Virginia Department of Transportation

Asphalt Field Certification Study Guide

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Asphalt Field Certification
Study Guide

Prepared by: The Virginia Department of Transportation
Materials Division
2012

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Acknowledgements

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IMPORTANT

This manual is a practical guide and not to be used as a source for VDOT specifications.

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Class Agenda

Day 1	
Time	Section
8:00-8:05	Opening Remarks
8:00-8:30	Ch 1: Introduction and Project Management, Communication and Safety
8:30-9:30	Ch 2: Surface Prep
9:30-10:30	Ch 3: Mix Delivery
10:30-11:30	Ch 4: Mix Placement
11:30-12:30	lunch
12:30-1:45	Ch 5: Joint Construction
1:45-3:00	Ch 6: Compaction
3:00-4:00	Ch 7: Mat Problems
Day 2	
Time	Section
8:00 – 9:30	Ch 8: Inspection and Quality Assurance
9:30-11:30	Ch 9: Density Testing
11:30-12:30	lunch
12:30-3:00	Ch 9: Density Testing (continued)
3:00-4:00	Ch 10: Math Problems
Day 3	
Time	Section
8:00	Written Exam

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Preface

This workbook covers asphalt paving, including transportation of materials, surface preparation, laydown, compaction and quality assurance processes. It is aimed at the field personnel who are responsible for these operations – both contractor personnel who do the work and department personnel who oversee and inspect the work.

The course will provide a working knowledge of the techniques and processes used to place asphalt concrete materials, including the surface preparation, hauling and discharging, paving, and compacting procedures. Each step in the placement of asphalt concrete has a role in the overall pavement performance. Additionally, the course attendees will have an understanding of improper handling of materials and the adverse affect to their properties and ultimately the behavior in the finished pavement. We feel having such information will give the technician confidence to make proper day-to-day decisions and will ensure that good quality control is maintained.

It is hoped that the guide will promote a common understanding of the processes involved and thereby result in improved asphalt concrete placement.

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Asphalt Field Certification Information

Listed are the different types of certifications related to asphalt concrete placement and a basic description of course relation to the job for each. A technician may be certified as any one or more of these, or possibly all of these. Some certifications require a lower level certification before advancement to the next level of certification.

Course	Certification Components	Pre-requisites
Field Certification Awareness of roadway laydown and compaction~~,~~ procedures.	Written Exam ▪ Before taking the exam you must show photo identification and sign the Technician Certification Application. ▪ You are allowed 3 hours to complete the exam. ▪ You must pass with a minimum score of 70% and have one opportunity for re-testing. ▪ Passing written exam score, results in an Asphalt Field Level I Certification. Proficiency Exam ▪ Before taking the exam you must show photo identification ▪ You have one opportunity for re-testing.	

Upon satisfactory completion of all requirements, the technician will be issued a certificate/certification. A certificate will be issued for each type certification. Initial certification will generally be effective for five (5) years beginning from the date of passing the appropriate written exam.

Failure of an exam will require the person to re-attend the regular class and pass the exam to become certified / re-certified.

Your test results and card may be found at the VDOT University website listed below.

- VDOT Employees: https://virtualcampus.vdot.virginia.gov
- All other students: https://virtualcampus.vdot.virginia.gov/external

If you are enrolled in this class or hold any VDOT Materials certifications, do not register as a new user when you go to this site.

If you do not know your logon or password, call (804) 328-3158.

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About This Guide

Various visual cues are used to symbolize several consistent concepts. Below you will see the visual cues as well as a description of each.

	DEFINITION A definition will be provided.

Tools/Equipment/Tests	
	TOOLS AND EQUIPMENT Describes what tools, equipment and tests are required to complete the job safely and with the highest level of quality.

Work Procedure 1.1. Best Practices 1.2. Awareness	
	PROCEDURE Describes a condition where equipment and procedure integrity is at risk. This is used to alert personnel to operating procedures and practices, which if not observed, could result in severe damage to the machine, its components or the end product.

	BEST PRACTICE Describes a best practice to be utilized when possible.

	IMPORTANT Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

Inspection List and Measurements	
	INSPECTION AND MEASUREMENTS Describes inspection, Quality Assurance and/or Quality Control practices.

Safety	
	SAFETY WARNING Describes a condition where personal safety may be at risk. This is used to alert personnel to operating procedures & practices which, if not observed, may result in personal injury.

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Introduction

The modern use of asphalt for road and street construction began in the late 1800s, and grew rapidly with the emerging automobile industry. Since that time, asphalt technology has made giant strides such that today the equipment and techniques used to build asphalt pavement structures are highly sophisticated.

One rule that has remained constant throughout asphalt's long history in construction is that an asphalt concrete layer is only as good as the materials and workmanship that go into it. No amount of sophisticated equipment can make up for use of poor quality materials, poor sampling and testing techniques or poor construction practices.

Asphalt concrete is composed of three basic components - asphalt binder, mineral aggregate and air voids. Aggregates are generally classified into two groups - coarse and fine, and normally constitutes 90 to 96 percent by weight of the total mixture. Asphalt binders are classified by various grading systems and normally constitutes 4 to 10 percent of the total mixture. Another very important but often overlooked component of an asphalt mix is air voids. In this course, only asphalt binder, aggregates and other additives are discussed.

There are many different types of asphalts and many different types of aggregates. Consequently, it is possible to make different kinds of asphalt pavements. Among the most common types of asphalt pavements are:

- Asphalt concrete (dense-graded hot or warm mix asphalt)
- Open-graded asphalt or porous friction course
- Ultra-Thin Bonded Wearing Course
- Asphalt Surface Treatments
- Emulsified asphalt mixes (cold mixes)
- Permeable Asphalt Drainage Course
- Others, SMA, In-Place Recycled Mixes (both hot and cold)

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This program primarily addresses asphalt concrete (AC) produced at conventional plant temperatures or through a warm mix technology. AC is a paving material that consists of asphalt binder and mineral aggregate with appropriate air voids. The asphalt binder, either an asphalt cement or a modified asphalt cement, acts as a binding agent to glue aggregate particles into a dense mass and to waterproof the mixture. When bound together, the mineral aggregate acts as a stone framework to impart strength and toughness to the system. The performance of the mixture is affected both by the properties of the individual components and the combined reaction in the system.

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Project Organization & Management, Communication, and Safety

Learning Outcomes:

- ☑ Describe the purpose of :
  - o project documents,
  - o pre-construction and pre-paving conferences, and
  - o cooperative communication on the job

Project Organization and Communication

The most essential part of project planning and organization is communication. Effective communication is vital to all elements of project organization:

- The project documents are written instructions that must describe the requirements clearly and in detail
- The preconstruction conference initiates verbal communication between the representatives of the department and contractor personnel; it sets the tone for both the working relationship and direct communications during project execution
- Ongoing communication between the contractor and the department is essential to performing high-quality work
- Project records make it possible to track events should doing so become necessary
- Safety on the job cannot be maintained if communication between parties is inadequate

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Project Documents

Project documents illustrate and describe work to be done under the contract. Project documents include:

Plans	Drawings that show the location, character, dimensions, and details of the work to be done
Standard specifications	Directions, provisions, and requirements for performing the work illustrated and described in the plans. The items in the standard specifications relate to or illustrate the method and manner of performing the work or describe the qualities and quantities of materials and labor to be furnished under the contract
Special or supplemental specifications	Approved additions and revisions to the standard specifications
Special provisions	Additions or revisions to the standard or supplemental specifications that are applicable only to an individual project
Special provision copied notes (SPCN)	A document that sets forth specifications or requirements usually limited in scope, for a particular project item or issue and as a modification to a Special Provision or Specification.
Standard Drawings	

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If there is a discrepancy between the instructions and specifications in any of the contract documents, a definite hierarchy exists among the above major types of documents. The order of priority, from highest to lowest, is special provision copy notes, special provisions, plans, supplemental specifications, specifications and standard drawings. This order of priority corresponds to the documents specific applicability to a project or contract.

Plans and specifications need to be accurate and complete and should leave little room for assumptions or later reinterpretation. In addition, plans and specifications need to define the responsibilities of both department and contractor.

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Project Communication

The quality of the work completed and the safety of those performing and inspecting the construction are directly related to the quality of the communication between the department and the contractor. It is important that the individuals in daily charge of the project for both the department and the contractor meet periodically, on both a formal and an informal basis, to discuss the progress and quality of the work done to date and the schedule for future work.

Preconstruction Conference	The preconstruction conference should be held before work on a project begins. The meeting should bring agreement on the proposed schedule, methods to be used to complete the project on schedule with a minimum of delays and change orders, material sources, plant production rates, haul distances and routes, paving widths and speed, and type and operation of compaction equipment. Additionally the role of each person associated with the project should be discussed and clarified. One of the most important items to be addressed at the preconstruction conference is job safety.
Formal Meetings	Key personnel from both the department and the contractor should be present at these meetings. The meetings should discuss; the quantity of work completed, test results obtained, what has yet to be accomplished, the schedule for the coming weeks, and changes in personnel, equipment, construction methods used and mix design. Written minutes containing those in attendance should be completed and distributed as quickly as possible.
Informal Meetings	Daily informal meetings provide a forum for the exchange of information, they can be held at the job site, asphalt plant or at the paver. The purpose of informal meetings is twofold. First, occurrences the day before such as work completed, test results, and any problem areas, should be discussed and resolved. Second, the discussion should address what is expected to happen during the next several days – an update on the information exchanged at the last formal meeting.
Written Communication	Much information can be communicated in oral form, but discussion of important information should be followed up in written form, particularly when conditions on the project change substantially. If an occurrence is important enough to be remembered later on, it is important enough to be written down immediately after it happens so the information will be accurate and complete.

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Project Safety

Working around an asphalt paving site can be hazardous. Communication is one of the keys to a safe work environment. Every individual involved in the project should know what is expected and how to perform the assigned tasks. Proper training in the operation of a piece of equipment is essential for its operators, for example. Retraining is necessary at frequent intervals because the longer a person continues to perform the same task, day after day, the more likely he or she is to do things by habit and ignore surrounding events.

Safety talks are a good way to start the day. People need to be reminded that they are operating in a potentially dangerous environment at both the plant and the laydown site, and daily talks are one way of meeting this need. Further, if an unsafe work practice is noticed, corrective action should be taken immediately, even if the paving operation must be shut down until the unsafe practice has changed.

Throughout the guide we have indicated areas highlighting safety practices using the icon symbol below.

SAFETY WARNING Describes a condition where personal safety may be at risk. This is used to alert personnel to operating procedures & practices which, if not observed, may result in personal injury.

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2 Surface Preparation

Learning Outcomes:

- ☑ List the steps involved in preparing bases and existing pavements for overlays.
- ☑ Understand how base surface properties impact paving decisions
- ☑ Recognize drainage considerations in creating lasting pavement structures

Surface Preparation

The performance of AC under traffic is directly related to the condition of the surface on which the pavement layers are placed. For a full-depth asphalt pavement, if the condition of the subgrade soil is poor (particularly if it is wet and rutting under the haul trucks), then the ultimate life of the roadway may be significantly reduced. For AC layers placed on top of a new, untreated granular base course, that base material should be stable, the surface should be dry, and the base should not be distorted by the trucks carrying mix to the paver. For mix laid on top of existing asphalt layers, that surface should be properly prepared – potholes filled, cracks sealed, and the surface cleaned. A tack coat shall also be used to ensure a bond between the existing pavement surface and the new asphalt overlay unless exempt per specification.

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Base Preparation for New Flexible Pavements

Subgrade Soil

If the asphalt pavement is to be placed directly on the subgrade soil, that subgrade material should meet all applicable specifications for moisture content, density, structural support, grade and uniformity. After the subgrade soil has been determined to be ready for paving and before paving is allowed to commence, the subgrade should be checked to ensure that it will be able to support the weight of the haul traffic. The subgrade must provide a firm foundation before the asphalt paving begins. If distortion of the subgrade soil occurs during the paving operation, placement of the mix should be stopped until the condition of the soil can be corrected.

Unless required in the contract, there is no need to place a prime coat of asphalt emulsion or cutback asphalt on the subgrade soil. This is especially true when the soil is a silty clay or clay material because the prime coat material cannot be absorbed into that subgrade material. The use of a prime coat on sandy subgrade soils is also questionable. If the sandy material displaces excessively under the wheels of the haul trucks, it should be stabilized with some type of binding material before paving to achieve the required load-bearing properties. In such cases, the application of a prime coat will generally not be enough to hold the sandy soil in place during paving operations. A prime coat should not be used as a substitute for proper preparation of the subgrade soil.

BEST PRACTICE

The subgrade material and/or granular base layer should meet all the specifications for moisture content, density, structural strength, grade and uniformity.

Describes a best practice to be utilized when possible.

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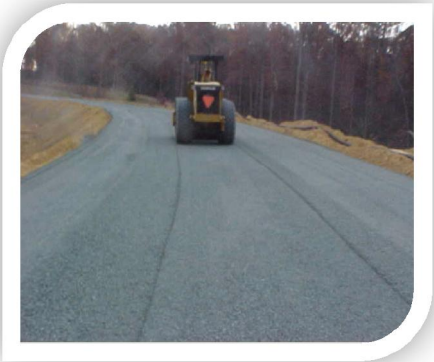
Granular Base Course

If the asphalt layer is to be constructed directly on a new or existing untreated granular base layer, that base material should meet all the specifications for moisture content, density, structural strength, grade and uniformity. As a final test of the base layer, proof rolling should be done, on top of the granular base material, and the amount of deflection of the base and the amount of indentation of the truck wheels in the granular base course material should be noted. If the base material is stable and dry and does not deflect and indent significantly under the wheels of a loaded tandem-axle truck, placement of the prime coat or the new asphalt mix should be permitted to start. If the condition of the granular material is not satisfactory, the base course should be reworked or stabilized until it is in the proper condition for overlaying.



DEFINITION
Proof Rolling A physical compaction test performed with a rear tandem axle dump truck with a gross weight of 50,000 pounds. The loaded dump truck will roll over the soil subgrade where the proposed concrete curb or asphalt concrete is to be placed. As the proof roll truck at two to five miles/hour rolls over areas being tested and does not yield or pump, it is considered passing and suitable for curbing and asphalt placement.
Describes and/or defines terminology.

When required, the prime coat acts as a temporary waterproofing layer that protects the base course and prevents it from absorbing excess moisture during rain before paving. It also allows the base course to be used for light traffic, binds together any dust on the surface of the granular base layer, promotes the bond between the base-course material and the new AC overlay, and prevents slippage of thin overlying pavement layers. Prime coats are only required by specification under stabilized open graded drainage layers, unless otherwise noted on the plan. Some contracts require the use of prime coats on secondary roads and subdivision streets.

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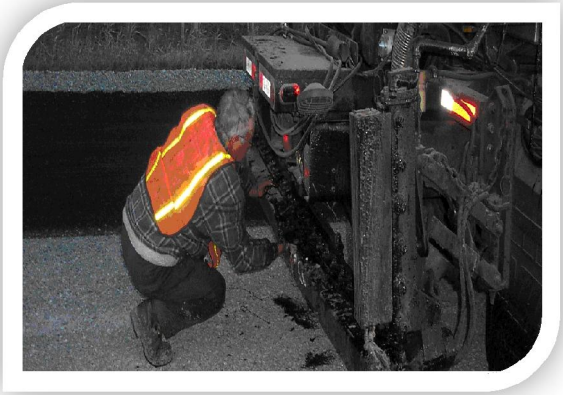
AWARENESS/IMPORTANT

Use cutbacks carefully because they pose an environmental risk. These materials are primarily composed of different fractions of petroleum oil, and can be washed into nearby creeks and streams if applied before a heavy rain.

Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

When a prime coat is used, the prime coat material should be applied to the base course with a pressure distributor at least 4 hours before paving is to begin. Typically, cutback asphalt (MC-30 or MC-70) is used as the prime coat material. An inverted asphalt emulsion (emulsion containing limited amounts of cutter stock material) also has been applied successfully. The application rate should vary with the openness (porosity) of the base course material. Typical application rates range from 0.15 gal/yd^2 for a very tight surface to 0.40 gal/yd^2 for an open surface.

No more prime coat material should be applied than can be absorbed completely by the granular base course in 24 hours. If all of the prime coat material is not completely absorbed, the excess should be blotted with sand and removed.



AWARENESS/IMPORTANT

A prime coat is not required on aggregate subbase or base materials prior to the placement of asphalt base, intermediate or surface layers, unless it is specified in the contract documents.

Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

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Preparation of Existing Surfaces for AC Overlays

AC over AC

The degree of preparation needed for an existing asphalt pavement depends on the condition of that surface. At a minimum, failed areas should be removed and replaced; potholes properly patched; cracks cleaned out and sealed; and ruts filled in or, preferably, removed by cold milling.

Pavement Replacement and Patching – Removal and replacement should be carried out on all existing pavement areas where severe load-related distress has occurred. Subgrade distortion should be repaired by undercutting and replacement with suitable backfill material. Proper sub-surface drainage should be installed as necessary. New granular base course material, stabilized base course layers, or AC mix should be placed in order to bring the strength of the pavement structure in each failed area to the same level as the surrounding good pavement layers. Localized failed areas should be patched properly.

BEST PRACTICE

Each distressed area should be cut back to sound pavement and squared up, with the sides as vertical as possible, the loose material and water in the hole removed, a tack coat applied to the sides and bottom of the hole, the mix placed in the hole, and the new material adequately compacted, preferably with a roller. If the pothole is deeper than 4 inches, the mix should be placed in more than one layer and each layer compacted properly.

Describes a best practice to be utilized when possible.

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Crack Filling

Badly cracked pavement sections, especially those with pattern cracking (e.g., map or alligator), must be patched or removed. If the cracks are narrow, less than 1/8 inch wide, it is doubtful that the crack-sealing material will actually enter the crack instead of pooling on the pavement surface. If wider cracks are present, they should be blown out with air and cleaned of debris. The crack-sealing material should be inserted when the cracks are clean and dry. If that pavement structure contains a great number of cracks, consideration should be given to applying a surface treatment instead of filling individual cracks.

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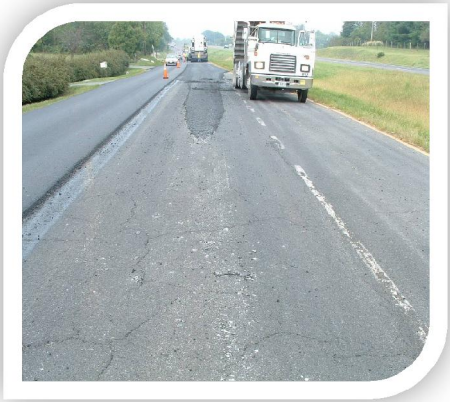
Leveling/Scratch Courses

Common practice in the past has been to place a leveling course on the existing pavement surface to improve the rideability of the pavement structure. This leveling course, sometimes called a wedge course or a scratch course, is designed to fill in the low spots on the pavement surface. This leveling action is accomplished using the floating screed on the paver, with more AC being placed in the low spots than on the high spots in the existing pavement surface since the areas with thicker mix typically compact more than areas with thinner mix.



This problem, termed differential compaction, requires that multiple courses be constructed over a pavement surface that is badly out of shape before a smooth surface can be obtained. As the mix passes from under the paver screed, it is in loose condition. Compaction by the rollers reduces the thickness of the newly placed layer. The rule of thumb is that conventional mixes will compact approximately ¼inch per 1 inch of compacted thickness. Thus to achieve a compacted course 1 inch thick, about 1¼ inch of mix would have to be placed by the paver. Similarly, approximately 3¾ inches of mix would need to pass from under the paver screed to construct a layer with a compacted thickness of 3 inches. With gap graded mixes (i.e., SMA) and open graded mixes (i.e. , porous friction course and open graded drainage layer), the amount of compaction is much less – approximately 1/8 inch per 1 inch compacted thickness.

When a leveling course is placed, the AC placed in the low areas (in the wheel paths if the pavement is rutted) will be thicker than the mix placed over the high points in the surface (between the wheel paths). The thicker mix will compact more under the rollers, particularly if a pneumatic tire roller is used, than will the mix that is thinner. Thus, low spots will still exist in the wheel paths where the mix has been compacted to a different degree (and thus a different air void content) than the mix between the wheel paths. Because of the problem of differential compaction on very rough roads, multiple layers of mix are usually needed to completely eliminate the roughness in the existing pavement surface.

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BEST PRACTICE

A rule of thumb is that one layer after compaction will remove approximately 80 percent of a low spot. Two layers, each being compacted separately, will remove approximately 95 percent of a low spot.

Describes a best practice to be utilized when possible.

Milling

Milling, also called cold planing, can be used to remove the high points in the existing surface in lieu of placing a leveling course (filling in the low spots) and to remove deteriorated pavement layers. Milling can be accomplished in any width necessary, from 6 inches to more than 13 ft. Equipped with automatic grade and slope controls similar to

those used on an asphalt paver, the milling machine is capable of producing a level surface in one pass over the existing surface. In addition, if the milled surface is properly cleaned, its texture can enhance the bond between the new

and old asphalt mat and may reduce the possibility of slippage of the overlay on the existing surface. The RAP produced by the milling process can be hauled back to the asphalt plant for future recycling.

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A pavement surface that has been milled is typically very dusty and dirty. Once the pavement has dried, multiple sweepings with a mechanical broom are usually needed to remove all of the residual grit from the milled surface. In some cases, it may be necessary to dampen the milled surface before sweeping or to air blow or flush the milled surface with water to remove dust and very fine material completely.

Also watch for “scabbing” where the milling machine leaves patches of uneven pavement. These areas may pop loose under traffic and take part of the new overlay with it.

AWARENESS/IMPORTANT

By milling and putting back the same lift thickness, bridge and guardrail clearance are properly maintained as well as providing the necessary interface with adjoining curb and gutters.

Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

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AC over Concrete Pavement

When AC is placed over a Portland cement concrete (PCC) pavement, the PCC surface should likewise be properly prepared. Any severely distressed areas in the concrete slabs should be cut out, removed, and replaced with either PCC or AC using full-depth slab repair techniques. Corrective work should also be completed on the underlying sub-base or subgrade material. Any severely spalled areas at joints should be repaired using partial-depth slab replacement methods, AC or PCC may be used for partial-depth repairs. Rocking slabs should be stabilized. Depending on the condition of the PCC pavement, procedures such as crack and seat, break and seat, or rubblization of the existing pavement can be used before the overlay is placed, particularly if the slabs are rocking under traffic loading. Consideration can also be given to the use of a crack-relief layer between the existing PCC pavement and the new overlay.

For joints that are poorly sealed, the old seal material – particularly rubberized, should be removed and the joints cleaned. When dry, the joints should be resealed with appropriate joint-sealing material. Care should be taken not to overfill the joints, particularly in cool weather when they are open wide. In all cases, as with crack sealant, the final level of the joint-sealing material should be below the top of the surrounding pavement surface. Once the patching and resealing have been accomplished, the surface of the PCC pavement should be cleaned completely using mechanical brooms and air blowing or water flushing, or both, where needed.

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Tack Coat

The purpose of a tack coat is to ensure a bond between the existing pavement surface and the new asphalt overlay. The tack coat should not be used in lieu of cleaning the existing surface – removing accumulated dust and dirt by mechanical brooming or by flushing with air and water. If a good bond is not formed between the existing surface and the new overlay, slippage and delamination may occur.

The new overlay may be shoved in a longitudinal direction by traffic, particularly at locations where the traffic accelerates or where vehicle brakes are applied. Delamination occurs when the two layers are no longer bonded. This creates a failure plane in the pavement structure and reduced the AC materials life. Thus the pavement surface must be clean before the tack coat is applied.

AWARENESS/IMPORTANT

Remove dried, caked mud and other foreign material. Spilled asphalt should be shoveled or picked up (especially if placing a thin overlay).

Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

The tack coat material – which is normally asphalt emulsion but can also be asphalt cement – shall be applied by a pressure distributor. All nozzles on the distributor should be fully open and functioning and should be turned at the same angle to the spray bar, approximately 30 degrees. In addition, the spray bar should be at the proper height above the pavement surface to provide for a double or triple lap of the liquid asphalt material. The result will be the proper amount of overlap between the nozzles and a uniform application of the tack coat to the road surface. The tack coat material should be heated to the proper temperature so that it is fluid enough to be sprayed uniformly from the nozzles instead of coming out in strings.

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Application Rate Versus Residual Rate

Uniformity of application and a proper application rate are keys to achieving a successful tack coat. If the correct amount of tack coat is sprayed on the surface, some of the existing surface will still be visible through the tack coat; not all of the existing pavement surface will be covered. Use of a diluted asphalt emulsion tack coat (slow-setting asphalt emulsion diluted 1:1 with water) will result in complete coverage and a very thin residual asphalt film on the pavement surface. In general, proper tack coat application will leave a residual asphalt cement content of approximately 0.04 to 0.06 gal/yd^2 on the roadway. The amount of residual tack coat needed will depend on the condition of the pavement surface and the tack coat material used. An open-textured surface requires more tack coat than a surface that is tight or dense, and a dry, aged surface requires more tack coat than a surface that is "fat" or flushed.

It is essential to differentiate between the residual tack coat rate (the amount of asphalt cement remaining on the pavement surface after the water has evaporated) and the application rate (the amount of emulsion sprayed from the distributor). Most asphalt emulsions contain 60-65 percent residual asphalt cement and 35-40 percent water, plus a small amount of emulsifying agent. For ease of calculation, it can be assumed that an asphalt emulsion is approximately two-thirds asphalt cement and one-third water. The amount of asphalt cement left on the pavement surface after the water has evaporated from the emulsion is the most important factor in obtaining a bond between the existing pavement surface and the new overlay. To determine the application rate for the tack coat material, start with the amount of residual asphalt cement required on the pavement surface and work backward.

If the amount of water in an asphalt emulsion is not taken into account when determining the application rate from the distributor, the correct degree of adhesion may not be achieved. Too little tack coat will not provide sufficient bond between the old and new pavement layers. On the other hand, too much tack coat may contribute to slippage of the overlay on the existing pavement surface and bleeding of the tack coat material through a thin overlay. If asphalt cement instead of an asphalt emulsion is used as the tack coat material, the residual amount of asphalt on the pavement surface should be the same as the applied amount. Thus if 0.04 gal/yd^{2}of residual binder material is desired, the application rate from the distributor should also be 0.04 gal/yd^2.

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Breaking and Setting Time

When an asphalt emulsion is applied as a tack coat, it is brown in color because it contains both asphalt cement and water. After a very short period of time, the emulsion will break – change color from brown to black – and the water will begin to evaporate. The rate of evaporation will depend on the type and grade of the emulsion used, the application rate, the temperature of the existing pavement surface, and environmental conditions. Once all the water is gone, the emulsion is said to have "set." The rate of set depends on the same conditions that control the rate of break of the emulsion. Under most circumstances, a conventional emulsion will set in 1-2 hours. For non-tracking emulsions, the set time may be as short as a few minutes.

New AC can usually be placed on top of an unset tack coat and even over an unbroken tack coat emulsion with no detrimental effect on pavement performance/ the bond will still be formed. While it is believed that the asphalt emulsion can be properly paved over before being fully set, and even before being broken it is also important that the tack coat material remain on the pavement surface to create the bond between the layers. If the tack coat material is not set and a significant amount of haul truck traffic runs over the unset material, much of the tack coat may be picked up by the truck tires and tracked down the roadway. Thus either the tack coat should be allowed to set before haul truck traffic is permitted to run over it, or the amount of truck traffic should be minimized.

If asphalt cement is used as the tack coat material, it will cool to ambient temperature very quickly. Further, because there is no carrier material (water) to evaporate, paving may immediately follow the asphalt cement tack coat application.

If the overlay is to be constructed under traffic, the tack coat is normally placed only a short distance in front of the paver – within the lane closure and far enough ahead for the tack to set properly before the AC is laid on top of it. Traffic is kept off of the tack coat at all times. If the roadway being paved is closed to traffic, the tack coat can be placed as much as 24 hours ahead of the laydown operation. Under unusual circumstances, if traffic must travel over the tack coat before the overlay is placed, a light layer of sand can spread on top of the tack coat to prevent its pickup by traffic. The application rate of the sand should be in the range of 4 to 8 lb/yd^2, depending on the application rate of the tack coat material and the gradation of the sand.

If equipment problems (plant or paver breakdowns) prevent tack coat material that has been applied from the distributor from being paved over before traffic must use the roadway, it is suggested that

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posted speed limits on that section of roadway be significantly reduced until the overlay operation can take place. It is not good practice to place the tack coat one day, permit traffic to run over the tack coat for a period of time, and then place the overlay at a later date. Depending on the amount of residual asphalt cement on the pavement surface and environmental conditions, the level of friction available for traffic at the pavement surface may be greatly reduced by the presence of the tack coat material. The excess tack will also be thrown on vehicles, creating a major public relations problem. In addition to lowering the posted speed limits, it may be advisable to apply sand to the tacked surface.

If a tack coat is used on a recently placed AC layer, the residual asphalt content could be minimal – in the range of 0.05 gal/yd^2.

AWARENESS/IMPORTANT

The application of tack coat material is essential when an overlay is being constructed on and old existing pavement surface – either AC, PCC or surface treatment.

Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

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Drainage Considerations

AWARENESS/IMPORTANT

Drainage is an important part of the process of placing a long-lasting, high-quality pavement. Water is the enemy of all good pavement structures. It can weaken the subbase and/or base materials causing them to lose their structural stability and can result in failure of the overlying asphalt layers. Similarly, if water is able to enter the asphalt pavement itself either due to poor density or other factors, it will strip away the binder that provides the stone-to-stone bond. Aggregate particles that lose their asphalt coating will no longer be able to hold together and the asphalt mix falls apart, a phenomenon called raveling on the surface and stripping within the pavement structure.

Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

Correcting Drainage Problems Before Overlay

Keep roadside drainage systems clear of vegetation and other foreign material to allow rainfall to quickly be carried away from the pavement structure.

Proper Crown and Slope

Avoid creating “birdbaths” or low spots on the asphalt surface. This prevents water from quickly moving to drainage systems such as curb and gutter or roadside ditches. Give pavement an effective crown and an adequate slope to assure rapid transit of water off of the pavement surface.

Pavements built adjacent to a hillside that slopes toward the pavement structure should have a ditch or buried interception trench to keep water from working its way under the pavement layers. Significant damage can result from such water intrusion.

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Curb and Gutter Elevations

Gutter systems that are higher than the adjoining asphalt surface serve little purpose. Water is allowed to collect on the asphalt surface and at the gutter joint instead of being conveyed away from the pavement to drop inlets or other parts of the drainage system.

Significant damage can result from failures to properly match the asphalt pavement to the curb and gutter system.

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Chapter Two Knowledge Check

1. A prime coat on aggregate base is required on all state jobs regardless of the thickness of the asphalt mat to be put down.
    a. True
    b. False

2. The purpose of a tack coat is to ensure a bond between the existing pavement surface and the new asphalt overlay.
    a. True
    b. False

3. The material taken off the roadway when milling may not be used again.
    a. True
    b. False

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3 Mix Delivery

Learning Outcomes:

- ☑ Understand the proper material delivery process to the job site.

Mix Delivery

Mix transport involves all actions and equipment required to convey AC from a production facility to a paving site including truck loading, weighing and ticketing, hauling to the paving site, dumping of the mix into the paver or material transfer vehicle hopper, and truck return to the AC production facility (Roberts et al., 1996).

Ideally, the goal of mix transport should be to maintain mix characteristics between the production facility and the paving site.

Transport practices can have a profound effect on mix temperature at the paving site, aggregate and/or temperature segregation of the mix and mat quality. This section will discuss the types of trucks used for mix transport and the various considerations involved with mix transport.

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Mix Delivery Planning and Preparation

Rain, equipment breakdown, and traffic delays all can ruin a well-intentioned paving plan. Have alternative plans in place; spare equipment available; night paving may need to be considered, depending on the nature of the project.

Mix transport can have a large impact on flexible pavement construction quality and efficiency. Mix characteristics such as laydown temperature, aggregate segregation and temperature differentials are largely determined by transport practices. In general, there is one type of AC transport trucks used in Virginia - the end dump. In rare instances a live bottom dump (flo-boy) is used by contractors. Key considerations in mix transport are:

- Truck bed cleanliness and lubrication.
- Proper mix loading techniques in order to prevent aggregate segregation.
- Haul distance and mix temperature.
- Timely mix unloading and unloading of the correct mix.

If properly managed, mix transport can successfully move AC from the production facility to the paving site with little or no change in mix characteristics.

TOOLS AND EQUIPMENT
One primary type of truck is usually employed to transport the mix- end dump trucks.
Describes what tools, equipment and tests are required to complete the job safely and with the highest level of quality.

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End Dump

An end dump truck delivers the mix directly into the hopper of the paver. When the bed is raised, it should not be in contact with the hopper and should not press down on or ride on the paver.

End dump trucks unload their payload by raising the front end and letting the payload slide down the bottom of the bed and out the back through the tailgate. End dump trucks are the most popular transport vehicle type because they are plentiful, maneuverable and versatile.

	The following terms will be used throughout this section:
Screed Tow Point	Tow point elevation will affect screed angle and thus mat thickness.
Paver Hopper	The hopper is used as a temporary storage area for AC delivered by the transport vehicle.
Aggregate Segregation	Segregation is a lack of homogeneity in the hot mix asphalt constituents of the in-place mat of such a magnitude that there is a reasonable expectation of accelerated pavement distress(es). *Stroup-Gardiner and Brown (2000)*

Contact between the truck bed and the paver can be a problem when large semi-tractor trailer units are used as haul vehicles, particularly when the truck bed is extended to its highest point. When the weight of the truck is being carried by the paver, care must be taken because the laydown machine may lose its ability to operate properly. Semi-trailer units typically haul more than single units and carry the maximum legal gross load. The payload depends on the number of axles, local regulations, and the empty weight of the vehicle. Normally, these trailers carry between 20 to 25 tons of mix. The disadvantages include more skill required to maneuver these units around the jobsite, overhead obstructions (wires, bridges) when the bed is raised, and a potential for segregation when loading.

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BEST PRACTICES
1. When the bed is raised it should not contact the paver. 2. The truck bed should be raised slightly before the tailgate lock is unlatched. 3. Truck-paver contact should be established by allowing the paver to move forward into a stationary truck. 4. Once the paver and truck are in contact, they should remain in contact.
Describes a best practice to be utilized when possible.

1. *When the bed is raised it should not contact the paver*. Bed contact with the paver may affect the screed tow point elevation, which can affect mat smoothness.

2. *The truck bed should be raised slightly before the tailgate lock is opened*. This allows the AC to slide back against the tailgate, which will cause it to flood into the paver hopper when the tailgate is opened. AC that trickles into the paver hopper is more susceptible to aggregate segregation.

3. *Truck-paver contact should be established by allowing the paver to move forward into a stationary truck*. This ensures that the truck does not bump the paver too hard and cause the paver to lurch to a sudden stop, which could cause a rough spot in the mat.

4. *Once the paver and truck are in contact, they should remain in contact*. This ensures that no AC is accidentally spilled in front of the paver because of a gap between the truck and paver. Usually the truck driver will apply the truck's brakes hard enough to offer some resistance to the paver but light enough so as not to cause the paver tracks to slip from excessive resistance. Most pavers can also be coupled to an unloading truck using truck hitches located on or near the push rollers.

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Live Bottom (Conveyor) Truck

A live bottom truck employs a conveyor belt or slat conveyor in the bottom of the truck bed to discharge the mix. This eliminates the need to raise the bed, and deposits the mix directly into the hopper of the paver as does an end dump truck.

Horizontal discharge units also can carry the legal load limit. The payload is dependent on the same factors as semi-trailers. The advantage here is that the unit can discharge directly into the paver.

Live bottom trucks are more expensive to use and maintain because of the conveyor system but they also can reduce segregation problems (because the AC is moved in a large mass) and can eliminate potential truck bed – paver contact (because the bed is not raised during discharge).

SAFETY WARNING	
	All trucks must have a back-up alarm. Trucks must be equipped with rotating beacons. Trucks must have a camera system or use a spotter near the paver.
	Describes a condition where personal safety may be at risk. This is used to alert personnel to operating procedures & practices which, if not observed, may result in personal injury.

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Each truck type is capable of adequately delivering AC from a production facility to a paving site. However, certain situations such as the ones listed below, may make one truck type advantageous over another.

Situation	Possible Truck Type	Reason
Paving on congested city streets	End Dump	Better maneuverability because it has no trailer and is smaller than a bottom dump or live bottom truck.
Paving using a mix highly vulnerable to segregation	Live Bottom	Live bottom trucks deliver the AC by conveyor, which minimizes segregation.
Paving on rural highways	Either	

Tarps

In Virginia every haul truck must be equipped with a waterproof, tear-resistant tarpaulin to protect the mix in case of inclement weather.

Holes in the tarp are unacceptable. For safety reasons, it is desirable to use tarps that can be extended by mechanical means over the bed of the truck without the driver having to climb up on the sides of the vehicle to unroll the tarp. If there is any water on the tarp when the truck is ready to discharge mix into the paver hopper, remove the water before removing the tarp by raising the bed of the truck and letting the water runoff before the truck backs into the hopper.

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Loading At the Production Facility

Loading at the production facility involves transferring AC from the storage silo or batcher (for batch plants) to the transport truck.

INSPECTION AND MEASUREMENTS
Pre-loading Inspection of Bed The bed of the haul truck should be free of all deleterious materials before mix is placed in it. The bed should be reasonably smooth and free from any major indentations or depressions where the truck bed release agent and the AC can accumulate.
Describes inspection, Quality Assurance and/or Quality Control practices.

There are two potential issues with this transfer:

1. *Truck bed cleanliness and lubrication*. Truck beds should be clean and lubricated to prevent the introduction of foreign substances into the AC and to prevent the AC from sticking to the truck bed. Non-petroleum based products should be used for lubrication such as lime water, soapy water or other suitable commercial products (Roberts et al., 1996). Petroleum based products, such as diesel fuel, should not be used because of environmental issues and because they tend to break down the asphalt binder.
2. *Aggregate segregation.* AC should be discharged into the truck bed so as to minimize segregation. Dropping AC from the storage silo or batcher (for batch plants) in one large mass creates a single pile of AC in the truck bed. Large-sized aggregate tends to roll off this pile and collect around the base. Dropping AC in several smaller masses (three is typical) at different points in the truck bed will largely prevent the collection of large aggregate in one area and thus minimize aggregate segregation.

BEST PRACTICE
There are several mix transport considerations, or best practices, that are essential to maintaining AC characteristics between the production facility and the paving site. These considerations are: ▪ Loading at the production facility ▪ Transport within the truck ▪ Unloading at the paving site ▪ Operation synchronization
Describes a best practice to be utilized when possible.

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Release agents

Once the bed is clean, coat it with a release agent. Uniformly spray a non-petroleum based release agent (from the VDOT Materials Approved List) over the sides and bottom of the truck bed. Use the minimum quantity necessary to cover the surface area of the bed without runoff. Drain out any excess liquid in the bed of the truck prior to loading the asphalt mix.

AWARENESS/IMPORTANT	
	Never use diesel fuel as a release agent for the truck bed. Diesel fuel can cause changes in the properties of the asphalt mix material with which it comes in contact. Diesel fuel can also contribute to environmental problems as it evaporates or if it soaks into the ground.
	Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

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Transport Within the Truck

Truck transport affects AC characteristics through cooling. AC is usually loaded into a truck at a fairly uniform temperature between 250°F to 350°F. During transport, heat is transferred to the surrounding environment by convection and radiation and the AC surface temperature drops.

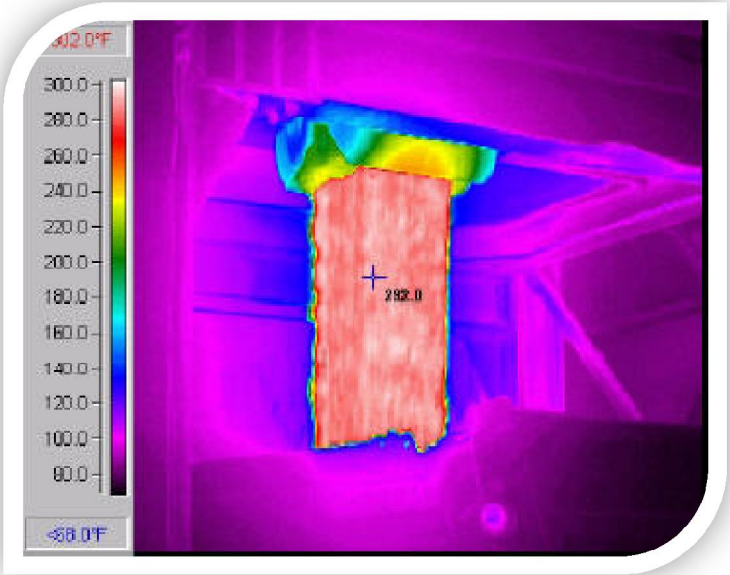

Figure: Infrared picture of an AC storage silo loading a truck showing the hot uniform temperature of the mix

This cooler AC surface insulates the interior mass and thus transported AC tends to develop a cool thin crust on the surface that surrounds a much hotter core. Things such as air temperature, rain, wind and length of haul can affect the characteristics and temperature of this crust. Several measures that can be taken to minimize AC cooling during transport are:

1. *Minimize haul distance.* This can be accomplished by choosing an AC production facility as close as possible to the paving site. Closer production facilities create shorter haul times and result in less AC cooling during transport. Unfortunately, many paving locations may not be near any existing production facilities and economics may prohibit the use of a mobile production facility.
2. *Insulate truck beds*. This can decrease AC heat loss during transport. Insulation as simple as a sheet of plywood has been used on the exterior of the truck bed.
3. *Place a tarpaulin over the truck bed*. A tarp over the truck bed provides additional insulation, protects the AC from rain and decreases heat loss. A study by the Quality Improvement Committee of the National Asphalt Pavement Association (NAPA) studied truck tarping and found that the AC surface temperatures of tarped loads dropped more slowly than untarped loads but temperatures 100 mm (4 inches) below the surface between tarped and untarped loads were not significantly different *(Minor, 1980)*.

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In most cases, truck transport appears to cool only the surface of the transported AC mass; however, this cool surface crust can have detrimental effects on overall mat quality if not properly dealt with.

Actions such as reducing transport time, insulating truck beds or tarping trucks can decrease AC surface cooling rate. Additionally, since the majority of the AC mass is still at or near its original temperature at loading, mixing the crust and interior mass together at the paving site ("remixing") will produce a uniform mix near the original temperature at loading.

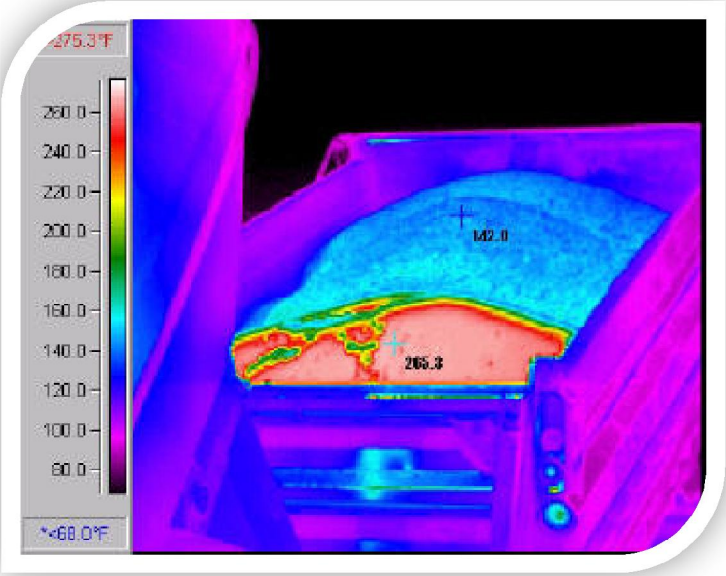

Figure: Infrared picture of a truck dumping AC showing the cold surface layer crust (blue) and the hot inner mass (red)

There is no set limit as to how far a load of AC can be transported. The key factors are the workability of the mix while it is passing through the paver and the ability to get the mix compacted. Both of these factors are highly dependent on the temperature of the mix.

The slight crust thickness that forms during transport should break up completely as the mix is discharged from the haul vehicle into the paver, is carried by the slat conveyors back to the augers, and is passed under the paver screed. As long as chunks of asphalt mix do not affect the quality of the mat behind the paver, the crust that forms on top of the mix during delivery will not be detrimental to the long-term performance of the mix.

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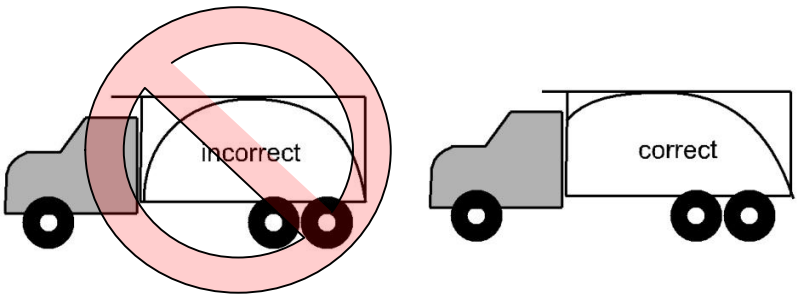
Axle Weights vs. Load Distribution

Most haul trucks need to be loaded with the load slightly forward in the truck bed to comply with axle weights and load distribution regulations.



Loading Sequence

One objective of the truck-loading operation is to get the vehicle filled with mix and on its way to the paver as quickly as possible. This objective must be balanced, however, with the need to minimize segregation of the mix that occurs during the loading process.

Some mixes are more prone to segregation than others and special care must be taken to ensure the mix load is as uniform as possible. Some mixes are not prone to segregation and conventional load out procedures work fine. There is no one correct way to load a truck. The method will depend on the mix type, truck type, and a host of other factors. Use the method that will minimize the potential for segregation to occur during the loading. This loading plan should be discussed and agreed upon at the pre-construction conference.

The load method will depend upon the mix type, truck type and other contributing factors. The method selected should be the one that minimizes the potential for segregation.

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The following scenarios assume the mix being loaded has a tendency to segregate and multiple drops are needed.

Scenario 1: From Pugmill

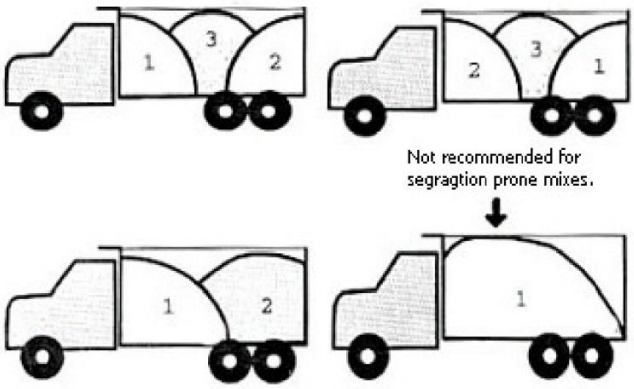
If it takes three batches of mix to reach the capacity of the haul truck, one pugmill batch should be loaded into the front of the truck bed. The truck should then be moved forward and the second batch of mix should be discharged into the rear of the truck, just in front of the tailgate. The third batch of material should be delivered into the center of the bed.

Scenario 2: From Silo

Segregation of the mix can occur when mix discharged from the surge silo is deposited into the haul truck in a single drop. This segregation problem can be minimized by loading the truck in multiple drops of mix from the silo, similar to the procedure used for loading from the batch plant pugmill. However, some silos are specially designed for mass flow for a single drop. These silos will not cause segregation when operated properly. The number of drops used depends on the length and capacity of the truck; the type of asphalt plant and the type of storage or surge silo used.

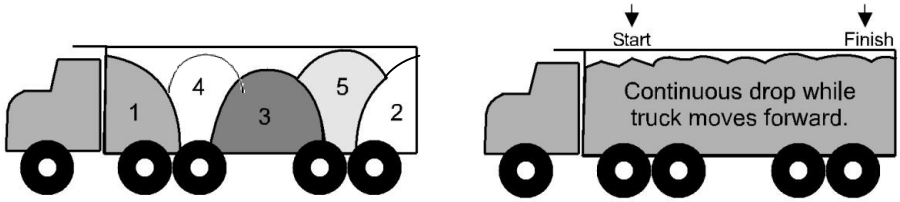
Scenario 3: For End Dump Types

For other numbers of batches, multiple drops of mix should be used, with the first batch delivered to the front of the truck bed, the second batch deposited at the tailgate end of the bed, and the remaining drops of mix placed evenly in between the first two. Such a loading sequence will minimize the distance the coarse aggregate particles can roll and thus minimize the amount of segregation that is produced in the mix. Some states have reversed this order. The first drop is placed at the tailgate, the second placed at the front, and the third placed in the middle.



Scenario 4: For Semi-Trailer Type

When a semi-tractor trailer truck is to be loaded, at least five and probably seven different discharges of mix should be made before the truck capacity is reached. In every case, the mix should first be deposited at the front of the bed and then at the tailgate of the truck. The space in between the first two drops should be filled in with small, separate piles of mix placed between the initial "batches" of mix. The use of multiple drops of mix is slower than loading the truck in a single discharge of material from the silo.



Topping Off

There is a tendency for the plant operator to fill the truck to its legal capacity to reduce haul costs, particularly if the truck is sitting on a scale under the silo. Although this is good economic practice, it should not be accomplished by dribbling mix into the truck from the silo after the majority of the mix is already in the truck. The discharge of small amounts of mix from the silo greatly increases the chance for segregation of the mix.

IMPORTANT	
	Overloading Overloading is illegal, dangerous, and can cause extreme stresses in pavements. Modern electronic weighout equipment and printed tickets have helped to eliminate this.
	Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

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Unloading the Mix

1. *AC should be unloaded quickly when it arrives at the paving site*. This will minimize mix cooling before it is placed.
2. *Before AC is loaded into the paver, the inspector and/or foreman should be certain it is the correct mix*. Occasionally, paving jobs require several different mix designs (i.e., one for the leveling course and one for the wearing course) and these mixes should not be interchanged.

Once loaded, ticketed, and tarped, the haul truck should proceed immediately to the jobsite. Stagger the asphalt deliveries to the project to reduce the time trucks have to wait before dumping the asphalt into the paver but not be spaced so far apart that the paver has to stop and wait for deliveries.

Waiting on Site

Haul trucks should park in designated areas and attempt to minimize tracking of tack coats. Trucks should stay far enough ahead of the paving train as to not interfere with operations, but close enough to back to the paver to keep the operation moving. Communication is again the key. Drivers should be informed about the paving plan.

INSPECTION AND MEASUREMENTS
When mix is delivered to the job site, two items must be checked. 1. First, is the right mix being delivered to the right job site. During the height of paving season, a single plant may be producing two or three different AC mixes. Occasionally the wrong mix is loaded into a truck or a truck driver goes to the wrong project. 2. Second, is the mix being delivered at the correct temperature. For most mixes, the maximum delivery temperature should not exceed 350°F. For polymer modified mixes using PG 76-22 binder, a temperature less than 350°F may be specified. The minimum mix temperature delivered in the field is a function of the production process. For surface AC materials not produced through a warm mix technology, the minimum temperature depends on the base temperature, number of rollers, application rate and virgin binder. With intermediate and base mixes not produced through a warm mix technology, the minimum placement temperature is 250°F. For those mixes produced using a warm mix technology, no minimum placement temperature is specified. Details on the specifications will be provided later in this manual.
Describes inspection, Quality Assurance and/or Quality Control practices.

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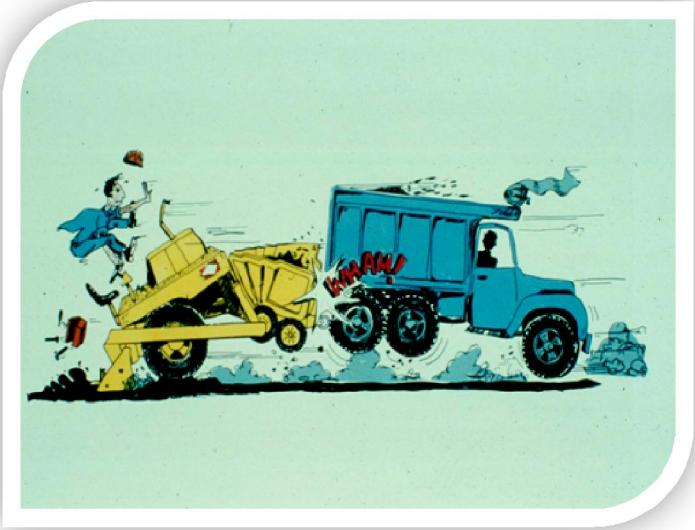
Backing



When an end dump or a live bottom truck is used to deliver mix to the paver, the truck driver should back the truck up to the laydown machine but stop just short of the push rollers on the front of the paver. It is very important that the truck be centered before the paver contacts it. Off-center positioning can push the paver out of alignment, create problems as the mix floods the hopper, and cause the truck bed to contact and damage the hopper wings. In addition, project personnel tend to tune out back-up alarms and are vulnerable while walking in the driver's blind spot. This is the area between the tailgate and the paver hopper. Too many accidents occur in this area.

SAFETY WARNING

Project personnel tend to tune out back-up alarms and are vulnerable while walking in the driver's blind spot. This is the area between the tailgate and the paver hopper. Too many accidents occur in this area.

Describes a condition where personal safety may be at risk. This is used to alert personnel to operating procedures & practices which, if not observed, may result in personal injury.

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Truck Hitches/Contact/Configuration

Once the truck has come to a halt and the driver has released the brakes on the vehicle, the paver operator should pick up the stopped truck. The key to this process is that the paver picks up the truck instead of the truck backing into and bumping the paver. As much as possible, the paver should maintain a constant speed throughout the paving operation. Use of the proper procedure will reduce the incidence of screed marks and roughness in the mat.

Dumping Into a Hopper - Raising Bed

If an end dump truck is used and the mix has a tendency to segregate, the bed of the truck should be raised a short distance in order to allow the mix in the bed to slide against the tailgate before the tailgate is opened.

Popping Gate and Flooding Hopper

Once the tailgate is opened, the mix is discharged from the truck in a mass and floods the hopper of the paver, reducing the possibility of segregation behind the paver screed. The same procedure should be employed, if possible, when a live bottom truck is used to transport the mix.

"Banging the Gate"

A common practice is to leave the truck gate up, speed up and stop quickly to bang the tailgate to expel any remaining mix. This should be discouraged.

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Dumping into a Material Transfer Vehicle (MTV)

This piece of equipment is basically a surge bin on wheels. Asphalt mix is deposited into the hopper on the front of the MTV. The mix is transported from the hopper to a conveyor, which delivers the mix to the extended hopper on the paver. The material transfer vehicle also allows the paver to be operated almost continuously when a continuous supply of mix is available from the asphalt plant. This provides for a smoother mat behind the paver screed by permitting the paver operator to keep the head of material in front of the screed constant. The equipment also eliminates the problem of the haul trucks bumping the paver and truck drivers holding the brakes on the truck when being pushed by the paver. Because of the weight of this piece of equipment when it is full of mix, it must be determined ahead of time that the pavement over which this machinery will be running can support the weight of the device without being over stressed and damaged.

Steering

While paving, the driver must focus not only on the dump person but in front of the truck also. The driver is responsible for steering within the “pull” of the paver, and keeping a slight pressure on the brakes to maintain contact with the paver and rollers.

Braking

Too much braking force from the haul truck may cause the paver to slip and affect the mat.

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Pulling Away

Once the final mix has exited the truck bed, the bed should be lowered so the apron can clear the hopper guards. The truck should immediately depart from the area to a clean up station, and let the next truck back up.

BEST PRACTICE	
	On Site Clean Up The contractor should designate a cleanup area for the drivers to clean the remaining mix from their trucks, the tailgate, and the apron.
	Describes a best practice to be utilized when possible.

Spillage on Pavement

"Banging the gate" and some other practices tend to drop some small piles of mix on the roadway which are subsequently rolled over by other trucks. If these piles are not removed, they affect the quality of the finished mat. If a spill occurs, the mix should be removed.

Summary

Ideally, AC production at the plant, truck transport and laydown at the paving machine should be synchronized to the same rate to minimize accumulation of excess AC in any one of the three segments. Realistically, however, this synchronization can be quite difficult because of varying laydown rates, unpredictable truck travel times and variable plant production.

If possible, all operations are designed to meet optimal mat laydown rates. However, these rates can vary based on paving width and lift thickness. Also, complicated paving locations such as intersections or near manholes and utility vaults can temporarily increase or decrease the laydown rate.
Truck transport should be planned such that the AC transport rate (expressed in tons/hr) closely matches plant production rate and laydown rate. Some factors to consider are:

- Number of trucks to be used
- Truck type
- Average truck hauling capacity
- Production facility output rate
- Availability and condition of storage silos at the production facility
- Time to lubricate the truck bed before transport
- Waiting time at the production facility
- Loading, weighing and ticketing time at the production facility
- Time to cover the load (tarps are required at all times)
- Distance between the production facility and the paving site
- Average truck speed

Traffic plays a large role in AC delivery rates because it affects truck speed. Especially in congested urban areas, heavy and/or unpredictable traffic may substantially increase, or at least vary, truck travel time. As truck travel time increases, more trucks are needed to provide a given AC delivery rate. Therefore, as traffic gets worse, trucking costs increase. Additionally, the unpredictability of traffic may result in either long paver idle times as it waits for the next truckload of AC or large truck backups as several trucks all reach the paving site or production facility at the same time.

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Finally, production facility output is typically controlled to match haul or laydown rate. However, this can result in suboptimal plant efficiency or AC uniformity, which may increase plant exhaust output, shorten emission control device lifetimes, and affect contractual payment if payment is tied to AC uniformity. It may often be more economical to run the production facility at maximum rate and store excess material in storage silos for discharge into trucks as they arrive. Storage silo insulation has progressed to a state where dense-graded AC can be stored in them for up to a week at a time without significantly affecting AC characteristics.

In conclusion, synchronization should be the goal but it is often difficult to achieve (based on varying laydown rates, haul time and traffic) and may result in plant inefficiency and AC quality degradation. If a production facility has modern well-insulated, airtight storage silos and is producing a dense-graded AC, it may be beneficial to run the plant at maximum production rate and store the mix until needed rather than try and match haul or laydown rate.

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Chapter Three Knowledge Check

1. When an “end dump” truck raises it’s bed to deliver mix into the hopper of the paver, the bed should not be in contact when the hopper and should not press down on or ride on the paver.
    a. True
    b. False
2. Contact between the hauling truck bed and the paver is never a problem.
    a. True
    b. False
3. In Virginia, haul trucks are required to be equipped with tarps_____
    a. Only during rain storms.
    b. Only when the roadway temperature goes below 40F.
    c. All the time.
    d. Only when your supervisor tells you to put one on.
4. The bed of the haul truck should be free of all deleterious materials before mix is placed in it.
    a. True
    b. False
5. When using diesel fuel as a release agent the residue must be dumped:
    a. In a container listed on the Departments approved list.
    b. Onto the ground in a well drained area.
    c. Diesel fuel should never be used as a release agent.
    d. Only at a VDOT Residency.
6. Some mixes are more prone to segregation than others and special care must be taken to ensure the mix load is as uniform as possible.
    a. True
    b. False
7. When a semi-tractor trailer is to be loaded, the mix should first be deposited at the_____
    a. Back of a trailer.
    b. Middle of the trailer.
    c. Front of the trailer.
    d. Middle and work towards the back.
8. When using an end dump or live bottom truck to deliver mix to the paver, the truck driver should back the truck up to the laydown machine but stop just short of the push rollers on the front of the paver.
    a. True
    b. False
9. The crust that forms on an asphalt mixture is acceptable if the temperature of the mix is greater than 225F.
    a. True
    b. False
10. Too much breaking force from the haul truck may cause the paver to slip and affect the mat.
    a. True
    b. False

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4 Mix Placement

Learning Outcomes:

- ☑ Explain the effect of various components of a paving machine on the finished mat.
- ☑ Select correct patching materials and placement techniques for pavement repair.

Mix Placement

Mix placement and compaction are the two of the most important elements in AC pavement construction and overlay. Mix placement involves any equipment or procedures used to place the delivered AC on the desired surface at the desired thickness. Mix placement can involve complicated asphalt paver operations or simple manual shoveling. This section provides a basic description of AC placement operations.

The basic concept of the asphalt paver has remained relatively unchanged: AC is loaded in the front, carried to the rear by a set of flight feeders (conveyor belts), spread out by a set of augers, then leveled and compacted by a screed. While this process may vary from paver manufacturer to manufacturer, the overall approach is the same. This set of functions can be divided into two main systems: the tractor and the screed.

TOOLS AND EQUIPMENT
• The tractor (or material feed system), and • The screed
Describes what tools, equipment and tests are required to complete the job safely and with the highest level of quality.

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Tractor (Material Feed System)

The tractor contains the material feed system, which accepts the AC. For most pavers, this is the front of the tractor. Once deposited at the front of the paver, the AC is transported to the rear and spreads it out to the desired width with augers in preparation for screed leveling and compaction. The basic tractor components are:

Push Roller and Truck Hitch	The push roller is the portion of the paver that contacts the transport vehicle and the truck hitch holds the transport vehicle in contact with the paver. They are located on the front of the hopper. Trucks should not be allowed to bump the paver.
Hopper	The hopper is used as a temporary storage area for AC delivered by the transport vehicle. Therefore, the paver can accept more material than is immediately needed and can use the volume in the hopper to compensate for fluctuating material demands created by such things as paving over irregular grades, utility access openings or irregular intersection shapes. Hopper sides (or "wings") can be tilted up (or "folded") to force material to the middle where it is carried to the rear by the conveyor system. Hoppers can also be fitted with inserts to allow them to carry more AC. These inserts are typically used in conjunction with Material Transfer Vehicles.
Material Transfer Vehicle (MTV)	Material transfer vehicles (MTVs) are used to assist the paver in accepting AC. Most pavers are equipped to receive AC directly from end dump trucks, however in certain situations it can be necessary or advantageous to use an MTV. Paving using bottom dump trucks and windrows requires a windrow elevator MTV, while other MTVs are used to provide additional surge volume, which is advantageous because it allows the paver to operate continuously without stopping, minimizes truck waiting time at the paving site and may minimize aggregate segregation and temperature differentials.
Conveyor	The conveyor mechanism carries the AC from the hopper, under the chassis and engine, then to the augers. The amount of AC carried back by the conveyors is regulated by either variable speed conveyors and augers or flow gates, which can be raised or lowered by the operator or, more often, by an automatic feed control system.
Auger	The auger receives AC from the conveyor and spreads it out evenly over the width to be paved. There is one auger for each side of the paver and they can be operated independently. Some pavers allow the augers to be operated in reverse direction so that one can be operated forward and the other in reverse to send all the received AC to one side of the paver. The auger gearbox can either be located in the middle (between the augers) or on the outside edge of each auger. If an inadequate amount of AC is distributed under a middle-located gearbox the result can be a thin longitudinal strip of mat aligned with the gearbox that exhibits lower densities from aggregate segregation and/or temperature differentials.

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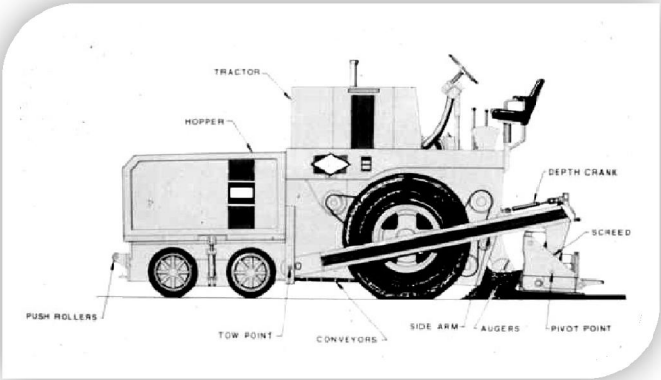
The purpose of the paver is to place the hot-mix asphalt to the desired width and thickness and to produce a satisfactory mat texture. The paver consists of two primary parts: the tractor unit and the screed unit. The tractor unit provides the motive power to the paver and transfers the asphalt mixture from the receiving hopper on the front of the machine to the spreading screws at the back of the paver. The tractor unit fulfills all of the functions necessary to receive the asphalt mix from the haul trucks, carry the material back to the spreading screws, and distribute the mix across the width of the screed. It is composed of several major components including the track push rollers, mix-receiving hopper, material flow gates, twin slat conveyors, and a pair of screw conveyors or augers.

Drive System

The tractor unit is powered by its own engine and provides the required propulsion energy to move the machine forward, either on rubber tires or crawler tracks.



Rubber Tire

If the paver is moved regularly under its own power between paving locations, the rubber tire machine is normally used because its travel speed is much greater than that of the crawler track paver.

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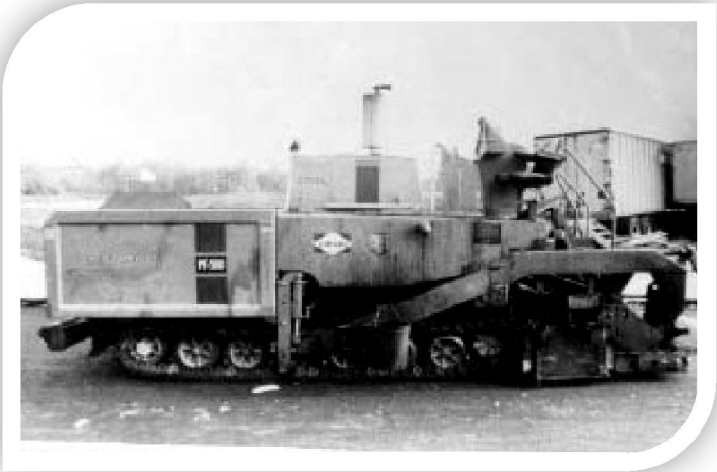
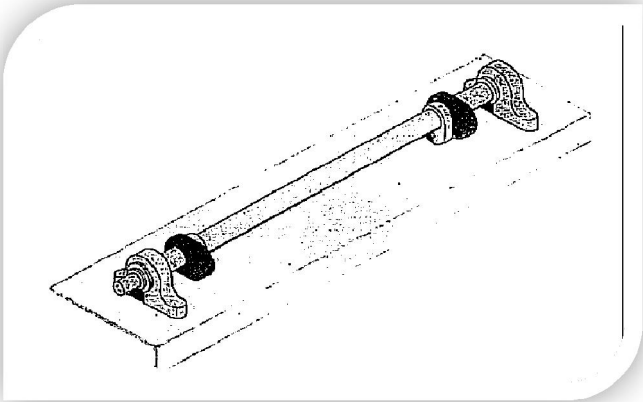
Track

The crawler tracks could be all steel, steel equipped with rubber pads, or flexible bands with steel shoes and rubber pads. If the paver is used on top of a yielding surface, the crawler track system will provide an increased area over which to spread and support the weight of the paver.



Screed Vibration Shaft with Weights

The applied amplitude is determined by the location of the eccentric weights on the shaft. The position of the weights can be altered to increase or decrease the amount of compactive effort applied to the mix by the screed. Typically the amplitude setting selected is related to the thickness of the mat being placed - low amplitude for thinner lifts and higher amplitude for thicker lifts.



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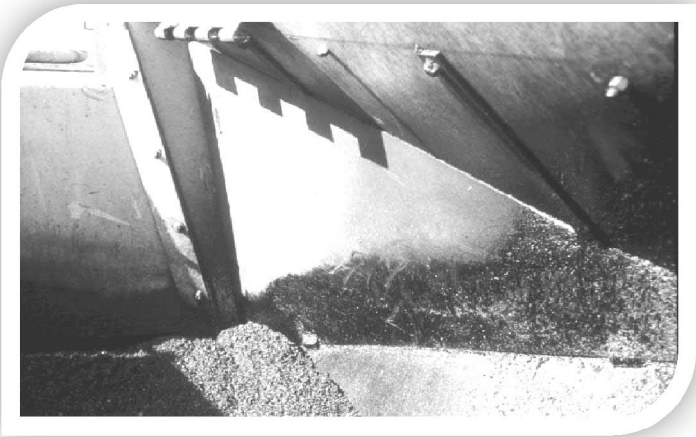
Hopper

The paver hopper is used to receive and temporarily hold the asphalt mix from the haul vehicle or the pickup machine.

Shape, Capacity, Wings

The hopper must be wide enough to allow the body of the haul truck to fit inside of it. In addition, particularly for smaller pavers, the hopper must be low enough to permit the truck bed to be raised without the bed placing excessive weight on the front of the hopper.

Some Contractors weld a diagonal wedge into the back corners of the hoppers to redirect the mix into the center of the hopper.



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Conveyor (Slat Conveyor)

At the bottom of the paver hopper is a set of slat conveyors. Their purpose is to carry the asphalt mix from the hopper through the tunnel on the paver and back to the spreading screws. The slat conveyors are on either side of the paver, operating independently of each other. This allows the paver operator to control the amount of material fed to each side of the paver in order to pave ramps, mail box turnouts, or tapers.

Conveyor Flow Gates (Hopper Gates)

At the back of the paver hopper is a set of flow gates, one over each of the two slat conveyors. These are used to regulate the amount of mix that can be delivered by the conveyors to the augers. The gates move vertically, either by manual manipulation or mechanically. The flow gates should be adjusted to provide a uniform head of material (at a level of or just above the center of the auger shaft) in front of the screed.

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Augers

Keep the amount of mix carried in the auger chamber as constant as possible. The proper depth of material on the augers should be at the center of the auger shaft. The level of material carried in front of the screed should not be so little as to expose the lower half of the screw conveyor flights. Further, the level of mix delivered to the screed should never be so great as to cover the upper portion of the auger, as shown in this same figure.

The mix that is carried to the back of the tractor unit by the slat conveyors is deposited in front of the screw conveyors or augers. Just as the two slat conveyors operate independently of each other, the augers on each side of the paver are run separately from one another.

The mix placed in the auger chamber from the slat conveyors is distributed across the width of the paver screed by the movement of the augers. At the junction of the two augers in the center of the paver, adjacent to the auger gear box, there typically is a different-shaped auger (reverse auger or paddle) to tuck mix under the gear box and assure that the mix placement at this location is the same as that across the rest of the width of the mix being laid. It is important that the augers carry a consistent amount of mix across the front of the screed so that the pressure (head of material) on the screed is kept as consistent as possible.

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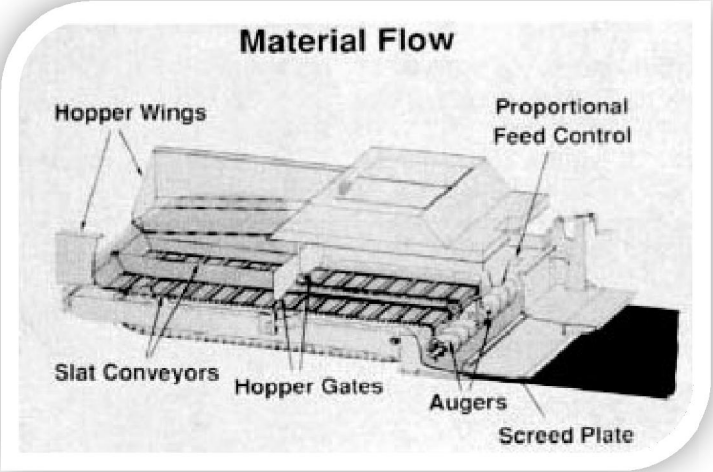
Material Feed System

If the feed system is set and operating properly, the slat conveyor and augers on each side of the paver will rarely shut off. This continuous action of the conveyors and augers is accomplished by setting the proper position for the hopper flow gates and determining the correct speed setting for the slat and screw conveyors.



The primary key to the placement of a smooth pavement layer is the use of the material feed system to keep the head (level) of material in front of the screed constant, primarily by keeping the slat conveyor and augers running as close to 100 percent of the time as possible.

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IMPORTANT / AWARENESS

Operation of the tractor, and specifically the material feed system, can have significant effects on overall construction quality and thus long-term pavement performance. Although there are many detailed operational concerns, the two broad statements below encompass most of the detailed concerns:

1. *AC must be delivered to maintain a relatively constant head of material in front of the screed*. This involves maintaining a minimum amount of AC in the hopper, regulating AC feed rate by controlling conveyor/auger speed and flow gate openings (if present), and maintaining a constant paving speed. As the next section will discuss, a fluctuating AC head in front of the screed will affect the screed angle of attack and produce bumps and waves in the finished mat.

2. *The hopper should never be allowed to empty during paving*. This results in the leftover cold, large aggregate in the hopper sliding onto the conveyor in a concentrated mass and then being placed on the mat without mixing with any hot or fine aggregate. This can produce aggregate segregation or temperature differentials, which will cause isolated low mat densities. If there are no transport vehicles immediately available to refill the hopper it is better to stop the paving machine than to continue operating and empty the hopper (TRB, 2000).

Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

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Screed

The most critical feature of the paver is the self-leveling screed unit, which determines the profile of the AC being placed (Roberts et al., 1996). The screed takes the head of AC from the material delivery system, strikes it off at the correct thickness and provides initial mat compaction.

DEFINITION	
	Screed Terminology The following is a list of basic screed components and terms:
	Describes and/or defines terminology.
Screed plate	The flat bottom portion of the screed assembly that flattens and compresses the AC.
Screed angle (angle of attack)	The angle the screed makes with the ground surface.
Strike-off plate	The vertical plate just above the leading edge of the screed used to strike off excess AC and protect the screed's leading edge from excessive wear.
Screed arms	Long beams that attach the screed to the tractor unit.
Tow point	Point at which the screed arm is attached to the tractor unit.
Depth crank	The manual control device used to set screed angle and ultimately, mat thickness.
Screed heater	Heaters used to preheat the screed to AC temperature. AC may stick to a cold screed and cause mat tearing. After the screed has been in contact with the AC for a short while (usually about 10 minutes) its temperature can be maintained by the AC passing beneath it and the heater can be turned off. If the screed is removed from contact with AC for an extended period of time, it may need to be pre-heated again before resuming paving.
Screed vibrator	Device located within the screed used to increase the screed's compactive effort. Screed compaction depends upon screed weight, vibration frequency and vibration amplitude.
Screed extensions	Fixed or adjustable additions to the screed to make it longer. Basic screed widths are between 2.4 m (8 ft.) and 3.0 m (10 ft.). However, often it is economical to use wider screeds or adjustable width screeds. Therefore, several manufacturers offer rigid extensions that can be attached to a basic screed or hydraulically extendable screeds that can be adjusted on the fly.

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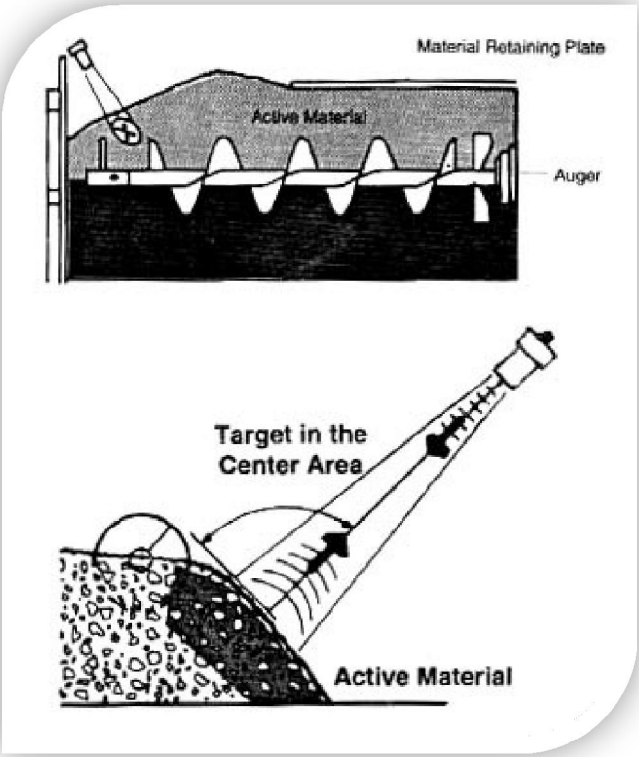
Sensor Types and Location

For the automatic feed control system to function properly, the feed sensor control arm should be located as close to the outside end of the augers as possible. If rigid paver screed extensions are used, as discussed later, the control arm should be mounted beyond the end of the augers, just inside the end gate on the paver screed.

Material Feed Sensor

For this system, a feed control sensor (a type of limit switch) is used to determine the amount of mix in the auger chamber. If the volume of mix available in front of the screed falls below the desired amount, the feed control sensor will move enough to engage the slat conveyor and auger system, pulling more mix back to the screed area. As the material is distributed in front of the screed, the feed control sensor will rise and disengage the feed system.



This action will maintain the pre-selected head of material in front of the screed. This sequence repeats itself, continuously maintaining consistent head of mix as long as material is available in the hopper. On some pavers, a variable-speed (potentiometer-type) feed system is used to control the amount of material in front of the screed. Instead of an on-off system, the speed of the delivery system is increased when more mix is needed and the speed of the slat conveyor and auger system (on each side of the paver) is decreased when the head of material in front of the screed is too great.

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In addition to these limit switch-type and variable-speed systems, both ultrasound and infrared sensing devices can be used to determine the amount of mix in the auger chamber. These two types of systems operate on the same basis as the limit switch system; measuring the amount of mix in front of the screed and controlling the slat conveyor and auger feed system to maintain a constant head of mix at the screed.

Tow Points

The screed unit is attached to the tractor at only one point on each side of the paver. This point is called the tow point or the pull point by the different paver manufacturers. The tow point is really a pin-type connection that allows the leveling arms (also called side arms or pull arms) of the screed to rotate or pivot around the point. This pin connection reduces the transmission of movement between the tractor unit and the screed unit.

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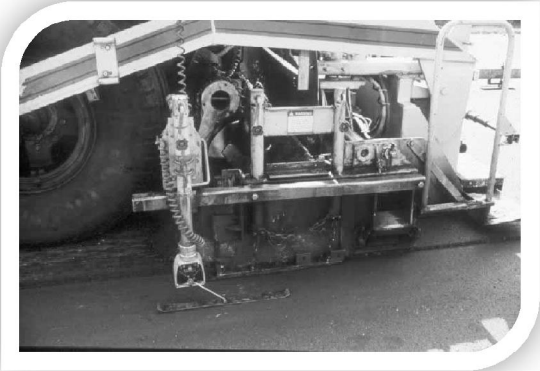
Screed Unit (Review of Equipment and Function)

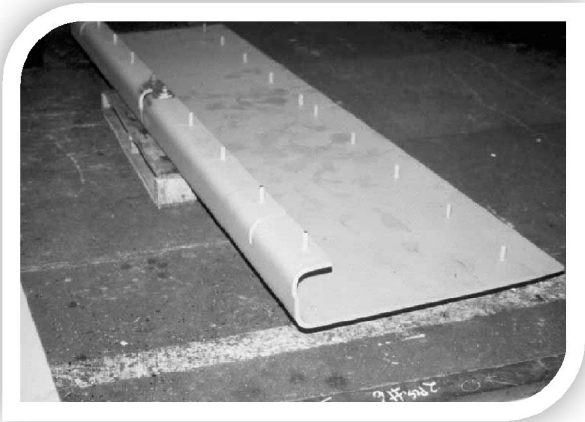
Paver Screed

The second unit consists of the paver screed. This leveling device is attached to the tractor unit at only one point on each side of the paver and is able to "float" on the asphalt mix and provide initial texture and compaction to that material as it passes out from under the screed.



The screed unit, which is towed by the tractor unit, establishes the thickness of the asphalt layer and provides the initial texture to the new surface. In addition, the screed imparts some level of density to the material being placed through the vibratory or combination tamping and vibratory action of the screed. The principle of the free-floating paver screed was developed in the early 1930's. That concept allows the paver screed which is attached to the tractor unit at only one point on each side of the machine (the tow or pull point), to average out changes in grade that are experienced by the wheelbase (rubber tires or crawler tracks) of the tractor unit. The floating-screed principle is employed on all of the modern asphalt pavers in use today.

Screed Plate



The screed plate is a formed piece of steel that bolts to the bottom of the screed. The screed plate is the only portion of the screed that develops the initial texture of the mat and can be adjusted. The center of the leading edge of a rigid screed has grooves cut into it to allow the screed to be flexed or warped.

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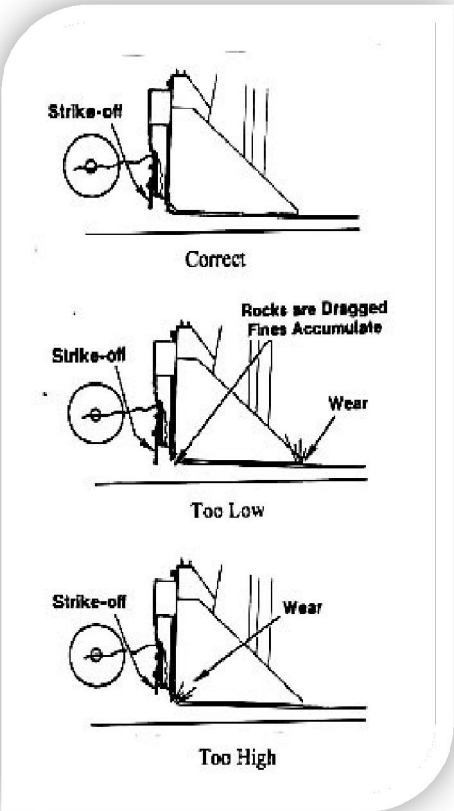
Strike-Off (Pre-Strike Off)

The screed may be equipped with a device on its front edge that is called a strike-off by some manufacturers and a prestrike-off by others. The purpose of this device is to control the feed of the asphalt mix under the paver screed, thereby regulating the amount of mix that reaches the nose of the screed plate. Further, the strike-off or prestrike-off is used to reduce the wear on the leading edge of the screed. When the strike-off is attached to the front of the screed, its position becomes important relative to the ability of the screed to handle the asphalt mix properly. If the strike-off is set too high, extra material will be fed under the screed. This action will cause the screed to rise. The resulting increase in the mat thickness will be overcome by manually reducing the angle of attack of the screed, using the thickness-control cranks. This, in turn, will cause the screed to pivot around its hinge point and ride on its nose. Rapid wear of the nose plate will result. In addition, the screed will settle when the paver is stopped between truckloads of mix because the weight of the screed is carried only on the front part of the screed.



When the strike-off is set too low, the thickness of the lift will be reduced because of the lack of mix being fed under the screed. In order to maintain the proper thickness, the angle of attack of the screed must be altered, causing the screed to ride on its tail. This increases the wear on the back of the screed and also causes the screed to settle whenever the paver is stopped because of the concentration of weight of the screed on a smaller surface area.

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Crown Control

The screed on the paver can be angled at its center to provide for positive or negative crown. The amount of crown that can be introduced into the screed varies. The adjustment of the crown is typically done using a turnbuckle device to flex the bottom of the screed and impart the desired degree of crown. Normally the lead crown setting is 1/32 to 3/16 inch greater than the tail crown position, with 1/8 inch being the average difference in the crown settings.

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Screed Extensions and End Plates

Hydraulically Extendible

Most paver manufacturers have developed hydraulically extendable paver screeds that trail the primary or basic screed on the paver. One make of pavers, however, is equipped with a power extendable screed that places the extendable portion of the screed in front of the main screed. For all hydraulically extendable screeds, it is very important that the angle of attack for the extendable screeds is the same as the basic screed. If the extensions on the extendable portion of the screed are not properly aligned with the main screed, a longitudinal mark or ridge will occur in the surface of the mix at the junction between the two screeds. In addition to the longitudinal mark, a mismatch in the elevation between the two screeds can also result in a possible difference in surface texture in the mix. Finally, the lack of proper alignment between the two screeds can cause a difference in the degree of compaction that is obtained in the mix under the extendable screed. In addition, proper placement of the material feed sensor is important to avoid segregation problems.

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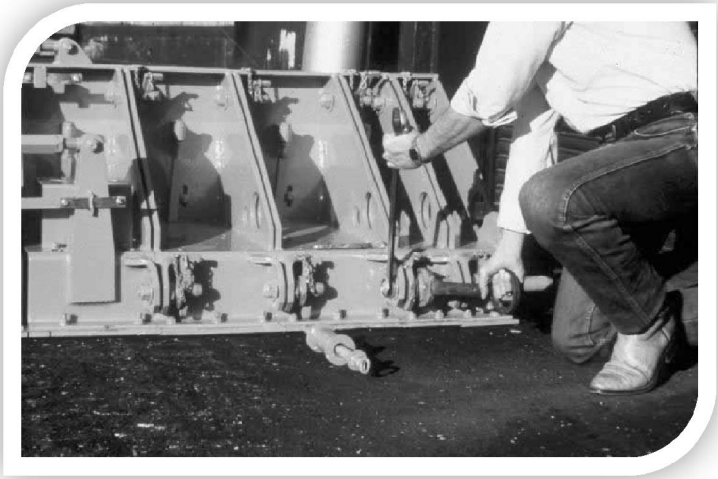
Rigid Screed Extension

When the basic width of the paver screed (8 feet for small pavers and 10 feet for the larger machines) needs to be changed to accommodate increased paving widths, rigid screed extensions can be employed. These extensions come in several widths, usually 6 in., 1 ft., 2 ft., 3 ft. and 5 ft. sections. Further, it is very important that the extension be set at the same elevation and angle as the basic screed to prevent the presence of a transition line or ridge at the intersection of the main screed and the extension or between different sections of extension. Whenever a rigid screed extension is employed on the basic paver screed, auger extensions and the accompanying auger tunnel extensions should also be added. The length of all the auger and tunnel extensions should, in general, be the same length as the added screed extensions to allow room between the end of the auger and the end plate of the screed. Typically the distance between the end of the auger extension and the end plate should be about 18 inches.

Hydraulic Strike-Off



The hydraulic strike off is an option for most screeds and allows the screed to be extended for brief periods to form turnouts, ramps, etc. Either a strike off or mini screed approximately 6 inches is available to impart initial texture and compaction to the mix that passes under it. However, this texture and compactive effort are normally different from that which develops under the screed. In addition, the mix will need to be left higher than the screed placed mix. The use of hydraulic strike-offs to place mainline paving instead of adding rigid extensions is not considered best practice.

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End Plate (End Gate)

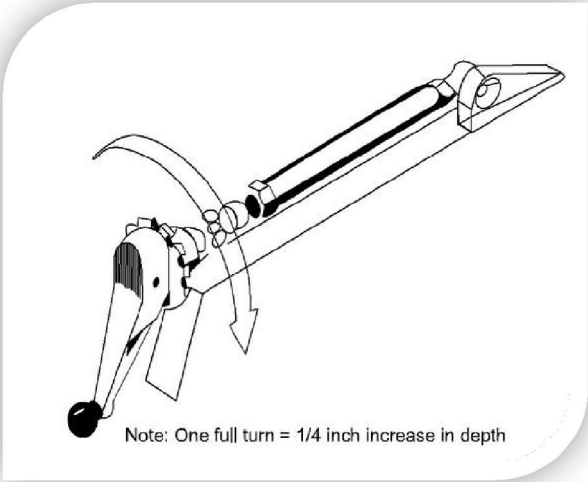
An end plate (or end gate or edger plate) is attached to the end of the screed to restrict the outward movement of the mix around the end of the screed. In typical operating mode, however, the end plate is positioned tight to the surface being paved to retain the mix and control the width of material being placed.

Cut-Off Shoes

Cut-off shoes can be used, if necessary, to reduce the width of mix placed to a width that is less than the basic main screed width. Typically the cutoff shoes come in widths of 1 - 2 feet, and are adjustable in increments of 1½ - 3 inches, depending on the manufacturer.

Thickness Control Screws

The thickness-control mechanism, usually either a crank or a handle, allows the screed to be moved or rotated around the pivot point. As the mix passes under the screed plate, the screed floats on the mix, determining the mat thickness and the texture of the material as well as providing the initial compaction of the asphalt mix. For a constant position of the tow point (the tractor unit running on a level surface and without automatic screed controls), altering the setting of the thickness-control devices changes the attitude (angle of attack) of the screed and changes the forces acting on the screed. This, in turn, causes the screed to move up to, or down to, a new elevation as the paver moves forward, and thus alters the thickness of the mat being placed. The reaction of the screed to changes in position of the thickness-control settings, however, is not instantaneous.



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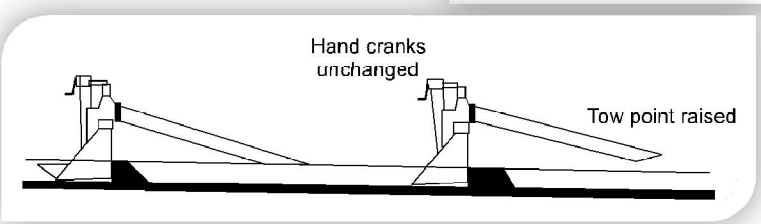
Screed Arm (Tow Arm)

The screed is attached to the leveling or tow arms on each side of the paver through a hinge or pivot point. The pivot point is located at the center of the wheelbase of the tractor. This allows the screed to use the tractor as a leveling device, much like a ski.



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Pre-Compaction Systems

Early pavers were equipped with tamper bars that were located on the leading edge of the paver screed. These tamper bars were used to tuck the asphalt mix under the screed and to provide some degree of initial compaction to the mix as it passed under the screed. The tamper bar system was replaced by the more efficient vibratory screed system.

Two factors within the screed itself also contribute to the degree of compaction. The first is the frequency of vibration and the second is the amplitude of the compactive effort. The frequency of vibration is controlled by the rotary speed of the vibrator shaft. Increasing the revolutions per minute of the shaft will increase the frequency of the vibration. The applied amplitude is determined by the location of the eccentric weights that are located on the shaft. The position of the eccentric weights can be altered to increase or decrease the amount of compactive effort applied to the mix by the screed. In general, the vibrators should be used near the maximum possible frequency. On screeds where it is possible to change the amplitude of the applied vibrational force, the amplitude setting selected is related to the thickness of the mat being placed; lower amplitude for thinner lifts and higher amplitude for thicker lifts.

The amount of density obtained by the paver screed is also a function of the speed of the paver. The faster the paver moves, the less time the screed sits over any particular point in the new mat, and, thus, the amount of compactive effort applied by the screed decreases. For asphalt concrete mixes, it can be expected that approximately 70 to 80 percent of the theoretical maximum density of the mix will be realized in the mix when it passes out from under the paver screed. A few of the most recent pavers (and many pavers used in other countries) are equipped with combination screeds--both tamper bars and a vibratory screed.

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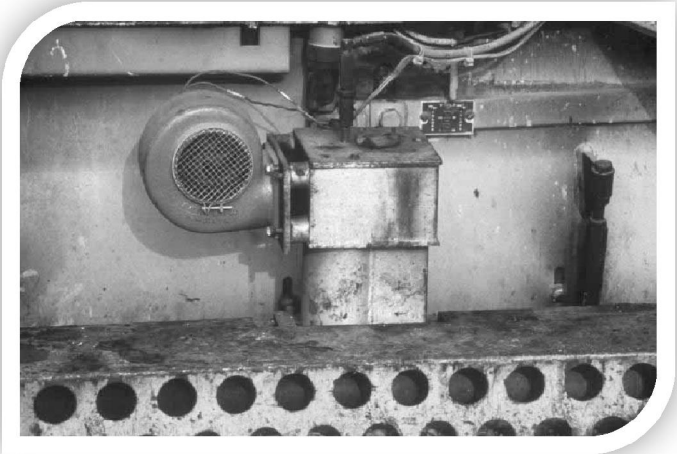
Heating Systems

The screed is equipped with heaters or burners, the primary purpose of which is to increase the temperature of a cold bottom screed plate to approximately 300°F. It is necessary for the screed to be at the same temperature as the asphalt material passing under it in order to assure that the mix does not stick to the screed plate and tear, providing a rough texture to the mat. A properly heated screed, particularly at the start of the day's paving operations or after any extended shutdown of the laydown process, provides for a more uniform mat surface texture.



The screed heaters cannot be used to increase the temperature of the mix being placed because the amount of time that the mix is actually under the screed is much too short to accomplish any temperature rise in the mix.

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Screed Forces

There are six basic forces acting on the screed that determine its position and angle (Roberts et al., 1996):

1. Towing force.	This is provided by the tractor and exerted at the tow point. Thus, towing force is controlled by paver speed.
2. Force from the AC head resisting the towing force.	This is provided by the AC in front of the screed and is controlled by the material feed rate and AC characteristics.
3. Weight of the screed acting vertically downward.	This is obviously controlled by screed weight.
4. Resistive upward vertical force from the material being compacted under the screed.	This is also a function of AC characteristics and screed weight.
5. Additional downward force applied by the screed's tamping bars or vibrators.	This is controlled by vibratory amplitude and frequency or tamping bar force.
6. Frictional force between the screed and the AC under the screed.	This is controlled by AC and screed characteristics.

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Factors Affecting Mat Thickness and Smoothness

Since the screed is free floating it will slide across the AC at an angle and height that will place these six forces in equilibrium. When any one of these forces is changed, the screed angle and elevation will change (which will change the mat thickness) to bring these forces back into equilibrium. Therefore, changing anything on the paver that affects these forces (such as paver speed, material feed rate or screed tow point) will affect mat thickness.

Furthermore, since mat thickness needs to be closely controlled, pavers have controls to manually set screed angle rather than rely on a natural equilibrium to determine mat thickness. In typical paving operations, the screed angle is adjusted to control mat thickness.

In order to understand how a manually controlled screed angle affects mat thickness, a brief discussion of how the paver parameters of speed, material feed rate and tow point elevation affect screed angle, screed height and therefore mat thickness is provided.

1. Speed

   Paver speed affects mat thickness by changing the screed angle. If a paver speeds up and all other forces on the screed remain constant, the screed angle decreases to restore equilibrium, which decreases mat thickness. Similarly, as paver speed decreases, screed angle increases, which increases mat thickness.

2. Material Feed Rate

   The amount of AC in front of the screed (the material "head") can also affect screed angle and thus mat thickness. If the material head increases (either due to an increase in material feed rate or a reduction in paver speed), screed angle will increase to restore equilibrium, which increases mat thickness. Similarly, if the material head decreases (either due to a decrease in material feed rate or an increase in paver speed), screed angle will decrease to restore equilibrium, which decreases mat thickness (TRB, 2000).

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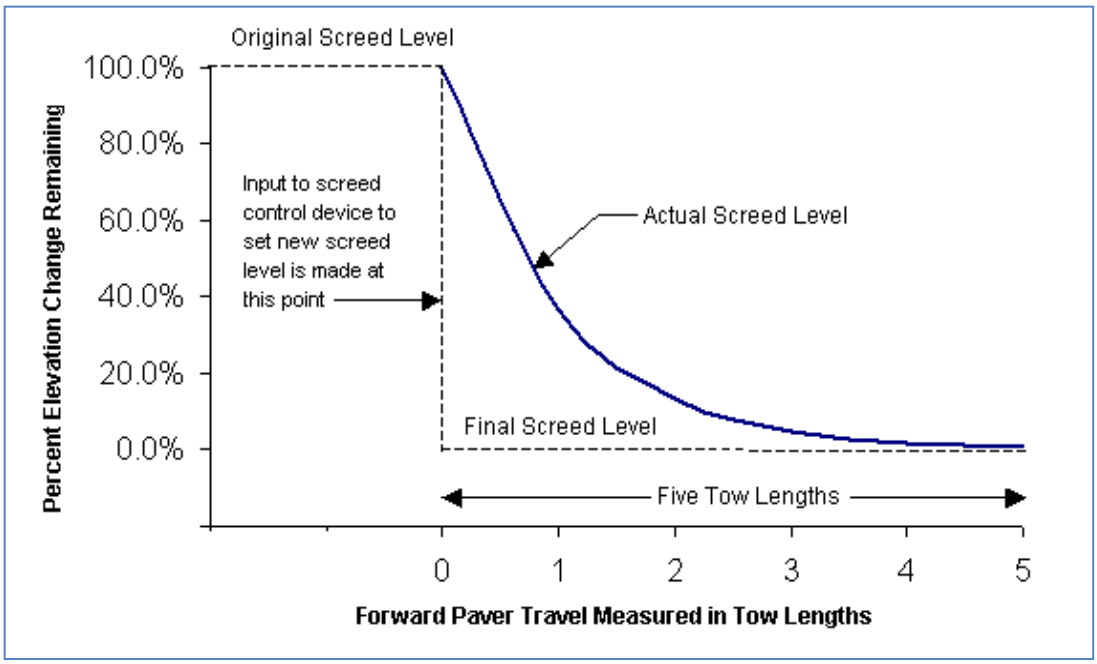
Therefore, in order to maintain a constant mat thickness for a change in paver speed or material head in front of the screed, the natural equilibrium of forces on the screed cannot be relied upon and the screed angle must be manually adjusted using a thickness control screw or depth crank. Screed angle adjustments do not immediately change mat thickness but rather require a finite amount of time and tow distance to take effect. It typically takes five tow lengths (the length between the tow point and the screed) after a desired level is input for a screed to arrive at the new level.



Because of this screed reaction time, a screed operator who constantly adjusts screed level to produce a desired mat thickness will actually produce an excessively wavy, unsmooth pavement.

3. Tow Point Elevation

Finally, tow point elevation will affect screed angle and thus mat thickness. As a rule-of-thumb, a 1-inch movement in tow point elevation translates to about a 0.125 inch movement in the screed's leading edge. Without automatic screed control, tow point elevation will change as tractor elevation changes. Tractor elevation typically changes due to roughness in the surface over which it drives. As the tow point rises in elevation, the screed angle increases, resulting in a thicker mat. Similarly, as the tow point lowers in elevation, the screed angle decreases, resulting in a thinner mat. Locating the screed tow point near the middle of the tractor significantly reduces the

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transmission of small elevation changes in the front and rear of the tractor to the screed. Moreover, because the screed elevation responds slowly to changes in screed angle, the paver naturally places a thinner mat over high points in the existing surface and a thicker mat over low points in the existing surface (TRB, 2000).

The interaction of paver speed, material feed rate and tow point elevation determine the screed position without the need for direct manual input. This is why screeds are sometimes referred to as "floating" screeds.

INSPECTION AND MEASUREMENTS
▪ Verify head of material at the auger – should be maintained at center of auger shaft for consistent mat thickness ▪ Augers should be turning slowly and consistently approximately 100% of the time ▪ Verifying material thickness behind screed by sticking the mat ▪ Placement of straightedge behind screed, parallel to the screed to verify correct cross-slope ▪ Minimizing folding of hopper wings to every third or fourth load ▪ Uniform mat appearance behind the screed to minimize streaking
Describes inspection, Quality Assurance and/or Quality Control practices.

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Automatic Screed Control

As discussed previously, the screed angle can be manipulated manually to control mat thickness. However, tow point elevation is not practical to manually control. Therefore, pavers usually operate using an automatic screed control, which controls tow point elevation using a reference other than the tractor body. Since these references assist in controlling AC pavement grade, they are called “grade reference systems” and are listed below (Roberts et al., 1996):

- Erected stringline. This consists of stringline erected to specified elevations that are independent of existing ground elevation. Most often this is done using a survey crew and a detailed elevation/grade plan. Although the stringline method provides the correct elevation (to within surveying and erecting tolerances), stringlines are fragile and easily broken, knocked over or inadvertently misaligned. Lasers can be used to overcome the difficulties associated with stringlines because they do not require any fragile material near the pavement construction area. Lasers can establish multiple elevation or grade planes even in dusty or high-electronic and light-noise areas and are therefore sometimes used to construct near-constant elevation airport runways. The laser method becomes quite complicated, however, when frequent pavement grade changes are required.
- Mobile reference. This consists of a reference system that travels with the paver such as a long beam or tube attached to the paver (called a "contact" device since it actually touches the road) or an ultrasonic device (called a "non-contact" device since it relies on ultrasonic pulses and not physical contact to determine road elevation). The mobile reference system averages the effect of deviations in the existing pavement surface over a distance greater that the wheelbase of the tractor unit. Minimum ski length for a contact device is normally about 25 ft. with a typical ski lengths being on the order of 40 to 60ft. (Asphalt Institute, 2001).
- Joint matching shoe. This usually consists of a small shoe or ski attached to the paver that slides on an existing surface (such as a curb) near the paver. Ultra sonic sensors accomplish the same task without touching the existing surface by using sound pulses to determine elevation. This type of grade control results in the paver duplicating the reference surface on which the shoe or ski is placed or ultra sonic sensor is aimed.

In addition to grade control, the screed can also be set to control pavement slope and/or crown. A slope controller uses a slope sensor mounted on a transverse beam attached to the screed to determine

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screed slope, then adjusts screed slope to the desired amount. Generally, one side of the screed is set up to control grade and the opposite side is set up to control slope based on that grade. The usual practice is to run grade control on the side of the screed nearest the pavement centerline and run slope control on the screed side nearest the pavement edge because it is easier to match the centerline joint if grade control is used on that side of the paver (TRB, 2000).

Screed crown (the elevation of the middle in relation to the edges) can also be controlled. Typically screeds offer separate front and rear crown controls. If crown control is used, the front control is usually set to a slightly more severe crown than the rear control to allow for easier passage of AC under the screed.

Screed Operation Summary

The floating screeds used by today's pavers are acted upon by six basic forces, which when left undisturbed result in an equilibrium screed angle and elevation that determines mat thickness. Adjusting paver speed, material feed rate or tow point elevation will change these forces and result in a new equilibrium screed angle and elevation and eventually a new mat thickness.

BEST PRACTICE	
	In order to achieve the most consistent thickness and smoothest possible surface, pavers attempt to maintain a constant speed, use automatic feed controls to maintain a consistent head of material in front of the paver, and use automatic screed control to maintain a consistent tow point.
	Describes a best practice to be utilized when possible.

Although the screed angle can be adjusted manually to change mat thickness, excessive adjustments will result in a wavy, unsmooth mat. In addition to grade, screeds can also control mat slope and crown to provide almost complete control over mat elevation at any location.

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Chapter Four Knowledge Check

1. The paver consists of two primary parts: the tractor unit and the screed unit.
    a. True
    b. False
2. The proper depth of material on the augers should be at the_____.
    a. Fill mark on the auger shaft.
    b. Top of the auger shaft
    c. Two inch mark of the auger shaft.
    d. Center of the auger shaft.
3. The primary key to the placement of a smooth pavement layer is the use of the new material feed system to keep a constant head (level) of material in front of the screed.
    a. True
    b. False
4. The screed unit is attached to the tractor at:
    a. One point on each side of the paver.
    b. Two points on each side of the paver.
    c. Three points on each side of the paver.
5. The amount of density obtained by the paver screed is also a function of the speed of the paver.
    a. True
    b. False
6. The primary purpose of the heater or burner on the screed is to assist in reheating the asphalt mix to make up for heat loss during transit.
    a. True
    b. False
7. When changing the thickness control screws or tow point position, it takes _____ before an adjustment is completed.
    a. 15 minutes
    b. One tow length of the paver
    c. Five tow lengths of the paver
8. When changing trucks during paving, it is best if the transfer is accomplished without slowing down or stopping the paver.
    a. True
    b. False
9. Auger operation and conveyor operation should be adjusted to keep them running as close to _____ percent of the time as possible.
    a. 80
    b. 90
    c. 95
    d. 100

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5 Joint Construction

Learning Objectives:

- ☑ Understand proper joint construction for maximum pavement lifespan.

All pavements have one potential internal weakness – joints. Whether concrete or asphalt, joints probably cause more problems than any other. However, when constructed properly a joint area will perform as well as the remainder of the asphalt pavement. It is difficult if not impossible to construct a pavement without any joints. Therefore, the real trick is to make as few joints as possible and to construct them carefully and properly. The appearance and quality of the joints determines the overall appearance and quality of the finished mat. Fortunately, it is not difficult to construct a good quality joint.

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Constructing Transverse Joints

A transverse joint occurs at any point where the paver ends work and then resumes work at a subsequent time. A poorly-constructed transverse joint is noticeable as a pronounced bump in the pavement. Consequently, the inspector must be on hand whenever a transverse joint is made in order to ensure it is done properly. Discovering hours after construction that a transverse joint does not meet the specifications does no good, because joint construction can only be corrected while the mix is still hot and workable. Once the mix cools, corrections can be made only by grinding out the bump, reheating the mix and re-rolling the joint, or cutting out the joint and replacing the mixture.

Terminal Joint

A straightedge should be used to determine the condition of the transverse joint before paving begins. If the mix upstream of the joint is level, the location of the transverse joint is fine. If the straightedge indicates that the previously placed mix is not level, the location of the transverse joint should be moved to a point where the proper thickness and smoothness of the pavement layer exists. The mix downstream of the new joint location should be removed and recycled.

As with the tapered joint that uses the board, one disadvantage of this type of joint is that it is often very difficult to remove the mix downstream of the saw cut from the existing roadway. As an alternative, a cold-milling machine can be used both to form the vertical edge of the transverse joint and to remove the mix in the taper.

After the existing joint materials are removed it is important to thoroughly clean the area exposed and properly tack the surfaces. It requires little work and is good practice to heavily tack the vertical edge of the joint such that slight puddling occurs at its base before paving resumes.

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Transverse Joint Construction

Transverse joints during paving are constructed in three steps:

1. ending the first lane or width of pavement at the close of work,
2. rolling the transverse joint, and
3. at the resumption of pavement operations at the start of work at a subsequent time

If traffic will not pass over the end of the paving, a butt joint will be permitted, provided proper compaction is achieved. If traffic will pass over the joint, construct a sloped wedge, at least three feet per inch of pavement depth, ahead of the end of the full depth pavement to provide for proper compaction and protection of the full depth pavement. Construct the joint square to the lane alignment and discard all excess material. A paper parting strip may be placed beneath this wedge to facilitate joint construction.

Before paving operations are resumed, remove the sloped wedge and cut back into the previously constructed pavement to the point of full pavement depth. Coat the exposed edge of the previously constructed pavement with tack coat.

When laying of the mixture is resumed at the joint, complete and then test the construction of the joint while the mixture is still in a workable condition with a 10-foot straight-edge per specification.

Care and attention to quality must be undertaken whenever a transverse joint is constructed to ensure a smooth riding pavement.

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Ending a Lane

When terminating paving operations at the end of a day's work, the mixture may be terminated through constructing a tapered joint (at least 3 feet per inch of pavement depth), feathering the remaining mix in the paver hopper, or constructing a vertical butt joint. For construction of a tapered or butt joint, the following steps are typically followed:

1. When the paver is placing the last load of the day, it is shifted into low gear as it approaches the location of the proposed joint.
2. As the hopper empties and the amount of material in the screed chamber decreases below normal operating level, the paver is stopped.
3. The screed is raised and the paver moved out of the way.
4. Hot-mix asphalt is then shoveled away from the end of the mat to form a clean, vertical edge.
5. A heavy wrapping paper may be placed along the edge (tapered joint only).
6. The material that was shoveled away in Step 4 is replaced and used to form a taper (tapered joint only).

Butt joints are acceptable when traffic will not pass over the joint prior to the next paving operation. For feathered joints, the paver operation is continued until the hopper is empty. This creates a longer transition. For tapered or feathered joints, the excess material must be removed prior to the next paving operation.

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Daily Construction Joint (Cold Joint/Temporary)

If a tapered joint has been constructed at the transverse joint, the mix in the ramp or taper must be removed before the paving can be started. For a taper built with treated paper, there is no bond between the mix in the ramp and the underlying pavement. The paver and the mix are readily removed and returned for recycling. A vertical face is left at the upstream edge of the joint.

For a taper constructed with the board and a ramp of asphalt mix, the material downstream of the board will be partially bonded to the existing pavement surface. A front-end loader typically is used to pry up the mix in the taper. This can be very difficult to do, depending on the amount of traffic that has passed over the transverse joint and the environmental conditions at the site. Once the mix has been removed, the board is then removed, exposing the vertical face of the joint.

If a non-formed tapered transverse joint is used, it is necessary first to saw a transverse joint in the asphalt mat. It can be placed far enough back from the taper to assure that the thickness of the layer is constant. Once the joint is cut completely through the asphalt mat, a front-end loader is used to pry up the mix that is downstream of the saw cut.

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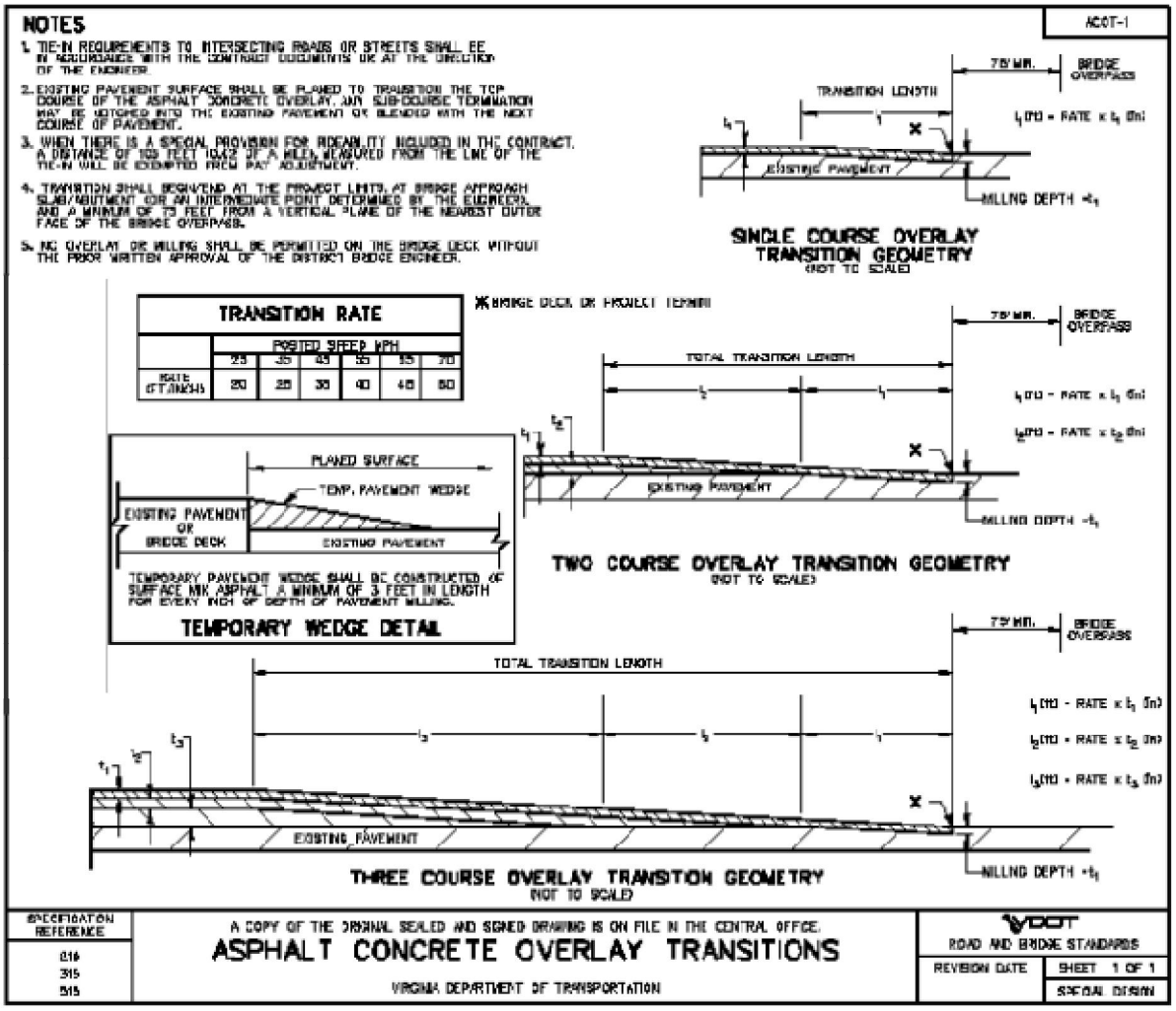
Transition into Bridges & Under Bridges (ACOT1)

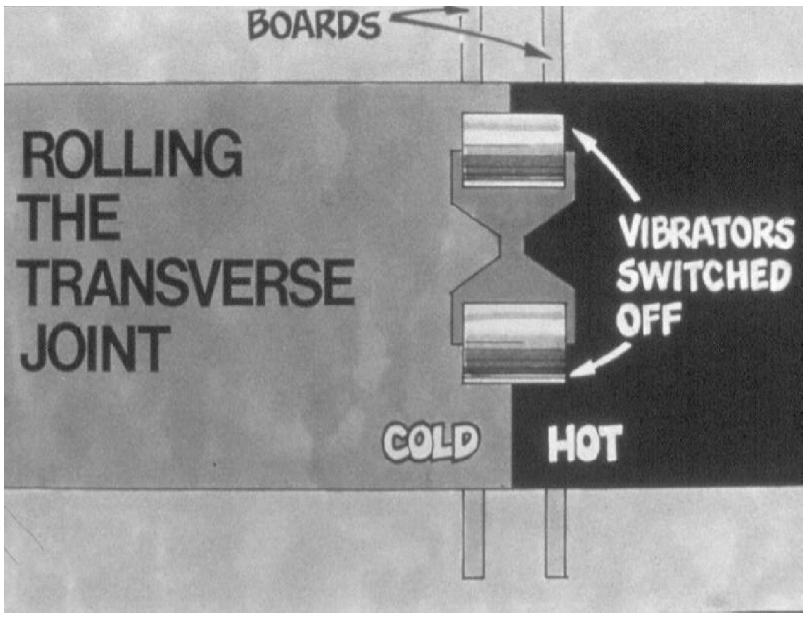
No pavement overlay shall decrease the vertical clearance under a bridge. In situations where the pavement under the overpass cannot be milled in direct proportion to the overlay, the new pavement is to be tied down to the existing pavement under the overpass 75 feet from the outer edge of the overpass.



Rolling Transverse Joints

When a transverse joint is placed next to an adjoining lane, the first pass is made with a steel-wheeled roller moving along the longitudinal joint for a short distance. The straightedge is then used to check for smoothness and to make corrections if necessary. Then the joint is rolled transversely, with the roller on the previously laid material, except for a 6 inches projection of the wheels when using a tandem wheel roller.

A transverse joint should be compacted transversely. If the rolling is done transversely, wood boards must be used to support the roller as it moves beyond the longitudinal edge of the pavement. If the roller cannot compact the joint in the transverse direction because of site restrictions (adjacent guardrail or steep side slope, for example) or traffic in the next lane, the transverse joint will have to be rolled in the longitudinal direction.



Resumption of Paving Operations

When paving is ready to resume, the following procedure is used to form a suitable transverse joint.

1. The taper of material is removed.
2. A 10 ft. straightedge is used to check the longitudinal grade of the mat. Because the paver was running out of material as it laid the last few feet of mat, it is possible that those last few feet taper slightly (ramp down) from the specified level of the mat. If this is the case, a new transverse edge must be cut to full pavement depth behind the point where the ramping down begins.
3. The vertical face of the mat is tack-coated.
4. The paver is backed up to the edge of the mat and the screed rested on the cold mat surface.
5. The screed is heated while it rests on the mat. This provides some heat to the material at the edge of the mat.
6. The heated screed is raised and at least 3 shims or starting blocks as thick as the difference between the uncompacted and compacted mat are positioned under it. The starting blocks should extend the full length of the screed, front to back.
7. The truck with the first load of AC is backed carefully to the hopper. During discharge of the mix from the truck bed to the paver, it is essential that the truck not bump the paver, and cause it to move.
8. The paver starts forward in a low gear.
9. Once the paver has moved away, excess AC is cleaned off the surface of the mat and the evenness of the joint is checked with a straightedge.
10. If a joint is satisfactory, a 6-inches width of the AC is rolled transversely and the joint checked for smoothness. If the joint is satisfactory, transverse rolling is continued in 6 to 12 inch wide increments until the entire width of the roller is on the new AC. If the straightedge shows an uneven joint, the surface of the new mat must be scarified while still warm and workable. Scarification is done, preferably with a tined lute. Excess material can then be removed or additional material added, and the joint rolled and rechecked.

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Constructing Longitudinal Joints

A longitudinal joint is the interface between two adjacent and parallel AC mats. Improperly constructed longitudinal joints can cause premature deterioration of multilane AC pavements in the form of cracking and raveling. These distresses, caused by relatively low density (high air voids) and surface irregularity at the joints, can largely be avoided through proper construction techniques and equipment.

	This section uses the following terms when referring to longitudinal joints:

Cold lane	A previously paved lane. Mix temperature is at or near ambient temperature and the lane can support traffic loads.
Hot lane	The lane being currently placed. AC is at placement temperature.
Joint overlap	The width that the hot lane overlaps the cold lane.
Low density area	That portion of the cold lane that is at a significantly lower density than the rest of the cold lane. This area is typically at the outer edge of the cold lane taper in the joint overlap area and can have low density
Extra material for compression	The material beyond the anticipated final mat thickness. As a newly placed mat is compacted, its thickness decreases and it becomes more dense.

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The solution to good longitudinal joint construction involves several aspects of the paving operation.

1. First, pavers can be operated in a way that either eliminates the longitudinal joint altogether or at least maximizes the likelihood of adequate material placement at the joint.
    - *Eliminate the joint altogether*. On some roadways it may be practical to pave the entire width in one single paver pass. Generally, without using multiple pavers, screed width limitations limit this solution to roadways narrower than about 24 ft. Further, most modern overlay paving is performed while traffic continues to flow, which necessitates that paving occur one lane at a time. Therefore, in most instances this is not a practical solution.
    - *Echelon paving*. Paving multiple lanes side-by-side (with adjacent pavers slightly offset) can improve the longitudinal joint between pavers because both mats are hot when initially compacted. Rollers behind the echelon pavers can pass directly over the longitudinal joint while both sides are hot, which results in better compaction.
2. Second, several different joint construction devices can be fitted onto the paver screed to assist in material placement and joint compaction.
3. Third, several techniques are available to better prepare the cold side of the longitudinal joint to adhere to the hot side.
    - *Proper mat overlap*. A proper mat overlay is about 1 inch. The hot lane should overlap the cold lane such that there is enough material for compression. A lack of material or inadequate overlap will lead to high longitudinal joint air voids. When possible, this extra material is bumped back with a lute overtop the joint to provide additional material for compression. Because joint overlaps are so small (about an inch), it is critical that the paver be operated on as straight a path as possible for both the cold lane and the hot lane.

Finally, several different roller techniques can be used to increase material compaction at the joint. The various techniques listed below have been field tested with varying degrees of success. In most cases, a combination of several different techniques is required to construct a high quality longitudinal joint.

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Joint Construction Devices

Several different devices or techniques have been used with varying degrees of success to aid in the construction of longitudinal joints. These devices, most of which are described in Kandhal et al. (2002) are:

- *Notched wedge joint (NAPA, 1998)*. An extended joint taper placed on the first paved lane that helps reduce joint air voids. An attachment on the paver screed forms the mat edge into a tapered section. Notches on either end of the taper eliminate the extremely thin taper extremities which might otherwise cause poor compaction. The notches are at least as deep as the nominal maximum aggregate size of the mix and the taper is usually spread out over about 1 ft. The hot lane overlaps the cold lane notch by about 0.5 to 1 inch and is bumped back to the notch to ensure enough material at the notch for adequate compaction. The notched wedge joint also provides a safe ramp for traffic transition between the cold lane and the yet unpaved portions of the hot lane.
- *Cutting wheel (Kandhal et al., 2002)*. 10 inch diameter cutting wheel mounted on an intermediate roller or a motor grader that cuts 1-2 inches of the unconfined, low density edge of the initial lane after compaction, while the mix is still plastic. This technique cuts away and discards the high air void portion of a typical longitudinal joint.
- *Joint maker (Kandhal et al., 2002)*. A boot-like device about 3 inches wide which is attached to the side of the screed at the corner during construction. The device forces extra material at the joint through an extrusion process prior to the screed. A kicker plate is also furnished which is attached to the side of the paver to lute back the overlapped AC mix.
- *Edge restraining device (Kandhal et al., 2002)*. A 3 inches wide hydraulically powered wheel mounted on a roller that, when operated is positioned alongside the roller drum that pinches the unconfined edge of the first lane towards the drum providing lateral resistance during the first roller pass.

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Joint Adhesion

Sometimes longitudinal joints can fail because the hot and cold sides fail to adequately bond with one another. There are three general techniques to increase the likelihood of bonding:

- *Heat the cold side before placing the hot side*. This will, in theory, increase the cold side AC temperature and make the constituent asphalt binder less viscous and stickier. Typically, an infrared heater is mounted on the paver and aimed at the cold joint side. It is possible to heat the cold side to about 200°F with this method (Kandhal et al., 2002).
- *Coat the cold side with an adhesive material*. A tack coat applied to the cold side before paving the hot side will assist in bonding just as a tack coat assists in bonding between pavement lifts. Kandhal et al. (2002) found a rubberized asphalt tack coat applied about 0.125 inches thick by hand worked very well.
- *Coat the cold side with a heavy tack coat*. A tack coat applied to the cold side before paving the hot side will assist in bonding. The cold side vertical face and at least 12 to 18 inches of the surface to be overlaid is tacked with tack puddling along the edge. This is the approach specified by VDOT.

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Compaction

Various longitudinal joint compaction techniques have been suggested to increase density and provide the proper confinement of the outside mat edge so that it compacts rather than deforms. The key differences in rolling techniques involve the exact placement of the roller on the initial pass over or near the joint. No matter which initial pass technique is used, subsequent passes are usually done in accordance with the "rolling from the hot side" technique. Typical initial roller pass techniques are (Kandhal et al., 2002):

1. *Rolling from the hot side 6 inches away from the joint*. Best practice. The first roller pass occurs in the vibratory mode with the entire roller wheel on the hot lane and about 6 inches from the joint. This technique pushes the material between the roller and joint towards the joint during the initial roller pass, which crowds the mix at the joint producing a higher density. This method is particularly recommended by some asphalt paving technologists for tender mix or thick lifts, which have the potential for the mix to be pushed towards the joint.

2. *Rolling from the hot side*. Not recommended. The first roller pass occurs in vibratory mode with the majority of the roller wheel on the hot lane and overlapped onto the cold lane by about a 6 inches.

3. *Rolling from the cold side*. Not recommended. The first roller pass occurs in the static mode with the majority of the roller wheel on the cold lane and overlapped onto the hot lane by about 6 inches. This technique is believed to pinch the joint together. Timing in this type of rolling is critical. When the roller is operated on the cold side of the joint, the hot side undergoes cooling which can make it difficult to achieve the desired compaction level before the hot side reaches cessation temperature.

VDOT specifications require rolling toward the cold mat joint. This indirectly incorporates the best practice technique of rolling from the hot side above when the last full pass is made 6 inches from the joint. The roller starts on the outside of the hot lane and progresses across the mat toward the cold lane. Prior to overlapping the joint, the last roller pass, on the hot mat, should be made 6 inches away from the joint. The next pass will overlap the joint and approximately 6 inches of the roller will be on the cold lane.

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BEST PRACTICES

The National Center for Asphalt Technology (NCAT) has participated in a number of studies aimed at determining longitudinal joint construction practices that result in long-lasting high performance joints.

The following is a brief list of best practices concluded from these studies:

- *Use a rubberized joint adhesive material or a notched wedge joint to obtain the most consistent high quality joint*. Kandhal et al. (2002) observed these to perform best. The notch in the notched wedge joint is critical to its performance (Kandhal and Mallick, 1997).
- *Roll the longitudinal joint from the hot side 6 inch away from the joint for the first roller pass*. Kandhal et al. (2002) observed this rolling technique to be the best with the rolling from the cold side being the worst.

The cutting wheel and edge restraining device techniques are highly operator dependent. Both these techniques can produce high quality joints but they are highly dependent on operator skill and therefore may not produce consistently good joints.

Describes a best practice to be utilized when possible.

Location of Longitudinal Joints

Width of pavement is controlled in many instances by the location of the longitudinal joint. The VDOT specification requires that when multi-lane multi-layer construction is required, the longitudinal joints in each layer shall be offset from the joint in the layer immediately below by approximately 6 inches.

Overlapping of successive courses rather than stacking the joint directly on top of the joint below helps to prevents cracking and separation along the longitudinal joint. The locations of joints must be planned such that the joint in the final layer of pavement is located, where possible, between designated travel lanes of the final traffic pattern. This will assure that the joint is not located in the wheel path of a lane. When possible, the joint should not be in the same location as the final pavement marking. Future maintenance operations to the joint such as crack sealing could obscure the marking and make placement of new marking difficult.

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Longitudinal Joints

Longitudinal joints are constructed in the following manner:

1. Tack the exposed edge of all longitudinal joints prior to placing the adjoining pavement.
2. From the hot side toward the joint, form longitudinal joints by allowing the paver to deposit the mixture adjacent to the joint to such depth that maximum compaction can be obtained along the joint. Pinch the joint by rolling immediately behind the paver from the hot side of the joint.
3. Construct the joints in the final layer, where possible, between designated travel lanes of the final traffic pattern.

Construction Procedures

Tack the exposed edge of all longitudinal joints prior to placing the adjoining pavement.

Form longitudinal joints by allowing the paver to deposit the mixture adjacent to the joint to such depth that maximum compaction can be obtained along the joint. The material should be overlapped 1 to 2 inches onto the cold mat and bumped back with a lute. Pinch the joint by rolling immediately behind the paver from the hot side toward the joint.

Construct the joints in the final layer, where possible, between designated travel lanes of the final traffic pattern.

The first lane placed should be true to line and grade, and the longitudinal joint or edge of the paving should have a near vertical face. It is most important that the paving machine keep on a straight, predetermined line of travel. In laying the first lane, the stringline, curb, or other reference line must be used to guide the paver on the proper course. It is also important, for good results, that the thickness adjustment controls on the paver not be over-controlled.

Before the lane is compacted, the material along the unsupported edges should be butted and slightly elevated with a tamping tool or lute. This sets up the edge and permits the full weight of the roller wheel to bear on the material at the extreme edges of the mat.

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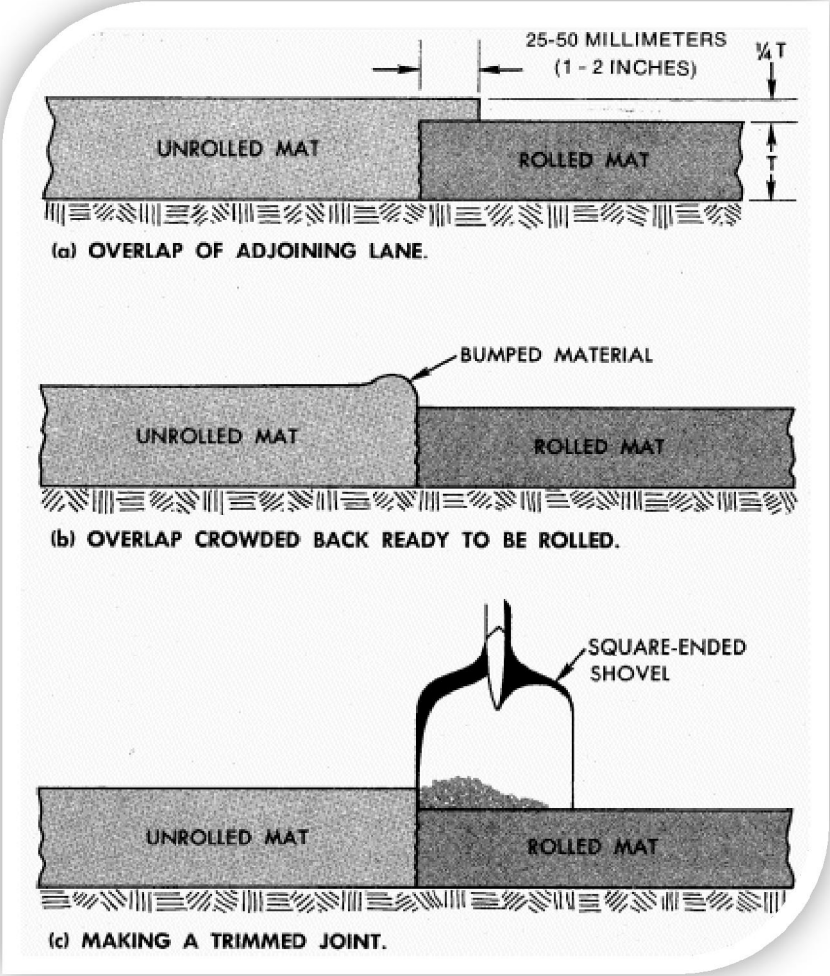
After the first lane has been placed and rolled, it is important that the adjoining lane be placed so that it uniformly overlaps the first lane by 1 to 2 inches. The thickness of the overlay should be left 1/4" per inch higher than the desired compacted pavement thickness. If another layer is to be placed over the course being spread, the excess coarse aggregate at the joint may be distributed over the unrolled lane with a broom or lute.



The overlapping material is then bumped or crowded back onto the hot lane so that the roller can crowd the small excess into the hot side of the joint. When the overlap is excessive, the excess material should be trimmed off so that the bumped ridge of material along the joint is uniform.

A trimmed joint is sometimes used. This joint is constructed by removing all freshly placed material that has overlapped the rolled lane. This is best done by trimming the joint immediately behind the paver with a square-ended shovel. In this way the operator can tell where the edge of the cold joint is and gauge his cutoff line accordingly.

If the lanes are placed simultaneously with two pavers moving in echelon, the loose depths of the mats should match exactly, with no overlap for a hot joint. The joints of a freshly paved mat are usually compacted before the rest of the paved width.

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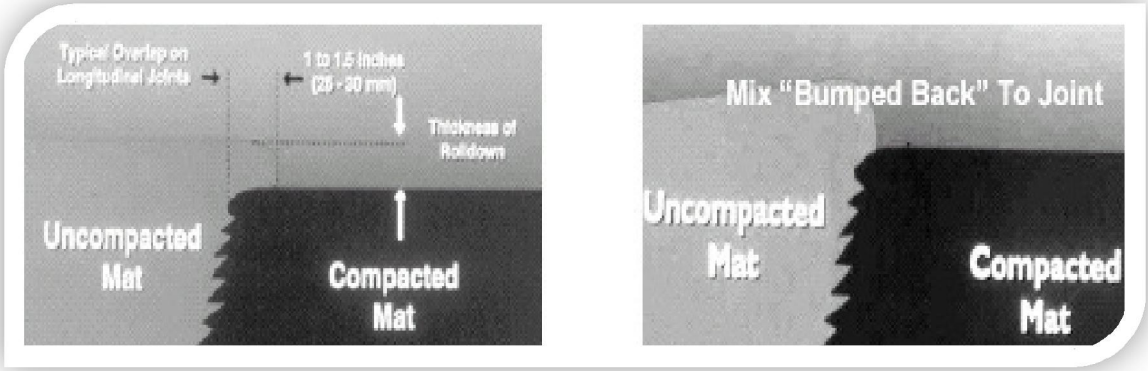
Compacting the Joint

As previously mentioned, if the level of the new, uncompacted mix is even with or below the level of the compacted mix in the adjacent lane, the compaction equipment will not be able to densify the mix along the joint properly. Whether the first pass of the roller is on the cold side of the joint or on the hot side of the joint, part of the weight of the roller will be supported on the previously compacted mat.



This means that the compaction equipment will bridge over the mix in the joint, leaving it essentially uncompacted or only partially compacted. (Use of an intermediate pneumatic tire roller instead of a steel wheel roller-static or vibratory can reduce this problem.)

The level of the mix at the longitudinal joint must be above the elevation of the compacted mix, by an amount equal to approximately ¼ inch for each 1 inch of compacted pavement, if proper compaction of the mix at the joint is to be accomplished.

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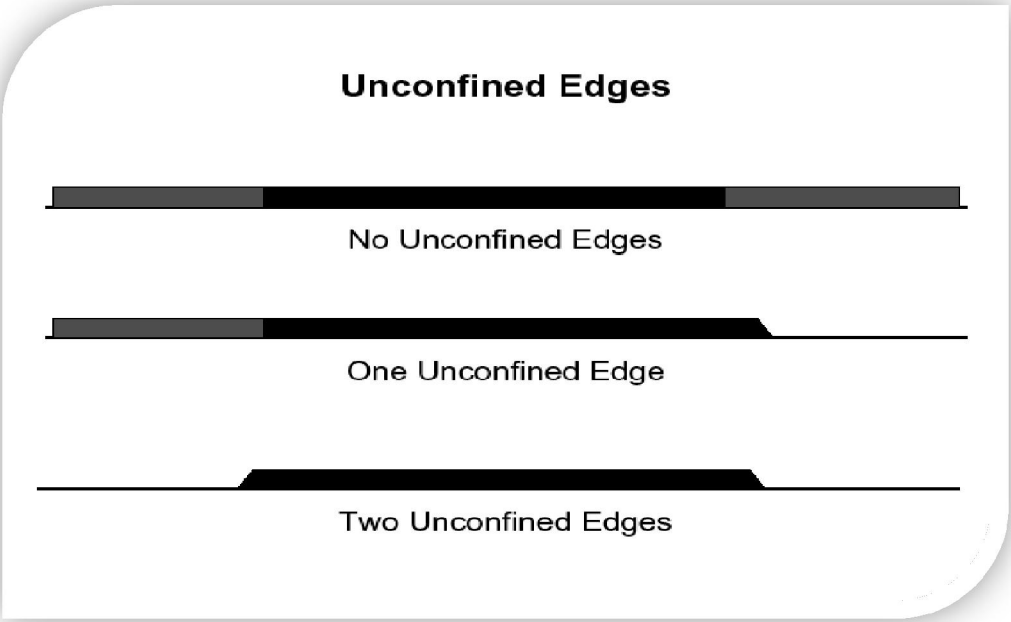
Edge Definitions



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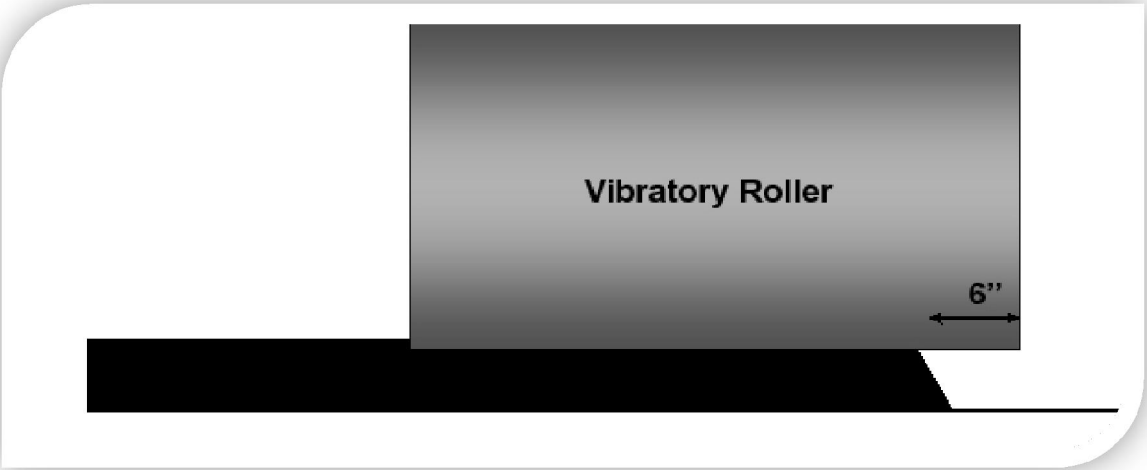
Rolling Unconfined or Unsupported Edge - First Paver Pass

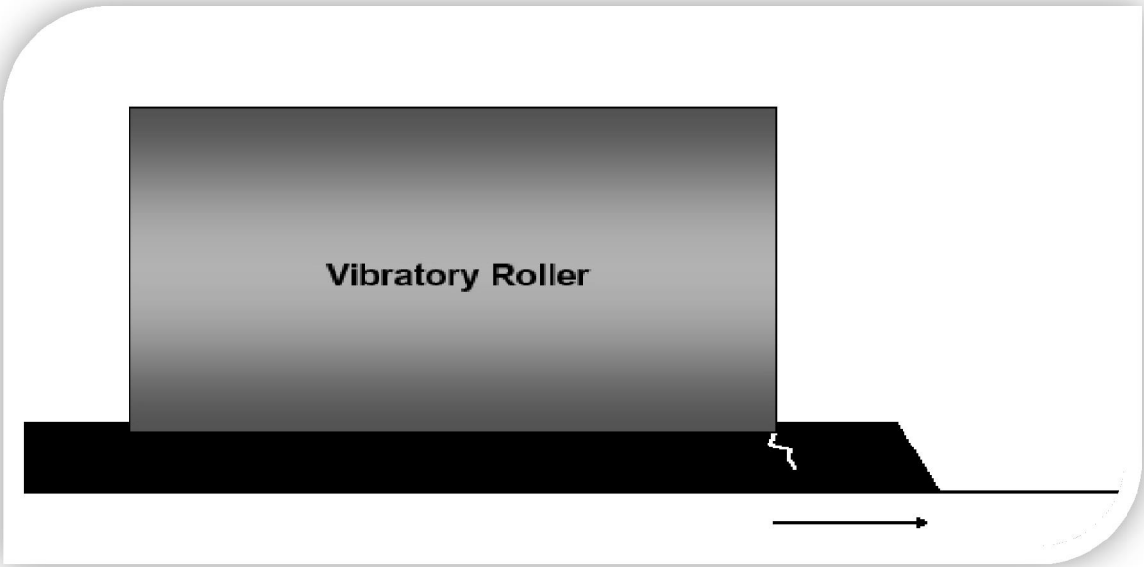
This method is usually best for achieving maximum density at the unsupported edge.

- Roll from the outside edge toward the middle.
- The preferred approach shown below is done by overlapping the outside edge with the drum by about 6 inches to obtain some confinement.



Edge of drum outside of unsupported edge - Preferred approach

Shown below is an alternate method of rolling the first pass on an unsupported edge. This method can cause cracking near the edge and lateral mix movement at the unsupported edge.



Edge of drum inside unsupported edge

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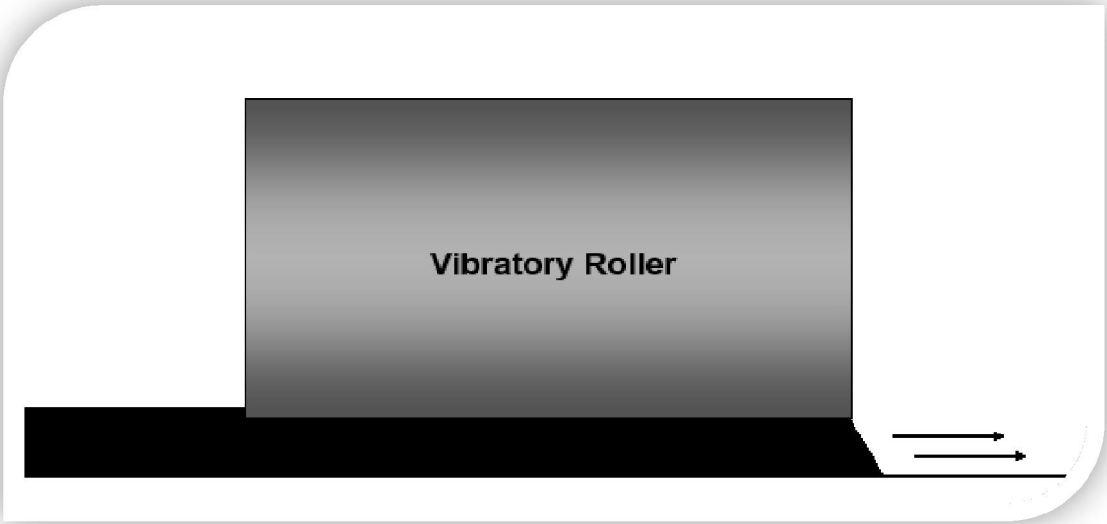
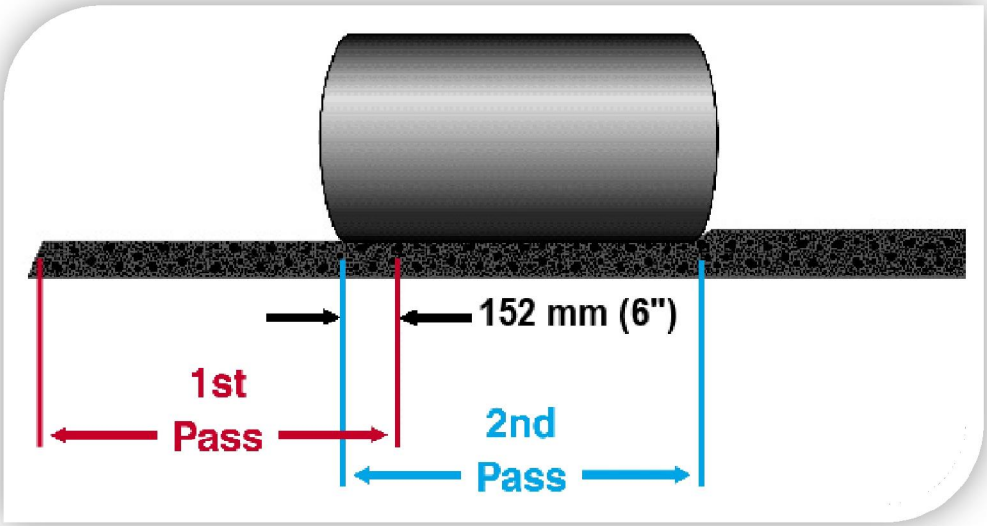
Here is another alternate method for rolling an uncompacted edge. This method can cause lateral mix movement at the unsupported edge.



Edge of drum on the unsupported edge

Mat Compaction - Subsequent Pass

The mat should be rolled from the unconfined/outside edge to the longitudinal joint (number of passes to cover the mat depends on the roller widths).



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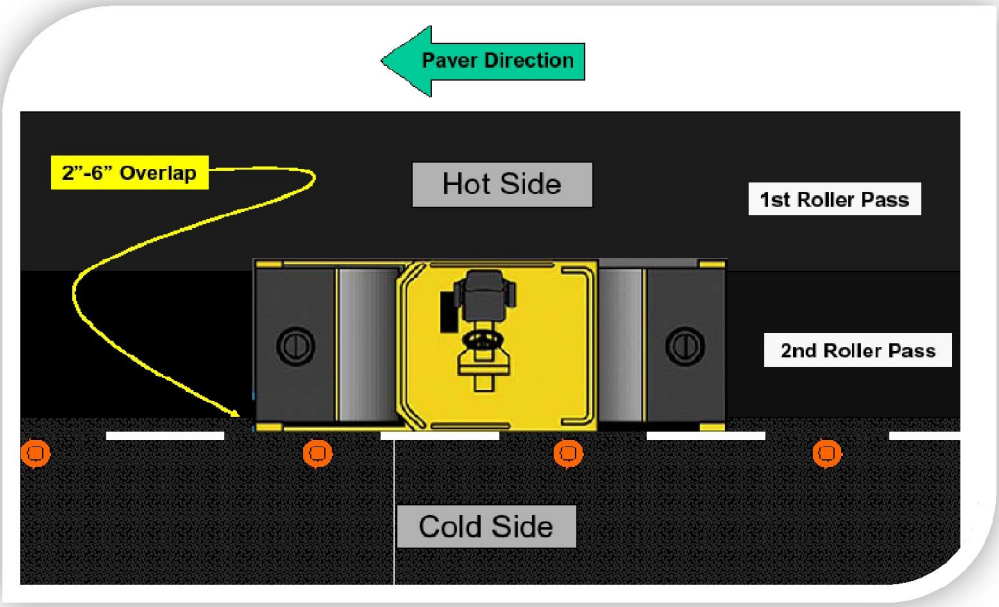
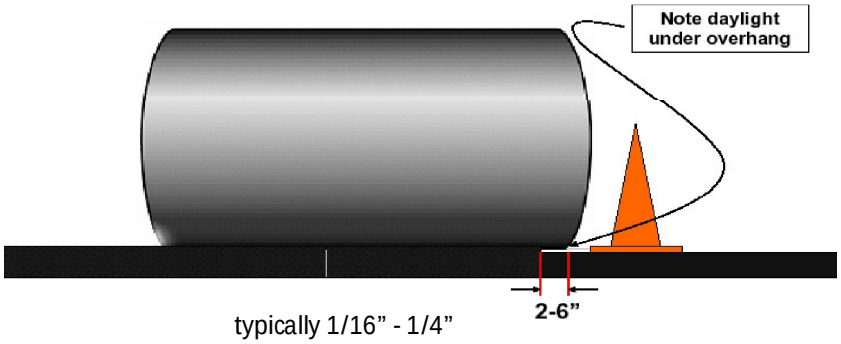
Confined Edge Compaction

Adjacent Lane Open to Traffic



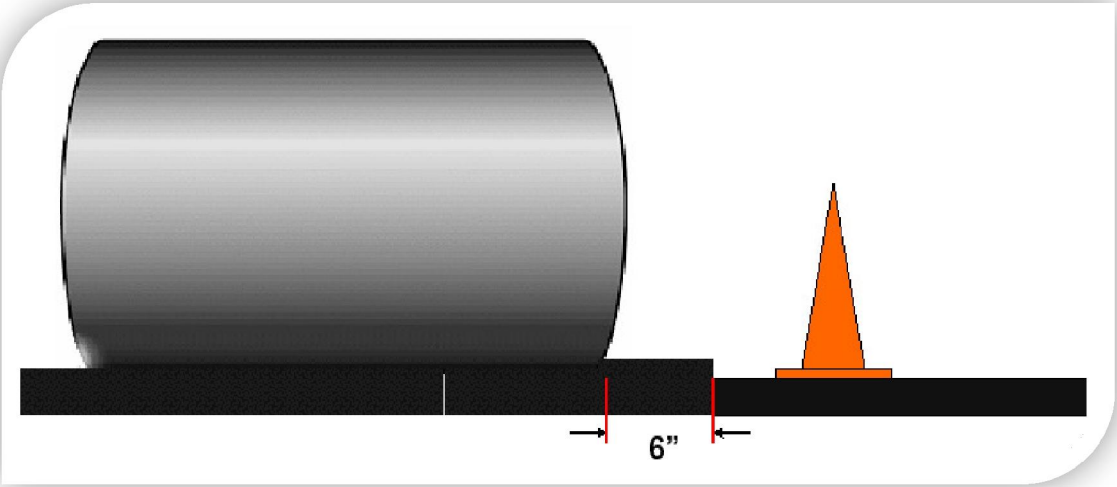
The last pass across the mat pinches the longitudinal joint.



Confined Edge Compaction - Alternate Method

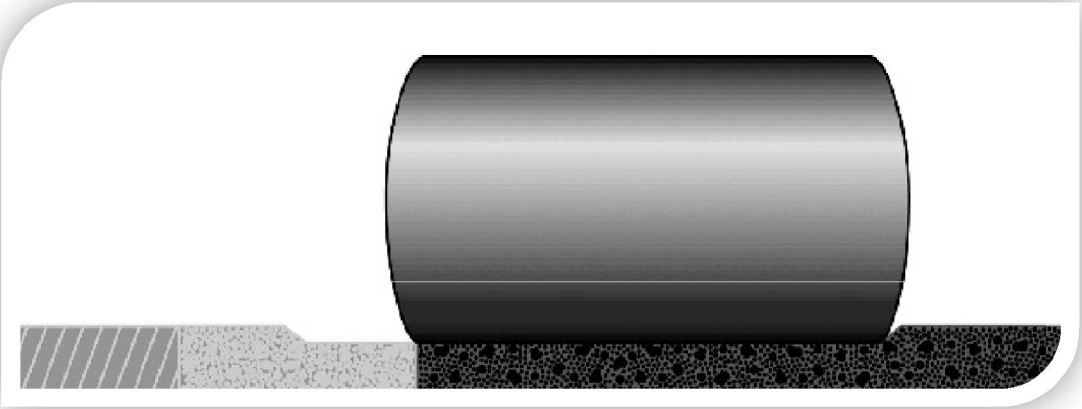
Adjacent Lane Open to Traffic

The next to the last pass across the mat leaves 6” uncompacted at the joint. The last pass pinches the longitudinal joint.



Confined Edge Compaction

This shows the first pass beside a curb and gutter section.



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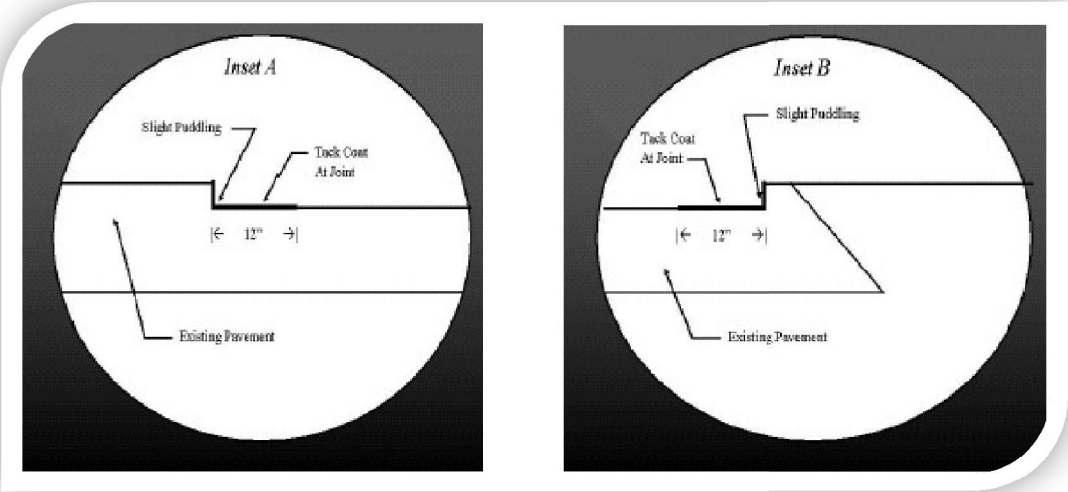
Tacking Joints

It is often a challenge to achieve proper density at both transverse and longitudinal joints. Additional tack must applied to vertical joint faces as well as underneath the joint area to aid in obtaining density requirements. Loose material should be removed before this area is tacked. (VDOT Road and Bridge Specification Section 315.05(b)1).



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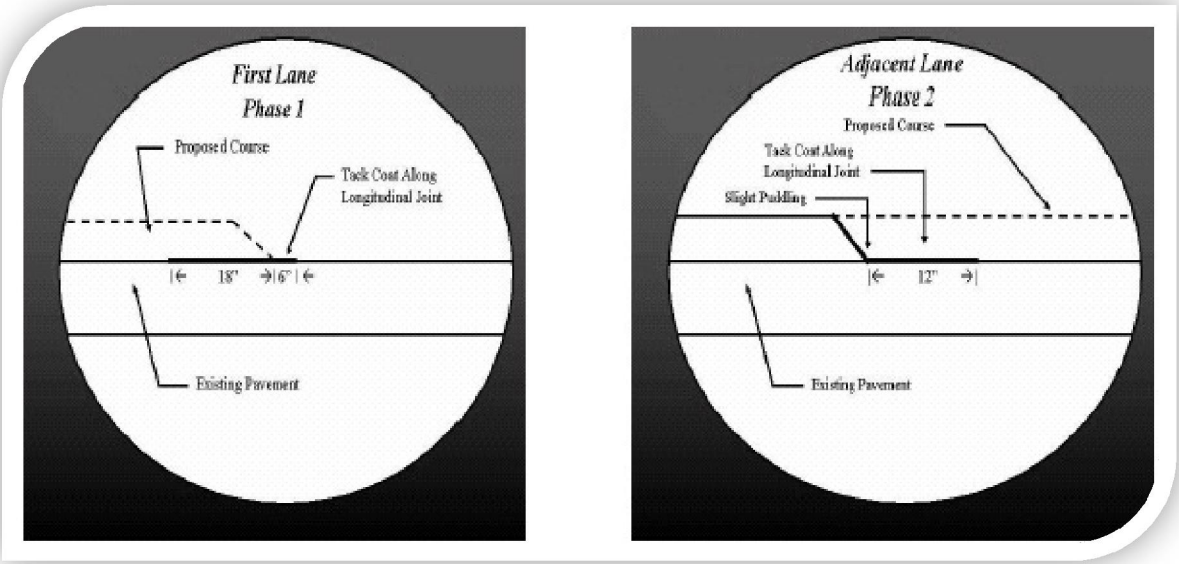
Tacking of Joints After Milling

Tack is to be applied to the vertical face with a hand wand or spray bar at the rate of 0.2 gal/yd^2. The application should be heavy enough that slight puddling occurs at the base of the vertical face. At the joints, the tack applied shall be 2 feet in width with 4-6 inches protruding beyond the first pass. Tack for the adjacent pass shall completely cover the vertical face of the mat edge so that slight puddling of asphalt occurs at the joints and extends a minimum of 1 foot into the lane to be paved.

Tacking of Joints During AC Placement



Tack is applied under the proposed first lift 18 inches from the joint edge with a 6 inch overlap onto the second lift area. Tack is then applied on the second course to the vertical face and within 12 inches of the joint area. A longitudinal joint should be tacked using a hand wand or spray bar at the rate of 0.2gal/yd^2 . There should be slight puddling at the joints and extend a minimum of 1 foot into the lane to be paved.

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Construction Problems

If no construction precautions are taken, the longitudinal joint of a multi-lane paving project will often be significantly less dense than the majority of the pavement and contain surface irregularities that may or may not be caused by segregation.

Low Density

Low density is a general AC problem that can lead to numerous distresses including decreased stiffness, reduced fatigue life, accelerated aging/decreased durability, rutting, raveling, and moisture damage (Hughes, 1984; Hughes, 1989). Keep in mind that "low density" and "high air voids" refer to the same thing.

Usually a well-constructed joint will be about 1 - 2 percent less dense than the rest of the lane away from the joint, however a poorly constructed joint can have significantly lower density - on the order of 5 - 10 percent (Kandhal and Mallick, 1996). Low joint density is common since the edge of the lane first paved (cold lane) is unconfined. As the roller passes over, this unconfined edge tends to deform laterally rather than compact. The subsequent lane (hot lane) is confined by the cold lane and therefore tends to be more dense. Typically, the hot side of the joint is about 2 - 4 percent more dense than the cold side (Kandhal and Mallick, 1996). Furthermore, the overall joint does not typically meet minimum density requirements established for the mat as a whole. Many agencies that specify minimum densities (maximum air void contents) for AC construction specifically exclude joint areas because of this.

Longitudinal joint densities that are slightly less than the mat average (on the order of 1 - 2 percent) are generally acceptable because, if properly placed, longitudinal joints with these densities (usually about 91 or 92 percent of TMD) are usually not subject to much loading, and their air void content is not high enough to cause significant raveling. Lower densities at unconfined shoulder edges are also generally acceptable because even if they are porous enough to allow water infiltration, they are not subject to much loading and they are usually sloped towards the shoulder, which allows any infiltrating water to quickly drain away (Brock and Skinner, no date given).

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Surface Irregularities

Longitudinal joints often look coarse, open-graded or segregated. This can happen for several reasons:

- *The joint contains segregated material*. Because longitudinal joints occur at the edge of the paver screed and auger system their constituent material can come from material pushed out beyond the end of the auger and/or screed. Because it has been moved more and moved beyond the end of the auger, this material has a higher likelihood of being segregated.
- *The joint deforms rather than compacts*. If a joint is unconfined (either at the roadway edge or as the first lane placed) roller passes over the joint will cause it to deform sideways rather than compact.
- *Handwork*. Typically, AC from the hot lane that overlaps the cold lane beyond its taper is luted back onto the hot side of the joint. This handwork usually results in a coarse surface texture and can, in extreme instances, result in segregation.

INSPECTION AND MEASUREMENTS
Inspection Items: ▪ Surface Tolerance for Transverse Joints using 10 feet Straight-edge ▪ Proper tacking of longitudinal and transverse joints ▪ Proper taper length for transverse joints ▪ Proper rolling procedures for Joints
Describes inspection, Quality Assurance and/or Quality Control practices.

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Chapter Five Knowledge Check

1. A _____ joint occurs when one lane of asphalt mix is constructed adjacent to a previously placed lane of mix.
    a. Longitudinal
    b. Conventional
    c. Transverse
    d. Uniform
2. One key to the construction of a good longitudinal joint between lanes of asphalt mix is the amount of overlap between the new mat and the previously placed mat.
    a. True
    b. False
3. When the placement of the asphalt mix is to be suspended for a period of time and traffic is going to be passing over the end of the paving, a vertical butt joint may be constructed.
    a. True
    b. False
4. Constructing a temporary tapered joint using sand or dirt as the bond-breaking medium is <u>not</u> an acceptable VDOT paving practice.
    a. True
    b. false

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6 AC Compaction

Learning Outcomes:

- ☑ Understand the importance of compaction efforts
- ☑ Recognize paving influences outside of operators control (environmental factors and mix properties)
- ☑ Learn paving influences under operators control (roller speed, number of roller passes, rolling zone, and roller pattern)

AC Compaction

Compaction is the process of compressing a given volume of asphalt concrete into a smaller volume. Compaction is accomplished by pressing the asphalt coated aggregate particles closer together, thereby reducing the air voids (space) in the mix and increasing the density (weight to volume ratio) of the mixture.

The single most important factor that affects the ultimate performance of asphalt concrete layers is compaction. Adequate compaction of the mix increases the fatigue life, decreases permanent deformation (rutting), reduces oxidation or aging, decreases moisture damage, increases strength and stability, and decreases low-temperature cracking. An asphalt mixture that has all the desirable mix design characteristics will perform poorly under traffic conditions if that mix is not compacted to the proper density level.

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Compaction Importance

The need for a pavement to be compacted to the required density is better understood when the effect of air, water, and traffic on an undercompacted layer(s) is realized.

The voids in an undercompacted mix tend to be interconnected creating open channels and permitting the intrusion of air and water throughout the pavement. Air and water carry oxygen which in turn, accelerates the oxidation of the asphalt binder in the mix, causing it to become brittle. Consequently, the pavement itself will ultimately fail as it can no longer withstand the repeated deflections due to traffic loading. The internal presence of water at freezing temperatures can also cause an early failure in the AC due to expansion and contraction of the freezing and thawing water.

A pavement which has not been adequately compacted during construction may push, shove and rut from traffic that is utilizing the pavement. However, unless the mix is properly designed and adequate voids remain in the compacted mix, the pavement will likely flush and tend to become unstable due to further reduction of void content under traffic and/or thermal expansion of the asphalt.

The desired constructed void content is approximately 8 percent or less for the dense-graded mixes. At this level, the voids are usually not interconnected. When the air void content is too high, the pavement will tend to ravel and disintegrate. When the air-void content is too low, there is a danger of the pavement flushing (leading to poor surface friction) and becoming unstable.

By pressing the aggregate particles closer together into a position in which the asphalt binder can hold them in place, compaction accomplishes two important goals:

1. It develops the strength and rut resistance of the mix
2. It closes passages through which water and air would otherwise penetrate thus causing faster aging, freeze-thaw damage, and stripping.

Compaction is the final stage of AC paving operations. It is the stage at which the full strength of the mixture is developed and the smoothness and texture of the mat is established. Therefore, the technician must be particularly observant of the compaction process.

The volume of air in an AC pavement is important because it has a profound effect on long-term pavement performance. An approximate "rule-of-thumb" is for every 1 percent increase in air voids

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(above 6-7 percent) about 10 percent of the pavement life may be lost (Linden et al., 1989). Keep in mind that this rule-of-thumb was developed using limited project data, should be used with extreme caution and applies to air voids above 6 - 7 percent. According to Roberts et al. (1996), there is considerable evidence that dense graded mixes should not exceed 8 percent nor fall below 3 percent air voids during their service life. This is because high air void content (above 8 percent) or low air void content (below 3 percent) can cause the following pavement distresses (this list applies to dense-graded AC and not open-graded AC or SMA):

Decreased stiffness and strength	Kennedy et al. (1984) concluded that tensile strength, static and resilient model, and stability are reduced at high air void content.
Reduced Fatigue Life	Several researchers have reported the relationship between increased air voids and reduced fatigue life (Pell and Taylor, 1969; Epps and Monismith, 1969; Linden et. al., 1989). Finn et al. (1973) concluded "...fatigue properties can be reduced by 30 to 40 percent for each one percent increase in air void content." Another study concluded that a reduction in air voids from eight percent to three percent could more than double pavement fatigue life (Scherocman, 1984a).
Accelerated Aging/Decreased Durability	In his Highway Research Board paper, McLeod (1967) concluded "compacting a well-designed paving mixture to low air voids retards the rate of hardening of the asphalt binder, and results in longer pavement life, lower pavement maintenance, and better all-around pavement performance."
Raveling	Kandhal and Koehler (1984) found that raveling becomes a significant problem above about eight percent air voids and becomes a severe problem above approximately 15 percent air voids.
Rutting	The amount of rutting which occurs in an asphalt pavement is inversely proportional to the air void content (Scherocman, 1984a). Rutting can be caused by two different mechanisms: vertical consolidation and lateral distortion. Vertical consolidation results from continued pavement compaction (reduction of air voids) by traffic after construction. Lateral distortion – shoving of the pavement material sideways and a humping-up of the asphalt concrete mixture outside the wheel paths – is usually due to a mix design problem. Both types of rutting can occur more quickly if the AC air void content is too low (Scherocman, 1984a).
Moisture Damage	Air voids in insufficiently compacted AC are high and tend to be interconnected with each other. Numerous and interconnected air voids allow for easy water entry (Kandhal and Koehler, 1984; Cooley et al., 2002) which increases the likelihood of significant moisture damage. The relationship between permeability, nominal maximum aggregate size and lift thickness is quite important and can change significantly as these parameters change.

Air voids that are either too great or too low can cause a significant reduction in pavement life. For dense graded AC, air voids between 3 and 8 percent generally produce the best compromise of pavement strength, fatigue life, durability, raveling, rutting and moisture damage susceptibility.

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Factors Affecting Compaction

AC compaction is influenced by a number of important factors:

- Some related to the environment,
- Some determined by mix and structural design, and
- Some under contractor and department control during the construction process.

FACTORS AFFECTING COMPACTION

Compaction Variables Outside of Operator Control		Compaction Variables Under Operator Control
Environmental Factors Temperature ▪ Ground temperature ▪ Air temperature ▪ Wind speed ▪ Solar flux	Mix Property Factors Aggregate ▪ Gradation ▪ Size ▪ Shape ▪ Fractured faces Volume Asphalt Binder ▪ Chemical properties ▪ Physical properties ▪ Amount	Construction Process Factors Rollers ▪ Type ▪ Number ▪ Speed and timing ▪ Number of passes ▪ Lift thickness Other ▪ AC production temperature ▪ Haul distance ▪ Haul time ▪ Foundation support

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Compaction Variables Outside of Operator Control: Environmental and Mix Property

Environmental Factors

Environmental factors are determined by when and where paving occurs. These factors are outside the operator's control of the process. Paving operations may have some float time, which allows a limited choice of "when" but paving location is determined by road location so there is essentially no choice of "where". Mix and structural design factors are determined before construction and although they should account for construction practices and the anticipated environment, they often must compromise ease of construction and compaction to achieve design objectives. Obviously construction factors are the most controllable and adaptable of all the factors affecting compaction. Although some factors like haul distance/time, AC production temperature, lift thickness and type/number of rollers may be somewhat predetermined, other factors associated with roller timing, speed, pattern and number of passes can be manipulated as necessary to produce an adequately compacted mat.

AC temperature has a direct effect on the viscosity of the asphalt cement binder and thus compaction. As AC temperature decreases, its asphalt cement binder becomes more viscous and resistant to deformation, which results in a smaller reduction in air voids for a given compactive effort. As the mix cools, the asphalt binder eventually becomes stiff enough to effectively prevent any further reduction in air voids regardless of the applied compactive effort. The temperature, at which this occurs, is commonly referred to as cessation temperature. In some literature it is reported to be about 175°F for dense-graded AC (Scherocman, 1984b; Hughes, 1989). Below cessation temperature rollers can still be operated on the mat to improve smoothness and surface texture but further compaction will generally not occur. Conversely, if the binder is too fluid and the aggregate structure is weak (e.g., at high temperatures), roller loads will simply displace, or "shove" the mat rather than compact it. In general, the combination of asphalt cement binder and aggregate needs to be viscous enough to allow compaction but stiff enough to prevent excessive shoving.

Mat temperature then, is crucial to both the actual amount of air void reduction for a given compactive effort, and the overall time available for compaction. If the initial temperature and cool-down rate are known, the temperature of the mat at any time after laydown can be calculated.

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BEST PRACTICE

Based on this calculation rolling equipment and patterns can be employed to:

1. *Take maximum advantage of available roller compactive effort*. Rollers can be used where the mat is most receptive to compaction and avoided where the mat is susceptible to excessive shoving.

2. *Ensure the mat is compacted to the desired air void content before cessation temperature is reached*. This can be done by calculating the time it takes the mat to cool from initial temperature to cessation temperature. All compaction must be accomplished within this "time available for compaction".

Describes a best practice to be utilized when possible.

Research work in the early 1970's determined the time available for compaction of various asphalt concrete mixes. The time available for compaction was defined as the time, in minutes; it took for a mix to cool from laydown temperature to a minimum compaction temperature. Laydown temperature is the mix temperature when the paver screed passes over the mix. Minimum compaction temperature for this study was set at 175°F. Below this temperature, it was found that the internal friction and cohesion of the mix increases to the point that little density gain is achieved with the application of additional compactive effort.

Six variables were found to have an effect on the rate of cooling (and, therefore, on the possibility of obtaining a required level of density) of a layer of asphalt placed on top of another existing layer of the same type of material.

Those variables are:

1. layer thickness
2. air temperature and base temperature
3. mix temperature
4. wind velocity
5. solar flux, and
6. laydown site conditions

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1.	Layer Thickness	Layer thickness is probably the single most important variable in the rate of cooling of asphalt mixtures, especially for thin lifts. It is very difficult to obtain the desired density on thin lifts of mix in cool weather because of the rapid loss in temperature in the mix. *For example, for a mix laydown temperature of 250°F and a base of 40°F, a 1 inch thick mat will cool from that 250°F temperature to the 175°F compaction cutoff point in less than 4 minutes. For a 2 inch thick layer, under the same mix and base temperature conditions, it will take about 10 minutes for the material to cool to 175°F.*
2.	Air and Base Temperature	A portion of the heat in the asphalt layer is lost to the air. All other factors being equal, an increase in the ambient air temperature decreases the rate of cooling of the mix. Heat in the mix is also lost to the layer on which the new material is placed. There usually is more rapid cooling of the mix downward into the base than upward into the air. Base temperature is actually more important than air temperature in determining the time available for compaction. It is often assumed that air and base temperature are the same. This is not necessarily true, particularly in cool weather. A moist base layer significantly increases the cooling rate of the new overlaying asphalt layer. Heat is lost from the mix to the moisture, turning water into steam and increasing the rate of heat transfer.
3.	Mix Laydown Temperature	Asphalt mixes are usually produced at temperatures between 250°F and 350°F. Depending on environmental conditions and the length of haul, the mixture can lose between 5°F and 25°F from the plant to the paver. As the temperature of the AC being placed is increased, the time available for compaction is greater. The effect of mat laydown is more significant at lesser mat thickness and lower base temperatures.
4.	Wind Speed	A thin layer of mix will cool more quickly in a strong wind than when there is little or no wind. Wind has a greater effect at the surface of the mix than within the mix, and can cause the surface to cool so rapidly that a crust will form.
5.	Solar Flux	The amount of radiant energy available from the sun (solar flux) is a function of many variables, including the position of the sun above the horizon, the distance above sea level of the paving project, the amount of turbidity in the air, and the degree of cloud cover. A mix will cool more slowly on a sunny day compared with a cloudy one. The amount of solar flux is more important in its effect on base temperature than its effect on mix temperature.
6.	Laydown Site Conditions	A number of factors at the laydown site directly affect the ability of the compaction equipment to gain the required level of pavement density. The relationship between lift thickness and nominal aggregate size in the mix is another variable that affects the amount of density that can be obtained. The uniformity of the lift thickness is another factor to be considered. It is easier to obtain a required level of density in an asphalt layer that has a constant thickness compared with a course that varies in depth. Asphalt leveling courses that, by their very nature and purpose are non-uniform in thickness, are often difficult to densify to a given air void content uniformly, especially when placed over a rutted or wavy road.

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Mix Property Factors

Aggregates - "The Rock Carries the Load"

Three properties of the coarse aggregate particles used in an asphalt mixture that can affect the ability to obtain the proper level of density are:

1. the particle shape of the aggregate,
2. the number of fractured faces, and
3. the surface texture

There is a simple statement that defines mix properties and the level of density: As the crushed content of the coarse aggregate increases, as the maximum size of the aggregate increases, and as the hardness of the aggregate (granite compared with limestone, for example) increases, the compactive effort needed to obtain a specific level of density also increases.

Angular particles offer more resistance to manipulation than do rounded aggregate particles. How well the mix will be compactive is also affected by the shape of the aggregate. A cubical or block-shaped aggregate needs a greater degree of manipulation than a rounded particle shape before achieving a given density level.

A continuously graded (dense-graded) aggregate, from coarse to fine, may be easier to compact than a mixture with any other aggregate gradation. A harsh mix typically requires a significant increase in compactive effort to obtain the desired level of density. An over sanded or finely graded mix, on the other hand, tends to be extremely workable. It still might be difficult to achieve density on such a mix, however, because of the inherent tender nature of such an over sanded mix. A mix designed with a high dust content will generally be more difficult to compact than a mix designed with a lower dust content.

At paving temperatures asphalt cement is a lubricating fluid. As cooling takes place, it becomes a glue-like binder.

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Asphalt Cement - "Binds the Rock Together"

The grade and amount of asphalt cement used in the mix affects the ability to densify the mix. An asphalt cement that is higher in viscosity or lower in penetration will generally provide for a stiffer mix at a given mix temperature and therefore require a greater compactive effort. The degree of hardening that occurs in the asphalt cement during the manufacture of the mix affects the compactibility of that material. The asphalt cement content of the mix influences its compactibility. In general, a mix with too little asphalt cement may be stiff and require an increase in compactive effort, whereas a mix with too much asphalt cement may shove under the rollers.

Mix Properties Summary

- For a traditional AC mix, a mix that is placed at a higher temperature will be easier to compact than a mix that is lower in temperature.
- The workability of the mix is affected by the temperature susceptibility of the asphalt cement.
- The fluids content of the mix, not just the asphalt content, affects the compactive effort needed.
- Fluids content is the sum of the asphalt cement content plus the moisture content of the mix.
- The moisture content of the mix should be less than 0.5 percent, by weight of mix, when the mix is leaving the plant.

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Compaction Variables Under Operator Control: Construction Factors

The roller operator is in control of more variables when using a vibratory roller and thus should be well educated in the proper selection and interaction of the variables. In addition to the roller speed, location on the layer being compacted, and number of passes made, both the nominal amplitude and the frequency of the vibratory impact can be varied. Roller speed and vibratory frequency are combined to determine the impact spacing. Further, for double-drum vibratory rollers, the operator can vibrate either one or both rolls. Care should be taken when operating a vibratory roller in areas where buildings are nearby. In addition, the use of vibration on the roller when underground utilities and drainage structures are directly under the pavement layer being compacted needs to be considered carefully.

The primary compaction variables for all types of rollers that can be controlled during the rolling process include:

- roller speed,
- number of roller passes,
- rolling zone, and
- roller pattern

In addition, for vibratory rollers the operator also has control over the vibration frequency, vibration amplitude, and direction of travel. Each of these factors has an effect on the level of density achieved under the compactive effort applied to the mix.

TOOLS AND EQUIPMENT
There are three basic pieces of equipment available for AC compaction: (1) the paver screed, (2) the steel wheeled roller and (3) the pneumatic tire roller.
Describes what tools, equipment and tests are required to complete the job safely and with the highest level of quality.

Compaction is done by any of several types of compactors, or rollers - vehicles which, by their weight or by exertion of dynamic force, compact the pavement mat by driving over it in a specific pattern.

Compaction aims at producing a mat of specific density (target density) and smoothness. Although the compaction process appears rather simple and straightforward, it is, in reality, a procedure requiring skill and knowledge on the part of the roller operator and the technician. Both must have a thorough understanding of the mechanics of compaction and the factors that affect the compaction effort.

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Compaction Equipment

How do Rollers Compact?

Rollers compact by applying their weight over the area of the drum/tires that touch the mat (contact pressure). The process packs the aggregate particles together and removes most of the air voids that exist. For example: If you walk across a new mat (not recommended) you will sink in because you exert a higher contact pressure (your weight divided by the area of the sole of your boots) than bearing capacity of the mix. As the roller passes over the mix repeatedly, the aggregate particles are packed closer together, the excess air is removed, the asphalt cement cools and acts more like a glue than a lubricant, and the bearing capacity of the mix increases.

When the bearing capacity of the mix equals the contact pressure exerted by the roller, the roller has "walked-out" of the mix. Further roller coverages may be necessary to further increase the mix density, orient the aggregate particles, seal the surface, and finally, "iron" out the roller marks.

In theory, that is how rollers compact. In practice, it isn't quite so simple because of the many compaction variables involved. In addition, most high-type asphalt concrete mixes are difficult to compact and new techniques and methods are constantly being tried to achieve the specified density.

There are three basic pieces of equipment available for AC compaction: (1) the paver screed, (2) the steel wheeled roller and (3) the pneumatic tire roller. Each piece of equipment compacts the AC by two principal means:

1. *By applying its weight to the AC surface and compressing the material underneath the ground contact area*. Since this compression will be greater for longer periods of contact, lower equipment speeds will produce more compression. Obviously, higher equipment weight will also increase compression.

2. *By creating a shear stress between the compressed material underneath the ground contact area and the adjacent uncompressed material*. When combined with equipment speed, this produces a shear rate. Lowering equipment speed can decrease the shear rate, which increases the shearing stress. Higher shearing stresses are more capable of rearranging aggregate into more dense configurations.

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DEFINITION

These two means of defining AC are often referred to collectively as "compactive effort".

1. By applying its weight to the AC surface and compressing the material underneath the ground contact area. Since this compression will be greater for longer periods of contact,

2. By creating a shear stress between the compressed material underneath the ground contact area and the adjacent uncompressed material.

There are several variables associated with rollers that can be adjusted from job to job. These variables are:

- The sequence and number of rollers
- Roller speed
- The number of roller passes over a given area of the mat
- The location at which each roller works
- The pattern that each roller uses

Not all these variables are infinitely adjustable, but by adjusting a combination of them, a rolling plan can be developed that will optimize mat compaction.

AC compaction is typically accomplished by a sequential train of compaction equipment. This allows each piece of equipment to be used only in its most advantageous situation resulting in a higher quality mat (both in density and in smoothness) than could be produced with just a single method of compaction.

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A typical compaction train consists of the following (in order of use):

1. Screed	The screed is the first device used to compact the mat and may be operated in the vibratory mode.
2. Breakdown Roller	The breakdown roller is the first roller behind the screed and therefore, generally effects the most density gain of any roller in the sequence. Breakdown rollers can be of any type but are most often vibratory steel wheel and sometimes pneumatic tire.
3. Intermediate Roller	The intermediate roller is used behind the breakdown roller if additional compaction is needed. Pneumatic tire rollers are sometimes used as intermediate rollers because they provide a different type of compaction (kneading action) than a breakdown steel wheel vibratory roller. This can help further compact the mat or at the very least, rearrange the aggregate within the mat to make it receptive to further compaction.
4. Finish Roller	The finish roller is last in the sequence and is used to provide a smooth mat surface. Although the finish roller does apply compactive effort, by the time it comes in contact with the mat, the mat may have cooled below cessation temperature. Static steel wheel rollers are almost always used as finishing rollers because they can produce the smoothest surface of any roller type.
5. Traffic	After the rollers have compacted the mat to the desired density and produced the desired smoothness, the new pavement is opened to traffic. Traffic loading will provide further compaction in the wheel paths of a finished mat. For instance, a mat compacted to eight percent air voids and then opened to heavy traffic (e.g., an interstate freeway) may further compact to about three to five percent air voids in the wheelpaths over time.

Each position in the roller train (breakdown, intermediate and finish) may be performed by one roller or several rollers in parallel. For instance, a large paving project may use two vibratory steel wheel rollers for breakdown rolling, one pneumatic tire roller for intermediate rolling and two static steel wheel rollers for finish rolling. The determination of the best rolling sequence and the number of rollers is generally made on a case by case basis and depends upon the desired final air voids, available rollers and their operating parameters, rolling patterns, mix properties, and environmental conditions.

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Static Steel Wheel Roller

Static steel wheel rollers normally range in weight from 3 to 14 tons and have compression drums or rolls that vary in diameter from approx. 40 inches to more than 60 inches. The gross weight of the roller can usually be altered by adding ballast to the roller, but this adjustment cannot be made while the roller is operating, and is not normally changed during the term of a paving project.

Effective weight or contact pressure, in terms of pounds per square inch of contact area, is the key variable for this type of equipment and is dependent on the depth of the penetration of the rolls into the mix. The greater the depth of penetration, the greater the contact area and then, the less the contact pressure.

The table below illustrates how the roller contact pressure increases as the mix's internal strength increases during the compaction process. Look at a typical ton roller. As the roller makes its first pass, the contact pressure may range from 48 to 36 psi as the drum sinks in 1/2 to 3/4 of an inch, depending on the initial stiffness of the mix. As additional passes are made, the mix becomes stiffer as the aggregate is packed together and the air voids are reduced. The drum eventually "walks out" of the mix and the contact pressure becomes extremely high. At 1/16 inch penetration, the contact pressure reaches 132 psi (A 266 percent increase over the original contact pressure at 3/4 inch penetration).

Roller Contact Pressure at Penetration Depths In Pounds per Square Inch

Static Roller Type	1/16 in.	1/8 in.	3/16 in.	1/4 in.	1/2 in.	3/4 in.
Two Axle Tandem 270 p.l.i. – Drive 190 p.l.i. – Guide						
8.5 ton (less ballast)	96	64	53	45	33	26
12 ton (less ballast)	132	88	74	63	46	36

Rollers with large-diameter rolls have lower drawbar pull (rolling resistance) because they do not tend to penetrate as far into the mix as does a roller with smaller-diameter rolls. Once the size and weight of a static steel wheel roller is selected, the variables under the control of the roller operator are the speed of the roller, the position of the roller on the mat in relation to the paver, operation with the drive wheel toward the paver, and the number of passes made with the roller.

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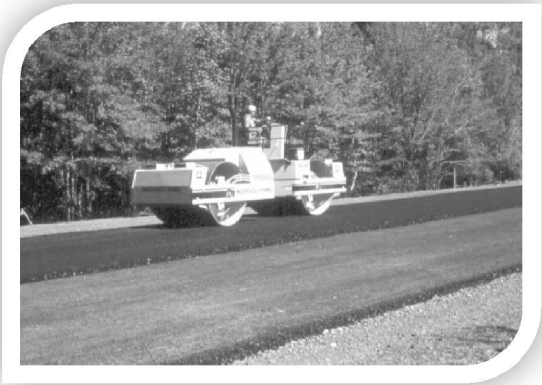
Pneumatic (Rubber Tire or Traffic) Roller

Most pneumatic rollers are operated in the intermediate roller position, behind a vibratory or static steel wheel breakdown roller and in front of a static steel wheel finish roller. These rollers are sometimes used, however, for initial rolling of the mix as well as occasionally for finish rolling.

Vibratory Roller

Vibratory rollers come in a variety of configurations. Single-drum vibratory rollers are manufactured with both a rigid frame and an articulated frame. Double-drum vibratory rollers come in rigid-frame, single-articulated-frame, and double-articulated-frame models. These rollers can be operated in any one of three modes: static (with the vibrator off), with one drum vibrating and one drum static, and with both drums vibrating.



These rollers thus have two types of compactive force that is applied to the AC:

1. Static weight, and
2. dynamic (impact) force.

The compactive effort derived from the static weight of the rollers is caused by the weight of the roller and frame. The compactive effort derived from the impact force is produced by a rotating eccentric weight located inside the drum (or drums). As the eccentric weight rotates about the shaft inside the drum, a dynamic force is produced. Changing the eccentric moment arm or adjusting the eccentric mass has a directly proportional effect on the dynamic force.

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The elements of comparison for dynamic component of a vibratory roller are the magnitude of the centrifugal force, its vibrating frequency, the nominal amplitude, and the ratio of the vibrating and non-vibrating masses acting on the drum.

DEFINITION

The nominal amplitude is defined as equal to the weight of the drum divided by the eccentric movement of the rotating weight and is a function of the weight of the drum and the location of the eccentrics.

Normal values of nominal amplitude range from 0.01 to 0.04 inches. Some rollers can operate at only one fixed amplitude. Other rollers have “high” and “low” amplitude positions. Still other rollers have 3 amplitude settings.

As the layer thickness increases, it is often advantageous to increase the nominal amplitude applied to the asphalt mix. Unless “high” amplitude is needed to achieve a particular density level, the vibratory roller should be operated in “low” amplitude.

The frequency of vibration is the number of complete cycles that the eccentrics rotate per minute. Simply stated, the faster the rotation of the eccentrics, the greater the frequency of vibration. Some vibratory rollers can operate at only one frequency or have a very limited selection of frequencies. Other vibratory rollers can alter the frequency of the applied load between 1600 and 3000 vibrations/minute.

IMPORTANT/AWARENESS

Frequencies below 2000 vibrations/minute are not normally acceptable to compact asphalt mixtures.

Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

The spacing of the impacts of the applied force is a function of the frequency of the vibration and the travel speed of the roller. A smaller impact spacing (a greater number of impacts per foot) is thus usually preferred.

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A recent survey of major roller manufacturers recommended the following impact spacing. The impact spacing should be in the range of 10-12 impacts per foot (1.2 - 1.0 in. between impacts) to ensure the highest efficiency of the vibratory rollers and reduce the possibility of leaving ripples in the finished pavement.

BEST PRACTICE

In general, the vibratory roller should be operated at as high a frequency as possible. The use of the highest possible frequency of vibration increases the number of impacts per foot at a given roller speed.

Describes a best practice to be utilized when possible.

Prior to beginning paving operations, the Materials Section or Inspector must inspect the Contractor's compaction equipment to see that it meets all requirements of the Specifications and is in good working order. If the equipment meets Specifications and is in satisfactory operating condition a statement shall be entered in the Technician's Daily Diary.

Before any of the rollers are used on a project they should be checked to see that they are in good mechanical condition and to assure their compliance with project specifications, if any.

Where applicable, the following should be checked on all rollers:

1. Total weight
2. Weight per unit of width (steel-wheeled rollers)
3. Average ground contact pressure (pneumatic-tired rollers)
4. Mechanical condition (Hydraulic Fluid & Fuel Leaks)
5. Precise steering

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Compaction of the pavement material must begin immediately after the material is spread, struck off, shaped to the required width, depth, cross-section, and edge irregularities adjusted. The mix must be compacted to the required degree of compaction for the type of mixture being placed. Compaction must be carried out in such a manner as to obtain uniform density over the entire section. Perform compaction rolling at the maximum temperature at which the mix will support the rollers without moving horizontally. Complete the compaction (including both breakdown and intermediate rolling) prior to the mixture cooling below a workable temperature. Perform finish rolling to remove roller marks resulting from the compaction rolling operations.

Most asphalt mixtures compact quite readily if spread and rolled at temperatures that assure proper asphalt viscosity. Rolling should start as soon as possible after the material has been spread by the paver, but should be done with care to prevent unduly roughening the surface.

A mix that is relatively stable at high temperatures as it leaves the spreader is compacted by the vertical movement of the aggregate particles under the roller. On any paving mixture the roller wheel must settle into the mix until the area of contact between the wheel and mix multiplied by the resistance of the mix is equal to the weight on the roller wheel. If the AC is quite firm, the roller will not cause any horizontal mix displacement.

Horizontal displacement results from apparent crawling of the mix ahead of the roller and the forming of ridges on either side of the roller path. If there is no horizontal displacement, there will be virtually no crawl or ridges along the edge of the roller path.

Horizontal displacement also results in a rough and uneven surface, thus defeating the intentions of careful grade control and good screed operation of the asphalt paver. Horizontal movement of the mix often occurs due to the breakdown roller being operated too fast.

Mix temperature is a principal factor affecting compaction. Compaction can only occur while the asphalt binder is fluid enough to act as a lubricant. When it cools enough to act as an adhesive, further compaction is extremely difficult to achieve. The best time to roll an asphalt mixture is when its resistance to compaction is the least, while at the same time it is capable of supporting the roller without excessive shoving.

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The best rolling temperature is influenced by the internal particle friction of the aggregates, the gradation of the mix, and the viscosity of the asphalt. Therefore, it can change if any of these factors change. The critical mix temperature in an asphalt concrete paving project is the temperature at the time of compaction. This should determine the temperature at which the plant is to produce the mixture. It is best to be able to compact the mix as quickly as possible after being spread, which means that it's best for the mixing temperature and the compacting temperature to be reasonably close to the same.

During rolling, roller wheels are kept moist with only enough water to avoid picking up material.

Fuel oil should not be used to moisten roller wheels since it will damage the mix.

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Phases of Rolling

Rolling freshly placed asphalt mix is generally done in the following order:

1. Transverse joints,
2. Longitudinal joints (when adjoining a previously placed lane),
3. Initial or breakdown rolling,
4. Second or intermediate rolling, and
5. Finish rolling.

BEST PRACTICE

Compacting Transverse Joints

Good practice is to make an initial breakdown pass and then check the joint with a straightedge. In case the new mat is too high, the mix can still be reworked and then recompacted. It is important to understand that the first pass will still leave the mat slightly high, but experience will determine if it is too high. The goal is to produce a transverse joint that rides as smooth as the rest of the mat.

Transverse Rolling

Ideally, it is best to compact transverse joints in the transverse direction. However, it is not always possible. If rolling in the transverse direction, run-off boards the thickness of the mat may be needed to keep the roller level. This drum should overlap the new mat with most of the drum on the cold mat and pinch the joint. Some contractors use multiple passes, each pass placing more of the drum on the hot mat. Again, the method that produces a dense, level joint most efficiently is the one to use.

Longitudinal Rolling

If a transverse joint is to be compacted in the longitudinal direction, it is important the first passes of the roller be made at very slow speeds. Higher speeds may force the new mix away from the joint creating a void or weakness. Some only roll in with one drum on the new mat and then reverse back. Angling the drum while entering the new mix can be effective also.

There is no one right way to roll a transverse joint; the method that works most efficiently and consistently is the one to use.

Describes a best practice to be utilized when possible.

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There are three basic phases in the compaction process of asphalt pavements: 1)Breakdown, 2) Intermediate, and 3) Finish phases. Each of these are described in detail below.

Breakdown	Breakdown rolling is best accomplished with steel-wheeled rollers. Either static-weight or vibratory tandem rollers may be used. Vibratory rollers may be used in the vibratory mode on all mixes, except that on the final wearing surface the thickness must be 1 inch or greater before use is permitted. The weight of the roller used for breakdown rolling depends to a large degree upon the temperature, thickness, and stability of the mix being placed. Generally, a roller weighing from 8 to 12 tons is used for this operation. It is important to start the rolling operation on the low side of the spread, which is usually the outside of the lane being paved, and progress toward the high side. The reason for this is that asphalt mixtures, when hot, tend to migrate towards the low side of the spread under the action of the roller. If rolling is started on the high side, this migration is much more pronounced than if rolling progresses from the low side. When adjoining lanes are placed, the same rolling procedure should be followed, by only after compaction of fresh mix at the longitudinal joint with a 6 to 8 in of roller width.
Intermediate	Second or intermediate rolling should closely follow breakdown rolling while the asphalt mix is still plastic and at a temperature that is still well above the minimum temperature at which compaction can be achieved, preferably 225° - 250°F. Pneumatic-tired, steel-wheeled static and vibratory rollers may be used for intermediate rolling. When using pneumatic rollers, keeping the tires hot is the most effective means of preventing pickup. Applying a small amount of non-foaming detergent or water soluble oil on the wetting mat of a pneumatic-tired roller at the beginning of rolling operations helps prevent asphalt from sticking to the tires until they warm up. Pneumatic-tired rollers have several advantages: ▪ They provide a more uniform degree of compaction than steel-wheeled rollers ▪ They improve the seal near the surface, thus decreasing the permeability of the layer; and ▪ They orient the aggregate particles for greatest stability, as high pressure truck tires do after using the asphalt surface for some time. Tire contact pressures should be as high as possible without causing displacement of mix that cannot be remedied in the final rolling. Pneumatic-tired rolling should be continuous after breakdown rolling until all of the mix placed has been thoroughly compacted. At least three passes should be made. Turning of pneumatic-tired rollers on the paving mix should not be permitted unless it can be done without causing undue displacement. Vibratory tandem rollers-of proper static weight, vibration frequency and amplitude are used to provide required densities with fewer roller passes than static-weight tandem or pneumatic-tired rollers (or combinations of the two). As mentioned previously, the vibratory roller may be used in the vibratory mode, at any time (subject to Specification requirements) on all pavement layers during the breakdown and intermediate phases of rolling.
Finish	Finish rolling is done primarily for the improvement of the surface. It should be accomplished with steel-wheeled, static-weight tandems or non-vibrating vibratory tandems while the material is still warm enough for removal of roller marks. Only enough passes should be made to remove the roller marks and smooth the mat. Finish roller operators should be cautioned about over rolling the mat since it can decrease the mix density. Vibratory rollers operated in the vibratory mode are not permitted as finish rollers.

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NOTE: Some SUPERPAVE™ mixes may exhibit a "tender zone" or lateral movement during compaction when the mix has cooled to the 250° - 210°F range. Because of this possibility, it is very important to obtain as much density as possible during the breakdown rolling phase. The use of vibratory rollers, more passes, additional rollers, compacting at a hotter temperature, adjusting the mix to get more "fines" in it, making certain that silicone has been added to the asphalt binder for surface mixes, excessive moisture in the aggregate, etc., are some things that may need to be considered. Some success has also been achieved by using rubber tired rollers during this "tender zone". If none of these solve the lateral movement problem, it may be necessary to hold back the intermediate and finish rollers until the mix has cooled below this "tender zone" temperature range and then continue rolling.

Rollers should move at a slow but uniform speed with the drive roller or wheels nearest the paver. The speed should not exceed 3 mph for steel-wheeled breakdown rollers or 5 mph for pneumatic-tired rollers. Rollers must be kept in good condition, capable of being reversed without backlash. The line of rolling should not be suddenly changed or the direction of rolling suddenly reversed, thereby displacing the mix. Any pronounced change in direction should be made on stable material.

If rolling causes material displacement, the affected areas are loosened at once with lutes or rakes and restored to their original grade with loose material before being re-rolled. Heavy equipment, including rollers, should not be permitted to stand on the finished surface before it has thoroughly cooled or set.

When paving in echelon, 2 or 3 inches of the edge that the second paver is following are left unrolled when the joint between the lanes is rolled. Edges should not be exposed for more than 15 minutes without being rolled. Particular attention must be given to the construction of transverse and longitudinal joints in all courses.

All final wearing surfaces except open-graded asphalt friction course shall be compacted using a minimum of 2 steel wheel tandem rollers. Steel wheel tandem vibratory rollers which have been specifically designed for the compaction of asphalt pavements may be used. Vibratory rollers, operating in the vibratory mode, may generally be used on all pavement layers 1 inch or greater in thickness during the breakdown and intermediate phases of rolling. Operation in the vibratory mode will not be permitted during the finish rolling phase on any mix type or pavement course or when the layer thickness is less than 1 inch.

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Vibratory rollers must have variable frequency and amplitude capability. The rollers must be equipped with controls which automatically disengage the vibration mechanism before the roller stops when being used in the vibratory mode. Vibratory rollers used on asphalt mixtures should normally be operated at high frequencies and low amplitudes and specifically designed for asphalt compaction.

Rolling of open-graded asphalt friction course will consist of one coverage with a tandem steel wheel roller weighing a maximum of 10 tons with additional rolling limited to one coverage where necessary to remove roller marks. Excessive rolling should not be allowed inasmuch as this leads to possible breakdown of the aggregate, thereby reducing the drainage capacity of the friction course layer. Vibratory rollers may be used on friction course provided they are operated in the static mode.

On all other mixtures, the number and weight of rollers shall be sufficient to compact the mixture to the required density while it is still hot and in a workable condition. Vibratory rollers may be used, as specified in above paragraphs, provided satisfactory results are obtained, excessive displacement or crushing of the aggregate does not occur, and no vibratory roller marks (indentations) remain in the finished surface. The Engineer may prohibit or restrict the use of vibratory rollers where damage to the underlying pavement structures, drainage structures, utilities, adjoining structures, or the pavement itself is likely to occur or is evident.

The use of a pneumatic rubber tired roller is optional for compaction purposes on all mixes except for surface layers where it is required. Some Project Special Provisions may require additional use of a rubber tired roller, therefore, it is essential that the technician review all contract Project Special Provisions for this possible requirement.

While it is the Contractor's responsibility to determine roller requirements based on contract specifications, the technician is an essential part of this determination. The exact number of passes that will be required to obtain adequate density is initially unknown and this is due to some uncertainty about the mixtures rate of cooling, among other things. These uncertainties are cleared up by careful observation, measuring, and testing during the early stages of the paving operation.

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Roller Speed

Rollers are slow; for the fastest, operating speeds may reach about 7 mph. In order to provide complete and uniform mat compaction, rollers should be operated at a slow, constant speed. Operating at high speeds will reduce compactive effort while varying roller speed can cause non-uniform compaction.

The following table provides an indication of the range of roller speed for three different types of rollers and three different operating positions:

Type of Roller	Breakdown	Intermediate	Finish
Static Steel Wheel	2.0 – 3.5 mph	2.5 – 4.0 mph	3.0 – 5.0 mph
Pneumatic	2.0 – 3.5 mph	2.5 – 4.0 mph	4.0 – 7.0 mph
Vibratory Steel Wheel	2.0 – 3.0 mph	2.5 – 3.5 mph	not used

Roller compactive effort comes in two forms:

1. material compression under the ground contact area and
2. shear stress between the compressed area and adjacent uncompressed areas

Compactive effort is significantly improved at slower roller speeds. Roller speed will also be governed by the lateral displacement or tenderness of the asphalt mix. If the mixture moves excessively under the rollers, the speed of the compaction equipment should be reduced. In addition, for vibratory compactors, roller speed also affects the impact spacing. Roller speed is usually established by the speed of the paver. Varying the speed of the compaction equipment merely causes variations in density. “Slow and steady” is the key to proper compaction.

Operating at lower speeds allows the roller to remain in contact with a particular mat location longer than it would at higher speeds. This results in more compression per roller pass and therefore increases compactive effort. Speed also affects the magnitude of shear stress developed. Lower speeds result in the shearing force between compressed and uncompressed areas being applied for a longer period of time for a particular area (giving a lower shear rate), which results in a higher shear stress. The higher the shear stress, the better able it is to rearrange aggregate into a denser configuration. Therefore, as roller speed decreases, shear stress increases and compactive effort increases.

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Because speed affects compactive effort, varying roller speed will vary compactive effort resulting in uneven compaction. Varying roller speed typically occurs when operators are not closely monitoring their speed or when they speed up to roll an area more quickly so that they can catch up to the paver. If the mat is being laid down at a faster rate than it can be rolled, the solution should not be to speed up the rollers but rather should involve one of the following options (TRB, 2000):

1. *Slow down the paver*. This may involve adjusting production and material delivery rate as well.
2. *Use more rollers*. Adding rollers can increase the number of roller passes in a given time without reducing the compactive effort per pass.
3. *Use larger, wider rollers*. Wider rollers allow greater coverage per pass.

Finally, rollers should not be stopped on a fresh mat because they can cause large indentations that are difficult, if not impossible, to remove.

Roller speed directly affects compactive effort. The best compactive effort and most uniform densities are achieved by slow, consistent roller speeds. If rollers cannot keep up with the pace of the paving operation, they should not be operated at higher speeds because this reduces compactive effort. Rather, the paving operation should be slowed or more/larger rollers should be used.

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Number of Roller Passes

Generally, it takes more than one roller pass over a particular area to achieve satisfactory compaction. A roller pass over a specific mat area is defined as one complete trip over the area in question by the entire roller. This means that if the roller uses two steel drums, both drums must travel over the area in question to make "one pass". In general, earlier passes over hotter AC will increase density (decrease air voids) more than later passes over cooler AC.

SAFETY WARNING

In addition to keeping accurate detailed records and observing that the operation is performed safely, the Technician must also be sure that compaction is done properly and that the finished pavement meets all specifications. To achieve this, the technician must understand the compaction procedure and the equipment involved. The Technician must acquire samples of the compacted mat or take readings with special instruments to determine mix density and smoothness.

Describes a condition where personal safety may be at risk.
This is used to alert personnel to operating procedures & practices which, if not observed, may result in personal injury.

Chapter Summary

The compaction process, which must be closely controlled to achieve a quality pavement, is the last chance you will have to make or break a job. The best pavement design, the latest mix design, and the most sophisticated AC facility don't stand a chance unless you compact the mix (while it is hot) to the specified density. Compaction determines the ultimate performance of the mix and pavement. Although simple in concept, it is often very difficult to achieve in the field because of a number of variables that affect the ability of the rollers to densify the mix. You must understand what these variables are, and how to control them, in order to ensure that you can achieve density under a variety of conditions.

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Chapter Six Knowledge Check

1. The density of a material is simply the weight of the material that occupies a certain volume of space.
    a. True
    b. False
2. A pass is defined as the entire roller moving over _____ point(s) in the mat at one time.
    a. One
    b. Two
    c. Three
    d. Four
3. A dense-graded aggregate may be easier to compact than a mixture with any other aggregate gradation.
    a. True
    b. False
4. A thin layer of mix will cool more quickly in a strong wind than when there is little or no wind.
    a. True
    b. False
5. The primary compaction variables for all types of rollers that can be controlled ruing the rolling process are:
    a. Roller speed
    b. Number of roller passes
    c. Rolling zone
    d. Rolling pattern
    e. All of the above
6. Compactive effort is significantly improved at slower roller speeds.
    a. True
    b. false

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7 Mat Problems: Causes & Solutions

Learning Outcomes:

- ☑ Identify QA techniques that apply to asphalt construction (laydown and compaction)
- ☑ Recognize causes of defects

Mat Problems

Mat problems can be defined as defects that occur in the asphalt mixture during or soon after the laydown and compaction operations have been completed.

These problems fall into two primary categories:

1. Equipment-related problems and
2. Mixture-related problems

In this chapter, major mat problems are reviewed and a description of each problem is presented, including its causes, solutions and effects on long-term pavement performance. Only those problems that occur at the time of the asphalt mix production, laydown and compaction will be addressed. A number of other deficiencies can occur on an asphalt pavement structure with time and traffic loading once construction has been completed.

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Segregation

Hot mix asphalt mixtures that are properly designed, produced, and placed provide a durable, long lasting pavement that requires very little maintenance. However, there are a number of potentially damaging problems that can occur in the design, production and placement of hot mix paving mixtures.

Of these problems, perhaps the most serious one is segregation. Segregation is a frequently recurring problem that has caused concern within the paving industry for decades and is receiving widespread attention by contractors, State Highway Departments and equipment manufacturers.

When segregation is present in a mixture, there is a concentration of course materials in some areas and finer materials in the other areas of the paved mat. Segregation creates non-uniform mixes that do not conform to the original job mix formula in gradation or PG binder. The resulting pavement exhibits poor structural and texture characteristics and has a shorter life expectancy. Problems associated with segregation are serious, and their elimination is essential to the production of high quality paving mixtures.

Elimination of segregation is the responsibility of those who produce and lay asphalt mix, those State Highway Departments who design the mix and inspect the final product, and those manufacturers who design and market machinery for the paving industry.

Proper mix design is important in the effort to eliminate segregation. Mixes that are uniformly designed with no gap grading are generally more forgiving.

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Asphalt Concrete Mixtures – Design Range Percentage by Weight passing Square Mesh Sieves (in)											
Type	% by Mass Passing Square Mesh Sieves										
	2 in.	1 1/2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No 4	No 8	No 30	No 50	No 200
SM-9.0, A, D, E					100*	90-100	90 max	47-67			2-10
SM-9.5, A, D, E					100*	90-100	80 max	38-67			2-10
SM – 1 2.5, A, D, E				100	95-100	90 max	---	34-50			2-10
IM-19.0 A, D			100	90-100	90 max	---	---	28-49			2-8
BM-25.0 A, D		100	90-100	90 max	---	---	---	19-38			1-7
C (Curb Mix)					100	92-100	70-75	50-60	28-36	15-20	7-9
Legend: SM = Surface Mixture; IM = Intermediate Mixture; BM = Base Mixture; C = Curb Mixture *A production tolerance of 1% will be applied to this sieve, regardless of the number ot tests in the lot.											

Gap graded mixes are by the same token unforgiving and any slight error in the plant, trucking or laydown process can result in non-uniform surfaces. If the mix is gap graded to a sufficient degree with a low PG binder, it simply cannot be produced without segregation occurring regardless of the techniques sued.

Segregation can also be caused by improper paver operation. Some likely contributing factors are:

- Unbalanced paver demand
- Drawing hopper empty between loads
- Dumping hopper wings between loads
- Truck not dumping to fill hopper
- Spot segregation during truck loading

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When loading a truck into a paver hopper, it is important to discharge the material as a mass instead of dribbling the material into the paver. To accomplish this objective, the bottom of the truck bed needs to be maintained in good condition and be lubricated so that the entire load will slide rearward. To further assure that the material is discharged as a mass, evaluate the truck bed to a large but safe angle.

Rapid truck discharge floods the paver hopper and minimizes material run around that often occurs at the tailgate ends. This rapid discharge stops an accumulation of coarse material at the outside portion of the paver wings.

Even though material is successfully processed through the cold feed bin, the plant, the surge or storage bin and then uniformly loaded on the truck, segregation can still occur in the asphalt paving machine. Improper operation of a paver can cause segregation in varying degrees.

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Consideration When Segregation is Occurring at the Paver

Dump hopper wings only as required to level the material load in the hopper. This dumping eliminates the valleys in the material bed, thus minimizing the rolling that occurs with unloading and allows the truck tailgate to swing open fully to flood the hopper with mix.

Open hopper gates as wide as possible to insure the augers are full. By closing the gates and starving the augers for mix, fine material will drop directly on the ground causing coarse materials to be channeled to each side.

Run the paver as continuously as possible. Start and stop only as necessary. Adjust the paver speed to balance paver production with plant production.

Run augers continuously. Auger speed should be adjusted so that a continuous, slow flow of material occurs. Augers that run at high speeds are cycling on and off continuously and contribute significantly to segregation at the paver. If augers are running too fast, the center of the mat will be deficient of material and this will generally result in a coarse strip.

If possible, adjust paver extensions so that the paver pulls the same amount of material from each side of the hopper. If one side is pulling a much higher amount of material, a valley will form in that side of the paver hopper causing segregation to occur in sensitive mixes. If correction cannot be made by adjusting the extension, offset the truck slightly to even out the material bed in the hopper.

Excessive handwork can turn a smooth mat into a segregated mat. Keep handwork to a minimum.

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PROBLEM \ CAUSE	Fluctuating Head of Material	Feeder Screws Overloaded	Finisher Speed Too Fast	Too Little Lead Crown in Screed	Too Much Lead Crown in Screed	Overcorrection of Thickness Control Screws	Screed Mechanical Connection	Screed Riding on Lift Cylinders	Screed Plates Worn Out or Warped	Screed plates Not Tight	Mouldboard on Sinkoff Too Low	Cold Screed	Kicker Screws Worn Out or Mounted Incorrectly	Feeder Gates Set Incorrectly	Running Hopper Empty Between Loads	Screed Extensions Installed Incorrectly	Screed Setting Blocks Too Short	Incorrect Nulling of Screed	Grade Control Mounted Incorrectly	Vibrators Running Too Slow	Grade Control Hunting (Sensitivity Too High)	Grade Control Wand Bouncing on Reference	Grade Reference Inadequate	Improper Mat Thickness for Max. Agg. Size	Setting Long Period Between Loads	Improper Joint Overlap	Trucks Bumping Finisher	Truck Making Brakes	Reversing or Too Rapidly Turning Rollers	Improper Base Preparation	Improper Rolling Operation	Parking of Roller on Hot Mat	Improper Mix Design (Aggregate)	Improper Mix Design (Asphalt)	Mix Segregation	Moisture in Mix	Variation of Mix Temperature	Cold Mix Temperature	
Wavy Surface - Short Waves (Ripples)	✓	✓	✓					✓	✓		✓															✓	✓	✓	✓					x	x			x	x	x		x	
Wavy Surface - Long Waves	✓	✓					✓	✓	✓					✓		✓										✓			✓	✓		x	x	x		x	x			x		x	
Tearing of Mat - Full Width			✓							✓			✓																							x	x	x	x	x	x	
Tearing of Mat - Center Streak						✓				✓			✓			✓	✓																								x	
Tearing of Mat - Outside Streaks					✓					✓			✓	✓		✓					✓																				x	
Mat Texture - Nonuniform	✓	✓	✓						✓	✓	✓	✓			✓						✓	✓											x			x	x	x		x	x	
Screed Marks								✓																								x	x									
Screed Not Responding to Correction			✓					✓	✓		✓															✓								x							x	x
Auger Shadows																																				x	x	x				
Poor Precompaction			✓						✓													✓											x								x	
Poor Longitudinal Joint	✓	✓					✓		✓																	✓	✓	✓			✓				x							x	
Poor Transverse Joint		✓						✓	✓		✓								✓	✓															x							x	
Transverse Cracking (Checking)																																		x	x			x	x	x		
Mat Shoving Under Roller																																		x	x	x		x	x	x		
Bleeding or Fat Spots in Mat																																						x	x	x		
Roller Marks																																		x	x	x	x				x	
Poor Mix Compaction																																		x	x	x	x	x	x	x	x	x

NOTE: Many times a problem can be caused by more than one item; therefore, it is important that each cause listed be eliminated to ensure that the problem will be solved.

Key	checks (✓) indicate causes related to the paver X's indicate other problems to be investigated

Table: "Mat Problems and Their Causes" *Hot-Mix Asphalt Paving Handbook 2000* p195

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PROBLEM \ CAUSE	Fluctuating Head of Material	Feeder Screws Overloaded	Finisher Speed Too Fast	Too Much Lead Crown in Screed	Too Little Lead Crown in Screed	Overcorrection of Thickness Control Screws	Excessive Play in Screed Mechanical Connection	Screed Riding on Lift Cylinders	Screed Plates Worn Out or Warped	Screed Plates Not Tight	Moldboard on Strikeoff Too Low	Cold Screed	Running Hopper Empty Between Loads	Feeder Gates Set Incorrectly	Kicker Screws Worn Out or Mounted Incorrectly	Incorrect Nulling of Screed	Screed Extensions Insta	Screed Starting Blocks To	Grade Co	Grade	Vibra	G
Wavy Surface - Short Waves (Ripples)	✓	✓	✓					✓	✓			✓										
Wavy Surface - Long Waves	✓	✓					✓	✓	✓								✓	✓				
Tearing of Mat - Full Width			✓							✓			✓									
Tearing of Mat - Center Streak						✓				✓			✓					✓	✓			
Tearing of Mat - Outside Streaks					✓					✓			✓	✓				✓				
Mat Texture - Nonuniform	✓	✓	✓						✓	✓	✓	✓	✓				✓					
Screed Marks								✓														
Screed Not Responding to Correction			✓					✓	✓			✓										
Auger Shadows																						
Poor Precompaction			✓						✓													
Poor Longitudinal Joint	✓	✓					✓		✓													
Poor Transverse Joint		✓						✓	✓			✓										
Transverse Cracking (Checking)																						
Mat Shoving Under Roller																						
Bleeding or Fat Spots in Mat																						
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									✓	✓	✓	✓						x	x			x	x	x		x	
		✓	✓						✓			✓	✓			x	x	x		x	x			x		x	
															x							x	x	x	x	x	x
			✓	✓																							x
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																		x	x	x		x	x		x	x	
																						x	x		x	x	
																		x	x	x	x					x	
																		x	x	x	x	x	x		x	x	x

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Key	checks (✓) indicate causes related to the paver X's indicate other problems to be investigated

Surface Waves

An asphalt surface can have two types of waves: short and long.

- Short waves, also sometimes called rippers or auger shadows, are generally one to three (1-3) feet apart, with one and one half to two (1.5-2) feet being the most common separation.
- Long waves are considerably farther apart. The distance between them may correspond to the distance between truck loads of mix. Long waves may also be associated with the reversal points of the compaction equipment, particularly on thick-lift construction or when the AC being placed is tender and moving longitudinally under the compaction equipment.

An additional type of defect in the pavement surface is a roughness or washboard effect caused by improper operation of a vibratory roller. The distance between the waves is generally very small, typically less than three or four (3 or 4) inches.

(a) Causes

- A major cause of short waves or ripples is a fluctuating head of material in front of the paver screed. The variation in the amount of mix being carried back to the augers by the slat conveyors and deposited in front of the screed causes the screed to rise and fall as the force pushing against it changes. Too much mix (at the top of the augers) and then too little mix (at the bottom of the augers) being carried in the auger chamber in front of the screed causes the wavy surface as the screed reacts to the variation in force. The fluctuating head of material causes the screed to rotate around its pivot point and "hunt" for an angle of attack. As the angle of attack of the screed changes, the thickness of the mat being placed also changes, and the smoothness of the new layer is directly affected.
- Another cause of short waves is a screed that is poor mechanical condition – one with excessive play in the screed control connections. Short waves can also be formed in the

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mat by improper mounting or sensitivity of the automatic grade control on the paver or by use of an inadequate grade reference device. The problem may also be related to a mobile reference (floating beam) that is bouncing, or the truck driver's holding the brakes while the truck is being pushed by the paver.

- Short waves can also be related to the mix design, particularly with a mix that varies in stiffness as a result of changes in the mix temperature or composition. As the stiffness of the mix varies, the forces of the mix pushing on the screed vary as well, causing the screed to rise and fall which results in a mat with short waves. Finally, if the mix design is improper in aggregate gradation, asphalt content, mix temperature or moisture content (the mix is tender), the rollers may shove and displace the mix during the compaction process. Normally, however, short waves are placed in the mat by the paver because of either its operation or changes in mix stiffness, rather than by the operation of the compaction equipment.
- Long waves are caused by some of the same variables that result in short waves. Fluctuation in the amount of material in front of the screed and variation in mix stiffness caused the screed to react to the change in the force exerted on it. If the distance between the wave peaks corresponds to the length of pavement between truckloads of mix, however, the waves may have been caused by incorrectly set hopper flow gates on the paver or by the paver hopper and slat conveyors being emptied between loads of mix. Poor mechanical condition and improper operation of the screed (continually changing the manual thickness control cranks, for example), as well as incorrectly mounted automatic grade controls, can cause a long-wave problem. If a stringline is being used as a grade reference, a sag in that line between support posts can also be a cause of long waves. Another factor contributing to long-wave roughness is improper delivery of the mix to the paver, particularly if the haul truck bumps into the paver or if the truck driver holds the brakes while the truck is being pushed by the paver. One additional factor can be the condition of the underlying surface: the long waves may be a reflection of the waves in the base material.
- Long waves may also be found at those points where the compaction equipment reverses direction. This problem is most prevalent when the asphalt layer being placed is more than about four inches thick. The problem may be exacerbated when the maximum-size aggregate used in the mix is relatively small compared with the lift

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thickness. The waves are caused by a bow wave that forms in front of the roller when the mix is tender.

- In terms of mix design, long waved can be caused by truckload-to-truckload segregation of the mix and by changes in the mix temperature. Both deficiencies cause the forces on the screed to vary, resulting in a wavy surface. The compaction equipment can also create a wavy mat if the roller operator turns or reverses the machine too abruptly.
- Roughness or washboarding is normally caused by improper operation of a vibratory roller. This type of equipment should be operated at as high a frequency as possible and at an amplitude setting related to the thickness of the layer being compacted – usually a higher amplitude setting for a thicker layer of mix and a lower amplitude setting for a thinner lift. Further, the washboard effect can be worse if the roller is operated a high speed, particularly if the frequency setting is less than 2,400 per minute.

(b) Solutions

- Short waves (ripples) can be eliminated only by preventing their formation. The most important factor in preventing short waves is to keep the amount of mix (head of material) in front of the screed as consistent as possible. In addition, the stiffness of the mix, which is related to both its temperature and its composition, should be maintained as constant as possible. The amount of mix is controlled by properly setting the hopper flow gates and by keeping the slat conveyors and augers operating as much of the time as possible (close to 100 percent) while the machine is moving forward. Mix stiffness is controlled at the asphalt plant by keeping the mix temperature, aggregate gradation, and fluids content (asphalt content plus moisture content) as consistent as possible. Any factors that cause either the volume or stiffness of the mix at the screed to change can cause short waves or ripples in the AC mat.
- Surface waves caused by problems with automatic grade controls can be detected by shutting off the grade controls and determining whether the waves continue to form. If the grade controls area at fault, the operation and maintenance manual supplied with those controls should be consulted to determine the proper corrective action. Sags in a stringline reference can be found by sighting down the line as the grade sensor wand passes along the string. Short or long waves caused by the mechanical condition or operation of the paver screed can usually be detected by careful observation of the

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paver during mix laydown. The long waves formed by incorrect operation of the haul truck or compaction equipment can also be detected easily by observing those operations.

- If washboarding is caused by incorrect operation of a vibratory roller, a change should be made in one or more of the following: the vibratory amplitude setting, the vibratory frequency, and the speed of the roller.

(c) Effects on Long-Term Pavement Performance

Long-term pavement performance is affected by surface waves, both short and long, in two ways.

1. The waves reduce the smoothness of the pavement, which lowers the pavement condition rating or the present serviceability index of the roadway. The structural performance of the pavement will be changed, however, only if the waves are severe enough to increase the dynamic or impact loading of the pavement under heavy truck traffic.
2. Short waves and the factors that cause them can affect pavement density levels. A tender mix is generally more difficult to compact properly than is a stable mix; the result may be a decrease in density and a corresponding increase in air void content.

Washboarding is basically toughness built into the pavement surface during the compaction operation. Because it affects the degree of density obtained during the compaction process, this type of defect can significantly reduce the long-term durability of the pavement layer. In addition, washboarding contributes to a rough ride for the vehicles using the pavement.

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Tearing (Streaks)

There are three general types of mat tearing or pulling of the asphalt mix under the screed of the paver. The three types are defined by the location of the tear marks in the mat:

1. In the center of the lane
2. On the outside edges, and
3. Across the full lane width

(a) Causes

- A gearbox streak can sometimes be seen in the surface of the mat directly behind the center of the main screed. This streak is typically six to eight (6-8) inches wide and is normally caused by a lack of asphalt mix being pushed under the auger gearbox located in front of the center of the screed. This lack of mix may be the result of improper flow gate settings – not enough mix being fed back to the screed. It is more likely to be caused, however, by missing, worn, or improperly set reverse augers or paddles on the augers (located adjacent to the gearbox) that are used to force mix underneath the gearbox.
- A gearbox streak is often thought to be a type of segregation. It is not. The rough surface texture is the result of lack of mix at the point in the pavement width – less mix passes under the screed at the auger gearbox than passes under the screed on either side of the gearbox. The rougher texture, or tearing, makes the surface appear more open or segregated. Gearbox streaks are more prevalent with harsher mixes – those containing larger-size aggregate, more crushed aggregate, or lesser amounts of asphalt.
- A centerline streak can also be caused by improper setting of the crown on the main paver screed. The appearance of streaks behind the screed is caused primarily by an improper relationship between the crows at the leading (front) and trailing (back) edges of the screed. A tearing or open texture about a meter (several feet) wide in the center of the mat may be caused by a lack of lead crown in the screed. Conversely, a tearing or open texture along both outside edges of the asphalt mixture is normally caused by an excess of lead crown in the screed. For most mixes the lead crown of the screed should

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be set slightly higher- (approximately one eighth of an inch (1/8 inch) - than the tail crown. A proper relationship between lead and tail crowns will result in a uniform texture of the mat across its full width. Edge streaks can be caused by improper flow gate settings or incorrect installation of the screed extensions. Partial-width tearing can also result from a cold screed plate if the screed has not been uniformly preheated before paving begins.

- Full-width tearing of the mat can be attributed to a number of factors. One such factor is warped or worn screed plates. Another is the forward speed of the power being too high for a particular mix. The use of a mixture with aggregate that is large compared with the mat thickness being laid can also be responsible for full-width tearing of the mat. A good rule of thumb for the relationship between the maximum aggregate size in the mix and the minimum compacted course thickness is that the depth of the compacted layer should be at least twice the largest coarse aggregate particle size or three times the nominal maximum aggregate size. Thus a mix containing a maximum aggregate size of three quarters (3/4) of an inch should be placed at least one and a half (1 1/2) inch thick. Lastly, cold mix temperatures, particularly when combined with a cold paver screed, can significantly affect the amount of tearing that occurs.

(b) Solutions

- A gearbox streak can usually be eliminated only by changing the amount of mix being forced under the screed at the auger gearbox. This change is made by installing reverse paddles or reverse augers on each side of the gearbox in order to push more mix under the gearbox. If the paver is already equipped with such devices, they should be checked to see whether they are worn and need to be replaced.
- Constant center or outside edge mat tearing can usually be eliminated by adjusting the relationship between the lead and tail crowns on the paver screed. If this change does not solve the problem, the setting of the paver flow gates should be modified. Full-width tearing can be eliminated by increasing the mix temperature, preheating the screed properly before paving starts, replacing warped or worn screed pates, or increasing the lift thickness.

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(c) Effects on Long-Term Pavement Performance

Tearing of the mat affects long-term pavement performance by causing changes in density in those areas where the tearing has occurred. Torn areas may appear segregated and are usually deficient in mix quantity. Pavement performance will be reduced in relation to the degree to which the tearing reduces the density and increases the air void content of the mat. In addition, the torn areas will be more susceptible to raveling and to the effects of moisture (stripping).

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Checking

Checking can be defined as short transverse cracks, usually one to three (1-3) inches in length and one to three (1-3) inches apart, which occur in the surface of the AC mat at some time during the compaction process. The checks are not visible immediately behind the paver screed. Rarely does checking occur during the first or second pass of the compaction equipment over the mat. If checking is going to occur, it will normally take place after the mix has cooled to a temperature of less than 240˚F and additional passes of vibratory or static steel wheel rollers (or both) are made over the mat. Checking does not usually occur when the mix is compacted with a pneumatic tire roller.

Most AC mixtures do not check at all during compaction, whereas others exhibit tender characteristics and check readily. As checking becomes severe, the cracks become longer and are spaced closer together. The cracks do not extend completely through the depth of the course, but are only three eighths (3/8) to one half (1/2) inch deep.

(a) Causes

- A mix that checks during compaction is a tender mix. The mix shoves or moves in front of the drums on either vibratory or static steel wheel rollers. Checks or cracks are formed when a bow wave occurs in front of the roller drums as the mix moves longitudinally before the roller reaches that location.
- Checking may be caused by two primary factors: (a) excessive deflection of the pavement structure under the compaction equipment and (b) one or more deficiencies in the asphalt mix design. A mix that checks is not internally table enough – does not have enough internal strength at elevated temperatures – to support the weight of the compaction equipment during the rolling process.
- When a yielding foundation is the cause of the checking problem, the underlying pavement on which the new AC layer is being placed is weak and yields under the movement of the compaction equipment. The weight of the rollers causes the layers in the pavement structure to move, shove, and bend excessively, placing the new mix in tension at its surface. The check marks are then formed when the surface of the new AC is pulled apart as the pavement structure deflects during the rolling operation. The checks should appear in the new mix surface only at locations where there is movement of the pavement structure under the compaction equipment. If the paver passes over a

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soft spot in the underlying structure, for example, the checking should occur only where the soft spot exists.

- A more common cause of checking is one or more deficiencies in the AC mixture: (a) an excess of fluids in the mix – too much asphalt cement or too much moisture in the mix, or both; (b) a hump in the sand gradation curve – too much midsize sand material and too little fine sand material and (c) a lack of room in the aggregate gradation for the asphalt cement (low VMA).
- An excess of fluids in the AC mix makes the mix tender and allows it to be displaced easily under the applied compaction effort of the rollers. The mix will be tender if the binder content is too high for the gradation and characteristics of the aggregate used, particularly if the mix has a low VMA content. If the mix contains too much moisture because the aggregate was not completely dried when passing through the batch plant drier or drum mixer (parallel flow or counter flow), the excess moisture will act as asphalt cement at elevated temperatures and over lubricate the mix. The moisture remaining in the aggregate pores will prevent the binder material from entering those pores in the aggregate in effect leaving more binder material between the aggregate particles instead of partly inside the aggregate.

(b) Solutions

- If checking is caused by the presence of a yielding foundation underneath the new AC layer, the solution is to repair and properly prepare the existing pavement structure before the new AC layer is placed. Soft spots should be removed and replaced. All areas of excessive deflection should be removed and replaced or stabilized. Uniform support is need in the underlying pavement structure if the new pavement layers are to perform adequately.
- If checking is caused by a deficiency in the mix design – an excess of fluids in the mix or a problem with the gradation of the fine aggregate or the VMA content of the mix – the long-term solution is to change the mix properties. Those changes must be made at the asphalt plant and cannot be made at the paving site. If the mix contains an excess of fluids – either asphalt cement or moisture – the binder content should be reduced or the aggregate properly dried to remove all of the moisture. In some cases, the production rate of the plant will have to be reduced for the moisture to be completely

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removed from the aggregate. In other cases, plant operating conditions may need to be changed (e.g., flights, drum angle).

- IF checking is caused by the gradation of the fine aggregate incorporated into the mix, the gradation should be changed. It may be necessary to increase or decrease the amount of fine aggregate used, add a small amount of fine aggregate with a different gradation, increase the angularity of the fine aggregate, or use a completely different material from a different source. If checking is caused by a lack of VMA in the AC mix, changes need to be made to increase the VMA.
- Checking is often thought to result from the mix being too hot. This is only partially correct; the mix is too hot at some temperatures to support the weight of the compaction equipment because the mix lacks internal strength and stability. If the mix were properly designed, it would not be too hot to be compacted at any temperature below about 300˚F. most checking occurs when the mix temperature is decreasing from about 240˚F down to about 190˚F; rarely does checking occur when the mix temperature is above approximately 240˚F or below approximately 190˚F.
- In the short term, changes in both the rolling zone and the type of rollers used to densify the mix can be made to reduce the amount of checking that occurs. If the mix is tender because of excess fluids, a problem with the fine aggregate gradation, or lack of BMA, it may be possible to densify the mix properly at an elevated temperature without causing the checking.
- A mix that checks is tender, but this mix can usually be compacted satisfactorily at high temperatures – above 250˚F. The required level of density can generally be obtained if enough roller passes can be applied to the mix before it cools to the point at which the checking begins. This can be done by suing two breakdown rollers instead of one – using two rollers operating in echelon (side by side) instead of using a breakdown roller followed by an intermediate roller. The two breakdown rollers each apply their compactive effort to one side of the newly placed lane. Many passes are made over each point in the pavement surface before the mix begins to check. Once checking starts the rolling process is temporarily suspended.
- If compaction operations are attempted when the mix is moving, shoving, and checking under the action of vibratory or static steel wheel rollers, the mix will decompact rather than compact. Rolling should not be carried out with steel wheel rollers when the mix is

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tender and checking. Most tender mixes will remain tender until the surface of the mix cools to a temperature of approximately 190˚F. AT this temperature, the mix has cooled sufficiently so that the viscosity of the asphalt binder has increased to the point where the mix can again support the weight of the compaction equipment. Static steel wheel rollers can then be used to achieve the final density in the mix and remove any roller marks in the pavement surface.

- When a tender mix is in the middle temperature range, between about 240˚F and 190˚F, rolling should not be attempted as discussed above, with either vibratory or static steel wheel rollers. A pneumatic tire roller, however, can be used in this temperature zone since the rubber tires on this roller will typically not shove the mix and a bow wave will not form in front of the tires. The tender mix will densify, instead of check, under the compactive effort of the pneumatic tire roller. Finish rolling using a static steel wheel roller can be completed once the mix has cooled to a temperature below about 190˚F.
- In most cases, when checking occurs in the mix, the roller operators tend to back off the mix and allow it to cool. This is the wrong approach to the problem. Delaying the compaction permits the mix to cool and stiffen but most often does not then allow enough time for the mix to achieve the required level of density. With a tender mix, it may not be possible to accomplish both objectives (no checking an adequate density) at the same time if the mix is allowed to cool before rolling operations if the mix is allowed to cool before rolling operations are stated. It is much better to compact the mix as much as possible before checking starts, stay off the mix in the middle temperature zone when checking is most likely to occur, and then finish roll the mix once it has cooled enough to support the weight of the final roller.
- If the mix delivered to the paver is too hot – above 325˚F – it should be allowed to cool after laydown before the compaction process is started. Improper rolling techniques should be corrected. The surface of the underlying pavement should be clean and properly tack coated before placement of the new mix begins.
- None of the solutions to the checking problem will work in all cases. Each mix will have its own compaction characteristics. For some extremely tender mixes, checking may occur at a wider range of temperatures, from as high as 270˚F down to as low as 170˚F. As noted, mixes that lack internal stability will generally check under steel wheel rollers

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(operated in either the vibratory or static modes) and thus these mixes should be redesigned.

(c) Effects on Long-Term Pavement Performance

Although checks extend only a short distance down from the surface, they are highly detrimental to long-term performance because the tender mix characteristics affect the level of density obtained. If the rollers are kept back from the paver in an attempt to decrease the amount of checking that occurs, the level of density obtained by the compaction equipment will normally be reduced significantly. Thus the air void content of the AC mat will increase. A mix that contains checks will therefore lack density and have a greatly reduced pavement life under traffic.

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Non-uniform Texture

Nonuniform mat texture can be described as differences in the appearance of the mix, both transversely and longitudinally, as it is placed and compacted. Normally, minor differences in surface texture will be apparent because of differences in the alignment of the larger coarse aggregate particles as the mix passes out from beneath the paver screed. In addition, a mix with a higher fine aggregate (sand) content will have a more uniform surface texture than a mix containing a larger percentage of coarse aggregate.

(a) Causes

- Many factors related to the operation of the asphalt paver affect the uniformity of the surface texture of the mix. A variable amount of mix against the screed, caused by overloading the augers or running the hopper empty between truckloads, can cause variations in the amount of mix tucked under the screed and thus produce a nonuniform texture. Improper screed maintenance, including worn or loose screed plates or screed extensions incorrectly installed, as well as low screed vibratory frequency, may alter the mat texture and cause nonuniformity. In addition, a low mix temperature, caused either by plant problems or by the paver sitting too long between truckloads of mix, can be a factor in uneven mat texture, especially if the paver screed is also cold. The tearing that results when the compacted layer thickness is less than twice the dimension of the largest aggregate particles (as discussed above) is still another contributing factor.
- A soft or yielding base under the course being constructed may cause the new layer to have a variable surface texture. Moreover, segregation of the mix caused by poor mix design or improper handling of the mix during mixing, loading, hauling, unloading, or placing operations can contribute to a nonuniform surface texture. The variability of the texture will be affected as well by any factors that cause nonuniformity in the mix, such as deviations in aggregate gradation, asphalt content, or mix temperature.

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(b) Solutions

- The solutions for nonuniform surface texture are as varied as the causes. Paver operation, particularly with regard to the need for a constant head of material in front of the screed, should be monitored closely. The paver and screed should both be well maintained and in good operating condition. The compacted thickness of the mat being placed should be designed so that it is at least twice the size of the largest coarse aggregate particles incorporated into the mix. Finally, a mix that is tender, variable in aggregate gradation or asphalt content or easily segregated should be modified to increase its stiffness and improve its properties before it is produced at the plant and delivered to the paver for laydown.

(c) Effects on Long-Term Pavement Performance

Nonuniform surface texture is usually associated with nonuniform density. The same compactive effort will generally achieve lower density in areas in which the coarse aggregate has been dragged by the paver screed or segregation of the mix has occurred, as compared with areas having uniform surface texture. As density decreases and air void content increases, the durability and serviceability of the asphalt mat decrease markedly.

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Screed Marks

Screed marks are transverse indentations in the surface of the asphalt mat. They occur when the paver stops between truckloads of mix. Depending on the mixture being placed, some screed marks are barely noticeable, whereas others are very distinct and deep. Screed marks can also occur in the longitudinal direction when rigid or hydraulic extensions are used and the elevation of the extension is not the same as that of the main screed.

(a) Causes

- There are several causes of transverse screed marks. One is excessive play in the mechanical connections on the screed. Such marks also result when the screed is set up incorrectly and rides heavily on its rear end. If the asphalt mix is tender and if the paver is equipped with a very heavy screed, such as hydraulic extensions with additional rigid extensions attached, the screed will tend to settle into the mix and leave marks. If any of these causes are involved, the screed marks will be visible each time the paver stops.

- Another cause is the haul truck bumping into the paver when preparing to discharge the mix or the truck driver holding the brakes on the truck when the paver starts to push the truck. In these cases, the screed marks will appear only when the truck – paver interchange is improper.
- Longitudinal screed marks are caused by improper setting of the screed extensions relative to the main screed. When extensions are used, their vertical position and angle of attack must be the same as those of the main screed. If rigid extensions are set at the wrong elevation, a longitudinal mark will occur at the point where the different screed sections are joined. If hydraulic extensions are used, two longitudinal marks may occur – one at the end of the main screed and one at the inside edge of the extension on each side of the machine.

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(b) Solutions

- If the transverse screed marks are a result of the mechanical condition or improper setup of the paver screed, the screed should be repaired. If the marks are caused by the truck bumping into the paver, the laydown operation should be altered so that the paver picks up the haul truck instead of the truck backing into the paver. In addition, once the paver has established contact with the truck, the truck driver should apply only enough pressure to the brakes to keep the truck in contact with the paver.
- In some cases, particularly if the mix is very tender, screed marks can be eliminated by not stopping the paver between truckloads of mix. This can be accomplished by using a window elevator or material transfer vehicle to deliver mix to the paver hopper. If dump trucks are used to haul the mix, however, it is generally better to stop the paver between truckloads of material (stopping and restarting the paver as quickly as possible) instead of allowing the paver operator to run the hopper dry, reduce the head of mix in front of the paver screed, and increase the opportunity for truckload-to-truckload segregation.
- To achieve uniform surface texture, the elevation and angle of attack of the screed extensions must be matched to those of the main screed. Longitudinal screed marks caused by improperly setting the elevation of the extensions can be eliminated by correcting the position of each extension relative to that of the main screed. Adjustments to both the vertical position and the angle of attack of the extensions may be needed. These adjustments should be made whenever hydraulic or rigid extensions are used.

(c) Effects on Long-Term Pavement Performance

Transverse screed marks generally are not detrimental to the durability of the mat. They may, however, affect the ride by creating a bump whenever the marks cannot be completely rolled out by the compaction equipment. In many cases, the screed marks have less of an effect o the performance of the mix than does the slowdown and startup of the paver when the operator attempts to keep it moving as the empty truck pulls away and the loaded truck backs into the hopper.

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Longitudinal screed marks indicate that the level of the mix under the screed extensions is different from that under the main screed. If the screed marks are severe, differential compaction may occur across the mark or “joint”, with the compaction equipment initially riding on the higher mat. The marks can leave a ridge in the mix if they cannot be completely rolled out.

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Screed Responsiveness

As the thickness control cranks on the screed are changed, the screed's angle of attack increases or decreases. As the paver moves forward to place the mix, the screed moves up or down to the new equilibrium point for the newly set mat thickness. When the screed fails to respond to changes in the setting of the thickness control cranks, the operator is unable to alter the depth of the layer being placed. The paver also loses its inherent ability, through the principle of the floating screed, to provide the self-leveling action needed to place a smooth asphalt mat.

(a) Causes

- An extremely high paver speed -more than eighty-three (83) feet per minute for thick lifts or more than fifty (50) feet per minute for layers more than two and a half (2.5) inches thick- may cause a lack of responsiveness of the screed. The mechanical condition of the screed affects its ability to react. The screed riding on its lift cylinders or loose connections on the thickness control cranks will cause the screed to be unresponsive. If automatic grade controls are used, an incorrect sensor location will render the screed unable to react to input signals from the grade sensors.
- If the maximum aggregate size used in the mix is too great compared with the depth of mix being placed, the screed will ride on or drag the largest aggregate pieces. As a result, the screed will be unable to change its angle and will thus be unresponsive to changes in the thickness control settings. Variations in mix temperature will also cause the screed to be unresponsive to changes in the angle of attack because the mix stiffness variations themselves will cause the screed to continually seek new equilibrium levels for the forces acting on it.

(b) Solutions

- The paver and screed must be in good operating condition. The sensor for automatic grade controls must not be located either at the tow points or behind the pivot points of the screed; rather, it should be located in the area between one-third (1/3) and two-thirds (2/3) of the length of the leveling arms. If the mix texture is uniform (indicating a proper relationship between course thickness and maximum aggregate size), the screed will be able to respond to changes in the thickness control settings.

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(c) Effects on Long-Term Pavement Performance

An unresponsive screed causes a rough asphalt mat. The screed is unable to react to manual changes in the thickness settings. It also loses its ability to self-level on an existing pavement surface because it cannot reduce the thickness of mix placed over the high points in that surface and increase the thickness placed in the low areas. Thus the ridability of the course being placed can be affected significantly if the paver screen is unresponsive.

Image below illustrates effect of improper Screed Temperature.

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Poor Precompaction

A modern asphalt paver is normally equipped with a vibratory screed. This type of screed allows the mix to be partially compacted as it passes beneath the screed. Depending on such variables as forward paver speed, layer thickness, mix temperature, and ambient environmental conditions, the density of the asphalt mixture measured behind the screed before compaction is usually in the range of seventy to eight (70-80) replace of the theoretical maximum density (a voidless mix).

A few pavers are equipped with combination screeds, which have both tamper bars and vibrators. At slow paver speeds, the combination screed typically achieves greater compaction of the mix than is obtained with the vibratory screed alone. At paver speeds greater than twenty five (25) feet per minute, however, the increased compactive effort achieved with the tamper bar is typically lost, and the degree of compaction obtained is similar to that achieved with a simple vibratory screed.

(a) Causes

- The amount of precompaction achieved with the screed decreases as the paver speed increases. Precompaction generally increases slightly as the frequency of the screed vibration increases. Precompaction decreases significantly, however, if the screed is riding on the screed lift cylinders, thereby limiting the available compactive effort. The level of precompaction obtained is also limited if the mat is too thin for the maximum aggregate size used in the mix (less than twice the largest size aggregate), if the mix being placed is too cold, or if the base on which the new layer is being laid is soft and yielding.

(b) Solutions

- Decreasing the paver speed and increasing the frequency of vibration of the screed should, within limits, increase the level of precompaction achieved during the laydown operation. It is also possible on some pavers to increase the amplitude of the vibration in order to increase the impact force of the screed on the mix. Proper maintenance of the screed helps as well in obtaining a uniform compactive effort form the screed.

(c) Effects on Long-Term Pavement Performance

As long as the required density level is obtained using conventional rollers behind the paver, the level of precompaction accomplished by the screed will not affect the long-term performance of

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the AC layer. It may be possible, however, to reduce the number of roller passes needed to meet the density and air void content criteria if the amount of precompaction obtained by the screed is higher. In addition, increased precompaction density can reduce the amount of differential compaction that occurs in low spots and rutted areas.

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Surface (Auger) Shadows

Surface (auger) shadows are dark areas that appear in the surface of an AC mix. In most cases, the shadows cannot be seen until sometime after the pavement has been used by traffic and some of the asphalt cement film has been worn off the exposed aggregate particles by the vehicle tires. Surface shadows are seen most easily when the sun is low on the horizon and the pavement is viewed when looking toward the sun. The shadows are also visible when the pavement surface is damp or when the surface is viewed from the shoulder of the roadway at night and vehicle headlights are shining on the surface.

In severe cases, surface shadows may be visible immediately behind the screed during the laydown operation. Even in this latter case, the shadows will disappear when the mix is being compacted by the rollers, only to be visible again later under the conditions described above. The shadows may be completely across the lane width being placed, or they may be only partially across the width. The extent of the shadows depends on how the paver is operated, particularly the portion of on to off time of the augers on each side of the machine.

(a) Causes

- Surface shadows are caused primarily by overloading of the augers on the paver. If the head of material in the auger chamber is large enough to “bury” the augers, the screed will react to the variable forces acting on it. The spacing between the shadows will normally correspond to the starting of the augers when operated in a stop/start manner. Whenever the amount of mix in front of the screed is at or above the top of the augers, the shadows will be formed and seen later in the pavement.
- On most pavers it is possible to adjust the distance between the screed and the tractor unit. This is accomplished by unbolting connections on the leveling or tow arms of the paver and moving the tractor forward (or backward) while the screed remains stationary on the pavement surface. Depending on the make and model of the paver, there is

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typically a four (4) inch length of slide for the screed connection. The severity of surface shadows may increase with the screed in the back position – when more mix is being carried in the auger chamber and the augers are being overloaded.

- The shadows are thought to be the result of a slight increase in mix density caused by the restating of the augers and the subsequent forcing of additional mix under the screed. There is no difference in surface texture associated with the location of the surface shadows; they can be seen only from an angle. Their intensity often increases when a tender mix is being laid.

(b) Solutions

- The AC mixture carried in the auger chamber should be maintained at a level near the center of the auger shaft. This means the flow gates should be set so that the augers operate as close to one hundred (100) percent of the time as possible and stopping and starting of the augers is minimized. In no case should the top of the augers be completely covered with mix. Further, the location of the screed should be set as far forward as possible so that the amount of material in the auger chamber is reduced and the head of material in front of the screed is kept to a minimum. The screed should not be set in the back position unless a large-stone mix one in which the maximum size of the aggregate is more than one and a half (1 1/2) inch is being placed.

(c) Effects on Long-Term Pavement Performance

Surface shadows are not necessarily detrimental to the performance of the mix, except for a minor effect on ridability. The difference in the density of the mix in areas with and between shadows is generally not great enough to be determined accurately. The main concern with surface shadows is the visual appearance of the mix to vehicle drivers.

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Joint Problems

Poor transverse joints are associated either with a bump at the joint, a dip in the pavement surface several feet beyond the joint, or both. Poor longitudinal joints between passes of the paver are usually characterized by a difference in elevation between the two lanes, by a raveling of the asphalt mix at the joint, or both. The area adjacent to the longitudinal joint is usually depressed below the level of the surrounding pavement surface.

(a) Causes

- Joint problems are caused by poor construction of the joint, inadequate compaction of mix placed along the joint, improper start-up procedures when paving resumes after a stoppage, or improper construction and removal of tapers.

(b) Solutions

- One key to a good transverse joint is to construct the joint at the end of the paving day at a location in the mat where the layer thickness is constant. This means the compacted thickness of the mat at the end of the paver run is the same as that of the previously placed mat.
- At the start of paving the following day, the paver screed should be placed on blocks on the cold side of the transverse joint. The thickness of the blocks should be related to the depth of the course being laid – approximately one quarter (1/4) inch thick for each one (1) inch of compacted layer thickness. The front edge of the paver screed should then be placed directly over the vertical face of the joint. Once the paver pulls away from the joint, the right amount of mix should be in the right place, and only minimal ranking, if any, normally needs to be done. The mix at the joint should then be compacted as quickly as possible.

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- For longitudinal joint construction, it is extremely important to compact the edge of the first lane properly. Doing so requires that the vibratory or static steel wheel roller hang out over the unsupported edge of the mat by about six (6) inches. This practice provides the most compactive effort along the unconfined edge without causing undue lateral displacement of the mix along the edge of the pavement.

- When placing the second (adjacent) pavement lane, the end plate on the paver screed should overlap the first lane by one to one and a half (1-1 1/2) inches. Minimal raking, if any, should be done on the mix placed over the first lane. The rollers – vibratory, pneumatic tire and static steel wheel – should operate on the hot side of the joint and extend over the joint on the cold side by approximately six (6) inches. The same number of roller passes should be made over the longitudinal joint as over each point in the interior of the AC mat.

(c) Effects on Long-Term Pavement Performance

A poor transverse joint will not affect pavement performance to any significant degree if proper density levels are obtained by the compaction equipment. A poor ride will usually be the only negative result. An improperly constructed longitudinal joint, however, can seriously decrease the serviceability of the pavement structure. A poorly placed and compacted joint will ravel and cause one side of the joint to be lower than the other. If the density level is too low, the

whole pavement layer thickness at the longitudinal joint may eat away under the action of traffic. A poor joint will also be porous, allowing water to enter the underlying pavement courses.

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Shoving and Rutting

Shoving of an AC layer is displacement of the mixture in a longitudinal direction. Such displacement may take place during the compaction operation or late under traffic. In most cases, shoving during construction is accompanied by a large bow wave in front of the breakdown roller, particularly if that roller is a vibratory or static steel wheel machine. Shoving may also occur in conjunction with mix checking if the mix is tender enough as a result of faulty aggregate gradation or excess fluids (asphalt binder or moisture) content. Finally, mat or mix shoving can occur at the reversal point of the rollers, especially at the location closest to the paver.

Rutting, shows displacement of the mixture in both vertical and transverse direction. Rutting occurs when heavy traffic passes over an unstable mix. In a few cases, the rutting is purely vertical (consolidation rutting). In this situation, the mix was not adequately compacted at the time of construction, and the traffic loads are essentially finishing the compaction process. The most common form of rutting is transverse distortion – the mix distorts or shoves transversely as a result of lateral flow of the mix under applied traffic loads.

(a) Causes

- Shoving and rutting are due primarily to an unstable AC mixture. This instability can be caused by the same variables that are responsible for checking – an excess of fluids (asphalt binder or moisture) in the mix, a hump in the fine aggregate grading curve, or the properties of the aggregate and the asphalt cement. A mix that has a high Marshall or Hveem stability may still distort longitudinally under the compaction equipment and later both longitudinally and transversely under traffic. Shoving and rutting can be highly prevalent when a sand mix is placed in a thick layer (more than one and a half (1 1/2) inch at a high temperature (more than 280˚F). Further, thicker lifts in proportion to the maximum-size aggregate used in the mix will tend to shove more than thinner lifts with the same aggregate size and grading.
- Improper roller operation, particularly sudden reversal of the roller, can also contribute to the shoving of the mix during construction. If a vibratory roller is

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run at too great a speed and the impact spacing is too far apart, the mat may develop a washboard effect, where the peak-to-peak distance is equivalent to impact spacing. Washboarding or shoving is more likely to occur at normal frequencies but at high speeds where the impact force is greater. If a pneumatic tire roller with high tire pressure is used for breakdown compaction, a tender mix may shove laterally under the tires. Shoving can occur under any roller that is operated improperly.

- Another possible cause of shoving is an excess of tack coat material that may be pulled into the mix. In a similar manner, excess asphalt from a bleeding underlying surface or from joint filler material can be pulled into the mix and increase its fluidity and tenderness. Shoving may occur as well when the underlying surface is dusty or dirty – a slippage failure.

(b) Solutions

- The solution to a mix that shoves under the compaction equipment is to increase its internal stability. This can be accomplished by reducing the fluids content (asphalt or moisture or both) of the mix, but only after determining the effect of a change in asphalt binder content on the mechanical properties of the mix. The internal friction can be increased by lowering the mix temperature. Alternatively, the internal friction among the aggregate particles can be increased by changing the aggregate gradation or increasing the amount of angular (crushed) particles in the mix.
- The compaction process for a tender mix should be changed, as discussed above under checking, to obtain sufficient density at the time of construction. An increase in the density achieved during the construction process will generally reduce the amount of shoving and rutting that may occur later under applied traffic. Sand mixes, because of their inherent tender nature, should be placed in several thin layers instead of one thick layer when used as base or binder courses.

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- The compaction equipment should be operated properly so as to reduce the opportunity to displace the mix during the rolling operation. Further, if the underlying pavement surface is dirty, it should be cleaned and a proper tack coat applied.

(c) Effects on Long-Term Pavement Performance

Mats that tend to shove under the compaction equipment are basically unstable. These mixtures will usually continue to distort under traffic, both longitudinally and laterally. Shoving of the AC mixture during construction is a strong indication that the pavement will rut later and not perform properly under traffic.

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Bleeding and Fat Spots

Bleeding of an asphalt mixture occurs when the asphalt cement flows to the top of the mix surface under the action of traffic loading. Bleeding is often seen as two flushed longitudinal streaks in the wheel paths of the roadway. Fat spots in an asphalt mixture are isolated areas where asphalt cement has come to the surface of the mix during the laydown and compaction operation or later under traffic. These spots can occur erratically and irregularly, or they may be numerous and in a fairly regular pattern.

(a) Causes

- Fat spots are caused primarily by excessive moisture in the mix. The problem is more common with mixtures that contain a high percentage of fine aggregate (oversanded mixes) and those that contain aggregates with a high porosity. If all the moisture in the coarse and fine aggregate is not removed during the drying and nixing operation at the asphalt plant, the moisture vapor will force asphalt cement to the surface of the mix behind the paver as the moisture escapes from the mix and evaporates. Fat spots occur more frequently when aggregate stockpiles are wet or when the moisture content varies in different portions of the stockpiles. Fat spots sometimes occur in areas where petroleum products, such as oil and diesel fuel, were spilled onto the pavement surface prior to overlay or have contaminated the mix. In addition, fat spots can be associated with segregated areas in the mix. If the mix deposited on the roadway by the paver is segregated, areas in which excess asphalt cement is present in the mix can result in free finder material on the top of the layer being placed.

- The causes of bleeding normally fall into two categories. The first is an excess of fluids in the asphalt mixture – either asphalt cement or moisture or both. Under traffic, the extra moisture and asphalt cement will be pulled to the surface by the passage of vehicle

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tires. This bleeding phenomenon usually occurs on new mix and during hot weather when the viscosity of the asphalt cement is at its lowest level. Typically the bleeding occurs shortly after traffic is allowed to travel over the fresh mix – while there is still some moisture in the mix and while the viscosity of the asphalt cement binder is still relatively low.

- Bleeding may also be associated with a lack of adequate space in the mix for the asphalt cement. If the VMA content and air void content of the mix do not provide enough room for the binder material, bleeding can occur as the mix is densified by traffic, both shortly after construction and later. The traffic compaction process will decrease the air void content of the mix and may, in turn, squeeze some of the asphalt cement out of the mix. The "extra" asphalt will appear as a longitudinal streak or fat spot throughout the length of each wheelpath.
- One additional possible cause of bleeding is the condition of the pavement layer on which the new mix is placed If the underlying

(b) Solutions

- Variations in the asphalt mix temperature behind the paver indicate that the moisture content of the mix may also be variable. Where moisture has evaporated, the temperature is lower. This latter phenomenon can contribute to both the bleeding of the mix during construction. It is important, therefore, that the aggregate used in the mix be relatively dry and that the moisture content of the mix upon discharge from the asphalt plant be as low as possible, but not more than half of one (0.5) percent. Extra care needs to be taken in drying when producing mixtures that incorporate highly absorptive aggregate.
- Bleeding problems caused by excess asphalt cement in the mix can most easily be solved by reducing the asphalt content, consistent with other properties of the mix, such as air voids, VMA, and strength or stability. Bleeding problems that occur in

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conjunction with pavement rutting usually can be solved, however, only by a complete redesign of the asphalt mixture, with emphasis on proper air void content and VMA criteria.

(c) Effects on Long-Term Pavement Performance

Occasional fat spots in the mix should not affect the ultimate durability of the pavement to a significant degree. A large number of fat spots or bleeding in the wheelpaths does affect pavement performance, however, because of variable asphalt and air void content in different parts of the mix. In addition, other mix problems, such as shoving, rutting and loss of skid resistance, may occur in a mix that contains many fat areas or bleeding in the wheelpaths. The design of the asphalt mixture, the operation of the asphalt plant (more complete removal of moisture), or both should be checked to ensure that the mix produced will provide adequate pavement performance under vehicular loading.

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Roller Marks

During the compaction process – whether vibratory static steel wheel or pneumatic tire rollers are used – longitudinal creases or marks are left in the surface of the mix. Once the mix has cooled to a temperature range of 160˚F-140˚F, these marks are typically removed by the finish roller. Roller marks are indentations that remain in the surface of the mix after the rolling has been completed.

Roller marks may also exist in the asphalt surface when any roller is parked on the hot mat for a period of time or when a vibratory roller is vibrated in place. Particularly when used in the breakdown position, pneumatic tire rollers can leave visible longitudinal marks that can still be seen after the finish rolling has been completed. Vibratory washboard marks may be visible if that roller is operated at an improper vibratory amplitude, frequency setting, or speed.

(a) Causes

- Roller marks can be an indication that the proper number of roller passes has not been made over the mix. If the compaction process is halted before the required amount of rolling has been completed or if the mix cools before the compaction process has been finished, the longitudinal marks or creases made by the rolling process will remain in the surface of the mix.
- Roller marks left in an asphalt layer also may indicate a tender mix. The roller operator will normally be unable to remove all the marks left by the compaction equipment if the mix is tender or unstable. A tender mix usually will not support the weight of the finish roller until it has cooled to the point at which the viscosity of the asphalt cement has increased enough to stiffen the mix. By the time the mix has decreased in temperature to this point, however, the required level of density can generally no longer be achieved because the mix has lost its workability. For this reason, the roller marks or indentations left during the breakdown and intermediate roller passes usually cannot be removed during the finish rolling process. All of the asphalt cement, aggregate, and mix properties that contribute to the formation of a tender mix, as discussed above, also contribute to the inability of the finish roller to eliminate roller marks.

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(b) Solutions

- If the cause of roller marks is inadequate compaction, additional roller passes should be made with the breakdown, intermediate, or finish rollers to properly densify the mix. The solutions for inadequate compaction related to mix design deficiencies all involve changes to the mix design and to the production of the mix at the asphalt plant. Asphalt cement quality and content, aggregate properties and characteristics, and mix temperature all play a significant role in the workability and stability of the asphalt material under the compaction equipment. Roller marks normally cannot be removed from a tender mix until the mix temperature has decreased to a relatively low level – usually less than 160˚F.
- Sometimes it is possible, depending on environmental conditions and the properties of the mix, to remove roller marks left in the mix by using a pneumatic tire roller. If the surface of the mix is hot enough (140˚F) or more, several passes with a pneumatic tire roller can be made to "iron out" the surface of the pavement. Finally, roughness or washboarding caused by incorrect operation of a vibratory roller should be eliminated by using proper operating techniques with this equipment.

(c) Effects on Long-Term Pavement Performance

Roller marks are normally an indication that the proper level of compaction has not been achieved. In terms of ultimate paving durability, the air void content or density of the mix is the single most important characteristic that governs the performance of the asphalt mixture under traffic. If the air void content of a dense-graded mix is high – the density is too low – the pavement generally will not perform well under traffic.

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Segregation

Segregation is the separation of the coarse aggregate from the rest of the mix in an AC mix. Segregation results from mishandling the mix at any of several points during the mix production, hauling, and placing operations. When segregation occurs in a paving project, it is likely to lead to forms of long-term pavement distress such as wavy surface and poor compaction. It can occur as the mix is delivered from the asphalt plant to a surge silo, as the mix is deposited into the haul truck from the silo, and as the mix is discharged from the truck into the paver hopper. Segregation that is evident behind the paver screed generally takes one of three forms: it may consist of areas of coarse aggregate (rock pockets) that occur randomly across the length and width of the layer; it may occur at a transverse location across the width of the lane (truckload-to-truckload segregation); or it may occur along one side of the paver width (longitudinal or side-to-side segregation).

(a) Causes

- The cause of segregation behind the paver is directly related to the type of segregation involved. Rock pockets are generally caused by improper handling of the aggregate in the stockpiles, cold-feed bins or storage of the AC at the asphalt plant. They seldom occur when a batch plant is used to produce the mix (without a silo), because the screens and hot bins in the plant recombine any segregated material before it is fed into the pugmill. Further, the pugmill blends all the aggregates together and normally eliminates any segregation that might have occurred previously. If a silo is used on a batch plant, however the mix may segregate for all the same reasons that affect a mix produced in a drum-mix plant and passed through a surge or storage silo.
- Rock pockets and random segregation are occasionally found on the roadway when the mix was manufactured in a drum-mix plant. If the loader operator places a bucketful of segregated aggregate in a cold-feed bin, that material can pass through the drum, surge silo, haul truck and paver without being completely mixed in with the other aggregate. This I because the drum-mix plant operates on a continuous-flow instead of a batch

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basis. If the aggregate in the cold-feed bins is segregated, that material will show up on the roadway in a random pattern both transversely and longitudinally.

- Some mixes are more prone to segregation than others. Asphalt mixes that have large maximum size coarse aggregate (1in. or greater), have low asphalt cement content, or are gap-graded will tend to segregate more readily when handled than a dense-graded mix containing optimum asphalt content and a smaller maximum-size coarse aggregate.
- Segregation that occurs on one side of the paver (side-to-side segregation) when a batch plant without a silo is used to produce the mix is normally caused by improper loading of the haul truck from the pugmill. If the mix is not loaded in the center of the width of the truck bed, the coarse aggregate particles in the mix may roll to one side of the truck and accumulate along that side. When the mix is delivered to the paver hopper, the segregated mix will be placed on the roadway along the same side, and the segregation will appear as a longitudinal streak on one side of the paver only.
- Segregation that occurs on one side of the paver when a batch plant with a silo or a drum-mix plant is used to produce the mix is typically caused by improper loading of the mix into the surge silo. As the mix is deposited into the silo from the conveying device (slat conveyors, belt conveyor, or bucket elevator), the mix is thrown to one side of the silo, and the coarse aggregate particles are separated from the finer materials. When the silo is emptied, the coarse aggregate is deposited on only one side of the truck. This segregated material then passes through the paver and is seen on one side of the mix after laydown. Further, as with a batch plant, if the truck is not loaded in the center of its width under the silo, rolling of the coarse aggregate particles may occur, and longitudinal segregation will then appear on one side of the new mat.
- Truckload-to-truckload segregation has many potential causes. The most common is improper loading of the haul truck from the silo. If mix is placed in the truck bed in one drop from the silo, the coarse aggregate particles in the mix have a tendency to run to both the front of the bed and the back tailgate. This rolling of the coarse aggregate is exacerbated if the plant operator continuously opens and closes the silo gates near the end of the truck-loading procedure to ensure that the full weight of mix is placed on the truck.
- Some believe that truckload-to-truckload segregation can also be caused by improper discharge of the mix into the silo. Mix that is dribbled into the silo from the conveying

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device is said to be susceptible to segregation inside the silo. Even if this occurs, the mix that is segregated in the silo will appear only as random rock pockets in the layer behind the paver, instead of in a systematic manner between truckloads of mix delivered to the paver. Thus it is doubtful that any segregation of the mix that occurs during the continuous process of loading the silo will appear on the roadway in a discontinuous pattern – only at the beginning or the end, or both, of a truckload of mix.

- Temperature segregation of the mix has also been shown to be a problem. The mix cools more quickly near the edge, bottom, and top of the truck during haul. This cooler material is not always remixed with the hotter HMA, leading to temperature segregation during the laydown operation. The result can be more variability in density during construction and a nonuniform surface. This problem can be monitored by infrared technology.

(b) Solutions

- The solution to each type of segregation is related to its cause. For random rock pockets that appear intermittently in the mat, the method of stockpiling the coarse aggregate at the asphalt plant and the charging of that material into the cold-feed bins by the front-end loader should be checked to ensure that proper aggregate handling techniques are used. Further, all points in the mix-production system at which coarse aggregate particles might accumulate should be inspected to determine whether the flow of the coarse and fine aggregate pieces is uneven. A batcher should be used at the top of the silo to direct the mix into the center of that piece of equipment.
- For longitudinal (side-to-side) segregation, the loading of the haul truck from the batch plant pugmill or from the silo at either the batch or drum-ix plant should be monitored to ensure that the mix is being delivered into the center of the width of the vehicle. When a drum-mix plant is used to manufacture the mix and the segregation plant is used to manufacture the mix and the segregation always appears on one side of the paver, several trucks should be loaded at the silo while facing in the opposite direction from their normal loading procedure. When the mix is passed through the paver, the longitudinal segregation should change sides – go from one side of the paver lane to the other. If the transverse position of the longitudinal segregation does change (and it should), the solution to the side-to-side segregation problem must take place at the top

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of the silo. The mix deposited into the silo from the conveying device must be directed into the center of the silo instead of to one side, so that the coarse aggregate particles in the mix are not thrown to only one side of the silo. IF the transverse position of the longitudinal segregation does not change, the segregation is probably caused by a paver problem.

- Most truckload-to-truckload segregation can be reduced significantly by using multiple drops of mix to load the haul trucks. If a tandem-axle truck is being loaded, at least three different drops of mix should be made – into the front of the truck near the front bulk – head, into the back of the truck near the tailgate and into the center of the truck bed between the first and second drops. If a larger truck is used, additional drops of mix should be made – the first into the front of the truck bed and the second near the tailgate. One of the main solutions for truckload-to-truckload segregation is to minimize the distance the coarse aggregate particles can roll. This is accomplished by making multiple drops of mix into the truck.
- The plant operator should be prohibited from topping off the load of mix at the end of the loading process. Each time the silo gates are opened and a little bit of mix is dribbled into the truck, the coarse aggregate particles will tend to separate from the finer material. This problem can be eliminated only be preventing it from occurring.
- If segregation does take place during the loading of the truck and there is an accumulation of coarse aggregate particles at the tailgate of the truck, at the front of the bed, or both, the amount of segregation that appears on the roadway can usually be reduced by proper unloading of the haul truck at the paver. First, the truck bed should be raised a short distance, before the tailgate of the truck is opened, so that the mix can shift in the bed and slide against the tailgate. This procedure surrounds any coarse particles that have rolled to the tailgate are with non-segregated mix. Instead of only the coarse aggregate being deposited first into the paver hopper, a mass of mix is discharged when the truck tailgate is opened, flooding the hopper with mix and typically incorporating the segregated coarse aggregate into that mass of AC mix.
- The operation of the paver can also increase or reduce the amount of segregation that occurs behind the screed. If the paver hopper is emptied of mix, if the slat conveyors are visible, and if the wings of the hopper are dumped after each truckload of mix, any coarse aggregate particles that have collected at the tailgate of the next truckload of

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mix will be deposited into the bottom of the hopper and then carried directly back to the empty auger chamber in front of the screed. This segregated material will appear behind the screed as soon as the paver moves forward. This transverse segregation, therefore, does not really occur at the end of the truckload, but rather at the beginning of the next truckload of mix.

- Segregation can be reduced by keeping the hopper full of mix between truckloads. The mass of mix that floods the hopper from the haul truck will be blended with the mix already in the paver hopper. Any segregated material will be further incorporated in the mix that is pulled back to the augers by the slat conveyors and passed under the paver screed. The amount of truckload-to-truckload segregation can be decreased significantly, but not always eliminated completely, by good paver operating techniques. The problem should really be solved during the truck-loading procedure.
- The use of MTV's has also shown some benefit in reducing segregation. The MTV remixes the HMA, and this reduces aggregate segregation, as well as differential temperatures within the mix (also known as temperature segregation).

(c) Effects on Long-Term Pavement Performance

Segregation can affect pavement durability directly by increasing the air void content of the mix in the segregated areas and increasing the potential for moisture damage. Further, the segregated locations are very susceptible to raveling and, if bad enough, to total disintegration under traffic. Segregation, whether in the form of rock pockets, longitudinal (side-to-side) segregation, or transverse (truckload-to-truckload) segregation, is extremely detrimental to the long-term performance of the pavement.

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Poor Mix Compaction

The AC mixture should be compacted so that the in place air voids are at an acceptable level. If the air voids are above seven to eight (7-8) percent, the mix will be permeable to air and water and will not have the required durability. If the initial compaction results in air voids of approximately 4replace or lower, the mix may become unstable under traffic after additional densification; the result will be shoving and rutting of the mixture. Most mixes require a significant level of compaction to reach the desired 7-8replace or less air voids.

(a) Causes

- When the mix is too stiff or too tender, compaction is difficult. The primary cause of poor compaction is low design mix density (high design air voids). Other causes include inadequate underlying support, improper type and weight of rollers, improper tire pressure in rubber tire rollers, improper rolling procedure, improper mix design, mix segregation, moisture in the mix, variation in mix temperature and low mix temperature.

(b) Solutions

- Solutions to compaction problems include taking the necessary steps to ensure adequate support, producing an acceptable mixture and using satisfactory laydown and rolling techniques. When support is inadequate, the compaction requirements may have to be relaxed, or the mix may have to be redesigned to allow for satisfactory compaction.
- When asphalt content is too high, the mix may compact too easily, resulting in low air voids (which leads to rutting). When the asphalt content is too low, the mix may be stiff and difficult to compact to the specified density. A satisfactory mix design will produce a mix with optimum asphalt content that can be compacted with reasonable effort to required density
- Good laydown and rolling techniques are necessary for good compaction. Density can normally be increased by reducing the speed of the paver or rollers. Density can also be increased by increasing the weight and number of rollers. The compaction process must be adjusted to produce optimum density.

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(c) Effects on Long-Term Pavement Performance

When the compaction is inadequate -more than seven to eight (7-8) replace air voids- the mix will be permeable to air and water. Water can flow through the AC and reduce the strength of the underlying base course. The high voids also result in excessive oxidation of the HMA, which leads to raveling, cracking and general deterioration of the AC over a period of time.

When the air voids are excessively low after compaction (less than 4replace) the mix is likely to rut and shove under traffic. The low voids are the result not of too much compaction, but of an unsatisfactory mixture.

Poor Roller Operation

Poor Roller Operation can also lead to mat problems. Images below reflect improper or poor roller operation.

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8 Inspection and Quality Assurance

Learning Outcomes:

- ☑ Understand and follow project plans and specifications.

Inspection Objectives:

- ☑ Ensure cross-section of roadway constructed to specified elevations and template prior to application.
- ☑ Ensure existing surface is prepared properly.
- ☑ Ensure new material is delivered to the project site within specifications.
- ☑ Ensure proper density is obtained.
- ☑ Ensure the quality assurance program is executed.

As representatives of VDOT (consultant or inspector) and the paving contractor, it is important to be familiar with the VDOT Road and Bridge Specifications as well as Special Provisions that are found in the contract. In addition, the VDOT field representative and contractor play a vital role in the execution of the Quality Assurance Program (QAP). The QAP focuses on the processes, procedures and individuals responsible for accepting asphalt concrete (AC) in the field. This chapter will cover the key aspects of inspection and QAP.

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Construction Inspection

The Construction Inspector performs a vital service for the Virginia Department of Transportation (VDOT). The placement of AC materials is a high cost operation and when constructed correctly will provide a smooth durable riding surface that will last ten to twenty years or longer. Pavement life depends on proper construction. Placement of the subbase, base material and paving materials, along with proper drainage all have an effect on the life of the riding surface. An improperly constructed AC pavement will result in a shorter life with increased maintenance and user costs.

A certain amount of commitment is required from VDOT personnel and the Contractor in order to obtain quality inspection and construction practices. VDOT personnel must be knowledgeable about paving practices and be able to provide timely decisions so that the Contractor's work is not delayed.

The Inspector and the Contractor need to be able to communicate effectively, and must have a common goal of end result construction being in conformance with the contract, plans, standards and specifications.

The Inspector must ensure the project plans and specifications are being followed. It is also important for the Contractor to provide competent personnel on the project and keep the Inspector informed of any scheduling changes that might affect the inspection process.

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Specification Practice

Below is an exercise in looking up specifications. All answers can be found in VDOT Road and Bridge Specifications Section 315 – Asphalt concrete Pavement and Special Provisions located in the Appendix of this document.

1. What section is equipment for asphalt concrete pavement found?

2. What is the equipment and application requirement for tacking joints? What section is this found in?

3. In section 315.05(d) the compacting sub-section of Procedures states, "Rolling shall not cause _____".

4. The variation of the surface from the testing edge of the straightedge between any two contacts with the surface shall not be more than _____. This is found in Section _____.

5. How much should a longitudinal joint in one layer be offset form the layer immediately below? What section is this found in?

6. What is the pay unit for asphalt concrete material? This is found in what section?

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Site Preparation

The first step in the paving process is ensuring the site is prepared properly. For new construction, site preparation includes the subgrade, subbase and base installation. The subbase and base will include either a chemically stabilized soil layer, an aggregate layer or a cement treated stone layer. The specifications regarding these operations are covered in other training materials and the VDOT specifications book. Once these layers are constructed, AC layers are laid to the depths and application rates called for in the contract.

With maintenance and rehabilitation projects, the existing pavement is the platform for laying new AC layers. The existing surface is either overlaid with AC or is milled and replaced with a new AC layer or layers. Like the base layer for a new construction project, the existing pavement platform must be prepared properly.

Repairs

In many cases, the existing pavement will be overlaid as part of a maintenance or rehabilitation project. If the existing pavement has cracks or potholes, it should be repaired prior to placement of the AC layer. The process to repair cracks is specified in *Special Provision for Sealing Cracks in Asphalt Concrete Surfaces or Hydraulic Cement Concrete Pavement*.

Unrepaired pavement failures will lead to future failures in the new AC layer(s). When not included as a contract quantity, the *Special Provision for Surface Preparation and Restoration Prior to Plant Mix Overlay* is typically included in contracts. The VDOT inspector can call for a Type I, Type II or Type III repair. Each type is separated by size of the area to patch and the depth of the patching.

Clean Surface

Prior to laying AC on an existing surface, it shall be cleaned properly. This means loose material must be swept, vacuumed or washed from the roadway. Loose material prevents the bonding of the new AC to the existing surface.

Milling

When the pavement surface is milled, the inspector must check the following:

1. Uniform Milled Surface – during the milling process, it is important that scabbing is avoided. Scabbing is caused when the milling machine is travelling too fast, the milling teeth are worn, or

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the incorrect depth is being milled or was specified in the contract. Milling is covered in Section 515.

2. Drainage – when roadways are milled, maintaining proper drainage is critical for safety. Section 315.05(c) paragraph 10 outlines the requirements.
3. Clean Surface – as will a straight overlay, the milled surface must be cleaned prior to application of the tack coat and AC layer. Cleaning is done with a broom and vacuum truck typically.
4. Performance Milling – for roadways with speed limits of 55 mph or higher, the contractor has the option to performance mill the surface in order to increase the amount of milling that can be exposed to traffic. Performance milling is done with a milling head that results in a surface with a smaller ridges and closer grooves when compared to a conventional milling head. The maximum mean texture depth (MTD) for performance milled surfaces is 2.0 mm.

Tacking

Tack coats provide the glue that holds the different AC layers together. Per Section 315.05(b), all AC layers are to be tacked. VDOT uses conventional and non-tracking tack coats. Tack coat materials must meet the requirements in Section 310 or the *Special Provision for Non-Tracking Tack Coats.*

For conventional tack coats, the application rate is 0.05 to 0.10 gal/sy for the mainline surface if the material is not diluted. If the tack coat is diluted with water, then the application rate increases to 0.10 to 0.15 gal/sy. When a non-tracking tack coat material is used, then the contractor shall follow the manufacturer's recommendations. Typically, this rate is between 0.05 and 0.10 gay/sy.

During the application of the tack coat, the material shall be spread uniformly using a pressure distributor meeting the requirements of Section 314.04(b).

Longitudinal and transverse joints require extra tack coat material. This extra material is used to improve the final AC density. Per Section 315.05(b)1, the application rate shall be 0.20 gal/sy. Tack can be applied with a hand wand or pressured distributor and shall be two feet in width for the first pass. At least 4 to 6 inches of tack should be applied beyond the edge of the joint. For the adjacent pass, the vertical face of the joint should be covered with puddling at the bottom. The tack should extend 1 foot into the lane to be paved. When milling occurs and the vertical face is to remain, the same tacking should occur. When the milled face will be removed, the tacking should still extend 1 foot into the lane to be paved. However, when paving in echelon, tacking of the longitudinal joint is not required.

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Mix Delivery

The quality of the AC material can be impacted by numerous steps in the paving process. Once the material is produced at an AC plant, it is loaded into trucks for delivery to the site. Within the VDOT specifications, the trucks must meet the following requirements found in the Special Provision for Section 315.03(a):

1. Smooth, tight, and clean beds – metal or a non-absorptive/inert material
2. Release agent from the Department's Approved list 8, lime solution or a aliphatic hydrocarbon invert emulsion shall be used (NO DIESEL FUEL)
3. Tarpaulin or other cover to protect the load from moisture, foreign material and rapid heat loss. The tarp/cover cannot have holes, must cover the entire load, and cannot be a mesh.

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INSPECTION AND MEASUREMENTS

Pre-loading Inspection of Bed

The bed of the haul truck should be free of all deleterious materials before mix is placed in it. The bed should be reasonably smooth and free from any major indentations or depressions where the truck bed release agent and the AC can accumulate.

Describes inspection, Quality Assurance and/or Quality Control practices.

Once at the project site, the AC mix may be discharged directly into the paver or it may be discharged into a material transfer vehicle (MTV). The use of the MTV is at the option of the contractor unless specified in the contract. For mixes such as stone matrix asphalt and porous friction courses, the MTV is a requirement. The MTV and paver must have a minimum 15 ton capacity and the ability to remix the AC mixture. This can be done in the MTV or in the paver insert.

Before the entire load of mix is discharged, the inspector should ensure:

1. The minimum base temperature exists. This is the temperature of the platform on which the AC will be laid. If the platform is too cold, then it will rob heat from the mix and make compaction difficult. Depending on the mix type, the minimum base temperature varies. There is no maximum base temperature.
2. The right mix has been delivered to the project. Some plants will run numerous mixes during a shift; therefore, check the job mix number and type.
3. The AC mix temperatures must be within specification. For AC produced with a warm mix technology, no minimum temperature exists. The maximum temperature for non-polymer modified mixes is 350F. For polymer and other modified mixes, the maximum temperature is set by the supplier. AC produced by traditional plant temperatures and processes, the temperature ranges are set by Section 315.04 and the Special Provision for Section 315.04.

INSPECTION AND MEASUREMENTS

When mix is delivered to the job site, three items must be checked.

1. First, is the base temperature at or above the minimum?
2. Second, is the right mix being delivered to the right job site?
3. Third, is the mix being delivered at the correct temperature?

Describes inspection, Quality Assurance and/or Quality Control practices.

When the base temperature is between 40°F and 80°F and a warm mix asphalt technology is not used, the Nomograph (Table III-2) found in Section 315.05 shall be used. The minimum base and lay down temperatures shall not be less than the following:

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PG Binder/Mix Designation	Percentage of Reclaimed Asphalt Pavement (RAP) Added to Mix	Minimum Base Temperature	Minimum Laydown Temperature
PG 64-22 (A)	≤ 25%	40°F	250°F
PG 64-22 (A)	≥ 25%	50°F	270°F
PG 70-22 (D)	≤ 30%	50°F	270°F
PG 76-22 (E)	≤ 15%	50°F	290°F
PG 64-22 (S)	≤ 30%	50°F	290°F

Stone Matrix Asphalt (SMA) shall be placed only when the ambient and surface temperatures are 50°F or above when a warm mix technology is not used. The mixture temperature in the truck shall not be less than 300 °F for mixtures containing PG 70-22 and 310 °F for mixtures containing PG 76-22.

The process to take the temperature measurements is described in detail in Section 501.02 of the Materials Division Manual of Instructions. In summary, the Project Inspector shall make a temperature measurement at the beginning of paving operations and every hour after the initial temperature check. When measurements are found to be outside of the temperature tolerances, a minimum of 3 additional measurements will be taken from different points of the load. The 4 readings will then be averaged and used as the temperature of the load or batch. All temperature measurements and the average shall be recorded.

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Mix Placement

Once the mix is in the paver hopper, the operation of the paver is governed by Section 315.03(b) and 315.05(c). For new construction, the contractor is to use a continuous line for steering the paver. On maintenance and rehabilitation projects, the contractor is able to follow the edge of pavement, stripping, or other continuous lines.

As the paver pulls away from the joint, the inspector will verify the smoothness of the compacted joint per Section 315.07(a). Other items for the inspector to check are:

1. Are the longitudinal joints offset by 6”?
2. Is a certified AC Technician for the contractor on site if more than 100 tons of mix will be placed at the location?
3. Are shoes or skis being used on the paver?

Observations by Inspector
▪ Verify head of material at the auger – should be maintained at center of auger shaft for consistent mat thickness ▪ Augers should be turning slowly and consistently approximately 100% of the time ▪ Verifying material thickness behind screed by sticking the mat ▪ Placement of straightedge behind screed, parallel to the screed to verify correct cross-slope ▪ Minimizing folding of hopper wings to every third or fourth load ▪ Uniform mat appearance behind the screed to minimize streaking
Describes inspection, Quality Assurance and/or Quality Control practices.

Joint Construction Inspection

The proper construction of the longitudinal and transverse joints is essential. For longitudinal joints, proper tacking and compaction is needed to keep water out. Transverse joints constructed poorly will lead to dips and bumps in the final mat.

INSPECTION AND MEASUREMENTS
Inspection Items: ▪ Surface Tolerance for Transverse Joints using 10 feet Straight-edge ▪ Proper tacking of longitudinal and transverse joints ▪ Proper taper length for temporary transverse joints ▪ Proper rolling procedures for Joints
Describes inspection, Quality Assurance and/or Quality Control practices.

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Compaction Inspection

For mixes where a minimum density requirement exists, the inspector must ensure the roller pattern is followed. The process to establish a roller pattern will be covered in the Density Chapter. In addition to the roller pattern, other aspects of the compaction process must be inspected. For SMA, the contractor is allowed a maximum of three vibratory passes at the higher frequency and lowest amplitude. For all AC mixes, the roller operator should roll toward the crown in the road or to the high side of the super-elevation. Once the first pass is compacted on a roadway, adjacent passes are to be rolled toward the cold or confined joint. Each rolling pass should overlap the previous pass by a minimum of 6 inches. And for SMA, the maximum roller speed is 3 miles per hour.

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Density Inspection

When the contractor is laying AC, the inspector must know the proper specifications to follow. The specifications vary based on the project characteristics. There are three common projects – thin overlays, small quantities, and large quantities. For thin overlays, defined as application rates of 125 lbs/sy or less, no density cores are required. All acceptance is based on establishing a roller pattern and control strip. The average density for the 10 random stratified locations becomes the target density during compaction. For each sublot and lot, the averages must be within 98% and 102% of the target. The same approach is followed when the AC overlay is placed on an existing surface treatment.

Small quantity contracts can be comprised of pavement patching, trench widening, and certain construction projects. For each contract, the quantity of AC is too small for establishing a roller pattern and control strip. Therefore, the contractor uses a combination of experience with the AC mix and the nuclear gauge to monitor density changes with each roller pass. When the rolling is completed, a core is obtained and the minimum density must be 91.5%. Patching requires the density to be verified within the first 20 tons and then every 500 tons thereafter. Trench widening contracts have the initial density determined in the first 500 linear feet and then every 2,500 linear feet. Finally, for construction contracts with short paving lengths, a roller pattern and control strip cannot be constructed. For each lift of AC, the lot should have a minimum density of 91.5%. The number of cores to determine the density is a function of the paving length. Most projects will be 3,000 feet or less.

Large quantity contracts have paving lengths that will allow for the construction of a roller pattern and control strip. For these contracts, VTM-76 must be followed. Once the target density is established and verified, then the project is divided into lots. A lot is defined as a minimum of 6 foot wide by 3,000 feet to 10,500 feet in length. The width of the lot corresponds to the width of the paving. The length is determined by the size of the project and the contractor's placement speed. Each production shift will define a new lot unless directed by the Engineer. A normal lot is 5,000 feet in length; however, it can be as short as 3,000 feet and as long as 7,000 feet. Within the lot, a sublot is 1,000 feet in length. A large lot is usually 7,500 feet long. Each sublot is 1,500 feet in length. A large lot may vary in size from 4,500 feet to 10,500 feet. Each sublot is monitored for density. The average density for the sublots determines the acceptability and any pay adjustments. The process for monitoring the density will be covered in the Density Chapter

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Quality Assurance Program

While there are many steps in the paving process, payment for the material is based on final in-place density. This density is monitored by either cores/plugs obtained from the compacted mat or through the use of a nuclear gauge on the compacted mat. The method to monitor density is at the discretion of the contractor and their results are used for acceptance purposes.

Per the code of federal regulations (23 CFR 637B), transportation agencies that use contractor test results for payment must have a quality assurance program (QAP). The Contractor is responsible for the density testing of the AC and is required to be under VDOT's Quality Assurance Program (QAP). The AC is accepted on a lot by lot basis. Each lot is divided into sublots and will be discussed further in the Density Chapter. The Project Inspector will see that the Contractor follows the specifications and will notify the Construction Manager of any misunderstandings, lack of cooperation, or any other situation that cannot be corrected by the Inspector. It is important for the Inspector to work with the Contractor so that maximum production is achieved while keeping with the plans and specifications. Operations should not be held up unnecessarily as continuous operations are important for uniform results. The Materials Section technician will carry out the independent assurance (IA) and Verification Sampling and Testing (VST) portions of the QAP. When the technician cannot be on-site to perform the IA or VST, the inspector will perform these duties.

Independent Assurance

The Independent Assurance (IA) processes purpose is to ensure the people, procedures and equipment are functioning properly. This is done by observation by the Materials Section Technician and by verifying the bulk specific gravity of cores obtained from the control strip. For every 10 control strips constructed by the contractor, VDOT will perform IA on a minimum of 1 control strip. This is done by obtaining the cores cut by the contractor on the control strip. At least 1 core will be re-bulked by VDOT and the results are compared to the contractor's results on that same core. If the contractor's and VDOT's bulk specific gravity do not compare within 0.015, then additional cores from the control strip are compared. If additional cores do not compare, then the VDOT Materials Engineer will investigate the cause of the discrepancies. The IA process is detailed in the Manual of Instruction Section 503.04.

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Verification Sampling and Testing (VST) Sections

Verification Sampling and Testing (VST) sections are established for each project. The VST section corresponds with the contractor's acceptance lots. If a project has 20 lots, then the project will have 20 VST sections. Per VDOT's Materials Division Manual of Instructions Section 500, VDOT will perform monitoring on a minimum of 20% of the VST sections. The sections monitored will be selected on a random basis. In general, for every five acceptance lots by the contractor, VDOT will select one for further evaluation. This evaluation involves the contractor obtaining one core in two different sublots at locations identified by VDOT. These cores are provided to VDOT for density verification in the VDOT lab to ensure the specifications are met. If the cores compare to the bulk specific gravity of the cores from the control strip (98% to 102%), then the VST section and acceptance lot are deemed to be acceptable. If the VST cores do not compare to the control strip, then payment for the lot will be in accordance to the VST cores density. The contractor will have the option to request the referee process. The referee process is detailed in the Special Provision for Section 315.05(e) and in the Manual of Instruction Section 503.03(a)(1).

The VST process is managed by the Materials Section. In most cases, the Materials Section Technician will be on-site to identify the core locations and obtain the cores. When the Technician cannot be present, the inspector will serve as their representative. The inspector will observe the coring process and obtain the cores. The contractor will be allowed to determine the bulk specific gravity of the cores in the field, but these cores cannot be used by the contractor in the acceptance process.

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Chapter Eight Knowledge Check

1. What are important qualifications for an Inspector?
    a. Knowledge, common sense
    b. Diplomacy, observation skills
    c. All of the above

2. The most effective learning tool for an Inspector is on-the-job training.
    a. True
    b. False

3. What is the minimum placement temperature for PG-64-22 mix type A?
    a. 375°F
    b. 200°F
    c. 250°F
    d. 270°F

4. The Paving Inspector must keep a daily diary.
    a. True
    b. False

5. What is the purpose of inspection?
    a. Control the quantity of work
    b. Inspector to act as foreman for the Contractor
    c. Ensure the quality of work
    d. All of the above

6. Each load arrives on the job site accompanied by a _____
    a. TL-52A
    b. Weigh ticket
    c. TL-102A
    d. Daily diary

7. In order to accept asphalt concrete the Department must have:
    a. An approved mix design
    b. A producer who is under VDOT's Quality Assurance Program
    c. A good water source
    d. Both A and B

8. It is important for an Inspector to have an understanding of what tests are required both on the road and at the plant.
    a. True
    b. False

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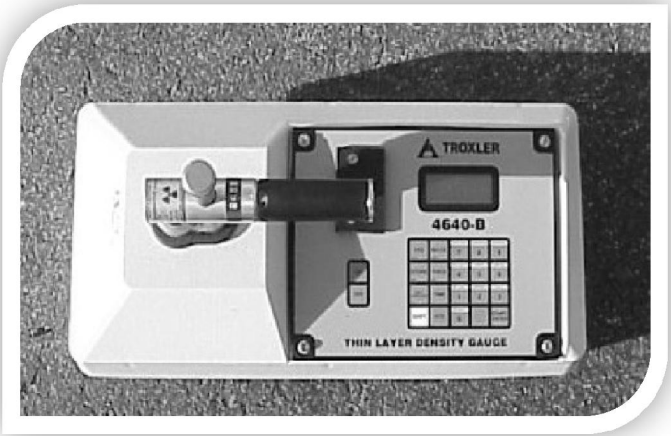
9 Density Testing

Learning Outcomes:

- ☑ Understand Density testing procedures to validate specifications can be met by the job-mix use.

Density Testing

The Virginia Department of Transportation (VDOT) requires that the Contractor perform density testing on the surface, intermediate and base courses of asphalt mats in order to determine if the specifications can be met by the job-mix used.

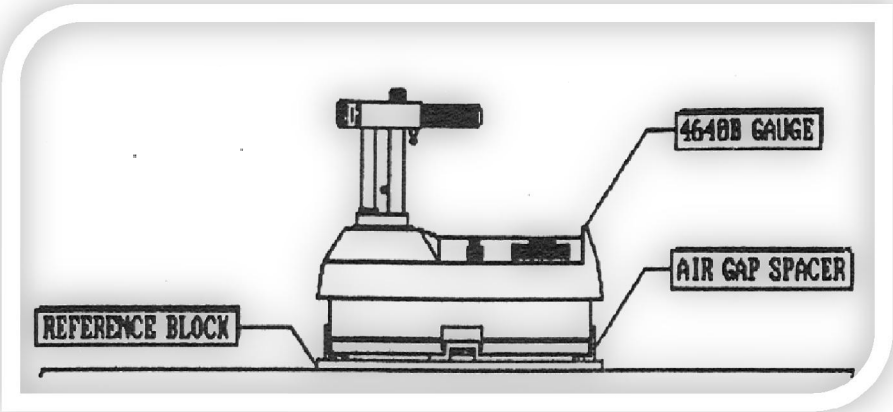


TOOLS AND EQUIPMENT
Performing the Standard Count Using a 4640 B Nuclear Density Gauge The gauge comes equipped with a reference block and an air gap spacer to perform the standard count procedure. A standard count is taken daily to check the gauge operation and naturally occurring background radiation. It also allows the gauge to compensate for natural source decay. Note: The nuclear density gauge must be provided by the Contractor.
Describes what tools, equipment and tests are required to complete the job safely and with the highest level of quality.

Virginia Test Method -76 (VTM-76) is the procedure used by VDOT and its Contractors to:

- determine the compaction required for the mix with the Roller Pattern,
- determine the density achieved by the roller pattern with the Control Strip, and
- then divide the rest of the project into Test Sections for acceptance testing.

Testing shall be performed by an individual who is Asphalt Field certified whether using a nuclear density gauge or extracting sawn plugs/cores.



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Procedure
1. Establish an area at least 10 feet from any structure, and 33 feet from other radioactive sources, such as another gauge, to take standard counts. Select a location that is flat, either concrete or asphalt with a minimum density of 100 lb/ft^3. Do not use truck beds, tailgates or tabletops. 2. Place the air gap spacer on the reference block. 3. Then place the gauge on the air gap spacer. The gauge must be in the “safe” position. The air gap spacer has three legs, two on one end and one on the other. For stability, set the handle side of the gauge on the two-legged side of the air gap spacer. A stable gauge is critical for obtaining accurate readings.

Taking the Standard Count

1. Press < STD > for the display:	Standard Count xxxx.xxxx Take a new Standard Count
2. Press < YES > for the display:	Place Gauge on Spacer & both on Block, Put Rod in Safe, Press ENTER
3. Check the gauge position.	
4. Press < ENTER> for the display:	Taking Standard Count xxx seconds remaining
5. At the end of the count, the gauge beeps. Enter the count in the standard log and accept the count by pressing < YES > .	
6. Test readings may be taken when the gauge is in the "Ready" mode.	
Note: If the count fails, refer to the gauge’s "Manual of Operation and Instruction Guide " for further instructions or contact your District Materials Section for assistance.	

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The Roller Pattern

The roller pattern determines the number of roller passes required to achieve maximum density for a given asphalt mix.

Roller Pattern Construction (VTM-76)

The following items are needed before beginning the Roller Pattern/Control Strip:

- Approved Mix Design
- Approved paving equipment
- Nuclear gauge template and white or other approved spray paint
- Thin-lift nuclear density gauge with printer, meeting requirements of VTM-81
- Magnesium nuclear gauge calibration block
- A rolling measuring device that will measure from 1 to 1000 linear feet or any other device approved by the Engineer
- Rotary saw or coring machine for sawing core/ or plug.
- Equipment to weigh cores or plugs (VTM-6)
- The Maximum Theoretical Specific Gravity of the mix as determined in VTM-22

This illustration of the roller pattern and control strip shows the way you will usually see them in the field. The material for the roller pattern is placed first, then the material for the control strip.

Initial Paving Prior to Roller Pattern 500 - 1000 ft	50 ft	Roller Pattern 75 ft	50 ft	Control Strip 300 ft

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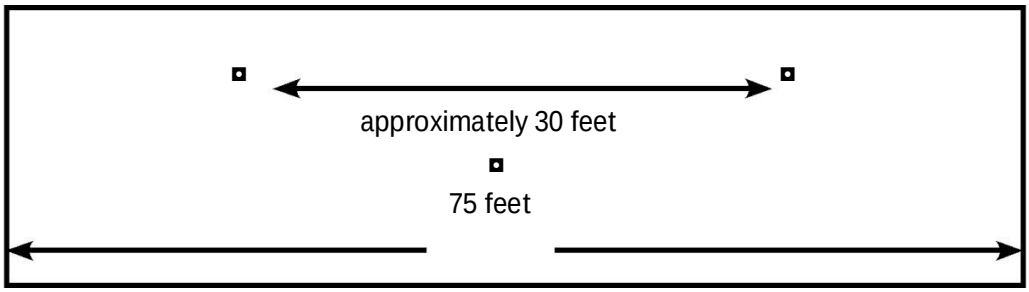
A roller pattern and control strip should only be constructed after a minimum of 500 feet of mix has been placed. Within 500 - 1000 feet of mix placement, a roller pattern and control strip must be constructed. The first 75 feet length will be the roller pattern and the next 300 foot length will be the control strip, regardless of the paver width. This mix should be of the same depth and application rate as called for in the plans and/or contract.

- Place enough asphalt to construct the roller pattern. Allow about 50 feet on either end of the roller pattern section for the roller to maneuver.
- It is recommended that the paving train stop while the roller pattern is being constructed.
- Begin the roller pattern by making (2) two passes of the roller over the 75-foot roller pattern area. Move the roller over and roll the same number of passes on the other section of the paver width. (One pass is "up", two passes is "up and back".)

  Note: Use judgment and experience to make the maximum number of passes before beginning the nuclear gauge readings. (If a mix has historically taken 6 vibratory passes of the roller to achieve compaction, make 4 vibratory passes before taking the first readings.)

- Select three locations to be tested in the 75-foot roller pattern. Two locations should be approximately 30-feet apart on one side of the lane and the third location on the opposite side of the lane about 15 feet from either of the first two locations.



Test Location

- Using the template shown below and approved spray paint, mark the test site locations after the first 2 passes of the roller. This is necessary since the same test site location must be used for each reading.

Nuclear Gauge Template

- To take the test, the gauge should be positioned so that it is parallel with the centerline of the roadway and set in the 30-second mode. It is important that the gauge is always oriented in the same direction so the same location is being tested. To do this, always position the gauge with the source rod towards the paving train.
- Density readings must not be taken in areas of overlap. For surface and intermediate courses, readings must not be taken within 1 foot of an unconfined edge; for a base mix the distance is 18 inches.
- Test the 3 locations after the first two passes of the roller. Record the readings on the Asphalt Nuclear Density Thin-Lift Roller Pattern Worksheet TL-56. Calculate the average density of the 3 locations and plot the average density in pounds per cubic foot versus the number of roller passes on the Asphalt Nuclear Density Thin-Lift Roller Pattern Graph on the TL-57 form.
- Continue this procedure - rolling and testing of the section until the roller pattern reaches its maximum density. To achieve maximum density, the mat shall be rolled until the average density decreases. This is observed by a “break” in the plotted curve. At this point, additional passes may cause the mat to decompact, or lose density.
- After the first decrease in density, make one additional pass, in the static mode, over the entire width of the mat to ensure that there is not a *false break. If the mat decreases in density again, then the maximum density will be the density achieved one roller pass before the initial decrease in density.
- At this point the roller pattern is complete, maximum density has been attained. You can begin laying the asphalt for the Control Strip.

AWARENESS/IMPORTANT
A false break occurs when the density <u>increases</u> after a decrease in density. If this happens, continue to make passes with the roller in the static mode until the density decreases a second time. Then make one additional pass to verify the break. The maximum density will be the greatest density achieved at the least number of passes. Note: Typically a decrease of 0.5 lb/ft^3 will indicate maximum density has been achieved.
Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

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ASPHALT NUCLEAR DENSITY THIN LIFT ROLLER PATTERN - WORKSHEET

TL-56(Rev- 4/05)

Control Strip No 1

Project or Schedule PM-2D-10 Item No. _____ Date 6/21/10

Route 81 From 13.76 To 11.04

Directional Lane (NBL, SBL, etc.) SBL Lane Inside (Inside, center, etc.)

Mix Type SM-9.5D Application Rate: 165 lbs/yd² (_____ kg/m²)

Producer Asphalt, Inc Location Ketchum, VA

Roller Type: Roller 1 DD-130 Roller 2 DD-110 Roller 3 _____

Roller Pattern Data

Gauge Model 4640B Serial No 401 Calibration Date 7/18/10 Depth Setting 1.5 in. (mm)

Pass No	2V	Nuclear Density	Pass No	6 (3s)	Nuclear Density
Site 1		135.5	Site 1		142.7
Site 2		136.6	Site 2		143.9
Site 3		134.8	Site 3		140.2
AVERAGE		135.6	AVERAGE		142.3

Pass No	3V	Nuclear Density	Pass No	7 (4s)	Nuclear Density
Site 1		139.5	Site 1		142.3
Site 2		142.4	Site 2		143.0
Site 3		137.9	Site 3		139.5
AVERAGE		139.9	AVERAGE		141.6

Pass No	4 (1s)	Nuclear Density	Pass No		Nuclear Density
Site 1		142.6	Site 1		
Site 2		144.0	Site 2		
Site 3		139.9	Site 3		
AVERAGE		142.2	AVERAGE		

Pass No	5 (2s)	Nuclear Density	Pass No		Nuclear Density
Site 1		142.7	Site 1		
Site 2		144.4	Site 2		
Site 3		140.5	Site 3		
AVERAGE		142.5	AVERAGE		

Testing Performed by _____ Observed by _____

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TL-67 (Rev. 4/06)

ASPHALT NUCLEAR DENSITY THIN LIFT ROLLER PATTERN -GRAPH

Control Strip No 1

Project or Schedule PM-2D-10 Item No _____ Date 6/21/10

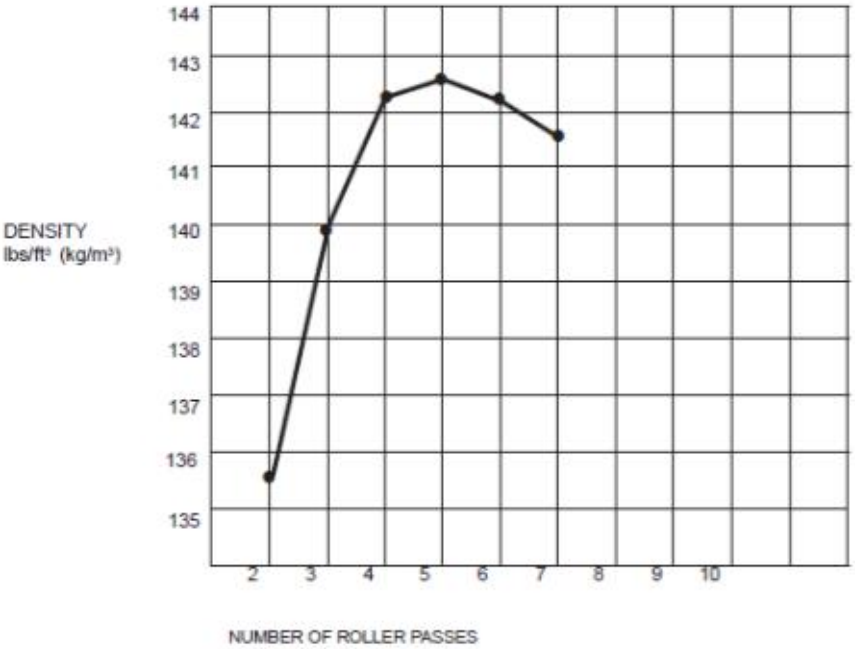
Route _____ From 13.76 To 11.04

Directional Lane SBI (NBL, SBL, etc) Lane Inside (Inside, Center, etc.)

Mix Type SM-9.5D Application Rate 165 lbs/yd² (_____ kg/m²)

Producer Asphalt, Inc Location Ketchum, VA

Gauge Model 4640B Serial No 401 Calibration Date 4/24/10 Depth Setting 1.5 in. (mm)



Optimum Density 142.5 lbs/ft³ (kg/m³)
(from peak of roller pattern curve)

Optimum Number of Passes: 5

Number of Roller Passes Roller 1 3 V Roller 2 2 S Roller 3 _____

Testing Performed By _____ Observed By _____
VDOT Inspector

The Control Strip

The Control Strip is built by following the procedure established in the roller pattern section to determine if the density can be achieved. VDOT specifications require that one control strip be constructed at the beginning of work on each roadway and shoulder course and on each lift of each course. An additional control strip is required when:

- A change is made in the type or source of materials
- Whenever a significant change occurs in the composition of the material being placed from the same source
- When there is a failing control strip.

During the evaluation of the initial control strip, paving operations may continue. However, paving and production shall be discontinued during construction and evaluation of additional control strips.

In the event that two consecutive control strips fail, subsequent paving operations shall cease until corrective action(s) has been made with the approval of the Engineer. If it is determined with the Engineer's approval that the density cannot be obtained because of the condition of the existing pavement structure, the target control strip density shall be determined from the roller pattern that achieves the optimum density and shall be used on the remainder of the roadway that exhibits similar pavement conditions.

Either the Department or Contractor may initiate an additional control strip at any time.

Determining Density Testing Locations

The stratified random sampling method is used to determine the locations for density testing in the contol strip. Stratified random sampling is "sampling from equal portions of a lot at locations that have been selected solely by chance". Any statistically acceptable method of randomization may be used to determine the location of the stratified random sample to be taken; however, the method must be approved by the Engineer prior to beginning testing. All random locations shall be determined for each test site prior to the beginning of the paving operation. This manual shows one of several acceptable methods of stratified random sampling for a control strip.

Selecting Random Numbers

To determine test site locations, select ten numbers from the Random Numbers Table (see next page) under "Distance from beginning of Control Strip" and the corresponding numbers under "Paving Width - Distance From Reference Line". Record these coordinates on the TL-58 form.

For this example, the pavement width is 12 feet and the reference line is on the right. The first test site location will be 17 feet from the start of the control strip and 1 foot from the left of the reference line. The diagram illustrates the test site locations for this control strip.

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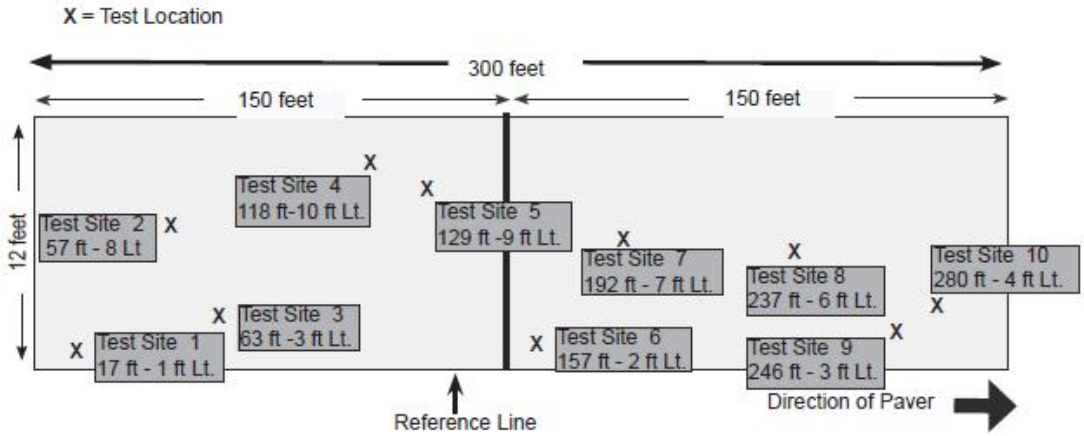
Random Numbers Table

Distance From beginning of Control Strip	Distance from Sublot Start	Paving Width						
		Distance From Reference Line						
Control Strip	Test Section	8 ft. width	9 ft. width	10 ft. width	11 ft. width	12 ft. width	13 ft. width	14 ft. width
17	16	Test Site 1 location			7	1	10	6
57	437	Test Site 2 location			7	8	3	1
63	412	Test Site 3 location			3	3	4	9
118	964	Test Site 4 location			6	10	9	6
129	113	Test Site 5 location			7	9	11	11
157	834	Test Site 6 location			8	2	7	8
192	92	Test Site 7 location			3	7	8	1
237	959	Test Site 8 location			6	6	6	4
246	716	Test Site 9 location			7	3	5	5
280	402	Test Site 10 location			7	4	8	10



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Control Strip Procedure

Control Strip Procedure
STEP 1) Lay Asphalt Concrete (AC) for the 300-foot control strip and compact the mat using the number of passes determined in the roller pattern. Stratify (divide into equal sections) the 300-foot control strip in a manner approved by the Engineer. Using the nuclear gauge template, mark the ten stratified random locations that will be used to determine the target density. Do not take readings within 12 inches of an unconfined edge for surface and intermediate mixes, or within 18 inches of an unconfined edge for base mixes. Place the nuclear gauge template on the mat and position it parallel to the roadway with the arrows pointing in the direction of the paver. Spray paint the template with white or other approved paint such that the underlying pavement is marked with paint through the cutouts in the template. These locations should be clearly visible when the template is removed. Once the gauge location is marked, remove the template. STEP 2) Place the nuclear gauge within the area marked by the template with the source rod toward the paver. Take the nuclear density readings in lb/ft^3 using the one-minute mode at the ten (10) stratified random locations marked in the 300-foot control strip section. Record the locations and density readings on the Asphalt Nuclear Density thin-Lift Worksheet, Control Strip Target Density - Form TL-58 (see page 8-10). The average of the 10 readings is the Target Density. STEP 3) Cores/plugs are cut to verify that the specified density has been achieved in the control strip. Two cores/plugs shall be taken for density determination from each of three (3) of the ten (10) nuclear gauge reading locations in the 300-foot control strip section. The sites for the three sets of cores should be the three sites closest to the target density (average of the ten readings). Dry cut the cores/plugs for density testing. The cores/plugs are to be 4”x 4” square if sawn or 4” in diameter if taken with a drill. If a drill is used to obtain the cores, no water shall be used. Mark the location of the core/plug. Freeze the roadway using CO_2, dry ice, or another approved method. Cut the core/plug using the saw or drill. Freeze the road a second time after cutting. Then gently pry around the core/plug to break it loose from the underlying layer. Take care not to damage the core/plug or break off any corners. If the core/plug is damaged, it must be discarded and another core/plug taken from the same area. Measure the thickness of the core/plug and record on the TL-60 form. The procedure for taking the cores/plugs is found in VTM-22. The apparatus and procedure for determining the bulk specific gravity of the cores/plugs is in VTM-6. (See Appendix A for these test methods.)

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Note: Calculations for the following steps follow on the next several pages of the guide.

STEP 4) Determine the density calculations on the two (2) cores/plugs from each of the three (3) sites. Record the weights and calculations for the cores/plugs on the TL-60 form.

Compute the average bulk specific gravity of the cores/plugs using VTM-6. If the average bulk specific gravity of the six cores/plugs meets the minimum specified density for that mix, the roller pattern is accepted and the target density will then be used to determine acceptance in the test sections.

The percent density of the cores/plugs is determined by dividing the Average SSD Bulk Specific Gravity by the Current Maximum Specific Gravity* (G_{mm}) of the mix, and multiplying by 100. The equation for this calculation is:

$$(\text{Avg. SSD BSG}/G_{mm}) \times 100 = \text{Avg \% Density}$$

**A current maximum specific gravity is defined in VTM-22 as:*

The theoretical maximum specific gravity (G_{mm}) used for this calculation is determined by a moving average of five (5) values. On the first day of production of a mix, the producer's lab should have a G_{mm} from the sample taken that morning by the time you are ready to determine the density of the cores/plugs on the road.

The average percent density is then compared to the Minimum Control Strip Density listed in the Road and Bridge Specifications - Section 315.05(e)1. Table III-3

Table III-3 Density Requirements	
Mix Type	Min. Control Strip Density %
SM-9.5A, SM-12.5A	92.5
SM-9.5D, SM-12.5D	92.2
SM-9.5E, SM-12.5E	92.2
IM-19.0A, IM-19.0D, IM-19.0E	92.2
BM-25.0A, BM-250D	92.2

After taking the ten readings in the control strip, verifying the density with the cores/plugs, and establishing the target density, divide the rest of the project into Test Sections.

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TL-58 (Rev. 4/05)

VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY THIN LIFT WORKSHEET
CONTROL STRIP TARGET DENSITY

Control Strip Number 1
Project or Schedule PM-2D-10 Item Number _____ Date 6/21/10
Route 81 From 8.23 To 16.25
Directional Lane SBL (NBL, SBL, etc) Lane Inside (Inside, Center, etc.)
Mix Type SM-9.5D Application Rate 165 lbs/yd² (kg/m³)
Producer Asphalt, Inc Location Ketchum, VA

CONTROL STRIP TARGET DENSITY DETERMINATION

Gauge Model 4640B Serial Number 401 Calibration Date 4/24/10 Depth Setting 1.5 in (mm)

TEST SITE	DISTANCE	OFFSET	ENTER GAUGE READING			
Site 1	17 ft	1 ft. Lt	141.1	lb/ft³	(	kg/m³)
Site 2	57 ft.	8 ft. Lt	137.4	lb/ft³	(	kg/m³)
Site 3	63 ft.	3 ft. Lt	141.9	lb/ft³	(	kg/m³)
Site 4	118 ft.	10 ft. Lt	144.1	lb/ft³	(	kg/m³)
Site 5	129 ft.	9 ft. Lt	142.8	lb/ft³	(	kg/m³)
Site 6	157 ft.	2 ft. Lt	143.8	lb/ft³	(	kg/m³)
Site 7	192 ft	7 ft. Lt	143.0	lb/ft³	(	kg/m³)
Site 8	237 ft.	6 ft. Lt	138.0	lb/ft³	(	kg/m³)
Site 9	246 ft.	3 ft. Lt	144.1	lb/ft³	(	kg/m³)
Site 10	280 ft.	4 ft. Lt	137.9	lb/ft³	(	kg/m³)
		Total	1414.1	lb/ft³	(	kg/m³)
		Average	141.4	lb/ft³	(	kg/m³)

Remarks: Numbers selected from the Random Numbers Table

Testing Performed by _____ Observed by _____
VDOT inspector

The density for acceptance of the rest of the project (Test Sections) is measured against this "Target Density".

TL 60 (Rev.4/05)

VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY WORKSHEET
ROLLER PATTERN/SAWN PLUGS & CONTROL STRIP TARGET DENSITY

Control Strip No. 1

Schedule PM-2D-10 Item No. Date 6/21/10

Route 81 From: 8.23

Lane Direction:

Step 1 E - D = Volume
1131 - 626 = 505

Step 2 A + F = SSD Bulk Specific Gravity
1125 ÷ 505 = 2.23

Mix Type SM- 165

Lot No 1 12

Step 3 E - D = Volume
1129 - 639 = 490

Step 4 A + F = SSD Bulk Specific Gravity
1121 ÷ 490 = 2.29

Mix Producer Plant Location

NUCLEAR CALIBRATION CHECK

Sawed Spec. Number	A Weight in Air (g)	B Weight in Water (Total g)	C Basket Tare Weight (g)	D Weight in Water (g) B - C	E SSD Weight In Air (g)	F Volume E-D	SSD Bulk Specific Gravity A ÷ F	G Average SSD Bulk Per Site	Sawed Specimen Thickness In. (mm)	H Target Test Site Nuclear (from TL-58)	
1	1125	626	xxx	626	1131	505	2.23		1.5	141.1	1
2	1121	639	xxx	639	1129	490	2.29	2.26	1.5	137.4	2
										141.9	3
3	1123	631	xxx						1.5	144.1	4
										142.8	5
4	1126	625	xxx							143.8	6
										143.0	7
5	1120	619	xxx	619	1126	507	2.21		1.5	138.0	8
								2.23		144.1	9
6	1123	632	xxx	632	1131	499	2.25		1.5	137.9	10
										1414.1	Total

Step 5 Average SSD Bulk Specific Gravity Per Site
2.23 + 2.29 = 4.52
4.52 ÷ 2 = 2.26

target nuclear density

Average _____ (Sum of G/3)

141.4 (Sum of H/10)

Max Specific Gravity (G_{mm}) 2.424

A. Sawed Specimen Average % Density _____ % (avg. SSD Bulk Sp. Gr. /G_{mm} x 100)

B. Minimum Design Density (Table III – 3 of sec. 315) _____ %
*(A must equal or exceed B)

C. Target Nuclear Density 141.4 lb/ft³

Gauge Model 4640B Serial No. 401 Calibration Date 4/24/10 Depth Setting 1.5 In (mm)

Pay Quantity _____ Ton (Metric Ton)
Lot length x width x application rate/ 18000

Testing Performed by G.O. Strait Observed by T.F. Baker

TL 60 (Rev.4/06)

VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY WORKSHEET
ROLLER PATTERN/SAWN PLUGS & CONTROL STRIP TARGET DENSITY

Control Strip No. 1

Schedule PM-2D-10 Item No. 16225 Date 6/21/10

Route 81 From: To:

Lane Direction: SBL (NBL, SBL, etc.) Lane Inside (inside, center, etc.)

Mix Type SM-9.5D Application Rate: 165 lbs/yd² (kg/m²)

Lot No 1 Width of Application 12 Lot Length 5000 ft (m)

Mix Producer Asphalt, Inc. Plant Location Ketchum, VA

NUCLEAR CALIBRATION CHECK

	A	B	C	D	E	F		G		H	
Sawed Spec. Number	Weight in Air (g)	Weight in Water (Total g)	Basket Tare Weight (g)	Weight in Water (g) B - C	SSD Weight In Air (g)	Volume E-D	SSD Bulk Specific Gravity A ÷ F	Average SSD Bulk Per Site	Sawed Specimen Thickness In. (mm)	Target Test Site Nuclear (from TL-58)	
1	1125	626	xxx	626	1131	505	2.23	2.26	1.5	141.1	1
2	1121	639	xxx	639	1129	490	2.29		1.5	137.4	2
										141.9	3
3	1123	631	xxx	631	1130	499	2.25	2.24	1.5	144.1	4
										142.8	5
4	1126	625	xxx	625	1132	507	2.22			143.8	6
										143.0	7
5	1120	619	xxx	619	1126	507	2.21	2.23	1.5	138.0	8
										144.1	9
6	1123	632	xxx	632	1131	499	2.25		1.5	137.9	10
										1414.1	Total

3 sites closest to target nuclear density

avg. SSD Bulk Sp. Gr./Gmm x 100
2.24 ÷ 2.424 = 0.924 x 100 = 92.4

Average 2.24 (Sum of G/3) 141.4

Sum of G/3 = Average
2.26 + 2.24+ 2.23 = 6.73
6.73 ÷ 3 = 2.24

Max Specific Gravity (G_{mm}) 2.424

A. Sawed Specimen Average % Density 92.4 (avg. SSD Bulk Sp. Gr./G_{mm} x 10

B. Minimum Design Density (Table III – 3 of sec. 315) 92.2 %
*(A must equal or exceed B)

C. Target Nuclear Density 141.4 lb/ft³

Gauge Model 4640B Serial No. 401 Calibration Date 4/24/10 Depth Setting 1.5 In (mm)

Pay Quantity Lot length x width x application rate/ 18000 Ton (Metric Ton)

Testing Performed by G.O. Strait Observed by T.F. Baker

TL 60 (Rev.4/08)

VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY WORKSHEET
ROLLER PATTERN/SAWN PLUGS & CONTROL STRIP TARGET DENSITY

Control Strip No. 1

Schedule PM-2D-10 Item No. 16225 Date 6/21/10

Route 81 From: To:

Lane Direction: SBL (NBL, SBL, etc.) Lane Inside (inside, center, etc.)

Mix Type SM-9.5D Application Rate: 165 lbs/yd² (kg/m²)

Lot No 2 Width of Application 12 Lot Length 5000 ft (m)

Mix Producer Asphalt, Inc. Plant Location Ketchum, VA

NUCLEAR CALIBRATION CHECK

Sawed Spec. Number	A Weight in Air (g)	B Weight in Water (Total g)	C Basket Tare Weight (g)	D Weight in Water (g) B - C	E SSD Weight In Air (g)	F Volume E-D	SSD Bulk Specific Gravity A ÷ F	G Average SSD Bulk Per Site	Sawed Specimen Thickness In. (mm)	H Target Test Site Nuclear (from TL-58)	
1	1125	626	xxx	626	1131	505	2.23	2.26	1.5	141.1	1
2	1121	639	xxx	639	1129	490	2.29		1.5	137.4	2
										141.9	3
3	1123	631	xxx	631	1130	499	2.25	2.24	1.5	144.1	4
										142.8	5
4	1126	625	xxx	625	1132	507	2.22		1.4	143.8	6
										143.0	7
5	1120	619	xxx	619	1126	507	2.21	2.23	1.5	138.0	8
										144.1	9
6	1123	632	xxx	632	1131	499	2.25		1.5	137.9	10
										1414.1	Total

Average 2.24 (Sum of G/3) 141.4 (Sum of H/10)

Max Specific Gravity (G_{mm}) 2.424

A. Sawed Specimen Average % Density 92.4 (avg. SSD Bulk Sp. Gr. /G_{mm} x 100) %

B. Minimum Design Density (Table III – 3 of sec. 315) 92.2
*(A must equal or exceed B)

C. Target Nuclear Density 141.4 lb/ft³

Gauge Model 4640B Serial No. 401 Calibration Date 4/24/10 Depth Setting 1.5 In (mm)

Pay Quantity _____ Ton (Metric Ton)
Lot length x width x application rate/ 18000

Testing Performed by G.O. Strait Observed by T.F. Baker

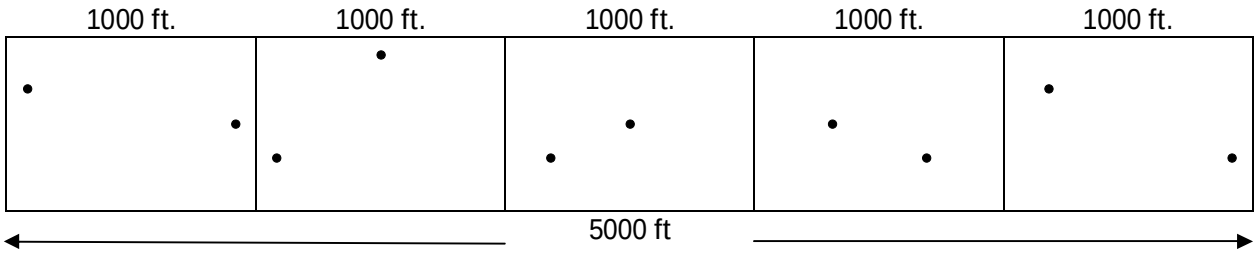
This control strip is acceptable because the Average Percent Density of the 3 core sites meets the Minimum Design Density required for Mix Type SM-9.5D as per Table III-3

Test Sections

After the roller pattern has been approved and the target density is set, the rest of the project is divided up into Test Sections. The density of the test sections is measured to determine the percent of payment for the asphalt mixture.

The typical size of a lot is 5,000 feet, with a paver width of 6 feet or greater, regardless of thickness. The tonnage of each lot varies as it is based on width and application rate as shown in the contract or revised by the Engineer. Density test sites are selected by stratified random sampling.

• = Test Location



Each lot is divided into 5 sublots. The size of the sublot may be 1,000 or 1,500 feet depending on the expected tonnage to be placed during the operation. Sublots will be 1,000 feet unless approved by the Engineer to be increased to 1,500 feet. When the sublot size is increased, then the typical lot size will increase to 7,500 feet. Take two nuclear readings in each sublot for a total of ten readings per lot or one core/plug in each sublot for a total of 5 cores/plugs.

5,000 Linear Feet	7,500 Linear Feet	Sublot
1 - 1,000	1 - 1,500	1
1,001 – 2,000	1,501 – 3,000	2
2,001 – 3,000	3,001 – 4,500	3
3,001 – 4,000	4,501 – 6,000	4
4,001 – 5,000	6,001 – 7,500	5

If at the end of a day a partial lot is left and the lot size is 5,000 feet, redefine the lot as follows:

- If the partial lot is 1-2,000 feet (1 or 2 sublots), add it to the previous lot. This lot will then have 6 or 7 sublots.
- If the partial lot has 2,001 – 4,500 feet (3 or 4 sublots), make it a lot on its own with 3 or 4 sublots.

If at the end of a day a partial lot is left and the lot size is 7,500 feet, redefine the lot as follows:

- If the partial lot is 1-3,000 feet (1 or 2 sublots), add it to the previous lot. This lot will then have 6 or 7 sublots.
- If the partial lot has 3,001 – 6,750 feet (3 or 4 sublots), make it a lot on its own with 3 or 4 sublots.

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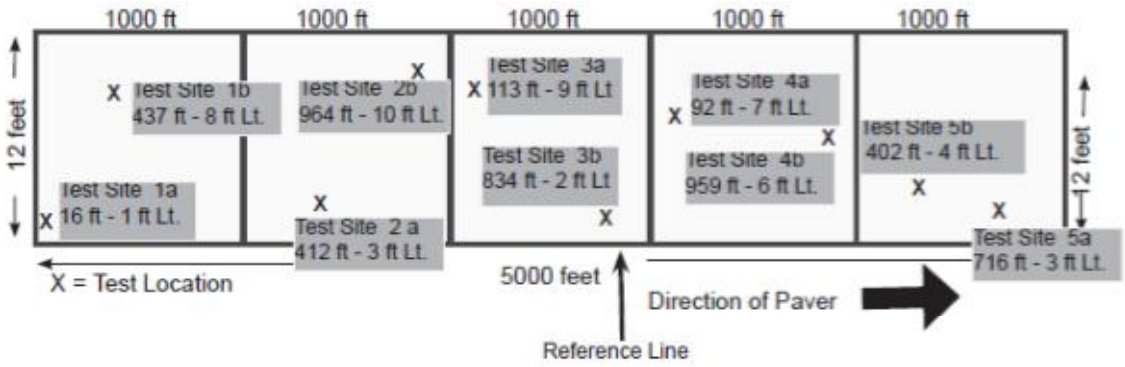
Selecting the Random Numbers

To determine test site locations, select ten numbers for nuclear gauges or five numbers for cores/ plugs from the Random Numbers Table under "Distance from Sublot Start" and the corresponding numbers under "Paving Width - Distance From Reference Line". Record these coordinates on the TL-58 form (Page 8-18).

For this example, the pavement width is 12 feet. The reference line is on the right. The first test site location will be 16 feet from the start of the control strip and 1 foot from the left of the reference line.

Distance From beginning of Control Strip	Distance from Sublot Start	Paving Width						
		Distance From Reference Line						
Control Strip	Test Section	8 ft. width	9 ft. width	10 ft. width	11 ft. width	12 ft. width	13 ft. width	14 ft. width
17	16	2	Test Site 1a location		2	1	2	4
57	437	6	Test Site 1b location		3	8	11	11
63	412	5	Test Site 2a location		2	3	7	11
118	964	5	Test Site 2b location		6	10	6	8
129	113	3	Test Site 3a location		10	9	2	11
157	834	3	Test Site 3b location		3	2	9	7
192	92	1	Test Site 4a location		3	7	5	1
237	959	3	Test Site 4b location		4	6	4	5
246	716	6	Test Site 5a location		2	3	4	7
280	402	1	Test Site 5b location		3	4	8	9



TL-59A (12/08)

Asphalt Concrete Density Quality Control (QC) Test Report - Nuclear

Project/Schedule Number:	PM2D-10	Item Number:	
Route Number:	81	County:	Mitchell
From (Station, MP, Int., etc.):		To (Station, MP, Int., etc.):	
Direction (e.g. NB, SB, etc.)	SBI	Lane (Inside, Center, Right, etc):	Inside
QC Lot #:	2	Application Rate (lbs/sy):	165
Asphalt Mix Type:	SM 9.5 D	Asphalt Job Mix Number:	2041-2010-05
Nuclear Gauge Model Number:	4640 B	Gauge Calibration Date:	5-08
Nuclear Gauge Serial Number:	401	Depth Setting (in/mm):	1.5"

Control Strip Information:

1. Control Strip Number and Date	1	6/21/10
2. Target Density from Control Strip	141.4	lbs/ft³ (kg/m³)
3. Minimum Density (96% Of Control Strip Target Density)		lbs/ft³ (kg/m³)
4. Maximum Density (102% Of Control Strip Target Density)		lbs/ft³ (kg/m³)

QC Testing Results By Nuclear Gauge:

	Location		Nuclear Density lbs/ft³ (kg/m³)	Sublot Average lbs/ft³ (kg/m³)	Joint Density lbs/ft³ (kg/m³)	
Sublot No.	Distance	Offset			Left (C or U)*	Right (C or U)*
1a	16 ft	1 ft Lt				
1b	437 ft	8 ft Lt				
2a	412 ft	3 ft Lt				
2b	964 ft	10 ft Lt				
3a	113 ft	9 ft Lt				
3b	834 ft	2 ft Lt				
4a	92 ft	7 ft Lt				
4b	959 ft	6 ft Lt				
5a	716 ft	3 ft Lt				
5b	402 ft	4 ft Lt				
6a						
6b						
			Average:			

Numbers selected from the Random Numbers Table (See next page)

* - C = Confined Jt U = Unconfined Jt

Does the QC Test Section: (circle one) PASS FAIL

Comments:

Random Number Table

Distance From Beginning of Control Strip	Distance From Sublot Start	Paving Width						
		Distance From Reference Line						
Control Strip	Test Section	8 ft. width	9 ft. width	10 ft. width	11ft. width	12 ft. width	13 ft. width	14 ft. width
4	73	2	2	3	7	10	10	6
33	653	4	8	7	7	5	3	1
89	955	5	7	5	3	10	4	9
110	583	6	4	2	6	10	9	6
120	351	2	4	7	7	7	11	11
155	715	2	7	3	8	5	7	8
203	49	3	7	8	3	10	8	1
219	11	1	7	2	6	9	6	4
254	358	5	2	2	7	2	5	5
282	239	1	6	6	7	8	8	10
17	16	2	4	5	2	1	2	4
57	437	6	4	8	9	8	11	11
63	412	5	4	8	2	3	7	11
118	964	5	3	8	6	10	6	8
129	113	3	7	7	10	9	2	11
157	834	3	4	3	3	2	9	7
192	92	1	6	5	9	7	5	1
237	959	3	3	6	4	6	4	5
246	716	6	8	8	2	3	4	7
280	402	1	4	2	3	4	8	9
18	81	7	7	2	4	2	8	4
59	142	1	4	5	5	7	2	6
83	67	6	5	2	3	2	2	12
93	569	2	4	6	3	5	3	1
120	728	2	6	7	5	4	12	12
151	902	1	3	5	4	4	1	12
192	726	2	3	2	5	8	5	6
210	242	2	7	3	9	6	5	13
267	172	6	3	1	5	4	6	4
286	82	6	7	4	9	2	9	5
22	481	4	1	4	7	5	7	1
41	40	3	7	2	4	8	5	6
74	871	5	6	8	4	9	6	12
111	414	7	5	3	5	6	3	13
144	528	6	4	2	6	10	9	6
152	982	3	4	3	3	2	9	7
205	9	5	3	8	6	10	6	8
229	889	1	4	2	3	4	8	9
255	448	3	3	6	4	6	4	5
288	872	4	1	4	7	5	7	1

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After the stratified random density test locations have been determined, the sites will be marked in the sublot with the nuclear gauge template described in VTM –76. The template shall be placed on the mat and positioned parallel to the roadway with the arrows pointing in the direction of the paver. The template shall be spray painted with white or other approved paint such that the underlying pavement is marked with paint through the cutouts in the template. These locations must be clearly visible when the template is removed. After marking the location with paint the gauge template can be removed. The nuclear gauge shall then be placed within the area marked by the gauge template with the source toward the direction of the paver. When cores/plugs are used, one core or plug will be cut from the pavement within the template area.

Nuclear Gauge Approach - Test the density for each lot by taking readings, using the one-minute mode, from two random locations within each sublot. The readings for the test section are recorded on Form TL-59A. Remember, readings shall not be taken within 12 inches of the edge of any application width for surface or intermediate mixes, nor within 18 inches of the edge of any application width for base mixes.

If two consecutive sublots have density readings less than 98% or more than 102% of the target density, notify the Engineer and take corrective action. (See next page for acceptance range calculations)

Cores/Plugs Approach – Test the density for each lot by taking one core/plug per sublot. The readings for the test section are recorded on Form TL-59B. Remember, readings shall not be taken within 12 inches of the edge of any application width for surface or intermediate mixes, nor within 18 inches of the edge of any application width for base mixes.

Compare the average of the sublot readings to the "target density from the control strip" to determine the acceptability of the lot.

If two consecutive sublots have density readings less than 98% or more than 102% of the target density, notify the Engineer and take corrective action. (See the table below for acceptance range calculations)

Compare the average of the sublot readings to the "target density from the control strip" to determine the acceptability of the lot.

The final pay quantity for density is determined by averaging all the tests contained within each lot. Then compare this average to the payment guidelines shown in the following chart. A separate pay factor is determined for each lot.

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Payment Schedule for Lot Densities

Percent of Target Nuclear Control Strip Density	Percent of Payment
Greater than 102.0	95
98.0 to 102.0	100
97.0 to 97.9	95
96.0 to 96.9	90
Less than 96.0	75

The Contractor shall submit density worksheets and printouts for each test section to the Inspector upon completion of each day's testing.

Note: Lines for joint densities have been added to the TL-59. There are concerns about lower densities obtained in some joint areas. Industry has agreed to take density readings on confined and unconfined joints, but this is not required by specification.

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TL-59 A(12/08)

Asphalt Concrete Density Quality Control (QC) Test Report - Nuclear

Project/Schedule Number:		Item Number:	
Route Number:	81	County:	Mitchell
From (Station, MP, Int., etc.):		To (Station, MP, Int., etc.):	
Direction (e.g. NB, SB, etc.)	SBL	Lane (Inside, Center, Right, etc):	Inside
QC Lot #:	1	Application Rate (lbs/sy):	165
Asphalt Mix Type:	SM 9.5 D	Asphalt Job Mix Number:	2041-2010-05
Nuclear Gauge Model Number:	4640 B	Gauge Calibration Date:	4/24/10
Nuclear Gauge Serial Number:	401	Depth Setting (in/mm):	1.5"

Control Strip Information:

1. Control Strip Number and Date	1	6/21/10
2. Target Density from Control Strip	141.4	
3. Minimum Density (98% Of Control Strip Target Density)	138.6	0.98 x 141.4 = 138.6
4. Maximum Density (102% Of Control Strip Target Density)	144.2	1.02 x 141.4 = 144.2

QC Testing Results By Nuclear Gauge:

Sublot No.	Location: Distance	Location: Offset	Nuclear Density lbs/ft³ (kg/m³)	Sublot Average lbs/ft³ (kg/m³)	Joint Density lbs/ft³ (kg/m³): Left (C or U)*	Joint Density lbs/ft³ (kg/m³): Right (C or U)*
1a	16 ft	1 ft	141.3	143.3	141.3 + 145.2 = 286.5 286.5÷2 = 143.3	143.9 C
1b	437 ft	8 ft	145.2			145.8 C
2a	412 ft	3 ft	144.6	142.6	144.6 + 140.5 = 285.1 285.1÷2 = 142.6	144.8 C
2b	964 ft	10 ft	140.5			140.0 C
3a	113 ft	9 ft	142.0	140.7	142.0 + 139.4 = 281.4 281.4÷2 = 140.7	141.3 C
3b	834 ft	2 ft	139.4			140.7 C
4a	92 ft	7 ft	138.0	139.4	138.0+ 140.8 = 278.8 278.8÷2 = 139.4	137.3 C
4b	959 ft	6 ft	140.8			141.5 C
5a	716 ft	3 ft	144.2	142.6		143.6 C
5b	402 ft	4 ft	141.0		144.2+ 141.0 = 285.2 285.2÷2 = 142.6	142.6 C
6a						
6b						
7a						
7b						
		Average:		141.7	142.1	142.4
				100.2%	100.5%	100.7

Total of density readings ÷ number of readings (10)
1417 ÷ 10 = 141.7

Does the QC Test Section: (circle one) PASS FAIL

* - C = Confined Jt, U = Unconfined Jt

Comments:

average density ÷ target density from control strip

141.7 ÷ 141.4 = 100.2

TL-59 A(12/08)

Asphalt Concrete Density Quality Control (QC) Test Report - Nuclear

Project/Schedule Number:	PM-2D-08	Item Number:	
Route Number:	81	County:	Mitchell
From (Station, MP, Int., etc.):		To (Station, MP, Int., etc.):	
Direction (e.g. NB, SB, etc.)	SBL	Lane (Inside, Center, Right, etc):	Inside
QC Lot #:	1	Application Rate (lbs/sy):	165
Asphalt Mix Type:	SM 9.5 D	Asphalt Job Mix Number:	2041-2010-05
Nuclear Gauge Model Number:	4640 B	Gauge Calibration Date:	4/24/10
Nuclear Gauge Serial Number:	401	Depth Setting (in/mm):	1.5"

Control Strip Information:

1. Control Strip Number and Date	1	6/21/10
2. Target Density from Control Strip	141.4	lbs/ft³ (kg/m³)
3. Minimum Density (98% Of Control Strip Target Density)	138.6	lbs/ft³ (kg/m³)
4. Maximum Density (102% Of Control Strip Target Density)	144.2	lbs/ft³ (kg/m³)

QC Testing Results By Nuclear Gauge:

Sublot No.	Location Distance	Location Offset	Nuclear Density lbs/ft³ (kg/m³)	Sublot Average lbs/ft³ (kg/m³)	Joint Density lbs/ft³ (kg/m³) Left (C or U)*	Joint Density lbs/ft³ (kg/m³) Right (C or U)*
1a	16 ft	1 ft	141.3	143.3	144.1 C	143.9 C
1b	437 ft	8 ft	145.2		144.9 C	145.8 C
2a	412 ft	3 ft	144.6	142.6	143.9 C	144.8 C
2b	964 ft	10 ft	140.5		139.8 C	140.0 C
3a	113 ft	9 ft	142.0	140.7	143.1 C	141.3 C
3b	834 ft	2 ft	139.4		139.7 C	140.7 C
4a	92 ft	7 ft	138.0	139.4	139.2 C	137.3 C
4b	959 ft	6 ft	140.8		140.3 C	141.5 C
5a	716 ft	3 ft	144.2	142.6	143.6 C	143.6 C
5b	402 ft	4 ft	141.0		141.7 C	142.6 C
6a						
6b						
7a						
7b			Average:	141.7	142.1	142.4
				100.2%	100.5%	100.7

Does the QC Test Section: (circle one) PASS FAIL

* - C = Confined Jt, U = Unconfined Jt

Comments:

Chapter Nine Knowledge Check

1. Before a roller pattern is constructed:
    a. The number of roller passes should established
    b. Three hundred feet must be measured off
    c. The roller operator must be Asphalt Field certified
    d. A minimum of 500 feet of mix should be placed
2. A roller pattern compares compactive effort vs. density?
    a. True
    b. False
3. To mark the locations for the roller pattern density testing:
    a. Marking is not necessary
    b. Use the nuclear gauge template and spray paint
    c. Place the gauge in position and spray paint around the edges
    d. First select numbers from the random number table
4. Who has the responsibility of furnishing and operating the thin-lift nuclear gauge?
    a. VDOT furnishes and operates the gauge.
    b. The Contractor furnishes the gauge and it must be operated by an Asphalt Field Certified Technician
    c. The Research Council furnishes the gauge and must be operated by the Engineer.
    d. VDOT furnishes the gauge, but it must be operated by the Contractor.
5. What determines whether the control strip passes?
    a. The average of the ten readings in the control strip meets or exceeds the minimum density requirement
    b. The average of 6 plugs/cores meets or exceeds the minimum density requirement
    c. One plug/core meets or exceeds the minimum density requirement
    d. The average of the ten readings in the control strip is between 98% and 102% of the job-mix density
6. Readings for the ten locations selected in the control strip are to be taken with the thin-lift nuclear gauge in the:
    a. 15 second mode
    b. 30 second mode
    c. 1 minute mode
    d. 2 minute mode
7. The density value to be entered in the thin lift gauge for the test sections must come from:
    a. The average of 10 readings in the control strip
    b. The average density of 3 plugs/cores from the control strip
    c. 92.5% of maximum theoretical density from the job mix
    d. The maximum density obtained in the roller pattern
8. How should the stratified reading locations be selected to determine the target nuclear control strip density?
    a. Daily
    b. Visually
    c. Professionally
    d. Randomly
9. CH.9 Practice Exercise #1

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10. CH.9 Practice Exercise #1

ASPHALT NUCLEAR DENSITY THIN LIFT
ROLLER PATTERN - WORKSHEET

Complete this worksheet.

Using the information on this worksheet complete the TL-57 on the next page.

Mix Type SM.12.5D Application Rate: 165 lbs/yd² (_____ kg/m²)

Producer Brand X Location Loafers Glory, VA

Roller Type: DD-130 Roller DD-110 Roller 3 _____

Roller Pattern Data

Gauge Model 4640B Serial No 1212 Calibration Date 7/18/08 Depth Setting 1.5 in. (mm)

Pass No 2V	Nuclear Density	Pass No _____	Nuclear Density
Site 1	144.6	Site 1	147.8
Site 2	145.8	Site 2	148.0
Site 3	144.9	Site 3	147.3
AVERAGE		AVERAGE	

Pass No 3V	Nuclear Density	Pass No _____	Nuclear Density
Site 1	146.5	Site 1	
Site 2	147.6	Site 2	
Site 3	146.8	Site 3	
AVERAGE		AVERAGE	

Pass No 4 (1s)	Nuclear Density	Pass No _____	Nuclear Density
Site 1	148.4	Site 1	
Site 2	149.2	Site 2	
Site 3	148.4	Site 3	
AVERAGE		AVERAGE	

Pass No 5 (2s)	Nuclear Density	Pass No _____	Nuclear Density
Site 1	147.9	Site 1	
Site 2	148.5	Site 2	
Site 3	147.8	Site 3	
AVERAGE		AVERAGE	

Testing Performed by _____ Observed by _____
VDOT Inspector

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CH.9 Practice Exercise #1

ASPHALT NUCLEAR DENSITY THIN LIFT
ROLLER PATTERN -GRAPH

Control Strip No 1 _____

Proje[illegible]08 _____

Route[illegible]7 _____

After completing this worksheet, answer the question at the bottom of the page.

Directional Lane NBL (NBL, SBL, etc) Lane Inside (Inside, Center, etc.)

Mix Type SM-12.5D Application Rate 165 lbs/yd² (_____ kg/m²)

Producer Brand X Location Loafers Glory, VA

Gauge Model 4640B Serial No 1212 Calibration Date 7/18/10 Depth Setting 1.5 in. (mm)

DENSITY lbs/ft³ (kg/m³)

NUMBER OF ROLLER PASSES

Optimum Density _____ lbs/ft³ (kg/m³)
(from peak of roller pattern curve)

Optimum Number of Passes: _____

Number of Roller Passes Roller 1 V Roller 2 S Roller 3 _____

Testing Performed By _____ Observed By _____
VDOT Inspector

Why did you select this for optimum (maximum) density?

CH.9 Practice Exercise #1

Using the random number table below, determine the test site locations for the Control Strip shown on the next page. The lane width is 11ft. It is an inside lane. The reference line is on the right.

Complete the TL-58 worksheet.

Distance From Beginning of Control Strip	Distance From Sublot Start	Paving Width						
	Test Section	Distance From Reference Line						
		8ft. width	9ft. width	10ft. width	11ft. width	12ft. width	13ft. width	14ft. width
23	12	2	4	5	2	1	2	4
44	429	6	4	8	9	8	11	11
81	358	5	4	8	2	3	7	11
141	812	5	3	8	6	10	6	8
149	105	3	7	7	10	9	2	11
176	620	3	4	3	3	2	9	7
187	167	1	6	5	9	7	5	1
213	589	3	3	6	4	6	4	5
239	726	6	8	8	2	3	4	7
275	412	1	4	2	3	4	8	9

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CH.9 Practice Exercise #1

VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY THIN LIFT WORKSHEET
CONTROL STRIP TARGET DENSITY

Control Strip Number 1

Complete this worksheet.

Project or Schedule PM-2D-10 9/15/10
Route 81
Directional Lane NBL (NBL, SBL, etc) Lane Inside (Inside, Center, etc.)
Mix Type SM-12.5D Application Rate 165 lbs/yd² (kg/m²)
Producer Brand X Location Loafers Glory, VA

Gauge Model 4640B Serial Number 1212 Calibration Date 7/18/10 Depth Setting 1.5 in (mm)

CONTROL STRIP TARGET DENSITY DETERMINATION

TEST SITE	DISTANCE	OFFSET	ENTER GAUGE READING		
Site 1			148.3	lb/ft³ (	kg/m³)
Site 2			147.2	lb/ft³ (	kg/m³)
Site 3			148.1	lb/ft³ (	kg/m³)
Site 4			149.2	lb/ft³ (	kg/m³)
Site 5			150.2	lb/ft³ (	kg/m³)
Site 6			148.7	lb/ft³ (	kg/m³)
Site 7			147.5	lb/ft³ (	kg/m³)
Site 8			149.4	lb/ft³ (	kg/m³)
Site 9			147.4	lb/ft³ (	kg/m³)
Site 10			147.6	lb/ft³ (	kg/m³)
		Total		lb/ft³ (	kg/m³)
		Average		lb/ft³ (	kg/m³)

Remarks:
Reference Line is on the right.

Testing Performed by _____ Observed by _____
VDOT Inspector

VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY WORKSHEET
ROLLER PATTERN/SAWN PLUGS & CONTROL STRIP TARGET DENSITY

Complete this worksheet.
Answer the questions at the bottom of the page.

15/10

Lane Direction: NBL (NBL, SBL, etc.) Lane Inside (inside, center, etc.)

Mix Type SM -12.5D Application Rate: 165 lbs/yd² (kg/m²)

Lot No 1 Width of Application 11 Lot Length 5000 ft (m)

Mix Producer Brand X Plant Location Loafers Glory, VA

NUCLEAR CALIBRATION CHECK

Sawed Spec. Number	A Weight in Air (g)	B Weight in Water (Total g)	C Basket Tare Weight	D Weight in Water (g) B - C	E SSD Weight In Air (g)	F Volume E-D	SSD Bulk Specific Gravity A ÷ F	G Average SSD Bulk Per Site	Sawed Specimen Thickness In. (mm)	H Target Test Site Nuclear (from TL-58)	
1	1215	730	xxx	730	1224				1.5		1
2	1218	732	xxx	732	1227				1.5		2
											3
3	1223	734	xxx	734	1232				1.6		4
											5
4	1220	728	xxx	728	1228				1.6		6
											7
5	1210	728	xxx	728	1222				1.5		8
											9
6	1214	729	xxx	729	1225				1.5		10
											Total
							Average	(Sum of G/3)		(Sum of H/10)	

Max Specific Gravity (G_{mm}) 2.644

A. Sawed Specimen Average % Density _____ % (avg. SSD Bulk Sp. Gr. /G_{mm} x 100)

B. Minimum Design Density (Table III – 3 of sec. 315) _____ %
*(A must equal or exceed B)

C. Target Nuclear Density _____ lb/ft³

Gauge Model 4640B Serial No. 1212 Calibration Date 7/18/10 Depth Setting 1.5 In (mm)

Pay Quantity _____ Ton (Metric Ton)
Lot length x width x application rate/ 18000

Testing Performed by _____ Observed by _____

What three sites would you core? Is this control strip acceptable? Why or why not?

CH.9 Practice Exercise #1

Using the random number table below, determine the test site locations for the test section shown on the next page. The lane width is 11ft. It is an inside lane. The reference line is on the right.

Distance From Beginning of Control Strip	Distance From Sublot Start	Paving Width						
	Test Section	Distance From Reference Line						
		8ft. width	9ft. width	10ft. width	11ft. width	12ft. width	13ft. width	14ft. width
23	12	2	4	5	2	1	2	4
44	429	6	4	8	9	8	11	11
81	358	5	4	8	2	3	7	11
141	812	5	3	8	6	10	6	8
149	105	3	7	7	10	9	2	11
176	620	3	4	3	3	2	9	7
187	167	1	6	5	9	7	5	1
213	589	3	3	6	4	6	4	5
239	726	6	8	8	2	3	4	7
275	412	1	4	2	3	4	8	9

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CH.9 Practice Exercise #1

Asphalt Concrete Density Quality Control (QC) Test Report - Nuclear

Complete this worksheet.
Answer the questions at the bottom of the page.

Project/Schedule Number:	PM-2D-10	Item Number:	14225
Route Number:	81	County:	
From (Station, MP, Int., etc.):		To (Station, MP, Int., etc.):	
Direction (e.g.			
QC Lot #:		Application Rate (lbs/sy):	side
Asphalt Mix Type:	1	Asphalt Job Mix Number:	165
Nuclear Gauge Model Number:	SM-12.5D	Gauge Calibration Date:	
Nuclear Gauge Serial Number:	46408	Depth Setting (in/mm):	7/18/10
	1212		1.5

Control Strip Information:

1. Control Strip Number and Date _____
2. Target Density from Control Strip _____ lbs/ft³ (kg/m³)
3. Minimum Density (98% Of Control Strip Target Density) _____ lbs/ft³ (kg/m³)
4. Maximum Density (102% Of Control Strip Target Density) _____ lbs/ft³ (kg/m³)

QC Testing Results By Nuclear Gauge:

Sublot No.	Location: Distance	Location: Offset	Nuclear Density lbs/ft³ (kg/m³)	Sublot Average lbs/ft³ (kg/m³)	Joint Density lbs/ft³ (kg/m³): Left (C or U)*	Joint Density lbs/ft³ (kg/m³): Right (C or U)*
1a			148.2		149.6 C	148.0 U
1b			148.7		150.1 C	147.8 U
2a			150.1		152.7 C	147.9 U
2b			147.3		148.9 C	145.2 U
3a			149.9		152.1 C	148.2 U
3b			149.5		150.0 C	148.4 U
4a			147.5		147.3 C	146.7 U
4b			148.3		150.7 C	146.7 U
5a			148.4		150.8 C	147.1 U
5b			147.7		148.8 C	146.6 U
6a						
6b						
7a						
7b						
			Average:			

* - C = Confined Jt, U = Unconfined Jt

Does the QC Test Section: (circle one) PASS FAIL

Comments: _____

Does this test section pass? Why or why not?

CH.9 Practice Exercise #2

ASPHALT NUCLEAR DENSITY THIN LIFT
ROLLER PATTERN - WORKSHEET

Complete this worksheet.

Using the information on this worksheet complete the TL-57 on the next page.

Mix Type SM-9.5D Application Rate: 165 lbs/yd² (_____ kg/m²)

Producer Asphalt, Inc. Location Blacktop, VA

Roller Type: Roller 1 DD-130 Roller 2 DD-110 Roller 3 _____

Roller Pattern Data

Gauge Model 4640B Serial No 1502 Calibration Date 7/18/10 Depth Setting 1.5 in. (mm)

Pass No	3V	Nuclear Density	Pass No		Nuclear Density
Site 1		149.0	Site 1		151.1
Site 2		145.1	Site 2		148.8
Site 3		146.9	Site 3		150.9
AVERAGE			AVERAGE		

Pass No	4V	Nuclear Density	Pass No		Nuclear Density
Site 1		145.4	Site 1		
Site 2		150.2	Site 2		
Site 3		154.3	Site 3		
AVERAGE			AVERAGE		

Pass No	5 (1s)	Nuclear Density	Pass No		Nuclear Density
Site 1		153.0	Site 1		
Site 2		152.3	Site 2		
Site 3		152.1	Site 3		
AVERAGE			AVERAGE		

Pass No	6 (2s)	Nuclear Density	Pass No		Nuclear Density
Site 1		152.1	Site 1		
Site 2		150.6	Site 2		
Site 3		151.7	Site 3		
AVERAGE			AVERAGE		

Testing Performed by Isaac Cline Observed by S. F. Mills
VDOT Inspector

CH.9 Practice Exercise #2

ASPHALT NUCLEAR DENSITY THIN LIFT
ROLLER PATTERN -GRAPH

Control Strip No 1

Project or S

Route

After completing this worksheet, answer the question at the bottom of the page.

Directional Lane EBL (NBL, SBL, etc)

Lane Outside (Inside, Center, etc.)

Mix Type SM-9.5D Application Rate 165 lbs/yd² (kg/m²)

Producer Asphalt, Inc Location Blacktop, VA

Gauge Model 4640B Serial No 1502 Calibration Date 7/18/08 Depth Setting 1.5 in. (mm)

DENSITY lbs/ft³ (kg/m³)

NUMBER OF ROLLER PASSES

Optimum Density _____ lbs/ft³ (kg/m³)
(from peak of roller pattern curve)

Optimum Number of Passes: _____

Number of Roller Passes Roller 1 _____ Roller 2 _____ Roller 3 _____

Testing Performed By Isaac Cline Observed By S. F. Mills VDOT Inspector

Why did you select this for optimum (maximum density?

CH.9 Practice Exercise #2

Using the random number table below, determine the test site locations for the Control Strip shown on the next page. Complete the worksheet. The lane width is 12ft. The reference line is on the right.

Distance From Beginning of Control Strip	Distance From Sublot Start	Paving Width						
	Test Section	Distance From Reference Line						
		8ft. width	9ft. width	10ft. width	11ft. width	12ft. width	13ft. width	14ft. width
8	81	7	7	2	4	3	8	4
43	142	1	4	5	5	4	2	6
81	67	6	5	2	3	2	2	12
99	569	2	4	6	3	6	3	1
111	728	2	6	7	5	3	12	12
172	902	1	3	5	4	2	1	12
192	726	2	3	2	5	8	5	6
210	242	2	7	3	9	6	5	13
243	172	6	3	1	5	3	6	4
278	82	6	7	4	9	2	9	5

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VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY THIN LIFT WORKSHEET
CONTROL STRIP TARGET DENSITY

Control Strip Number

Complete this worksheet.

Project or Schedule _____ Date 8/21/10

Route _____ To 17.25

Directional Lane _____ (NBL, SBL, etc) Lane Outside (Inside, Center, etc.)

Mix Type SM-9.5D Application Rate 165 lbs/yd² (kg/m²)

Producer Asphalt, Inc Location Blacktop, VA

Gauge Model 4640B Serial Number 1502 Calibration Date 7/18/10 Depth Setting 1.5 in (mm)

CONTROL STRIP TARGET DENSITY DETERMINATION

TEST SITE	DISTANCE	OFFSET	ENTER GAUGE READING			
Site 1			153.5	lb/ft³	(	kg/m³)
Site 2			152.4	lb/ft³	(	kg/m³)
Site 3			154.6	lb/ft³	(	kg/m³)
Site 4			157.0	lb/ft³	(	kg/m³)
Site 5			150.2	lb/ft³	(	kg/m³)
Site 6			151.9	lb/ft³	(	kg/m³)
Site 7			152.0	lb/ft³	(	kg/m³)
Site 8			154.1	lb/ft³	(	kg/m³)
Site 9			155.6	lb/ft³	(	kg/m³)
Site 10			153.0	lb/ft³	(	kg/m³)
		Total		lb/ft³	(	kg/m³)
		Average		lb/ft³	(	kg/m³)

Remarks:

Application Width is 12 feet and Reference Line is on the right.

Testing Performed by Isaac Cline

Observed by S.F. Mills
VDOT Inspector

CH.9 Practice Exercise #2

VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY WORKSHEET
ROLLER PATTERN/SAWN PLUGS & CONTROL STRIP TARGET DENSITY

Control Strip No. 1

Schedule PM-2A-10 Item No. _____ Date 8/21/10

Route _____ From: _____ To: 17.25

Lane Dir

Complete this worksheet.
Answer the questions at the bottom of the page.

Mix Type

Lot No 1 Width of Application 12 Lot Length 5000 ft (m)

Mix Producer Asphalt, Inc Plant Location Blacktop, VA

NUCLEAR CALIBRATION CHECK

Sawed Spec. Number	A Weight in Air (g)	B Weight in Water (Total g)	C Basket Tare Weight	D Weight in Water (g) B - C	E SSD Weight In Air (g)	F Volume E-D	SSD Bulk Specific Gravity A ÷ F	G Average SSD Bulk Per Site	Sawed Specimen Thickness In. (mm)	H Target Test Site Nuclear (from TL-58)	
1	1014	641	xxx	641	1021				1.5		1
2	1024	618	xxx	618	1031				1.5		2
											3
3	1158	691	xxx	691	1167				1.6		4
											5
4	1082	660	xxx	660	1091				1.5		6
											7
5	1190	699	xxx	699	1196				1.5		8
											9
6	1099	679	xxx	679	1107				1.5		10
											Total

Average _____ (Sum of G/3) _____ (Sum ofH/10)

Max Specific Gravity (G_{mm}) 2.653

A. Sawed Specimen Average % Density _____ (avg. SSD Bulk Sp. Gr. /G_{mm} x 100) %

B. Minimum Design Density (Table III – 3 of sec. 315) _____ %
*(A must equal or exceed B)

C. Target Nuclear Density _____ lb/ft³

Gauge Model 4640B Serial No. 1212 Calibration Date 7/18/10 Depth Setting 1.5 In (mm)

Pay Quantity _____ Ton (Metric Ton)
Lot length x width x application rate/ 18000

Testing Performed by Isaac Cline Observed by S. F. Mills

Is this control strip acceptable? Why or why not? What three sites would you core?

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CH.9 Practice Exercise #2

Using the random number table below, determine the test site locations for the Test Section shown on the next page. Complete the worksheet. The lane width is 12ft. It is an outside lane. The reference line is on the right.

Distance From Beginning of Control Strip	Distance From Sublot Start	Paving Width						
	Test Section	Distance From Reference Line						
		8ft. width	9ft. width	10ft. width	11ft. width	12ft. width	13ft. width	14ft. width
8	81	7	7	2	4	3	8	4
43	142	1	4	5	5	4	2	6
81	67	6	5	2	3	2	2	12
99	569	2	4	6	3	6	3	1
111	728	2	6	7	5	3	12	12
172	902	1	3	5	4	2	1	12
192	726	2	3	2	5	8	5	6
210	242	2	7	3	9	6	5	13
243	172	6	3	1	5	3	6	4
278	82	6	7	4	9	2	9	5

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CH.9 Practice Exercise #2

Asphalt Concrete Density Quality Control (QC) Test Report - Nuclear

Complete this worksheet.
Answer the questions at the bottom of the page.

Project/Schedule Number:		Item Number:	
Route Number:	PM-2A-10	County:	
From (Station, MP, lat, etc.):		To (Station, MP, lat, etc.):	
Direction (e.g. NB,			
QC Lot #:			outside
Asphalt Mix Type:		Asphalt Job Mix Number:	165
Nuclear Gauge Model Number:	SM -9.5D	Gauge Calibration Date:	
Nuclear Gauge Serial Number:	4640B	Depth Setting (in/mm):	7/18/10
	1212		1.5

Control Strip Information:

1. Control Strip Number and Date
2. Target Density from Control Strip _____ lbs/ft³ (kg/m³)
3. Minimum Density (98% Of Control Strip Target Density) _____ lbs/ft³ (kg/m³)
4. Maximum Density (102% Of Control Strip Target Density) _____ lbs/ft³ (kg/m³)

QC Testing Results By Nuclear Gauge:

Sublot No.	Location: Distance	Location: Offset	Nuclear Density lbs/ft³ (kg/m³)	Sublot Average lbs/ft³ (kg/m³)	Joint Density lbs/ft³ (kg/m³): Left (C or U)*	Joint Density lbs/ft³ (kg/m³): Right (C or U)*
1a			150.6		151.4 C	150.1 C
1b			151.2		151.8 C	150.9 C
2a			152.5		153.6 C	152.3 C
2b			153.1		152.8 C	151.8 C
3a			153.8		153.8 C	152.9 C
3b			152.4		153.1 C	152.1 C
4a			155.7		155.7 C	154.6 C
4b			156.5		155.9 C	156.2 C
5a			154.4		154.2 C	153.3C
5b			153.9		152.7 C	153.0 C
6a						
6b						
7a						
7b						
			Average:			

* - C = Confined Jt, U = Unconfined Jt

Does the QC Test Section: (circle one) PASS FAIL

Comments:

Does this Test Section pass? Why or why not?

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10 Math Problems

Learning Outcomes:

- ☑ Demonstration of practical application of mathematics as it relates to the job

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This section of the guide provides you with the equations and practice exercises to assist you in your work.

DEFINITION	
	L = Length of spread in feet R = Rate of application (asphalt in gallons per sq. yd. or aggregate in lb. per sq. yd.) W = Width of roadway T = Total gallons or pounds

Useful Formulas		
To find length of spread	L=	$\frac{9 \text{ X } T}{W \text{ x } R}$
To find length of spread per ton	L=	$\frac{9 \text{ x } 2000}{W \text{ x } R}$
To find rate of application for asphalt or aggregate	R=	$\frac{9 \text{ x } T}{W \text{ x } L}$

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Determining Length of Spread

Formula	
$L = \frac{9 \times T}{W \times R}$	Example: Application rate = 170 lb/yd^2 Total weight shipped = 132,940 lb Pavement width = 26 feet

Number of square feet in a square yard

Total pounds shipped

$$L = \frac{9 \times 132{,}940}{26 \times 170}$$

Width of roadway in feet

Application rate in lb/yd^2

$$L = \frac{1{,}196{,}460}{4420} = 270.69 \text{ or } 270.70 \text{ linear feet}$$

How many feet per ton will this material cover?

Formula		Formula
9 X 2,000 (2,000lbs/ton)	9 X 2,000 (2,000lbs/ton) W x R	$\frac{18{,}000}{26 \times 170} = \frac{1{,}800}{4{,}420}$ L = 4.07 or 4.1 linear feet per ton

Paving Math Problems

1. Using the information below:
    a. Calculate the linear feet this truckload of AC should cover at the specified application rate.
    b. How many linear feet will each ton of AC pave?

Application Rate = 185 lb./yd^2
Total weight shipped = 33,135 lb.
Pavement width = 11 feet

2. Using the information below:
    a. Calculate the linear feet this truckload of AC should cover at the specified application rate.
    b. How many linear feet will each ton of AC pave?

Application Rate = 165 lb./yd^2
Total weight shipped = 127,580 lb.
Pavement width = 24 feet

3. Using the information below:
    a. Calculate the linear feet this truckload of AC should cover at the specified application rate.
    b. How many linear feet will each ton of AC pave?

Application Rate = 158 lb./yd^2
Total weight shipped = 46,778 lb.
Pavement width = 12 feet

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Determining Application Rate

Formula	
$R = \frac{9 \times T}{W \times L}$	Example: The contractor has uniformly applied 495 gallons of undiluted CRS-1 emulsion to a section of roadway for a tack coat. It covers 5750 linear feet of roadway at a width of 13 feet. ▪ What is the application rate of the tack coat? ▪ Does it meet the specification requirement? *(See VDOT Road & Bridge Spec. 310.03)* **Diluted spec= 0.10 to 0.15, Non-diluted spec=0.05 to 0.10*

Number of square feet in a square yard

Total gallons

$$R = \frac{9 \times 495}{13 \times 5{,}750}$$

Width of roadway in feet

Length of spread

$$R = \frac{4{,}455}{7{,}4750} = 0.059 \text{ or } 0.06 \text{ gal/yd}^2$$

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Paving Math Problems

4. The Contractor has uniformly applied 610 gallons of undiluted CRS-1 emulsion to a section of roadway for a tack coat. The tack covers 5250 linear feet in length at a width of 11 feet.
    a. What is the application rate of the tack coat? _____gal/yd^2.
    b. Does this meet specification?

5. The Contractor has uniformly applied 2154 gallons of undiluted CRS-1 emulsion to a section of roadway for a tack coat. The tack covers 38,016 linear feet in length at a width of 12 feet.
    a. What is the application rate of the tack coat? _____gal/yd^2.
    b. Does this meet specification?

6. The Contractor has uniformly applied 3320 gallons of undiluted CRS-1 emulsion to a section of roadway for a tack coat. The tack covers 29,040 linear feet in length at a width of 12 feet.
    a. What is the application rate of the tack coat? _____gal/yd^2.
    b. Does this meet specification?

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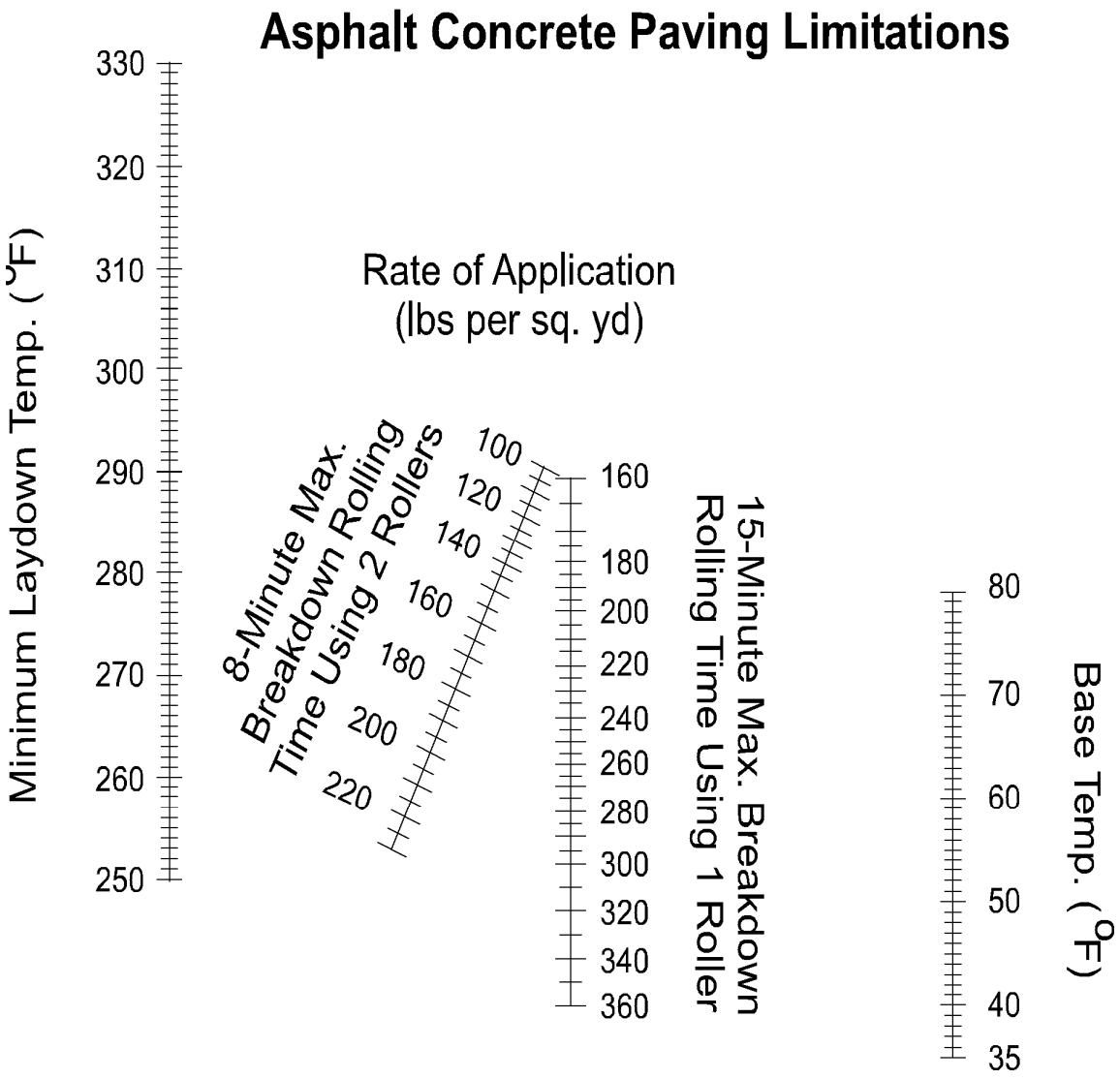
Placement Limitations

Section 315.04 of the Road and Bridge Specifications provide for the placement limitations of hot mix asphalt. Table III-2, also called the nomograph, is used to determine the minimum laydown temperature for a mix at a specific rate of application using either the 8-minute maximum breakdown rolling time (using two rollers) or the 15 minute maximum breakdown rolling time (using 1 roller), at a specific base temperature.



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7. A load of IM-19.0A arrived at the project to be placed at 220 lb./yd.^{2} with one breakdown roller on the job and a base temperature of 50°F, what is the minimum laydown temperature?

   a. 250°F
   b. 304°F
   c. 295°F
   d. 353°F

8. A load of SM-12.5A arrived at the project to be placed at 175 lb./yd.^{2} with two breakdown rollers on the job and a base temperature of 40°F, what is the minimum laydown temperature?

   a. 330°F
   b. 338°F
   c. 250°F
   d. 289°F

9. A load of SM-12.5A arrived at the project to be placed at 185 lb./yd.^{2} with one breakdown roller on the job and a base temperature of 45°F, what is the minimum laydown temperature?

   a. 300°F
   b. 318°F
   c. 287°F
   d. 307°F

10. A load of IM-19.0A arrived at the project to be placed at 190 lb./yd.^{2} with two breakdown rollers on the job and a base temperature of 52°F, what is the minimum laydown temperature?

    a. 308°F
    b. 338°F
    c. 281°F
    d. 274°F

11. The 8 minute maximum breakdown rolling time is specified when 2 or more rollers are used in breakdown rolling.

    a. True
    b. False

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A Answers

Chapter Two Knowledge Check (Ch.2 – p.33)

1. A prime coat on aggregate base is required on all state jobs regardless of the thickness of the asphalt mat to be put down.
    a. True
    b. False

2. The purpose of a tack coat is to ensure a bond between the existing pavement surface and the new asphalt overlay.
    a. True
    b. False

3. The material taken off the roadway when milling may not be used again.
    a. True
    b. False

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Chapter Three Knowledge Check (Ch.3 – p.55)

1. When an "end dump" truck raises it's bed to deliver mix into the hopper of the paver, the bed should not be in contact when the hopper and should not press down on or ride on the paver.
    a. True
    b. False
2. Contact between the hauling truck bed and the paver is never a problem.
    a. True
    b. False
3. In Virginia, haul trucks are required to be equipped with tarps_____
    a. Only during rain storms.
    b. Only when the roadway temperature goes below 40F.
    c. All the time.
    d. Only when your supervisor tells you to put one on.
4. The bed of the haul truck should be free of all deleterious materials before mix is placed in it.
    a. True
    b. False
5. When using diesel fuel as a release agent the residue must be dumped:
    a. In a container listed on the Departments approved list.
    b. Onto the ground in a well drained area.
    c. Diesel fuel should never be used as a release agent.
    d. Only at a VDOT Residency.
6. Some mixes are more prone to segregation than others and special care must be taken to ensure the mix load is as uniform as possible.
    a. True
    b. False
7. When a semi-tractor trailer is to be loaded, the mix should first be deposited at the_____
    a. Back of a trailer.
    b. Middle of the trailer.
    c. Front of the trailer.
    d. Middle and work towards the back.
8. When using an end dump or live bottom truck to deliver mix to the paver, the truck driver should back the truck up to the laydown machine but stop just short of the push rollers on the front of the paver.
    a. True
    b. False
9. The crust that forms on an asphalt mixture is acceptable if the temperature of the mix is greater than 225F.
    a. True
    b. False
10. Too much breaking force from the haul truck may cause the paver to slip and affect the mat.
    a. True
    c. False

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Chapter Four Knowledge Check (Ch.4 – p.84)

1. The paver consists of two primary parts: the tractor unit and the screed unit.
    a. True
    b. False
2. The proper depth of material on the augers should be at the_____.
    a. Fill mark on the auger shaft.
    b. Top of the auger shaft
    c. Two inch mark of the auger shaft.
    d. Center of the auger shaft.
3. The primary key to the placement of a smooth pavement layer is the use of the new material feed system to keep a constant head (level) of material in front of the screed.
    a. True
    b. False
4. The screed unit is attached to the tractor at:
    a. One point on each side of the paver.
    b. Two points on each side of the paver.
    c. Three points on each side of the paver.
5. The amount of density obtained by the paver screed is also a function of the speed of the paver.
    a. True
    b. False
6. The primary purpose of the heater or burner on the screed is to assist in reheating the asphalt mix to make up for heat loss during transit.
    a. True
    b. False
7. When changing the thickness control screws or tow point position, it takes _____ before an adjustment is completed.
    a. 15 minutes
    b. One tow length of the paver
    c. Five tow lengths of the paver
8. When changing trucks during paving, it is best if the transfer is accomplished without slowing down or stopping the paver.
    a. True
    b. False
9. Auger operation and conveyor operation should be adjusted to keep them running as close to _____ percent of the time as possible.
    a. 80
    b. 90
    c. 95
    d. 100

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Chapter Five Knowledge Check (Ch.5 – p.111)

1. A _____ joint occurs when one lane of asphalt mix is constructed adjacent to a previously placed lane of mix.
    a. Longitudinal
    b. Conventional
    c. Transverse
    d. Uniform
2. One key to the construction of a good longitudinal joint between lanes of asphalt mix is the amount of overlap between the new mat and the previously placed mat.
    a. True
    b. False
3. When the placement of the asphalt mix is to be suspended for a period of time and traffic is going to be passing over the end of the paving, a vertical butt joint may be constructed.
    a. True
    b. False
4. Constructing a temporary tapered joint using sand or dirt as the bond-breaking medium is <u>not</u> an acceptable VDOT paving practice.
    a. True
    b. false

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Chapter Six Knowledge Check (Ch.6 – p.139)

1. The density of a material is simply the weight of the material that occupies a certain volume of space.
    a. True
    b. False
2. A pass is defined as the entire roller moving over _____ point(s) in the mat at one time.
    a. One
    b. Two
    c. Three
    d. Four
3. A dense-graded aggregate may be easier to compact than a mixture with any other aggregate gradation.
    a. True
    b. False
4. A thin layer of mix will cool more quickly in a strong wind than when there is little or no wind.
    a. True
    b. False
5. The primary compaction variables for all types of rollers that can be controlled ruing the rolling process are:
    a. Roller speed
    b. Number of roller passes
    c. Rolling zone
    d. Rolling pattern
    e. All of the above
6. Compactive effort is significantly improved at slower roller speeds.
    a. True
    b. false

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Chapter Eight Knowledge Check (Ch8 – p.207)

1. What are important qualifications for an Inspector?
    a. Knowledge, common sense
    b. Diplomacy, observation skills
    c. All of the above

2. The most effective learning tool for an Inspector is on-the-job training.
    a. True
    b. False

3. What is the minimum placement temperature for PG-64-22 mix type A?
    a. 375°F
    b. 200°F
    c. 250°F
    d. 270°F

4. The Paving Inspector must keep a daily diary.
    a. True
    b. False

5. What is the purpose of inspection?
    a. Control the quantity of work
    b. Inspector to act as foreman for the Contractor
    c. Ensure the quality of work
    d. All of the above

6. Each load arrives on the job site accompanied by a _____ .
    a. TL-52A
    b. Weigh ticket
    c. TL-102A
    d. Daily diary

7. In order to accept asphalt concrete the Department must have:
    a. An approved mix design
    b. A producer who is under VDOT's Quality Assurance Program
    c. A good water source
    d. Both A and B

8. It is important for an Inspector to have an understanding of what tests are required both on the road and at the plant.
    a. True
    b. False

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Chapter Nine (Ch. 9 – p.196)

Specification Practice

Below is an exercise in looking up specifications. All answers can be found in VDOT Road and Bridge Specifications Section 315 – Asphalt concrete Pavement and Special Provisions.

1. What section is equipment for asphalt concrete pavement found?

   315.03 Equipment

2. What is the equipment and application requirement for tacking joints? What section is this found in?

   Tack at joints applied with a hand wand or spray bar at the rate of 0.2 gal/yd^2.

   Special Provision Section 315.05 (b) 1.b.

3. In section 315.05(d) the compacting sub-section of Procedures states, "Rolling shall not cause _____".

   "undue displacement, shoving or cracking."

4. The variation of the surface from the testing edge of the straightedge between any two contacts with the surface shall not be more than _____. This is found in Section _____.

   "1/4 inch"

   "315.07(a) Surface Tolerance"

5. How much should a longitudinal joint in one layer be offset form the layer immediately below? What section is this found in?

   6"

   Section 315.05 (c)

6. What is the pay unit for asphalt concrete material? This is found in what section?

   Tons
   Section 315.08

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Chapter Nine Knowledge Check (Ch. 9 – p.233)

1. Before a roller pattern is constructed:
    a. The number of roller passes should established
    b. Three hundred feet must be measured off
    c. The roller operator must be Asphalt Field certified
    d. A minimum of 500 feet of mix should be placed
2. A roller pattern compares compactive effort vs. density?
    a. True
    b. False
3. To mark the locations for the roller pattern density testing:
    a. Marking is not necessary
    b. Use the nuclear gauge template and spray paint
    c. Place the gauge in position and spray paint around the edges
    d. First select numbers from the random number table
4. Who has the responsibility of furnishing and operating the thin-lift nuclear gauge?
    a. VDOT furnishes and operates the gauge.
    b. The Contractor furnishes the gauge and it must be operated by an Asphalt Field Certified Technician
    c. The Research Council furnishes the gauge and must be operated by the Engineer.
    d. VDOT furnishes the gauge, but it must be operated by the Contractor.
5. What determines whether the control strip passes?
    a. The average of the ten readings in the control strip meets or exceeds the minimum density requirement
    b. The average of 6 plugs/cores meets or exceeds the minimum density requirement
    c. One plug/core meets or exceeds the minimum density requirement
    d. The average of the ten readings in the control strip is between 98% and 102% of the job-mix density
6. Readings for the ten locations selected in the control strip are to be taken with the thin-lift nuclear gauge in the:
    a. 15 second mode
    b. 30 second mode
    c. 1 minute mode
    d. 2 minute mode

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7. The density value to be entered in the thin lift gauge for the test sections must come from:
    a. The average of 10 readings in the control strip
    b. The average density of 3 plugs/cores from the control strip
    c. 92.5% of maximum theoretical density from the job mix
    d. The maximum density obtained in the roller pattern
8. How should the stratified reading locations be selected to determine the target nuclear control strip density?
    a. Daily
    b. Visually
    c. Professionally
    d. Randomly

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Problem No. 1

ASPHALT NUCLEAR DENSITY THIN LIFT
ROLLER PATTERN - WORKSHEET

TL-56(Rev- 4/05)

Complete this worksheet.

Using the information on this worksheet complete the TL-57 on the next page.

Mix Type SM-12.5D Application Rate: 165 lbs/yd² (_____ kg/m²)

Producer Brand X Location Loafers Glory, VA

Roller Type: Roller 1 DD-130 Roller 2 DD-110 Roller 3 _____

Roller Pattern Data

Gauge Model 4640B Serial No 1212 Calibration Date 7/18/10 Depth Setting 1.5 in. (mm)

Pass No	2V	Nuclear Density	Pass No	6 (3s)	Nuclear Density
Site 1		144.6	Site 1		147.8
Site 2		145.8	Site 2		148.0
Site 3		144.9	Site 3		147.3
AVERAGE		**145.1**	AVERAGE		**147.7**

Pass No	3V	Nuclear Density	Pass No		Nuclear Density
Site 1		146.5	Site 1		
Site 2		147.6	Site 2		
Site 3		146.8	Site 3		
AVERAGE		**147.0**	AVERAGE		

Pass No	4 (1s)	Nuclear Density	Pass No		Nuclear Density
Site 1		148.4	Site 1		
Site 2		149.2	Site 2		
Site 3		148.4	Site 3		
AVERAGE		**148.7**	AVERAGE		

Pass No	5 (2s)	Nuclear Density	Pass No		Nuclear Density
Site 1		147.9	Site 1		
Site 2		148.5	Site 2		
Site 3		147.8	Site 3		
AVERAGE		**148.1**	AVERAGE		

Testing Performed by _____ Observed by _____

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TL-57 (Rev. 4/05)

Problem No. 1 (continued)
ASPHALT NUCLEAR DENSITY THIN LIFT
ROLLER PATTERN -GRAPH

Control Strip No 1

Project or Schedule PM-2D-10 Item No _____ Date 9/15/10

After completing this worksheet, answer the question at the bottom of the page.

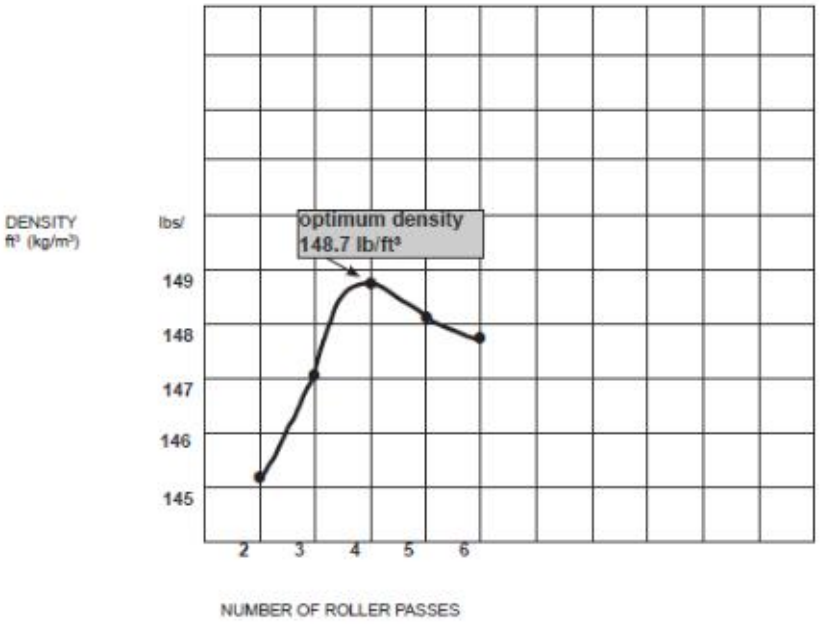
Route _____

Direction _____ (NBL, SBL, etc) (Inside, Center, etc.)

Mix Type SM-12.5D Application Rate 165 lbs/yd² (_____ kg/m²)

Producer Brand X Location Loafers Glory, VA

Gauge Model 4640B Serial No 1212 Calibration Date 7/18/10 Depth Setting 1.5 in. (mm)



Optimum Density 148.7 lbs/ft³ (kg/m³)
(from peak of roller pattern curve)

Optimum Number of Passes: 4

Number of Roller Passes Roller 1 3 V Roller 2 1 S Roller 3 _____

Testing Performed By _____ Observed By _____ VDOT Inspector

Why did you select this for optimum (maximum) density? *It was the highest density reading before a decrease in density, and with an additional pass the density decreased again*

Answers - 12 2011 v1.0

TL-68 (Rev. 4/05)

Problem No.1 (continued)

VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY THIN LIFT WORKSHEET
CONTROL STRIP TARGET DENSITY

Control Strip Number 1

Project or Schedule PM-2D-10 Item Number Date 9/15/10
Route 81 7
Directional Lane NBL (NBL, SBL, etc.) nside (Inside, Center, etc.)

Complete this worksheet

Mix Type SM-12.5D Application Rate 165 lbs/yd³ (kg/m³)
Producer Brand X Location Loafers Glory, VA

Gauge Model 4640B Serial Number 1212 Calibration Date 7/18/10 Depth Setting 1.5 in (mm)

CONTROL STRIP TARGET DENSITY DETERMINATION

TEST SITE	DISTANCE	OFFSET	ENTER GAUGE READING		
Site 1	23 ft.	2 ft. Lt.	148.3	lb/ft³ (	kg/m³)
Site 2	44 ft.	9 ft. Lt.	147.2	lb/ft³ (	kg/m³)
Site 3	81 ft.	2 ft. Lt.	148.1	lb/ft³ (	kg/m³)
Site 4	141 ft.	6 ft. Lt.	149.2	lb/ft³ (	kg/m³)
Site 5	149 ft.	10 ft. Lt.	150.2	lb/ft³ (	kg/m³)
Site 6	176 ft.	3 ft. Lt.	148.7	lb/ft³ (	kg/m³)
Site 7	187 ft.	9 ft. Lt.	147.5	lb/ft³ (	kg/m³)
Site 8	213 ft.	4 ft. Lt.	149.4	lb/ft³ (	kg/m³)
Site 9	239 ft.	2 ft. Lt.	147.4	lb/ft³ (	kg/m³)
Site 10	275 ft.	3 ft. Lt.	147.6	lb/ft³ (	kg/m³)
		Total	1483.6	lb/ft³ (	kg/m³)
		Average	148.4	lb/ft³ (	kg/m³)

Remarks:
Reference Line is on the right.

Testing Performed by Isaac Cline Observed by S.F. Mills
VDOT inspector

TL 60 (Rev 4/05)

Problem No. 1 (continued)
VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY WORKSHEET
ROLLER PATTERN/SAWN PLUGS & CONTROL STRIP TARGET DENSITY

Control Strip No. 1

Complete this worksheet.
Answer the questions at the bottom of the page.

Schedu
Route
Lane Direction: NBL (NBL, SBL, etc.) Lane Inside (inside, center, etc.)

Mix Type SM-12.5D Application Rate: 165 lbs/yd² (kg/m²)

Lot No 2 Width of Application 11 Lot Length 5000 ft (m)

Mix Producer Brand X Plant Location Loafers Glory, VA

NUCLEAR CALIBRATION CHECK

Sawed Spec. Number	A Weight in Air (g)	B Weight in Water (Total g)	C Basket Tare Weight	D Weight in Water (g) B - C	E SSD Weight In Air (g)	F Volume E-D	SSD Bulk Specific Gravity A ÷ F	G Average SSD Bulk Per Site	Sawed Specimen Thickness In. (mm)	H Target Test Site Nuclear (from TL-58)	
1	1215	730	xxx	730	1224	494	2.46	2.46	1.5	148.3	1
2	1218	732	xxx	732	1227	495	2.46		1.5	147.2	2
										148.1	3
3	1223	734	xxx	734	1232	498	2.46	2.45	1.6	149.2	4
										150.2	5
4	1220	728	xxx	728	1228	500	2.44		1.6	148.7	6
										147.5	7
5	1210	728	xxx	728	1222	494	2.45	2.45	1.5	149.4	8
										147.4	9
6	1214	729	xxx	729	1225	496	2.45		1.5	147.6	10
										1483.6	Total
							Average	2.45 (Sum of G/3)		148.4 (Sum of H/10)	

Max Specific Gravity (G_{mm}) 2.644

A. Sawed Specimen Average % Density 92.7 (avg. SSD Bulk Sp. Gr. /G_{mm} x 100) %

B. Minimum Design Density (Table III – 3 of sec. 315) 92.2 %
*(A must equal or exceed B)

C. Target Nuclear Density 148.4 lb/ft³

Gauge Model 4640B Serial No. 1212 Calibration Date 7/18/10 Depth Setting 1.5 In (mm)

Ton (Metric Ton)

Is this control strip acceptable? why or why not?

Yes, the Average Percent Density exceeds the Minimum Design Density required for Mix Type SM-12.5D as per Table III-3

What three sites would you core? ***1, 3, 6***

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Calculations for the TL-60 on the previous page.

Specimen 1 & 2	Specimen 3 & 4	Specimen 5 & 6
Column F Volume E - D Specimen 1 1224 - 730 = **494** Specimen 2 1227 - 732 = **495**	Column F Volume E - D Specimen 3 1232 - 734 = **498** Specimen 4 1228 - 728 = **500**	Column F Volume E - D Specimen 5 1222 - 728 = **494** Specimen 6 1225 - 729 = **496**
SSD Bulk Specific Gravity A ÷ F Specimen 1 1215 ÷ 494 = **2.46** Specimen 2 1218 ÷ 495 = **2.46**	SSD Bulk Specific Gravity A ÷ F Specimen 3 1223 ÷ 498 = **2.46** Specimen 4 1220 ÷ 500 = **2.44**	SSD Bulk Specific Gravity A ÷ F Specimen 5 1210 ÷ 494 = **2.45** Specimen 6 1214 ÷ 496 = **2.45**
Average SSD Bulk Per Site 2.46 + 2.46 = 4.92 / 2 = **2.46**	Average SSD Bulk Per Site 2.46 + 2.44 = 4.90/ 2 = **2.45**	Average SSD Bulk Per Site 2.45 + 2.45 = 4.90 /2 = **2.45**

Average SSD Bulk Specific Gravity

2.46 + 2.45 + 2.45 = 7.36 / 3 = **2.45**

Column H Target Test Site Nuclear Density
Sum of H/10

148.3 + 147.2 + 148.1 + 149.2 + 150.2 + 148.7 + 147.5 + 149.4 + 147.4 +147.6 = 1483.6/10 = 148.4

Sawed Specimen Average % Density

Avg. SSD Bulk Sp. Gr./ G_{mm} X 100

2.45/ 2.644 = 0.927 x 100 = **92.7**

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TL-59A

Problem No. 1 (continued)
Asphalt Concrete Density Quality Control (QC) Test Report - Nuclear

Complete this worksheet.
Answer the questions at the bottom of the page.

Project/Schedule Number:	PM2D-10	Item Number:	
Route Number:			
From (Station, MP, Int., etc.):		To (Station, MP, Int., etc.):	
Direction (e.g. NB, SB, etc.)	NBL	Lane (Inside, Center, Right, etc):	Inside
QC Lot #:	2	Application Rate (lbs/sy):	165
Asphalt Mix Type:	SM12.5D	Asphalt Job Mix Number:	2041-2008-05
Nuclear Gauge Model Number:	4640 B	Gauge Calibration Date:	7/18/10
Nuclear Gauge Serial Number:	1212	Depth Setting (in/mm):	1.5"

Control Strip Information:

1. Control Strip Number and Date	1	6/28/2010
2. Target Density from Control Strip	148.4	lbs/ft³ (kg/m³)
3. Minimum Density (98% Of Control Strip Target Density)	145.4	lbs/ft³ (kg/m³)
4. Maximum Density (102% Of Control Strip Target Density)	151.4	lbs/ft³ (kg/m³)

QC Testing Results By Nuclear Gauge:

Sublot No.	Location: Distance	Location: Offset	Nuclear Density lbs/ft³ (kg/m³)	Sublot Average lbs/ft³ (kg/m³)	Joint Density lbs/ft³ (kg/m³): Left (C or U)*	Joint Density lbs/ft³ (kg/m³): Right (C or U)*
1a	12 ft	2 ft Lt	148.2	148.5	149.6 C	148.0 U
1b	429 ft	9 ft Lt	148.7		150.1 C	147.8 U
2a	358 ft	2 ft Lt	150.1	148.7	152.7 C	147.9 U
2b	812 ft	6 ft Lt	147.3		148.9 C	145.2 U
3a	105 ft	10 ft Lt	149.9	149.7	152.1 C	148.2 U
3b	620 ft	3 ft Lt	149.5		150.0 C	148.4 U
4a	167 ft	9 ft Lt	147.5	147.9	147.3 C	146.7 U
4b	589 ft	4 ft Lt	148.3		150.7 C	146.7 U
5a	726 ft	2 ft Lt	148.4	148.1	150.8 C	147.1 U
5b	412 ft	3 ft Lt	147.7		148.8 C	146.6 U
6a						
6b						
7a						
7b						
			Average:	148.6	150.1	147.3
				100.1	101.1	99.3

Does the QC Test Section: (circle one) PASS FAIL

* - C = Confined Jt, U = Unconfined Jt

Does this test section pass? Why or why not?

Yes it passes. The density is 148.6 which falls within the acceptance range of 98-102 1(45.4 - 151.4) percent of the target density and no two consecutive sublot densities are lower than 98% or greater than 102%.

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TL-56(Rev- 4/05)

Problem No. 2

ASPHALT NUCLEAR DENSITY THIN LIFT ROLLER PATTERN - WORKSHEET

Control Strip No 2

Complete this worksheet.

Using the information on this worksheet complete the TL-57 on the next page.

Producer Asphalt, Inc Location Blacktop, VA

Roller Type: Roller 1 DD-130 Roller 2 DD-110 Roller 3

Roller Pattern Data

Gauge Model 4640B Serial No 1502 Calibration Date 7/18/08 Depth Setting 1.5 in. (mm)

Pass No	3V	Nuclear Density	Pass No	7 (3s)	Nuclear Density
Site 1		149.0	Site 1		151.1
Site 2		145.1	Site 2		148.8
Site 3		146.9	Site 3		150.9
AVERAGE		**147.0**	AVERAGE		**150.3**

Pass No	4V	Nuclear Density	Pass No		Nuclear Density
Site 1		145.4	Site 1		
Site 2		150.2	Site 2		
Site 3		154.3	Site 3		
AVERAGE		**150.0**	AVERAGE		

Pass No	5 (1s)	Nuclear Density	Pass No		Nuclear Density
Site 1		153.0	Site 1		
Site 2		152.3	Site 2		
Site 3		152.1	Site 3		
AVERAGE		**152.5**	AVERAGE		

Pass No	6 (2s)	Nuclear Density	Pass No		Nuclear Density
Site 1		152.1	Site 1		
Site 2		150.6	Site 2		
Site 3		151.7	Site 3		
AVERAGE		**151.5**	AVERAGE		

Testing Performed by Observed by VDOT Inspector

TL-57 (Rev. 4/05)

Problem No. 2 (continued)
ASPHALT NUCLEAR DENSITY THIN LIFT
ROLLER PATTERN -GRAPH

Control Strip No 2

Project or Schedule PM-2A-10 Item No _____ Date 8/21/10

Route _____

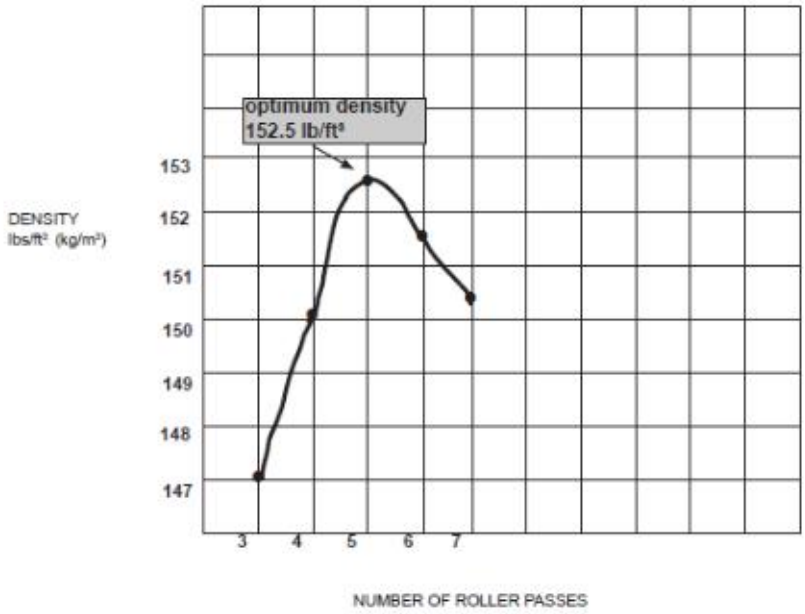
Directio _____

After completing this worksheet, answer the question at the bottom of the page.

Mix Type SM-9.5D Application Rate 165 lbs/yd² (_____ kg/m²)

Producer Asphalt, Inc Location Blacktop, VA

Gauge Model 4640B Serial No 1502 Calibration Date 7/18/10 Depth Setting 1.5 in. (mm)



Optimum Density 152.5 lbs/ft³ (kg/m³)
(from peak of roller pattern curve)

Optimum Number of Passes: 5

Number of Roller Passes Roller 1 4 V Roller 2 1 S Roller 3 _____

Testing Performed By _____ Observed By _____
VDOT Inspector

Why did you select this for optimum (maximum)density? *It was the highest density reading before a decrease in density, and with an additional pass the density decreased again*

TL-68 (Rev. 4/05)

Problem No. 2 (continued)

VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY THIN LIFT WORKSHEET
CONTROL STRIP TARGET DENSITY

Control Strip Number 2

Project or Schedule PM-2A-10 Item Number Date 8/21/08
Route 64 To
Directional Lane EB Complete this worksheet. ne Outside
(Inside, Center, etc.)
Mix Type SM-9.5D Application Rate 165 lbs/yd² (kg/m³)
Producer Asphalt, Inc Location Blacktop, VA

Gauge Model 4640B Serial Number 1502 Calibration Date 7/18/10 Depth Setting 1.5 in (mm)

CONTROL STRIP TARGET DENSITY DETERMINATION

TEST SITE	DISTANCE	OFFSET	ENTER GAUGE READING		
Site 1	8 ft.	3 ft. Rt	153.5	lb/ft³ (	kg/m³)
Site 2	43 ft.	4 ft. Rt	152.4	lb/ft³ (	kg/m³)
Site 3	81 ft.	2 ft. Rt	154.6	lb/ft³ (	kg/m³)
Site 4	99 ft.	6 ft. Rt	157.0	lb/ft³ (	kg/m³)
Site 5	111 ft.	3 ft. Rt	150.2	lb/ft³ (	kg/m³)
Site 6	172 ft.	2 ft. Rt	151.9	lb/ft³ (	kg/m³)
Site 7	192 ft.	8 ft. Rt	152.0	lb/ft³ (	kg/m³)
Site 8	210 ft.	6 ft. Rt	154.1	lb/ft³ (	kg/m³)
Site 9	243 ft.	3 ft. Rt	155.6	lb/ft³ (	kg/m³)
Site 10	278 ft.	2 ft. Rt	153.0	lb/ft³ (	kg/m³)
		Total	1534.3	lb/ft³ (	kg/m³)
		Average	153.4	lb/ft³ (	kg/m³)

Remarks:

Testing Performed by _____ Observed by _____
VDOT Inspector

TL 60 (Rev.4/08)

Problem No. 2 (continued)
VIRGINIA DEPARTMENT OF TRANSPORTATION
ASPHALT NUCLEAR DENSITY WORKSHEET
ROLLER PATTERN/SAWN PLUGS & CONTROL STRIP TARGET DENSITY

Control Strip No. 2

Schedule

Route

Lane Directi

Complete this worksheet.
Answer the questions at the bottom of the page.

Mix Type SM -9.5D Application Rate: 165 lbs/yd² (kg/m²)

Lot No 1 Width of Application 12 Lot Length 5000 ft (m)

Mix Producer Asphalt, Inc. Plant Location Blacktop, VA

NUCLEAR CALIBRATION CHECK

Sawed Spec. Number	A Weight in Air (g)	B Weight in Water (Total g)	C Basket Tare Weight	D Weight in Water (g) B - C	E SSD Weight In Air (g)	F Volume E-D	SSD Bulk Specific Gravity A ÷ F	G Average SSD Bulk Per Site	Sawed Specimen Thickness In. (mm)	H Target Test Site Nuclear (from TL-58)	
1	1014	641	xxx	641	1021	380	2.67	2.58	1.5	153.5	1
2	1024	618	xxx	618	1031	413	2.48		1.5	152.4	2
										154.6	3
3	1158	691	xxx	691	1167	476	2.43	2.47	1.6	157.0	4
										150.2	5
4	1082	660	xxx	660	1091	431	2.51		1.5	151.9	6
										152.0	7
5	1190	699	xxx	699	1196	497	2.39	2.48	1.5	154.1	8
										155.6	9
6	1099	679	xxx	679	1107	428	2.57		1.5	153.0	10
										1534.3	Total

Average 2.51 (Sum of G/3) 153.4 (Sum of H/10)

Max Specific Gravity (G_{mm}) 2.653

A. Sawed Specimen Average % Density 94.6 (avg. SSD Bulk Sp. Gr. /G_{mm} x 100) %

B. Minimum Design Density (Table III – 3 of sec. 315) 92.2 %
*(A must equal or exceed B)

C. Target Nuclear Density 153.4 lb/ft³

Gauge Model 4640B Serial No. 1212 Calibration Date 7/18/10 Depth Setting 1.5 In (mm)

Is this control strip acceptable? Why or why not?

The Average Percent Density exceeds the Minimum Design Density required for Mix Type SM-9.5D as per Table III-3

What three sites would you core? *1, 8, 10*

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These are the calculations for the TL-60 on the previous page.

Specimens 1 & 2	Specimens 3 & 4	Specimens 3 & 4
Column F Volume E - D Specimen 1 1021 - 641 = **380** Specimen 2 1031 - 618 = **413**	Column F Volume E - D Specimen 3 1167 - 691 = **476** Specimen 4 1091 - 660 = **431**	Column F Volume E - D Specimen 5 1196 - 699 = **497** Specimen 6 1107 - 679 = **428**
SSD Bulk Specific Gravity A ÷ F Specimen 1 1014 ÷ 380 = **2.67** Specimen 2 1024 ÷ 413 = **2.48**	SSD Bulk Specific Gravity A ÷ F Specimen 3 1158 ÷ 476 = **2.43** Specimen 4 1082 ÷ 431 = **2.51**	SSD Bulk Specific Gravity A ÷ F Specimen 5 1190 ÷ 497 = **2.39** Specimen 6 1099 ÷ 428 = **2.57**
Average SSD Bulk Per Site 2.67 + 2.48 = 5.15/2 = **2.58**	Average SSD Bulk Per Site 2.43 + 2.51 = 4.94/2 = **2.47**	Average SSD Bulk Per Site 2.39 + 2.57 = 4.96/2 = **2.48**

Average SSD Bulk Specific Gravity
2.58 + 2.47 + 2.48 = 7.53/3 = **2.51**

Column H Target Test Site Nuclear Density
Sum of H/10
153.5+ 152.4 + 154.6 + 157.0 + 150.2 + 151.9 + 152.0 + 154.1 + 155.6 + 153.0 = **1534.0**/ 10 = **153.4**

Sawed Specimen Average % Density
Avg. SSD Bulk Sp. Gr./ G_{mm} X 100
2.51/ 2.653 = 0.946 x100 = **94.6**

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Problem No. 2 (continued)
Asphalt Concrete Density Quality Control (QC) Test Report - Nuclear

Project/Schedule Number:	PM-2A-10	Item Number:	
Route Number:	64	County:	
From (Station, MP, Int., etc.):		To (Station, MP, Int., etc.):	
Direction (e.g. NB, SB, etc.)			
QC Lot #:			
Asphalt Mix Type:	SM-9.5D	Asphalt Job Mix Number:	
Nuclear Gauge Model Number:	4640 B	Gauge Calibration Date:	7/18/10
Nuclear Gauge Serial Number:	1502	Depth Setting (in/mm):	1.5"

Complete this worksheet.
Answer the questions at the bottom of the page.

Control Strip Information:

1. Control Strip Number and Date	2	8/21/10
2. Target Density from Control Strip	153.4	lbs/ft³ (kg/m³)
3. Minimum Density (98% Of Control Strip Target Density)	150.3	lbs/ft³ (kg/m³)
4. Maximum Density (102% Of Control Strip Target Density)	156.5	lbs/ft³ (kg/m³)

QC Testing Results By Nuclear Gauge:

Sublot No.	Location: Distance	Location: Offset	Nuclear Density lbs/ft³ (kg/m³)	Sublot Average lbs/ft³ (kg/m³)	Joint Density lbs/ft³ (kg/m³): Left (C or U)*	Joint Density lbs/ft³ (kg/m³): Right (C or U)*
1a	81t	3 ft Lt	150.6	150.9	151.4 C	150.1C
1b	142 ft	4 ft Lt	151.2		151.8C	150.9 C
2a	67 ft	2 ft Lt	152.5	152.8	153.6 C	152.3 C
2b	569 ft	6 ft Lt	153.1		152.8 C	151.8 C
3a	728 ft	3 ft Lt	153.8	153.1	153.8 C	152.9 C
3b	902 ft	2 ft Lt	152.4		153.1 C	152.1 C
4a	726 ft	8 ft Lt	155.7	156.1	155.7 C	154.6 C
4b	242 ft	6 ft Lt	156.5		155.9 C	156.2 C
5a	172 ft	3 ft Lt	154.4	154.2	154.2 C	153.3 C
5b	82 ft	2 ft Lt	153.9		152.7 C	153.0 C
6a						
6b						
7a						
7b						
			Average:	153.4	153.5	152.7
			PASS FAIL	100.0 %	100.1 %	99.5%

Does the QC Test Section: (circle one)

* - C = Confined Jt, U = Unconfined Jt

Does this test section pass? Why or why not? Yes, passes. Density is 153.4 which falls within the acceptance range of (150.3 -156.5) 98-102 percent of the target density and no two consecutive sublot densities are lower than 98% or er than 102%.

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Chapter Ten (Ch.10 – questions begin on p.252)

Paving Math Problems

1. Using the information below:
    a. Calculate the linear feet this truckload of HMA should cover at the specified application rate.
    b. How many linear feet will each ton of HMA pave?

Application Rate = 185 lb./yd^2
Total weight shipped = 33,135 lb.
Pavement width = 11 feet

a. Coverage of truckload in linear feet:

L	=	9 x T / W x R	=	9 x 33135 / 11 x 185	=	298215 / 2035	146.54 or 146.5 linear feet

a. Coverage per ton in linear feet:

L	=	9 x T / W x R	=	9 x 2000 / 11 x 185	=	18000 / 2035	8.84 or 8.8 linear ft/ton

2. Using the information below:
    a. Calculate the linear feet this truckload of HMA should cover at the specified application rate.
    b. How many linear feet will each ton of HMA pave?

Application Rate = 165 lb./yd^2
Total weight shipped = 127,580 lb.
Pavement width = 24 feet

a. Coverage of truckload in linear feet:

L	=	9 x T / W x R	=	9 x 127580 / 24 x 165	=	1148220 / 3960	289.95 OR 290 linear feet

b. Coverage per ton in linear feet:

L	=	9 x T / W x R	=	9 x 2000 / 24 x 165	=	18000 / 3960	4.54 or 4.5 linear ft/ton

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3. Using the information below:
    a. Calculate the linear feet this truckload of HMA should cover at the specified application rate.
    b. How many linear feet will each ton of HMA pave?

Application Rate = 158 lb./yd^2
Total weight shipped = 46,778 lb.
Pavement width = 12 feet

a. Coverage of truckload in linear feet:

L	=	9 x T / W x R	=	9 x 46778 / 12 x 158	=	421002 / 1896	222.04 OR 222 linear feet

b. Coverage per ton in linear feet:

L	=	9 x T / W x R	=	9 x 2000 / 12 x 158	=	18000 / 1896	9.49 or 9.5 linear ft/ton

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4. The Contractor has uniformly applied 610 gallons of undiluted CRS-1 emulsion to a section of roadway for a tack coat. The tack covers 5250 linear feet in length at a width of 11 feet.
    a. What is the application rate of the tack coat? _____gal/yd^2.
    b. Does this meet specification?

What is the application rate of the tack coat?							0.1 gal/yd^2
Does this meet specification?							Yes
R	=	9 x T / W x L	=	9 X 610 / 11 X 5250	=	5490 / 57750	0.095 = 0.1 gal/yd^2
Spec for undiluted: 0.05-0.10 gal/yd^2							
Spec for diluted: 0.10-0.15 gal/yd^2 (Section 310.03)							

5. The Contractor has uniformly applied 2154 gallons of undiluted CRS-1 emulsion to a section of roadway for a tack coat. The tack covers 38,016 linear feet in length at a width of 12 feet.
    a. What is the application rate of the tack coat? _____gal/yd^2.
    b. Does this meet specification?

What is the application rate of the tack coat?							0.04 gal/yd^2
Does this meet specification?							No
R	=	9 x T / W x L	=	9 X 2154 / 12 X 38016	=	19386 / 456192	0.042 = 0.04 gal/yd^2
Spec for undiluted: 0.05-0.10 gal/yd^2							
Spec for diluted: 0.10-0.15 gal/yd^2 (Section 310.03)							

6. The Contractor has uniformly applied 3320 gallons of undiluted CRS-1 emulsion to a section of roadway for a tack coat. The tack covers 29,040 linear feet in length at a width of 12 feet.
    a. What is the application rate of the tack coat? _____gal/yd^2.
    b. Does this meet specification?

What is the application rate of the tack coat?							0.09 gal/yd^2
Does this meet specification?							Yes
R	=	9 x T / W x L	=	9 X 3320 / 12 X 29040	=	29880 / 348480	0.085 = 0.09 gal/yd^2
Spec for undiluted: 0.05-0.10 gal/yd^2							
Spec for diluted: 0.10-0.15 gal/yd^2 (Section 310.03)							

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7. A load of IM-19.0A arrived at the project to be placed at 220 lb./yd.^{2} with one breakdown roller on the job and a base temperature of 50°F, what is the minimum laydown temperature?

   a. 250°F
   b. 304°F
   c. 295°F
   d. 353°F

8. A load of SM-12.5A arrived at the project to be placed at 175 lb./yd.^{2} with two breakdown rollers on the job and a base temperature of 40°F, what is the minimum laydown temperature?

   a. 330°F
   b. 338°F
   c. 250°F
   d. 289°F

9. A load of SM-12.5A arrived at the project to be placed at 185 lb./yd.^{2} with one breakdown roller on the job and a base temperature of 45°F, what is the minimum laydown temperature?

   a. 300°F
   b. 318°F
   c. 287°F
   d. 307°F

10. A load of IM-19.0A arrived at the project to be placed at 190 lb./yd.^{2} with two breakdown rollers on the job and a base temperature of 52°F, what is the minimum laydown temperature?

    a. 308°F
    b. 338°F
    c. 281°F
    d. 274°F

11. The 8 minute maximum breakdown rolling time is specified when 2 or more rollers are used in breakdown rolling.

    a. True
    b. False

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B

Virginia Test Methods

VTM-6, VTM-22, VTM-76

Virginia Test Method – 6
Field Determination of Bulk Specific Gravity of
Compacted Asphalt Mixtures Using Saturated
Surface Dry Specimens Appendix B, p.2

Virginia Test Method - 22
Field Determination of Percent Density
of Compacted Asphalt Concrete Mixtures Appendix B, p.4

Virginia Test Method – 76
Control Strip Density And Roller Pattern
And Control Strip Procedure Using A Thin-Lift
Nuclear Density Gauge For Asphalt Concrete Mixtures Appendix B, p.6

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Virginia Test Method - 6

Field Determination of Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface Dry Specimens

October 1, 2008

1. Scope

1.1 This method of test covers the field determination of bulk specific gravity of compacted asphalt mixtures.

1.2 The bulk specific gravity of the compacted asphalt mixtures may be used in calculating the unit of mass of the mixture.

1.3 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

ASTM D 7227 Standard Practice for Rapid Drying of Compacted Asphalt Specimens Using Vacuum Drying Apparatus.

3. Test Specimens

3.1 Test specimens are from any course of asphalt pavements.

3.2 Size of specimen shall be as specified in VTM-22.

4. Apparatus

4.1 Balance: A 2000 gram balance with an accuracy of 1.0 gram. The balance shall be equipped with suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of scale pan of balance. (Note 1).

NOTE 1: The holder shall be immersed in water to a depth sufficient to cover it and the test sample during weighing. Wire suspending the holder should be the smallest practical size to minimize any possible effects of a variable immersed length.

4.2 Water Bath: For immersing the specimen in water while suspended under the balance.

4.3 Water used in water bath shall meet the requirements for water used with cement or lime in the Road and Bridge Specifications.

5. Procedure

5.1 Mass of dry specimen in air Note 2, 3, 4 - Weigh the specimen in air. Designate this mass as “A”.

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5.2 Mass of specimen in water - Immerse the specimen in water bath for a minimum of one minute and determine the weight. Designate this mass as “C”.

5.3 Mass of saturated surface dry specimen in air - Surface dry the specimen by blotting all sides quickly with a damp towel and then weigh in air. Designate this mass as “B”.

NOTE 2: Specimens removed by a process that does not use water will require no further drying.

NOTE 3: Samples saturated with water initially either from wet coring or other source of water shall be dried to a constant mass until further drying does not alter the mass by more than 0.1 percent. Specimens shall be dried overnight at 125 ± 5°F and then weighed at two-hour intervals, or vacuum-dried in accordance with ASTM D7227, until constant mass is obtained.

NOTE 4: If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass (C) can be taken, then the surface dry mass (B), and finally the dry mass (A). When the sequence of testing operations is changed, the method outlined in Note 3 shall be used to the Dry Mass of the Specimen in Air (A) once the specimen has cooled to room temperature.

6. Calculation

6.1 Calculate the bulk specific gravity of the specimen as follows: (Report the value up to two decimal places.)

$$\text{Bulk Specific Gravity} = \frac{A}{B-C}$$

Where:
A = mass, in grams, of sample in air.
B = mass, in grams, of surface dry specimen in air.
C = mass, in grams, of sample of water.

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Virginia Test Method - 22

Field Determination of Percent Density of Compacted Asphalt Concrete Mixtures

October 1, 2008

1. Scope

This method covers the procedure for determining the percent density of compacted Asphalt Concrete mixtures in the field.

2. Apparatus

2.1 Rotary saw or coring machine as specified in VDOT specifications or special provisions.

3. Test Specimens

3.1 Two 4x4 in. sawed specimens shall be taken per site or two 4 in. diameter core specimens.

3.2 Care shall be taken to avoid distortion, bending or cracking of specimens during and after removal from the pavement.

3.3 To aid in cooling specimens, CO2, or dry ice is recommended for use prior to sawing and removing from the pavement.

3.4 If necessary, specimen may be separated from other pavement layers by sawing or other satisfactory means.

4. Procedure

4.1 Measure thickness of test specimen.

4.2 Determine the bulk specific gravity of the specimen in accordance with VTM-6.

4.3 The initial theoretical maximum specific gravity of an asphalt concrete mixture may be the job-mix value determined at the job-mix asphalt content until the production value has been determined on the material being placed in accordance with AASHTO T-209.

NOTE: The initial theoretical maximum specific gravity value shall be verified by the District or Central Office laboratory.

4.4 For dense graded asphalt concrete mixes (i.e. SUPERPAVE™ mixes), the theoretical maximum specific gravity used as the denominator for the percent density calculation shall be determined by a moving average of five values based on the contractor's test results. For stone matrix asphalt concrete mixes, the theoretical maximum specific gravity used as the denominator for the percent density calculation shall be determined by using the simple of average of the contractor's daily production test results. Only the theoretical maximum specific gravity used shall be a simple average.

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4.5 Until five values are obtained from the contractor's testing, the theoretical maximum specific gravity used shall be a simple average.

5. Calculation

5.1 Calculate the percent density of each site as follows:

$$\text{Percent Density} = \frac{\text{Average Bulk Specific Gravity}}{\text{Theoretical Maximum Specific Gravity}} \times 100$$

Where the Average Bulk Specific Gravity is either the average of the two specimens per site or the average bulk specific gravity of the total sites being evaluated, report to 3 decimal places.

6. Report

6.1 Report depth to nearest 0.1 inch.

6.2 Report percent density of each test specimen to nearest 0.1 percent.

7. Precision

7.1 If the difference in the bulk specific gravity between two specimens from the same test site varies by more than 0.045, discard and obtain two more specimens from a new test site.

7.2 If the difference in theoretical maximum specific gravity between the VDOT monitor sample and the contractor sample varies by more than 0.019 per AASHTO T-209, then the results VDOT and contractor) shall not be used in the calculation of percent density unless testing error is identified. If testing error is identified, then VDOT will determine which maximum theoretical specific gravity result to use in the percent density calculation.

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Virginia Test Method – 76

Control Strip Density And Roller Pattern
And Control Strip Procedure Using A Thin-Lift
Nuclear Density Gauge For Asphalt Concrete Mixtures

October 1, 2008

1. Scope

1.1 This method details the establishment of the minimum control strip density using the Thin-Lift Nuclear Gauge and a recommended procedure for setting up the Control Strip/Roller Pattern. Other procedures for setting up the Control Strip/Roller Pattern may be used when approved by the Engineer.

1.2 Within the first 500' to 1000' of mix placement a Roller Pattern and Control Strip will be constructed. The first 75' (approximate) length will be the Roller Pattern, and the next 300' (approximate) length will be the Control Strip, regardless of the paver width, and should be of the same depth or application rate as called for in the plans and/or contract.

*Note : A Roller Pattern and Control Strip should only be constructed after a minimum of 500' of mix has been placed.

1.3 The Roller Pattern and Control Strip shall be constructed using the same material, the same paving equipment and in the same manner as the remainder of the project.

1.4 To prevent delay in Density Determination, cores/plugs from surface and intermediate mixes shall be cut using a dry method of sawing. Cores/plugs from base mixes may be cut using either a dry method or a wet method of sawing.

1.5 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Apparatus

2.1 Approved Mix Design.

2.2 Approved Paving Equipment.

2.3 Nuclear Gauge Template and white/other approved spray paint.

2.4 Thin-Lift Nuclear Density Gauge with printer, must meet requirements of VTM-81.

2.5 Magnesium Nuclear Gauge Calibration Block.

2.6 A rolling measuring device that will measure from 1 to 1000 linear feet, or any other device approved by the Engineer.

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2.7 Rotary Saw or Coring machine for sawing a core/plug.

2.8 Equipment to weigh cores/plugs (VTM-6).

2.9 All apparatus to be furnished by the Contractor.

2.10 The Maximum Theoretical Specific Gravity as determined in VTM-22.

3. Procedure

3.1 At the beginning of each day a standard count check of the nuclear gauge should be performed at the project site.

3.2 To begin the Roller Pattern, make several passes (up and back) on 75' (approximate) of one section of the paver width. Move the roller over and roll the same number of passes on the other section of the paver width. (Refer to sketches in section 4.3) Record the number and type of Roller passes placed on the asphalt mat on the Asphalt Nuclear Density Roller Pattern Worksheet.

*Note: Use judgment and experience to make the maximum number of passes before beginning the nuclear gauge readings. (ex. If a mix has historically taken 6 vibratory passes of the roller to achieve compaction, then 4 vibratory passes should be made on the roller pattern section before any nuclear density readings are recorded. If there were no prior experience with a specific type of mix, then 2 passes (one (1) up and one (1) back) would be recommended as a starting point.) The Roller Pattern should be constructed in the same manner and with the same compaction equipment that the rest of the pavement will be constructed. If the paver width is wider than 12' and a breakdown roller will take more than two roller widths to get coverage over the entire mat then the roller pattern should reflect the procedure that will be used in production.

3.3 Select three (3) locations to be tested for density in the 75' roller pattern area. Two (2) locations shall be approximately 30' apart on one side of the lane and one (1) location on the opposite side of the lane approximately 15' from each of the first two sites. The exact location the gauge is placed shall be marked. The Nuclear Gauge shall always be positioned parallel with the roadway, with the source end toward the direction of the paver anytime a reading is taken. To prevent erroneous readings, care must be taken to ensure that the gauge is sitting flat on the asphalt surface and does not rock. Care must also be taken by the gauge operator to ensure that the gauge's source is in the proper test position when readings are taken. Nuclear readings for the Roller Pattern shall be taken using the 30-second mode. Tests will be taken after each additional pass from the same three (3) locations, with the gauge sitting in the same position as the first test. It is recommended that the paver stop while the roller pattern is being constructed. Once the roller pattern has been established the control strip will be placed using the same process except the paver will not pause or stop.

3.4 The average of the three (3) readings shall be plotted on the Roller Pattern Z Graph, in Density, lb/ft^3, vs. number of passes. The Roller Pattern shall be rolled until maximum density for the asphalt mixture is obtained. To achieve maximum density, the mat shall be rolled until the average density reading decreases. After the first decrease, the mat shall receive one

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additional pass of the roller to ensure that this was not a false break. If the mat continues to decrease in density, then the maximum density will be the density achieved one roller pass before the initial decrease in density. If a false break occurs (the density increases on the additional pass), then continue to make roller passes until the density decreases a second time. Once the density has decreased, make an additional pass. If the density decreases on this pass, then the maximum density will be the density achieved one roller pass before the second decrease. If the density increases, repeat these steps until maximum density has been achieved.

Note: Typically a decrease in density of 0.5 lb/ft^3 will indicate that maximum density has been achieved.

3.5 Build a 300' Control Strip by following the procedure established in the 75' Roller Pattern section. Ten stratified random selected locations will be marked in the 300' Control Strip section with the Nuclear Gauge Template . The template shall be placed on the mat and positioned parallel with the roadway with the arrows pointing in the direction of the paver. The Template shall be spray painted with white/other approved paint such that the underlying pavement is marked with paint through the cutouts in the template. These locations must be clearly visible when the template is removed. After marking its location with paint the Gauge Template shall be removed and a number painted near the site (not within the template's boundary.

3.6 The Nuclear Gauge (the special calibration and offset modes will be disabled and set in the one (1) minute mode for testing) shall then be placed within the area marked by the Gauge Template with the source toward the direction of the paver. Nuclear density readings in lb/ft^3 using the one-minute mode will be taken at the ten (10) locations marked in the 300' Control Strip section. The average of the ten (10) nuclear density tests, in lb/ft^3 will become the target density if the average bulk density of the cores/plugs determined in this Control Strip is satisfactory.

3.7 One set of plugs/cores (two 4" x 4" sawed plugs or two 4" diameter cores) shall be taken for density determination from three of the ten nuclear gauge reading locations in the 300' Control Strip section. The sites for the sawed plugs/cores should be the three sites that are the closest to the average nuclear gauge target density established in Section 3.6. The plugs/cores shall be taken within the gauge template's boundary directly beneath where the nuclear source of the gauge was located. Compute the bulk density of the 6 plugs/ cores (VTM-6). If one plug/core from a site is damaged, then the remaining undamaged plug/core will represent the bulk density of that specific site. If both plugs are damaged, then another set of plugs will be taken from the next site whose nuclear density is closest to the target density. The average bulk density for each site will be determined. The percent density (VTM-22) will be calculated from the three average bulk densities determined at each site. If the average percent density of the three sites meets density requirements of Section 315 of the Road and Bridge Specifications the average nuclear density determined in Section 3.6 will become the Target Density, in lb/ft3.

> 3.7.1 Lift Thicknesses 2.5" and Less - Artificial and rapid cooling methods (such as dry ice and CO_2) are used to chill fresh warm mats sufficiently to dry saw/ core the mat for density testing without damaging the sample. Note, use of flammable materials such as propane shall not be used as a rapid cooling method.

3.7.2 Lift Thicknesses In Excess of 2.5” - Wet cooling methods may be used to obtain density plugs/cores on lift thicknesses in excess of 2.5”. When wet cooling is used, the cores/plugs must be dried back in the lab and VTM-6 followed to determine the percent density. Artificial and rapid cooling methods are not effective. When wet cooling methods are not used, a period of not less than 12 hours after placement of the mix must pass before density plugs/cores are obtained. Note: use of flammable materials such as propane shall not be used as a rapid cooling method.

3.8 When the same approved mix design is to be used on a roadway other than the one for which the cores/plugs were taken for density determination, a new 375’ (approx.) Roller Pattern/Control Strip shall be constructed to determine the Roller Pattern and Target Density for this roadway. The Roller Pattern/Control Strip for this roadway will be determined in the same manner as the original with the exception that only one set (2 sawed plugs/cores) shall be taken from one of the ten nuclear gauge reading locations in the 300’ Control Strip section. The site for the plugs/cores should be the site that the nuclear density reading is closest to the target density established in Section 3.6. The average bulk density for the site will be determined. The percent density (VTM- 22) will then be calculated from the average bulk density. If the percent density meets specification, the average of ten (10) nuclear readings taken at random locations from the stratified 300’ (approx.) section shall become the Target Density, in lb/ft^3, for this roadway.

3.8.1 Lift Thicknesses 2.5” and Less - Artificial and rapid cooling methods (such as dry ice and CO2) are used to chill fresh warm mats sufficiently to dry saw/core the mat for density testing without damaging the sample. Note: use of flammable materials such as propane shall not be used as a rapid cooling method.

3.8.2 Lift Thicknesses In Excess of 2.5” - Wet cooling methods may be used to obtain density plug/cores on lift thicknesses in excess of 2.5”. When wet cooling is used, the plugs/cores must be dried back in the lab and VTM-6 followed to determine the percent density. Artificial and rapid cooling methods are not effective. When wet cooling methods are not used, a period of not less than 12 hours after placement of the mix must pass before density plugs/cores are obtained. Note: use of flammable materials such as propane shall not be used as a rapid cooling method.

4. Report

4.1 The calculations to determine the percent of Target Density obtained for each lot shall be recorded in the project notebook and used to determine any pay adjustment.

4.2 The forms recommended for use with this test method include, but are not limited to, TL-56, TL-57, TL-58, TL-59, TL-60, and TL-60A.

4.3 Sketches of Roller Pattern/control Strip

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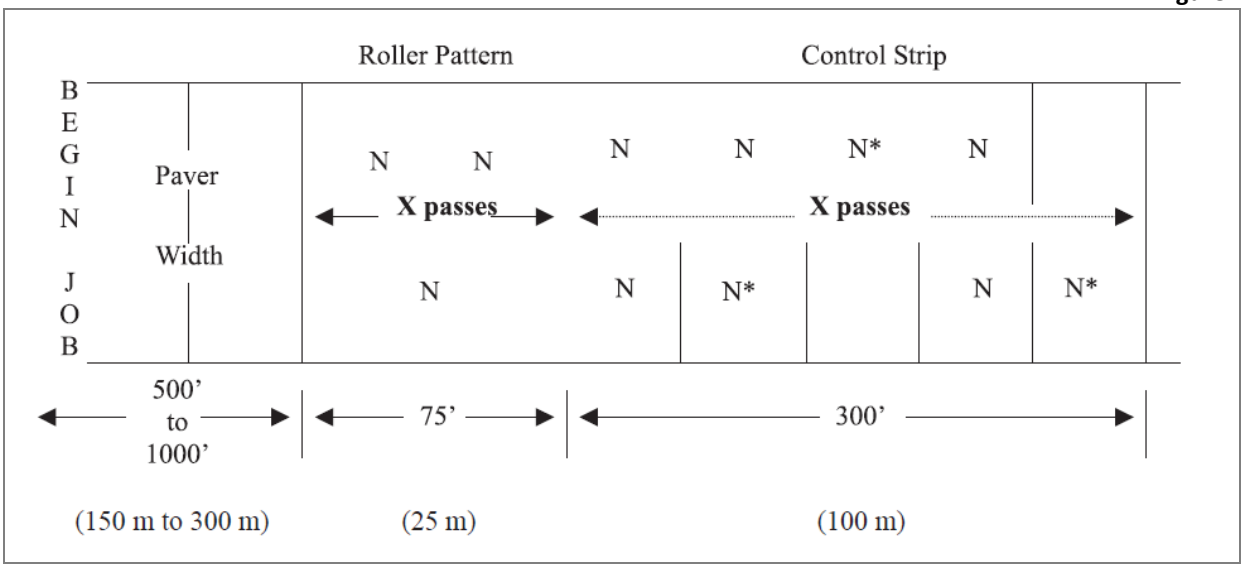
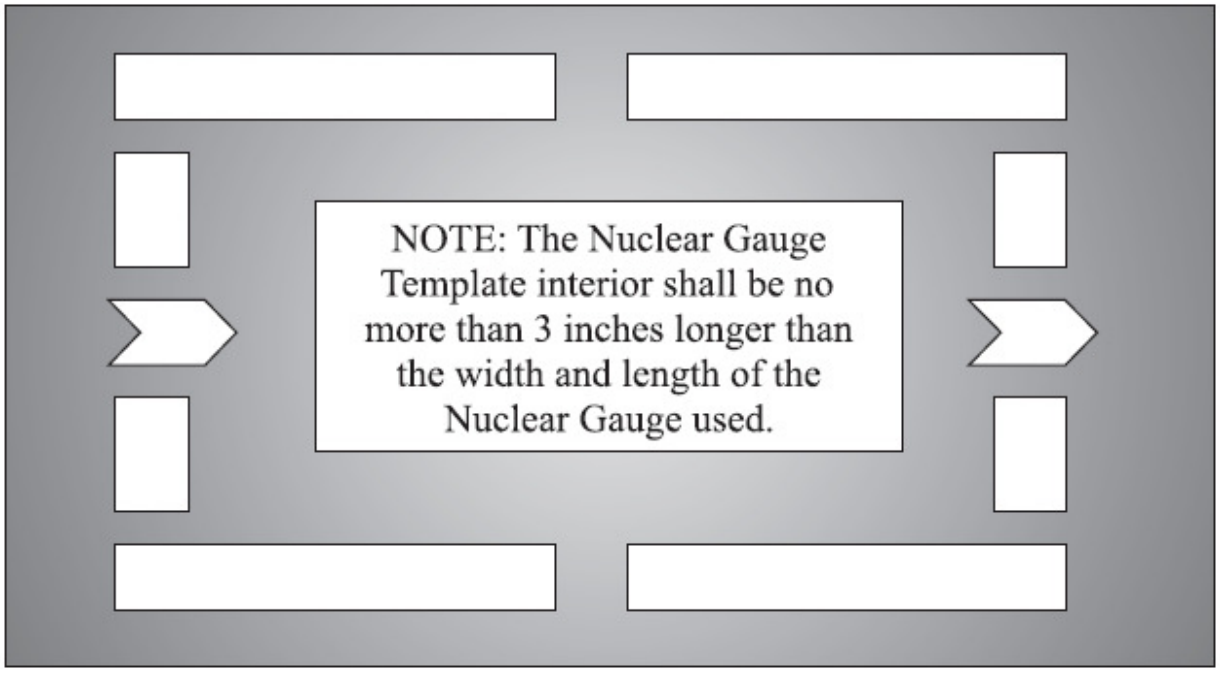
Figure 1



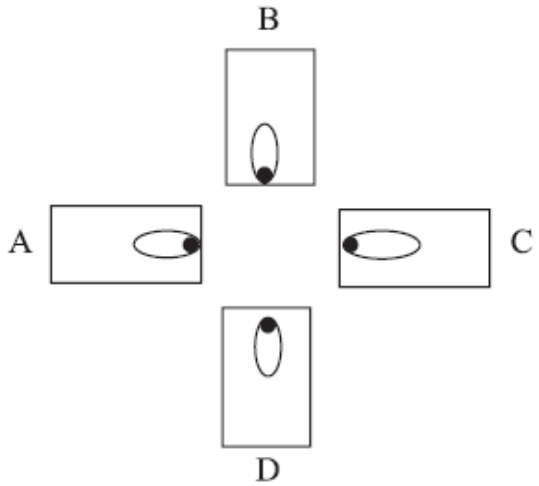
X = Number of passes by roller
N = Location of Nuclear Readings (Must be selected by random method and sites marked with template before taking readings.)
***** = Location of Cores/Plugs(Three sites closest to target density.)

Figure 2. Nuclear Gauge Template

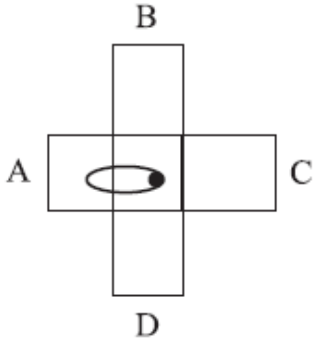


5. Nuclear Density vs Core/plug Density

5.1 When making any comparison of a core/plug density with that of a Nuclear Gauge Density, the Nuclear Gauge Density shall be an average of four (4) readings taken from the core/plug density, as shown in one of the sketches shown below. Also, if a comparison is to be made of any nuclear Density Reading sites, then each site should be an average of four (4) reading taken from each site location in the manner as shown in the sketch below for a core/plug site.



Gauge positions for comparison to a cut core/plug



Gauge positions for comparisons over a core/plug site

- Source

C Reference Materials

Division III, Roadway Construction, Section 304 – Constructing Density Control Strips	p.2
Division III, Roadway Construction, Section 310 – Tack Coat	p.4
Division III, Roadway Construction, Section 311 – Prime Coat	p.6
Division III, Roadway Construction, Section 315 – Asphalt Concrete Pavement (SUPERPAVE) (October 22, 2008)	p.8
Division III, Roadway Construction, Section 317 – Stone Matrix Asphalt Concrete Pavement (October 27, 2007)	p.23
Division III, Roadway Construction, Special Provision for Trench Widening Asphalt Mixtures	p.26
MEMORANDUM, Quality Hot Mix Asphalt Construction, Longitudinal Joint Construction and Application of Tack Coat for	p.28
TL-59A	p.40
Manual of Instructions, Chapter 5, Section 503	p.41

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SECTION 304--CONSTRUCTING DENSITY CONTROL STRIPS

304.01--Description.
This work shall consist of constructing control strips in accordance with the requirements of these specifications for the purpose of determining density requirements.

304.02--Materials.
Materials shall conform to the requirements for the material to be used in the course. Material used in each control strip shall be furnished from the same source and shall be of the same type as the material used in the test sections whose density requirements are established by the control strip.

304.03--Equipment.
Equipment shall be approved by the Engineer prior to use. The type and weight of compaction equipment shall be such that a uniform density is obtained throughout the depth of the layer of material being compacted. Control strips shall be compacted using equipment of the same type and weight to be used on the remainder of the course.

304.04--Procedures.
The subgrade or pavement structure course upon which a control strip is constructed shall be approved by the Engineer prior to construction of the control strip.

One control strip shall be constructed at the beginning of work on each roadway and shoulder course and each lift of each course. An additional control strip shall be constructed when a change is made in the type or source of material or whenever a significant change occurs in the composition of the material from the same source.

The project will be divided into “control strips” and “test sections” by the Engineer for the purpose of defining areas represented by each series of tests. The size of each control strip and test section will be in accordance with the requirements of VTM-10.

Control strips shall be constructed using the same procedure to be used in the construction of the remainder of the course. Rolling of the control strip shall be continued until no appreciable increase in density is obtained by additional roller coverages.

Upon completion of rolling, the mean density of the control strip will be based on 10 tests taken at randomly selected sites within the control strip area using a nuclear testing device. Compaction of the remainder of the course shall be governed by the density obtained in the control strip.

Each test section will be tested for required thickness. Areas that are deficient by more than the specified allowable tolerance shall be corrected in accordance with the applicable requirements of these specifications.

The Department may require an additional control strip after the completion of each 10 test sections.

Each control strip shall remain in place and become a section of the completed roadway.

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304.05--Tolerances.
If the mean density of a test section (roadway or shoulder) does not conform to the applicable requirements stated herein, the Contractor shall continue his compactive effort or shall rework the entire test section until the required mean density is obtained. If an individual test value does not conform to the requirements stated herein, the Contractor shall continue his compactive effort or shall rework the entire area represented by that test until the required density is obtained.

(b) **Shoulders:**

1. **Aggregate shoulders:** The density of each test section of select or aggregate material used in the construction of shoulders will be evaluated based on the results of five tests performed at randomly selected sites within the test section. The mean density obtained for the five tests in each test section shall be within 95 ± 2 percent of the mean density obtained in the approved control strip. In addition, each individual test value obtained in a test section shall be within 95 ± 5 percent of the mean density obtained in the approved control strip.

2. **Asphalt shoulders:** The density of each test section of asphalt concrete used in the construction of shoulders will be evaluated based on the results of five tests performed at randomly selected sites within the test section. The mean density obtained for the five tests in each test section shall be at least 98 percent of the mean density obtained in the approved control strip. In addition, each individual test value obtained within a test section shall be at least 95 percent of the mean density obtained in the approved control strip.

304.06--Measurement and Payment.
This item is considered incidental to the cost of furnishing, placing, and compacting the specified course and will not be measured for payment. The cost of constructing density control strips shall be included in the cost of the material for which the control strip is required.

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SECTION 310--TACK COAT (Oct. 25, 2007)

310.01--Description.

This work shall consist of preparing and treating an existing asphalt or concrete surface with asphalt in accordance with the requirements of these specifications and in reasonably close conformity with the lines shown on the plans or as established by the Engineer.

310.02--Materials.

Asphalt for tack coat shall be CRS-1, CRS-2, CRS-1h or CSS-1h and shall conform to the requirements of Section 210. CMS-2, conforming to the requirements of Section 210, may be used during the winter months. With the exception of CMS-2, asphalt for tack coat may be diluted with 50 percent water provided that resulting material produces a uniform application of the tack.

310.03--Procedures.

Equipment for heating and applying asphalt shall conform to the requirements of Section 314.04(b). The maximum application temperature of liquid asphalt shall conform to the requirements of Table III-1.

TABLE III-1
Liquid Asphalt Application Temperature

Grade	Max. Temperature (°F)
RC-70	180
RC-250	220
RC-800	225
RC-3000	290
MC-70	180
MC-250	220
MC-800	255
MC-3000	290
AC-5	300
AC-10	300
AC-20	300
AC-40	300
RS-2	175
SS-1h	180
AE-4	150
CRS-2	175
CSS-1h	180
CMS-2	200
CRS-1h	175
CRS-1	175

The existing surface shall be patched, cleaned, and rendered free from irregularities to the extent necessary to provide a reasonably smooth and uniform surface. Unstable corrugated areas shall be removed and replaced with suitable patching materials. The edges of existing

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pavements that are to be adjacent to new pavement shall be cleaned to permit adhesion of asphalt.

Tack material shall be uniformly applied with a pressure distributor conforming to the requirements of Section 314.04(b). Hand spray equipment shall not be used except in areas inaccessible by a pressure distributor. Undiluted asphalt shall be applied at the rate of 0.05 to 0.10 gallons per square yard. Diluted asphalt shall be applied at the rate of 0.10 to 0.15 gallons per square yard.

The tack coat shall be applied in a manner to offer the least inconvenience to traffic and permit one-way traffic without pickup or tracking of the asphalt.

The tack coat shall not be applied immediately prior to the course being placed. The tack coat shall be applied in accordance with the same weather limitations that apply to the course being placed. The quantity, rate of application, temperature, and areas to be treated shall be approved prior to application.

During the application of asphalt, care shall be taken to prevent spattering adjacent items. The distributor shall not be cleaned or discharged into ditches or borrow pits, onto shoulders, or along the right of way. When not in use, equipment shall be parked so that the spray bar or mechanism will not drip asphalt on the surface of the traveled way.

310.04--Measurement and Payment.
Tack coat, when a pay item, will be measured in liters and will be paid for at the contract unit price per liter. When not a pay item, the cost thereof shall be included in the price for other appropriate pay items.

Patching will be paid for at the contract unit price for the various items used unless a reconditioning item is included in the Contract.

Payment will be made under:

Pay Item	Pay Unit
Tack Coat	Gallons

SECTION 311--PRIME COAT (Oct. 22, 2008)

311.01--Description.
This work shall consist of preparing and treating an existing surface with asphalt, and cover material if required, in accordance with the requirements of these specifications and in reasonably close conformity with the lines shown on the plans or as established by the Engineer.

311.02--Materials.

(a) **Asphalt** may be changed one viscosity grade by the Engineer during construction at no change in the contract unit price. Asphalt shall conform to the applicable requirements of Section 210.

(b) **Cover material** shall conform to the applicable requirements of Section 202 or 203. Lightweight aggregate shall conform to the requirements of Section 206. Cover material shall not be hauled directly from a washing plant for immediate use in the work.

311.03--Procedures.
The rates of application of materials shall be determined in accordance with the method described in Education Series No. 12 of the Asphalt Institute entitled *Asphalt Surface Treatments Construction Techniques.*

The weather limitations of Section 314.03 shall apply to asphalt prime coat work. When asphalt is to be used as a cover for cement stabilization or as a primer for asphalt concrete, the weather limitations specified for these particular operations shall apply.

Equipment for heating and applying asphalt and cover material shall conform to the requirements of Section 314.04. The maximum application temperature of the liquid asphalt shall conform to the requirements of Table III-1.

The surface to be primed shall be shaped to the required grade and section; rendered free from ruts, corrugations, segregated material, or other irregularities; and uniformly compacted.

Delays in priming may necessitate reprocessing or reshaping to provide a smooth compacted surface.

Asphalt shall be applied by means of a pressure distributor in a uniform continuous spread. When traffic is maintained, not more than 1/2 the width of the section shall be treated in one application. Care shall be taken that the application of asphalt at junctions of spreads is not in excess of the specified amount. Excess asphalt shall be removed from the surface by a squeegee. Skipped areas or deficiencies shall be corrected.

During the application of asphalt, care shall be taken to prevent spattering adjacent items. The distributor shall not be cleaned or discharged into ditches or borrow pits, onto shoulders, or along the right of way. When not in use, equipment shall be parked so that the spray bar or mechanism will not drip asphalt on the surface of the traveled way.

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When traffic is maintained, one-way traffic shall be permitted on the untreated portion of the roadbed. When the asphalt has been absorbed by the treated surface and will not pick up, traffic shall be transferred to the treated portion and the remaining width of the section primed.

The quantity, rate of application, temperature, and areas to be treated shall be approved before application of the prime coat.

If after application of the prime coat the asphalt fails to penetrate within the time specified and the roadway must be used by traffic, cover material shall be spread at the Contractor's expense in an amount that will prevent pickup of the asphalt.

311.04--Measurement and Payment.

Prime coat will be measured and paid for at the contract unit price per gallon for asphalt and per ton for cover material, in accordance with the requirements of Section 313.

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SECTION 315--ASPHALT CONCRETE PAVEMENT (December 3, 2009)

315.01--Description.
This work shall consist of constructing one or more courses of asphalt concrete on a prepared foundation in accordance with the requirements of these specifications and within the specified tolerances for the lines, grades, thicknesses, and cross sections shown on the plans or as established by the Engineer. At the Contractor's option, Warm Mix Asphalt (WMA) additive or process may be used in lieu of the appropriate Hot mix Asphalt (HMA).

315.02--Materials.

(a) **Asphalt concrete** shall conform to the requirements of Section 211. If SUPERPAVE design densities begin to exceed 98 percent of the theoretical maximum density during construction, the Contractor shall alter the design.

(b) **Asphalt for tack coat and prime coat** shall conform to the requirements of Section 310. Asphalt may be changed one viscosity grade by the Engineer at no change in the contract unit price.

(c) **Curb backup material** shall be asphalt concrete conforming to any surface or intermediate mixture listed in Table II-13 and II-14.

(d) **Liquid asphalt coating (emulsion) for rumble strip** shall conform to the requirements of Section 210 of the Specifications. For centerline rumble strips, CSS-1h or CQS-1h conforming to Section 210 of the Specifications shall be used. The CSS-1h or CQS-1h may be diluted by up to 30 percent at the emulsion manufacture's facility.

315.03--Equipment.

(a) **Hauling Equipment:** Trucks used for hauling asphalt mixtures shall have tight, clean, smooth metal or other non-absorptive/inert material bodies equipped with a positive locking metal tailgate. Surfaces in contact with asphalt mixtures shall be given a thin coat of an aliphatic hydrocarbon invert emulsion release agent (nonpuddling), a lime solution, or other material on the Department's list of approved release agents. Except where a nonpuddling release agent is used, the beds of dump trucks shall be raised to remove excess agent prior to loading. Only a nonpuddling agent shall be used in truck beds that do not dump. Each truck shall be equipped with a tarpaulin or other cover that will protect the mixture from moisture and foreign matter and prevent the rapid loss of heat during transportation.

(b) **Asphalt Pavers:** The asphalt paver shall be designed and recommended by the manufacturer for the type of asphalt to be placed and shall be operated in accordance with the manufacturer's recommendations. Written recommendations pertaining to handling and placing of the mix shall be made readily available on the project site to the Engineer. In the absence of manufacturer's recommendations, the recommendations of the National Asphalt Pavement Association shall be followed. The paver (including when screed extensions are used) shall be capable of producing a smooth uniform texture, dense joints and a smooth riding surface.

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(c) **Rollers:** Rollers shall be steel wheel, static or vibratory, or pneumatic tire rollers and shall be capable of reversing without backlash. Rollers shall be operated at speeds slow enough to avoid displacement of the mixture. The number and mass of rollers shall be sufficient to compact the mixture to the required density while it is still in a workable condition. The use of equipment that results in excessive crushing of aggregate or marring of the pavement surface will not be permitted. If, during construction, it is found that the equipment being used mars the surface to the extent that imperfections cannot satisfactorily be corrected or produces permanent blemishes, the use of the equipment shall be discontinued and it shall be replaced with satisfactory units.

(d) **Rotary Saw:** A gasoline-powered rotary saw with a carbide blade shall be furnished for cutting test samples from the pavement. The Contractor shall furnish gasoline, oil, additional carbide blades, and maintenance for the rotary saw. The Contractor shall cool the pavement prior to sawing the sample. In lieu of a rotary saw, the Contractor may furnish the necessary equipment for coring and testing 4 inch core samples in accordance with the requirements of VTM-22.

(e) **Material Transfer Vehicle (MTV):** When required in the contract, a MTV shall be a self-propelled storage unit capable of receiving material from trucks, storing the material and transferring the material from the unit to a paver hopper insert via a conveyor system. The required paver hopper insert and unit shall have a combined minimum storage capacity of 15 tons. Prior to placing the asphalt material on the roadway surface, the storage unit or paver hopper insert must be able to remix the material in order to produce a uniform, non-segregated mix, having a uniform temperature.

315.04--Placement Limitations.

Asphalt concrete mixtures shall not be placed when weather or surface conditions are such that the material cannot be properly handled, finished or compacted. The surface upon which asphalt mixtures are to be placed shall be free of standing water, dirt, and mud and the base temperature shall conform to the following:

(a) **Warm Mix Asphalt (WMA):**

1. **When the base temperature is above 40 degrees F,** laydown will be permitted at any temperature below the maximum limits given in Section 211.08 of the Specifications.

2. **When the laydown temperature is between 301 oF and 325 oF**, the number of compaction | rollers will be the same number as required for 300 oF or less.

(b) **Hot Mix Asphalt (HMA):**

1. **When the base temperature is above 80 oF**, mixture laydown will be permitted at any temperature conforming to the limits specified in Section 211 of the Specifications.

2. **When the base temperature is between 40 o F and 80 oF**, the Nomograph, Table III-2, shall be used to determine the minimum laydown temperature of the asphalt concrete mixes. At no time should the minimum base temperature for base (BM) and Intermediate (IM) mixes be less than 40 degrees. at no time should the minimum laydown temperature for base (BM) and intermediate (IM) mixes be less than 250 degrees F.

For surface mixes (SM), at no time should the minimum base and laydown temperature be less than the following:

PG Binder/Mix Designation	Percentage of Reclaimed Asphalt Minimum Base Temperature	Minimum Base Temperature	Minimum Placement Temperat ure
Pg 64-22 (A)	<=20%	40 °F	250 °F
Pg 64-22 (A)	> 20 %	50 °F	270 °F
Pg 70-22 (D)	<= 30%	50 °F	270 °F
Pg 76-22 (E)	<= 15 %	50 °F	290 °F
Pg 64-22 (S)	<= 30%	50 °F	290 °F

3. **When the laydown temperature is between 301°F and 325°F**, the number of compaction rollers will be the same number as required for 300°F.

Intermediate and base courses which are placed at rates of application which exceed the application rates shown in Table III-2 shall conform to the requirements for the maximum application rate shown for 8 minute and 15 minute compaction rolling as per number of rollers used.

Should the Contractor be unable to complete the compaction rolling within the applicable 8 minute or 15 minute period, the placing of asphalt mixture shall either cease until sufficient rollers are utilized or other corrective action taken to complete the compaction rolling within the specified period.

Compaction rolling shall be completed prior to the mat cooling down to 175°F. Finish rolling may be performed at lower mat temperature.

The final asphalt pavement finish course shall not be placed until construction pavement markings are no longer required.

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315.05--Procedures.

(a) **Base Course:** The subgrade or subbase shall be prepared as specified in Section 305. The course upon which the pavement is to be placed, including the area that will support the paving equipment, shall be graded and compacted to the required profile.

(b) **Conditioning Existing Surface:** When the surface of the existing pavement or base is irregular, it shall be brought to a uniform grade and cross section as directed by the Engineer. The surface on which the asphalt concrete is to be applied shall be prepared in accordance with the requirements of the applicable specifications and shall be graded and compacted to the required profile and cross section.

When specified, prior to placement of asphalt concrete, longitudinal and transverse joints and cracks in hydraulic cement concrete shall be sealed by the application of an approved joint sealing compound.

Contact surfaces of curbing, gutters, manholes, and other structures projecting into or abutting the pavement and cold joints of asphalt shall be painted with a thick, uniform coating of asphalt prior to placement of asphalt mixture.

A tack or prime coat of asphalt will be required as specified below and shall conform to the applicable requirements of Section 310 and Section 311 of the Specifications. Asphalt classed as cutbacks or emulsions shall be applied ahead of the paving operations, and the time interval between applying and placing the pavement mixture shall be sufficient to ensure a tacky residue providing maximum adhesion of the paving mixture to the base. The mixture shall not be placed on tack or prime coats that have been damaged by traffic or contaminated by foreign material. Traffic shall be excluded from such sections.

1. **Priming and Tacking:**

a. Priming aggregate base or subbase: Unless otherwise specified in the contract documents, priming with asphalt materials will not be required on aggregate subbase or base materials prior to the placement of asphalt base, intermediate or surface layers.

b. Tacking: Application of tack at joints, adjacent to curbs, gutters, or other appurtenances shall be applied with a hand wand or spray bar at the rate of 0.2 gallons per square yard. At joints, the tack applied by the hand wand or a spray bar shall be 2 feet in width with 4 to 6 inches protruding beyond the joint for the first pass. Tack for the adjacent pass shall completely cover the vertical face of the mat edge, so that slight puddling of asphalt occurs at the joint, and extends a minimum of 1 foot into the lane to be paved.

Milled faces that are to remain in place shall be tacked in the same way for the adjacent pass. Use of tack at longitudinal joint vertical faces of longitudinal joints will not be required when paving in echelon.

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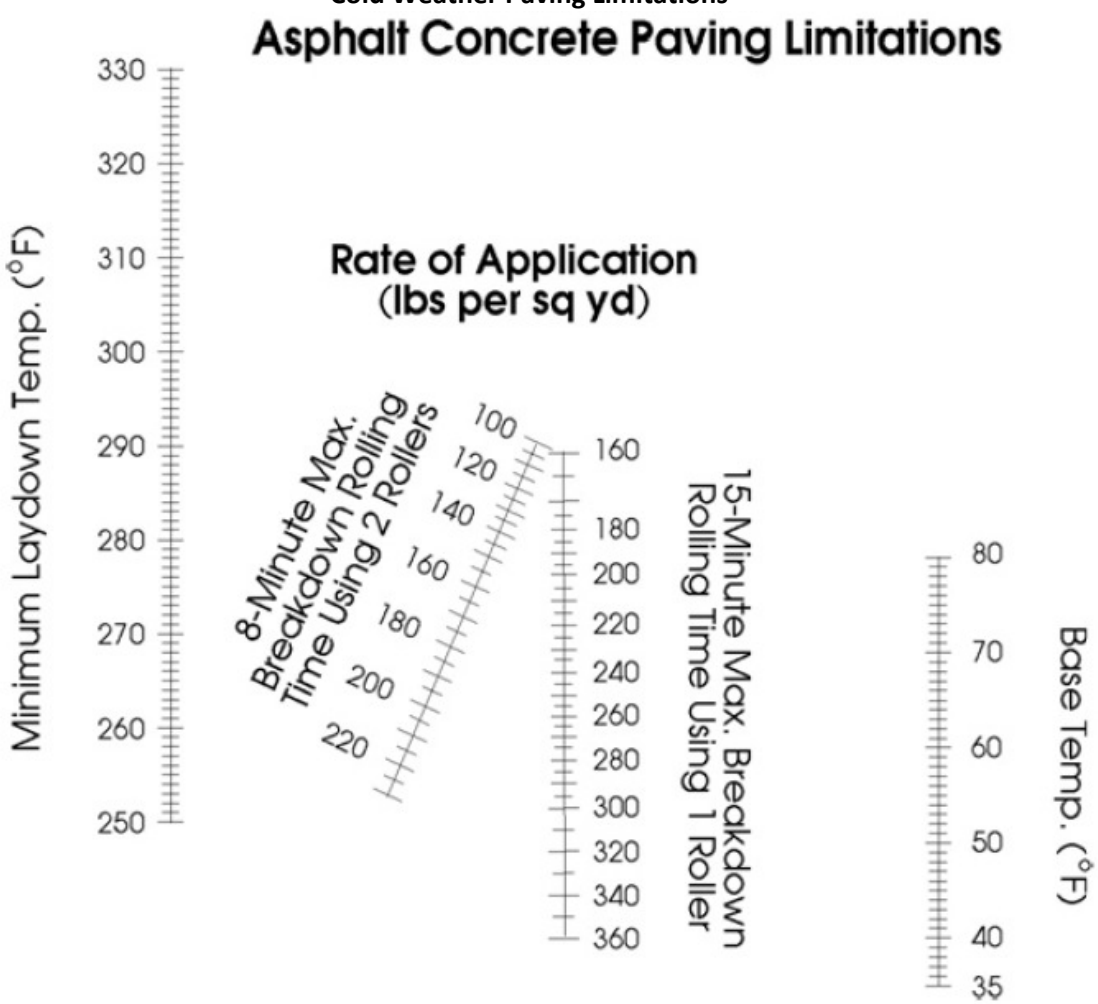
On rich sections or those that have been repaired by the extensive use of asphalt patching mixtures, the tack coat shall be eliminated when directed by the Engineer.

Tack shall not be required atop asphalt stabilized open-graded material drainage layers.
Tack shall be applied between the existing asphalt surface and each asphalt course placed thereafter.

2. **Removing depressions and elevating curves:** Where irregularities in the existing surface will result in a course more than 3 inches in thickness after compaction, the surface shall be brought to a uniform profile by patching with asphalt concrete and thoroughly tamping or rolling until it conforms with the surrounding surface. The mixture used shall be the same as that specified for the course to be placed.

When the Contractor elects to conduct operations to eliminate depressions, elevate curves, and place the surface course simultaneously, he shall furnish such additional spreading and compacting equipment as required to maintain the proper interval between the operations.

TABLE III-2
Cold Weather Paving Limitations



(c) **Placing and Finishing:** Asphalt concrete shall not be placed until the surface upon which it is to be placed has been approved by the Engineer.

A continuous line to mark the edge of the pavement and provide proper control of pavement width and horizontal will not be required for this project.

An asphalt paver shall be used to distribute asphalt concrete over the widest pavement width practicable. Wherever practicable and when the capacity of sustained production and delivery is such that more than one paver can be operated, pavers shall be used in echelon to place the wearing course in adjacent lanes. Crossovers, as well as areas containing manholes or other obstacles that prohibit the practical use of mechanical spreading and finishing equipment, may be constructed using hand tools. However, care shall be taken to obtain the required thickness, jointing, compaction, and surface smoothness.

Prior to application of tack coat and commencement of paving operations the Contractor shall clean the existing pavement surface of all accumulated dust, mud, or other debris that may affect the bond of the new overlay, as determined by the Engineer. The Contractor shall ensure the surface remains clean until commencement of paving operations. The cost for cleaning and surface preparation shall be in the bid price for hot mix asphalt concrete.

When required in a Schedule, an MTV shall be used during the placement of designed asphalt mixes on full lane width applications.

The longitudinal joint in one layer shall offset that in the layer immediately below by approximately 6 inches. However, the joint in the wearing surface shall be at the centerline of the pavement if the roadway comprises two traffic lanes or lane lines if the roadway is more than two lanes in width. Offsetting layers will not be required when adjoining lanes are paved in echelon and the rolling of both lanes occurs within 15 minutes after laydown.

The Contractor shall have a certified Asphalt Field Technician present during paving operations where more than 100 tons of material is placed in a single location. Immediately after placement and screeding, the surface and edges of each layer shall be inspected and straighedged by the technician and necessary corrections performed prior to compaction. The finished pavement shall be uniform and smooth.

The placement of asphalt concrete shall be as continuous as possible and shall be scheduled such that the interruption occurring at the completion of each day's work will not detrimentally affect the partially completed work. Material that cannot be spread and finished in daylight shall not be dispatched from the plant unless the use of artificial lighting has been approved. When paving is performed at night, sufficient light shall be provided to properly perform and thoroughly inspect every phase of the operation. Such phases include cleaning planed surfaces, applying tack, paving, compacting, and testing. Lighting shall be provided and positioned such as to not create a blinding hazard to the traveling public.

During compaction of asphalt concrete, the roller shall not pass over the end of freshly placed material except when a construction joint is to be formed. Edges shall be finished true and uniform.

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Asphalt concrete SUPERPAVE pavement courses shall be placed in layers not exceeding 4.0 times the nominal maximum size aggregate in the asphalt mixture. The maximum thickness may be reduced if the mixture cannot be adequately placed in a single lift and compacted to required uniform density and smoothness. The minimum thickness for a pavement course shall be no less than 2.5 times the nominal maximum size aggregate in the asphalt mixture. Nominal maximum size aggregate for each mix shall be defined as one sieve size larger than the first sieve to retain more than 10 percent aggregate as shown in the design range specified in Section 211.03, Table II-13. Base courses to be placed in irregular shaped areas of pavement, such as transitions, turn lanes, crossovers, and entrances may be placed in a single lift.

Overlays in excess of 165 pounds per square yard or a milled depth greater than 1 ½ inches shall be squared up at the completion of each day's work.

The milled roadway areas that are to be opened to traffic, excluding curb and gutter sections, shall have drainage outlets cut through the shoulders at locations designated by the Engineer. The Contractor shall plan and prosecute the milling operation to avoid trapping of water on the roadway. Drainage outlets shall be restored to original grade, unless otherwise directed by the Engineer. The cost for cutting and restoring the drainage slots in the roadway shoulder shall be included in the price bid for other items of work.

The Contractor shall plan and prosecute a schedule of operations so that milled roadways will be overlaid with asphalt concrete as soon as possible, and, in no instance, shall the time lapse exceed 10 days after the milling operations, unless otherwise specified. The milled areas of the roadway shall be kept free of irregularities and obstructions that may create a hazard or annoyance to traffic in accordance with the requirements of Section 104.

A short ski or shoe shall be used to match the grade of the newly overlaid adjacent travel lane on all primary, interstate and designated secondary routes. Unless otherwise directed by the Engineer a nine 24 foot minimum automatic grade control ski shall be used on all asphalt mixtures on all divided highways, with the exception of less than full width overlays and the first course of asphalt base mixtures over aggregate subbases. Care shall be exercised when working along curb and gutter sections to ensure a uniformed grade and joint.

The Contractor shall construct the final riding surface to tie into the existing surface by an approved method, which shall include the cutting of a notch into the pavement. In addition to notching, the Contractor may use an asphalt design containing a fine graded mix to achieve a smooth transition from the new asphalt concrete overlay to the existing pavement, with the approval of the Engineer. The material shall be of a type to insure that raveling will not occur. All cost for constructing tie-ins in the asphalt concrete overlay shall be included in the price bid for asphalt concrete.

(d) **Compacting:** Immediately after the asphalt mixture is placed and struck off and surface irregularities are corrected, the mixture shall be thoroughly and uniformly compacted by rolling.

The surface shall be rolled when the mixture is in the proper condition. Rolling shall not cause undue displacement, cracking, or shoving.

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The number, mass, and type of rollers furnished shall be sufficient to obtain the required compaction while the mixture is in a workable condition. The sequence of rolling operations and the selection of roller types shall provide the specified pavement density.

Immediately after the hot mixture is placed, it shall be sealed with rollers. Thereafter, rolling shall be a continuous process, insofar as practicable, and all parts of the pavement shall receive uniform compaction.

Rolling shall begin at the sides and proceed longitudinally parallel to the center of the pavement, each trip overlapping at least 6 inches, gradually progressing to the crown of the pavement. When abutting a previously placed lane, rolling shall begin at the outside unconfined side and proceed toward the previously placed lane. On super elevated curves, rolling shall begin at the low side and proceed to the high side by overlapping of longitudinal trips parallel with the centerline.

Displacements occurring as a result of reversing the direction of a roller, or from other causes, shall be corrected at once by the use of rakes or lutes and addition of fresh mixture when required. Care shall be taken in rolling not to displace the line and grade of the edges of the asphalt mixture.

To prevent adhesion of the mixture to the rollers, the wheels shall be kept properly moistened with water or water mixed with a very small quantity of detergent or other approved material. Excess liquid will not be permitted.

Along forms, curbs, headers, walls, and other places not accessible to rollers, the mixture shall be thoroughly compacted with hot hand tampers, smoothing irons, or mechanical tampers. On depressed areas, a trench roller may be used or cleated compression strips may be used under the roller to transmit compression to the depressed area.

Edges of asphalt pavement surfaces shall be true curves or tangents. Irregularities shall be corrected. The surface of the compacted course shall be protected until the material has cooled sufficiently to support normal traffic without marring.

(e) **Density:** Density shall be determined in accordance with the following:

1. The Contractor shall perform roller pattern and control strip density testing on surface, intermediate and base courses in accordance with the requirements of VTM – 76. The contractor shall have a certified Asphalt Field Technician perform all density testing.

   Density shall be determined by the backscatter method of testing using a thin-lift nuclear gage with printer, conforming to the requirements of VTM-81. All density test locations for control strips and test sections shall be marked and labeled in accordance with the requirements of VTM-76. The Contractor shall furnish and operate the nuclear gage, which shall have been calibrated within the previous 12 months by an approved calibration service. In addition, the Contractor shall maintain documentation of such calibration service for a 12 month period.

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The required density of the compacted course shall be no less than 98.0 percent and not more than 102.0 percent of the target control strip density.

Nuclear density roller pattern and control strip density testing shall be performed on asphalt concrete overlays placed directly on surface treatment roadways and when overlays are placed at an application rate less than 125 pounds per square yard (based on 110 pounds per square yard per inch) on any surface. In these situations, sawed plugs or core samples will not be required and the minimum control strip densities as shown in Table III-3 will be waived. The required density of the compacted course shall not be less than 98.0 percent and not more than 102.0 percent of the target control strip.

TABLE III-3
Density Requirements

Mixture Type	Min. Control Strip Density (%)
SM-9.5A, 12.5A	92.5
SM-9.5D, 12.5D	92.2
SM-9.5E, 12.5E	92.2
IM-19.0A, IM-19.0D, IM-19.0E	92.2
BM-25.0A, BM-25.0D	92.2

Note: The control strip density requirement is the percentage of theoretical maximum density of the job-mix formula by Superpave Mix Design or as established by the Engineer based on two or more production maximum theoretical density tests.

The project will be divided into “control strips” and “test sections” by the Engineer for the purpose of defining areas represented by each series of tests.

a. **Control Strip:** Construction of control strips shall be accomplished in accordance with the requirements of these specifications and VTM-76. The term *control strip density* is defined as the average of 10 nuclear determinations selected at stratified random locations within the control strip.

One control strip shall be constructed at the beginning of work on each roadway and shoulder course and on each lift of each course. An additional control strip shall be constructed when a change is made in the type or source of materials, or whenever a significant change occurs in the composition of the materials being placed from the same source or when there is a failing control strip. During the evaluation of the initial control strip paving operations may continue. However, paving and production shall be discontinued during construction and evaluation of additional control strips. In the event that two consecutive control strips fail, subsequent paving operations shall cease until corrective action(s) has been made with the approval of the Engineer. If it is determined with the Engineer’s approval that the density cannot be obtained because of the condition of the existing pavement structure, the target control strip density shall be determined from the roller pattern that achieves the optimum density and shall be used on the remainder of the roadway that exhibits similar pavement conditions.

Either the Department or Contractor may initiate an additional control strip at any time.

The length of the control strip shall be approximately 300 feet regardless of the width of the course being placed. On the first day of construction or beginning of a new course, the control strip shall be started between 500 and 1000 feet from the beginning of the paving operation. The control strip shall

be constructed using the same paving, rolling equipment, procedures and thickness as shall be used on the remainder of the course being placed.

One nuclear reading shall be taken at each of 10 stratified random locations. No determination shall be made within 12 inches of the edge of any application width for surface and intermediate mixes, nor within 18 inches of the edge of any application width for base mixes. The average of these 10 determinations shall be the Control Strip Density recorded to the nearest 0.1 pound per cubic foot. The minimum Control Strip Density shall be determined in accordance with the requirements of VTM-76.

The control strip shall be considered a lot. If the control strip density conforms to the requirements of Table III-3, the control strip will be acceptable and the control strip density shall become the target control strip density. If the density does not conform to the requirements of Table III-3, the tonnage placed in the control strip will be paid for in accordance with Table III-4 on the basis of the percentage of the Table III-3 value achieved. The Contractor shall take corrective action(s) to meet the density requirement specified in Table III-3.

TABLE III-4
Payment Schedule for Lot Densities

% of Target Control Strip Density	% of Payment
Greater than 102.0	95
98.0 to 102.0	100
97.0 to less than 98.0	95
96.0 to less than 97.0	90
Less than 96.0	75

b. **Test section (lot):** For the purposes of acceptance, each day's production shall be divided into lots (test section). The standard size of a lot shall consist of 5,000 linear feet of any pass made by the paving train regardless of the width of the pass or the thickness of the course. Pavers traveling in echelon will be considered as two passes. Each lot shall be divided into five sublots of equal length. When a partial lot occurs at the end of a day's production or upon completion of the project, the lot size shall be redefined as follows: If the partial lot contains one or two sublots, the sublots will be added to the previous lot. If the partial lot contains three or four sublots, the partial lot will be redefined to be an entire lot. Each lot shall be tested for density by taking a nuclear density reading from two random locations selected by the Engineer within each sublot. Readings shall not be taken within 12 inches of the edge of any application width for surface or base mixes, nor within 18 inches of the edge of any application width for base mixes. The average of the sublot nuclear density readings will be compared to the target nuclear control strip density to determine the acceptability of the lot. Once the average nuclear density of the lot has been determined, the Contractor will not be permitted to provide additional compaction to raise the average. If two consecutive sublots produce nuclear density results less than 98 or greater than 102 percent of the target nuclear control strip density, the Contractor shall immediately notify the Engineer and institute corrective action. By the end of the day's operations, the Contractor shall furnish the test data developed during the day's paving to the Engineer.

The tonnage of each lot will be based on the lot's width and length and the mixture application rate as designated in the Contract or as revised by the Engineer. Payment will be made in accordance with the requirements of Table III-4.

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The Engineer at any time on any project may perform Lot Density Verification testing. Lot Density Verification can be performed by either using a nuclear gage or plugs. The Contractor shall be responsible for taking plugs for testing. Testing of the plugs shall be done by or in the presence of the Department.

Surface, Intermediate, and Base mixes:

When a nuclear gage is used, the Department shall take 10 stratified random readings per lot. If, based on the average of the 10 readings, the density does not meet the requirement for 100 percent pay or the same pay percentage determined by the Contractor's testing for that lot, the Department will read the 10 Contractor sites then average all 20 sites together. If the density still does not conform to the requirements for 100 percent pay, payment for that lot shall be in accordance with Table III-4 on the basis of the Department's 20 test results. If the Contractor questions the payment for the lot, the Contractor can request the referee procedure.

The referee procedure shall consist of taking 5 plugs from the 5 sites closest to the average of the Department readings of the Contractor and Department sites. The density of the plugs shall be determined. If the average density of the plugs does not conform to the requirements for 100 percent pay for the lot in question, payment for that lot shall be in accordance with Table III-4 on the basis of the percentage of the Table III-3 value achieved.

When plugs are used for Lot Density Verification, 5 plugs shall be taken per lot. If the density of the plugs does not conform to the requirements for the lot in question, payment for that lot shall be in accordance with Table III-4 on the basis of the percentage of the Table III-3 value achieved.

(e) **Surface, intermediate and base courses** not having a sufficient quantity of material to run a nuclear density roller pattern and control strip shall be compacted to a minimum density of 91.5 percent of the theoretical maximum density as determined in accordance with the requirements of VTM-22. The Contractor shall be responsible for cutting cores or plugs for testing by the Department. If the density is less than 91.5 percent, payment will be made in accordance with the requirements of Table III-5.

For asphalt patching, the minimum density of 91.5 percent maximum theoretical density will be determined in accordance with the requirements of VTM-22. The Contractor shall be responsible for cutting cores or sawing plugs. One set of plugs/cores shall be obtained within the first 20 tons of patching material and every 500 tons thereafter for testing by the Contractor or the Department. Core/ plug locations shall be randomly selected. If the density is less than the 91.5 percent, payment will be made in accordance with the requirements of Table III-5.

Table III-5

Payment Schedule for Surface, Intermediate and Base Courses
(Not sufficient quantity to perform nuclear density roller pattern and control strip)

% Theoretical Maximum Density	% of Payment
Greater than or equal to 91.5	100
90.2-91.4	95
88.3-90.1	90
Less than 88.2	75

Any section in which a mixture (i.e. SM-9.0) is being placed at an application rate of less than 125 pounds per square yard, based on 110 pounds per square yard per inch, that does not have a sufficient quantity of material for a nuclear density roller pattern and control strip shall be compacted by rolling a minimum of three passes with a minimum 8 ton roller. No density testing will be required.

(f) **Joints:** Transverse joints shall be formed by cutting back on the previous run to expose the full depth of the course. A coat of asphalt shall be applied to contact surfaces of transverse joints just before additional mixture is placed against the previously rolled material.

Joints adjacent to curbs, gutters, or adjoining pavement shall be formed by hand placing sufficient mixture to fill any space left uncovered by the paver. The joint shall then be set up with rakes or lutes to a height sufficient to receive full compression under the rollers.

(g) **Rumble strips:** This work shall consist of constructing rumble strips on mainline shoulders of highways by cutting 1/2 -inch-deep concave depressions into existing asphalt concrete surfaces as shown on the detail drawings and as directed by the Engineer.

Rumble strips shall be installed in accordance with detail drawings for rumble strips (asphalt shoulder). The depressions shall have a concave circular shape with minimum 1/2-inch depth at center and maximum 5/8-inch allowable depth at center. Depressions shall have as smooth finish with a maximum 1/16-inch variance between peaks and valleys of the depression.

Prior to beginning production work on mainline shoulders, the Contractor shall demonstrate to the Engineer the ability to achieve the desired surface regarding alignment, consistency, and conformity with these specifications and the plans. The test site shall be approximately 25 feet longitudinally at a site mutually agreed upon by the Contractor and Engineer.

Following cutting and cleaning of the depressions of waste material, the entire rumble strip area shall be coated with liquid asphalt coating (emulsion) using a pressure distributor. For rumble strips installed on the shoulder, the approximate application rare shall be 0.1 gallon per square yard. For rumble strips installed in a new asphalt concrete surface (new construction or overlay) along the centerline, no sealing of the rumble strip area shall be performed. When the rumble strip is installed along the centerline in an existing asphalt concrete (i.e. more than one year since placement), the approximate application rate shall be 0.05 gallons per square yard. The application temperature shall be between 160 degrees f and 180 degrees F. For shoulder rumble strips only, overspray shall not extend more than 2 inches beyond the width of the cut depressions and/or shall not come in contact with pavement markings.

Rumbles strips shall not be installed on shoulders of bridge decks, in acceleration /deceleration lanes, on surface drainage structures, or in other areas identified by the Engineer.

Waste material resulting from the operation shall be removed from the paved surface and shall not be disposed of where waterways may be at risk of contamination.

(h) **Saw-cut Asphalt Pavement:** This work shall consist of saw-cutting the existing asphalt pavement to a depth shown on the plans and as directed by the Engineer.

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315.06--Pavement Samples.
The Contractor shall cut samples from the compacted pavement for testing by the Department. Samples shall be taken for the full depth of the course at the locations selected by the Engineer. The removed pavement shall be replaced with new mixture and refinished. No additional compensation will be allowed for furnishing test samples and reconstructing areas from which they were taken.

315.07--Pavement Tolerances.

(a) **Surface Tolerance:** The surface will be tested by using a 10-foot straight edge. The variation of the surface from the testing edge of the straightedge between any two contacts with the surface shall be not more than 1/4 inch. Humps and depressions exceeding the specified tolerance shall be corrected, or the defective work shall be removed and replaced with new material.

(b) **Finished Grade Tolerance:** After placement of the final pavement layer, finished grade elevations shall be within ±0.04 foot of the elevations indicated in the plans, unless otherwise specified, provided that the actual cross slope does not vary more than 0.20 percent from the design cross slope indicated in the plans and the pavement thickness conforms to the thickness tolerances specified herein.

If determined by the Engineer that either the finished grade elevations or cross slope exceed the tolerances specified, the Contractor shall submit to the Engineer for approval a plan of corrective action.

(c) **Thickness Tolerance:** The thickness of the base course will be determined by the measurement of cores as described in VTM-32B.

Acceptance of asphalt concrete base for depth will be based on the mean result of measurements of samples taken from each lot of material placed. A *lot* of material is defined as the quantity being tested for acceptance except that the maximum lot size will be 1 mile of 24-foot-width base course.

A lot will be considered acceptable for depth if the mean result of the tests is within the following tolerance of the plan depth for the number of tests taken except that each individual test shall be within ±0.60 inch of the plan depth: mean of two tests, ±0.45 inch; mean of three tests, ±0.35 inch; mean of four tests, ±0.30 inch.

If an individual depth test exceeds the ±0.60-inch tolerance, that portion of the lot represented by the test will be excluded from the lot. If an individual test result indicates that the depth of material represented by the test is more than 0.60 inch, the Contractor will not be paid for that material in excess of the tolerance throughout the length and width represented by the test. If an individual test result indicates that the depth of the material represented by the test is deficient by more than 0.60 inch, correction of the base course represented by the test shall be made as specified hereinafter.

If the mean depth of a lot of material is excessive, the Contractor will not be paid for that material in excess of the tolerance throughout the length and width represented by the tests.

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If the mean depth of a lot of material is deficient by more than the allowable tolerance, correction will not normally be required and the Contractor will be paid for the quantity of material that has been placed in the lot.

For excessive depth base courses, the rate of deduction from the tonnage allowed for payment as base course will be calculated at a weight of 115 pounds per square yard per inch of depth in excess of the tolerance. For sections of base course that are deficient in depth by more than 0.60 inch and less than 1.50 inch, the Contractor shall furnish and place material specified for the subsequent course to bring the base course depth within the tolerance. This material will be measured on the basis of tonnage actually placed, determined from weigh tickets, and paid for at the contract unit price for the base course material. Such material shall be placed in a separate course. If the deficiency is more than 1.50 inches, the Contractor shall furnish and place base course material to bring the base course thickness within the tolerance. Corrections for deficient base course depth shall be made in a manner to provide a finished pavement that is smooth and uniform.

When the Contract provides for the construction or reconstruction of the entire pavement structure, the surface and intermediate courses shall be placed at the rate of application shown on the plans within an allowable tolerance of ±5 percent of the specified application rate for application rates of 100 pounds per square yard or greater and within 5 pounds per square yard for application rates of less than 100 pounds per square yard. The amount of material exceeding the allowable tolerance will be deducted from the pay quantities.

When the Contract provides for the placement of surface or intermediate courses over existing pavement, over pavements constructed between combination curb and gutter, or in the construction or reconstruction of shoulders, such courses shall be placed at the approximate rate of application shown on the plans. However, the specified rate of application shall be altered where necessary to produce the required riding quality.

315.08—Measurement and Payment

Asphalt concrete base will be measured in tons and paid for at the contract unit price per ton. This price shall include preparing and shaping the subgrade or subbase, constructing and finishing shoulders and ditches, and removing and replacing unstable subgrade or subbase.

Asphalt concrete will be measured in tons and paid for at the contract unit price per ton. Net weight information shall be furnished with each load of material delivered in accordance with the requirements of Section 211. Batch weights will not be permitted as a method of measurement unless the Contractor's plant is equipped in accordance with the requirements of Section 211, in which case the cumulative weight of the batches will be used for payment.

Asphalt used in the mixtures, when a pay item, will be measured in tons in accordance with the requirements of Section 109.01 except that transporting vehicles shall be tarred prior to each load. The weight shall be adjusted in accordance with the percentage of asphalt indicated by laboratory extractions.

Tack coat shall be included in the price for other appropriate pay items.

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Asphalt curb backup material will be measured in tons and will be paid for at the contract unit price per ton. This price shall include placing, tamping, and compacting.

Liquid asphalt cement, when a pay item, will be measured in tons and will be paid for at the contract unit price per ton.

Rumble strips will be measured and paid for in linear feet of shoulder where the rumble strips are actually placed and accepted, excluding the test site. This distance will be measured longitudinally along the edge of pavement with deductions for bridge decks, acceleration/deceleration lanes, surface drainage structures, and other sections where the rumble strips are not installed. This price shall be full compensation for application; disposal of waste material; and all labor, tools, equipment, and incidentals necessary to complete the work. The test site will not be measured for payment but shall be included in the unit price for rumble strip.

Liquid asphalt coating (rumble strips) will be measured and paid for in square yards as described herein. This price shall be full compensation for cleaning rumble strips prior to application of the coating; furnishing and applying coating as specified herein; and all labor, tools, equipment, and incidentals necessary to complete the work.

Saw-cut asphalt concrete pavement will be measured in linear feet for the depth specified and will be paid for at the contract unit price per foot, which price shall be full compensation for saw-cutting the asphalt pavement to the depth specified.

Material Transfer Vehicle (MTV), when required in the contract, will not be measured for separate payment. The cost for furnishing and operating the MTV shall be included in the price bid for other appropriate items.

Warm Mix Asphalt (WMA) additive or process will not be measured for separate payment, the cost of which, shall be included in the price bid for other appropriate items.

These prices shall include heat stabilization additive, furnishing samples, and maintaining traffic.

Payment will be made under:

Pay Item	Pay Unit
Asphalt concrete base course (Type)	Ton
Asphalt concrete (Type) (Class)	Ton
Asphalt concrete curb backup material	Ton
Liquid asphalt cement	Ton
Rumble strip (Asphalt)	Linear foot
Liquid asphalt coating (Rumble strips)	Square yard
Saw-cut asphalt concrete (depth)	Linear foot

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SECTION 317 - STONE MATRIX ASPHALT CONCRETE PAVEMENT (Oct. 2, 2008)

317.01—Description

This specification covers the furnishing, installation, and acceptance criteria for stone matrix asphalt (SMA) concrete pavement.

317.02—Materials

(a) **Coarse aggregate** shall conform to the requirements of Section 248.02(a):
(b) **Fine aggregate** shall conform to the requirements of Section 248.02(b).
(c) **Asphalt binder** shall conform to the requirements of Section 248.02(c).
(d) **Mineral filler** shall conform to the requirements of Section 248.02(d).
(e) **Fiber additive** shall conform to the requirements of Section 248.02(e).

317.03—Composition of SMA Mixture

This section shall conform to the requirements of Section 248.

317.04—Acceptance

This section shall conform to the requirements of Section 248.

317.05—SMA Mixing Plant

(a) **Mineral filler** handling shall be in accordance with the requirements of Section 248.05(a).
(b) **Fiber addition** shall be in accordance with the requirements of Section 248.05(b).
(c) **Hot-mixture** storage shall conform to the requirements of Section 248.05(c).
(d) **Mixing temperatures** shall conform to the requirements of Section 248.05(d).

317.06—Weather Restrictions

SMA mixture shall be placed only when the ambient and surface temperatures are 50 degrees F or above.

317.07—Placing and Finishing

For mixtures containing PG 70-22, the mixture temperature shall not be less than 300 degrees F in the truck and less than 290 degrees F immediately behind the screed. For mixtures containing PG 76-22, the mixture in the truck and immediately behind the screed shall not be less than the minimum compaction temperature provided by the liquid supplier for mixtures.

A continuous paving operation that provides for constant steady movement of the paver shall be maintained. In the event that excessive stop and go of the paver is occurring, production and laydown of the mixture shall be stopped until the Contractor has made satisfactory changes in the production, hauling, and placement operations resulting in a constant steady movement of the paver.

A Material Transfer Vehicle (MTV) shall be used during the placement of SMA mixes. The paving operation shall have remixing capability in either the MTV or a paver-mounted hopper to produce uniform, nonsegregated mix with uniform temperature. The MTV and paver combination shall have a minimum storage capacity of 15 tons. In the event of a break down, paving shall be discontinued and no more material shall be shipped from the hot-mix plant.

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317.08—Compaction

Immediately after the mixture has been spread and struck off, it shall be thoroughly and uniformly compacted by rolling. Rolling shall be accomplished with steel wheel roller(s) with a minimum weight of 10 tons. A minimum of three rollers shall be available at all times for compaction and/or finish rolling.

To minimize coarse aggregate fracture/breakage in the aggregate skeleton of SMA mixes, the use of vibratory rollers on SMA should be approached with caution. If a vibratory roller is used, the mat shall receive not more than three vibratory passes. The roller shall use only the highest frequency and lowest amplitude setting.

Rolling procedures shall be adjusted to provide the specified pavement density. Rollers shall move at a uniform speed not to exceed 3 mph with the drive wheel nearest the paver. Rolling shall be continued until all roller marks are eliminated and the minimum density has been obtained. The Contractor shall monitor density during the compaction process by use of nuclear density gages to ensure that the minimum required compaction is being obtained. During the trial section, The Department will randomly select 3 plugs or cores locations to determine the in-place density in accordance to VTM-22.

To prevent adhesion of the mixture to the rollers, the wheels shall be kept properly moistened with water that may be mixed with very small quantities of detergent or other approved material.

The Contractor shall perform acceptance testing for density for each day's production by obtaining one sawed specimen, 4 by 4 inch, or a 4-inch diameter core at five stratified random locations specified by the Engineer. The five cores or plugs shall be obtained and the in-place density determined in accordance with the requirements of VTM-22. Core locations shall be numbered sequentially per roadway, marked on the pavement, filled with SMA mixture, and compacted prior to completion of each day of production. The average density of the five cores as determined in accordance with the requirements of VTM-22 shall be 94 to 98 for 100 percent pay. Cores or plugs shall be bulked in the presence of the Department. The Department reserves the right to have the cores or plugs bulked on the project site. The payment for density will be in accordance with the following:

Payment Schedule

% Density Achieved	% of Payment
More than 98.0	97
94.0 to 98.0	100
92.0 to 93.9	85
90.0 to 91.9	65
Less than 90.0	Remove and replace

317.09—Trial Section

A trial section(s), a maximum of 300 tons, shall be constructed at a site approved by the Engineer at least 1 week prior to, but not more than 30 days prior to, roadway construction to examine the mixing plant process control, mixture drain down characteristics, placement procedures, SMA surface appearance, and compaction patterns and to calibrate the nuclear density device. In addition, the percentage of flat and elongated particles will be calculated on the SMA material produced for the trial section in accordance with the requirements of VTM-121 and compared to the maximum limits specified in the Coarse Aggregate Table in Section 248.02(a). A passing F&E sample is required for acceptance of the trial section. Acceptance of trial section shall be in accordance to section 317.04.

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The material placed in the trial sections shall be placed at the specified application rate using the same equipment that will be used during production.

317.10—Prepaving Conference
Prior to the start of production, the Department will hold a prepaving conference. Those attending shall include the Contractor's production supervisor and laydown supervisor, a representative of the fiber supplier, and a representative of the asphalt binder supplier.

317.11—Measurement and Payment
Stone matrix asphalt will be measured in tons and paid for at the contract unit price per ton for the mix type specified, which price shall include all materials, additives, and equipment as described herein.

The initial trial section will be paid for at the contract unit price for the mix type specified. Up to one additional trial section of the mix type specified will be paid for at the contract unit price. If additional trial sections are needed, the Department and the Contractor shall negotiate the price based on a reduced percentage of the contract unit price. No more than four trial sections will be paid for by the Department; any additional test sections will be provided solely at the Contractor's expense.

Payment will be made under:

Pay Item	Pay Unit
Stone matrix asphalt, SMA-9.5 (70-22)	Ton

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S315OM0-0609

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR
TRENCH WIDENING ASPHALT MIXTURES
BM-25.0(T), IM-19.0D(T) or IM-19.0A(T)

October 17, 2008c

SECTION 315—ASPHALT CONCRETE PAVEMENT of the Specifications is amended as follows:

Section 315.01—Description is amended to include the following:
Certain routes in the Contract are designated to use asphalt concrete type BM-25.0(T), IM-19.0A(T) or IM-19.0D(T). Those routes are referred to herein as trench widening routes.

Section 315.02—Materials is amended to add the following:
(e) Trench widening route materials shall conform to the requirements of Section 211 of the Specifications. IM-19.0A shall be used for IM-19.0A(T) and IM-19.0D shall be used for IM-19.0D(T). Where BM-25.0(T) is designated, either BM-25.0A or BM-25.0D shall be used by the Contractor.

Section 315.05(e)2 Surface, Intermediate and Base Courses is amended to include the following:

Trench Widening Routes — The minimum lift density as determined in accordance with the requirements of VTM-22 is based on the type of trench widening as defined below and specified in the Contract. Where trench widening is 2 foot in width compaction may be performed with small single drum walk-behind rollers or other mechanical means acceptable to the Engineer at the Contractor's discretion.

Type 1 — Paved Shoulder Only:

Trench widening routes where the widening will serve as a paved shoulder and will not be subjected to constant traffic: The painted edge line will not be on the trench widening. The minimum density requirement will not be enforced. Steel double drum rollers weighing no less than 8 tons shall perform compaction of the hot mix asphalt. No less than five passes shall be completed.

Type 2 — Widened Travel Lane and Paved Shoulder:

Trench widening routes where the widening will serve as a wider travel lane and paved shoulder that will be subjected to traffic: The widening will not include removal of existing travel lane pavement, i.e., inside the edge line marking. The painted edge line will be on the trench widening. The minimum density of 91.5 percent shall be enforced.

Type 3 — Repaired Travel Lane and Paved Shoulder:

Trench widening routes where the widening will include a portion of the existing travel lane, serve as a paved shoulder and will be subjected to traffic as a part of the travel lane: The widening will include

removal of existing pavement (i.e. inside the edge line marking). The painted edge line will be on the trench widening. The minimum density of 91.5 percent will be enforced.

Where density requirements apply, the Contractor is responsible for cutting cores or sawing plugs for density testing. One set of plugs/cores per course of material shall be obtained within the first 500 linear feet and every 2,500 linear feet thereafter of the trench widening route for testing by the Contractor or the Department. Core/plug locations shall be randomly selected within each section. If the density achieved is less than 91.5 percent for the Type 2 or 3 trench widening routes, payment will be made on the theoretical tonnage within the 500 or 2,500 linear feet lot in accordance with the requirements of Table III-5 of the Specifications.

Section 315.05—Procedures is amended to include the following:
(i) Trench widening routes shall be widened by trenching on one or both sides of the existing roadway and placing BM-25.0(T), IM-19.0A(T) or IM-19.0D(T) commensurate with the required width and depth specified for that route.

Any remaining material, after final grading, shall be classified as excess material, and will be disposed of in accordance with the requirements of Section 106.04 of the Specifications or as directed by the Engineer.

The trench shall be shaped to have vertical sides, the width, depth and type as specified in the contract documents (2-foot minimum to 6-foot maximum width), be free of excess material, and shall be tacked against the existing pavement side before BM-25.0(T), IM-19.0D(T) or IM-19.0A(T) is placed.

The Contractor shall ensure that disruption to driveways, entrances, mail boxes and intersections are minimized and that precautions are taken to ensure that roadway drainage does not pond on the roadway surface.

Section 315.08 Measurement and Payment is amended to include the following:

Asphalt Concrete Type BM-25.0(T), IM-19.0A(T) or IM-19.0D(T) will be measured in tons and will be paid for at the contract unit price per ton, which price bid shall include furnishing and placing the BM-25.0(T), IM-19.0A(T) or IM-19.0D(T) mix, trenching, tack grading and disposal of excess material.

Payment will be made under:

Pay Item	Pay Unit
Asphalt Concrete Type BM-25.0(T)	Ton
Asphalt Concrete Type IM-19.0A(T)	Ton
Asphalt Concrete Type IM-19.0D(T)	Ton

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COMMONWEALTH of VIRGINIA
DEPARTMENT OF TRANSPORTATION
1401 EAST BROAD STREET
RICHMOND, VA 23219-2000

PHILIP A. SHUCET
COMMISSIONER

June 21, 2005

To: District Administrators, Asset Management Director, District Construction Engineers, Resident Engineers, District Materials Engineers, District Maintenance Engineers, FHWA, Virginia Asphalt Association Members

From: Andrew Mergenmeier, P.E., State Materials Engineer, VDOT
Richard Schreck, Executive Director, Virginia Asphalt Association
Signatures on original copy of memorandum.

Subject: Quality Hot Mix Asphalt Construction
Longitudinal Joint Construction and Application of Tack Coat for Plant Mix Schedules

The Virginia Department of Transportation (VDOT) and the hot mix asphalt industry represented by the Virginia Asphalt Association (VAA) are working together to enhance hot mix asphalt quality. We must choose appropriate and adequate maintenance strategies for our pavements; accomplish them with a high level of quality; and do so with minimal impact to the traveling public. Truly this can be a real challenge in today's traffic environment and limited resources. However, sometimes our focus on traffic safety, not inconveniencing the traveling public, speed of construction and other areas can sacrifice our pavement quality and performance.

VDOT and VAA have identified two of the most significant areas leading to premature distress in our asphalt pavements, low-density longitudinal joints and inadequate bond at the interface of new overlays and the existing pavement. VDOT and VAA have recognized these problem areas and have investigated different approaches to remedy these issues. Based on this effort, we have developed the attached guidance/procedures. By having VDOT and industry follow these procedures, we expect to see an Improvement in asphalt pavement performance.

LONGITUDINAL JOINTS - The durability and performance of asphalt pavement longitudinal joints are becoming problems in an increasing number of locations across Virginia. For days after a rain or snow event, water or moisture is often observed at these joints. After a short period of time under traffic, some of these joints are opening up and beginning to ravel. In some cases the raveling has been severe

enough to completely erode the mix at the joint within a couple of years. When these types of premature failures occur it compromises the performance of even our best asphalt mixes and can result in sooner than scheduled resurfacing.

TACK APPLICATION – Approximately fifteen years ago the application of tack materials was an individual pay item. Misuse and over application became a problem to the point some pavements flushed, failed skid and had to be overlaid within three years. AS a result of these problems VDOT removed tack as a pay item from asphalt contracts and made it incidental to the cost of the hot mix asphalt. Today, we are often experiencing the opposite problem, not enough tack causing delamination, potholes, and other premature pavement failures.

In an effort to address these two important asphalt pavement quality issues we have put together the attached documents on Best Practices for Constructing Longitudinal Joints and Tack Coat Application. The attached procedures have application to all hot mix asphalt operations, but were developed specifically for the work performed in plant mix schedules.

Please ensure that all your employees involved in the placement of hot mix asphalt receive a copy of this memorandum and its attachments. WE believe that with all parties having the same expectations for longitudinal joint construction and tack coat application, we will increase the quality and life of our hot mix asphalt pavements.

Attachments

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June 21, 2005

Subject: Quality Hot Mix Asphalt Construction
Longitudinal Joint Construction and Application of Tack Coat for Plant Mix Schedules

Attachment A

Longitudinal Joint Construction Focus Areas

Longitudinal joints in asphalt are unavoidable. However, insufficient mix and/or poor joint construction and compaction create a point of weakness in the mat compromising long-term pavement performance. The following is a brief overview of 5 key focus areas of good longitudinal joints.

5 Key Focus Areas of Good Longitudinal Joints

1. **Joint Location**
2. **Proper Paver Mix Placement During the Screed Paver Pass at a Longitudinal Joint**
3. **Adequate Depth of Compacted Second Paver Pas**
4. **Joint Handwork and Tacking**
5. **Proper and Effective Joint Compaction**

1. Joint Location

Even the best longitudinal joints will have lower density than the surrounding mat, typically 1-2% lower. These lower densities can result in reduced performance and higher maintenance costs. Joint location is also important. Generally, longitudinal joints in wearing courses are placed to coincide with the centerline striping, between lane line striping, and edge line striping. It is preferred to have the longitudinal joint offset no more than 6” from the striping. This will allow for future crack sealing operations without damaging the striping. When practical, longitudinal joints in successive layers should be offset by at least 6”.

2. Proper Paver Mix Placement During the Second Paver Pass at a Longitudinal Joint

The proper depth of uncompacted mix placed by a paver at the longitudinal joint during the second pass of the joint can best be illustrated by the following example:

D2 = D1 +25%

Where D1 is the compacted mat thickness of the first paver pass at the joint, D2 is the uncompacted mat thickness behind the paver screed at the same joint, and 25% is the mix roll down.

If the mat is being placed with access to both sides (both lanes closed) the paver overlap should be 1”-2”. However, much of out paving has only one lane closed and traffic using the adjacent lane. Under these conditions the paver overlap may have to be reduced to within ½” of the cold side of the joint.

3. Adequate Depth of Compacted Second Paver Pass

The “Toe Drag Test” (TDT) to determine if both sides of the joint are even or “smooth” is the most common test used by inspection, paving and management personnel to assess the quality of longitudinal joints. It is a false test. In fact, it almost guarantees that at least one side of the joint will have poor density. ***When compacted, the second placed side of a longitudinal joint should always be slightly higher than the first placed side (typically 1/16” – ¼”).***

4. Joint Handwork and Tacking

Improper “bumping” of the joint is one of the most common mistakes made in constructing longitudinal joints. In an effort to meet TDT the 1”-2” overlap placed by the paver is kicked away leaving both the compacted side and uncompacted side even. When the roller(s) go over this area there is little or no additional compaction of the hot mat at the joint.

VDOT specifications require that tack be applied at the longitudinal joint because the extra liquid asphalt fills some of the voids and makes the mix at the joint less permeable. Too often, the longitudinal joint is not tacked adequately. This can be from concerns that tack overspray may be carried on to the open lanes and the traveling public or the tack material may blemish new pavement markings. There are even cases of the distributor bars nozzle closest to the longitudinal joint being closed off to prevent applying tack too near the open lane. These failures to adequately tack bond the new mat to the existing pavement have severe impact on the performance of the new pavement.

5. Proper and Effect Joint Compaction

The number of unsupported edges on the first lane/pass of the paver (figure 2) can be none (full inlay), one (curb & gutter or unmilled pavement on one side) or two (not touching anything on either side). How this first paver pass should be rolled depends on how many uncompacted edges there are. The type and location of the roller are critical to obtaining density at the unsupported edge (figures 3, 4, 5). Failure to roll the first pass correctly can result in poor densities at the edges, cracking along the edge or both.

Roller overlap and compaction technique, when compacting the second mat or hot side of a longitudinal joint, are also critical to maximizing joint density. For most applications, rollers should roll from the outside (side away from longitudinal joint) toward the longitudinal joint (figure 6). The movement of the roller over the hot mat will cause some lateral movement of the mix. Therefore rolling form the outside in will push mix laterally into the joint. Roller overlap at the joint should be 2”-6” (6” if work zone permits) over the cold side of the mat (figures 7, 8). An alternative method is to stay off the joint about 6” leaving an area of uncompacted mix to be compacted on a subsequent pas that includes a 2”-6” roller overlap (figure 9). Regardless of method used, if proper placement and compaction procedures have been followed, the second paver pass or “hot” side of the longitudinal joint will have a higher density than the first or “cold” side (assuming it was unconfined).

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It should be noted that longitudinal joints between inlays and the existing pavement are always treated as the “hot side” of the joint.

The above identification of focus areas and their brief discussion are intended to make you aware of these important aspects of asphalt pavement performance. If you have any questions, please contact the Central Materials Division, District Materials Section, and/or Virginia Asphalt Association.

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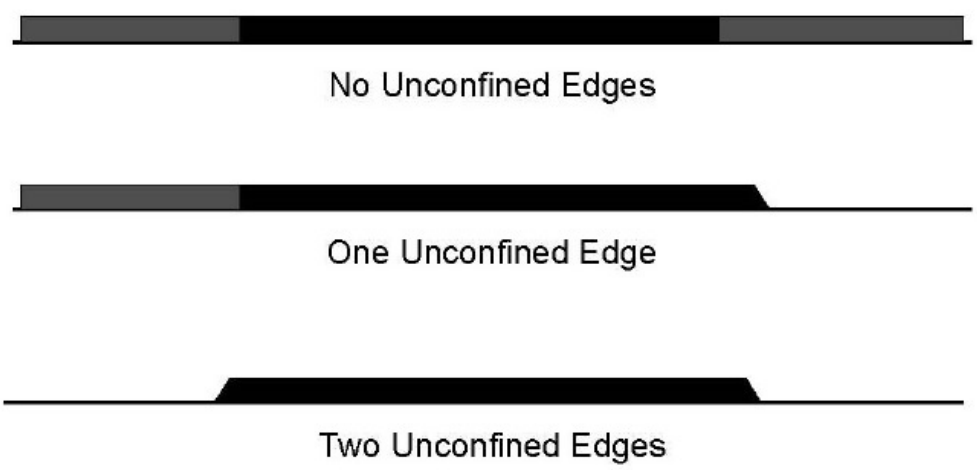
Figure 1

Constructing and Compacting Longitudinal Joints

Virginia Department of Transportation
&
The Virginia Asphalt Association

Figure 2

Unconfined Edges



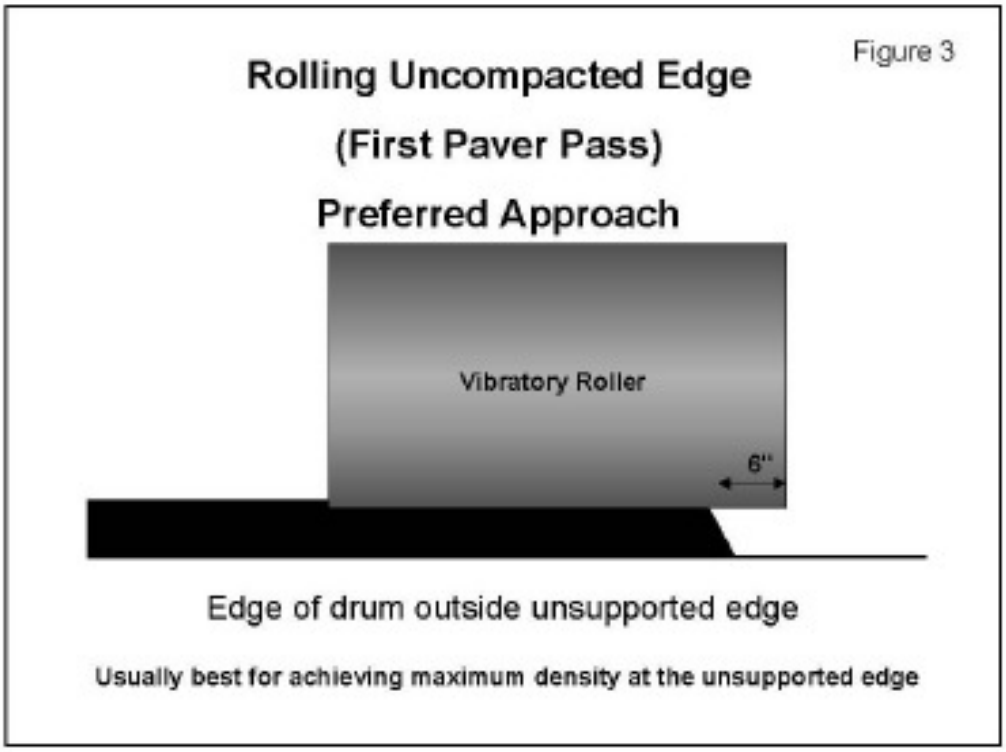


Figure 3
Rolling Uncompacted Edge
(First Paver Pass)
Preferred Approach
Vibratory Roller
6"
Edge of drum outside unsupported edge
Usually best for achieving maximum density at the unsupported edge

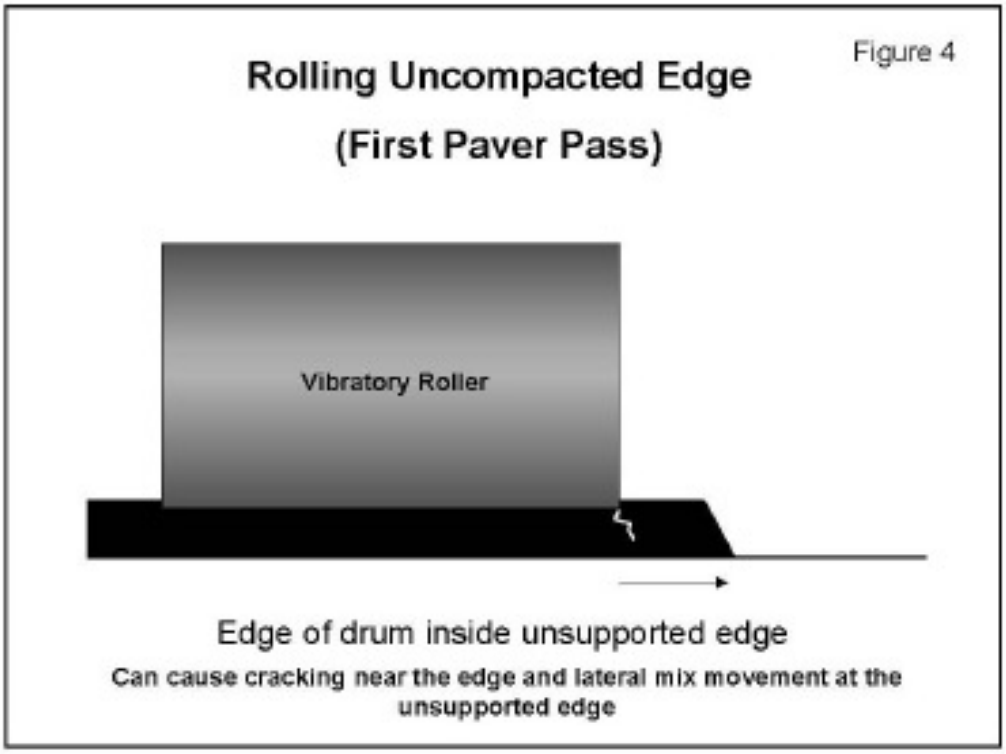


Figure 4
Rolling Uncompacted Edge
(First Paver Pass)
Vibratory Roller
Edge of drum inside unsupported edge
Can cause cracking near the edge and lateral mix movement at the unsupported edge

Figure 5

Rolling Uncompacted Edge

(First Paver Pass)

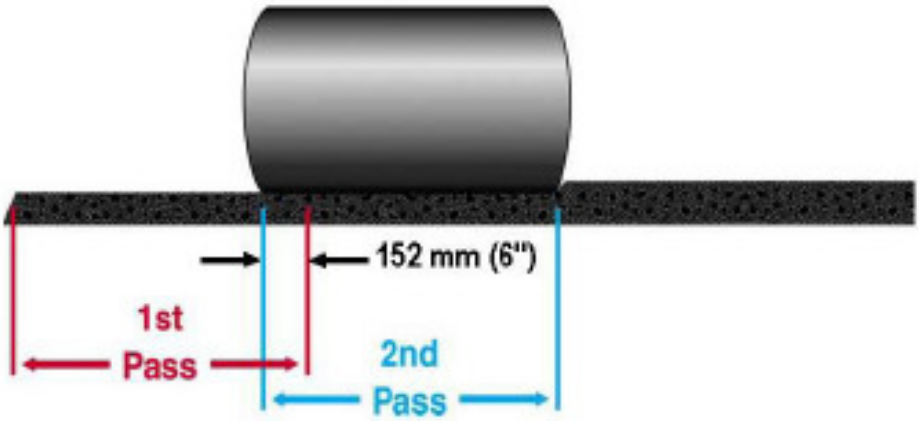
Edge of drum on the unsupported edge

Can cause lateral mix movement at the unsupported edge

Figure 6

Mat Compaction

Mat should be rolled from the unconfined/outside edge to the longitudinal joint (number of passes to cover the mat depends on roller widths).



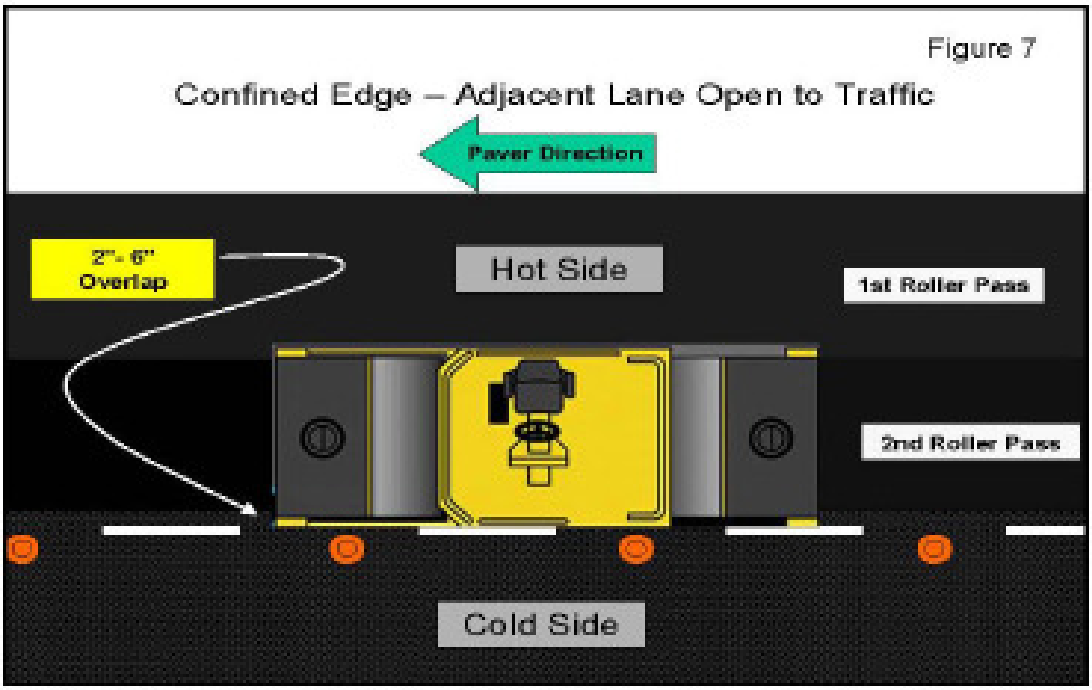


Figure 7
Confined Edge – Adjacent Lane Open to Traffic
Paver Direction
2"- 6" Overlap
Hot Side
1st Roller Pass
2nd Roller Pass
Cold Side

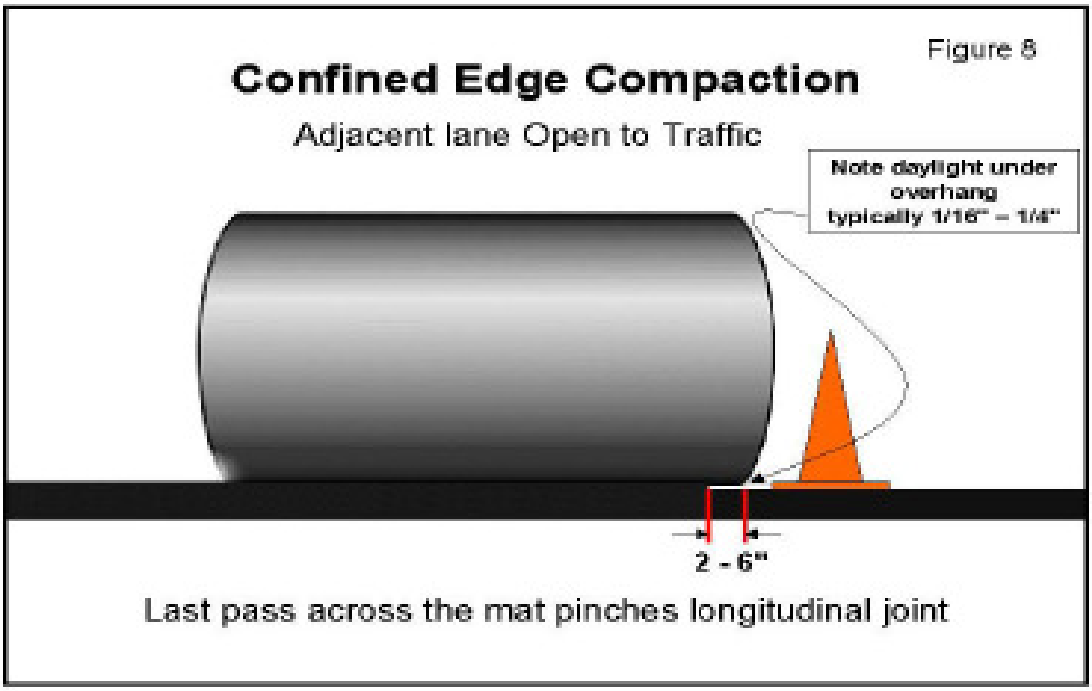


Figure 8
Confined Edge Compaction
Adjacent lane Open to Traffic
Note daylight under overhang typically 1/16" – 1/4"
2 - 6"
Last pass across the mat pinches longitudinal joint

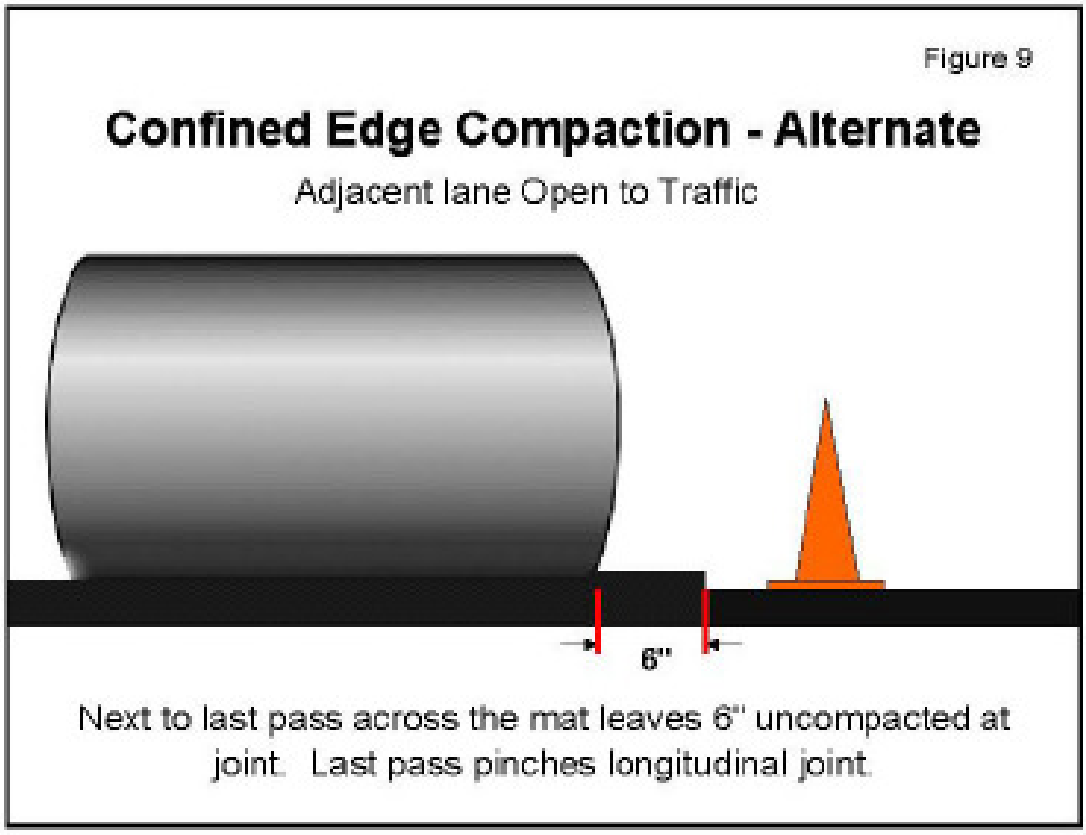


Figure 9
Confined Edge Compaction - Alternate
Adjacent lane Open to Traffic
6"
Next to last pass across the mat leaves 6" uncompacted at joint. Last pass pinches longitudinal joint.

June 21, 2005

Subject: Quality Hot Mix Asphalt Construction
Longitudinal Joint Construction and Application of Tack Coat for Plant Mix Schedules

Attachment B

High Performance Tack Application Focus Areas

A tack coat is a pressurized spray application of liquefied asphalt, typically an asphalt emulsion, to a pavement to ensure a bond between the existing pavement surface and the new asphalt overlay. Too little tack can cause slippage problems and delamination of pavement layers. Excessive tack, or tacking areas that do not need tack can lead to pavement bleeding, loss of skid characteristics and rutting. The following 5 Focus Areas are key to achieving the proper and effective application of tack materials.

5 Tack Application Focus Areas

1. **Application Rate, Temperature, Pressure, and Timing**
2. **Start and End of Tack Application**
3. **Tacking Longitudinal and Transverse Joints**
4. **Proper Use of Hand Wands**
5. **Tacking Milled Surfaces**

1. Application Rate, Temperature, Pressure and Timing

Uniformity of application and use of the proper application rates are key to the success of the tack coat. The tack coat should be applied with a pressure distributor with all nozzles open and angled to spray at approximately 30 degrees (see distributor manufacturers recommendations). The distributor bar should also be at the proper height to ensure that double or triple lap of the material is achieved. Too little pressure or low temperatures will cause clogging of nozzles and/or tack "stripes" on the pavement. The proper tack coat application will leave a residual asphalt binder content of approximately 0.04 to 0.06 gal/sy on the roadway. If the correct application rate is used some of the existing surface will show through the tack coat. Finally, timing the application of the tack coat is critical to minimize tracking. Tack coat should be applied in advance of the paving operation to allow the emulsion to break and reduce sticking to tires.

2. Start and End of Tack Application

On a truck mounted distributor the application rate is controlled by metering equipment synchronized with the axles of the vehicle. When starting from a dead stop this can result in too heavy of an application of the first 25-100 feet of the spray application. Shutting the track spray off at the exact end of the area to be paved can also be very challenging. Therefore, extra care must be

taken at start up and ending areas. Startup and application end areas should not be located at intersections or there will be an even greater risk of pavement slippings, loss of skid and/or rutting due to the higher pavement stresses associated with braking traffic.

3. Tacking Longitudinal and Transverse Joints

Longitudinal joints are the weakest are of an asphalt mat and are, therefore, to be minimized. It is extremely important that there be a good bond between the existing or underlying surface and the new layer of asphalt at the joints. Tack coats at longitudinal joints have several functions. First, they form the bond between the underlying pavement and the new asphalt layer, Secondly, by using a hand want to spray extra tack on the vertical face of the exposed side of the longitudinal joint, a tighter, less permeable seal is obtained between the two sides of the joint. And thirdly, the additional tack in the area of the joint aids in achieving better compaction at the joint. Longitudinal joints should not be located in the wheel paths or traffic areas so this additional asphalt will not result in slippage, loss of skid, flushing or rutting like it would if the wheel paths were tacked this heavy.

4. Proper Use of Hand Wands

A hand wand is a hand-held section of piping with a single distributor nozzle on the end connected to the distributor tank by a hose. Hot, pressurized tack is sprayed through the nozzle in a controlled and operator directed manner. Low pressure and/or temperature can result in heavy, dribbling applications. Holding the hand want too high above the pavement will result in a wide, fan like spray of tack material and loss of application control.

5. Tracking Milled Surfaces

Most pavements require some degree of surface preparation prior ot tack application. This may include sweeping/dirt removal, patching, crack sealing, or leveling courses. Milled surfaces present unique challenges due to their pre-tack surface preparation needs. Milled surfaces ideally should be left open to traffic and the environment for a period of time to be swept and washed clean. However, scabbing, loose aggregates, drainage issues and safety considerations may prevent this. Milled surfaces should be swept clean with a power broom and/or vacuum truck. A heavier than normal tack application rate is typically used due to the irregular and uneven surface texture and milled pavements. When the pavement surface is not cleaned properly, the tack material will bond to the dirt/dust and then stick to the tires of the paving equipment.

The above identification of focus areas and their brief discussion are intended to make you aware of these important aspects of asphalt pavement performance. If you have any questions, please contact the Central Materials Division, District Materials Section, and/or the Virginal Asphalt Association.

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TL-59A (12/08)

Asphalt Concrete Density Quality Control (QC) Test Report - Nuclear

Project/Schedule Number: _____ Item Number: _____

Route Number: _____ County: _____

From (Station, MP, Int., etc.): _____ To (Station, MP, Int., etc.): _____

Direction (e.g. NB, SB, etc.) _____ Lane (Inside, Center, Right, etc): _____

QC Lot #: _____ Application Rate (lbs/sy): _____

Asphalt Mix Type: _____ Asphalt Job Mix Number: _____

Nuclear Gauge Model Number: _____ Gauge Calibration Date: _____

Nuclear Gauge Serial Number: _____ Depth Setting (in/mm): _____

Control Strip Information:

1. Control Strip Number and Date _____ _____
2. Target Density from Control Strip _____ lbs/ft^3 (kg/m^3)
3. Minimum Density (98% Of Control Strip Target Density) _____ lbs/ft^3 (kg/m^3)
4. Maximum Density (102% Of Control Strip Target Density) _____ lbs/ft^3 (kg/m^3)

QC Testing Results By Nuclear Gauge:

	Location		Nuclear Density	Sublot Average	Joint Density lbs/ft^3 (kg/m^3)	
Sublot No.	Distance	Offset	lbs/ft^3 (kg/m^3)	lbs/ft^3 (kg/m^3)	Left (C or U)*	Right (C or U)*
1a						
1b						
2a						
2b						
3a						
3b						
4a						
4b						
5a						
5b						
6a						
6b						
7a						
7b						
		Average:				

Does the QC Test Section: (circle one) PASS FAIL

* - C = Confined Jt, U = Unconfined Jt

Comments: _____

QC Technician: _____ **Date:** _____

Observed By: _____

SECTION 503 ROAD SAMPLING, TESTING, AND INSPECTION OF ASPHALT PAVEMENTS

The following instructions cover the sampling, testing, and inspection of asphalt concrete pavements at the job site. Specific instructions are contained herein for the density and depth tests.

Sec. 503.01 General

The Project Inspector will see that the Contractor follows all instructions, and will notify the Construction Manager or Area Construction Engineer if there is any misunderstanding, lack of cooperation, or any other situation that cannot be promptly corrected. The Inspector will maintain an attitude of cooperation and helpfulness with the Contractor to secure maximum production within specification limits. The Inspector should not hold up or delay operations unnecessarily, as continuous operation is essential to uniform results, as well as to economical operation. All instructions shall be issued to the Superintendent or Foreman in charge of the work.

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Sec. 503.02 Density QC Testing (Contractor)

The density testing method to be used for asphalt concrete pavement will be one of the following:

1) The thin lift nuclear method outlined in VTM-76 and Special Provisions or Specifications for Sec. 315.05 *Road and Bridge Specifications*. Only designated scratch courses do not require density testing.
2) Plugs/Cores obtained as outlined in VTM-22 and AASHTO T166.

The method to be used will be as specified in the *Road and Bridge Specifications* or Special Provisions, or as directed by the Engineer. It should be emphasized that the frequencies given for testing are the minimums considered desirable to provide effective control of materials under ideal conditions, and more testing than that specified should be done if deemed necessary by the Engineer.

(a) Method A – Thin Lift Nuclear Method (Dense Graded Mixes)

(1) General

See Secs. 105.02 through 105.04 for details and safety precautions for the use of nuclear equipment. The thin lift nuclear method shall be conducted in accordance with VTM-76 and Special Provisions or Specifications for Sec. 315 of the *Road and Bridge Specifications*. The thin lift gauge shall be furnished and operated by the Contractor.

Thin lift density testing will be conducted using the Control Strip Method of testing as outlined in VTM-76. Under this procedure, the density reading obtained in the test section is compared with the corresponding control strip density. The VST density testing will be accomplished as outlined in Sec. 503.03 Verification Density Testing. The method for IA will be performed as outlined in Section 503.04 Independent Assurance for Density.

A roller pattern and control strip density must be established for each layer or lift placed in order to establish the target density required before testing of test sections.

(2) Frequency of Tests

For thin lift nuclear density testing, the reported density will normally be the average of 5 sublots readings representing a lot of asphalt pavement approximately 5,000 linear feet (1500 meter) in length for each lift and pass of the paver. Each sublot (1,000 linear feet or 300 meters) will have two locations randomly selected for measurement. See Section 315 of the *Road and Bridge Specifications* for the handling of partial length lots and the evaluation of sublots. The reported density will be considered the density of the entire length and width of the roadway represented by that lot. Payment for the tonnage of asphalt mixture contained in the lot will be in accordance with the density payment schedule in Section 315 of the *Road and Bridge Specifications*.

If there is a breakdown in the nuclear testing equipment, then density tests should be continued using other methods such as sawed plugs or cores as approved by the Engineer.

(b) Method B – Plugs/Cores (Dense Graded and SMA Mixes)

(1) General

With cores and plugs, the percent compaction of the completed asphalt concrete pavement is determined by dividing the actual bulk specific gravity of the pavement samples by the theoretical maximum specific gravity of a completely voidless mixture composed of the same materials in like proportions. The actual bulk specific gravity shall be determined, as outlined in AASHTO T166 and

modified by VTM-6. The maximum specific gravity shall be determined, as outlined in VTM-22, together with AASHTO T209, if desired.

(2) Frequency of Tests

Sampling for density determination on the mainline will be at the rate of no less than one plug/core per 1,000 feet (300 m) paver pass. Crossovers and connections will not be sampled for density; however, the tonnage contained therein will be included in the lot. The lot size will be 5,000 linear feet (1500 m) and will be determined by the quantity of asphalt concrete furnished by each plant for the contract item. Tests will be performed in accordance with VTM-22.

(3) Obtaining the Test Specimens

The test specimens shall be obtained as follows:

(1) Test specimens shall be cut from the pavement with a portable saw or other approved method. If water is used as a cooling agent, then the contractor must have an approved method to dry the core/plug.

(2) The length of the sides of the sawed specimens shall not be less than 3 in. (75 mm) nor more than 4.5 in. (113 mm) [4 in. (100 mm) diameter cores may be used]. The thickness of the specimens shall not be less than 1.0 in. (25 mm)

(3) Mark out squares of pavement as indicated in sketch below.

1	2

(4) Cool marked area with gas (CO_2) or dry ice.

(5) Cut out specimens using the approved method. (It will be necessary to cut out past the marked lines, so that a full-depth cut is obtained.

(6) Recool marked area with gas sufficiently to pry out specimens without distorting.

(7) Pry out Square 1 by applying pressure to either side and discard. Pry out Square 2 to use as the test sample. (Do not distort.)

(8) Carefully remove saw tailings and clean any loose material from surface of specimens. When placing specimens in basket to weigh in water, take care not to entrap air under the specimen. (Again, do not distort specimens.)

(9) Determination of bulk specific gravity will be in accordance with VTM-6; maximum specific gravity will be determined in accordance with AASHTO T209; and percent compaction will be determined in accordance with VTM-22 section 5.

<u>(c) Computation of Pay Factor</u>

Price adjustment factors will be applied to the quantity of material in accordance with Sec. 315 of the *Road and Bridge Specifications*.

<u>(d) Reports</u>

Results of job acceptance density tests in the field shall be reported on Forms TL-56, TL-57, TL-58, TL-59A/B and TL-60. Results of density tests by other methods shall be reported on forms

Sec. 503.03 Verification Density Testing (Department)

Verification sampling and testing will be performed on surface, intermediate and base mixes that have been evaluated by the Contractor. VST will be performed by either obtaining 4" (100 mm) diameter core or 4"x 4" (100 mm x 100 mm) plug according to VTM-6 and VTM-22. The Contractor will be responsible for obtaining the specimens for VST. VST will be performed by or under the direction of a District Materials representative. VST is to be performed on Federal-Aid projects on the NHS and should also be performed on as many non-NHS and state funded projects as practicable (see Table 1).

(a) Procedure for VST on Lot Density Testing

(1) General

Department personnel will randomly select locations for VST Density tests by a randomization procedure similar to the randomization procedure shown in VTM-32, Depth Test of Bituminous Concrete Base Course. VST Density tests obtained by plugs/cores will be sampled and tested under the direction of the Materials Division according to VTM 6 and VTM 22.

Perform VST Density testing by obtaining a plug/core from two (2) stratified random sites in a test section or lot on the roadway. The plugs/cores will be extracted by the Contractor at the sites identified by the Department. The test section for dense graded asphalt is defined as 5,000 linear feet (1500 m) of paved lane width with subsections of 1,000 linear feet (300 m). For SMA, the test section is defined as the length of daily production. For dense grade asphalt, two of the five subsections will be randomly selected for sampling. When practical, the VST test section limits should coincide with the QC lot limits for comparison purposes. For SMA, two random locations from the daily production will be selected.

Determine the in place density for each individual plug/core at each selected location using VTM 6 and VTM 22. The average density of the plug/core from the two individual sites will be compared to the average of the plugs taken from the control strip used to establish the target nuclear density for that mix. For SMA, the average density of the plugs/cores will be compared to the minimum density specified in Section 317 of the *Road and Bridge Specifications*. Once the comparison is performed, the following steps shall be followed:

Step 1) If the test section for dense graded asphalt meets the full payment criteria for density (98% to 102% of the average density of the plugs taken from the control strip density), then continue obtaining two stratified random plugs/cores on 20% of the test sections until completion of the project. If the daily production for SMA meets the full payment criteria for density, then continue obtaining two stratified random plugs/cores on 20% of the daily production lots until completion of the project. The VST densities will be expressed in % and will be reported to the nearest 0.1%.

Step 2) In the event a dispute arises over the average density of the two plugs/cores failing the density testing comparison criteria, then one additional plug/core from the remaining

3 subsections will be obtained for dense graded asphalt. For SMA, three additional cores will be obtained from the daily production lot. If deemed necessary by the District Materials Engineer, one additional plug/core from the previously tested subsections will be obtained for dense graded asphalt. For SMA, two additional cores may be obtain if deemed necessary by the District Materials Engineer. The average density of these five (or 7) plugs/cores will then be compared to the Density testing comparison criteria. If this average density meets the comparison requirement, then the lot is acceptable. Continue obtaining two stratified random plugs/cores on 20% of the test sections/daily production lots until completion of the project.

Step 3) If the density comparison criteria is not met, then the production Rice value(s) corresponding to the test section will be used to determine the average density for the 5 plugs/cores. If this average density meets the comparison requirement, then the QC lot is acceptable. Continue obtaining two stratified random plugs/cores on 20% of the test sections until completion of the project.

Step 4) If the average density in a lot fails the Density testing comparison criteria, then the lot preceding (if accessible) and the lot after must be evaluated by repeating steps 1 thru 3 until the boundaries of the failing lots have been established. Each failing lot will be documented.

(2) Timing of VST Density Testing Using Plugs/Cores

The VST density testing must be completed prior to traffic being placed on the section being evaluated but during or after the Contractor has completed all it's QC density testing for that lot.

(3) Frequency for VST Density Testing Using Plugs/Cores

The VST density tests for base, intermediate and surface mixes per project will be conducted on a paver width 5,000 linear foot (1500 m) long test section of roadway. The minimum tonnage of a mix type to warrant VST density testing shall be 500. Mix types are based on the maximum nominal aggregate size (i.e. 4.75, 9.5, 12.5, 19.0 and 25.0) and not the binder used in the mix. The minimum number of VST density test sections required for a given project or contract will be at least 20% of the paved lane length (one test section for every 25,000 lane feet (7500 m) of paving) for all AC lifts. For example, for a one lift AC overlay 10 lane miles long, 2 test sections must be checked through VST. For a two lift AC overlay 10 lane miles long, 4 test sections must be checked through VST. The four test sections should be randomly selected between the first and second lift test sections. The same approach should be used in determining the total number of test sections on construction and maintenance projects (see Table 4 for Guidance).

For construction projects, the total amount of AC placed should be used to determine the total number of VST sections. This total should include not only mainline AC, but shoulders, adjoining roads, etc. For maintenance projects (i.e. RAAP or plant mix schedule), the VST rate is based on the total number of lane miles on the project – not an individual site. A random approach should be used in selecting the test sections for VST.

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Sec. 503.04 Independent Assurance for Density (Department)

IA density observations and sampling/testing will be performed on surface, intermediate and base mixes which are evaluated by the Contractor. IA will be performed by District Materials personnel. IA is to be performed on Federal-Aid projects on the NHS and should also be performed on as many non-NHS and state funded projects as practicable. Observation of the QC Technician will be on a system basis approach. For IA of plugs/cores, the minimum tonnage of a mix type to warrant IA density observations testing shall be 500.

(a) Observation of QC Technician (System Basis)

(1) Procedure

District Materials personnel will verify the Contractor's method of random determination of production reading locations and will verify QC processes by witnessing/observation. The Contractor is required to mark the location and orientation of the gauge at each test location. The Contractor may be required to supply a list of the randomly selected production test locations. The department representative will initial beside the QC readings observed on the Contractors TL-59 (see Section 803.44) form. (Please note, a QC reading is defined as a nuclear gauge test at a single location.) Additionally, the department representative will verify the nuclear gauge calibration date and serial number, and will initial beside this information on the TL-59A form.

(2) Timing of IA Testing

The IA must be completed while the Contractor is performing density (QC) testing.

(3) Frequency

Ideally, each Certified Asphalt Density Technician, performing this duty for the Contractor, will be observed at least once annually. At a minimum, seventy-five percent of the Asphalt Density Technicians will be observed on an annual basis.

Number of Lifts	VST Samples Per Project						
	Project's Paved Lane Miles						
	1	2	3	4	5	10	20
1	1	1	1	1	1	2	4
2	1	1	2	2	2	4	8
3	1	2	2	3	3	6	12
4	1	2	3	4	4	8	16
5	1	2	3	4	5	10	20

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(4) Recording/Reporting

In the annual report prepared for FHWA, VDOT will list the number of technicians observed, any problem(s) encountered and the actions taken by the Department/Contractor to remedy the problem(s). These observations will be recorded on TL-141A (See Section 803.71).

(b) IA Density Testing on Plugs/Cores

During the production of asphalt concrete, VDOT will perform IA testing by the approach outlined below. This approach applies to control strips for dense graded asphalt mixes (where the nuclear gauge is used for density acceptance) and stone matrix asphalt (SMA). If the Contractor elects to perform density QC on dense graded asphalt by the plug/core approach, then the procedure following the guidelines for SMA shall apply. No IA of control strip plugs/cores will be required when the contractor uses plugs/cores as the asphalt acceptance procedure.

(1) Procedure for IA Density Testing on Contractor Plugs/Cores

For acceptance of control strips and SMA percent density, plugs/cores are used. At the stratified random plug/core locations provided by VDOT for SMA or the control strip locations per VTM-76, Department personnel or an authorized representative will observe the extraction of plugs/cores (VTM-76), observe the determination of percent density (VTM-6 and VTM-22) by the Contractor and maintain control over the samples throughout this process. Immediately after testing by the contractor, the Department will secure the plugs/cores for IA of results. The Department will retain **all** plugs/cores during the production and placement of SMA as well as from control strips. SMA plugs/cores will be marked identifying the lot and plug/core number (i.e. Lot 10 and plug/core 3 will be marked as 10C [A = 1, B = 2, C = 3, D = 4, E = 5]). Control strip plugs/cores will be marked with the control strip number and plug/core number from the strip. IA Density tests of contractor obtained plugs/cores will be tested under the direction of the Materials Division according to VTM 6 and VTM 22.

Determine the in place bulk specific gravity (G_{mb}) and percent density for each individual plug/core using VTM 6 and VTM 22. The G_{mb} calculated by the Department will be compared to the contractor's result on the same plug/core. Once the comparison is performed, the following steps shall be followed:

Step 1) If the Department bulk specific gravity (G_{mb}) results are within 0.015 of the contractor's results, then no additional analysis is required. The IA G_{mb} will be reported to the nearest 0.015. The plug/core can be discarded.

Step 2) In the event that the VDOT G_{mb} results are not within the 0.015 tolerance, then the Department will re-run VTM-6 on the non-comparing plugs/cores and compare the new G_{mb} to the contractor's results. If the Department results are now all within 0.015 of the contractor's result, then no additional analysis is required.

Step 3) If the Department's G_{mb} results are not within the 0.015 tolerance after the re-calculation in Step 2, then the sister cores/plugs (remaining plugs/cores from the lot or control strip) to the failing core/plug will be analyzed. A new percent density will be calculated for the plugs/cores on the basis of the Department's G_{mb} results in accordance with VTM-22. If the average of the five density results from the Department's testing does not comply with the specification requirement, then the contractor will be notified of the failing IA comparison. The District Materials representative will conduct an investigation of the contractor's QC technician's testing procedures and equipment to determine the source of the error. Results of this

investigation will be documented and provided to the State Materials Engineer. Based on the average percent density determined by Department's test results (for those plugs that did not compare with the contactors) and the contractor's acceptable plugs from the lot, the corresponding percent pay will be applied.

(2) Timing of IA Density Testing on Contractor Plugs/Cores

Step 1 of the IA density testing must be completed within three business days of the production date. If necessary, Step 2 must be completed within one business day of Step 1 in order to minimize the placement of failing material.

(3) Frequency for IA Density Testing on Contractor Plugs/Cores

The IA density tests for SMA mixes per project may be conducted for each lot. The minimum number of IA density test plugs/cores required for a given contract will be at least 10% plugs/cores obtained by the Contractor. For control strips, at least one plug/core will be required per project. If more than 10 control strips are constructed (combination of all mixes laid on a project), then additional control strip plugs/cores will be tested to meet a minimum frequency of 10% of control strips tested.

(4) Recording/Reporting for IA Density Testing on Contractor Plugs/Cores

IA densities will be recorded on form TL-141B. (see Sections 803.71).

Sec. 503.05 Independent Assurance of Department Personnel (Department)

IA personnel will be required to obtain and maintain the proper Materials Division certifications.

Sec. 503.06 Determination of VST/IA Requirements (Example)

VTM-76 is followed in constructing Roller Patterns and Control Strips for dense graded asphalt mix layers. The flowchart shown is to be applied to each mix type (i.e. SM-9.0, SM-9.5, SM-12.5, SM-19.0, IM-19.0 and BM-25.0) as described in Section 503.03(c) and Section 503.04 in a contract or maintenance plant-mix schedule to determine the level of VST testing and IA observations.

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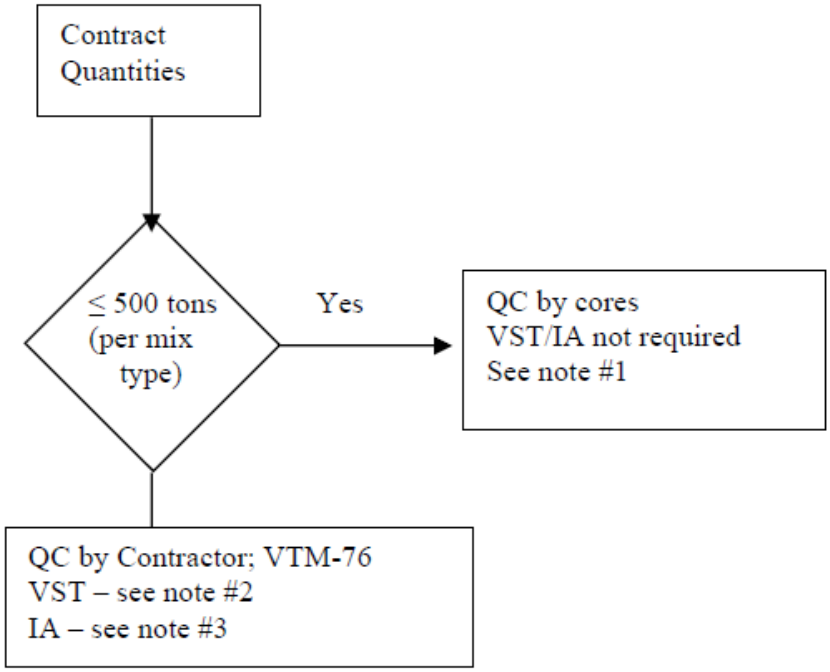
Note #1:

VST/IA testing is not required for any mix type with 500 tons (500 metric tons) or less of that mix on the contract. Contractor QC testing is required for the roller pattern, control strip (see VTM-76) and for all test sections. Projects of this size are typically complete once the roller pattern/control strip is finished, or they may have a single short test section. [See *Road and Bridge Specifications* section 315.05(e)1 for exceptions to following VTM-76.]

Note #2:
VST testing is required per Section 503.03

Note #3: IA testing is required per Section 503.04

NoQC by Contractor; VTM-76
VST – see note #2
IA – see note #3



(a) Example to Determine VST and IA Regulations:

Given: A contract has the following combination of asphalt types and quantities: SM-9.5A	300 ton	BM-25.0A	300 ton
SM-9.5D	150 ton	BM-25.0D	1000 ton
IM-19.0A		750 ton	

Solution: For each mix type, the total quantities are: SM = 450 tons (450 metric tons), IM = 750 tons (750 metric tons), and BM = 1300 tons (1300 metric tons). These are the quantities to use with the flowchart.

NOTE: The amount of project level VST and IA testing shown in this example is the *minimum* required for a Federal aid project on the NHS.

Surface Mix: The total quantity of all surface mixes on the project is 450 tons (450 metric tons). This quantity is less than 500 tons (500 metric tons) so QC testing by the Contractor is done with cores. The density of the cores is compared to the theoretical maximum density of the mix (see VTM-22 for the procedure). If the average density of the cores meets the requirements of Table III-3 in Section 315.05 of the *Road & Bridge Specifications*, then the pavement's density is deemed acceptable. VST/IA density testing will not be required if the cores are verified by testing in the Department's laboratory before determining acceptance. Possession of the **Cores must be maintained until project completion or until verified by the Department for Federal Aid Projects on NHS routes**.

IM Mix: The total quantity of all IM mixes on the project is 750 tons (750 metric tons). This quantity is greater than 500 tons (500 metric tons) so VST and IA testing is required. QC testing for this project would likely consist of the roller pattern/control strip (VTM-76), and one test section of 10 stratified nuclear test locations.

One full VST test section (2 cores) is required. VST testing performed by coring 2 stratified random locations; the density is determined following VTM-22. The average density of the cores are compared to the requirements of Table III-3 in Section 315.05 of the *Road & Bridge Specifications* to determine if the test section density meets specification.

The *minimum* number of IA tests on this project is one plug/core from the control strip. If the Contractor is performing plugs/cores for density acceptance, then one plug/core must be verified by the Department.

BM mix: The total quantity of base mix on the project is 1300 tons (1300 metric tons). This quantity is greater than 500 tons (500 metric tons) so both VST and IA testing are required.

Case 1a – Assume all the base mix is placed in a single 4" (100 mm) thick lift and covers approximately 4400 lane feet (lf) (1340 m). The Contractor tests the roller pattern, the control strip (see VTM-76), and a test section of about 3900 lf (1200 m). Contractor QC testing consists of 2 nuclear readings in each of the 4 sublots of the test section for a total of 8 readings.

One VST test is needed for the 'short' test section, i.e. two cores/plugs.

IA is needed by reweighing one core/plug from the control strip or by reweighing one core/plug used by the contractor for density acceptance from the test section.

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Case 1b – Assume the BM is placed in 2 - 4" (50 – 100 mm) lifts. The first lift is placed on the aggregate base and the second is placed on top of the first BM lift. Separate roller patterns and control strips are required for each lift since the surface upon which the base mix is placed is different for each lift.

For each lift, QC testing consists of the roller pattern /control strip testing, and a single test section of about 1700 lf. (500 m) QC testing of the test section consists of 4 stratified random nuclear test readings in the 1700 ft. (500 m) (test section (2 readings in the first 1000 ft. (300 m) sublot plus 2 readings in the last 700 ft. (200 m)).

VST testing needs to be done for only one of the two BM lifts. Each lift constitutes a lot of material and the minimum testing requirement is 20% of the lots. VST will require two plugs/cores from one of the lifts of BM – not both lifts.

IA is needed by reweighing one core/plug from one of the control strips or by reweighing one core/plug used by the contractor for density acceptance from the test section.

Example Summary – VST/IA testing is not required on the surface mix due to the limited quantity. For the intermediate and base mixes, VST/IA testing is required.

Sec. 503.06 Depth Control (Department)

(a) General

Job acceptance depth tests are to be made by a person other than project personnel. This person shall be an impartial party, namely the District Materials Engineer's representative.

Measurements are to be taken periodically for each course after completion of the course depth as the work progresses. This should not be construed as requiring that the entire project be completed before conducting depth tests. Depth tests should be made as sections of the project are completed. It shall be the responsibility of the Inspector or Construction Manager to notify the District Materials Engineer when any part of the construction is ready for depth tests.

(b) Frequency of Depth Tests

For the purpose of determining depth, and to define areas of deficient or excessive depth, the asphalt concrete base course will be sampled, as outlined in VTM-32B. (Tests of asphalt concrete binder and surface courses are required only if specific plan depths are specified, not when plans specify a rate of application.)

The project shall be divided into lots, with each lot stratified, and the location of each test within the stratified section determined randomly. A lot of material is defined as the quantity being tested for acceptance, except that the maximum lot size will be one mile of 24 ft. width base course. The randomization procedure used will be at the discretion of the Engineer. (See VTM-32B for example.) Samples will be taken from the lot at the following rate:

Lot Size	No. of Samples Required
0 - 1/2 Mile (0 – 1.0 km)	2
1/2 - 3/4 Mile (1.0 – 1.5 km)	3
3/4 - 1 Mile (1.5 – 2.0 km)	4

A separate boring will be taken from each intersection, entrance, crossover, storage lane, or ramp having an area of 500 yds^2 (500 m^2). or more. This boring will not be taken at random; however, care is to be taken not to set up a uniform pattern of testing. The tolerance for an individual test result shall apply for these miscellaneous borings.

The same frequency of testing as used on the mainline will be used for asphalt concrete shoulders requiring specific plan depths, except that the tests will be alternated from one shoulder to the other.

It is not the intent of the test procedure to prohibit sampling and testing of the material at any location which is visually determined to be out of specification tolerance for an individual test.

(c) Corrections for Areas Outside of Tolerance

If any areas are found to be outside of specification tolerances for depth, then corrections shall be made in accordance with the particular specification related to the material in question.

(d) Reports

Results of job acceptance depth tests of the above noted materials shall be retained as part of the permanent project records. The data may be kept in the form of a worksheet. Those depth tests that fail to meet specification requirements and subsequent delineation determinations shall be recorded on Form TL-105. See Sec. 800 for details of completing and distributing these forms.

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D

Asphalt Field Technician

Proficiency Test

- Nuclear Gauge Standard Count Procedure
- Field Determination of Percent Density of Compacted Asphalt Concrete Mixtures by VTM-22
- Field Determination of Bulk Specific Gravity of Asphalt Concrete Mixtures by VTM-6
- Roller Pattern by VTM-76
- Control Strip by VTM-76
- Stratified Random Numbering
- Test Section by VTM-76 / Rd. & Bridge Spec. 315

For thorough testing procedures, see the VTMs and specifications.

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Nuclear Gauge Procedures

Gauge Warm Up and Standard Count Procedure

Demonstrate

- Standard counts should be taken on the job site at the beginning of each workday.
- Select site at least 10 feet from any structure and 33 feet from other radioactive sources.
- The site selected should be dry and firm with a minimum density of site of 100lb/ft^3.
- Wear TLD. Warm up gauge.
- Place reference block on flat surface and place air gap spacer on it.
- Gauge handle in “Safe” position. Handle side of gauge on the 2-legged side of spacer.
- Take standard count.
- After beep - record the count and accept count by pressing “yes”.

What would you do if the count fails?

Refer to the Operator’s manual or contact the district nuclear technician.

- Gauge is set to use when the gauge displays the “ready” mode.

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You will set up a Roller Pattern, Control Strip and Test Section on a SM-12.5D mix. You must explain how to run each test. When needed, you will be given the appropriate worksheet to complete.

Roller Pattern

The Roller Pattern determines the number of roller passer required to achieve maximum density for a given asphalt mix.

Procedure:
A minimum of 500 feet of mix must be placed before constructing a Roller Pattern.

- The Roller Pattern and Control Strip must be constructed within the first 500 -1000 feet of mix placement.
- Roller pattern length is 75 feet plus an additional 50 feet on either end to accommodate roller positioning. Measure off with a rolling device that will measure from 1-1000 feet or any other device approved by the engineer.
- Place the material with an approved paver
- It is recommended that the paving train stop while the Roller Pattern is being constructed.
- If it is a mix that you have no experience with, it is recommended that you start by making two passes with an approved roller .
- Take 3 random density readings over most of the 75-foot section.
- Two readings - 30 feet apart on one side and the third reading should be on the opposite side about 15 feet from each of the other two.
- Using the nuclear gauge template and white or other approved spray paint, mark and number each location.
- Nuclear gauge readings should be taken with the gauge parallel with the roadway with the source rod toward the paving train and no closer than **12 inches** to an unsupported edge for this surface mix.

How close to an unsupported pavement edge can readings be taken for a base mix? 18” **Intermediate mix?** - 12 “

- Gauge should be in backscatter position and set in **30 second** mode.
- Record and average the 3 readings.
- Plot density versus passes on the TL-57 worksheet.

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Two sets of readings are already averaged. Plot them on the TL-57. You will be given 3 more readings to calculate density and plot. Tell the proctor when to stop giving you sets of numbers (when you have obtained maximum density) then fill in answers on the shaded areas of the forms.

Roller Pattern (continued)

- Continue making passes, taking and recording readings, adding and averaging readings until maximum density is obtained.
- Process shall continue until average density decreases. After the first decrease, make 1 additional pass to insure this was not a false break. This pass will be made with roller in static mode. If mat continues to decrease in density, then maximum density is density achieved one roller pass before the initial decrease in density.

How much of a decrease in density usually alerts you that maximum density has been achieved?

Typically a **decrease in density of 0.5 lb/ft3** indicates that maximum density has been achieved.

What is a false break?

Density increases on next roller pass after a decrease in density.

What would you do if a false break occurs?

Continue to make passes with roller in static mode until the density decreases a second time. Once the density has decreased, make an additional pass in the static mode. If the density decreases on this pass, then the maximum density will be the highest density achieved with the least amount of passes.

After completing the Roller Pattern, you will tell the proctor how many passes you made in the vibratory and static mode to achieve maximum density.

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Control Strip Density

The Control Strip is constructed to determine if density can be achieved and establishes the target density.

Procedure:

- The Control Strip is placed immediately following the Roller Pattern.
- Control strip length is 300 feet.
- Roll, using the same number of passes it took to obtain maximum density in Roller Pattern.
- Select the 10 reading sites, using Stratified Random numbers - given to VDOT inspector before testing begins.
- Use template to mark and number test site locations. The numbers should be outside of the test area. The template should be parallel with the roadway with the arrows toward the paving train.
- Test no closer than 1 foot to edge of application width for the surface mix.
- Nuclear gauge readings shall be taken in the backscatter position and **one minute mode.**
- Record readings on the TL-58 worksheet

Using the TL-58 and TL-60 worksheet forms:

- Add and average readings.
- Transfer densities to column H of the TL-60.
- Select sites to be cored - 3 sites closest to target density (circle them).
- Core and run bulk density by VTM-6. (See page 7 for procedure)
- Average SSD Bulk Specific Gravity per site.
- Average percent density - VTM-22.

Is this Control Strip acceptable? Why or why not?

- Density meets or exceeds minimum density requirement of Table III-3 of Section 315 Road & Bridge Spec.
- This becomes the target density if acceptable.

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VTM-22

Field Determination of Percent Density of Compacted Asphalt Concrete Mixtures

Procedure:

- Using a rotary saw as specified by VDOT cut two 4 x 4 inch specimens or using a coring machine, cut two 4 inch diameter core specimens.
- Three sites selected for coring/sawing are closest to target density.
- Cores shall be cut dry.
- Freeze the roadway using CO2 or dry ice.
- Cut the core and freeze road again.
- Gently pry around core or plug to break it loose from underlying layer.
- Care taken not to crack or break off any part of the core.
- Measure thickness of test specimen and record it on the TL-60 worksheet.
- Determine bulk specific gravity according to VTM-6.

What would you do if the core/plug is damaged?

- Discard and use another core/plug taken from the same area.

$$\text{Percent Density} = \frac{\text{Bulk Specific Gravity X 100}}{\text{Theoretical Maximum Specific Gravity}}$$

- Report depth to nearest 0.1 inch.
- Report percent density to nearest 0.1 percent.

Is this theoretical maximum specific gravity used throughout the job?

- It shall be determined by a moving average of 5 values. Until 5 values are obtained, the theoretical maximum specific gravity used shall be a simple average.
- Theoretical maximum specific gravity of mixture is supplied by lab testing.

What percent difference in density is allowed between two specimens from the same test site.

- No more than 2.0%.

What would you do if the difference was more than allowed?

- Discard and obtain two more specimens from a new test site.

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VTM-6

Field Determination of Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface Dry Specimens

Equipment

- Balance - 2000 gram - accuracy 1.0 gram
- Balance equipped with suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of scale pan of balance.
- Water Bath - for immersing the specimen in water while suspended under the balance.
- Holder shall be immersed in water to a depth sufficient to cover it and the test sample during weighing.

Procedure:

Show work on TL-60 worksheet. (No need to designate A,B,C.)

- Weigh specimen in air. Column A on TL-60. (This is "A" in the VTM calculation.)
- Immerse specimen in water bath for a minimum of one minute and determine the weight. Column B on TL-60. (This is "C" in the VTM calculation.)
- Surface dry the specimen by quickly blotting all sides with a towel and then weigh in air. Column E on TL-60. (This is "B" in the VTM calculation.)
- If specimen removed by a process that does not use water, no further drying is needed.
- Wet specimens removed by coring shall be dried to a constant mass a 125± 5°F until further drying does not alter the mass 0.1percent. (Initially dried overnight and then weighed at 2 hour intervals).
- Calculate the bulk specific gravity :

$$\frac{A}{B-C}$$

Show work on TL-60.

- Report value to two decimal places.

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Test Section

Test Sections are used to determine if density requirements are being met.

Procedure:

- Standard Test Section lot shall be 5000 feet in length. Each lot is divided into five sublots of equal length.
- Roll using the same number of passes as used for the Control Strip.
- 10 density reading locations are determined by stratified random numbers given to VDOT inspector before testing begins.
- Mark with template and paint parallel with the roadway with the arrows toward the paving train.
- Test no closer than 1 foot from the edge of application width.
- Nuclear gauge readings shall be taken in the **backscatter position** and one **minute mode**.
- Record readings on the TL-59.

Give student TL-59 to Complete

- Average each set of sublot readings.
- Determine average density reading.
- Compare average density with Control Strip Target Density to determine if acceptable. [Divide Average Density by Control Strip Target Density x 100.]

Is this Test Section acceptable? Why or why not?

Average density must fall within acceptance range of 98-102% of target density. No two consecutive sublot readings shall have density readings outside of the acceptance range.

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