Tennessee Department of Transportation
Division of Materials and Tests

Hot Mix Asphalt Roadway Certification

2015-2016

Hot Mix Asphalt
Roadway Certification School

Purpose-
WHY you're here

- TDOT Specifications §407.14
  - "The Contractor and the Department will be required to have a certified Roadway Asphalt specialist present on any paving project…"
- Investment!!!
  - In 2008- 2.5 million tons of HMA were placed!!
    - $89.5 million!!

The Problem

- The HMA Industry is under increasing pressure to design, manufacture, and construct better performing pavements faster and at lower costs.
- The skills and abilities of those in the field are a limiting factor due to lack of uniform training and staffing problems.

The TDOT Objective

- To produce technically competent decision-makers in the field who produce the highest quality HMA Pavements possible.
- To discuss: WHAT is important, and WHY it is important, and Best Paving Practices

"The Course"

- Originally a NHI course developed by FHWA, AASHTO, and Industry
- Now, same but modified to meet TDOT needs

Course Objectives

- Develop a working knowledge of all aspects of HMA construction
- Develop an understanding of how construction quality affects performance
- Recommend and encourage good construction practices

Course Objectives

- Identify and solve problems quickly
- Facilitate communication and cooperation
- Review TDOT Specification requirements and procedures

Course Schedule

DAY 1

9:00- 9:30 a.m.	**Introduction**
9:30- 10:30 a.m.	**Project Organization and Communication**
10:30- 10:45 a.m.	**Break**
10:45- 11:30 a.m.	**Surface Preparation**
11:30- 1:00 p.m.	**Lunch**
1:00- 1:45 p.m.	**HMA Delivery**
1:45- 2:00 p.m.	**Break**
2:00- 4:00 p.m.	**HMA Placement (w/ break)**

Course Schedule (Cont'd)

DAY 2

9:00- 9:45 a.m.	**Joint Construction**
9:45- 10:00 a.m.	**Break**
10:00- 10:45 a.m.	**Compaction**
10:45- 11:00 a.m.	**Break**
11:00- 11:45 a.m.	**Compaction**
11:45- 1:15 p.m.	**Lunch**
1:15- 2:00 p.m.	**Density and QC/QA**
2:00 – 2:15 p.m.	**Break**
2:15- 4:00 p.m.	**Density and QC/QA**

Course Schedule (Cont'd)

DAY 3

9:00- 9:15 a.m.	**Question & Answer, Review**
9:15- 12:15 p.m.	**Exam (3 hour limit)**

Terminology

Group Rules

- Relax, and have a good time
- Don't be late
- Attendance is a must
- Participation is a must
- There are no dumb questions
- Respect your neighbor (especially their opinions)

Quick Rundown of TDOT Asphalt Mix Types

- Before we go any further, let's get caught up on the different types of TDOT mixes and what they're names are.

Quick Rundown of TDOT Asphalt Mix Types

- 307 Mixes: A, ACRL, AS, B, BM, BM-2, CS, &CW
  - *These mixes are called "307" mixes because they are specified in Section 307 of the spec book for "Bituminous Plant Mix Base"*
  - *Oddly enough, not all of the mixes listed above are true "base" mixes.*

Quick Rundown of TDOT Asphalt Mix Types

- 307 Mixes:
  - *BASE Mixes (lowest in the pavement structure)*
    - *A – Dense graded Base*
    - *ACRL – Crack relief base*
    - *AS – Gap graded base*

Quick Rundown of TDOT Asphalt Mix Types

- 307 Mixes:
  - *BINDER Mixes (intermediate – in between base and surface*
    - *B – Not used often. Can be base or binder*
    - *BM – aka "B Modified"*
    - *BM2 – Most common binder mix*

Quick Rundown of TDOT Asphalt Mix Types

- 307 Mixes:
  - *OTHER*
    - *CW – Occasionally used for surface mix in areas with low traffic volume and slow-moving traffic. (i.e. – county, local programs projects.)*
    - *CS – "scratch" mix or leveling course. Fine-graded, higher asphalt content mix used to correct uneven surface or other surface deficiencies prior to placement of final surface mix.*

Quick Rundown of TDOT Asphalt Mix Types

- 313 Mixes:
  - *TPB – Treated Permeable Base*
    - *Drainable base mostly used under concrete pavements*

Quick Rundown of TDOT Asphalt Mix Types

- 411 Mixes: D, E, E-shoulder
  - *Surface mixes, aka "where the rubber meets the road"*
  - *D – Most common TDOT surface mix.*
  - *E – Occasionally in low-traffic areas*
  - *E-shoulder – Hmmmm? Shoulders?*

Quick Rundown of TDOT Asphalt Mix Types

- More 411 Mixes: TL, TLD, OGFC
  - *TL – Fine-graded (~1/4") mix for thin surface paving. Placed as thin as 5/8".*
  - *TLD – Moderately fine-graded (~3/8") mix for thin surface paving. Placed as thin as 7/8".*
  - *Open-Graded Friction Course (OGFC) – A porous, open-graded mixture used at surface to reduce hydroplaning.*

Liquid Asphalts

- Many different names:
  - AC (asphalt cement)
  - Binder
  - Liquid
  - Etc, etc.

Liquid Asphalts

- Section 904 of the TDOT spec book addresses these materials
  - What do you need to know?
    - TDOT typically uses 5 different “grades”
    - PG64-22 (pronounced PG 64 “minus” 22 or just 64), PG 67-22, PG 70-22, PG 76-22, PG 82-22
    - As the first two digits get higher, the material gets stiffer
    - 70, 76, and 82 are all considered “modified”.

QUESTIONS???

???

2

Organization

&

Communication

Project Organization and Communication

- *A better understanding of the roles and responsibilities of each person on the job is going to make your job easier.*
- *Who is responsible? Who answers questions?*
- *Project documents, may give conflicting instructions; you have to know which one supersedes the other and which one to go to get the right answer.*

Objectives

- **Communication**
- **Project Organization**
- **Contract Provisions**
- **Project Records**
- **Pre-Construction/Paving Conference**
- **Balancing Act**

- *The most essential part of project planning and organization is communication.*
- *The project documents are written instructions that describe in detail the requirements.*
- *The pre-construction conference initiates verbal communication between the representatives of the agency and the contractor personnel.*
- *Requires listening*
- *Oral and written communication*

Communication

- **Most important part of project- planning and organization**
- **Sharing information and open dialogue**

- *Communication must be on-going.*
- *Importance of communication, project organization, project documents, pre-paving conferences, project records.*
- *Cooperative spirit and communication on the jobsite is a priority.*
- *Trust , Cooperation, and Partnering .*

What do you mean "there's a pet cemetery in the Right-Of-Way"?!!!

- *Asphalt paving projects, like many construction projects, are not always built as originally scheduled.*
- *When such changes do occur, it is important that they be communicated between the contractor and the agency and between the agency and the contractor.*
- *Communication is a two-way process.*
- *Informal meetings on a daily basis provide a forum for the exchange of such information.*

Project Documents

- Order of Hierarchy (§105.04)
  - Special Provisions
  - Plans
  - Supplemental Specifications
  - Standard Specifications

- *Project documents describe work to be done*
- *Other documents are often referenced into the standard specifications, supplemental specifications, and special provisions.*
- *When a conflict or discrepancy exists, the hierarchy of control from highest to lowest of special provisions, the plans, the special or supplemental spec's, and then the standard spec's.*

Project Documents

- **Special Provisions**
  - **Additions or revisions to the standard or supplemental specifications that are applicable only to an individual project**
  - **Examples of special provisions could include specialty mix types (OGFC, Novachip, thin lift), requiring a transfer device, and other items that are not "run of the mill".**

- *Can be found in the Proposal contract.*
- *Proposal contracts can be found online at:*

http://tn.gov/tdot/topic/spec-procedures

Project Documents

- Plans
  - The drawings that show the location, character, dimensions, and details of the work to be done
  - Include pavement cross-sections, which mix types are to be used, spread rates, etc.

- *Plans need to be prepared professionally, accurately, and with great care to minimize hours of disputes.*

Project Documents

- **Supplemental Specifications**
  - **Approved additions and/or revisions to the standard specifications**
  - **Typos are issued as errata**

- *Between the publication of an updated standard specification comes many additions and/or revisions.*
- *The existing standard specification is updated through the use of supplemental specifications.*

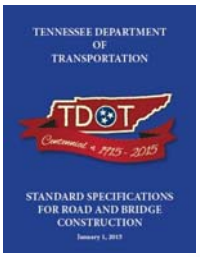
Project Documents

- **Standard Specifications**
  - **The directions, provisions, and requirements for performing the work illustrated and described in the plans**
  - **Describe the qualities and quantities of materials and labor to be furnished under the contract**

- *Always review the current CONTRACT and PLANS to check for Changes to Specifications or SPECIAL PROVISIONS*
- *Notice SPECIFICATIONS come LAST in the list of hierarchy*

TDOT Standard Specifications for Road and Bridge Construction

- Sections 403, 407, 415 attached
- Supplemental Specifications 400 attached



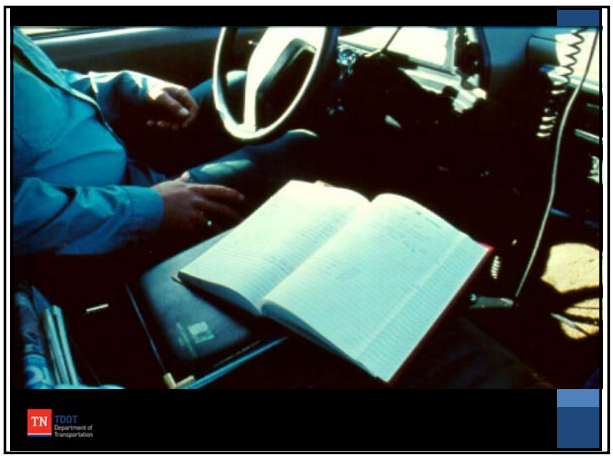
Referenced Manuals or Documents

- **AASHTO or ASTM Specifications for Sampling and Testing**
- **Manual on Uniform Traffic Control Devices (MUTCD)**
- **TDOT Circular Letters, Policy/Procedure memorandums, etc...**

Project Records

- **Checklist- Completed at start-up *(Circular letter – Back of this book)***
- **Test Strip- Roller patterns/ Nuclear Gauge Calibration**
- **Diaries- Daily production info., guests, incidents, weather, etc.**
- **Daily Reports- Density *(Standard form for density also in back of book)***

- *It is important that accurate, complete records be kept for all construction projects, by all.*
- *Trying to reconstruct events at a later time without written notes and complete test data is usually frustrating and often results in conflicting opinions as to exactly what happened.*
- *One procedure should consistently be followed: if in doubt about whether the information is important or beneficial, write it down.*



- *All project supervisors and inspectors, both agency personnel and contractor employees, should keep a detailed diary.*
- *The diary is used to report any different or unusual events that occur on the job as well as a listing of visitors to the project.*
- *What goes in a diary? Weather, equipment, work being performed, location.*
- *The data must be recorded shortly after the events occur for the info. to be accurate and meaningful.*
- *Continuous summaries, such as midday and end of day, are best. (Diaries are becoming electronic, too.)*
- *The importance of the information contained in each daily diary entry cannot be overemphasized, as many lawsuits have been settled based on diary data.*
- *AS MUCH AS POSSIBLE.*

Pre-Construction/Paving Conference

- **WHO:**
  - **TDOT Input**
  - **Contractor Input**
  - **Testing**
  - **Safety**
  - **Utilities ?**
  - **Cities or Municipalities?**
  - **Suppliers ?**

- ***A.k.a. – "pre-con"***
- ***Pre-paving meetings are critical to establish the GOALS of the project***
- ***Any individual with a stake in the project, or community, should be involved***
- ***It is vital that each party completely understand the other to build trust and foster a team spirit.***

Pre-Construction/Paving Conference

- **WHAT:**
  - **Plans- Details, Mix type, Spread rate, Thickness, General Notes**
  - **Traffic Control Plans- Lane Closure restrictions, Signing, Striping, Drop-off policy, etc…**
  - **Specifications- Seasonal/Temperature/Weather limits, Density requirements, etc..**
  - **Testing- What and Who**

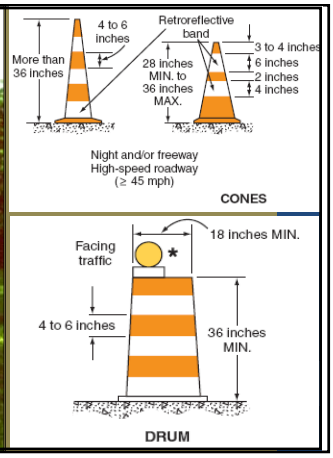
- *The Purpose of the pre-paving meeting is to go over the "Do's and Don'ts" for the project, discuss WHO is responsible for WHAT, establish the COMMUNICATION network, etc..*
- *Emphasis on Traffic Control*

Pre-Construction/Paving Conference

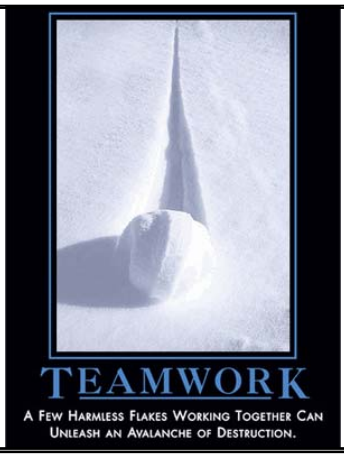
- **WHAT: (cont'd)**
  - **Responsibilities- Decision Making, Communication**
  - **Paving Plan- Methodologies, begin and end dates/locations**
  - **Plant Operations- Mixture Quality and Consistency**
  - **"Shut Down"- due to weather, mix quality, paving quality, density**
  - **SAFETY**

- *Most projects share the worksite with passenger and truck traffic.*
- *Review of paving plan with respect to location, start time, lift thickness, material type, and thickness.*
- *It is crucial that the traveling public get through your worksite safely and at the highest practical speed.*
- *The traffic control plan must meet the minimum standards spelled out in the MUTCD and/or local regulations.*

- *All project personnel are responsible for reporting a problem with traffic control*
- *You can't be too safe out on a project,*
- *Remember, you are probably very familiar with your site, but always assume the public is making their first drive through your worksite.*
- *Most projects share the worksite with passenger and truck traffic.*
- *The traffic control plan must meet the minimum standards spelled out in the MUTCD and/or local regulations.*



- *Is this sign in Conformance with the MUTCD ???*
- *If there was an accident, do you think the Lawyers would find fault with this sign?*
- *It is crucial that the traveling public get through your worksite safely and at the highest practical speed.*
- *All channelizing devices, such as drums and cones must meet the requirements of the MUTCD. All reflective surfaces must be kept CLEAN in order to remain effective.*



- *Rarely can a project team complete a project as originally planned.*
- *Invariably there is an overrun on one bid item and an under run on another.*
- *Change orders modify contract documents; it is important that all parties involved understand as soon as possible if a change order situation exists, especially if it requires an increase in the total contract amount.*
- *Early and constant communication is the key to avoiding a problem involving change orders.*

CONTRACTOR'S ASPHALT QUALITY CONTROL PLAN

CONTRACT NUMBER _____ COUNTY _____

PROJECT NO. _____ PROJECT REF. NO. _____

1. Stockpiles: Determine gradation of all aggregates; inspect stockpiles for separation, contamination, and segregation. Conduct a fractured face count when gravel is used as coarse aggregate, determine the percent of glassy particles in slag coarse aggregate when used as a surface mix. Determine the gradation, asphalt content, and percent moisture of reclaimed asphalt pavement when used as a component material in accordance with the latest version of AASHTO T-27 and T-11, a minimum of every 2000 tons used.
2. Cold Bins: Calibrate the cold gate settings and observe operation of cold feed for uniformity. Document gate settings and calibration. Ensure bins have proper dividers to prevent materials from spilling over into other bins.
3. Dryer: Observe pyrometer for aggregate temperature control and efficiency of burner.
4. Hot Bins: Determine gradation for each mix, determine theoretical combined grading, determine the percent dust coating on +4 materials, and check dried aggregate for contamination due to incomplete combustion of fuel in accordance with the latest version of AASHTO T-27 and T-11.
5. Bituminous Mixture: Check AC content, gradation, temperature, percent moisture in reclaimed asphalt, verify L.O.I. daily, check for uncoated aggregates, and ensure handling procedures do not segregate the mix.

   Minimum frequency of Tests: A random numbers table will be used to determine when to collect samples for each ½ day's production for mix quality control testing and verification of mix.
6. Scale Checks: Minimum requirements – Check AC weekly and aggregate monthly. Check anti-strip additive meter daily and compare reading with theoretical.
7. Batch Plants: Check batch weights to determine percent used and weight to be pulled from each bin to assure compliance with job mix formula, check mixing time (both dry and wet), and check operations of weigh bucket and scales. Document accuracy of all weighing and metering devices for AC, aggregates and anti-stripping additive according to the specifications.

- *Sampling methods, frequencies, and WHO tests what should be discussed.*
- *What is the procedure to be used if failing test results are obtained and what are failing results?*

- *These meetings can range from a formal sit-down to a plans-on-the-hood-of-the-pickup-held-down-by-a-can-of-pavement-marking-paint kind of meeting.*
- *It depends on the project's requirements and what everyone feels comfortable with.*
- *Make sure you have the meeting with the right personnel in attendance and record any decisions made.*
- *Keep good records.*

- *After both parties explain their plans, it is crucial that a time be set aside for discussion of the big picture.*
- *Openly discuss procedures or practices that may help the job run smoother and make the pavement to be constructed better than any pavement before.*
- *Everyone must be committed to try to make this project an award winning pavement.*
- *Meeting minutes need to be taken and distributed to all attendees in a timely manner.*
- *Produce action items with priority listing, person in charge of its disposition, and a deadline for action.*

Safety…
Is *Everyone's* Business!

Worker Safety and the Motoring Public Safety are a PRIORITY!!!

- *Safety is not only a legal and financial responsibility of all the people on the project but a moral responsibility as well.*
- *This topic should include not only the safety of those individuals working on the job but also the safety of the traveling public.*
- *Clear responsibility for maintenance of all traffic control devices-such as signs, pavement marking, and flagging-should be delineated.*
- *Review the plan before set-up and after set-up and always take into account special conditions.*

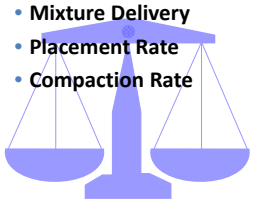
TDOT Policy 101-03

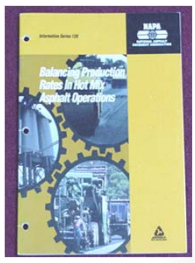
Class 3 ~~(night)~~ ALL THE TIME

- *"Safety is Everyone's Business" is certainly true on an HMA paving project.*
- *An orange vest or hard hat has never stopped a vehicle moving 10, or 70, MPH*
- *All TDOT employees are required to conform to TDOT Policy 101-03 and wear the appropriate personal protective equipment (PPE)*

Balancing Act

- **Plant Production**
- **Mixture Delivery**
- **Placement Rate**
- **Compaction Rate**





- *Throughout the course we will discuss the importance of BALANCING Production and Placement and Compaction*
- *Review NAPA publication- worksheets*

3

Surface Preparation

TN TDOT Department of Transportation

Surface Preparation and Milling Techniques

- *The performance of an HMA pavement under traffic is directly related to the condition of the surface on which it was placed.*
- *Surface can be subgrade, aggregate base, or existing HMA or concrete pavement.*
- *Surface preparation often doesn't get the attention it needs.*
- *It is easy to cover up problems with HMA, but rarely do the problems go away.*

Objectives

- Proper techniques for overlay preparation
- Proper materials and construction techniques for patching
- Proper milling techniques
- Proper tack coat application
- Proper techniques for placing leveling courses

Preparation of an Existing Surface

- *Preparing an existing pavement for an overlay may be as simple as sweeping the surface and spraying a tack coat…*

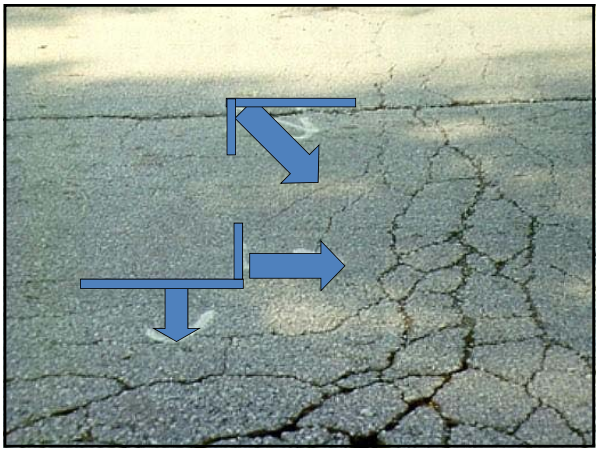
- *… or it may involve numerous other procedures:*
  - *patching*
  - *placing a leveling course*
  - *milling the existing surface*
- *Depends on the nature of the problem*

Pavement Repair

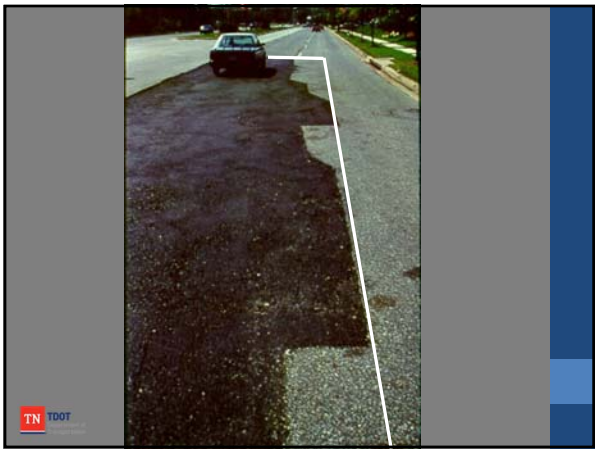
- Matching Techniques
- Materials
- Procedure

- *Pavement repair techniques must:*
  - *Match the repair technique to the existing conditions.*
  - *Use the proper materials and procedures to complete the repair and achieve long term performance.*
- *If the pavement failure is load related, the pavement material must be removed and replaced down to sound material.*

- *Sometimes, pavement preparation before an overlay may involve coming back to replace someone else's handiwork.*

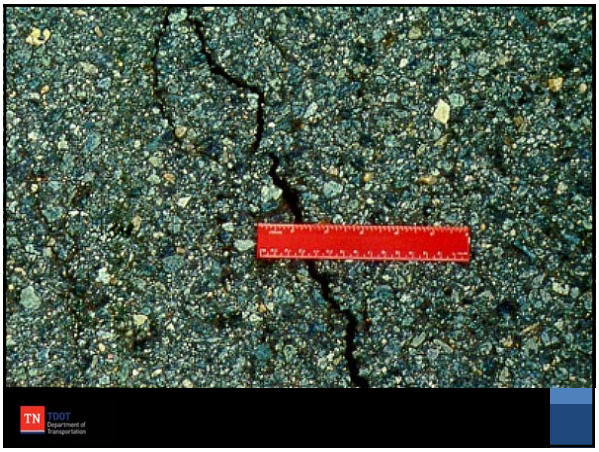


- *The first step is marking the outline for the repair. The failed area should be cut back to sound pavement.*



- *This patch would have been easier to repair if the edges were kept straight.*

- *Properly constructed patches will perform well, whether or not the patch is part of pavement preparation prior to an overlay.*
- *Pre-construction meeting item: Utility repair coordination, so that utilities are not cutting trenches across a brand new pavement.*



- *What about crack filling / sealing?*
- *This is an average size crack, a candidate for filling.*
- *Cracks must be cleaned and prepared properly prior to filling so the sealant will adhere to the pavement.*

- *Typically, cracks less than 3/8" wide are too small to be filled effectively. The sealant does not enter the crack.*
- *The amount of reflective cracking in an overlay may be reduced by using a surface treatment (chip seal or slurry seal), depending on the cause of the cracking.*
- *TDOT does not use surface treatments as crack fillers even though they can be more economical than crack sealing, since crack sealing is more labor intensive.*

- *This crack is large enough to be treated with a patch.*

concrete pavement failure

- *Concrete pavement surface preparation is similar to other existing surfaces.*
- *Problems with reflective cracking in asphalt overlays of concrete have led to several techniques to prevent or control the reflective cracking.*

- *After patching and sealing, and prior to applying the tack coat, the surface <u>MUST</u> be properly cleaned.*
- *Typically, a power broom or street sweeper is used.*
- *Any foreign material (dried mud, spilled asphalt, etc.) must be removed to insure a strong bond between layers.*
- *Cleaning is typically done immediately prior to placing the tack coat.*

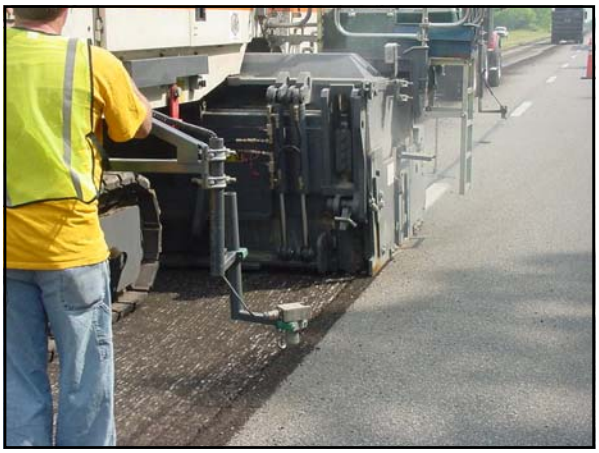
Preparing a Milled Surface

Why do we mill?

- Removal of the existing pavement to the desired depth
- To restore the pavement surface to the specified grade and slope
- To help improve the ride-ability of an existing surface

- *Milling can be used in lieu of leveling to remove the high spots from an existing surface.*
- *Milling is frequently used when maintaining the surface profile is necessary, such as in curb and gutter situations.*
- *Milling can also be used to remove mix related problems.*

- *Milling can be varied in width from 0.5 ft to over 13 ft.*
- *The largest milling machines can remove to depths over 8 inches.*
- *The RAP removed from the surface can be saved for future recycling.*



- *Proper pavement repairs when milling and overlaying are even more important, since milling removes some of the pavement structure.*
- *Underlying pavement problems may be uncovered during milling.*
- *As this photo shows, milling often leaves a very dirty and dusty surface. Multiple sweepings are often necessary to make sure all of the dust and dirt is removed.*

- *Traffic control may be more critical in repair operations.*
  - *Closures may be short*
  - *Many locations, with frequent equipment moves*
- ***Refer to chapter 6 of the MUTCD for guidance regarding mobile work zones***

Proper Milling Techniques

- Smooth Milling and Smooth Roads go hand in hand

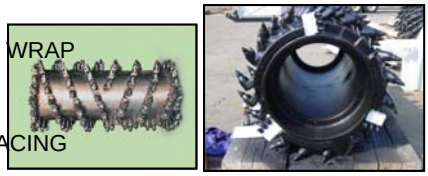
The Future

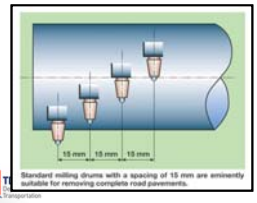
- *Less projects with Binder and Scratch*
- *More projects with Mill and Overlay*
- *Fewer chances to improve smoothness*
- *Forced to look at the front of the paving train*

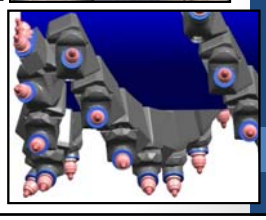
STANDARD CUTTING PATTERN

TRIPLE WRAP

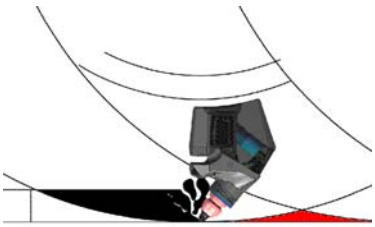
5/8" SPACING





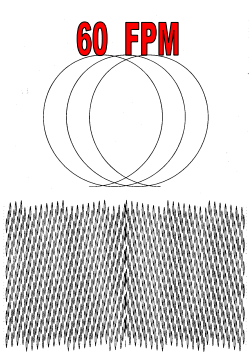


Speed is a factor



CUTTING PATTERN

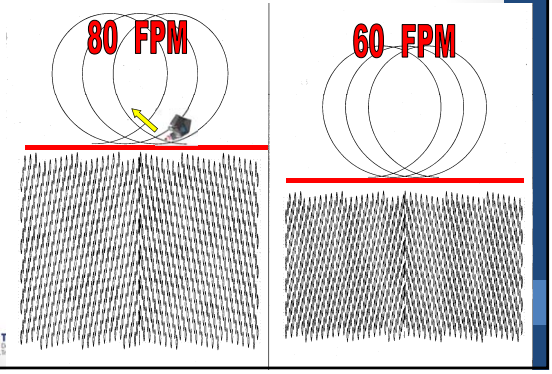
60 FPM



CUTTING PATTERN

80 FPM

60 FPM



Section 415.03

When milling the roadway for hot mix overlays the maximum allowable forward speed shall be:

- **60 ft/min when the teeth spacing is ½ - 5/8 in.**
- **80 ft/min when the teeth spacing is < ½ in.**

NOTE: Maximum of 5/8" tooth spacing

Section 415.03 cont'd.

415.03-General Requirements.
…. After planing, the finished surface shall provide a smooth riding surface *free from gouges*, ridges, oil film, and other imperfections of workmanship, *having a uniform texture*, and true to the required grade and cross section

Tack Coat

SECTION 403

- *All equipment shall be on hand and approved before work begins.*
- *Application Temperature ranges found in Section 403.02*
- *The surface shall be dry at application.*

Tack Coat

TACK COAT – A thin layer of bituminous material placed between layers of hot mix asphalt.

Tack Coats

- Materials allowed for use as tack on TDOT projects*:
  - Asphalt emulsions:
    - SS-1, SS-1h, CSS-1, CSS-1h, CQS-1h, CQS-1hp, TST-1p, and TTT-1
- *TDOT Spec – Section 403

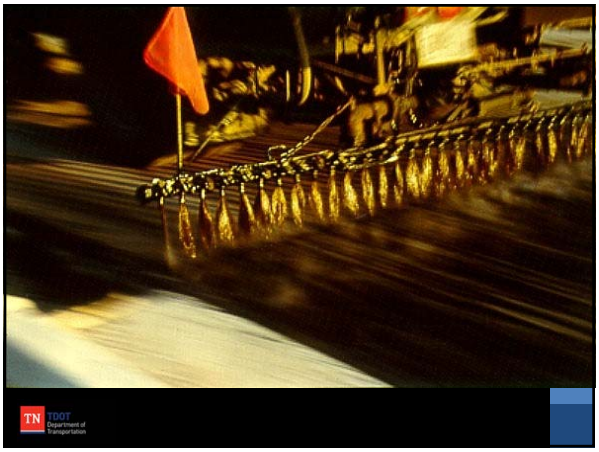
Tack Coat

- "SS" = slow-set
- "CSS" = cationic slow set
- "CQS" = cationic quick set
- "TTT"= Tennessee Trackless Tack

- Asphalt cement *is not permitted in TN* because it must be kept at hotter temperatures and is harder to spray-apply.

Tack Coats

- Emulsions are typically approximately 60% asphalt and 40% part water.



- *While the surface is still clean, place the tack coat.*
- *The tack coat ensures a bond between the existing pavement and the overlay.*
- *Slippage cracking can occur if a good bond is not formed.*
- *Distributor must be working properly for even application.*

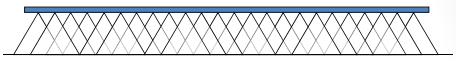
- This application was on a job in Tennessee.

- This type of application will not make full use of the tack coat.

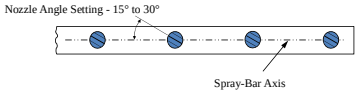
Tack : How much is enough?

- *Too much tack is a bad thing.*
- *Start with the application rate shown in the Paving Schedule on the PROJECT PLANS*
- *Place a test strip in accordance with section 403.05 of the TDOT specs.*
- *Even if the rate is correct, the material MUST be distributed EVENLY.*

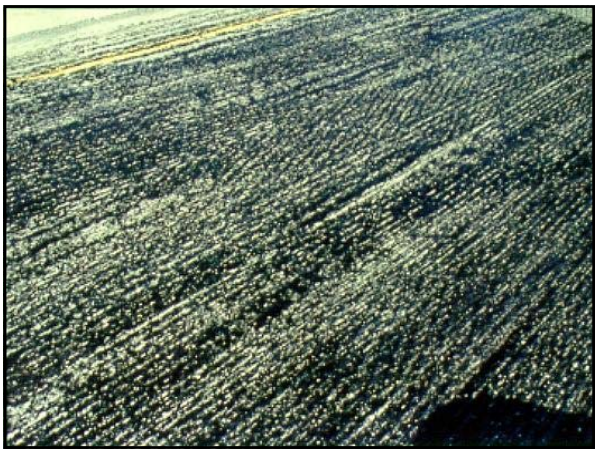
Correct Spray with Triple Overlap



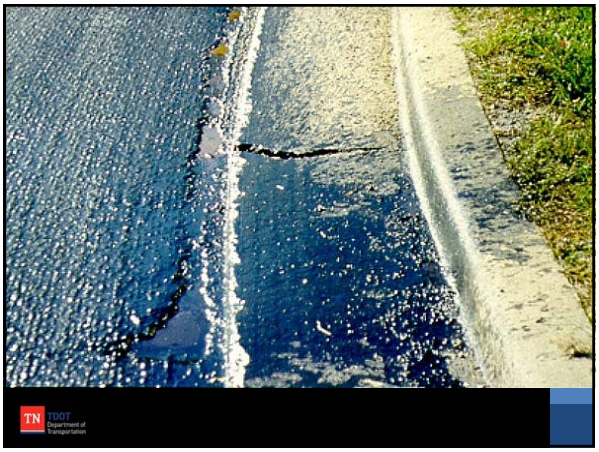
Proper Settings of Nozzles



- Nozzles must be relatively clean and positioned correctly to achieve a triple overlap.



- *Asphalt emulsions are applied brown, and then turn black after they break.*
- *The emulsion must be allowed break before placing the HMA.*
- *Typical tack coat application rate not to exceed 0.1 gallons per square yard.*
- *Tack coat application rate on milled surface not to exceed 0.12 gallons per square yard.*
- ***The actual application rate for your project will be shown on the plans.***



- *Make sure the tack coat goes where it is supposed to go….*

Tack Coat Application Rate Problem

- **Initial Reading on Tack Truck: 470 gal**
- **Final Reading on Tack Truck: 320 gal**
- **Tack applied to 2500' of a 12' wide lane**
- **Roadway Surface not milled**

A) What's the application rate?

B) Does it pass TDOT specifications?

Tack Coat Application Rate Problem

Gallons Used = Initial Reading – Final Reading

= 470 – 320 = **150 gallons**

Feet^2 = 2500' x 12' = **30,000 ft^2**

Yards^2= 30,000/9 = **3333.3 yd^2**

Rate = gal/yd^2

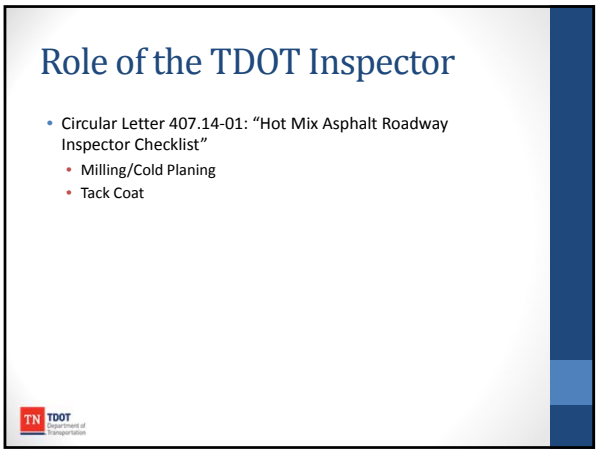
= 150/3333 = **0.045 gal/yd^2**

- *Leveling can be used to correct low spots and cross section deficiencies.*
- *Other terms include scratch course, wedge, and leveling course.*
- *The extent of leveling course is marked off, and then placed with a paver or by hand. (This leveling was paver placed.)*
- *Compaction of leveling courses is best achieved with a rubber-tired roller, rather than steel wheel rollers, since thickness will vary.*

- *Even small areas need to be leveled prior to overlay, as in this hand placed leveling.*

NOT ACCEPTABLE!

- *Be careful with the maximum aggregate size in the HMA and leveling course thickness…*
- *The center was thinner than the edges– the white aggregate pieces were being crushed and drug by the screed.*


Role of the TDOT Inspector
• Circular Letter 407.14-01: "Hot Mix Asphalt Roadway Inspector Checklist"
• Milling/Cold Planing
• Tack Coat
TN TDOT Department of Transportation

TN TDOT Department of Transportation

HMA Delivery

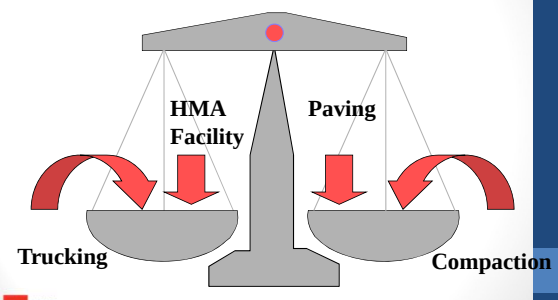
- *Delivery is the start of the HMA construction process.*
- *Like any process, if it is planned properly, it will go smoothly.*
- *The smoother the process, the better the product.*

Objectives

- Types of haul trucks
- TDOT Specifications for trucks
- Proper loading of haul trucks
- Proper haul truck operating techniques
- Role of the Inspector
- Example problem

- *The theme to this module is looking at HMA construction as a process, and how keeping the process running smoothly lessens problems and improves the product.*
- *Balance the haul rate with the others to produce the best job possible.*
- *Why is consistent HMA delivery so important?*
- *What works against keeping a steady supply of mix coming to the paver?*

Balancing Production



- **Paving is a constant balancing act.**
- **Mix production and delivery must be balanced with lay down and compaction to ensure a smooth operation and a high quality mat. Mix production:**
- **Haul trucks: Adequate numbers (and no pack driving!)**
  - **Lay down production: dependent on width and depth**
  - **Compaction: How many rollers do you need?**

Types of Trucks

- Two types commonly used in TN
  - End Dump
  - Semi-trailer Dump

- Each are loaded at the plant in the same manner from the silo or pugmill. The difference is in how they unload the mix at the paver.
- End dump truck delivers mix directly to the paver hopper, 3 to 6 axles,
- Capacity: 15-22 tons (more axles, more capacity)
- Advantage: Shortest wheel base, easiest to maneuver
- Disadvantage: Limited capacity

- Semi-trailer truck–essentially a large end dump truck
- Capacity: 18 to 27 tons
- Advantage: capacity
- Disadvantage:
  - more maneuvering skill needed (turns)
  - overhead obstructions (wires, bridges, trees)
  - greater segregation potential during loading
  - truck bed weighing on paver

Truck Weight Limits

- Legal limits found in TDOT Circular Letter 109.01-02*
  - Example (Interstate)
    - End dump 4-axle-
    - Legal Limit- 68,000 lbs.
- TDOT Spec 107.02 *(supplemental)* – "All delivery trucks shall conspicuously display the tare weight, the allowable gross weight for State Highways, and the allowable gross weight for the Interstate System on the side of each truck."
- *Back of this book

Truck Maintenance

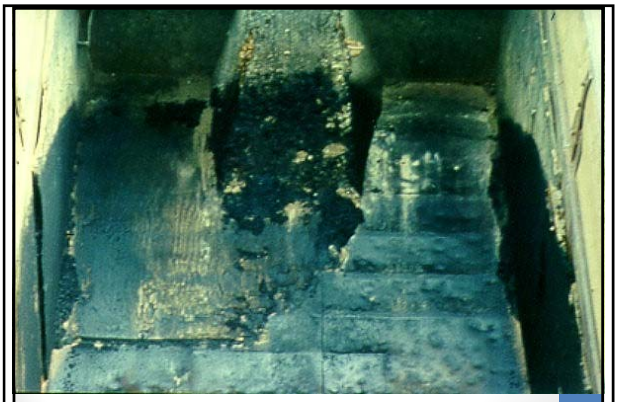
- **Trucks must be in mechanically sound condition**
- **Items to maintain include engine, drive train, hydraulic system, brakes, and lights**
- **Back-up warning devices**
- **Driver is responsible for maintenance**

- **Hydraulics must be checked daily.**
- **Hydraulics raises and lowers bed. Problems with this could be dangerous.**
- **Fuel leaks must be checked**

TDOT Truck Requirements

- **407.05-Hauling Equipment.** Trucks used for hauling bituminous mixtures shall have …

…tight, clean, smooth metal beds which have been thinly coated with a minimum amount of paraffin oil, hydrated-lime solution or other approved material from the Department's QPL to prevent the mixture from adhering to the beds.



NOT ACCEPTABLE!

- **The truck bed must be inspected and properly cleaned prior to loading the HMA.**
- **Free from old mix, extraneous materials, debris.**
- **No dents or depressions.**
- **Modified asphalts can cause greater sticking problems in the bed.**

- **The outside of the truck should also be kept clean and free of extraneous materials.**
- **Look for loose rock and dirt near the truck's tail lights.**

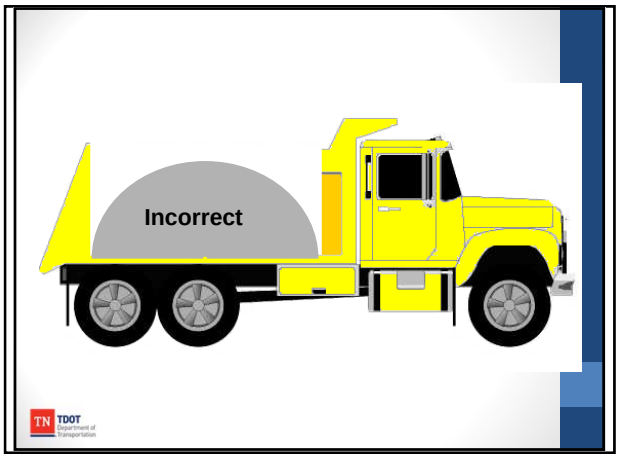
Truck Loading Operations

- Applying APPROVED release agents
- Proper loading at the plant
  - Multiple Dumps
- Covering Mix with tarps

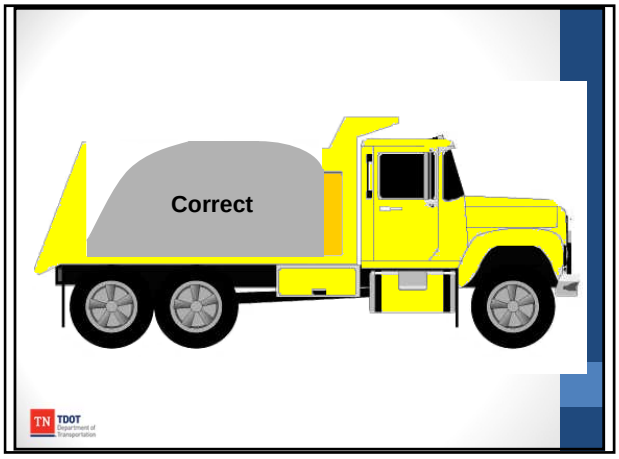
- **Drivers must be made part of the paving team from the beginning. They should understand their role and purpose in the team.**
- **Safety is paramount around the jobsite. Drivers must act responsibly, and adequate traffic control must be available to ensure safe passage.**
- **Truck tracking systems are now available using GPS .**

- **Once the bed is clean, apply an approved release agent.**
- **Non-petroleum materials sprayed uniformly on the sides and bottom–just enough to coat the bed without runoff.**
- **Diesel fuel can cause problems with the mix, and is hazardous to the environment.**
- **Local agencies have different approved material lists.**

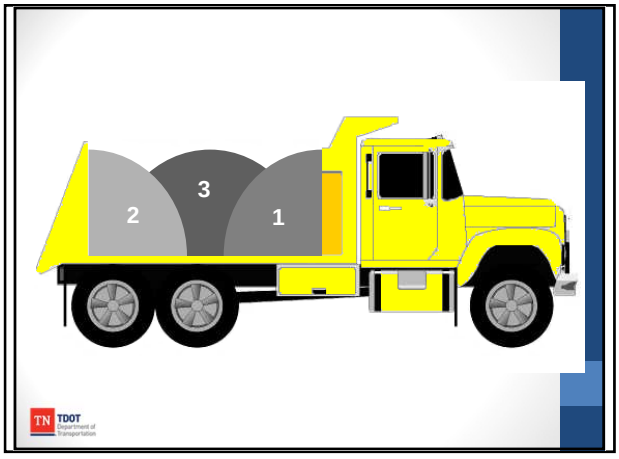
- **Next we are going to look at truck loading practices.**
- **This photo shows silo gates discharging mix into the truck.**
- **This subject may seem to be fairly simple, but improper loading is a prime source for mix segregation.**
- **Proper loading can help eliminate a segregation problem.**
- **The loading plan should be discussed and agreed upon at the preconstruction conference.**



- Most trucks need to have the load slightly forward in the truck bed to comply with axle weights and load distribution regulations.
- This load is centered too much in the truck bed.



- This load is more properly placed–slightly forward of the center of the bed.



- The objective of truck loading is to get the mix loaded into the truck as uniformly as possible.
- The greatest concern in uniformity is segregating the mix as it is loaded into the truck.
- Getting the HMA against the front and back is an important consideration in preventing segregation. If the mix is not crowded to the ends, the larger rocks in the mix can roll down the slopes and gather in one place.
- Especially for segregation-prone mixes, multiple drop procedures are recommended.
- With multiple drops, end dump trucks are loaded at the front and rear of the bed, and then in the middle.

- **Haul trucks should be equipped with tarps.**
- **Tarps protect the mix during inclement weather and prevent wind drafts from cooling the mix**
- **Water-repellent, resist tearing, without holes.**
- **Mechanically extendable tarps are preferred (to keep the driver off the side of the truck).**
- **Once Loaded, tarped, pick up ticket and go directly to jobsite**

TDOT Truck Requirements

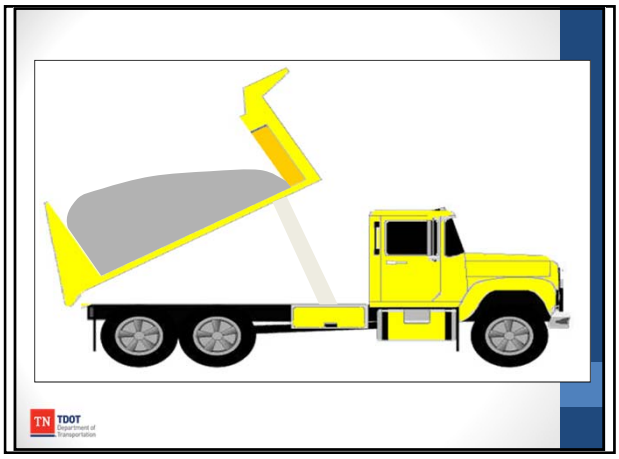
- **407.05-Hauling Equipment.** Trucks used for hauling bituminous mixtures shall be covered immediately after loading at the plant with a cover of canvas or other suitable material. The covers shall be of sufficient size to protect the mixture from the weather. The cover shall lap down along the sides and rear of the truck bed a minimum of 6 inches(150 millimeters) and be secured by tie downs at a maximum of 5 ft. (1.5 m) spacing along the sides and rear of the truck bed.

- *Haul trucks should park in designated areas, and minimize the tracking of tack coats.*
- *Here, one truck has just finished loading the paver, and it pulls away as another truck waits.*
- *The waiting truck was far enough ahead so not to interfere, but close enough to get to the paver and keep the operation moving smoothly.*
- *Again, communication is the key–the drivers should be informed about the paving plan.*

- *The next truck slowly backs toward the paver, while the paver lowers its wings (to give the truck access to the hopper) and continues to move forward.*

- **The truck brakes to a halt in front of paver, ready to be picked up on the fly.**
- **It is important that the truck be centered on the paver before the paver makes contact. Damage to the mat and the paver can result from off-center positioning.**
- **The area between the truck and paver is off limits to personnel. Too many accidents occur in this area.**

- **Once the truck has stopped, the driver releases the brakes and the paver "picks up" the stopped truck. In this photo, the truck is also beginning to lift the bed.**
- **The key is that the truck does not back into the paver and bump it. Bumping the paver can leave a screed mark and roughen the mat.**
- **Once the paver picks up the truck, it pushes the truck forward. A light touch on the brakes keep the truck against the paver.**



- *With end dump trucks, the proper procedure for dumping the mix into the hopper is to raise the truck bed slightly and allow the mix to slide against the tailgate before it is released.*
- *This procedure will allow the mix to flood the hopper–not allowing mix to dribble from the truck into the hopper before the bed is raised.*
- *With live bottom trucks, try to use the same procedure to flood the hopper from the truck.*

- *After the hopper is filled, the truck bed is gradually raised, continually charging the hopper and maintaining a smooth operation.*

- **Mix is often dumped into a material transfer device (MTD)**
- **These vehicles receive the mix from the trucks, and then feed the paver.**
- **This vehicle allows the paver to be operated almost continuously, eliminating the exchange between the truck and paver.**
- **On the other end of the material transfer vehicle, a conveyor discharges mix into the paver hopper.**
- **Note the oversized hopper insert used with this equipment.**

Crusted Mix

- **No set distance limit for hauling HMA.**
- **Any crust that does form during transport should break up completely as the mix is dumped into the paver and carried back to the screed provide the mix temperature is adequate and especially with the MTD.**
- **The crust must not affect the mat behind the paver.**
- **The increasing use of modified asphalt, mix temperature may be more of a concern.**

- *While paving, the truck driver must concentrate both ahead and behind.*
- *The driver must steer between the "pull" of the paver, and keep slight pressure on the brakes to maintain contact with the paver.*
- *Too much braking force may make the paver slip and affect the mat.*

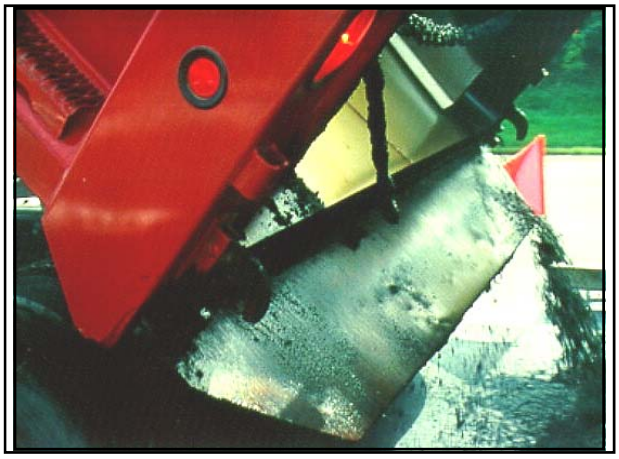
- *Always be wary of any possible obstructions on the paving site.*

- *Once the truck is empty, the bed has to be lowered before pulling away.*
- *Lowering the bed will allow the truck apron to clear the hopper guards.*

- *Once the truck has cleared the paver, it should immediately depart from the area to a clean up station, and let the next truck back up.*

- **And we're back to the beginning of the cycle.**
- **(Emphasize the continuous nature of the exchanges, another truck waiting as the finished one departs.)**

- *There should be a designated clean up area for the drivers to clean any remaining mix from the rear of the truck, the apron, and the tailgate.*
- *The clean up area is <u>not</u> the paving site.*
- *Again, modified asphalt can make this a more troublesome task.*



- *Aside from catching the paver hopper, another problem with not lowering the truck bed before pulling away is spilling mix onto the paving surface.*
- *Any practice that spills mix onto the paving surface should be discouraged.*

- *"Banging the gate" (leaving the truck bed up, speeding up, and then stopping quickly to allow the tail gate to bang the truck) should be discouraged.*
- *"Flying Rock"*

- *If this does occur, the mix must be cleaned off the surface, not just paved over.*
- *What could happen if this mix is allowed to stay on the pavement?*

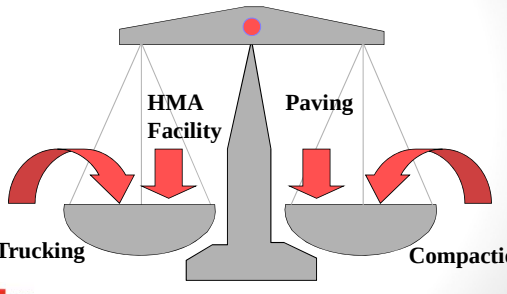
- *This truck is ready to leave the jobsite for another load. The back of the truck is clean. No mix is left to spill from the truck.*
- *Once the truck has completed on-site cleanup, is should proceed immediately back to the asphalt plant.*
- *The trucks should not delay departure, or the smooth, continuous nature of the entire operation could be affected.*

Scheduling Problem

- How do you determine the number of trucks needed to balance production rates?

TN TDOT Department of Transportation

Balancing Production



TN TDOT Department of Transportation

Scheduling Problem

- Today we are attempting to pave 2000 tons in 10 hours
- What production rate are we going to need from the plant?

Scheduling Problem

- The average truck can carry 20 tons of mix to the job in one trip.
- How many loads will be necessary to haul today's mix?

Scheduling Problem

- It's going to take each truck 1-1/2 hours to haul mix to the project, unload, clean out the bed, and return to the plant.
- How many trips can one truck make in today's workday?

Scheduling Problem

- We now know we need 100 loads to be hauled and each truck can haul 6 loads a piece today.
- How many trucks will be necessary to haul today's mix on time?

Scheduling Problem

- Today we are attempting to pave 2000 tons in 10 hours
- What production rate are we going to need from the plant?

2000 tons / 10 hours =

200 tons/hour

Scheduling Problem

- The average truck can carry 20 tons of mix to the job in one trip.
- How many loads will be necessary to haul today's mix?

2000 tons / 20 tons per load =

100 loads

Scheduling Problem

- It's going to take each truck 1-1/2 hours to haul mix to the project, unload, clean out the bed, and return to the plant.
- How many trips can one truck make in today's workday?

10 hours / 1.5 hours per trip=

6.7 trips per truck

→6 trips per truck

(0.7 of a trip ain't worth much)

Scheduling Problem

- We now know we need 100 loads to be hauled and each truck can haul 6 loads a piece today.
- How many trucks will be necessary to haul today's mix on time?

100 loads/ 6 loads per truck =

16.7 trucks

→17 trucks

(Once again, 0.7 of a truck probably doesn't drive well. I want whole trucks)

TDOT MTD Requirements

TDOT Spec., 407.14, Paragraph 3

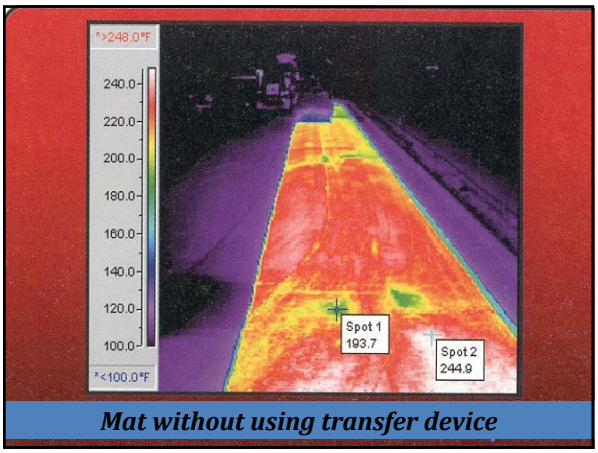
- "Repetitive interruptions or stopping of the paver shall be cause for the Engineer to stop the work until the cause of the stoppage is corrected."

TDOT MTD Requirements: Special Provision 407G

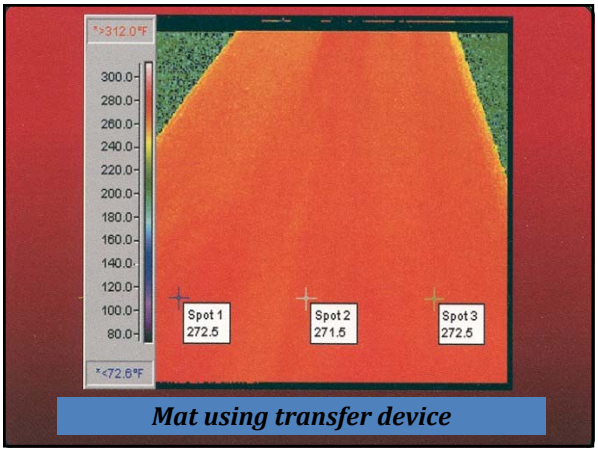
- An MTD shall be utilized for all mixes (Except CS)
- The MTD shall have a capacity of 15 Tons, and be capable of remixing the material
- The paver shall have a surge hopper with sloping sides (60º) and a capacity of 15 tons

Why use a MTD?

- To stabilize a paving operation so the paver can maintain a constant unchanging paving speed, eliminating the stops and starts traditionally associated with trucks dumping directly into the paver
- Eliminate aggregate and temperature segregation which will provide for more uniform compaction and eliminate high air void areas associated with truck end segregation.



Mat without using transfer device



Mat using transfer device

QUALITY PAVING WITH MTD's:

- 1. MTD's will not correct for improper paving techniques. Nothing replaces a well trained and conscientious crew.
- 2. Use the MTD to allow the paving crew to match the paver speed to plant output (see production chart).

QUALITY PAVING WITH MTD's:

- 3. Use the storage capacity of the MTD and hopper insert to ensure a constant paver speed and eliminate the need to start and stop the laydown operation. If you allow the paver to run too fast, you will still run out of material and will be forced to stop. As a rule, with MTV's you can pave slower and still lay more tons per day since you are eliminating the starts and stops between trucks.
- 4. Keep the MTD hopper and the paver hopper insert 1/3 full at all times to allow for sufficient heat transfer with each new load and to eliminate any aggregate segregation.

PAVER SPEED FPM (m/min)	MAT THICKNESS - INCHES (MILLIMETERS) 1 (25.4)	2 (50.8)	3 (76.2)	4 (101.6)	5 (127.0)	6 (152.4)	7 (177.8)	8 (203.2)
10 (3.0)	42 (38)	84 (76)	126 (114)	165 (150)	210 (191)	252 (229)	294 (267)	336 (305)
15 (4.6)	63 (57)	126 (114)	189 (171)	252 (229)	315 (286)	378 (343)	441 (400)	504 (457)
20 (6.1)	84 (76)	168 (152)	252 (229)	336 (305)	420 (381)	504 (457)	588 (533)	672 (610)
25 (7.6)	105 (95)	210 (191)	315 (286)	420 (381)	525 (476)	630 (572)	–	–
30 (9.1)	126 (114)	252 (229)	378 (343)	504 (457)	630 (572)	–	–	–
35 (10.7)	147 (133)	294 (267)	441 (400)	588 (533)	–	–	–	–
40 (12.2)	168 (152)	336 (305)	504 (457)	672 (610)	–	–	–	–
45 (13.7)	189 (171)	378 (343)	567 (514)	756 (686)	–	–	–	–
50 (15.2)	210 (191)	420 (381)	630 (572)	–	–	–	–	–
55 (16.8)	231 (210)	462 (419)	693 (629)	–	–	–	–	–
60 (18.3)	252 (229)	504 (457)	756 (686)	–	–	–	–	–
65 (19.8)	273 (248)	546 (495)	819 (743)	–	–	–	–	–
70 (21.3)	294 (267)	588 (533)	–	–	–	–	–	–
75 (22.9)	315 (286)	630 (572)	–	–	–	–	–	–
80 (24.4)	336 (305)	672 (610)	–	–	–	–	–	–

Based on 12' (3.7 m) wide lane — Mix compacted to 140 lbs/cf (2243 kg/cu. m)

PAVER SPEED vs. TPH (MTPH) & MAT THICKNESS

QUALITY PAVING WITH MTD's:

- 5. Wherever possible, use a steep walled 10 to 20 ton hopper insert in the pavers hopper to promote live feeding of the HMA directly to the feeder tunnels. If a hopper insert is not available, keep the MTD conveyor low to the paver hopper to eliminate "splashing" the material.
- 6. Remember that the MTD does not need to be physically tied to the paver. To make better use of the MTV, use it to unload trucks where safest (away from overpasses and power lines) and shuttle back to the paver to keep the hopper insert charged.

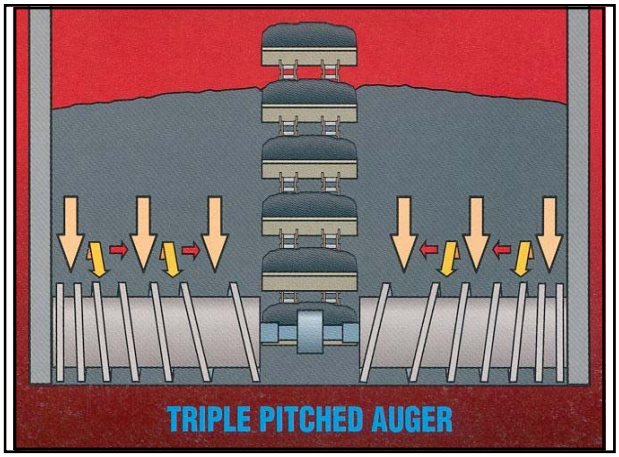
QUALITY PAVING WITH MTD's:

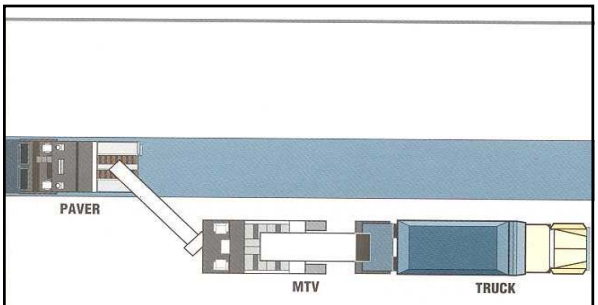
- 7. Use the MTD pivoting conveyor to allow offset paving. This can help to keep haul trucks off of tack and away from stringlines.
- 8. At the beginning of the day, take the first truck from the plant and move it back to third or fourth in line. Then take the second and third loads from the plant and run them straight through the MTD and into the paver. This will preheat the metal surfaces of the MTD and will insure the paver starts with hot material in the hopper.

QUALITY PAVING WITH MTD's:

- 9. A good rule of thumb is that any base that will support a rubber tired paver will support most MTD's.
- 10. Above all, use the MTD to promote quality paving practices:

  * Constant, uniform head of material.
  * Eliminate spillage in front of the paver.
  * Use constant paver speed to enhance a good roller pattern so as to always achieve proper densities.





Feeding paver in adjacent lane

Role of the TDOT Inspector

- Temperature Check every 3rd load
  - TDOT SOP 1-1 Sampling and Testing Guide
- Check mixture in truck for:
  - Segregation
  - Uniform Asphalt coverage
  - Contamination

Mix Delivery Temperatures

- 407.14- The temperature of the mixture at the time of depositing in the paver hopper shall be in accordance with section 407.11, table B.

PG Binder Grade	Minimum Temp.	Maximum Temp.
PG 64-22, PG67-22	270° F	310° F
PG 70-22	290° F	330° F
PG 76-22	290° F	330° F
PG 82-22	290° F	330° F

Role of the TDOT Inspector

- Circular Letter 109.01-01
  - Each load must have a stamped and signed Weight Ticket- "Copy of Record"
  - Ticket Number, time, gross, tare, and net weights, running total, legal limit and check legal limit
  - Inspector shall sign each ticket at point and time of delivery

Role of the TDOT Inspector

- Circular Letter 407.14-01: "Hot Mix Asphalt Roadway Inspector Checklist"
  - Material Transfer Device
  - Delivery

4

Mix Delivery

5

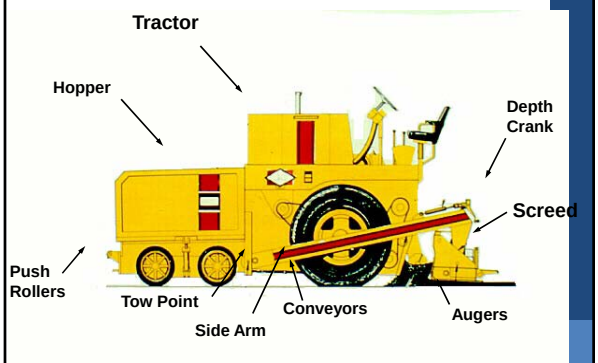
HMA Placement

HMA Placement

- *This module will cover all the aspects of placing HMA.*
- *Again, focus on the balance aspects of the paving operation–forces on the paver must be in balance to produce a uniform, dense, and smooth mat.*
- *Principles of paver operation are applicable to a variety of HMA mix types, including dense-graded, Open-Grade Friction Courses (OGFC), and Stone Matrix Asphalt (SMA).*

Objectives

- Objective of HMA Placement
- Components and Function – Tractor and Screed Unit
- Grade and Slope Control Systems
- Yield-Thickness-Smoothness Relationship
- Types of Paving and When to Use Them
- Night Paving
- Paver Maintenance
- Operating Techniques



- *The purpose of the paver is to place the HMA to the desired width and thickness and to produce a satisfactory mat texture.*
- *The paver consists of two primary components: the tractor unit and the screed.*
- *The tractor unit provides all of the power for the paver, and carries the mix from the hopper back to the screed.*
- *The screed is towed by the tractor unit, and provides the initial density and smoothness to the mat.*

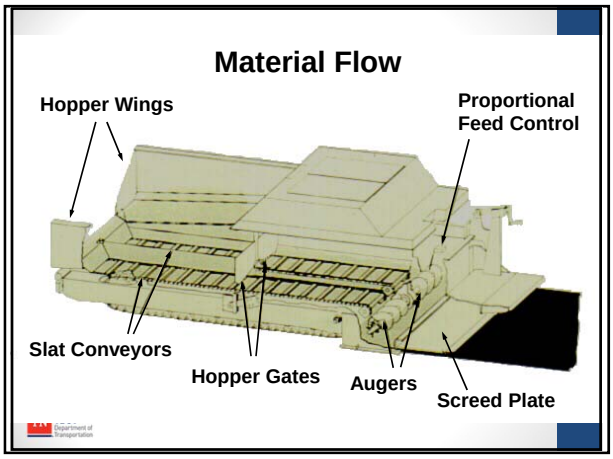
Tractor Unit

- Drive Systems
- Push Rollers and Truck Hitches
- Hopper
- Slat Conveyer
- Conveyer Flow Gates
- Augers
- Materials Feed System
- Tow Points
- Maintenance

- **This list gives the major components of the tractor unit and the subject areas that will be covered during this part of the module.**

- **The tractor unit has its own engine that provides the power to move the pave forward.**
- **Pavers travel on either rubber tires or tracks.**
- **Rubber tired pavers can be moved around more readily. The have a faster travel speed than a track paver.**
- **The rubber tires are inflated to between 240 and 585 kPa. The tires are also ballasted with a calcium chloride solution to reduce bounce in the paver.**

- *Pavers also come with track drive systems.*
- *The tracks spread the weight of the paver over a larger area.*
- *These types can be more effective on paving grades.*
- *The tracks can be all steel, steel with rubber pads, or flexible bands with steel shoes and rubber pads.*
- *QUESTION: Who has a preference between rubber tired and track pavers? Why?*

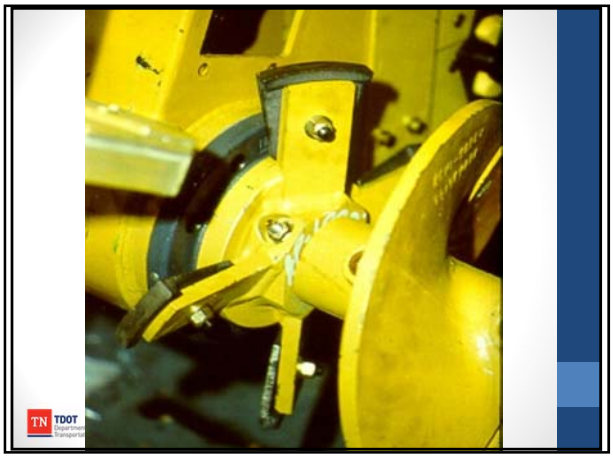


- *The goal of the material feed system is to get a constant head of material in front of the screed.*
- *If the material feed system is set and operating properly, the slat conveyors and augers on each side of the paver will rarely shut off.*
- *If the conveyors and augers are constant speed (only on or off), the flow gate settings control the flow.*
- *For variable speed augers and conveyors, material flow is controlled by all three.*

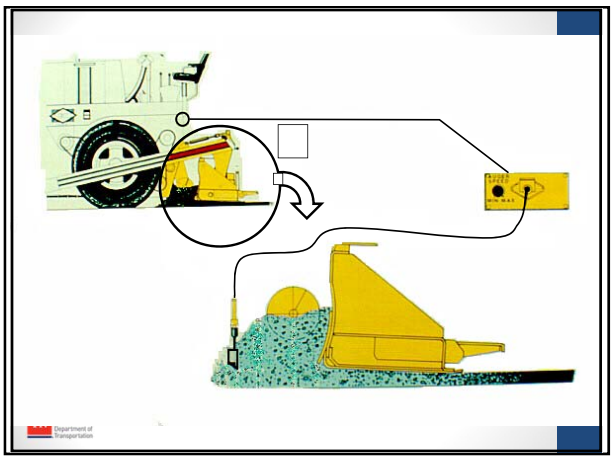
- *The paver hopper is where the mix is received from the truck or pickup machine.*
- *The hopper must be low enough to allow the truck bed to be raised.*
- *What is the actual purpose of the wings being able to fold? How often should the wings be folded? (Minimally, to reduce segregation.)*
- *The wings should be folded while the hopper is relatively full of mix.*

- *At the bottom of the hopper are slat conveyors.*
- *They transport the mix from the hopper back through the tunnel in the tractor unit to the spreading screws.*
- *The slat conveyors move independently, each of them feeding one side of the screed.*
- *Why would one conveyor need to be moving faster than the other?*
- *Above the slat conveyors at the back wall of the hopper are flow gates.*

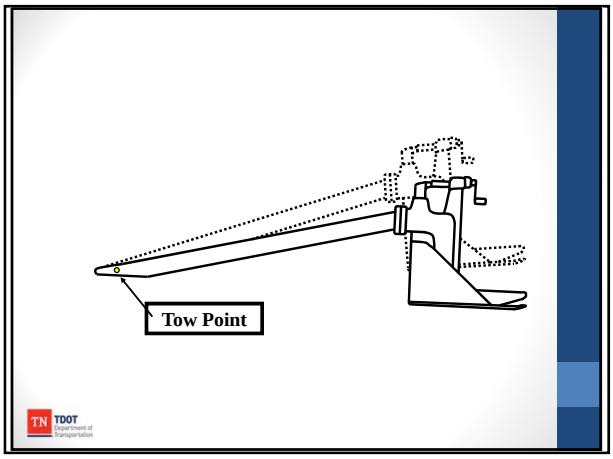
- *The augers reside directly between the tractor and screed units, in the auger chamber.*
- *This photo shows the proper head of material in the auger chamber and in front of the screed. <u>The proper head of material is at the center of the auger shaft.</u> The mix should not cover the augers, nor should the bottom of the augers be visible.*
- *It is important that the head of material is consistent across the screed, to keep forces on the screed constant.*



- *In the center of the augers is a gear box. Kick back paddles are used to "tuck" mix under the gear box.*
- *If the paddles were not there, the proper amount of mix would not get under the gear box.*
- *These are a high wear item, and must be replaced when they are worn.*
- *How could the finished the finished mat look if these paddles were either worn or missing?*



- *Many material feed systems have automatic feed control.*
- *A sensor measures the head of material and controls the slat conveyors and augers.*



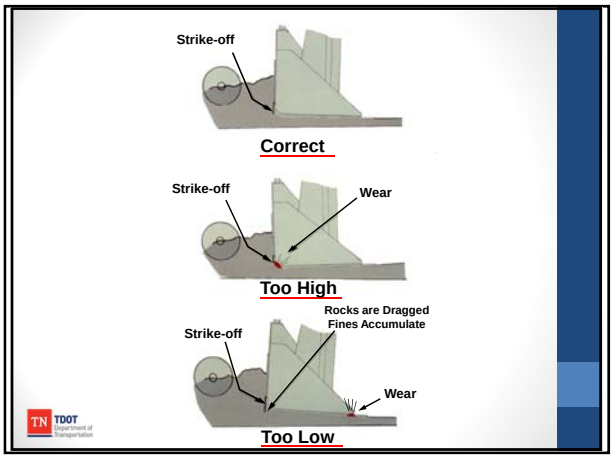
- **The last part of the tractor unit is the tow points (or pull points).**
- **The tow points are a pin connection where the screed is attached to the tractor unit.**
- **The tow point is the only place the tractor and screed units are connected together.**
- **The screed pivots around the tow point. (The forces acting on the screed and how the tow point is positioned are discussed later.)**

Screed Unit

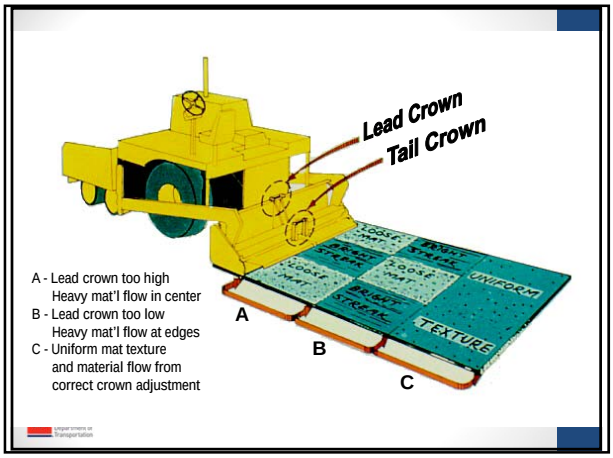
- Screed plate
- Strike-off
- Crown control
- Extensions and end plates
- Thickness Control Screws
- Screed Arm
- Pre-Compaction System
- Heating Systems

- **The second major part of the paver is the screed unit.**
- **The screed unit is towed by the tractor unit and consists of these parts.**

- *The screed unit establishes the thickness of the asphalt layer and provides the initial texture of the HMA surface.*
- *The screed also provides the initial compaction to the mat with its weight and through vibratory action or with a combination of vibration and tamping.*
- *The free floating screed was developed in the 1930s. The concept allows the screed to level out the changes in grade experienced by the wheel base of the tractor unit.*



- *Typically, a strike-off (or pre-strike-off) plate is mounted in front of the leading edge of the screed.*
- *The strike-off regulates the amount of mix fed under the screed plate. It also reduces wear to the leading edge of the screed.*
- *If the strike-off is too high, too much material is fed under the screed, causing it to rise. If the strike-off is too low, too little material goes under the screed.*



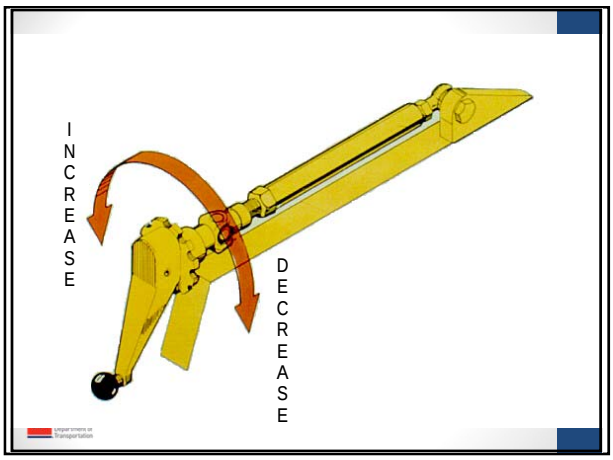
- *If the lead crown is too high, more material will be forced under the center of the screed, and the mat will be shinier there.*
- *If the tail crown is too high, more mix will be forced under the screed at the edges.*
- *A difference in texture will result from either–the loose mat texture is caused by the lower amount of material in that location.*
- *The angle of the screed is called the "angle of attack."*

- *The basic width of the screed (2.4 to 3 m) can be increased with rigid screed extensions.*
- *The extensions come in varied widths.*
- *It is important that the extensions be set at the same elevation and angle of attack as the main screed.*
- *Auger and auger tunnel extensions should be added when using rigid extensions.*
- *Not used much in road paving now — replaced by hydraulic screed extensions.*

- *The end plate is attached to the end of the screed to keep the mix contained behind the screed.*
- *While paving, the end plate is typically positioned tightly to the existing surface to retain the mix and control the width of the mat.*

- *Various shaped edge plates are also available to form longitudinal joints.*
- *The most common type is a wedge shaped joint.*
- *Many states have been conducting research in the styles and shapes of these edges to try and improve the performance of the longitudinal joints formed between paving lanes.*
- *This is a joint is called the "Safety Edge". Very safe.*

Are wedge shaped joints used locally?



- *The thickness of the mat can be controlled one of two ways: with the thickness control screws (or hydraulic lifts), or with the tow points.*
- *The thickness control screws rotate the screed about its pivot point.*
- *The rotation changes the screed's angle of attack; as the angle of attack changes, the screed rises or falls to balance the forces acting on the screed.*

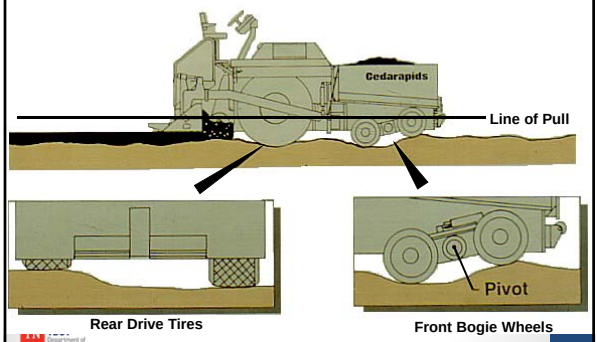
- *Screeds also contain a screed heater, to heat a cold screed to about 150 °C prior to the start of paving.*
- *A properly heated screed, particularly at the start of the day or after a prolonged shutdown, provides for a more uniform mat surface texture.*
- *Heating the screed prevents the mix from sticking to the screed plate and tearing the mat, causing a rough texture.*
- *Screed heaters cannot be used to raise the heat of the mix.*

Operational Principles of the Screed

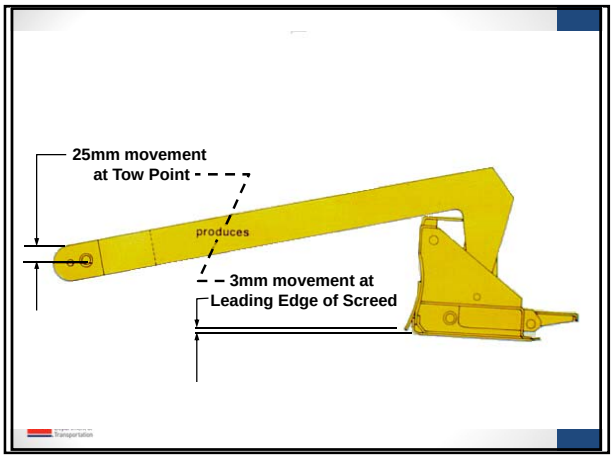
- Self-leveling Concepts
- Screed Response versus Distance
- Forces Acting on a Screed

- *The next item to discuss is the operational principles of the screed.*
- *This topic will cover...*

Self Leveling - Rubber Tired Paver



- *As the paver moves along the road, the tractor unit follows the ups and downs of the existing surface.*
- *While the tow point moves up and down, the screed reacts slowly to this up and down movement, so it moves along relatively unchanged. One further step toward producing a level surface is setting up a reference unattached to the paver.*
- *The tow point is guided by the reference, instead of the motion of the tractor unit, to keep the screed level. Use of the reference is guided by automatic grade controls.*

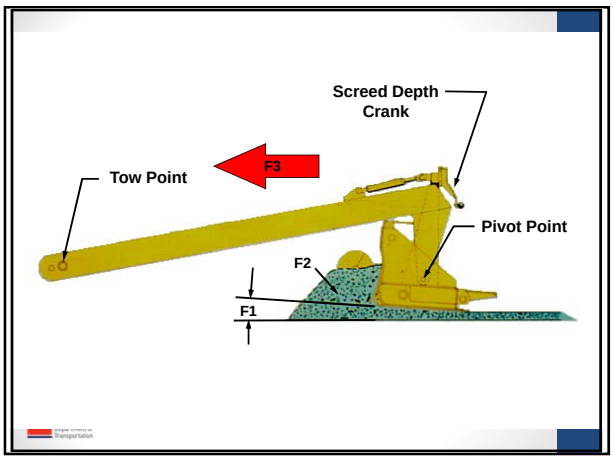


- *The change in thickness "command" can be made with the thickness control screw, or can be made by adjusting the tow point.*
- *If the tow point is moved, the paver must still move forward about five lengths of the tow arm before the screed fully reacts to the change.*
- *A 25 mm change in the tow point will produce a 3 mm change in the leading edge of the screed.*

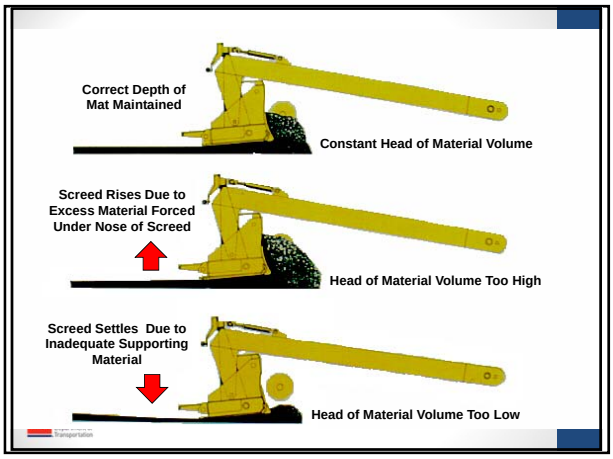
Main Forces Acting on Screed

1. Speed of Paver
2. Head of Material
3. Angle of Attack
4. Other Forces
   - Pre-compaction
   - Screed Weight

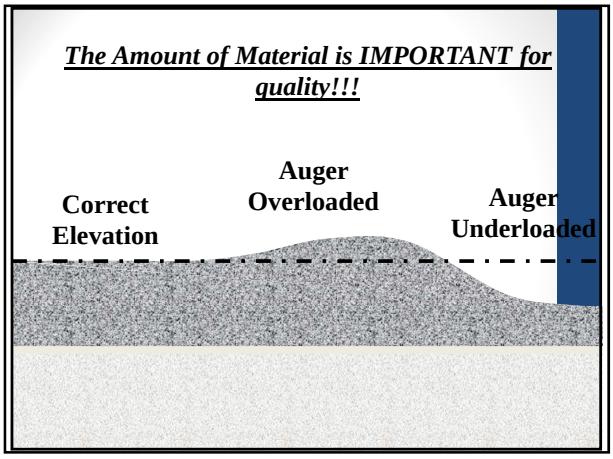
- *The self-leveling action of the screed means it will respond to the various forces acting on it to find its balance or equilibrium.*
- *The three main forces acting on the screed and how thick it places the mat are...*



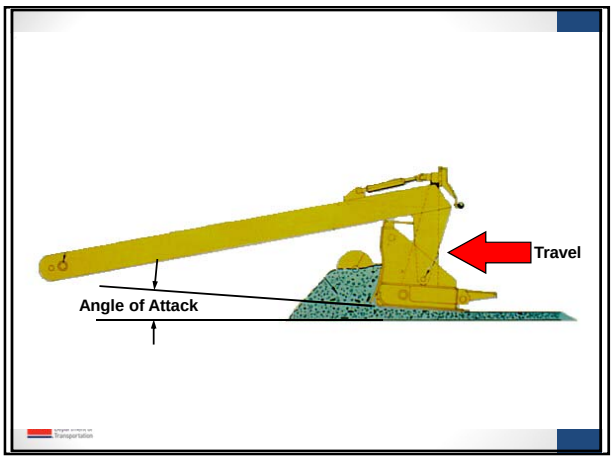
- *Ask: How does the speed of the paver affect mat thickness?*
- *If everything else is constant:*
  - *Faster = thinner mat*
  - *Slower = thicker mat*
- *If you change the speed of the paver, you will need to change the amount of mix delivered to the augers to compensate for the change.*
- *Automatic material flow control will adjust for these changes.*
- *Speeding up the paver will change the precompactive effort into the mat, requiring more compactive effort from the roller.*



- *Ask: How does the head of material affect mat thickness?*
- *As discussed earlier, the ideal head of material covers the center of the screw augers.*
- *If head of material is more than ideal, then the force on the front of the screed increases, and the screed compensates by moving upward.*
- *If head of material is less than ideal, then the force on the screed decreases, and the screed compensates by moving downward.*

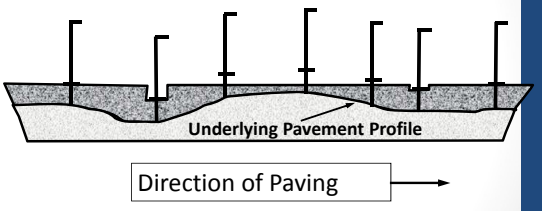


- *If the augers are underloaded, the thickness placed is too thin.*
- *If the augers are overloaded, the thickness placed is too thick.*
- *The head of material is the most important force acting on the screed. Some paving experts feel that 90 to 95 percent of paver-related problems can be solved by maintaining a uniform head of material during paving.*



- *We discussed earlier how moving the tow point or thickness control screw (and hence adjusting the angle of attack) changes the thickness.*
- *Increase the angle of attack, increase the thickness.*
- *Decrease the angle of attack, decrease the thickness.*

Checking Mat Depth/Thickness



Direction of Paving →

- *Ask: If the screed operator stuck the mat this frequently on this project, what would most likely happen?*
- *The mat thickness would be adjusted too frequently.*
- *Ask: What part of the paver is trying to adjust for the unevenness? (The tow point.)*
- *Sticking the mat can be useful during on-the-job training to show how long it takes for the screed to react.*

Grade/Slope Control Systems

- Ski Type
- Non-Contact

- *These are the two types of grade control references most often used in TN.*
- *Grade references can be used alone on either side of the paver, or on both sides.*
- *One type can be used on one side (e.g. non-contact) and one on another (e.g. ski).*
- *A joint-matching shoe may be used when placing a secondary mat.*

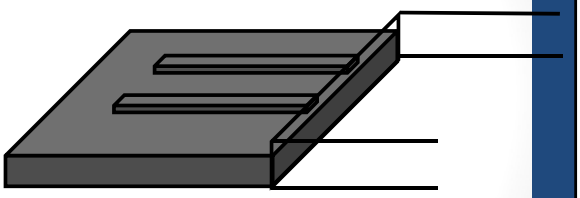
- *A mobile reference system can come in various styles, although they function in the same manner.*
- *This style is a contact ski with a wire stretched between the ends.*
- *The ski rides directly on the surface, and the grade sensor rides on the wire to detect changes in elevation.*
- *The ski is available in several lengths (up to 15 m) to increase the length of the reference.*

- *Non-contact systems use ultrasonic pulses to determine the roadway's elevation.*

Paving Process (in order)

1. Determine Projected Paver Speed
2. Warm up Machine
3. Position on Joint
4. Null the Screed
5. Input Initial Settings
6. Charge the Hopper, Tunnels, Screed
7. Pull off Joint
8. Re-checking Settings
9. Check Yield
10. Manage Truck Exchanges
11. Fold Hopper Wings

A good rule of thumb is to raise the screed 25 percent more than the compacted thickness.



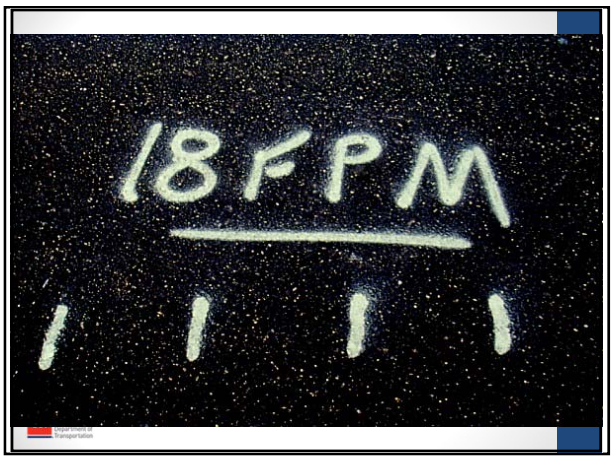
- *A good rule of thumb is to raise the screed 25 percent more than the compacted mat thickness.*
- *SMA mixes will have only about half as much "roll down" change in height between compacted and uncompacted thickness as conventional HMA.*

Re-Checking Settings

- Is thickness okay?
- Is cross slope okay?
- Is mat texture okay?

- *Once you get moving, recheck all the settings, and adjust if necessary.*
- *Mat texture with SMA and Superpave mixes will look much more open than conventional mixes. However, still look for a uniform appearance.*
- *(The next few slides provide opportunities for discussion of these points.)*

- *Cross slope (also known as "crown" or "crossfall) should be between 1.5 and 2.0 percent.*
- *Cross slope can either be checked with a level and ruler, or by using a "smart level".*
- *How is the mat texture? Some screed adjustments may be needed in this photo.*



- *Before you began paving, you calculated an ideal paver speed.*
- *This speed should be checked and maintained.*
- *Remember, balance of all the production rates is the key to quality pavement.*
- *Rates of placement for specialty mixes do not typically have to be any different than those for conventional HMA.*

Section 407.06 Bituminous Pavers

- "All paver extensions shall be full assembly extensions, including activated and heated
- screeds, auger extensions, auger guards, and throw-back blades to place mix beneath the auger gearbox."
- Extensions shall be full extension, including heated screed, augers and auger guards, MAXIMUM distance shall be 18 inches from end plate
- Screed and Strike-off shall not cause tearing, shoving, or gouging of the mixture

Section 407.09- Weather Limitations

- The surface upon which the mix is to be placed **SHALL BE FREE OF EXCESSIVE MOISTURE**
- Only when **weather conditions permit** the pavement to be properly placed, compacted, and finished and in accordance with the following temperature limitaions:

Section 407.09- Weather Limitations cont'd.

Compacted Thickness	Minimum Air or Surface Temperature	
	Unmodified Mixtures	Modified Mixtures
1.5" or less *	45°F	55°F
>1.5" **	40°F	50°F
>3.0" **	35°F	45°F

*** No mix placed between Nov 30 and April 1 without an approved Cold Weather Paving Plan.**

**** No mix placed between Dec 15 and March 16 without an approved Cold Weather Paving Plan.**

Section 407.14 -Spreading and Finishing

- Paver shall be fed from 1 plant
- Plant production and paving operations shall be coordinated such that constant forward movement
- Repetitive interruptions or stopping the paver shall be cause to STOP the work

Section 407.14 -Spreading and Finishing

- Unevenness in texture, segregation, tearing, or shoving that occurs during paving shall be reason to STOP the paving
- Unacceptable mix shall be removed and replaced at the Contractors expense

Section 407.14 -Spreading and Finishing

- Automatic screed controls using either string line, ski type grade reference, or non-contact averaging system is required
- If ski type is used, it shall be 40' minimum
- Longitudinal joint offset by 1' of preceding layers, top on Center
- Contractor SHALL be required to pave in the direction of Traffic

Section 407.18 - Surface Requirements

- The surface shall be tested with a 12 foot straightedge parallel with the centerline, maximum deviation
  - D-mix - 1/4 inch
  - B and C mixes - 3/8 inch
  - A mixes - 1/2 inch
- The transverse slope shall be checked with straightedge, shall not deviated by more than 0.5% of the plans

Spread Rate Problem

Given: The contractor has managed to put down 1.5 miles of surface mix. The gross weight for the day is 643 tons. The TDOT project plans call for a spread rate of 132.5 lbs/SY.

Spread Rate Problem

A: Assuming the paver width is 12 feet, calculate the actual spread rate of the mix.

B: According to the plans, is this rate OK?

C: If not, what should we do?

Spread Rate Problem

A: Spread Rate is Calculated in pounds per square yard. This requires us to convert tons into pounds and square feet into square yards.

$$643 tons * \frac{2000 lbs}{1 ton} = 1{,}286{,}000 lbs$$

$$1.50 miles * \frac{5280\ feet}{1 mile} = 7920\ feet$$

Spread Rate Problem

A: therefore...

$$7920\ feet * 12\ feet = 95{,}040\ ft^2 * \frac{1 yd^2}{9\ ft^2} = 10{,}560\ yd^2$$

A: and...

$$\frac{1{,}286{,}000 lbs}{10{,}560\ yd^2} = 121.8 \frac{lbs}{yd^2}$$

Spread Rate Problem

A: Assuming the paver width is 12 feet, calculate the actual spread rate of the mix.

$$121.8 \frac{lbs}{yd^2}$$

B: According to the plans, is this rate OK?

Not enough!!!

Role of the TDOT Inspector

- Circular Letter 407.14-01: “Hot Mix Asphalt Roadway Inspector Checklist”
  - Paver
- Circular Letter 407.09-01: “Cold Weather Paving Plan”

6

Joint Construction

Joint Construction

- The theme for this module is preparation, care, and teamwork.
- All pavements have one internal weakness–joints
- Joints probably cause more problems than any other area.
- The final appearance and quality of the joints determines the overall appearance and quality of the finished mat.
- Fortunately, it is easier and quicker to construct a good joint than a bad one. It just requires teamwork.
- Good joints are a measure of a construction crew's skill.
- Corps and FAA have always had joint specifications.
- Many state DOT's (including TDOT) also have joint specs.

Objectives

- Objective of Joint Construction
- Types of Transverse Joint Construction Methods
- Types of Longitudinal Joint Construction Methods
- Proper Joint Luting

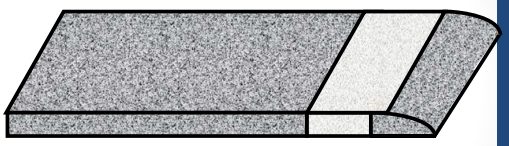
- After introducing objectives, Ask:
- What is your biggest problem with constructing joints?
- Which is easier to build, longitudinal or transverse?

- It may be beneficial to write any problems down, and address how to improve upon them at the appropriate time during the module.

- *A transverse joint must be constructed across the pavement whenever paving is being suspended*
- *This joint is being constructed at the end of the job, and must smoothly match the grade of the existing pavement.*
- *When ending paving (for the day or the job), run the paver in normal fashion right up to where the transverse joint is being constructed.*
- *While commonly done, do not run the paver dry right at the joint. Keep a full head of material in front of the screed to the end. (This practice can be seen in this photo–a smooth mat to the end.)*

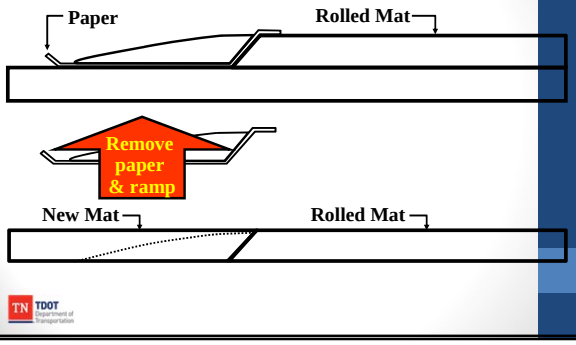
- *Tying into the existing pavement requires skill to ensure a smooth transition.*
- *There will almost always be some handwork necessary to complete the joint. Do not get carried away with overworking the mix.*
- *Notice how the paver finish comes right up to the joint.*
- *When handworking mix, "leave the mix high" to allow compaction. Handworked mix is looser than paver-laid mix. Leave about 0.2" per 1" of mix laid.*
- *Compact this immediately. Handworking (and the time to do it) results in a cooler mix.*

Butt Joint



- *Several types of temporary transverse joints are used. Terms may vary locally, and there are pros and cons to each.*
- *A butt joint can be used when traffic will not be passing over the joint. There are several ways to construct this.*
- *A joint location is selected, and the upstream side is not touched. The downstream side is raked away, and boards are laid lengthwise to allow the roller to compact the edge without rolling it over.*
- *This style places a board at the end of the mat, and then builds a small ramp for getting equipment off of the mat.*

Papered Transverse Joint



- *Paper joints are often left open to traffic. This should only be done when vehicle speeds are less than 40 mph.*
- *Paper joints may not hold up well during wet weather conditions.*

- *Instead of a board, a paper transition can be used.*
- *Again, at a point where the mat is still uniform in thickness and density, the paver is stopped and pulled away.*
- *Mix is shoveled away from the joint location, and treated paper is placed downstream of the joint.*
- *Mix is shoveled onto the paper, formed into a ramp, and then the mat and the transition are compacted.*
- *This is the most commonly seen joint in TN.*

- *Another option is to run out the paver, and feather the joint into the existing mat.*
- *The joint location will be upstream of the taper, where the mat thickness and density match the specs.*
- *When starting up again, the transition point must be found, if a butt or paper joint was not used.*
- *Use a straightedge to determine where the pavement thickness began decreasing and mark the joint location.*
- *Even if using a butt or papered joint, it must be straightedged to ensure that it was smooth up to the transition. If the mat is not level at the formed transition, the joint must be moved back*

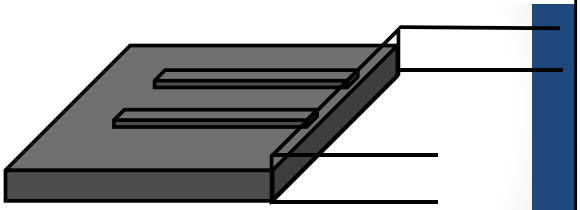
- *Once the joint location is determined, the material downstream of the joint is removed.*
- *For a papered joint, there is no bond between the paper and pavement, and the taper is easily removed.*
- *For a butt or nonformed taper joint, the mix will have bonded to the existing pavement, so a mechanical device must be used to remove the mix.*

- *This contractor is using a small milling machine to remove the taper. The milling machine could also have been used to create the vertical edge.*
- *A front-end loader can also be used to pry loose the mix.*
- *Care must be taken to create a clean, vertical transition for re-starting the paving operation.*

- *After the transition has been removed, the exposed joint area must be thoroughly cleaned, removing any mix and dust.*

- All transverse joints must be properly tack coated to ensure a good bond between the mix and the existing pavement.
- See section 407.16 in TDOT specs.

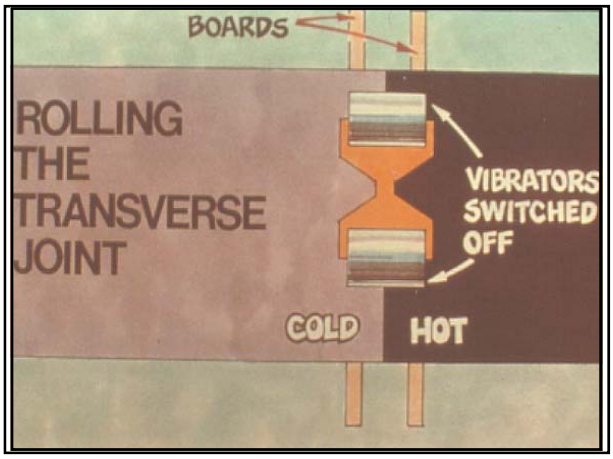
A good rule of thumb is to raise the screed 25 percent more than the compacted thickness.



- *Remember that boards must be placed on the upstream side of the joint to raise the screed to allow for mix compaction at the joint.*
- *Rolldown will typically range from 0.2”-0.3” per inch of mix placed, depending on the mix.*

- *After the screed is set on the blocks, remember all of the paver start-up procedures:*
  - *Null the screed,*
  - *induce the angle of attack,*
  - *flood the hopper with mix,*
  - *fill the auger chamber with a full head of material,*
  - *turn on any automatic material, grade, and slope sensors, and*
  - *pull off the blocks and bring the paver up to the laydown speed.*

- *If the transverse joint is constructed properly up to this point, there should be minimal luting necessary.*
- *If the paver starts out on the blocks and the screed begins with a full head of material, the thickness of the downstream mat will be correct.*
- *There is never a reason to lute a transverse joint excessively.*
- *Remove and recycle any excess coarse aggregate left from luting the joint. Shouldn’t broadcast material back onto the mat.*



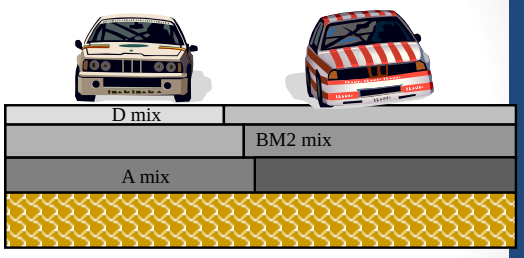
- *Ideally, a transverse joint should be compacted in the transverse direction.*
- *If traffic allows, use boards to allow the roller to make the first pass in the transverse direction.*
- *Some debate as to whether this happens or not, but it is in the HMA Handbook.*

- *Here, the joint has been pinched in the transverse direction, and the first longitudinal pass has been made.*

- *After compaction is complete and before the mix has cooled, straightedge the mat again to check the level of the joint.*
- *In colder temperatures, might consider starting with the third truck or so, so that the mix is warmer.*

- *A longitudinal joint is formed when a new mat is placed against an existing mat.*
- *The first pull of the paver almost always leaves an unsupported longitudinal edge in the mat. This joint will be a potential weakness in the finished pavement, and it must be handled carefully to minimize problems.*
- *Construction of good longitudinal joints is especially important with coarse mixes and SMA.*

Staggered Paving Joints



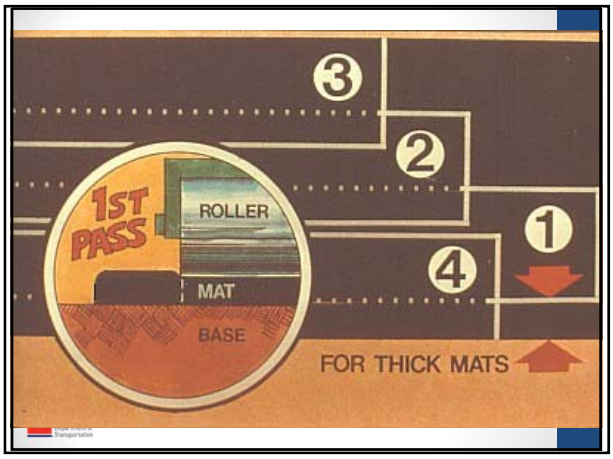
- *When building multiple layers of HMA, longitudinal joints must be staggered so a single vertical joint does not run the full depth of the pavement.*
- *Should be greater than 6 in.*
- *See TDOT Spec., 407.14, 2nd Paragraph*

- *A conventional, unconfined longitudinal joint is common.*
- *The joint is formed by mix extruded under the screed and restrained by the edge plate.*
- *The tendency is for this edge to have less density than the middle of the mat, which has adequate confinement from all directions.*
- *Construct longitudinal joints as cleanly and as straight as possible. Matching a clean, straight joint has a much higher success rate than matching a meandering joint.*
- *(Here, a longitudinal joint was eliminated at the shoulder.)*

- *States have been researching whether performance and increased safety can be derived from tapered joints.*
- *This style of taper is excellent for fine mixes.*
- *Michigan wedge—allows traffic to run on it.*
- *The problem is coming back to pave up against it.*
- *NCAT's study showed the cut joint was best, but that this is the next best. Cut joints cost more.*

- *Some feel the taper produces more surface area for bonding with the next, hot mat.*
- *Some believe this joint is less likely to crack in the future.*
- *Others believe this style of joint can be more easily passed over at highway speeds.*
- *An edge plate forms the wedge joint, and a small roller compacts the wedge.*
- *Ask: Has anyone used this joint technique? Successes? Problems?*

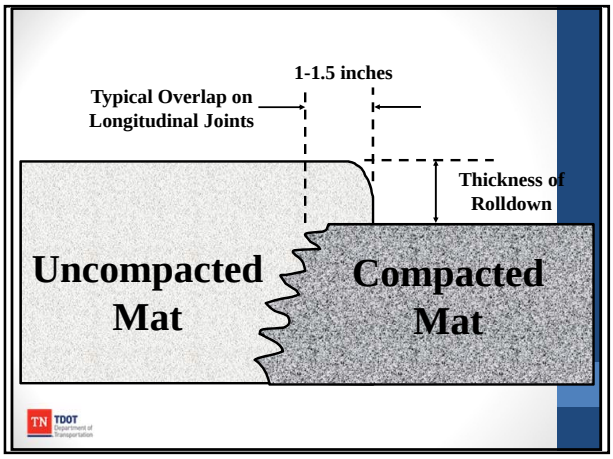
- *There are a variety of ways to compact a longitudinal joint.*
- *One way is to hang the edge of the drum 6 inches over the unsupported edge to provide some confinement.*



- On thicker lifts, another technique is to keep the first pass of the roller 12 inches inside the unconfined edge, and make the second pass over the remaining strip.
- With the roller coming back here on the fourth pass, lateral displacement is also reduced since the mix is cooler.

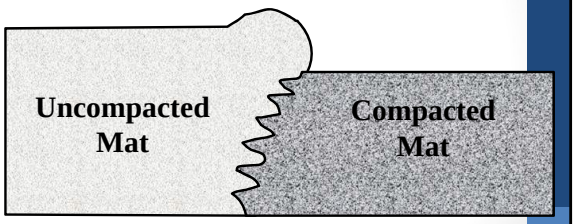
- The key to good longitudinal joint construction is the proper overlap of mix between the new and old mat.
- The proper overlap provides just enough material on top of the joint to allow proper compaction without having extra mix, which would have to be removed by a luter.
- (This photo is not a cold joint, but a hot one resulting from paving in echelon. Note: Keep personnel off the mat!)

- *Here is a picture of a local contractor paving in echelon on I-24 in Davidson County.*
- *Cores taken on the joint revealed densities of 94%*

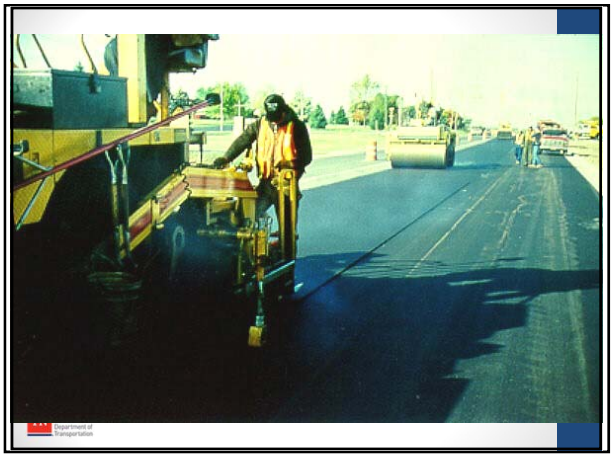


- *Provide enough overlap to provide a tight joint and allow for the steering tolerance of the paver.*
- *1-1½ inches is successful in most cases.*
- *The end gate should be in contact with the surface and leave a tight edge.*

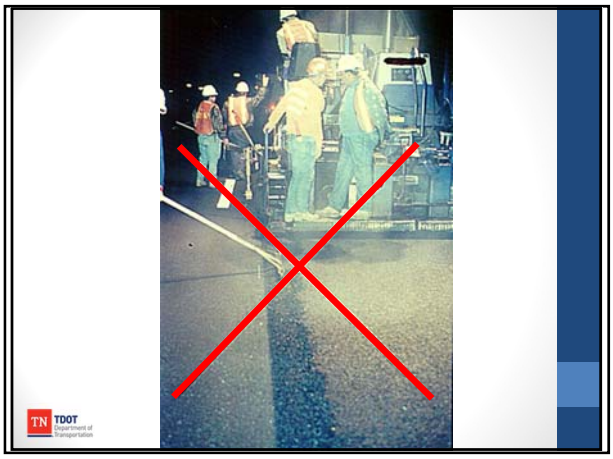
Mix "Bumped Back" to Joint



- *If the amount of material is properly placed, a simple "bump" of the mix with the lute will prepare the joint for compaction.*
- *Do not "cast" mix across the mat.*



- *Here is a crew creating a very tight joint, such that it doesn't need any luting.*



- *Unfortunately, this happens too often, and it does not have to.*
- *This luter is flattening out the joint, pushing all of the coarse aggregate away from the joint and onto the mat.*
- *This action will produce both an unsightly and poorly performing joint.*

- *It takes less effort to construct the joint properly.*
- *Pave the first lane straight, set the screed end gate properly on the second lane, and produce a clean joint.*

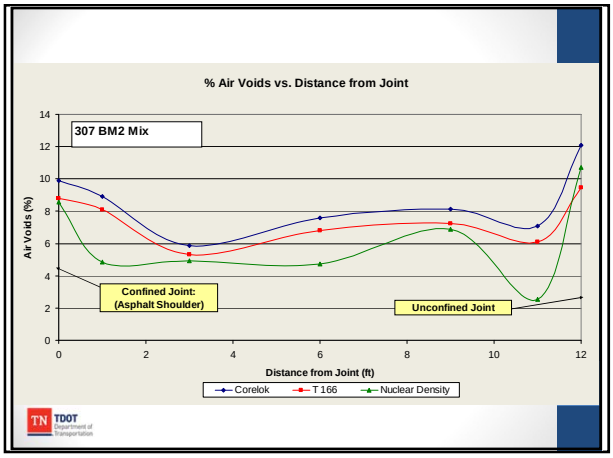
- *If the level of the second lane is at or below the first lane, proper compaction along the joint cannot be achieved.*
- *When the roller is properly placed with some of the roller on on the cold mat, the roller will bridge the joint and not fully compact the hot side.*
- *This roller is improperly positioned in that it should be rolling from the low side to the high side.*

TDOT Joint Specs 407.16

- Continuous
- Transverse Joints formed by cutting back
- Brush coat of Bituminous Material (Tack) on both Longitudinal and Transverse Joints (see supplemental spec.)

407.16-Joints. *Placing of the bituminous paving shall be as continuous as possible. Rollers shall not pass over the unprotected end of a freshly laid mixture unless authorized by the Engineer. Transverse joints shall be formed by cutting back on the previous run to expose the full depth of the course. A brush coat of bituminous material shall be used on contact surfaces of longitudinal and transverse joints just before additional mixture is placed against the previously rolled material.*

- *Here is a picture on I-24 in Rutherford County of a joint failure. What caused this?*



Role of the TDOT Inspector

- Circular Letter 407.14-01: "Hot Mix Asphalt Roadway Inspector Checklist"
  - Longitudinal Joint
  - Transverse Joint

7

HMA Compaction

HMA Compaction

- *Ask: Why do we compact?*
- *The last chance to make a job is during the compaction process, which must be closely controlled to achieve a quality pavement.*
- *Compaction determines the ultimate performance of the mix and pavement.*
- *Compaction is often very difficult to achieve in the field because of a number of variables.*
- *You must manage these variables and control them, in order to ensure that you achieve density.*
- *The key is to recognize the advantages and disadvantages of each type of roller per project.*
- *Setting up and maintaining the rolling pattern involves much effort on the part of the operator.*

Objectives

- Objective of Compaction
- Factors Affecting Compaction
- Types of Rollers
- Compaction Variables
- Roller Maintenance
- Roller Productivity
- Operating Techniques
- Roller Patterns

- *During this unit, we will look specifically at what compaction does for a mix design and for a pavement.*
- *We will look at the variables and factors that affect the compaction process.*
- *We will look specifically at the types of rollers or compaction equipment available and how to pick the best roller for the job.*
- *We will look specifically at the variables facing the compaction process and the importance of keeping rollers maintained.*
- *Slow and steady is the right way to do it!*

Why Compact?

- Improve Mechanical Stability
- Improve Resistance to Permanent Deformation
- Reduce Moisture Penetration
- Improve Fatigue Resistance
- Reduce Low-Temperature Cracking Potential
- REDUCE AIR VOIDS!

- *Compaction is the single most important factor that affects the ultimate performance of a hot-mix asphalt pavement.*
- *An asphalt mixture that has all the desirable mix design characteristics will perform poorly under traffic if that mix is not compacted to the proper density level.*

Time Available for Compaction

- *The time available for compaction is the time (in minutes) that a particular mix is at the right temperature range for efficient compaction.*
- *Ideally, there is a TAC for breakdown, intermediate, and finish rolling.*
- *Compaction must be accomplished before the mat cools to a temperature below 175-185 °F.*

Factors Affecting Compaction

- Properties of the Materials
- Environmental Variables
- Laydown Site Conditions

- Properties of the materials include the surface texture, porosity and particle shape of the aggregate and the viscosity of the liquid asphalt.
- Environmental variables are temperature, wind, and solar flux.
- Laydown site conditions include the existing road surface texture, lift thickness and profile or the sub-base stability.

Properties of the Materials

- Aggregate
- Asphalt Cement
- Mix Properties

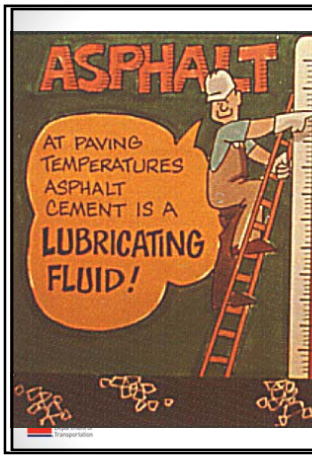
- Aggregates vary greatly across the nation from sedimentary to metamorphic and igneous.
- Aggregates may be natural deposits with little to no processing, processed aggregates such as limestone, dolomite, expanded shale, quartzite, and granite, and synthetic aggregates such as steel and blast furnace slags.
- Asphalt is graded by performance, and varies in hardness based on climate. IE PG 64-22, PG 76-22
- Mixture properties vary based on type of mixture specified.
- Type of mixture specified varies directly with traffic loading.

Non- crushed Aggregate

- *While most gravels are crushed, not all of their particles are fractured. Some may still remain round.*
- *Most natural sands, especially those dredged from a body of water are also quite round.*
- *These round aggregate particles act as ball bearings and aid in the compaction of HMA*

100 % Crushed Aggregate

- *Angular , 100% crushed particles offer more compactive resistance than rounded particles.*
- *Other factors affecting compaction may be an aggregate's surface texture, or the mix's nominal maximum aggregate size.*



- The grade and amount of asphalt cement used in the mix affects the ability to compact the mix.
- Modifying the asphalt increases the compactive effort needed to obtain density. (PG 70, 76, 82-22)
- In general, a mix with too little AC may be stiff and require an increase in compactive effort, whereas a mix with too much AC may shove under the rollers.
- As the temperature of liquid AC increases, it's viscosity *decreases*. In general, the lower the viscosity of the AC, the easier it will be to compact a mix.

Environmental Variables

- Layer thickness
- Air and base temperature
- Mix laydown temperature
- Wind velocity
- Solar flux

- *Research work and field experience show that once a pavement cools to 175 ° F, the internal friction and cohesion of the mix increases to the point that little density gain is achievable.*
- *Layer thickness, air temperature, base temperature, mix temperature, wind velocity, and solar flux have an effect on the rate of cooling a layer of asphalt placed on top of another existing layer of the same material.*

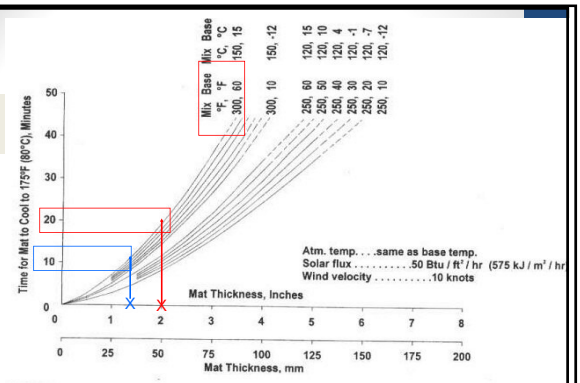
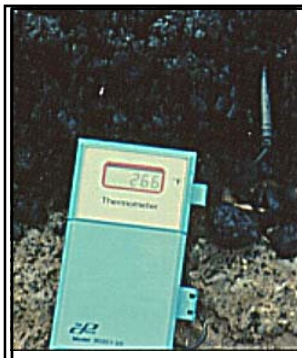


FIGURE 18-1 Time for mat to cool to 80°C (175°F) versus mat thickness for lines of constant mix and base temperatures [121°C (250°F) or 149°C (300°F) behind paver].

- *A series of "cooling curves" for asphalt mixtures illustrate the amount of time available for compaction under different combinations of the variables.*
- *The figures shown assume air temperature to be equal to the surface temperature of the base.*
- *A constant wind velocity of 10 knots and a constant degree of solar radiation is also used to generate the graphs.*
- *The curves then provide the time in minutes, for the mix to cool from the laydown temperature to a minimum compaction temperature for different compacted layer thicknesses.*

Major Factors Affecting Rolling Time	allows MORE time	allows LESS time
Mat Thickness	THICK	THIN
Mix Temperature	HIGH	LOW
Base Temperature	HIGH	LOW

- *Layer thickness is the thickness of an asphalt pavement layer, and it is the most important variable in the rate of cooling of asphalt mixtures.*
- *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.*
- *Depending on the air and base temperature as well as moisture content, the loss of temperature could be large or small.*



What about wind?

- *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 and checking of the HMA may occur.*
- *Refer to the section HMA Delivery in which thermometers were discussed.*

Types of Rollers

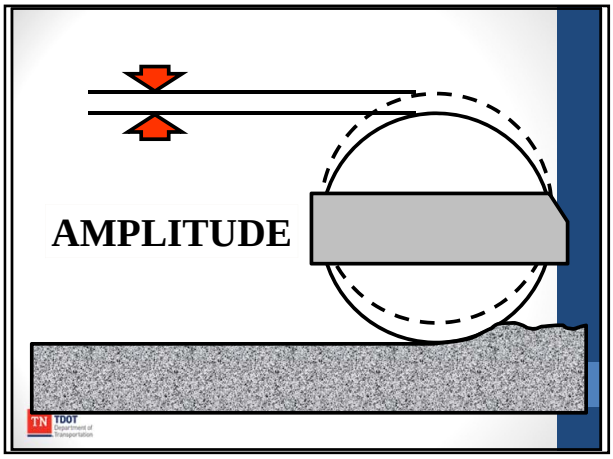
- Static Steel Wheel
- Pneumatic (Rubber Tire)
- Vibratory
- Oscillatory

- The type of equipment used to compact the asphalt mix obviously has a significant effect on the degree of density that can be obtained in a given number of passes of a particular roller.
- Three types of self-propelled compaction equipment are currently being used: static steel wheel rollers, pneumatic tire rollers, and vibratory/oscillatory rollers.

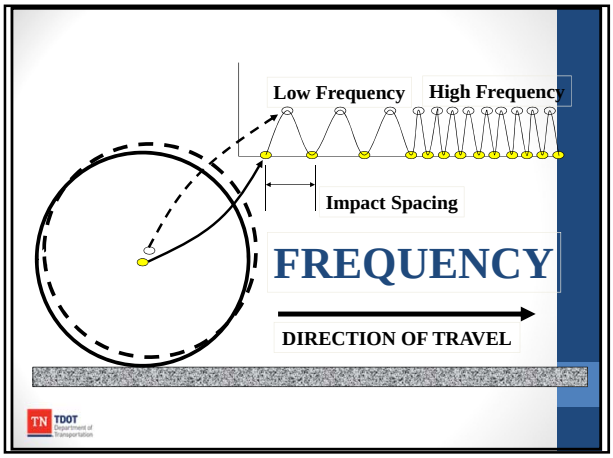
Vibratory Rollers

- Amplitude
- Frequency
- Impact Spacing

- *Vibratory rollers have two types of compactive forces that are applied to the hot-mix asphalt: static weight, caused by the weight of the rolls and frame; and dynamic (impact) force, produced by a rotating eccentric weight located inside the drum(s), which rotates about the shaft inside the drum.*
- *The operator is in control of more variables when using a vibratory roller and should be well educated in the selection and interaction of these variables.*



- *Amplitude is basically defined how hard the drum hits the mat.*
- *Normal values of nominal amplitude range from 0.01 to 0.04 inches.*
- *Some rollers can operate at only one fixed amplitude, while others have "high" and "low" amplitude positions.*
- *Typically 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 basically the number of cycles that the eccentrics rotate per minute.*
- *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 per minute.*
- *Frequencies below 2000 vibrations per minute are not normally acceptable to compact asphalt mixtures.*

- *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 and thus a greater number of impacts per meter, is usually preferred.*
- *Manufacturers recommended the following impact spacings.*
  - *The impact spacing should be in the range of 10-12 impacts per foot, or 1 to 1.25 in between impacts, to ensure the highest efficiency of the vibratory rollers and reduce the possibility of leaving ripples in the finished pavement.*
- *Proper impact spacing and amplitude are the keys to successful pavement compaction.*

Oscillatory Rollers

- *Oscillatory rollers, similar to vibratory rollers, also have 2 types of compactive forces that are applied to the hot-mix asphalt.*
- *The difference is that the directional axis of the impact force has effectively been rotated 90°; thus providing more of a side-to-side compactive effort.*
- *This is far less likely to break aggregate, while still providing dynamic compaction.*

Pneumatic Tired Rollers

- Wheel load
- Tire design
- Inflation pressure
- Contact area

- *The tire pressure used depends in part on the number of plies used in the tires.*
- *If the mix is tender, a lower tire pressure will displace the mix less than will a higher pressure in the tire.*
- *For a stiff mix, a higher tire pressure can be used, because the mix will be stable enough to support the weight of the roller without the mix shoving laterally under the tires.*
- *Tire pressure is normally kept constant for a particular project, but the level selected should be dependent on the properties of the mix being compacted and the position of the roller on the mat.*

- *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.*
- *For this type of roller, the compactive effort applied to the mix is a function of the wheel load of the machine, the tire pressure, the tire design, and the depth of penetration of the tires into the mix.*
- *All of the tires on the roller should be the same size, ply, and tire pressure.*
- *The greater the contact pressure between the tire and the mix, the greater the compactive effort applied by the roller.*

- *Damage like this needs to be avoided.*
- *Although the density of the pavement is probably being achieved, the finished surface is mottled and will most likely have surface blemishes which may hold water.*
- *The key is to get the tires hot and keep them hot by keeping the roller moving.*
- *Modified asphalt may be more of a problem…but it can be done.*

- *Get the tires hot by running the pneumatic roller on existing pavement first and then by slowly getting them hot on the new pavement.*
- *The use of 'skirts' not only helps in getting the tires hot but also ensures that they will stay hot all day by limiting the winds cooling effects.*

- *This is a typical amount of surface pickup when using the pneumatic tired roller properly.*
- *Once the size of the pneumatic roller and the pressure to be used are selected, the only variables that can be controlled easily by the operator are the rolling speed, the location of the roller with respect to the paver, and the number of roller passes over each point in the pavement surface.*

- *Many times attempts are made to eliminate the mix pickup problem by spraying water or a release agent on the tires during the rolling process.*
- *A better solution is to allow the tires on the roller to reach the same temperature as the mix being compacted without adding water or release agent to the tires.*
- *This roller was photographed on a project in East TN while compacting a mix with PG 70-22 AC.*

Static Steel Wheel Roller

- Contact Pressure
- Operation

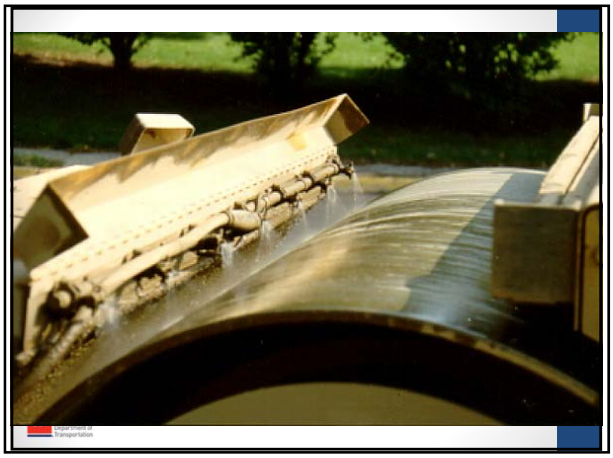
- *Mass may be increased by adding ballast to static rollers, which in turn increases the contact pressure per linear inch.*
- *Maintenance ensures not only that the equipment will work but that the finished surface will not be blemished.*
- *Poor scraper performance or an overloaded roller both cause blemishes in finished pavement surfaces.*

- *Static steel wheel rollers normally range in weight from 3 to 14 tons and have compression drums that vary in diameter from approximately 3 to 4.5 ft.*
- *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 project.*
- *Normally used as the finish roller on a paving project, removing any marks left in the mat by previous rollers.*

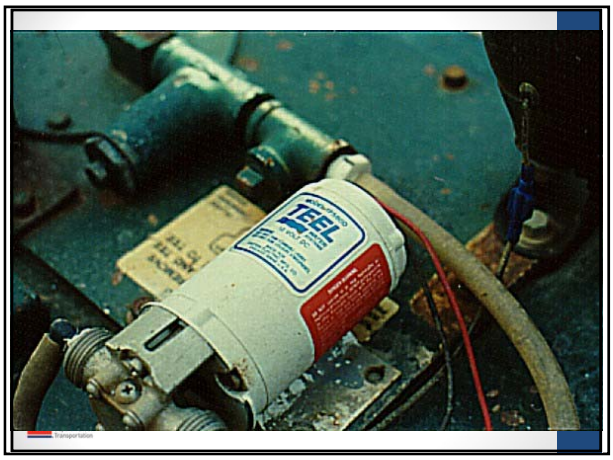
Roller Maintenance

- Water Systems
- Hydraulic Systems
- Mechanical Systems
- Rolls, Tires, Pads, Scrapers

- *The water system is designed to keep the mix from sticking to the drums or tires, and is typically the highest maintenance item on a roller.*
- *Mechanical and Hydraulic systems need to be properly maintained or the roller will become uselessly defective.*
- *Rolls, tires, and pads should be inspected for wear or damage and need to be replaced periodically.*



- *This slide shows a well maintained and operating water discharge system on a steel wheeled roller.*
- *A uniform, solid stream of water ensures uniform wetting and uniform pavement smoothness.*
- *Spray systems that clog will cause asphalt to pick up onto the steel or rubber tired rollers.*



- *Whether gravity feed or pressure feed, only enough water should be used to keep the drum wet.*
- *Any more water is wasteful and will require the roller to be out-of-service more frequently while re-watering.*
- *For pressure fed systems without a gravity flow backup, keeping an additional water pump available is a good idea.*

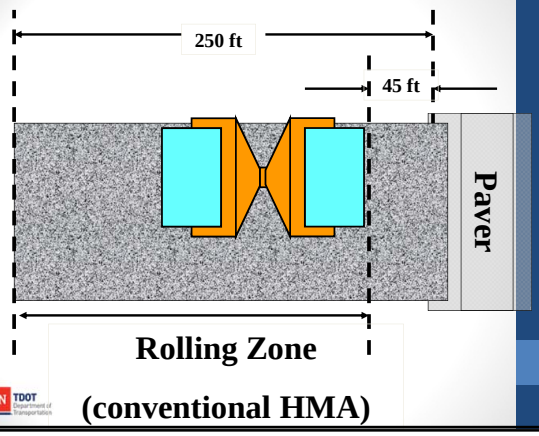
- *It is a good idea to have spare pads, especially with pneumatic rollers, because they wear down.*
- *Scrapers on rubber tired rollers are as important as those on steel rollers.*

- *Scrapers also wear down and need replacing.*
- *Scrapers should be made of softer material than the drums or tires or they may gouge the surface.*

Compaction Rate Variables

- Rolling Zone
- Roller Speed
- Number of Coverages
- Rolling Pattern

- *The primary compaction variables for all types of rollers that can be controlled during the rolling process are: (a) roller speed, (b) number of roller passes, (c) roller pattern, and (d) rolling zone.*
- *Each of these factors has an effect on the level of density achieved under the compactive effort applied to the mix.*



- *This slide shows a typical rolling zone which ranges from 45 feet behind the paver to 250 feet.*
- *The idea is that the material within 45 feet of the paver is too hot, or "tender".*
- *Once rollers get a certain distance back from the paver, the mat may be too cold for sufficient breakdown compaction.*
- *The values shown here are approximate and will change depending on variables such as air temp, AC grade, mat thickness, etc.*

Typical Range of Roller Speeds (mi/hour)

Type of Roller	*Breakdown*	*Intermediate*	*Finish*
Static Steel Wheel	**2 to 3.5**	**2.5 to 4**	**3 to 5**
Pneumatic	**2 to 3.5**	**2.5 to 4**	**4 to 7**
Vibratory	**2 to 3**	**2.5 to 3.5**	**-------**

mph	**2**	**3**	**4**	**5**	**6**	**7**
fpm	**176**	**264**	**352**	**440**	**528**	**616**

- *Compactive effort is significantly improved at slower roller speeds.*
- *If the mixture moves excessively under the drums, the speed of the rollers 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.***
- *Speeds change substantially with an increase to the thickness of loose mixture being placed.*

Test Strip Construction
(reasons for)

- Simulating Actual Conditions
- Establishing Roller Patterns
- Calculating Effective Roller Speed
- **CALIBRATING NUCLEAR GAUGES**

- *The actual rolling pattern to be used to compact the mix on a paving project should be determined at the start of the project through the construction of a roller test strip.*
- *The mix should be representative of the material to be produced for the project; generally the plant should produce mix for a short period of time before mix is made for the compaction test section.*
- *The thickness of the layer should be the same as that used for the rest of the project and **400 sq. yd.***

Establishing Roller Pattern

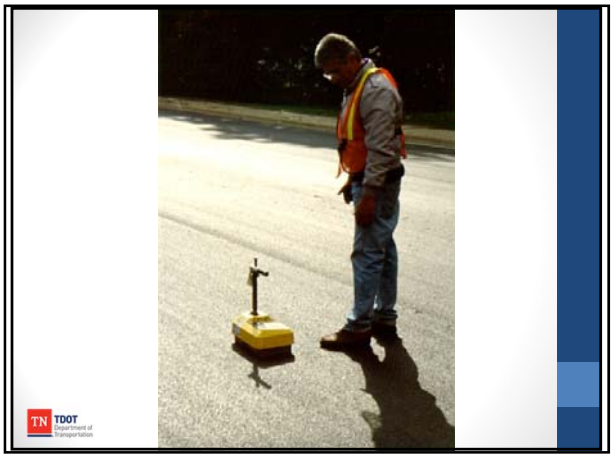
- *Different mixes may require considerably different levels of compactive effort and thus different compaction equipment and rolling procedures.*
- *An asphalt mix containing large aggregate, for example, may need different types of rollers to achieve a required level of density than an asphalt concrete mix made with smaller size coarse aggregate.*

DEFINITION: One "Pass"

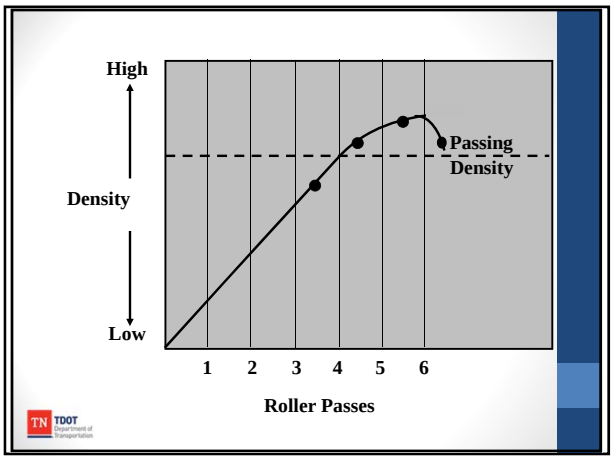
One pass occurs when a roller goes over a particular point in the mat *one* time.

- *The number of roller passes needed over each point on the pavement surface is a function of a large number of variables, the most important of which is the level of density required in the pavement layer.*
- *If a certain percentage of laboratory density or theoretical maximum density is needed, the higher the required percentage, the more compactive effort that will have to be applied to the pavement layer.*

- *Standard paving width of 10, 12, 14 and 16 feet can affect the efficiency of certain rollers.*
- *Ideally, the roller that can cover the width of paving with the fewest number of passes will be the most efficient.*
- *Other smaller width rollers are routinely used, but the number of total passes will increase.*

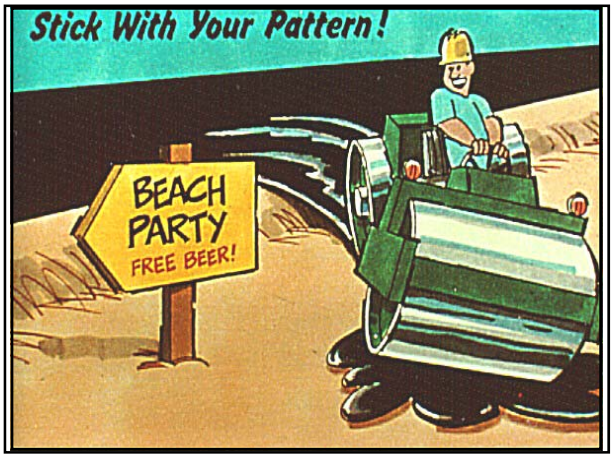


- *The most common method for monitoring changes in density with roller passes is through the use of a nuclear density gauge. The count data that are obtained can be related to the relative density of the layer.*
- *Nuclear gauge readings should be taken after each pass of each roller, and the rate of increase in density after each pass determined.*
- *When no appreciable increase in density is obtained with additional roller passes (or if the density reading actually decreases), the maximum relative density for that mix has been obtained.*



- *Nuclear gauge readings should be taken after each pass of each roller, and the rate of increase in density after each pass determined.*
- *When no appreciable increase in density is obtained with additional roller passes (or if the density reading actually decreases), the maximum relative density for that mix has been obtained.*

- *The density value determined with the nuclear gauge is relative and is generally **not** the same as the density value obtained from cores cut from the pavement.*
- *Thus a correlation must be developed between the nuclear density reading and the actual unit weight of the pavement.*
- *That unit weight must be compared to the maximum theoretical unit weight of the mix in order to calculate the actual in-place air void content of the layer.*



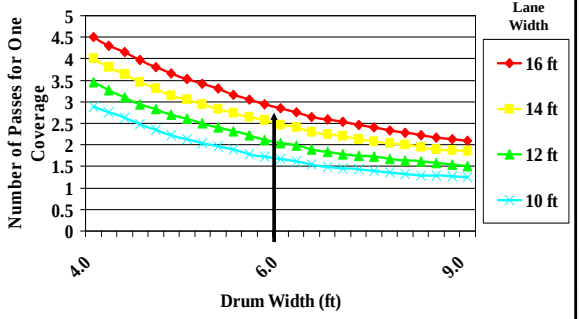
- *The roller operator is in control of more variables when using a vibratory roller and thus should be well educated in the proper selection and interaction of the variables.*
- *In addition to roller speed, location on the layer being compacted, and number of passes made, both the nominal amplitude and the frequency of the vibratory impact can be varied.*

DEFINITION: One "Coverage"

The number passes of the roller that are needed to cover the width of the mat one time.

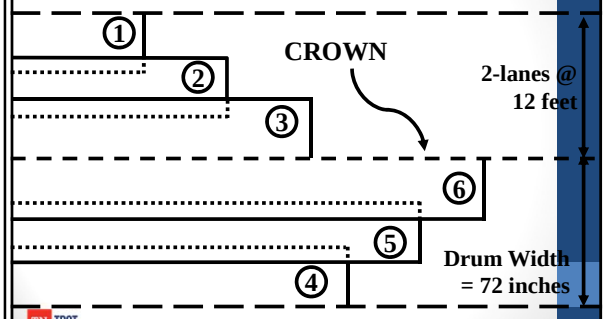
- *To obtain the target air void content and uniform density in an asphalt mixture, it is necessary to roll over each point in the pavement mat a certain number of times.*
- *The actual number of passes depends on many variables such as the type of compaction equipment used.*
- *The capabilities of each type of roller vary, however, with mat thickness, mix temperature, mix design and environmental conditions.*
- *In addition, the number of passes required depends on the position of the rollers in the roller train.*
- *A test strip aids us in this decision process.*

Drum Width vs. Lane Width



- *Graph showing number of passes for one coverage for various pavement and drum widths.*

One Roller Coverage



- *If the width of the roller drum is 78 in, only two passes of the roller are needed to cover the 12 ft wide lane, including a 6 inch overhang at each edge of pavement.*
- *A roller that is 72 inches wide cannot cover the complete 12 ft wide lane in only two passes.*
- *Three passes of the 72 inch wide roller would be necessary to properly compact the lane.*
- *If the roller had drums that were 60 inch wide, three passes of the roller would be required, similar to the roller with the 72 inch wide drums.*
- *A 55 inch drum needs four passes for one coverage.*
- *For thick lifts, first pass should be about 1 ft in from edge to prevent shoving.*

Coverage Problem

- How many passes are necessary with a 48-inch roller to complete one full coverage of a 14-foot mat? Assume we overlap 6 inches.

48 inches – 6inch overlap = 42 inches

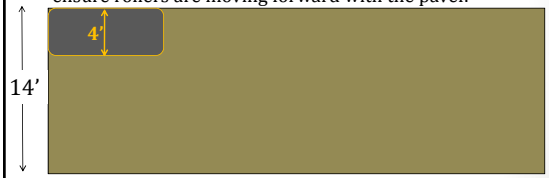
= 3.5 feet

14 feet / 3.5 feet = 4 passes

Is 4 passes satisfactory? Why not?!

Coverage Problem

An odd number of passes is necessary for one full coverage to ensure rollers are moving forward with the paver.



What am I doing back here?!

→ We will need 5 passes for one coverage.

Calculating *Your* Rolling Zone

- Effective Compaction (C-Rate) Production Rate equals 30 feet per minute.
- TAC from Environmental Variables chart equals 10 minutes for 2 inch thick mat with mix temperature of 250°F and base temperature of 50°F.
- C-Rate times TAC =

30 fpm x 10 minutes = 300 feet

- *As discussed, the rolling zone is that area of the mat which is at the right temperature range to be most efficiently compacted.*
- *This will vary by mix type and other compaction variables already discussed. In addition, each roller in the rolling train will have its own rolling zone, whether it be in the breakdown, intermediate, or finish rolling stage.*
- *A commonly accepted rolling zone is approximately 250 feet for normal paving operations.*
- *The estimated length depends on many factors and should be checked during production; it is the length where uniform density can be maintained.*

Breakdown Rolling

- Breakdown rolling is the first interaction between the roller and the HMA mat and can be a friendly or a troublesome meeting.
- Determine the rolling zone by:
  - Experience
  - Estimating

- *Most contractors use steel drums. Rollers should stop and start slowly on uncompacted mix and angle the drum when stopping to reverse.*
- *The majority of the compaction is obtained during breakdown rolling, so it is important to keep this roller moving as much as possible.*
- *When the roller does stop, it is best practice to park on a cold mat. Otherwise, you may leave marks.*

- *If you are monitoring compaction, one of the most important tools you should have at your side is a thermometer.*
- *Knowing your pavement temperature at placement and the time it takes to cool to the point where no more passes increase density is crucial especially at certain times of the year.*
- *The following section discusses a method used to determine your rolling zone through knowing temperatures.*

Intermediate Rolling

- *If adequate density cannot be achieved with the breakdown roller, an intermediate roller may be needed.*
- *Intermediate rollers can typically be operated at higher speeds than a roller in a breakdown mode.*
- *Intermediate rollers should follow a roller pattern and not concentrate on running down the middle of the mat.*
- *TDOT Spec 407.15 !!!!!*

Finish Rolling

- Finish rolling is the last step of the operation and is normally used to "iron" out any roller marks left by a breakdown or intermediate roller.
- This roller is typically a static steel wheel roller, or a vibratory roller operating in a static mode.
- Finish rolling is not the place to count on obtaining additional density.
- It is a cosmetic process.

What about thin lifts?

- *Some mixtures (Cs, TL, TLD, OGFC) are likely to be placed in thinner lifts and may have reduced need for compaction or different specs.*
- *Check TDOT specs for requirements.*
- *407.15.A*

Compacting Thin Lifts

- TDOT Spec, 407.15.A.2:

"Provide a minimum of <u>two rollers when placing 307 CS, 411TL, or 411 TLD mixtures.</u> Perform breakdown rolling, as soon as possible and while the mixture is sufficiently hot, using a pneumatic tire roller having a minimum contact pressure of 85 pounds per square inch. Do not substitute a combination roller for a pneumatic roller when placing CS mix. Regulate the paver speed so rollers can maintain proper compaction of the mixture as determined by the Engineer."

Compacting OGFC

- TDOT Spec, 407.15.A.4:

"Compaction of <u>411-OGFC mixtures shall consist of a minimum of two passes with a steel double drum asphalt roller</u> with minimum weight of 10 tons, before the material temperature has fallen below 185 °F. Provide a minimum of two roller units so as to accomplish the compaction promptly following the placement of the material. At no time shall a pneumatic tire roller be used or a steel wheel roller be used in vibratory mode. If the roller begins to break the aggregate, immediately stop rolling."

- *<u>NOTE</u> – OGFC can often be "stickier" than other mixtures. Rollers should be kept far enough away from pavers on OGFC jobs so that mixture does not stick to roller.*
- *Even if mix sticking to rollers scrapes off and rolls into mat, this is not a quality process and rollers should back off some from paver.*

Re-Watering During Paving

- *Rollers must re-water periodically during paving.*
- *It is best to re-water during a temporary lull in paving, and refill a half empty tank, than to wait until production is peaking and run out of water.*
- *If this cannot be avoided, and the mix is cooling too rapidly to wait, the intermediate or finish roller should be moved to the breakdown position until the original breakdown roller is available.*

Concluding Operations

- *Rollers are the last equipment on and off the pavement.*
- *The last section of a pavement placed must receive the same attention to detail and compactive effort as the first section.*
- *Rollers should be checked, and maintained at the end of each day.*
- *If something needs repair, repair it now.*

Opening to Traffic

- *If the mix hasn't cooled below a mix-specific temperature before opening to traffic, additional densification can occur in the mix, primarily in the wheel paths.*
- *It is possible that heavy traffic could over-densify the mix and cause rutting.*
- *Therefore, agreement should be reached in the pre-construction meeting as to the minimum temperature before the pavement is opened to traffic.*
- *Intersections, night paving, and ramps are key areas.*
- *In some areas, a water truck has been used to cool the pavement temperature.*

Role of the TDOT Inspector

- Circular Letter 407.14-01: "Hot Mix Asphalt Roadway Inspector Checklist"
  - Rollers (407.07)
  - Test Strip (407.15)

8

Density and QA/QC

Density and QA/QC

Objectives

- What is QC/QA?
- TDOT Density Specification
- Random Sampling
- TDOT Acceptance Testing
- Test Strip Constuction

What is Quality ??

- Quality means different things to different people
- Is quality measurable?
- Is quality meeting minimum specifications?
- Management philosophy – includes agency and industry personnel

What is QC/QA?

- Method Specifications
  - The DOT provides the mix design, sets up the plant, determine roller pattern and makes adjustments
- End Result Specifications
  - The DOT Specifies what the end product shall be and the Contractor is responsible for providing it

Quality Control/ Quality Assurance

- QC/QA is a System
- The primary goal of a QUALITY ASSURANCE SYSTEM is to provide CONTROL and maintain ASSURANCE. This partnering approach will help to maintain program credibility

Quality Control/ Quality Assurance

- Separates responsibility for process control and product acceptance
- Ensures that inspection plays an essential role

Quality Control

- QC is the CONTROL portion of the inspection system. QC ensures the production of uniform materials that meet required specifications through periodic inspection and testing.
- QC is the producer's/contractor's responsibility!

Quality Assurance

- QA is the ASSURANCE portion of the inspection system. QA assures the owner that the producer's test results are accurate. Random sampling and testing are at greater intervals than the producer's process.
- QA is the buyer's responsibility!

What Does TDOT Test for Acceptance?

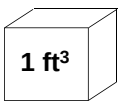
- Checklist Criteria
  - Mix Temp, Equipment Specs, Spread Rate, etc.
- Roadway Density (Compaction)
  - Standard method is by using nuclear densometer (gauge).
  - Projects incorporating SP407DEN require cores to be cut daily.

DENSITY

Density

Density is a measurement of MASS divided by VOLUME…
Or
How much something weighs, vs. how much space it takes up.

Density



1 cubic foot of water weighs 62.4 lbs. In other words…

The *density* of water is 62.4lbs/ft^3.

(or 1gram/cm^3)

Density vs Specific Gravity

- ***Specific gravity*** **is the density of a substance divided by the density of water.**
- **Since water has a density of 1 gram/cm^3, and since all of the units cancel …**
- **…the specific gravity of water is 1.**

Density vs Specific Gravity

If an aggregate has a specific gravity of 2.54…

…then we know that it's density is *2.54 times* that of water.

Density vs Specific Gravity

If an aggregate has a specific gravity of 2.54…

…then what is its density in lb/ft^3?

…g/cm^3?

HMA Specific Gravities

- Maximum (theoretical) Gravity
  - Symbolized by G_{mm}
  - Also called "Rice" Gravity
  - Found on the Job Mix Formula
  - Determined using cooled, loose mix

HMA Specific Gravities

- Bulk Gravity
  - Symbolized by G_{mb}
  - Can be determined by testing cores cut from roadway

HMA Specific Gravities

- Bulk Gravity
  - Symbolized by G_{mb}
  - …or with a corrected nuclear density gauge

NUCLEAR GAUGES

Nuclear Density Testing

- You must have attended a Radiation Safety course pric to using a Nuclear Gauge!

(click for example)

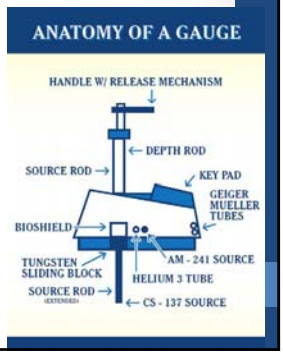
- TDOT's SOP references ASTI D2950 as the standard test method.
- SAFETY FIRST!!!!

Nuclear Density/Moisture Testing

- Never handle a nuclear gauge without wearing your own personal radiation dosimeter.
- Never leave a nuclear gauge unattended on a job site.

Nuclear Density/Moisture Testing

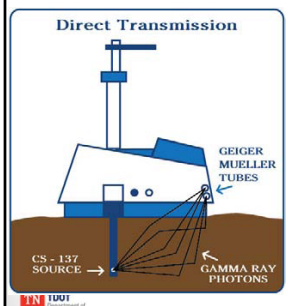
- Regardless of gauge manufacturer (Troxler, Humbolt, Instrotek, etc.), all gauges utilize the same basic components.
- All tests performed on asphalt will be using the *Backscatter* method.



Nuclear Density Testing

Standard Support Gear

How a Nuclear Density Gauge Works



When taking a test the gauge measures the amount of radiation detected over a predetermined timeframe, such as one minute. The detector tubes count the radiation that is able to pass through the material between the bottom of the source rod and the detector tubes. The denser the material, the lower the amount of radiation that is able to reach the detector tubes to be counted.

Standard Counts

- Standard counts measure the number of counts received from the density and moisture sources and provide a quick reference check to ensure that the gauge is operating correctly.
- A standard count should be taken daily and the results should be very close to previous standard counts, typically 1% for density and 2% for moisture.

Standard Counts, continued:

- If the last count has been longer than 60 days a new standard count average may need to be established. This can be done by taking three more tests and averaging these most recent results to establish a new count.
- If the gauge still does not match it's standard count values, it must ***not*** be used.
- Check the gauge manual and ASTM D2950 for additional information.

Nuclear Density Testing

Enter the pre-determined G_{mm} for the mix you will be testing. This will enable the gauge to calculate the mat density and determine the percent compaction.

Where does this information come from?

Nuclear Density/Moisture Testing

- Perform tests in accordance with the TDOT Nuclear Gauge S.O.P.
- The gauge may be rotated about the axis of the probe to obtain additional readings.
- Do not stand right next to the gauge while running a test.
- Never run a test within 30 ft of another gauge.

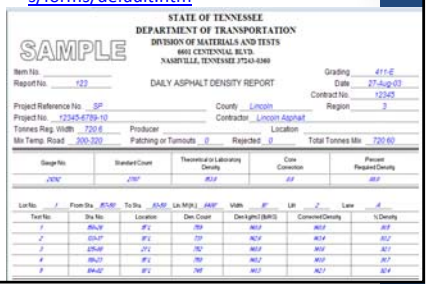
Nuclear Density Testing

- Report test results on TDOT Form no. DT-0315

How do we know if the results are acceptable?

If they're not, what should we do?

- This (and other forms) is available at: http://www.tdot.state.tn.us/materials/fieldops/forms/default.htm


STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

SAMPLE

DAILY ASPHALT DENSITY REPORT

Nuclear Gauge Contacts

Headquarters Radiation Safety Officer (RSO):
Chris Smith (615)-350-4441
(615) 476-8799 (cell)

Regional RSOs
Region 1: Scott Ault (865) 594-2300
Region 2: Dennis Beaty (423) 510-1290
Region 3: Darrell Palmore (615) 350-4316
Region 4: Marc Turner (731) 352-5327

Nuclear Density Testing

- Always return the gauge to its case after use.
- Make sure the case is secured properly before transporting to another test location.
- Do not store the gauge in your basement.

TESTING CALCULATIONS (% DENSITY)

Field Density

- By comparing the Maximum gravity to a specimen's Bulk gravity, we can determine it's level of compaction (field) density.
- The greater the field density, the fewer the air voids.
- % Density = Bulk density / Max density *100

OR

- % Density = Gmb/ Gmm *100

Field Density Example

A density test indicates a bulk density of 148 lb/ft^3. The maximum theoretical density from the job mix formula is 160 lb/ft^3.

- % Density = Bulk density / Max density*100

Field Density Example

What would we need to do if we got the bulk as a density (lb/ft^3) and the maximum as a specific gravity (i.e. 2.600)?

Density Requirements Section 407.15

Mix Type	ADT	% of Theoretical (Average)	Minimum of single test %
A, B, B-M,B-M2, C, D, E	1000 or Less	90	87
	1000- 3000	91	89
	> 3000	92	90

Density Requirements Section 407.15, con't

Mix Type	ADT	% of Theoretical (Average)	Minimum of single test %
C-W	< 1000	88	85
D, E Shoulders	Any	88	85
A-S,A-CRL, C-S	Any	None*	None*

*Compaction method must be approved

TEST STRIPS

Test Strips Section 407.15

- Required for A, B-M, B-M2, C, C-W, D, and E mixes
- Used to calibrate nuclear gauges, verify the mixture can meet the density requirements, and to establish roller patterns
- Preceding layer shall be approved prior to placing test strip

Test Strips
Section 407.15

- Rollers shall meet §407.07
- Each test section shall be 1 paver width/lane width wide and a minimum of 400 SY
  - 9’ wide= 400’ long
  - 10’ wide= 360’ long
  - 11’ wide= 330’ long
  - 12’ wide= 300’ long

Test Strips
Section 407.15

- The compaction of the test strip shall continue until there is NO appreciable increase in density, 1 LB/FT^3 (should also document the temperature of the mat)
- The roller pattern to obtain the greatest density shall be used the remainder of the project

Test Strips
Section 407.15

- The Contractor shall take 10 cores randomly on the test section pavement
- The DOT will use the cores to calibrate the gauge and assure density compliance
- If density is not obtained by core results, the contractor shall make adjustments

Test Strips
Section 407.15

- A new test strip will be required when:
  - the JMF changes
  - the material sources change
  - the material from the source changes
  - the density is not believed to be representative of the mix being placed
  - A different gauge is used
  - paving equipment changes

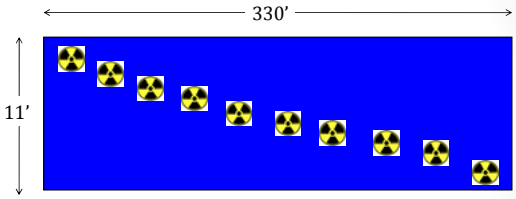
Test Strip Example

- We're setting up a test strip for some BM-2.
- Lane width is 11 feet.
- How long is our test strip?

Test Strip Example

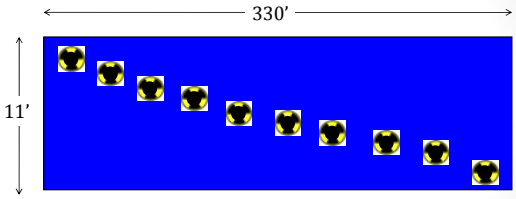
- Allow the compactors to compact the test strip until there is no appreciable increase in density. (~1 lb/ft^3)
- Now let's run 10 (12 if you're in Region 4) density tests with the nuclear gauge...

Test Strip Example



Write down the density (lb/ft^3) at every location and mark the location so we can cut cores.

Test Strip Example



Cut cores at marked locations.

Test Strip example

- Now we can run the density of the cores in the lab to find the TRUE density of what we tested.

Test Strip example

Nuclear Gauge Results:	Core Density:
• 140.5 lb/ft^3	• 142.1
• 139.7	• 142.7
• 139.3	• 142.3
• 134.3	• 139.1
• 137.8	• 141.1
• 143.1	• 141.6
• 135.4	• 140.4
• 138.1	• 141.2
• 134.1	• 137.8
• 137.6	• 140.2

Test Strip example

- The difference between these two averages,

  is our nuclear gauge correction factor.

- What this means is that any time we use THIS nuclear gauge on THIS mix on THIS project, we should add _____to our reading.
- This correction factor ONLY applies to THIS PROJECT and THIS MIX DESIGN.

ACCEPTANCE TESTING

Acceptance Testing

- Let's take a moment to discuss the difference between the testing that occurs during *test strips* and *Acceptance Testing*

Acceptance for Density Section 407.15

- The pavement will be divided into LOTs for Acceptance, and there are 5 tests per LOT, 1 per sub-lot
  - Mixtures C, C-W, D, E
    - Lot Size= 10,000 SY
  - Mixtures A, B, B-M, B-M2
    - Lot Size= 5,000 SY

Lots sizes for Density

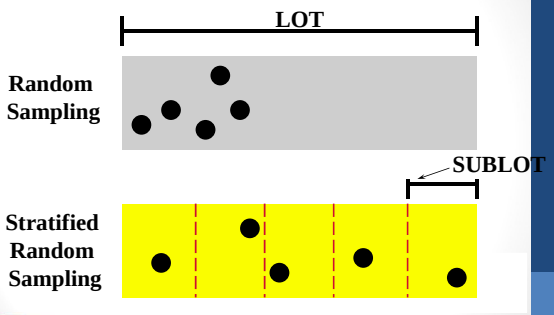
- As of mid-2015, the lot sizes for density changed from being based on square yards to being based on mix tons.
- The new lot size for density testing is **1,000 tons**

RANDOM SAMPLING AND STATIONS

TDOT SOP 1-1 on Nuclear Density Testing

- "PART TWO: ACCEPTANCE SAMPLES AND TESTS"
  - "Each lot shall be divided into 5 equal-sized sublots, and one test should be performed per each sublot. Longitudinal test locations should be determined randomly. No single transverse test location shall be duplicated within any single lot."

Lots and Sublots

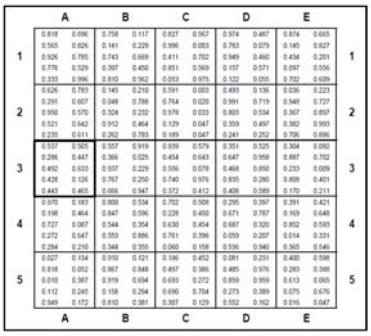


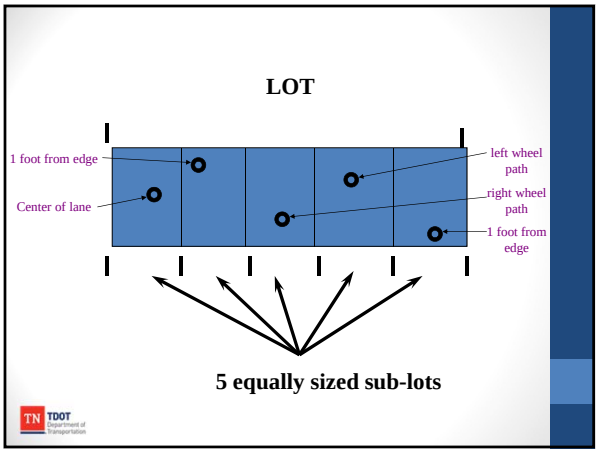
Random Number Table

.20	.68	.98	.30	.27	.84	.54	.31	.05	.88
.61	.17	.38	.62	.55	.59	.67	.73	.43	.23
.27	.38	.84	.99	.72	.51	.48	.81	.77	.76
.24	.38	.40	.34	.76	.87	.60	.75	.49	.56
.88	.52	.25	.51	.79	.41	.33	.08	.32	.47
.62	.36	.97	.61	.28	.50	.81	.29	.75	.82
.94	.83	.35	.66	.42	.70	.44	.30	.54	.45

**For additional random # tables, see SOP 1-1*

Random Number Table





Testing Locations

STATIONS

- A “station” is a unit used in roadway construction to indicate a longitudinal location along the roadway.
- One station = 100 feet
- i.e. Station 1+00 equals 100 feet

  Station 4+50.37 equals 450.37 feet

  Station 105+60.00 equals 10,560 feet

Testing Locations

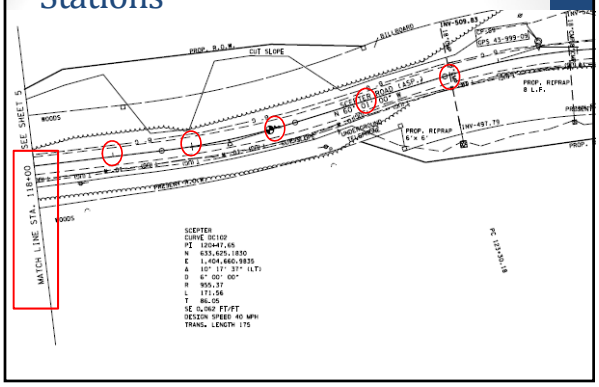
STATIONS

See a trend forming?

Station 85+20.15 = 85 20.15

= 8520.15 feet

Stations



Testing Locations

- STEP 1-
  - Determine LOT size, and with known lane width, determine LOT and sub-lot lengths
- STEP 2-
  - With known beginning station, determine beginning sub-lot stations

Testing Locations

- STEP 3-
  - Using random number table, or calculator, select 5 numbers
- STEP 4-
  - Multiply random number by Sub- Lot Length, and add to beginning Sub-lot stations to determine longitudinal testing locations

Testing Locations

- STEP 5-
  - Randomly select the transverse location for testing
    - 1 foot from left and right edge
    - center of lane
    - left and right wheel path

Determining Lot Length

- Since lots are now always 1,000 tons, determining lot lengths has changed:

LOT Size (yd^2) = 1,000 Tons x $\frac{2000\ lb}{Ton}$ x $\frac{1}{Spread\ Rate}$.

"Spread rate" is in lbs/yd^2

Lot Length (ft) = $\frac{Lot\ Size\ (yd2)\ x\ 9}{Width\ (ft)}$

Sublot Length (ft) = Lot Length (ft) / 5

Example Problem

- Situation
  - Placing B-M2 mix, lane is 12 feet wide
  - Road has 18,000 ADT
  - Spread Rate is 132.5 lb/yd^2
  - Beginning Station 100+00
  - It's Tuesday at 2:00 p.m.
  - It's 71ºF

Example Problem, con't

- STEP 1- Determine Lot Length
  - 1,000 Ton lot
  - 132.5 lb/yd2
  - 12-feet wide

LOT Size (yd^2) = 1,000 Tons x $\frac{2000\ lb}{Ton}$ x $\frac{1}{Spread\ Rate}$.

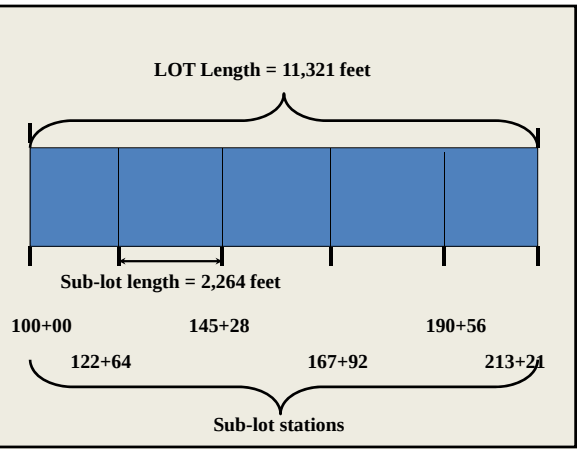
Lot Length (ft) =

Example Problem – Lot Length

- So what would the staion #'s be for the beginning of each sublot?

Example Problem, con't

- STEP 1-
  - LOT= 11,321' SUB-LOT=2,264'
- STEP 2- (Beginning Station 100+00)
  - [100+00] + 2,264



Example Problem – Lot Length

- How else could we check to make sure our lots were averaging around 1,000 tons?

Example Problem, con't

- STEP 3- Using a random number table, select 5 numbers

Random Number Table

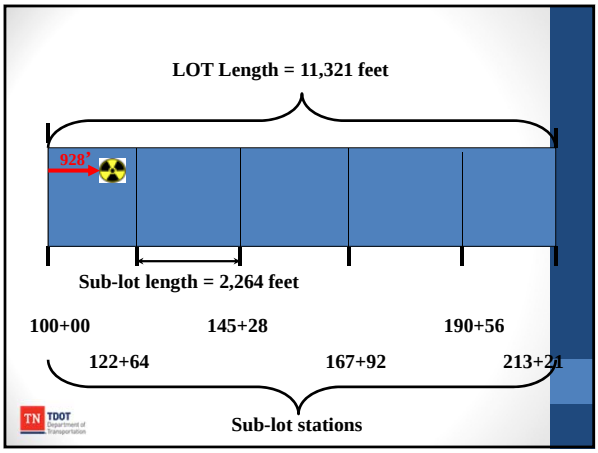
.20	.68	.98	.30	.27	.84	.54	.31	.05	.88
.61	.17	.38	.62	.72	.59	.67	.73	.77	.23
.27	.38	.84	.99	.72	.51	.48	.81	.77	.76
.27	.38	.40	.34	.76	.87	.60	.75	.49	.56
.88	.52	.25	.51	.79	.50	.33	.08	.32	.47
.62	.36	.97	.61	.28	.50	.81	.29	.75	.82
.94	.83	.35	.66	.42	.70	.44	.54	.54	.45

Example Problem, contd

- Step 4 -
- Use
  - Sub-lot Length from Step 1
  - Sub-lot Stations from Step 2
  - Random Numbers from Step 3

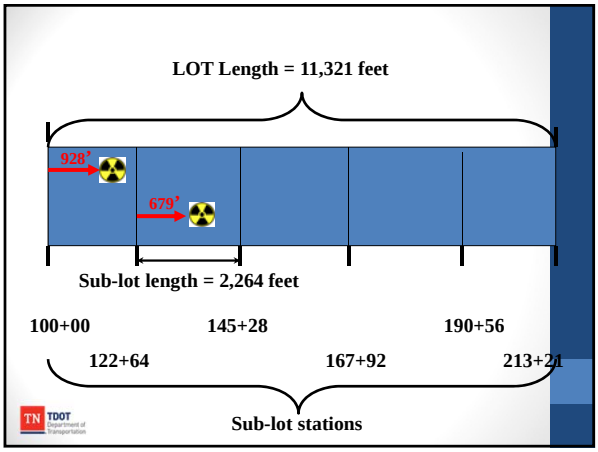
Example Problem, con't

- STEP 4 -
  - Sublot #1… 0.41 x 2,264' =



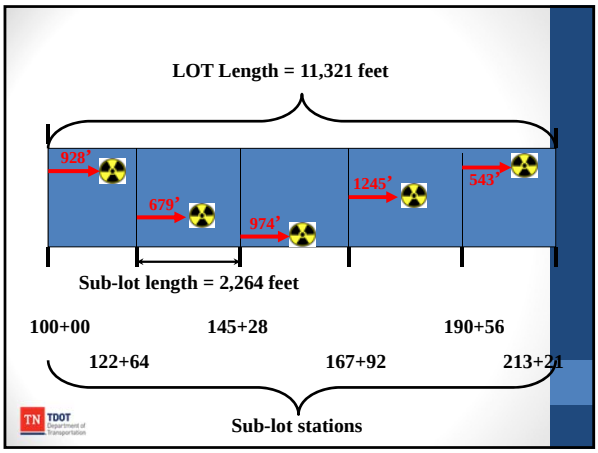
Example Problem, con't

- STEP 4 -
  - Sublot #1… 0.41 x 2,264' = 928'
  - Test 1 Station = 928' + [100+00] = 109+28
  - Sublot #2…
  - Test 2 Station =



Example Problem, con't

- STEP 4 -
  - Sublot #3…
  - Test 1 Station =
  - Sublot #4…
  - Test 2 Station =
  - Sublot #5..
  - Test 2 Station =


LOT Length = 11,321 feet
928'
679'
974'
1245'
543'
Sub-lot length = 2,264 feet
100+00
145+28
190+56
122+64
167+92
213+21
Sub-lot stations


Questions?

TDOT CIRCULAR LETTERS, SOPs, SPECIFICATIONS, & SPECIAL PROVISIONS

Standard Operating Procedures

TDOT Specifications

Supplemental Specifications as of 7-13-15

Special Provisions

Circular Letters

Best Practice Guides

TDOT Forms

June 9, 2009
June 4, 2010
November 28, 2011
February 25, 2014
REVISED: July 29, 2015

Tennessee Department of Transportation
Division of Materials and Tests

Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)

Purpose: The purpose of this document is to establish the procedures and minimum requirements for the acceptance, verification, and certification of materials and products used on Tennessee Department of Transportation (TDOT) projects and projects under the oversight of TDOT (Local Projects, Grants, etc. that include Federal Funds).

Background: Acceptance of materials, or combination of materials, may be accomplished in several different ways. Federal requirements state that each State Highway Agency shall develop a Quality Assurance Program which assures all materials, on projects in which Federal monies are used, conform to the requirements of the approved plans and specifications. In addition, these procedures assure projects using state funds will also be constructed using the highest quality materials.

Policy: All materials used on TDOT projects must be accepted prior to use. Acceptance of materials is normally by:

A. Testing during the production of a product (e.g. hot mix asphalt, portland cement concrete, base materials),

B. By manufactures certifications, followed by random verification testing (e.g. reinforcing steel, cement, liquid asphalt) (refer to SOP 1-1, Part 4 using Random Numbers for Sampling and Testing)

C. Pre-approval and testing of a product or its components prior to being used (e.g. aggregate quality, gray iron castings, reinforced concrete pipe, corrugated metal pipe)(usually TDOT stamped), or

D. From the Qualified Products List (QPL) with certifications (e.g. sign sheeting, erosion control blankets, pavement marking materials).

The procedures set forth in the TDOT Materials and Testing Standard Operating Procedures Manual (SOP), the Sampling and Testing Schedule, the Sampling and Testing Guide, the Verification procedures, and the Independent Assurance Procedures, shall be used to document the minimum requirements for product acceptance.

NOTE: For those projects constructed under the oversight of TDOT (Local Projects, Grants, etc. that include Federal Funds) any reference in SOP 1-1 Part 1 and SOP 1-1 Part 2 that refers to TDOT Personnel being the sampled by party, is replaced by the Agency's CEI or Certified sampling and testing technician.

Types of Tests:

There are three basic types of sampling and tests routinely conducted: acceptance, verification, and assurance.

Acceptance Sampling and Testing: These tests are conducted to approve or accept a product, or construction method, by generally comparing the test results to specification requirements. Most products where TDOT conducts acceptance testing are based on a lot, or frequency, during the production and/or placement of that product, to assure specification compliance. For example, hot mix asphalt is accepted by gradation, asphalt content, and in place density, etc…, portland cement concrete is accepted by temperature, air content, slump, (and strength) at the time of placement, pavement base material is accepted based on gradation and density at the time of placement, etc…. Aggregate sources, however, are accepted for quality and gradations before the aggregate can be used in a particular application. There are products that are sampled and tested, and then accepted at the manufactures facility and then delivered to TDOT projects for use. These products must have the TDOT emblem stenciled on before being incorporated for use. These products would include: pre-cast drainage structures, pipes (reinforced concrete and corrugated metal), pre-stressed beams, and gray iron castings.

Verification Sampling and Testing: These tests are conducted at a much lower frequency than acceptance tests to verify/validate that products accepted by manufactures certifications are in compliance with the applicable Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction January 1, 2015 (Standard Specifications). Verification sampling and testing are also completed to assure that contractors' quality control results are acceptable.

Independent Assurance Sampling and Testing: These are tests conducted to assure that acceptance sampling and testing procedures are done in accordance with the specified procedures and to compare testing equipment.

Quality Control of Samples: These tests are conducted by Contractors in an effort to maintain standards by testing samples against specifications.

Material Certifications:

All materials that are accepted on certification must have a DT-0044 (T-2) form, completed by the Contractor, showing contract number, project number, county, item number and quantity of material being accepted. Attach the DT-0044 (T-2) form to the manufacturer's certification and forward to the Regional Materials and Tests Supervisor. The Manufacturer's certification certifies that TDOT requirements (specifications) have been met.

In many instances, the manufacturer's certification will not be project specific, i.e. it will not have the contract or project number on the certification. When this occurs, do not write the contract or project number on the certification. Instead, require the contractor or jobber to fill out a DT-0044 (T-2) form, have it notarized, and attach manufacturer's certification. Copies of certifications (including by e-mail or fax) will be acceptable provided originals are kept on file by the contractor, supplier or manufacturer and available for inspection.

Any material that is on the Department's QPL may be accepted by a certification from the manufacturer stating that the material furnished to the project is of the same formulation

and has the same physical characteristics as the material evaluated for the QPL. The Contractor shall forward the certification and a completed DT-0044 (T-2) form to the Project Supervisor for review.

Most materials will arrive at the project site pre-tested. It is the project personnel's responsibility to provide the final inspection on all material. If for any reason the material is suspect, it should not be used until further evaluations are conducted. The Regional Materials Supervisor will be contacted to conduct these evaluations.

All manufacturers' certifications must be signed. However, for sod and nursery materials, the Tennessee Department of Agriculture will provide the certification.

Miscellaneous materials used on special projects (such as rest areas) that are overseen by an architect or consulting engineer for the Architecture Department may be accepted by a blanket certification from them stating that the materials meet specification requirements.

All transfers shall be completed by the contractor and sent to the Project Supervisors overseeing the projects the material is being transferred from and to. The project office will be responsible to verify that the quantity of material is available for transfer. The contractor will be responsible for completing the DT-0044 (T2) form and transfer request with all of the project information needed including applicable bill of lading and the material certification. At completion of the project, the Project Supervisor must submit a signed Materials and Tests Certification (Form DT-1696) to Regional Operations and the Materials and Tests Supervisors. The form shall then be forwarded to the Headquarters Materials and Tests Director.

Buy America Certifications:

All iron and steel products must meet TDOT Special Provision 106A, "Buy America," requirements as set forth in the contract.

Table of Contents:

There are five parts to these procedures, each designed to assist the project personnel to carry out their responsibilities. Each part has a specific purpose and must be checked for any material to be put in use.

Part 1- Sampling and Testing Guide

This is a field guide that lists some of the materials that are accepted on certification, by acceptance tests, or verification tests. If field personnel is unsure as to how a material is accepted, they need to contact a Materials and Tests representative for clarification. It will assist the project personnel in assuring that acceptable material is utilized on projects.

Part 2 - Acceptance Sampling and Testing Schedule

This part lists construction materials by type of construction. It identifies the tests to be run, who is to take the samples, and how frequently the samples are to be taken and their location. It also states if certification or further testing (i.e. Verification Testing) is required.

Part 3 - Verification Sampling and Testing Schedule

This part is similar to Part 2, but gives the details for Verification Test requirements. All verification samples must be submitted for testing within 2 weeks of the sample date.

Part 4 - Quality Control of Sampling and Testing Schedule

This part is also similar to Part 2, but gives the details for quality control for contractors.

Part 5 - Using Random Numbers for Sampling and Testing

This part outlines the procedures that will help you to choose random and representative test locations using random number tables.

PART TWO: ACCEPTANCE SAMPLES AND TESTS

Type of Construction	Material	Test	Sampled By	Frequency	Location or Time of Sampling	Remarks
Precast concrete noise w all panels, retaining w all panels, and precast drainage structures including pipes, headw alls, manholes, catchbasins, box culverts, and structural spans.	Finished Product	Acceptance by Certification in accordance w ith SOP 5-3 (Verification sampling required)				Each shipment must be accompanied by a completed certification form. Each item shall be inspected after delivery to the project for cracks, spalls and/or appearance by project personnel prior to incorporating product into the w ork.
Precast Concrete Abutment Blocks and Approach Slabs	Finished Product	Slump, Temperature, and Air	Materials & Tests or Contractor monitored by TDOT personnel.	Minimum 1 set of test per pour	Precast Producer Pant	
		Cylinders	Materials & Tests or Contractor monitored by TDOT personnel.	One set at beginning, and 1 set at the end of the pour	Precast Producer Pant	
Earth Retaining Structures	Backfill	Density	Project inspector	1 per every 500 tons or fraction there of.	Project site	
		Acceptance from Producer's Supplier's List (Verification Sampling Required)				Must be approved material.
	Select Granular Backfill	Quality Ph Internal angle of friction.	Materials & Tests	1 @ beginning of Project and then every 6 months	Aggregate plant	
		Density	Project inspector	1 per every 500 tons	Project site	
		Eletro-Chemical Analysis	Producer	1 per Source @ Beg of Project & every 2 years thereafter	Aggregate plant	Add'l Test required w / appearance change
		Gradation	Materials & Tests	Beginning of project	Aggregate plant or Roadw ay	
			Project Inspector	One test every 1000 tons (Min. 1 per w eek)	Aggregate plant or Roadw ay	
	Finished Product	Precast concrete Products	Acceptance in accordance w /SOP 5-1 and Special Provision 624 (Verification testing required)			
		Modular block	Acceptance in accordance w /Special Provision 624 (Verification testing required)			Verification required before use
Prime, Tack and Sealer	Emulsions	Acceptance by Certification in accordance w ith SOP 3-2 (Verification Sampling Required)				Each shipment must be accompanied by TDOT form DT-0293E materials certification report.
Prime Tack and Sealers (small Quantities)	Emulsions	Visually inspect for contamination	Project Inspector	1 per project	Project Site	Not to exceed 3 tons tack and 3 tons prime per project. Supplier to furnish certification (may be non-project specific) and delivery tickets show ing quantities.
Bituminous Plant Mix Pavements	Aggregate	Acceptance from Producer's Supplier's List (Verification Sampling Required)				Must be approved material.
		Fractured Face Count, Glassy particles by w eight	Project Inspector	Min. of 1 per project	Coarse aggregate Stockpile	Plus #4 (4.75mm) Material
	Performance-Graded Asphalt Cement	Acceptance by Certification in accordance w ith SOP 3-1 (Verification Required in accordance w ith Part Three herein)			Governed by process See SOP 3-1.	Each shipment must be accompanied by TDOT form DT-0293PG materials certification report.
	All Plant Mix Asphalt	Mix temperature	On Roadw ay by Project Insp.	Every fifth load.	From truck prior to leaving plant and on roadw ay prior to deposit into paver or transfer device.	Temperatures to be recorded on the delivery ticket. Tests at the plant by producer at the discretion of Materials & Tests Supervisor.
		Stripping-10 min. boil	Project Inspector	Once daily	Truck and Asphalt Plant	Plus #4 (4.75mm) Material on selected
	Plant Mix Asphalt Gradings A, B, BM, BM2, C, CW, D, E, and E Shoulder	Density	Project Inspector	1,000 tons	As soon as practical after compaction, w hen nuclear method is used. When used, cores w ill be obtained in accordance w ith SP407DEN.	Each lot shall be divided into 5 equal-sized sublots, and one test should be performed per each sublot. Longitudinal test locations should be determined randomly. No single transverse test location shall be duplicated w ithin any single lot.

PART TWO: ACCEPTANCE SAMPLES AND TESTS

Type of Construction	Material	Test	Sampled By	Frequency	Location or Time of Sampling	Remarks
Bituminous Plant Mix Pavements	Plant Mix Asphalt Grading B, BM, BM2, C, CW, D, E, CS, TLD, & TL	Asphalt Content AASHTO T-164, Method E-II by extraction, or AASHTO T-308 by ignition oven Aggregate Gradation AASHTO T-30	Project Inspector	1 test for every 1000 tons randomly.	Completed mix in truck or on roadway.	AASHTO T-164 Method E-II will be performed by pouring the extracted asphalt and solvent through nested No. 16 and No. 200 mesh sieves. AASHTO T 164 Method A may be used for modified asphalt or when problems are encountered filtering according to Method E-II. May not be required on production days of less than 100 tons. Ignition oven may be utilized to determine AC content and gradation.
		Air Voids & Volumetric Properties (T166, T209, T269)	Project Inspector or Materials and Tests	During Test Strip Construction or Mix Verification.	Completed mix in truck or on roadway.	Applies only to mixes requiring a design. Verification Sample required to be submitted to Regional Lab.
		LOI (Surface Mix only)	Project Inspector	One sample per day for Surface Mix only.	Completed mix in truck.	If daily sample fails, take 3 cores per lot placed that day to determine LOI. Penalty for failure to meet.
	Plant Mix Asphalt Grading A, A-S, A-CRL, & Asphalt Treated Permeable Base	Aggregate Gradation AASHTO T-27	Project Inspector	1 test for every 1000 tons randomly.	Bin sample for Batch Plant. Belt sample for Dryer-Drum Plant.	Normally, dry gradation through the No. 200 sieve for control and acceptance. AASHTO T-27 for referee tests, including AASHTO T-11. May not be required on production days of less than 100 tons. No extraction required.
Bituminous Plant Mix Pavements for Small Quantities	Bituminous Mixture	Visual Inspection	Project Inspector	Occasionally. Delivery ticket must accompany each load & contain weight of mix.	Placement site	Not to exceed 1000 tons of each type mix per project. Supplier to furnish certification showing type of mix and compliance with TDOT specifications. TDOT reserves right to perform any testing deemed necessary. Mix shall be formulated from a previously approved Job Mix Formula.
Bituminous Surface: Surface Treatment, Microsurfacing, Slurry Sealing, and related similar processes	Aggregate	Gradation & Washing	Project Inspector or Materials & Tests	One each 500 tons for each size aggregate.	At source or at project prior to incorporating into work.	Inspection required before material use.
		Fractured face count	Project Inspector or Materials & Tests	Minimum of 1 per project.	At project prior to incorporating into work.	Plus No. 4 (4.75mm) sieve material, gravel mixes only.
		Loss on Ignition (LOI)	Project Inspector or Materials & Tests	Minimum of 1 per week	From stockpiled materials. If blended aggregate, then after blending.	Accept/deduct in accordance with 411.10, pgf 6
		Glassy particles by weight	Project Inspector or Materials & Tests	Minimum of 1 per project.	At project prior to incorporating into work.	Plus No. 4 (4.75mm) sieve material, slag mixes only.
		Acceptance from Producer's Supplier's List (Verification Sampling Required)				Must be approved material.
	Emulsions	Acceptance by Certification in accordance with SOP 3-2. (Verification Sampling Required)				Each shipment must be accompanied by a notarized materials certification report. DT0293E See attached Verification/Check Samples & Tests section.
Treated Permeable Base	Asphalt Treated Permeable Base or Portland Cement Treated Permeable Base	Thickness	Contractor to obtain specimen at locations identified by Project Inspector	One core per unit or fraction of unit. A unit is equal to a paver mat width 1,000 ft in length.	Prior to being overlaid.	When thickness of core from a unit is deficient more than 1/4" and not more than 1" from Plan thickness, take 2 additional cores at intervals of not less than 300' within the unit. Use the averaged of the three cores to determine thickness.

Tennessee Department of Transportation
Division of Materials and Tests

Part Five: Using Random Numbers for Sampling and Testing
(With Examples and Random Number Tables)

Significance

The selection of test locations is critical in ensuring control of materials and construction work. If the results from the test locations conform to specified tests, the rest of the work is assumed to conform as well.

Test sites, then, are samples of construction work under your inspection. Their locations should be random and representative of the entire lot of material.

The procedures outlined below will help you to choose random and representative test locations.

Random Number Tables

Randomness in transportation construction inspection indicates unpredictability in the time or location of sampling and testing of a material or procedure in a construction phase.

Random numbers occur in no pattern or sequence. When you review a series of random numbers, you do not know what number may come next; there is no particular order in which random numbers occur.

A sample random-number table is shown below.

	A		B		C		D		E		
	0.814	0.759	0.651	0.947	0.965	0.994	0.581	0.877	0.500	0.208	
	0.105	0.015	0.323	0.630	0.223	0.616	0.070	0.469	0.672	0.931	
1	0.035	0.841	0.590	0.184	0.488	0.794	0.909	0.940	0.062	0.031	1
	0.741	0.336	0.346	0.926	0.237	0.967	0.385	0.657	0.521	0.921	
	0.278	0.697	0.423	0.365	0.010	0.210	0.264	0.745	0.378	0.337	
	0.834	0.355	0.952	0.924	0.591	0.003	0.280	0.363	0.175	0.254	
	0.204	0.159	0.006	0.006	0.764	0.020	0.768	0.209	0.959	0.147	
2	0.426	0.860	0.160	0.009	0.978	0.033	0.394	0.445	0.682	0.600	2
	0.990	0.330	0.581	0.946	0.129	0.047	0.384	0.363	0.038	0.275	
	0.837	0.658	0.140	0.344	0.189	0.047	0.675	0.923	0.101	0.122	
	0.537	0.505	0.909	0.794	0.249	0.339	0.850	0.326	0.510	0.961	
	0.286	0.447	0.286	0.975	0.458	0.484	0.992	0.078	0.947	0.756	
3	0.492	0.633	0.262	0.660	0.451	0.511	0.255	0.439	0.185	0.712	3
	0.428	0.126	0.884	0.203	0.199	0.222	0.638	0.492	0.062	0.967	
	0.443	0.927	0.626	0.542	0.746	0.683	0.822	0.242	0.481	0.077	
	0.343	0.529	0.955	0.122	0.692	0.721	0.393	0.774	0.986	0.485	
	0.070	0.948	0.408	0.338	0.921	0.355	0.252	0.916	0.255	0.456	
4	0.832	0.666	0.385	0.337	0.918	0.098	0.209	0.163	0.921	0.241	4
	0.858	0.470	0.756	0.923	0.799	0.250	0.101	0.615	0.891	0.120	
	0.153	0.773	0.722	0.819	0.626	0.393	0.340	0.202	0.120	0.793	
	0.142	0.636	0.217	0.005	0.597	0.628	0.994	0.150	0.375	0.969	
	0.882	0.905	0.272	0.637	0.201	0.768	0.002	0.568	0.176	0.702	
5	0.369	0.985	0.930	0.070	0.891	0.835	0.340	0.283	0.863	0.566	5
	0.423	0.658	0.311	0.795	0.174	0.419	0.909	0.600	0.885	0.145	
	0.461	0.878	0.363	0.644	0.890	0.278	0.219	0.312	0.585	0.923	
	A		B		C		D		E		

Lot sizes vary depending on the type of construction and the material. For example, a lot for earthwork construction is defined by the width and length of roadway, while concrete tests for bridge decks (slump, temperature, and air content) are determined by the volume of concrete delivered to the site.

Determine the lot size and the number of samples and tests required per lot from the Sampling and Testing (S&T) Guide and Schedule (SOP 1-1).

Knowing the type of construction and the material to be tested, use the S&T Schedule to determine the type of test and frequency of testing.

This SOP changes as construction materials, equipment, and practices change, so you must consult the current Part 2: Acceptance Sampling &Test Schedule.

Below are three examples using random numbers.

Example 1: Moisture and density must be measured on a lift of aggregate for subgrade preparation of a roadbed. The proposed roadway is 48-feet wide.

According to the Sampling and Testing Schedule (SOP 1-1, Part 2, shown below), five tests for moisture and density are required for every 10,000-square-yard lot of aggregate placed.

Subgrade Preparation	Soil	Proctor Density & Optimum Moisture	Materials & Tests	As required by material changes.	May be sampled before grading construction or after grading prior to sub-grade preparation.	
		Density, Moisture	Project Inspector	5 tests per10, 000 yd^2 lot for top 6 inches.	Immediately before placing pavement structure.	Average of 5 tests in lot used to determine pass-fail, with no individual test below 95% of Proctor. Average lot to be no less than 100%.

Since the project is 48 feet wide, the lot length will be, *at most*,

$$\frac{10000\ yd^2 \text{ area of aggregate } \times 9\frac{ft^2}{yd^2}}{48 \text{ feet wide}} = 1875 \text{ feet per lot}$$

We decide to use 1000 linear feet of roadway as our designated lot since this is shorter than the allowable lot length of 1875 feet.

Using the table of random numbers shown below, we randomly choose a block of numbers, say, block C2.

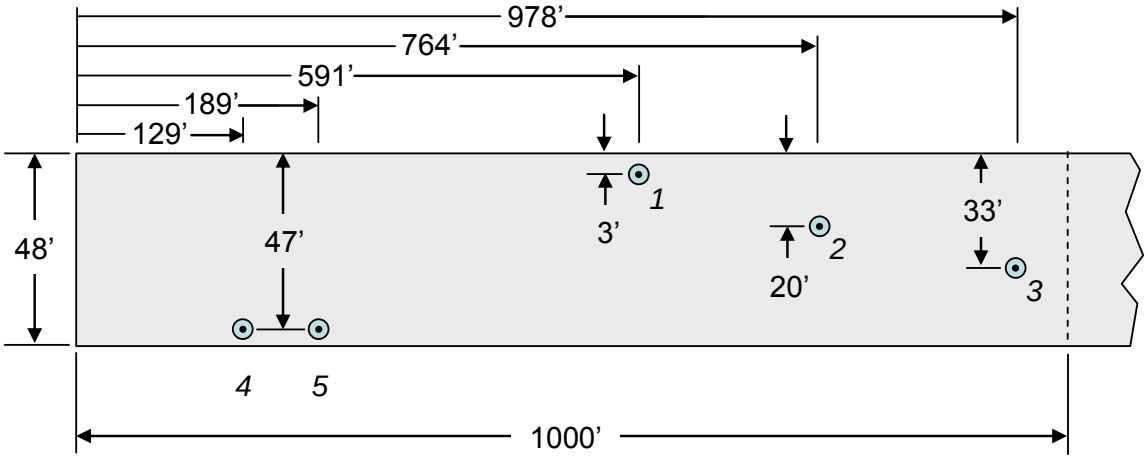
	A		B		C		D		E		
	0.271	0.584	0.674	0.883	0.379	0.976	0.555	0.083	0.967	0.812	
	0.185	0.905	0.686	0.491	0.424	0.566	0.724	0.582	0.393	0.176	
1	0.283	0.202	0.692	0.475	0.436	0.304	0.375	0.660	0.731	0.384	1
	0.567	0.800	0.642	0.205	0.827	0.129	0.598	0.216	0.124	0.787	
	0.703	0.621	0.893	0.063	0.755	0.194	0.133	0.110	0.795	0.824	
	0.103	0.338	0.620	0.594	0.591	0.069	0.639	0.203	0.313	0.733	
	0.536	0.826	0.362	0.321	0.764	0.408	0.487	0.515	0.591	0.676	
2	0.017	0.218	0.365	0.209	0.978	0.688	0.546	0.490	0.795	0.241	2
	0.840	0.594	0.341	0.006	0.129	0.986	0.350	0.437	0.927	0.782	
	0.161	0.720	0.366	0.219	0.189	0.985	0.899	0.501	0.793	0.889	
	0.251	0.496	0.741	0.314	0.014	0.839	0.124	0.209	0.292	0.099	
	0.380	0.901	0.262	0.180	0.459	0.843	0.640	0.720	0.131	0.132	
3	0.637	0.274	0.959	0.050	0.924	0.773	0.314	0.390	0.819	0.410	3
	0.310	0.324	0.111	0.760	0.706	0.165	0.930	0.515	0.639	0.116	
	0.568	0.379	0.600	0.362	0.697	0.006	0.080	0.680	0.028	0.206	
	0.378	0.392	0.910	0.202	0.512	0.156	0.336	0.465	0.813	0.471	
	0.805	0.641	0.118	0.878	0.932	0.196	0.018	0.094	0.419	0.211	
4	0.830	0.106	0.643	0.706	0.720	0.299	0.252	0.598	0.955	0.021	4
	0.367	0.538	0.050	0.448	0.896	0.669	0.968	0.984	0.890	0.117	
	0.274	0.509	0.848	0.645	0.890	0.998	0.389	0.611	0.586	0.137	
	0.566	0.802	0.283	0.151	0.399	0.316	0.559	0.684	0.318	0.516	
	0.078	0.505	0.541	0.962	0.868	0.007	0.192	0.610	0.255	0.081	
5	0.458	0.811	0.454	0.476	0.156	0.385	0.198	0.102	0.762	0.372	5
	0.486	0.345	0.786	0.759	0.465	0.222	0.487	0.355	0.935	0.223	
	0.783	0.432	0.275	0.218	0.942	0.054	0.641	0.278	0.957	0.778	
	A		B		C		D		E		

Using block C2, we have 10 random numbers that range between 0 and 1 carried to the thousandth decimal place. We will use these as multiplication factors to determine our test locations in the following table. The left-hand column of numbers in block C2 will be used to determine the longitudinal coordinates (length of the proposed roadway) by multiplying the lot length by the random number, then rounding to the nearest whole number. The right-hand column of numbers in block C2 will be used to determine the lateral coordinates (perpendicular to the proposed roadway) by multiplying the lot width by the random number, then rounding to the nearest whole number.

SAMPLE NO.	LENGTH	RANDOM NO.	LONGITUDINAL COORDINATE
1	1000	0.591	591
2	1000	0.764	764
3	1000	0.978	978
4	1000	0.129	129
5	1000	0.189	189

SAMPLE NO.	WIDTH	RANDOM NO.	LATERAL COORDINATE
1	48	0.069	3
2	48	0.408	20
3	48	0.688	33
4	48	0.986	47
5	48	0.985	47

Now, we simply match the first longitudinal coordinate with the first lateral coordinate to locate the first test location. Then, we match the remainder of the longitudinal and lateral coordinates to determine the remaining 4 test locations. The figure below shows the locations of the tests on the roadbed.



PLAN VIEW OF TEST AREA
(NOT TO SCALE)

Example 2: Nuclear gauge tests of density on 3.5 inches of Grading 307-A asphalt pavement that is 12 feet wide. The spread rate for 3.5 inches is 402.5 lbs/yd^2.

According to the Sampling and Testing Schedule (SOP 1-1, Part 2, shown below), five tests for density are required for every 1,000 ton lot of asphalt placed.

Bituminous Plant Mix Pavements	Plant Mix Asphalt Gradings A, B, BM, BM2, C, CW, D, E, and E Shoulder	Density	Project Inspector	1,000 tons	As soon as practical after compaction, when nuclear method is used. When used, cores will be obtained in accordance with SP407DEN.	Each lot shall be divided into 5 equal-sized sublots, and one test should be performed per each sublot. Longitudinal test locations should be determined randomly. No single transverse test location shall be duplicated within any single lot.

Since the lot size is 1,000 tons, the maximum lot size will be,

$$\frac{1{,}000\ \text{tons} \times 2{,}000\ \frac{\text{lb}}{\text{ton}}}{402.5\ \frac{\text{lb}}{\text{yd}^2}} = 4{,}969\ \text{square yards}$$

Converting this into square feet,

$$4{,}969\ \text{yd}^2 \times 9\ \frac{\text{ft}^2}{\text{yd}^2} = 44{,}721\ \text{ft}^2$$

Since the project is 12 feet wide, the maximum lot will be,

$$44{,}721\ \text{ft}^2 \div 12\ \text{ft wide} = 3{,}726.8\ \text{ft}$$

Dividing this lot into five equal sub-lots, $3727\ \text{ft} \div 5 = 745\ \text{feet per sub-lot}$

LOT SIZE (yd^2)		LANE WIDTH (ft)			
		10	11	12	13
5,000	LOT LENGTH	4500	4091	3750	3462
	SUB-LOT LENGTH	900	818	750	692
10,000	LOT LENGTH	9000	8182	7500	6923
	SUB-LOT LENGTH	1800	1636	1500	1385

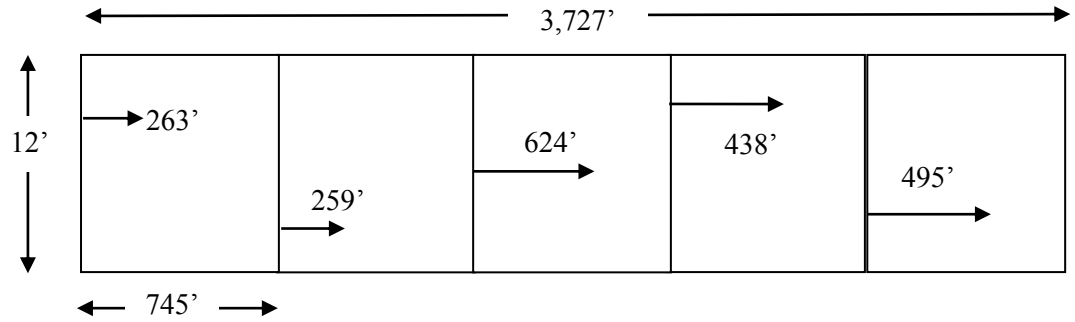
Using the table of random numbers shown below, we randomly choose a block of numbers, say, block D5.

	A		B		C		D		E		
	0.781	0.437	0.811	0.662	0.105	0.135	0.509	0.792	0.137	0.779	
	0.311	0.114	0.878	0.378	0.984	0.741	0.177	0.558	0.725	0.807	
1	0.746	0.926	0.294	0.674	0.952	0.597	0.559	0.685	0.891	0.909	1
	0.381	0.729	0.057	0.378	0.166	0.332	0.807	0.034	0.628	0.090	
	0.954	0.130	0.447	0.548	0.199	0.658	0.897	0.349	0.396	0.742	
	0.265	0.732	0.808	0.566	0.484	0.163	0.114	0.631	0.992	0.934	
	0.769	0.313	0.280	0.451	0.035	0.787	0.223	0.994	0.111	0.777	
2	0.729	0.963	0.946	0.178	0.198	0.252	0.085	0.630	0.677	0.055	2
	0.140	0.111	0.712	0.641	0.576	0.558	0.407	0.384	0.653	0.181	
	0.923	0.316	0.508	0.284	0.406	0.228	0.920	0.875	0.403	0.503	
	0.602	0.516	0.251	0.954	0.268	0.197	0.809	0.004	0.769	0.678	
	0.138	0.246	0.819	0.198	0.418	0.126	0.835	0.187	0.680	0.855	
3	0.178	0.399	0.550	0.565	0.071	0.916	0.560	0.219	0.537	0.856	3
	0.613	0.157	0.218	0.001	0.535	0.576	0.146	0.010	0.215	0.190	
	0.097	0.155	0.388	0.403	0.252	0.987	0.775	0.596	0.365	0.231	
	0.373	0.974	0.929	0.104	0.447	0.449	0.447	0.147	0.424	0.195	
	0.880	0.803	0.036	0.846	0.058	0.834	0.010	0.314	0.011	0.621	
4	0.749	0.231	0.217	0.206	0.869	0.810	0.804	0.426	0.157	0.881	4
	0.020	0.048	0.404	0.368	0.917	0.374	0.444	0.214	0.432	0.827	
	0.052	0.601	0.318	0.016	0.766	0.513	0.623	0.065	0.409	0.816	
	0.777	0.941	0.140	0.401	0.171	0.139	0.353	0.481	0.209	0.735	
	0.406	0.017	0.252	0.730	0.476	0.188	0.347	0.656	0.945	0.149	
5	0.044	0.413	0.782	0.032	0.459	0.856	0.838	0.594	0.322	0.654	5
	0.980	0.185	0.574	0.166	0.025	0.962	0.588	0.134	0.198	0.704	
	0.237	0.162	0.155	0.373	0.673	0.104	0.665	0.070	0.849	0.957	
	A		B		C		D		E		

Using block D5, we have 10 random numbers that range between 0 and 1 carried to the thousandth decimal place. We will use the multiplication factors in the left-hand column to determine our longitudinal test locations. Transverse locations are determined randomly with one test 12" off each edge, one test in each wheelpath, and one test in the center of the lane.

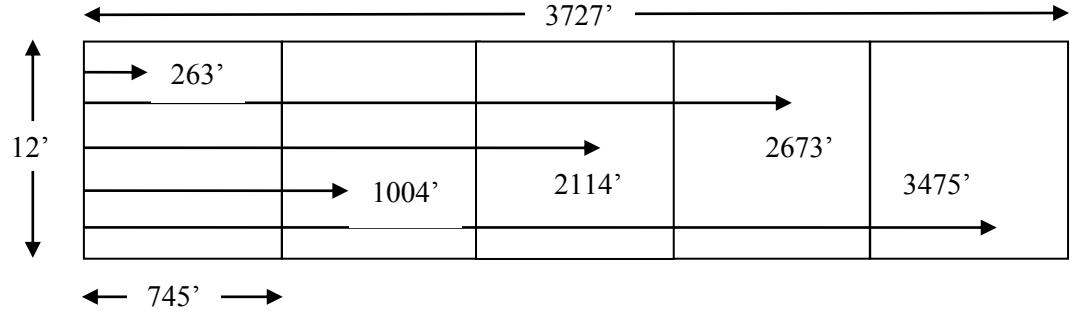
The distances into each sublot,

$$745\,\text{ft} * 0.353 = 263\,\text{ft}$$
$$745\,\text{ft} * 0.347 = 259\,\text{ft}$$
$$745\,\text{ft} * 0.588 = 438\,\text{ft}$$
$$745\,\text{ft} * 0.838 = 624\,\text{ft}$$
$$745\,\text{ft} * 0.665 = 495\,\text{ft}$$



If we wanted to know the total distance into the 3750’ lot for each test:

$$\text{Test } 1 = 263 \text{ ft}$$
$$\text{Test } 2 = 745 \text{ ft} + 259 \text{ ft} = 1004 \text{ ft}$$
$$\text{Test } 3 = 745 \text{ ft} + 745 \text{ ft} + 624 \text{ ft} = 2114 \text{ ft}$$
$$\text{Test } 4 = 745 \text{ ft} + 745 \text{ ft} + 745 \text{ ft} + 438 \text{ ft} = 2673 \text{ ft}$$
$$\text{Test } 5 = 745 \text{ ft} + 745 \text{ ft} + 745 \text{ ft} + 745 \text{ ft} + 495 \text{ ft} = 3475 \text{ ft}$$



	A		B		C		D		E		
	0.678	0.694	0.141	0.441	0.836	0.182	0.274	0.829	0.365	0.881	
	0.023	0.158	0.948	0.763	0.555	0.741	0.157	0.869	0.811	0.789	
1	0.504	0.635	0.730	0.899	0.719	0.357	0.284	0.140	0.644	0.082	**1**
	0.704	0.941	0.361	0.863	0.882	0.404	0.704	0.933	0.667	0.571	
	0.830	0.617	0.154	0.081	0.109	0.741	0.503	0.974	0.301	0.911	
	0.247	0.737	0.402	0.169	0.871	0.830	0.069	0.276	0.998	0.499	
	0.710	0.346	0.012	0.836	0.233	0.885	0.077	0.341	0.607	0.719	
2	0.205	0.290	0.040	0.804	0.638	0.987	0.353	0.539	0.208	0.676	**2**
	0.980	0.629	0.424	0.081	0.002	0.761	0.185	0.940	0.997	0.568	
	0.360	0.766	0.117	0.032	0.588	0.049	0.407	0.388	0.535	0.464	
	0.120	0.852	0.163	0.852	0.201	0.487	0.713	0.696	0.914	0.080	
	0.413	0.327	0.839	0.949	0.724	0.728	0.508	0.471	0.327	0.850	
3	0.955	0.924	0.285	0.028	0.299	0.064	0.953	0.791	0.437	0.745	**3**
	0.131	0.616	0.223	0.213	0.027	0.024	0.484	0.030	0.533	0.552	
	0.037	0.500	0.803	0.546	0.093	0.401	0.750	0.189	0.417	0.078	
	0.096	0.483	0.713	0.576	0.935	0.281	0.506	0.994	0.014	0.491	
	0.818	0.855	0.950	0.195	0.142	0.392	0.380	0.786	0.063	0.423	
4	0.689	0.685	0.742	0.863	0.906	0.966	0.617	0.375	0.908	0.685	**4**
	0.443	0.857	0.239	0.770	0.181	0.241	0.982	0.373	0.150	0.316	
	0.020	0.898	0.158	0.365	0.497	0.139	0.864	0.937	0.392	0.026	
	0.245	0.510	0.670	0.082	0.483	0.403	0.524	0.338	0.387	0.406	
	0.658	0.596	0.690	0.737	0.899	0.567	0.655	0.231	0.508	0.374	
5	0.107	0.682	0.077	0.763	0.593	0.877	0.094	0.929	0.268	0.973	**5**
	0.057	0.478	0.230	0.623	0.339	0.942	0.239	0.839	0.074	0.854	
	0.312	0.193	0.428	0.947	0.185	0.197	0.642	0.537	0.590	0.876	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.439	0.107	0.450	0.340	0.181	0.794	0.186	0.814	0.350	0.112	
	0.460	0.661	0.706	0.123	0.648	0.988	0.750	0.968	0.955	0.196	
1	0.631	0.799	0.355	0.746	0.842	0.268	0.445	0.942	0.430	0.324	**1**
	0.398	0.177	0.993	0.666	0.377	0.609	0.533	0.840	0.271	0.270	
	0.258	0.732	0.905	0.314	0.200	0.640	0.736	0.970	0.804	0.352	
	0.099	0.586	0.938	0.597	0.883	0.855	0.489	0.003	0.290	0.397	
	0.024	0.789	0.120	0.111	0.274	0.627	0.731	0.654	0.482	0.637	
2	0.536	0.280	0.146	0.968	0.044	0.326	0.097	0.326	0.228	0.370	**2**
	0.087	0.955	0.770	0.328	0.492	0.940	0.554	0.913	0.888	0.758	
	0.192	0.771	0.968	0.688	0.247	0.770	0.194	0.621	0.847	0.848	
	0.183	0.040	0.020	0.172	0.625	0.262	0.170	0.501	0.930	0.626	
	0.605	0.948	0.688	0.893	0.686	0.840	0.799	0.047	0.936	0.752	
3	0.924	0.795	0.113	0.148	0.316	0.956	0.536	0.701	0.440	0.702	**3**
	0.569	0.213	0.626	0.960	0.240	0.823	0.196	0.335	0.663	0.630	
	0.799	0.128	0.560	0.843	0.951	0.600	0.609	0.256	0.292	0.681	
	0.597	0.815	0.412	0.439	0.189	0.094	0.782	0.515	0.809	0.303	
	0.014	0.033	0.240	0.170	0.824	0.248	0.118	0.570	0.344	0.203	
4	0.916	0.958	0.802	0.089	0.958	0.677	0.515	0.843	0.127	0.868	**4**
	0.989	0.291	0.184	0.927	0.089	0.780	0.214	0.277	0.105	0.138	
	0.545	0.849	0.884	0.192	0.617	0.416	0.763	0.558	0.027	0.098	
	0.227	0.322	0.069	0.477	0.984	0.112	0.207	0.110	0.196	0.615	
	0.342	0.472	0.531	0.716	0.337	0.880	0.593	0.881	0.195	0.188	
5	0.059	0.058	0.688	0.504	0.418	0.197	0.894	0.298	0.843	0.959	**5**
	0.056	0.926	0.214	0.016	0.050	0.692	0.256	0.966	1.000	0.084	
	0.033	0.489	0.768	0.354	0.855	0.839	0.670	0.853	0.934	0.012	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.001	0.411	0.562	0.371	0.511	0.010	0.189	0.340	0.529	0.991	
	0.095	0.690	0.070	0.561	0.412	0.123	0.060	0.580	0.614	0.151	
1	0.742	0.355	0.526	0.217	0.848	0.774	0.923	0.542	0.653	0.385	**1**
	0.914	0.676	0.912	0.868	0.085	0.281	0.924	0.704	0.371	0.600	
	0.257	0.536	0.951	0.713	0.939	0.987	0.637	0.536	0.129	0.917	
	0.586	0.163	0.710	0.254	0.744	0.846	0.979	0.344	0.333	0.481	
	0.271	0.577	0.487	0.484	0.408	0.704	0.901	0.347	0.850	0.286	
2	0.480	0.538	0.017	0.074	0.427	0.225	0.452	0.049	0.233	0.846	**2**
	0.967	0.187	0.657	0.775	0.251	0.877	0.169	0.977	0.879	0.635	
	0.471	0.416	0.107	0.334	0.565	0.735	0.549	0.763	0.850	0.113	
	0.398	0.095	0.496	0.726	0.650	0.498	0.266	0.727	0.355	0.209	
	0.265	0.801	0.509	0.718	0.181	0.286	0.928	0.200	0.588	0.881	
3	0.937	0.348	0.446	0.688	0.955	0.834	0.796	0.045	0.292	0.019	**3**
	0.999	0.804	0.217	0.945	0.601	0.122	0.897	0.535	0.170	0.606	
	0.871	0.270	0.269	0.056	0.555	0.907	0.732	0.709	0.224	0.424	
	0.550	0.650	0.779	0.280	0.914	0.303	0.377	0.896	0.428	0.791	
	0.262	0.325	0.785	0.248	0.748	0.291	0.552	0.560	0.806	0.450	
4	0.194	0.754	0.700	0.244	0.521	0.673	0.196	0.495	0.227	0.995	**4**
	0.484	0.315	0.295	0.267	0.637	0.202	0.082	0.750	0.626	0.107	
	0.925	0.002	0.940	0.406	0.756	0.942	0.745	0.665	0.398	0.519	
	0.769	0.126	0.227	0.521	0.395	0.853	0.606	0.467	0.716	0.376	
	0.786	0.339	0.246	0.850	0.310	0.413	0.966	0.387	0.222	0.035	
5	0.121	0.278	0.807	0.006	0.872	0.081	0.317	0.163	0.942	0.763	**5**
	0.794	0.721	0.766	0.883	0.285	0.936	0.363	0.154	0.021	0.304	
	0.138	0.381	0.875	0.566	0.802	0.077	0.888	0.634	0.880	0.916	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.213	0.416	0.998	0.713	0.003	0.826	0.353	0.763	0.835	0.398	
	0.761	0.812	0.959	0.598	0.771	0.105	0.414	0.251	0.305	0.385	
1	0.071	0.848	0.185	0.978	0.881	0.329	0.822	0.690	0.779	0.126	**1**
	0.745	0.888	0.662	0.041	0.589	0.145	0.125	0.617	0.474	0.200	
	0.619	0.972	0.230	0.780	0.224	0.463	0.846	0.098	0.541	0.002	
	0.770	0.801	0.055	0.852	0.289	0.381	0.023	0.911	0.736	0.387	
	0.794	0.193	0.499	0.827	0.235	0.046	0.168	0.789	0.543	0.594	
2	0.768	0.053	0.915	0.063	0.541	0.687	0.848	0.742	0.891	0.091	**2**
	0.752	0.363	0.172	0.583	0.183	0.234	0.105	0.650	0.456	0.330	
	0.746	0.920	0.088	0.285	0.125	0.514	0.795	0.366	0.144	0.758	
	0.676	0.579	0.181	0.237	0.249	0.376	0.805	0.306	0.050	0.951	
	0.524	0.502	0.975	0.401	0.741	0.518	0.312	0.284	0.444	0.002	
3	0.408	0.575	0.505	0.360	0.774	0.546	0.635	0.758	0.440	0.299	**3**
	0.875	0.176	0.145	0.011	0.174	0.516	0.317	0.560	0.775	0.488	
	0.045	0.320	0.449	0.079	0.726	0.455	0.934	0.341	0.912	0.963	
	0.589	0.945	0.644	0.339	0.984	0.115	0.517	0.414	0.834	0.261	
	0.338	0.428	0.777	0.803	0.755	0.264	0.481	0.030	0.186	0.953	
4	0.034	0.715	0.499	0.896	0.934	0.827	0.601	0.527	0.282	0.758	**4**
	0.642	0.976	0.896	0.449	0.361	0.777	0.297	0.484	0.949	0.629	
	0.864	0.440	0.059	0.265	0.072	0.879	0.779	0.421	0.657	0.146	
	0.979	0.318	0.153	0.682	0.066	0.806	0.003	0.163	0.249	0.012	
	0.253	0.995	0.678	0.459	0.166	0.223	0.132	0.558	0.377	0.663	
5	0.922	0.764	0.313	0.247	0.330	0.167	0.098	0.416	0.378	0.585	**5**
	0.711	0.516	0.731	0.061	0.387	0.520	0.865	0.596	0.456	0.745	
	0.341	0.350	0.431	0.984	0.583	0.321	0.142	0.508	0.040	0.741	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.764	0.375	0.774	0.880	0.109	0.349	0.121	0.861	0.612	0.200	
	0.614	0.527	0.172	0.266	0.018	0.374	0.036	0.623	0.341	0.427	
1	0.017	0.694	0.456	0.638	0.812	0.271	0.423	0.329	0.644	0.041	**1**
	0.823	0.132	0.112	0.039	0.319	0.312	0.565	0.634	0.124	0.199	
	0.001	0.938	0.180	0.639	0.207	0.918	0.905	0.490	0.938	0.019	
	0.281	0.761	0.733	0.457	0.424	0.063	0.159	0.247	0.546	0.975	
	0.503	0.360	0.556	0.533	0.829	0.490	0.527	0.286	0.557	0.078	
2	0.689	0.948	0.589	0.816	0.370	0.794	0.913	0.324	0.529	0.041	**2**
	0.260	0.313	0.841	0.771	0.752	0.282	0.669	0.749	0.420	0.451	
	0.204	0.118	0.165	0.209	0.865	0.429	0.366	0.493	0.509	0.945	
	0.546	0.394	0.643	0.855	0.104	0.120	0.201	0.987	0.640	0.240	
	0.230	0.569	0.865	0.696	0.044	0.494	0.030	0.699	0.204	0.105	
3	0.808	0.107	0.645	0.308	0.094	0.288	0.391	0.885	0.069	0.994	**3**
	0.423	0.022	0.370	0.008	0.125	0.774	0.091	0.523	0.700	0.599	
	0.819	0.415	0.405	0.856	0.065	0.079	0.408	0.541	0.723	0.309	
	0.212	0.347	0.045	0.359	0.420	0.422	0.720	0.767	0.983	0.589	
	0.444	0.389	0.427	0.634	0.055	0.337	0.519	0.444	0.644	0.703	
4	0.224	0.571	0.271	0.859	0.636	0.175	0.255	0.080	0.027	0.877	**4**
	0.840	0.401	0.917	0.099	0.600	0.715	0.332	0.335	0.405	0.983	
	0.233	0.580	0.966	0.419	0.092	0.243	0.175	0.179	0.743	0.611	
	0.668	0.678	0.304	0.650	0.646	0.623	0.290	0.246	0.680	0.359	
	0.430	0.392	0.388	0.807	0.455	0.004	0.586	0.442	0.179	0.162	
5	0.309	0.373	0.239	0.392	0.490	0.549	0.773	0.695	0.917	0.797	**5**
	0.681	0.901	0.637	0.195	0.392	0.093	0.091	0.642	0.389	0.492	
	0.134	0.119	0.276	0.503	0.096	0.319	0.135	0.225	0.953	0.169	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.975	0.023	0.046	0.500	0.806	0.260	0.202	0.319	0.813	0.862	
	0.600	0.130	0.373	0.995	0.048	0.501	0.552	0.519	0.846	0.403	
1	0.536	0.018	0.935	0.372	0.090	0.931	0.311	0.579	0.466	0.979	**1**
	0.567	0.042	0.182	0.483	0.143	0.473	0.838	0.578	0.894	0.070	
	0.956	0.913	0.130	0.915	0.895	0.415	0.558	0.554	0.975	0.636	
	0.348	0.419	0.682	0.262	0.536	0.984	0.886	0.878	0.009	0.877	
	0.141	0.217	0.422	0.261	0.384	0.716	0.326	0.212	0.353	0.610	
2	0.625	0.370	0.164	0.966	0.722	0.236	0.548	0.137	0.851	0.053	**2**
	0.357	0.688	0.676	0.757	0.630	0.527	0.817	0.041	0.235	0.790	
	0.114	0.741	0.129	0.805	0.802	0.800	0.615	0.417	0.741	0.455	
	0.515	0.566	0.935	0.755	0.055	0.412	0.083	0.253	0.174	0.826	
	0.557	0.484	0.163	0.242	0.221	0.150	0.397	0.763	0.868	0.113	
3	0.787	0.758	0.735	0.302	0.391	0.540	0.043	0.991	0.537	0.459	**3**
	0.111	0.507	0.695	0.634	0.251	0.587	0.386	0.533	0.585	0.449	
	0.824	0.682	0.521	0.056	0.088	0.302	0.128	0.562	0.334	0.244	
	0.597	0.828	0.318	0.337	0.736	0.029	0.891	0.709	0.700	0.134	
	0.768	0.644	0.400	0.481	0.528	0.573	0.928	0.824	0.537	0.445	
4	0.778	0.664	0.687	0.607	0.493	0.515	0.269	0.363	0.662	0.947	**4**
	0.833	0.812	0.289	0.346	0.923	0.478	0.941	0.580	0.976	0.509	
	0.635	0.995	0.723	0.558	0.349	0.432	0.155	0.276	0.129	0.326	
	0.880	0.025	0.952	0.801	0.596	0.565	0.407	0.303	0.620	0.153	
	0.624	0.276	0.934	0.715	0.372	0.111	0.823	0.740	0.650	0.676	
5	0.084	0.459	0.616	0.230	0.955	0.787	0.486	0.817	0.420	0.599	**5**
	0.028	0.943	0.707	0.336	0.442	0.751	0.009	0.025	0.406	0.638	
	0.257	0.953	0.580	0.071	0.474	0.137	0.481	0.277	0.533	0.292	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.772	0.571	0.975	0.511	0.489	0.398	0.089	0.964	0.379	0.313	
	0.838	0.849	0.592	0.814	0.914	0.928	0.438	0.875	0.712	0.507	
1	0.447	0.478	0.176	0.084	0.317	0.169	0.755	0.741	0.821	0.134	**1**
	0.960	0.192	0.970	0.442	0.856	0.621	0.500	0.912	0.814	0.895	
	0.941	0.780	0.393	0.912	0.252	0.713	0.386	0.158	0.941	0.599	
	0.819	0.432	0.555	0.447	0.866	0.737	0.363	0.382	0.615	0.705	
	0.937	0.970	0.331	0.751	0.633	0.711	0.234	0.174	0.518	0.644	
2	0.408	0.983	0.714	0.499	0.782	0.417	0.849	0.013	0.325	0.064	**2**
	0.848	0.718	0.096	0.035	0.021	0.484	0.146	0.233	0.744	0.090	
	0.814	0.540	0.268	0.199	0.913	0.387	0.614	0.335	0.493	0.194	
	0.373	0.229	0.458	0.544	0.138	0.753	0.825	0.441	0.521	0.304	
	0.748	0.235	0.421	0.304	0.568	0.329	0.098	0.348	0.371	0.646	
3	0.365	0.098	0.826	0.053	0.931	0.166	0.835	0.384	0.716	0.951	**3**
	0.711	0.021	0.531	0.549	0.727	0.539	0.111	0.627	0.036	0.867	
	0.111	0.106	0.980	0.418	0.757	0.475	0.157	0.525	0.793	0.326	
	0.171	0.226	0.276	0.734	0.265	0.190	0.452	0.998	0.520	0.857	
	0.749	0.458	0.832	0.004	0.218	0.492	0.375	0.428	0.966	0.285	
4	0.074	0.807	0.868	0.560	0.526	0.077	0.236	0.430	0.861	0.112	**4**
	0.463	0.256	0.120	0.567	0.237	0.012	0.136	0.075	0.617	0.974	
	0.903	0.948	0.531	0.315	0.050	0.839	0.977	0.882	0.196	0.982	
	0.611	0.524	0.293	0.749	0.367	0.958	0.348	0.109	0.780	0.254	
	0.438	0.791	0.982	0.027	0.170	0.127	0.820	0.943	0.075	0.887	
5	0.973	0.410	0.313	0.035	0.949	0.848	0.720	0.672	0.530	0.799	**5**
	0.382	0.458	0.800	0.781	0.242	0.564	0.019	0.139	0.338	0.176	
	0.751	0.263	0.344	0.467	0.941	0.795	0.019	0.880	0.515	0.415	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.817	0.093	0.254	0.779	0.563	0.409	0.263	0.244	0.026	0.340	
	0.267	0.817	0.444	0.908	0.830	0.238	0.270	0.990	0.287	0.607	
1	0.287	0.574	0.016	0.879	0.159	0.232	0.440	0.553	0.799	0.461	**1**
	0.416	0.330	0.913	0.890	0.426	0.746	0.078	0.374	0.190	0.396	
	0.116	0.197	0.178	0.223	0.794	0.327	0.401	0.499	0.666	0.475	
	0.554	0.784	0.841	0.113	0.606	0.687	0.319	0.268	0.793	0.461	
	0.777	0.671	0.420	0.990	0.215	0.825	0.222	0.591	0.264	0.230	
2	0.215	0.696	0.455	0.127	0.976	0.774	0.761	0.437	0.664	0.164	**2**
	0.174	0.315	0.788	0.300	0.037	0.258	0.464	0.286	0.575	0.581	
	0.262	0.845	0.246	0.789	0.815	0.539	0.766	0.646	0.034	0.860	
	0.372	0.973	0.530	0.319	0.021	0.337	0.755	0.423	0.182	0.877	
	0.696	0.264	0.848	0.895	0.963	0.121	0.620	0.738	0.446	0.657	
3	0.551	0.612	0.469	0.596	0.767	0.900	0.050	0.859	0.210	0.652	**3**
	0.940	0.828	0.328	0.224	0.861	0.612	0.640	0.783	0.952	0.292	
	0.493	0.163	0.854	0.979	0.858	0.562	0.690	0.143	0.796	0.904	
	0.963	0.877	0.075	0.714	0.414	0.351	0.829	0.246	0.447	0.060	
	0.441	0.183	0.880	0.986	0.755	0.034	0.642	0.540	0.393	0.665	
4	0.558	0.228	0.709	0.238	0.572	0.599	0.504	0.971	0.698	0.744	**4**
	0.811	0.758	0.092	0.848	0.312	0.436	0.017	0.438	0.916	0.304	
	0.017	0.260	0.953	0.564	0.947	0.011	0.425	0.468	0.083	0.789	
	0.178	0.881	0.468	0.731	0.604	0.324	0.398	0.753	0.278	0.130	
	0.979	0.811	0.476	0.125	0.423	0.314	0.456	0.090	0.189	0.066	
5	0.057	0.136	0.483	0.100	0.712	0.204	0.372	0.385	0.918	0.405	**5**
	0.717	0.633	0.348	0.744	0.255	0.781	0.443	0.625	0.300	0.705	
	0.305	0.247	0.661	0.493	0.889	0.764	0.577	0.169	0.261	0.398	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.815	0.125	0.006	0.653	0.614	0.455	0.968	0.103	0.150	0.154	
	0.872	0.226	0.619	0.637	0.585	0.566	0.331	0.028	0.369	0.751	
1	0.685	0.964	0.937	0.948	0.969	0.454	0.194	0.425	0.852	0.500	1
	0.427	0.348	0.222	0.129	0.690	0.911	0.996	0.115	0.681	0.569	
	0.181	0.115	0.519	0.715	0.508	0.308	0.525	0.584	0.694	0.427	
	0.917	0.628	0.054	0.928	0.817	0.812	0.264	0.776	0.756	0.610	
	0.759	0.891	0.311	0.612	0.247	0.044	0.668	0.389	0.953	0.931	
2	0.510	0.632	0.371	0.037	0.667	0.681	0.730	0.638	0.965	0.925	2
	0.836	0.525	0.342	0.752	0.638	0.403	0.687	0.245	0.403	0.785	
	0.669	0.875	0.824	0.842	0.565	0.756	0.401	0.371	0.576	0.689	
	0.931	0.450	0.955	0.323	0.696	0.790	0.021	0.127	0.753	0.550	
	0.771	0.631	0.896	0.968	0.870	0.312	0.764	0.665	0.113	0.610	
3	0.855	0.525	0.056	0.255	0.921	0.282	0.301	0.401	0.775	0.246	3
	0.897	0.753	0.246	0.763	0.259	0.293	0.613	0.154	0.743	0.574	
	0.393	0.878	0.401	0.459	0.134	0.655	0.433	0.323	0.393	0.038	
	0.965	0.130	0.181	0.909	0.940	0.399	0.200	0.724	0.673	0.397	
	0.745	0.233	0.460	0.361	0.935	0.018	0.405	0.945	0.183	0.576	
4	0.204	0.623	0.771	0.120	0.859	0.314	0.880	0.447	0.680	0.938	4
	0.804	0.213	0.903	0.488	0.425	0.685	0.584	0.676	0.717	0.220	
	0.526	0.018	0.323	0.978	0.407	0.197	0.827	0.102	0.641	0.302	
	0.620	0.343	0.587	0.878	0.922	0.977	0.162	0.523	0.011	0.409	
	0.558	0.383	0.880	0.541	0.422	0.466	0.186	0.004	0.457	0.446	
5	0.128	0.893	0.685	0.864	0.349	0.413	0.273	0.971	0.970	0.311	5
	0.455	0.032	0.141	0.835	0.705	0.898	0.958	0.945	0.095	0.779	
	0.790	0.312	0.258	0.518	0.141	0.448	0.185	0.599	0.546	0.751	
	A		B		C		D		E		

	A		B		C		D		E		
	0.982	0.498	0.720	0.906	0.269	0.565	0.296	0.393	0.537	0.124	
	0.636	0.192	0.769	0.017	0.448	0.457	0.458	0.148	0.917	0.987	
1	0.499	0.185	0.016	0.919	0.847	0.967	0.794	0.258	0.641	0.288	1
	0.364	0.861	0.261	0.407	0.639	0.643	0.277	0.830	0.989	0.178	
	0.141	0.417	0.721	0.393	0.860	0.021	0.952	0.944	0.606	0.721	
	0.947	0.752	0.693	0.734	0.577	0.119	0.499	0.032	0.834	0.328	
	0.923	0.669	0.770	0.400	0.790	0.700	0.758	0.099	0.198	0.201	
2	0.885	0.025	0.563	0.815	0.063	0.269	0.244	0.711	0.418	0.517	2
	0.925	0.002	0.216	0.406	0.812	0.309	0.596	0.883	0.385	0.725	
	0.793	0.877	0.783	0.064	0.047	0.225	0.891	0.588	0.179	0.565	
	0.397	0.152	0.590	0.640	0.534	0.558	0.191	0.466	0.655	0.062	
	0.366	0.478	0.991	0.455	0.152	0.652	0.480	0.136	0.072	0.729	
3	0.537	0.039	0.970	0.382	0.927	0.865	0.663	0.873	0.119	0.835	3
	0.211	0.621	0.042	0.023	0.155	0.347	0.124	0.371	0.589	0.016	
	0.103	0.030	0.040	0.042	0.556	0.822	0.376	0.970	0.938	0.386	
	0.773	0.420	0.378	0.039	0.905	0.484	0.544	0.225	0.554	0.459	
	0.543	0.777	0.482	0.921	0.940	0.841	0.738	0.763	0.096	0.528	
4	0.996	0.200	0.554	0.421	0.334	0.556	0.359	0.592	0.237	0.736	4
	0.799	0.698	0.399	0.104	0.422	0.949	0.157	0.505	0.772	0.341	
	0.309	0.918	0.954	0.852	0.639	0.035	0.226	0.409	0.116	0.945	
	0.109	0.364	0.613	0.650	0.741	0.248	0.628	0.157	0.318	0.069	
	0.362	0.657	0.943	0.683	0.948	0.675	0.367	0.288	0.914	0.896	
5	0.651	0.328	0.501	0.552	0.218	0.951	0.936	0.198	0.531	0.307	5
	0.770	0.936	0.461	0.907	0.282	0.864	0.880	0.444	0.499	0.223	
	0.800	0.658	0.705	0.107	0.561	0.076	0.355	0.604	0.847	0.205	
	A		B		C		D		E		

Tennessee Department of Transportation
Division of Materials and Tests

Nuclear Density Testing (SOP 7-1)

Purpose: The purpose of this document is to provide guidance for conducting nuclear density tests on hot mix asphalt, backfill, soil, aggregate base, embankments, and other materials requiring density tests in accordance with SOP 1-1.

Discussion: Many compacted materials on TDOT projects are accepted by means of testing with nuclear density gauges. This document intends to provide guidance and define best practices for operation of these gauges to unify testing operations statewide. Testing details of common concern include proper setup of gauge information, depth of test probes, time length of tests, and recording of data.

Basic Procedure: All test procedures shall be in accordance with AASHTO T310, "*In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)"* and ASTM D2950, "*Standard Test Method for Density of Bituminous Concrete In-Place by Nuclear Methods"* except as revised herein.

Specific instructions on conducting standard counts, entering maximum specific gravity values, offsets, correction factors, and proctor information can be found in the users' manuals corresponding to the make and model of the gauge in use.

PART ONE – ACCEPTANCE TESTING

Hot Mix Asphalt

Mixtures: 307-A, 307-B, 307-BM, 307-BM2, 307-C, 307-CW, 411-D, 411-Es

Step 1: Conduct Standard Count

Step 2: Enter maximum specific gravity (Gmm) value from asphalt mix design.

Step 3: Enter gauge correction factor from test strip. See Part Two for determining correction factors.

Step 4: Set gauge setting to Backscatter.

Step 5: Place gauge in location to be tested.

Footnote 1: For guidance on testing frequencies, random numbers, and selecting test locations, see SOP 1-1.

Step 6: Activate a test. When collecting a density test, the following approach shall be used:

- *"Four Nineties" Test:* Four tests may be conducted at a single location, rotating around the test location 90 degrees at a time, as shown in Figure 1. The four test results will then be averaged to obtain a single test value for that location. Test counts for this approach should be 15 seconds or longer.

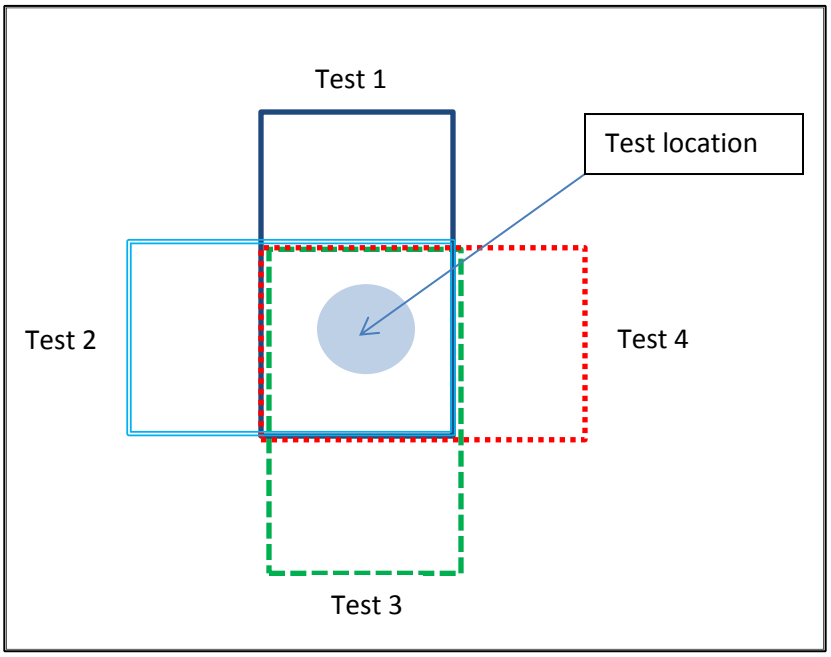


Figure 1. Testing at four 90° locations

Step 7: Record the test value into the appropriate paperwork.

- DT-0315, Daily Asphalt Density Report

Soil and Aggregate Materials

Materials: Backfill (Earth retaining structures), Select granular backfill (Earth retaining structures), Embankments, Subgrade preparation, Lime-treated subgrade, Soil-Cement Base, Mineral Aggregate Base and Surface, Aggregate for Underdrains, Aggregate-Cement base course, Aggregate Lime fly ash base course, & Conditioned mineral aggregate base.

Step 1: Conduct Standard Count

Step 2: Enter maximum dry density and optimum moisture content from Proctor Density report.

Step 3: Select Test location. Create a test hole using the scraper plate and drill rod provided with the gauge.

Footnote 2: For guidance on selecting test locations, see SOP 1-1.

Step 4: Set gauge setting to Direct Transmission at a depth reasonably close to one half the depth of the compacted lift.

Step 5: Place gauge in location to be tested and insert test probe into test hole at a depth reasonably close to one half the depth of the compacted lift. Pull gauge back to ensure probe makes contact with material being tested.

Step 6: Activate a test. When collecting a density test, the following approach shall be used:

Single Count Test: A single test may be conducted at any test location, given that the test count is greater than or equal to 60 seconds.

Step 7: Record the test value into the appropriate paperwork.

- DT-0298, Daily Report on Soil and Aggregate Stabilization
- DT-0304, Daily Report on Embankment
- DT-0307, Daily Report on Mineral Aggregate Base
- DT-0314, Density Worksheet – Nuclear Method (Aggregate, Soil)

PART TWO – DETERMINATION OF ASPHALT CALIBRATION FACTORS

- Conduct test strips in accordance with most current version of TDOT Standard specifications, subsection 407.15
- Test strips are required for the following mixtures:
  307-A, 307-B, 307-BM, 307-BM2, 307-C, 307-CW, 411-D, 411-Es
- The minimum size of a single test strip is 400 yd^2, but a larger area is recommended. The following roadway lengths provide an area of 400 yd^2 :
  - 9’ wide= 400’ long
  - 10’ wide= 360’ long
  - 11’ wide= 330’ long
  - 12’ wide= 300’ long
- Compaction of the test strip shall commence immediately after placement of the bituminous mixture.
- TDOT form DT-0316, Density and Roller Pattern Test Strip

Step 1: After a single pass of the breakdown roller, conduct a density test in accordance with Part One, above. Record the uncorrected test value in lbs/ft^3.

Step 2: After a second pass of the breakdown roller, conduct a second density test and record the uncorrected test value in lbs/ft^3.

Step 3: Repeat the roller pass/testing process until a value is obtained that does not increase from the previous pass more than 1 lb/ft^3. This number of passes or the pass before it shall be the target number of passes for the breakdown roller.

Step 4: After compacting an additional area with the breakdown roller at the correct target number of passes, repeat steps 1-3 for the intermediate roller.

Step 5: After compacting an additional area with the breakdown and intermediate rollers at the correct target number of passes, repeat steps 1-3 for the finish roller. Often times, the resulting target number of passes will only be 1 or 2 passes for finish rollers.

Step 6: Compact test strip area with all three rollers at the correct target number of passes.

Step 7: Layout test strip test locations and conduct and record ten uncorrected density tests on the compacted test strip area and record test information

Step 8: Cores should be cut at same locations as nuclear density tests and tested by TDOT Plant Technician for laboratory density in accordance with AASHTO T166.

Footnote 3: Only Method A of T166 shall apply when testing test strip cores for density. Cores shall be COMPLETELY DRY before testing. Accelerated drying in accordance with ASTM D 7227 (core drying device) is permitted.

Step 9: The nuclear gauge correction factor shall be the difference between the average of ten nuclear gauge readings and the average of ten core density values.

Additional notes on test strips and correction factors:

- Nuclear gauges are specific to an individual gauge, mix, and project. It is poor practice to develop a correction factor with a different gauge unit than the one to be used during mainline acceptance testing.
- Developing correction factors based on cores that were not allowed to dry completely will influence results in a manner that can mislead test results into appearing as if they are higher than they actually are. In other words, wet cores appear heavier or denser than they actually are.
- In accordance with TDOT Specifications, a new test strip is required when:
  - There is a change in job mix formulas
  - A change in the source of materials occurs
  - A change in the material from the same source is observed
  - There is reason to believe that the test strip density is not representative of the mixture being placed. For example, test results are consistently above 100% density or test results have been consistent for a steady number of days and had suddenly changed significantly.
  - A change in paving or compaction equipment occurs.
- Test variables selected during test strips (i.e. - length of count, single test for 60 seconds, testing at "four 90's", backscatter, driving test holes, etc) must be consistent between what is chosen during development of correction factors and what is done during subsequent acceptance testing. *i.e. – If a correction factor is set up by testing 307A mix in backscatter, then all acceptance tests using that correction factor must be tested in backscatter.*
- When testing large aggregate mixtures such as 307-A mixture that have a large amount of surface texture, clean natural sand may be spread to fill surface voids prior to testing.

SECTION 307 – BITUMINOUS PLANT MIX BASE (HOT MIX)

DESCRIPTION

307.01 Description

This work consists of constructing one or more base course layers of aggregate and asphalt, prepared in a hot bituminous mixing plant and spread and compacted on a prepared subgrade, granular sub-base, or base.

MATERIALS

307.02 Materials

Provide materials as specified in:

Aggregate for Mixture,
Grading A, ACRL, AS, B, BM, BM2, C, CS, or CW **903.06**
Asphalt Cement, Grade PG 64-22, 70-22, 76-22, 82-22..... **904.01**
Chemical Additive **921.06.B**

The specific grading of aggregate to be used will be specified in the Contract or shown on the Plans. The Engineer will accept mineral aggregate, bituminous material, and the plant mix in accordance with **407.02**.

307.03 Composition of Mixtures

A. General

The bituminous base and/or leveling course shall be composed of aggregate and bituminous materials. The hot plant mixes shall comply with the applicable requirements of **407.03**.

Combine the specified mineral aggregate and asphalt cement in proportions that will meet the design composition limits specified in Table 307.03-1.

Table 307.03-1: Mixture Composition

Mixtures	Proportions of Total Mixture, Percent by Weight	
	Combined Mineral Aggregate, %	Asphalt Cement, % [1]
Grading AS and ACRL	96.3 - 97.7	2.3 - 3.7
Grading A	95.8 - 96.7	3.3 - 4.2
Grading B, BM and BM2	93.8 - 95.8	4.2 - 6.2
Grading C and CW	93.8 - 95.8	4.2 - 6.2
Grading CS	92.3 - 94.7	5.3 - 7.7

[1] If the effective combined specific gravity of the aggregate exceeds 2.80, the Engineer may adjust the proportions specified.

In addition, combine the materials with the required amount of bitumen to meet the design properties specified in Table 307.03-2, except that on low volume roads (ADT 1,000 or below), the minimum stability shall be 1,500 pound-feet and the VMA and dust-asphalt ratio will be waived for 307-B, 307-BM, 307-BM2 and 307-C mixes.

Table 307.03-2: Mixture Design Properties

Mix [1]	Stability (minimum) lbf [2]	Design Void Content % [2]	Production Void Content, % [2]	VMA (minimum) % [2]	Dust-Asphalt Ratio [3]
307-B	2,000	4.0±0.2	3-5.5	11.5	0.6-1.5
307-BM	2,000	4.0±0.2	3-5.5	13.5	0.6-1.5
307-BM2	2,000	4.0±0.2	3-5.5	13.5	0.6-1.5
307-C	2,000	4.0±0.2	3-5.5	13.0	0.6-1.5
307-CS	2,000	3.0±0.5	1-5	---	---
307-CW	1,500	4.0±0.2	3-5	13.0	0.6-1.5

[1] To identify critical mixes and make appropriate adjustments, the mix design shall meet these design properties for the bitumen content range of Optimum Asphalt Cement ±0.25%.

[2] Tested according to AASHTO T 245 with 75 blows with the hammer on each end of the test specimen, using a Marshall Mechanical Compactor.

[3] The dust-asphalt ratio is the percent of the total aggregate sample that passes the No. 200 sieve, as determined by AASHTO T 11, divided by the percent asphalt in the total mix.

If the materials proposed for use do not meet the design criteria specified in Table 307.03-2, find other suitable sources of materials. If the material at the asphalt plant will not combine within the tolerances of the Job Mix Formula (JMF), provide a new design.

B. Recycled Asphalt Pavement and Recycled Asphalt Shingles

1. Recycled Asphalt Pavement (RAP). The Contractor may use asphaltic concrete removed from a Department project or other State Highway Agency project by an approved method and stored in a Department approved stockpile. RAP combined with the appropriate aggregate, asphalt cement, and anti-strip additive when required shall produce a mixture that meets **903.06** and this Section **307**. The Contractor may incorporate RAP in the mixes specified in Table 307.03-3.

Table 307.03-3: Mixtures Using RAP

Mix Type	% RAP (Non-processed)[1]	Maximum % RAP (Processed)[2]	Maximum % RAP Processed & Fractionated [3]	Maximum Particle Size (inches)
307-ACRL	0	00	-	-
307-AS	0	00	-	-
307-A	15	20	35	1-1/2
307-B	15	30	35	1-1/2
307-BM	15	30	35	3/4
307-BM2	15	30	35	3/4
307-C	15	30	35	3/8
307-CW	15	30	35	1/2
307-CS	0	15	25	5/16

(1) "Non-processed" refers to RAP that has not been crushed and screened or otherwise sized prior to its use.

(2) "Processed" refers to RAP that has been crushed and screened or otherwise sized such that the maximum recycled material particle size is less than that listed in Table 307.03-3 prior to entering the dryer drum.

(3) "Fractionated" refers to RAP that has been processed over more than one screen, producing sources of various maximum particle sizes (e.g., 3/4 to 1/2 inch, 1/2 inch to #4, etc.). The Contractor may use the larger percentages of fractionated RAP specified only if individual fractions of two different maximum particle size are introduced into the plant as separate material sources for increased control.

All mixes shall contain at least 65% virgin asphalt.

The Contractor shall obtain a representative sample from the recycled material stockpile, and shall establish a gradation and asphalt cement content. The Contractor shall determine the gradation and asphalt content of the recycled material at the beginning of a project and every 2,000 tons thereafter. The stockpile asphalt cement content for all recycled material shall not

vary by more than 0.8%. The stockpile gradation tolerance for all recycled material on each sieve is specified in Table 307.03-4.

Table 307.03-4: Stockpile Gradation Tolerance

Sieve Size	Tolerance
3/8 inch and larger	± 10%
No. 4	± 8%
No. 8	± 6%
No. 30	± 5%
No. 200	± 4%

The Engineer will accept the mixture for aggregate gradation and asphalt content in accordance with **407.20.B**.

Provide a special mix design with asphalt content in the range of 5 to 7% where 307-C Mix is used as a surface on the shoulder.

Perform sampling and testing of the planings as well as new materials for bid purposes, and for the submission of the Job Mix Formula (JMF) as specified in **407.03**. Submit all additives to the Engineer for approval at the same time other materials are submitted for design verification.

After mixing, verify the moisture content of the total mix is no more than 0.1% as determined by oven drying. Provisions for lowering the temperature because of boiling or foaming shall not apply.

2. **Recycled Asphalt Shingles (RAS).** RAS may be included to a maximum of 5% of the total weight of mixture. The percentage of RAS used will be considered part of the maximum allowable RAP percentage. The ratio of added new asphalt binder to total asphalt binder shall be 65% or greater for all 307 mixes. Either the mix producer or the RAS supplier shall obtain a representative sample from the recycled material stockpile and establish a gradation and asphalt cement content as required. Determine shingle asphalt binder content according to AASHTO T 164 Method A, with a minimum sample size of 500 grams. Determine the gradation and asphalt content of the recycled material at the beginning of the

Project and every 2,000 tons of recycled material used thereafter. The stockpile asphalt cement content for all recycled material shall not vary by more than 0.8%. All RAS material shall be processed to a minimum 100% passing the 3/8 inch sieve and a minimum 90% passing the No. 4 sieve.

To conduct the gradation testing, air dry a 500 to 700-gram sample of processed shingle material, dry sieve over the 3/8-inch and No. 4 sieves, and weigh. For mix design purposes, the Contractor may use the aggregate gradation specified in Table 307.03-5 as a standard gradation instead of determining the shingle gradation according to AASHTO T 30.

Table 307.03-5: Standard Gradation (for Mix Design Purposes)

Sieve Size	Total Percent Passing
3/8 inch	100
No. 4	97
No. 8	95
No. 16	80
No. 30	60
No. 50	50
No. 100	40
No. 200	30

An aggregate bulk specific gravity (G_{sb}) of 2.650 may be used instead of determining the shingle aggregate G_{sb} according to AASHTO T 84. In addition, the effective binder available for mixing with additional aggregates shall be considered as 75% of the total binder content as determined by AASHTO T 164 and shall be the value listed as the RAS binder content on the JMF.

Scrap asphalt shingle shall not contain extraneous waste materials. Extraneous materials including, but not limited to, asbestos, metals, glass, rubber, nails, soil, brick, tars, paper, wood, and plastics, shall not exceed 0.5% by weight as determined on material retained on the No. 4 sieve. To conduct deleterious material testing, take a representative 500 to 700-gram sample of processed shingle material, place over the No. 4 sieve, and pick

and weigh all extraneous waste material retained on the No. 4 sieve. Base the percent of extraneous material on the total sample weight.

RAS shall contain less than the maximum percentage of asbestos fibers based on testing procedures established by the Department, or State or Federal environmental regulatory agencies. Analyze a minimum of one sample of processed asphalt roofing material for every 500 tons of material processed for the presence of asbestos.

Before a JMF for a particular design is approved, submit the following, along with the materials and information specified in **407.03**:

a. Certification by the processor of the shingle scrap describing the shingle scrap content and source.

b. A 1000-gram sample of the processed RAS material for inspection (new designs only).

Stockpile RAS separate from other salvage material. Do not blend RAS material in a stockpile with other salvage material. Do not blend Manufacture Waste Scrap Shingles (MWSS) and Tear-Off Scrap Shingles (TOSS). In addition, do not blend virgin sand material with the processed shingles, to minimize agglomeration of the shingle material.

All RAS supplied to a Department project shall come from a certified shingle processor/supplier approved by the Division of Materials and Tests.

C. Anti-Strip Additive

Check asphaltic concrete mixtures (Grading A, AS, ACRL, B, BM, BM2, C, CS, and CW) for stripping by the following methods:

1. The Ten Minute Boil test for dosage rate and the Root-Tunnecliff procedure (ASTM D4867) for moisture susceptibility.

   Do not use the Root-Tunnecliff procedure (ASTM D4867) with the following mixtures: Grading A, AS, ACRL, and B.

2. For mixtures not requiring design, the Ten Minute Boil test for dosage rate and moisture susceptibility.

If test results indicate moisture susceptibility, mix an approved anti-strip agent with the asphalt cement at the dosage recommended by the respective test and as specified in **921.06.B**.

EQUIPMENT

307.04 Equipment

Provide equipment as specified in **407.04** through **407.08**.

If using recycled mix, modify the asphalt plant as approved by the Engineer to accommodate the addition of asphalt planings. If using a batch plant to produce recycled mix, heat the aggregate to a temperature that will transfer sufficient heat to the cold planings to produce a mix of uniform temperature within the specified range.

CONSTRUCTION REQUIREMENTS

307.05 General

Conform to the construction requirements specified in **407.09**, and **407.11** through **407.17**.

307.06 Preparing the Subgrade, Sub-base, or Surface

The Plans will indicate whether the plant-mixed base is to be constructed on a treated or untreated subgrade or sub-base, on a granular base, or on an existing surface. Ensure that the surface upon which the plant mix base is to be constructed meets **205**, **207**, **302**, **303**, **304**, or **309**, whichever is applicable. If shown on the Plans, condition the surface as specified in **407.10**. Condition existing mineral aggregate base as specified in **310**. Construct prime coat or tack coat, when shown on the Plans, as specified in **402** or **403**, respectively.

Only place bituminous plant-mix base mixture on a surface that is dry and free of loose particles and other undesirable materials.

307.07 Thickness and Surface Requirement

Control thickness during the spreading operation by frequently measuring the freshly spread mixture to establish a relationship between the uncompacted mixture and the completed course. Thickness or spread rate in pounds per square yards shall be within reasonably close conformity with that shown on the Plans. Each course shall have a thickness after compaction of not more than 4 inches, unless otherwise approved by the Engineer.

The surface of the base shall meet the requirements specified in **407.18**, and when tested in accordance with **407.18**, the deviation of the surfaces from the testing edge of the straightedge shall not exceed the amounts specified in Table 307.07-1.

Table 307.07-1: Maximum Surface Deviation

Mixture	Maximum Deviation (inches)
Grading A, ACRL, and AS	1/2
Grading B, BM, BM2, C, CS, and CW	3/8

COMPENSATION

307.08 Method of Measurement

The Department will measure Mineral Aggregate, including Mineral Filler when required, and Asphalt Cement for Bituminous Plant Mix Base and other related items in accordance with **407.19**.

307.09 Basis of Payment

The Department will pay for accepted quantities at the contract prices in accordance with **407.20**.

For bidding purposes, use the asphalt cement content specified in Table 307.09-1 for the designated mix.

Table 307.09-1: Asphalt Cement Content

Mix Type	Asphalt Content
307 A	4.0%
307 AS	3.5%
307 ACRL	3.5%
307 B	4.3%
307 BM	5.0%
307 BM2	5.0%
307 C	5.0%
307 CW	6.0%
307 CS	6.5%

If the Engineer sets an asphalt content other than that specified in Table 307.09-1, the Department will calculate a price adjustment, based on the asphalt content set by the Engineer and the Monthly Bituminous Index for the specific grade asphalt on the mix design, in accordance with **407.20**.

SECTION 313 – TREATED PERMEABLE BASE

DESCRIPTION

313.01 Description

This work consists of constructing treated permeable base, composed of either a mixture of aggregate, Portland cement, and water, or a mixture of aggregate with asphalt binder, on a prepared sub-base. The Contractor may use either cement treated or asphalt treated permeable base.

MATERIALS

313.02 Materials

Provide materials as specified in:

Portland Cement, Type I	**901.01**
Aggregate for Portland Cement Treated Mixture	**903.03**
Aggregate for Bituminous Treated Mixture	**903.06**
Asphalt Cement, Grade PG 64-22, 70-22, 76-22, 82-22	**904.01**
Liquid Membrane – Forming Compounds	**913.05**
Water	**921.01**

313.03 Composition of Mixtures

A. Portland Cement Treated Permeable Base

In accordance with **604**, submit a concrete mix design, meeting the requirements specified in Table 313.03-1, to the Engineer for approval.

Table 313.03-1: Mix Design Properties

Property	Value
Water-Cement Ratio	0.43 (approximately)
Portland Cement Content	$\geq$ 282 lbs/yd^3
Compressive Strength at 7 days (AASHTO T 22)	$\geq$ 500 psi

B. Bituminous Treated Permeable Base

Asphalt treated permeable base shall be Bituminous Plant Mix Base (Hot Mix) as specified in **307** and **407**. Use liquid asphalt at the rate of 3% by weight of the total mixture. Asphalt content shall be such that all aggregate is visibly coated. Submit a mix design to the Engineer for approval as specified in **407.03**.

EQUIPMENT

313.04 Equipment

To construct Portland cement treated base, provide equipment meeting **501.04.A** and **501.04.B**.

To construct bituminous treated base, provide equipment meeting **407.04** through **407.08**.

The spreading equipment shall meet either **501.04.D.11** or **407.06**.

CONSTRUCTION REQUIREMENTS

313.05 Construction Requirements

Construct cement treated permeable base and asphalt treated permeable base as specified in **309** and **307** respectively, unless otherwise specified below.

A. Cement Treated Permeable Base

1. **Consolidation and Finishing.** Immediately after placing the cement treated permeable base, compact the mixture using a steel wheel roller weighing not less than 6 tons. Continue rolling until maximum densification is achieved; immediately cease rolling if aggregate breakage occurs. Do not use vibratory rollers. Instead of using a steel wheel roller, the Contractor may place the cement treated permeable base with a high-density screed with dual tamping bars.

2. **Curing.** Immediately after spreading and compacting operations, cover the entire surface and exposed edges of the cement treated permeable base with transparent or white polyethylene sheeting as specified in **501.18**, or a white pigmented wax base curing compound meeting AASHTO M 148.

   Use polyethylene sheeting having a thickness of at least 4 mils, and hold the sheeting in place for a minimum of 7 days using a method approved by the Engineer. Before placing the sheeting, thoroughly wet the surface of the cement treated permeable base.

   Place wax-based curing compound at a rate of 0.04 to 0.05 gallons per square yard.

B. Asphalt or Cement Treated Permeable Base

From the time of placement until placement of the following pavement layer, protect the treated permeable base from severe weather conditions, particularly freezing rain, snow, and icing, and from contamination by dust, dirt, mud, or other fine grained material. Remove and replace, at no additional cost to the Department, all portion(s) of the treated permeable base that become contaminated to the extent that drainage is reduced or inhibited.

Do not allow traffic on the treated permeable base, with the exception of equipment required to place the following layer of pavement, provided that it enters and exits as near as possible to the paving operation. Repair damage to the treated permeable base caused by the Contractor's equipment at no additional cost to the Department.

313.06 Limitations

If using asphalt treated permeable base, adhere to the limitations specified in **407.09**. Do not place any treated permeable base that cannot be covered by the next course of pavement within the same construction season.

313.07 Surface Requirements

The Department will test the finished surface of the treated permeable base with a 12-foot straightedge in both transverse and longitudinal directions. The finished surface shall be uniform and shall not vary by more than 1/2 inch from the lower edge of the straightedge. If the tested surface varies by more than 1/2 inch, adjust the surface to a new grade, as established by the Engineer, as follows:

1. Fill the low areas with Portland cement concrete during the concrete paving operation, or

2. Apply emulsified asphalt, RS-2, at a rate not to exceed 0.2 gallons per square yard, as determined by the Engineer, over the specified low areas, and fill the low areas with No. 8 mineral aggregate. Seat the size No. 8 mineral aggregate with a pneumatic tire roller.

313.08 Tolerance in Pavement Thickness

Place treated permeable base to the thickness designated on the Plans. Before beginning any further work, take core samples from the treated permeable base, at locations established by the Engineer, in accordance with **501.24** for verification of base thickness. Take core samples at locations determined and witnessed by a Department representative, and document on the appropriate form.

The Department will make adjustments to the contract unit price in accordance with **501.26** if the base thickness is determined by the Engineer to be deficient.

COMPENSATION

313.09 Method of Measurement

The Department will measure treated permeable base by the square yards complete in place for the width and thickness specified.

313.10 Basis of Payment

The Department will pay for accepted quantities at the contract prices as follows:

Item	*Pay Unit*
Treated Permeable Base	Square Yard

The Department will adjust payment in accordance with **501.26.B** for all base found to be deficient in thickness by more than 1/4 inch. The Department will not make additional payment over the contract unit price for base that has an average thickness in excess of that shown on the Plans.

If the Department orders any increase or decrease in the cement content of the Cement Treated Base from the approved mix design, the measurement and payment for this change will be computed in accordance with **501.25** and **501.26**.

The Department will consider the cost of taking cores for verification of pavement thickness to be included in the contract unit price of treated permeable base.

The Department will not allow additional compensation for leveling of the treated permeable base except on ramps that contain 4,500 square yards or less of Portland cement concrete pavement. The Department will measure and pay for additional concrete used on these ramps in accordance with **501.25** and **501.26**.

SECTION 403 – TACK COAT

DESCRIPTION

403.01 Description

This work consists of furnishing and applying emulsified asphalt to a previously prepared base or surface course to provide bond for a superimposed course.

MATERIALS

403.02 Bituminous Materials

Provide materials as specified in:

Emulsified Asphalt, SS-1, SS-1h, CSS-1, CSS-1h, TST-1P, CQS-1h, CQS-1hp, TTT-1, TTT-2 ..... **904.03**

Apply tack coat at the temperature ranges specified in Table 403.02-1.

Table 403.02-1: Tack Coat Application Temperatures

Material	Temperature Range
SS-1, SS-1h, CSS-1, TST-1P, CQS-1h, CQS-1hp and CSS-1h	60 to 140 °F
TTT-1	160 to 180 °F
TTT-2	120 to 160 °F

Dilution of asphalt emulsion used for tack coat on hot mix asphalt paving projects after leaving the terminal is not allowed. Apply the emulsion as delivered from the terminal.

EQUIPMENT

403.03 Equipment

Provide a power broom, equipment for heating bituminous material, a pressure distributor meeting the requirements of **402.03**, and such other equipment and small tools as may be required to perform the work in a satisfactory manner.

403.04 Preparing the Surface

Prepare the designated surface as specified in **404.05**. Ensure that the surface is dry when applying tack coat.

403.05 Applying Emulsified Asphalt

A. Emulsified Asphalt

Immediately after cleaning the surface, apply emulsified asphalt with the pressure distributor at a rate, established by the Engineer, within the range of 0.05 to 0.10 gallons per square yard of applied emulsion. If the bituminous material is to be placed upon a milled surface, apply at a rate, established by the Engineer, within the range of 0.08 to 0.12 gallons per square yard of applied emulsion. When applying tack coat on freshly-placed asphalt, lower application rates may be permitted, provided a full coverage application is still achieved.

For slurry seal and microsurface, apply a tack coat of SS-1h, CQS-1h, or CQS-1hp emulsion. The tack coat shall consist of one part emulsion

and three parts water. The application rate shall be 0.10 to 0.15 gallons per square yard of the diluted emulsion. The Engineer will determine the actual application rate.

Protect the surfaces of trees and structures adjacent to the area being treated so as to prevent their being splattered or marred.

Allow the tacked surface to dry until it is in a proper condition to receive the next course. Apply tack coat only so far in advance of the paving operations as is necessary to obtain this proper condition of tackiness. Protect the tack coat from damage until the next course is placed.

B. Test Strip

When setting up an initial roller pattern and density test strip for the first layer of asphalt mixture, prepare a tack coat test strip to demonstrate that the proposed equipment and methods will achieve proper application of tack coat.

For the test strip, apply the tack material at a rate of between 0.05 and 0.10 gallons of applied emulsion per square yard. If placing the bituminous material upon a milled surface, apply the tack material at a rate of between 0.08 and 0.15 gallons of applied emulsion per square yard.

In all cases, ensure that the application will result in a minimum double overlap of the actual tack spray as it lands on the surface. Adjustment of the spray-bar and the nozzles may be necessary to achieve this minimum double overlap. Corn-rows or any other pattern that would result in less than double overlap coverage of the tack coat are not acceptable for the tack application. The goal is to have a very thin but uniform coating of asphalt left on the surface when the emulsion has broken.

Once the test strip has been demonstrated and approved by the Engineer, use the same procedure and application rates for the entire project or until another design is proposed and accepted.

C. Fog Sealing of Shoulders

When the Contract requires bituminous material for fog sealing of shoulders, provide emulsified asphalt meeting **403.02**. Apply diluted

emulsified asphalt at a rate of 0.10 to 0.15 gallons per square yard based on a dilution rate of one part emulsified asphalt to one part water. This application may require two equal increments if run-off occurs.

COMPENSATION

403.06 Method of Measurement

The Department will measure Emulsified Asphalt for Tack Coat and Fog Sealing by the ton, as delivered from the terminal, in accordance with **109**.

403.07 Basis of Payment

The Department will pay for accepted quantities, complete in place, at the contract prices as follows:

Item	*Pay Unit*
Emulsified Asphalt for Tack Coat	Ton
Emulsified Asphalt for Fog Seal	Ton

The Department will measure and pay for the work required to prepare the designated surface, as provided for under **403.04**, in accordance with the applicable Section or Subsection under which the work is performed.

SECTION 407 – BITUMINOUS PLANT MIX PAVEMENTS (GENERAL)

DESCRIPTION

407.01 Description

This Section 407 is applicable to all types of bituminous pavements of the asphalt plant mix type as described in **307**, **313**, and **411**. Deviations from these general requirements will be indicated in the specific requirements for each pavement type.

This work consists of constructing one or more courses of bituminous mixture on a prepared foundation in accordance with this Section **407** and the specific requirements of the pavement type under contract.

MATERIALS

407.02 Materials

Provide materials as specified in:

Aggregates	**903**
Mineral Filler	**903.16**
Bituminous Materials	**904**
Chemical Additive	**921.06.B**

Separate aggregate into coarse and fine aggregate stockpiles. If stockpiling of coarse aggregate causes segregation, separate into coarse and medium coarse stockpiles.

Store each size and type of aggregate in a separate pile, bin, or stall. Maintain the storage yard in an orderly condition, clearing a walkway between stockpiles that are not separated by partitions. Make the stockpiles readily accessible for sampling.

The Engineer will conditionally accept the mineral aggregate for quality in the stockpile at the producer's site. The Engineer may conditionally accept the bituminous material at the asphalt terminal. The Engineer will accept for aggregate gradation and asphalt cement content from hot bin samples or sample(s) taken from the completed mix at the asphalt plant after it has been loaded onto the trucks for transport to the Project.

If anti-stripping additive, other than hydrated lime, meeting **921.06.B.1** is required, use approved in-line blending equipment, as specified in **407.04.A.6**, to add it at the mixing plant or inject it at the asphalt terminal.

If the resurfacing plans call for a Performance Grade (PG) asphalt mix with properties greater than that of PG 64-22 and this is the only asphalt grade on the Project, the Contractor may use either the asphalt grade shown on the Plans or an asphalt grade equal to or better than PG 64-22 for driveways and business entrances unless otherwise directed by the Engineer. The Department will pay for this material at the same unit price as bid for the

asphalt or asphalt mix. Mark the material tickets "**FOR DRIVEWAYS AND BUSINESS ENTRANCES ONLY**" at the point of delivery.

If using a warm mix asphalt additive meeting **921.06.B.3**, use approved blending equipment to add it at the mixing plant, or deliver it premixed with the asphalt cement.

For 411-OGFC mixtures, include a stabilizing additive listed on the Department's Qualified Products List (QPL). Do not use fiber pellets. Slag wool fiber or cellulose fiber shall be blown into the asphalt plant measured by a flow meter or sensing device that is accurate to within ±10% of the amount required. For batch plants, add fibers in to the pugmill or weigh hopper. For drum plants, place the fiber line 1 foot upstream of the asphalt binder line so that the fibers are captured by the asphalt binder before being exposed to high-velocity gases in the drum. The minimum additive for a slag wool fiber shall be 0.4% and the minimum for a cellulose fiber shall be 0.3% of the total mix. The addition of a stabilizing additive material (fiber) shall be included in the cost of the asphalt cement.

407.03 Composition of Mixtures

A. General

Develop a bituminous mixture composed of aggregate (coarse, fine, or mixtures thereof), mineral filler if required, anti-strip additive if required, and bituminous material. Ensure that the aggregate fractions are sized, uniformly graded, and combined in such proportions so that the resulting mixture will meet the grading and physical properties of the approved Job Mix Formula (JMF).

B. Gradation and Bituminous Material Requirement

The requested aggregate gradation and bituminous material percentages shown on the JMF shall be within the design ranges specified in **903**, **307**, and **411**, respectively. Establish a recommended asphalt cement content for all mixes, with the final optimum asphalt cement content to be determined by the Engineer.

C. Job Mix Formula (JMF)

1. **General.** At least 14 working days before the scheduled start of production of any asphaltic paving mixture, submit a proposed Job Mix Formula (JMF) and Laboratory Design in electronic form,

alternatively, the Contractor may proportion the aggregate by a linear system based on measured RPM of each feeder belt at a constant gate opening to feed aggregate at a predetermined rate that is set in the control office and that has a readout in the control office. Ensure that the rate of feed as determined from the bin settings agrees with the load cell on the collection belt feeding the dryer within a tolerance of ±10%. If the predetermined tolerance is exceeded, an alarm shall sound, and if corrections are not made within 60 seconds, the plant shall automatically shut down. The aggregate feed system shall employ computer controlled adjustments to automatically produce mix of the correct proportions over the plant's entire range of production rates.

If the Engineer has previously calibrated and approved the plant for temporary manual operation, the plant may run for a period not to exceed 2 working days, or portions thereof, on manual should a computer breakdown occur.

9. **Electronic Data Retention.** The computer system and automatic weighing system shall include means to retain all electronic data during electrical power failures.

407.05 Hauling Equipment

Trucks used for hauling bituminous mixtures shall have tight, clean, smooth metal beds that have been thinly coated with a minimum amount of paraffin oil, hydrated-lime solution, or other approved material from the Department's QPL to prevent the mixture from adhering to the beds. Immediately after loading at the plant, cover each truck with a cover of canvas or other suitable material that is of sufficient size to protect the mixture from the weather. Allow the cover to lap down along the sides and rear of the truck bed a minimum of 6 inches, and use tie downs to secure the cover at a maximum of 5-foot spacing along the sides and rear of the truck bed. When necessary to ensure the mixture will be delivered on the road at the specified temperature, insulate truck beds and securely fasten the covers. Provide a 3/8-inch hole in the side of each truck bed for inserting a thermometer.

407.06 Bituminous Pavers and Material Transfer Devices

A. Pavers

Bituminous pavers shall be self-contained, power-propelled units provided with an activated screed, equipped to be heated, and capable of spreading and finishing courses of bituminous plant mix material in lane widths applicable to the specified typical section and thickness shown on the Plans. All paver extensions shall be full assembly extensions, including activated and heated screeds, auger extensions, auger guards, and throw-back blades to place mix beneath the auger gearbox. When augers are extended, the maximum distance from the augers to the end plate shall be 18 inches. Augers shall be within 4 feet of the end plate on trailing edge extendible screeds; however, if using bolt-on extensions, extend the augers a distance equal to the length of the bolt-on extensions. Do not use strike-off boxes, except on sections of continuously varying width. For shoulders less than 8 feet in width and similar construction, the Contractor may place materials using approved mechanical spreading equipment.

Equip the paver with a receiving hopper that has sufficient capacity for a uniform spreading operation. The hopper shall be equipped with a distribution system to place the mixture uniformly in front of the screed.

The screed or strike-off assembly shall produce a finished surface of the required evenness and texture without tearing, shoving, or gouging the mixture.

Equip all asphalt paving machines with automatic grade and slope controls. Both the grade and slope controls shall be in working order at all times; however, if the automatic controls fail, the Contractor may finish the day's work using manual controls, but shall not resume work the following day until both the grade and slope controls are in first class working order.

The Engineer may allow the Contractor to pave the inside shoulder concurrently with the inside traffic lane, subject to the Engineer's approval of the price adjustment for the mix used on the shoulder and of the paving and rolling equipment. In addition, the paver shall have an articulated screed that can be adjusted to fit the pavement cross-section and a power unit capable of handling the increased loading without undue stress.

B. Material Transfer Devices (MTDs)

Provide a Material Transfer Device (MTD) capable of transferring the asphalt from the truck or trailer to the asphalt paver without coming in contact with the asphalt paver. Use a MTD when placing all asphalt mixes, including shoulder mixes, with the exception that it will not be required when placing CS mix. An exception may be allowed due to lane width or safety issues if approved by the Engineer.

The MTD shall have a minimum storage capacity of 15 tons, and shall be equipped with mixing augers in the bottom of the storage hopper that are capable of remixing or re-blending the material as the material is removed from the storage hopper. The mixing augers shall be operational and used at all times during placement of the asphalt mixes. The MTD shall have a rear discharge conveyor that swivels a minimum of 150 degrees to allow feeding the paving machine from the front, side or rear.

Insert a stationary surge hopper into the paving hopper of the paver being fed by the MTD. The stationary surge hopper shall be considered as part of the MTD and shall have sloping sides (minimum of 60 degrees from horizontal) and a minimum storage capacity of 15 tons.

Obtain the Department's approval of models and manufacturers of MTDs before using on the Project. The Department will make no direct payment for use of an MTD and will consider all cost of furnishing and operating the MTD as incidental to the work.

407.07 Rollers

Provide self-propelled rollers, of steel-wheel, pneumatic tire, and/or vibratory type, which are in good condition and capable of reversing without backlash. Operate rollers at speeds slow enough to avoid displacement of the bituminous mixture. Equip rollers with a device for moistening and cleaning the wheels as required.

The required rollers shall be on the job, inspected, and approved before the start of paving operations.

Rollers shall meet the following additional requirements:

1. The steel-wheel roller shall weigh a minimum of 8 tons and may be either a three wheel or tandem type.

2. The pneumatic tire rollers shall have a minimum contact pressure of 85 pounds per square inch. The roller shall contain two axles upon which at least seven pneumatic-tire wheels are mounted so as to ensure the rear set of tires will not track the front set. The axles shall be mounted in a rigid frame provided with a loading platform or body suitable for ballast loading. Uniformly inflate the tires. Provide the Engineer with charts or tabulations of the contact area and contact pressures for the full range of tire inflation pressures and loadings for each size of roller tire provided. In place of a pneumatic tire roller, the Contractor may substitute a combination roller (pneumatic and steel wheel combination) of the make and model approved by the Department.

3. The Contractor may use vibratory rollers if the Engineer approves the particular roller proposed for use.

When paving the inside shoulder concurrently with the inside traffic lane, provide an additional roller, having a minimum width of 4 feet to a maximum width of 1 foot wider than the inside shoulder being paved, to compact the shoulder. Do not allow either the roller(s) on the inside traffic lane or the roller on the shoulder to traverse between the inside shoulder and the inside traffic lane.

407.08 Small Tools

Provide all necessary small tools, and keep them clean and free from accumulations of bituminous materials.

CONSTRUCTION REQUIREMENTS

407.09 Weather Limitations

The Contractor may place bituminous plant mix on properly constructed and accepted subgrade or previously applied layers if:

1. The subgrade and the surface upon which the bituminous plant mix is to be placed is free of excessive moisture, and

2. The bituminous plant mix is placed according to the temperature limitations specified in Table 407.09-1 and when weather conditions otherwise allow the pavement to be properly placed, compacted, and finished.

Table 407.09-1: Temperature Limitations

Compacted Thickness	Minimum Air or Surface Temperature (°F)	
	Unmodified mixes (PG 64, 67)	Modified mixes (PG 70, 76, 82)
≤ 1.5 inches	45	55
> 1.5 inches to < 3.0 inches	40	50
≥ 3.0 inches	35	45

3. Do not place bituminous plant mix, with a compacted thickness of 1.5 inches or less, between November 30 and April 1. Do not place bituminous plant mix, with a compacted thickness greater than 1.5 inches, between December 15 and March 16. Only place 411-TL, 411-TLD, and 411-OGFC mixtures when the pavement surface temperature and the ambient air temperature are a minimum of 55 °F and rising; limit placement to the period from April 1 to November 1.

4. The Contractor may request a variance from the above required temperature and seasonal limitations to pave at lower temperatures if there is a benefit to the public. Submit such requests in writing at least one week before the anticipated need, and include a Paving and Compaction Plan for Cold Weather that meets the Department's Procedure. The plan shall identify what practices and precautions the Contractor intends to use to ensure the mixture is placed and compacted to meet the specifications. The plan shall include compaction cooling curves estimating the time available for compaction, the intended production, haul, and compaction rates, with paver and roller speeds estimated. The Contractor may consider using such practices as the addition of rollers, reduced production and paving rates, insulated truck beds, and heating the existing surface.

If the specified densities are not obtained, stop all paving operations and develop a new plan. All mixture failing to meet specifications will be subject to price adjustments or removal and replacement at no cost to the Department.

407.10 Conditioning the Existing Surface

If bituminous mixes are to be placed upon an existing concrete pavement, with or without a bituminous overlay, remove all excess bituminous material from joints and cracks. Remove sections of existing pavement that are broken and pumping under traffic. Remove pavement where blowups have occurred at joints or cracks to provide a minimum opening of 1 foot for the full width of the pavement.

If the bituminous mixture is to be placed upon an existing bituminous pavement, remove areas containing excess bitumen and failures in the existing surface and base as directed by the Engineer.

Adjust all manholes and catch basin frames, which are associated with the storm sewer system, to the finished grades of the pavement. Unless otherwise specified, make such adjustments at no additional cost to the Department. The respective Utility Owner(s) will properly adjust all utility manholes, utility valve covers, and similar structures, to the finished grades of the pavement, unless otherwise shown on the Plans.

Remove unsatisfactory subgrade material encountered when removing the existing pavement and replace with approved material. Use overlay mixture or other approved material to fill openings left by the pavement and base removal to the full depth of the existing pavement, as directed by the Engineer, and compact the material in layers not to exceed 3 inches in thickness.

Paint contact surfaces of curbing, gutters, manholes, and other structures with a thin, uniform coating of bituminous material before placing the mixture against them.

When shown on the Plans, bring existing surfaces that are warped and irregular to uniform grade and cross-section using the leveling mixture specified in **307**.

407.11 Preparing the Bituminous Material

A. Hot Mix Asphalt (HMA)

Heat the bituminous materials for hot mixes to the required mixing temperature specified in Table 407.11-1.

Table 407.11-1: Mixing Temperatures

PG Binder Grade	Minimum Temperature (°F)	Maximum Temperature (°F)
PG 64-22, PG 67-22	270	310
PG 70-22	290	330
PG 76-22	290	330
PG82-22	290	330

The temperature for Grading AS, Grading ACRL, and Grading TPB mixtures shall be between 225 and 275 °F, except when modified binders are used, and then the temperatures shall be between 250 and 310 °F. Aggregate should be coated and no visible drain down should occur in storage silos or hauling equipment.

B. Warm Mix Asphalt (WMA)

The Contractor may subject the produced mixture to reduced production and placement temperatures by adding a chemical warm mix additive meeting **921.06.B.3** or by making plant modifications as specified in **407.04.A.12.**

When using either WMA technology, the maximum mixing temperature for any grade of asphalt cement shall be no more than 300 °F. At the beginning of a day's production, the producer may produce up to five truckloads at the temperatures specified in Table 407.11-1 to pre-heat placement equipment (pavers, transfer devices) before producing WMA. Indicate the laboratory mixing and compaction temperatures on the JMF during the mix design approval process. A tolerance of ±5.0 °F for each temperature will be allowed.

During test strip construction, ensure that all plant-produced WMA exhibits the ability to meet the test requirements for tensile strength ratio (TSR), conditioned tensile strength, Marshall Stability and flow,

volumetrics, and boil test, as specified for HMA in specifications **307**, **407**, and **411**. Procedures for testing shall be in accordance with that which is defined for quality control and acceptance in **407.03.D.2.h** and **407.20.B.3**, respectively.

407.12 Preparation of Aggregates

Unless otherwise specified, dry and heat the aggregate for hot mixes so as to produce a completed mix of a uniform temperature as specified in Table 407.11-1. Adjust flames used for drying and heating to avoid damage to the aggregate and to avoid soot on the aggregate.

On all plants requiring screens, screen the hot dried aggregate into two or more fractions as specified. Convey the separated fractions into separate compartments ready for batching and mixing with bituminous material.

407.13 Mixing

Combine the dried aggregates within the mixer in the amount of each fraction of aggregates required to meet the JMF. Measure the bituminous material and introduce it into the mixer in the amount specified by the JMF.

After introducing the required amounts of aggregate and bituminous material into the mixer, mix the materials as long as necessary to obtain a complete and uniform coating of the particles and a thorough distribution of the bituminous material. The Engineer will determine wet-mixing time for each plant and for each type of aggregate used, but in no case shall the wet-mixing time be less than 25 seconds for batch type plants and 40 seconds for continuous mix plants.

The temperature of the completed mixture (determined at the time it is dumped from the mixer), made with aggregates containing absorbed moisture that causes foaming or boiling in the completed mix, shall be not less than 225 °F. The temperature of the mix when it is discharged from the mixer shall not deviate from that specified in **407.11.A**.

The Contractor may place hot-mixed bituminous mixtures in surge or storage silos if the mixture as used from the silos meets all the specification requirements for the particular mix involved.

When using surge or storage silos, as approved by the Engineer, meet the following additional requirements:

1. Provide a surge bin or storage silo system meeting **407.04.A.11**.

2. Empty the storage silos or surge bins when directed by the Engineer to check material quantities.

3. Limit hours of plant operation, whether for storage or direct shipment to the road, to reasonable working hours to allow normal inspection of plant operations.

4. Remove bituminous mixtures placed in a surge bin on the same day in which it is stored.

5. The Contractor may store bituminous mixtures of Gradings A, AS, ACRL, and B for up to 48 hours, and Gradings BM, BM2, C, CS, CW, D, E, and F for up to 96 hours, in a storage silo by complying with the following:

   (a) Add an approved silicone additive to the asphalt cement for mixes to be stored beyond the day of mixing.

   (b) Keep the stored bituminous mixture sealed at all times during storage.

   (c) Fill the storage silo to at least 90% of capacity.

6. The Inspector will take samples of the stored material following the period of storage.

7. The stored material is subject to the same temperature, segregation, and laying requirements as required for unstored plant production.

8. The Engineer will reject mixtures having excessive segregation, lumpiness, or stiffness.

9. Locate the surge bins and storage silos in a position that enables the top of the truckload to be visible to the load operator during the loading operation.

407.14 Spreading and Finishing

For Contracts requiring night work, supply sufficient lighting and equipment as specified in **712.04.H**.

The temperature of the mixture at the time of depositing in the paver hopper shall be as specified in Table **407.11-1**.

Place the mixture upon an approved surface, and spread and strike-off to the established line, grade, and elevation using approved asphalt paving machine(s). The Engineer may approve use of echelon or full-width paving if plant production is capable of supplying the paver so that a constant forward speed can be maintained. Use preset control string lines to control the alignment of the outside edge of the pavement. Where multi-course pavements are placed, offset the longitudinal joint in one layer from that in preceding layer by approximately 1 foot; however, construct the joint in the top layer at the center-line of the pavement if the roadway comprises two lane widths, or at lane lines if the roadway is more than two lanes in width. Pave in the direction of traffic.

Do not feed a paving machine from more than one asphalt plant. Coordinate plant production and paving operations to ensure constant forward movement of the pavers. The Engineer will consider repetitive interruptions or stopping of the paver as cause for stopping the work until the Contractor corrects the situation. If the paver must be stopped for a significant period of time, construct a joint and move the paver from the roadway before the bituminous mixture has cooled sufficiently to prevent proper compaction. If the bituminous mixture cools to the extent that the required density cannot be obtained, remove and replace the mixture at no cost to the Department.

Unevenness of texture, segregation (including end-of-load segregation) as measured by a properly calibrated nuclear gauge, or tearing or shoving of bituminous mixture during the paving operation, shall be reason to stop the paving. Only resume paving operations when the condition is corrected. Immediately remove unacceptable mix and replace at no cost to the Department. The Department will not allow excessive throwing back of the bituminous mixture.

Provide automatic screed controls using either the string line, ski type grade reference system, or a non-contact averaging system on all work regardless of the paver width. The Engineer may require a string line reference system on new construction. If the base has been finished with equipment having automatic grade control or the Contractor demonstrates that an alternate method of spreading and finishing will result in a satisfactory riding surface, the Engineer may conditionally waive the string line requirement and authorize use of the ski type reference system. Regardless, the Engineer may at any time require the use of a string line reference system,

even if previously waived, if in the Engineer's opinion, the use of the string line will result in a superior riding surface. When the string line system is required on a multi-course pavement, use it on at least two courses exclusive of the surface course. When using the ski type system, the ski shall have the maximum practical length and in no case shall it be less than 40 feet in length. Pavement lanes previously placed with automatic controls or to form grade may serve as the longitudinal control reference for placing adjacent lanes by using a ski or joint matching shoe.

The string line reference system shall consist of suitable wire or twine supported by approved devices that are compatible with the type of automatic paver control system used. The string line and supports shall be capable of maintaining the line and grade shown on the Plans at the point of support while withstanding the tensioning necessary to prevent sag in excess of 1/4 inches between supports spaced 50 feet apart. Install additional supports to provide a minimum spacing of 25 feet, or less as directed by the Engineer, to remove the apparent deviation of the string line from theoretical grade.

Provide all materials, equipment, labor, and incidentals necessary to construct the string line reference system, and maintain the system until its use is no longer required. Include the cost of erecting and maintaining the string line reference system in the unit price bid for other items of construction. Have the string line reference system be complete in place at least 300 feet in advance of the point where the pavement is being placed. Automatic screed controls are not required on sections of projects where service connections and other conditions interfere with their efficient operation.

On areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impracticable, take the mixture from the hopper of the spreading machine and distribute it immediately into place using suitable shovels and other tools, and spread the mixture with rakes and lutes in a uniformly loose layer of such depth as will result in a completed course having the required thickness.

The Contractor and the Department will each be required to have an individual onsite that is certified by the Department through the HMA Roadway Certification Course.

407.15 Compaction

A. General

After spreading and striking-off the bituminous mixture and adjusting surface irregularities, thoroughly compact the mixture using methods approved by the Engineer and that are capable of achieving the specified density while the material is in a workable condition. When no density requirements are specified, use a system of compaction for roadway pavements that has previously produced the required bituminous pavement densities. The Engineer may require a control strip and random density samples to evaluate the system.

In general, accomplish compaction using a combination of the equipment specified in **407.07**. As a minimum, meet the following roller requirements, but increase the number of rollers if the required results are not being obtained.

1. Except as noted below, each paving train shall consist of a minimum of three rollers meeting **407.07**. The intermediate roller in each train shall be a pneumatic type. If the surface course contains a latex or polymer additive, the Contractor may use a steel wheel type roller for intermediate rolling instead of a pneumatic type provided the surface course meets density requirements.

2. Provide a minimum of two rollers when placing 307 CS, 411 TL, or 411 TLD mixtures. Perform breakdown rolling, as soon as possible and while the mixture is sufficiently hot, using a pneumatic tire roller having a minimum contact pressure of 85 pounds per square inch. Do not substitute a combination roller for a pneumatic roller when placing CS mix. Regulate the paver speed so rollers can maintain proper compaction of the mixture as determined by the Engineer.

3. With the Engineer's approval, the Contractor may reduce the minimum number of rollers listed above to one roller of either the steel-wheel or vibratory type on the following types of construction and projects:

    a. Shoulder construction,

b. Incidental construction such as bridge approaches and driveways, and

c. Projects containing less than 10,000 square yards of bituminous pavement.

4. Compaction of 411-OGFC mixtures shall consist of a minimum of two passes with a steel double drum asphalt roller with minimum weight of 10 tons, before the material temperature has fallen below 185 °F. Provide a minimum of two roller units so as to accomplish the compaction promptly following the placement of the material. At no time shall a pneumatic tire roller be used or a steel wheel roller be used in vibratory mode. If the roller begins to break the aggregate, immediately stop rolling.

Unless otherwise directed by the Engineer, begin rolling at the low side and proceed longitudinally parallel to the road centerline. When paving in echelon or abutting a previously placed lane, roll the longitudinal joint first, followed by the regular rolling procedure. When paving in echelon, rollers shall not compact within 6 inches of an edge where an adjacent lane is to be placed. Operate rollers at a slow uniform speed with the drive wheels nearer the paver, and keep the rollers as nearly as possible in continuous operation. Continue rolling until all roller marks are eliminated. Do not park rollers on the bituminous pavement.

To prevent adhesion of the mixture to the rollers, keep the wheels properly moistened with water or water mixed with very small quantities of detergent or other approved material. Limit excess use of liquid.

Do not refuel rollers on bituminous pavements.

Along forms, curbs, headers, walls and other places not accessible to the rollers, compact the mixture thoroughly using hot hand tampers, smoothing irons, or with mechanical tampers. On depressed areas, the Contractor may use a trench roller to compact the mix.

B. Density Requirements

Meet the applicable density requirements specified in Tables 407.15-1 to 407.15-4.

Table 407.15-1: Density Requirements for ADT 1,000 or less

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
A	90	87
B, BM & BM2	90	87
C & CW	90	87
D	90	87
E	90	87

Table 407.15-2: Density Requirements for ADT 1,000 to 3,000

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
A	91	89
B, BM & BM2	91	89
C & CW	91	89
D	91	89
E	91	89

Table 407.15-3: Density Requirements for ADT 3,000 or greater

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
A	92	90
B, BM & BM2	92	90
C & CW	92	90
D	92	90
E	92	90

Table 407.15-4: Density Requirements for any ADT

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
Shoulder Mix (B, BM, BM2, D or E)	88	85
AS and A-CRL	None [1]	None
CS	None [1]	None
TL, TLD, and OGFC	None	None

[1] The Department will waive density requirements on Bituminous Plant Mix Base Grading ACRL, Grading AS and Bituminous Plant Mix Leveling Course, Grading CS; however, the Contractor shall use a system of compaction for roadway pavements that has been approved by the Engineer. When placing Bituminous Plant Mix Base Grading ACRL and Grading AS, the Contractor may replace the specified intermediate roller (pneumatic tire) with a steel-wheel type if irreparable damage to the pavement is occurring.

Correct base or surface course that tests below the minimum density so that the density of the area is equal to or above the minimum, at which point it can be used to determine the average density of the lot. Do not place any successive layers until the area has been corrected. As necessary to determine the classification of open graded or dense graded mixes and to measure segregation, use AASHTO T 269 or ASTM D3203.

Repair or replace defective mixture to the satisfaction of the Engineer and at no cost to the Department.

The Department will perform density testing in accordance with **407.20.B.5**.

C. Test Strips

Construct test strips for all A, B, BM, BM2, C, CW, D, and E mixes to establish rolling patterns, to calibrate nuclear gauges, to verify that the base course or surface course meets the density requirements of the specifications, and for mix design and production verification as required.

Before constructing the test strip, obtain the Engineer's approval of the underlying base or other pavement course. Compact the test strip using equipment as specified in this subsection and **407.07**.

Construct the test strip at the beginning of work on the pavement course. Prepare new test strips when:

1. A change in the JMF is necessary;

2. A change in the source of materials occurs;

3. A change in the material from the same source is observed;

4. There is reason to believe that the test strip density is not representative of the bituminous mixture being placed; and when

5. A change in paving or compaction equipment occurs.

With the approval of the Engineer, the Contractor may construct additional test strips.

Construct each test strip with approved bituminous mixture. The test strip shall remain in place as a section of the completed work. Construct each test strip to be 1 paver width wide, with an area of at least 400 square yards and of the depth specified for the pavement course concerned.

Immediately after placing the bituminous mixture, begin compacting the test strip. Perform compaction in a continuous and uniform manner over the entire test strip.

Continue compacting the test strip until additional roller coverage will produce no appreciable increase in density (1 pound per cubic foot), as measured using a nuclear gauge. Use the roller coverage necessary to obtain this maximum density as the rolling pattern for the remainder of the project.

Take cores on the test strip at ten randomly selected locations as designated by the Engineer. Do not take cores within 2 feet of the longitudinal edges for calibration. Provide these cores to the Department for use in calibrating the nuclear gauge and to verify that

the average density of the test strip meets the density requirements of the specifications. The Department will report all densities using the corrected nuclear gauge readings. Correction factors are specific to the nuclear gauges used during the test strip construction. If a different nuclear gauge needs to be used for acceptance, it will be necessary to cut new cores from the ongoing pavement construction to calibrate the new gauge.

When testing test strip cores, the Department will determine density (bulk specific gravity) in accordance with AASHTO T 166, Method A only. All core samples shall be completely dry before testing. Air drying is permitted provided core samples are weighed at 2-hour intervals until dry in accordance with AASHTO T166, Section 6.1. Cores may also be dried in accordance with ASTM D7227.

If the density of the asphaltic concrete in the test strip does not meet specification requirements, make whatever changes are necessary to obtain the specified density. Use other sources and combinations of aggregates as necessary, subject to the Engineer's approval, to produce a mix meeting the required density.

407.16 Joints

Place bituminous paving as continuously as possible. Do not pass rollers over the unprotected end of a freshly laid mixture unless approved by the Engineer. Form transverse joints by cutting back on the previous run to expose the full depth of the course. Use a brush or sprayed coat of bituminous material on contact surfaces of longitudinal and transverse joints just before placing additional mixture against the previously rolled material.

407.17 Pavement Samples

When directed, cut samples from the compacted pavement for testing by the Engineer. Take samples of the mixture for the full depth of the course at locations selected by the Engineer. Cut the samples with a power saw or core drill. Samples shall have a top surface area of at least 10 inches.

Fill holes left by taking samples with the same type mixture that was used to construct the course sampled, and compact to conform to the surrounding pavement. Cut samples and repair sample holes at no cost to the Department.

407.18 Surface Requirements

Test the surface with a 12-foot straightedge applied parallel to the centerline of the pavement. The deviation of the surface from the testing edge of the straightedge shall not exceed that specified for the respective types of bituminous construction under the applicable Subsections of these Specifications.

Test the transverse slopes of tilted pavements with a string-line and string-level applied at right angles to the centerline of the pavement. The percent of slope, when computed for the full width of the pavement, shall not deviate more than 0.5 percentage points from that shown on the Plans.

Test the crown in crowned pavements with a string-line applied at right angles to the centerline of the pavement. The crown shall not deviate more than 1/2 inch from that shown on the Plans.

Correct deviations that exceed the specified tolerances. Remove and replace pavement that cannot be corrected to comply with the specified tolerances at no cost to the Department.

COMPENSATION

407.19 Method of Measurement

The Department will measure:

1. Asphalt cement and mineral aggregate, including mineral filler when required, by the ton and as follows:

    a. If the mix is loaded from a storage or surge bin, the Department will determine quantities by weighing the completed mix on truck scales meeting **109** and calculating the weight of asphalt cement and mineral aggregate based on the percentages measured into the mix by the appropriate scales or meters as specified in **407.04**.

    b. If the mix is loaded directly into the hauling equipment from a batch plant, the Department will measure asphalt cement and mineral aggregate in batch quantities by scales or scales and meters as specified in **407.04.B.**

c. If a continuous mix plant is used, the Department will measure Bituminous Material for Bituminous Plant Mix Pavement by the ton in accordance with **109**. The Department will determine quantities of mineral aggregate, including mineral filler when required, by weighing the bituminous pavement mixture on truck scales meeting **109**, and deducting the weight of the bituminous material from the weight of total mixture accepted.

d. If recycled mix is permitted, the Department will measure the completed mix, including new mineral aggregate, planings, asphalt cement, and additive, by the ton in accordance with **109**.

2. Removal and disposal of existing surface (concrete) by the square yards in accordance with **109,** if such work is required as specified in **407.10**. Such measurement will include the removal of bituminous overlay.

3. Removal and Disposal of Existing Surface (Bituminous) by the square yards in accordance with **109**. Such measurement shall include the removal of base material, except concrete, as directed by the Engineer.

4. Removal of unsatisfactory subgrade material where existing pavement has been removed by the cubic yard, in accordance with **203.09**. The Department will measure material used to replace such undercutting in accordance with the specification for the type of material used.

5. Adjustment of catch basin grates and frames, water valve boxes, gas valve boxes and manhole covers and frames by each when required.

6. Liquid anti-strip additive by the gallon.

7. Hydrated lime by the ton.

The Department will measure bituminous mixtures used to fill openings left by pavement removal as specified in this Subsection **407.19**. The Department will measure base materials used to fill openings left by base removal as provided for in the respective Sections for each type specified.

The Department will not measure chemical additives or modifiers, when required, for payment, but will consider them incidental to asphalt cement.

The Department will not measure mineral filler separately for payment, but will consider it incidental to mineral aggregates.

407.20 Basis of Payment

A. General

The Department will pay for accepted quantities of Asphaltic Concrete (Hot Mix) with or without recycled material, at the contract prices, complete in place, as follows:

Item	*Pay Unit*
Bituminous Plant Mix Base (Hot Mix)	Ton
Aggregate	Ton
Asphalt Cement	Ton

The Department will pay for liquid anti-strip additive and hydrated lime anti-strip additive based on certified invoices of material cost not to exceed $15 per gallon and $90 per ton, respectively. This payment is full compensation for all labor, materials, equipment, and other incidentals incurred in using the anti-strip additive.

The Department will pay for accepted quantities of Prime Coat or Tack Coat as specified in **402** or **403**, respectively.

The Department will pay for the work required to prepare the subgrade, sub-base, base, or surface in accordance with **307.06** and **411.06** as provided for in the applicable Section or Subsection under which the work is performed.

The Department will not make direct payment for polymer or latex additives, but will consider such additives to be included in the price bid for the modified asphalt cement or modified mixture.

B. Acceptance of the Mixture

1. **General.** The Department will perform all necessary sampling and testing for acceptance purposes in strict conformance with the Department's Policies in addition to monitoring and observing the

Contractor's quality control test procedures and results. However, the Engineer will reject for use in the work any load or loads of mixture which, in the Engineer's opinion, are unacceptable due to excessive segregation, improper coating of aggregates, or excessively high or low temperature.

The Engineer will accept bituminous mixture at the plant with respect to gradation and asphalt content, on a lot basis. A standard size lot at the asphalt plant will consist of a day's production. The number of sublots in a lot will vary from n=1 to n=4 according to Table 407.20-1.

Table 407.20-1: Sublot Requirements

Quantity (tons)	Number of Sublots
3001 – 4000	4 tests
2001 – 3000	3 tests
1001 – 2000	2 tests
Less than 1000	1 test

When the total plan quantity of any mix is less than 500 tons, the Department will accept the mix on the basis of visual inspection and Contractor Quality Control certification. The Department may run extraction, gradation analysis, or other tests deemed necessary for acceptance purposes.

2. Defective Materials

a. Acceptance or Rejection. Consider the Engineer's decision to be final as to the acceptance, rejection, or acceptance at an adjusted payment of the lots.

It is the intent of these specifications that each lot of material will meet specification requirements at the time of acceptance testing. The Department will not take check samples for acceptance purposes.

All acceptance samples will be split, and half of the sample will be retained by the Inspector. If the results of an acceptance test are questioned, the Central Laboratory will test the remaining half of the acceptance sample. The Department

will use the results obtained by the Central Laboratory to evaluate the quality of the lot.

b. Disposition of Lots. Remove and replace, at no cost to the Department, nonconforming lots of materials, products, or complete construction that cannot be corrected by reworking. Alternatively, the Department may accept the nonconforming work at an adjusted payment as specified in these Specifications or as directed by the Engineer.

When a deficiency is determined, the Department will apply the applicable payment as specified in these Specifications to the entire lot. When multiple deficiencies occur, the Department will apply the applicable partial payments to the lot of material that is identified by each deficiency. The Department will apply the payment adjustment for each deficiency separately so as not to affect any other payment adjustment occurring for the same lot; however, if there are two or more deficiencies in the gradation acceptance tests, the Department will apply only the greater payment adjustment. When an area or linear measurement is used to specify lot size, the Department will determine the equivalent tons of mix placed in each lot by using the average calculated spread from the plant inspector's daily report for that day's production.

3. Acceptance. The Engineer will base acceptance of the mixture on test results of consecutive random samples taken from each lot. One random sample will be taken from each sublot. The bituminous mixture will be sampled at the plant according to AASHTO T 168. The percent bitumen content of the mixture will be determined according to AASHTO T 164 or by AASHTO T 308 except as herein revised.

The Contractor may use an approved ignition furnace instead of a vacuum extractor for the use in determining asphalt content and gradation. The method of calibration and test procedures shall comply with AASHTO T 308 Method A and the following.

At least once per week, per mixture, during production, check the AASHTO T 308 correction factors with a sample of the aggregate mixture proportions, blended at the optimum asphalt content. Adjust the correction factor accordingly. Keep records of all correction factors for all mixtures. Adjusted payment for asphalt

content and gradation will be based on the ignition furnace results as specified in Table 407.20-2. Use of this alternative equipment shall be at no additional cost to the Department.

The percents passing the sieves will be determined in accordance with AASHTO T 30.

Table 407.20-2: Acceptance Schedule of Payment (Asphalt Plant Mix Characteristics)

Characteristics	Pay Factor	Average Arithmetic Deviation of the Lot Acceptance Test from the JMF	
		1 Test	2 Tests or more
Asphalt Cement Content [1] (Extraction or ignition oven)	1.00	0.00-0.30	0.00-0.25
	0.95	0.31-0.35	0.26-0.30
	0.90	0.36-0.40	0.31-0.35
	0.80 [2]	over 0.40	over 0.35
Gradation 3/8 inch sieve and larger	1.00	0.00-6.50	0.00-5.70
	0.95	6.51-7.08	5.71-6.20
	0.90	7.09-7.66	6.21-6.69
	0.80 [2]	over 7.66	over 6.69
Gradation No. 4 sieve [3]	1.00	0.00-4.62	0.00-4.00
	(0.95	4.63-5.20	4.01-4.50
	0.90	5.21-5.77	4.51-5.00
	0.80 [2]	over 5.77	over 5.00

Characteristics	Pay Factor	Average Arithmetic Deviation of the Lot Acceptance Test from the JMF	
		1 Test	2 Tests or more
Gradation No. 8, 16, 30 & 50 sieves [3]	1.00	0.00-3.80	0.00-3.30
	0.95	3.81-4.46	3.31-3.91
	0.90	4.47-5.12	3.92-4.52
	0.80 [2]	over 5.12	over 4.52
Gradation No. 100 & 200 sieves [3]	1.00	0.00-1.80	0.00-1.60
	0.95	1.81-2.00	1.61-1.75
	0.90	2.01-2.20	1.76-1.90
	0.80 [2]	over 2.20	over 1.90

[1] Does not apply to 307 Grading A, AS, or ACRL mixes.

[2] If approved by the Engineer, the Contractor may accept the indicated partial pay. The Department may require removal and replacement at no cost. The Contractor may remove and replace at no cost to the Department at any time.

[3] When there is more than one reduced payment relating to gradation in 1 lot of material, only the greatest reduction in payment will be applied. Reductions applicable for any other reason will be cumulative.

Deduction for both asphalt content and gradation deficiencies will be cumulative. The Department will apply deductions to the total price of the mix (asphalt cement and aggregate combined) under the item for Asphalt Cement Content and Gradation Deduction.

4. **Additional Tests.** The Engineer may perform any test at any time to determine the effectiveness of the Contractor's quality control. In addition, the Department will conduct production verification tests parallel to that which is defined for quality control in **407.03.D.2.h**.

5. **Acceptance for Mix Density on the Roadway.** The Department will apply a deduction in payment, not as a penalty but as liquidated damages, for failure to meet the density requirements specified in **407.15**. As soon as practicable after the final rolling is completed on each lot, the Department will perform 5 density tests at locations determined by the Engineer, and will compute an average of all such tests. Deductions for failure to meet density requirements will be computed to the nearest 0.1% as a percentage

of the total payment otherwise due for each lot. The percent of total payment to be deducted will be 5 times the percent the average in-place density for each lot that fails to meet **407.15**. The Department will make deductions in monies due the Contractor for failure to meet the density requirements under the item for Density Deduction. The Department will conduct acceptance testing for density in accordance with ASTM D2950 unless otherwise specified. The Department inspector will be a certified Asphalt Roadway Technician.

For density testing purposes, the Department will divide the pavement into lots of 10,000 square yards, except for 307 Gradings A, B, BM, and BM2, which will be divided into lots of approximately 5,000 square yards. Five density tests will be performed in each lot and the average results compared with the requirements specified in Tables **407.15-1** to **407.15-4**. At the beginning of a project or at any time it is deemed advisable, the Department may consider smaller lots to evaluate compaction methods or for other reasons as approved or directed by the Engineer.

The Department will randomly select acceptance test samples that are representative of the lot or sublot. Although performing compaction after the acceptance test is acceptable, the Department will use the original test result to determine lot density. The Department may take information only samples to spot check compaction, but will not use these tests for acceptance testing.

C. Adjustments

1. **Asphalt Cement Adjustment.** If the Engineer sets an asphalt content other than that specified in Tables **307.09-1** and **411.09-1**, the Department will calculate a price adjustment, based on the asphalt content set by the Engineer and the Monthly Bituminous Index for the specific grade asphalt on the mix design, according to the following formula:

$$PA = \frac{MBI \times (DA - BA) \times T}{100}$$

Where:

PA = Price Adjustment

MBI	=	Monthly Bituminous Index
DA	=	Percent asphalt set on the mix design
BA	=	Percent asphalt specified above to be used for bidding
T	=	Total tons asphalt mix for price adjustment

2. Specific Gravity. In cases where the effective combined specific gravity of the mineral aggregate exceeds 2.80, the Department will adjust the tonnage of mineral aggregate, or plant produced mixture, for payment by multiplying the tonnage of mineral aggregate, or plant produced mixture, used by a specific gravity of 2.80 and dividing by the higher specific gravity.

3. Loss on Ignition (LOI). If the approved JMF includes a surface mixture of limestone with gravel, granite, slag, quartzite or gneiss, perform tests for the percent LOI of the limestone aggregate in the asphalt paving mix as specified in **407.03.E.3**.

If the percent of LOI in the aggregate differs by more than ±2% from the LOI indicated in the JMF, the Department will make a payment deduction in the price bid for the mix, not as a penalty but as liquidated damages. The percent of total payment to be deducted will be 5 times the percent that the LOI exceeds the JMF tolerance of ±2%.

Replace or overlay all mix produced with aggregate tested and found to have a LOI that differs more than ±6% from the LOI indicated in the JMF at no additional cost to the Department.

To determine the deduction, the Department will use lots of approximately 5,000 square yards. The Department inspector will perform sampling and testing to establish the LOI according to the Department's sampling and testing procedures. If the initial tests indicate a variation in the LOI of greater than ±2% than the value shown on the mix design, the Contractor shall perform the additional sampling necessary to establish the LOI of the aggregate in each lot, with the cost of the sampling being included in the contract unit prices bid for the paving items.

The Department will make deductions for excess variation in LOI under the item for Material Variation (Deduction).

SECTION 411 – ASPHALTIC CONCRETE SURFACE (HOT MIX)

DESCRIPTION

411.01 Description

This work consists of constructing an asphaltic concrete pavement, composed of a mixture of coarse aggregate, fine aggregate, mineral filler if specified or required, and asphalt cement, on a prepared roadbed at the rate of application shown on the Plans or established by the Engineer.

The provisions of **407** shall apply to this work unless otherwise stipulated.

MATERIALS

411.02 Materials

Provide materials as specified in:

Mineral Aggregate	**903.11**
Mineral Filler	**903.16**
Asphalt Cement, PG 64-22, 70-22, 76-22 or 82-22	**904.01**
Chemical Additive	**921.06.B**

The Engineer will accept mineral aggregate, bituminous material, and plant mix in accordance with **407.02**.

411.03 Composition of Mixtures

A. General

Composition of mixtures shall be as specified in **407.03**.

B. Proportioning

Combine the specified mineral aggregate and asphalt cement according to the proportions specified in Table 411.03-1.

Table 411.03-1: Proportions of Total Mixture, Percent by Weight

Surface Course	Effective Combined Mineral Aggregate	Asphalt Cement
Grading D	93.0 - 94.3	5.7 - 7.0 [1]
Grading E [2]	93.0 - 94.3	5.7 - 7.0 [1]
Grading E (shoulders)	92.0 - 94.7	6.0 - 6.5 [1]
Grading TL	92.5 - 94.3	5.7 - 7.5 [1]
Grading TLD	93.0 - 94.3	5.7 - 7.0 [1]
Grading OGFC	92.0 - 94.0	6.0 - 8.0 [1]

[1] If the effective combined specific gravity of the aggregate exceeds 2.80, the above proportions may be adjusted as directed by the Engineer. The upper limit for flow values shall not apply to mixes with modified asphalt liquids.

[2] The minimum allowable asphalt cement content for 411E low volume mixtures is 5.3%.

1. **Grading D.** In addition to the other requirements of these Specifications, the composition of the mineral aggregate shall be such that when combined with the required amount of bitumen, the resultant mixture will meet Table 411.03-2.

Table 411.03-2: Mixture Properties (All Roads)

Mix[1]	Stability, Min. lb-ft [2]	Flow 0.01 inch [3]	Design Void Content % [2]	Production Void Content % [2]	VMA, Min. % [2]	Dust-Asphalt Ratio [4]
411D	2,000	8 – 16	4.0 ± 0.2	3 - 5.5	14	0.6 - 1.2

[1] In order to identify critical mixes and make appropriate adjustments, the mix design shall have these required production properties for the bitumen content range of Optimum Asphalt Cement ±0.25%.

[2] Tested in accordance with AASHTO T 245 with 75 blows of the hammer on each side of the test specimen, using a Marshall Mechanical Compactor.

[3] Flow will only be required when using a non-modified binder (PG 64-22 or 67-22).

[4] The dust to asphalt ratio is the percent of the total aggregate sample that passes the No. 200 sieve, as determined by AASHTO T 11, divided by the percent asphalt in the total mix.

2. Grading E. In addition to the other requirements of these Specifications, if using Grading E for the riding surface, the composition of the mineral aggregate shall be such that, when combined with the required amount of bitumen, the resultant mixture will meet Table 411.03-3.

Table 411.03-3: Mixture Properties (High vs. Low Volume Roads)

Mix	Traffic Volume	Stability Minimum lb-ft [1, 3]	Flow 0.01 inch [2]	Design Void Content % [1]	Production Void Content % [1]	VMA, Min % [1]
411E	High Volume (ADT > 1,000)	2,000	8 - 16	4.0 ± 0.2	3 - 5.5	14
411E	Low Volume (ADT ≤ 1,000)	1,500	8 - 16	3.5 ± 0.5	2 - 5	n/a

[1] Tested according to AASHTO T 245 with 75 blows of the hammer on each side of the test specimen, using a Marshall Mechanical Compactor.

[2] Flow will only be required when using a non-modified binder (PG 64-22 or 67-22)

[3] Minimum stability for shoulder mixes will be 1,500 lb-ft and optimum asphalt cement content for shoulder mixes shall be as directed by the Regional Materials Supervisor.

If the design criteria specified above cannot be obtained with the aggregate submitted to the laboratory for design, provide another source of aggregate.

3. Gradings TL and TLD. In addition to the other requirements of these specifications, the composition of the mineral aggregate shall be such that, when combined with the required amount of bitumen, the resultant mixture will meet Table 411.03-4.

Table 411.03-4: Mixture Properties (Gradings TL and TLD)

Mix	Stability, Min lb-ft [1]	Design Void Content % [1]	Production Void Content % [1]	Minimum VMA % [1]	Dust-Asphalt Ratio [2]
411TL	2,000	4.0 ± 0.2	3 - 5.5	16	1.0 - 2.0
411TLD	2,000	3.8 ± 0.3	3 - 5.5	14	0.6 - 1.2

[1] Tested according to AASHTO T 245 with 75 blows of the hammer on each side of the test specimen, using a Marshall Mechanical Compactor.

[2] The dust to asphalt ratio is the percent of the total aggregate sample that passes the No. 200 sieve, as determined by AASHTO T 11, divided by the percent asphalt in the total mix.

4. Grading OGFC. In addition to the other requirements of these specifications, the composition of the mineral aggregate shall be such that, when combined with the required amount of bitumen, the resultant mixture will meet Table 411.03-5.

Table 411.03-5: Mixture Properties (Grading OGFC)

Mix	Minimum Void Content %	Voids in Coarse Aggregate % [1]	Max. Cantabro Abrasion Loss (Non-Aged) % [1]	Drain Down Loss % [2]
411OGFC	20	$VCA_{DRC} > VCA_{MIX}$	20	<0.3%

[1] As described in National Asphalt Pavement Association (NAPA) Publication IS-115, "Design, Construction and Maintenance of Open-Graded Friction Courses"

[2] Tested in accordance with AASHTO T 305.

C. Recycled Asphalt Pavement and Recycled Asphalt Shingles

1. Recycled Asphalt Pavement. The Contractor may use asphalt pavement that has been removed from a Department project or other State Highway Agency project by an approved method and stored in a Department approved stockpile. RAP combined with the appropriate aggregate, asphalt cement, and anti-strip additive

when required shall produce a mixture that will otherwise meet all the requirements specified in **903.11** and this Section **411**. The Contractor may use RAP in each mix specified in Table 411.03-6.

Table 411.03-6: Use of Recycled Asphalt Pavement

Mix Type	% RAP (Non-processed) (1)	Maximum % RAP (Processed) (2)	Maximum % RAP Processed and Fractionated (3)	Maximum Particle Size (inch)
411D (PG64-22, PG67-22)	0	15	20	1/2
411D (PG70-22, PG76-22, PG82-22)	0	10	15	1/2
411E (Roadway)	0	15	20	1/2
411E (Shoulder)	15	30	35	1/2
411TL (PG64-22, PG67-22)	0	15	15	5/16
411TL (PG70-22, PG76-22, PG82-22)	0	10	10	5/16
411TLD (PG64-22, PG67-22)	0	15	15	5/16
411TLD (PG70-22, PG76-22, PG82-22)	0	10	10	5/16

(1) "Non-processed" refers to RAP that has not been crushed and screened or otherwise sized such that the maximum recycled material particle size is less than that listed above prior to entering the dryer drum.

(2) "Processed" refers to RAP that has been crushed and screened or otherwise sized such that the maximum recycled material particle size is less than that

Mix Type	% RAP (Non-processed) (1)	Maximum % RAP (Processed) (2)	Maximum % RAP Processed and Fractionated (3)	Maximum Particle Size (inch)

above prior to entering the dryer drum.

(3) "Fractionated" refers to RAP that has been processed over more than one screen, producing sources of various maximum particle sizes (e.g., 3/4 to 1/2 inch, 1/2 inch to #4, etc.). The Contractor may use the larger percentages of fractionated RAP specified only if individual fractions of two different maximum particle size are introduced into the plant as separate material sources for increased control.

All mixes shall contain at least 80% virgin asphalt, except for 411E Shoulder Mix which shall have at least 65% virgin asphalt.

Obtain a representative sample from the recycled material stockpile and establish a gradation and asphalt cement content as required. Determine the gradation and asphalt content of the recycled material at the beginning of a project and every 2,000 tons thereafter. The stockpile asphalt cement content for all recycled material shall not vary from the JMF by more than ± 0.8%. Table 411.03-7 specifies the stockpile gradation tolerance for all recycled material on each sieve.

Table 411.03-7: Stockpile Gradation Tolerances for Recycled Material

Size	Tolerance
3/8 inch sieve and larger	± 10%
No. 4 sieve	± 8%
No. 8 sieve	± 6%
No. 30 sieve	± 5%
No. 200 sieve	± 4%

The Contractor is responsible for its own sampling and testing of the RAP as well as new materials for bid purposes, and for submitting the JMF as specified in **407.03**. After mixing, the moisture content of the total mix shall be no more than 0.1% as

determined by oven drying, and the provisions for lowering the temperature because of boiling or foaming shall not apply.

The Engineer will accept mixture for aggregate gradation and asphalt content based on extractions in accordance with AASHTO T 164 or in accordance with AASHTO T 308.

2. **Recycled Asphalt Shingles (RAS).** Recycled Asphalt Shingles (RAS) may be included to a maximum of 5% of the total weight of mixture. The percentage of RAS used will be considered part of the maximum allowable RAP percentage. The ratio of added new asphalt binder to total asphalt binder shall be 80% or greater for all 411 mixes. Either the mix producer or the RAS supplier shall obtain a representative sample from the recycled material stockpile and establish a gradation and asphalt cement content as required. Determine shingle asphalt binder content according to AASHTO T 164 Method A, with a minimum sample size of 500 grams. Determine the gradation and asphalt content of the recycled material at the beginning of the Project and every 2,000 tons of recycled material used thereafter. The stockpile asphalt cement content for all recycled material shall not vary by more than 0.8%. All RAS material shall be processed to a minimum 100% passing the 3/8 inch sieve and a minimum 90% passing the No. 4 sieve.

   To conduct the gradation testing, air dry a 500 to 700-gram sample of processed shingle material, dry sieve over the 3/8-inch and No. 4 sieves, and weigh. For mix design purposes, the Contractor may use the aggregate gradation specified in Table 411.03-8 as a standard gradation instead of determining the shingle gradation according to AASHTO T 30.

Table 411.03-8: Standard Gradation (for Mix Design Purposes)

Sieve Size	Total Percent Passing
3/8 inch	100
No. 4	97
No. 8	95
No. 16	80
No. 30	60
No. 50	50
No. 100	40
No. 200	30

An aggregate bulk specific gravity (G_{sb}) of 2.650 may be used instead of determining the shingle aggregate G_{sb} according to AASHTO T 84. In addition, the effective binder available for mixing with additional aggregates shall be considered as 75% of the total binder content as determined by AASHTO T 164 and shall be the value listed as the RAS binder content on the JMF.

Scrap asphalt shingle shall not contain extraneous waste materials. Extraneous materials including, but not limited to, asbestos, metals, glass, rubber, nails, soil, brick, tars, paper, wood, and plastics, shall not exceed 0.5% by weight as determined on material retained on the No. 4 sieve. To conduct deleterious material testing, take a representative 500 to 700-gram sample of processed shingle material, place over the No. 4 sieve, and pick and weigh all extraneous waste material retained on the No. 4 sieve. Base the percent of extraneous material on the total sample weight.

RAS shall contain less than the maximum percentage of asbestos fibers based on testing procedures established by the Department, or State or Federal environmental regulatory agencies. Analyze a minimum of one sample of processed asphalt roofing material for every 500 tons of material processed for the presence of asbestos.

Before a JMF for a particular design is approved, submit the following, along with the materials and information specified in **407.03**:

a. Certification by the processor of the shingle scrap describing the shingle scrap content and source.

b. A 1000-gram sample of the processed RAS material for inspection (new designs only).

Stockpile RAS separately from other salvage material. Do not blend RAS material in a stockpile with other salvage material. Do not blend Manufacture Waste Scrap Shingles (MWSS) and Tear-Off Scrap Shingles (TOSS). In addition, do not blend virgin sand material with the processed shingles, to minimize agglomeration of the shingle material.

All RAS supplied to a Department project shall come from a certified shingle processor/supplier approved by the Division of Materials and Tests.

D. Anti-Strip Additive

Check asphaltic concrete surface mixtures (Grading D and E) for stripping by the Ten Minute Boil test for dosage rate and ASTM D4867 (Root-Tunnecliff procedure) for moisture susceptibility.

If moisture susceptibility is indicated, then mix an approved anti-strip agent with the asphalt cement at the dosage recommended by the respective test and as specified in **921.06.B**.

EQUIPMENT

411.04 Equipment

Provide equipment as specified in **407.04** through **407.08**.

To construct shoulder mixes with recycled material, provide equipment that complies with **407**, except modify the asphalt plant as approved by the Engineer to accommodate the addition of asphalt planings. If using a batch plant to produce recycled mix, heat the aggregate to a temperature that will transfer sufficient heat to the cold planings to produce a mix of uniform temperature within the specified range.

CONSTRUCTION REQUIREMENTS

411.05 General Requirements

Construct the pavement as specified in **407.09**, **407.11**, **407.12**, and **407.14** through **407.17** and the following Subsections.

411.06 Preparing the Designated Surface

Prepare the designated surface upon which the material is to be placed as specified in **404.05.**

Ensure that loops used for traffic signals are installed before applying the final surface.

411.07 Mixing

Perform mixing as specified in **407.13**. In addition, the mixing cycle for surface course mixtures may require a dry-mixing period.

411.08 Surface Requirements

The surface shall meet the requirements specified in **407.18**, and when tested according to the provisions of that Subsection, the deviation of the surface from the testing edge of the straightedge shall not exceed 1/4 inch.

COMPENSATION

411.09 Method of Measurement

The Department will measure Mineral Aggregate, including Mineral Filler when required, Asphalt Cement for Asphaltic Concrete Surface (Hot Mix), and other related items in accordance with **407.19**.

For bidding purposes, use the asphalt cement content specified in Table 411.09-1.

Table 411.09-1: Asphalt Cement Content

Mix Type	Asphalt Content, %
411-D	5.9
411-E Roadway	6.3
411-E Shoulder	6.3
411-TL	6.3
411-TLD	5.9
411-OGFC	6.0

If the Engineer sets an asphalt content other than that specified above, the Department will make a price adjustment based on the asphalt content set by the Engineer and the Monthly Bituminous Index for the specific grade asphalt cement on the mix design. The Department will calculate a price adjustment in accordance with **407.20**.

411.10 Basis of Payment

The Department will pay for accepted quantities of Asphaltic Concrete Surface (Hot Mix) or asphaltic Concrete Surface (Hot Mix) (Shoulders) with or without recycled material, at the contract prices, complete in place, in accordance with **407.20**.

SECTION 415 – COLD PLANING OF BITUMINOUS PLANT MIX PAVEMENTS

DESCRIPTION

415.01 Description

This work consists of cold planing an existing bituminous plant mix pavement.

EQUIPMENT

415.02 Equipment

Provide a power broom, a water truck, and a planing machine, as well as equipment to remove the material planed from the pavement.

The planing machine shall be a power operated, self-propelled milling machine or grinder capable of removing bituminous concrete to the required width, depth, profile, cross-slope, and surface texture. The machine shall be capable of accurately establishing profile by referencing from either the existing pavement or from an independent grade control and shall have positive means for controlling cross-slope. The machine shall have a floating moldboard with sufficient down pressure to plane the milled surface. The machine shall have an effective means of removing cuttings from the pavement and for preventing dust from escaping into the air.

When milling the Interstate or controlled access freeways, the planing machine shall be capable of restoring pavement profile with a non-contact

leveling system. The non-contact leveling system shall have a minimum of three sensors dispersed the length of the machine.

The maximum spacing between teeth on the cutter drum shall not exceed 5/8 inches. Provide supplemental equipment as necessary to remove material in areas that cannot be reached by the planing machine.

CONSTRUCTION REQUIREMENTS

415.03 General Requirements

Coordinate operations so that vertical longitudinal faces do not exceed 1-1/4 inches in height in areas to be used by public traffic. Taper transverse faces in a manner approved by the Engineer to avoid creating a traffic hazard. Perform cold planing in the direction of traffic.

When milling roadways for hot mix overlays, operate the planing machine at a consistent forward speed to provide an acceptable surface texture. The maximum allowable forward speed shall be 60 feet per minute when the teeth spacing is between 1/2 and 5/8 inches, and 80 feet per minute when the teeth spacing is less than 1/2 inch.

After planing, ensure that the finished surface provides a smooth riding surface free of scallops, scabs, gouges, ridges, oil film, and other imperfections of workmanship, has a uniform texture, and is true to the required grade and cross-section. The elevation of the longitudinal edges of adjacent cuts shall not differ more than 1/8 inch.

Do not begin milling unless the subsequent layer of pavement can be placed within the limitation specified in **407.09**.

Thoroughly sweep the planed pavement immediately behind the machine, and haul away all materials swept up. When the Engineer deems necessary, provide and use a water truck to control dust.

Where sound pavement has been gouged, torn, or otherwise damaged during the milling operations, or damage is done to any other property of any kind including utility frames, grates, and covers, make repairs at no cost to the Department. Take appropriate measures so that the cold planing operation does not trap water.

415.04 Surface Requirements

Where the planed pavement is not to be resurfaced, provide a uniform texture throughout the Project and a satisfactory riding surface. The average texture depth shall be no less than 0.20 inches.

The finished surface on the Interstate and controlled access freeways shall be of uniform profile throughout, without any scabbing, scallops, gouges, ridges, or other imperfections resulting from worn cutter teeth, improper operating speeds, poor equipment maintenance, or other instances of poor workmanship. The cross-slope shall be as shown on the Plans in the tangent, transition, and super-elevated curve sections.

The finished surface after the final cut shall not show a deviation greater than 1/8 inch from a 10-foot straightedge, and the cross-slope shall not deviate more than 3/8 inches in 10 feet. Correct all irregularities exceeding these limits.

Texture all approaches and tapers when required by the Engineer. Length, width, and depth of cut on approaches and tapers shall be as determined by the Engineer. Match the approaches and tapers to the finished cut on the main line, and transition to the existing surface to within ±1/8 inch.

When deemed necessary by the Engineer, transition private entrances to provide a smooth approach to the roadway.

Unless otherwise shown on the Plans, take ownership of the cuttings and remove them from the Project.

COMPENSATION

415.05 Method of Measurement

The Department will measure Cold Planing of Bituminous Pavement by the quantity of material removed in tons or cubic yards, or by the square yard of planed pavement. The method of measurement will depend upon the pay item designated in the proposal.

Where payment is by the square yard, the Department will measure the pavement acceptably planed by the square yard in accordance with **109.**

Unless otherwise specified, the Department will not measure water used to control dust for separate payment but will consider it incidental to the planing operation.

415.06 Basis of Payment

The Department will pay for the accepted quantity of Cold Planed Bituminous Pavement at the contract unit price, which payment shall be full compensation for all labor, materials, equipment, hauling, and incidentals necessary to plane the pavement, control dust, and dispose of the cuttings.

SECTION 712 – TEMPORARY TRAFFIC CONTROL

DESCRIPTION

712.01 Description

This work consists of furnishing, erecting, and maintaining all construction warning signs, barricades, flexible drum channelizing units, temporary pavement markings, and other traffic control devices in accordance with the provisions of the current edition of the MUTCD, including all addenda, or as shown on the Plans or as directed by the Engineer for the purpose of safely directing traffic through construction zones. This work shall include installing additional devices as necessary in construction work zones.

MATERIALS

712.02 Materials

Provide traffic control and marking devices in accordance with the current edition of the MUTCD, except as herein modified.

Provide materials as specified in:

Signs:
Aluminum 916.02

Reflective Sheeting	916.06
Paint	916.09
Cold Rolled Carbon Steel -16 gauge	ASTM A1008
Non-metallic Drums and Barricades	QPL
Reflective Sheeting	916.06

A. Sign Sheeting Material

Sign sheeting material for all temporary construction signing shall be Type B or better, Fluorescent Orange color meeting the requirements of AASHTO M 268 and 916.06. For all interstate projects, provide new fluorescent orange sign sheeting material; for all other construction projects, provide new or previously used sign sheeting that is in good condition.

B. Temporary Pavement Marking Material

Unless otherwise specified, the material for pavement marking line shall be either temporary pavement marking tape, or reflectorized paint with raised reflective pavement markers placed as shown on the Plans.

Where Removable Pavement Markings are specified, provide materials listed on the Department's QPL. Before use, the manufacturer shall certify to the Department that the removable tape is identical to that listed on the Department's QPL. Failure of the removable tape to perform satisfactorily with regard to installation or removability is cause for rejection of the material.

C. Cones

Cones shall be a minimum of 28 inches high and weighted at the base.

D. Portable Barrier Rail

Portable barrier rail shall be in accordance with the Plans or as listed on the Department's QPL.

All portable barrier rail shall comply with NCHRP 350 or MASH. Provide certification from the supplier that the proposed rail replicates an NCHRP 350 or MASH approved rail documented in an acceptance letter from FHWA. Attach to the certification the acceptance letter stating that the proposed rail complies with NCHRP 350 or MASH. Submit all certification documents to the Engineer before delivery to

the Project. Do not use different shapes, lengths, or connections of rail in the same continuous run.

E. Portable Impact Attenuators

Portable impact attenuators shall be in accordance with the Plans and Specifications, comply with the requirements of NCHRP 350 or MASH for the appropriate test level, and be selected from the Department's QPL.

F. Sign Supports

Stationary sign supports shall be steel posts meeting **916**. Do not use wood for stationary or portable sign supports. Provide portable sign supports that have been pre-approved by the Engineer and comply with the requirements of the NCHRP 350 or MASH. In splicing supports, use 5/16-inch diameter galvanized ASTM A449 (SAE J429 Grade 5) or galvanized ASTM A325 bolts.

G. Vertical Panels

The substrate material for vertical panels shall be aluminum, meeting the requirements of **916.02**, or a high density copolymer polyethylene. The high density copolymer polyethylene shall be flexible and shatterproof for temperatures to -50 °F (ASTM D746). The reflective sheeting shall be AASHTO M 268 Type B or better, meeting the requirements for Fluorescent Orange material as specified in **916.06**. Attach the vertical panel (aluminum or copolymer) to a steel "U" post (weight 2.0 pounds per foot) meeting the requirements of **916.03**.

H. Flexible Drums, Flashing Arrow Boards, and Changeable Message Signs

Select Flexible Drums, Flashing Arrow Boards, and Changeable Message Signs from the Department's QPL.

Traffic control devices defined by the FHWA as Work Zone Category 1 and Category 2 devices weighing less than 100 pounds shall comply with NCHRP 350 or MASH. Select all Category 1 and Category 2 devices from the Department's QPL. Alternatively, the Contractor may submit a notarized letter, along with documentation from the FHWA, stating Category 1 devices and Category 2 devices weighing less than 100 pounds meet NCHRP 350 or MASH criteria.

Submit all certification documents to the Engineer before delivering these traffic control devices to the Project.

712.03 Reserved

CONSTRUCTION REQUIREMENTS

712.04 General

At the pre-construction conference, designate a responsible person who will be assigned to the Project to supervise traffic control.

Erect signs in a workmanlike manner such that all supports are plumb, sign panels are generally perpendicular to the travelway, and legends are horizontal so that they effectively convey the intended message. Do not display advanced warning signs more than 48 hours before physical construction begins. The Contractor may erect signs up to one week before needed, if the sign face is fully covered in a manner approved by the Engineer. Ensure that the sign sheeting is free of any damage that would reduce the reflectivity. Do not use overlay plates on signs. Mount signs on stationary or portable supports dependent on the type work being performed. Drive sign supports a minimum of 3.5 feet into soil or 1 foot into solid rock. Where soil and solid rock are both encountered, the depth of the sign support in the ground shall be:

$$d_1 + 3.5d_2 = 42,$$

where

d_1 = depth in inches of support in soil
d_2 = depth in inches of support in solid rock

The Contractor may splice stationary sign supports, provided the splice is a minimum of 18 inches. In addition, drive the stubs for the splice as required above and so as not to extend above 18 inches from ground level. Fasten the splice with four bolts, two placed at each end of the splice. In general, work being performed at spot locations and of short duration will necessitate the use of portable supports properly weighted for stability.

During periods of non-use, remove warning signs and other devices from the work area, and cover or otherwise position them so they do not convey their message to the traveling public and do not present a safety hazard to

drivers. If covered, maintain the covering material in a neat and workmanlike manner during its use. The method of covering the sign face shall not deface or damage the sheeting of the sign.

Use flashing or steady burning lights to light barricades and other devices that require lighting, as shown on the Plan details or as directed by the Engineer. Procure and bear the expense of a continuous power source.

A. Flaggers

Provide flaggers with proper attire and paddle when necessary to safely handle traffic through the construction zone. Ensure that flaggers are trained and certified in flagging operations by one of the following training programs:

1. American Traffic Safety Services Association (ATSSA)
2. National Safety Council (NSC)
3. Tennessee Transportation Assistance Program (TTAP)

The Department will accept flagger training programs developed and conducted by construction industry associations, consultant organizations, and contractors if they have an established, written program that meets all MUTCD requirements and Department Policy.

The Department will consider flaggers to be a general requirement of traffic control and will not make direct payment for such.

B. THP Troopers and Uniformed Law Enforcement Officers

When requested by the Engineer or the Contractor and approved by the Regional Safety Coordinator or Regional Operations Office, a Tennessee Highway Patrol (THP) Trooper may be provided to enforce motor vehicle laws and otherwise assist in securing the public safety. Submit requests for the THP at least 48 hours in advance of the requested time of service. If the THP is scheduled to work and the work is canceled, or the schedule is changed, notify the THP and the Engineer at least 2 hours before the scheduled start of work.

When a THP Trooper is not available, the Contractor may provide a Uniformed Police Officer if approved by the Engineer and the Regional Safety Coordinator or Regional Operations Office. The Uniformed Police Officer shall maintain a detailed written log of enforcement

activities and shall submit the log to the Engineer for verification each month.

All Uniformed Law Enforcement Officers working on Department projects shall have training from a Peace Officer Standards and Training (POST) certified police training academy in the State of Tennessee and an additional 4 hours of FHWA approved work zone training. Submit records of this training to the Engineer.

C. Flashing Arrow Board

Install Flashing Arrow Board(s), meeting all requirements of the MUTCD, at the locations shown on the Plans or as directed by the Engineer. Ensure that the Flashing Arrow Board(s) will perform as specified herein. Correct or immediately replace all Flashing Arrow Boards that exhibit any type of malfunction, including improper dimming.

The Flashing Arrow Board shall be capable of displaying the following configurations:

1. Right Arrow – ten lamps flashing in unison forming an arrow
2. Left Arrow – ten lamps flashing in unison forming an arrow
3. Double Arrow – five lamps in each arrow head and three lamps in a common shaft all flashing in unison
4. Four Point Caution – four outermost corner lamps flashing in unison

Use the Flashing Arrow Board(s) in the single arrow mode for lane closure only, and situate and align them so that the flashing arrow is clearly visible and legible. The single arrow mode display shall have ten lamps flashing in unison. Do not use the sequential arrow configuration, chevron arrow configuration, and horizontal bar configuration. The flash rate shall not be less than 25 flashes per minute or more than 40 flashes per minute. Minimum lamp "on-time" shall be 50% of the cycle.

Mount the Flashing Arrow Board(s) so as to provide a minimum of 7 feet between the bottom of the panel and the roadway.

D. Signs

The Contractor may use portable signs when the duration of the work is less than 3 days or as allowed by other conditions in the proposal. Ensure that all portable signs and sign mounting devices used in work are NCHRP 350 or MASH compliant. When not being used, remove portable signs from the clear zone. Do not turn signs sideways or backwards while the signs are in the clear zone. Mount portable interim signs a minimum of 1 foot above the level of the pavement edge and at the height recommended by the manufacturer's crashworthy testing requirements.

All regulatory sign blanks shall be rigid.

Make every effort to eliminate the use of interim signs as soon as the Work allows for the installation of permanent signs.

Maintain existing street name signs at street intersections.

Cover all signs or portions of a sign(s) that are not applicable to the Traffic Control Plan so as not to be visible to traffic, or remove such sign(s) from the roadway when not in use.

Do not remove existing signs and supports without the Engineer's prior approval. Store and protect all existing signs and supports that are to be removed if this material will be required later in the Work.

Furnish, install, reuse, and maintain interim guide, warning, or regulatory signs required to direct traffic in accordance with the MUTCD. Mount the bottom of all interim signs at least 7 feet above the level of the pavement edge when the signs are used for long-term stationary operations as defined by Section 6G.02 of the MUTCD.

Maintain existing guide and exit directional signs on the Project until conditions require a change in location or legend content. When change is required, the signs shall be in accordance with the Traffic Control Plan. When an existing guide and exit directional signs sign is in conflict with work to be performed, remove the conflicting sign and reset it in a new, non-conflicting location that has been approved by the Engineer.

When it is not possible to use existing signs, either in place or relocated, furnish, erect, maintain, modify, relocate, and remove new

interim guide and exit directional signs as shown on the Plans or as directed by the Engineer.

Complete the installation of new permanent guide and exit directional signs, and the permanent modification or resetting of existing guide and exit directional signs, when included in the Contract, as soon as practicable to minimize the use of interim guide and exit directional signs.

E. Worker Visibility and Safety

Ensure that all workers within the Project's right-of-way, who are exposed to either vehicular traffic or to construction equipment in the work area, wear high-visibility safety apparel. Consider high-visibility apparel to be personal protective clothing that meets performance Class 2 or Class 3 of the ANSI/ISEA 107 publication. Provide Class 3 apparel for night work.

F. Portable Barrier Rail

Place all portable barrier rail as far away from the travel lanes as possible while serving the intended purpose. Move or remove all portable barrier as directed by the Engineer. The Department will make no additional payment for removing barrier that is no longer required.

G. Lane Closures

Hold the length of a lane closure to the minimum length required to accomplish the Work. Locate advanced warning signs for the Project so as to not overlap with the advanced warning signs for lane shifts and lane closures.

Use drums in all transition tapers for lane closures on multi-lane roads.

H. Night Work Lighting

When the Contract requires night work, supply sufficient lighting and equipment as specified herein.

1. **Lighting Plan.** Submit the following information regarding the lighting plan to the Engineer:

a. Descriptions and sketches of the layout of lighting devices including spacing, luminary height, lateral placement, and anticipated illuminance provided.

b. Photometric and physical specifications of all lighting equipment.

c. Detailed description of all lighting to be used on construction equipment.

d. Methods to be employed to reduce glare.

e. Contractor's frequency and procedure for checking illumination levels.

2. Protective Equipment and Lighting. In addition to their standard protective equipment, equip construction personnel and equipment as follows:

a. Traffic Control Persons, all equipment operators, and all other workers shall:

(1) Wear high-visibility apparel that meets performance Class 2 or Class 3 of the ANSI/ISEA 107 publication. Class 3 apparel shall be required for night work.

(2) Have a minimum of 12 square inches of reflective material added to their hard hats that is visible from all sides.

b. Also equip Traffic Control Persons with:

(1) A flashlight complete with semi-transparent red cone, and

(2) Radios or cell phones so that they may communicate with each other.

c. All workers shall receive specific training on night work operations.

d. All vehicles in the work area must operate rotating or flashing incandescent amber lights visible in 360 degrees around the vehicle.

e. All work vehicles including trucks must have red and white reflective tape applied to all sides such that it defines the outline of the vehicle.

Provide the equipment specified in Table 712.04-1 with non-glare balloon style lights or equivalent. The lights will be required on each piece of equipment in operation.

Table 712.04-1: Night Work Lighting Requirements

Equipment Type	Illuminance Requirement
Paver, Milling Machine, Material Transfer Devices	One 4000-watt assembly or two 2000-watt assemblies
Grader, Roller, Rumble Strip Machine, Shoulder Machine	One 400-watt assembly
Paint truck	One 400-watt assembly or a non-glare 300-watt floodlight assembly
Guardrail driver, stationary operation	One 4000-watt assembly or two 2000-watt assemblies or equipment light plant
Trail Vehicle	One 4000-watt assembly or two 2000-watt assemblies

A trail vehicle will be required to follow the last piece of equipment in a mobile operation (i.e. finish roller, pavement marking, etc.) depicting the beginning of the working area. In addition, ensure that portable lighting of at least 400 watts is available for the density testing inspector. The Engineer will determine the illuminance requirement for other vehicles not listed in Table 712.04-1. The Contractor may substitute a 400-watt metal halide lamp or equal approved by the Engineer for a 2000 or 400-watt balloon light assembly.

Locate and direct all luminaries in such a way to minimize glare to both motorists and work vehicles. If glare is noted from any travel path, adjust the lighting to reduce the glare to a level acceptable to the Engineer.

Replace non-functioning lamps immediately. Check the luminary aiming daily. Regularly clean the luminaries.

I. Specification Compliance

The Engineer will notify the Contractor of failure to comply with this Specification or the Plans. The safe passage of pedestrians and traffic through and around the temporary traffic control zone, while minimizing confusion and disruption to traffic flow, shall have priority over all other Contractor activities. Continued failure of the Contractor to comply with the requirements of the Traffic Control Standard Specification or Special Provisions will result in non-refundable deductions of monies from the Contract for non-performance of Work as long as the deficiency remains.

Failure of the Contractor to comply with this Specification or take immediate correction actions required within 48 hours of written notice shall be reason for the Engineer to suspend all other work on the Project, except erosion prevention and sediment control and traffic control, to apply non-refundable deductions of monies from the Contract at a rate of $2,500 per calendar day per notice, and to withhold payment of monies due to the Contractor for any work on the Project until traffic control deficiencies are corrected. These other actions shall be in addition to the deductions for non-performance of traffic control.

712.05 Pavement Marking Removal

Remove conflicting pavement markings, in a manner acceptable to the Engineer, to prevent confusion to vehicle operators.

Remove final surface pavement markings by sand blasting, water blasting, or acceptable grinding methods that will cause the least possible damage to the pavement.

Remove intermediate surface pavement markings by sand blasting or water blasting, or other approved methods that will cause the least possible damage to the pavement. The following methods are acceptable for removing intermediate surface pavement markings: sand blasting using air or water, high pressure water, steam or superheated water, or mechanical devices such as grinders, sanders, scrapers, scarifiers, and wire brushes.

At no cost to the Department, repair damage to the pavement or surface resulting from pavement marking removal using methods and materials

acceptable to the Engineer. The removal shall not result in what appears to be a line that conflicts with the current markings.

Accomplish traffic shifts on the final surface using interim traffic marking tape unless otherwise shown on the Plans.

Do not remove an existing pavement marking by painting over with black paint or asphalt.

When the method of removal causes sand or other material to accumulate on the pavement, remove the residue as the work progresses.

712.06 Temporary Centerline and Lane Marking

Unless otherwise specified, install temporary pavement marking as follows:

1. Provide 4-inch wide pavement marking line as shown on the Plans for projects that will have traffic maintained overnight. For temporary pavement line markings on intermediate layers of pavement, use reflective tape, reflectorized paint, and raised pavement markers, or a combination thereof as shown on the Plans or as required by the Engineer, and install to permanent standards before dark hours. Short, unmarked sections will not be allowed. The Department will measure and pay for these markings as Painted Pavement Marking (Line) in accordance with **716.08** and **716.09**. Preserve established no-passing zones, if any, on the existing pavement; if no-passing zones have not previously been established, establish them before beginning the work. Mark two-lane, two-way highways with 10-foot long center lines applied on 40-foot centers and appropriate no-passing barrier lines.

2. Where required on the completed permanent surface, for 10-foot lane lines, no-passing barrier line, and edge line, use reflectorized paint applied as specified in **716**.

3. Maintain pavement markings at no additional cost to the Department until they are covered by the subsequent paving course or the Project is accepted.

4. It will not be necessary to remove pavement markings except for markings that convey conflicting or incorrect information to the traveling public.

712.07 Maintenance

Assume full responsibility for the continuous and expeditious maintenance of all signs, barricades, temporary impact attenuators, and all other traffic control devices to meet the "acceptable" category as described in *Quality Guidelines for Temporary Traffic Control Devices and Features* published by ATSSA. Such maintenance will be considered a part of the original installation cost. Failure to maintain all traffic control devices so as to provide continuous safety to the public will be cause for suspension of construction operations until proper traffic control is re-established.

712.08 Adjustment to Plans

Maintain traffic through the Project in accordance with the traffic control plan and the MUTCD. To request a change to the traffic control plan, submit a plan revision request in writing to the Engineer for approval, with the requested change marked in red on the traffic control plans sheets. The Engineer may adjust the traffic control plan as deemed necessary to ensure the safety of the workmen and traveling public.

COMPENSATION

712.09 Method of Measurement

The Department will measure the following for payment:

1. Signs, including Vertical Panels, erected on suitable supports by the actual area in square feet installed, with no deductions made for corner radii.

2. Flexible Drums for channelizing traffic by the unit, per each, as determined by counting the maximum number of drums on a jobsite and in use at any one time. This shall be designated by making a notation such as "On October 29, 2013, there were 242 Flexible Drums in use. Pay quantity is 242 Each." This will not apply to phase construction projects. On phase construction projects, each phase is treated as a separate project to arrive at a final pay quantity. The highest number used on Phase I, plus the highest number used on subsequent phases, will constitute the final pay quantity.

3. Barricades by the linear foot for the type designated.

4. Delineators and Temporary Flexible Tubular Delineators by the unit, per each.

5. Warning Lights and Flashing Arrow Boards by the unit, per each for the type designated.

6. Portable Barrier Rail by the linear foot. Separate measurement will be made for the initial installation of portable barrier rail at each site that the rail is used on the Project as shown on the Plans or approved by the Engineer. No separate measurement will be made for removing and resetting portable barrier rail on new alignment at the same site to provide for changes in traffic control required by the different phases of construction. The following conditions apply to measurements of portable barrier rail:

    a. The sites on one directional roadway of a divided highway will be considered independently of the sites on the other directional roadway.

    b. Each bridge for which portable barrier rail is shown on the Plans or approved by the Engineer will be a separate site.

    c. Additional relocations of barrier rail due to safety of work zone or traffic, as established in the traffic control plans or as directed by the Engineer laterally up to 10 feet, will be paid at 10% of the interconnected portable barrier bid amount unless a separate item is in the proposal.

7. Portable Impact Attenuators based on the initial installation of each portable impact attenuator. No additional payment will be made for removal, moving, and reinstalling impact attenuators at other locations on the Project as directed by the Engineer. Payment will be based on the maximum number of portable impact attenuators in place at one time.

8. Temporary pavement marking line as described for Painted Pavement Marking Line in **716.07** regardless of whether the lines are painted, taped markings, or raised pavement markers, or a combination of the above as shown on the Plans or as required by the Engineer, except that Removable Pavement Marking (Line) will be measured by the linear foot of installed line.

Unless otherwise specified, the Department will not separately measure or pay for traffic cones, removal of pavement marking, and flaggers, as these items will be considered incidental to the lump sum item Traffic Control.

The Department will pay for THPs, but the Contractor is responsible for notifying the THP and the Engineer when work has been canceled within 2 hours of the scheduled start of work. If the THP is not notified of work cancellation and the THP elects to monitor/patrol the project for a maximum of 2 hours, the Department will deduct from the monies owed the Contractor an amount equaling the THP pay rate for 2 hours of work.

The Department will pay for Uniformed Police Officers provided by the Contractor at the invoice price of the work plus 5%, not to exceed $50 per hour for the hours present on the Project. No compensation will be made for drive time.

712.10 Basis of Payment

The Department will pay for accepted quantities, complete in place, at the contract prices as follows:

Item	*Pay Unit*
Traffic Control	Lump Sum
Portable Barrier Rail	Linear Feet
Portable Impact Attenuator	Each
Signs	Square Feet
Vertical Panels	Square Feet
Flexible Drums	Each
Temporary Barricades (Type)	Linear Feet
Removable Pavement Marking (Description)	Linear Feet

The lump sum payment for Traffic Control is full compensation for providing Temporary Workzone Lighting and all equipment, labor, and materials, and for furnishing flaggers and traffic cones, and for removing conflicting and incorrect pavement markings, as required, until Project completion.

Payment for Portable Barrier Rail is full compensation for all materials, installation, maintenance, and all incidentals necessary to complete the work.

Payment for Portable Energy Absorbing Terminals will be made at the contract price per Portable Energy Absorbing terminal, complete in place,

with total payment based on the maximum number of portable energy absorbing terminals in place at one time as specified in **712.09**.

Payment for Signs and Vertical Panels is full compensation for providing sign panels with proper sheeting and legend, erecting on proper supports, furnishing all mounting hardware, covering when not in use, relocating, handling, and maintaining until Project completion.

Payment for Barricades is full compensation for materials, equipment, relocating, handling, maintaining, and all incidentals of the work.

Unless otherwise designated, all signs, barricades, and other traffic control devices covered by this section shall become the property of the Contractor at the completion of the Project. The salvage value for these items shall be reflected in the contract unit price bid.

The Department will pay for 10-foot lane line/center line and solid barrier line as Painted Pavement Marking (Line) in accordance with **716.08**.

Payment for Removable Pavement Marking Line, 8-inch Barrier Line, Channelization Striping or Stop Line, is full compensation for the installation, maintenance, and removal of the marking line when it is no longer required.

Payment for Uniformed Police Officers is full compensation for providing the Officer, official law enforcement vehicle, all necessary equipment, and administrative costs associated therewith.

S T A T E **O F** **T E N N E S S E E**

January 1, 2015

(Rev. 5-18-15)
(Rev. 7-13-15)

Supplemental Specifications - Section 400

of the

Standard Specifications for Road and Bridge Construction

January 1, 2015

Subsection 407.06 (pg. 327),7-13-15; - A. Pavers. Replace the entire first paragraph with the following: "Bituminous pavers shall be self-contained, power-propelled units provided with an activated screed, equipped to be heated, and capable of spreading and finishing courses of bituminous plant mix material in lane widths applicable to the specified typical section and thickness shown on the Plans. All screed extensions shall be full assembly extensions, including activated and heated screeds. Pavers shall include throw-back blades, reverse augers, or equivalent to place mix beneath the auger gearbox. Auger extensions shall be incorporated in a manner such that the maximum distance from the augers to the end plate shall be 18 inches. Screed extensions may extend beyond the 18-inch maximum from auger extensions only when extending for short-term temporary deviations in pavement width such as driveways. Do not use strike-off boxes, with the exception of sections with continuously varying width." For shoulders less than 8 feet in width and similar construction, the Contractor may place materials using approved mechanical spreading equipment.

Subsection 407.20 (pg. 346) 5-18-15; Basis of Payment; B. Acceptance of Mixture; Modify the last paragraph as follows: "When the total plan quantity of any mix is less than 1000 tons, the Department will accept the mix on the basis of visual inspection and Contractor Quality Control certification. The Department may run extraction, gradation analysis, or other tests deemed necessary for acceptance purposes."

S T A T E **O F** **T E N N E S S E E**

(Rev. 02-22-08)
(Rev. 11-10-08)
(Rev. 12-15-09)
(Rev. 12-28-10)
(Rev. 09-27-11)
(Rev. 1-7-2015)

January 1, 2015

SPECIAL PROVISION

REGARDING

BITUMINOUS PLANT MIX PAVEMENTS (HOT MIX)

ROADWAY DENSITY

Description: This specification covers the requirements for acceptance of asphalt roadway density by use of core samples. This provision also includes language for testing and acceptance of asphalt longitudinal joint density.

All sections of Section 407 of the Standard Specification, and Supplemental Specifications are applicable except as modified herein.

Section 407.03(D)2.h.- Contractor Quality Control System- Add the following between the second and third paragraphs:

The Contractor will be required to conduct quality control testing of surface and binder mixes for roadway density throughout placement to verify that the mixture being placed meets specified density requirements. A Quality Control Plan (QCP) for this density testing is required. Acceptable methods of quality control testing include coring, nuclear gauge testing, and non-nuclear gauge testing.

Section 407.07- Rollers. Replace the entire section with the following:

The Contractor shall use a sufficient number and type of rollers to obtain proper compaction and obtain the specified densities.

Section 407.15- Compaction. – Replace the entire section with the following:

A. General

After the bituminous mixture has been spread, struck off, and surface irregularities adjusted, it shall be thoroughly compacted. The method employed must be determined by the contractor and be capable of compacting the mixture to the specified density while it is in a workable condition. Rollers shall not park on the bituminous pavement nor shall rollers be refueled on the bituminous pavements.

B. Density Requirements

- Mix Types: A, B, BM, BM-2, D, E
- All levels of ADT
- %Gmm values specified here are for lot averages.

Travel Lane Density		
% Gmm		% Pay
Min	Max	
99.1	100	90
98.1	99	94
97.1	98	98
96.1	97	100
95.1	96	101
94.1	95	102
93.1	94	101
92.1	93	100
91.1	92	98
90.1	91	94
89.1	90	90
88.1	89	86
87.1	88	*
86.1	87	*
85.1	86	*
<85	85	*

Table 407DEN-1

Joint Density Incentive/Disincentive		
%Gmm		
Min	Max	$/L.F./Lot
99.1	100	*
98.1	99	*
97.1	98	-0.70
96.1	97	-0.42
95.1	96	0.00
94.1	95	0.00
93.1	94	0.07
92.1	93	0.14
91.1	92	0.07
90.1	91	0.00
89.1	90	-0.14
88.1	89	-0.42
87.1	88	-0.70
86.1	87	-0.98
85.1	86	*
<85	85	*

Table 407DEN-2

*Shall be removed and replaced at the contractors expense or as directed by the engineer.

Payment shall be for travel lanes only, even when the shoulder and travel lane are placed concurrently. No incentive shall be paid for the second travel lane mat unless the joint for that lot is a minimum of 90.1%.

Any lot of joint density tests averaging below 87% shall be sealed at the Contractor's expense. Approved sealers are listed on the TDOT Qualified Products List (QPL), Listing #40 for Pavement Sealers. Sealing of deficient longitudinal joint lots will only be required for surface mixes.

- Mix Types: All shoulder mixes
- All levels of ADT
- %Gmm values specified here are for lot averages.

Shoulder Density		
% Gmm		% Pay
Min	Max	
99.1	100	*
98.1	99	*
97.1	98	96
96.1	97	98
95.1	**96**	**100**
94.1	**95**	**100**
93.1	**94**	**100**
92.1	**93**	**100**
91.1	**92**	**100**
90.1	**91**	**100**
89.1	**90**	**100**
88.1	**89**	**100**
87.1	88	98
86.1	87	94
85.1	86	90
<85	85	*

Table 407DEN-3

*Unacceptable or as directed by the engineer.

% Pay for shoulders shall be applied to the quantity of mix on the shoulder even when the travel lane and shoulder are place concurrently.

The density (bulk specific gravity) determination for a compacted asphalt mixture shall be performed in accordance with AASHTO T-166, Method A only. All core samples shall be COMPLETELY DRY before testing. Air drying is permitted provided core samples are weighed at 2-hour intervals until dry in accordance with AASHTO T166, Section 6.1. Cores may also be dried in accordance with ASTM D 7227.

Section 407.20.B.5 - Acceptance of the Mixture –Replace the entire subsection with the following:

It is intended that acceptance density testing will be accomplished as soon as is practicable.

After obtaining the cores, all core holes shall be properly filled and compacted in kind with hot mix asphalt. There will be no additional compensation to comply with this section.

Cores shall be clearly labeled in a discrete, sequential manner (i.e. – M1, M2,...,M30; J1, J2,...,J15) throughout the course of the project. After testing, cores shall be retained along with copies of test results and will be periodically obtained by the regional materials office for spot-check verification testing.

Mat Density (Travel Lanes and Shoulders)- For density acceptance purposes, the pavement shall be divided into lots of 15,000 linear feet and sublots of 3,000 linear feet, or fraction thereof, per paving width per mixture type. Control strips shall not be included as part of acceptance lots. At the beginning of the project, the first lot will begin immediately after the end of the control strip. When possible, attention should be provided to avoid cutting cores in areas where signal/loop wire may be affected. If test location selections indicate testing locations in these areas, a new random number should be selected.

Five randomly selected cores (4" min./ 6" max. diameter), from the travel lane, will be tested to determine density compliance and acceptance. One core shall be taken from each sublot. The Bulk Specific Gravity (G_{mb}) of the cores shall be determined as stated above and the average calculated. The maximum theoretical gravity (G_{mm}) from acceptance testing for that shift's production will be averaged and the percent density will be determined for compliance by dividing the G_{mb} average by the Gmm average. The Contractor will be responsible for obtaining the cores at the locations randomly selected by TDOT. Cores shall be tested by TDOT, by a certified plant technician.

Turn lane and ramp density cores shall be determined as described above when the total turn lane or ramp length is 15,000 linear feet or greater. When the total turn lane or ramp length is less than 15,000 linear feet, one density core shall be taken for each 3,000 linear feet. An average density shall be determined from the total number of cores taken from the turn lane or ramp.

Longitudinal Joints - Longitudinal density cores shall be taken as described above for Travel Lanes and Shoulders with the exception that the maximum theoretical gravity (G_{mm}) from acceptance testing for both travel lanes will be averaged.

Section 407.20, Basis of Payment, Revise section B.5. as follows:

5. Acceptance for Mix Density on the Roadway:

Mat Density -A deduction in payment, not as a penalty but as liquidated damages, shall be made for failure to meet the density requirements as outlined within this provision in Subsection 407.15.B. As soon as practical after the final rolling is completed on each lot, 5 density tests (1 per sublot) shall be performed by the Department at locations determined by the Engineer, and an average of all such tests shall be computed. Test locations shall be as defined above in revisions to Subsection 407.20.B.5. Any deduction for failure to meet density requirements or incentive for exceeding density requirements shall be computed to the nearest 0.1% as a percentage of the total payment otherwise due for each lot.

The percent of total payment shall be in accordance with tables shown in Subsection 407.15.B., "Density Requirements" above. Any deduction in monies due the Contractor for failure to meet the Density Requirements shall be made under the item for Density Deduction.

Longitudinal Joints – The total incentive/disincentive payment shall be in accordance with tables shown in Subsection 407.15.B., "Density Requirements" above**.** Any deduction in monies due the Contractor for failure to meet the Density Requirements shall be made under the item for Density Deduction. Any incentive payment due the contractor shall be under item Density Incentive.

CIRCULAR LETTER

SECTION: **109.01 MEASUREMENT OF QUANTITIES**
NUMBER: **109.01-02**
SUBJECT: **TRUCK WEIGHT LIMITS**
DATE: **JANUARY 1, 2010**

The Department now will require that all weight tickets conform to the new limits outlined on these sheets as required by law.

Interstate weight limits shall apply when hauling on any of the following:

a) Ramps entering or exiting the interstate system.
b) Any portion of an existing interstate open or previously opened to traffic.
c) The surface course of a new interstate facility (never opened to public traffic). However, Non-Interstate Highway limits will apply to hauling on the subgrade or base courses of newly constructed interstate widening projects if accessed by non-interstate routes.
d) New and existing structures on interstates.

In consideration of the status of construction, relative to the present federal interstate system, it is considered that the above determinations provide adequate guidance as to the applicability of interstate truck weights.

SECTION I: Non-Interstate Highway

1) Two axle truck (one front, one rear)
20,000# each axle
Maximum gross weight = 40,000# *

2) Three axle straight (one front, tandem rear)
Front axle = 20,000#
Tandem axle = 34,000#
Maximum gross weight = 54,000# *

Exception: Class 9 tag or zone tag
Maximum gross weight = 66,000# *

3) Four axle straight (one front, three rear)
Front axle = 20,000#
Single axle rear = 20,000#
Tandem axle = 34,000#
Maximum gross weight = 74,000# *

4) Three axle truck tractor and trailer (one axle front of tractor, one rear of tractor, one rear of trailer)
Front axle = 20,000#
Rear axle Tractor = 20,000#
Rear axle Trailer = 20,000#
Maximum gross weight = 60,000# *

5) Four axle truck tractor and trailer (one front of tractor, one rear of tractor, tandem rear of trailer)
Front axle Tractor = 20,000#
Rear axle Tractor = 20,000#
Tandem axle Trailer = 34,000#
Maximum gross weight = 74,000# *

6) Four axle truck tractor and trailer (one front of tractor, tandem rear of tractor, one rear of trailer)
Front axle Tractor = 20,000#
Tandem rear Tractor = 34,000#
Single axle Trailer = 20,000#
Maximum gross weight = 74,000# *

7) Five axle tractor and trailer (one front of tractor, tandem rear of tractor, tandem rear of trailer)
Maximum gross weight = 80,000# *

* A tolerance of up to 500 pounds will be allowed over the maximum gross weight.

SECTION II: Interstate Highway (Contracts Let On or After October 31, 2008)

Per Section 107.02 of the Standard Specifications, all trucks delivering material (rock, asphalt, concrete, etc.) to construction projects shall display the allowable gross weight for the Interstate System on the side of the truck. The Bridge Formula shall be used to determine Interstate System gross weights as defined below and in the attached Bridge Formula Weights brochure:

Weight Distribution Formula (Bridge Formula)

$$W = 500 ((L N)/(N-1) + 12N + 36)$$

W = overall gross weight
N = number of axles under consideration
L = distance in feet between extremes of axles under consideration

SECTION III: Interstate Highway (Contracts Let Prior to October 31, 2008)

A. Weight based on axle loadings

1) Two axle truck (one front, one rear)
   18,000# each axle
   Total = 36,000#

2) Three axle straight (one front, tandem rear)
   Front axle = 18,000#
   Tandem rear = 32,000#
   Total = 50,000#

3) Four axle straight (one front, three rear)
   Front axle = 18,000#
   Single axle rear = 18,000#
   Tandem axle rear = 32,000#
   Total = 68,000#

4) Three axle truck tractor and trailer (one axle front of tractor, one rear of tractor, one rear of trailer)
   Front axle = 18,000#
   Rear axle Tractor = 18,000#
   Rear axle Trailer = 18,000#
   Total = 54,000#

5) Four axle truck and trailer (one front of tractor, one rear of tractor, tandem rear of trailer)
   Front axle Tractor = 18,000#
   Rear axle Tractor = 18,000#
   Tandem axle Trailer = 32,000#
   Total = 68,000#

6) Four axle truck tractor and trailer (one front of tractor, tandem rear of tractor, one rear of trailer)

Front axle Tractor = 18,000#
Tandem rear Tractor = 32,000#
Single axle Trailer = 18,000#
Total = 68,000#

7) Five axle tractor and trailer (one front of tractor, tandem rear of tractor, tandem rear of trailer)

Total = 73,280#

B. Weight Distribution Formula (Bridge Formula)

$$W = 500 ((L N)/(N-1) + 12N + 36)$$

W = overall gross weight
N = number of axles under consideration
L = distance in feet between extremes of axles under consideration

The weights shown in Sub-Section A above can be increased if the Weight Distribution Formula is <u>not</u> violated. However, the weights shown in the section for Non-Interstate Highways may <u>not</u> be exceeded on Interstate Highways regardless of the Weight Distribution Formula.

Copy of Bridge Formula Weights brochure is attached.


Note
This pamphlet paraphrases the provisions in 23 U.S.C. 127 and 23 CFR 658 for the sake of clarity. In case of a dispute, the statue and regulations take precedence.
Previous editions of this pamphlet, entitled *Bridge Gross Weight Formula* (April 1984) and *Bridge Formula Weights* (January 1994), remain valid. Neither the Bridge Formula nor any resulting maximum gross weight values (table entries) has been changed.
U.S. Department of Transportation
Federal Highway Administration
Office of Freight Management and Operations
Phone: 202-366-9210
Fax: 202-366-3302
Web site: http://www.ops.fhwa.dot.gov/freight
August 2006
FHWA-HOP-06-105
Bridge Formula Weights
August 2006
U.S. Department of Transportation
Federal Highway Administration

Bridge Formula Weights

With a few exceptions noted in this pamphlet, the Bridge Formula establishes the maximum weight any set of axles on a motor vehicle may carry on the Interstate highway system. This pamphlet describes the Bridge Formula, why it was established, and how it is used.

What Is It?

Congress enacted the Bridge Formula in 1975 to limit the weight-to-length ratio of a vehicle crossing a bridge. This is accomplished either by spreading weight over additional axles or by increasing the distance between axles.

Compliance with Bridge Formula weight limits is determined by using the following formula:

$$W = 500 \left[\frac{LN}{N-1} + 12N + 36 \right]$$

W = the overall gross weight on any group of two or more consecutive axles to the nearest 500 pounds.

L = the distance in feet between the outer axles of any group of two or more consecutive axles.

N = the number of axles in the group under consideration.

In addition to Bridge Formula weight limits, Federal law states that single axles are limited to 20,000 pounds, and axles closer than 96 inches apart (tandem axles) are limited to 34,000 pounds. Gross vehicle weight is limited to 80,000 pounds (23 U.S.C. 127).

Is the Formula Necessary?

Bridges on the Interstate System highways are designed to support a wide variety of vehicles and their expected loads. As trucks grew heavier in the 1950s and 1960s, something had to

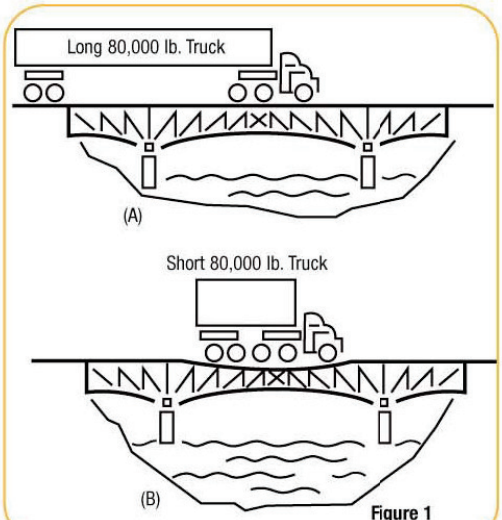


Figure 1

be done to protect bridges. The solution was to link allowable weights to the number and spacing of axles.

Axle spacing is as important as axle weight in designing bridges. In Figure 1A, the stress on bridge members as a longer truck rolls across is much less than that caused by a short vehicle as shown in Figure 1B, even though both trucks have the same total weight and individual axle weights. The weight of the longer vehicle is spread out, while the weight of the shorter vehicle is concentrated on a smaller area.

How Is the Formula Used?

The weight on various axle configurations must be checked to determine compliance with the Bridge Formula. Three definitions are needed to use the Bridge Formula correctly.

Gross Weight—the weight of a vehicle or vehicle combination and any load thereon. The Federal gross weight limit on the Interstate System is 80,000 pounds unless the Bridge Formula dictates a lower weight limit.

Single-Axle Weight—The total weight on one or more axles whose centers are spaced not more 40 inches apart. The Federal single-axle weight limit on the Interstate System is 20,000 pounds.

Tandem-Axle Weight—The total weight on two or more consecutive axles whose centers are spaced more than 40 inches apart but not more than 96 inches apart. The Federal tandem-axle weight limit on the Interstate System is 34,000 pounds.

Interstate System weight limits in some States may be higher than the figures noted above due to "grandfather" rights. When the Interstate System axle and gross weight limits were first adopted in 1956, and amended in 1975, States were allowed to keep or "grandfather" weight limits that were higher.

Bridge Formula calculations yield a series of weights (Bridge Table, pages 5-6). It is important to note that the single-axle weight limit replaces the Bridge Formula weight limit on axles not more than 40 inches apart, and the tandem-axle weight limit replaces the Bridge Formula weight limit for axles over 40 but not more than 96 inches apart. At 97 inches apart, for example, two axles may carry 38,000 pounds (Figure 2A), and three axles may carry 42,000 pounds, as shown in Figure 2B.

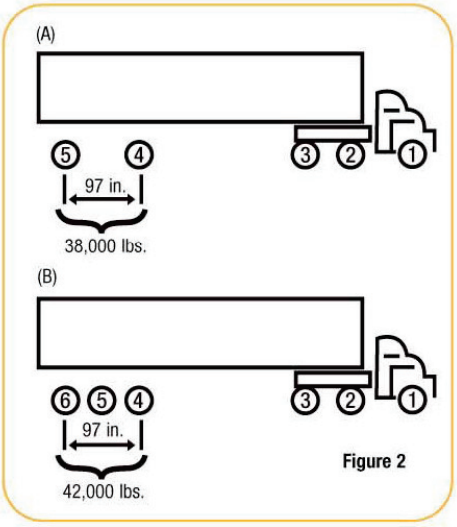


Figure 2

Federal law states that any two or more consecutive axles may not exceed the weight computed by the Bridge Formula even though single axles, tandem axles, and gross weight are within legal limits. As a result, the axle group that includes the entire truck—sometimes called the "outer bridge" group—must comply with the Bridge Formula. However, interior combinations of axles, such as the "tractor bridge" (axles 1, 2, and 3) and "trailer bridge" (axles 2, 3, 4, and 5), must also comply with weights computed by the Bridge Formula (Figure 3).

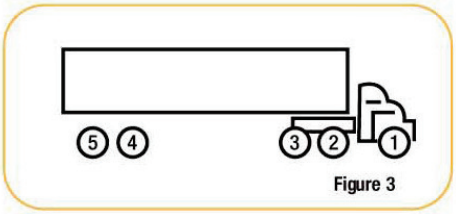


Figure 3

Figure 3 shows the most common vehicle checked for compliance with weight limit requirements. Although the Bridge Formula applies to each combination of two or more axles, experience shows that axle combinations 1 through 3, 1 through 5, and 2 through 5 are critical and must be checked. If these combinations are found to be satisfactory, then all of the others on this type of vehicle normally will be satisfactory.

The vehicle with weights and axle dimensions shown in Figure 4 is used to illustrate a Bridge Formula check.

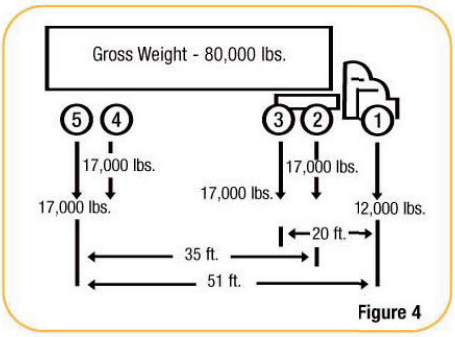


Figure 4

Permissible Gross Loads for Vehicles in Regular Operation[1]

Based on weight formula $W = 500\left[\frac{LN}{N-1} + 12N + 36\right]$

Distance in feet (L) between the extremes of any group of 2 or more consecutive axles

Maximum load in pounds carried on any group of 2 or more consecutive axles[2]

L	N=	2 AXLES	3 AXLES	4 AXLES	5 AXLES	6 AXLES	7 AXLES	8 AXLES	9 AXLES
Tandem Axle Weight (see pages 3 & 4) 4		34,000	.....	.....	.....	.....	.....	.....	.....
5		34,000	.....	.....	.....	.....	.....	.....	.....
6		34,000	.....	.....	.....	.....	.....	.....	.....
7		34,000	.....	.....	.....	.....	.....	.....	.....
8		34,000	34,000	.....	.....	.....	.....	.....	.....
More than 8/less than 9		38,000	42,000	.....	.....	.....	.....	.....	.....
9		39,000	42,500	.....	.....	.....	.....	.....	.....
10		40,000	43,500	.....	.....	.....	.....	.....	.....
11		.....	44,000	.....	.....	.....	.....	.....	.....
12		.....	45,000	50,000	.....	.....	.....	.....	.....
13		.....	45,500	50,500	.....	.....	.....	.....	.....
14		.....	46,500	51,500	.....	.....	.....	.....	.....
15		.....	47,000	52,000	.....	.....	.....	.....	.....
16		.....	48,000*	52,500	58,000	.....	.....	.....	.....
17		.....	48,500	53,500	58,500	.....	.....	.....	.....
18		.....	49,500	54,000	59,000	.....	.....	.....	.....
19 Example		.....	50,000	54,500	60,000	.....	.....	.....	.....
20 (see page 7)		.....	51,000	55,500	60,500	66,000	.....	.....	.....
21		.....	51,500	56,000	61,000	66,500	.....	.....	.....
22		.....	52,500	56,500	61,500	67,000	.....	.....	.....
23		.....	53,000	57,500	62,500	68,000	.....	.....	.....
24		.....	54,000	58,000	63,000	68,500	74,000	.....	.....
25		.....	54,500	58,500	63,500	69,000	74,500	.....	.....
26		.....	55,500	59,500	64,000	69,500	75,000	.....	.....
27		.....	56,000	60,000	65,000	70,000	75,500	.....	.....
28		.....	57,000	60,500	65,500	71,000	76,500	82,000	.....
29		.....	57,500	61,500	66,000	71,500	77,000	82,500	.....
30		.....	58,500	62,000	66,500	72,000	77,500	83,000	.....
31		.....	59,000	62,500	67,500	72,500	78,000	83,500	.....
32		.....	60,000	63,500	68,000	73,000	78,500	84,500	90,000
33		.....	.....	64,000	68,500	74,000	79,000	85,000	90,500
34		.....	.....	64,500	69,000	74,500	80,000	85,500	91,000
35		.....	.....	65,500	70,000	75,000	80,500	86,000	91,500
36		.....	Exception (see page 9)	66,000	70,500	75,500	81,000	86,500	92,000
37		.....		66,500	71,000	76,000	81,500	87,000	93,000
38		.....	.....	67,500	71,500	77,000	82,000	87,500	93,500
39		.....	.....	68,000	72,000	77,500	82,500	88,500	94,000
40		.....	.....	68,500	73,000	78,000	83,500	89,000	94,500
41		.....	.....	69,500	73,500	78,500	84,000	89,500	95,000
42		.....	.....	70,000	74,000	79,000	84,500	90,000	95,500
43		.....	.....	70,500	75,000	80,000	85,000	90,500	96,000
44		.....	.....	71,500	75,500	80,500	85,500	91,000	96,500
45		.....	.....	72,000	76,000	81,000	86,000	91,500	97,500
46		.....	.....	72,500	76,500	81,500	87,000	92,500	98,000
47		.....	.....	73,500	77,500	82,000	87,500	93,000	98,500
48		.....	.....	74,000	78,000	83,000	88,000	93,500	99,000
49		.....	.....	74,500	78,500	83,500	88,500	94,000	99,500
50		.....	.....	75,500	79,000	84,000	89,000	94,500	100,000
51		.....	.....	76,000	80,000	84,500	89,500	95,000	100,500
52		.....	.....	76,500	80,500	85,000	90,500	95,500	101,000
53		.....	.....	77,500	81,000	86,000	91,000	96,500	101,500
54		.....	.....	78,000	81,500	86,500	91,500	97,000	102,000
55		.....	.....	78,500	82,500	87,000	92,000	97,500	102,500
56		.....	Interstate Gross Weight Limit (see page 2)	79,500	83,000	87,500	92,500	98,000	103,000
57		.....		80,000	83,500	88,000	93,000	98,500	104,000
58		.....	.....	.....	84,000	89,000	94,000	99,000	104,500
59		.....	.....	.....	85,000	89,500	94,500	99,500	105,000
60		.....	.....	.....	85,500	90,000	95,000	100,500	105,500

[1]The values in this table reflect FHWA's policy of rounding down when calculated weights fall exactly halfway between 500-pound increments. Because the Bridge Formula is designed to protect highway infrastructure, FHWA determined that this conservative policy is consistent with the statutory mandate.

[2]The following loaded vehicles must not operate over H15-44 bridges; 3-S2 (5-axle tractor semitrailer with a wheelbase of less than 38 feet), 2-S1-2 (5-axle semitrailer combination with a wheelbase of less than 45 feet), 3-3 (6-axle truck trailer combination with a wheelbase less than 45 feet), and any truck with 7 or more axles. H15-44 bridges are designed for a specific vehicle load; H15 refers to a 15-ton 2-axle truck; 44 refers to the year AASHTO published the loading information. See *AASHTO Standard Specifications for Highway Bridges.*

5

6

Before checking for compliance with the Bridge Formula, a vehicle's single-axle, tandem-axle, and gross weight should be checked. Here the single axle (number 1) does not exceed 20,000 pounds, tandems 2-3 and 4-5 do not exceed 34,000 pounds each, and the gross weight does not exceed 80,000 pounds. Thus, these preliminary requirements are satisfied. The first Bridge Formula combination is checked as follows:

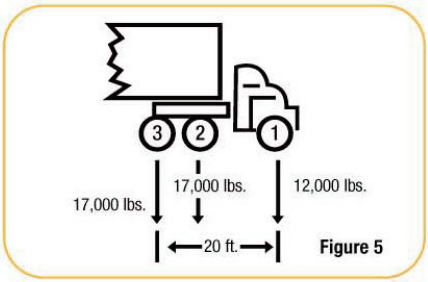


Figure 5

Check axles 1 through 3 (Figure 5)

Actual weight = 12,000 + 17,000 + 17,000 = 46,000 pounds.

N = 3 axles

L = 20 feet

$$W = 500 \left[\frac{LN}{N-1} + 12N + 36 \right]$$

$$W = 500 \left[\frac{(20 \times 3)}{(3 - 1)} + (12 \times 3) + 36 \right] = 51{,}000 \text{ lbs.}$$

Maximum weight (W) = 51,000 pounds, which is more than the actual weight of 46,000 pounds. Thus, the Bridge Formula requirement is satisfied.

Example From the Bridge Table (pages 5 & 6)
The same number (51,000 pounds) could have been obtained from the Bridge Table by reading down the left side to L = 20 and across to the right where N = 3.

7

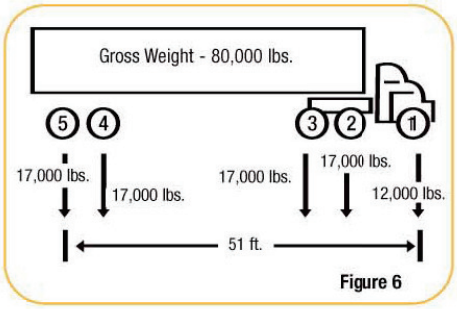


Figure 6

Now check axles 1 through 5 (Figure 6)

Actual weight = 12,000 + 17,000 + 17,000 + 17,000 + 17,000 = 80,000 pounds.

Maximum weight (W) = 80,000 pounds (Bridge Table for "L" of 51 feet and "N" of 5 axles).

Therefore, this axle spacing is satisfactory.

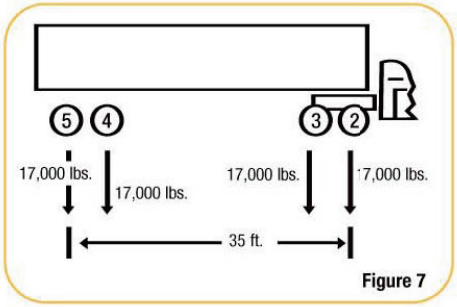


Figure 7

Now check axles 2 through 5 (Figure 7)

Actual weight = 17,000 + 17,000 + 17,000 + 17,000 = 68,000 pounds.

Maximum weight (W) = 65,500 pounds (Bridge Table for "L" of 35 feet and "N" of 4 axles).

This is a violation because the actual weight exceeds the weight allowed by the Bridge Formula. To correct the situation, some load must be removed from the vehicle or the axle spacing (35 feet) must be increased.

8

Exception to Formula and Bridge Table

In addition to the grandfather rights noted on page 3, Federal law (23 U.S.C. 127) includes one other exception to the Bridge Formula and the Bridge Table—two consecutive sets of tandem axles may carry 34,000 pounds each if the overall distance between the first and last axles of these tandems is 36 feet or more. For example, a five-axle tractor-semitrailer combination may carry 34,000 pounds both on the tractor tandem (axles 2 and 3) and the trailer tandem (axles 4 and 5), provided axles 2 and 5 are spaced at least 36 feet apart. Without this exception, the Bridge Formula would allow an actual weight of only 66,000 to 67,500 pounds on tandems spaced 36 to 38 feet apart.

Bridge Formula Application to Single-Unit Trucks

The procedure described above could be used to check any axle combinations, but several closely spaced axles usually produce the most critical situation.

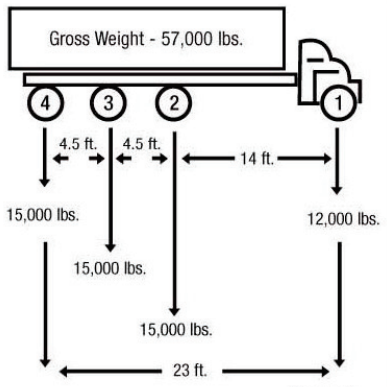


Figure 8

The truck shown in Figure 8 satisfies the single-axle weight limit (12,000 pounds are less than 20,000 pounds), the tandem-axle limit (30,000 pounds are less than 34,000 pounds) and the gross-weight limit (57,000 pounds are less than 80,000 pounds). With these restrictions satisfied, a check is done for Bridge Formula requirements, axles 1 through 4.

Actual Weight= 12,000 + 15,000 + 15,000 + 15,000 = 57,000 pounds.

Maximum weight (W) = 57,500 pounds (Bridge Table for "L" of 23 feet and "N" of 4 axles).

Since axles 1 through 4 are satisfactory, check axles 2 through 4:

Actual weight = 15,000 + 15,000 + 15,000 = 45,000 pounds.

Maximum weight (W) = 42,500 pounds (Bridge Table for "L" of 9 feet and "N" of 3 axles).

This is a violation because the actual weight exceeds the weight allowed by the Bridge Formula. The load must either be reduced, axles added, or spacing increased to comply with the Bridge Formula.

CIRCULAR LETTER

SECTION: **407.14 SPREADING AND FINISHING**
NUMBER: **407.14-01**
SUBJECT: **HOT MIX ASPHALT ROADWAY INSPECTOR CHECKLIST**
DATE: **NOVEMBER 1, 2006**

The attached checklist shall be completed during the start of paving for each project and rechecked as needed as the project progresses. The checklist shall be completed during the test strip construction while verifying mixture properties by the Project Supervisor, or their designated representative.

If the contractor does not comply with the specifications, as outlined in the checklist, then paving shall be stopped and not allowed to proceed until in compliance.

When paving at nighttime, the contractor shall not be allowed to begin paving unless the lighting is in accordance with the approved lighting plan.

Asphalt Laydown Checklist

Date: _____ Contract No.: _____

Project Number: _____ County: _____

Prime Contractor: _____ Paving Contractor: _____

Inspection made by: _____

Project Description: _____

The inspection checklist shall be completed by the Project Supervisor, or their designated representative, during the test strip construction.

Asphalt Laydown			
Lighting (Section 712.02)	**YES**	**NO**	**COMMENTS**
If applicable, has a Lighting plan been submitted and approved?			
Is lighting on all paving equipment (Paver, Transfer Device, Rollers, trail vehicle) per the approved plan?			
Is the lighting adequate?			
Milling/Cold Planing (Sect. 415)	**YES**	**NO**	**COMMENTS**
What is the width of the milling machine(s)?			
Are the milling teeth in good condition and all in place?			Teeth spacing =
Is the milled surface free of scabbing, scallops, gouges, ridges, etc…			
What is the forward speed (ft./min.)			Speed=
Is the proper depth and cross-slope being obtained by milling?			
Tack Coat (Sect. 403)	**YES**	**NO**	**COMMENTS**
Has the tack coat test strip been completed and is acceptable? What is the application rate to obtain the proper residual rate?			Application rate=
Has the existing surface been cleaned and all foreign materials been removed?			

Material Transfer Device (MTD) (SP407G)	**YES**	**NO**	**COMMENTS**
Does the MTD have a minimum of 15 tons storage capacity and capable of remixing the material?			
Does the paver have a surge hopper with a minimum of 15 tons storage capacity and sloping sides?			
Rollers (407.07)	**YES**	**NO**	**COMMENTS**
Are three rollers of the required size being used as required (except CS mix) (407.15)?			
If the inside shoulder and inside traffic lane are being paved concurrently, is there a 4th roller (min. 4 ft wide) for the shoulder?			
Is a pneumatic roller (rubber tire) used for intermediate rolling? *If a latex or polymer additive is used a steel wheel roller may be used instead of a pneumatic roller for the intermediate roller provided the surface course meets density requirements.			
Are rollers equipped with a device for moisten and cleaning the wheels as required? (407.07)			
Are all spray nozzles working properly (no dry spots or asphalt being picked up on the wheels)?			
Is a release agent being used on the tires of the pneumatic roller? If yes, what type and is it approved?			
Paver (407.06)	**YES**	**NO**	**COMMENTS**
Is a minimum 40-foot ski or non contact grade control system used for grade control? (407.14)			
Is the mix maintained at half the auger height?			
Are auger extensions within 18 inches of the end plate?			
Is the paver screed heated?			
Is the screed producing effectively a finished surface of required evenness			

and texture without tearing, shoving or gouging the mixture?			
Are temperature limitations being adhered to? Is there an approved "cold weather paving plan" if out of season?(407.09)			
Is the surface upon which the mix is to be placed free from excessive moisture?			
Does the mix have an even texture, free from segregation, tearing or shoving?			
Is the pavement and shoulder cross slope being checked. Are they correct (within 0.5% of the plans)?			
Are depth checks being made? Is the thickness correct?			
Delivery	**YES**	**NO**	**COMMENTS**
Are truck beds covered with tarps extending 6 inches over the sides and secured at 5-foot intervals? (407.05)			
Are truck beds tight, clean, and smooth, with a thin coat of approved release agent?			
Is the TDOT inspector accepting the weight tickets and signing them?			
Does each truck bed have a ¼" hole for checking temperature?			
Is the TDOT inspector recording temperatures every 3rd load. (Sampling and Test Guide)			
Is the mix temperature in the paver hopper within the allowable specification limits? (407.11)			
Longitudinal Joint	**YES**	**NO**	**COMMENTS**
Is the joint area along the edge clean prior to placement of the adjacent mat? Tack coat applied?			
Is the material slightly high at the joint to allow for compaction (about 0.2" per 1" laid)?			
Is the longitudinal joint being overlapped 1 to 1.5 inches over the adjacent mat to create a tight joint?			
Is the luter casting mix across the mat?			
On a multiple course pavement, is the			

longitudinal joint offset by one foot of the preceding layer?			
For surface course, is the longitudinal joint at the lane/center line of roadway?			
Transverse Joint	**YES**	**NO**	**COMMENTS**
When tying into existing pavement is a full head of material maintained in front of the screed to the end?			
Is the material slightly high at the joint to allow for compaction (about 0.2" per 1" laid)?			
When continuing paving, is the joint thoroughly cleaned and tack applied to ensure a good bond?			
Is the joint straightedged to ensure smoothness?			
Test Strip (407.15)	**YES**	**NO**	**COMMENTS**
Is the test strip a minimum of 400 SY as required?			
Is the mix being compacted to achieve maximum density?			
Are cores taken where directed to calibrate the nuclear gauges?			
Do the average and individual nuclear densities meet minimum requirements for the ADT and type of mix (expressed in percent of maximum theoretical density)? What density is required?			Required density:

COMMENTS:

CIRCULAR LETTER

SECTION: **407.09 WEATHER LIMITATIONS**
NUMBER: **407.09-01**
SUBJECT: **PROCEDURE FOR "PAVING AND COMPACTION PLAN FOR COLD WEATHER ASPHALT PAVING"**
DATE: **JANUARY 15, 2013**

TDOT Supplemental Specification 407.09 allows the contractor to request approval for a variance from specified temperature and seasonal limitations to pave at lower temperatures when there is a benefit to the public. The request shall be in writing, be submitted at least one week prior to the anticipated need, and must include a "Paving and Compaction Plan for Cold Weather Asphalt Paving" in accordance with the attached procedure.

January 10, 2013

Tennessee Department of Transportation

Procedure for "Paving and Compaction Plan for Cold Weather Asphalt Paving"

Purpose- The purpose of this document is to establish the TDOT requirements for a "Paving and Compaction Plan for Cold Weather" as specified in **subsection 407.09** of the TDOT Standard Specifications.

Background- TDOT supplemental specification 407.09 allows paving below the specified surface and air temperatures if the Contractor submits a "Paving and Compaction Plan for Cold Weather" when there is a benefit to the public. The temperature limitations are:

TEMPERATURE LIMITATIONS

Compacted Thickness	Minimum Air or Surface Temperature	
	Unmodified mixes (PG 64, PG 67)	Modified mixes (PG 70, 76, 82)
1.5 in. (40 mm) or less	45° F (7° C)	55° F (13° C)
> 1.5 in. (40 mm) to < 3.0 in. (75 mm)	40° F (5° C)	50° F (10° C)
≥ 3.0 in. (75mm)	35° F (2° C)	45° F (7° C)

Requirements- As noted in **subsection 407.09**, Cold Weather Paving Plans shall identify what practices and precautions the contractor intends to utilize to assure all mixtures meet standard specifications. Plans shall include/address all of the following:

- Mix type(s)
- Tonnage intended to be placed
- Compaction cooling curves estimating the time available for compaction (TAC). *PaveCool* software is available for such calculations at:
  http://www.dot.state.mn.us/app/pavecool/

  (NOTE- When estimating the TAC for PG 70-22 or PG 76-22 or PG 82-22 you must adjust the default values (Options→User Defined→Stop rolling

temperature) for Stop temperature to 200^{o}F for PG 70, to 215^{o}F for PG 76 and 240^{o}F for PG 82 for a more accurate TAC)

- Intended production rates
- Anticipated haul times
- Anticipated paver speed
- Estimated roller speed
- Estimated air temperature
- Estimated surface temperature
- Estimated wind speed
- Production temperature range

Additionally, plans shall include some or all of the following measures to ensure mixtures being placed meet standard specifications:

- Insulated truck beds
- Additional rollers
- Automated measurement of existing surface temperature
- Automated measurement of mix temperature immediately behind screed
- Automated temperature measurement on rollers
- Surface heaters
- Compaction aids or warm mix asphalt additives (must be listed on TDOT Qualified Products List for WMA)
- Additional third-party testing documenting all mixtures placed meet density requirements.
- Reduced production and paving rates

The Contractor's request shall be approved by the TDOT Regional Director. If approved, all other Departmental specifications for testing requirements, payment, and deduction except for limitations listed in subsection 407.09 shall still apply.

COLD WEATHER PAVING AND COMPACTION PLAN

Date:	
Contract ID:	
Proposed Construction Date(s):	
Estimated Air Temp:	°F
Estimated Surface Temp:	°F
Estimated Wind Speed:	mph
Mix Type(s):	
AC Grade(s):	
Lift Thickness(es):	in
Minimum Production Temperature:	°F
Maximum Production Temperature:	°F
Warm Mix Asphalt?	Yes / No
Maximum Paver Speed:	ft/sec
Maximum production rate:	tph

ADDITIONAL COLD WEATHER TACTICS

Tactic	Yes/No?	Comments
Insulated truck beds		
Additional rollers		
Automated measurement of existing surface temperature		
Automated measurement of mix temperature immediately behind screed		
Automated temperature measurement on rollers		

Surface heaters		
Compaction aids or warm mix asphalt		
Additional third-party testing documenting all mixtures placed meet density requirements		
Reduced production and paving rates		

TENNESSEE DEPARTMENT OF TRANSPORTATION

INTERSTATE 40 WIDENING FROM CENTRAL PIKE TO EAST OF SR 109

CONTRACT NO. DB 1101

PAVING AND COMPACTION PLAN FOR COLD WEATHER

IN ACCORDANCE WITH SUPPLEMENTAL SPECIFICATION 407.09

PREPARED BY:

THE LANE CONSTRUCTION CORPORATION

4992 BECKWITH RD

MT JULIET, TN 37121

NOVEMBER 29, 2012

1. Introduction

The purpose of this plan is to provide a standard operating procedure by the contractor for ensuring the density requirements as outlined in the specifications are met during the seasonal limitations specified. This plan shall encompass the contractor's procedures for meeting density requirements during calendar restricted dates while in temperatures outlined in the supplemental specifications.

2. Description of Work

Specifically, this plan will cover the quality control processes necessary to satisfy the density requirements for all asphalt placements between January 1, 2013 and March 16, 2013.

3. Personnel Performing Work

All asphalt paving operations will be performed by Lane Construction. Density testing for the A-S and A mixes will be performed by the Tennessee Department of Transportation. Density testing for the BM-2, D, and E mixes will be performed by Lane Construction.

The paving operation will be supported by Lane Construction team members including Robert Heibel, Jr. (Project Manager), Brian Jones (Project Superintendent), Keith Wray (Paving Superintendent), Blair Willard (Project Engineer), Andy Greene (Quality Control Manager), Jake Herrick (Field Engineer), and Joe Winfrey (Field Engineer). These Lane team members will provide continual assistance in the planning, execution, and inspection of the work, to ensure that the work is performed in a safe, efficient, and high caliber manner.

4. Testing Practices

4.1 Temperature Verification

Prior to the beginning of daily production, the contractor will utilize a cooling curve program (PaveCool 2.4) to determine the available timeframes to achieve density. A cooling curve will be generated for the beginning of the production day and for the end of the production day, under the assumption that these will be the coldest portions of the work day. Real-time weather conditions will be monitored, and new cooling data will be generated as necessary. Sample PaveCool cooling curves are provided in the Appendices.

A combination of infrared thermometers and conventional thermometers will be utilized to monitor the asphalt temperature versus the information provided in the cooling curves.

4.2 In-Situ Compaction Testing

Acceptance testing via nuclear methods will be performed by TDOT for the A-S and A mixes. Density requirements during the cold season will adhere to Standard Specification 407.15 for average daily traffic greater than 3,000.

ADT 3,000 or greater		
A	92	90
B, BM & BM2	92	90
C & CW	92	90
D	92	90
E	92	90

*Table excerpted from the Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction, dated March 1, 2006.

For the BM-2, D, and E mixes, Lane Construction will test for density via nuclear methods and will cut cores for acceptance as per Special Provision 407DEN of the contract.

5. Operational Methods

5.1 Production Rates

Daily production rates will be predetermined. The number of trucks required to meet the anticipated daily production shall be calculated based on the load capacity of each truck and the nominal hauling timeframe.

5.2 Compaction

Paver and roller speeds will be established utilizing the times provided by the cooling curves in PaveCool. Roller patterns determined in the test strip will be followed. An additional breakdown roller will be utilized if the allowable time for compaction does not allow a single roller to complete its pattern in a satisfactory manner. Breakdown rolling will follow the paver as closely as practical in order to achieve density within the given time.

5.3 Quality Control

Paving will be permitted when temperature restrictions outlined in Supplemental Specification 407.09 are satisfied. Temperatures will be measured from every third load as per TDOT Standard Operating Procedure 1-1.

Regardless of the dates at which paving occurs, temperature limitations as described in Supplemental Specification 407.09 will be adhered to. Loads not meeting temperature requirements are subject to rejection from the project site.

TEMPERATURE LIMITATIONS

Compacted Thickness	Minimum Air or Surface Temperature	
	Unmodified mixes (PG 64, 67)	Modified mixes (PG 70, 76, 82)
1.5 in. (40 mm) or less	45° F (7° C)	55° F (13° C)
> 1.5 in. (40 mm) to < 3.0 in. (75 mm)	40° F (5° C)	50° F (10° C)
≥ 3.0 in. (75mm)	35° F (2° C)	45° F (7° C)

Table

PG Binder Grade	Minimum Temp.	Maximum Temp.
PG 64-22, PG 67-22	270° F(132° C)	310° F(154° C)
PG 70-22	290° F(143° C)	330° F(166° C)
PG 76-22	290° F(143° C)	330° F(166° C)
PG82-22	290° F(143° C)	330° F(166° C)

"The temperature for Grading AS and Grading ACRL mixtures shall be between 225 and 275° F(110 and 135° C), except when modified binders are used, and then the temperatures shall be between 275 and 330°F (135 and 166°C). Aggregate should be coated and no visible drain down should occur in storage silos or hauling equipment."

* Tables are excerpted from the Supplemental Specifications to the Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction, March 1, 2006, revised February 13, 2012.

5.4 Special Considerations

Daily production rates will be reduced if it becomes evident that the breakdown rollers are not completing the necessary patterns to achieve density within the window provided by the cooling curves.

Care will be exercised to minimize the loss of mix temperature in the truck bed. Considerations include, but are not limited to, tightly covering the loads with tarps and manufacturing the mix at the maximum allowable temperature.

6. Affirmation of Quality Control

This task-specific Quality Control Plan hereby satisfies the requirements of Supplemental Specification 407.09 and will be upheld with the utmost vigilance.

Date: 11-29-12

Robert J. Heibel

Lane Construction Project Manager

Date: 11/29/12

Andrew [illegible] Greene

Lane Construction Project Quality Control Manager

EXAMPLE

APPENDIX

PaveCool 2.4 - Simulation Results

Input File: PaveCool

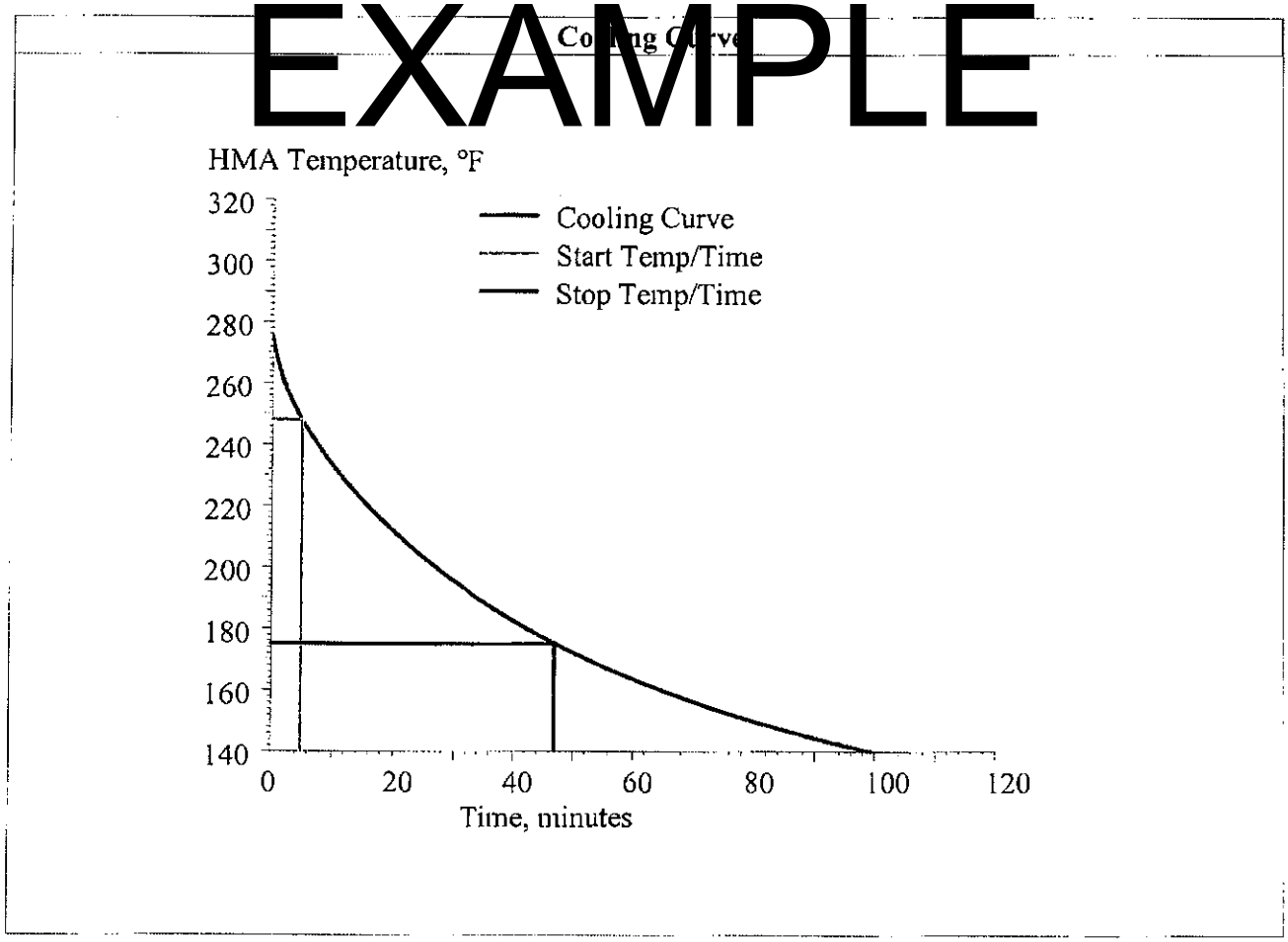
Project:

Project Date & Time	Start Rolling*	Stop Rolling*
11/29/12 11:46 AM	5 min. (248 °F)	47 min. (175 °F)

HMA Mix Type	Binder Grade	Thickness	Delivery Temp.
Coarse/SMA	PG 76-22	3.00 in.	275 °F
Air Temp.	**Wind Speed**	**Sky**	**Latitude**
50.0 °F	5 mph	Clear & Dry	45.0 ° North
Existing Surface	**Moisture**	**State**	**Surface Temp.**
Unbound - Coarse	Dry	Unfrozen	50.0 °F

* Some asphalt mixtures will require compaction start and stop times different from those recommended by this program. As always, good judgement must be exercised in order to ensure a properly compacted surface. Special considerations should be made for polymer modified asphalt binders. In this case, manufacturer guidelines should supersede recommendations made by this program. Consult the Help file for further details. In no event will the Minnesota Department of Transportation, the University of Minnesota or their suppliers be liable for damages or expenses arising out of the use of this program.

Simulation Time: 11/29/12 11:46 AM



PaveCool 2.4 - Simulation Results

Input File: PaveCool

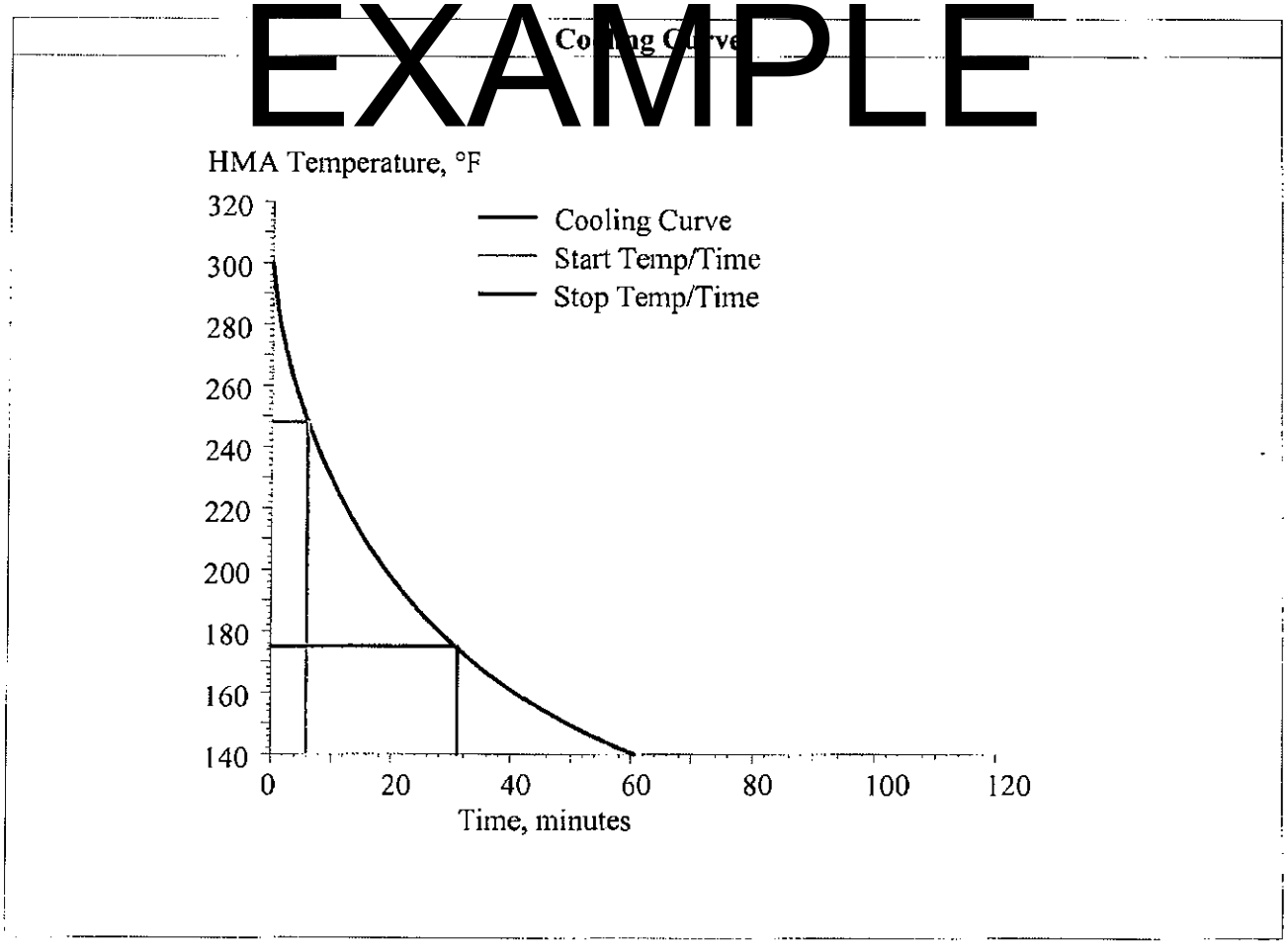
Project:

Project Date & Time	Start Rolling*	Stop Rolling*
11/29/12 11:46 AM	6 min. (248 °F)	31 min. (175 °F)

HMA Mix Type	Binder Grade	Thickness	Delivery Temp.
Coarse/SMA	PG 76-22	2.00 in.	300 °F
Air Temp.	**Wind Speed**	**Sky**	**Latitude**
40.0 °F	5 mph	Clear & Dry	45.0 ° North
Existing Surface	**Moisture**	**State**	**Surface Temp.**
Unbound - Coarse	Dry	Unfrozen	50.0 °F

* Some asphalt mixtures will require compaction start and stop times different from those recommended by this program. As always, good judgement must be exercised in order to ensure a properly compacted surface. Special considerations should be made for polymer modified asphalt binders. In this case, manufacturer guidelines should supersede recommendations made by this program. Consult the Help file for further details. In no event will the Minnesota Department of Transportation, the University of Minnesota or their suppliers be liable for damages or expenses arising out of the use of this program.

Simulation Time: 11/29/12 11:47 AM



PaveCool 2.4 - Simulation Results

Input File: PaveCool

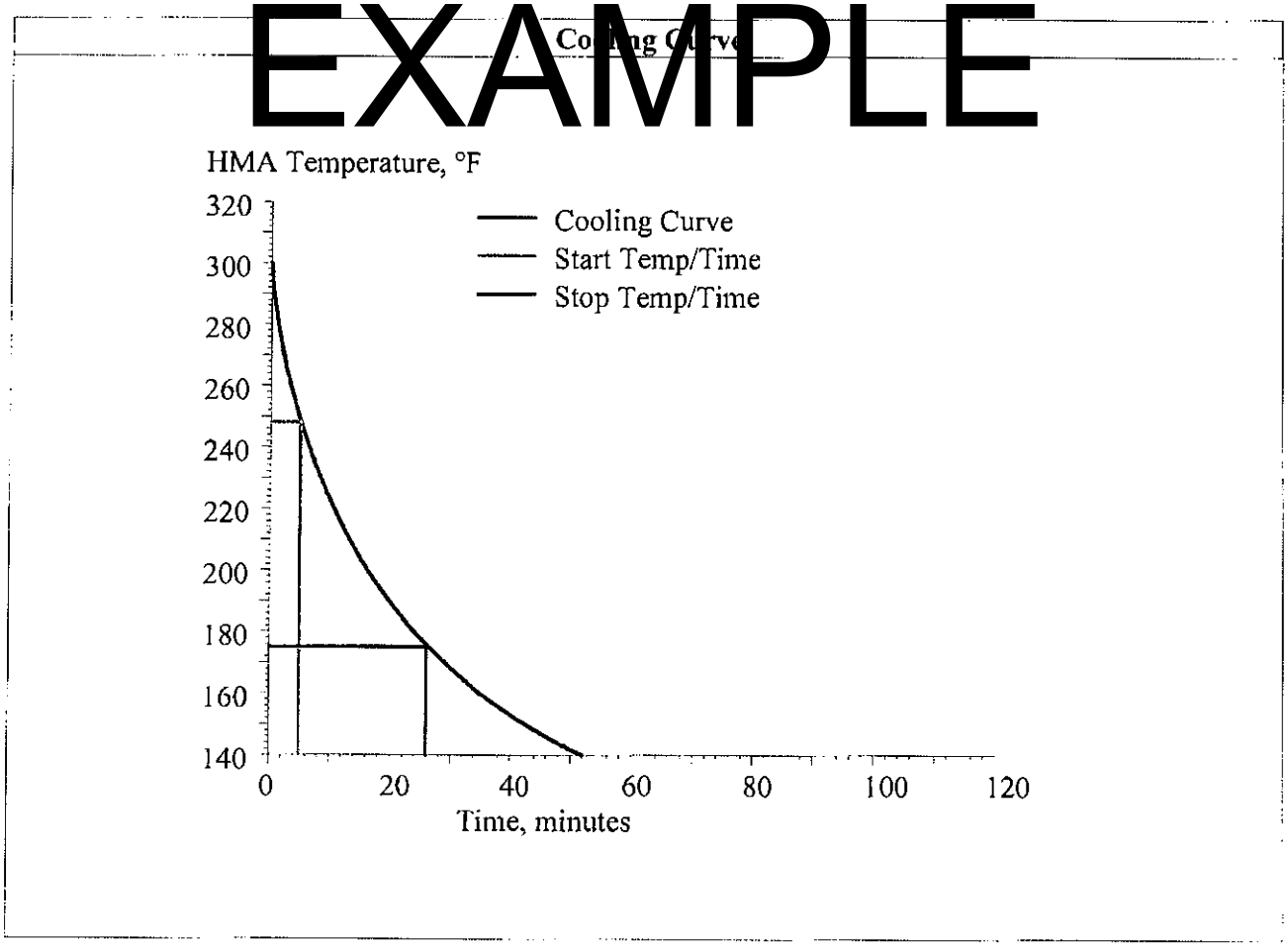
Project:

Project Date & Time	Start Rolling*	Stop Rolling*
11/29/12 11:46 AM	5 min. (248 °F)	26 min. (175 °F)

HMA Mix Type	Binder Grade	Thickness	Delivery Temp.
Fine/Dense Graded	PG 76-22	2.00 in.	300 °F
Air Temp.	**Wind Speed**	**Sky**	**Latitude**
35.0 °F	5 mph	Clear & Dry	45.0 ° North
Existing Surface	**Moisture**	**State**	**Surface Temp.**
Unbound - Coarse	Dry	Unfrozen	40.0 °F

* Some asphalt mixtures will require compaction start and stop times different from those recommended by this program. As always, good judgement must be exercised in order to ensure a properly compacted surface. Special considerations should be made for polymer modified asphalt binders. In this case, manufacturer guidelines should supersede recommendations made by this program. Consult the Help file for further details. In no event will the Minnesota Department of Transportation, the University of Minnesota or their suppliers be liable for damages or expenses arising out of the use of this program.

Simulation Time: 11/29/12 11:47 AM

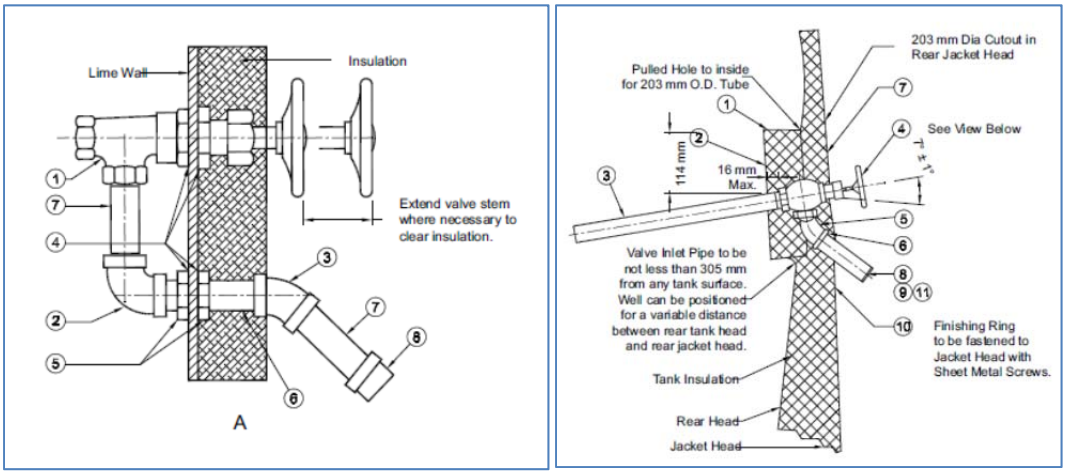


Sampling Asphalt Emulsions

TDOT Standard Operating Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1) state that *Emulsions for prime coats, tack coats, and sealers (fog seals*) AND *Emulsions for Surface Treatment, Microsurfacing, Slurry sealing and related similar processes* should be Sampled by the project inspector and once per week thereafter.

Proper sampling of these materials should include the following:

- All samples should be taken by contractor personnel, observed by TDOT employee, either from the contractor's storage tank or directly from the distributor.
- All samples should be taken from the sample valve, and a MINIMUM of 1-gallon of material should be run through the sample valve and wasted prior to collecting the sample.
- Samples should NOT be taken from distributor spray bars. This can cause contaminated samples.
- All emulsion samples should be collected in wide-mouth jars or bottles made of plastic or wide-mouth plastic-lined cans with lined screw caps. (Sample containers can be obtained from Regional or HQ M&T)
- Containers should be completely filled to eliminate possible crusting or condensation in the container.
- Samples shall be not exposed to direct sunlight for long periods of time and not allowed to freeze.
- Per TDOT M&T SOP 1-1, samples should be received at the TDOT central laboratory in Nashville as soon as reasonably possible. Samples taken more than two weeks after sampling are considered expired and will be discarded.
- Samples should be *properly labeled*, accompanied by a completed T-2 form for identification.



Example diagram of emulsion sample valves (AASHTO T-40)

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS

6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

Item No. ____________________ Grading ____________________

Report No. ____________________ **DAILY ASPHALT DENSITY REPORT** Date ____________________

Contract No. ____________________

Project Reference No. ____________________ County ____________________ Region ____________________

Project No. ____________________ Contractor ____________________

Mix Temp. Road ____________ Producer ____________________ Location ____________________

Tons Reg. Width ____________ Patching or Turnouts ________ Rejected ________ Total Mix (Pay Qty.) ____________

Gauge No.	Standard Count	Theoretical or Laboratory Density	Core Correction	Percent Required Density

Lot No. ________ From Sta. ________ To Sta. ________ Lin. M (ft.) ________ Width ________ Lift ________ Lane ________

Test No.	Sta. No.	Location	Den. Count	Den kg/m3 (lb/ft3)	Corrected Density	% Density

Lot No. ________ From Sta. ________ To Sta. ________ Lin. M (ft.) ________ Width ________ Lift ________ Lane ________

Test No.	Sta. No.	Location	Den. Count	Den kg/m3 (lb/ft3)	Corrected Density	% Density

Lot No. ________ From Sta. ________ To Sta. ________ Lin. M (ft.) ________ Width ________ Lift ________ Lane ________

Test No.	Sta. No.	Location	Den. Count	Den kg/m3 (lb/ft3)	Corrected Density	% Density

Remarks:

kg/yd^2 (lb/yd^2) ____________	
Lot No.	Ave. % Density

Original to:
Headquarters Materials and Tests
Copies to:
Regional Materials and Tests
Project Supervisor
Form DT-0315 (Rev. 10-02)

Signature ____________________

Title ____________________

CALIBRATING NUCLEAR DENSITY GAUGE WITH ASPHALT CORES

Ref. No. _____ County _____ Region _____ Date _____

Project No. _____ Contr. No _____ Type Mix _____

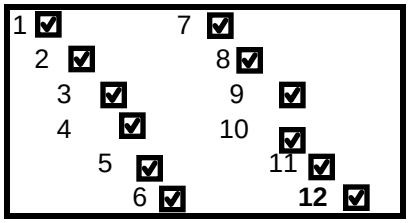
Gauge No. _____ Standard Count _____ _____

A control strip one paver width wide and having an area of at least 400 SY per roller * shall be constructed with an approved bituminous mixture. It shall be compacted until there is no appreciable increase in density (1.0 lbs/cu.ft.) as measured with the nuclear gauge.

NO. OF CORES

_____

Typical test pattern for end section combining all rollers



Min. Size
9' x 400'
10' x 360'
11' x 330'
12' x 300

		(1)	(A)	(C)	(B)	Theoretical Density =				lbs/cu.ft.
Site No.	Gauge Reading	Density lbs/cu.ft.	Core Wt. (Dry)	Core Wt. (Wet)	(Blot Dry)	Core * Sp. Gr.	Density lbs./cu.ft.	% Density	Cores Depth	% H_2O ** Absorbed
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
	Avg. =	#DIV/0!	lbs./ft.^{3}		Avg. =	#DIV/0!	#DIV/0!	#DIV/0!		

NOTE: Nuclear Density Gauge Correction = + or - $\frac{\text{\#DIV/0!}}{\text{(core - gauge)}}$ lbs./ft.^{3}

***** Core Sp. Gr. = $\frac{\text{(Wt. Dry)}}{\text{(Blot Dry) (Wt. Water)}}$

Example: wt. dry =699grams; water =385grams; blot dry =710grams

Core Sp. Gr. = $\frac{699}{710 - 385}$

Sp. Gr. = 2.15

****** Percent Water Absorbed by Volume = $\frac{B - A}{B - C} \times 100$

A= mass in grams of sample in air
B= mass in grams of SSD specimen in air
C= mass in grams of sample in water

T.D.O.T Insp. .....

9

Appendix