DEPARTMENT OF TRANSPORTATION

MnDOT Bituminous Manual

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MnDOT Pavement Engineer **Date**

Contents

Acronyms and Definitions

Below is a list of definitions and acronyms commonly associated with bituminous pavement. For definitions pertaining to specifications, see MnDOT Spec Book section 1103, Definitions.

Definitions

Air Voids - The small pockets of air between the asphalt coated aggregate particles throughout a compacted paving mixture. It is reported as a percentage of the bulk volume of the compacted mixture.

Base - Aggregate foundation that the asphalt mixture is placed on

Binder - The bituminous material in an asphalt mixture that holds the aggregates together

Cores - Cylinders of bituminous pavement cut from the mat to determine pavement density

Emulsion - Mixture of asphalt cement, water, and an emulsifying agent

Gradation - Amount of aggregate passing individual sieves to determine the aggregate size distribution in an aggregate mix

Gyratory Compactor - Superpave mix design laboratory compaction device.

Lift - A paved layer of asphalt

Longitudinal Joint - A seam that runs parallel to the direction of travel, it is the match point where one paver pass meets the paver pass of an adjacent lane.

Lottman Test - The Lottman Test, is a moisture susceptibility test. It is sometimes referred to as the stripping test or the Tensile Strength Ratio (TSR) Test.

Marshall Mix Design - Marshall mix design sets asphalt binder content at a desired density that meets minimum flow and stability values. Mixture specimens are compacted using a Marshall hammer, a device that applies pressure to a sample through a tamper foot.

Mixture Bulk Specific Gravity (G_{mb}) - The specific gravity of a compacted asphalt mixture specimen, including air voids.

Mixture Maximum Specific Gravity (G_{mm}) - The theoretical maximum specific gravity of the mixture excluding air voids.

Non-Wear Mixture - Any asphalt pavement located 4” below the top of the pavement surface (3” for local agencies).

Nuclear Density Gauge - Commonly referred to as a Nuke Gauge, it is a device used to quickly measure the inplace density of the bituminous mat in a non-destructive manner.

Rice Test - A test of the Mixture Maximum Specific Gravity (G_{mm}).

Ride - The smoothness of the road as measured with an inertial profiler.

Roller Pass - One compaction operation with a steel or pneumatic tired roller.

Specific Gravity - The ratio of the density of a substance to the density of water.

Spray Paver - A paving machine with integrated spray bars in front of the screed for applying tack coat immediately before the asphalt is laid.

Stone Matrix Asphalt (SMA) - A premium high traffic mix based on European technology. Features a gap gradation with stone on stone contact for ultimate rutting resistance.

Superpave - Superpave (Superior Performing Asphalt Pavements) is a mix design system that is the result of a research initiative completed by the Strategic Highway Research Program (SHRP). Superpave developed a new mix design method using the Superpave gyratory compactor and a new asphalt grading system called Performance Grading (PG).

Tack Coat - An asphalt emulsion sprayed on the pavement surface to bond multiple lifts together.

Thickness - The depth of asphalt mixture placed on the roadway.

Transverse Crack - A crack in the pavement which is perpendicular to the direction of travel.

Transverse Joint - A seam that runs perpendicular to the direction of travel.Transverse joints occur at the beginning and end of the project and as daily construction joints.

Ultrathin Bonded Wearing Course (UTBWC) - A gap graded, thin (typically 5/8”) hot mix asphalt mixture placed over a thick polymer modified emulsion membrane. UTBWC is applied with a spray paver.

Wear Mixture - The top 4” of asphalt mix on a pavement (top 3” for local agencies). Generally placed in multiple lifts.

Acronyms

AFT - Asphalt Film Thickness

ALR - Areas of Localized Roughness

CAA - Coarse Aggregate Angularity. The degree of crushing in the material retained on the No. 4 sieve.

ESAL - Equivalent Single Axle Loads

FAA - Fine Aggregate Angularity. The degree of crushing in the material which passes the No. 4 sieve.

HMA - Hot Mix Asphalt Pavement

IA - Independent Assurance testing

IRI - International Roughness Index

JMF - Job Mix Formula

LJD - Longitudinal Joint Density

MDR - Materials Design Recommendation or Mix Design Report, depending on context.

MnDOT - Minnesota Department of Transportation

NW - Non-wearing Course. See non-wear mixture in the Definitions section.

QA - Quality Assurance testing performed by the Agency or Owner.

QC - Quality Control testing performed by the Contractor

RAP - Recycled Asphalt Pavement

SSD - Saturated Surface Dry

SP - State Project Number in reference to a project or Super Pave in reference to a super pave mix designation. Depends on context.

VFA - Voids in Fine Aggregate

VMA - Voids in Mineral Aggregate

WE - Wear Course. See wear mixture in the Definitions section.

WMA - Warm Mix Asphalt Pavement

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Chapter 1 – General


100 – Introduction

What is bituminous? Bituminous, or asphalt, is a dark brown or black cementitious material which is a natural constituent of most crude oils found throughout the world (Asphalt Institute, 1994). It is made by the fractional distillation of crude petroleum. Asphalt is used in the transportation community to bond and seal aggregate particles together to produce a durable and smooth surface.

Minnesota has a roadway network comprised of 138,794 centerline miles. Of that total, 70,154 miles are Gravel, 61,960 miles are Bituminous, 4,470 miles are Dirt, and 2,154 miles are Concrete. Therefore, bituminous pavements make up the majority of the paved roads in the state, providing a smooth and durable driving surface. This manual will outline and explain the practices, procedures, and specifications required to construct and maintain quality bituminous pavements. The intended audience for this manual are members of the Agency, Consulting, and Industry community that design, construct, test, and maintain Minnesota's bituminous roadways. From the aggregate pits to the asphalt plant to the finished road surface, this manual will cover all aspects of bituminous pavement construction.

Bituminous related pay items represent about two thirds of the Minnesota Department of Transportation (MnDOT) construction budget. It is therefore critical to ensure that bituminous pavements are constructed and maintained using the best practices and materials available.

110 – Types of Bituminous Pavement

There are many types of bituminous pavements that can be manufactured. Below are the most common types of bituminous pavement used in Minnesota.

110.1 – Dense Graded Plant Mixed Asphalt Pavement - MnDOT Specification 2360

Dense graded plant mixed asphalt pavement is the most common pavement type used in Minnesota and can be placed on roadways, runways, parking lots, recreational trails, alleyways, and other areas requiring a smooth durable surface to drive or walk on. Also known as Hot Mix Asphalt (HMA), it is a combination of well-graded aggregates (coarse and fine aggregates and sand) and asphalt binder that is mixed in an asphalt plant at an elevated temperature (~300°F). It is typically placed in 1.5 to 3.0 inch lifts, although some mixtures are designed to be placed in lifts as thin as ½" thick. Using a special additive or process, asphalt mixture can also be produced at lower temperatures (230°F to 275°F) to produce Warm Mix Asphalt (WMA). In either case, the basic ingredients remain aggregate and binder.

Figure 100.1 – Plant Mixed Asphalt Pavement

The bituminous material (also known as asphalt binder or asphalt cement) is the "glue" in the mixture. It is a viscoelastic product, meaning that the material characteristics change with temperature. At ambient temperatures, the product acts as a solid; at higher temperatures it becomes liquid. The amount of asphalt binder needed in the mixture to properly bond all the aggregate particles together is determined volumetrically. The bituminous material can be chemically modified to change its characteristics and properties. Regardless of modification, its chief role is to bond aggregates together.

Aggregates provide the structural skeleton of the mixture. Most of the strength of the mixture comes from the aggregates, which represent up to 95% of the mix by volume. Depending on the mix, aggregates of different proportions and characteristics are used, along with different grades of asphalt binders. Recycled Asphalt Pavement (RAP) is often a portion of the mixture, replacing some of the virgin aggregate.

110.2 – Ultrathin Bonded Wearing Course – MnDOT Specification 2353

Ultrathin Bonded Wearing Course (UTBWC) is a plant mixed, durable, gap-graded asphalt mixture typically placed in a 5/8"-3/4" layer using a spray paver. Much of the durability of the mix comes from a high quality crushed aggregate bonded to a thick asphalt membrane. The thick asphalt membrane layer is wicked up into the aggregate structure to create a strong bond while maintaining resistance to stress. This type of mixture is meant as a flexible, durable wearing surface. It can also be used as an interlayer between the existing pavement and a bituminous overlay to mitigate reflective cracking.

Figure 100.2 – Spray paver applying tack and UTBWC

Figure 100.3 – Ultrathin Bonded Wearing Course

110.3 – Permeable Asphalt Stabilized Stress Relief Course and Permeable Asphalt Stabilized Base – MnDOT Specification 2363

Permeable Asphalt Stabilized Stress Relief Course (PASSRC) and Permeable Asphalt Stabilized Base (PASB) are other examples of plant mixed asphalt pavement products. PASSRC is typically constructed on the inplace concrete or bituminous surface to act as a separation or stress relief layer and to move water rapidly from beneath an un-bonded concrete overlay. PASB is typically constructed on a prepared base under a new concrete or bituminous surface to quickly drain infiltrated water accumulating under the pavement. PASB has also been used to act as a stress relief course, to mitigate reflective cracking, on bituminous over bituminous construction. These mixtures are only meant to carry limited construction traffic. The pavement layer placed over top of the PASSRC or PASB will carry normal traffic.

Figure 100.4 – PASSRC

110.4 – Stone Matrix Asphalt – MnDOT Specification 2365

Developed in Germany in the 1960's, this durable plant produced mix has a gap-graded aggregate structure that is designed to resist rutting and withstand high traffic volumes using a stone on stone structure. Stone Matrix Asphalt (SMA) is considered a "premium" mixture that typically contains 55-80% coarse aggregate, 8-12% mineral filler, 6-7% binder, and 0.3%

cellulose fibers. SMA is typically 20-25% more expensive than traditional HMA due to the use of durable aggregates, increased asphalt content, and cellulose fibers. The addition of fibers is used to prevent the asphalt binder from draining down through the mix during production and delivery.

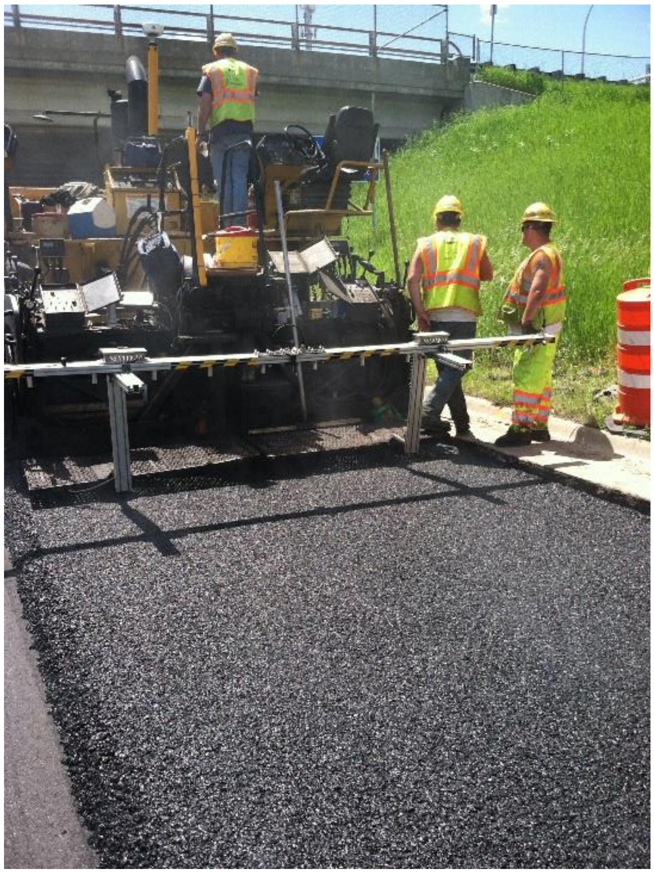

Figure 100.5 – SMA being placed over a bituminous surface.

110.5 – Bituminous Tack Coat – MnDOT Specification 2357

Tack coat is not a type of bituminous pavement, but is a critical element to the success of a bituminous paving project. Tack coat is a light application of bituminous emulsion that is sprayed onto the pavement surface to act as a bonding agent between multiple lifts of bituminous pavement or between new bituminous pavement and the existing surface. In other words, it is the glue between layers of asphalt. Tack coat allows the layers of asphalt to behave as a monolithic structure and improves the long term durability of the pavement. Without it, asphalt pavements have the potential to de-bond from the underlying layers, resulting in shortened pavement life and costly repairs. Tack is sometimes considered an incidental item in paving contracts, but this should not diminish the importance of ensuring that a uniform application is placed between all bituminous layers, including multiple lifts paved on the same day.

Figure 100.6 – Bituminous tack coat being used to bond an asphalt overlay to the milled surface of an existing bituminous pavement.

120 – Maintenance and Rehabilitation

Like a car or truck, bituminous pavements require maintenance to ensure their best performance. The following are bituminous-based maintenance and rehabilitation activities that are used to extend the life and maximize performance of bituminous pavements. For more detailed information on many of these treatments, see the MnDOT Pavement Preservation Manual.

120.1 – Bituminous Seal Coat – MnDOT Specification 2356

A seal coat, or chip seal, is a layer of bituminous emulsion that is sprayed onto the existing road surface followed immediately by a single layer of aggregate applied over the emulsion. This combination of emulsion and aggregate seals the underlying bituminous pavement surface, retards oxidation, and seals minor cracks. These are used to extend the useful life of a bituminous pavement. On MnDOT projects, seal coats typically receive a fog seal on top of the aggregates (after sweeping) to promote greater aggregate retention and enhance the surface sealing properties of the seal coat.

Figure 100.7 – Bituminous Seal Coat.

120.2 – Micro Surfacing – MnDOT Specification 2354

Micro surfacing is a cold mix process where high-quality aggregate, emulsion, water, and mineral filler are mixed in a specialized machine and placed on the road with a spreader box. It is often placed in two courses. The base course, or scratch course, is used to fill in minor surface irregularities and ruts. When placing a scratch course, the Micro surfacing machine uses a steel strikeoff that rides over the highest part of the existing roadway, allowing the mixture to fill in the low spots. The second course, or wear course, uses a rubber screed to produce a smooth driving surface. The mixture is like a slurry when it is placed on the road. One of the benefits of this technology is that it is able to accept rolling traffic about one hour after placement. Micro surfacing is effective at sealing the underlying bituminous pavement surface, filling in minor road imperfection, retarding oxidation, and sealing minor cracks.

Figure 100.8 – Micro Surfacing

120.3 – Bituminous Otta Seal – MnDOT Special Provision 2356

This is a process where a thick layer of soft emulsion is sprayed onto a gravel surface followed by a graded aggregate layer. Bituminous Otta Seals are used as thin surface treatments on gravel roads and shoulders to eliminated dust, prevent washboarding, and provide smooth driving surfaces. It does not provide any structural capacity to the road.

Figure 100.9 – Bituminous Otta Seal (Left). Not a Bituminous Otta Seal (Right).

120.4 – Bituminous Fog Seal – MnDOT Specification 2355

This is the process of sealing the existing pavement by spraying a light application of asphalt emulsion directly onto the bituminous surface without any aggregate cover. It is used to protect the bituminous surface from the elements and retard oxidation of the pavement. Fog Seal is commonly used on bituminous shoulders, parking lots, recreational trails, and over the top of chip seals. Fog sealing travelled lanes may have friction consequences and increase stopping distances.

Figure 100.10 – Bituminous Fog Seal being placed on a bituminous shoulder.

120.5 – Cold-In-Place Recycling and Cold Central Plant Recycling – MnDOT Specification 2390

Cold-In-Place Recycling (CIR) and Cold Central Plant Recycling (CCPR) are methods of recycling existing bituminous pavement. See the MnDOT Grading and Base Manual for more information.

120.6 – Full Depth Reclamation and Stabilized Full Depth Reclamation – MnDOT Specification 2215

Full Depth Reclamation (FDR) is the process of pulverizing and blending the in-place bituminous pavement with a portion of the underlying base material to produce a uniformly mixed aggregate base. Stabilized Full Depth Reclamation (SFDR) is similar to FDR, with the addition of a specified bituminous material or cement as well as any additional materials specified in the mix design. See the MnDOT Grading and Base Manual for more information.

120.7 – Bituminous Pavement Crack Treatment – MnDOT Special Provision 2331

When cracks develop in a bituminous pavement, they can be sealed with a specially formulated hot-poured elastic sealant. This sealant is applied through a wand attached to a melting kettle, which heats the sealant to very high temperatures prior to application. Pre-treatment of the cracks is critical to success, as the existing cracks need to be clean, dry, and free of debris and/or vegetation. Some Agencies prefer to rout cracks prior to sealing to create a uniform reservoir for the sealant. Cracks are typically routed to a ¾” x ¾” square reservoir, but different sizes may be specified. Crack sealant is typically only effective on cracks up to one inch wide. Whether or not routing is used, crack sealant is designed to seal pavement cracks to prevent harmful materials from entering into the pavement structure.

Figure 100.11 – Crack sealant applied from the wand.

120.8 – Mastic for Void Filling – MnDOT Special Provision 2331

An alternative to traditional crack sealing is a product called Mastic. Mastic is a mixture of asphalt, fine aggregates, polymers, and other modifiers. Unlike traditional hot-pour sealant, the addition of fine aggregates allows Mastic to be load-bearing, which means it can be used to fill cracks and voids that are either too wide for hot-pour crack sealant or are cupped. Cupped cracks occur when the combination of moisture and cycles of freeze-thaw soften and erode the base material under the cracks. The result is a dip centered at the crack that is felt as a bump when a vehicle drives over it. To fill and level these dips, mastic can be applied via a special pour box that rides over the cupped area of the crack, filling the void and providing a level finished product.

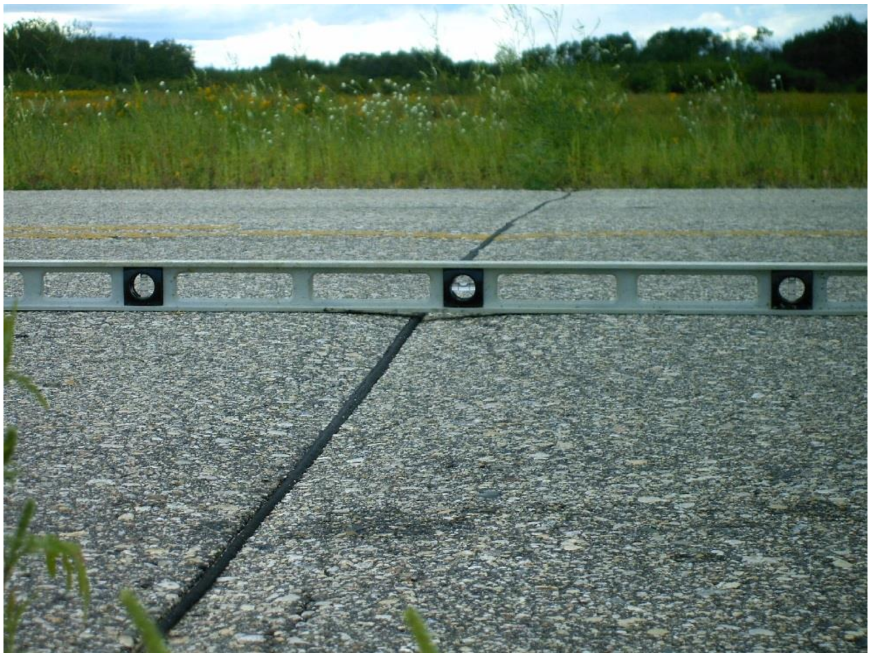

Figure 100.12 – Cupped transverse crack. Mastic has not been applied to this crack.

Figure 100.13 – Mastic being applied to a cupped transverse crack.

120.9 – Bituminous Pavement Patching

When a bituminous pavement is in the advanced stages of deterioration, fatigue cracking and deteriorated joints and cracks can begin to form potholes of varying sizes. If the roadway is not programmed for rehabilitation soon after these distresses occur, an interim solution is needed. Bituminous pavement patching is the process of filling these potholes and deteriorated areas with asphalt mixture. For best results, the distressed areas should be milled out prior to patching to create a neat, rectangular patch. Whether or not milling is performed prior to patching, loose material should be removed and tack coat should be applied to the distressed area to facilitate bonding with the patch material. The overall purpose of patching is to restore functionality to the pavement until a more substantial rehabilitation activity can occur.

Figure 100.14 – Bituminous patch over raveled pavement.

130 – Pavement Distresses

As bituminous pavements age and are subjected to traffic loading, they develop distresses. The type and severity of distress depends on many factors including climate, roadway type (interstate, city street, etc.), traffic loadings, subgrade conditions, and quality of initial construction. Also, whether or not preventive maintenance has been performed on a bituminous pavement will affect the type and severity of distresses present. This section will briefly detail some of the common distresses experienced by bituminous pavements. For more detailed information on pavement distresses, see MnDOT's Pavement Distress Identification Manual.

130.1 – Cracking

At some point in the life of all of these asphalt pavements, it is inevitable that they will develop some level of cracking. Cracks are a passageway for moisture, salt, and other deleterious materials to enter the pavement structure and cause damage. The infiltration of moisture combined with salt is a particularly damaging combination during winter, as the cycle of freezing and thawing causes expansion and contraction of the base and subgrade materials, which in turn causes them to weaken and erode. This can cause cupping of the cracks (see section 120.8 – Mastic for Void Filling) as well as premature failure of an otherwise sound pavement structure. Cracks can form in many different ways and are classified differently based on the method of formation.

Reflective Cracking

One of the most common types of pavement cracking is reflective cracking. Reflective cracking is a common distress on overlay, and mill and overlay projects, occurring when the underlying cracks reflect through the newly placed surface. In other words, existing distresses cause stress concentrations as the underlying pavement contracts, producing differential movements. These cracks can form either parallel or perpendicular to the pavement centerline.

Transverse Cracking

Transverse cracks form perpendicular to the pavement centerline. In Minnesota, transverse cracks often form due to cold weather shrinkage and expansion of the pavement, in which case they are referred to as thermal cracks. As pavement ages and becomes more brittle, the pavement will crack in smaller and smaller intervals.

Figure 100.15 – Transverse Thermal Crack

Longitudinal Cracking/Longitudinal Joint Deterioration

Any cracks that form parallel to the pavement centerline are considered longitudinal cracks. Longitudinal cracking often occurs due to a weak base or subgrade, inadequate pavement structure, through reflection from the underlying pavement, or from poor longitudinal joint construction.

Block Cracking

Also known as multiple cracking, block cracking is characterized by interconnected transverse and longitudinal cracks that form rectangular shapes, or blocks. This is commonly due to the pavement binder aging and not being able to expand and contract with the changes in the environment.

Figure 100.16 – Block Cracking

Fatigue Cracking

Repeated traffic loadings over a long period of time can create fatigue cracking, also known as alligator cracking. Fatigue cracking is exacerbated by weak subgrade and/or aggregate base. Fatigue cracking is a severe pavement distress and a sign that a pavement is in need of rehabilitation or reconstruction.

Figure 100.17 – Severe Fatigue Cracking

130.2 – Rutting

Pavement rutting is a permanent deformation characterized by longitudinal channeling or depressions in the pavement, typically in the vehicle wheel paths. Rutting usually occurs during periods of high temperature extremes combined with heavy vehicle axle loads on the affected pavement. Rutting is also common at intersections with stop signs or stop lights due to the forces exerted on the pavement from stopping vehicles. Rutting may occur due to a weak subgrade, weak base layer, or in the hot mix asphalt itself. If properly designed and constructed, asphalt mixes should not experience rutting. Rutting potential can be minimized by the following:

- Specifying the appropriate asphalt binder grade
- Not using too much asphalt binder
- Progressively increasing crushed aggregate (both coarse and fine) for increasing traffic conditions
- Providing proper aggregate gradation
- Proper compaction of the mat

Figure 100.18 – Pavement Rutting

130.3 – Raveling

As bituminous pavements age and are exposed to the elements, the binder oxidizes, causing the pavement to become dry and brittle. This can cause raveling, which is characterized by the progressive disintegration of a pavement layer from the surface downward. This results in a greater quantity of exposed coarse aggregates on the surface of the bituminous pavement and loss of fine aggregates. If a pavement has excessive permeability at the surface, moisture infiltration can cause raveling through stripping of the asphalt binder from the aggregates (see section 130.4 - Stripping). Surface treatments and thin overlays are good options to retard the effects of raveling on otherwise structurally sound pavements.

Figure 100.19 – Raveled pavement.

130.4 – Stripping

When excessive moisture gets into the bituminous pavement structure, typically through cracks in the pavement, it can cause the aggregates to lose their bond with the asphalt binder. This phenomenon is called stripping and can happen either through loss of adhesion, which is the ability of the aggregates to stick to the asphalt binder, or through loss of cohesion, which is the ability of the asphalt binder to hold the coated particles together. Stripping typically occurs at the bottom of the bituminous pavement layer at the interface between the aggregate base and the asphalt pavement. When coring a bituminous pavement that has stripped from the bottom up, the bottom of the core will crumble and fall apart while the top of the core will remain intact.

Figure 100.20 – Stripping of an asphalt core from the bottom of the asphalt layer.

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Chapter 2 – Materials

200 – Introduction

Asphalt binder and aggregates are the basic building blocks of all asphalt pavements. The design requirements of a roadway will determine the binder grades as well as the quality and size of the aggregates used in the bituminous mix design. Special project requirements may also require additional materials be used in the asphalt mixture. This chapter will provide information about the materials used in the design and construction of Minnesota's bituminous road network.

210 – Aggregate

Aggregates, as described in this manual, are defined as sand, gravel, crushed rock, salvaged rock, salvaged crushed concrete, recycled asphaltic pavement (RAP), mineral filler, or combinations of these materials. These are the basic building blocks of the pavement structure. See Table 200.1 to determine a link to the appropriate aggregate requirements.

Mixture Type and Specification	Aggregate Specification
Ultrathin Bonded Wearing Course (2353)	3139.4
Micro Surfacing (2354)	3139.5
Bituminous Seal Coat (2356)	3127
Plant Mixed Asphalt Pavement (2360)	3139.2
PASSRC/PASSB (2363)	3139.3
Stone Matrix Asphalt (2365)	2365

Table 200.1 – Aggregate Specifications for Different Mixture Types.

210.1 – Aggregates in Roadway Construction

In roadway construction, aggregates are generally used to provide structure, drainage, and surface friction. The aggregate base provides the structural foundation needed to support the paved surface and distribute weight from traffic loads. The aggregate base also provides a drainage path for subsurface moisture. Aggregates within the pavement provide the majority of the load support and stress distribution. Finally, the aggregates used in a surface treatment such as a chip seal can provide improved surface friction as well as protection to the underlying layers.

The strength, workability, and durability of a bituminous mixture are dramatically affected by the size, shape, texture, and gradation of the aggregates used in that mixture. A high quality end product that is durable under heavy traffic loading and able to withstand varying weather conditions is dependent on aggregates that are hard, strong, and resistant to abrasion, moisture damage, and freeze-thaw damage. See Table 200.1 above for aggregate quality specifications pertaining to specific bituminous mixtures.

210.2 – Mineral Filler

Mineral filler may be added to a bituminous mixture to improve its stability and durability. Mineral filler can consist of limestone dust, Portland cement, hydrated lime, crushed rock screenings, or rotary limekiln dust, depending on the needs of the project. The requirements for mineral fillers are specified in MnDOT Specification 3145.

210.3 – Aggregate Production

Virgin aggregates used in bituminous mixes either come from natural gravel deposits or quarries. The selection of the quarry or quarries from which the aggregates originate may be specified in a contract or left up to the contractor. The Engineer and Inspector should analyze the quarry to become familiar with the locations and depths of suitable material. Gravel deposits in Minnesota are primarily of glacial origin and are highly variable in gradation and mineral content. Several different types of operations have been used to produce uniform products from highly variable, non-uniform deposits.

Stratified pits containing seams of sand and gravel can be worked with excavating equipment to reach the desired depth. Processing the aggregate through a crusher and screening equipment will separate the aggregate into desired components and create uniform piles of aggregate of known gradations. See section 420.1 – Inspection of Materials for more information about aggregate handling during production.

210.4 – Aggregate Classification

Aggregates used in bituminous mixtures are categorized by class depending on their physical characteristics. Below is a list of the different aggregate classes. See MnDOT Specifications 2365, 3127, and 3139 for more information.

Class A
This hard, durable aggregate from igneous bedrock can be used in any mixture, but is required for thin surfacing applications such as micro-surfacing and ultrathin bonded wearing course. The following aggregates are included in this category.

Figure 200.1 – Andesite

Figure 200.2 – Basalt

Figure 200.3 – Diorite

Figure 200.4 – Gabbro

Figure 200.5 – Gneiss

Figure 200.6 – Granite

Figure 200.7 – New Ulm Quartzite

Class B

This is crushed rock from carbonate and metamorphic bedrock sources.

Figure 200.8 – Schist

Figure 200.9 – Carbonate

Class C

This is naturally or partially crushed aggregate from a natural gravel deposit.

Figure 200.10 – Natural Gravel

Class D
This is 100% crushed natural gravel obtained from crushing material at least twice as large as the maximum aggregate size of the specified mixture.

Class E
This a mixture of at least two of the following classes of aggregate: Class A, B, and D.

Steel Slag
This aggregate is a byproduct of the steel making process. It can constitute no more than 25% of the total aggregate in a 2360 specification mixture.

Figure 200.11 – Steel Slag

Taconite Tailings
A byproduct of taconite ore mining used in HMA. See specification 3139.2.B.7 for acceptable locations of origin for taconite tailings.

Figure 200.12 – Taconite Tailings

Recycled Asphalt Shingles (RAS)

Recycled Asphalt shingles are a by-product of shingle manufacturing in the form of tabs. Asphalt shingles from a roof can also be used. Shingles include a hard, durable aggregate and stiff asphalt binder. RAS fit into one of two categories: Manufactured Waste Scrap Asphalt Shingles (MWSS) or Tear-Off Scrap Shingles (TOSS).

The shingle processor must show compliance with MnDOT's RAS Certification by completeing the form for Scrap Aspahlt Shingles from Manufacture Wast or the form for Tear-Off Scrap Asphalt Shingles. These forms are on the MnDOT Bituminous Engineering website.

Figure 200.13 – Recycled Asphalt Shingles

Crushed Concrete and Salvaged Aggregate

These aggregates may constitute up to 50% of the aggregate mixture in a bituminous non-wearing course. They are not allowed in wearing course mixtures.

Figure 200.14 – Pile of recycled concrete ready for crushing

Recycled Asphalt Pavement (RAP)

RAP is the term given to removed and reprocessed materials containing asphalt and aggregates. It is generally obtained by milling an asphalt pavement. Oftentimes, a Contractor will incorporate RAP from the paving project in the mix for that project. MnDOT's Specification 2360 allows the permissive use of RAP in all Superpave mixes. The specification limits RAP usage based on the ratio of new asphalt binder to total asphalt binder in the mix. The ratio depends on the asphalt binder grade specified in the mixture. RAP may not contain objectionable material such as metal, glass, wood, plastic, brick, silicone sealant, or rubber.

Figure 200.15 – A stockpile of processed RAP

Figure 200.16 – Examples of RAP contaminants including loop detector wires, rubber sealant, and wood

210.5 – Aggregate Properties

Below is a list of the chief characteristics of aggregates that determine their suitability for a given application.

Gradation

A key component of aggregates used in asphalt paving is the distribution of particle sizes, or gradation. Aggregates having different maximum particle size can have different degrees of workability. Typically, the larger the maximum aggregate size in relation to layer thickness the more difficult it is to compact the mix. To determine particle size distribution, a gradation is performed. In a gradation, aggregate is passed through a series of sieves stacked with progressively smaller openings from top to bottom. To facilitate aggregate movement through the sieves, the stack is shaken by a mechanical device. The aggregate gradation is represented by the percent of the aggregate mixture passing through each sieve. Within a gradation, aggregates are classified as either coarse or fine based on whether they are retained on or pass through the #4 (4.75 mm) sieve. See Lab Manual sections 1202 and 1203 for gradation procedures.

The aggregate gradation directly affects the pavement's void structure, which is a fundamental property of an asphalt pavement. The void structure is checked by measuring the Laboratory Compacted Air Voids, the Laboratory Compacted Voids in Mineral Aggregate (VMA), and the Field Compacted Air Voids (density). In practical terms, voids represent the density and permeability of an asphalt pavement. The higher the voids, the less dense and more permeable the asphalt is. Lower voids mean the pavement is denser and less permeable. Very low or complete lack of voids will result in a mixture subject to plastic deformation or rutting. Achieving the proper void structure is paramount to a successful asphalt pavement.

There are different types of aggregate gradations. Asphalt mixtures are generally identified by the type of gradation used to design the mixture. A mixture can be Dense Graded, Gap Graded, or Open Graded:

Dense Gradation

This is the typical gradation used in HMA mixtures. It is characterized by an even distribution of coarse and fine aggregates.

Gap Gradation

Used in UTBWC and SMA mixes, this gradation provides a dense, impervious service with aggregates ranging in size from coarse to fine with some intermediate sizes missing or present in small amounts. Typically, a mineral filler will be used to fill the small voids.

Open Gradation

Typically used in permeable asphalt mixes and high-friction wearing courses, this consists of aggregate with a relatively uniform gradation possessing interconnected voids to allow the passage of water through the pavement.

Figure 200.17 – Sieves and sieve shaker used to run an aggregate gradation.

Crushing

The amount of crushing, or angularity, of the aggregate is an important component to the mixture structure. The more angular the particles, the more they will resist deformation and shear forces, reducing the potential for rutting.

Percent Crushed Particles (MnDOT laboratory test method 1214, ASTM D 5821)

Specific Gravity

The volumetric mix design method that MnDOT uses requires the measurements of the aggregate specific gravities. Specific gravity of an aggregate is the ratio of the weight of a unit volume of the material to the weight of an equal volume of water. It is useful in making weight-volume conversions and in calculating the void content in a compacted HMA.

Specific Gravity & Absorption of Coarse Aggregate (MnDOT laboratory test method 1204, based on AASHTO T85)

Specific Gravity & Absorption of Fine Aggregate (MnDOT laboratory test method 1205, based on AASHTO T84)

Aggregate Quality

Aggregate quality measures specific characteristics that determine an aggregate's ability to remain durable and resilient throughout the life of a bituminous pavement.

Durability and Soundness

Durability and soundness are characteristics of the aggregate's ability to resist breakdown due to weathering, due to aging, during handling, during construction, and under traffic. Durability and soundness are tested with the Los Angeles Rattler (LAR) test and the Magnesium Sulfate soundness test. Specifically, the LAR tests the mechanical strength of the aggregates (especially during construction), while the Magnesium Sulfate Soundness test measures the aggregate's ability to withstand breakdown from freeze-thaw cycles.

Los Angeles Rattler (MnDOT laboratory test method 1210, based on AASHTO T 96)

Magnesium Sulfate (Soundness) (MnDOT laboratory test method 1219, based on AASHTO T 104)

Spall Materials and Lumps

Spall materials include shale, iron oxide, unsound chert, clayey limestones, and other materials with similar characteristics. The percentage of spall materials is determined by a manual lithological count. These are soft aggregates that typically will stain or pop out of the finished surface of the mat.

Spall Materials and Lumps (Lithological Summary) (MnDOT laboratory test method 1209)

Insoluble Residue

This gives an indication of the potential for the carbonate aggregate to polish and become slippery.

Insoluble Residue (MnDOT laboratory test method 1221, based on ASTM D 3042)

Flat and Elongated Particles

This determines the proportion of flat and elongated particles in the aggregate mix. Flat and elongated particles tend to lock up more readily during compaction making compaction more difficult. And, they also have a tendency to fracture, along their weak, narrow dimension, during compaction. In bituminous seal coats, flat and elongated particles increase the potential for bleeding of the emulsion and chip loss.

Flat and Elongated Particles in Coarse Aggregate (MnDOT laboratory test method 1208, based on ASTM D4791)

Flakiness Index (MnDOT laboratory test method FLH T 508, MnDOT Modified)

Stripping Potential

Stripping is the loss of bond between aggregates and asphalt binder and is caused by the action of water interaction with the mixture. Aggregates coated with too much dust can also cause poor bonding resulting in stripping. The inherent electrical charges of the binder and the aggregate may result in a bond that is susceptible to stripping. This is due to two similar electrical charges between the aggregate and asphalt binder, causing them to repel each other. The Tensile Strength Ratio, or Lottman Test, is a predictor of the potential for stripping to occur. The Hamburg Wheel-Track (HWT) test is another test that can predict stripping potential. As of the writing of this Manual (2018), MnDOT is reviewing the HWT for future implementation.

Tensile Strength Ratio (Lottman Test) (MnDOT laboratory test method 1813, based on ASTM D 4867)

Hamburg Wheel-Track Testing of Compacted Hot Mixtures (AASHTO T324)

Sand Equivalent

This test quantifies the amount of plastic fines in the aggregate. Excessive clay-like fines may coat the aggregate and prevent adhesion of the binder to the coarse aggregate.

Sand Equivalent Test (ASTM 176)

Aggregate Contamination

At no point should any deleterious or objectionable material be allowed into the aggregate used in a bituminous mixture. Examples of objectionable materials include metal, glass, wood, plastic, brick, or rubber. Coarse aggregate must also be free of clay and silt coatings. Soil materials such as clay, loam, or silt must not be added to compensate for a lack of fines in the aggregate mixture. See MnDOT Specification 3139 for more information.

Figure 200.18 – Aggregate mix contaminated with pieces of wood, which is considered deleterious material.

220 – Asphalt Binder

While aggregates provide the structural backbone of a bituminous pavement, asphalt binder is what holds the aggregates together and gives a bituminous pavement flexibility, smoothness, and dark appearance. This chapter will describe the properties and classifications of asphalt binders.

220.1 – Asphalt Binder Grades

The asphalt binders used in Minnesota's bituminous pavements are designated based on the AASHTO M332 Performance Grading (PG) system. The PG system designates an upper temperature limit, a traffic loading designation, and a lower temperature limit. Below is an example of a typical PG binder grade:

PG 58S - 28

Where:

PG stands for Performance Grade, which is the asphalt grading system that was developed by the Strategic Highway Research Program (SHRP).

58 is the maximum seven day average pavement temperature in °C at a depth of 20 mm into the pavement where the binder will resist rutting.

S is the traffic loading designation, and relates to the rutting resistance of the binder. Below are the possible traffic loading designations:

S – Standard (No Polymer)
H – High (Some Polymer)
V – Very High (More Polymer than H)
E – Extremely High (Most Polymer)

- 28 is the minimum one day low temperature in °C where the binder will resist cracking. It is measured at the pavement surface.

The specific grade of binder used in a bituminous mixture will depend on the predicted traffic loading, whether the proposed project is an overlay or new construction, whether the mixture will be wearing or non-wearing, and the weather conditions the road will be subjected to. MnDOT's PG Binder Guidelines gives specific guidance on the selection of binder grades.

220.2 – Performance Characteristics of Asphalt Binders

From a performance standpoint, an asphalt binder has two main objectives besides aggregate bonding: resist rutting and resist cracking. This is where the upper and lower design temperature limits of the Performance Grading designations come into play. The upper temperature limit and traffic loading designation are indications of a binder's ability to resist rutting at high temperatures. The lower temperature limit is an indication of the binder's ability to remain flexible and resist cracking at low temperatures. Both characteristics are extremely important to consider when selecting the correct binder grade for a project.

The use of RAP in today's paving mixtures is very common. However, when the asphalt binder from the recycled material mixes with the virgin asphalt binder, it can affect the physical characteristics of the virgin asphalt binder and ultimately affect the long-term performance of the mixture. Recycled asphalt materials usually come from a roadway or a roof that has been in service for many years. Over the service life of that material, the asphalt becomes aged or oxidized, which stiffens the asphalt binder. While stiffening of the asphalt binder may help an asphalt mixture in terms of resisting rutting, it hurts the mixture in terms of remaining flexible to resist low temperature cracking. To minimize the stiffening effects of recycled asphalt materials, MnDOT limits recycled materials by comparing the new added asphalt in a mix to the total asphalt in the mix. A PG XX-34 grade asphalt binder is normally specified in the upper 4" of a newly constructed pavement because it has the ability to resist low temperature cracking up to -34 °C. To ensure that the cracking resistance of that binder is not marginalized by the addition of recycled asphalt materials, MnDOT limits the ratio of new added asphalt to total asphalt to 80%. MnDOT limits this ratio to 70% when a PG XX-28 is specified.

In addition to the performance characteristics of an asphalt binder, economics must be considered when selecting a binder. It is very possible to use an asphalt binder that has performance characteristics that far exceed its design needs. However, the greater the performance characteristics of a binder, the more expensive it will become. It is therefore essential to select a binder that meets the design needs of the project, but does not greatly exceed those needs.

230 – Cutback Asphalts

Cutback asphalts, or cutbacks, are liquid asphalts manufactured by adding petroleum solvents to asphalt cements. Currently, these are rarely used. It is recommended to become familiar with special handling by reviewing the Materials Safety Data Sheet for each. Cutbacks are classified by the speed in which they cure. Below are the common classifications of cutbacks:

Rapid Curing Cutback Asphalt

Rapid Curing Cutback Asphalts (RC) are typically produced by adding gasoline or naptha to asphalt cement. RCs are primarily used for tack coats, stabilization, and seal coats. MnDOT no longer specifies the use of this material due to its flammability and effect on the environmental.

Medium Curing Cutback Asphalt

Medium Curing Cutback Asphalts (MC) are produced by adding a diluent such as kerosene to asphalt cement. Grades of MC indicate the amount of diluent in the mixture. MC-30 grade contains the most diluent, while MC-3000 contains the least.

Medium curing cutbacks can be used for prime coats, tack coats, stabilization, and road mixtures, but their use is decreasing due to environmental concerns. Emulsions are typically used in place of MCs. When specified, material requirements for MCs are listed under MnDOT Specification 3151.2.B.

Slow Curing Liquid Asphalt

Slow Curing Liquid Asphalts (SC), or Road Oils, are produced by adding light end fuels, such as kerosene, to asphalt cement. As the name indicates, these materials change very slowly in a mixture. They can be used for prime coats, stabilization, and road mixtures, but are no longer specified by MnDOT.

240 – Asphalt Emulsions

Asphalt emulsions are a mixture of asphalt, water, and an emulsifying agent used to keep the asphalt in suspension. Emulsions are widely used in Minnesota for tack coats, fog seals, chip seals, micro surfacing, CIR, and SFDR. Shortly after application, asphalt emulsion will begin to "break". When the emulsion breaks, the material changes color from brown to black. Breaking indicates the emulsion is beginning to adhere to the surrounding material. Once all of the water in the emulsion evaporates the emulsion is said to have "set."

There are two main classifications of asphalt emulsion: anionic and cationic. Cationic emulsions have a positive charge, while anionic emulsions have a negative charge. When combining an emulsion with aggregate, such as for use with a chip seal, care must be taken to ensure the aggregate charge is compatible with the emulsion's charge. Material requirements for asphalt emulsions can be found in MnDOT Specification 3151.2.C. More information regarding the naming conventions of asphalt emulsions can be found below:

Charge

The first letter, or lack thereof, denotes the emulsion's charge:

C = Cationic (Positive Charge)
No Letter = Anionic (Negative Charge)

Float

HF = High Float. If applicable, HF comes after the charge designation of the emulsion. High float emulsifiers are designed to form a gel or thick asphalt film around the aggregate. High float emulsions are typically used in Otta Seals or in cases of dirty aggregate (Chip Seals), but not as tack coat or fog seal.

Set Time

The next two letters designate the emulsion's set time:

QS = Quick Set. These emulsions are used with Microsurfacing treatments in Minnesota.
RS = Rapid Set. These are the least stable type of emulsions, breaking quickly when in contact with aggregate. The break is a chemical process.

MS = Medium Set. These emulsions are designed to allow time for the emulsion to mix with and coat the aggregate, but will cure soon after application to the pavement.
SS = Slow Set. With a break controlled by evaporation, slow set emulsions are designed to allow extended time for the emulsion to mix with the fine aggregate.

Viscosity
If applicable, the next number designates the viscosity of the emulsion:

No Number = Standard viscosity emulsion
1 = Low viscosity emulsion
2 = High viscosity emulsion

Hardness
If applicable, the next letter denotes the hardness of the asphalt.

No letter = Standard base asphalt
h = Hard base asphalt
s = Soft base asphalt

Polymers
If an emulsion is polymer-modified, a "P" is added at the end of the emulsion name. Polymers can provide emulsions with added benefits, including improved strength, elasticity, adhesion, or durability.

Dilution
If an emulsion is specified to be diluted, a "d" is added at the very end of the emulsion name. For emulsions used for Tack Coat (MnDOT Specification 2357), dilution is only allowed by the manufacturer at a rate of 7 parts emulsion and 3 parts water. Field dilution by the Contractor is not allowed. A Fog Seal (MnDOT Specification 2355) is diluted by the manufacturer 1 part water to 1 part emulsion.

Below is an example of a typical asphalt emulsion:

CRS-2Pd

CRS-2Pd is a **d**iluted, **C**ationic, **R**apid **S**et, High Viscosity, **P**olymer modified emulsion specified for use with fog seals in Minnesota. For more information on different emulsions and their applications within the State of Minnesota, see Table 230.1 below:

Emulsion Designation	Tack Coat	Fog Seal	Chip Seal	Micro Surfacing	Otta Seal
CRS-2P			X		
CRS-2Pd		X			
CSS-1	X				
CSS-1h	X	X			
CQS-1P				X	
CQS-1hP				X	
HFMS-2s					X

Table 200.2 – Emulsion Usage by Treatment Type

250 – Crack Treatment

The sealants used to treat cracks have specific properties that make them suitable for their intended purpose. This section will highlight the different types of crack treatment materials used in Minnesota. Products used for crack treatment in Minnesota must be on the Approved Products List.

MnDOT Specification 3719 Sealant
This is a hot-poured crumb rubber sealant containing a percentage of recycled rubber. It is typically the least expensive and the least elastic crack treatment product that MnDOT specifies and is only used with the Clean and Seal method of crack sealing bituminous pavements.

MnDOT Specification 3723 Sealant
This is a hot-poured elastic crack and joint sealant. It is typically in the midrange in terms of cost and elasticity. 3723 sealant can be used with the Clean and Seal method of crack sealing bituminous pavement and with the Saw and Seal method of jointing bituminous pavement. Saw and Seal is a method of controlling where a bituminous pavement will crack by preemptively sawing joints into the new mat at locations of probable crack development and sealing those joints with hot-pour sealant. While Saw and Seal does control cracking, it may result in the same poor smoothness conditions experienced with cracks on heavily travelled routes.

Figure 200.19 - Saw and Seal roadway.

MnDOT Specification 3725 Sealant

This is a hot-poured, extra-low modulus, elastic crack and joint sealant. Of the crack and joint sealants used in Minnesota, it is typically the most expensive sealant with the greatest elasticity. 3725 sealant is used with the Rout and Seal method of crack sealing bituminous pavement and can be used with the Saw and Seal method of jointing bituminous pavement.

Mastic

Mastic is used to level depressed cracks and fill other small voids in the pavement. See special provision 2331: Mastic for Void Filling in the most recent version of the MnDOT Special Provision Boiler Plates for a list of approved mastic products.

260 – Asphalt Additives

Additives are specialized chemicals used to address deficiencies or improve characteristics of an asphalt cement or emulsion. Over the years, many types of additives and modifiers have been used. Some of these would include crumb rubber, polyphosphoric acid, polymers, sulfur, and anti-stripping additives. Below are the additives used in Minnesota's bituminous pavements:

Polymer Modified Asphalt Cement

Polymers are a large group of products that include elastomers and plastomers. In cases where traffic or the environment require a greater resistance to rutting or cracking, a virgin asphalt binder may be modified. MnDOT adopted AASHTO M332 for binder testing in 2018 to test for a minimum amount of polymer to help resist rutting potential.

Anti-Stripping

This is a chemical designed to promote coating of the aggregates and resist the tendency of bitumen to strip from the aggregates. It is mixed with the bituminous material and constitutes less than 1 ½ percent of the bituminous material by volume. MnDOT Specification 3161 addresses the required qualities for anti-stripping additive. If the Contractor adds the anti-strip themselves at the plant, they must follow all the requirements of 2360.2.C.2 and 2360.2.C.3.

Recycled Engine Oil Bottoms

Recycled engine oil bottoms (REOB) are produced from the process of refining used engine oil and can be added to asphalt binders. These have been used since the 1980s to soften virgin binders (drop the PG grade) and to counteract the stiffening of binders to allow for the use of recycled asphalt pavements (RAP) or shingles (RAS). Their use has been banned in some states due to unknown effects on long term performance. Currently, research is being done on the effects and use of REOB.

Silicone Anti-Foaming

This additive is designed to reduce foaming when hot asphalt comes in contact with moisture. The quantity of additive used is typically very small (about one ounce per 5000 gallons of binder) and is normally added at the refinery.

Chapter 3 – Asphalt Mixtures

300 – Introduction

Once the appropriate aggregates and binders have been selected for a project, they are combined in specific proportions to produce plant mixed asphalt. From city streets to interstate highways, plant mixed asphalt is the material used to pave the majority of the roads in Minnesota.

Plant mixing provides uniform proportioning of the aggregate and thorough mixing with the bituminous material. The type of mixture specified is dependent upon the anticipated traffic to which the road will be subjected, whether the mixture is used for a wearing or non-wearing course, the thickness of the proposed paving lifts, and the temperatures the road will be subjected to in the summer and winter months. These mixtures are generally paver-laid and compacted with self-propelled steel-wheeled rollers and pneumatic tired rollers. This chapter will describe the important characteristics of plant mixed asphalt.

310 – Asphalt Mixture Properties

There are several important properties of an asphalt mixture that must be taken into account during design, production, and placement. These properties include stability, durability, flexibility, fatigue resistance, skid resistance, permeability, workability, asphalt binder content, and air voids. Below are descriptions of these key properties.

Stability
This is the ability to support traffic loads without experiencing deformations such as rutting or shoving. A stable pavement is able to maintain its shape and smoothness under repeated traffic loadings. The stability of a mixture depends on both internal friction between aggregate particles and particle cohesion. Internal friction relates to the shape and surface texture of the aggregate particles, while cohesion is the bond strength between the asphalt-coated particles. The primary sources of pavement instability are excess asphalt binder in the mix, excess medium sized-sand in the mix, or rounded aggregate with little or no crushed surfaces.

Durability
The durability of an asphalt pavement is its ability to maintain its structural integrity throughout its expected service life when exposed to the damaging effects of the environment and traffic loads. A lack of durability can result in aging or oxidation of the asphalt binder, disintegration of the aggregate, and stripping of the asphalt film from the aggregate. Poor durability can be caused by low asphalt content, high air voids, lack of compaction, or aggregates that are susceptible to stripping. Durability can be enhanced by ensuring adequate asphalt film thickness, using a dense gradation of sound, tough, strip resistant aggregate, and by properly compacting the mixture for density and impermeability.

Flexibility
Flexibility is the ability of a hot mix asphalt pavement to adjust to gradual settlements and movements in the subgrade without cracking. Since virtually all subgrades either settle under loading or rise from soil expansion (heaving), flexibility is a desirable characteristic for all hot mix asphalt pavements. Flexibility becomes especially important in a cold climate like that of Minnesota. In the cold winter months, asphalt becomes less flexible and more brittle, making it more susceptible to thermal cracks from material contraction. Because of this, it is important to select an asphalt mixture that is appropriate for the climate in which it is used. Section 320 – Asphalt Mixture Selection and Design will detail the important characteristics of an asphalt mixture that helps it withstand a variety of temperatures.

Fatigue Resistance
Fatigue resistance is the pavement’s resistance to repeated bending under wheel loads from traffic. Air voids, asphalt binder viscosity, and binder modifications all have a significant effect on fatigue resistance. As air voids in the pavement increase, either by design or lack of compaction, fatigue resistance is reduced. Likewise, a pavement containing asphalt that has aged and hardened significantly has reduced resistance to fatigue. Other factors that help prevent fatigue cracking include pavement thickness, pavement strength, and support from the subgrade.

Skid Resistance
Skid resistance is the ability of an asphalt pavement surface to minimize skidding or slipping of vehicle tires, particularly when wet. In general, the more coarse or angular the aggregate, the better the skid resistance will be. Aggregates that tend to “polish” smooth under traffic have poor skid resistance. Flushing or bleeding from excess asphalt binder on the pavement surface, or from over application of emulsion in a surface treatment can create serious skid resistance problems.

Permeability

Permeability is the degree to which a pavement allows the passage of air and water through the void spaces in the asphalt pavement. This characteristic is directly related to the density of the compacted mixture. Even though void content is an indication of the potential for passage of air and water through a pavement, the character of the voids is more important than the number of voids. The size of the voids, whether or not they are interconnected, and the access to the voids from the pavement surface all determine the degree of permeability.

Figure 300.1 – Falling-Head Permeameter used to measure permeability of the mat

Workability

Workability describes the ease with which a paving mixture can be placed and compacted. “Harsh” mixes contain a high percentage of coarse aggregate, have a tendency to segregate with handling, and may be difficult to compact. “Tender” mixes are too easily worked or shoved, and may be too unstable to place and properly compact. Tender mixes may be caused by too much medium sized sand, smooth or rounded aggregate particles, too much moisture in the mix, and/or excessive mix temperature. Tenderness can vary depending upon the mixture temperatures. The simplest way to limit issues with tenderness is to avoid compaction operations during the range of temperatures that exhibit tenderness. See Section 610.4 – Tender Zone (Tender Mixes) for more information about tender mixes.

Asphalt Binder Content

The asphalt binder content in the mixture is a critical characteristic of an asphalt pavement. It must be accurately determined in the laboratory and controlled during production. Binder content is usually expressed as a percentage of asphalt binder in the mix by weight. The optimum asphalt binder content of a mix is highly dependent on the aggregate gradation and absorption. Highly absorptive aggregates increase the quantity of asphalt binder required to satisfy mix demands. Likewise, a relatively fine mix gradation has a larger total surface area, requiring a greater amount of asphalt binder to effectively coat the particles. Conversely, a relatively coarse mix gradation has less total aggregate surface area and therefore demands less asphalt binder to coat particles.

Air Voids and Density

Air voids are small pockets of air between the coated aggregate particles in the final compacted mix. The durability of a hot mix asphalt pavement is a function of the air void content. An asphalt pavement with an air void content that is too high will have excess passageways allowing the entrance of damaging water and air into the mat. This can cause premature raveling and pothole formation. An air void content that is too low can lead to flushing under compaction by traffic. Flushing is a condition in which excess asphalt binder squeezes out of the mix onto the pavement surface since there are not enough voids in the pavement to accept the displaced asphalt binder. A mix that is too low in air voids can also be prone to rutting under traffic and temperature extremes. Air void content and density are directly related. The higher the density the lower the air voids in the mixture, and the lower the density the higher the air voids in the mixture.

In general terms, it has been determined by Washington State DOT that each 1% increase in air voids above 7% tends to result in a 10% loss in pavement life. This highlights the importance of the relationship between air voids, density, and compaction.

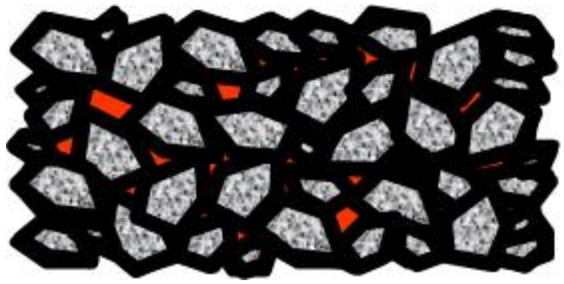


Figure 300.2 – Representation of Aggregates (gray), Asphalt Binder (black), and Air Voids (red)

320 – Asphalt Mixture Selection and Design

Asphalt pavement mix designs are currently based on the Superpave mix design process. Superpave technology is the result of a $50 million Strategic Highway Research Program (SHRP) research effort that was used to develop performance based specifications to relate laboratory analysis to field performance. The Superpave gyratory mix design process replaced the Marshall mix design process in Minnesota in the late 1990's.

Superpave mix design is a structured design approach consisting of the following four steps:

1. Selection of materials
2. Selection of design aggregate structure
3. Selection of design asphalt binder content
4. Evaluation of moisture susceptibility

Typically, the Agency will select the type of mixture they want to use, it is then up to the Contractor to determine the specific aggregate and asphalt binder content required to satisfy the project specifications. The following section will go into the details of the Superpave mix selection and mix design process.

320.1 – Specification 2360: Superpave Gyratory Mixtures

Superpave gyratory mixtures are the most common bituminous mixtures used in Minnesota. They are called gyratory mixtures because they are compacted in the laboratory with a gyratory compactor at the time of design, which simulates field compaction. MnDOT gives them a mixture designation code that identifies the specific characteristics of that mix. This code is used during design and construction. The following is a description of each designation within the code:

Mixture Design Type

The first two letters indicate the mixture design type:

SP = Superpave Gyratory Mixture Design
SM = Stone Matrix Asphalt (MnDOT Specification 2365)

Course Designation

The third and fourth letters indicate the course:

WE = Wearing Course Mixture
NW = Non-Wearing Course Mixture

Wearing Course is considered to be the top 4” of the pavement section (top 3” for non-trunk highways (local agency) with traffic levels less than 3 million ESALs).

Non-Wearing Course is considered to be anything below the top 4” of the pavement section (3” for non-trunk highways (local agency) with traffic levels less than 3 million ESALs).

Maximum Aggregate Size

The fifth letter indicates the maximum aggregate size:

A = ½ in [Nominal size 9.5 mm per Superpave definition]
B = ¾ in [Nominal size 12.5 mm]
C = 1 in [Nominal size 19.0 mm]
D = ⅜ in [Nominal size 4.5 mm]
E = SMA

Lift thickness should be considered when specifying the aggregate size (A, B, C, or D). To optimize density and minimize the potential for segregation, the lift thickness to maximum aggregate size of the mix should ideally have a minimum ratio of 1 to 3 for fine mixtures and 1 to 4 for coarse mixtures. For example, an A gradation should have a minimum lift thickness of 1.5” and B gradations should use 2” as the minimum lift thickness.

Aggregate sizes A and B are specified most often, with aggregate size A frequently used in wearing course mixtures due to the tight surface it produces when compacted properly. Aggregate size B is most often specified and will accommodate RAP more readily than size A. C gradations are rarely used, but can be incorporated into non-wearing mixtures with a 3” minimum lift thickness. Size D gradations will produce the finest, tightest driving surface. They are typically specified with thinlift overlays, a type of preventive maintenance treatment. As shown above, E gradations are only used with SMA mixtures.

Traffic Level

The sixth digit indicates the Traffic Level (ESAL’s × 10^6) in accordance with Table 2360-1:

2 = Traffic Level 2 (<1.0 and Shoulders)
3 = Traffic Level 3 (1 – 3)
4 = Traffic Level 4 (3 – 10)
5 = Traffic Level 5 (10 – 30)
6 = Traffic Level 6 (SMA)

Traffic Level is based on ESALs. For areas with particularly slow traffic, or for shoulders where traffic is allowed onto the shoulders, consider using a higher traffic level than what is determined by the ESALs.

Design Air Voids

The seventh and eighth digits represent the design air voids:

30 = 3.0% Design Air Voids
40 = 4.0% Design Air Voids

Traffic volumes should be considered when specifying air voids in the mixture. A non-wear mixture will always have 3.0 percent air voids. Mainline wear mixtures will have 4.0 percent air voids and shoulder wear mixes will have 3.0 percent air voids. The Engineer should consider modifying mainline wear traffic level 2 mixtures to 3.0 percent air voids for low-volume local agency pavements having less than 0.3 million ESALs. Use 4.0 percent air voids on higher volume facilities.

Asphalt Binder Grade

The final letter indicates the asphalt binder grade:

A = PG 52S – 34
B = PG 58S – 28
C = PG 58H – 34
E = PG 58H – 28
F = PG 58V – 34
H = PG 58V – 28
I = PG 58E – 34
L = PG 64S – 22
M = PG 49S – 34

Guidelines for selecting asphalt binder grades can be found in MnDOT's PG Binder Guidelines. Below are some general binder selection considerations:

For any new construction, including CIR, FDR, SFDR, and reconstruction projects, specify PG 58H-34 or PG 58V-34 in the wearing course of the pavement structure. Typically, PG 58S-28 or PG 58H-28 is specified for overlay construction. The same PG grade should be used throughout the wearing course.

In most cases, specify a PG 58S-28 in a non-wearing mixture. Research at MnROAD has shown that the pavement typically does not reach temperatures below -28 °C in the non-wearing course. The use of a more expensive asphalt binder below these depths is usually not warranted, unless it makes economic sense. The same PG grade should be used throughout the non-wearing course.

For areas with particularly slow traffic, consider specifying a binder grade with a higher traffic loading designation than would otherwise be specified.

For shoulders where traffic is allowed, the same binder grade as mainline should typically be specified. For shoulders where traffic is prohibited, either PG 52S-34 or PG 58S-28 should be selected by matching the mainline low PG number. For example, if PG 58H-28 is specified on the mainline paving, PG 58S-28 should be specified for the shoulders if traffic is prohibited on the shoulders.

For temporary construction (2 years or less) and crossovers that will be removed, consider using PG 64S-22 when PG 58H-28 or PG 58V–28 is otherwise recommended.

In special situations, or when varying from these guidelines, consult the MnDOT Bituminous Office in the Office of Materials and Road Research, 651-366-5592.

Putting it All Together

Below is an example of a superpave mix code incorporating all the designations listed above:

SPWEB440E

The above example denotes a superpave wearing course using ¾” maximum aggregate sizing for a traffic level 4 road designed for 4.0% air voids. This mix uses PG 58H – 28 binder.

320.2 – Asphalt Mixture Design

Selection of Aggregate Structure

The Agency selects the traffic level and nominal aggregate size they want to use in a bituminous mixture. It is then up to the Contractor to select and proportion aggregates to satisfy the gradation and quality requirements of the Specifications. This will be based on economics and availability. For more information, see MnDOT Specifications 2360.2.E and 3139.2.

Asphalt Binder Content

The Contractor will use the specified grade of asphalt binder and determine the amount of binder required in the mixture to meet Specifications.

Moisture Susceptibility

To determine the moisture susceptibility (stripping potential) of a mix, a Lottman Test is performed. See the MnDOT Laboratory Manual, section 1813 for specific details regarding the Lottman Test.

Figure 300.3 – Apparatus used to perform a Lottman test.

Mix Design Report (MDR)

After the Contractor submits their proposed aggregate proportions, MnDOT develops a Mix Design Report (MDR). The MDR includes upper and lower aggregate gradation limits and target asphalt binder content, expressed as a percent of the total mixture. For more information, see MnDOT Specification 2360.2.E.

320.3 – General Mixture Selection Guidelines

Below are some general considerations to keep in mind when specifying an asphalt mixture for a project:

- Be careful when specifying air voids in the mixture. A non-wear mixture will always have 3.0% air voids (SPNWXX30X). Mainline wear mixtures typically have 4.0% air voids and shoulder wear will have 3.0% air voids.

- Bikeway Trail mixture designation should be **SPWEA230B**. Consider using aggregate size **A** for all bikeways and trails. See the Bicycle Path Design Manual for additional guidance. If the trail is a small portion of the project, use one of the mixtures already specified for the roadway paving if possible.

- RAP shall be used in the non-wear courses and is encouraged in the wear courses.

- The use of warm mix asphalt is permissible on both Federal Aid and State Aid projects provided the requirements of specification 2360 are met. There may be economical and environmental incentives to use this type of asphalt.

- Minimize the number of mixtures and PG grades on any one project. Typically, it is not economical to specify another bituminous mixture less than 2000 tons.

- The project designer should consider whether to specify fewer, thicker lifts or thinner lifts in the typical section. The greatest benefit of paving thicker lifts is improved density. The greatest benefit of paving more lifts is the ability to improve ride. However, it has been shown that ride improvements from 2 to 3 lifts are not as great as from 1 to 2 lifts. In some situations, it may make more sense to pave fewer lifts.

- For special or unique design considerations, contact the MnDOT Bituminous Office in the Office of Materials and Road Research, 651-366-5592.

320.4 – Determining Quantity of Mix

Once the mixture has been selected, and the area to be paved is determined, the designer needs to estimate a quantity of mixture to specify in the Statement of Estimated Quantities and in the plan tabs. To determine this quantity, the designer needs to know the total area to be paved, in square yards, as well as the proposed pavement thickness, in inches. For estimation purposes, the unit weight of bituminous pavement is 113 pounds per square yard inch. In other words, one square yard of one inch thick bituminous pavement weighs 113 pounds. The following formulas can assist the designer in converting their proposed asphalt section to an estimated quantity in tons.

$$\frac{Design\ Length\ (ft) \times Design\ Width\ (ft)}{9} = Design\ Paved\ Area\ (Square\ Yards)$$

__________ Square Yards x _________ Inches Thick x 0.0565 = Tons of Bituminous Mixture

Where:

$$0.0565 = \frac{113\ pounds\ per\ sqare\ yard\ inch}{2000\ pounds\ per\ ton}$$

Example:
Proposed Roadway Length = 20,000 ft
Proposed Roadway Paved Width = 24 ft
Proposed Bituminous Thickness = 5.0”

$$\frac{20{,}000\ (ft) \times 24\ (ft)}{9\ ft^2/SY} = 53{,}333.3\ SY$$

$$53{,}333.3\ \times\ 5.0\ inches\ \times \frac{113\ pounds\ per\ sqare\ yard\ inch}{2000\ pounds\ per\ ton} = 15{,}066.7\ Design\ Tons$$

330 – Submitting a Mixture Design

Prior to use on a project, a mixture design must be submitted by the Contractor to a MnDOT District Materials Laboratory for approval. See the following table for more information on the submittal process for a mixture design:

Mixture Type	Mixture Design Submittal Location	MnDOT Standard Specification Location
Plant Mixed Asphalt Pavement (2360)	The MnDOT District Materials Laboratory in same district as the project.	2360.2.E "Mixture Design" on **page 180** of the Spec Book (page 194 of the pdf file).
Stone Matrix Asphalt (2365)	The MnDOT District Materials Laboratory in same district as the project.	2365.2.E "Mixture Design" on **page 214** of the Spec Book (page 228 of the pdf file).
Bituminous Seal Coat (2356)	The MnDOT District Materials Laboratory in same district as the project.	2356.2.E "Sealcoat Design" on **page 172** of the Spec Book (page 186 of the pdf file)
Ultrathin Bonded Wearing Course (2353)	MnDOT Central Office Materials Laboratory	2353.2.C "Mix Design." and 2353.2.D "Mix Design Submittal" on **page 162** of the Spec Book (page 176 of the pdf file)
PASSRC/PASSB (2363)	MnDOT Central Office Materials Laboratory	2363.2.C "Mixture Design" on **page 210** of the Spec Book (page 224 of the pdf file)
Micro Surfacing (2354)	The MnDOT District Materials Laboratory in same district as the project.	2354.2.E "Mixture Requirements" on **page 166** of the Spec Book (page 180 of the pdf file)

Table 300.1 – Mixture Design Submittal Information.

330.1 – Acceptance of Submitted Bituminous Mix Designs

The District Lab Chief or designee will review a submitted mix design and issue a Mix Design Report if all of the quality and specification requirements are met. Issuance is based on the following:

Option 1 or Option 2 submittal differs on experience of the Contractor's Mix Designer and if mixture samples and gyratory specimens need to be submitted and tested. Option 2 is only available with at least two years of experience in mixture design. See MnDOT Specification 2360.2.E.5.a for Option 1 requirements and 2360.E.5.b for Option 2 requirements.

Option 1 Mix Design Submittal (submittal of testing results and materials for agency testing):

1. Do not verify any mix design where any required test value from MnDOT testing falls outside the Specification limits.

2. When MnDOT test values differ from the Submitter's values, the mix design will be verified if the two values fall within the allowed working range/tolerance.

3. When the two values fall outside the normal working range/tolerance but still within the Specification limits, inform the submitter that this condition exists.

4. When the results of a Lottman Test are out of Specification, the Submitter must resubmit Trial Mix samples until the samples pass the Lottman test. It may be necessary for the Submitter to add Anti-Strip additive to the mixture.

5. Aggregate quality requirements must be met.

Option 2 Mix Design Submittal (Submittal of testing results only):

1. All the submitted testing results must meet required specifications.

2. Aggregate quality requirements must be met.

Option 3 Mix Design Submittal (Requirement of Option 2):

1. Used for 1 added aggregate product.

2. If directed by the Engineer, submit an optimum asphalt content point on paper for the proposed JMF (new design).

330.2 – Mix Design Submittal Packet

When submitting a trial mixture design, the Submitter must include several forms indicating specific properties of the mixture. An example of this form can be found in the Appendix. The following will describe the required forms included with the submission.

Cover Sheet

This sheet contains all contact information from the submitter, the mix design designation, the asphalt binder to be used, a signature of a Level 2 Bituminous Plant mix designer, and the corresponding information for the MnDOT District in which the mixture is to be used.

Job Mix Formula Sheet

The Job Mix Formula Sheet (JMF) is essentially the "recipe" for the proposed asphalt mixture. The JMF includes information such as aggregate sources, types, proportions, and composite gradations. The JMF also includes information about the asphalt binder, such as binder content and Asphalt Film Thickness.

Gyratory Blend

This worksheet determines several key properties of specimens produced with a Gyratory Compactor. These specimens are representations of the proposed asphalt mixture after placement and compaction in the field. Information about the specimen is input into the spreadsheet, such as dimensions, dry weight, SSD weight, and immersed weight. The spreadsheet then calculates the air voids and max specific gravity of the specimen.

0.45 Power Chart (Maximum Density Curve)

These charts use sieve sizes raised to the 0.45 power and represent the composite aggregate gradation of the proposed mix, and where it falls in relation to the Maximum Density line. The Maximum Density line is drawn from the origin to the maximum aggregate size and indicates a gradation where successively smaller particles are packed within the voids of larger particles. On the maximum density line, aggregates would be rearranged so they can be compacted to their maximum density leaving little volume for asphalt binder. Different shapes of the gradation curve indicate the type of gradation (i.e. dense, gap, open, uniform, coarse, or fine).

Corrected Maximum Specific Gravity Worksheet

This worksheet is used to correct variances of the maximum specific gravity at each asphalt content.

Voids in Mineral Aggregate Information

This worksheet shows the calculations and data at each asphalt content for VMA and VFA of the mixture.

Mixture Graphs
This form is a composite of the Trial Mix run for mixture submittal. The Trial Mix contains, at a minimum, 3 points to determine optimal air voids and asphalt content of the proposed mixture.

Gyratory Lottman Test Worksheet
This worksheet compiles the data for the Lottman/TSR/Moisture Sensitivity Test.

Fine and Course Aggregate Angularity Test Sheet
This worksheet compiles the results of the Fine Aggregate Angularity and Coarse Aggregate Angularity Tests.

Flat and Elongated Particles Worksheet
The flat and elongated particle worksheet compiles the results of the ASTM D-4791 test. This test measures the proportion of flat and elongated (arrowhead shaped) particles in the coarse aggregate mix.

Aggregate Specific Gravity Worksheet
This worksheet shows the calculations required to determine an Aggregate Specific Gravity for an individual product for Coarse, Fine, and Combined Gravities.

Asphalt Film Thickness Worksheet
This is a separate worksheet from the submittal packet, but is still required for Trial Mix submittal. It calculates the required AFT for the optimum point of the design mixture.

330.3 – Guidelines for Interpretation of Test Results

It is impossible to cover every possible situation where mix sample results do not meet the design air void requirements/criteria. Agency testing equipment must be calibrated with the Central Laboratory. For more information on testing procedure and calibration procedures of required equipment, see Chapter 4, Section 430 - Equipment Requirements.

- For the same aggregate and asphalt content, maximum mix gravity tests are very repeatable.

- If the percent air void content is changing with a constant maximum mix gravity it means the bulk gravity is changing. The bulk gravity will change (Assuming no aggregate type or proportion change) due to a change in the shape of the particles but most often from a change in gradation; the #200 sieve is especially critical.

- Adjustments must be made when the air void trend based on a moving average of 4 tests is outside of the mix design criteria. The calculation and recording of moving average data for acceptance for each project and course shall be the responsibility of the District Materials Engineer (Metro Inspection in the Metro District).

- Reaction time is imperative when values exceed twice the JMF bands for air voids for individual tests. Low air voids can cause rutting and shoving of the bituminous mat and can result in flushing which could create a hazardous situation in wet weather.

- High air voids may lead to raveling or a shortened service life.

340 – Safety

Asphalt binder and asphalt mixture are produced and placed at temperatures that can exceed 300°F. To avoid injury, care must be taken when working with these materials. This section contains information to help those who work with asphalt products to make safety conscious decisions.

340.1 – Safety Data Sheets

Safety Data Sheets (SDS) contain safety information about specific products and chemicals. The product manufacturer, distributor, and importer are required to provide SDS's for their products. Each SDS has 16 sections that are categorized as follows:

- Section 1: Identification

- Section 2: Hazard Identification

- Section 3: Composition/Information on Ingredients

- Section 4: First Aid Measures
- Section 5: Fire-Fighting Measures
- Section 6: Accidental Release Measures
- Section 7: Handling and Storage
- Section 8: Exposure Controls/Personal Protection
- Section 9: Physical and Chemical Properties
- Section 10: Stability and Reactivity
- Section 11: Toxicology Information
- Section 12: Ecological Information
- Section 13: Disposal Considerations
- Section 14: Transport Information
- Section 15: Regulatory Information
- Section 16: Other Information

MnDOT employees can access a list of SDS's available in MnDOT through the iHUB by clicking on A to Z, navigating to "S," and scrolling to "Safety Data Sheet." If a product of concern is not on the list, contact the product manufacturer, distributor, or importer to obtain the relevant SDS.

340.2 – High Temperatures

As stated previously, asphalt products often exceed 300°F. This warrants extreme caution when working with asphalt products, especially hot liquid asphalt. This video by the Asphalt Institute shows some steps to treat asphalt burns. The full video is available on the Asphalt Institute's website.

340.3 – Construction Safety

Construction projects present a wide range of potential safety hazards to those working in and around the construction zone. Familiarizing oneself with potential hazards as well as practices to mitigate and/or avoid those hazards is extremely important when working on a construction project. See chapter 5 - Asphalt Paving for more information about construction safety. Contact your Agency's Safety Administrator for additional information about construction safety.

Chapter 4 – Asphalt Mixture Production

400 – Introduction

Mixtures of heated aggregate and semi-solid asphalt cements mixed together in a central plant is called plant-mixed bituminous. Plant-mixing is the final step before the mixture is placed in a truck and hauled to the jobsite for paving. The plant in which the asphalt mixture is produced must follow proper procedures to ensure a high-quality product results from their operations. The mixing may be done in either drier drum or batch plants. This section will provide information about the plant mixing process as well as things to look for when inspecting a bituminous plant.

410 – Asphalt Mixing Plants

Figure 400.1 – Dryer-Drum Asphalt Plant

Asphalt mixing plants are classified into two main categories: batch plants and dryer-drum plants. Within these two categories exist several variations. The section below will describe the different types of asphalt mixing.

Batch Plants

The major components of a batch plant are the cold-feed system, asphalt cement supply system, aggregate dryer, mixing tower, and emission-control system (bag house). To begin production, the aggregates are taken from stockpiles and placed into individual cold-feed bins. Next, the aggregates pass through a dryer to be dried and heated. The aggregates are then sent over a screening unit that separates the aggregate mixture into different sized fractions. The aggregates are then stored in hot bins. From the hot bins, the aggregates are discharged into a hopper that determines their weight. The weigh hopper is then emptied into a pugmill and mixed for a short time. Asphalt binder is then added to the pugmill to produce a batch of asphalt mixture. The batch is then mixed and discharged from the mixing unit into trucks before additional materials are introduced to produce the next batch.

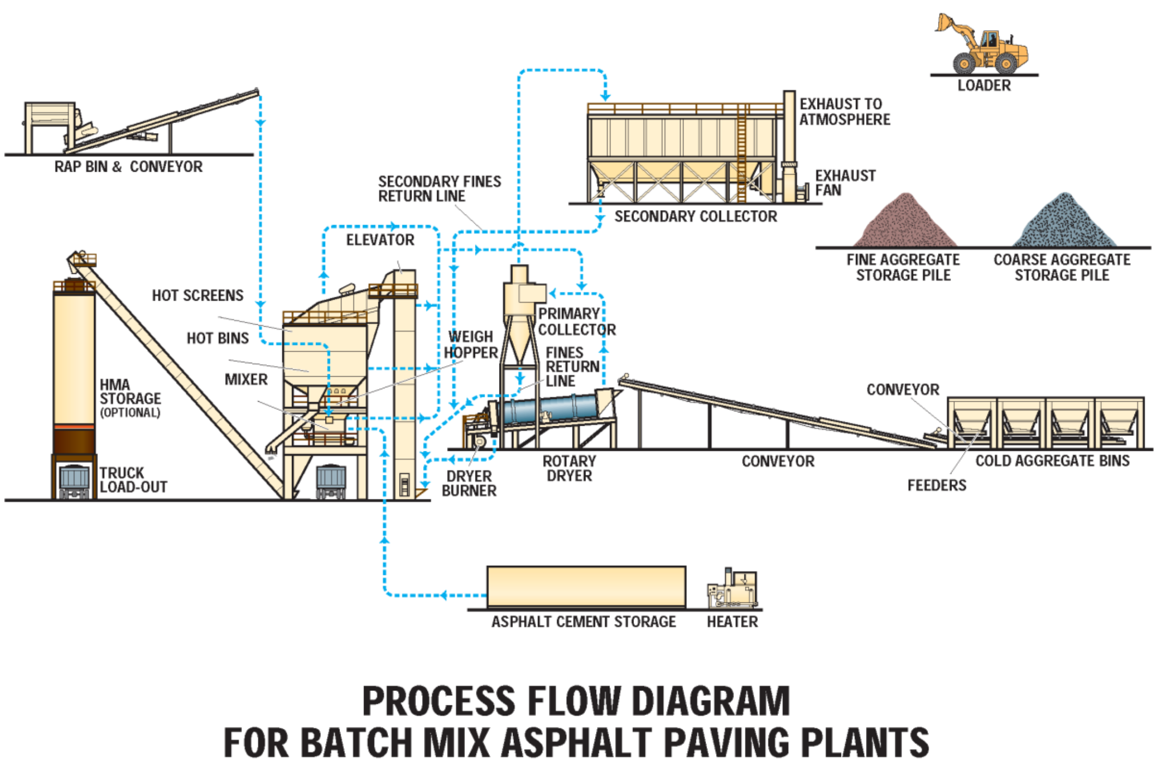


Figure 400.2 – Batch Plant Layout and Components. (Photo courtesy of Astec)

Dryer Drum Plants

The major components of a drum plant are the cold-feed system, asphalt cement supply system, drum mixer, storage silos, and emission-control system (bag house). Aggregates are first proportioned by belt feeders which control the amount of each material type. The aggregates are then sent to the drying portion of the drum, then into the mixing portion of the drum where the asphalt and fines from the baghouse are introduced. RAP is added downstream of the exhaust gases from the burner. The mixing drum heats and dries the aggregate mixture and blends it with the asphalt cement. The hot mixed asphalt is discharged continuously into a silo where it is temporarily stored and then loaded into delivery trucks. Drum plants are the most common type of asphalt plant in Minnesota. Below are descriptions of the two different types of Drum plants:

Parallel Flow Drum Plant

In a parallel flow drum plant the exhaust gases and the aggregate move in the same direction. The burner is located at the aggregate inlet end of the drum. The aggregates enter the drum by a conveyor belt and move ahead inside the drum by a combination of gravity and a configuration of flights located inside the drum. As the aggregates travel along the drum, they are heated and dried. RAP is added near the center of the drum by a conveyor belt from the RAP cold feed bin. Adding RAP near the center of the drum prevents overheating of the asphalt cement in the RAP. Parallel flow is the most common type of drum plant in Minnesota (Scherocman & Cominsky, 2000).

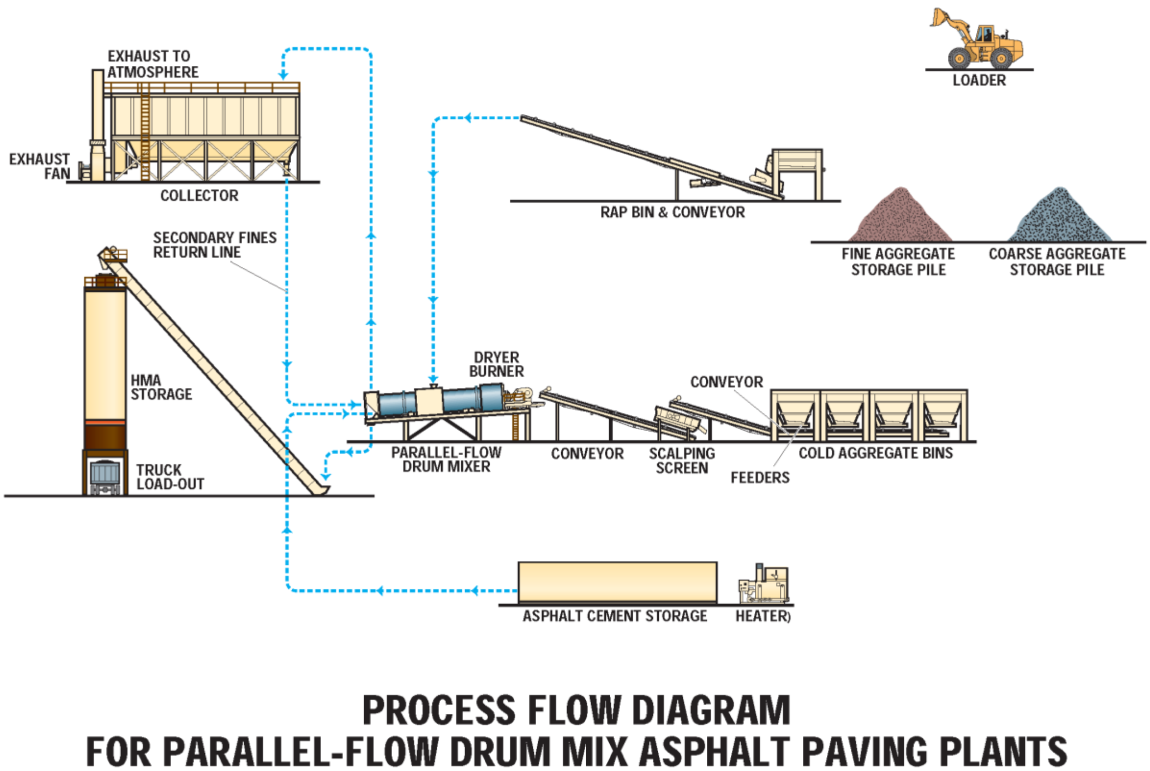


Figure 400.3 – Parallel-Flow Drum Plant Layout and Components. Photo courtesy of Astec.

Figure 400.4 – Parallel-Flow Mixing Drum

Counter-Flow Drum Plant

In a counter-flow drum plant the aggregate moves down the drum against the flow of the exhaust gasses. The mixing of the asphalt binder with the heated and dried aggregate is done outside the exhaust gas stream.

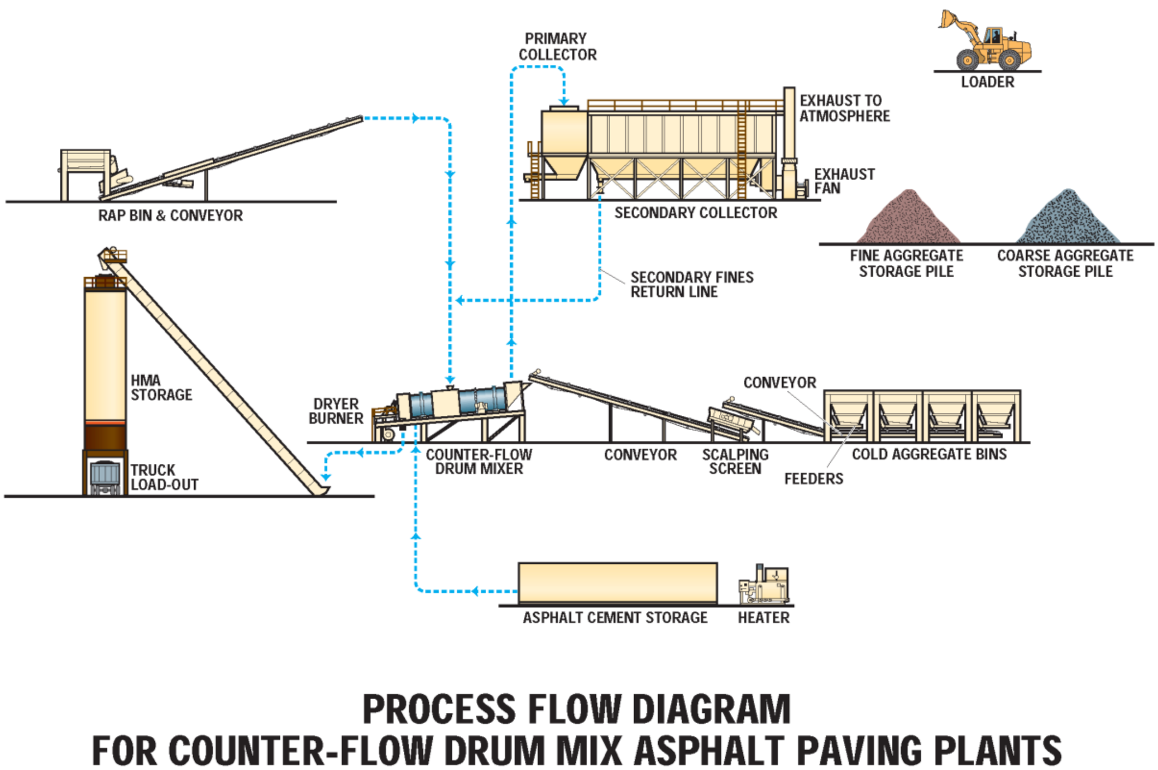


Figure 400.5 – Counter-Flow Drum Plant Layout and Components. Photo courtesy of Astec.

420 – Plant Inspection

Inspection of the mixing plant is the responsibility of the Project Engineer or the designated person (Plant Inspector, IA, etc.). Inspection of the mixing plant needs to be performed by project personnel prior to beginning production. The plant should meet all requirements set forth in the Specifications and Special Provisions and be in a satisfactory condition to produce high quality, uniform asphalt mixture. Requirements of the various mixing plants and the items to be inspected are covered in 420.2 - Plant Calibration and Certification and 430 - Equipment Requirements.

Inspectors should be thoroughly familiar with the project plans and specifications, as well as any other relevant contract documents before construction begins. It is a good practice to talk over each new operation with the Contractor before the work begins. Knowledge of each other's duties and responsibilities will lead to better understanding and working relationships. The Plant Inspector's duties include inspection of equipment and materials, monitoring of calibrations, and inspection of the bituminous mixture produced by the plant. See below for a resource guide that can assist a Plant Inspector:

List for Plant Mixed Asphalt Pavement – Plant Monitor	Specifications	Bituminous Manual
Complete a Contact Report (Signed by Contractor and Agency) • Batch Plant • Drum Plant	2360.2.G.1.a	420.2
Test and calibrate scales	2360.3.B.1.b	420.3
Obtain Mix Design Recommendation (MDR) for all mixes	2360.2.G.1.a	Appendix
Identify items to be sampled, and rates of sampling and testing	Schedule of Materials Control	Chapter 7
Familiarize with aggregates and binders used in the mixture	MDR	
Monitor calibration of plant equipment (pumps, aggregate bins, etc.)	2360.2.G.1.a	420.2
Monitor mix and asphalt temperatures	2360.3.A.5 & 2360.3.B.1.e, 2360.3.B.1.g	420.3
Observe stockpiles for possible contamination	3139.2.A	210.5
Ensure that proper release agents are used (No Diesel Fuel)	2360.3.A.1	420.3
Observe loading of trucks to ensure segregation is not occurring and that trucks are covered when necessary	2360.3.B.1.a	610.1
Make sure Contractor is performing weekly scale checks.	1901, 2360.2.G.8	-

List for Plant Mixed Asphalt Pavement – Plant Monitor	Specifications	Bituminous Manual
Observe loader operator for proper aggregate handling and check for segregation issues	2360.3.B.1.a, 2360.3.E	420.1
Make sure weigh tickets are complete	2360.2.G.8	520.5
Monitor asphalt shipments for contract compliance. Collect Bills of Lading	2360.2.G.7.I & 3151.2.A	-
Obtain copy of Technical Certification Card for all lab technicians and certified street personnel	2360.2.G.4.a	-
Observe the following tests that will be entered on the Test Summary Sheet • Maximum Specific Gravity (Rice Test) • Bulk Specific Gravity • Extraction • Ignition • Course Aggregate Angularity (CAA) • Fine Aggregate Angularity (FAA) • Coarse/Fine Gradation Washing the aggregate to obtain the P200	2360.2.G.8	Chapter 7
• Check tolerances between Contractor's QC & Agency QA results	Table 2360-9	-
Check water bath temperature is 77 ± 1.8°F	MnDOT Lab Manual 1810	720.6
Check G_{mm} (Rice) Container Weight (Dry & Underwater)	MnDOT Lab Manual 1807	720.6
Observe the bulk specific gravity test and record the saturated surface dry and immersed weight of the cores.	MnDOT Lab Manual 1810, 2360.3.D.1.i	-
Check that Contractor is recording daily records (cold feed percentages, JMF changes, etc.) on Test Summary Worksheet	2360.2.G.8	-
Obtain 20 minute recordation files	2360.2.G.8	-
Check Recordation Files (Temperature, Add AC, Proportions, Span Values, etc.)	2360.2.G.8	-
Keep a daily diary	MnDOT Contract Administration	Bituminous Engineering Webpage

List for Plant Mixed Asphalt Pavement – Plant Monitor	Specifications	Bituminous Manual
	Manual 5-591.390	
Do not pave outside of the following unless the Engineer waives the restrictions: • Outside of seasonal road restrictions in the area • Unfavorable road conditions • Final Wearing course ○ October 15 - North of East/West Line (Browns Valley to Holyoke) November 1 – South of East/West Line (Browns Valley to Holyoke)	2360.3.A.4	-

Table 400.1 – Plant Monitor Resource Guide

420.1 – Plant Monitor Checklist

The Bituminous Plant Daily Diary (found on the Bituminous Engineering webpage) is a very important document for a Plant Monitor to be familiar with and fill out properly. The following is an example Plant Daily Diary along with instructions for its use:

DEPARTMENT OF TRANSPORTATION

Bituminous Plant Daily Diary

Bituminous Plant:	Black Gold #1	Arrival Time:	6:00 AM
Date:	Thursday, August 23, 2018	Departure Time:	7:30 PM
QA Plant Monitor	Art Jones		

QC Tester:	Becky Johnson	TECH ID:	999999	IAI VERIFIED:	☑ Yes ☐ No
QC Tester:	Tom Warner	TECH ID:	999997	IAI VERIFIED:	☐ Yes ☑ No
Visitor:	Dave Leornard - MnDOT Bituminous Office				
Visitor:					

Temperature °F:	70	Plant Start Time:	6:50 AM
Sky Cover:	Partly Cloudy	Plant End Time:	7:30 PM
Precip. (inches):	None		

									PROD	MAX
SP/Contract:	9999-88	MDR:	05-2018-001	Mix:	SPWEB340B	Day of Paving:	8/23/2018	Tonnage:	1200	1000
SP/Contract:		MDR:		Mix:		Day of Paving:		Tonnage:		
SP/Contract:		MDR:		Mix:		Day of Paving:		Tonnage:		
SP/Contract:		MDR:		Mix:		Day of Paving:		Tonnage:		

Plant:		MIXTURE:			
New Aggregate:	☑ Checked?	Correct MDR	☑ Checked?	Sample Method (Drop Down)	Truck Box
Cold Feed Bins:	☑ Checked?	PG Grade (Drop Down)	B= PG 58S-28 (MSCR)	Splitting Method (Drop Down)	Pan Quartering
Scalping Screen:	☑ Checked?	AC SpG:	1.035	Water Bath Temp, °F:	77
Objectionable Material:	☑ Checked?	Mix Temp. °F:	300	Gradation Wash Efficiency:	15
Observe Trucks:	☑ Checked?	%New AC:	70	Sampled AC:	
Release Agent:	☑ Checked?	Corr. Factor:	1.04	AC Bills of Lading:	☑ Collected?
20 minute Recordation:	☑ Collected?	QC Tests:	312-313	Spot Check Lab Equipment:	☑ Checked?
Verify Proportions:	☑ Checked?	Verification Test:	312	Weigh Ticket:	☑ Checked?
Span Value:	☑ Checked?	Gyratory Batch Weight, g:	4800	Weekly Scale Check Date:	8/20/2018
H2O FOAMING:	☐ Yes ☑ No	Gyratory Mixing Temp, °F:	280		

Gmm (Rice) Underwater Wt.

Container:	A	WET Wt. (g):	775.1	DRY Wt. (g):	890.5
Container:		WET Wt. (g):		DRY Wt. (g):	

VERIFICATION TESTING

Tolerance Issues?	☐ Yes ☑ No	Notes:
Failures?	☐ Yes ☑ No	Notes:

Blend/Comments:

PG 58-28 AC Sample ID# AC-#2 taken and submitted. Received AC chemical extraction for oven correction factor this morning. % new AC is an issue. Rap % was reduced. RAP Bin Scalping screen 4" X 6" has been installed. Blend for SPWE312 - 32% BA Sand, 36% 1/2 Rock,10% HF Chips, 24% RAP, 3.3% Add AC.Additional blend changes during production day.

Cores:

SP:	9999-88	Lots:	10-12	Date Paved:	Wednesday, August 22, 2018	Result (Drop down)	Passing
SP:		Lots:		Date Paved:		Result (Drop down)	
SP:		Lots:		Date Paved:		Result (Drop down)	
SP:		Lots:		Date Paved:		Result (Drop down)	
SP:		Lots:		Date Paved:		Result (Drop down)	
SP:		Lots:		Date Paved:		Result (Drop down)	
SP:		Lots:		Date Paved:		Result (Drop down)	

Comments:

12 haul trucks, Round trip time 1 hour

Figure 400.6 - Example Plant Monitor Daily Diary

Fill this document out every day the plant is making mix similar to what is shown.

Notes:

- An Independent Assurance (IA) Verification of each tester must be done at least once per year. Contact the IA in your district if this has not been done yet this year.
- List all mixes that are being produced each day and the tonnage of each.
- **PROD** = Total number of tons produced for that type of mix each day.
- **MAX** = Number of tons that are placed in areas that will be evaluated for compaction under maximum density (where cores will be taken). I.e. tonnage would be subtracted from the total tons for the day if some of the mix was placed on a shoulder 6 feet wide or less, trail, or areas called out as ordinary compaction.

Plant Section, Check the Following:

- New Aggregate: If any new aggregates were brought into the plant site, they must pass quality testing, and specific gravities before they can be used.
- **Cold Feed Bins:** No intermixing between bins. Minimize aggregate sticking to belt.
- **Scalping Screen:** Should be inplace over the RAP conveyor to eliminate oversize particles.
- **Objectionable Material:** Check the virgin aggregate and RAP piles for contamination.
- **Observe Trucks:** Note how many trucks, round time, and how many drops they are being loaded with.
- **20 Minute Recordation:** Review plant recordation files or recordation printout.
- **Verify Proportions:** Ensure the proportions on the recordation files and plant screen match the values listed on the Test Summary Sheet.
- **Span Values:** Once a day the plant is to output the SPAN values. These are values that are the calibration factors for the weigh bridges on the plant. Verify they match the original values when the plant was certified.

- **H_2O Foaming:** Indicate whether the plant is using the foaming device to create a bubbling action of the hot AC which can improve the coating of the aggregate and assist compaction.

Mixture Section, Check the Following:

- **Correct MDR:** Ensure the mix produced matches the MDR.
- **PG Grade:** Type of AC being used in the mix.
- **AC SpG:** Record the Asphalt Cement (AC) Specific Gravity from the AC Bill of Lading.
- **Mix Temp:** From plant recordation or plant screen.
- **% New AC:** From recordation files.
- **Corr. Factor:** AC correction factor between Contractor’s ignition oven and Agency’s oven.
- **QC Tests:** Note the QC tests that were done that day.
- **Verification Test:** Daily verification test number.
- **Gyratory Batch Weight:** Mass of mixture used to make gyratory puck by QC Tester.
- **Gyratory Mixing Temp:** Temperature QC Tester is heating mix to make the gyratory puck.
- **Sample Method:** Either from Truck Box (at the plant) or Behind the Paver
- **Splitting Method:** Pan Quartering or Quartermaster to split sample between for QC/QA portions.
- **Water Bath Temp:** Must be 77 ± 1.8°F

- **Gradation Wash Efficiency:** MnDOT Lab Manual procedure 1203.3E states that the material retained on the bottom pan should not be greater than 10% of the total amount passing the #200 sieve. If it is, the sample should have been washed more thoroughly.

- **Sampled AC:** Record a sample of AC that was submitted to the MnDOT Chemical laboratory for testing.

- **AC Bills of Lading:** Collect any asphalt Bills of Lading from transports that were delivered that day.

- **Spot Check Lab Equipment:** Is equipment working properly? Holes in sieves? Use a check weight if you have one to verify the scales that are being used.

Gmm (Rice) Underwater Wt. Section, Check the Following:

- **Container:** ID of container

- **WET Wt:** Weight of container underwater

- **DRY Wt:** Weight of container dry in air

Verification Testing Section, indicate the following:

- **Tolerance Issues:** Indicate if any of the mixture tests were outside of the tolerances indicated in MnDOT Standard Specification Table 2360-9 - Allowable Differences between Contractor and Department Test Results [Gmb, Gmm, AFT, CAA, FAA, Asphalt Content, Gradation].

- **Failures:** After retesting, indicate if any tests were still failures.

Blend/Comments section, Record the Following:

- Changes in aggregate/RAP proportions.

- Changes in AC.

- Proportions Contractor was using that day.
- Verification Tests that were submitted to lab.
- Any testing issues noted.

Cores section, Record the Following:

- **SP:** Project number of cores that were tested that day at the QC lab.
- **Lots:** Lot numbers that were tested.
- **Date Paved:** Note the paving dates that the cores represent.
- **Result:** Passing/Low/Removal (See MnDOT Standard Specification 2360.3.D.1 for limits).

420.2 – Inspection of Materials

Materials used in the asphalt mixture should be inspected prior to beginning production as per the Schedule of Materials Control.

Aggregates
Prior to incorporation into a mixture, aggregates must meet the requirements of MnDOT Specification 3139 - Graded Aggregate for Bituminous Mixtures. Stockpiles of different aggregates must be separated so that they will not intermingle or be contaminated. From production to placement, aggregates must be handled in such a manner as to avoid:

- Alteration of the gradation due to segregation
- Contamination by deleterious foreign materials
- Non-uniformity in moisture content

The Inspector must keep these points in mind during observations of routine operations, and bring to the attention of the Contractor any operation that is conducive to the development of these conditions. Non-uniform materials cannot produce uniform quality pavements regardless of the number of quality control tests. The best form of control is a uniform procedure in handling the aggregates to reduce the risk of the three conditions mentioned previously.

Listed below are general guidelines to help ensure the highest quality aggregates are incorporated into the mixture as described in *Hot-Mix Asphalt Paving Handbook 2000*:

- Stockpiles should be built on a clean, dry, and stable foundation with positive drainage away from the pile. Aggregates of different sizes should be separated from each other.

- Stockpiles should be built in horizontal or gently sloping layers. Any stockpiling procedure that results in aggregate being pushed or dumped over the side of the stockpile should be avoided in order to prevent segregation. Travel on stockpiles by trucks and front-end loaders should be minimized to prevent aggregate breakage and generation of fine aggregates.

- The front-end loader should work the full face of the stockpile, removing the aggregate in a direction perpendicular to the front of the aggregate into the stockpile. The front-end loader operator should go straight into the stockpile, roll the bucket up, and then back out instead of scooping up through the stockpile. The front-end loader operator is key in providing a consistent proportion of material to the plant and in the minimizing segregation.

- Segregated materials should be blended by the loader before introduction to the cold feed bins or trucks.

- Cold feed bins should be separated by bulkheads so aggregate cannot overflow into an adjoining bin.

- A scalping screen should be placed in the cold feed charging system to remove oversized materials.

- For drum mix plants, the weight bridge should be checked to see if the weigh idler is free to move and that the conveyor belt is tight around the gravity take-up pulley to assure accurate readings.

- The cold feed bins for RAP should have steep sides to prevent the material from bridging the gate opening at the bottom of the bin.

- The reclaimed aggregate feed system should include a scalping screen over the cold-feed bin or some point in the material flow process.

- Cold-feed bins should be calibrated.

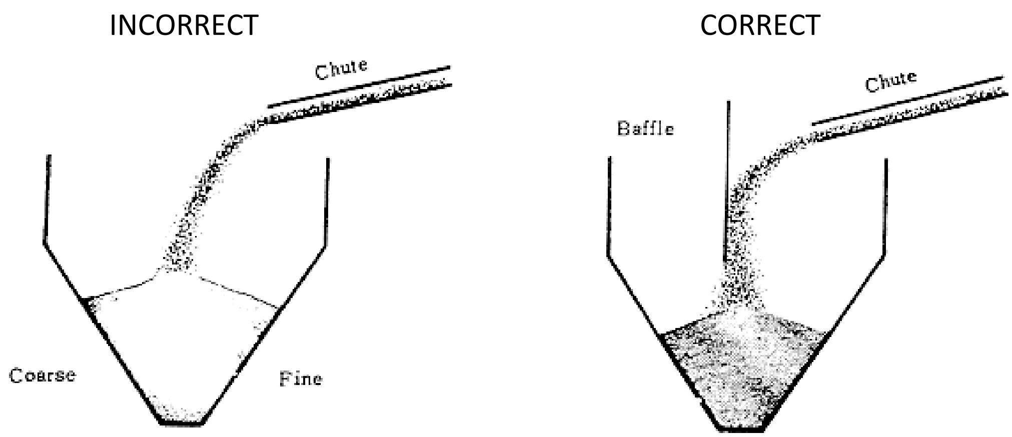


Figure 400.6 – Baffle Placement

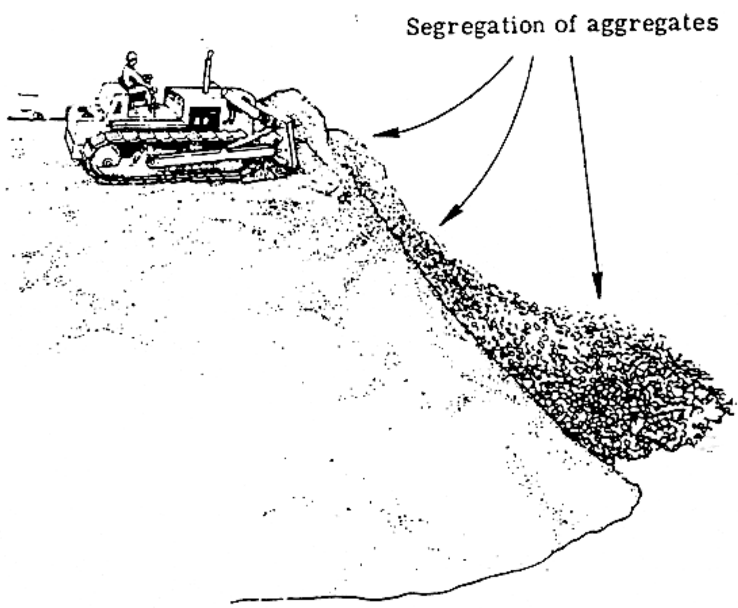


Figure 400.7 – Segregation of Aggregate Stockpile

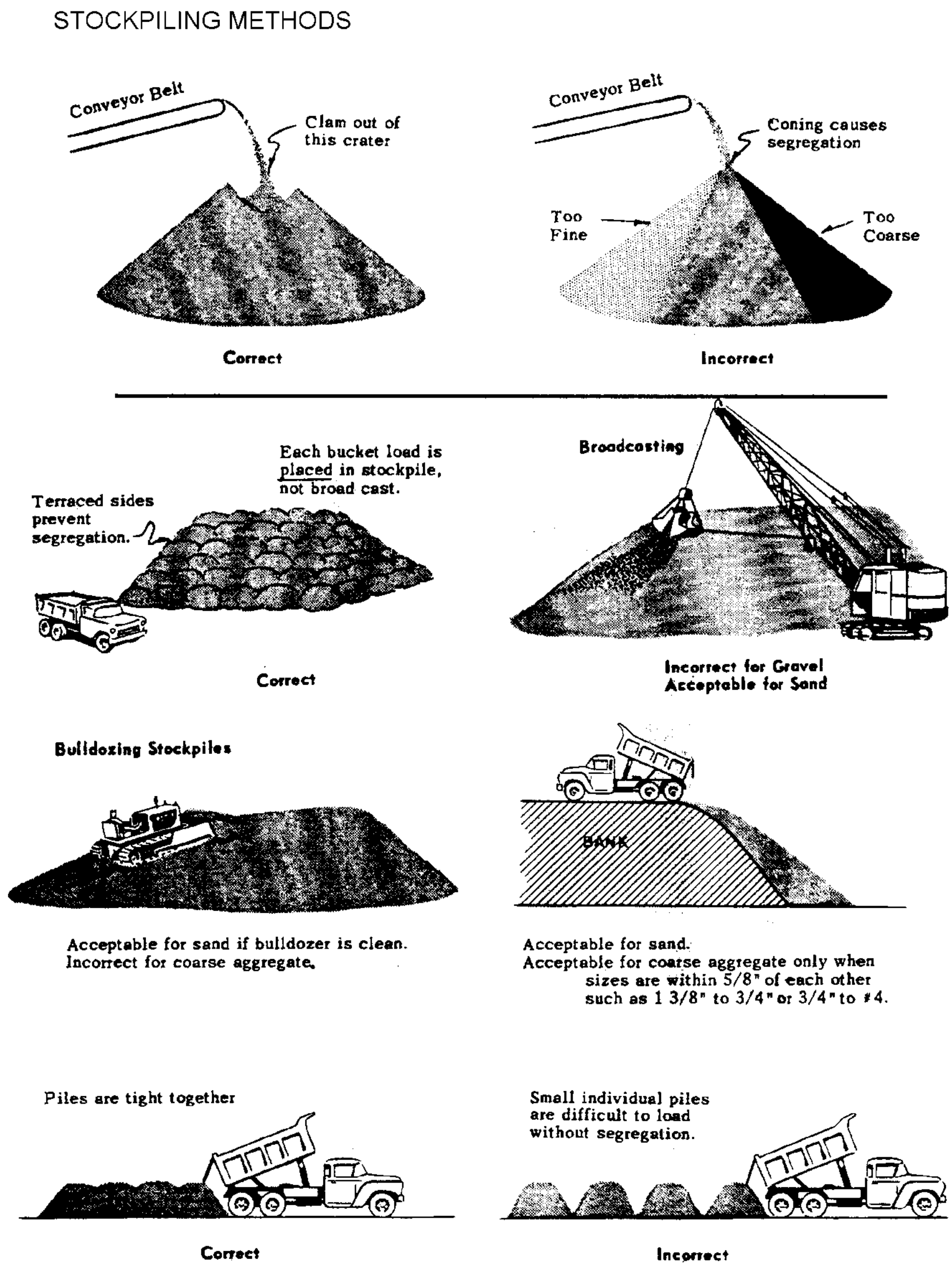


Figure 400.8 – Correct and incorrect stockpiling methods

The source of supply and quality is governed by MnDOT Specification 1601. Stockpiles of materials which are non-uniform in gradation and quality present serious problems and should be reworked or rejected. See chapter 7 - Quality Management for information about Aggregate Sampling and Testing.

Asphalt Binder

Asphalt binder is supplied by a certified supplier under the Combined State Binder Group.

420.3 – Plant Calibration and Certification

Plant Calibration

Prior to beginning production, the mixing plant must be properly calibrated for the materials to be used on the project. This calibration is done by the Contractor in the presence of the Inspector. Agency personnel should make no adjustments to Contractor's equipment. Such adjustments might be in error or might damage equipment and tends to remove the Contractor's responsibility and liability. See section 430 - Equipment for more details on calibration procedures.

Initial Pump Calibration

The following form is required to calibrate the asphalt pump at the beginning of the season, and may be required in certain situations (such as the plant changing locations, damage to the plant, etc.).

Asphalt Plant Certification

Asphalt Meter Calibration

PLANT# ______________________

DATE ______________________

The process is to determine that the asphalt meter is within the +/- 1% tolerance.
The process may vary from asphalt plant to asphalt plant.

Asphalt Source ______________ **AC Temp** ______ **AC-Gal. Weight @ 60F** ______ **

Performance Grade # ______________ **Correction Factor (Bit Manual 5-693.240)** ______ *
(Not needed if Meter is Temp. Corr.)

(Use Lbs. or Tons)

1	**End Meter Reading**		**Lbs or Tons**
2	**Begin Meter Reading**		**Lbs or Tons**
3	**Total (1-2)**		**Lbs or Tons**
4	**Total Load Weight**		**Lbs or Tons**
5	**Load Tare Weight**		**Lbs or Tons**
6	**Total (4-5)**		**Lbs or Tons**
7	**Difference (3 - 6)**		**Lbs or Tons**
8	**Total ((7/6)*100)**		**Variation**
	Tolerance Check =		**(+ or - 1%)**

*For non-temp.corr.meters ▶ ______ **Gallons X**
______ **60F Wt. X**
______ **Corr. Fact. =**
______ **Lbs. /2000 =**
______ **Tons**

* To convert Gallons to Lbs or Tons for a non-temp. corrected meter, Multiply the total gallons times the weight @ 60F times the asphalt temp correction factor = total Lbs. Divide the total Lbs by 2000 to calculate tons, if needed.

For temp.-corr.meters ▶ ______ **Gallons X
______ **60F Wt. =**
______ **Lbs./2000 =**
______ **Tons**

NOTES:

____

Inspector Signature

Alternative Pump Calibration

When approved by the Engineer, the following form can be used to calibrate the asphalt pump at any time after the initial pump calibration.

Asphalt Plant Calibration

Project ______________________________ Date: ______________

Contractor ______________________________ Pit: ______________

Asphalt Pump Calibration			
		Begin	End
Temperature Degree F			
Inches down in tank			
Tank Volume in Gallons	A		
Gallons Out of Tank	B		
Gallons left in Tank	A-B=C		
Temperature Correction Factor*	D		
Corrected Gallons @ 60 F.	C*D=E		
Wt. / Gal. @ 60 F, see Bill of Lading.	F		
Asphalt Lbs. at 60 F	E*F=G		
Asphalt Tons at 60 F	G/2000=H		
Total Asphalt Hauled In, Tons	I		-
Total Asphalt (Begin) Tons	H+I=J		**% Asphalt**
Total Asphalt (End) Tons	K		
Total Asphalt Used (sticking)	J-K=L		(L/P)*100
Total Asphalt Used (meter)	M		
Accuracy of Tank Stickings to Asphalt Meter			((L-M) /M)*100
Tolerance is plus or minus 1%		MEETS / FAILS CALIBRATION REQUIREMENTS	

Bituminous Scale Calibration		
Tons of Bituminous Mixture (Certified Scale Tickets, include tons in the silo) (P)		
Tons of Bituminous Mixture (Plant Recordation Report, see 2360.2G8) (Q)		
Accuracy of Certified Scale to Plant Recordation print out		((P-Q/P)*100
Tolerance is plus or minus 1%	MEETS / FAILS CALIBRATION REQUIREMENTS	

NOTES: 1st day of production, Tanks stuck before start up and again after approximately 1,000 tons of production. Signed and dated by Agency and Producer

Plant Mixed Asphalt Equipment Requirements

Mixing plants shall be equipped as specified in MnDOT Specification 2360. The Inspector should be familiar with these requirements. They are listed as follows for the Inspector's reference:

1. All Plants

    a. Bitumen Storage

        i. Heating Unit – to maintain temperature within 10°F of recommended temperature.

        ii. Circulating system – discharge outlet below surface of liquid in tank.

        iii. Outage table, measuring stick, or electronic level for each working tank.

        iv. Thermometer – installed to accurately measure the temperature of the tank contents.

        v. Provision for taking samples between the tank and drum.

    b. Dryers

        i. Aggregates shall be free of unburned fuel.

        ii. Dust collector – with provision for wasting or returning all or part of product. Discharge must comply with Minnesota Pollution Control Administration (MPCA) standards.

    c. Cold Feed Bins

        i. Partitions – solid, continuous, and high enough to prevent overrun between bins.

        ii. Outlet gate – for each bin in good condition

        iii. Adequate dry storage for filler – when used.

2. Dryer Drum Plants

   a. In addition to the requirements for all plants, drier drum plants must be equipped with the following:

      i. Aggregate Feeder gate – for each bin and have a positive locking device and measuring gauge.

      ii. Asphalt Cement Pump – Positive displacement

      iii. Drive Interlock – between aggregate and bitumen feed

      iv. Protection Switch – for stopping the aggregate and asphalt cement feed if the material from any aggregate compartment stops flowing.

      v. Surge Bin/Silo – for storing the plant mix

      vi. Continuous weighing monitoring system

      vii. Automatic coupling of weighing system with bitumen flow to maintain required proportions.

      viii. A weighing system with provisions to enable easy calibration without having the material enter the mixer.

      ix. Provisions enabling the obtaining of representative samples of the aggregate.

      x. Approved Drum for heating, coating, and mixing of the asphalt mix.

      xi. Automatic burner controls to prevent damage to the aggregate or bitumen.

      xii. System for temperature sensing of the bituminous mixture at the discharge end.

   b. The mixing period and temperature shall be such as to produce a uniform mixture in which all aggregate particles are thoroughly coated.

Plant Certification

As part of the Plant Certification procedure, the Contractor must complete the following four steps:

1. Complete Plant Certification Application form and request for plant Inspection.
2. Provide a site map of stockpile locations.
3. Pass plant and testing facility inspection by having the Plant Monitor or IA and Bituminous Plant Authorized Agent complete and sign the Asphalt Plant Inspection Report (Batch Contact Report - TP 02143-02, Drum Contact Report - TP 02142-02). By signing the Asphalt Plant Inspection Report, the HMA plant Authorized Agent agrees to calibrate and maintain all plant and laboratory equipment within allowable tolerances set forth in the specifications and the MnDOT Bituminous Manual.
4. Obtain a Mixture Design Report prior to production. See the Appendix for an example Mixture Design Report.

420.4 – Asphalt Production

Plant Operation

The purpose of plant monitoring during production is to assure that the specified mixture is being produced within Specification (correct asphalt content, gradation, temperature, uniformity, etc.). Plant monitoring responsibilities should include, but are not limited to, the following:

1. Keep a Plant Monitor's Daily Diary.
2. Determine if bituminous mixtures are to be produced in accordance with Plant Mixed Bituminous Pavement 2360 and review the Special Provisions of the Contract.
3. Familiarize oneself with plant equipment and check for compliance with specifications. Review schematic of plant or site map.
4. Use the Schedule of Materials Control to identify materials to be sampled as well as rates of sampling and testing. Know the procedures for safely securing samples.
5. Familiarize oneself with material, flow controls, and settings established to comply with design mix. Review the Mixture Design Report for current and correct data. Verify that the correct mixture is produced per plan and proposal.

6. Monitor the calibration of plant equipment (pumps, aggregate bins, etc.).
7. Ensure that the Contractor is obtaining the required aggregate samples and performing the necessary tests per the Schedule of Materials Control.
8. Know the proper production temperatures and ensure they are being maintained. Production temperatures are allowed to exceed the manufacturer's recommended maximum mixing temperature by no more than 30°F.
9. Maintain surveillance of mix appearance to ensure uniformity and to identify potential plant malfunction.
10. Observe stockpiles for possible contamination during storage or handling.
11. Ensure truck boxes are clean and protected against buildup of asphalt mixture, yet free of excessive cleaning/releasing agents. **No petroleum distillates are allowed as release agents.**
12. Observe loading of trucks to ensure segregation is not occurring and that trucks are covered when necessary.
13. Proper scale procedures shall be followed per MnDOT Specification 1901. Weigh tickets are to be completely and properly filled out. Automatic scale printer operations are to be properly monitored. A full list of weigh ticket requirements is found in Specification 2360.2.G.8. Make sure Contractor is performing weekly scale checks. Scales must be calibrated and tested in accordance with Specification 1901.8.C.
14. Monitor asphalt shipments for contract compliance and see that the Contractor is obtaining the necessary asphalt samples, including asphalt emulsion for tack coat. Collect manifest or Bills of Lading for all shipments.
15. If bituminous mixtures are being provided in accordance with 2360 Plant Mixed Bituminous Pavement, monitor Contractor's testing to ensure that the required number of tests are done and that the proper procedures are followed:

    a. Check for current Technical Certification Card on lab technicians.
    b. Check for current forms and documents by using the MnDOT Bituminous Office website
    c. Review Contractor's on site quality control records and charts for accuracy and completeness.
    d. Observe maximum specific gravity test (Rice test). Observe the Bulk specific gravity, extraction/ignition test, gradation, and CAA & FAA tests. Verify entry on the Test Summary Sheets.
    e. Monitor Agency tests and confirm that they are within the allowable tolerances for Contractor and Agency tests. In cases of property failures, missing tests and out of tolerances, notify the Project Engineer, Project

Supervisor, and Office of Materials and Road Research.

16. Observe the bulk specific gravity test and record the saturated surface dry and immersed weight of the cores. Verify that core information is recorded on the proper forms (Core worksheets).
17. Check that the Contractor is keeping daily records (adjustment of cold feed percentages or add AC, changes in JMFs, if an additive or foamer is being used, etc.). Ensure these records include a description of QC actions taken and include all changes or adjustments on the test summary sheets. At a minimum, the Contractor should be keeping one record per mix per day.
18. Take or observe the taking of verification samples (a minimum of one per day). Retain half of the sample for Agency testing and provide the Verification companion to the Contractor for testing. Deliver Verification sample to Agency lab. Verification companions must be tested by the Contractor.
19. Review the Contractor’s electronic 20 minute printout from the automated plant blending control system.

Mixture Temperature

The inspector should periodically check the temperature of the mix to ensure compliance with Specifications. Mixing temperatures should fall within the asphalt binder manufacturer’s specified temperature ranges for the binder used in the mix. The check should be made in the truck box immediately after loading, or via a temperature probe at the discharge of the mixing drum. The mixing temperature should be recorded in the Plant Inspector's Diary. The mixture temperature from the truck box should be compared to the mixture temperature recorded on the Contractor’s electronic printout from the automated plant blending control system. Discrepancies should be discussed and resolved with the Contractor. Typically, mix temperature should not exceed 325°F.

Mixture Uniformity

Mixture uniformity control is accomplished by checking to see that the gradation does not vary, that aggregate segregation does not occur, and that the aggregate is being properly coated with asphalt binder. These items are checked as follows:

Particle Coating

Proper aggregate coating is achieved with proper mixing time. The fine aggregates will get coated first, followed by the coarse aggregates. If mixing time is not sufficient, the aggregate particles will not be properly coated by the asphalt binder (Scherocman & Cominsky, 2000). Ensure the Contractor is following proper mixing procedure:

Batch Plants should have a minimal dry-mix time of 1-2 seconds to mix the aggregates. When the binder is added, the wet mix time should be between 27 and 33 seconds. The wet cycle may be lengthened by the Engineer in order to thoroughly coat all aggregate particles. The mixing times must be locked into the batching cycle. Generally, a 30 second wet-mix time is more than adequate to uniformly distribute the asphalt binder and coat the aggregate (Scherocman & Cominsky, 2000).

Continuous Plants must provide sufficient mixing time to properly coat the aggregate particles. Particle coating should be checked when production begins, when the calibration or rate of production changes, or when job conditions warrant.

Segregation

Check for segregation, the separation of coarse and fine aggregate particles, as the mix is loaded into the trucks and on the street after placement. Segregation can be difficult to identify and requires careful judgement on the part of the Inspector.

420.5 – Spot Check Procedure

Spot Checks provide a periodic verification of the asphalt binder proportioning for plants which proportion the asphalt binder by volume. Spot checks are not to be performed for batch-type plants, which proportion the asphalt binder by volume.

A spot check is typically performed on approximately 30 to 150 tons of mixture. To be meaningful, all measurements must be carefully made using the proper techniques discussed below. The spot check represents the amount of asphalt added to the mixture and therefore must be complete and accurate.

Procedure

The percent asphalt binder in the mixture is determined by measuring the weight of the asphalt binder used and the weight of the mixture produced in a given time interval. If necessary, the mixing operation shall be stopped at the beginning and end of the time interval to ensure accurate measurement of these quantities.

1. **Measurement of Asphalt Binder Used**
   The quantity of asphalt binder incorporated into a specific lot of mixture is determined by means of an approved and calibrated asphalt binder flow meter or a calibrated working tank of 1000 to 2000 gallons in capacity. Most working tanks are

temperature corrected, but measurement of the working tank can be made with a graduated stick or calibration chart at the beginning and end of the spot check. This volume is converted into pounds of asphalt at 60°F using the appropriate density and temperature correction factors given in the Appendix. The quantity of asphalt binder used in calculating a spot check should not exceed 2000 gallons.

2. **Measurement of Mixture Produced**
   The weight of mixture in the spot check lot is determined by weighing the mixture produced in the given time interval. If the drum or pugmill is full when the spot check begins, then it should be full when the spot check ends. If the bituminous plant is equipped with a mixture storage silo, the spot check will begin with an empty silo and end with an empty silo. For silos with load cells that give a continuous tonnage read out, spot checks can be run at any silo level. If the mixture weights are to be determined by weighing trucks on a scale, it may be necessary to obtain new tare weights just before the spot check to ensure accuracy. If the plant is a batch plant, batch weights may be used for this determination as follows:

$$Weight\ of\ Mixture = Weight\ of\ Batch\ \times No.of\ Batches$$

3. **Percent Asphalt Binder in Mixture**
   The percent asphalt binder in the mixture is calculated as follows:

$$Percent\ Bitumen = \frac{Weight\ of\ Bitumen\ Used}{Weight\ of\ Mix\ Produced} \times 100\%$$

   The measurements and computations should be recorded on the following Bituminous Plant Spot Check form. An electronic spreadsheet version of this form is also available on the MnDOT Bituminous Engineering Website.

420.6 - Plant Recordation Files

History

In 2012, MnDOT started requiring Contractors to supply a record of plant settings every 20 minutes during mixture production in order to verify certain mixture properties. This record was initiated when the percent new asphalt cement to total asphalt cement parameter was added to Specification 2360. In order to document and verify the new asphalt cement, a record of the plant was required.

Requirements

MnDOT Specification 2360.2.G.8 indicates the required data on a plant recordation file. Please check the most current version of the specification in case the requirements have changes since the writing of this manual.

Drum Plant:

Every 20 minutes, the Contractor must provide an electronic printout including the following:

1) Both the virgin and recycle belt feed rates (ton/hr)
2) Feeder bin proportions (%)
3) Total Percent asphalt cement in mixture
4) Virgin asphalt cement added (%)
5) Mixture Temperature (°F)
6) Mixture code
7) Date and time stamp
8) Current tons of mixture produced and daily cumulative tons of mixture produced at time of printout

Once per day, the Contractor must provide the Plant Monitor the plant calibration (SPAN) numbers for each bin and meter.

Batch Plant:

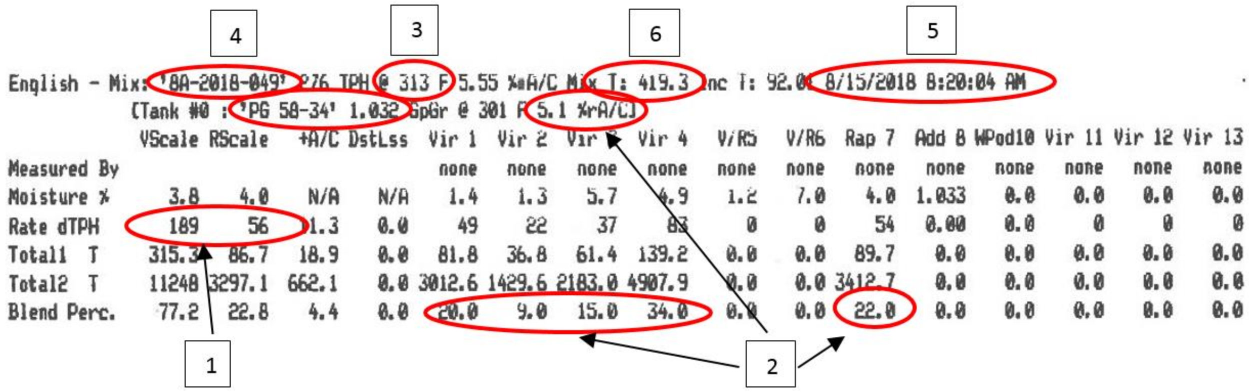
Every 20 minutes, the Contractor must provide an electronic printout including the following:

1) Both the virgin and recycle belt feed rates (ton/hr)
2) Feeder bin proportions (%)
3) Mixture Temperature, °F
4) Mixture code
5) Date and time stamp
6) Current tons of mixture produced and daily cumulative tons of mixture produced at time of printout

Once per day, the Contractor must provide the Plant Monitor the plant calibration (SPAN) numbers for each bin and meter.

Interpreting a Recordation File

Different plants will have a different layout for the same information, but this example will indicate what to look for.



English - Mix: '8A-2018-049' 276 TPH @ 313 F 5.55 %mA/C Mix T: 419.3 Inc T: 92.0 8/15/2018 8:20:04 AM
[Tank #0 : 'PG 58-34' 1.032 SpGr @ 301 F 5.1 %rA/C]

	VScale	RScale	+A/C	DstLss	Vir 1	Vir 2	Vir [illegible]	Vir 4	V/R5	V/R6	Rap 7	Add 8	WPod10	Vir 11	Vir 12	Vir 13
Measured By					none	none	none	none	none	none	none	none	none	none	none	none
Moisture %	3.8	4.0	N/A	N/A	1.4	1.3	5.7	4.9	1.2	7.0	4.0	1.033	0.0	0.0	0.0	0.0
Rate dTPH	189	56	1.3	0.0	49	22	37	83	0	0	54	0.00	0.0	0	0	0
Total1 T	315.3	86.7	18.9	0.0	81.8	36.8	61.4	139.2	0.0	0.0	89.7	0.0	0.0	0.0	0.0	0.0
Total2 T	11248	3297.1	662.1	0.0	3012.6	1429.6	2183.0	4907.9	0.0	0.0	3412.7	0.0	0.0	0.0	0.0	0.0
Blend Perc.	77.2	22.8	4.4	0.0	20.0	9.0	15.0	34.0	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0

Item 1: Virgin and recycle belt feed rates (ton/hr).

Item 2: Feeder bin proportions - Make sure feeder bin proportions and % new AC match the proportions of mix on the bottom of the Test Summary Sheet.

Item 3: Mixing Temperature - Per spec 2360.3.A.5, the maximum mixing temperature is no more than 30°F above the recommended maximum mixing temperature as provided by the asphalt supplier (No mix should be above 325°F).

Item 4: This is the MDR code number and will match the code on the Test Summary Sheet.

Item 5: Date and time stamp.

Item 6: Current tons of mixture produced and daily cumulative tons of mixture produced at time of printout.

DEPARTMENT OF TRANSPORTATION

Minnesota Department of Transportation
BITUMINOUS PLANT SPOTCHECK

SP		Engineer	Time	Test No.
Contractor		Plant Name & #		Date
Bituminous Source	PG Grade	MDR #	Mix Designation	Target AC %

TEMPERATURE ° F

Bituminous ____________ Mix ____________

BITUMINOUS

GALLONS (NOT TO EXCEED 2,000)	
METER READING	
Final	
Initial	
NET (T)	

AC is Temp Corrected ____________
Bituminous Wt per Gallon @ 60 ° F ____________ lbs.
Temperature Correction Factor ____________
Corrected Weight per Gallon (C) = ____________ lbs.
Wt of Bituminous in Mixture (C x T) = ____________ lbs.

MIXTURE (not to exceed 150 tons)

TRUCK NO.	NET WEIGHT (TONS)	TRUCK NO.	NET WEIGHT (TONS)

TOTAL WEIGHT IN LBS (W) =

* % BITUMINOUS in MIX

____________ X 100 =

***note:** if spotcheck fails to meet tolerance requirements, a new spotcheck shall be taken immediately following plant correction

REMARKS:

QC Technician Name: ____________

3/2008

QA Inspector's Name: ____________

430 – Equipment Requirements

This section will detail the equipment requirements for an asphalt plant. While the Plant Inspectors should not use any of the Contactor's equipment, they should familiarize themselves with equipment operations to be able to properly inspect the Contractor's activities.

430.1 – Equipment Properties and Calibration Procedures

Ovens

The requirements of ovens for heating molds and samples will vary based upon the test being performed. See the MnDOT Schedule of Materials Control for more information. Ovens must be calibrated in accordance with the latest version of AASHTO R18.

Gyratory Compactor

Gyratory Compactors must possess the properties described in MnDOT Lab Manual Section 1820 and be calibrated per AASHTO T312.

Balances

Electronic Balances must possess the properties described in MnDOT Lab Manual Section 2001 and be calibrated per AASHTO M231.

Vacuum Pump for Maximum Specific Gravity Tests

The vacuum pump must possess the properties described in MnDOT Lab Manual Section 1807 and be calibrated per AASHTO T209.

Vibration Device

A mechanical device for continuous agitation while performing the AASHTO T209 test.

Lottman Apparatus

The Lottman apparatus must possess the properties described in MnDOT Lab Manual 1813 and be calibrated per ASTM D4867.

Thermometers

Thermometers must be calibrated by an AASHTO Accredited entity.

Literature
The plant must have copies of any applicable manuals, documents, equipment specifications, test procedures, plans, proposals, and calibration records.

430.2 – General Calibration and Verification Policies

Definitions

- Calibration: to check, adjust, or systematically standardize the attributes of the equipment based upon the appropriate procedure.
- Verification: to correlate the attributes of the equipment to the calibration values to assure the equipment is operating properly.

General Policies

1. When any of the test equipment is overloaded, mishandled, giving results that are suspect, or is not meeting specification tolerances, that piece of equipment shall be removed from service. The equipment shall be returned to service only after appropriate repairs are made and calibration and verification show the equipment to function satisfactorily and meet specification tolerances.
2. Newly acquired equipment shall be calibrated before being placed into service.
3. Equipment shall be calibrated or verified at the frequency indicated in the respective AASHTO standards.
4. The calibration or verification of each piece of equipment shall be performed by the equipment owner or authorized designee and reviewed by Agency personnel once per year minimum. Both occurrences shall be documented in the appropriate equipment file.

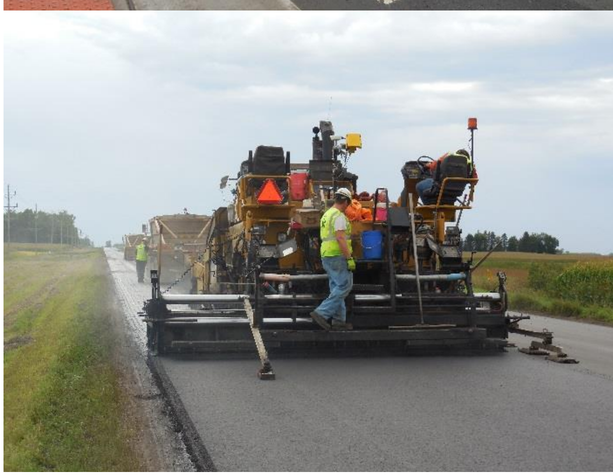
General Procedures

1. A file or log shall be maintained for each piece of equipment that requires calibration or verification. The file or log for each piece of equipment shall contain records of calibration or verification work performed in chronological order and shall be kept in the same facility as the equipment.
2. Each piece of equipment shall be uniquely marked in a permanent manner to

designate the most recent calibration date.

Chapter 5 – Asphalt Paving






500 – Introduction

After the bituminous mixture is produced at the plant, it is hauled to the jobsite for paving. The paving operation is essentially a three-step process consisting of transferring the mix from the truck to the paver, placement of the mix by the paver, and compaction of the mix with rollers. This process is repeated until the paving is complete and a smooth, durable, drivable surface is produced. This chapter will detail the equipment, construction practices, inspection practices, and other relevant details needed to produce quality bituminous pavement.

510 – Preconstruction Meeting

The preconstruction meeting is arranged by the Agency and provides an opportunity for the Agency, Contractor, utility owners, and other relevant project personnel to get together and discuss pertinent details of an upcoming construction project. These meetings should be held as close as possible to the start of production.

The primary goals of the preconstruction meeting are to establish personnel duties and points of contact, discuss the Contractor's proposed schedule, discuss potential construction and scheduling problems, and discuss any Contract documents needing clarification, such as plans or special provisions.

Typical attendees include the Project Engineer, Inspectors, Surveyors, Prime Contractor representatives, Subcontractor Representatives, Representatives from any affected Utility Owners, and any other relevant personnel.

Introduction of Individuals

The first step of the preconstruction meeting should be to go around the room and let all attendees introduce themselves and state their role in the project. The Agency should keep track of all attendees and their contact information via sign-in sheet or by other means. The Contractor must submit a listing of lead project personnel along with their contact information. This list should include all subcontractors and suppliers.

Meeting Agenda

The meeting agenda serves as an outline to discuss the key components of the project, but attendees should feel free to ask questions and raise concerns that are not explicitly listed on the agenda. The preconstruction meeting is a great time to get these issues dealt with or clarified, rather than waiting until construction has begun.

Paving-Specific Discussion

The Contractor should explain, in detail, the activities associated with the paving operation including the materials to be used, plant operations, haul routes, rolling patterns, and any specialized equipment or operations. The Contractor should also discuss traffic control and safety, especially if there are any unusual traffic control layouts or safety hazards on the project. Finally, the Agency should present best practices that help ensure the best possible finished product.

Bituminous Addendums and Special Provisions Requirements

The Agency should discuss Special Provisions and Addendum requirements for the project. The Agency should also take this time to discuss any specific Contract requirements for the project.

Contract Documents

There should be time allotted for attendees to voice concerns regarding the plans, specifications, required materials, and any other aspect of the Contract documents.

Special Activities Discussion

If the project includes any unusual or specialty activities, take the time to discuss these activities.

Questions and Answers

Before adjourning the meeting, the meeting chair should allow time for questions from the attendees. This is the last chance for attendees to ask any questions that were not specifically addressed during the meeting. After all questions have been answered, the meeting is adjourned.

Pre-Paving Meeting Document

An essential part of an excellent project is the Pre-Paving meeting. Details can be found in this Pre-Paving Meeting Document.

520 – Equipment

There are many specialized and varied types of equipment necessary for a successful paving operation. Some of the key pieces of equipment are detailed bellow.

520.1 – Traffic Control

The first step in any paving project is to set up traffic control. The extent of required traffic control will vary greatly depending on the scale and scope of work of the project. Traffic control can be as simple as several warning signs with some cones to complex setups with full lane closures, detours, and temporarily constructed crossovers. See the project plans for the traffic control layout specific to the project.

Figure 500.1 – Paving operation within a traffic control setup.

520.2 – Milling Machine

Before paving, all or part of the existing surface is often ground up and removed with a milling machine. A mill is a revolving drum with teeth that grinds up the existing pavement to a specified depth. Milling machines vary from small 1-2 foot wide units mounted to the front of a skid loader to large self-propelled machines capable of milling an entire lane width at once.

There are several types of milling used in Minnesota, including conventional milling, which removes the existing pavement down to a specified depth, and micro milling, which removes high spots in the existing pavement to improve ride quality prior to thin surface treatments. Milling is covered by MnDOT Specification 2232. As of 2018, Micro Milling is covered under Special Provision 2232.

There are several differences between micro milling and conventional milling. A micro milling drum has roughly three times as many cutting teeth as a conventional milling drum. This allows for increased cutting contact with the milled surface per revolution of the milling head, which produces a finer surface texture. Micro mills also typically use sonic sensors to automatically adjust the depth of cut in order to reduce profile irregularities, whereas conventional mills are typically used to mill to a specified depth.

Whether using a micro mill or conventional mill, maintaining a relatively slow forward speed of the machine is important to produce a desirable milled surface. If the forward speed of the milling machine is too fast, a chevron type pattern will emerge in the milled surface, as shown in the following photo. The milled pattern should be parallel to centerline.

Figure 500.2 – Chevron pattern after milling. Note the angled grooves in the milled surface.

Figure 500.3 – Close up of a micro milling drum. This particular drum is capable of milling 4 feet wide.

520.3 – Broom

When paving over an inplace or milled surface, the existing surface must be cleaned such that it is free of debris and other loose material. If the surface is not cleaned prior to paving, there is a risk that the new mat will not bond properly to the existing surface. Surface cleaning is typically accomplished through the use of a self-propelled broom. This is the first step in the paving operation, occurring before the placement of the tack coat.

Figure 500.4 – Broom truck preparing the existing surface for overlay.

520.4 – Tack Coat Distributor

A critical element to a successful asphalt paving job is the tack coat. The tack coat is an asphalt emulsion that functions as a glue between layers of asphalt. Before fresh asphalt is paved, a tack coat must be applied to the existing surface ahead of the paver. Tack should be consistently and evenly applied to the entire paved surface by a distributor truck. Streaks of tack, often referred to as "corn rows," on the pavement indicate plugged distributor nozzles, incorrectly sized nozzles, inadequate emulsion temperature, insufficient spray bar pressure, or incorrect spray bar height. If streaking occurs, the Contractor must re-spray the section until uniform coverage is achieved.

Tack coat emulsion is tested per the Schedule of Materials Control to ensure it meets specifications. Acceptance of tack coat is based on penetration and residual asphalt.

Penetration relates to the softness of the tack coat and residual is the asphalt which remains after the water has evaporated.

A common problem that affects the penetration of the emulsion is contamination of the tack coat with diesel fuel. It is a common practice for the Contractor to flush the spray bar and nozzles at the end of the day with diesel fuel. This helps to prevent the nozzles and spray bar from getting plugged with excess emulsion. If this is not done correctly, diesel can enter the distributor tank and contaminate the load. It only takes 4-5 gallons of diesel fuel in 1000 gallons of tack coat to raise the penetration value and bring it out of specification. A tack coat sample can also be contaminated from the diesel fuel remaining in the spray bar if no tack is wasted before taking the sample.

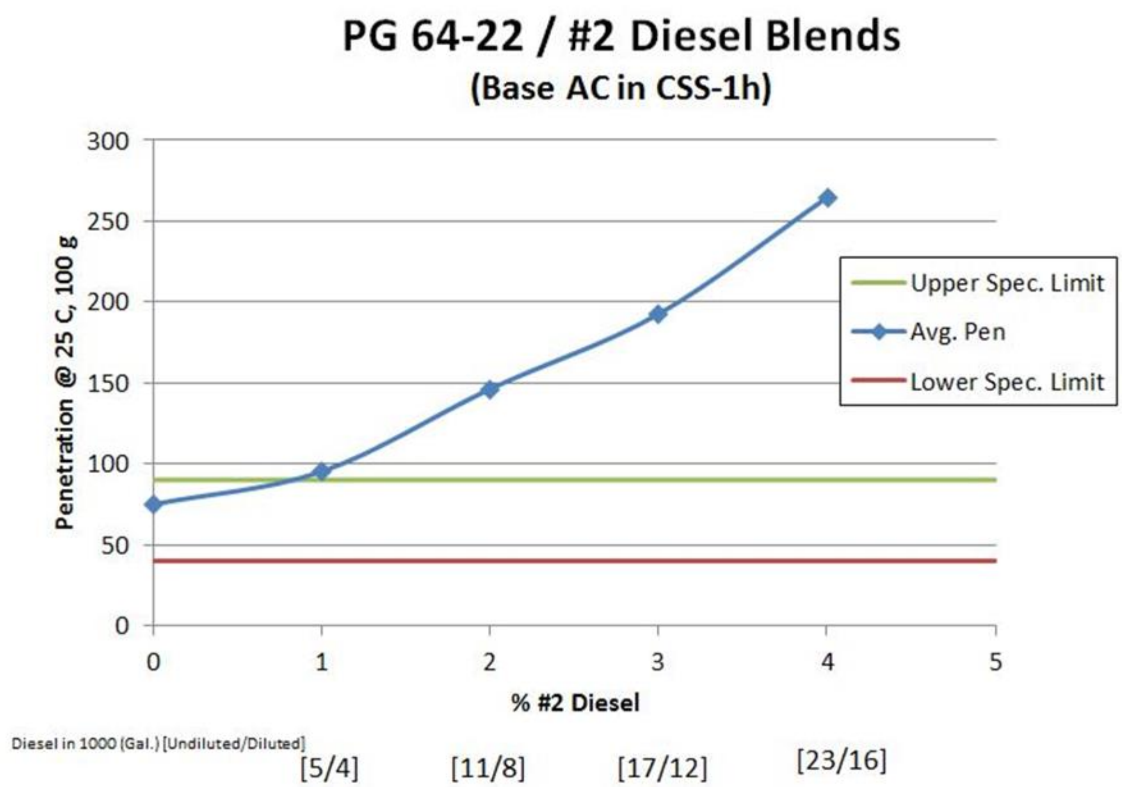


Figure 500.5 – Tack Coat Contamination Graph

Another common source of tack coat failure is low residual asphalt. Residual asphalt is affected by adding water to the emulsion. <u>Tack coat emulsion must never be diluted in the field.</u> Any water being added to a tack coat distributor is an immediate red flag.

MnDOT Specification 2360 requires the tack coat to “break” before paving. When a tack coat emulsion is sprayed on a pavement, it typically appears brownish in color. As it loses water, it will become black in color as the increased percentage of asphalt dominates the material’s appearance. When this color change happens, the emulsion break is said to have occurred. Some water will still be present at this stage. When all the water has evaporated, the emulsion has “set.” To minimize tracking of the tack coat, it is important to try and keep mix delivery vehicles off the tack until it has broken. Even after the tack has broken, it is a good idea to have delivery vehicles avoid driving in the tack unless it is absolutely necessary.

Figure 500.6 – Tack coat distributor truck. Note the streaked appearance. The Contractor should respray this area to achieve uniform coverage.

Yield Check

One of the Inspector’s duties is to run a yield check on tack. The process is performed as follows:

1. Before tack coat applications, read the meter on the distributor truck to determine starting gallons.

2. Determine the length of the roadway section to be included in the yield check.

3. Multiply that length by the width of application to get the area in square feet.

4. Divide that area by 9 to get the area in square yards.

5. After application, read the meter on the distributor truck to determine ending gallons.

6. Subtract ending gallons from starting gallons to determine gallons used.

7. Divide gallons used by the surface area in square yards to determine gallons in square yards.

8. Record the results on the following tack coat form:

Mn/DOT TP-21841-02 (8/81)

STATE OF MINNESOTA
DEPARTMENT OF TRANSPORTATION
BITUMINOUS APPLICATION RECORD

S.P. ______________________ T.H. __________
Location ______________________________________
Date ______________________ Spec. __________

Asphalt Source ______________________________
Type & Grade ______________________ Temp. __________ °F
Start Gal. ______________________ Start Lbs. __________
Stop Gal. ______________________ Stop Lbs. __________
Net Gal. ______________________ Net Lbs. __________

FORMULA A **FORMULA B**

Blt. Lbs. Gal. 60 F ______________________ Corr. Lbs. Gal __________
Temp. Corr. Factor ______________________ Corr. Gal. __________

Sta. Start ______________________ Width (w) __________ Ft.
Sta. Stop ______________________ $\frac{L \times W}{9}$ __________ Sq. Yds.
Length (L) ______________________ Ft.

FORMULA A

Net Gallons x Temp. Corr. Factor = ______________________ Gal./60 F

FORMULA B

$\frac{\text{Net Lbs.}}{\text{Wt./Gal. @ } 60^{o}\text{F}}$ = ______________________ Gal. @ 60°F

$\frac{\text{Gal. @ } 60^{o}\text{F}}{\text{Sq. Yds.}}$ = ______________________ Gal./Sq. Yd.

Weather ______________________ Air Temp. __________ °F

REMARKS: ______________________________________

____

____

____

ENGINEER'S FILE INSPECTOR

Shot No.		Start		Stop		Net		
	Gal.		Gal.		Gal.		Temp.	
	Sta.		Sta.		Sq. Yds.			
	Gal.		Gal.		Gal.		Temp.	
	Sta.		Sta.		Sq. Yds.			
	Gal.		Gal.		Gal.		Temp.	
	Sta.		Sta.		Sq. Yds.			
	Gal.		Gal.		Gal.		Temp.	
	Sta.		Sta.		Sq. Yds.			
	Gal.		Gal.		Gal.		Temp.	
	Sta.		Sta.		Sq. Yds.			
	Gal.		Gal.		Gal.		Temp.	
	Sta.		Sta.		Sq. Yds.			
	Gal.		Gal.		Gal.		Temp.	
	Sta.		Sta.		Sq. Yds.			
	Gal.		Gal.		Gal.		Temp.	
	Sta.		Sta.		Sq. Yds.			
	Gal.		Gal.		Gal.		Temp.	
	Sta.		Sta.		Sq. Yds.			
	Gal.			Temp.		Gal. @ 60°F		
	Gal.			Temp.		Gal. @ 60°F		
	Gal.			Temp.		Gal. @ 60°F		
	Total Gal. @ 60°F							
	Total Sq. Yds.							
	Gallons per Sq. Yd.							
	Remarks							

Example Calculation
Beginning Tank Reading = 250 gallons
Application Length = 1000 ft
Application Width = 12 ft
Ending Tank Reading =150 gallons

$$Yield = \frac{(250\ gal - 150\ gal)}{\left(\frac{1000ft \times 12ft}{9\ sf/sy}\right)} = 0.075\frac{gallons}{square\ yard}$$

520.5 – Haul Trucks

Haul trucks are responsible for delivering the bituminous mixture from the asphalt plant to the jobsite at the correct temperature, in the right quantity, and above all, safely. The trucks must be in sufficient operating condition to reliably and consistently make their delivery to the jobsite and return to the plant for another round. To accomplish this task, there are three main types of haul trucks used in asphalt paving: end-dump trucks, belly-dump trucks, and flow-boys.

End-Dump Truck
This is the most common and typically the most maneuverable type of haul truck, but is also the most prone to thermal and material segregation. These trucks are characterized by a rear-hinged, hydraulically-lifted dump box that releases the bituminous mixture out of the rear of the vehicle either directly into the paver hopper, or onto the roadway for a pickup machine to deliver to the paver. They can be tractor-trailer configurations, but are typically straight-frame trucks.

Straight-frame end-dumps are ideal for paving in tight quarters, such as on city streets or parking lots, but are inherently limited in haul capacity when compared to belly-dump trucks and flow-boy trailers. Because of this, they are not the ideal choice for large-quantity, high-production paving projects. To minimize segregation of the mixture from the truck box into the paver hopper, the operator should raise the truck box to the point where the mixture slides against the end gate. Once this occurs, open the end gate to release the mixture into the paver hopper.

Figure 500.7 – An end-dump truck delivers bituminous mix directly into the paver hopper.

Belly-Dump Truck

A belly-dump truck is a tractor-trailer unit that is characterized by a hydraulically-actuated gate on the bottom of the trailer that releases the bituminous mixture in a windrow directly onto the road for pickup by a pick-up machine or material transfer vehicle. Belly-dump trucks have a higher haul capacity than end-dumps, but are less maneuverable due to the tractor-trailer configuration.

When belly-dump trucks release their material, they should begin their release with some overlap over the previously windrowed material. This will help minimize end of load material and temperature segregation. To do this successfully, the truck operator must keep the existing windrow between the wheels of the trailer when reversing the truck. If not done correctly, the rear wheels of the trailer can run over parts of the existing windrow, creating areas of thermal and material segregation.

Figure 500.8 – A belly-dump truck windrowing a load of asphalt.

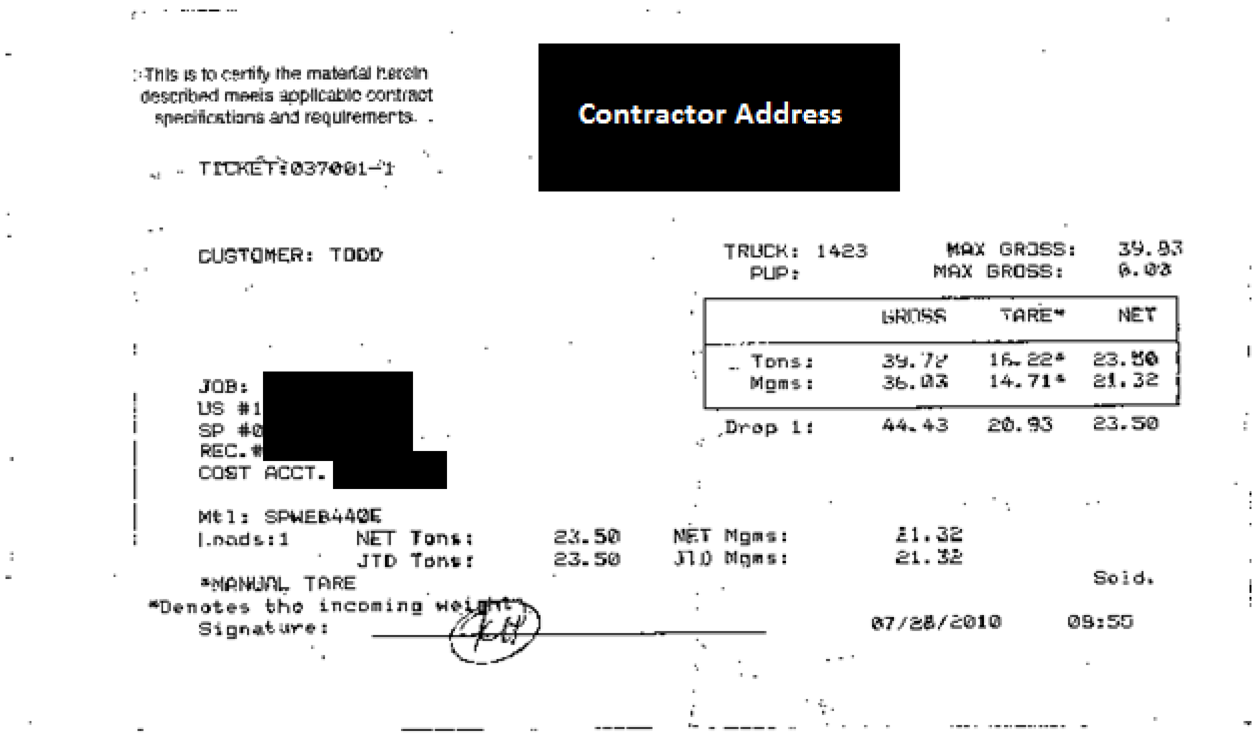
Flow-Boy

A flow boy can either be a tractor-trailer unit or a straight-frame truck. Flow-boys, sometimes called live bottoms, are characterized by a conveyor belt in the haul box that delivers the bituminous mixture out the rear of the vehicle. Flow-boys can either deliver the mix directly to the paver hopper or windrow the material onto the ground for a pickup machine or material transfer vehicle. The capacity and maneuverability of a flow-boy will depend on the configuration of the truck.

Figure 500.9 – A flow-boy windrows bituminous mix

Weigh Tickets

Regardless of truck type, all haul truck operators must provide the Inspector with a weigh ticket that includes ticket number, project number, load origin, date and time, weight of the load, accumulated weight, truck number, and mix designation. Weigh tickets must be furnished for each load.



This is to certify the material herein described meets applicable contract specifications and requirements.

TICKET:037001-1

Contractor Address

CUSTOMER: TODD

TRUCK: 1423 MAX GROSS: 39.93
PUP: MAX GROSS: 0.00

	GROSS	TARE*	NET
Tons:	39.72	16.22*	23.50
Mgms:	36.03	14.71*	21.32
Drop 1:	44.43	20.93	23.50

JOB: [redacted]
US #1[redacted]
SP #0[redacted]
REC.#[redacted]
COST ACCT. [redacted]

Mtl: SPWEB440E
Loads:1 NET Tons: 23.50 NET Mgms: 21.32
JTD Tons: 23.50 JTD Mgms: 21.32
*MANUAL TARE Sold.
*Denotes the incoming weight.
Signature: 07/28/2010 09:55

Figure 500.10 – Example Weigh Ticket

The Street Inspector must check each ticket for correctness and sign or initial each weigh ticket. The weight tickets must be saved for pay records. If all or part of the material will not become a payment record, the weigh ticket should be promptly marked "No Payment." A separate written explanation should be made detailing the reason for no payment. This explanation should include the weigh ticket numbers and the amounts of each material.

Erasing and overwriting is not permitted. If an error is made, it must be neatly crossed out and the correct figure written above it. If it is necessary to void the ticket and prepare a new one, the voided ticket should be attached to the replacement ticket and retained as proof of the voiding. If it is necessary to correct a ticket or alter it, the person making the alteration must explain it on the ticket where the alteration is made, and initial the change.

If an original weigh ticket is lost, a new ticket should not be created. If the Contractor's copy of the original ticket is available, a photocopy should be made. A signed explanation regarding the lost original should be attached to the copy. If the Contractor's copy is not available, the Inspector must prepare a signed statement giving the reason and the amount of materials to be paid for by the Agency. A complete explanation should be provided regarding the loss of the ticket.

520.6 – Delivering the Mix

There are several methods of delivering asphalt mix to the paver besides dumping it directly from a truck into the paver hopper. A pickup machine, or windrow elevator, is used to deliver the bituminous mixture from a windrow to the paver hopper. Pickup machines are typically pushed by the paver. Some pickup machines have remixing capabilities that can help to reduce thermal and material segregation by mixing the material before delivering it to the paver hopper. Material Transfer Vehicles (MTV's) are self-propelled units that function similarly to pick up machines. MTV's typically have remixing capabilities and can be equipped with either a hopper or a windrow elevator at the front of the machine.

Pickup Machine

This machine simply picks up the bituminous mixture off the road and delivers it to the paver without mixing. Poorly set up pickup machines will leave a significant amount of mixture on the pavement. Little, if any, material should pass under the pickup machine and be run over by the paver.

Figure 500.11 – A non-remixing pickup machine transfers bituminous mixture to the hopper.

Remixing Pickup Machine

This is a pickup machine that has an additional auger, or remixer, to mix the material before placing it into the paver hopper. This helps prevent thermal and material segregation.

Figure 500.12 – Remixing Pickup Machine. Note the auger bearing just above the point of discharge.

Material Transfer Vehicle

MTV's function similarly to the examples given above, only they are separate vehicles with built-in drive systems. There are several advantages of an MTV over a pickup machine. First, the discharge chute can swivel, so the MTV can be in an adjacent lane to the paver. This allows some additional flexibility in the paving operation. MTV's also have some internal storage capacity, making it possible to deliver mix to the paver even if no haul truck is immediately available. If equipped with a hopper, MTV's can also eliminate some of the segregation associated with end-dump trucks due to the remixing that occurs before delivery to the paver. It should be noted that a fully loaded MTV is extremely heavy and may exceed bridge or pavement load carrying capacity.

Figure 500.13 – A Material Transfer Vehicle delivers bituminous mixture to the paver. Note that, due to space limitations around the paver, the MTV is in an adjacent lane to the paver. This allows the haul trucks more room to deliver the mix to the MTV.

Figure 500.14 – Material Transfer Vehicle from the rear. The area between the front and rear wheels can store and remix several tons of asphalt mixture.

520.7 – Pavers

Pavers are self-propelled asphalt laydown machines where bituminous mixture is loaded in the front, carried to the rear by conveyors, spread out by augers, and leveled and compacted by a screed. The paver laid mixture is referred to as a lift or course. The key components of a paver are the tractor unit and the screed.

Tractor Unit

The tractor unit is the material feed system that pulls the screed. It includes the hopper, slat conveyors, and augers. The hopper stores the mix before it is transferred to the augers by the slat conveyors. Some re-mixing pavers have replaced the slat conveyors with an auger system. Upon delivery to the rear of the tractor unit, transverse augers spread the mixture in front of the screed. There is one auger for each side of the paver. Typically, there is an auger gearbox located between the augers. If the kick back paddles on the auger are not properly maintained, the area around the gear box can be a source of segregation. The augers need to maintain a constant amount of material across the full width of the screed, including any extensions.

Screed

The screed is a horizontal plate that takes the head of material from the augers, strikes it off at the correct thickness, and gives the mat its initial compaction. The screed is the component that has the greatest effect on the final cross slope, smoothness, and appearance of the bituminous mat. The vibrating screed is capable of achieving 70-80% density before roller compaction. The positioning of the screed is typically controlled by automatics which use information from sensors to detect the longitudinal profile of the road surface. Sensors can either be contact skis, which physically contact the road surface, or sonics, which sense the road surface without contact. Layer thickness is controlled by adjusting the angle of the screen with respect to the underlying surface.

Types of Pavers

There are several types of pavers as detailed below:

Wheeled Paver

This is a paver that typically has two large drive wheels in front of the screed and several small bogie wheels beneath the hopper.

Figure 500.15 – A wheeled paver with contact sensors and pickup machine

Track Paver

This type of paver is driven by a track system instead of wheels.

Figure 500.16 – A tracked paver using sonics to adjust the screed.

Spray Paver

This paver sprays tack and applies asphalt mixture seconds later. This type of paver incorporates spray bars in front of the screed as well as a tack storage tank, which is mounted to the paver. Spray pavers are required for placing Ultra-Thin Bonded Wearing Course in Minnesota, and can be used for paving thinlift overlays. Since the spray paver applies the tack coat onto the roadway, a tack distributor truck is not required in conjunction with a spray paver.

Figure 500.17 – Spray paver in action. Note the tack coat spray bars in front of the screed.

520.8 – Rollers

After the paver places the mix on the roadway, it must be compacted to achieve the proper mix density. The type of equipment used to compact the mixture has an impact on the density that can be obtained. Different types of self-propelled compaction equipment include: static steel wheel rollers, pneumatic tired rollers, and vibratory steel wheel rollers. A combination of these rollers, called the rolling train, is used to densify the asphalt mixture. Typically, the rolling train includes a breakdown roller, an intermediate roller, and a finish roller. This section will detail the different types of rollers. The next section will detail the different rollers within a rolling train.

Vibratory Double Steel Drum Roller
Double steel drum rollers have a steel drum at the front and rear of the vehicle. They can be operated in vibratory mode or in static mode. Vibratory steel drum rollers apply a dynamic load

to the compaction process to provide a greater total compactive effort. The dynamic load also helps rearrange the aggregate particles to help improve greater friction and interlock. Steel drum rollers in static mode compact with compressive forces only. Steel drum rollers build density in the pavement from the top down.

Figure 500.18 – Vibratory Double Steel Drum Breakdown Roller

Pneumatic Tired Roller

The pneumatic tired roller, commonly referred to as a rubber tired roller, drives over the mat with multiple smooth tires on each axle. Pneumatic tired rollers compact the mix with static compressive forces that knead the mixture together. The pneumatic tired roller builds density from the bottom up. If the pneumatic-tired roller is used for break-down compaction, it will be followed by a vibratory steel-drum roller.

Before rolling operations begin, the tires should be warmed up and sprayed with a non-petroleum distillate release agent. Warming the tires can be accomplished by simply driving the roller back-and-forth or in circles on an existing pavement. If the tires are not warm and treated with a release agent, they will have a tendency to pick up the hot mix, which can cause serious problems with the fresh bituminous mat. Mixture pick up is especially a problem during cold weather paving and when the bituminous mixture contains a highly polymer modified asphalt cement. The tires must be fully skirted in order to retain heat. See Figure 600.27 for an image of a skirted pneumatic tired roller.

Several other items of note regarding pneumatic tired rollers:

- Uniform tire pressure is essential for proper compaction. Adjusting the tire pressure based upon lift thickness and underlying support may be necessary.

- Placing the first lift of asphalt mixture on a jointed concrete pavement may result in bumps at each joint. While the cause can be disputed, using a pneumatic roller has shown to alleviate this issue.

Figure 500.19 – Pneumatic Tired Rollers.

520.9 – Rolling Train

The rolling train is a combination of any or all of the rollers mentioned above. Typically, the rolling train includes a breakdown roller, an intermediate roller, and a finish roller.

Breakdown Roller

The first roller following the paver is called the breakdown roller and provides the greatest compactive effort of all the rollers. Breakdown rollers are typically vibratory double steel-drum rollers, but pneumatic (rubber) tired rollers are occasionally used for breakdown compaction. When using vibratory double steel-drum rollers with paving thicknesses of 3 inches or less, vibration should be set to a high frequency and low amplitude to avoid breaking aggregates.

High frequency and high amplitude should be used for paving thicknesses greater than 3 inches. Rollers should not be allowed to stand (remain stationary) on uncompacted or newly rolled mat with a surface temperature greater than 140°F. Doing so could cause depressions and unnecessary roughness in the mat surface. Break down rolling should typically occur immediately upon placement to ensure compaction occurs at the optimal temperature.

Intermediate Roller

Intermediate rollers are positioned behind the breakdown rollers. Either pneumatic or steel wheeled rollers can be used in the intermediate position. The tender mix phenomena typically occurs in the intermediate rolling temperature ranges. If mix adjustments do not provide relief, intermediate rolling should commence once the tenderness has subsided from cooling.

Finish Roller

The final roller in the train is the finish roller. This is typically a static (non-vibratory) steel-drum roller whose purpose is to work out surface imperfection, roller marks, and produce a smooth and aesthetically pleasing pavement surface. When a pneumatic-tired roller is placed as an intermediate roller in the rolling train, it is important that the finish roller compacts the mat at a warm enough temperature to press out any indentations left by the individual tires. There may be tire shadows in the mat even after the indentations are removed.

530 – Construction Inspection

Possibly the biggest contributing factor to the success of a bituminous paving project is the manner in which the pavement is constructed. The construction Inspector has the responsibility to monitor the construction operations and to ensure that the final product conforms to the standards of the Agency. During construction, issues will inevitably arise that have the potential to negatively impact the finished product. In these cases, it is critical to have knowledgeable and experienced construction Inspectors to bring these problems to the attention of the Contractor and the Engineer if necessary.

To be precise, the Inspector is responsible, per MnDOT Specification 1510, for monitoring the day to day operations of the project to track quantities, and ensure compliance with the Contract Specifications. This section will detail common duties of an Inspector during asphalt paving. Examples of common problems in bituminous paving will be detailed in Chapter 6 of this manual. See the following checklist for guidance when inspecting bituminous paving projects:

List for Plant Mixed Asphalt Pavement – Paving Inspector	Specifications	Bituminous Manual
Check equipment for compliance with specifications	2360.3.B	-
Familiarize self with adjustments available on paver such as flow gates, auger control, vibratory screed, screed angle, screed crown	2360.3.B.2.a	-
Check grade for smoothness, compactness, cross slope, grade, and alignment.	2360.3.E	530.1
Discuss paving and rolling sequence with Contractor	-	510
Observe tack placement for uniformity of coverage and quantity	2357, 2360.3.B.3	520.4
Collect, check, and initial each delivery ticket	2360.G.8	520.5
Inspect material in load for possible deficiencies	2360.3.B.1.a	Chapter 6

List for Plant Mixed Asphalt Pavement – Paving Inspector	Specifications	Bituminous Manual
Observe dumping and paver feed operation for possible segregation problems	2360.3.B.2.a, 2360.3.D, 2360.3.E	Chapter 6
Maintain surveillance of line, grade, cross-slope, and screed control	2360.3.E	530.1
Monitor laydown temperature	2360.3.A.5	530.1
Observe mat for uniformity of texture, segregation, debris	2360.3.E	Chapter 6
Measure mat for proper thickness and width	2360.3.E	530.3
Perform yield checks	2360.5	530.3
Observe roller operation for uniformity and continuity (Vibratory rollers using high frequency and low amplitude)	-	520.8
On the day the pavement is analyzed for smoothness • Check for current certification of operator and equipment • Obtain a printout of the profiler settings • Obtain a copy of the raw PPF file	2399	530.7
Ensure cores are cut at marked locations	2360.3.D.1.i,j	720.14
Maintain a diary (include the following) • Hours of operation • Stations paved • Lift • Thickness • Tonnage • Yield Checks • Delivery Temperature • Weather conditions • Photos	MnDOT Contract Administration Manual 5-591.390	-
Collect asphalt emulsion (tack) sample(s)	Schedule of Materials Control	-

Table 500.1 – Bituminous Paving Inspection Checklist

530.1 – Bituminous Paving Inspection

Construction projects are highly variable in terms of location, scope of work, site conditions, and Contractor practices. Because of this, the types of problems encountered on a construction project can be just as variable as the projects themselves. The Inspector must use their best judgement and instincts to determine if something is wrong with the operation. When problems arise, the first step is to immediately notify the Contractor. If the problem cannot be resolved by the Contractor and Inspector, the Project Engineer should then be notified.

In cases of serious error by the Contractor, or if the Contractor is operating in an unsafe manner, the Inspector has the authority to stop work until the issues can be resolved. Any work completed by the Contractor after the Inspector stops work falls under MnDOT Specification 1512.2 - Unauthorized Work. For more information about construction inspection, see MnDOT Specifications 1510 – Authority and Duties of the Inspector, 1511 – Inspection of Work, and 1512 – Unacceptable and Unauthorized Work.

Duties of the Inspector

The Inspector's primary duties are to help assure that all work on the project is performed in reasonably close conformity with the plans and specifications, and that payment is made to the contractor commensurate with the work performed. This requires that the Inspector understands the plans and specifications for the work they inspect, stays alert to the Contractor's activities, and keeps accurate records of construction activities and quantities. The Inspector also needs to recognize problems, anticipate problems whenever possible, and exercise diplomacy in resolving them with the contractor.

Bituminous inspection is a team effort that consists of the following jobs:

- Inspection of aggregate production and stockpiling
- Pre-paving grade inspection
- Milling inspection
- Tack Coat Inspection
- Plant Inspection
- Paving Inspection
- Materials Testing
- Density Testing
- Traffic Control Inspection

The Inspector may be responsible for any of the jobs listed. The Project Engineer must define the Inspector's duties if uncertainty exists. If the Inspector is not responsible for these duties, they should know who is.

General Responsibilities

The general responsibilities of the Inspector include:

- Know the plans and specifications for the pay items you are inspecting, including specifications that are project specific (special provisions, etc.).

- Be alert for any potentially unsafe conditions or any situations that may delay construction and report them to your Supervisor.

- Identify nonconforming work or materials as early as possible and anticipate problems where possible. Notify the Contractor immediately and make a record of it. Follow up on corrective work and make a record of it as well. If the Contractor can't or won't fix the problem, notify your Supervisor.

- Avoid any inspection, testing, or other activity that could be construed as the Contractor's responsibility. If you perform the Contractor's work, the Contractor may not be held accountable for their work if there is a claim or other Contract dispute.

- Be prepared to make inspections and tests promptly, but do not make hasty or premature decisions. The Contractor is expected to give you adequate notice of when they will be ready for inspection and testing.

- If Specifications don't cover a particular situation, or tolerances seem unrealistic, contact your Supervisor for guidance. Report problems you can't handle and see that they get resolved before an expensive and time-consuming correction is required.

Records

Complete and accurate records of the quantity and quality of the work performed are required. They document that work is performed in accordance with the Plans and Specifications, and assure the Contractor receives proper payment for their work. Records also provide a means to maintain control of the work during construction and document the reasons for decisions made and actions taken. Project records must be sufficiently clear and complete to be understood by people unfamiliar with the details of the project and to sustain audit. Failure to keep such records is a failure to account properly for the expenditure of public funds. The importance of maintaining adequate and proper records cannot be overemphasized. Memory cannot replace valid permanent documents. Records of the quantity and quality of work performed should include the “four W’s” as follows:

What
Identify the pay item involved (by both name and item number) and the quantity involved.

Where
List the project name and number as well as the specific location, such as project station and lane or offset.

When
Note both the date and the time of day.

Who
Sign the record. Initials are not acceptable unless your signature also appears in the record (in a book this may be done once on an index page in the front of the book).

It is particularly important to have a record of any problems on the job (such as nonconforming work or changed conditions). This record should include any instructions given to or agreements made with the Contractor to resolve the problem. Remember that the records have legal importance if there is a claim or other contract dispute. Forms are available for nearly all materials tests and for inspectors’ daily reports. Pay item books and diaries may be organized somewhat differently on every project. You should know what records you are to keep and in what form before you begin work on any project. If unsure, ask your supervisor.

Authority of the Inspector

- The inspector has the authority to approve materials and workmanship that meet the contract requirements. Approval should be given promptly. MnDOT Specification 1510 authorizes the inspector to reject work or materials. The inspector must keep the Project Engineer informed of any material rejection. The inspector must thoroughly document the reason for rejection and the amount of material rejected.

- The Inspector may suspend portions of the work when a decision is required by the Engineer regarding interpretation of the Contract, Unacceptable or Unauthorized work, or safety reasons.

- The Inspector does not have the authority to approve deviations from the contract requirements.

- The Inspector should not require the Contractor to furnish more than what is required by the plans and specifications, nor allow anything less.

- The Inspector should not under any circumstances attempt to direct the Contractor's work; otherwise, the Contractor may be relieved of their responsibility under the contract.

- Instructions should be given to the Contractor's supervisors, not to the laborers or subcontractors.

Relationship with Contractor
The Inspector should maintain a professional, agreeable, and cooperative attitude with the Contractor and their work force. The goal should be to help build a good facility within the contract time, not to harass and delay the Contractor. The Inspector should accept no personal favors from the Contractor. Tact should be used when pointing out deficiencies to the Contractor and their staff. The Inspector's behavior can improve or disrupt the relationship between the Contractor, inspection personnel and the Agency. Below are some general guidelines to follow regarding conduct with a Contractor:

- Don't let personality differences or your opinions of the Contractor interfere with your working relationship. Don't pre-judge the Contractor. Begin with the premise that the Contractor is fair-minded and intends to do a good job. Honor commitments made during partnering with the Contractor.

- Criticism on or off the job of the Contractor or the Contractor's employees by the Inspector is unwarranted and hurts Contractor relations.

- If you make a wrong decision, admit it. It is recognized that no one is perfect.

- Be courteous to the public and respect their rights. The resulting good public relations will benefit all concerned.

- Never get involved in the Contractor's labor relations. That is the Contractor's responsibility.

Some additional Inspection best practices include:

- Check equipment for compliance with specifications. Familiarize self with operation and various functions of equipment.

- Familiarize self with adjustments available on pavers such as flow gates, auger control, tamper bar, screed angle, screed vibration, and screed crown.

- Check base for smoothness, compactness, cross slope, grade, and alignment as appropriate. Ensure the existing surface is free of ravel, loose patches or excessive patch, and joint material.

- Identify areas of instability that require repair.

- Discuss paving and rolling sequence with Contractor.

- Observe tack placement for uniformity of coverage and desired quantity.

- Collect, check, and initial each delivery ticket.

- Inspect material in load for possible deficiencies evidenced by physical appearance.

- Observe dumping and paver feed operation for possible segregation problems.

- Maintain surveillance of paver operation to ensure against incorrect line, grade, cross slope or malfunctioning automatic screed control.

- Monitor laydown temperature to ensure compliance with minimum laydown temperatures if specified.

- Observe mat for uniformity of texture, presence of spot segregation, and the presence of debris, such as wood, pine cones, otters, clay balls, or trash. Measure for proper thickness and width, and perform yield checks per plan and proposal.

- Observe roller operation for uniformity and continuity of operation with attention to speed, pattern, location of drive wheel, and vibration (if used). Typical settings are high frequency and low amplitude.

- Maintain surveillance of roller operation to ensure timely performance geared to remove marks and bumps.

- Ensure adequacy and mechanical condition of rolling equipment.

- Check surface for compliance with smoothness requirements. Make sure each Inertial Profiler (IP) has been certified by MnDOT.

- Cores will be taken and tested by the Contractor. Core locations will be determined and marked by the Agency. Ensure cores are cut at marked locations. Properly store and transport cores within a timely manner to Agency lab. Monitor density tests for compliance with requirements. The Contractor shall schedule the approximate time of testing during normal project work hours so that the Agency may observe and record at least the saturated surface dry and immersed weight of the cores.

- Maintain a daily street diary that may include such things as hours of operation, stations paved, course, depth, width, tonnage, yield, measured delivered temperature, weather, and other events bearing on quality and quantity of work.

- Include photos and descriptions of items outside the range of normal.

- The inspector will witness all QC mixture sampling and take possession of their QA-Verification split of this sample immediately after the sample is split. At the end of the day, randomly submit one of the QA-Verification splits to the District Lab for testing. All samples are to be put in a 12 inch concrete cylinder. Obtain 3 full cylinders of mix and put properly filled out sample cards in each cylinder.

- Obtain Summary Sheets, Density Core Worksheets, Agency's Density Core Worksheets, and Agency's Verification Results and keep track of the tonnage where samples were obtained for evaluating Density Incentives and Disincentives.

- Collect asphalt emulsion (tack oil) samples as per the Schedule of Material Control.

530.2 – Sampling

Bituminous mix should be sampled per the Schedule of Materials Control. Any split sampling should be done in the presence of the Inspector. The Inspector should take possession of their verification sample after the sample is split. See **Chapter 7 – Quality Management** for more information.

530.3 – Bituminous Yield Checks

A yield check is a mathematical calculation comparing the actual tons of asphalt paved to the design asphalt quantity within a certain station range. There will often be slight variation between the actual tonnage and the design tonnage, but when this variation becomes excessive, it is an indication that some part of the paving operation is not in compliance with the Contract Specifications. For example, excessive lift thickness during paving is a common reason for exceeding plan quantities. These issues should be brought to the Contractor's attention immediately. The design tonnage is calculated with the following formula, and is then compared to the actual paved tonnage for a given section (unit conversions have been removed for simplicity. See the example below the formula for unit conversions):

$$Design\ Tonnage = \left(\frac{\_\_\_\_\_\_\_\boldsymbol{ft\ wide} \times \_\_\_\_\_\_\_\ \boldsymbol{ft\ long}}{9}\right) \times \left(\frac{113 \times \_\_\_\_\_\_\_\boldsymbol{in\ thick}}{2000}\right) = \_\_\_\_\_\_\_\boldsymbol{tons}$$

Example
Below is an example of a typical yield check:

Roadway Details
Paved Length = 6000 ft
Paved Width = 12 ft
Design Lift Thickness = 2 inches
Actual Tons Paved = 934 tons

Step 1. Determine Design Tonnage

$$Area\ Paved\ (Square\ Yards) = \frac{6000\ ft\ \times 12\ ft}{9\ ft^2/SY} = 8000\ SY$$

$$Design\ Tonnage = 8000\ SY\ \times\ 2\ inches\ \times \frac{113\ pounds\ per\ square\ yard\ inch}{2000\ pounds\ per\ ton} = 904\ tons$$

Step 2. Compare Actual Tons Paved to Design Tonnage
From the haul truck weight tickets, it is determined that 934 tons has been paved in this section. Find the difference between the actual tons paved and the design tonnage:

$$934\ Actual\ Tons\ Paved - 904\ Design\ Tons = 30\ Tons$$

The paving operation is 30 tons over design quantity for this section. The Inspector should note this in their field diary and bring it to the attention of the Contractor.

Figure 500.20 – Inspectors measuring the paved width of the road

530.4 – Longitudinal Joint Placement

Because longitudinal joints are often subject to premature deterioration in bituminous pavements, it is critical that they are placed and constructed properly. The existing surface type plays a large role in determining where the longitudinal joint must be placed along the roadway. Regardless of surface type, longitudinal joints should never be placed within the wheelpath of a lane as this can cause premature joint deterioration.

Bituminous on Bituminous Paving (BOB)
When constructing multiple lift bituminous pavement, the longitudinal joints should be staggered transversely by 6 inches with respect to the longitudinal joint of the previous lift. As stated previously, longitudinal joints should not be placed in a wheelpath.

Bituminous on Concrete Paving (BOC)
When placing bituminous pavement over existing concrete pavement, the longitudinal joints in the bituminous pavement should not be staggered. Rather, they should be stacked so they line up with the longitudinal joints in the existing concrete pavement.

Echelon Paving
Echelon paving involves two pavers working at the same time with their respective paving passes butting against each other. One paver is staggered ahead of the other, creating an echelon formation. By using this technique, two adjacent paving passes are placed and compacted in one continuous operation. If properly executed, echelon paving can produce a longitudinal joint between the paving passes which is virtually indistinguishable from the center of the mat, both in terms of density and appearance.

Echelon paving comes with a host of logistical issues. To start, the Paving Contractor must have two pavers available at the same time. Additional rollers are needed to properly compact the bituminous mat. Three lane closures (or two lane closures and a wide shoulder) will likely be required - two lanes for the pavers and rollers, and one lane (or wide shoulder) for haul trucks to access the work site. If all these requirements are met on a project, echelon paving can produce an exceptional bituminous pavement.

Figure 500.21 – Two pavers in echelon. Two lanes are paved in one operation.

530.5 – Longitudinal Joint Construction and Compaction

There are many factors that go into the performance of the longitudinal joint, even before the bituminous mixture is placed on the road. The ease of compaction of the mix depends on the lift thickness, aggregate size, amount of asphalt, type of asphalt and mixture temperature. It is also important to realize that, although the layers below the surface course will not be visible after construction, it is just as critical to use quality construction practices on the first paving pass as it is on the final paving pass. The following are guidelines to constructing a quality longitudinal joint.

First Paving Pass

The first paving pass sets the stage for the rest of the project. Constructing the first pass correctly will aid the entire process:

A. Using a string line will give the paver operator and screed operator a reference to follow and promote a straight longitudinal joint that will be easier to match into with the second pass.

B. Have the end gate down on the paving surface to confine the mix at the outside of the screed.

C. Make sure there is a uniform head of mix across the width of the screed so the outside edge is not starved of mix. If the head of mix is not uniform, the outside edge will not have enough mix or be coarse and segregated.

D. Make sure the vibratory screed is vibrating. This is the initial compaction of the mix at its hottest temperature.

Compacting the First Pass (Unconfined Longitudinal Joint)

An unconfined longitudinal joint is a joint with a free edge. There is no abutment on the side of the mat being placed with another mat or pavement surface. When paving the first pass, an unconfined longitudinal joint is created where the second pass will meet the first. Most Contractors in Minnesota use vibratory double steel drum rollers for breakdown compaction of the first pass. To make this compaction as effective as possible, the roller should be right behind the paver.

The best method for compacting the unsupported edge is to hang the outside edge of the roller over the edge of the mat by 6 inches. If done correctly, the majority of the roller drum will be on the hot mat. If this is not done correctly, it can affect the quality of the longitudinal joint. For example, if the edge of the roller is placed directly over the unconfined edge, the mat will likely move laterally out along the edge. Alternatively, if the roller is kept inside the unconfined edge, the mat may crack along the edge of the roller nearest to the joint.

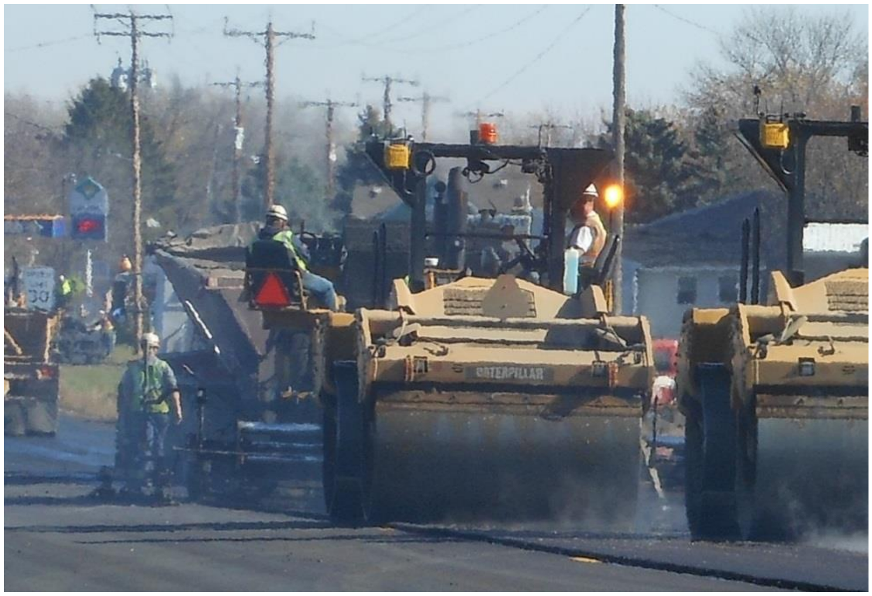


Figure 500.22 – Compacting an unconfined edge. Note the roller at the front of the train hanging the drum over the edge by several inches.

Placement of the Second Pass (Confined Joint)

The joint where the second paving pass meets the first is considered a confined joint. A confined joint is one that is placed against another mat, or abutting a vertical surface such as curb and gutter. Proper matching and placement of mix during the second pass is just as important to the overall performance of the joint as the construction of the first pass. There must be 1 to 1 ½ inches of overlap of the second paver pass onto the first paving pass. This will ensure that there is enough mix present so the joint will not have excess voids. Additionally, the thickness of mix placed during the second pass must be such that the compacted height of the second pass is equal to or slightly higher than the first pass. This again is to ensure there is enough mix at the longitudinal joint (so it is not starved of mix). It will depend on mix characteristics, but a typical rule is that mix compacts ¼ inch for every 1 inch of mix that is placed. For example, if a final thickness of 2 inches is specified, then 2 ½ inches of mix needs to be placed by the paver prior to compaction.

Compacting the Second Pass at the Longitudinal Joint (Confined edge):

When compacting a confined joint with a vibratory double steel drum roller, there are two methods generally used for compaction. The first method is rolling from the hot side with the drum extending over the top of the joint by 6 inches. The second method is to "pinch the joint." With pinching the joint the first pass with the steel wheel roller is placed about 6 inches inside the longitudinal joint on the hot side of the joint. The second pass, again from the hot side, positions the drum extending over the top of the joint by 6 inches. If a pneumatic tired roller is used, center the outside wheel of the roller directly over the longitudinal joint between the two passes.

Figure 500.23 – Roller Option 1 Diagram

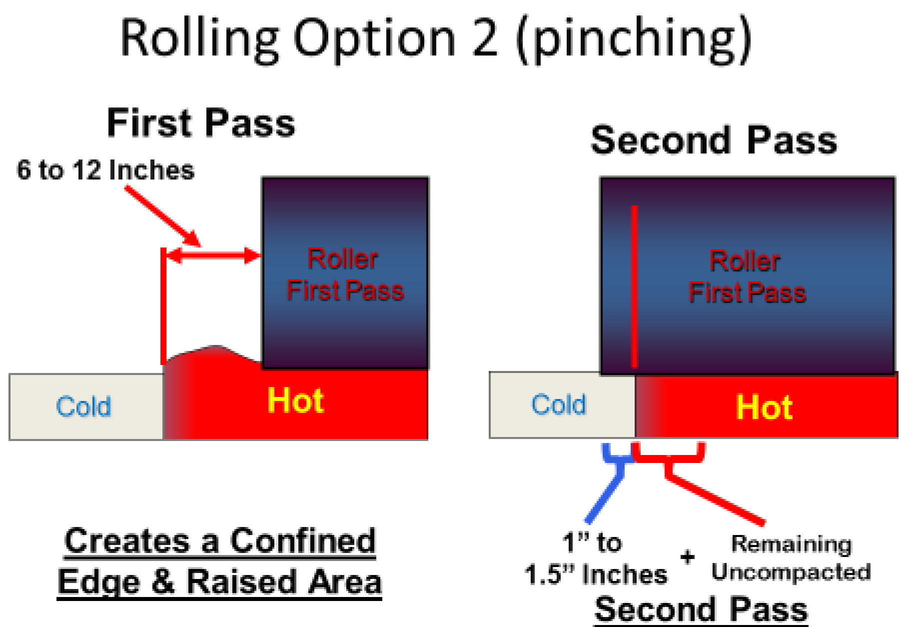


Figure 500.24 – Roller Option 2 Diagram

Maryland Joint

One method to help achieve proper joint density is the Maryland Joint construction technique. Shown in the diagram below, this method entails overlapping the cold side of the joint 1-1½ inches wide by 1/8 inch high with hot mix. As the joint is compacted, the overlapping material helps achieve proper density by ensuring that there is enough bituminous mixture at the joint interface. Note that the roller will crush the overlapped aggregate, leaving a white dust line, but this is normal.

The figure at the bottom of the following diagram shows the wrong way to construct a longitudinal joint. By leaving the hot side equal to or lower than the cold side of the joint, an inadequate amount of material is placed and the edge of the roller drum will ride on the cold side, preventing it from achieving enough down pressure on the hot mat for proper compaction.

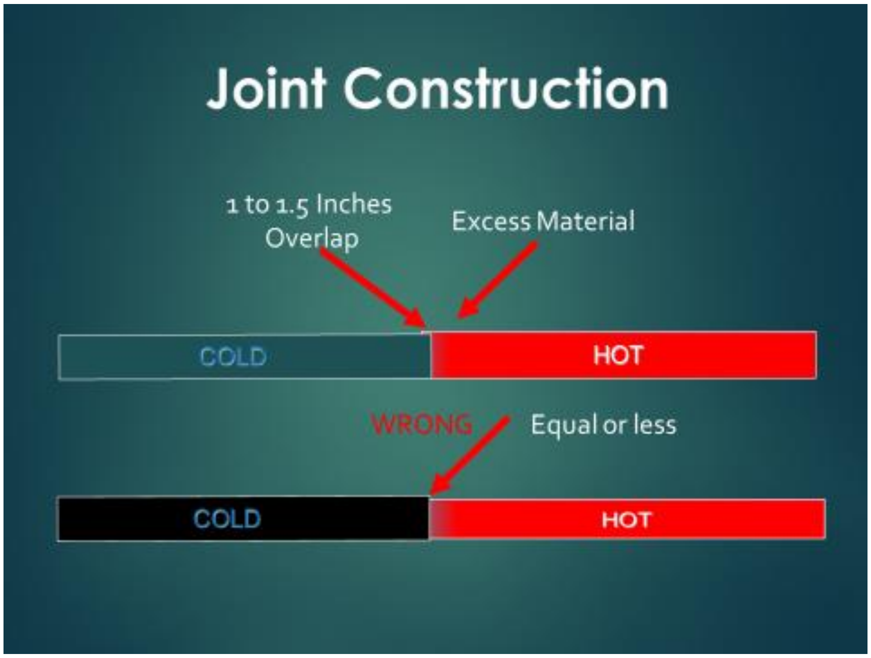


Figure 500.25 – Maryland Joint diagram

530.6 – Bituminous Pavement Compaction

There are two possible compaction requirements in MnDOT Specification 2360. The default requirement is Maximum Density, while the other is Ordinary Compaction. Maximum Density involves measuring cores taken from the road to determine the density. Ordinary compaction requires that a rolling pattern be determined and followed to achieve required compaction. According to a Washington State study, each 1% increase in air voids above 7% results in the loss of a year of pavement life. Therefore, it is critical to compact the mix to specified requirements.

Ordinary Compaction

With Ordinary Compaction, proper density is determined by establishing a rolling pattern through the use of a portable nuclear density gauge. Ordinary Compaction is often used for:

- Paving thickness less than 1.5 inches

- Thin Lift Leveling
- Driveways
- Areas which cannot be compacted with standard highway equipment

Ordinary Compaction must not be used in the following cases:

- On mainline, ramp, or loop paving unless otherwise designated in the plans or special provisions.
- When the air temperature is less than 32°F

Maximum Density

On projects that specify maximum density, cores must be taken after each day's paving to determine the asphalt density at randomly-determined locations along the roadway. The coring locations are determined using Core Stationing Worksheets, which are found on MnDOT's Bituminous Engineering Webpage. Cores are essentially used as data points that represent the density of a given quantity of bituminous mixture known as a "lot." The average density of a lot is then used to determine a Contractor pay incentive or disincentive depending on whether target density was attained, surpasses, or not reached.

With each core lot, the Contractor has the potential for incentive payment, even payment, or disincentive payment depending on the densities achieved. The Bituminous Engineering Webpage contains spreadsheets for determining Contractor pay incentives and disincentives. After coring is completed, core holes must be patched for safety and to avoid creating a starting point for futures pavement distresses. Consult MnDOT Specification 2360.3.D.1 for more details regarding the maximum density method. Also, **Chapter 7 – Quality Management** gives a comprehensive procedure for taking and measuring field cores.

The mix must be compacted to at the least the minimum density listed in the following Table:

Required Minimum Lot Density (Mat)

	3% Design Voids	4% Design Voids	3% Design Voids (One Percent Reduced)	4% Design Voids (One Percent Reduced)
% of Gmm	93	92	92	91

Table 500.2 – Required Minimum Lot Density

Four percent design air void mix is the MnDOT standard, while three percent can be specified on shoulders and low-volume roads.

Figure 500.26 – Core Drill

Companion Cores

When cores are cut, the Contractor will take possession of a set of cores, and the Inspector will take possession of a set of cores, called companions. Companions are cut one foot longitudinally from the Contractor's cores and are used to verify the Contractor's results. It is imperative that these cores are transported carefully to avoid damage and to maintain the integrity of the cores. When there are disparities between the Contractor and Agency core densities, the integrity of the cores should be checked, as core damage can cause inaccurate test results. Any damaged cores should be recored. Core holes must be refilled within 24 hours of coring.

One Percent Reduced Density

The mat density requirement is reduced by 1% for the first lift of Asphalt mix placed over Concrete pavements. Also, the Contractor can request that the density requirements be reduced one percent in the following cases:

- First lift on aggregate base
- Reclaimed base or over CIR
- First lift on a road with a spring load restriction no greater than 7 tons

The Contractor must notify the Engineer in writing of their intent to use the reduced density allowance. This written notification must be made to the Engineer by the end of the third day of paving. The reduced density will remain in effect for the duration of mixture placement on that lift. Longitudinal joint cores are not cut when 1% reduced density is in effect.

Figure 500.27 – A cooler modified for core transportation. This is an example of good core handling.

530.7 – Surface Smoothness

One of the chief reasons for resurfacing or reconstructing a roadway is to improve ride quality. Smooth roads have many benefits including enhanced driver comfort, increased fuel economy, reduced vehicle wear-and-tear, reduced chance of cargo damage, and reduced stress on the roadway from vertical vehicle movements, potentially leading to improved pavement performance and durability. There are several ways to measure smoothness on a bituminous pavement as detailed below:

10-Foot Straight Edge

The 10-foot straight edge is used to evaluate the finished mat surface for vertical deviations both parallel and perpendicular to the pavement centerline. Table 2360-27 in the MnDOT Standard Specifications for Construction details the requirements for surface evaluation using a 10-foot straight edge.

Table 2360-27
Surface Requirements

Course/Location	Description	Tolerance
Leveling/1st lift using automatics	Tolerance also applies to 1st lift placed other than leveling when automatics are used.	½ in
Wear	Tolerance of final 2 lifts from the edge of a 10 foot straightedge laid parallel to or at right angles to the centerline.	¼ in
Shoulder Wear, Temporary Wear & bypasses	Tolerance from the edge of a 10 foot straightedge laid parallel to or at right angles to the centerline.	¼ in
Transverse joints/construction joints	Tolerance from the edge of a 10 foot straightedge centered longitudinally across the transverse joint. Correction by diamond grinding required unless the Engineer and the Contractor agree to a deduct of $1,500.	¼ in
20 ft. pavement section excluded from IRI and ALR testing in Table 2399-3.	Tolerance from the edge of a 10 foot straightedge placed parallel to or at right angles to centerline. Does not include measurement at terminal header, bridge deck, and approach panels. Corrective Works required unless both the Engineer and the Contractor agree to a deduct of $1,500 per lane.	¼ in
Transverse Slope	Tolerance for surface of each lift exclusive of final shoulder wear.	Not to vary by more than 0.4 % from plans.
Distance from edge of each lift and established centerline.	No less than the plan distance or more than 3 inches greater than the plan distance. The edge alignment of the wearing lift on tangent sections and on curve sections of 3 degrees or less can’t deviate from the established alignment by more than 1 inch in any 25 foot section.	See Description
Final wear adjacent to concrete pavements.	After compaction the final lift wear adjacent to concrete pavements must be slightly higher but not to exceed 1/4 inch than the concrete surface.	See Description
Final wear adjacent to fixed structures.	After compaction the final lift wear adjacent to gutters, manholes, pavement headers, or other fixed structures must be slightly higher but not to exceed 1/4 inch than the surface of the structure.	See Description

Table 2360-27 Surface Requirements		
Course/Location	**Description**	**Tolerance**
Finished surface of each lift.*	Must be free of segregated and open and torn sections and deleterious material. *Excluding tight blade and scratch courses.	See Description

Figure 500.28 – 10-foot Straight Edge

Inertial Profiler

An Inertial Profiler (IP) is a vehicle equipped with laser sensors that measure the amount of vertical movement of the road surface for a given distance in each vehicle wheel path. The output figure is called the International Roughness Index (IRI), measured in inches per mile. It represents the amount of vehicular suspension travel in inches for every mile driven. The average of the IRI values from the left and right wheelpaths is called the Mean Roughness Index (MRI). MnDOT uses MRI to evaluate Smoothness and Areas of Localized Roughness (ALR).

Smoothness is a composite MRI value measured over a 528 foot section of roadway, whereas ALR is a 25 foot continuous MRI, based on a threshold given in the Specified ride equation. Smoothness can yield either an incentive payment, disincentive deduction, or corrective work based on the roughness of the measured roadway. Sections that exceed the ALR threshold are subject to either disincentive or corrective work, depending on the severity of the ALR values. Two types of Corrective Work exist: Smoothness Corrective Work and ALR

Corrective Work. Smoothness Corrective Work is always required when one or more Smoothness values exceed an equation's Smoothness Corrective Work threshold. In contrast, ALR Corrective Work can be substituted with a monetary deduction if both the Engineer and the Contractor agree. However, if either party desires Corrective Work, a monetary deduction will not be allowed in lieu of Corrective Work.

Data from an IP is stored in a Pavement Profile Format (PPF) file and is evaluated with ProVAL software. When a road is profiled, the Contractor must submit the PPF file to the Engineer on the same day the profiling occurs. If this is not done, the Contractor must re-profile the roadway.

When working on a project incorporating Specification 2399, it is advisable to read the Ride Guide for Inspectors and Project Engineers. For more information about surface smoothness requirements for bituminous pavements when using MnDOT Specification 2399, see the Ride Quality Guidelines document on the Bituminous Engineering webpage. The checklist below can assist an Inspector implementing Specification 2399. An example Bituminous Profile Summary can be found in **Chapter 7 – Quality Management**.

List for Pavement Surface Smoothness	Specifications	Other Resources
Provide equipment and operator are certification	2399.2.D.1	See the MnDOT Ride Guide for Inspectors and Project Engineers
On the day of Profiling obtain the following: • IP setting • Each IRI values from right & left wheel path • Signature of Operator • ERD format raw data from profiler	2399.2.D.2	See the MnDOT Ride Guide for Inspectors and Project Engineers
Within 5 calendar days of placement of all mainline pavement and before corrective work obtain the following: • ProVAL summary report for each lane and areas of corrective work (For an example ProVAL summary report, see the MnDOT Ride Guide for Inspectors and Project Engineers)	2399.2.D.3	See the MnDOT Ride Guide for Inspectors and Project Engineers
Have the Engineer decide if corrective work or a monetary deduction will be assessed	2399.2.D.4	See the MnDOT Ride Guide for Inspectors and Project Engineers

List for Pavement Surface Smoothness	Specifications	Other Resources
Re-profile from corrective work	2399.2.D.5	See the MnDOT Ride Guide for Inspectors and Project Engineers
Run the IP in the direction of traffic	2399.3.A	See the MnDOT Ride Guide for Inspectors and Project Engineers
Perform corrective work using a surface diamond grinding device	2399.3.E	See the MnDOT Ride Guide for Inspectors and Project Engineers
Perform corrective work across entire lane width	2399.3.E	See the MnDOT Ride Guide for Inspectors and Project Engineers

Table 500.3 – Pavement Smoothness Checklist

Figure 500.29 – Inertial Profiler

530.8 – Structures in the Pavement

Any structures, such as manhole castings and utility valve boxes must be adjusted to grade with respect to the final wearing surface. Typically, these adjustments are made prior to the placement of the final wearing course. Structures should be slightly lower than the adjacent wearing surface, but no more than ¼” lower. If the structures are allowed to be too low, drivers will experience a dip when driving over the structures. Similarly, if the structures are adjusted higher than the adjacent wearing surface, it will create a bump for motorists. More importantly, structures that are adjusted too high are likely to be caught by snow plow blades, causing damage to the structures and the plow equipment.

Figure 500.30 – Water valve box that has been adjusted too low.

530.9 – Intelligent Compaction

A relatively new technology for improving density of bituminous pavements is called Intelligent Compaction (IC). IC uses GPS devices mounted to the rollers to evaluate the number of roller passes and the total mat coverage over the bituminous pavement. The system also tracks speed and mat temperature for both pneumatic and vibratory rollers and frequency and amplitude for vibratory rollers. This information is displayed to the roller operator on a screen, which gives a real-time, bird’s-eye view of the roadway with color coding to designate the number of roller passes.

With this tool at their disposal, Contractors and Agencies are better able to track exactly what the rollers are doing, leading to more efficient rolling operations and the ability to troubleshoot low density areas. For example, if there is a section of roadway that shows low density after coring, a Contractor or Agency Inspector can look at the IC information for that section to see how it was compacted and if any anomalies are present. Items to look for include verifying that the correct number of roller passes were made, if the roller was vibrating or not, mat temperature, and if there was complete roller coverage of the mat. If IC is specified on a project, the Inspector must ensure that the equipment is running and collecting data. Currently, most MnDOT projects with over four lane miles of paving will include IC in the project. For more information, consult the MnDOT Advanced Materials and Technology webpage.

530.10 – Paver-Mounted Thermal Profiler

Paver-Mounted Thermal Profilers (PMTP) are used to track the temperature of the bituminous mat as it is placed on the roadway. A thermal scanner mounted to the paver records surface temperature data of the new mat at 1 foot intervals as the paver moves forward. The information is presented in real-time to the paver operator on a screen. Using this technology, Agencies and Contractors can locate and correct thermal segregation issues. If a PMTP is specified on a project, the Inspector must ensure that the equipment is running and collecting data. For more information, consult the MnDOT Advanced Materials and Technology webpage.

Figure 500.31 – The readout for a PMTP

530.11 – Cold Weather Paving

In a perfect world, paving would always be done in warm weather to maintain the heat of the bituminous mixture. Unfortunately, in a highly variable climate such as that of Minnesota, cold weather paving is a fact of life. The combination of a short construction season and the fact that bituminous paving is often one of the last activities completed on a construction project means that many projects are paved in late fall when temperatures are cooling off.

Cold weather paving presents many challenges that can affect the long-term performance and durability of the pavement. There are, however, things that can be done to help ensure the work performed is the best possible and will result in a long lasting pavement. The Inspector can always discuss alternate ways for the Contractor to do things, but should never direct the Contractor in their operations. The following is a list of things the Inspector should discuss with the Contractor during late fall paving. It should be noted that some of these items are required by specification and some are good practices that can be used as needed. Delaying the placement of the final lift until the subsequent spring should be considered if feasible.

Tarping Loads

Specification 2360 gives the Inspector the ability to require that loads be covered with a truckbox tarp. Tarping loads will help protect the mix from the elements and keep the wind from forming a "cold crust" on the top of the load. Tarps will not insulate the load. The lack of tarps may cause negative impacts on the PMTP data.

Pave Thicker Lifts

There may be some situations on a paving project where the typical section can be modified to allow a thicker lift to be placed on the project during late fall paving. Thicker lifts retain heat longer and improve the ability to achieve desired density.

Maintaining Minimum Mixture Temperature (Ordinary Compaction)

Under the Ordinary Compaction density method, no paving is allowed when ambient temperature is below 32°F. Also included under Ordinary Compaction is minimum mixture temperature based on paving thickness and ambient temperature. Maximum Density has no minimum paving temperature or mixture temperature requirements.

Rolling Technique

On cold days, it is especially important to follow proper compaction techniques because the window to get the rollers on the mat before the mix cools is much shorter. Waiting too long to compact the pavement will result in excessive heat loss from the fresh mat, making it much harder to achieve density. Because of this, rollers should be directly behind the screed, compacting the fresh mat when it is as hot as possible. If necessary, the Contractor may consider bringing in additional rollers to achieve density. Sometimes, two rollers may have to run in echelon directly behind the screed in order to get density during cold weather paving.

Watching for Mixture Pickup on Pneumatic Tired Rollers
Pneumatic-tired rollers have a greater tendency to pick up fines from the bituminous mat in cold weather. See Section 520.8 – Rollers for information on ways to mitigate mixture pickup on pneumatic-tired rollers. If the problem occurs consistently, it may be best for the Contractor to remove the pneumatic-tired rollers from the operation, but that is their decision to make. The finished surface cannot be open or torn in appearance. See MnDOT Specification 2360.3.E - Surface Requirements for more information.

Figure 500.32 – Unacceptable mixture pickup from pneumatic tired roller

Keeping the Mix En-Masse
The mixture will lose heat quickly if the entire load is windrowed in front of the paver when using a pick-up machine. Rather than dumping the entire load in front of the paver, dump the load at the same rate that the paver is moving and picking up the material. If the paver stops for any reason, discontinue dumping and resume only when the paver is moving again.

Mixing Temperatures
Typically, the Contractor will increase plant mixing temperatures as the ambient temperatures drop. Additional heating of the mixture will aid in getting density. Make sure the Contractor is not overheating the mix. Specification 2360.3 A.5 states, “Unless authorized by the Engineer, do

not produce the mixture more than 30°F above the recommended maximum mixing temperature.” Contact the Bituminous Office if you see mixture temperatures either at the plant or behind the paver over 330F.

PaveCool Software

PaveCool is a program designed to give the user the amount of time available for compaction based on various inputs. It can be found on MnDOT’s Pavement Design webpage.

Paving Dates

Do not place the final wearing course of an asphalt pavement after October 15 if the project is north of an east-west line between Browns Valley and Holyoke, or after November 1 if the project is south of an east-west line between Browns Valley and Holyoke. The Engineer may waive these restrictions when:

1) The Contractor is not placing mix on the traveled portion of the roadway

2) The roadway involved is closed to traffic during the following winter, or

3) The Engineer provides written direction to place the mixture.

540 – Construction Safety

This Section contains information about the equipment and practices one should follow when working on an asphalt paving project. All required safety training should be completed prior to visiting a construction project. The Project Engineer or Project Inspector must be notified before entering the site. The Project Inspector must notify the Contractor prior to entering the project site.

This section is considered informational and is not an Agency safety policy or set of safety rules. Consult your Agency’s Safety Coordinator for the most current and complete safety protocols.

540.1 – Safety Checklist

Below is a checklist to assist in preparing for a site visit.

When on site, you should:

❑ Wear a hard hat
❑ Wear a reflective safety vest
❑ Wear approved safety footwear
❑ Know emergency contact phone numbers
❑ Know your Agency's safety protocol
❑ Know the Contractor's safety protocol

When working around hot asphalt (e.g. at plants and distributors), you should have:

❑ Heavy gloves
❑ Heavy, long-sleeved shirt or jacket
❑ Eye and face protection

Your vehicle should have:

❑ First aid kit
❑ Fire extinguisher
❑ Safety Beacon that is visible 360° around the vehicle

540.2 – Safety on the Construction Project

Immediately report unsafe conditions to the Contractor. If the Contractor does not correct the problem, inform the Project Engineer. The problem should be documented including who was informed of the problem. Do not work in an unsafe situation.

Hot Asphalt Burns

Asphalt temperatures commonly exceed 300°F. Metal surfaces of plant equipment often range between 150°F and 400°F. Consequently, contact with hot asphalt or with plant equipment can severely burn exposed flesh. You should:

❑ Be familiar with the equipment you work around and its operation
❑ Avoid hazardous situations and remain alert at all times
❑ Stand well back during asphalt loading operations
❑ Use only safe and properly operating sampling equipment

Steam and Explosions

Water can expand over 1,000 times when it boils. Even a small amount of water trapped in the piping of a distributor or tank can turn to steam and explode when loaded with hot asphalt. Tanks that have been used for emulsion or which have been empty long enough for condensation to occur must be cleaned before using for heated asphalt binder. Partially empty asphalt tanks are extremely dangerous.

Tank inspections may be made using a mirror to reflect sunlight or with a flashlight. Never use a match or open flame when looking into a storage tank. Never smoke around an asphalt storage tank. Tanks can explode if pressure is allowed to build inside the tank while the contents are heated. This may happen on some distributors if a top hatch is not opened while the contents are being heated.

Open Belts or Pulleys

Belts and hazardous machinery are required to have guards. Reciprocating feeders, cold-feed belts, and other similar equipment should have emergency electrical cutoffs. Know where these cutoffs are. Stay clear of areas you have no business in.

Fumes from Asphalt Tanks

Asphalt fumes in sufficient concentrations can be harmful to your health. The intensity of the fumes when a storage tank hatch is opened is very significant. They can cause you to lose consciousness if you are not careful.

Hydrogen sulfide, a gas contained in some asphalts, can be lethal in high concentrations. Asphalt cement may have high concentrations of this gas. To prevent overexposure to hydrogen sulfide and other fumes, follow these guidelines:

❑ Keep your face at least two feet away from asphalt tank hatch openings
❑ Stay upwind of open hatches
❑ Avoid breathing fumes when opening hatches or taking samples

In case of overexposure to fumes, do the following:

❑ Move the victim immediately to fresh air
❑ Administer oxygen if breathing is difficult
❑ Start artificial respiration if breathing stops
❑ Have the victim examined by a physician immediately

Rotary Broom Dust Cloud Accidents

Visibility around a rotary broom may be reduced to zero, if water isn’t applied to the surface before sweeping. Safety beacons should be attached to all rotary brooms.

Slippery Surface on Tack Coat

Special caution is needed on newly primed or tacked surfaces. Rain on fresh oil can create slippery conditions. Keep all traffic off tack or prime coat that hasn't broken.

Electric Lines

All electric lines around crushers and plants should be located where construction equipment cannot run over or otherwise damage them. End dumps can also reach high voltage wires while dumping into the paver. The paving crew should be vigilant where potential hazards exist.

Blind Spots

Most types of construction equipment have blind spots where the operator or driver cannot see. Anyone working in close proximity to construction equipment must be aware of these blind spots. The Inspector must never enter a blind spot without first getting the operator or spotter's attention. Blind pinch points, such as pinch points around dump boxes, require extreme caution.

Night Operations

Nighttime paving operations occur frequently in metropolitan areas. Construction at night allows work to be done with less interruption to the traveling public. While traffic volumes adjacent to the construction site are typically lower at night than they are during the day, the visibility of workers, equipment, and the travelling public is reduced at night. It is important that all workers wear full PPE gear and all construction vehicles are equipped with sufficient lighting. It is also important that the work zone is lit such that everyone can perform their work safely and effectively. Visibility of all is of paramount concern. It should be noted that rollers finish working after the rest of the crew is finished with their work. Traffic control and site lighting must be maintained until all project personnel have left the roadway.

Traffic

Above all, ensure that traffic control is in place and being heeded by both the public and the construction personnel. Everyone on site must maintain constant awareness and alertness of adjacent traffic conditions. Traffic causes more injuries and fatalities than any other aspect of road construction.

DEPARTMENT OF TRANSPORTATION

Chapter 6 – Construction Problems

600 – Introduction

It takes experience to judge the appearance of the finished asphalt surface. The texture of the mat should be smooth, uniform, and free of segregated, raveled, and open or torn sections. Is should also be true to the grade and cross section shown on the plans. The mat should be free of contaminants, such as pieces of wood or large stones. There should be no fat spots or bleeding (areas of excessive binder on the pavement surface). Lastly, there should be no cracking, checking, or tearing of the mat.

Most defects in the finished mat can be avoided by careful inspection and attention to detail during construction. The earlier defects are detected, the easier it is to correct them. Patched areas are almost never as high in quality as a pavement that is produced and placed correctly in the first place.

Any areas of pavement that are determined to be defective should be marked by the Inspector and brought to the attention of the Contractor and the Engineer. The Engineer should determine whether the defective area should be removed and replaced by the Contractor or whether a price adjustment is appropriate. When necessary, The Inspector or Engineer should advise the Contractor of MnDOT Specification 1512, Unacceptable and Unauthorized Work, if material is not meeting specification requirements.

This chapter contains examples of real-world problems faced on actual Minnesota construction projects. Hopefully, these examples will help the reader to identify the cause of problems encountered in the field. As a starting basis, see the following table for a list of common bituminous mat problems and their possible causes.

Causes

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

Problem	Grade Control Mounted Incorrectly	Grade Control Hunting (Sensitivity Too High)	Grade Control Wand Bouncing on Reference	Grade Reference Inadequate	Sitting Long Period Between Loads	Improper Joint Overlap	Improper Mat Thickness for Max. Agg. Size	Trucks Bumping Finisher	Truck Holding Brakes	Improper Base Preparation	Improper Rolling Operation	Reversing or Too Rapidly Turning Rollers	Parking of Roller on Hot Mat	Improper Mix Design (Aggregate)	Improper Mix Design (Asphalt)	Mix Segregation	Moisture in Mix	Variation of Mix Temperature	Cold Mix Temperature
Wavy Surface—Short Waves (Ripples)	✓	✓	✓	✓						X	X			X	X	X		X	
Wavy Surface—Long Waves	✓			✓	✓			X	X	X		X	X			X		X	
Tearing of Mat—Full Width							X							X	X	X	X	X	X
Tearing of Mat—Center Streak																			X
Tearing of Mat—Outside Streaks																			X
Mat Texture—Nonuniform					✓		X			X				X	X	X		X	X
Screed Marks								X	X										
Screed Not Responding to Correction	✓						X											X	X
Auger Shadows														X	X	X			
Poor Precompaction							X			X									X
Poor Longitudinal Joint	✓	✓	✓			✓					X								X
Poor Transverse Joint											X								X
Transverse Cracking (Checking)										X	X			X	X		X	X	
Mat Shoving Under Roller										X	X	X		X	X		X	X	
Bleeding or Fat Spots in Mat														X	X		X	X	
Roller Marks										X	X	X	X					X	
Poor Mix Compaction										X	X	X	X	X	X		X	X	X

1. Find problem above.
2. Checks indicate causes related to the paver. X's indicate other problems to be investigated.

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

Table 600.1 – Mat Problems and their Causes (Scherocman & Cominsky, 2000)

610 – Bituminous Mixture Issues

Incorrect proportioning, mixing, and handling of bituminous mixtures can lead to a variety of issues in the finished product. This section will detail some of the common problems associated with bituminous mixtures.

610.1 – Segregation

Segregation is the separation of the coarse and fine aggregate particles in an asphalt mix that causes non-uniformity. This non-uniformity will deviate from the approved mix design and mixture volumetrics. Segregation can affect pavement durability by increasing the air void content of the mix in the segregated areas and increasing the potential for moisture damage. In other words, segregation can make the pavement permeable and lead to accelerated deterioration. Segregated locations are also susceptible to raveling and further disintegration of the pavement. There are several types of segregation as detailed below:

Random Segregation

Random segregation occurs at irregular intervals in the surface of the roadway. In general, there is not any consistent pattern to the occurrence of the segregated areas. Random segregation is primarily caused by the handling of the coarse aggregate materials as they are stockpiled and then fed into the asphalt plant. If a stockpile of coarse aggregate is built using a conveyor and a conical pile is formed, the largest aggregate particles typically roll down the sides of the pile and collect at the bottom of the pile (Figure 600.1). If the operator of the front end loader at the asphalt plant picks up a bucket-full of the aggregate from the bottom of the pile and delivers the large aggregate particles into the cold feed bins at the plant, random segregation may occur on the roadway behind the paver, depending on the type of asphalt plant being used.

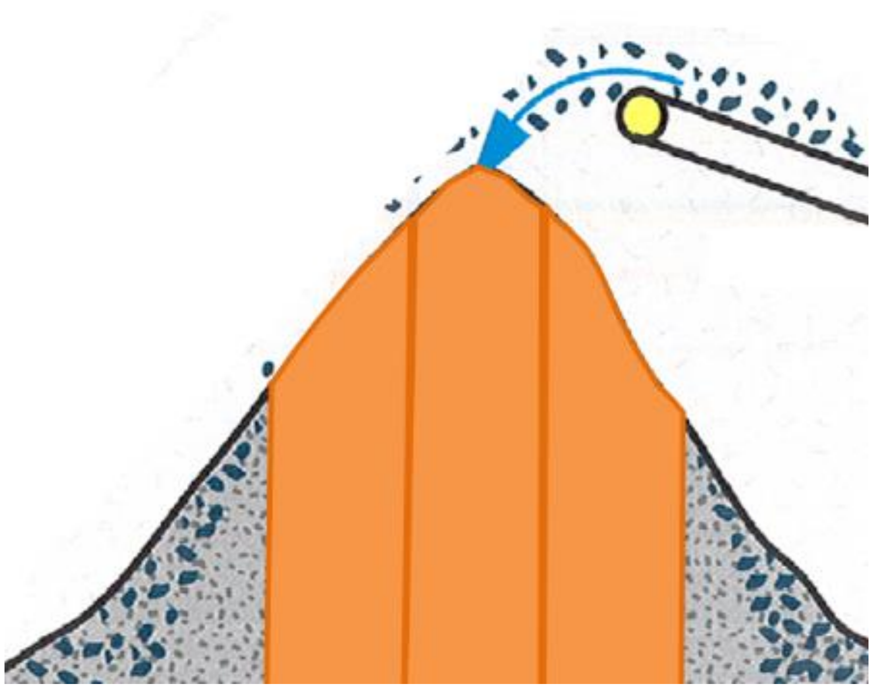


Figure 600.1 – Coarse aggregates rolling down the stockpile

In general, random segregation is not a major problem on most paving projects and is easily resolved by having the front end loader operator rework the pile by re-blending the large aggregate at the bottom of the pile with the rest of the aggregate.

Side to Side Segregation

Side to side segregation, sometimes called longitudinal segregation, shows up on the paved surface as a very rough texture on only one side of the paver.

Figure 600.2 – Side to side segregation

Side to side segregation is typically caused by issues with delivery of the mix into the mixture silo at the plant site. Delivery issues may include clam shells not opening at the same time on the batcher, mixture being thrown against the side of the silo (causing segregation similar to the large aggregate rolling down to the bottom of an aggregate stockpile), or how baffles in the mixture delivery system are functioning.

Truckload to Truckload Segregation

Truckload to truckload segregation shows up on the paved surface as two rough textured areas in a transverse direction, one on each side of the centerline of the paver. The primary cause of truckload to truckload segregation is the delivery of the asphalt mix from the silo into the haul truck. Segregation of the mix occurs in the same way as segregation of the aggregate occurs when the material is dropped on top of a conical pile. The largest aggregate particles in the mix roll down the sides of the pile and collect at the bottom of the pile.

Figure 600.3 – Incorrect loading of asphalt mixture.

In order to completely eliminate the truckload to truckload segregation problem, it is necessary to load the trucks correctly. This means loading the truck with three drops of mix instead of one. The first drop of mix is against the front bulkhead, the second drop of mix is against the rear of the truck, and the third drop of mix is in the center of the truck or trailer.

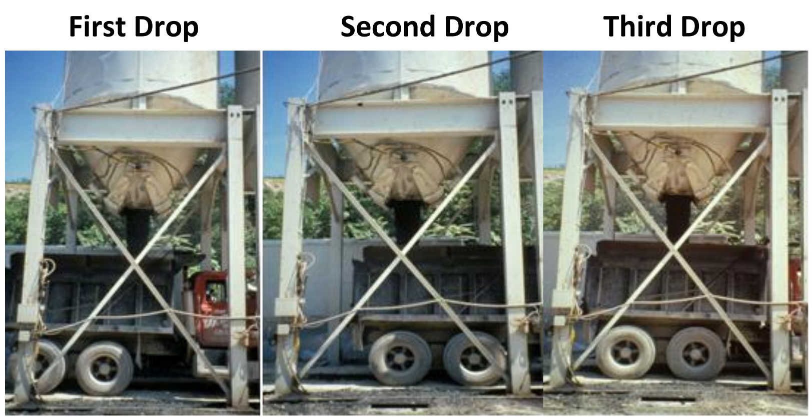


Figure 600.4 – Proper truck loading sequence

Segregation from Emptying the Pave Hopper and Folding the Hopper Wings
Improper mix handling in the paver hopper can also cause segregation. One way this can occur is if the Contractor allows the hopper to become empty during paving. The paver hopper should always remain at least half full throughout the day's paving. If a truck is

unloading directly into the hopper, the driver should slowly raise the bed of the truck before releasing the end gate. This allows the mixture to move in mass into the hopper.

Another common source of segregation from the hopper occurs when the paver operator folds the hopper wings and empties the paver hopper. This is not a good practice since the segregated mix around the perimeter of the hopper will be pulled through the paver on the slat conveyors and deposited on the empty augers. This will result in segregation that looks like chevrons on the roadway behind the screed.

Figure 600.5 – Empty hopper

Figure 600.6 – Hopper half full

Figure 600.7 – Chevrons from folding hopper wings

610.2 – Degrees of Segregation

There are varying levels of segregation – from slight to severe. These levels are detailed below.

Slight Segregation
In a pavement with slight segregation, there is very little separation of the coarse and fine aggregate particles. The binder is inplace between the aggregate particles but the surface has a slightly coarser appearance. Generally, slightly segregated pavement is accepted by the Engineer without any corrective action required.

Figure 600.8 – Slightly segregated pavement

Moderate (Medium) Segregation
In a pavement with moderate segregation, there is significantly more separation of the coarse and fine aggregate particles. There is also a lack of the surface binder making the segregation more noticeable. Generally, moderately segregated pavement is left inplace for lower lifts. However, surface courses are subject to a price adjustment, removal and replacement, or resurfacing at the Contractor's cost.

Figure 600.9 – Moderate segregation of the pavement

Severe Segregation

In a pavement with severe segregation there is complete separation of the coarse and fine aggregate particles. There is little or no surface binder, which makes the segregation very noticeable. Typically, low density and high permeability are associated with severely segregated pavements. Because of the potential for raveling and further disintegration of the pavement, full lane removal and replacement is often required at the Contractor's expense.

Figure 600.10 – Severely segregated pavement

610.3 – Excess Binder

Excessive asphalt binder in a bituminous mixture can cause several problems in the finished bituminous mat, as described below.

Flushing

Flushing (also known as bleeding) is the upward movement of excess asphalt binder in the pavement, resulting in the formation of a film of excess binder on the surface of the pavement. The most common cause of flushing is too much asphalt binder in one or more of the pavement courses, resulting in all the voids being filled with asphalt. Flushing can also be caused by an improperly constructed seal coat, too heavy a tack coat, or a solvent (such as diesel fuel) carrying asphalt binder to the surface. It may also occur when a new mat is opened to traffic before it has sufficiently cooled or by over compaction during rolling operations.

Possible solutions to resolve flushing or bleeding problems include reducing the asphalt binder content, checking the plant calibration, reducing the tack rate, ensuring solvents aren't being used on the roadway, and by allowing the mat to cool longer before opening to traffic.

Figure 600.11 – Pavement Flushing

Fat Spots

Fat spots are isolated areas of pavement where the asphalt binder has risen through the mat to the surface.

Figure 600.12 – Fat Spots

610.4 – Tender Zone (Tender Mixes)

Some asphalt mixtures exhibit tenderness within a temperature range of approximately 170° – 240°F. In this temperature range, called the tender zone, the mixture tends to push laterally (becoming thinner and wider than specified), blister, and can even tear under steel-wheeled rollers. Rolling with a steel roller in a tender zone may actually have an adverse effect on mat compaction. However, a pneumatic-tired roller can be used to effectively compact a mixture in the tender zone.

When a mixture is being produced that is found to have a tender zone, the preferred method to compact the mix is to obtain density before the mix drops down into the tender zone. This may require using 2 steel wheel rollers in echelon close behind the paver screed and rolling until the mixture reaches the tender zone. A pneumatic tired roller can now be used to further compact the mix until the lower tenderness limit is reached. Once the mixture reaches the tender zone, the steel wheeled rollers are pulled off the mat. The steel wheeled finish roller can get on the mat once the mixture has cooled below the tender zone. Again, a pneumatic-tired roller can be utilized within the tender zone to add density, but the use of a steel wheeled roller in the tender zone will result in reduced densification of the mat. It is important for the Inspector to have a temperature gun to establish the limits of the tender zone, if there is one.

Figure 600.13 – Tender Zone

Figure 600.14 – Blistering of the mat in the tender zone

Figure 600.15 – Tearing of the mat in the tender zone

610.5 – Excessive Spall Material in the Mixture

Spall materials are limited to a certain percentage of the bituminous mixture based on traffic level and whether the mix is used as a wearing course or non-wearing course (See Table 3139-3 in the MnDOT Standard Specifications for Construction). Excessive spall material in a bituminous mixture increases the chance of “pop-outs” in the finished mat. Pop-outs occur when freeze-thaw cycles act on highly absorptive pockets of aggregates (spall aggregates), which cause the spall aggregates to break free of the compacted pavement. This results in a pocked, raveled appearance in the mat. One type of spall material, Iron Oxide, can cause unsightly stains on the pavement in addition to pop-outs.

Figure 600.16 – The effect of excessive Iron Oxide in the bituminous mixture.

Figure 600.17 – The result of excessive spall material in a mix. This may have a profound effect on the long-term durability of the pavement.

620 – Paver Issues

Bituminous pavers are complex pieces of equipment designed to place the asphalt mixture at the specified width, grade, cross slope, and thickness in order to produce a uniform mat texture. Incorrect paver setup and operation can result in problems with the bituminous mat. This section will detail some of the common problems associated with paver setup and paver operation. Note that the Inspector or Engineer should not tell a Contractor how to setup their equipment, as this puts liability for construction issues on the Agency. Rather, if problems are encountered, they should be brought to the attention of the Contractor, and the Contractor must then determine how to correct the issues.

620.1 – Incorrect Material Head at Screed

It is important to maintain the correct amount, or head, of asphalt mixture in front of the screed. Ideally, the material head should be maintained at roughly half the height of the augers in front of the screed. Since the screed rides on the asphalt mixture, non-uniformity in material head can cause the screed to rise or fall depending on the amount of material being carried. If there is too little head, this will cause a dip in the final mat. Conversely, if there is too much material head, a bump will result in the final mat. Incorrect material head can also cause segregation as the augers will not be working the correct amount of mixture. Segregation stripes can be caused by an incorrectly functioning feeder system that varies the head of material.

Figure 600.18 – Excessive material head in front of the screed. The augers should not be buried.

620.2 – Auger Extensions

If the planned paving width is wider than normal for the paver, auger and tunnel extensions should be installed on the paver. Extensions will help ensure even flow of material toward the end gates. This will help control the head of material and help minimize segregation. Note that auger extensions should only be used when paving a relatively constant width. If the screed will be continuously changing width during paving to the point where extensions would have to be constantly removed and reinstalled, auger extensions are not appropriate.

Figure 600.19 – This photo shows the correct material head in front of the screed. However, auger extensions should have been used in this case.

620.3 – Bumping the Paver

When a new mix delivery truck is preparing to empty into the paver hopper, the truck should not back into the paver. Doing so will bump the paver, causing a bump in the finished mat. Instead, the paver should smoothly move forward until contact is made with the truck.

620.4 – Longitudinal Marks

If there are continuous lines in the mat, this may be an indication that the screed extensions are at the wrong angle or height compared to the main screed. The screed extensions should be adjusted to correct this issue.

Figure 600.20 – Lines in the mat from incorrectly adjusted screed extensions.

620.5 – Running the Paver out of Mix

The amount of mix in the paver hopper should always be kept above the top of the flow gates. This amounts to always keeping the hopper about half full during the day's paving. When the hopper is emptied on a frequent basis, the potential for segregated material to be carried by the slat conveyors to the augers is greatly increased. This can cause mat problems such as segregation and voids. The picture below illustrates what happens when the paver keeps moving forward regardless of whether it has any bituminous mixture in the hopper or not.

Figure 600.21 – The result of "paving" without bituminous mixture present in the paver hopper

630 – Checking

Checking is defined as short transverse cracks about 1 to 4 inches in length and 1 to 3 inches apart in the mat. The cracks typically do not extend completely through the lift but are approximately ½ inch in depth. These surface cracks usually occur after several roller passes with a steel wheel roller. Checking is primarily due to mix deficiencies resulting in a tender mix, but may also be caused by excessive deflection in pavement structure under the compaction equipment. To a lesser extent, overheated mix can contribute to checking as well. The long-term solution is to change mix properties. In the short-term, the amount of checking can be reduced by changing the rolling zone and type of rollers used to compact the mix.

Figure 600.22 – Checking of the mat

640 – Weak Base

Paving on a weak base can result in rutting or lateral displacement of the mixture. For the new asphalt pavement to perform adequately, there needs to be uniform support from the base and subgrade. If the base is soft due to excessive moisture, the base material should be dried or replaced and re-compacted before paving is allowed. An easy method for determining if the base is yielding is to watch for deflections from the tires of a loaded truck moving slowly over the base. Soft areas will exhibit a distinctive “spongy” effect when a loaded truck drives over them.

Figure 600.23 – Yielding of the aggregate base

650 – Rolling Issues

The following section will detail common issues that can result from improper rolling procedures, as well as other issues that become present after rolling.

650.1 – Roller Marks

Roller marks are longitudinal creases that remain on the surface of the mat after the final rolling is completed. Roller marks are an indication that the proper number of roller passes has not been made on the mix. If the compaction process is stopped before the required amount of rolling is completed, or if the mix cools before the compaction process is completed, the longitudinal marks will remain in the mix. Because roller marks are an indication that the proper level of compaction has not been achieved, long term performance of the pavement can potentially be affected.

Figure 600.24 – Roller marks

650.2 – Pneumatic-Tired Roller Marks

Sometimes, when a pneumatic-tired roller is used in the rolling train, there may appear to be roller marks or shadows remaining on the pavement surface after compaction. These marks are typically cosmetic and will generally fade or disappear from the pavement surface within a year or two after construction. However, pneumatic-tired roller indentations can be left on the pavement surface if the finish roller does not roll at a warm enough temperature to press them out. Marks from pneumatic-tired rollers typically are not an indication of inadequate compaction.

650.3 – Mixture Pick-Up

Mixture pickup, most often associated with pneumatic-tired rollers, has always been a concern when compacting asphalt mixes. The problem seems to be even more pronounced when mixtures include polymer-modified binders. Polymer-modified binders tend to be more “sticky” than conventional binders and require additional attentiveness on the part of the Contractor during compaction operations.

When the binder sticks to the roller, asphalt mixture (often fines, but can include entire mix) is pulled from the surface of the mat. This creates an open or torn texture on the mat surface, which can lead to similar consequences as mix segregation. In the case of pneumatic tired rollers, the mix accumulates on the tires until it sloughs off, forming "patties" on the surface of the pavement. Though very undesirable from roughness and cosmetic standpoints, the patties themselves are not usually detrimental to pavement performance. If possible, remove the loose patties from the pavement surface before performing additional rolling.

The best technique to minimize mix pickup on pneumatic-tired rollers is to keep the roller tires hot, as close to mix temperature as possible, and to keep the rubber-tired roller moving at all times. The asphalt pavement cannot be over-rolled from a pneumatic-tired roller running continually on the mat. Roller tires and drums should be kept clean to prevent mix from accumulating. Once the tires begin picking up mix, they will continue to pick up more and more mix, similar to a snowball effect. Cleaning off any mix on the tires with a shovel and then wetting the tires with a non-petroleum based release agent before rolling helps to minimize mix pick-up. The pneumatic-tired roller should be equipped with a skirt to help keep the tires as hot as possible. Steel drum rollers need to have the spray system working properly so the drum is wetted evenly. A wetting agent may also be desirable to aid adhesion problems.

Figure 600.25 – Pneumatic Tired Roller picking up mix.

Figure 600.26 – Steel drum roller picking up mix.

Figure 600.27 – Pneumatic-tired roller with skirt to retain wheel heat

650.4 – Bumps in Bituminous Overlays over Concrete

Bumps sometimes reflect through to the mat surface at the existing concrete joints on the first lift of asphalt placed on top of concrete. This results in poor ride quality and will often lead to the formation of a crack in the asphalt pavement over the concrete joint. The severity of the bump is lessened with each subsequent lift that is placed on top of the previous lift. There are several different theories as to the cause of these bumps, including:

1. Existing sealant in the concrete joint expands from the heat of the bituminous mixture, resulting in a bump.

2. The new mixture heats up the existing sealant and causes the mixture to "slip" over the sealant as it is being rolled, resulting in a bump. This is caused by differential friction planes.

3. Rocking concrete slabs create a bump at the existing joint.

4. After the new mixture is placed, the heat causes moisture from the subgrade or the crack itself to be wicked up through the mixture, creating a tender mix at the joint.

Of these theories, the one that seems most plausible is moisture in the cracks wicking up to the surface and creating a tender zone in the mixture over the joints. On multiple MnDOT projects, sealant has been removed from existing joints before the asphalt lift is placed and bumps have still formed during the compaction process. On other projects, it has been noted that the bumps do not form with the first roller pass, but form when the mixture has cooled to a certain temperature. The steel wheeled rollers simply accentuate the bump as they roll across the joint location. Again, it is important for the inspector and contractor to have a temperature gun to identify the range where bumps form when utilizing a steel wheeled roller and to stay off the mat with steel wheeled rollers in this temperature range. The use of pneumatic tired rollers has also helped to alleviate this problem.

Figure 600.28 – Bump over concrete joint

Figure 600.29 – Analysis of a bump over a concrete joint. Note that the bump actually forms a bit downstream of the existing concrete joint.

660 – Longitudinal Joint Issues

Longitudinal joints are often subject to premature deterioration when compared to the rest of the pavement. Because of this, care must be taken when constructing longitudinal joints during bituminous paving to achieve the best possible finished product. Below are some common issues related to longitudinal joint construction.

660.1 – Wavy Longitudinal Joint

Longitudinal joints should be constructed parallel to the roadway centerline. In other words, they should be straight (unless paving on a curve, in which case the joint should still be uniformly parallel to the roadway centerline). If the Contactor is constructing wavy joints, the Inspector should bring it to their attention and make sure the issue is corrected. If necessary, the Contractor may need to use stringline as a guide to properly align the joint and give a reference for the paver operator to follow.

Figure 600.30 – Wavy Longitudinal Joint

Figure 600.31 – Contractor setting stringline to guide the paver

660.2 – Open Longitudinal Joint

Poor compaction on a longitudinal joint results in low density and high air voids. A poorly compacted joint will often have an open appearance. The image below shows the result of poor longitudinal joint compaction. This joint is susceptible to premature failure due to moisture infiltration and traffic wear. Recommended paving practice is to use the Maryland joint construction method detailed in Chapter 5. This entails overlapping the second paving pass at the butt joint by 1 to 1.5 inches to make sure the joint is not starved for material.

Figure 600.32 – Poorly compacted longitudinal joint

660.3 – Excessive Height Differential

The Maryland Joint method of longitudinal joint construction was discussed in Chapter 5 of this manual. One potential issue that can arise from the Maryland joint is an excessive differential in height from one side of the joint to the other. MnDOT Specification 2360 allows a tolerance of ¼ inch for this differential. A differential greater than ¼” can present a safety hazard to the traveling public.

Figure 600.33 – Excessive height differential at a longitudinal joint

670 – General Issues

This section will detail other problems that can occur during asphalt pavement construction that don't necessarily fit into the categories above.

670.1 – Paving in the Rain

Paving in the rain is not advisable for many reasons. One of the biggest problems is washing away of the tack coat, which reduces the bond between the new mat and the underlying layer. If the roadway or base being paved is wet, de-bonding of the new mat can occur, as well as shoving of the mat. Both of these issues may require substantial repairs. Rain will also prematurely cool the hot bituminous mixture, which can lead to segregation and poor compaction.

Figure 600.34 – Paving in the rain. When the paver creates a wake through the water, it is well past time to halt production. The situation pictured above should never be allowed to occur.

Figure 600.35 – This is what the road can look like the day after paving in the rain. All of the distressed areas shown will need to be removed and replaced.

670.2 – Excessive Haul Truck Queue

As haul trucks arrive on a project, they will queue in order of arrival, with the first truck directly ahead of the paver. As the trucks wait to empty their load, the hot asphalt mixture they are hauling is continuously cooling off. Usually, this is not a big problem as the load will remain within an acceptable temperature range during transfer to the paver. However, load temperatures can become a problem when the truck queues get excessively long and trucks have to wait for an extended period of time. This can be exacerbated if there is a long haul distance between the plant and the project, especially in cold weather.

Tarping of the truck loads can help retain some heat, but the best solution to minimize trucks in the queue is to match plant production with mixture placement. The paving operation and plant need to have consistent communication to ensure plant production matches the pace of the paving operation. The Contractors need to be especially diligent around midday when the paving crews need to “walk” the paver back to the area where the day’s paving began in order to match the paving lanes. It takes a substantial amount of time to reposition the paver, so mix production should be coordinated such that mix is not arriving on the jobsite until the paver is repositioned and ready to pave the next pass. This repositioning is needed to fulfill the requirement that adjoining lanes be matched transversely at the end of each paving day.

Figure 600.36 – Excessively long truck queue. The bituminous mixture in the truck waiting at the far end of the queue will likely have cooled to an unacceptable temperature.

670.3 – Asphalt Chunks in the Mix

As bituminous mixture is transported to the jobsite in a haul truck, the edges of the load can cool off more than the rest of the mix, resulting in chunks of mix in the delivered load. Long truck queues, as described previously, can exacerbate the issue. Additionally, chunks of mix that have accumulated on the flights of the dryer drum can fall off the flights and end up in the delivered load.

The following figure shows chunks along the top of the windrow. These chunks should be removed from the windrow before the paver picks them up.

Figure 600.37 – Cold chunks in a windrow. These should be removed.

If these chunks are not removed from the mix, they will be future trouble spots if allowed through the paver. The following image shows what happens after these chunks pass through the paver.

Figure 600.38 – Removal of cold chunks from the bituminous mat. The areas will have to be filled in by hand, and will likely be areas of localized segregation. Paving operations should halt if this continues.

670.4 – Broadcasting Mix Across the Mat

A common practice when a Contractor notices segregation behind the paver is for the screed worker to broadcast asphalt mix across the mat surface to fill or cover the voids. While this can be a necessary practice to fill depressions in the mat, it often leads to further segregation which will typically not be removed with the roller. Broadcasting mix should be avoided. The image below shows the mix being broadcast across the mat surface.

Figure 600.39 – Screed worker broadcasting mix across the mat surface.

670.5 – Insufficient Tack Coat

As discussed earlier in this manual, tack coat is an important means to ensure a strong bond is achieved between the new asphalt mat and the underlying surface. The following image shows extreme longitudinal shoving, which is one possible outcome if tack coat is not applied to the underlying surface.

Figure 600.40 – Longitudinal shoving of the bituminous mat as a result of insufficient or nonexistent tack coat. In this case, the wrong bituminous mixture was used for the application in addition to insufficient tack coat prior to paving.

680 – Correcting Workmanship Issues

As stated previously, it is best to eliminate workmanship issues and get a quality finished product on the first try. If areas of the pavement need to be patched or ground to correct problems, the roadway will often look worse than if it had been paved without any corrective action. This is not to say that corrective action should not be taken. If the pavement has areas of excessive segregation, rough ride, or other issues affecting pavement performance and longevity, these issues should be corrected. Depending on the type of defects, corrective actions can include milling and patching with new bituminous mixture, applying a surface treatment to seal open sections, grinding off high spots to improve ride quality, or removal and replacement of the mat in the very worst cases.

The image below shows a roadway that has been spot ground to correct ride quality issues. It is clear to see that, had the roadway been constructed in such a way that didn't require grinding, the finished appearance would have been more aesthetically pleasing.

Figure 600.41 – A recently constructed roadway after surface grinding was completed to improve ride quality.

DEPARTMENT OF TRANSPORTATION

Chapter 7 – Quality Management

700 – Introduction

During asphalt production and paving, materials need to be tested periodically to ensure compliance with MnDOT specifications. This is done through Quality Management. Quality Management goes hand-in-hand with plant inspection and construction inspection to ensure a quality product is achieved from a bituminous paving project. A comprehensive listing of Quality Management documents can be found on the MnDOT Bituminous Engineering webpage.

710 – Schedule of Materials Control

The Schedule of Materials Control (SMC) is a document that defines the type and frequency of materials sampling and testing that needs to occur during a project, as well as the relevant forms needed. The SMC has two categories of testing – Producer/Contractor testing (Quality Control) and Agency testing (Quality Assurance/Verification).

710.1 – Quality Control

Quality Control (QC) is testing performed by the Contractor to control operations and to ensure that the materials used on a project conform to the Specifications. It is also known as Process Control testing. An example of QC is when the Contractor tests asphalt cores for density.

710.2 – Quality Assurance

Quality Assurance (QA) is the Agency's testing regime used to validate the Contractor's QC sample results. These tests are performed on a companion sample to the Contractor's QC sample. An example of this would be Agency testing of asphalt density cores.

710.3 – Verification Sample

This is a sample taken and tested by the Agency used to assure compliance of the Contractor's Quality Control program. The results are included as part of the QA testing program.

710.4 – Verification Companion

This is a companion to the Verification Sample. The Verification Companion is sampled by the Agency, but given to the Contractor, who is required to test it. The results are used as part of the QC testing program.

710.5 – Independent Assurance Sampling and Testing

Independent Assurance Sampling and Testing (IAST) is used to ensure that the parties performing QC and QA are following the proper sampling, testing, and equipment calibration procedures. It is not part of the acceptance process for a project. See the MnDOT Independent Assurance Webpage.

720 – Sampling and Testing in Asphalt Construction

The construction of asphalt pavement requires a variety of specialized materials. These materials need to be tested to ensure they will perform as expected. This section will provide details and examples to help clarify the procedures outlined in the Schedule of Materials Control.

Small Quantity Paving

It should be noted that testing is not required if less than 300 tons of bituminous mixture are produced for a job. Jobs with 300 tons or more are subject to testing per the Schedule of Materials Control.

720.1 – Aggregate Sampling

The Schedule of Materials Control defines the number of tests required. When gradations or quality tests are running close to the tolerance limits, additional tests are required (process and acceptance verification (audit) tests) to assure that only materials meeting the Specifications are used. Once a year, and at least one month prior to use of material the Contractor shall provide a 24 hour notice of intent to sample and coordinate with the Agency to monitor taking the sample. Submit samples to the MnDOT District Materials Laboratory for complete quality tests and design constants. The required sample size is given in the table below.

Aggregate Type	Quality Sample Size for Lab Submittal (lb.)
Plus #4 Aggregate	80
Minus #4 Aggregate	35
Mineral Filler	2
RAP	80
RAS	10

Table 700.1 – Quality Sample Size by Aggregate Type

Sampling Coarse Aggregate

1. Sampling from a Conveyer Belt

   When the aggregates are carried to the stockpile by a conveyer belt, obtain a sample by stopping the belt and completely removing all the material in a short section.
2. Sampling from a Stockpile

   Coarse material has a marked tendency to segregate when allowed to fall freely from any height resulting in a pile of material much coarser at the outside of the pile. For this reason, it is very difficult to obtain a truly representative sample from large stockpiles of coarse aggregate. Stockpile sampling is the least reliable of methods and therefore is the least preferable method. If power equipment is available for use, secure several samples from a stockpile by taking portions from several areas of the pile. Combine the samples and quarter to provide a representative sample.

   When power equipment is not available, take samples by hand shoveling. Take samples near the top of the pile, at or near the base of the pile, and at an intermediate point. To provide a representative sample, mix the individual samples, reduce to a single sample size by quartering and test the sample. When information on variations within the stockpile are desired in addition to the average condition, test the individual samples.

Sampling Fine Aggregate (Sand)

Unlike coarse aggregate, damp sand does not segregate easily. However, the gradation can vary considerably as it comes from natural seams, crusher, wash plant, or the dehydrator during production. For this reason, do not sample sand during production. Sample sand with either a sampling tube or hand shoveling.

When using a sampling tube, brush the dry sand aside and sample only the moist sand beneath. (Dry sand segregates easily.) Ram the tube into the pile perpendicular to the surface of the pile. Discard this sample. The tube is then lined with fine sand and the actual sample is not robbed of this fine sand. Ram the tube into the pile again to obtain the actual sample. Take samples from a number of locations and combine to get the proper sample size.

When using a hand shovel to secure samples, dig a 3 to 4 ft. vertical face in the side of the pile and then scrape the shovel up the vertical face. A board shoved into the pile above the point of sampling will prevent the dry sand from running down and contaminating the sample. Take the samples from the sand stockpile near the top, near the base and at intermediate points. Either combine or run separately, depending on the information desired. Because samples near the base are normally “dirtier,” it is good practice to run a “Percent Passing the No.200 Sieve” test on a sample representing this area.

Whether the aggregate has been previously inspected or not, it is necessary to test the material for final approval just prior to mixing.

Riffle Splitter Method

1. Place the sample splitter on a flat surface.

2. Place two sample pans under the discharge chutes so that no material is lost.

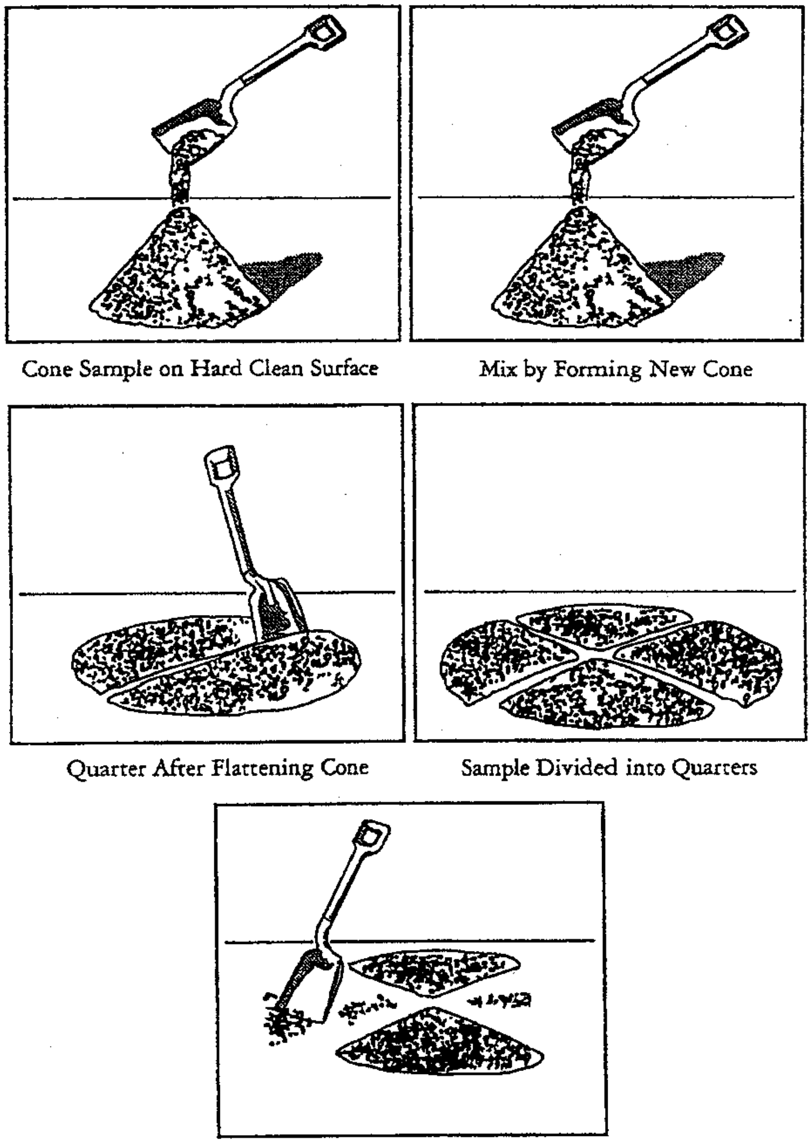
3. Pour the sample into the splitter, moving back and forth over all the chutes to distribute the flow of material evenly. Continuously clear away material flowing into the pans to prevent clogging of discharge chutes. Repeat procedure at least four times to ensure the sample is thoroughly blended.

4. After the material has been blended it is then split in consecutive operations to the desired sample size. The last two pans should contain well-blended companions of the approximate sample size.

Figure 700.1 - Riffle Splitter

Quartering Method

1. Place the aggregate on a clean flat smooth surface and mix well.
2. Form a low flat pile.
3. Cut the pile into four pie-shaped parts with a trowel.
4. Remove and discard two opposite quarters.
5. Remix the remainder of the aggregate. Take care to include the fines and dust
6. Continue to reduce the sample to a size that is satisfactory for testing by repeating the process. For samples requiring a companion, save both portions remaining in the last reduction process.



Cone Sample on Hard Clean Surface

Mix by Forming New Cone

Quarter After Flattening Cone

Sample Divided into Quarters

Retain Opposite Quarters
Reject the Other Two Quarters

Figure 700.2 - Quartering Method

Submitting Samples to the Laboratory

Take samples on the day the material is used unless they are considered preliminary samples. As shown in the Schedule of Materials Control, it is very important that these samples are accurately and completely identified. When more than one fraction of coarse aggregate is used, separation of bags for each size is required.

If a split sample is run in the field for paving either by the Contractor or by the Agency, record the results on the back of the sample card. This is done to check the accuracy of the field testing. Obtain all of these samples by splitting or quartering.

Independent Assurance Sampling and Testing

Independent Assurance Sampling and Testing (IAST) is required on all Federal Aid projects. See the Current IAST Schedule for more information. The purpose of IAST is to verify the Contractor and Agency sampling and testing procedures. The testing equipment used is also checked during Independent Assurance sampling. The project personnel are required to notify the District Materials Section when beginning any work requiring Independent Assurance sampling. It is necessary for scheduling to provide early notification. It is the responsibility of the project personnel to keep a record of Independent Assurance contacts to assure a sufficient number and timely contacts are made. Independent Assurance sampling is not a paper requirement; it is for the benefit of the Project Engineer that equipment and procedures meet requirements so that QA and QC testing are accurate.

Aggregate Quality

Before mixing operations begin, the Inspector should make it a standard practice to examine the materials for general quality. The point of final inspection and approval of any material is at the time the material is placed in the work. For this final approval, the Project Engineer is responsible. Even though material was previously inspected and tentatively approved at the source, it may become altered or contaminated before it is used, or was shipped prior to inspection and testing without the knowledge of the Agency Inspector.

Physical properties of the material relative to aggregate class and gradation are readily checked, but factors affecting the general quality of the material are sometimes given slight attention or ignored entirely by the Agency. These factors include cleanliness and the presence of various kinds of deleterious materials. Inspect the aggregates for presence of soil lumps and clay balls. Before any material is actually used in the mixture, the Project Engineer must assure that it meets all specification requirements relative to general quality.

720.2 – Asphalt Binder Sampling

All bituminous materials must be sampled at the destination.

Producer/Contractor Testing

Shown below are the procedures as of the authoring of this Manual. See the current edition of the Schedule of Materials Control for the most up to date procedures.

Asphalt Supplier

QC testing is the responsibility of the bituminous material supplier as part of the Combined State Binder Certification program. The list is available on MnDOT's approved products website.

During Asphalt Mixture Production

Obtain asphalt binder samples from a sampling valve located between the pump and the drum. Sample each type of asphalt binder used in mixture production after 50 tons of mixture has been produced, then sample at a rate of one per 250,000 gal [1,000,000 L]. A minimum of 1 gallon of binder must be drawn and wasted from the sampling valve before the actual sample is drawn.

For batch plants, obtain the asphalt binder sample from the weigh pod.

Provide asphalt binder sample in clean one L (1 qt.) steel container. The Inspector will monitor the sampling the Contractor performs.

Agency Testing

Shown below are the procedures as of the authoring of this Manual. See the current edition of the Schedule of Materials Control for the most up to date procedures.

Asphalt Supplier

Random sampling of bituminous material at the asphalt supplier is discussed in the Combined State Binder Certification program arranged by the MnDOT Chemical Laboratory.

During Asphalt Mixture Production

Observe contractor personnel taking sample from sampling valve and submit to MnDOT Chemical Laboratory.

720.3 – Mineral Filler Sampling

Sample and test Mineral Filler in accordance with the latest edition of the Schedule of Materials Control.

720.4 – Random Sampling (ASTM D3665)

MnDOT Specification 2360 and the Schedule of Materials Control outline sampling requirements based on the tons of bituminous mixture the Contractor plans to produce for the day. Sampling occurs at specific tonnages, which are determined at random. This is accomplished using random number generation. It should be noted that sampling rates are different at the start of a project. See Specification 2360 and the Schedule of Materials Control for more information.

There are several methods that can be used to generate random numbers. One method is to use an electronic Random Number function, which is available on many calculators and on Microsoft Excel. The other method is to use a random number table. ASTM D3665 provides several random number tables and instruction for their use. The following is an example of randomly determining tonnage for sampling:

Example:
It is expected that 5000 tons of bituminous mixture are to be paved on a particular day. Specification 2360 states that 5 samples must be taken that day.

$$\frac{5000\ tons}{1000\ \frac{tons}{lot}} = 5\ lots = 5\ samples$$

Using an approved random number generation method, the following random numbers are generated: 0.15, 0.54, 0.35, 0.02, and 0.96.

Sample #	Lot Tons	Random #	Sample Point (Tons)	Prior Lots (Tons)	Sampling Tons
1	1,000	0.15	150	0	150
2	1,000	0.54	540	1,000	1,540
3	1,000	0.35	350	2,000	2,350
4	1,000	0.02	20	3,000	3,020
5	1,000	0.96	960	4,000	4,960

Table 700.2 - Sampling with Random Numbers

Mixture samples are takes at the tonnages shown in the “Sampling Tons” Column.

Important:
If a testing lot is required based on the tons produced, a sample must be taken regardless of whether the random tonnage is achieved. In the previous example, the sample for lot 5 was to be taken at 4960 tons. If the Contractor only produced 4,800 tons, a 5^{th} sample is still required. Additionally, if the contractor actually produced 5,200 tons, a 6^{th} sample would be required. If the actual tonnage is greater than the planned tonnage, repeat the calculation to determine the number of required lots and take additional samples if the calculation results in a higher number of required lots.

720.5 – Bituminous Mixture Production Sampling

QC sampling is the Contractor's responsibility and should be taken at random tonnage or locations, quartered from a larger sample of mixture. Samples may be taken behind the paver or from the truck box at the plant, unless another location is approved by the Engineer. The Contractor must decide and notify the Engineer where samples will be taken before production begins. Check the 2360 Special Provision for your project to see if there is a particular location specified. (Example: Most Metro samples must be taken behind the paver.)

Sampling from Behind a Paver (ASTM D979)

1. Contractor personnel obtaining the sample must be certified in Bituminous Plant 1 or Bituminous Street.
2. Equipment
    a. Clean, flat-nosed shovel
    b. Insulated container
    c. Metal or Plastic Container
    d. Putty Knife
    e. Insulated Gloves
3. Procedure

a. Use random numbers to identify the tons to be sampled. Sample from the truckload which corresponds to the sample tonnage.

b. Select a random sampling area where the mixture is uniform and displays no visible segregation. The random sample should be taken to represent a cross-section of the mat.

c. Obtain the sample at least one foot from the outer edge of the pavement. (Note: Asphalt mixture is hot. Wear insulated gloves when sampling)

d. Using a clean, flat-nosed shovel, shovel the amount of mixture needed into the metal or plastic container. Be careful not to pick up any of the underlying material, such as tack, or contaminate the sample with any foreign matter. Try not to disturb the sampling area more than necessary to obtain the representative sample. Extreme care should be taken to minimize coarse and fine particle separation while the sample is being taken.

e. Immediately after obtaining the sample, fill in the area with loose mixture obtained from the paver hopper or windrow. Since the paver is constantly moving, it is convenient to obtain mixture for filling the sampled area prior to taking the sample. After filling, the contractor's lute person should smooth out the area before rolling.

f. The sample, whether for routine voids update or for verification should be split in the field or lab promptly by quartering. This should be done according to any of the following methods:

    i. AASHTO R 47 (Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size).

        1. Mechanical Splitter Method

        2. Quartering Method

    ii. MnDOT Grading & Base Manual

        1. Ring and Cone Method

Note: Placing incremental scoops into Agency and Contractor containers in the field is not recommend since it will likely not give a representative sample.

The Contractor's half of the split (QC sample) should be placed in an insulated transporter to maintain temperature and immediately be returned to the field lab for additional quartering and testing. If the Inspector cannot deliver the QA sample to the Agency lab until the end of the day, an insulated transporter is not necessary because the mix will have cooled by that time.

g. Following MnDOT procedure, label both samples with the same field ID number to facilitate later comparison of test results.

Sampling from Truck Box

Truck box sampling presents several safety hazards. Care must be taken to prevent falls or burns during sampling. See the procedures below for truck box sampling:

1. Use random numbers to identify the tons to be sampled. Sample from the truckload which corresponds to the sample tonnage.

2. After the truck has been fully loaded, choose three sampling locations as shown in Figure 700.3. Keep all sample locations at least one foot away from the sides of the truck box.

3. Take the sample using a square nosed shovel. The square nose will help minimize segregation when sampling. At each sample location, remove the top 6" of mix and then take approximately equal amounts of material from each location so that the total sample size equals or exceeds the quantity requirements in the SMC. Note: welding two 4" vertical sides to the scoop of the shovel will help prevent roll off or spilling of the material and will further minimize the potential of obtaining a segregated sample.

4. Combine all three samples and use a field quartering procedure to obtain the QC/QA portions for testing. The minimum amount of mix for a standard QC/QA sample is 130 pounds, or 6 full cylinders (three cylinders per party).

5. The Inspector must be present to monitor all truck box sampling and must take their representative fraction after the sample is split.

6. Include “TBS” and a Truck I.D. in the comment section at the bottom of the Test Summary Sheet when using truck box sampling.

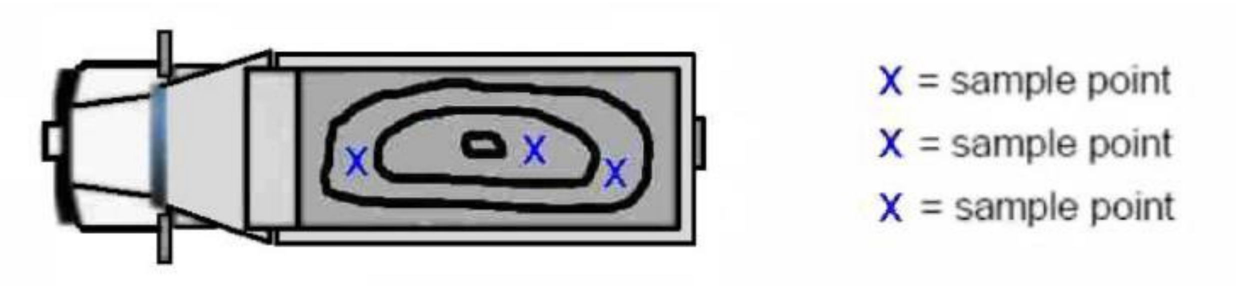


Figure 700.3 – Truck Box Sampling Locations

Sampling for the Maximum Specific Gravity Test (Rice Test)
When sampling and testing at the plant, in order to account for asphalt absorption, the sample needs to be kept heated at the compaction temperature for 30 minutes before splitting and batching into test portions. See guidance temperatures from the asphalt supplier. The manometer or vacuum gauge needs to be verified that it is reading correctly and paperwork needs to be on file to show this. Pycnometer (Rice container) weight should be verified daily including the weight of container underwater. Water bath temperature is required to be at 77°F ± 1.8°F.

720.6 - Verification Sampling and Testing

Mixture Verification is the process of validating Contractor’s test data. The State performs Verification sampling and testing as part of its Quality Assurance program. Quality assurance sampling and testing is conducted by state personnel or their representative. To ensure complete independence, random sampling techniques are used to determine when samples are to be taken. Once the Verification Sample has been obtained, it must be controlled by the State. Proper sample splitting technique is just as critical as the testing itself. Due diligence must be given to ensuring split samples are representative of the material being tested. Non-representative sample splitting will yield non-representative test results. See Section 720.7 for acceptable sample splitting techniques.

The Inspector can use the services of the contractor's personnel to assist in obtaining Verification samples when the following requirements are adhered to:

a) The verification sample location has been randomly selected by the Inspector and is only given to the contractor immediately prior to sampling.

b) The contractor's personnel are used only to provide labor to assist in physically obtaining and splitting the verification sample of the material.

c) The Inspector is present to witness the taking of the verification sample.

d) Both the Inspector and contractor labor are qualified sampling and splitting personnel.

e) The Inspector controls the sampling process by choosing the location and directing the taking and splitting of the verification sample.

f) The Inspector immediately takes possession of the verification sample.

720.7 – Splitting Mixture Samples for Testing

The following lists the procedure for splitting a bituminous mixture sample for testing:

1. If the sample is cold, bring it up to splitting temperature in an oven (160° to 230°).

2. Put the hot or reheated sample into a pan. Blend thoroughly, making sure to go all the way to the bottom of the pan with the scoop (This will help minimize segregation).

3. Evenly distribute and quarter the mix in the pan after you have it blended (If there are more than four items to split out, you may have to continuously blend the sample).

4. Weigh out the correct amount of material for the tests you will be running (such as rice test, gyratory pucks, ignition oven burn, or chemical extraction. See the test procedures in the MnDOT Lab Manual for the correct weights).

720.8 – Density and Specific Gravity

Maximum Specific Gravity

The Maximum Gravity test, also known as the Rice Test (named after its inventor, James Rice), measures the specific gravity of a loose mix sample. Since specific gravity is a way of expressing density, an explanation of these terms is in order. Because the word "density" has different meanings in different contexts, the writer or speaker must use it with precision. For this discussion, density refers to a fundamental property of matter, the relationship between weight and volume. The greater the weight contained in a given volume of a material, the denser it is.

In some branches of highway work, such as grading and base, soil density is expressed as a unit weight. An example might be 120.0 pounds per cubic foot (abbreviated pcf). The units are a clear reminder of the relationship between weight and volume. In bituminous work, however, the preferred method of expressing density is specific gravity. It is a unitless number that compares the density of an object or a material to the density of water. For example, an object having a specific gravity of 2.345 is 2.345 times denser than water. Water's own specific gravity is 1.000 at standard temperature and pressure. Some other specific gravities are: aluminum - 2.7, steel - 7.8, and lead - 11.34. Most bituminous aggregates and mixtures have specific gravities between 2 and 3.

Specific gravity is defined as the weight of an object or material divided by the weight of an equal volume of water.

$$Specific\ Gravity = \frac{Weight\ of\ Object}{Weight\ of\ Equal\ Volume\ of\ Water}$$

Because the numerator and denominator in the above fraction are both weights, their units cancel, leaving specific gravity as a pure number. Note also that specific gravity is a ratio, not a percent; the fraction is not multiplied by 100.

The laboratory method for measuring specific gravity parallels the formula in the definition. Measuring the weight of an object is easy enough: simply place it on a scale. However, determining the weight of an equal volume of water might be a mystery were it not for the legendary scientist of antiquity, Archimedes, who discovered that the weight of an object in air minus its weight immersed is the weight of an equal volume of water. Now the formula becomes:

$$Specific\ Gravity = \frac{Dry\ Weight\ of\ Object}{Dry\ Weight\ of\ Object - Immersed\ Weight\ of\ Object}$$

This is a practical and accurate formula for calculating specific gravity of non-porous objects such as metal, glass and the oil-coated aggregate particles of the Maximum Specific Gravity test. This gives rise to another form of the specific gravity formula, often used in this manual:

$$Specific\ Gravity = \frac{Weight}{Volume} = \frac{W}{V}$$

The formula above has two variations that are also useful in some calculations:

$$V = \frac{W}{G}$$

$$W = V \times G$$

The symbol G, with appropriate subscripts, represents specific gravity in formulas, but in informal usage the symbol SpG is often used. When spoken, it is pronounced “spee gee.” Specific gravity is always rounded to three decimal places.

Maximum Specific Gravity Test Overview

- A compacted specimen contains entrapped air, which “bulks up” its volume and reduces its specific gravity, G_{mb}

- In the Maximum Specific Gravity test, a vacuum pump removes the air from loose mix, minimizing its volume and “maximizing” its specific gravity, G_{mm}

- For a given mix, then, $G_{mm} > G_{mb}$

Maximum Specific Gravity Sample Volume Diagram

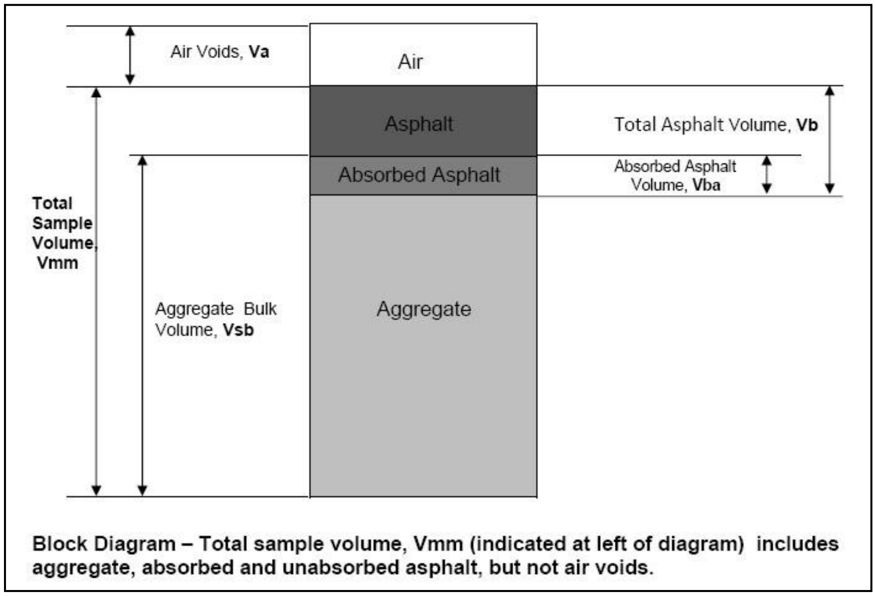


Figure 700.4 – Sample Volume Block Diagram

Laboratory Procedure

See MnDOT Lab Manual procedure 1807 for the Maximum Specific Gravity Test Laboratory Procedure.

720.9 – Compaction and Volumetrics

The process of compaction is a central concern of bituminous road building and therefore of bituminous testing. During compaction, pressure is applied to oil-coated aggregate particles, squeezing them closer together and reducing the amount of space between them. The pressure is called compactive effort, and the spaces between particles are called air voids. The interaction between these two parameters can be stated as a basic relationship: increasing compactive effort decreases air voids. The measurement of this relationship is called volumetrics. A key strategy in volumetric testing involves making compacted samples in the lab to predict compaction in the field. Measurement of volumetrics in HMA is the foundation of the Quality Control and Quality Assurance program in Minnesota.

Gyratory Compaction

Gyratory compactors operate on the same basic principle of applying a strong, steady, hydraulic pressure to a hot mix sample confined in a steel mold which gyrates around a vertical axis. It is meant to simulate the compactive effort of a steel drum roller. The amount of compactive effort is measured by the number of gyrations applied to the specimen. MnDOT uses five levels of compactive effort corresponding to five levels of expected traffic as measured in Equivalent Single Axle Loads (ESALs). An ESAL is a design number that takes into account the amount of truck traffic on the roadway. Trucks cause significantly more structural damage to the roadway when compared to passenger vehicles.

	Traffic Level 2	Traffic Level 3	Traffic Level 4	Traffic Level 5	SMA Level 6
20 year design ESALs	< 1 million	1 < 3 million	3 < 10 million	10 ≤ 30 million	Used in Special Applications
Gyrations for N design	40	60	90	100	75

Table 700.3 – Gyratory Compactive Effort and Traffic Level

Figure 700.5 – Gyratory Compactor

Laboratory Procedure

See MnDOT Lab Manual procedure 1820 for the laboratory procedure for measuring density with a gyratory compactor.

720.10 – Air Voids

All compacted HMA contains air voids. Final air voids in pavement are key to longevity of the pavement. It is an essential part of the QC technician's daily responsibility to keep laboratory air voids on target so as to produce a consistent product.

Calculating Basic Air Voids

The following is the basic formula used to calculate air voids:

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) \times 100\%$$

Where:

V_a = Percent air voids
G_{mm} = Maximum Specific Gravity
G_{mb} = Bulk Specific Gravity

Air Voids Three Ways

There are three types of air voids, each calculated differently with its own row on the summary sheet:

Isolated Air Voids

Isolated air voids are calculated from the maximum specific gravity and the bulk specific gravity from that single test:

$$ISO\ V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) \times 100\%$$

Individual Air Voids

Individual air voids are calculated from the moving average maximum specific gravity and the bulk specific gravity from that single test:

$$IND\ V_a = \left(\frac{MA\ G_{mm} - G_{mb}}{MA\ G_{mm}}\right) \times 100\%$$

Moving Average Air Voids

Moving average air voids are calculated from the average of the last four individual air voids:

$$MA\ V_a = \left(\frac{Sum\ of\ 4\ IND\ V_a's}{4}\right)$$

720.11 – Asphalt Binder Extraction

This section will cover two main topics related to the asphalt binder content (AC Content) of a bituminous mixture: test procedures to measure that content (extraction tests), and calculations to determine the adequacy of the measured AC (effective AC and Adjusted AFT).

Extraction

Why must AC content be measured at all, given the care with which plant personnel meter AC into the mix during production? There are a few reasons:

- In dryer drum plants, the continuous nature of the process is variable
- When used as a salvage ingredient, RAP contributes a variable amount of AC
- Plant metering equipment can go out of calibration unexpectedly
- An accurate AC content, P_b, is needed for a particular sample so that other calculations requiring P_b will also be accurate.

There are two main methods to determine asphalt content in the mixture:

- Solvent (chemical)
    - Uses a centrifuge
    - Can be used in conjunction with MnDOT's chemical extraction value to develop correction factors for ignition burns by averaging the Contractor and Agency chemical extraction values.
    - Used in determining G_{sb} of RAP aggregate
- Ignition Oven
    - The Contractor can use MnDOT's chemical extraction value and perform two ignition oven extractions to determine a calibration factor.

Extraction by Centrifuge

Unlike an ignition extraction, which burns the AC out of the mix, the centrifuge method uses a solvent to dissolve the AC out. The centrifuge machine spins the mixture-solvent slurry at high speed, forcing the AC-laden solvent through a filter paper, which retains most of the aggregate particles. The principle of operation resembles the spin cycle of an automatic washing machine.

Although newer chemicals pose fewer health and environmental risks than the chlorinated hydrocarbons once widely used, handling and disposal of solvents remain inconvenient and expensive. Because of these considerations and the time-consuming nature of solvent extractions, the ignition oven has replaced the centrifuge in many labs. However, solvent extractions still have a place in measuring the AC content of RAP and of production mix when determining ignition calibration factors.

Safe working practices and equipment are essential, even with the newer, safer solvents. A well ventilated work area, face shield, chemical-resistant gloves, and respirator are all necessary. The laboratory procedure for a centrifuge extraction is found in procedure 1852 in the MnDOT Lab Manual.

Figure 700.6 – Centrifuge Extractor

Extraction by Ignition

An ignition extraction determines the asphalt content of bituminous mixture by burning off asphalt from the aggregate. The mixture is burned at 538°C in a forced air ignition oven. At the high temperatures of the ignition oven, some aggregate is burned away along with the asphalt binder. Carbonate aggregates, which include limestone, are particularly susceptible to aggregate loss. When a mixture contains more than 20 percent carbonate, MnDOT requires the burn temperature be reduced to 482°C. To measure asphalt content in the ignition oven accurately, a calibration factor must be determined for each oven and each mix type to account for aggregate loss and for differences between ovens.

Calibration Factor

On the first day of mixture production, both MnDOT and the Contractor perform a chemical extraction on a split sample and agree on the asphalt content of the mixture, however the Contractor can accept the Agency's extracted AC value instead of determining their own value. This chemically extracted asphalt content will be used to correct the ignition oven. The difference between the results from the chemical extraction and the ignition oven is the percent of aggregate loss, or mix calibration factor, Cfm. Once the calibration factor is determined, the corrected asphalt content can be determined. The laboratory procedure for an ignition oven extraction is found in procedure 1853 in the MnDOT Lab Manual. The Appendix of the Lab Manual lists the procedure for Establishing an Ignition Oven Correction Factor on Production Mix.

Remember to dry the mixture to a constant mass before splitting the sample and placing one portion in the ignition oven. If that is not done, another sample must be split and placed in a drying oven at the same time another sample is placed in the ignition oven. This is to determine the amount of retained moisture in the sample that would otherwise be counted as AC.

Effective or Unabsorbed Asphalt

When asphalt cement and aggregate are mixed together, asphalt is absorbed into the pores of the aggregate particles. Effective asphalt or the unabsorbed asphalt is what is available to "glue" aggregate particles together. Effective, unabsorbed, and free are all terms used to describe this part of the total oil.

Effective asphalt content, Pbe, is used in the calculations for Adjusted AFT and Fines to Effective asphalt ratio, both of which will be discussed later in this section. Because effective asphalt is a part of total asphalt, it is always true that Pb > Pbe.

Adjusted AFT

The extraction test, whether by ignition oven or by centrifuge, measures the total AC content, or Pb, in the mix. The formula for Effective asphalt content, Pbe, reveals how much of that total is available to coat aggregate particles, the unabsorbed asphalt.

The Adjusted AFT calculation is intended to indicate the thickness of the asphalt film coating the particles. It has been found that a film thickness of at least eight microns provides enough glue to bind the particles together satisfactorily. Note: In casual conversation, the entire calculation is sometimes referred to simply as "AFT," but to be precise, the third and final step results in Adjusted AFT, a number which is typically slightly different from the "plain" AFT of the second step.

The minimum film thickness spec is the same for all mixes, regardless of gradation: 8.0 microns for moving average and 7.5 microns for individual tests (A micron is one 1000th of a millimeter.).

Greater surface area, SA, requires more binder to achieve minimum film thickness, and more binder means higher production cost. Material passing the 200 sieve contributes disproportionately to SA. Producers may seek to minimize dust in the gradation by using thoroughly washed aggregates or wasting baghouse fines (dust). See MnDOT Lab Manual procedure 1854 to determine Adjusted AFT.

Fines to Effective Asphalt Ratio

In addition to AFT, the effective asphalt content, Pbe, appears in another formula, the Fines to effective AC ratio. It has the effect of specifying some minus 200 material (dust) in the composite blend. The formula is as follows:

$$\frac{Fines}{Effective\ AC} = \frac{P200}{Pbe}$$

Where,

P200 = the percent passing the 200 sieve in the mix gradation
Pbe = the effective AC content (to the nearest tenth).

Note that this is a unitless ratio, so it is not multiplied by 100%. The fines to effective asphalt ratio for all mixes must be between 0.6 and 1.2 (except for SMA, which is 1.2 to 2.0). See Table 2360-7 in the Standard Specifications for Construction.

720.12 – Fine Aggregate Angularity

Angular aggregate particles, whether coarse or fine, enhance the stability of bituminous pavement, giving it resistance to rutting and shoving. The aggregate crushing process produces angular particles by creating fractured faces and sharp edges. Naturally occurring particles in gravel pits generally lack angularity, being rounded and smooth. As natural sand passes through a crusher, it is largely unaffected and remains rounded in the stockpile.

Quarried aggregate, on the other hand, originates from solid rock ledges and must be 100% crushed, from the largest particles to the smallest. Quarried fines are thought of as being manufactured and are often called "man sand."

In the lab, coarse aggregate angularity (CAA) is measured by "picking" a sample of plus 4 material, separating angular from rounded particles by hand and eye. Fine Aggregate Angularity (FAA) is the corresponding test for fines and uses a special test apparatus. As sand flows from the reservoir of the apparatus into the receiving cylinder, the particles slide past each other as they settle into place. Smooth particles slide more readily and fill the cylinder more completely, while angular particles catch on each other, leaving loose, uncompacted voids. The FAA apparatus tests for voids - the more angular the sand, the greater the voids. See MnDOT Lab Manual Section 1206 for the FAA Procedure.

Figure 700.7 – FAA Apparatus

720.13 – Lottman Test

The tests that have been discussed up to this point are routinely run in Contractor labs. The Lottman test, or Tensile Strength Ratio, is seldom run in the field during production because of its complexity. It is, however, a required test for mix designs.

As discussed in previous chapters, if the chemical bond between aggregate and binder is not strong (or the bond between asphalt coated particles is not strong), water can come between and separate them in a process called stripping. In extreme cases, stripping can reduce a bituminous pavement to gravel. The Lottman test measures the susceptibility of a bituminous mixture to stripping by subjecting lab-compacted specimens to heat and forced saturation by water. If the treated specimen loses too much strength in a tensile splitting test as compared to an untreated specimen (i.e., if the tensile strength ratio is too low), the test fails. Liquid anti-stripping agents can be added to the asphalt binder to improve tensile strength. Some states add lime to improve moisture susceptibility. See MnDOT Lab Manual procedure 1813.

Figure 700.8 – Lottman Load Frame

720.14 – Field Density Cores

Cores are MnDOT's method for measuring pavement density. As discussed previously, density is a critical component of an asphalt pavement's longevity and strength. Density cores are unlike other test parameters in that two types of tolerance apply: individual and shrinking tolerance. In the individual tolerance, mixture bulk specific gravity (G_{mb}) for a single Contractor's core is compared to that of the corresponding Agency companion. If the two G_{mb}'s differ by more than 0.030, they are out of tolerance, and the Agency's G_{mb} will be substituted for the Contractor's in the calculation of lot density.

In the day's shrinking tolerance, the average G_{mb} of Agency cores is compared with the average G_{mb} of Contractor cores. As more cores are included in the average, the tolerance "shrinks." The exact value of the tolerance is given by the following formula:

$$Tolerance = \frac{0.030}{\sqrt{N}}$$

Where,

N = the number of cores in the average

Any cores found out of tolerance in the individual comparison, which is applied first, will not be included. If the averages differ by more than the shrinking tolerance, all the Agency G_{mb}'s will be substituted.

The computerized MnDOT core worksheet (discussed later in this chapter) makes these substitutions and subsequent calculations automatically as soon as both the Contractor and Agency results are entered.

720.15 – Bituminous Test Summary Sheet

The Test Summary Sheet (TSS) is a spreadsheet that summarizes Contractor QC test results and Agency QA test results. The Test Summary Sheet as well as other applicable bituminous spreadsheets are available on the Bituminous Engineering webpage. During mixture production, the Contractor maintains a separate TSS for each mixture type. The Contractor records their volumetric testing results in the required yellow shaded areas and the Agency uses the green shaded cells. Currently (2019) the spreadsheet only checks for tolerance issues between the Contractor and Agency results and will replace the Contractor's result with the Agency result if the specified tolerance is exceeded. The plant monitor must check for results that are out of specification. If results indicate that the material is out of specification, it may result in a monetary deduction or be removed and replaced depending on the extent to which the result is out of specification. Any monetary deductions are based on the tonnage of mix that the failing result represents.

On the Test Summary Sheet, moving averages are calculated on an ongoing basis per specification. The orange text on the spreadsheet (usually labeled "Calc" or "Working") indicates the numerical results that the spreadsheet uses for its calculations after any out of tolerance substitutions are used. Therefore, the spreadsheet displays all the Contractor and Agency test results before and after substitution. Here are a few notes on individual fields:

- Make sure the correct Asphalt binder grade is selected for each test.
- Change the Asphalt Specific Gravity if a different binder is used.
- Check for Quality Control Actions that describe any changes the Contractor made to the plant settings.
- If the words “Stop Production” appear, the Contractor is required to stop production and make an adjustment to the mix to get it back into specification.
- The “Add AC” cell represents the percent of add AC determined off of the recordation document that the plant is required to create every 20 minutes during mixture production. This must match the recordation form.
- At the bottom of each test column, verify that the tester is listed.

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TEST SUMMARY SHEET - GYRATORY DESIGN

Project/Plant Drum Plant 1 **Mix Designation** SPWEA330

Location Midtown **Plant Name** 904 Maple Grove **Course** WE (Wear) - 3% Voids

SPEC. YEAR "2013-2017"

			Cont'r	Agency	Cont'r	Agency	Cont'r	Agency	Cont'r	Agency
Test#			301		302	MnDOT	303		304	
Date/Day:			6/1/2017 Day1		6/2/2017 Day2		6/2/2017 Day2		6/2/2017 Day2	
MDR #			2017-999		2017-999		2017-999		2017-999	
- 4 Aggregate Bulk SpG.(Gsb) =			2.656		2.656		2.656		2.656	
Mix Aggregate Bulk SpG.(Gsb) =			2.657		2.657		2.657		2.657	
Project Number =			Maintenance Patch		SP 9999-99		SP 9999-99		SP 9999-99	
Asphalt Binder Grade			C = PG 58H-34 (MSCR)		C = PG 58H-34 (MSCR)		C = PG 58H-34 (MSCR)		C = PG 58H-34 (MSCR)	
RAP in Mixture?			Yes		Yes		Yes		Yes	
Shingles (RAS) in Mixture?			No		No		No		No	
ACsg (Asphalt Spec. Grav.)			1.030		1.030		1.030		1.030	
1"	min.	max.	100		100	100	100		100	
Mov Avg.	100	100							**100**	
1" Calc. %			**100**		**100**		**100**		**100**	
3/4 in.			100		100	100	100		100	
Mov Avg.	100	100							**100**	
3/4" Calc. %			**100**		**100**		**100**		**100**	
1/2 in.			100		100	100	100		100	
Mov Avg.	100	100							**100**	
1/2" Calc. %			**100**		**100**		**100**		**100**	
3/8 in.			96		97	95	95		94	
Mov Avg.	85	100							**96**	
3/8" Calc. %			**96**		**97**		**95**		**94**	
#4			78		81	78	78		76	
Mov Avg.	60	90							**78**	
#4 Calc. %			**78**		**81**		**78**		**76**	
#8			61		64	61	62		60	
Mov Avg.	45	70							**62**	
#8 Calc. %			**61**		**64**		**62**		**60**	
# 16			49		51	49	49		47	
#16 Calc. %			**49**		**51**		**49**		**47**	
# 30			36		37	36	36		35	
#30 Calc. %			**36**		**37**		**36**		**35**	
# 50			18		19	19	18		18	
#50 Calc. %			**18**		**19**		**18**		**18**	
# 100			9		9	9	8		8	
#100 Calc. %			**9**		**9**		**8**		**8**	
#200			4.8		5.0	5.2	4.6		4.5	
Mov Avg.	2.0	7.0							**4.7**	
#200 Calc. %			**4.8**		**5.0**		**4.6**		**4.5**	
% Asphalt Content		Individual	6.0		6.3	6.3	6.3		6.2	
Design =	**6.2**	Mov. Avg.							**6.2**	
		Calc. %AC	**6.0**		**6.3**		**6.3**		**6.2**	
Gmm - Max.SpG		Individual	2.457		2.449	2.460	2.456		2.456	
(Rice Test)		Mov. Avg.							**2.454**	
		Calc. Gmm	**2.457**		**2.449**		**2.456**		**2.456**	
Gmb - N-design calc.		Individual	2.378		2.379	2.375	2.373		2.381	
60 Gyrations		Calc. Gmb	**2.378**		**2.379**		**2.373**		**2.381**	
		Isolated	3.2		2.9	3.5	3.4		3.1	
% Air Voids		Individual	3.1		3.1		3.3		3.0	
Design =	**3.0**	Mov. Avg.							**3.1**	
% VMA		Individual	15.9		16.1	16.2	16.3		15.9	
		Calc. VMA	**15.9**		**16.1**		**16.3**		**15.9**	
Design =	**0.0**	Mov. Avg.							**16.0**	
Effective Asphalt Content, P_{be}			5.5		5.7	**5.600**	5.6		5.6	
Fines / Effective Asphalt Content			0.9		0.9	0.9	0.8		0.8	
		Individual	8.8		9.0	8.9	9.2		9.3	
Adjusted AFT	**8.5**	Working AFT	**8.8**		**9.0**		**9.2**		**9.3**	
	8.0	Mov. Avg.							**9.1**	
% Add AC/Total AC		Individual	83		79		81		82	
		Mov. Avg.							81	
Mix Moisture Content										
% Crushing	CAA -1 Face	55	89		86	96	89		87	
	CAA -2 Face	-	89		86	92	89		87	
	FAA	42	42		42	41	42		42	
Sample Ton Number / Tons Represented				50	298	714	714	419	1133	610
Daily Project Total / Cummulative Tons			50	50	714	764	1133	1183	1743	1793
NOTES	**Ignition oven Cf**		0.81		0.80		0.80		0.80	
	Quality Control Actions									
Source #	Aggregate Source		Agg. SpG.	% of mix	Agg. SpG.	% of mix	Agg. SpG.	% of mix	Agg. SpG.	% of mix
1	Aggregate 1/2"		2.644	34	2.644	34	2.644	34	2.644	34
2	Rock 1/2" Clear		2.676	15	2.676	15	2.676	15	2.676	15
3	Rock		2.690	16	2.690	16	2.690	16	2.690	16
4	RAP		2.640	20	2.640	20	2.640	20	2.640	20
5	Washed Sand		2.655	15	2.655	15	2.655	15	2.655	15
6	Sand		2.637	0	2.637	0	2.637	0	2.637	0
7										
8										
9										
10										
Add AC				5.0		5.0		5.1		5.1
Tested By:			Jody	Steve	Jody	Steve	Jody	Steve	Jody	Steve

Figure 700.9 – Example Test Summary Sheet

720.16 – Core Lots and Core Stationing Sheet

Lots

Each Core represents a given quantity of bituminous mixture known as a “lot.” A lot is determined with the following table:

Daily Production, ton	Lots
300* - 600	1
601 – 1,000	2
1,001 – 1,600	3
1,601 – 2,600	4
2,601 – 4,600	5
>4,600	‖

*If producing no greater than 300 ton of mix, establish the first lot when the total weight is greater than 300 ton.

‖Add one lot for each additional 900 tons or part thereof.

Table 700.4 – Lot Determination

If your daily production is less than 300 tons, add the tonnage onto the next production day’s quantity until the total quantity exceeds 300 tons and lots can be determined. For 24 hour paving projects, break the tonnage into 12 hours segments.

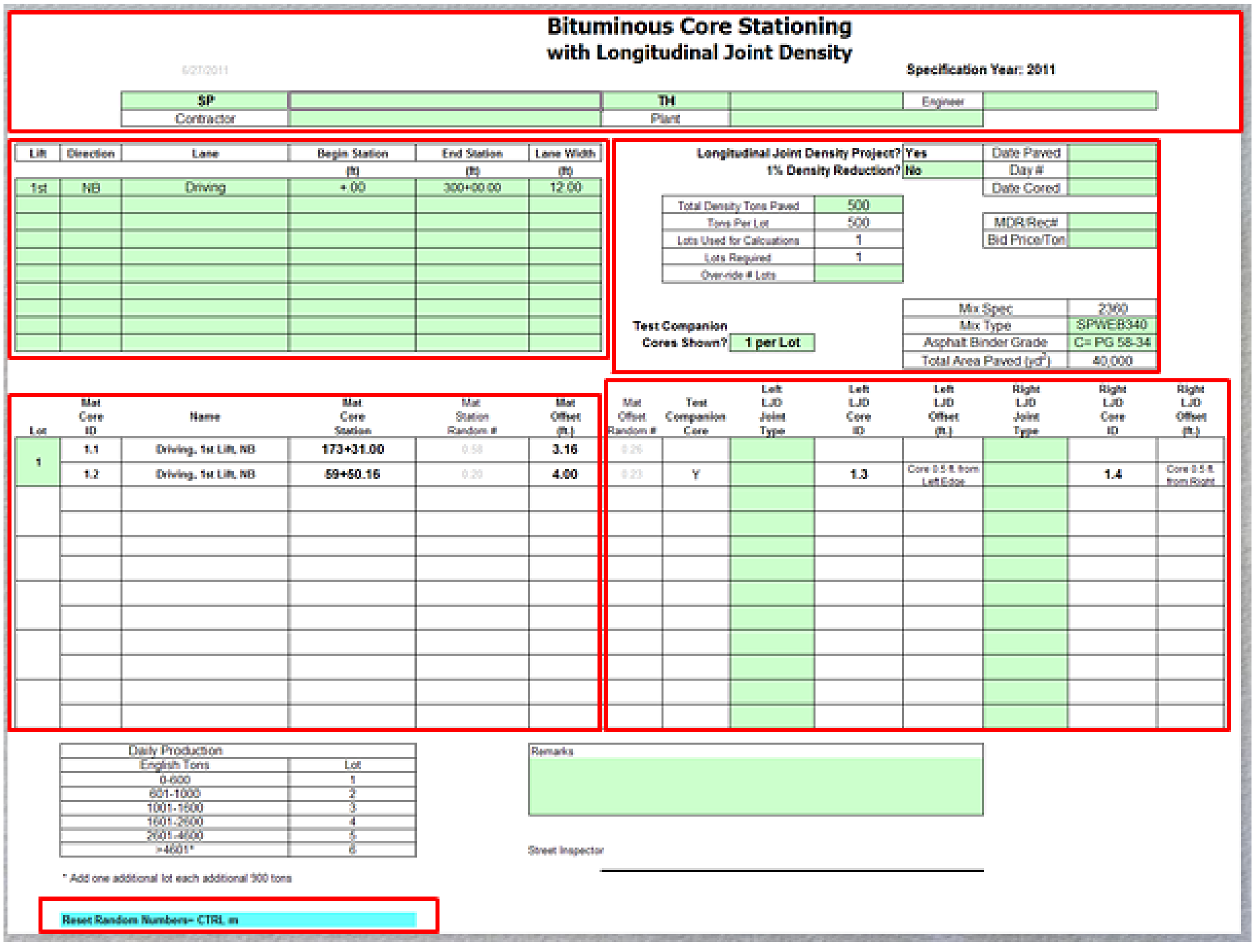
Determining Core Locations (Core Stationing Sheet)

The Core Stationing Sheet is a spreadsheet (found on the Bituminous Engineering Webpage) that Agency Inspectors use as a tool to determine where to take the density cores on a random number basis. A new spreadsheet is required for each day a coring layout is needed. The sheet must be used in the following way:

- Input stationing as 0000 to get 00+00 and 12345 to get 123+45
- Determine the tonnage that was under maximum density.
- Use a Ctrl-m keystroke to reset the random number after a new spreadsheet is opened.
- Input the starting lot number for the day
- Insert the amount of mix that will be evaluated under maximum density

- Now describe the limits of the day's paving under maximum density
    - Lift
    - Location
    - Beginning and Ending Station
    - Width
- The spreadsheet has the option to show longitudinal joint density core locations or not (use the drop down to indicate if the edge was confined or unconfined).
- An Agency companion core is taken 1 foot longitudinally from the Contractor's core.
- The Contractor must test a core at each location. Out of the two core locations in each lot, the agency must test at least one core (they can test both like the Contractor).

The following diagram is an example Core Stationing Spreadsheet. The agency will mark the core locations after the final rolling is completed:



Bituminous Core Stationing
with Longitudinal Joint Density

6/27/2011

Specification Year: 2011

SP		TH		Engineer	
Contractor		Plant			

Lift	Direction	Lane	Begin Station (ft)	End Station (ft)	Lane Width (ft)
1st	NB	Driving	+ 00	300+00.00	12.00

Longitudinal Joint Density Project?	Yes	Date Paved	
1% Density Reduction?	No	Day #	
		Date Cored	

Total Density Tons Paved	500
Tons Per Lot	500
Lots Used for Calcuations	1
Lots Required	1
Over-ride # Lots	

MDR/Rec#	
Bid Price/Ton	

Test Companion Cores Shown? 1 per Lot

Mix Spec	2360
Mix Type	SPWEB340
Asphalt Binder Grade	C= PG 58-34
Total Area Paved (yd^2)	40,000

Lot	Mat Core ID	Name	Mat Core Station	Mat Station Random #	Mat Offset (ft.)	Mat Offset Random #	Test Companion Core	Left LJD Joint Type	Left LJD Core ID	Left LJD Offset (ft.)	Right LJD Joint Type	Right LJD Core ID	Right LJD Offset (ft.)
1	1.1	Driving, 1st Lift, NB	173+31.00	0.58	3.16	0.26							
	1.2	Driving, 1st Lift, NB	59+50.16	0.20	4.00	0.23	Y		1.3	Core 0.5 ft. from Left Edge		1.4	Core 0.5 ft. from Right

Daily Production English Tons	Lot
0-600	1
601-1000	2
1001-1600	3
1601-2600	4
2601-4600	5
>4601*	6

* Add one additional lot each additional 900 tons

Remarks

Street Inspector

Reset Random Numbers= CTRL m

Figure 700.10 – Example Bituminous Core Stationing Worksheet

The Inspector will now go and mark the core locations on the road for the contractor to cut. Remember there is always a companion (Agency) core cut 1 foot longitudinally away from the contractor's core. The following diagram is an example where longitudinal joint cores are not included:

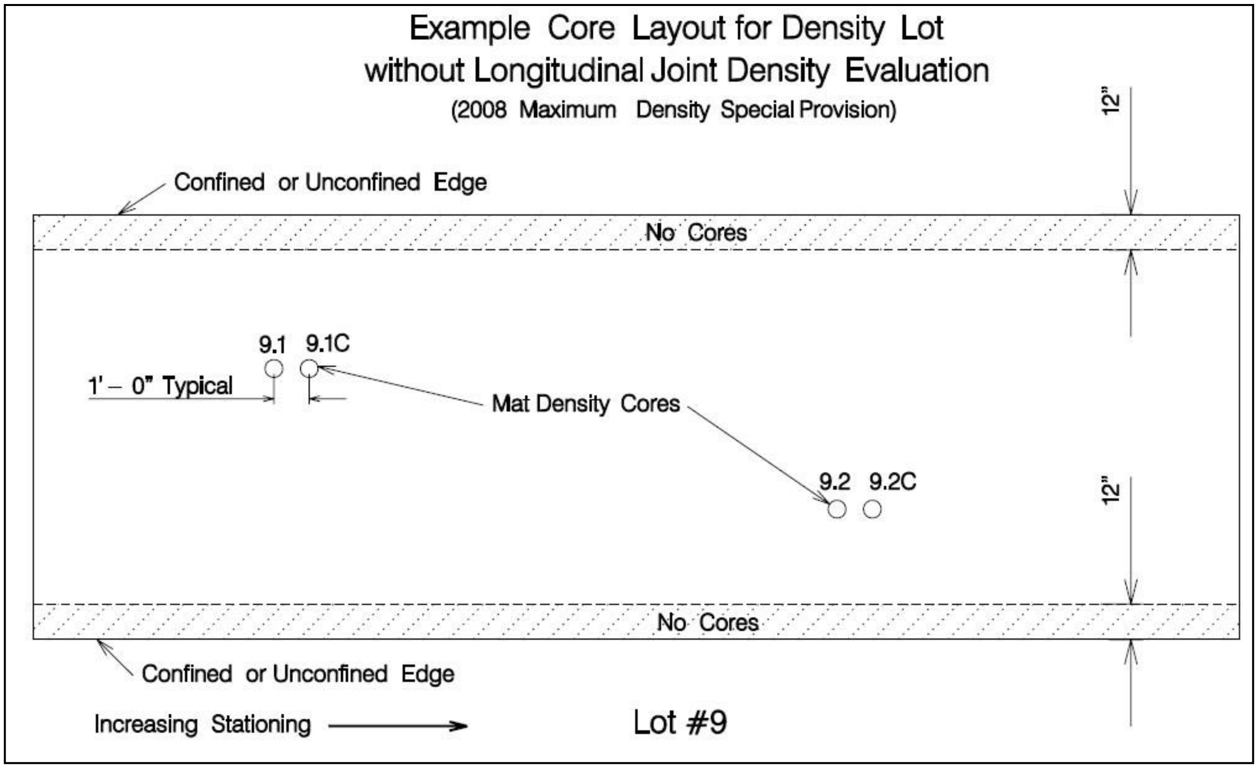


Figure 700.11 – Example Core Layout without Longitudinal Joint Density. The Contractor will obtain four cores in each lot. The location (station & offset) will be determined randomly by the Engineer.

The cores must be cut within the marks on the road painted by the Inspector. The cores in the following picture should be recored at the proper locations.

Figure 700.12 – Core locations marked on the roadway. Note that the cores were not taken in the marked locations. These cores must be recored at the proper locations.

Longitudinal Joint Cores

Written into the standard specification is taking additional cores at the longitudinal joint in one lot per day if the total daily maximum density tons is 5000 tons or less (two if greater than 5000 tons). The cores will be taken according to the following diagram.

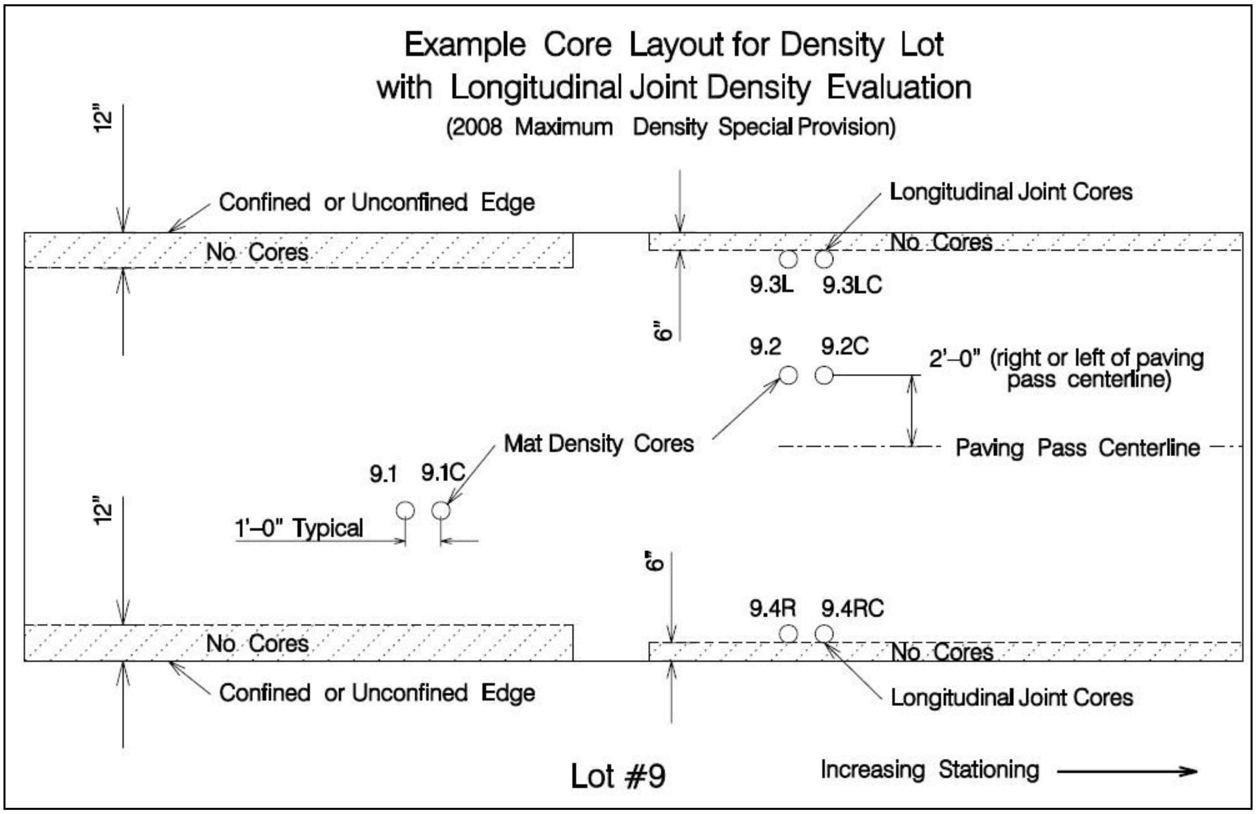


Figure 700.13 – Example Core Layout with Longitudinal Joint Density

The outside of the core barrel should be 6 inches from the outside edge of the mat. The Contractor will trim the cores so only the paved lift remains. Measure the cores for thickness. Bulk the cores and input results onto the Density Incentive/Disincentive worksheet, as described in section 720.14 - Density Incentive/Disincentive Worksheet.

720.17 – Density Incentive/Disincentive Worksheet

To assess the density of the pavement, the Agency uses density cores cut from the pavement. The core density testing results from the lab are input into the Density Incentive/Disincentive spreadsheet, which then outputs the associated incentive or disincentive payment. The inspector can use one spreadsheet for each type of mix on a project. Each day of paving, a new tab can be copied or created to input that day's data. Typically, the Contractor will cut 4 inch diameter cores, but some will cut 6 inch diameter cores. Here are some items to keep in mind when using this spreadsheet:

- If the mix has less than 45% of the aggregate passing the #4 sieve, the Engineer should request that the Corelok method be used (different spreadsheet). This is because there is a possibility that the voids in the core are interconnected and the standard density method would over-estimate the in-place density.

- Start a new tab in the workbook (worksheet) for each mix each day.

- The Contractor will place their results in the QC rows, while the Agency will use the QA rows.

- Insert names of QC & QA individuals.

- Enter the type of mix.

- Indicate whether the mix is paid by the Ton or by the Square Yard Inch.

- Indicate whether it is a one percent reduced density project. If the project is one percent reduced density, refer to MnDOT Specification 2360.3.D.1.m. It should be noted that the requirements for one percent reduced density usually only apply to a specific lift or portion of a project. Also note that the Contractor must notify the Engineer, in writing, by the end of the third day of paving of their intent to waive maximum density.

- Indicate whether the paving day included longitudinal joint cores.

- If a shoulder is paved in the same pass as a driving lane, the location where the longitudinal joint would have fallen between the shoulder and the driving lane is considered an imaginary joint. Do not cut a core on an imaginary joint. See MnDOT Specification 2360.3.D.1.o.

- Verify the Bid Price (price per ton or price per square yard).

- Verify all the mixture information is transferred correctly from the Test Summary Sheet for the project (Sample Number, Sample Tons, Ind. Air Voids, Ind. G_{mm}, and Moving Avg. G_{mm}).

- Start the lot number at 1 for your project and increment them up for each lot as required for the amount of tonnage produced. Do not start lot numbers over again for each type of mix on the project.

- Input the total tons used on the project that day.

- Input how many of those tons were placed in areas that the density will be evaluated by maximum density.

- If the project includes Longitudinal Joint Density cores:

    - Insert the core ID of the mat core at the same station at which the Longitudinal Joint Density cores were taken.

    - In the “Joint Type” cell, use the drop down box to specify whether the core was taken next to a confined or unconfined edge.

- Complete bulk specific gravity testing of cores per Lab Manual Section 1810 and enter results on worksheet.

Review the Results

If the lot pay is in the negative dollar range, then the lot has failed for the day. If all the day’s lots fail, or more than 50% of multiple days’ paving lots fail, the Contractor must stop production and change their compaction operation so passing density values are achieved.

Total all the incentives and disincentives and add this as a Change Order to the Contract. If more than 25% of all mainline density lots fail to meet minimum density requirements for the project, no incentives (including smoothness) will be paid to the Contractor.

Unique Situations

Below are several unique paving situations for core layout determination:

- Paving driving (maximum density) and shoulder 6 feet or less (ordinary compaction) at the same time. Subtract the tons that were used to pave the shoulder from the total tons of that mix paved on that day. Enter the quantity in the maximum density cell on the worksheet. Also, do not mark or take the outside longitudinal joint cores on the shoulder.

- Shoulders greater than 6 feet are considered their own paving pass and would default to maximum density with longitudinal joint cores.

Ver: 8/17/2011

Plant Mixed Asphalt Pavement (Mn/DOT Specification 2360) Density Incentive/Disincentive Worksheet

Specification Year 2011

S.P.	9999-99	Contractor	XYZ Contracting	MDR #	2012-001	Bid Price ($/ton)	$55.00	Max. Density Tons:	2050
TH	111	Engineer	Smith	Plant:	Urban 1	% Passing #8 Sieve:	48	Max./Total Ratio:	1.00
Locati				Date Pav	5/1/2012	1% Reduced Prjct?	No		2
	SPWEB340C			Date Cor	5/2/2012	Long. Jnt. Density?	Yes		

otal Tons Produced: 2050 — Lots Required: 4 — Over-ride # of Lots: — Tons/Lot: 512.5

Mix Design Type	SP (Gyratory)
Mix Course	WE (Wear)
Max. Aggr. Size	B (3/4 inch)
ESALS [Traffic Level	1 to <3 [Level 3]
Air Voids	4%
Asphalt Binder Grade	C - PG58-34
Shoulder?	No
Tons or SqYd in. Prjct	Tons

Sample Number	209	210
Sample Tons	610	1050
Tons Represented	1050	1000
Density Tons	1050	1000
Individual Air Voids	4.4	4.2
Individual Gmm	2.514	2.526
Moving Avg. Gmm	2.528	2.530

Average Gmm ---> 2.530 — Design Air Voids: 4.0 — Min. Air Voids: 3.5 — Day's Weighted Avg. Air Void: 4.3

Use Laboratory Method 1810

..Mat Density Re: 92

Lot		Core #	Core Thickness (inches)	Air Dry (g)	Pan ID	Core + Pan (g)	Pan (g)	SSD (g)	Immersed (g)	Dry Weight (g)	% water absorbed	Gmb/ Bulk Sp.G	Density % of Gmm	Bulk Sp.G used	Lot Avg. Density % of Gmm	Mat Pay Factor "A"	Total Pay Factor AxBxC	Tons Represent	Incentive Disincentive
1	Contr. QC	1.1	2.10	718.1	A	958.6	241.2	718.8	421.5	717.4	0.2	2.413	95.4	2.413	94.8	1.03		512.5	$845.63
	Contr. QC	1.2	2.30	714.2	B	844.2	130.7	714.9	415.6	713.5	0.2	2.384	94.2	2.384					
	Agency QA	1.1C	2.00	730.7		997.9	268.8	731.9	431.8	729.1	0.4	2.430	96.0						
	Agency QA	1.2C												2.398	- Avg.Gmb				
2	Contr. QC	2.1	1.90	743.3	C	872.3	132.0	744.0	432.6	740.3	0.2	2.377	94.0	2.377	95.1	1.03		512.5	$845.63
	Contr. QC	2.2	2.10	1311.4	D	1548.5	237.8	1312.3	774.1	1310.7	0.2	2.436	96.3	2.436					
	Agency QA	2.1C																	
	Agency QA	2.2C	2.20	1306.0		1562.6	257.9	1307.4	771.3	1304.7	0.3	2.434	96.2	2.406	- Avg.Gmb				
3	Contr. QC	3.1	1.80	875.8	E	1019.2	145.6	876.5	507.3	873.6	0.2	2.366	93.5	2.366	94.0	1.03		512.5	$845.63
	Contr. QC	3.2	2.00	716.8	F	867.9	152.6	717.7	418.7	715.3	0.3	2.392	94.5	2.392					
	Agency QA	3.1C																	
	Agency QA	3.2C	1.90	640.0		891.1	253.9	640.8	372.3	637.2	0.3	2.373	93.8	2.379	- Avg.Gmb				
4	Contr. QC	4.1	2.40	794.8	G	943.5	151.6	796.0	463.0	791.9	0.4	2.378	94.0	2.378	94.9	1.03		512.5	$845.63
	Contr. QC	4.2	2.00	826.5	H	965.0	139.4	827.3	486.3	825.6	0.2	2.421	95.7	2.421					
	Agency QA	4.1C	1.80	816.3		1066.4	256.9	817.8	474.2	809.5	0.4	2.356	93.1						
	Agency QA	4.2C												2.400	- Avg.Gmb				

Longitudinal Joint Density Cores — Min. Confined LJD Required: 89.5 — Min. Unconfined LJD Required: 88.1

Assoc. Mat Core		Core #	Joint Type	Core Thickness (inches)	Air Dry (g)	Pan ID	Core + Pan (g)	Pan (g)	SSD (g)	Immersed (g)	Dry Weight (g)	% water absorbed	Gmb/ Bulk Sp.G	Density % of Gmm	Bulk Sp.G used	Lot Avg. Density % of Gmm	Edge Pay Factor B or C
2.2	Contr. QC	2.3L	No Core	2.20	650.8	I	912.3	263.3	651.2	373.7	649.0	0.1	2.339	92.5	2.339	92.5	
	Contr. QC	2.4R	No Core	2.30	753.4	J	886.8	137.3	755.2	426.4	749.5	0.5	2.280	90.1	2.28	90.1	
	Agency QA	2.3LC															

Net Inc./Disinc. $3,382.52

Figure 700.14 – Example Density Incentive/Disincentive Worksheet

720.18 – Bituminous Profile Summary

As discussed in Chapter 5, when projects incorporate MnDOT Specification 2399 – Pavement Surface Smoothness, the Contractor has the potential to receive incentive payments, to pay disincentive deductions, or to perform corrective work based on the smoothness of the finished roadway. The Contractor can also receive disincentive deductions or be required to perform corrective work for Areas of Localized Roughness (ALR). Incentives, deductions, and corrective work are all tracked on a Bituminous Profile Summary. The following is an example of a Bituminous Profile Summary. This particular example uses the equation HMA-A, which details the target ride quality requirements for the finished surface. See MnDOT Specification 2399 for more information.

It should be noted in the following example that the "Total Pay Adjustment" field at the bottom of the summary does not show a monetary value and is indicating the need for corrective work. Corrective work for Smoothness must be completed before any pay adjustments are assessed. Because the HMA-A equation is used in the following example, corrective work must be performed until the CW sections reach an MRI of 50 inches per mile or less.

19-Jan-2018

2018 Bituminous Profile Summary

File Name(s)	Asphalt Contactor 18-07-02-TH-0-E-1-+0-85+00-SECT 1
Date Measured	July 2, 2018
S.P./S.A.P.	1234-56
T.H./CSAH	TH 0
Lane Description	Mainline: lane 1

Smoothness Equation	HMA-A
Posted Vehicle Speed	> 45 mph
Mainline Density Lots	Failure Rate: ≤ 25%
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	+		
End	85+00		

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	25
ALR ≥ 225.0 (linear ft)	5

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	+	5+28	528	45.0	$80.00	S1
↓	5+28	10+56	528	42.0	$128.00	↓
↓	10+56	15+84	528	65.0	-$240.00	↓
↓	15+84	21+12	528	75.0	-$400.00	↓
↓	21+12	26+40	528	80.0	CW	↓
↓	26+40	31+68	528	85.0	CW	↓
↓	31+68	36+96	528	55.0	-$80.00	↓
↓	36+96	42+24	528	49.0	$16.00	↓
↓	42+24	47+52	528	35.0	$240.00	↓
↓	47+52	52+80	528	35.0	$240.00	↓
↓	52+80	58+08	528	40.0	$160.00	↓
↓	58+08	63+36	528	45.0	$80.00	↓
↓	63+36	68+64	528	65.0	-$240.00	↓
↓	68+64	73+92	528	51.0	-$16.00	↓
↓	73+92	79+20	528	50.3	-$4.80	↓
↓	79+20	84+48	528	42.0	$128.00	↓
↓	84+48	85+00	52	43.0	$11.03	↓

Total Pay Adjustment	Smoothness Corrective Work Required
Areas of Localized Roughness Deduction	-$1,250.00
Total Pay Adjustment + Areas of Localized Roughness Deduction	

Data Entered By		Data Checked By	
Signature		Signature	

Figure 700.15 – Example Bituminous Profile Summary with corrective work

The following example shows the project after corrective work has been performed on the two CW sections. The sections that have been corrected are highlighted yellow, and are both below

50 inches per mile, so this is acceptable corrective work. Note that the “Total Pay Adjustment” field has been automatically populated to show a dollar amount because there are no longer any Smoothness sections calling for corrective work.

19-Jan-2018

2018 Bituminous Profile Summary

File Name(s)	Asphalt Contactor 18-07-02-TH-0-E-1-+0-85+00-SECT 1		**Smoothness Equation**	HMA-A
Date Measured	July 2, 2018		**Posted Vehicle Speed**	> 45 mph
S.P./S.A.P.	1234-56		**Mainline Density Lots**	Failure Rate: ≤ 25%
T.H./CSAH	TH 0		**Certified Inertial Profiler**	Yes
Lane Description	Mainline: lane 1		**Certified Operator**	Yes
			Additional Information	Corrective Work Measured 07/20/2018

Stationing	**Section 1**	**Section 2**	**Section 3**
Beginning	+		
End	85+00		

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	25
ALR ≥ 225.0 (linear ft)	5

	Beginning Station	**End Station**	**Segment Length (ft)**	**Final Smoothness (in/mi)**	**Segment Pay Adjustment**	
S1	+	5+28	528	45.0	$80.00	S1
↓	5+28	10+56	528	42.0	$128.00	↓
↓	10+56	15+84	528	65.0	-$240.00	↓
↓	15+84	21+12	528	75.0	-$400.00	↓
↓	21+12	26+40	528	42.0	$128.00	↓
↓	26+40	31+68	528	38.0	$192.00	↓
↓	31+68	36+96	528	55.0	-$80.00	↓
↓	36+96	42+24	528	49.0	$16.00	↓
↓	42+24	47+52	528	35.0	$240.00	↓
↓	47+52	52+80	528	35.0	$240.00	↓
↓	52+80	58+08	528	40.0	$160.00	↓
↓	58+08	63+36	528	45.0	$80.00	↓
↓	63+36	68+64	528	65.0	-$240.00	↓
↓	68+64	73+92	528	51.0	-$16.00	↓
↓	73+92	79+20	528	50.3	-$4.80	↓
↓	79+20	84+48	528	42.0	$128.00	↓
↓	84+48	85+00	52	43.0	$11.03	↓

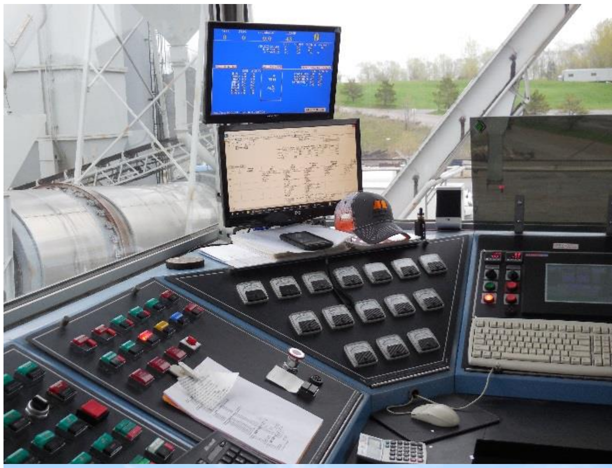
Total Pay Adjustment	**$422.23**
Areas of Localized Roughness Deduction	**-$1,250.00**
Total Pay Adjustment + Areas of Localized Roughness Deduction	**-$827.77**

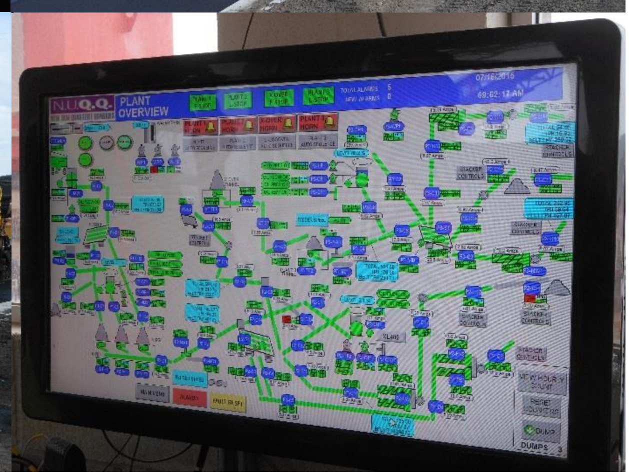
Data Entered By			**Data Checked By**	
Signature			**Signature**	

Figure 700.16 – Example Bituminous Profile Summary after Corrective Work has been completed.

DEPARTMENT OF TRANSPORTATION

Appendix





A-1 Mixture Design Submittal Packet

The following is an example of a Mixture Design Submittal Packet. These forms must be included when submitting a Trial Mix Design.

For Agency Use Only
Mix Design # ____
Date Received ____
Time Received ____
Received By ____

Mix Design Submittal Form

Contractor/Company Name		Date Submitted	
Project Number		Specification Year	
Submitter		Submitter's Contact Person	
Submitter's Phone		Submitter's FAX#	
Plant Name		Plant Number	

Mix Designation(s) Requested: ____

This submittal will replace Mix Design Report (MDR) Number(s) (Where Applicable) ____

Representative's Signature ____
(Level 2 Bituminous Plant Certification required for signiture here. Include Tech ID#)

Submit to : Mix Design Specialist
Phone #: ____
Fax #: ____

Note : Mix Design shall be submitted to the District Laboratory in the District where the project is located. Send Metro District designs to the Central Laboratory at Maplewood.

MD#

Date Mixed

Job Mix Formula

Mix Designation (s)

	Aggregate : Pit or Source Name	Agg Information Product	Class	Location (Including Pit # or Legal Description)	% Proportion
1					
2					
3					
4					
5					
6					
RAP					
				Total % =	

	1	2	3	4	5	6	**RAP**	Composite		For Agency Use Only
% Proportion								Virgin	Total	
	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	
Sieve										
1 1/2										
1										
3/4										
1/2										
3/8										
#4										
#8										
#16										
#30										
#50										
#100										
#200										

+4 Gsb									
For Agency Use								Virgin	Total
-4 Gsb									
For Agency Use									
Total									
For Agency Use									
% H_2O Absorption									

For Agency Use

% +4 Crushing	1 Face		2 Face	
% Calculated -4 Crushing			or FAA	
AFT			RAP FAA	

AC Content

1) Extracted AC Content from Recycled Asphalt Pavement (Avg. of at least 3 tests) ______ New AC Total AC
2) Mix Design AC Info **Source =** ______ **PG =** ______ G_{b} = ______
Compaction Temperatures **Max in Lab =** ______ **Max in Field =** ______
3) Percent Optimum Asphalt Content (New Asphalt) ______ %
4) Percent Asphalt Content in Total Mixture [(# 1x %Rap used)+ # 3] ______ %
5) Effective Asphalt Content in Total Mixture ______
6) Fines/Effective AC Ratio (%Passing the #200 sieve/# 5) ______
7) Does This Mixture Contain Anti-Strip? (Yes or No) ______

Mix Designation (s) __________ Date __________

Point No. ____ (Opt. Pt.) New % A.C. : ____ Total% A.C. : ____

Gyratory Bulk Specific Gravity Information

						Avg Gmb's	Density
	No. Max Gyrations :						
Gyratory ID							
Height @ Initial		=					
Height @ Design		=					
Height @ Max		=					
Dry Weight		A					
SSD Weight		B					
Imm. Weight		C					
Volume	(B-C)	D					
Gmb Measured	(A/D)	E					
Estimated Vmx @ Initial	(17.6715 x Ht @ Initial)						
Estimated Vmx @ Design	(17.6715 x Ht @ Design)						
Estimated Vmx @ Max	(17.6715 x Ht @ Max)						
Estimated Gmb @ Initial	(A/Vmx @ Initial)						
Estimated Gmb @ Design	(A/Vmx @ Design)						
Estimated Gmb @ Max	(A/Vmx @ Max)						
Correction Factor	(E/Est Gmb @Max)						
Corrected Gmb @ Initial	Est Gmb x Corr. Factor						
Corrected Gmb @ Design	Est Gmb x Corr. Factor						
Corrected Gmb @ Max	Est Gmb x Corr. Factor						

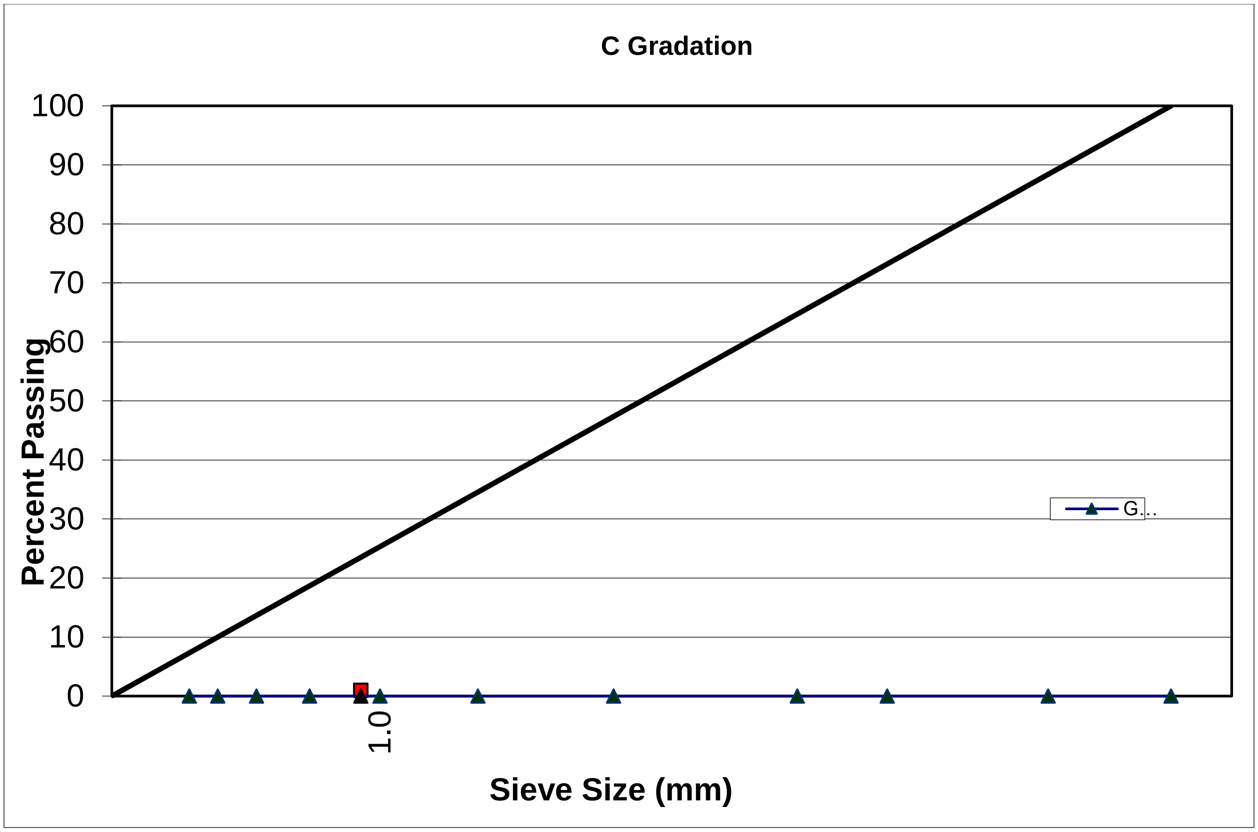
Max Gravity Information

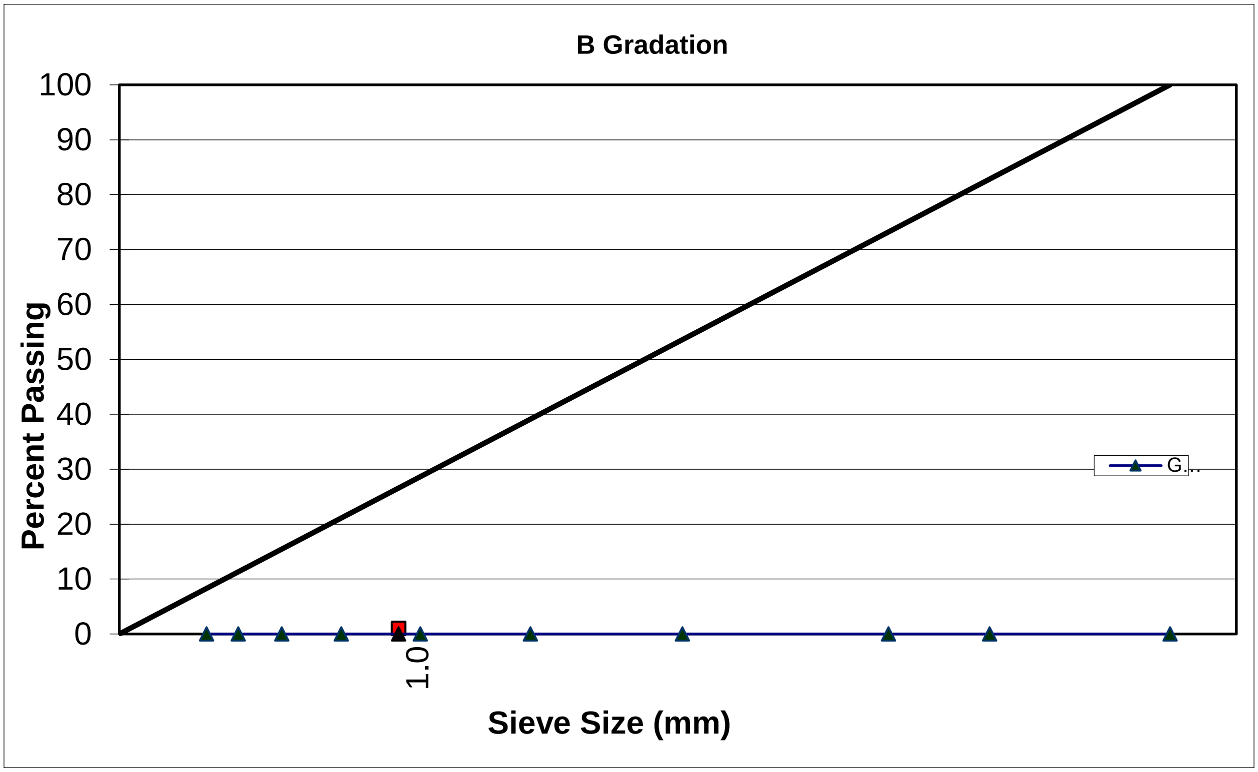
					Avg
Cont. ID					
Cont. Dry		k			
Cont. Imm.		l			
Cont.+Sample Dry		m			
Sample Dry	(M-K)	n			
Cont.+Sample Imm.		o			
Sa Imm.	(O-L)	p			
Sa Volume	(N-P)	q			
Max. Sp. G.	(N/Q)	r			
Corrected Max Spg		T			

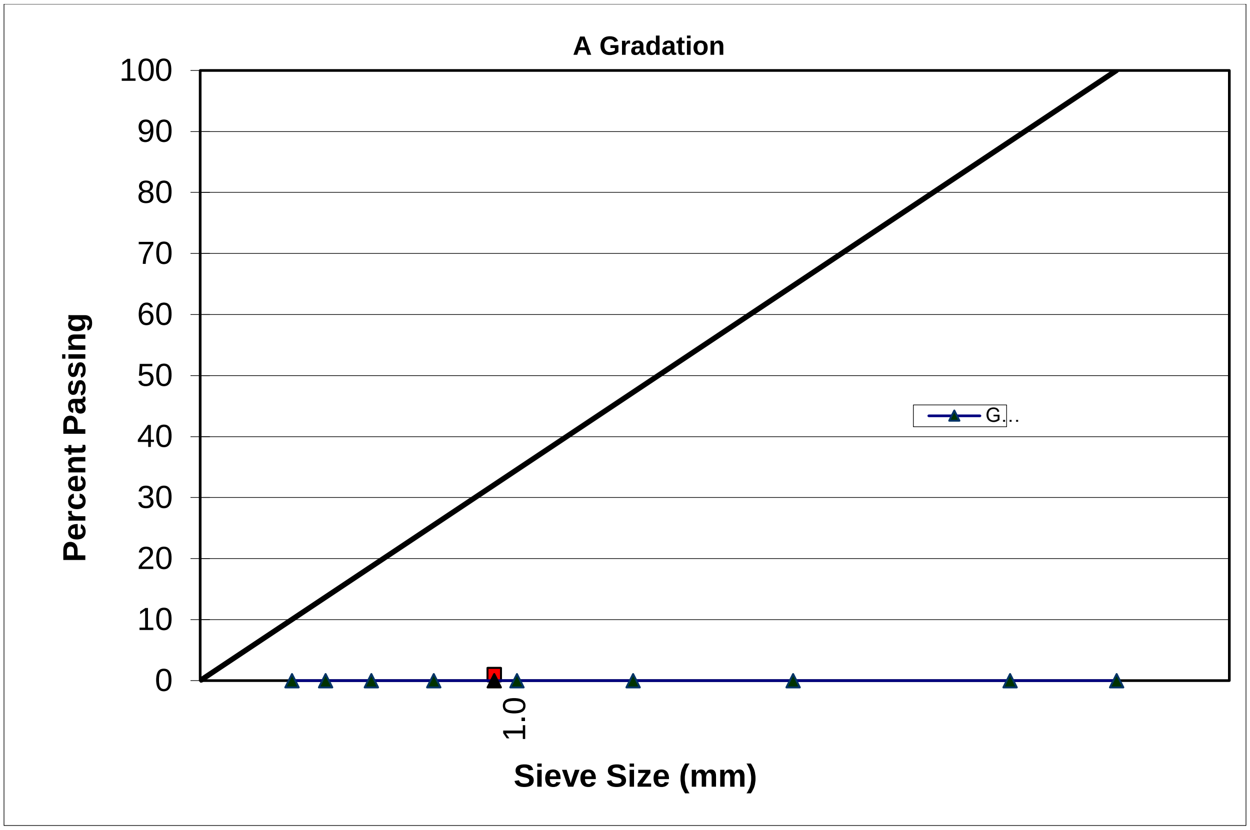
Air Void and % Gmm Information

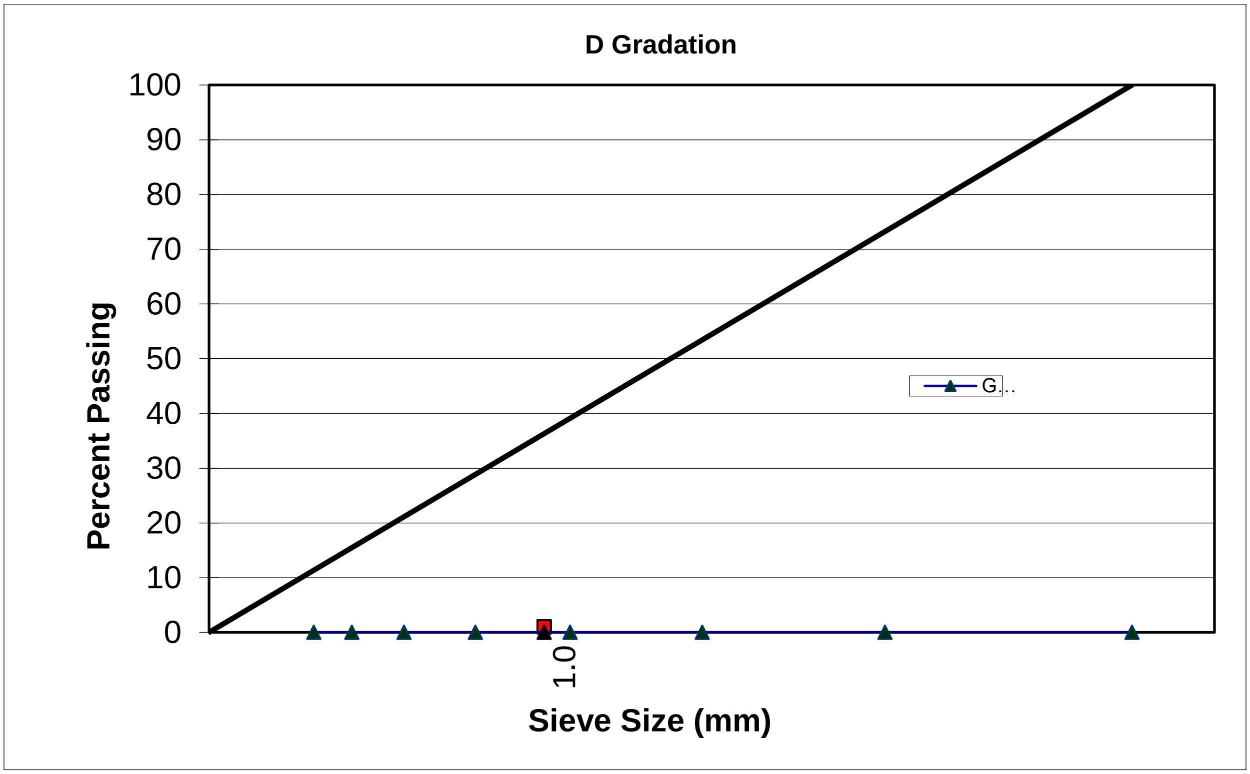
			Avg Va's	Avg %Gmm's
Gyratory ID				
Va @ Initial				
Va @ Design				
Va @ Max				
Corrected Va @ Design	100((T-E)/T)	U		

Tested By : __________


C Gradation
100
90
80
70
60
50
40
30
20
10
0
Percent Passing
G...
1.0
Sieve Size (mm)


B Gradation
100
90
80
70
60
50
40
30
20
10
0
Percent Passing
G...
1.0
Sieve Size (mm)


A Gradation
Percent Passing
100
90
80
70
60
50
40
30
20
10
0
1.0
G...
Sieve Size (mm)


D Gradation
Percent Passing
100
90
80
70
60
50
40
30
20
10
0
1.0
G...
Sieve Size (mm)

Date ____________ MD # ____________

Corrected Maximum Specific Gravity Worksheet

Point #		1	2	3	4
% New Asphalt	(A)				
G_b of NEW AC	(B)				
% RAP In Mix	(C)				
% Asphalt in RAP	(D)				

Actual Gmm - Test 1				
Actual Gmm - Test 2				
Actual Avg.Gmm				
Actual Avg.Gmb				

Note : %Total AC includes the %Asphalt in RAP

% TOTAL AC	(E)				

Composite AC G_b (RAP Mixture Formula) = ((A / E * B) + (((C / 100) * D) / E * 1.035))))

(Virgin Mixture Formula) = A / E * B

Composite AC G_b				

Effective Specific Gravity =

$$\frac{100-\%AC}{\frac{100}{Avg.Gmm} - \frac{\%\ Total\ AC}{Composite\ AC\ Gb}}$$

EFFECTIVE SP.G.				

AVG. EFFECTIVE SP.G ____________

Corrected Gmm				
Voids (Corrected)				

Void in Mineral Aggregate Information

Gmb = Avg. Bulk of Marshall Specimens @ each % AC
(From Trial Mix Worksheet)
Ps = Percent of aggregate by total weight of mix
(100 - %AC)
Gsb = Bulk Specific Gravity of total aggregate

Method used : AASHTO [x]

VMA = 100-((Gmb * Ps) / Gsb)

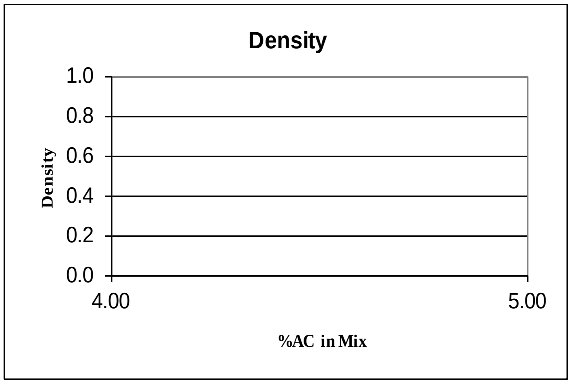
VFA = (100 * (VMA - Air Voids)) / VMA

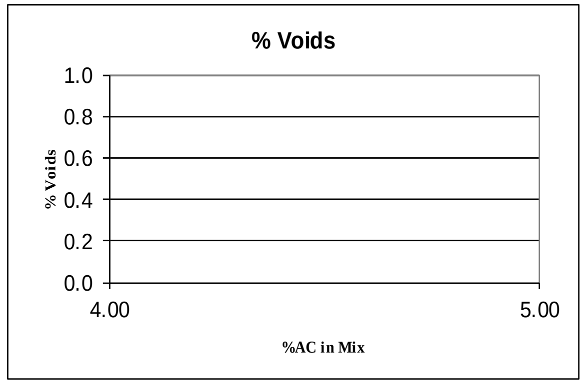
Point	1	2	3	4
Total % AC				
VMA @ each % AC				
VFA @ each % AC				
ines/Effective AC Ratio				

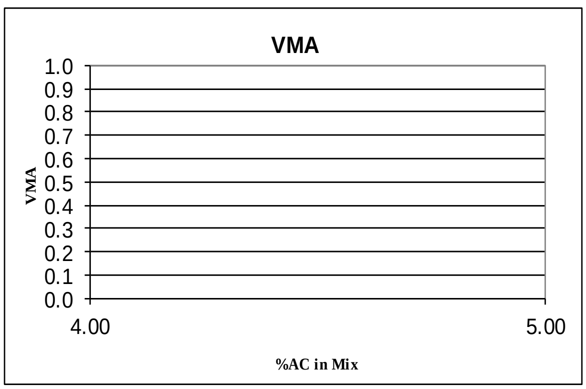
Pba=
Pbe=

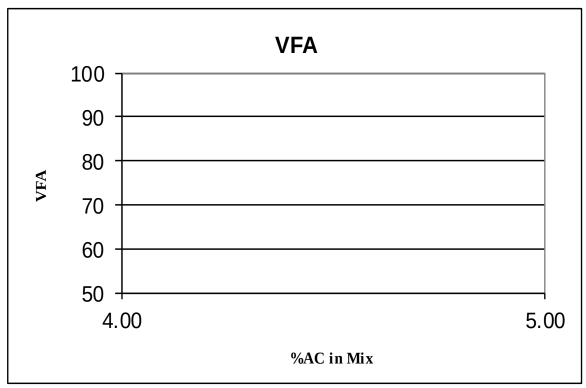
Mix Graph Information

Point	% AC in Mix	Density	%Voids	VFA	VMA	Stability	Flow
1							
2							
3							
4							









GYRATORY LOTTMAN TEST WORKSHEET

PROJ. # ______ DATE: ______
SPEC. # ______ TYPE: ______ Height : ______ mm

RMKS: ______

			TREATED SPECIMENS			UNTREATED SPECIMENS		
SAMPLE I.D.								
Diameter (inches)		A						
Thickness (inches)		B						
DRY WT.		C						
SSD WT.		D						
WT. IN H2O		E						
VOLUME	D-E	F			AVG.			AVG.
BULK SP.G.	C/F	G						
MAX. SP.G.		H						
% VOIDS	100*[(H-G)/H]	I						
VOLUME VOIDS	I * (F/100)	J						
LOAD, LBS.		K						

SATURATED FOR: ______ MIN. @ ______ IN. Hg.

SSD WT.		L			
WT. IN H2O		M			
VOLUME	L - M	N			
ABS. VOL. H2O	L - C	O			AVG.
% SATURATION	100 * (O/J)				
% SWELL	100 * [(N-F)/F]				

CONDITIONED 24 HRS. IN 140 DEG. F WATER

Diameter (inches)		P							
Thickness (inches)		Q							
SSD WT.		R							
WT. IN H2O		S							
VOLUME	R - S	T							
ABS. VOL. H2O	R - C	U			AVG.				
% SATURATION	100 * (U/J)								
% SWELL	100 * [(T-F)/F]								
LOAD LBS.		V							AVG.
DRY STRENGTH	(2*K)/(B*A*Pi)	W							
WET STRENGTH	(2*V)/(Q*P*Pi)	Y							
T.S.R.	**100 * (Y/W[1])**								
EST. % STRIPPING									
EST. % BROKEN AGG.									

[1]Note : Use the Average value in the calculations.

COMMENTS: ______

TESTED BY : ______

FAA & CAA Test

Mix Type	
Date Tested	

FAA Test

Ave Specific Gravity		
Volume of Cylinder		
Tare WT of Cylinder		
WT of Cylinder & Agg	run 1	
	run 2	

FAA Results run 1	
FAA Results run 2	
FAA Avg of 1 & 2	

CAA TEST

	One Faced	Two Faced
WT of Crushed		
Total WT		
% +4 Crushed		

Technician: ____________________

Flat & Elongated Particles in Coarse Aggregate Worksheet

(ASTM D-4791)

Sieve Sizes		Original % Retained (A)	Mass Tested (g) (D)	Mass Failing (g) (C)	% Flat & Elongated Wt. Average
37.5mm	(1 1/2")				
25.0mm	(1")				
19.0mm	(3/4")				
12.5mm	(1/2")				
9.5mm	(3/8")				
Total % Retained (B)					

SPECIFIC GRAVITY WORKSHEET

Coarse Aggregate Source # ______

Material Name ______

Date ______
Source ______
Tested by ______

Sample #	#1	#2	#3	Average
Dry Wt.(pan + sample)				
Pan Tare Wt.				
SSD Wt.				
Immersed Wt.				
Oven Dry Wt.				
Absorption				
Water Displaced (Appar.)				
Water Displaced (Bulk)				
% Absorption				
Sp. Grav. (Appar.) Gsa				
Sp. Grav. (Bulk) Gsb				

Fine Aggregate Source # ______

Type of Material ______

Date ______
Source ______
Tested by ______

Sample #	#1	#2	#3	Average
Dry Wt.(pan + sample)				
Pan Tare Wt.				
Flask + Water (gm)				
Flask + Water + Material (gm)				
SSD + Tare (gm)				
Flask Tare (gm)				
Oven Dried (gm)				
Surface dried (SSD)				
Absorption				
% Absorption				
Apparent Specific Gravity Gsa				
Bulk Specific Gravity (SSD)				
Sp. Grav. (Bulk) Gsb				

Percent Passing #4 Sieve	
COMBINED SP.G. for SOURCE 1	

ADJUSTED ASPHALT FILM THICKNESS (AFT) CALCULATION
and Fines /Effective AC

					% Passing	Multiplication	
(Mix)Gsb=							
% AC(Pb)=				#4 =		0.02	
Gmm=				#8 =		0.04	
AC SpG=				#16 =		0.08	
Gsb (-4)		Gse=		#30 =		0.14	
Stone(Ps)=				#50 =		0.30	
		Pba=		#100 =		0.60	
				#200 =		1.60	
		Pbe=					

Surface area (SA) =		SF/lb
lj. Surface area (SA) =		SF/lb
Fines/Effective AC(F/Pbe) =		ratio
Asphalt Film Thickness (AFT) =		microns
Adjusted AFT =		**microns**

Guideline notes based on Bituminous Office Consultation

* Use Combined Mix Aggregate for Gsb
* %AC Must be Tenth ex.(5.4)
* Gmm Must be to Thousandth ex.(2.497)
* AC SpG Must be to Thousandth ex.(1.030)
* % Stone will Calculate to Tenth ex.(94.6)
* Gse Calculates to Thousandth ex.(2.718)
* Pba is a mid-step calculation.(not rounded)
* Pbe Calculates to Tenth ex.(4.5)
* % Passing Sieves must be entered to Whole Number ex.(66)
* % Passing #200 sieve must be entered to Tenth ex.(3.6)
* Surface Area (SA) Calculates to Tenth ex.(27.8)
* Asphalt Film Thickness (AFT) is Calculated to Tenth ex.(8.3)
*Fines to Effective % AC is calculated to the tenth ex.(0.9)

A-2 Example Mix Design Report

DEPARTMENT OF TRANSPORTATION

BITUMINOUS PLANT MIX DESIGN REPORT

Test District
123 Sesame Street
Lake Wobegon, MN 98765
Phone: 234-567-8901
Fax: 987-654-3210

 # TS-2018-100
Date: 12/3/2018

SPEC	**2360 AFT**
SPEC YEAR	**2018**
MIX TYPE	SPWEB440(R)
AC GRADE	PER PROPOSAL

THIS MIX DESIGN REPORT IS NOT VALID UNTIL PLANT NO. INDICATED BELOW IS CERTIFIED.

ENGINEER	**FOR**
PROJECT NUMBER	
CONTRACTOR SIGN.	

THIS MIXTURE HAS BEEN REVIEWED FOR VOLUMETRIC PROPERTIES ONLY, IT DOES NOT ASSURE THAT FIELD PLACEMENT AND COMPACTION REQUIREMENTS HAVE BEEN MET.

PLANT NO. **909901** - JOB MIX FORMULA

Begin With Test Number

SP	**WE**	**409**
- -	- -	- - -

AFT Properties

Pbe	5.1
SA	26.2
Adj. AFT	9.9

Sieve Size (mm) (in.)	Composite Formula	Broad Band			For Information Only Virgin Formula (PER PASSING)
25.0 (1)			–		
19.0 (3/4)	100	100	–	100	
12.5 (1/2)	94	85	–	100	
9.5 (3/8)	85	35	–	90	
4.75 (#4)	74	30	–	80	
2.36 (#8)	56	25	–	65	
1.18 (#16)	41		–		
0.600 (#30)	27		–		
0.300 (#50)	14		–		
0.150 (#100)	6		–		
0.075 (#200)	3.5	2.0	–	7.0	
Spec. Voids	4.0	3.0	–	5.0	%AC (NEW) 4.1
% AC	5.4 (TOTAL)	5.0			

TM # TS-2018-118 Indicates a Gyratory Density of 148.9 (lbs/ft3) at 90 Design Gyrations
Use of anti-strip required: No

%	Pit	Source of Material	Total Sp. G	Minus #4 % Passing	Minus #4 Sp. G
20 %	12345	MAPLEWOOD GRANITE 1/2	2.672	22 %	2.672
25 %	92030	CMI 3/4 ROCK	2.704	5 %	2.704
20 %	12345	MAPLEWOOD GRANITE 3/8	2.682	33 %	2.682
10 %	67001	N. CON AGG WASH SAND	2.653	100 %	2.653
25 %	RAP	PLANT RAP	2.654	68 %	2.654
0 %	45645	MAPLEWOOD GRANITE SAND	2.622	98 %	2.622
0 %	55555	MAPLEWOOD SCREENED SAND	2.655	96 %	2.655
%				%	
		Mix Aggregate Specific Gravity at the Listed Percentages =	**2.675**		**2.662**

This Mix Design Report supersedes MDR # TS-2016-199 Dated: 5/15/2018

Remarks: PER JMF 12/1/2018

Mix Design Reviewed by:

Deb Evans

Mix Design Specialist

TS-2018-100 Ver. 1

cc:
Contractor - HARD WORKING PAVING #1

A-3 Tank Volumes and Temperature Correction Factors

The temperature correction factor is used to adjust gallons of bituminous material at any temperature to gallons at 60° F. The volume at the observed temperature is simply multiplied by the corresponding correction factor.

A series of tables with the necessary correction factors is shown below. It is important to use the correct Temperature –Volume Table for the application. The Tables shown are as follows:

Table A: Quantities for Various Depths of Cylindrical Tanks in the Horizontal Position

Table B: Temperature – Volume correction factors for Group 0, weight per gallon over 8.046.

Table C: Temperature – Volume correction factors for Group 1, weight per gallon 7.081 to 8.046.

Table D: Temperature – Volume correction factors for Asphalt Emulsion.

Table A

Quantities for Various Depths of Cylindrical Tanks in the Horizontal Position

Percent Depth Filled	Percent of Capacity	Percent Depth Filled	Percent of Capacity	Percent Depth Filled	Percent of Capacity	Percent Depth Filled	Percent of Capacity
1	0.20	26	20.73	51	51.27	76	81.50
2	0.50	27	21.86	52	52.55	77	82.60
3	0.90	28	23.00	53	53.81	78	83.68
4	1.34	29	24.07	54	55.08	79	84.74
5	1.87	30	25.31	55	56.34	80	85.77
6	2.45	31	26.48	56	57.60	81	86.77
7	3.07	32	27.66	57	58.86	82	87.76
8	3.74	33	28.84	58	60.11	83	88.73
9	4.45	34	30.03	59	61.36	84	89.68
10	5.20	35	31.19	60	62.61	85	90.60
11	5.98	36	32.44	61	63.86	86	91.50
12	6.80	37	33.66	62	65.10	87	92.36
13	7.64	38	34.90	63	66.34	88	93.20
14	8.50	39	36.14	64	67.56	89	94.02
15	9.40	40	37.39	65	68.81	90	94.80
16	10.32	41	38.64	66	69.97	91	95.55
17	11.27	42	39.89	67	71.16	92	92.26
18	12.24	43	41.14	68	72.34	93	96.93
19	13.23	44	42.40	69	73.52	94	97.55
20	14.23	45	43.66	70	74.69	95	98.13
21	15.26	46	44.92	71	75.93	96	98.66
22	16.32	47	46.19	72	77.00	97	99.10
23	17.40	48	47.45	73	78.14	98	99.50
24	18.50	49	48.73	74	79.27	99	99.80
25	19.61	50	50.00	75	80.39	100	

Full capacity of a horizontal storage tank:

$$V = \frac{0.7854 \times D^2 \times L}{231}$$

Where:

V = Tank Volume (U.S. Gallons)
D = Tank Diameter (inches)
L = Length of Tank Interior (inches)

231 = Constant to convert from cubic inches to U.S. gallons

Note: The formula for direct computation of volume when the tank is less than half full is shown below. When more than half full, compute the full capacity of the tank as noted above, then compute the partially filled volume as shown below (in this case, the partially filled volume represents the unfilled portion of a tank that is more than half full). Deduct the unfilled volume from the total volume of the tank to determine the volume of the filled portion.

First, compute θ:

$$\cos\theta = \frac{d}{R} = \frac{R-h}{R}$$

Where:

θ = The angle where the interior tank radius meets the surface of the liquid at the edge of the tank (see Figure A-1)
R = Radius of tank interior (inches)
h = Depth of liquid (inches)
d = R-h (inches)

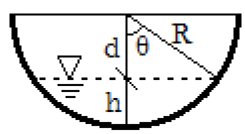


Figure A-1 – Diagram of horizontal storage tank.

Next, find the filled area, A:

$$A = \frac{\pi R^2 \theta}{180^{\circ}} - R\sin\theta\, d$$

Where:

A = Cross section area of filled portion of rank (sq. in.)
D = Diameter of tank interior (inches)
L = Length of tank interior (inches)

Finally, find the filled volume, V_f:

$$V_f = \frac{L \times A}{231}$$

Where:

V_f = Volume of the filled portion of the tank (U.S. gallons)
231 = Constant to convert from cubic inches to U.S. gallons

Note: The volume occupied by any piping, fittings or other material inside the tank must be deducted from the volume computed by use of the table or formula.

Volumes of elliptical shaped tanks, irregular shaped tanks, and tanks with large heating coils or flues may be calibrated by filling the tank with fuel oil through a metering pump, and calibrating a measuring stick to match the metering pump.

The tank should be calibrated in small enough increments to ensure an accurate calibration and minimize the error in measuring quantities.

Table B

Temperature-Volume Correction Table: Group 0
Asphalt Cement, Cut-back Asphalts, and Road Oil over 8.046 lbs. per gallon

°F	Factor	°F	Factor	°F	Factor	°F	Factor
50	1.0035	90	0.9896	130	0.9758	170	0.9621
51	1.0031	91	0.9892	131	0.9754	171	0.9618
52	1.0028	92	0.9889	132	0.9751	172	0.9614
53	1.0024	93	0.9885	133	0.9747	173	0.9611
54	1.0021	94	0.9882	134	0.9744	174	0.9607
55	1.0017	95	0.9878	135	0.9740	175	0.9604
56	1.0014	96	0.9875	136	0.9737	176	0.9601
57	1.0010	97	0.9871	137	0.9734	177	0.9597
58	1.0007	98	0.9868	138	0.9730	178	0.9594
59	1.0003	99	0.9864	139	0.9727	179	0.9590
60	1.0000	100	0.9861	140	0.9723	180	0.9587
61	0.9997	101	0.9857	141	0.9720	181	0.9584
62	0.9993	102	0.9854	142	0.9716	182	0.9580
63	0.9990	103	0.9851	143	0.9713	183	0.9577
64	0.9986	104	0.9847	144	0.9710	184	0.9574
65	0.9983	105	0.9844	145	0.9706	185	0.9570
66	0.9979	106	0.9840	146	0.9703	186	0.9567
67	0.9976	107	0.9837	147	0.9699	187	0.9563
68	0.9972	108	0.9833	148	0.9696	188	0.9560
69	0.9969	109	0.9830	149	0.9693	189	0.9557
70	0.9965	110	0.9826	150	0.9689	190	0.9553
71	0.9962	111	0.9823	151	0.9686	191	0.9550
72	0.9958	112	0.9819	152	0.9682	192	0.9547
73	0.9955	113	0.9816	153	0.9679	193	0.9543
74	0.9951	114	0.9813	154	0.9675	194	0.9540
75	0.9948	115	0.9809	155	0.9672	195	0.9536
76	0.9944	116	0.9806	156	0.9669	196	0.9533
77	0.9941	117	0.9802	157	0.9665	197	0.9530
78	0.9937	118	0.9799	158	0.9662	198	0.9526
79	0.9934	119	0.9795	159	0.9658	199	0.9523
80	0.9930	120	0.9792	160	0.9655	200	0.9520
81	0.9927	121	0.9788	161	0.9652	201	0.9516
82	0.9923	122	0.9785	162	0.9648	202	0.9513
83	0.9920	123	0.9782	163	0.9645	203	0.9509
84	0.9916	124	0.9778	164	0.9641	204	0.9506
85	0.9913	125	0.9775	165	0.9638	205	0.9503
86	0.9909	126	0.9771	166	0.9635	206	0.9499
87	0.9906	127	0.9768	167	0.9631	207	0.9496
88	0.9902	128	0.9764	168	0.9628	208	0.9493
89	0.9899	129	0.9761	169	0.9624	209	0.9489

Table B (cont'd)

°F	Factor	°F	Factor	°F	Factor	°F	Factor
210	0.9486	250	0.9352	290	0.9220	330	0.9089
211	0.9483	251	0.9349	291	0.9217	331	0.9086
212	0.9479	252	0.9346	292	0.9213	332	0.9083
213	0.9476	253	0.9342	293	0.9210	333	0.9079
214	0.9472	254	0.9339	294	0.9207	334	0.9076
215	0.9469	255	0.9336	295	0.9204	335	0.9073
216	0.9466	256	0.9332	296	0.9200	336	0.9070
217	0.9462	257	0.9329	297	0.9197	337	0.9066
218	0.9459	258	0.9326	298	0.9194	338	0.9060
219	0.9456	259	0.9322	299	0.9190	339	0.9060
220	0.9452	260	0.9319	300	0.9187	340	0.9057
221	0.9449	261	0.9316	301	0.9184	341	0.9053
222	0.9446	262	0.9312	302	0.9181	342	0.9050
223	0.9442	263	0.9309	303	0.9177	343	0.9047
224	0.9439	264	0.9306	304	0.9174	344	0.9044
225	0.9436	265	0.9302	305	0.9171	345	0.9040
226	0.9432	266	0.9299	306	0.9167	346	0.9037
227	0.9429	267	0.9296	307	0.9164	347	9.0340
228	0.9426	268	0.9293	308	0.9161	348	0.9031
229	0.9422	269	0.9289	309	0.9158	349	0.9028
230	0.9419	270	0.9286	310	0.9154	350	0.9024
231	0.9416	271	0.9283	311	0.9151	351	0.9021
232	0.9412	272	0.9279	312	0.9148	352	0.9018
233	0.9409	273	0.9276	313	9.1450	353	0.9015
234	0.9405	274	0.9273	314	0.9141	354	0.9011
235	0.9402	275	0.9269	315	0.9138	355	0.9008
236	0.9399	276	0.9266	316	0.9135	356	0.9005
237	0.9395	277	0.9263	317	0.9132	357	0.9002
238	0.9392	278	0.9259	318	0.9128	358	0.8998
239	0.9389	279	0.9256	319	0.9125	359	0.8995
240	0.9385	280	0.9253	320	0.9122	360	0.8992
241	0.9382	281	0.9250	321	0.9118	361	0.8989
242	0.9379	282	0.9246	322	0.9115	362	0.8986
243	0.9375	283	0.9243	323	0.9112	363	0.8982
244	0.9372	284	0.9240	324	0.9109	364	0.8979
245	0.9369	285	0.9236	325	0.9105	365	0.8976
246	0.9365	286	0.9233	326	0.9102	366	0.8973
247	0.9362	287	0.9230	327	0.9099	367	0.8969
248	0.9359	288	0.9227	328	0.9096	368	0.8966
249	0.9356	289	0.9223	329	0.9092	369	0.8963

Table C

Temperature-Volume Correction Table: Group 1

Cut-back Asphalts and Road Oils from 7.081 to 8.046 lbs. per gallon

°F	Factor	°F	Factor	°F	Factor	°F	Factor
50	1.0040	90	0.9881	130	0.9725	170	0.9570
51	1.0032	91	0.9877	131	0.9721	171	0.9566
52	1.0032	92	0.9873	132	0.9717	172	0.9562
53	1.0028	93	0.9869	133	0.9713	173	0.9559
54	1.0024	94	0.9865	134	0.9709	174	0.9555
55	1.0020	95	0.9861	135	0.9705	175	0.9551
56	1.0016	96	0.9857	136	0.9701	176	0.9547
57	1.0012	97	0.9854	137	0.9697	177	0.9543
58	1.0008	98	0.9850	138	0.9693	178	0.9539
59	1.0004	99	0.9846	139	0.9690	179	0.9536
60	1.0000	100	0.9842	140	0.9686	180	0.9532
61	0.9996	101	0.9838	141	0.9682	181	0.9528
62	0.9992	102	0.9834	142	0.9678	182	0.9524
63	0.9988	103	0.9830	143	0.9674	183	0.9520
64	0.9984	104	0.9826	144	0.9670	184	0.9517
65	0.9980	105	0.9822	145	0.9666	185	0.9513
66	0.9976	106	0.9818	146	0.9662	186	0.9509
67	0.9972	107	0.9814	147	0.9659	187	0.9505
68	0.9968	108	0.9810	148	0.9655	188	0.9501
69	0.9964	109	0.9806	149	0.9651	189	0.9498
70	0.9960	110	0.9803	150	0.9647	190	0.9494
71	0.9956	111	0.9799	151	0.9643	191	0.9490
72	0.9952	112	0.9795	152	0.9639	192	0.9486
73	0.9948	113	0.9791	153	0.9635	193	0.9482
74	0.9944	114	0.9787	154	0.9632	194	0.9478
75	0.9940	115	0.9783	155	0.9628	195	0.9475
76	0.9936	116	0.9779	156	0.9624	196	0.9471
77	0.9932	117	0.9775	157	0.9620	197	0.9467
78	0.9929	118	0.9771	158	0.9616	198	0.9463
79	0.9925	119	0.9767	159	0.9612	199	0.9460
80	0.9921	120	0.9763	160	0.9609	200	0.9456
81	0.9917	121	0.9760	161	0.9605	201	0.9452
82	0.9913	122	0.9756	162	0.9601	202	0.9448
83	0.9909	123	9.7520	163	0.9597	203	0.9444
84	0.9905	124	0.9748	164	0.9593	204	0.9441
85	0.9901	125	0.9744	165	0.9589	205	0.9437
86	0.9897	126	0.9740	166	0.9585	206	0.9433
87	0.9893	127	0.9736	167	0.9582	207	0.9429
88	0.9889	128	0.9732	168	0.9578	208	0.9425
89	0.9885	129	0.9728	169	0.9574	209	0.9422

Table C (cont'd)

°F	Factor	°F	Factor	°F	Factor	°F	Factor
210	0.9418	245	0.9286	280	0.9157	315	0.9029
211	0.9414	246	0.9283	281	0.9153	316	0.9025
212	0.9410	247	0.9279	282	0.9149	317	0.9021
213	0.9407	248	0.9275	283	0.9146	318	0.9018
214	0.9403	249	0.9272	284	0.9142	319	0.9014
215	0.9399	250	0.9268	285	0.9138	320	0.9010
216	0.9395	251	0.9264	286	0.9135	321	0.9007
217	0.9391	252	0.9260	287	0.9131	322	0.9003
218	0.9388	253	9.2570	288	0.9127	323	0.9000
219	0.9384	254	0.9253	289	0.9124	324	0.8996
220	0.9380	255	0.9249	290	0.9120	325	0.8992
221	0.9376	256	9.2450	291	0.9116	326	0.8989
222	0.9369	257	0.9242	292	0.9113	327	0.8985
223	0.9369	258	0.9238	293	0.9109	328	0.8981
224	0.9365	259	0.9234	294	0.9105	329	0.8978
225	0.9361	260	0.9231	295	0.9102	330	0.8960
226	0.9358	261	0.9227	296	0.9098	331	0.8971
227	0.9354	262	0.9223	297	0.9094	332	0.8967
228	0.9650	263	0.9219	298	0.9091	333	0.8963
229	0.9346	264	0.9216	299	0.9087	334	0.8960
230	0.9343	265	0.9212	300	0.9083	335	0.8956
231	0.9339	266	0.9208	301	0.9080	336	0.8952
232	0.9335	267	0.9205	302	0.9076	337	0.8949
233	0.9331	268	0.9201	303	0.9072	338	0.8945
234	0.9328	269	0.9197	304	0.9069	339	0.8942
235	0.9324	270	0.9194	305	0.9065	340	0.8938
236	0.9320	271	0.9190	306	0.9061	341	0.8934
237	0.9316	272	0.9186	307	0.9058	342	0.8931
238	0.9313	273	0.9182	308	0.9054	343	0.8927
239	0.9309	274	0.9179	309	0.9050	344	0.8924
240	0.9305	275	0.9175	310	0.9047	345	0.8920
241	0.9301	276	0.9171	311	0.9043	346	0.8916
242	0.9298	277	0.9168	312	0.9039	347	0.8913
243	0.9294	278	0.9164	313	0.9036	348	0.8909
244	0.9290	279	0.9160	314	0.9032	349	0.8906

Table D

Temperature-Volume Correction Table
Asphalt Emulsion (Anionic & Cationic)

°F	Factor	°F	Factor	°F	Factor	°F	Factor
40	1.00500	77	0.99575	114	0.98650	151	0.97725
41	1.00480	78	0.99550	115	1.98625	152	0.97700
42	1.00450	79	0.99525	116	0.98600	153	0.97675
43	1.00430	80	0.99500	117	0.98575	154	0.97650
44	1.00400	81	0.99475	118	0.98550	155	0.97625
45	1.00380	82	0.99450	119	0.98525	156	0.97600
46	1.00350	83	0.99425	120	0.98500	157	0.97575
47	1.00330	84	0.99400	121	0.98475	158	0.97550
48	1.00300	85	0.99375	122	0.98450	159	0.97525
49	1.00280	86	0.99350	123	0.98400	160	0.97500
50	1.00250	87	0.99325	124	0.98400	161	0.97475
51	1.00225	88	0.99300	125	0.98375	162	0.97450
52	1.00150	89	0.99275	126	0.98350	164	0.97400
53	1.00175	90	0.99250	127	0.98325	164	0.97400
54	1.00150	91	0.99225	128	0.98300	165	0.97375
55	1.00125	93	0.99200	129	0.98275	166	0.97350
56	1.00100	93	0.99175	130	0.98250	167	0.97325
57	1.00075	94	0.99150	131	0.98225	168	0.97300
58	1.00050	95	0.99125	132	0.98200	169	0.97275
59	1.00025	96	0.99100	133	0.98175	170	0.97250
60	1.00000	97	0.99075	134	0.98150	171	0.97225
61	0.99975	98	0.99050	135	0.98125	172	0.97200
62	0.99950	99	0.99025	136	0.98100	173	0.97175
63	0.99925	100	0.99000	137	0.98075	174	0.97150
64	0.99900	101	0.98975	138	0.98050	175	0.97125
65	0.99875	102	0.98950	139	0.98025	176	0.97100
66	0.99850	103	0.98925	140	0.98000	177	0.97075
67	0.99825	104	0.98900	141	0.97975	178	0.97050
68	0.99800	105	0.98875	142	0.97950	179	0.97025
69	0.99775	106	0.98850	143	0.97925	180	0.97000
70	0.99750	107	0.98825	144	0.97900	181	0.96975
71	0.99725	108	0.98800	145	0.97875	182	1.96950
72	0.99700	109	0.98775	146	0.97850	183	0.96925
73	0.99675	110	0.98750	147	0.97825	184	0.96900
74	0.99650	111	0.98725	148	0.97800	185	0.96875
75	0.99625	112	0.98700	149	0.97775		
76	0.99600	113	0.98675	150	0.97750		

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