

8. PAVEMENT DESIGN

Practices and Procedures

8-1 INTRODUCTION

A flexible pavement structure is composed of layers of various materials that function to distribute the applied traffic loads, and then reduce and transfer these loads to the underlying layers. These layers typically include hot mix asphalt (HMA) at the surface, and aggregate and/or recycled HMA or concrete underneath it. The HMA layer experiences the greatest amount of stress from traffic loads and therefore needs to be the strongest layer within the structure. The goal of a well-designed pavement is to ensure that traffic loadings will not damage the subgrade and that the pavement will not reach distress levels where rehabilitation is required prior to the end of the specified design life.

Pavement structure design begins with an appropriate project scope of work. That scope is determined based on the existing and historical pavement and roadway performance, existing pavement structure materials information, roadway deficiencies, and economics.

A pavement design should be completed prior to the Preliminary Design Report to ensure that pavement design is used to calculate project cost and that the desired performance of the pavement is met.

8-1.01 Definitions

ARAN (Automatic Road Analyzer) - an advanced pavement data collection vehicle that can measure pavement smoothness, pavement rutting, and roadway geometry including cross slope, profile grade, and vertical and horizontal curvatures.

Asphalt Rich Base – an HMA base layer mix that is higher in asphalt content and lower in air voids than typical Superpave HMA mixes. Used to reduce bottom-up fatigue cracking under high truck loadings.

Base Course Aggregate - an aggregate layer in a pavement structure that is located directly under the HMA surface layer and above the subbase aggregate. Base courses typically consist of compacted crushed stone or gravel.

Composite Pavement - composed of an asphalt surface layer over a rigid Portland Cement concrete pavement.

Emulsion – a suspension of small asphalt binder droplets in water, which is aided by an emulsifying agent (a surfactant) that puts an electrical charge on the surface of the asphalt binder droplets so that they repel each other. Emulsions reduce asphalt viscosity making it easier to apply at a large temperature range. Emulsions initially appear as a thick brown liquid when applied and change to black, or “breaks”, as the water begins to evaporate and the asphalt particles stick together. Emulsions are used for tack coats, fog seals, and as a stabilizer for reclaimed asphalt.

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ESAL (Equivalent Single Axle Load) – a summation of the equivalent 18-kip single axle loads used to combine mixed traffic to design traffic for a specific design period.

Foamed Asphalt - small amounts of water and air are injected into the hot asphalt binder at high pressure, creating tiny asphalt bubbles (the foaming) and expanding the asphalt to approximately 20 times its original volume. When combined with reclaimed asphalt pavement, the bubbles burst and adhere to the fine sand and smaller particles creating a mortar between the larger particles.

Full Depth Reclamation (FDR) - a rehabilitation technique in which the full thickness of the asphalt layer plus a predetermined portion of the underlying subbase/base aggregate is uniformly pulverized in place and blended to provide a homogeneous material that acts as a new base aggregate. The pulverized material is typically stabilized with foamed asphalt, emulsion, or cement to increase the materials strength.

Ground Penetration Radar (GPR) - a nondestructive geophysical method that uses radar pulses to image the subsurface. GPR can be used to detect HMA thicknesses, changes in material properties, voids and cracks, concrete pavement thickness and location in the roadway if located under HMA, presence of reinforcing steel in a concrete pavement, and other buried structures such as culverts.

Heavy Load Pavements– a type of pavement structure that is designed to support loads from heavy vehicles including log-hauling trucks, forklift trucks, straddle carriers, and container loading vehicles. Gross vehicle weights (GVW) will typically exceed Maine GVW and axle weight laws and may exceed 250,000 pounds GVW.

Hot Mix Asphalt (HMA) - the surface layer in a pavement structure. HMA is a combination of stone, sand, or gravel bound together by a liquid asphalt binder. HMA is produced in a plant that proportions, blends, and heats aggregate and asphalt to produce an HMA that conforms to the job mix formula (JMF) requirements.

Material Transfer Vehicle (MTV) – MTV's receive HMA from the haul unit, remixes it, and then transfers the HMA directly to a paver. MTV's allow the paver to operate continuously without stopping therefore minimizing aggregate segregation and temperature differentials.

Performance Graded Asphalt Binder (PGAB) – Superpave performance grading (PG) is a method of categorizing an asphalt binder used in asphalt pavement relative to its rated performance at different temperatures. The grading is reported using the average seven day maximum and minimum temperature (°C) that the pavement is likely to be exposed to. A PG 64-28 is intended for use where the average seven-day maximum pavement temperature is 64°C (147°F) and the expected minimum pavement temperature is -28°C (-18°F).

Perpetual Pavement - a full depth HMA pavement that if properly maintained and rehabilitated, can be designed and built to last longer than 50 years without requiring major structural

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rehabilitation or reconstruction. Distresses are confined to the surface layer and therefore this type of pavement needs only periodic surface replacement.

Plant Mixed Recycled Asphalt Pavement (PMRAP) - a rehabilitation technique in which the existing asphalt layer is removed and hauled to a processing site where it is mixed with additives including cement, emulsion and water in a pug mill. The processed material is then hauled back to the project and placed to a specified thickness with a paver.

Polymer Modified Asphalt – polymer modified asphalts are elastomeric binders formulated to increase durability and reduce temperature susceptibility of HMA. The benefits of using polymer modified asphalt includes improved rutting resistance in higher temperatures, less thermal cracking in cold temperatures, and overall improved mixture durability.

Porous Pavement - a pavement structure with a high porosity that allows stormwater to pass through it slowly and infiltrate into the ground below. Typically composed of a pervious open graded HMA surface course, an asphalt treated base, a reservoir stone layer thick enough to hold a prescribed volume of stormwater, and a granular filtration layer so it can slowly infiltrate into the subgrade.

Reconstruction (Pavement) - complete removal and replacement of the existing pavement structure with new and/or recycled materials.

Rehabilitation (Pavement) - restores serviceability and extends the service life of an existing pavement. This may include recycling of the existing pavement, placement of additional surface materials, or other work necessary to return an existing pavement, including shoulders, to a condition of structural or functional adequacy.

Rigid Pavement - a concrete slab placed over base or subbase aggregate and a prepared subgrade. Types of concrete pavements commonly constructed are jointed plain concrete pavement (JPCP), jointed reinforced concrete pavement (JRCP), continuously reinforced concrete pavements (CRCP), and precast/pre-stressed concrete pavement (PPCP).

Rubblization - the process of fracturing an existing Portland cement concrete pavement into small, interconnected pieces that serve as a base course for a new hot mix asphalt (HMA) overlay. Rubblization destroys the integrity of existing concrete and eliminates reflective cracking, moisture damage, rough riding roads, faulting, and ASR and other degenerative reactions.

Shim – a fine HMA mix that is used to correct deficiencies in a roadway's grade or cross slope.

Stabilizer – a chemical or bituminous additive used to improve materials engineering properties by increasing strength, durability, and reducing moisture susceptibility.

Structural Pavement Design – determines the required HMA, aggregate and recycled layer thicknesses needed to support traffic loads for a specified time period.

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Subbase Course Aggregate - an aggregate layer in a pavement structure that lies between the subgrade and base course or between the subgrade and the HMA surface layer. Subbase typically consists of a mix of compacted sand and gravel.

Subgrade - the foundation that the pavement structure is placed on. A subgrade's performance generally depends on its load bearing capacity and frost heaving/thaw weakening susceptibility.

Variable Gravel - The addition of new subbase/base aggregate at varying thicknesses on top of existing roadway aggregate. Typically used on rehabilitation projects for correcting the vertical profile, increasing the roadway aggregate thickness for structural improvements, ensuring positive drainage of pavement, or for reducing frost penetration into the subgrade.

8-2 STRUCTURAL PAVEMENT DESIGN

8-2.01 Design

Flexible Pavement

For projects with 10,000,000 ESAL's or less, refer to the Design Guidance - Structural Pavement Design.

For projects with ESAL's greater than 10,000,000, a design is requested from the Pavement Design & Quality section.

Flexible Pavement with a Recycled Layer

MaineDOT currently uses FDR of asphalt stabilized with Foamed Asphalt, Cement, or Emulsion, PMRAP, Cold In-Place Recycling (CIPR), Hot In-Place Recycling (HIPR), and concrete rubblization as recycling treatments.

Selecting the appropriate FDR process and stabilizer is essential in producing a material that will be strong and durable. To determine the process and stabilizer that is best suited for the project, contact the Pavement Design & Quality section for recommendations.

The thickness of HMA over a recycled layer depends on the process, type of stabilizer used, the thickness of the recycled layer, the thickness of the underlying aggregate, and the future ESAL's. To determine the thickness of the HMA layer over FDR with Foamed Asphalt, Cement, or Emulsion, PMRAP, and rubblization, contact the Pavement Design & Quality section for recommendations.

Processes like CIPR and HIPR can be used when rehabilitation of the pavement structure is not needed. Both of these processes are used to treat the HMA pavement layers only, leaving existing aggregate base and subbase layers unaltered.

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CIPR is a continuous process done by a train of equipment where the HMA pavement is cold milled to produce RAP, then blended with asphalt emulsion (and aggregate if necessary) to improve the RAP's strength and durability. The cold recycled asphalt mix is then placed onto the existing milled roadway using conventional paving equipment and compacted using vibratory and pneumatic tire rollers, followed by an HMA wearing surface.

HIPR is an in-place rehabilitation recycling process that consists of heating, softening, milling, mixing, placing and compacting the upper layer of the HMA surface. As the heated surface is milled, a rejuvenating agent or new aggregate is often added and mixed into the millings to improve the material properties of the recycled material. The heated recycled asphalt mix is then placed onto the existing milled roadway using conventional paving equipment and compacted using vibratory and pneumatic tire rollers, followed by an HMA wearing surface.

Vertical and Horizontal Alignments on Full Depth Recycling and Rubblization Projects

Once the appropriate recycling process, stabilizer to be used and thickness of HMA that is needed to support future traffic loadings is determined, consideration must be given to the new vertical and horizontal alignments.

With all FDR processes and rubblization (in-place processes), the vertical alignment is generally a standard offset based on the surface of the recycled layer plus the thickness of the new HMA layer. The HMA reclamation process will generally create a "fluff factor" of 1" that is to be added to the new HMA layer for the offset. Concrete rubblization does not produce "fluff", therefore the offset will be the HMA layer thickness only.

Shifts in the horizontal alignment as well as roadway widenings may require the addition of new aggregate on FDR and rubblization projects. FDR projects are widened with ASCG – Type D aggregate topped with a layer of reclaimed HMA at the same thickness as the adjacent roadway. Rubblization projects are widened with ABC – Type C aggregate at the same thickness as the existing aggregate under the slabs plus the slab thickness.

The PMRAP process requires that the existing HMA is removed and processed off site, therefore the new vertical and horizontal alignments can be designed to meet safety requirements or other needs because subbase aggregate can be easily added or removed.

Composite Pavement

The minimum HMA thickness to be placed over an existing concrete pavement is 3". Typically, all existing HMA is milled off the concrete pavement and a tack coat of emulsified asphalt (meeting grade SS-1) is applied to the milled surface to ensure bonding between the new HMA base layer and the concrete surface.

To widen an existing composite pavement, the widened section should be constructed with 12" of subbase aggregate, 7" to 9" of high strength concrete fill (typical concrete slab thicknesses), and a minimum 3" of HMA.

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Perpetual Pavement

Perpetual pavement is a concept of designing, constructing, and maintaining HMA pavements for long-lasting structural support. The perpetual pavement structure is designed to be thick enough to greatly reduce load induced strains at the bottom of the HMA pavement layer. This reduction in strains ensures that no failure by rutting of the subgrade or fatigue-induced (bottom up) cracking is probable. Deterioration is typically in the surface layer, therefore milling and overlaying to eliminate these distresses and improve ride quality can be done multiple times.

Perpetual pavements are designed to last structurally for 40 to 50 years and should be considered in high priority locations and corridors where the cost and impact of any future rehabilitation is significant. A perpetual pavement design is requested from the Pavement Design & Quality section.

Porous Pavement

A porous pavement structure is highly effective in reducing pollution in stormwater runoff from roadways and parking lots. These pavements function by allowing stormwater to drain through an open graded HMA surface, then into a stone reservoir where the water is held and slowly infiltrated into a filtration layer, then into the subgrade soils. Some natural soils in Maine do not allow for efficient subgrade infiltration, therefore water from the reservoir stone can be collected in a drainage system and discharged to an outlet structure, ditch, or detention pond.

Porous pavements need to be designed, constructed, and maintained to function correctly. A porous pavement can be used at many locations including travel lanes and shoulders, travel lanes only, shoulders only, sidewalks, parking lots, and industrial/marine yards. Consideration required for the design of a porous pavement structure includes the site location and soils present, rainfall and runoff rate and future traffic types and loads. All porous pavements should use polymer-modified binders to withstand traffic loads due to the increased air void contents. A porous pavement structural design is requested from the Pavement Design & Quality section. A hydrological and the reservoir design is typically completed by the Environmental Office along with the Pavement Design & Quality section.

8-2.02 Shoulder HMA Thickness

The minimum HMA thickness allowed on paved shoulders on reconstruction and rehabilitation projects is 3". There are cases where thicker HMA is required on the shoulders due to constructability issues and off-tracking of heavy vehicles on the inside of horizontal curves.

Full-depth shoulders are HMA surfaced shoulders that have the same cross-sectional thickness and material types as the adjacent travel lane. Full-depth shoulders should be used 50 feet in advance of the P.C. and end 10 feet beyond the P.T. of any side road. Full-depth shoulders should also be considered opposite the leg of a T-intersection. Where right-turning traffic might

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frequently (and illegally) use the shoulder as a turn lane, full depth shoulders should begin 100 feet in advance of the P.C.

The following tables lists the thickness of shoulder HMA based on the pavement structure type and shoulder width:

HMA Pavements

HMA Thickness – Travel Lane	HMA Thickness - Shoulder Width > 4' -	HMA Thickness - Shoulder Width < 4'
4"	4"	4"
5" +	3" (minimum)	Same as travel lane

Off-Tracking on Horizontal Curves

It is standard practice to provide full-depth pavement for off-tracking for a partial width of the shoulder. Refer to Design Guidance - Off-Tracking to determine the appropriate width.

8-2.03 Auxiliary Lanes/Widenings/Ramps

Roadway widenings and auxiliary lanes should be designed to increase construction and paving quality. Long and narrow tapers of base widening should be avoided when possible. Additional material costs resulting from wider placed tapers are often offset from the gained efficiencies in placement by avoiding handwork that results in poor quality compaction.

To determine the thickness of the HMA and aggregate for auxiliary lanes, lane widenings and Interstate ramps, refer to Design Guidance - Structural Pavement Design. Shoulder HMA thickness is determined using Section 8-2.02.

8-2.04 Side Roads

The HMA and aggregate thicknesses for side roads are determined using the Design Guidance - Structural Pavement Design, and shoulder HMA thicknesses from Section 8-2.02.

For low-volume, local side roads, a minimum of 4" of HMA over 18" of ASCG- Type D aggregate is allowable.

8-2.05 On Street Parking Areas

On street parking areas should have a pavement structure thickness (HMA and aggregate) that is the same as the adjacent travel lane.

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8-2.06 Miscellaneous Pavement

Sidewalks, Driveways, Entrances, Multi-Use Paths

Location	HMA (min)	Subbase Aggregate (min)
Sidewalks	2"	9"
Residential Entrances	2"	12"
Commercial Entrances*	3"	12"
Parking Lots*	3"	12"
Shared Use Paths w/pedestrians, bikes only	2"	12"
Shared Use Paths w/maintenance vehicles	3"	12"

*Areas may require a thicker pavement structure depending on vehicle type and traffic volume.

Industrial and Marine Yards

Pavements in yards that are used for industrial and marine purposes typically are subjected to loadings from extremely heavy vehicles used for moving goods for shipping, receiving and storage. These heavy vehicles include log hauling trucks, log handlers, fork-lift trucks, straddle carriers, rubber-tired hoists and many other special vehicles. Truck weights can exceed 400,000 pounds with many tires spaced and configured very differently than heavy trucks used on roadways. Yards are typically paved with asphalt, concrete, roller compacted concrete, and concrete pavers. Because of the extreme loads, vehicle configurations, and how these vehicles move in yards, the pavement design methodology is different than the methodology used for roadways.

The pavement structure design for industrial and marine yards is requested from the Pavement Design & Quality section. This request should include the yard site design, vehicles being used including manufacturer, model number, gross vehicle weight and tire configurations, and where these vehicles will be used in the yard.

8-2.06 HMA Layer Thickness Selection

Recommended HMA layer thicknesses per nominal aggregate size are as follows:

Nominal Aggregate Size	Layer	Recommended Layer Thickness
4.75 mm	shim layer, variable depth	0" to 1½"
9.5 mm-fine	shim layer, variable depth	½" to 2"
12.5 mm-fine	shim layer, variable depth	¾" to 3"
9.5 mm-fine	surface layer, uniform depth	¾" to 1¼"
9.5 mm-coarse	surface layer, uniform depth	1¼" to 1½"

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12.5 mm-fine	surface layer, uniform depth	1½" to 1¾"
12.5 mm-coarse	surface layer, uniform depth	1½" to 2"
12.5 mm-coarse	base layer, uniform depth	1¾" to 3"
19.0 mm-fine	base layer, uniform depth	2" to 3"
19.0 mm-coarse	base layer, uniform depth	2¼" to 3"

The layer thickness may be modified depending on the HMA mix design traffic level. The Pavement Design & Quality section will determine what aggregate size is appropriate for the project location.

8-2.07 Specifications

Special Provision 403

The Department has developed a project specific Special Provision for Standard Specification-Section 403 paving items. Special Provision 403 (SP 403) is used to outline the additional requirements of Standard Specification-Section 401 and addresses the following, but is not limited to:

- HMA mix design requirements – aggregate requirements and PGAB additives (polymer, warm mix, liquid anti-strip), etc.
- Testing requirements – testing methods A, B, C and D as well as density requirements.
- Placement requirements – specified rollers, pavement joint locations, material transfer vehicle requirements, etc.
- Supplemental Special Provisions – Hamburg wheel tracker, joint density, specialized mix designs, etc.
- Tack coat type and application rate

Once all the HMA items and quantities are determined, the designer will submit a SP 403 Request Form with all the necessary information to the Pavement Quality Manager and/or the Pavement Quality Engineer in the Pavement Design & Quality section who will develop a draft SP 403 for the PDR and the final SP 403 for the project bidding documents.

Use of Polymer-Modified Asphalt in HMA

The primary benefit of polymer-modified asphalt is improved rutting resistance, with less thermal (cold-temperature) cracking and overall improved mixture durability being secondary benefits. Additionally, some modified binders provide improved stripping (moisture damage) resistance. Projects meeting one or multiple of the following selection criteria will be considered for use of polymer-modified asphalt:

- Highway corridor priority (HCP) 1, 2
- Traffic levels with loading exceeding 4.5 million ESALs for 20-year design life
- Projects with slow moving traffic or where truck traffic exceeds 15% of AADT

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- Intersections with stopped traffic, turning movements, or an excess of 6% grade
- Locations where construction activities have significant impact to traffic

The use of polymer-modified asphalt in HMA is generally limited to surface and intermediate courses unless heavy rutting or loads are expected, then it can be used in the base layers.

Use of a Material Transfer Vehicle for HMA Placement

Projects meeting one or multiple of the following selection criteria will be considered for use of a material transfer vehicle (MTV):

- The use of an MTV will be required for any projects on the Interstate system for mainline and ramps of sufficient length
- Highway corridor priority (HCP) 1 and 2
- Projects with total HMA tonnage exceeding 6,000 tons
- Locations where construction activities have significant impact to traffic

The use of an MTV will be generally limited to longer project length. Projects where paving will occur at night should receive extra consideration for usage of an MTV.

Use of Centerline Joint Density Specification

Centerline longitudinal joints are often a weak area of a pavement that fails first. Centerline joint density specifications create an incentive and disincentive for attaining acceptable compaction at centerline joints. Projects meeting any of the following selection criteria will be considered for use of the centerline joint density specification:

- All Interstate or divided, controlled access highway projects
- Scope of mill & fill, overlay, rehabilitation, or reconstruction with a design life of 12 years or more
- Highway corridor priority (HCP) 1 and 2
- Scope of reconstruction or rehabilitation with a design life of 12 years or more
- May or may not include a recycling layer
- Total HMA thickness of 5" or greater