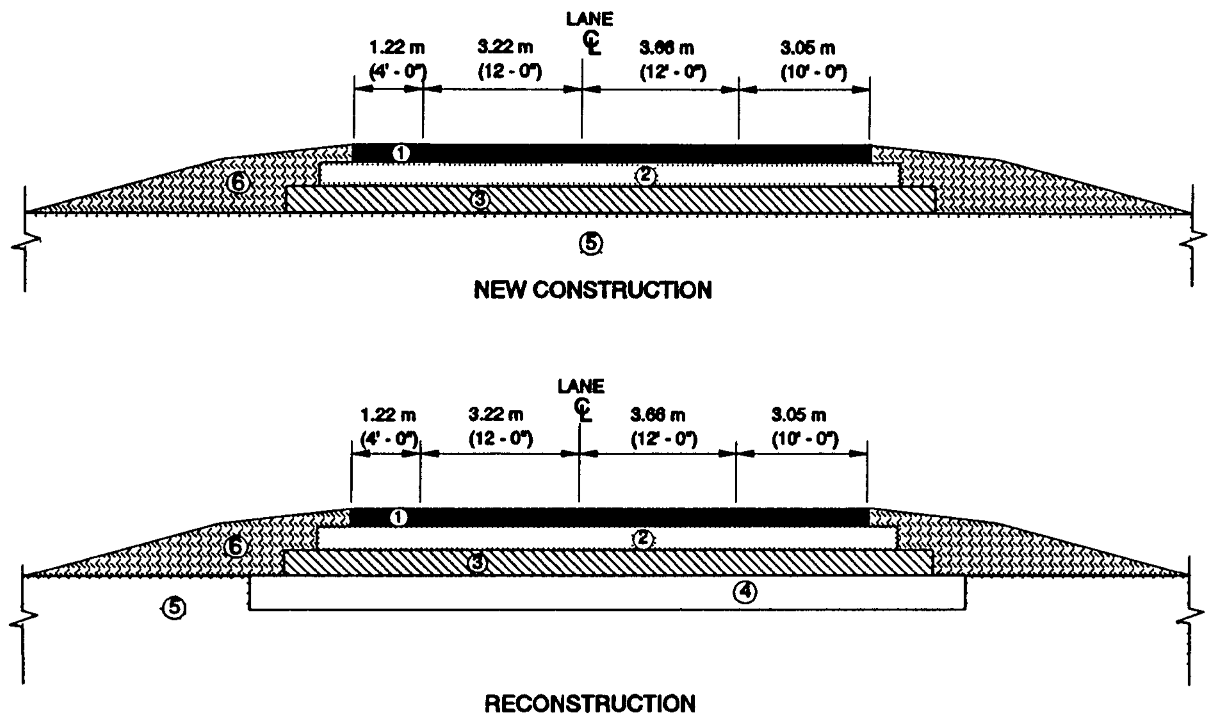
Figure A - 3. Test Sections 3 and 15 (with 203 mm (8) ATB).



LEGEND

1. Section 4. 178 mm (7") HMAC Surface/Binder
   Section 16. 102 mm (4")HMAC Surface/Binder
2. 305 mm (12") Dense Graded Asphalt Treated Base
3. Recompacted Subgrade
4. Subgrade
5. Fill Material

Figure A - 4. Test Sections 4 and 16 (width 305 mm (12") ATB).



LEGEND

① Section 5. 102 mm (4") HMAC Surface/Binder
Section 17. 178 mm (7") HMACSurface/Binder

② 102 mm (4") Dense Graded Asphalt Treated Base

③ 102 mm (4") Dense Graded Aggregate Base

④ Recompacted Subgrade

⑤ Subgrade

⑥ Fill Material

Figure A - 5. Test Sections 5 and 17 (with 102 mm (4") ATB over 102 mm (4") DGAB).

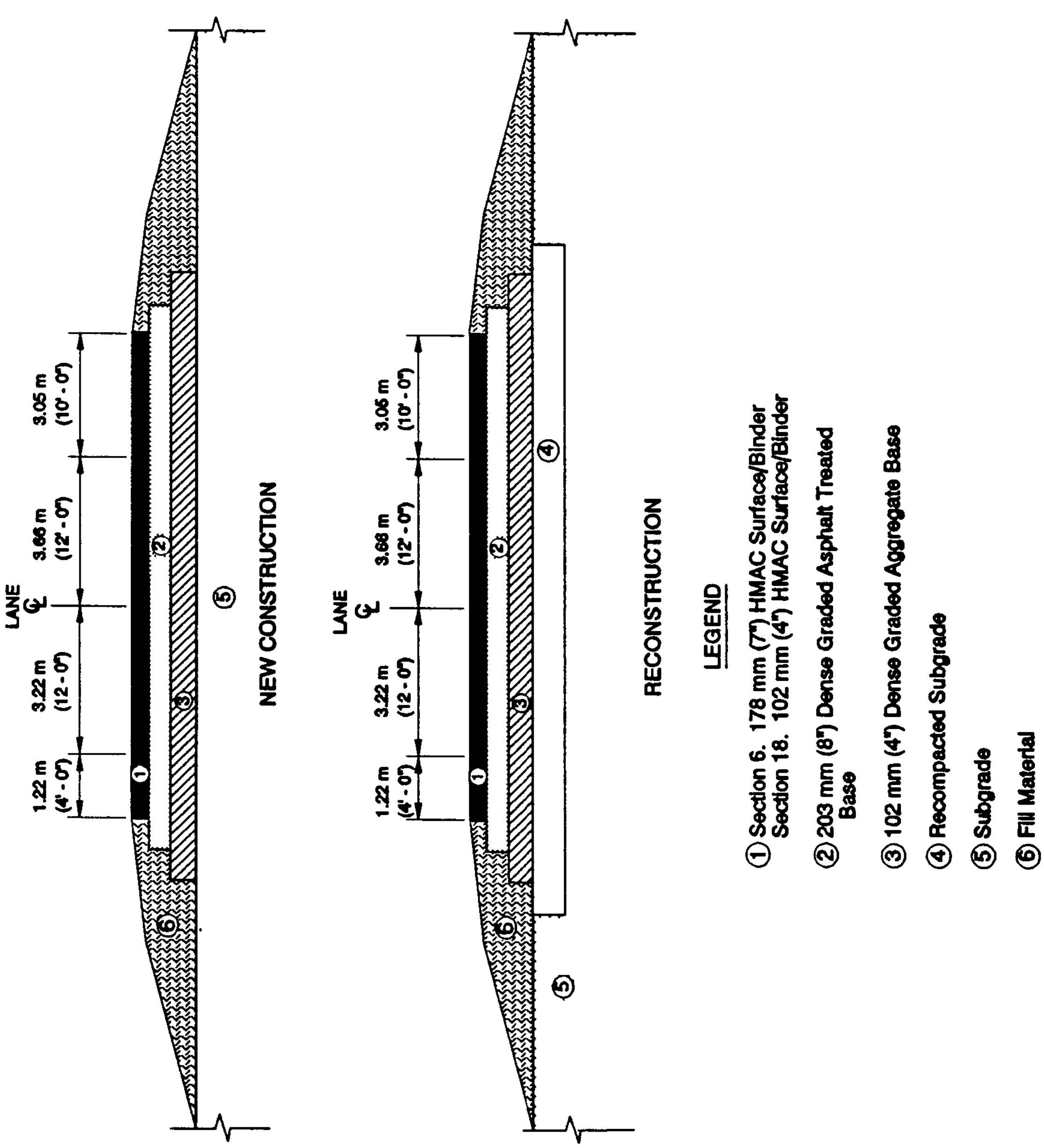
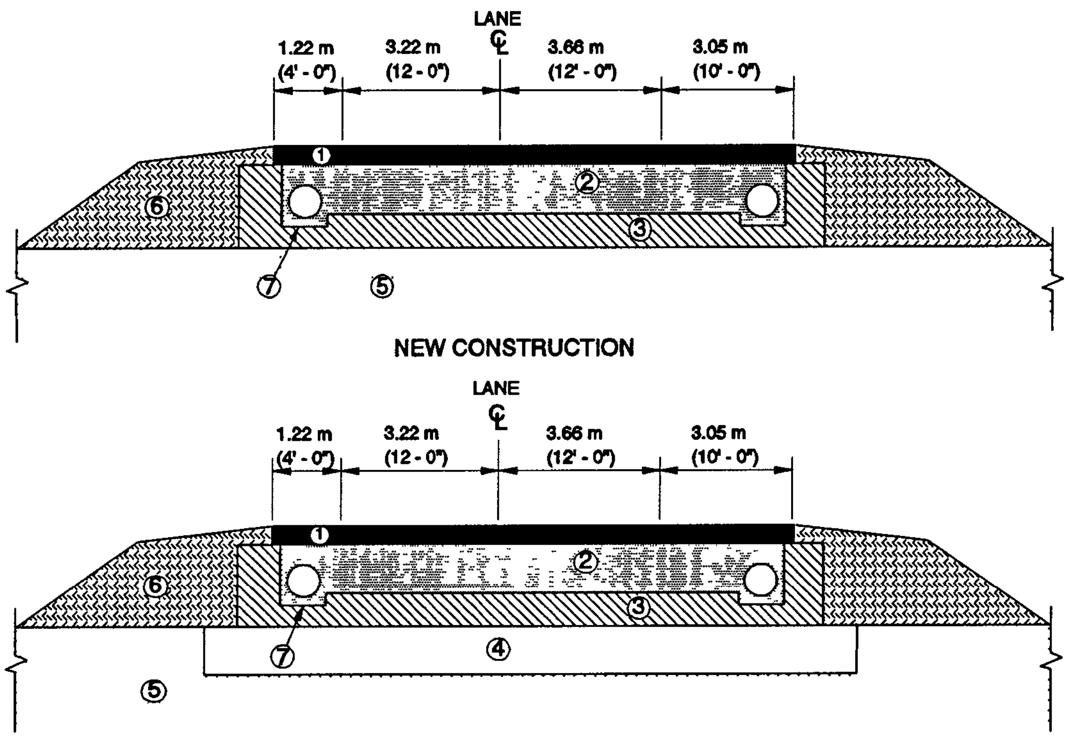


Figure A - 6. Test Sections 6 and 18 (with 203 mm (8") ATB over 102 mm (4") DGAB).



LEGEND

① Section 7. 102 mm (4") HMAC Surface/Binder
Section 19. 178 mm (7") HMAC Surface/Binder

② 102 mm (4") Permeable Asphalt Treated Base

③ 102 mm (4") Dense Graded Aggregate Base

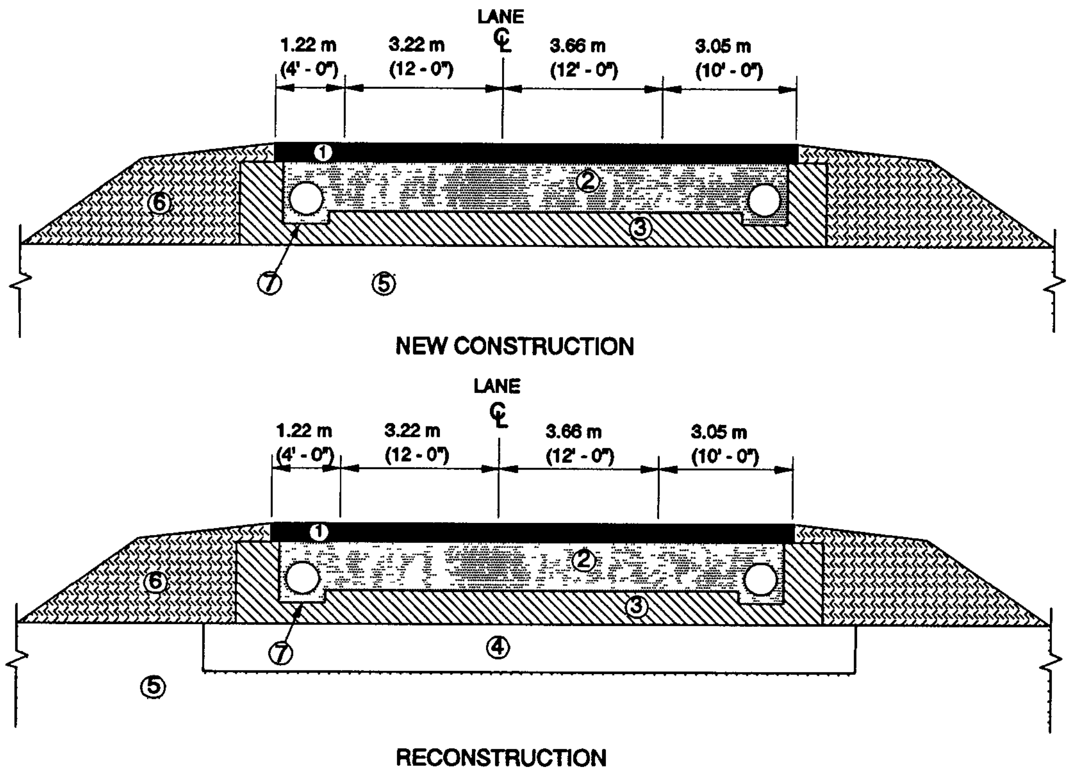
④ Recompacted Subgrade

⑤ Subgrade

⑥ Fill Material

⑦ Filter Fabric (Class B, Trench Only)

Figure A - 7. Test Sections 7 and 19 (with 102 mm (4") PATB over 102 mm (4") DGAB).



LEGEND

① Section 8. 178 mm (7") HMAC Surface/Binder
Section 20. 102 mm (4") HMAC Surface/Binder

② 102 mm (4") Permeable Asphalt Treated Base

③ 203 mm (8") Dense Graded Aggregate Base

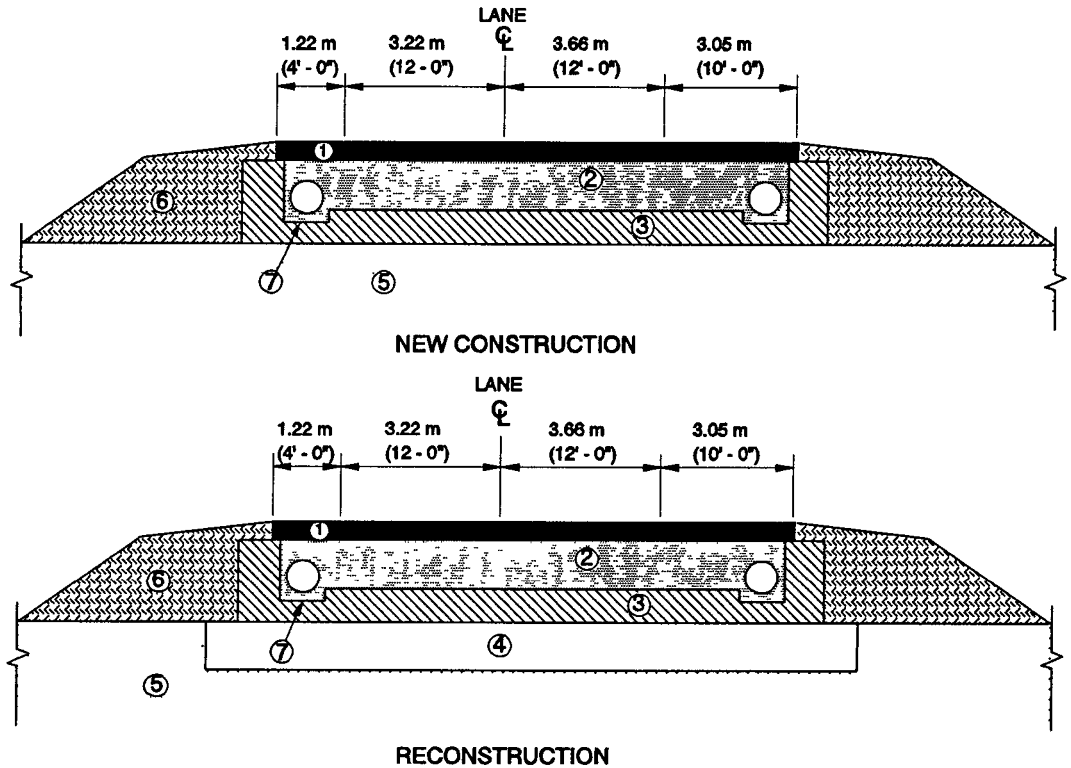
④ Recompacted Subgrade

⑤ Subgrade

⑥ Fill Material

⑦ Filter Fabric (Class B, Trench Only)

Figure A - 8. Test Sections 8 and 20 (with 102 mm (4") PATB over 203 mm (8") DGAB).



LEGEND

① Section 9. 178 mm (7") HMAC Surface/Binder
Section 21. 102 mm (4") HMAC Surface/Binder

② 102 mm (4") Permeable Asphalt Treated Base

③ 305 mm (12") Dense Graded Aggregate Base

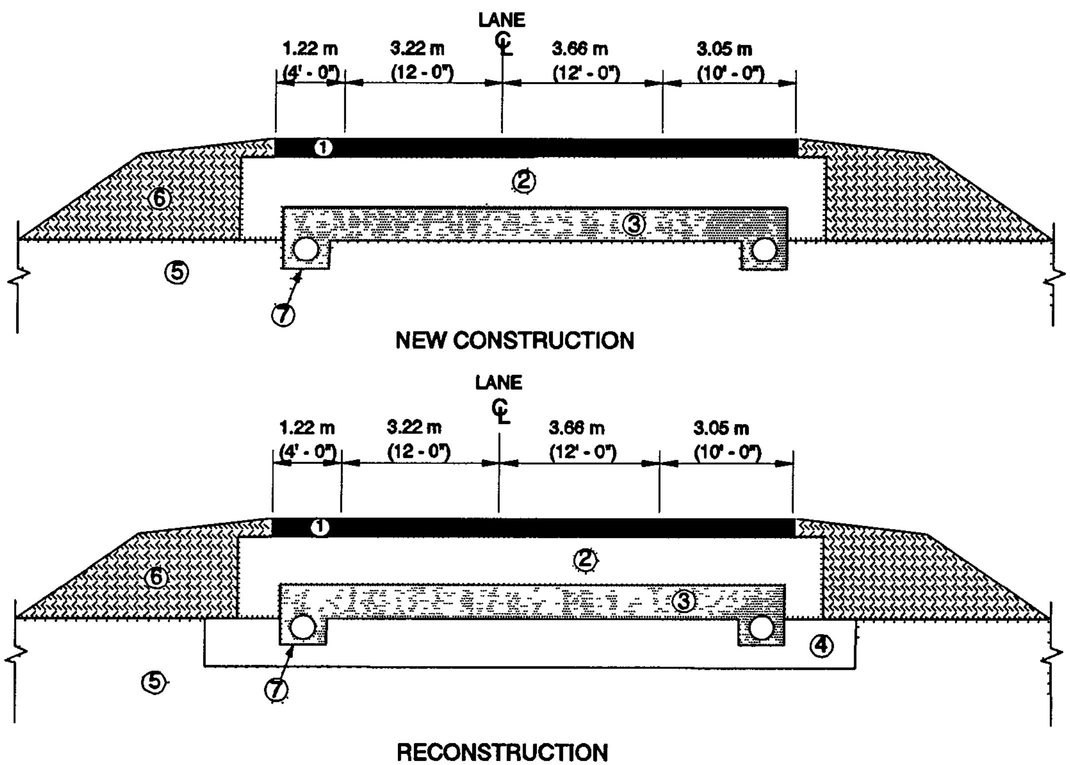
④ Recompacted Subgrade

⑤ Subgrade

⑥ Fill Material

⑦ Filter Fabric (Class B, Trench Only)

Figure A - 9. Test Sections 9 and 21 (with 102 mm (4") PATB over 305 mm (12") DGAB).



LEGEND

① Section 10. 178 mm (7") HMAC Surface/Binder
Section 22. 102 mm (4") HMAC Surface/Binder

② 102 mm (4") Dense Graded Asphalt Treated Base

③ 102 mm (4") Permeable Asphalt Treated Base

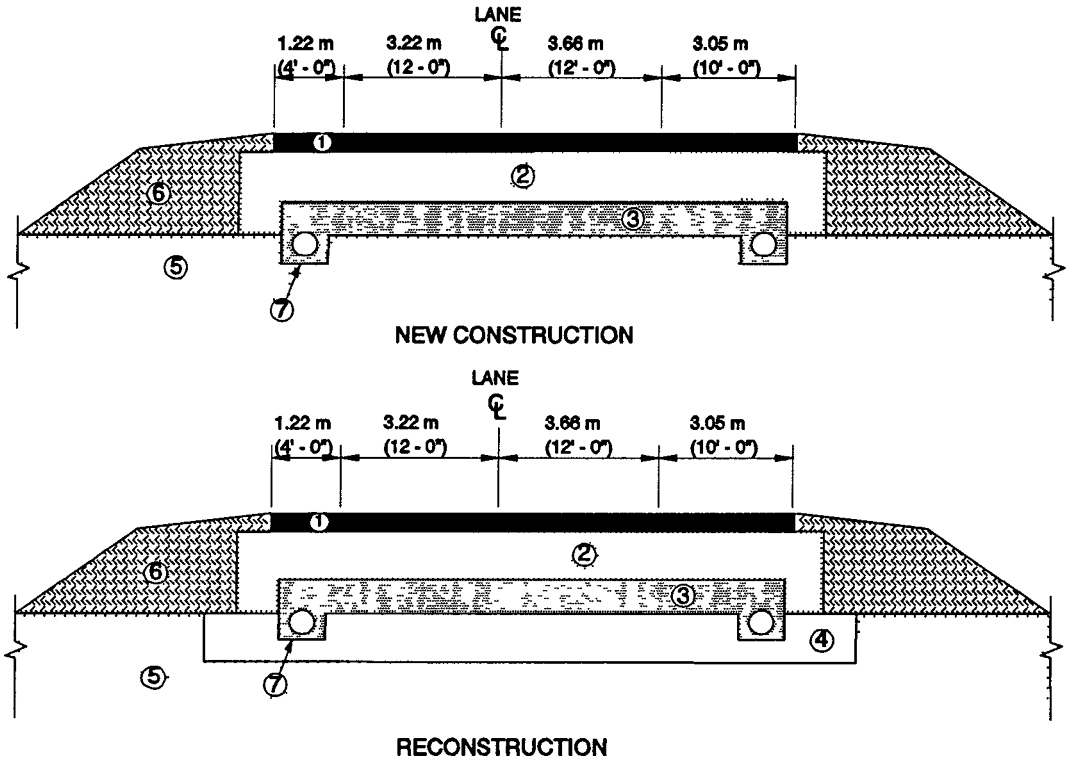
④ Recompacted Subgrade

⑤ Subgrade

⑥ Fill Material

⑦ Filter Fabric (Class A, Full width and Trenches)

Figure A - 10. Test Sections 10 and 22 (with 102 mm (4") ATB over 102 mm (4") PATB).



LEGEND

① Section 11. 102 mm (4") HMAC Surface/Binder
Section 23. 178 mm (7") HMAC Surface/Binder

② 203 mm (8") Dense Graded Asphalt Treated Base

③ 102 mm (4") Permeable Asphalt Treated Base

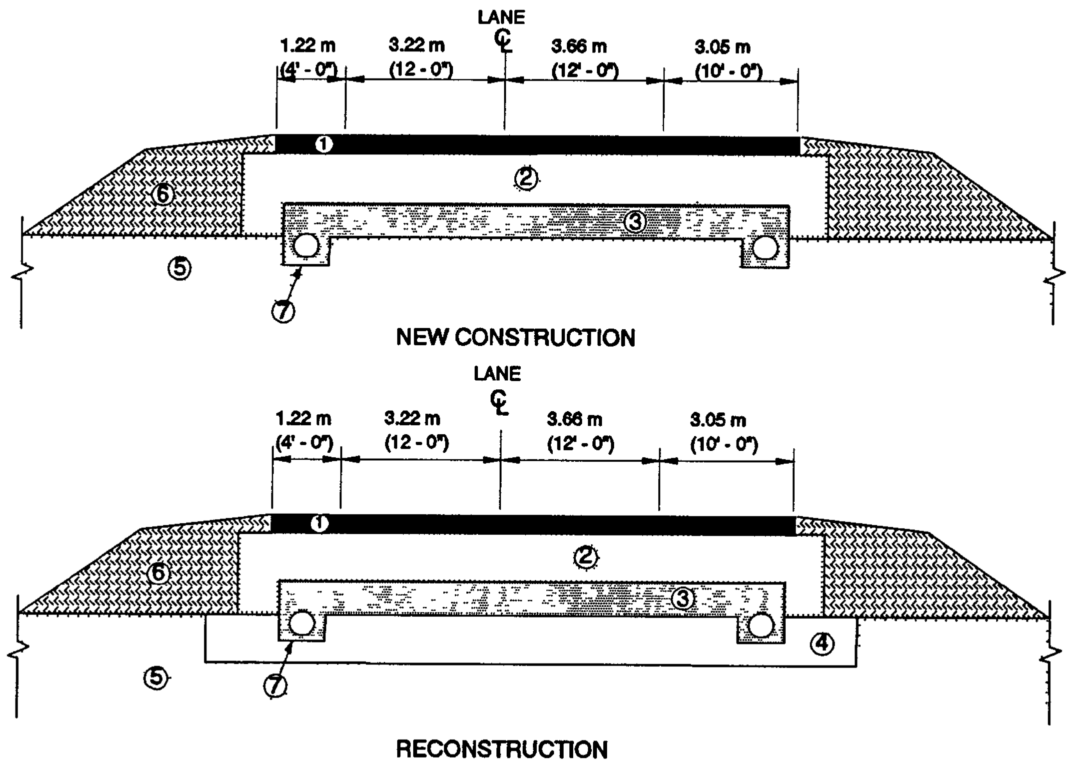
④ Recompacted Subgrade

⑤ Subgrade

⑥ Fill Material

⑦ Filter Fabric (Class A, Full width and Trenches)

Figure A - 11. Test Sections 11 and 23 (with 203 mm (8") ATB over 102 mm (4") PATB).



LEGEND

① Section 12. 102 mm (4") HMAC Surface/Binder
Section 24. 178 mm (7") HMAC Surface/Binder

② 305 mm (12") Dense Graded Asphalt Treated Base

③ 102 mm (4") Permeable Asphalt Treated Base

④ Recompacted Subgrade

⑤ Subgrade

⑥ Fill Material

⑦ Filter Fabric (Class A, Full width and Trenches)

Figure A - 12. Test Sections 12 and 24 (with 305 mm (12") ATB over 102 mm (4") PATB).

APPENDIX B

ASPHALT CONCRETE MIX DESIGN AND FIELD CONTROL

FHWA Technical Advisory T5040.27

March 10, 1988

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

SUBJECT	FHWA TECHNICAL ADVISORY
ASPHALT CONCRETE MIX DESIGN AND FIELD CONTROL	T 5040.27 March 10, 1988

Par. 1. Purpose
2. Cancellation
3. Background
4. Materials
5. Mix Design
6. Plant Operations
7. Laydown and Compaction
8. Miscellaneous

1. PURPOSE. To set forth guidance and recommendations relating to asphalt concrete paving, covering the areas of materials selection, mixture design, and mixture production and placement. The procedures and practices outlined in the Technical Advisory (TA) are directed primarily towards developing quality asphalt concrete pavements for high-type facilities. The TA can also be used as a general guide for low-volume facilities.

2. Cancellation. Federal Highway Administration (FHWA) Technical Advisory T 5040.24, Bituminous Mix Design and Field Control, dated August 22, 1985, is cancelled.

3. BACKGROUND

a. Over one-half of the Interstate System and 70 percent of all highways are paved with hot-mix asphalt concrete. Asphalt concrete is probably the largest single highway program investment today and there is no evidence that this will change in the near future. However, there is evidence that the number of premature distresses in the nation's recently constructed asphalt pavements is increasing. Heavier truck axle weights, increased tire pressures, and inadequate drainage are some of the factors leading to the increase in premature distress. The FHWA has been concerned with the deterioration in quality of asphalt concrete pavements for many years and in 1987 a special FHWA Ad Hoc Task Force studied two of the most common distresses existing today and subsequently issued a report titled "Asphalt Pavement Rutting and Stripping." The report contained both short-term and long-term recommendations for improving the quality of asphalt pavements.

b. With the variables of environment, component materials, and traffic loadings found throughout the United States, it is not surprising that there are many State-to-State or regional variations of design and construction requirements. No one set of specifications can achieve the same results in all States because of the factors mentioned above. However, there are many things that States can do to improve their current mix design and field control procedures to ensure that quality asphalt pavements will be constructed. This TA incorporates many of the FHWA Task Force recommendations and presents the current

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state-of-the-art in materials, mix design, plant operation, laydown and compaction, and other areas relating to quality hot-mix asphalt pavements.

4. MATERIALS

a. Aggregate is the granular material used in asphalt concrete mixtures which make up 90-95 percent of the mixture weight and provides most of the load bearing characteristics of the mix. Therefore, the quality and physical properties of the aggregates are critical to the pavement performance. The following is recommended:

(1) Aggregates should be non-plastic. The presence of clay fines in an asphalt mix can result in problems with volume swell and adhesion of asphalt to the rock contributing to stripping problems. The minus #4 sieve material should have a minimum sand equivalent value of 45 using the test method described in the American Association of State Highway and Transportation Officials (AASHTO) specification (AASHTO T176).

(2) A limit should be placed on the amounts of deleterious materials permitted in the aggregates. Specifications should limit clay lumps and friable particles to a maximum of one percent.

(3) Durability or weathering resistance should be determined by sulfate soundness testing. Specifications should require a sodium or magnesium sulfate test using the limits described in the AASHTO specification M29.

(4) Aggregate resistance to abrasion should be determined. Specifications should require a Los Angeles abrasion loss of 45 percent or less (AASHTO T96).

(5) Friction between aggregate particles is dependent on aggregate surface roughness and area of contact. As surface friction increases, so does resistance of the mix to deformation. Specifications should require at least 60 percent of the plus #4 sieve material to have at least two mechanically induced fractured faces.

(6) The quality of natural sand varies considerably from one location to another. Since most natural sands are rounded and often contain a high percentage of undesirable materials, the amount of natural sand as a general rule should be limited to 15 to 20 percent for high volume pavements and 20 to 25 percent for medium and low volume pavements. These percentages may increase or decrease depending on quality of the natural sand and the types of traffic to which the pavement will be subjected.

(7) For adequate control, aggregate gradations should be specified from the maximum particle size to the #200 sieve so each successive sieve opening is about 1/2 the previous sieve opening (for example, 1 inch, 1/2 inch, #4, #8, #16, #30, #50, #100, #200). The only accurate method to determine the amount of minus #200 sieve material is to perform a wash gradation in accordance with AASHTO T27 and AASHTO T11.

(8) The ratio of dust (minus #200 sieve material) to asphalt cement, by mass, is critical. Asphalt concrete mixes should require a maximum dust asphalt ratio of 1.2 and a minimum of 0.6.

(9) A tool which is very useful in evaluating aggregate gradations is the 0.45 power gradation chart. All mixes should be plotted on these charts as part of the mix design process (Attachment 1).

(10) An aggregate's specific gravity and absorption characteristics are extremely important in proportioning and controlling the mixture. It is recommended that AASHTO T209 be used to determine the maximum specific gravity of asphalt concrete mixes. States not using AASHTO T209 should be aware of the difficulty of determining the theoretical maximum density using individual ingredient specific gravities and their percentages in the mixture. These difficulties will result in inaccuracies in determining the specific gravity of the mixture. These inaccuracies will carry through to the calculation of the densities in the compacted mat and may result in improperly compacted pavements. It is also necessary to determine the bulk dry specific gravity of the aggregate in order to determine the voids in the mineral aggregate (VMA).

The target value for VMA should be obtained through the proper distribution of aggregate gradation to provide adequate asphalt film thickness on each particle and accommodate the design air void system. In addition, tolerance used in construction quality control should be such that the mix designed is actually produced in the field.

b. Asphalt grade and characteristics are critical to the performance of the asphalt pavement. The following is recommended:

(1) Grade(s) of asphalt cement used in hot-mix paving should be selected based on climatic conditions and past performance.

(2) It is recommended that asphalt cement be accepted on certification by the supplier (along with the testing results) and State project verification samples. Acceptance procedures should provide information on the physical properties of the asphalt in a timely manner.

(3) The physical properties of asphalt cement that are most important to hot-mix paving are shown below. Each State should obtain this information (by central laboratory or supplier tests) and should have specification requirement(s) for each property except specific gravity.

(a) Penetration 77° F

(b) Viscosity 140° F

(c) Viscosity 275° F

(d) Ductility/Temperature

(e) Specific Gravity

(f) Solubility

(g) Thin Film Oven (TFO)/Rolling TFO; Loss on Heating

(h) Residue Ductility

(i) Residue Viscosity

(j) Low temperature cracking is related to the physical properties of the asphalt and may be increased by the presence of wax in the asphalt. The low temperature ductility test at 39.2° F (4° C) can indicate where this may be a problem. The test is performed at a pull speed of 1 cm/min. Typical specification requirements are:

AASHTO M226	Table 2
AC 2.5	50 + cm
AC 5	25 + cm
AC 10	15 + cm
AC 20	5 + cm

(4) The temperature viscosity curves or absolute and kinematic viscosity information should be available at the mixing plant for each shipment of asphalt cement. This can identify a change in asphalt viscosity which necessitates a new mix design. Each State should provide temperature/viscosity information on the asphalt used in the laboratory mix design to the projects. Differences in the viscosity (as well as the penetration) of the asphalt from the asphalt used in the mix design may indicate the necessity to redesign the mix (Attachment 2).

5. MIX DESIGN

a. Asphalt concrete mixes should be designed to meet the necessary criteria based on type of roadway, traffic volumes, intended use, i.e., overlay on rigid or flexible pavements, and the season of the year the construction would be performed. Each State's mix design criteria should be as follows.

Property	Heavy Traffic Design (>1,000,000 ESAL*)	Medium Traffic Design (10,000-1,000,000 ESAL)	Light Traffic Design (<10,000 ESAL)
Marshall			
Compaction Blows	75	50	35
Stability (min.)	~~1,500~~ 1,800**	~~750~~ 1,200**	~~500~~ 750**
Flow	8-~~16~~ 14**	8-~~18~~ 16**	8-~~20~~ 18**
Hveem			
Stability (min.)	37	35	30
Swell (max)**	0.030 in.	0.030 in.	0.030 in.
Void Analysis			
Air Voids	3-5	3-5	3-5

* Equivalent Single Axle Load

** Revised to conform to the Asphalt Institute MS-2, Table III-2, 1988

MINIMUM PERCENT VOIDS IN MINERAL AGGREGATE (VMA)

Nominal Maximum Particle Size U.S.A. Standard Sieve Designation	Minimum Voids in Mineral Aggregate Percent
No. 16	23.5
No. 8	21
No. 4	18
3/8 in.	16
1/2 in.	15
3/4 in.	14
1 in.	13
1-1/2 in.	12
2 in.	11.5
2-1/2 in.	11

b. Standard mix design procedures (Marshall, Hveem) have been developed and adopted by AASHTO, however, some States have modified these procedures for their own use. Any modification from the standard procedure should be supported by correlation testing for reasonable conformity to the design values obtained using the standard mix design procedures.

c. Stripping in the asphalt pavements is not a new phenomenon, although the attention to it has intensified in recent years. Moisture susceptibility testing should be a part of every State's mix design procedure. The "Effect of Water on Compacted Bituminous Mixtures" (immersion compression test) (AASHTO T165) and "Resistance of Compacted Bituminous Mixture to Moisture Induced Damage" (AASHTO T283) are currently the only stripping test procedures which have been adopted by AASHTO. The AASHTO T283, commonly known as the Lottman Test, requires that the test specimens be compacted so as to have an air void content of 7 $\pm$ 1 percent, while AASHTO T165 does not. This air void content is what one would expect in the mat after construction compaction. There is considerable research underway on developing better tests for determining moisture damage susceptibility of the aggregate asphalt mixtures. One of the most promising test procedures is that developed by Tunnicliff and Root as reported in the National Cooperative Highway Research Program (NCHRP) Report 274. This test is similar to AASHTO T283, but it takes less time to perform. In the majority of cases hydrated lime and portland cement have proven to be the most effective anti-stripping additives.

d. The determination of air voids in the laboratory mix is a critical step in designing and controlling asphalt hot-mix. In order to determine air voids, the theoretical maximum density or the maximum specific gravity of the mix must be determined. This can be accomplished by using the "Maximum Specific Gravity of Bituminous Paving Mixtures" (Rice Vacuum Saturation) (AASHTO T209).

e. Proper mix design procedures require that each mix be designed using all of the actual ingredient materials including all additives which will be used on the project.

f. The complete information on the mix design should be sent to the plant. The following information should be included in the mix design report and sent to the plant.

(1) Ingredient materials sources

(2) Ingredient materials properties including:

(a) Specific gravities

(b) L. A. Abrasion

(c) Sand equivalent

(d) Plastic Index

(e) Absorption

(f) Asphalt temperature/viscosity curves or values

(3) Mix temperature and tolerances

(4) Mix design test property curves

(5) Target asphalt content and tolerances

(6) Target gradations for each sieve and tolerances

(7) Plot of gradation on the 0.45 power gradation chart, and

(8) Target density

g. Formal procedures should be established to require that changes to mix designs be approved by the same personnel or office that developed the original mix design.

h. After start-up, the resulting mixture should be tested to verify that it meets all of the design criteria.

6. PLANT OPERATIONS

a. In order to assure proper operation, an asphalt plant must be calibrated and inspected. Plant approval should be required and should cover each item on the asphalt plant checklist (Attachment 3).

b. To avoid or mitigate unburned fuel oil contamination of the asphalt mixture, the use of propane, butane, natural gas, coal or No. 1 or No. 2 fuel oils is recommended.

c. If the asphalt cement is overheated or otherwise aged excessively, the viscosity of the recovered asphalt will exceed that of the original asphalt by more than four times. However, if the viscosity of the recovered asphalt is less or even equal to the original viscosity, it has probably been contaminated with unburned fuel oil.

d. For drum mixer and screenless batch plants there should be three separate graded stockpiles for surface courses and four for binder and base courses. Each stockpile should contain between 15 to 50 percent by weight of the aggregate size in the mix design. The plus #4 sieve aggregate stockpile should be constructed in lifts not exceeding 3 feet to a maximum height of 12 feet. There should be enough material in the stockpiles for at least 5 days of production. The plant should be equipped with a minimum of four cold feed bins with positive separation.

e. Control testing of gradation and asphalt content should be conducted to assure a quality and consistent mixture. In many States, the contractor or supplier is required to do this testing.

f. Acceptance testing should be conducted for gradation and asphalt content of the final mixture.

g. The plotting of control and acceptance test results for gradation, asphalt content, and density on control charts at the plant provides for easy and effective analysis of test results and plant control.

h. The moisture content of the aggregate must be determined for proper control of drum mixer plants. The asphalt content is determined by the total weight of the material that passes over the weigh bridge with the correction made for moisture. Sufficient aggregate moisture contents need to be performed throughout the day to avoid deviations in the desired asphalt content.

i. Moisture contents of asphalt mixtures is also important. The extraction and nuclear asphalt content gauge procedures will count moisture as asphalt. For this reason, a moisture correction should be made. In addition, high moisture contents in asphalt mixtures can lead to compaction difficulty due to the cooling of the mix caused by evaporation of the moisture. This is particularly important with drum mixer mixes which require moisture for the mixing process. Some States specify a maximum moisture content behind the paver. A recommended maximum moisture content behind the paver is 0.5 percent.

7. <u>LAYDOWN AND COMPACTION</u>

a. Prior to paving start-up, equipment should be checked to assure its suitability and proper function. Project equipment approval should include the items shown on the project inspection checklist (Attachment 4).

b. Paving start-up should begin with a test strip section. This will allow for minor problems to be solved, establishment of roller patterns and number of passes, and will assure that proper placement and compaction can be attained.

c. In order to assure proper placement and compaction, it is essential that the mat be placed hot. Establishment of and compliance with the following items should be included; minimum mix, underlying pavement, and ambient temperatures. Cold weather and early or late season paving should be avoided. The practice of raising the temperature of the mixture to combat the cold conditions should not be permitted, as this will contribute to excessive aging of the asphalt cement.

d. The use of a pneumatic roller in the compaction process is strongly encouraged. When used in the intermediate rolling it will knead and seal the mat surface and aid in preventing the intrusion of surface water into the pavement layers. It will also contribute to the compaction of the mat.

e. Density requirements should be established to result in an air void system in the mat of 6-8 percent immediately after construction. This allows for the inherent additional densification under traffic to an ultimate air void content of about 3-5 percent. Density acceptance specifications should require a percentage of maximum density as determined by AASHTO T209. A percentage of test strip density or Marshall laboratory density can be used provided each is related to the maximum density. The specified density should be attained before the mat temperature drops below 175° F.

f. Density measurement should be accurate, taken frequently, and the results made available quickly for each day of production. Density should be determined by test cores, or by properly calibrated nuclear test gauges. Specifications should require several tests to be averaged to determine density results for acceptance.

g. Successive hot-mix courses should not be placed while previous layers are wet. To avoid, or minimize the penetration of water into base and binder courses, paving operations should be scheduled so that the surface layer(s) is placed within a reasonable period after these courses are constructed. To the greatest extent possible, construction should be planned to avoid the necessity of leaving layers uncovered during wet seasons of the year.

8. MISCELLANEOUS

a. Some States have established procedures to accept out-of-specification material and pavement with a reduction in price. These procedures include definition of lot size/production time, tolerances, and pay factor reductions for ingredient materials, combined mixture properties, pavement density, pavement smoothness, and lift thickness.

b. Prior to the start of production and placement operations, a preplacement conference, including all the paving participants, should be held. This conference would define duties and responsibilities for each phase of the operation as well as problem solving procedures.

c. During start-up it is very effective to have a construction and/or materials specialist at the project site to assist in identifying and solving any problem that develops.

d. Because asphalt hot-mix pavement construction is complex, it requires that each person involved understand his/her function thoroughly. It is also helpful if each person has a basic understanding of each of the many phases involved. It is recommended that States develop or use existing training to address these phases of asphalt paving.

Ronald E. Heinz
Ronald E. Heinz
Associate Administrator for
Engineering and Program Development

4 Attachments

AGGREGATE GRADATION

It has long been established that gradation of the aggregate is one of the factors that must be carefully considered in the design of asphalt paving mixtures, especially for heavy duty highways. The purpose in establishing and controlling aggregate gradation is to provide sufficient voids in the asphalt aggregate mixture to accommodate the proper asphalt film thickness on each particle and provide the design air void system to allow for thermal expansion of the asphalt within the mix. Minimum voids in the mineral aggregate (VMA) requirements have been established and vary with the top aggregate size.

Traditionally, gradation requirements are so broad that they permit the use of paving mixtures ranging from coarse to fine and to either low or high stability. To further complicate matters, different combinations of sieve sizes are specified to control specific grading ranges. Standardization of sieve sizes and aggregate gradations, which has often been suggested, is not likely to occur because of the practice of using locally available materials to the extent possible.

In the early 1960's, the Bureau of Public Roads introduced a gradation chart (Figure #1) which is especially useful in evaluating aggregate gradations. The chart uses a horizontal scale which represents sieve size openings in microns raised to the 0.45 power and a vertical scale in percent passing. The advantage in using this chart is that, for all practical purposes, all straight lines plotted from the lower left corner of the chart, upward and toward the right to any specific nominal maximum particle size, represent maximum density gradations. The nominal maximum particle sieve size is the largest sieve size listed in the applicable specification upon which any material is permitted to be retained. An example is shown in Figure #2.

The gradations depicted in Figure #3 and #4 are exaggerated to illustrate the points being made. By using the chart, aggregate gradations can be related to maximum density gradation and used to predict if the mixture will be fine or coarse textured as shown in Figure #3.

Soon after the chart was developed, it was used to study gradations of aggregate from several mixtures that had been reported as having unsatisfactory compaction characteristics. These mixtures could not be compacted in the normal manner because they were slow in developing sufficient stability to withstand the weight of the rolling equipment. Such mixtures can be called "tender mixes." This study identified a consistent gradation pattern in these mixes as is illustrated in Figure #4.

Most notable is the hump in the curve near the #40 sieve and the flat slope between the #40 sieve and the #8 sieve. This indicates a deficiency of material in the #40 to 8# sieve range and an excess of material passing the #40 sieve. Mixtures with an aggregate exhibiting this gradation characteristic are susceptible to being tender, particularly if the fines are composed of natural sand.

As part of the bituminous mix design process, the aggregate gradation should be plotted on the 0.45 power gradation chart.

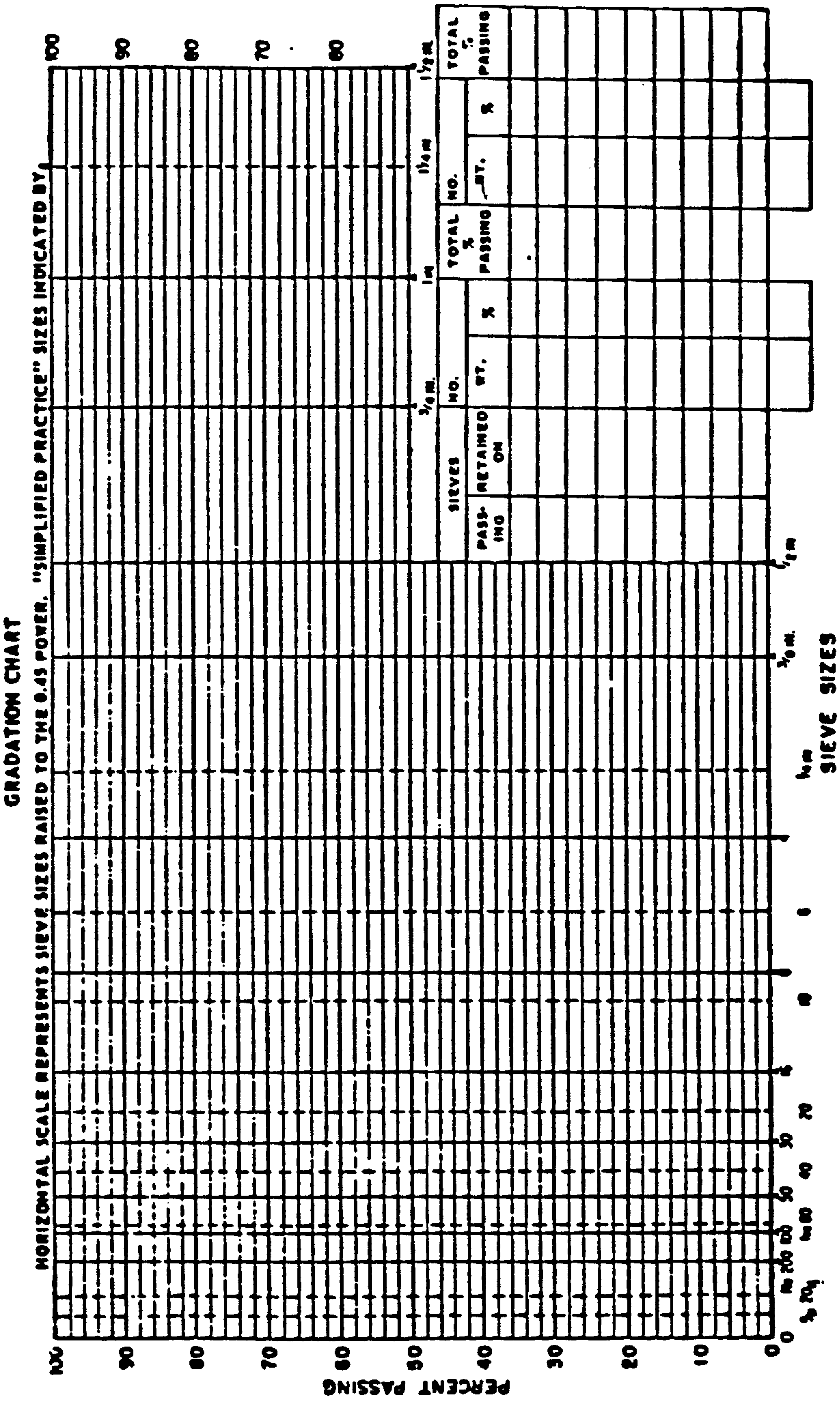


Figure #1

GPO 882-415

0.45 Power Gradation Chart

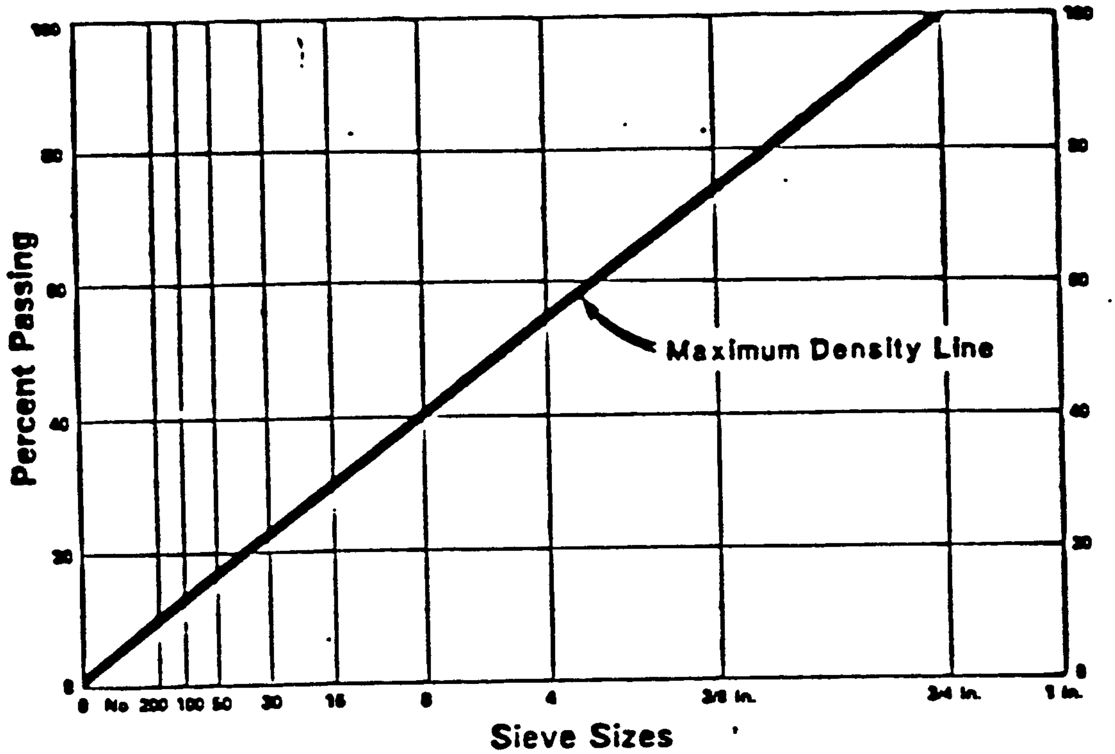


Figure #2

0.45 Power Gradation Chart

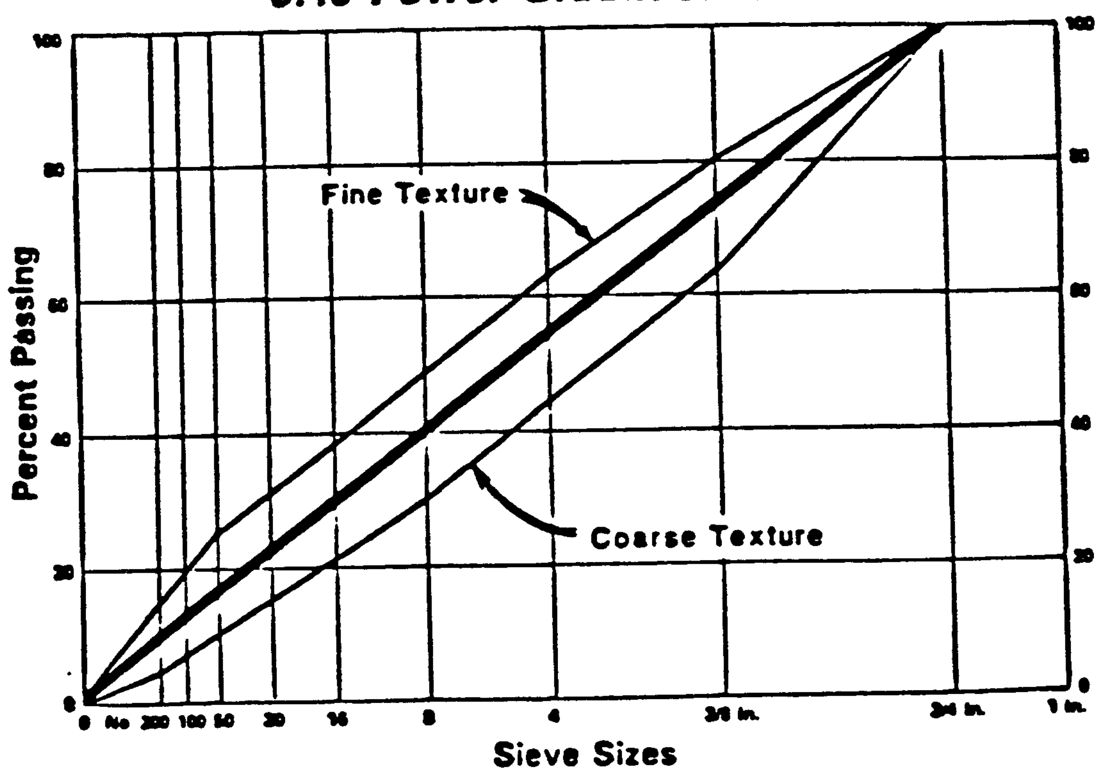


Figure #3

0.45 Power Gradation Chart

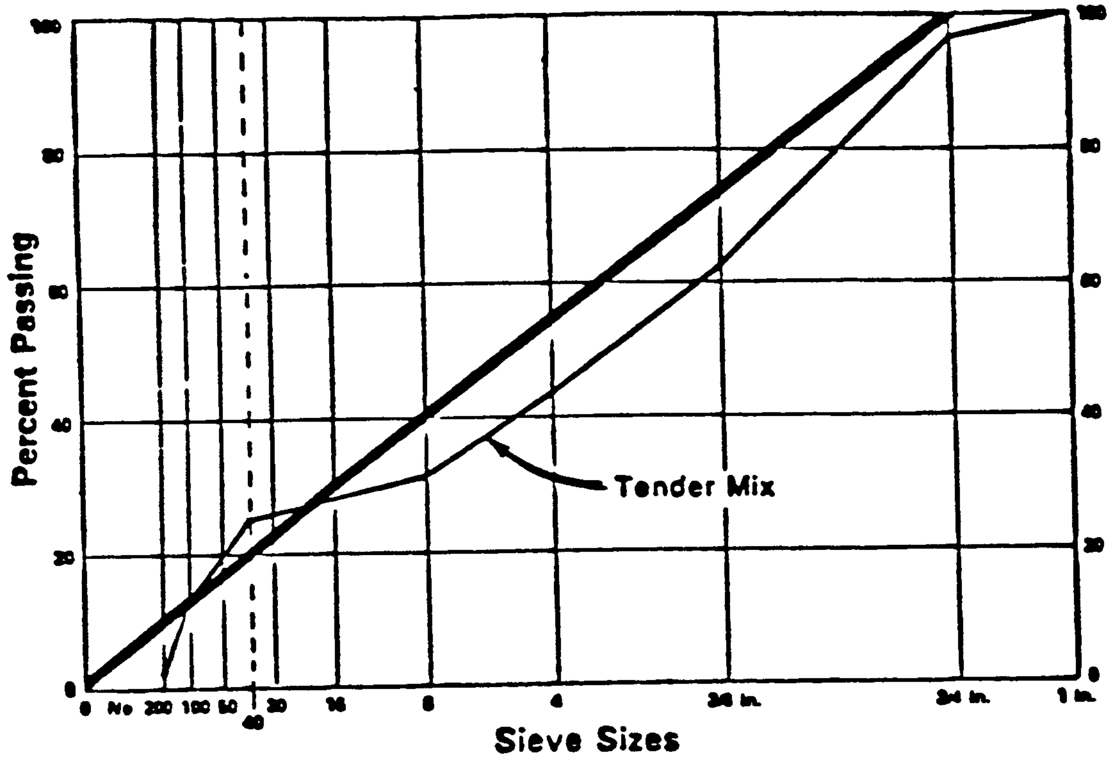


Figure #4

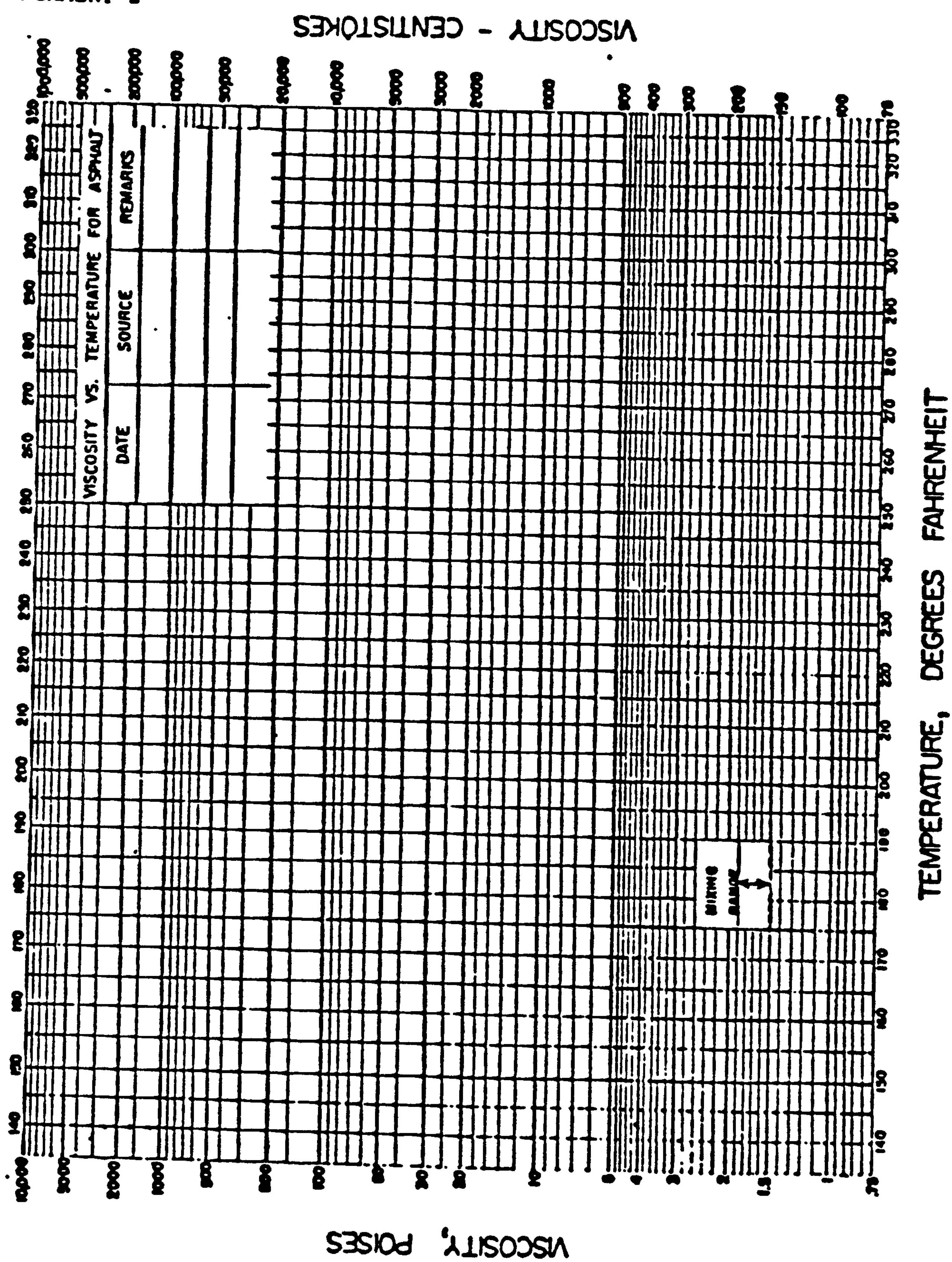
ASPHALT VISCOSITY

Each particular asphalt has a unique temperature-viscosity relationship. This relationship is sometimes described as temperature susceptibility. This temperature-viscosity relationship can be plotted on a modified semi-log chart as shown on the attached chart. These charts are very useful in determining the optimum mixing and compacting temperature of a particular asphalt. Past research has identified the optimum mixing temperature as that corresponding to a viscosity of 170 $\pm$ 20 centistokes, and the optimum compaction temperature as that corresponding to a viscosity of 280 $\pm$ 30 centistokes for laboratory mix design. The optimum mixing temperature should be identified for the asphalt used in the mix design and included in the mix design report which is sent to the production plant.

Prior to the oil embargo, there was a relatively fixed distribution system for crude oil. This allowed for a relatively uniform asphalt cement from each refinery. Highway agencies became familiar with the handling and performance characteristics of those asphalt cements. As a result of the embargo, a new variable distribution system is in place which allows shifting and blending of crude oils resulting in production of asphalt cements with very different temperature viscosity characteristics.

The attached chart will allow plotting the temperature-viscosity curve for the asphalts used in a State or a particular asphalt from a project. If the kinematic viscosity (275° F) of the asphalt being used changes from the kinematic viscosity of the asphalt used in the mix design by a factor of more than about two, a new mix design should be required.

FHWA TECHNICAL ADVISORY T 5040.27
March 10, 1988
ATTACHMENT 2



MODEL CHECK LIST FOR ASPHALT PLANT

COMPANY ______________________________

LOCATION ______________ INSPECTED BY ____________ DATE ________

TYPE PLANT AND MANUFACTURER NAME ______________________

MAXIMUM BATCH ______________ LBS.

RATED TONS PER HOUR ____________

PROJECT NO. ______________ COUNTY ______________

I. Stockpiles

1. Properly separated.
2. Material segregated.
3. Has contractor submitted and received approval of intended materials sources and job mix formula?
4. Is area clean and properly kept?

II. General Requires for all Plants

1. Are tanks for storage of asphalt cement equipped for heating the material under effective and positive control at all times?
2. Are tanks or storage material properly heated?
3. Is a circulating system for the asphalt cement of adequate capacity to provide proper and continuous circulation between storage tank and proportioning units during the entire operating period?
4. Is the discharge end of the asphalt cement circulating pipe kept below the surface of the material in the storage tank?
5. Are all pipe links and fittings steamed, oil jacketed, or otherwise properly insulated to prevent heat loss?
6. Is storage tank capacity such as to ensure continuous operation of the plant and uniform temperature of the asphalt cement when it is mixed with the aggregate?
7. Are tanks accurately calibrated to 100 gallons (378.5 L) and accessible for measuring the volume of the asphalt cement?
8. Is a sampling outlet provided in the asphalt feed lines?
9. Is a drainage receptacle provided for flushing the outlet prior to sampling?

III. Anti-Strip and Other Additive Systems

1. Is anti-strip material added at plant site?
2. If anti-strip material is added at plant site, does the anti-strip system meet specifications?
3. If other approved additives are used, are they handled in accordance with an established procedure?

IV. Cold Feed System

1. Number of cold bins.__________
2. Does plant have mechanical or electrical means for uniformly feeding the aggregates into the dryer?
3. Does cold feed have a synchronized proportioning method when blending aggregates from two or more bins?
4. If mineral filler is required, is a separate bin provided?
5. Is the feeder for mineral filler furnished with the feeder drive positively interlocked and synchronized with the aggregate feeds?

V. Drier

1. Number of driers.__________
2. Is a drier of satisfactory design provided?

VI. Dust Collectors and Emission Controls

1. What type dust collector is provided?
2. Can the material collected in the dust collector be wasted or any part or all of the material be returned to the aggregate mixture?
3. Does the plant meet applicable limitations on emissions?
4. Has company received a permit to operate from EPA?

VII. Thermometric Equipment

1. Is a recording pyrometer or armored thermometer located in the asphalt cement feed line near the discharge end at the mixer unit?
2. Is the plant equipped with recording pyrometers, or armored thermometers or other approved thermometric instruments at the discharge end of the drier?
3. Has accuracy of pyrometers or thermometers been checked?

VIII. Surge and Storage Bins

1. Is plant equipped with surge or storage bins?
2. What type bin? Surge or storage?
3. Is unit enclosed, insulated, weather proof?
4. Is unit equipped with material level indicator?
5. Is the indicator visible from plant operator or weigh master's station?
6. Does unit have approved thermometric instrument so placed to indicate automatically the temperature of mixture at discharge?

7. Is conveyer system covered and insulated (if necessary) so as to prevent excessive loss of heat during transfer of material from mixing plant to storage bin?
8. Does storage bin have acceptable heating system?
9. Has surge or storage bin received prior evaluation and approval before using?

IX. Safety and Inspection Provisions

1. Are gears, pulleys, chains, sprockets, and other dangerous moving parts thoroughly protected?
2. Is an unobstructed and adequately guarded passage provided and maintained in and around the truck loading space for visual inspection purposes?
3. Does plant have adequate and safe stairways or guarded ladders to plant units such as mixer platforms, control platforms, hot storage bins, asphalt storage tanks, etc. where inspections are required?
4. Is an inspection platform provided with a safe stairway for sampling the asphalt mixture from loaded trucks?

X. Truck Scales

1. Are scales capable of weighing the entire vehicle at one time?
2. Do scales have digital printing recorder or automatic weight printer?
3. Have scales been checked and certified by a reputable scale company in the presence of an authorized representative of the highway department?
4. Date checked ________________ Agency Name ________________________
5. Is copy of certification available?
6. Remarks ____
____
____
____
____

XI. Transportation Equipment

1. Are truck bodies clean, tight, and in good condition?
2. Do trucks have covers to protect material from unfavorable weather conditions?
3. Is soapy water or other approved products available for coating truck bodies to prevent material from sticking? Diesel fuel should not be used.
4. Type of material used. ________________

XII. Provisions for Testing

1. Does size and location of laboratory comply with specifications?
2. Is laboratory properly equipped?
3. Is laboratory acceptable?

SPECIAL REQUIREMENTS FOR BATCH PLANTS

XIII. Weigh Box or Hopper

1. Is weigh box large enough to hold full batch?
2. Does gate close tightly so that material cannot leak into the mixer while a batch is being weighed?

XIV. Aggregate Scales

1. Are scales equipped with adjustable pointers or markers for marking the weight of each material to be weighed into the batch?
2. Are ten 50-lb. (22.7 kg) weights available for checking scales?
3. Has accuracy of weights been checked?
4. Have scales been checked and certified by a reputable scales company in the presence of an authorized representative of the highway department?
   Date checked ______________ Agency Name ______________
   Is copy of certification available?
   Remarks ____
   ____
   ____
   ____
   ____
5. If the plant is equipped with beam type scales, are the scales equipped with a device to indicate at least the last 200 lb. (97 kg) of the required load?

XV. Asphalt Cement Bucket

1. Is bucket large enough to handle a batch in a single weighing so that the asphalt material will not overflow, splash or spill?
2. Is the bucket steamed, or oil-jacketed or equipped with properly insulated electric heating units?
3. Is the bucket equipped to deliver the asphalt material over the full length of the mixer?

XVI. Asphalt Cement Scales

1. Have scales been checked and certified by a reputable scale company in the presence of an authorized representative of the highway department?
   Date checked ______________ Agency Name ____________________
   Is copy of certification available?
   Remarks ____

   ____

2. Are scales equipped with a device to indicate at least the last 20 lb. (9.1 kg) of the approaching total load?

XVII. Screens

1. Condition of screens. Satisfactory _______ Unsatisfactory _______
2. Do the plant screens have adequate capacity and size range to properly separate all the aggregate into sizes required for proportioning so that they may be recombined consistently?

XVIII. Hot Bins

1. Number of bins? _______________
2. Are bins properly partitioned?
3. Are bins equipped with overflow pipes?
4. Will gates cut off quickly and completely?
5. Can samples be obtained from bins?
6. Are bins equipped with device to indicate the position of aggregate at the lower quarter point?

XIX. Asphalt Control

1. Are means provided for checking the quantity or rate of flow of asphalt material?
2. Time required to add asphalt material into pugmill.

XX. Mixer Unit for Batch Method

1. Is the plant equipped with an approved twin pugmill batch mixer that will produce a uniform mixture?
2. Can the mixer blades be adjusted to ensure proper and efficient mixing?
3. Are the mixer blades in satisfactory condition?
4. What is the clearance of the mixer blades? _____________ in.
5. Does the mixer gate close tight enough to prevent leakage?
6. Does the mixer discharge the mixture without appreciable segregation?
7. Is the mixer equipped with time lock?
8. Does timer lock the weigh box gate until the mixing cycle is completed?

9. Will timer control dry and wet mixing time?
10. Can timer be set in 5 second intervals throughout the designated mixing cycles?
11. Can timer be locked to prevent tampering?
12. Is a mechanical batch counter installed as part of the timing device?

XXI. Automation of Batching

1. If the plant is fully automated, is an automatic weighing, cycling and monitoring system installed as part of the batching equipment?
2. Is the automatic proportioning system capable of weighing the materials within ± 2 percent of the total sum of the batch sizes?

SPECIAL REQUIREMENT FOR DRUM MIXERS

XXII. Aggregate Delivery System

1. Number of cold feed bins? ________________
2. Are cold feed bins equipped with devices to indicate when the level of the aggregate in each bin is below the quarter point?
3. Does the cold feed have an automatic shut-off system that activates when any individual feeder is interrupted?
4. Are provisions available for conveniently sampling the full flow of material from each cold feed and the total cold feed?
5. Is the total feed weighed continuously?
6. Are there provisions for automatically correcting the wet aggregate weight to dry aggregate weight?
7. Is the flow of aggregate dry weight displayed digitally in appropriate units of weight and time and totaled?
8. Are means provided for diverting aggregate delivery into trucks, front-end loaders, or other containers for checking accuracy of aggregate delivery system?
9. Is plant equipped with a scalping screen for aggregate prior to entering the conveyor weigh belt?

XXIII. Asphalt Cement Delivery System

1. Are satisfactory means provided to introduce the proper amount of asphalt material into the mix?
2. Does the delivery system for metering the asphalt material prove accurate within ± 1 percent?
3. Does the asphalt material delivery interlock with aggregate weight control?
4. Is the asphalt material flow displayed in appropriate units of volume or weight and time and totaled?
5. Can the asphalt material be diverted into distributor trucks or other containers for checking accuracy of delivery systems?

XXIV. Drum Mixer

1. Is the drum mixer capable of drying and heating the aggregate to the moisture and temperature requirements set forth in the specifications, and capable of producing a uniform mix?
2. Does plant have provisions for diverting mixes at start-up and shutdowns or where mixing is not complete or uniform?

XXV. Is plant approved for use?
If not, explain what needs to be corrected. (Show Item Number)

PROJECT INSPECTION CHECKLIST

Compaction of Foundation

1. Have all courses of the foundation been compacted to required density?

Old Asphalt Pavement

1. Have all potholes been patched?
2. Have all necessary patches been made?
3. Have all loose material and "fat" patches been removed?
4. Have all depressions been filled and compacted?
5. Has fog seal been used on surface that has deteriorated from oxidation?
6. Has an emulsified asphalt slurry seal been applied on old surfaces with extensive cracking?

Rigid Type Pavement

1. Has pavement been under sealed where necessary?
2. Has premolded joint material and crack filler been cleaned out?
3. Have all "fat" patches been removed?
4. Has badly broken pavement been removed and patched?
5. Have all depressions been filled and compacted?

Incidental Tools

1. Do incidental tools comply with specifications? ________
2. Are all necessary tools on job before work begins?

The Engineer and the Contractor

1. Have the engineer and inspectors held a preliminary conference with the appropriate contractor personnel?
2. Has continuity of operations been planned?
3. Has the number of pavers to be used been determined?
4. Have the number and type of rollers to be used been determined?
5. Has the number of trucks to be used been determined?
6. Has the width of spread in successive layers been planned?
7. Is it understood who is to issue and who is to receive instructions?
8. Have weighing procedures and the number of load tickets to be prepared been determined?
9. Have procedures for investigation of mix been agreed upon?
10. Has method of handling traffic been established?

Preparation of Surface

1. Have all surfaces that will come into contact with the asphalt mix been cleaned and coated with asphalt?
2. Has a uniform tack coat of correct quantity been applied?

Asphalt Distributor

1. Does the asphalt distributor comply with specifications?
2. Are the heaters and pump in good working condition?
3. Have all gauges and measuring devices such as the bitumeter, tachometer, and measuring stick been calibrated?
4. Are spray bars and nozzles unclogged and set for proper application of asphalt?

Hauling Equipment

1. Are truck beds smooth and free from holds and depressions?
2. Do trucks comply with specifications?
3. Are trucks equipped with properly attached tarpaulins?
4. For cold weather or long hauls, are truck beds insulated?
5. When unloading, do trucks and paver operate together without interference?
6. Is the method of coating of contact surfaces of truck beds agreed upon?

Paver

1. Does the paver comply with specifications?
2. Is the governor on the engineer operating properly?
3. Are the slat feeders, the hopper gates, and spreader screws in good condition and adjustment?
4. Are the crawlers adjusted properly?
5. Do the pneumatic tires contain correct and uniform air pressure?
6. Is the screed heater working properly?
7. Are the tamper bars free of excessive wear?
8. Are the tamper bars correctly adjusted for stroke?
9. Are the tamper bars correctly adjusted for clearance between the back of the bar and the nose of the screed plate?
10. Are the surfaces of the screed plates true and in good condition?
11. Are mat thickness and crown controls in good condition and adjustment?
12. Are screed vibrators in good condition and adjustment?
13. Is the oscillating screed in proper position with respect to the vibrating compactor?
14. Is the automatic screed control in adjustment and is the correct sensor attached.

Spreading

1. Are the required number of pavers on job?
2. Is the mix of uniform texture?
3. Is the general appearance of the mix satisfactory?
4. Is the temperature of the mix uniform and satisfactory?
5. Does the mix satisfy the spreading requirements?
6. Has proper paver speed been determined?
7. Is the surface smoothness tolerance being checked and adhered to?
8. Is the depth of spread checked frequently?
9. Has the daily spread been checked?

Rolling

1. Are the required number of rollers on the job?
2. Is proper rolling procedure being followed?
3. Is the proper rolling pattern being followed?
4. Are joints and edges being rolled properly?

Miscellaneous

1. Are all surface irregularities being properly corrected?
2. Is efficient control of traffic being maintained?
3. Are sufficient samples being taken?
4. Are samples representative?
5. Have assistant inspectors been properly instructed?
6. Are inspection duties properly apportioned among assistants?
7. Are records complete and up-to-date?
8. Are safety measures being observed?
9. Has final clean-up and inspection been made?