GUIDANCE FOR SUPERPAVE BITUMINOUS CONCRETE MIXES

Introduction

The intent of this document is to provide guidance for the use of Superpave bituminous concrete mixes on Connecticut Department of Transportation (CTDOT) projects. It may be used by State and/or consultant personnel that are responsible for designing these transportation facilities.

Please contact the Pavement Design Unit at 860-594-3287 if you have any questions.

Mix Definitions

Bituminous concrete mix designations are composed of five main elements: the specified layer (lift or course) thickness, the asphalt material type, the mix design method, the aggregate size for the mixture gradation, and the traffic level based on the accumulated loading the structure will be subjected to. These basic elements are defined below and will be discussed further throughout the document.

1) Lift = Material Placed in Single Pass, or Course = Lift or Multiple Lifts of Same Mixture
2) HMA = Hot Mix Asphalt, or PMA = Polymer Modified Asphalt
3) S = Superpave Mix Design Method
4) NMAS = Nominal Maximum Aggregate Size (0.25, 0.375, 0.5, or 1.0)
5) Traffic Level (1, 2, or 3) based on ESALs = Equivalent Single Axle Load

For example, a call out for **4" HMA S0.5 Traffic Level 2 (two equal lifts)** represents a 4-inch thick Hot Mix Asphalt (HMA) pavement course, placed in two 2-inch lifts, each designed under the Superpave method (S), with a Nominal Maximum Aggregate Size (NMAS) of 1/2-inch (0.5), and an expected Traffic Level 2 loading given a certain calculated ESAL value.

Available Mix Types and Usage Guidelines

HMA S0.25 – Ideal for leveling of deteriorated and raveled surfaces, milled surfaces, or repaired concrete surfaces prior to overlay. Ideal for first lift of bridge deck overlays due to compatibility with waterproofing membrane systems. Surface mix of choice for walkways, bikeways, and multi-use trails. Not to be used as a permanent surface course on any roadway, or a long-term temporary surface on high-speed, wet weather/skid sensitive roadways. May be suitable for very short-term or temporary thin lift maintenance overlays of roadways with posted speeds of 40 mph or less.

HMA S0.375 – Ideal as a surface course for most local roads and many secondary roadways with speed limits less than 50 mph. May be suitable for some moderate to high volume roadways depending on speeds as well as surface texture and wet weather/skid sensitive pavement needs. Can be used for leveling of deteriorated and raveled surfaces, milled surfaces, or repaired concrete surfaces. Also good for short-term or temporary thin lift maintenance overlays of any roadway. It is the preferred mix for patching small areas that require handwork. Mix of choice for paving driveways and parking lots. Most versatile mix for wedge course applications.

HMA S0.5 – Ideal as a surface course and intermediate course for all types of roadways. Primary surface for secondary roadways and higher volume roadways. Can also be used for some wedge course applications. The most widely used bituminous concrete mix. Very few limitations.

HMA S1 – Ideal as a base course mix. Usually placed on granular material – Processed Aggregate Base or Subbase. Not suitable as a permanent surface course due to larger aggregate size and required to be covered by a Superpave mix with smaller NMAS, typically one or two lifts/courses of S0.375 or S0.5. May be suitable for short-term or temporary surface. Can be used in thicker filling/wedging applications as needed.

PMA mixes follow most of the same usage guidelines as their HMA counterparts, but because they are modified with polymer, they provide increased strength and durability. Adding polymer increases the bituminous concrete stiffness at elevated temperatures and increases elasticity at lower temperatures (more detailed explanation in section below). There are two main reasons to specify a PMA mix instead of the standard HMA mix item:

1) To increase mix stability and resistance to rutting.
2) To increase the overall durability for resistance to raveling and cracking.

PMA S0.25 – Can be used as an intermediate course on high volume or rut sensitive roadways to support a thin/ultra-thin surface treatment or other surface course.

PMA S0.375 – Can be used as a surface lift for secondary and local roadways where increased strength and durability (resistance to rutting and cracking) is warranted. Can be used as an intermediate course on high volume or rut sensitive roadways to support the placement of a thin/ultra-thin surface treatment or other surface course.

PMA S0.5 – Can be used for the surface lift on very high volume, limited-access roadways such as interstates and divided highways where increased strength/durability and extended surface life is desired. Can also be used as a surface for lower volume roadways subjected to heavy, slow-moving loads (trucks, buses, or specialized vehicles) where increased mix stiffness to prevent rutting is warranted (such as frequent braking or turning areas). Can be used as an intermediate course on high volume or rut sensitive roadways to support a thin/ultra-thin surface treatment or other surface course.

PMA S1 – Can be used as a high strength/high resiliency base course for high volume or heavily loaded roadways to support a surface course.

Mix Designation Equivalencies

The Superpave mix design method currently is the only system being used by CTDOT for bituminous concrete pavements, consistent with the latest construction and material requirements. The previous designation system, known as the Marshall mix design method, has since been completely removed from the recent publications of the CTDOT Standard Specifications and Supplements. **As a result, Marshall mix types are no longer acceptable on projects administered by the State of Connecticut or any Municipality-administered project following CTDOT specifications.** Any Marshall mixes called out on these contract documents should be replaced with equivalent Superpave mix designations using the table below.

Outdated Mix Designation (Marshall)	Equivalent Mix Designation (Superpave)
Class 1	HMA/PMA S0.5
Class 2 (lift ≥ 1.25”)	HMA/PMA S0.375
Class 2 (1.0” ≤ lift < 1.25”), or Class 12	HMA/PMA S0.25
Class 4	HMA/PMA S1
Class 3	Curb Mix

Traffic Level Rationale

The Superpave design method includes Traffic Levels for each mix type, which are based on the accumulated traffic to which they will be subjected over their in-service life. The accumulated traffic in the Superpave design method is characterized by standardizing volumes from different vehicle types into an equivalent number of repetitions of a single, 18-kip reference axle. These loads, called Equivalent Single Axle Loads (ESALs), are accumulated over the design life of the pavement and determine which Traffic Level is used – see table below. Typically, the higher the volume of traffic of the roadway, the higher the number of ESALs, and the higher the Traffic Level of the mix. Expressways require the highest Superpave Traffic Level mixtures, whereas many secondary roadways with low traffic loadings are best served by the lower Superpave Traffic Level mixtures.

CTDOT has reduced the number of Superpave Traffic Levels needed for the State roadway system to two – Traffic Level 2 (typically needed on secondary roadways) and Traffic Level 3 (typically needed on expressways/interstates). Traffic Level 1 and Traffic Level 4 mix design requirements were eliminated for State routes due to relatively low demand for these mixes across the network. However, Traffic Level 4 mix characteristics are still needed on high volume roadways. Traffic Level 4 design characteristics can be achieved by stiffening the high temperature end of the asphalt binder and applying that to a Traffic Level 3 aggregate structure. By altering the binder only, Traffic Level 4 performance characteristics can be achieved. This is typically accomplished by the addition of a polymer modifier to the HMA binder. When polymer is added, the bituminous concrete shall be designated as Polymer Modified Asphalt (PMA) and should be specified, measured, and paid for under the appropriate PMA item. In addition, Traffic Level 1 mixes are still an available option and desirable choice for sidewalks, driveways, parking lots, trail pavements, and lower volume local roadways.

Traffic Level	**Design ESALs (million)**
1*	< 0.3
2	0.3 to < 3.0
3**	≥ 3.0

* Traffic Level 1 is not to be used on CTDOT State routes
** HMA not allowed, PMA required for Traffic Level 3 (see below)

Lower Traffic Level mixes may sometimes be called for on higher Traffic Level roadways if the mix is not being used as a permanent surface course. For example, an HMA S0.25 Traffic Level 2 mix could be used on a Traffic Level 3 roadway as a thin lift maintenance overlay or as a leveling course that would be covered with a PMA S0.5 Traffic Level 3 mix permanent surface course.

Modified Mixes

The term "modified" in this context refers to any bituminous concrete that has been altered from its normal/original/neat state. Almost always it is the liquid asphalt binder portion of the mixture that is modified from its original state.

Much like multi-grade motor oils, asphalt binders are manufactured to perform over various temperature ranges. Different refining methods can produce varying grades of liquid binders, but during a typical refining process, the most commonly produced asphalt binder is PG 64S-22. PG refers to Performance Grade, S refers to Standard, 64 refers to the upper temperature performance limit, and -22 ("negative 22") refers to the lower temperature performance limit. The upper limit is the average 7-day maximum design temperature, and the lower limit is the 1-day minimum design temperature, both in degrees Celsius.

However, there are limitations to the performance grades that can be achieved through the refining process alone. Using other modification technologies allows asphalt producers to extend the performance characteristics of commonly produced binders. The two primary forms of asphalt modification currently being used by CTDOT are 1) Polymer Modified Asphalt and 2) Warm Mix Asphalt.

1) Polymer Modified Asphalt (PMA)

Polymer is the technical term for plastic. Plastics can be formulated to have certain strength and stiffness characteristics throughout various temperature ranges. When the right polymer, at the right amount, is added to a liquid binder it can greatly enhance the properties of the asphalt without any detrimental effect to other performance characteristics. The polymer used by CTDOT is known as an SBS (Styrene-Butadiene-Styrene).

Asphalt naturally softens with increases in temperature. Higher volume roadways see frequent trucks/other heavy vehicles and are more susceptible to rutting during the summer months. It is when temperatures are hottest and traffic is the heaviest that bituminous concrete pavements are most vulnerable to deformation (flushing, bleeding, rutting, and shoving). There are two ways to stiffen asphalt – make the aggregate interlock stronger through increased Traffic Level and/or stiffen the liquid binder properties at higher temperatures. Substituting a more effective binder is the easiest and most effective way to accomplish this. Strengthening the aggregate matrix, while increasing the mix's ability to withstand high temperature loading, typically leads to a reduction in asphalt content to make room for more tightly packed aggregate. Lower asphalt contents can negatively impact the durability of the bituminous concrete. This usually makes polymer modification of liquid asphalt a good choice.

A standard asphalt binder (PG 64S-22) can be modified to create other PG grades, specifically ones that are stiffer on the high temperature end of their grade, while still maintaining the low temperature grade desired. For example, a relatively small amount of polymer can be added to generate a PG 64E-22, which in practice performs like a PG 76-22. The "E" in this case stands for Extreme. A PG 76-22 binder has the same low temperature performance as a PG 64-22, but better rut resistance and durability at higher temperatures approaching 76°C. A Traffic Level 3 mix design using PG 64E-22 will generally deliver the same rut resisting performance as a Traffic Level 4 mixture with PG 64S-22, without reducing the asphalt content. The Department has adopted the use of PMA for all interstate/highway resurfacing as well as for any rut prone section of roadway. For such roadway sections, specifying PMA Traffic Level 3 is desired.

Adding polymer also increases the overall durability of bituminous concrete and can be added to help better resist cracking and raveling/disintegration of any Traffic Level and type of Superpave mixture. Using polymer modification for enhanced durability and cracking resistance should be evaluated on a case by case (project by project) basis. Note that polymer can make the mix "stickier" and causes hand placement applications to be more difficult. It is not appropriate for pothole patching or most trenches for this reason.

Polymer modification generally increases the cost of the mix, but it also can be expected to increase the surface life by 3 to 4 years in comparison to conventional HMA pavement, and is a worthwhile additional cost to resist specific distress types. If polymer modification of bituminous concrete is required, it should be specified, measured, and paid for under the appropriate PMA item. All PMA specification requirements can be found in the most recent versions of Section 4.06 – "Bituminous Concrete" and Section M.04 – "Bituminous Concrete Materials."

2) Warm Mix Asphalt (WMA)

Warm mix asphalt, best known as WMA, is a term describing a technology used to reduce the production and placement temperatures of bituminous concrete. This is generally accomplished by adding some type of additive to the liquid asphalt binder to change its viscosity or act as a “lubricant” at various temperature ranges. Like polymer modification, the natural temperature performance range of neat or normally refined asphalts can be manipulated or changed with an added ingredient. The difference is that warm mix modification aims at changing the viscosity characteristics of the binder or acting as a lubricant only in the production and placement range of temperatures, while not affecting the final ambient temperature performance characteristics of the in-place asphalt mixture.

Current warm mix technologies typically reduce the production and placement temperatures of bituminous concrete by 40 - 50°F. In general, Superpave mixes are produced in the 300 - 325°F range with compaction primarily achieved in the 300 - 250°F range. Warm mix technology shifts these ranges to 250 - 275°F and 250 - 200°F, respectively.

A 40 - 50°F reduction in temperature for both the production and placement phases has several positive effects on the entire bituminous concrete operation. Lower production costs, possible increase in the ability to achieve compaction/meet density requirements, reduction in environmental impacts, and increased worker safety are some of the benefits. Because of these positive impacts, WMA additives are becoming more frequently used. The use of WMA additives is an option for all Superpave mixtures. Both HMA and PMA can utilize a WMA additive, but it is required for all PMA mixes at CTDOT. The decision to use WMA additives for other mixes will be made at the Contractor’s discretion. There will be no separate item or payment made for the use of WMA. The cost (or savings) shall be included in the general cost of the HMA or PMA item. If a WMA additive is added to HMA or PMA it shall be included in the submissions required for the “Job Mix Formula” (JMF) and “Contractor Quality Control (QC) Requirements for Placement.”

Lift Thickness Guidelines

Below are recommended *compacted* lift thicknesses for Superpave bituminous concrete mixes. These recommended lift thicknesses apply to both unmodified [Hot Mix Asphalt (HMA)] and modified [Polymer Modified Asphalt (PMA)] Superpave bituminous concrete mixes.

The recommended lift thicknesses listed refer to the thickness of the mix after placement and compaction. This is the value used by pavement engineers to specify design lift thickness and for construction engineers to measure as-built thicknesses. Individuals who have to address the actual placement of the mix may make use of the “rule of thumb” that uncompacted mix placed by a paver is generally 1/4” higher per inch of compacted thickness desired. For example, to achieve a 2” compacted lift thickness, the uncompacted thickness should be approximately 2-1/2”.

Mix Designation	Minimum Lift Thickness	Recommended Lift Thickness	Maximum Lift Thickness
HMA/PMA S0.25*,**	0.75”	1.0”	1.25”
HMA/PMA S0.375***	1.25”	1.5”	2.0”
HMA/PMA S0.5****	2.0”	2.0”	3.0”
HMA/PMA S1*	3.0”	4.0”	5.0”

* This mix is not to be used for a permanent surface course in any case

** Use Traffic Level 2 for HMA/PMA S0.25 mixes – S0.25 Traffic Level 3 mixes should only be specified when recommended for use by the Pavement Design Unit
*** Surface lift minimum thickness on bridges for HMA/PMA S0.375 = 1.5 inches
**** Surface lift maximum thickness on bridges for HMA/PMA S0.5 = 2.5 inches; minimum top lift of 1.75 inches for HMA S0.5 may be considered in certain extenuating circumstances (for friction or texture sensitive areas, e.g. steep grade, curve, posted speed limit >= 50 mph)

Note 1: Placement of lifts outside these guidelines incurs a significantly greater risk of early in-service failure and is therefore not recommended. Lift thicknesses above and below the recommended ranges present challenges with compaction, workmanship, durability, and rideability that may result in roughness, raveling, rutting, or delamination failures. These failures could occur within a short period of time. Surface or wearing courses should never be placed outside of the recommended min/max thickness tolerances above.

Note 2: Only in non-surface placement applications (such as to develop the proper cross-slope and grade) should lift thicknesses be allowed to fall outside of the tolerances recommended above. Recommendations for such placement can be found below.

Wedge Courses

Wedge courses are defined as those that have a cross-section approximating a triangle (or have a distinct elevation difference from one side of the cross-section to the other, such as a “trapezoidal” cross-section), with one end approaching 0 inches and the other end being placed as thick as the particular mix allows in order to develop an elevation difference in the cross-section. The table below presents the wedging lift thickness practical limits.

Mix Designation	Minimum Lift Thickness (Wedge)	Maximum Lift Thickness (Wedge)
HMA/PMA S0.25*	0.0”	1.5”
HMA/PMA S0.375*	0.5”	2.5”
HMA/PMA S0.5**	1”	3.5”
HMA/PMA S1***	2”	6.0”

End wedge at a minimum distance of:
* One foot from minimum thickness edge (or thin edge of following wedge lift)
** Two feet from minimum thickness edge (or thin edge of following wedge lift)
*** Three feet from minimum thickness edge (or thin edge of following wedge lift)

Note 1: PMA mixes may be used in a wedge course application as shown in the above table; however, the polymer modification of the asphalt binder typically results in a stiffer and less workable material during laydown compared to a traditional HMA. This may be a concern, especially if hand application methods are used to form the wedge. Consider using HMA mixes for wedging wherever possible.

Note 2: S1 mixes may be used in a wedge course application as shown in the above table; however, the aggregate size/gradation of the mixture typically results in a coarser and less workable material during laydown compared to the other NMAS mix types. This may be a concern, especially if hand application methods are used to form the wedge. Consider using S0.25, S0.375, and/or S0.5 mixes for wedging wherever possible.

Note 3: All wedge courses should be covered by a uniform 1.5” or 2” pavement thickness from curb-to-curb without exception.