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SPECIFIC PAVEMENT STUDIES
CONSTRUCTION GUIDELINES FOR EXPERIMENT SPS-6, REHABILITATION OF JOINTED PORTLAND CEMENT CONCRETE PAVEMENTS

STRATEGIC HIGHWAY RESEARCH PROGRAM
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TABLE OF CONTENTS

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INTRODUCTION

This report describes the guidelines for the construction of test sections for the Specific Pavement Studies' SPS-6 experiment, Rehabilitation of Jointed Portland Cement Concrete Pavements. These guidelines have been developed by SHRP in cooperation with state and provincial highway agency personnel participating in various meetings, including a construction guidelines review meeting held in Ames, Iowa, May 8-9, 1990. The recommendations of the participants from seven states, Canada, United Kingdom, and the Federal Highway Administration and comments furnished by other highway agency personnel are incorporated in the guidelines outlined in this report. These guidelines will help participating highway agencies develop acceptable construction plans for test sections for this experiment.

The SPS-6 experiment, Rehabilitation of Jointed Portland Cement Concrete Pavements, requires the construction of multiple test sections with similar details and materials at each of twenty-four sites distributed in the four climatic regions. The experimental design and construction considerations for this experiment are described in the document, "Specific Pavement Studies: Experimental Design and Research Plan for Experiment SPS-6, "Rehabilitation of Jointed Portland Cement Concrete Pavements," April 1989. The experiment has been developed as a coordinated national experiment to address the needs of the highway community at large and not only the participating highway agencies. 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 int his 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-6 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 three major experimental levels of test section preparation (minimal and intensive restoration and crack/break and seat).
- To provide specifications for materials to be used such as joint and crack sealants and asphalt concrete.
- To provide specifications and details for typical repair and restoration items such as patches, retrofitted dowels, and joint and crack sealing.
- To describe the construction operations and as-built requirements (surface roughness).

In addition, special considerations related to geometric corrections and treatments that should not to be performed on the test sections are addressed in this document.

TEST SECTIONS

The combinations of experimental factorsfor the seven SPS-6 test sections, designated Section 2 through Section 8, are listed in Table 1. In addition, a control section which receives only limited routine-type maintenance, designated Section 1, is included in the experiment. The test section numbers shown in this table are used to reference the test sections in the remainder of this document.

Table 1. SPS-6 test section numbering scheme.

SPS-6 SECTION NO.	PREPARATION	OTHER TREATMENTS	OVERLAY THICKNESS, inch
1	Routine Maintenance	-	0
2	Minimum Restoration	-	0
3	Minimum Restoration	-	4
4	Minimum Restoration	Saw and Seal Joints in AC Overlay	4
5	Intensive Restoration	-	0
6	Intensive Restoration	-	4
7	Crack/Break and Seat	-	4
8	Crack/Break and Seat	-	8

Typical cross sections illustrating the combinations of restoration and/or overlay for the test sections are presented in Appendix A for illustrative purposes. The details of the cross sections at a test site will probably differ from those shown in Appendix A depending on the characteristics of the existing pavement structure. The participating highway agency must develop the typical sections for the proposed test site following the guidelines outlined in this document.

Table 2 presents a summary of the types of treatments and/or restoration that should be applied to each test section. Table 3 highlights the applicable rehabilitation treatments for each test section. Only those treatments listed in Table 3 are required and no other repairs or treatments should be performed.

ACTIVITIES ON CONTROL SECTION

Repairs and other activities on the control test section (Section 1) should be limited to only those maintenance activities needed to keep the section in a safe and functional condition. Although the project has fallen to a condition level requiring rehabilitation, overlay and extensive repairs on the control section must be avoided at the start of the study. The rate of change in the condition of the control section will be used as an indicator of the change be expected on the other test sections had they not been rehabilitated.

Maintenance activities should be performed on the control test section (Section 1) in accordance with the standard procedures of the agency. These procedures may differ from those described in this document for the rehabilitation of the other test sections (Sections 2 through 8).

In general, maintenance treatments on the SPS-6 control section should be limited to those permitted in "Guidelines for Maintenance of General Pavement Studies' (GPS) Test Sections," SHRP-LTPP-OM-001, July, 1988.

Table 2. Summary of rehabilitation treatments for SPS-6 test sections.

TEST SECTION DETAILS AND TREATMENT OPTIONS	SURFACE PREPARATION							
	Routine	Minimal			Intensive		Crack & Seat	
Section number	1	2	3	4	5	6	7	8
Section length (100 ft)	5	10	5	5	10	5	5	5
Overlay thickness (in.)	0	0	4	4	0	4	4	8
Joint sealing	X	X	N	N	R&R	N	N	N
Crack sealing	X	X	N	N	R&R	N	N	N
Partial depth patch	N	X	X	X	R&R	R&R	N	N
Full depth patch/joint repair	N	X	X	X	R&R	R&R	N	N
Load transfer restoration	N	N	N	N	B	B	N	N
Full surface diamond grinding	N	X	N	N	A	N	N	N
Undersealing	N	N	N	N	X	X	N	N
Subdrainage	N	N	N	N	A	A	A	A
Crack/Break and seat	N	N	N	N	N	N	A	A
Saw and seal	N	N	N	A	N	N	N	N

X - Apply treatment as warranted
R&R -Remove & replace existing, and apply additional as warranted
N - Do not perform
B - Full depth dowelled patch or retrofit dowels in slots
A - Apply treatment regardless of condition or need

Table 3. Highlights of rehabilitation treatments for SPS-6 test sections.

Section 1	Routine maintenance only as per agency practice 3-5 years of service desired
Section 2	Minimal surface preparation, no overlay • perform joint and crack sealing, if warranted • perform partial and full depth patching, if warranted • perform full surface diamond grinding, if warranted
Section 3	Minimal surface preparation with 4 inch overlay • perform partial and full depth patching, if warranted • place a 4-in. thick HMAC overlay
Section 4	Minimal surface preparation with saw and seal 4 inch overlay • perform partial and full depth patching, if warranted • place a 4-in. thick HMAC overlay • saw and seal overlay over existing PCC pavement joints and working cracks
Section 5	Intensive surface preparation, no overlay • remove and replace existing joint and crack sealing • perform additional joint and crack sealing, if warranted • remove and replace existing partial and full depth patches • perform additional partial and full depth patching, if warranted • correct poor load transfer at joints and/or working cracks by full depth patching or retrofitting dowels • perform full surface diamond grinding • retrofit subsurface edge drainage system • perform undersealing, if warranted
Section 6	Intensive surface preparation with 4 inch overlay • remove and replace existing partial and full depth patches • perform additional partial and full depth patching, if warranted • correct poor load transfer at joints and/or working cracks by full depth patching or retrofitting dowels • retrofit subsurface edge drainage system • perform undersealing, if warranted • place a 4-in. HMAC overlay

Table 3. Highlights of rehabilitation treatments for SPS-6 test sections (continued).

Section 7	Crack/break and seat section with 4 inch overlay • crack/break and seat • retrofit subsurface edge drainage system • total section length including transitions should be at least 1500 ft (500 ft transitions at each end) • place a 4-in. HMAC overlay
Section 8	Crack and seat section with 8 inch overlay • crack/break and seat • retrofit subsurface edge drainage system • place an 8-in. thick HMAC overlay

Patching in the control section (Section 1) should be limited to that normally performed by agency maintenance personnel as a short duration activity. This repair should be made with a cold mix or HMAC, unless the agency commonly uses other materials and procedures for this maintenance activity. The types of distress treated in this activity would be limited to spalling or scaling confined to the upper 1/3 of the slab. However, if cracking or deterioration extends into the lower portion of the slab and thus restoration with full depth patching is required, the SHRP regional office should be notified. The following guidelines should be observed for patching as part of routine maintenance on the control sections:

- Only materials with a successful performance history should be used.

- Agency practice should be used to prepare the surface before patching. This generally requires saw cuts at least 2 inches deep at locations 3 to 4 inches outside the defective area, and carefully removing the deteriorated concrete without fracturing underlying sound concrete. If the repair is required at a joint, all joint sealant adjacent to the patch should be removed and a bond breaker is placed to separate patch area from the adjacent joints.

- The final surface shall be smooth and flush with existing surface. Transverse joint openings must be preserved and sealed. Traffic should not be allowed until after the repair material has fully cured.

PAVEMENT PREPARATION/RESTORATION

In the experimental design, preparation and/or restoration of the existing pavement is classed into three levels: minimal, intensive and crack and seat or break and seat. These preparation treatments and/or restoration levels are applied with and without HMAC overlays. In one test section, the overlay will be sawed and sealed over the existing pavement joints and working cracks. The types of treatments and/or restoration required for each test section are listed in Tables 2 and 3. Guidelines for performing these treatment and restoration items are described in this report. These guidelines should be followed when constructing the test sections to ensure a reasonable construction uniformity among all test sites.

Joint and Crack Sealing

No joint or crack sealing repair or replacement should be performed on the test sections receiving overlays (Sections 3, 4, 6, 7, and 8). The following guidelines should be followed for performing joint and crack cleaning and sealing on those sections receiving no overlay (Sections 2 and 5):

- For the test section receiving minimal preparation and no overlay (Section 2), only those cracks and joints that have not been previously sealed or those exhibiting defective seals (sealant has either become dislodged or cracked so that the sealant no longer provides an effective barrier to entry of moisture or debris) should be cleaned and resealed following the guidelines described later in this section. A sealant type similar to that previously used in the test section may be used.

- For the test section receiving intensive preparation and no overlay (Section 5), all crack and joint sealants should be removed and replaced. Also, cracks and joints that have not been previously sealed should be cleaned and sealed. Sealant type may be different than that previously used in the test section. However, the same sealant type should be used for both crack and joint sealing.

- The following guidelines should be observed for preparation, sealing and repair of cracks:

    - Cracks that are less than 1/8 inch wide and exhibiting no spalling shall not be widened or sealed.

- Cracks that are less than 1/8 inch wide and exhibiting faulted and/or rough edges but no spalling shall be routed or sawed and than sealed.

- Crack that are 1/8 to 3/4 inch wide and exhibiting no or minor spalling shall be routed or sawed and then sealed.

- Cracks that are 1/8 to 3/4 inch wide and exhibiting moderate to severe spalling shall be repaired by partial-depth patch and then sealed. Use backer rod if required by agency practice.

- Cracks that are more than 3/4 inch wide and exhibiting no spalling shall be routed and then sealed. Use backer rod if required by agency practice.

- Cracks that are more than 3/4 inch wide and exhibiting moderate to severe major spalling shall be repaired by full depth patch.

The following guidelines should be observed for joint and crack sealing:

- Procedures and materials which have proven to work best for the agencies are to be used for the test sections. No new experimental sealants shall be used for the test sections.

- Field Poured Liquid Sealant (FPLS) use should conform to ASTM D/3405, "Joint Sealants, Hot-Poured, for Concrete and Asphalt Pavements." Requirements for penetration and bond may be modified for cold climates. Silicone sealant should be used according to agency requirements.

- A rectangular joint plow or diamond saw blade (for hardened sealant) shall be used for cleaning joints. Use of "V" shaped plow, high pressure water blasting or sand blasting are not allowed. Preformed compression seals should be manually removed.

- Refacing is required to provide the specific shape factor or when old sealants are not completely removed. In no case shall the refaced joint opening be larger than 1 1/2 inch. A shape factor (width to depth ratio) between 0.67 and 1 is suitable for field poured type sealants. Low modulus silicone sealant may have a shape factor up to 2 or as recommended by the manufacturer.

- After sawing, sandblasting is required for removal of fines on the sidewalls before sealing.

- A single blade cut shall be used to remove incompressible materials from the bottom of the joints. Power driven wire brushes and high pressured water shall not be used.

- The FPLS shall not over fill the joint reservoir. A gap of 1/4 to 1/8 inch is required between the top of the surface of the sealant and the surface of the pavement. Traffic should not be allowed until the sealant has fully cured.

- Resealing and shape factor requirements for the longitudinal centerline joints are less stringent. These joints should be cleaned to a depth of approximately 3/4 inch and a width of 1/4 inch.

- The longitudinal shoulder joints should be at least one inch wide if vertical settlement is expected to occur. A sealant with a proven satisfactory performance history should be used. Otherwise, improved rubber asphalt sealant, silicones or crumb rubber asphalt can be used.

- Crack cleaning and sealing or sealant replacement should be performed using the same procedures and materials used for the joints. However, rotary impact routers should not be used during routing and sawing.

Partial Depth Patching

Partial depth patching, as illustrated in Figure 1, shall be performed to repair areas with spalling or scaling confined to the upper half of the concrete slab and contains no cracks that extend throughout the slab thickness. Coring at representative joints may be necessary to determine the depth of deterioration. Full depth patching will be required if full depth cracks exist. Partial depth patching should be performed on all minimal preparation test sections (Sections 2, 3, and 4) only if warranted. However, all existing partial depth patches on the intensive preparation test sections (Sections 5 and 6) should be removed and replaced. The following guidelines should be observed when performing partial depth patching:

- Vertical saw cuts, approximately 1.5 to 2 inch deep, should be performed outside of deteriorated area so that the remaining vertical faces are sound and provide a suitable bonding surface. The unsound material should be carefully removed to prevent damage to the edges.

- Patch material should be portland cement concrete (PCC) or other approved materials. Cement grout may be used for developing bond.

- No organic compounds (asphalt concrete, epoxies, etc.) should be used.

Full Depth Patching

Full depth patches, as illustrated in Figure 2, shall be used to repair deteriorated joints and working cracks that are too wide to be sealed. Full depth patching should be performed on all minimal preparation test sections (Section 2, 3, and 4) only if warranted. However, all existing full depth patches on the intensive preparation test sections (Section 5 and 6) should be

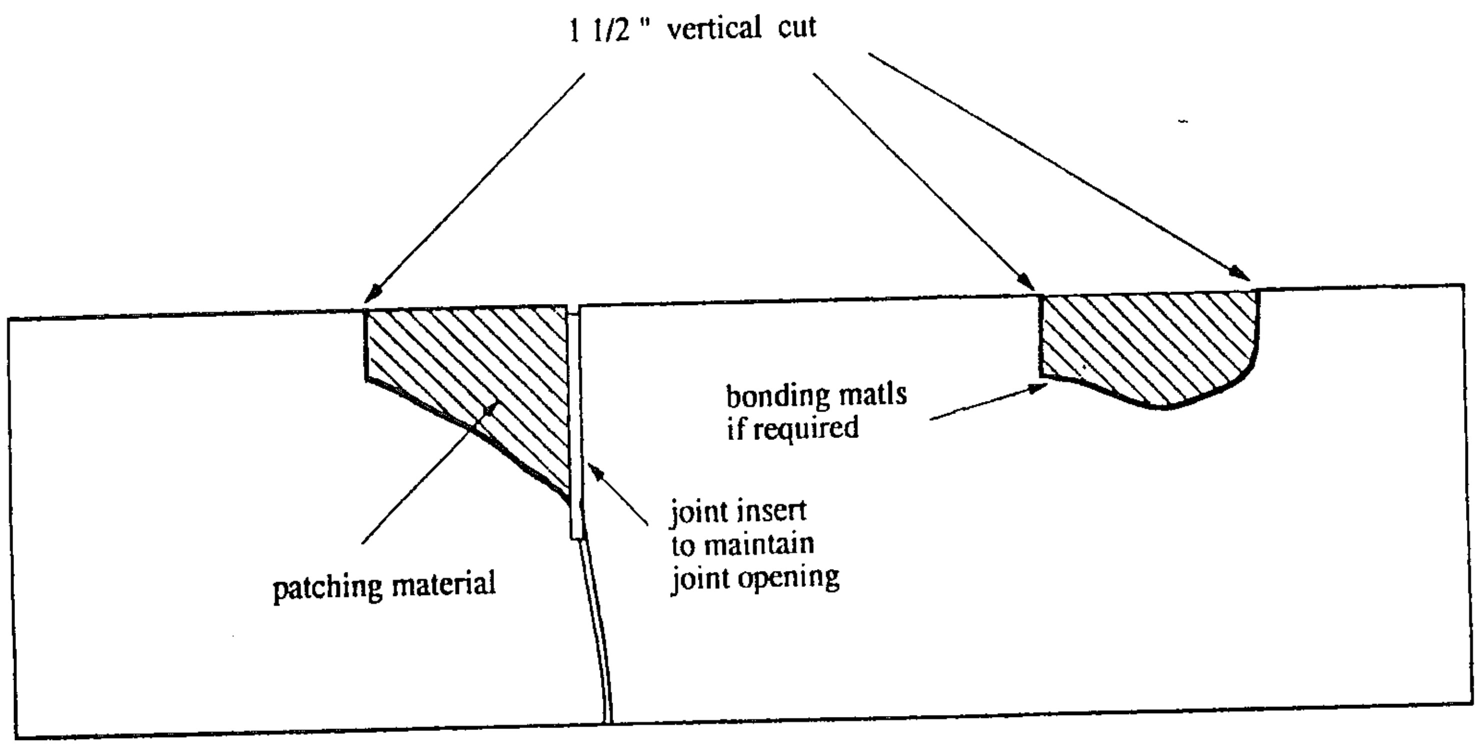
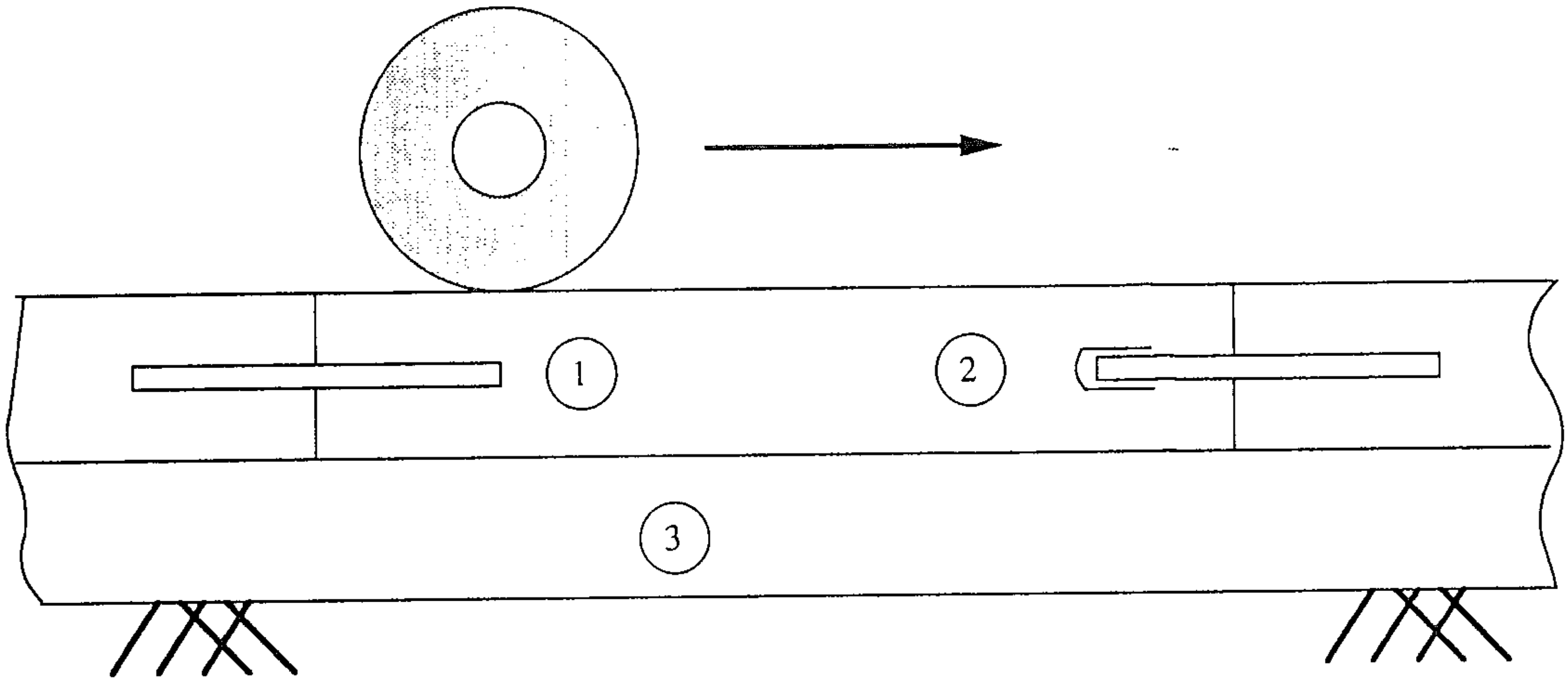


Figure 1 . Partial Depth Patching



(1) Dowel or Deformed bar - Agency practice

(2) Smooth dowel grouted in old pavement capped or debonding agent in patch

(3) Subbase restored to proper condition

Figure 2. Full Depth Patch

removed and replaced. Full depth patching shall be performed in accordance with the following guidelines:

- Patches should be a minimum 6 feet in length and full lane width.
- Only portland cement concrete patching material should be used.
- After removal of the deteriorated pavement section, the exposed subbase must be restored to a suitable condition. Undercuts must be replaced to the existing grade level with similar materials. Patch thickness must be the same as the adjacent pavement slabs.
- Deformed tie bars or smooth dowels shall be used along the transverse edges of the patch and spaced according to agency requirements. However, at least 4 bars should be used per wheel path. Eighteen inch long, epoxy coated dowels with 1 1/4 inch (1 1/2 inch preferred) diameter and spaced 12 inches on centers are recommended.

<u>Load Transfer Restoration</u>

Restoration of load transfer shall be performed as required only on the intensive preparation test sections (Sections 5 and 6). Restoration of load transfer across joints without load transfer devices and working cracks shall be performed when the load transfer across these discontinuities is less than 70%. Load transfer should be measured with a heavy load (~ 9,000 lb) in early morning or during cool weather. Air temperature at time of testing should not be greater than 70° F. Load transfer is computed as follows:

$$LT = A * \delta_{ul}/\delta_l * 100$$

where

LT = percent load transfer

A = 1 if $X \leq 12"$

A = δ_o/δ_x if $X > 12"$

X = distance between deflection measurements points δ_o and δ_x, and δ_l and δ_{ul}, inches (it is preferred that $X \leq 12"$)

δ_o - center load deflection for midslab test (at same load level as δ_l)

δ_x - midslab deflection measured X distance from δ_o

δ_l - center load deflection for test at edge of crack or joint

δ_{ul} - deflection of the surface of the unloaded slab X distance from δ_l

Load transfer at joints and working cracks shall be restored by means of full depth patching or by use of retrofitted dowel bars. The following guidelines should be observed when performing load transfer restoration by means of retrofitted dowel bars:

- Retrofit smooth round dowels shall be installed in slots cut into the pavement surface, as shown in Figure 3.

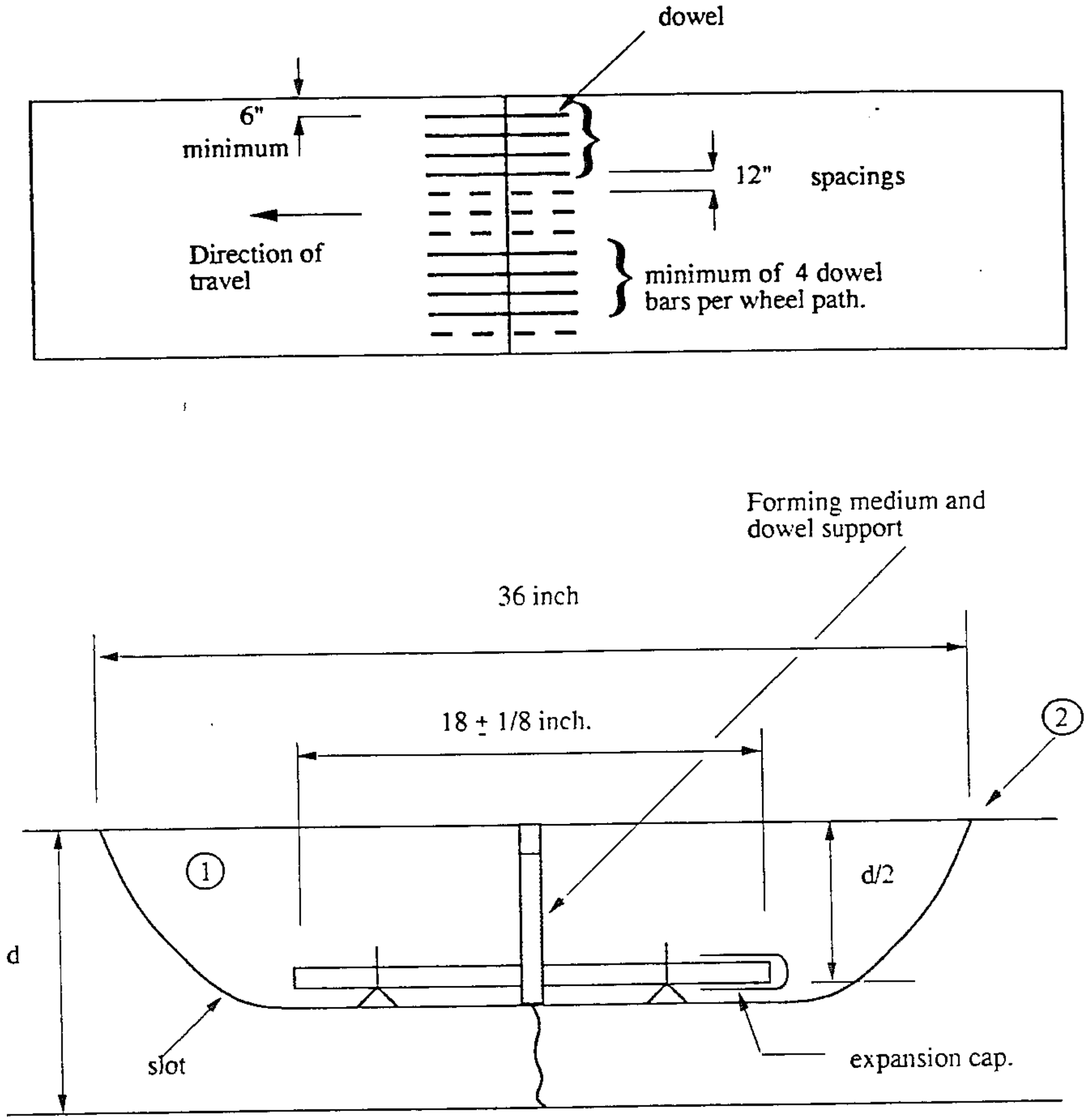
- Only 18-inch long epoxy coated, smooth, round dowel bars, with a minimum diameter of 1.25 inches (1.5 inches preferred) shall be used.

- Dowel bars should be spaced according to agency requirements, but at least 4 bars should be used per wheel path.

- Portland cement concrete or other suitable material shall be used to back fill around dowels.

Full Surface Diamond Grinding

The primary purpose of full surface grinding is to restore the transverse and longitudinal profile distorted due to the effects of faulting, warping, abrasive wear in the wheel paths, or non-uniform volume change of the subgrade. Full surface grinding should be performed on Section 2 if warranted. However, the entire surface of Section 5 must be ground regardless of the surface condition.



① Clean and prime saw area with cement grout, backfill with PCC after dowel installation. Maintain joint opening

② Slot width 3 1/2 " min. and 4 " max.

Figure 3. Retrofitted Dowel Bar System

Grinding of the surface of Section 2 may be performed if warranted by the following criteria:

- At least 10% of the joints and working cracks in the section exhibit faulting over 25% or more of each joint or crack length of ≥ 0.25 and ≥ 0.40 inch for JPCP and JRCP, respectively.
- At least 10% of the transverse cracks and joints in JRCP that are spaced at 20 to 30 feet intervals exhibit faulting ≥ 0.25 inches.
- Transverse cross slope is less than 1.5% (to improve cross slope for drainage considerations).
- Prorated profile index over the test section length is greater than 20 inches per mile, as measured with the California Profilograph.

To be suitable for grinding, pavement sections candidate must be structurally sound regardless of the extent of cracking. Grinding shall be performed continuously over the entire length of the test section. Spacing of the diamond blades may be adjusted depending on the hardness of the concrete aggregates following the local practices. Grinding shall be performed to obtain a pavement surface with a prorated profile index less than 7 inches per mile as measured with a California Profilograph.

Undersealing

Undersealing (also known as subsealing) beneath the concrete slab may be reformed only on the intensive preparation test sections (Sections 5 and 6). The purpose of undersealing is to fill small voids between the slab and subbase and help restore full support to the slab and seal interface water flow channels. Undersealing should not be used to adjust the vertical profile of the slabs. Undersealing should be performed only where the existence of voids beneath the concrete slab can be demonstrated according to current engineering practice used by the agency. Undersealing should be performed following those representing the agency's practice. However, the following guidelines should be observed when performing undersealing:

- Undersealing should be performed prior to surface diamond grinding.

- Only pozzolanic-cement grouts (natural or synthetic) or limestone-cement grouts are permitted. Fly ash shall conform to ASTM designation C 618 for either Class C or Class F.

- Limestone and crystalline structures used in the grout shall be spherical with a gradation of 95% passing No. 30 sieve and 30% passing the No. 200 sieve.

- Additives and admixtures may be used if proven to work successfully.

- Injection grout holes shall be placed at least 3 ft away from any existing subsurface drainage structures.

- An inspection hole should be located near pavement edge to monitor the entry of grout into any existing subsurface drainage system.

- Grout pumping shall be stopped if any of the following conditions occur:

    - Vertical movement of the slab or shoulder is detected.
    - Grout is observed coming out of observation holes or subsurface drainage structures.
    - A rapid increase in pumping pressure occurs.

- Any grout entering pavement joints shall be removed to maintain proper joint openings.

- Any cracks developed due to the undersealing operations must be sealed by epoxy injection (structural repair) or repaired by full depth patches.

- Traffic should be kept off the subsealed area until the grout cures or for a minimum of 2 hours.

- Undersealing should be performed before installing subdrainage.

Follow-up testing should be performed to assess undersealing effectiveness using the agency's procedure. Alternatively, undersealing effectiveness may be evaluated by measuring slab deflection at joints under truck loading before and after undersealing using the procedure described in AASHTO Guide Specification for Highway Construction, 1988.

Subdrainage

Retrofitted subsurface drainage systems are required on all intensive preparation and crack/break and seat test sections (Sections 5,6,7, and 8). The following guidelines shall be followed for retrofitted subsurface drainage:

- Retrofitted subsurface drainage systems shall be limited to longitudinal edge drains and outflow pipes.

- Edge drains on the crack/break and seat sections (Sections 7 and 8) should be installed prior to crack and seat or break and seat operation.

- The agency shall design the subsurface edge drainage system following local design practice. Local design details such as drain geometry (width, depth), filter materials, permeable drainage materials, collector pipes and outlet system which have been used successfully by the agency may be used. Aternatively, the procedures used by another agency or those recommended by AASHTO may be used. Experimental or unproven treatments should not be used.

- Trenching must be performed with care to maintain correct line and grade. Plowing is not permitted. Excess soil remaining on the side of the concrete slab shall be removed. Care must be taken to eliminate unplanned local high points in edge drain trenches during installation.

- Edge drains that exist prior to rehabilitation must be cleaned and restored to ensure working condition.

Shoulder Rehabilitation

Agencies should perform routine repair, maintenance and level up of the existing shoulders as required. Tied portland cement concrete shoulders shall not be added to any of the test sections. The shoulder for Section 8 (crack/break and seat with an 8-inch overlay) may need to be widened to accomodate slope requirements.

Crack/Break and Seat

Sections 7 and 8 will be subjected to crack/break and seat operations prior to placement of the overlay. Appendix B contains construction specifications for crack/break and seat operations. The terms "crack and seat" and "break and seat" are used for JPCP and JRCP, respectively.

Saw and Seal

Saw and seal treatment applies only to Section 4, (minimum preparation with 4 inch overlay). This work consists of marking, sawing, cleaning, and sealing of joints in the HMAC overlay. The following guidelines should be followed for these operations:

- The location of the joints and working cracks in the existing pavement must be referenced prior to placement of the overlay so that the joints in the overlay can be sawed within one inch of these locations.

- Sawing of the joints in the overlay shall be initiated between 3 to 7 days after the placement of the asphalt concrete surface course. For a two lift construction, joints must be sawed in the first lift if the second lift will be placed more than 7 days after the first lift.

- Saw and seal should be performed above only transverse joints and working transverse cracks. The saw cut must extend beyond the edge of the existing concrete pavement into the asphalt concrete shoulder for a minimum of 36 inches.

- The saw cut should be at least 1 1/2 inches deep and a minimum of 3/8 inch wide.

- Shape factors (width to depth ratio) should be based on agency practice or as recommended by the sealant manufacturer.

- The sawing and sealing operations must be performed continuously on the test section using a diamond saw capable of producing a straight, uniform, vertical cut. All saw cuts in the test section must be performed during the same day.

- The saw cuts must be thoroughly cleaned by water blasting and should be completely dry before sealing.

ASPHALT CONCRETE OVERLAY

This section of the report addresses material requirements, mix design, and construction operations for the HMAC overlays required for Sections 3, 4, 6, 7, and 8.

Materials and Mix Design

It is not practical nor 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 revised FHWA Technical Advisory T5040.27, "Asphalt Concrete Mix Design and Field Control," March 10, 1988 with the mix design criteria revision to conform to the Asphalt Institute Manual, MS-2, "Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types," 1988. A copy of these guidelines is reproduced in Appendix C of this report.

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

Marshall	-	Compaction blows	75
		Stability (Minimum)	1,800
		Flow	8 to 14
Hveem	-	Stability (Minimum)	37
		Swell (Maximum)	0.03 in.
Air Voids	-		3 to 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 be mixed using only virgin materials which have not been used in previous construction. Recycled asphalt pavement (RAP) materials shall not be used for the test sections.

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

- A minimum of 60% crushed coarse material (retained on #4 sieve) with two crushed faces.

- A minimum sand-equivalent value of 45 as obtained following AASHTO Method of test T 176.

- A dense aggregate gradation.

Grade and characteristics of the asphalt cement used in the mix should be selected by the agency based on normal practice. Asphalt cements with low temperature susceptibility (PVN ≥ -0.5) are recommended.

Additives, such as lime, which are routinely used by an agency are permitted in the mix design. Experimental additives or modifiers should not be used in the test sections, but may be used in supplemental test sections.

Construction Operations

Asphalt concrete 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 on the test sections to prevent construction practices which are known to result in poor performance of pavements. In addition, care should be taken to ensure that the construction of the test sections is performed in a manner consistent with normal highway construction practices.

The following construction related guidelines shall be followed:

- Lift thickness shall be limited to a maximum of 4.0 inches.

- 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 within 1 foot of the center of a lane or within 1 foot of the center of two adjacent lanes.

- All transverse construction joints in the overlay shall be placed outside the test sections, e.g. within the transitions between test sections.

- The as-compacted average thickness of the asphalt concrete overlay in the test sections shall be constructed to within ± 1/4 and ± 1/2 in. for the 4 and 8-in. thick overlays,respectively (i.e. 4 ± 1/4 and 8 ± 1/2 inch).

- The finished surface of the asphalt concrete overlay should be smooth and provide an excellent ride level. Construction should be aimed to achieve a pro-rated profile index of less than 10 inches per mile as measured by a California type Profilograph and evaluated as outlined in California Test 526.

SPECIAL CONSIDERATIONS

The following treatments are specifically not to be performed on any of the test sections:

- Lane widening. Widening of the test lane will alter the characteristics and behavior of the test sections and thus "confound" the factors and effects to be evaluated.

- Geotextiles. The use of geotextiles on the pavement or as part of the overlay is not included as a main factor in this experiment. Geotextile may be used by participating agencies in supplemental test sections.

These exclusions are not intended to lessen the importance of these treatments in concrete pavement rehabilitation, but to enable a proper evaluation of the main study factors in a reasonable experiment. The inclusion of such factors as geotextiles or lane widening on an uncontrolled basis would confound measurement of the main factor effects included in the study and diminish the results of this experiment. Further, the inclusion of such factors would require a larger size experiment to properly evaluate the effects of these factors on pavement performance.

Surface friction courses may be used on asphalt concrete overlays if required by the participating agency. In this case, the thickness of the friction course should be limited to 3/4 inch and should not be considered as part of the thickness of the dense graded asphalt overlay specified for the test section.

DEVIATIONS FROM GUIDELINES

An agency that desires to participate in the SPS-6 experiment but finds it necessary to deviate from some of the guidelines described in the report should review these deviations with the SHRP Regional Office or SHRP headquarters. SHRP 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 SHRP will suggest alternatives for consideration by the participating agency.

APPENDIX A

TYPICAL PAVEMENT SECTIONS
FOR SPS-6 EXPERIMENT,
REHABILITATION OF JOINTED PORTLAND CEMENT CONCRETE PAVEMENTS

APPENDIX A - TYPICAL PAVEMENT SECTIONS FOR SPS-6 EXPERIMENT, REHABILITATION OF JOINTED PORTLAND CEMENT CONCRETE PAVEMENTS

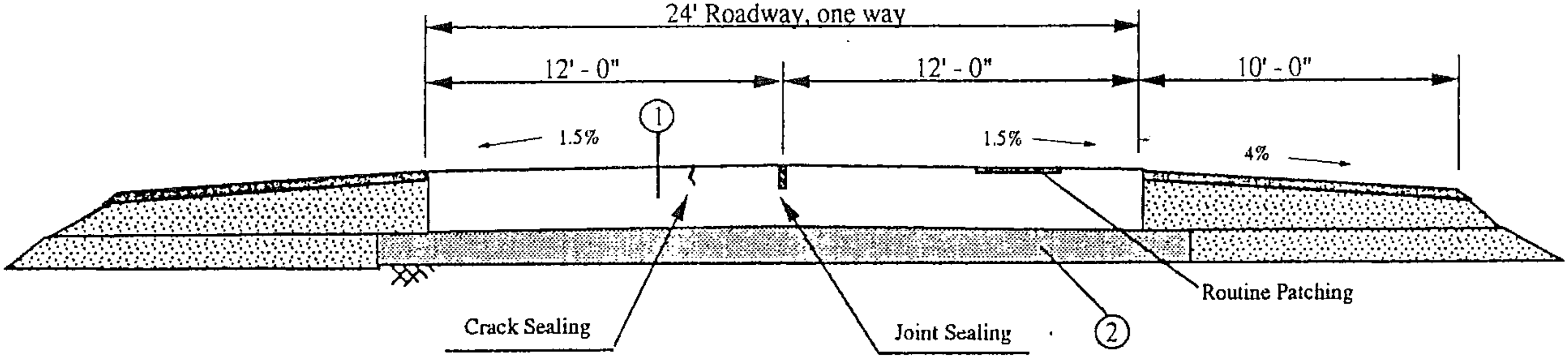
The typical cross sections presented in this document were developed for the hypothetical existing pavement structure shown in Figure A1. The depicted pavement structure is two lanes of a four lane divided highway structure with a crowned cross section. The pavement structure is assumed to consist of a subbase (treated or untreated) and a concrete slab (JPCPor JRCP). Since no rehabilitation treatments will be applied to the control section at the start of the study, this figure also represents the cross section of the control section (Section 1).

The typical sections for the test sections are shown in Figures A2 through A9. The specific restoration combinations and thicknesses shown in these figures illustrate the expected treatments for the test sections. Participating agencies may alter some of the cross section details to meet local design and construction practice, but must stay within the limits defined in this document.

Test sections requiring miminal level of restoration with and without an overlay (Sections 2, 3, and 4) are shown in Figures A2, A3, and A4. Section 2, shown in Figure A2, is a 1,000 ft long test section that will receive no overlay. Figure A3 illustrates Section 3, a 500 ft long test section that will receive a 4 in. thick HMAC overlay. The overlay may be placed in one or two lifts. Section 4, shown in Figure A4, is a 500 ft long test section similar to Section 3, except that joints must be sawed and sealed in the overlay over existing joints and working cracks in the existing concrete pavement.

Test sections requiring an intensive level of restoration with and without an overlay (Section 5 and 6) are shown in Figure A5 and A6. Section 5, shown in Figure A5, is a 1,000 ft long test section that will receive no overlay. Figure A6 illustrates Section 6, a 500 ft long test section that will receive a 4-in. thick HMAC overlay.

Test section requiring crack/break and seat operations prior to overlay placement (Sections 7 and 8) and shown in Figures A7 and A8. Section 7, shown in Figure A7, is a 500 ft long test section that will receive a 4-in. thick HMAC overlay. Section 8, shown in Figure A8, is a similar to Section 7 except that an 8-in. thick HMAC overlay will be placed. The 8-in. overlay may be placed in two or more lifts so that lift thickness does not exceed 4 in.

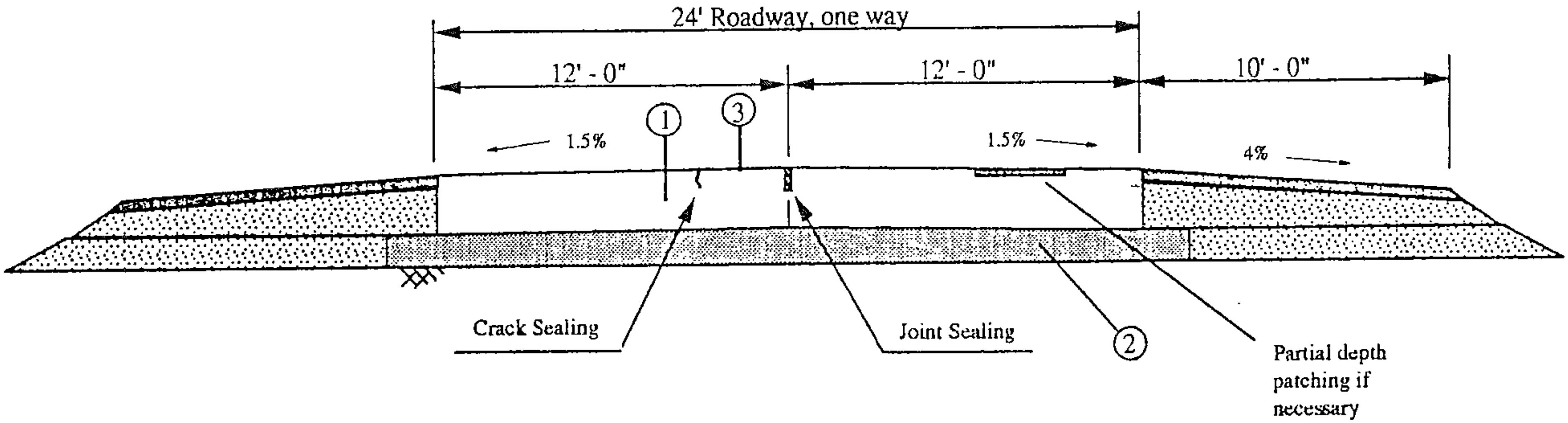


LEGEND

① 8" - 10" JPCP/ JRCP

② Treated Subbase / Untreated Subbase

Figure A 1. SPS-6 Section 1 with routine maintenance no overlay. (500 ft.)



LEGEND

① 8" - 10" JPCP/ JRCP

② Treated Subbase / Untreated Subbase

③ Full Surface Grinding if Necessary
Also Perform Full Depth Patching if
Necessary

Figure A 2. SPS-6 Section 2 with minimum restoration and no overlay. (1000 ft.)

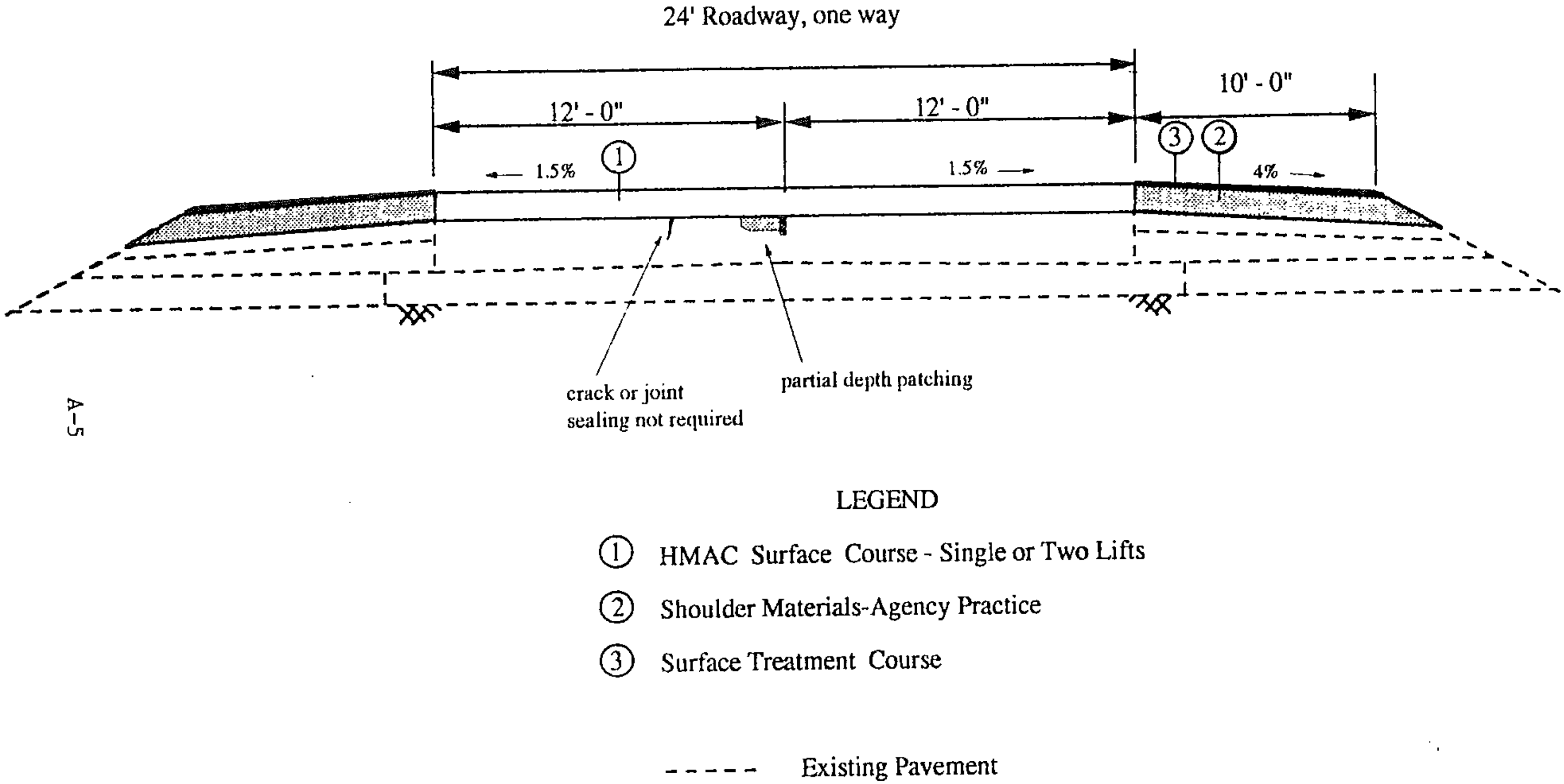


Figure A 3. SPS-6 section 3 with minimum restoration with 4-inch overlay. (500 ft.)

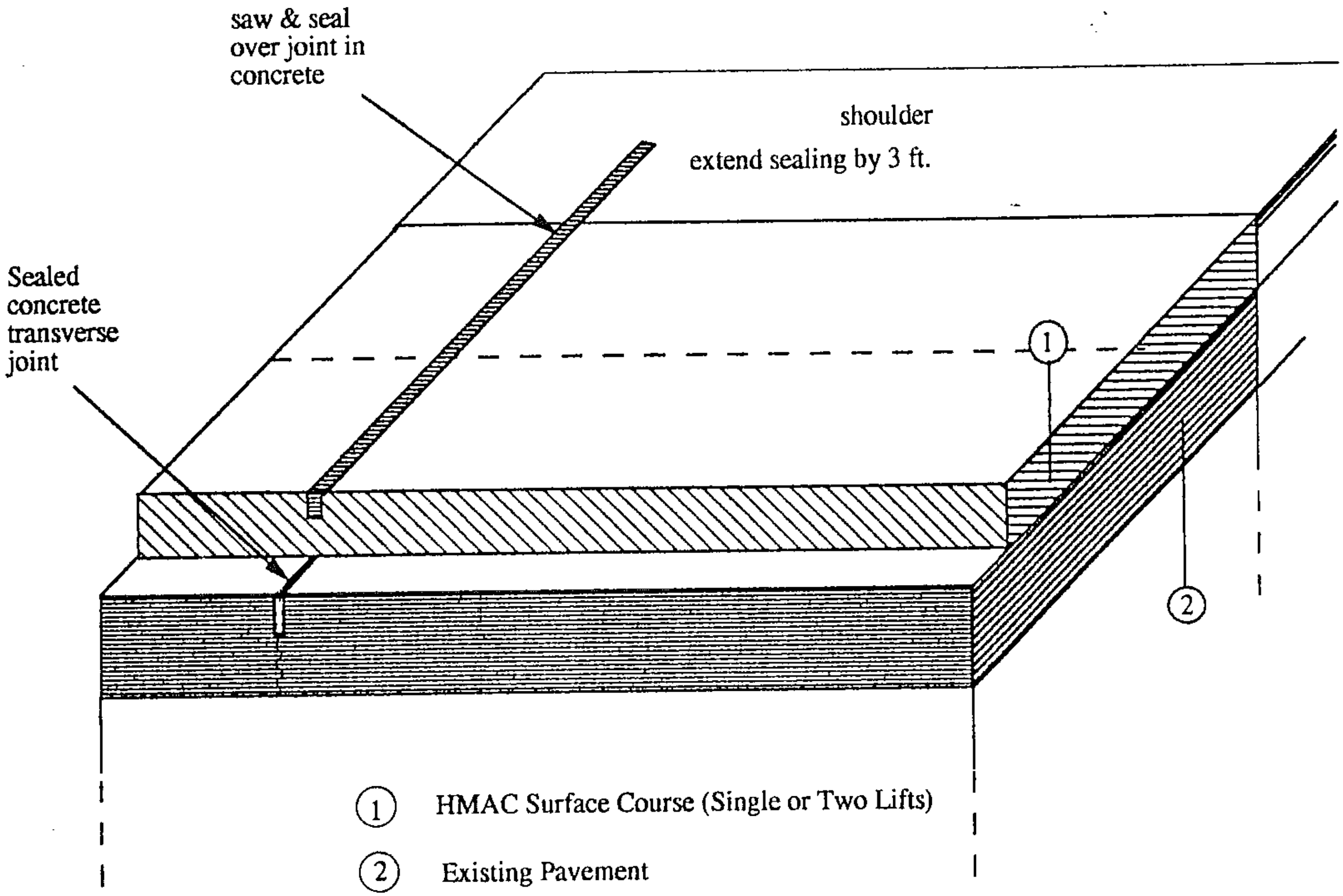
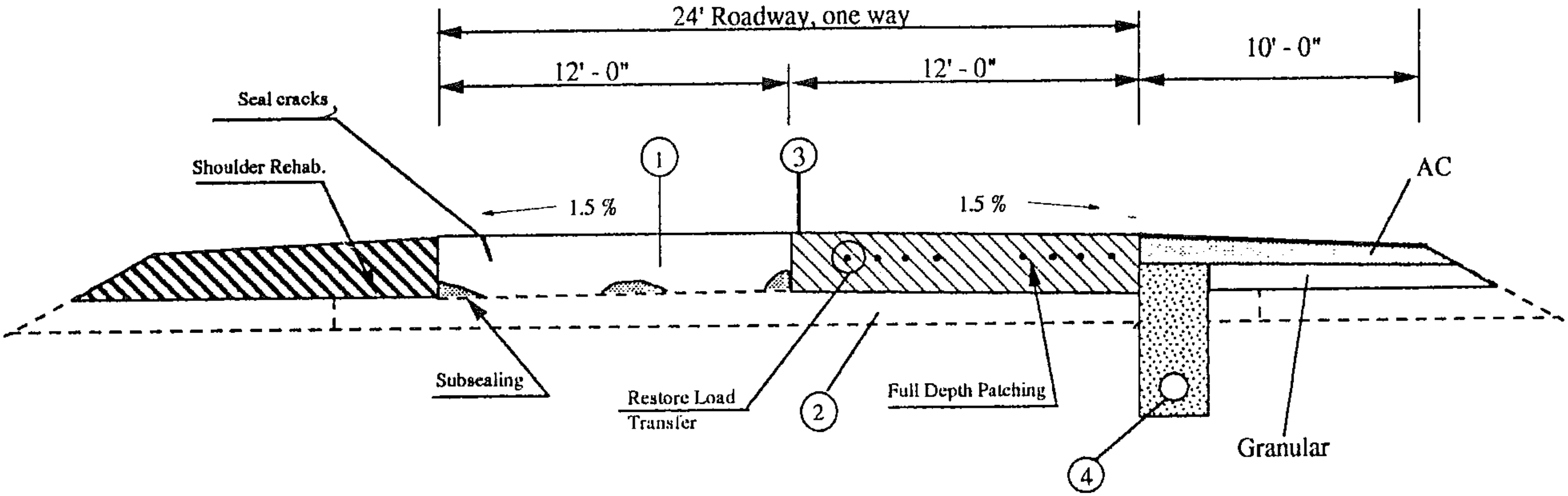


Figure A 4. SPS-6 section 4 with minimum restoration and saw and seal joints in 4-inch overlay. (500 ft.)



LEGEND

① 8"- 10" JPCP/JRCP

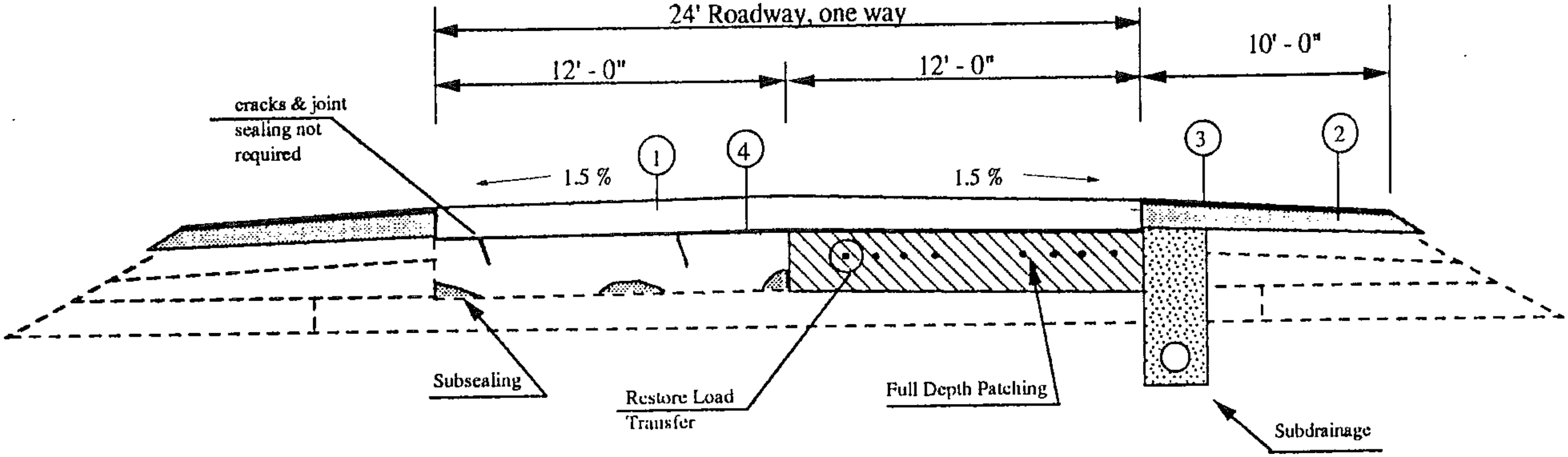
② Treated/Untreated Subbase

③ Grinding of Whole Pavement

④ Subdrainage at Edge

------ Existing Pavement

Figure A 5. SPS-6 section 5 with maximum restoration and no overlay. (1000ft.)



LEGEND

(1) HMAC Surface Course Single or Two Lifts

(2) Shoulder Materials -Agency Practice

(3) Surface Treatment Course

(4) Surface grinding - Grinding of Whole Pavement Not Required.

------ Existing Pavement

Figure A 6. SPS-6 section 6 with maximum restoration and 4-inch overlay. (500ft.)

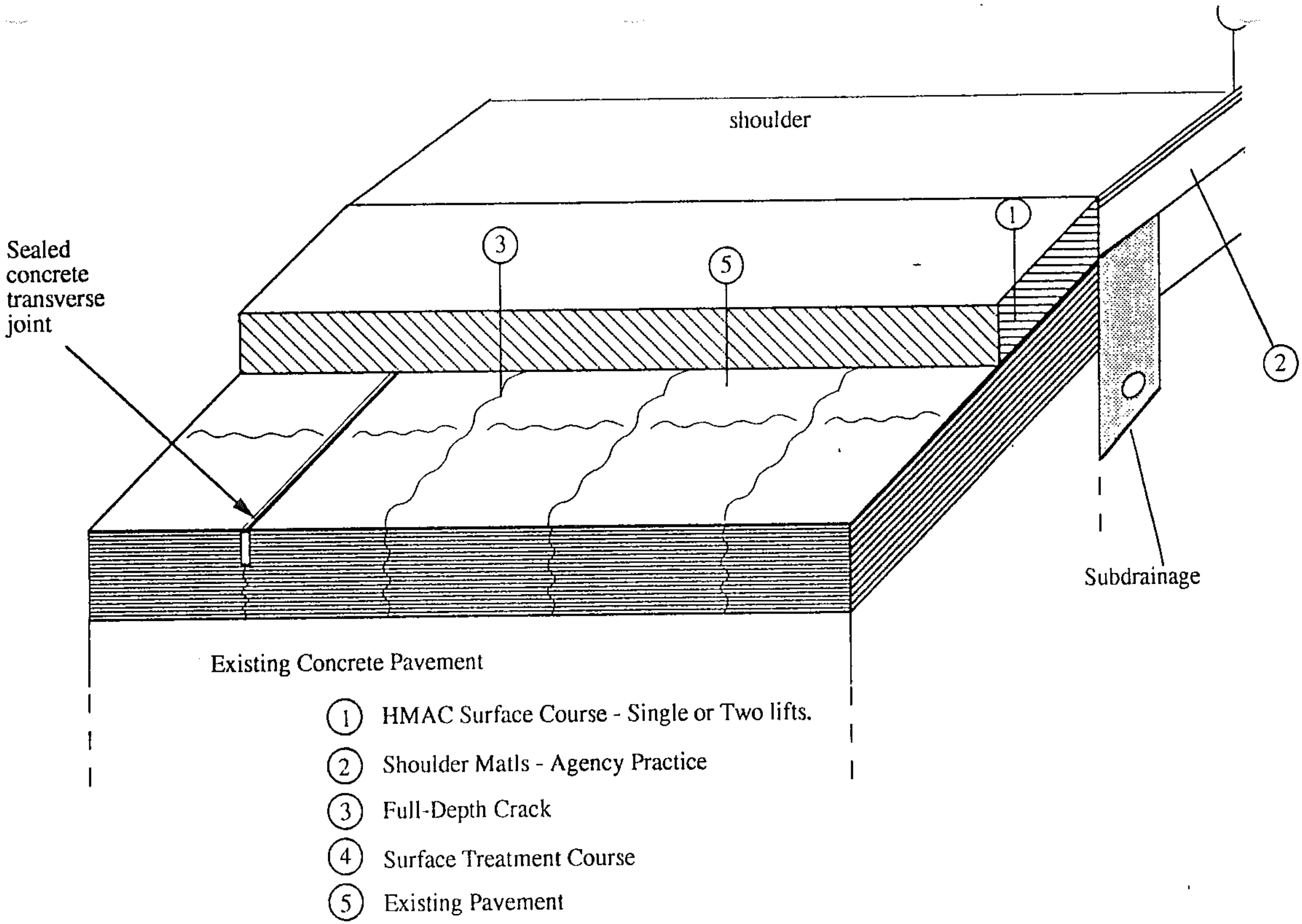


Figure A 7. SPS-6 section 7 with Crack and Seat with 4-inch overlay. (500 ft.)

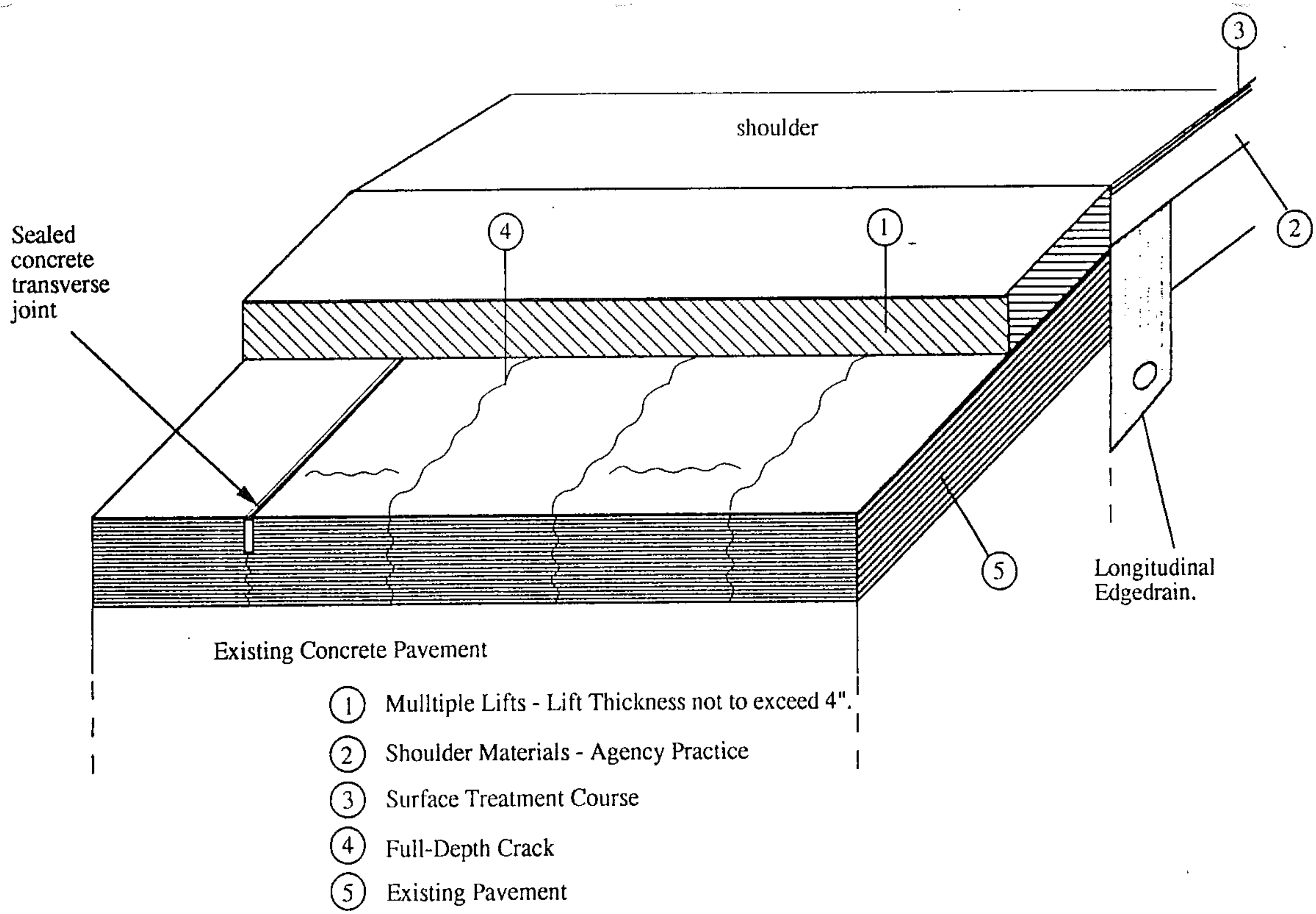


Figure A 8. SPS-6 section 8 with Crack and Seat with 8-inch overlay. (500 ft.)

APPENDIX B

MODEL SPECIFICATION FOR CRACK/BREAK AND SEAT OPERATIONS

APPENDIX B - MODEL SPECIFICATION FOR CRACK/BREAK AND SEAT OPERATIONS

DESCRIPTION

Crack and seat will be performed on jointed plain concrete pavements (JPCP) and break and seat on jointed reinforced concrete pavements (JRCP) prior to placement of a bituminous concrete overlay. Both of these processes will be "generically" referred to as cracking/breaking and seating (CBS) on existing Jointed Concrete Pavements (JCP) unless specifically differentiated for clarification. The work shall be performed in accordance with these specifications and in conformity with the lines, grades, and typical sections shown in the plans.

EQUIPMENT

The equipment for breaking the exposed JCP shall be approved by the Engineer and limited to the use of a "Guillotine" hammer or a "Pile Driver" hammer. The type of equipment used shall be capable of producing the desired cracking patterns described in these specifications and in the plans without significant displacement or spalling of the concrete. Further, the type of equipment used shall deliver such energy as necessary to provide a crack, distinguishable to the naked eye from a standing position, without the use of water or other materials, unless full-depth cracking has been established by coring.

A pneumatic tired roller of at least 50 tons shall be used for seating the broken slabs. Towing equipment shall have pneumatic tires and shall be capable of moving the roller forward and backward along predetermined lines.

The roller shall consist of four heavy pneumatic tire wheels mounted on a rigid steel frame. The wheels shall be evenly spaced in one line across the width of the roller and shall be arranged so that all wheels will carry approximately equal loads when operated over an uneven surface. The maximum center to center spacing between adjacent wheels shall not exceed 32 inches.

The tires shall be capable of operating at inflation pressures ranging from 90 to 150 pounds per square inch. The Contractor shall furnish the Engineer charts or tabulations showing the contact areas and contact pressures for the full range of tire inflation pressures and for the full range of loading for particular tires furnished.

Ballast to obtain the weight directed by the Engineer shall consist of ingots of known unit weight, or sand bags with a unit weight of 100 pounds or bags of other material of known unit weight, or other suitable material such that the total weight of the ballast used can be readily determined at all times. There shall be a sufficient amount of ballast available to load the equipment to a maximum gross weight of at least 30 tons, preferably 50 tons.

CONSTRUCTION DETAILS

Before CBS operations begin, the Engineer will designate test strips. The Contractor shall crack/break the test strips using varying impact energies and striking patterns until full-depth breaking/cracking is established to the satisfaction of the Engineer. The pavement shall then be seated in a uniform manner to determine the number of passes so as to firmly seat the broken pieces against the subgrade. The impact energy, striking pattern, and number of passes for seating will then be required on the test sections. Cores should be taken within the test strips and as necessary throughout the rest of the breaking sections at locations designated by the Engineer to assure that full depth slab breaking is being achieved in accordance with the plans and this Specification. Debonding of the concrete from the reinforcing steel is required.

The full width of the existing JCP slab shall be broken by such equipment and by such a method so as to produce full-depth cracks.

Existing JRCP slabs shall be broken such that the majority of the broken pieces shall be 18 inches in size. No remaining piece should exceed 24 inches in any edge dimension. No more than 20 percent of the material shall have the maximum edge dimension. The pieces must generally be rectangular or diamond in shape.

Existing JPCP slabs shall be cracked such that the majority of the cracked surface material shall be no more than 3 feet in any edge dimension. The pieces must be generally in rectangular or square in shape.

Care must be taken to prevent the formation of continuous longitudinal breaks. The pavement shall be broken transversely such that the cumulative length of longitudinal breaks do not exceed 125 percent of the slab length.

CBS of JCP slabs will not be permitted over drainage facilities or utility lines such as gas, water, telephone, etc. nor on bridge approach slabs or decks.

The Contractor shall conduct the CBS operation in such a manner as to protect vehicles in the adjacent lane from flying debris.

Following CBS, the pavement shall be seated with a number of passes determined in the test section and conforming to the requirements for Equipment in this Specification. Any dust, dirt and debris in joints, cracks or on the surface shall be removed or swept away by use of a power broom or compressed air prior to placement of the overlay. Loose pieces of broken concrete that are not firmly seated shall be removed and replaced by patching as directed by the Engineer.

No traffic will be permitted on the broken and seated portion of the roadway until after the first course of the bituminous concrete overlay has been placed.

Placing of the first course of bituminous concrete shall follow the CBS, seating, and sweeping operation as closely as practicable, but in no case shall the broken JCP slab remain exposed more than 48 hours. If this 48-hour requirement is not met, CBS operations shall be suspended until all existing broken/cracked pavement has been covered by at least one course of the bituminous concrete overlay. All bituminous concrete overlay base and/or binder courses shall be placed and completed within a 10 working-day period.

The sequence of operations in conjunction with this item shall be performed in the following order:

1. Determine crack/break configuration, load energy, and number of passes for seating in test site

2. CBS existing JCP (core to check crack propagation)

3. Clean all joints, cracks and surface

4. Remove loose pieces and patch as directed by the Engineer

5. Apply tack coat

6. Place overlay

APPENDIX C

ASPHALT CONCRETE MIX DESIGN AND FIELD CONTROL

FHWA Technical Advisory T 50540.27

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

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
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.

FHWA TECHNICAL ADVISORY T 5040.27
March 10, 1988
ATTACHMENT 1

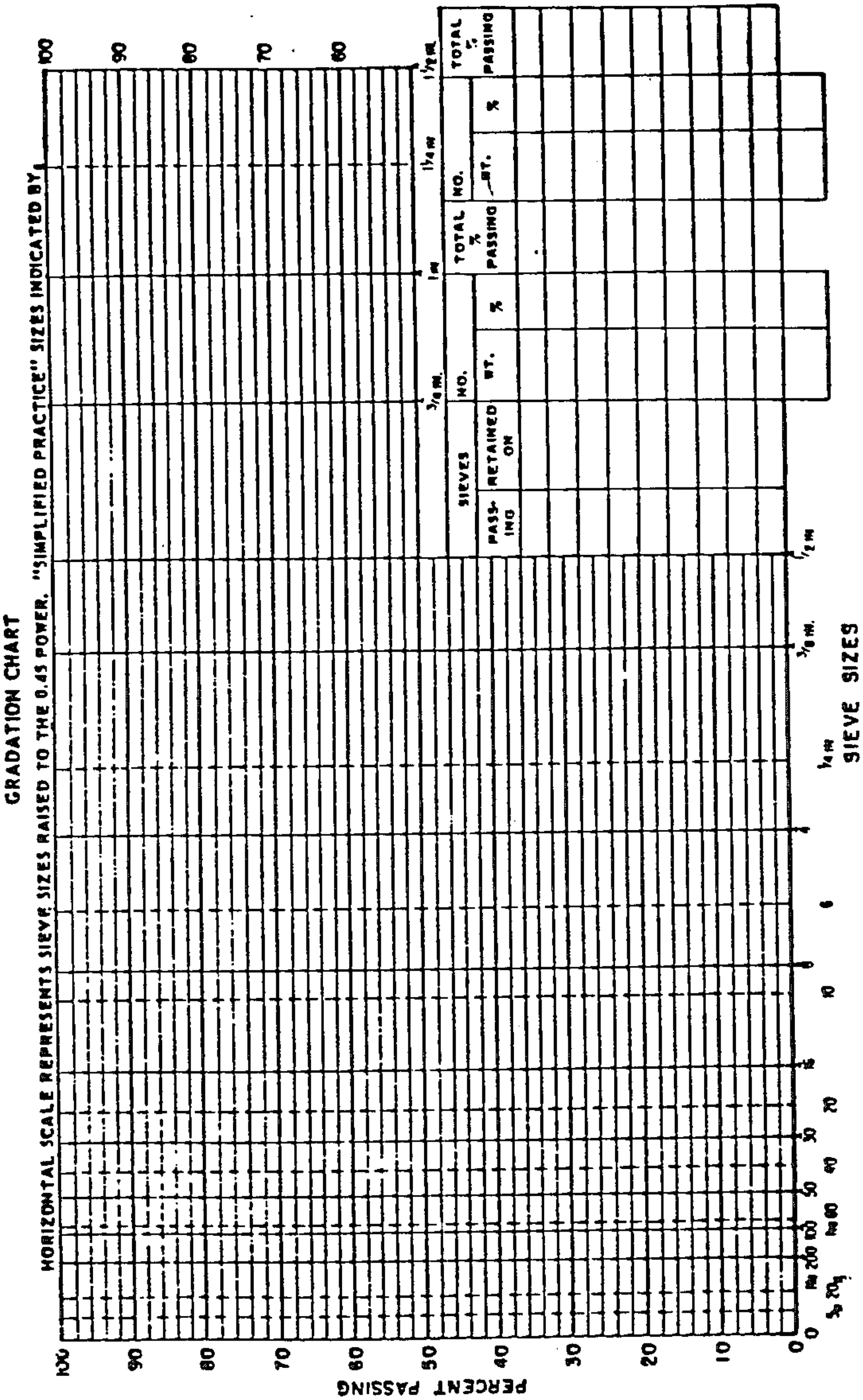


Figure #1

0.45 Power Gradation Chart

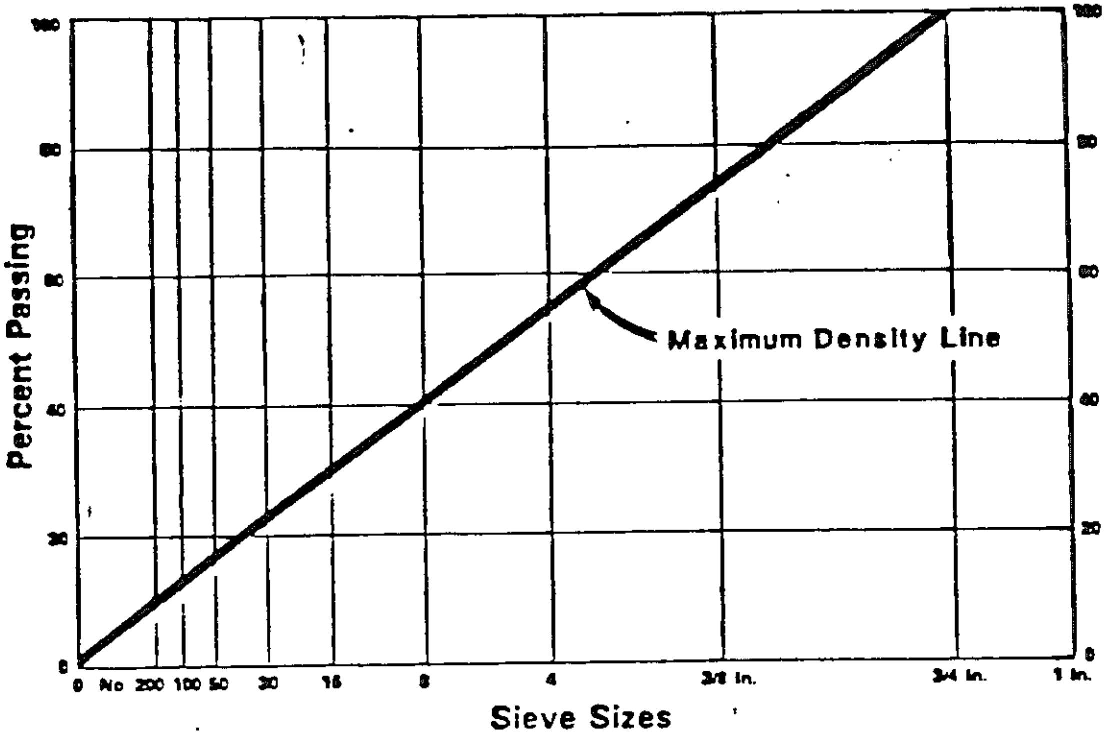


Figure #2

0.45 Power Gradation Chart

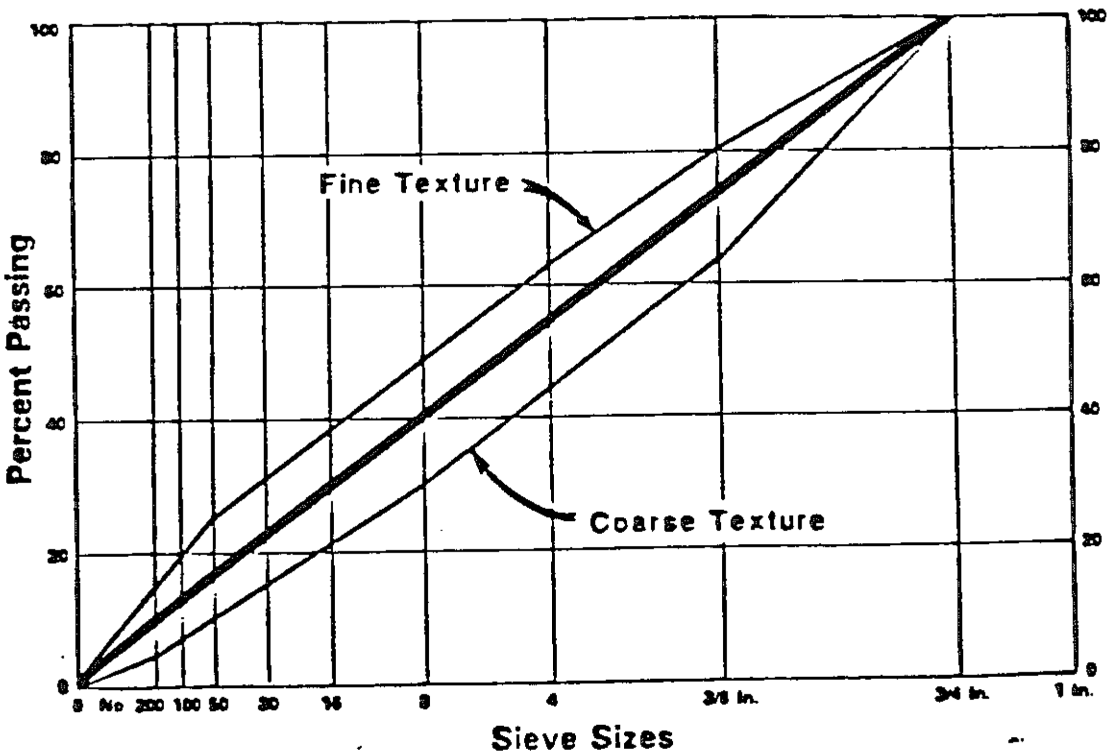


Figure #3

0.45 Power Gradation Chart

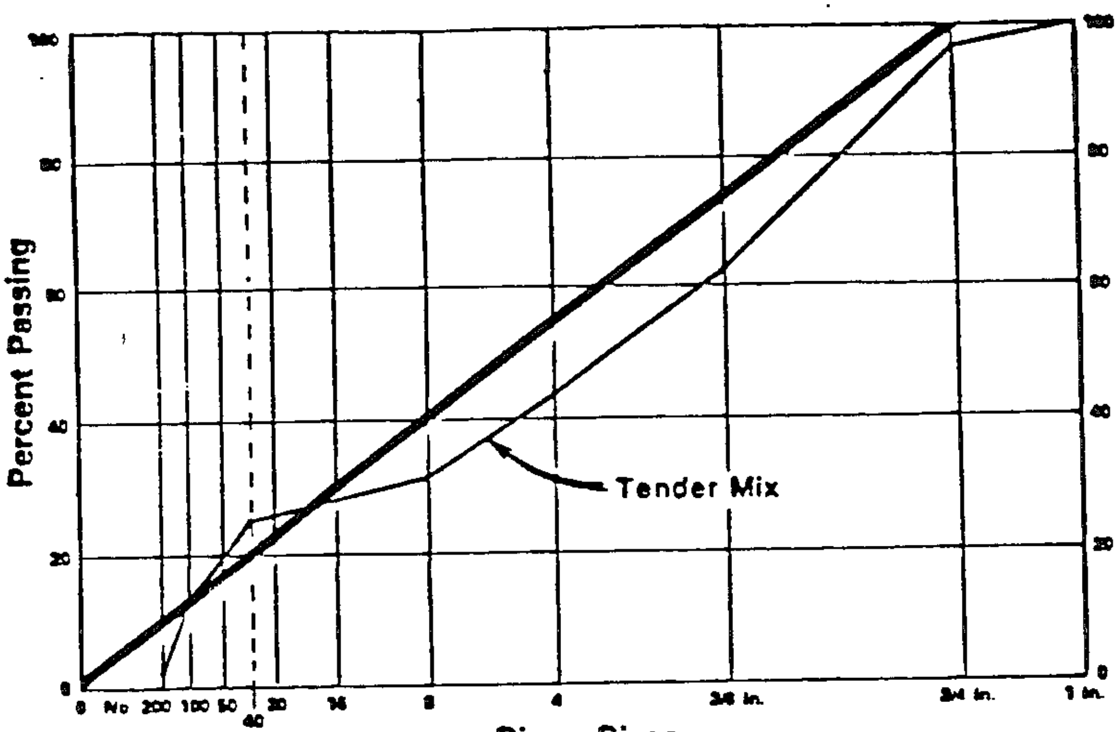


Figure #4

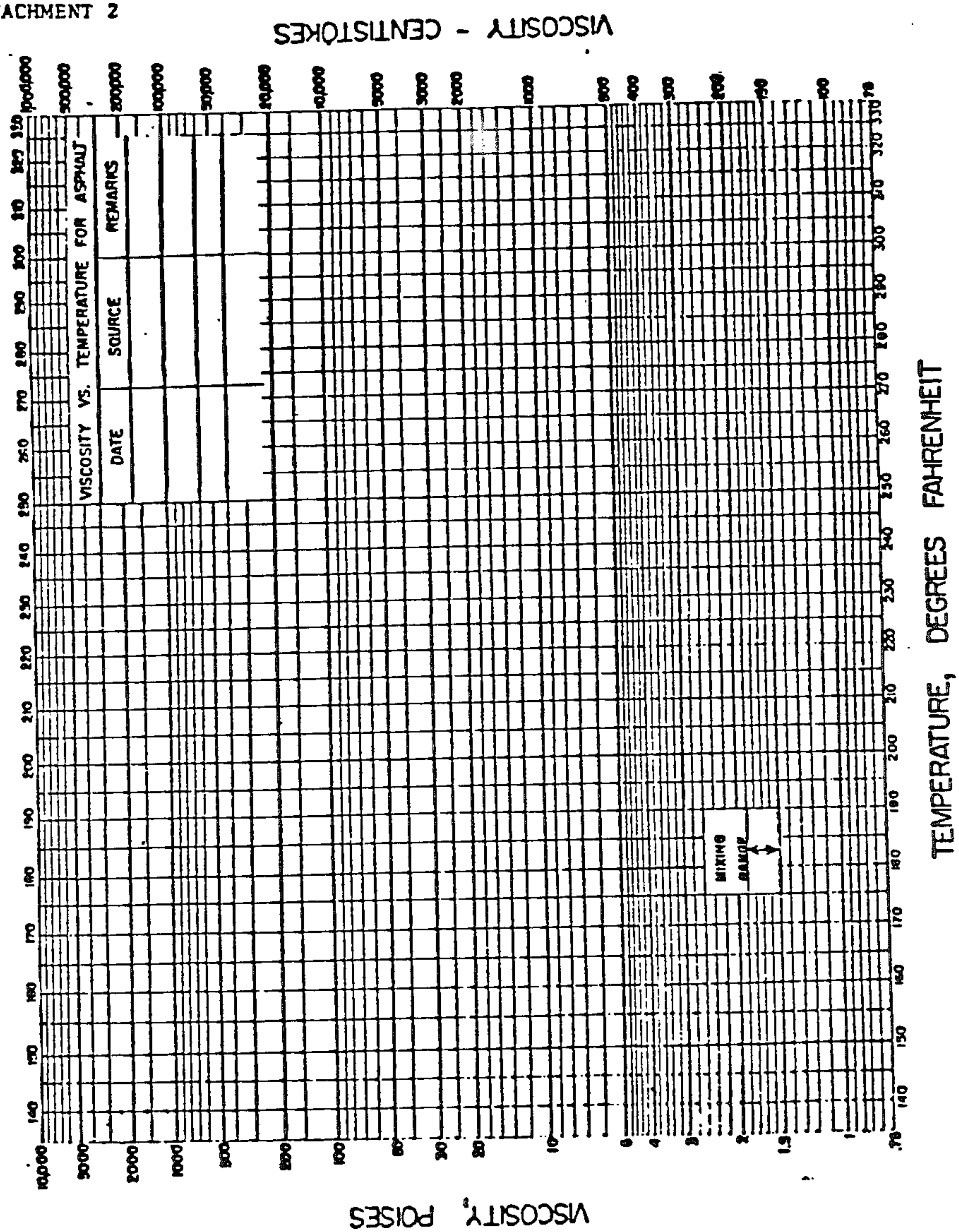
ASPHALT VISCOSITY

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 ± 20 centistokes, and the optimum compaction temperature as that corresponding to a viscosity of 280 ± 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. <u>Drum Mixer</u>

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?