***DRAFT* Guidance Specification for Porous or Dense-Graded Asphalt Pavement Structures for Storm Water Management**

Revised July 28, 2016

INTRODUCTION

Storm water management is a challenge facing our ever expanding communities. Porous or dense-graded asphalt pavement structures offer an opportunity to address this challenge through parking lot and other paved area applications. Multi-purpose applications can also be utilized such as storm water management with commercial, residential, and recreational facility design concepts. With proper design and installation, the system is designed to allow infiltration of storm water into the pavement structure, then release the treated water to replenish the groundwater, eliminating the need for a detention basin that often requires additional land. The system is comprised of a porous or dense-graded asphalt pavement surface placed over a granular working platform on top of a reservoir of large stone. The reservoir layer is designed to have the storage capacity to hold the water. If dense-graded asphalt pavement is used as the surface material instead of porous asphalt, the system needs to be designed to allow storm water to infiltrate into the reservoir layer (e.g. riverjack, draintiles, pipes, etc.) as determined by the engineered design.

This document provides guidance and recommendations for specifying the storm water management system. More information is available through various reports including the National Asphalt Pavement Association Information Series 131 titled *Porous Asphalt Pavements*, and through websites including **www.AsphaltIsBest.com** and **www.AsphaltPavement.org.**

SUBGRADE PREPARATION

- Existing subgrade under bed areas shall NOT be compacted or subject to excessive construction equipment traffic prior to geotextile and stone bed placement.
- Bring subgrade of stone infiltration bed to line, grade, and elevations indicated. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction before the placing of stone. All bed bottoms are one (1) to five (5) percent grade.

INFILTRATION BED INSTALLATION

- Place geotextile in accordance with manufacturer's standards and recommendations. Adjacent strips of geotextile shall overlap a minimum of 16-inches. Secure geotextile at least four (4) feet outside of bed and take any steps necessary to prevent any runoff or sediment from entering the storage bed.
- Install coarse aggregate in 8-inch maximum lifts. Lifts of 12-inches are allowed over pipe to prevent damage. Lightly compact each layer with equipment, keeping equipment movement over storage bed subgrades to a minimum. Install aggregate to grades indicated on the drawings.
- Install choker base course (see Materials section) aggregate evenly over surface of stone bed, sufficient to allow placement of pavement, and notify Engineer for approval. Choker base course shall be sufficient to allow for even placement of asphalt pavement but typically not thicker than nominal 1-inch in depth.
- Following placement of bed aggregate, the geotextile shall be folded back along all bed edges to protect from sediment washout along bed edges. At least a four (4) foot edge strip shall be used to protect beds from adjacent bare soil. This edge strip shall remain in place until all bare soils contiguous to beds are stabilized and vegetated. In addition, take any other necessary steps to prevent sediment from washing into beds during site development. When the site is fully stabilized, temporary sediment control devices shall be removed.

All aggregates (choker and large stone aggregates) within infiltration bed shall meet the following:

- Maximum Wash Loss of 1.5 %
- The Los Angeles Rattler (LAR) loss on the coarse aggregate fraction (material retained on the 4.75 mm [No. 4] sieve) shall not exceed 40% for any individual source used within the mix. The composite maximum LAR loss shall not exceed 35
- Material shall be 80% crushed (one fractured face)
- The use of recycled materials will not be permitted in the aggregate base materials. Recycled materials shall include, but are not limited to: glass, recycled asphaltic pavement, crushed concrete, and roofing shingles.

Coarse aggregate for the infiltration bed shall be uniformly graded with a minimum void space of 40% according to AASHTO T19. Gradations may be modified AASHTO #2, #3, #5 or comparable.

Modified AASHTO size number 2*

U.S. Standard Sieve Size	Percent Passing
3”	100
2 ½”	80-100
1 ½”	20-60
¾”	0-10

Modified AASHTO size number 3*

U.S. Standard Sieve Size	Percent Passing
2 ½”	100
2”	70-100
1 ½”	35-70
½”	0-5

Modified AASHTO size number 5*

U.S. Standard Sieve Size	Percent Passing
1 ½”	100
1”	100
½”	0-15
#4	0-5

*As an Alternate, a uniformly graded gradation with a minimum void space of 40% is allowed according to AASHTO T19.

Compaction of the coarse aggregate for the infiltration bed shall be by **ordinary compaction**. One pass with vibration is allowable (low amplitude, high frequency) for aggregate interlock. **Continuous vibratory passes are not allowed**.

Choker base course aggregate for infiltration bed shall have the following or comparable gradation (AASHTO size number 57):

U.S. Standard Sieve Size	Percent Passing
1 ½”	100
1”	95-100
½”	25-60
4	0-10
8	0-5

Non-woven geotextile shall be Mirafi 140 N, Mirafi 160N, Amoco 4547, Geotex 451, or approved equal.

DENSE-GRADED ASPHALT PAVEMENT
Modify MnDOT Specification 2360 and 3139 obtained from the following MnDOT Bituminous Office web page http://www.dot.state.mn.us/materials/bituminous.html.

Utilize MnDOT Spec 3139 and mineral aggregate shall meet aggregate size A (1/2" maximum size) gradation, traffic level 2 of MnDOT 3139 for the type and thickness of mixture specified. As an alternate, aggregate size B (3/4" maximum size) and/or traffic level 3 may be substituted.

Bituminous material shall be PG (Performance Grade) 58-28 or PG 64-22. Design asphalt content by weight shall be in accordance to MnDOT 2360.

[Note: It is estimated that the mixture unit weight of the dense graded asphalt pavement will be approximately 113 lbs./sq.yd.-inch]

POROUS ASPHALT PAVEMENT
This work consists of the construction of a porous asphalt wearing course mixture (porous asphalt). The work shall be in accordance with these specifications and shall conform to the lines, grades, thicknesses, and typical cross-sections shown on the plans or established by the Engineer.

Aggregate Gradation Broad Band (or comparable gradation to meet this specification):
(% passing of total washed gradation)

U.S. Standard Sieve Size	Porous Asphalt
¾"	100
½"	85-100
3/8"	55-75
#4	10-25
#8	5-15
#200	2-4

[Note: It is estimated that the mixture unit weight of the porous asphalt pavement will be approximately 95 to 100 lbs./sq.yd.-inch]

Los Angeles Rattler [LAR] Test
The Los Angeles Rattler loss on the coarse aggregate fraction (material retained on the 4.75-mm [#4] sieve) shall not exceed 35 percent for any individual source used within the mix.

Soundness (Magnesium Sulfate)
The magnesium sulfate soundness requirements shall only apply to Class D aggregate (including the Class D portion of combination materials) containing more than 20 percent non-igneous particles by mass. If the wearing course aggregate contains non-igneous particle in excess of 20 percent but less than or equal to 45 percent by mass, the total non-igneous fraction shall not show a magnesium sulfate soundness loss of more than 20 percent. If the wearing course aggregates contain non-igneous particles in excess of 45 percent, by mass, the total non-igneous fraction shall not show a magnesium sulfate soundness loss of more than 10 percent.

Additives, Mineral Filler, Hydrated Lime

An additive is any material added to an asphalt mixture or material, such as mineral filler, asphalt additives, anti-strip, stabilizers, and similar products that do not have a specific pay item. When a Contract requires additives, compensation is included with the pay items for the appropriate mixture. If the Engineer directs the Contractor to incorporate additives, the compensation will be as Extra Work, at the unit price specified in the proposal. The Contracting Authority will not compensate the Contractor for additives incorporated at the Contractor's option.

Additives shall not be incorporated into the mixture without approval of the Engineer. Anti-foaming agents shall be added to asphalt cement at the manufacturer's recommended dosage rate.

Mineral filler shall consist of carbonate dust, Portland cement, hydrated lime, crushed rock screening, or rotary limekiln dust.

Crushed rock screenings to be used as mineral filler shall be of such composition and quality that the bituminous mixture containing the rock screenings will have stability and durability equivalent to those of the comparable mixture containing one of the other acceptable filler materials. The rock screenings shall be free from clay and shale.

Mineral filler prepared from rock dust, slag dust, and similar materials shall be free from organic impurities and have a plasticity index not greater than 4 (AASHTO T 90).

Hydrated lime used in asphalt mixtures shall meet the requirements of ASTM C977 and have a maximum of eight percent unhydrated oxides (as received basis).

Gradation

Mineral filler shall be graded within the following limits:

Percent finer than #30……..100
Percent finer than #50……..95-100
Percent finer than #200…….70-100

Mineral filler that is to be added directly to the dried aggregate for the bituminous mixture shall be thoroughly dry and free from lumps consisting of aggregations of fine particles.

Crushed rock screenings used as mineral filler shall be of uniform gradation and shall be processed and handled un such a manner as will prevent segregation. The rock screenings shall be dried by passing through the dryer**.**

Sampling and Testing

1) Sampling……MnDOT Bituminous Manual
2) Fineness
   Sieve Analysis……AASHTO T 27
   Hydrometer Analysis……..AASHTO T 88
   (A) This procedure is modified to permit the use of Gum Arabic as a dispersing agent if flocculation occurs.
3) Plasticity Index……AASHTO T 89 & 90
4) Specific Gravity……..AASHTO T100

Porous Asphalt Stabilizer **AASHTO MP8-02**

An asphalt stabilizer additive may be used to control drain-down. The stabilizer additive shall be a cellulose fiber conforming to AASHTO MP8-02.

Stabilizer dosage rate shall be within 0.2-0.4 percent by weight of the total mix.

Asphalt Binder Material

The recommended asphalt binder material is PG 58-28 or PG 64-22.

MIXTURE DESIGN

Mixture Design General

Include:

a) No paving will be allowed without a Contractor or consultant laboratory job mix formula design using Gyratory (50 gyrations) mix design. The Contractor shall provide all data necessary (aggregate and mixture) and pay all costs.
b) All mixture shall be designated as wearing course.
c) Additional information can be found in Appendix A of NAPA's Porous Asphalt Pavements, Quality Improvement Series 131, however these specs shall take precedence.

Desired Aggregate Blend

Prior to the start of asphalt production, the Contractor shall provide:

1. Dry-rodded voids in coarse aggregate of the coarse aggregate fraction (VCA_{DRC}). Coarse aggregate is defined as the aggregate fraction retained on the #4 sieve.
    a. Compact coarse aggregate according to AASHTO T19
    b. Calculate VCA_{DRC}

$$VCA_{DRC} = \frac{G_{CA}\gamma_W - \gamma_S}{G_{CA}\gamma_W} \times 100$$

Where,

G_{CA} = bulk specific gravity of the coarse aggregate (AASHTO T85)

γ_S = unit weight of the coarse aggregate fraction in the dry-rodded condition (AASHTO T19)

γ_W = unit weight of water

2. Voids in the coarse aggregate of the mix (VCA_{MIX}) according to the following steps.
    a. For each trial gradation prepare three batches at the approximate designed total asphalt binder content. Include fibers if used.
    b. Compact two specimens from each trial gradation using 50 gyrations of the Superpave gyratory compactor.
        i. Determine the bulk specific gravity (G_{mb}^*) of each specimen by Corelok (ASTM D6752) or Calculation (AASHTO T 269 or ASTM 3203) following the method stated in section 6.2 to determine the density of the compacted specimen.
        ii. Determine the VCA_{MIX} of each compacted specimen.

$$VCA_{MIX} = 100 - \left[\frac{G_{mb}}{G_{CA}} \times P_{CA}\right]$$

Where:

G_{CA} = bulk specific gravity of the coarse aggregate
G_{mb} = bulk specific gravity of compacted specimens
P_{CA} = percent coarse aggregate in the total mixture

c. Use the remaining sample from each trial gradation to determine the theoretical maximum specific gravity (G_{mm}) of each trial
d. To select design gradation, choose the trial gradation with the $VCA_{MIX} < VCA_{DRC}$ with high air voids.

Mixture Aggregate Requirements

Aggregate Blend Property	Porous Asphalt
Coarse Aggregate Angularity (ASTM D5821) (one face), %- Wear & Non-Wear	55
Coarse Aggregate Absorption, % AASHTO T85, Mn/DOT modified	≤ 2
Voids in Coarse Aggregate (VCA_{drc}) AASHTO T19	$VCA_{mix} < VCA_{drc}$
Flat and Elongated Particles, max % by weight, (ASTM D 4791)	≤ 5 (5:1 ratio)
Clay Content (AASHTO T 176)	30
Total Spall in fraction retained on the #4 sieve	2.5
Maximum Spall Content in Total Sample	2.5
Maximum Percent Lumps in fraction retained on the #4 sieve	0.5
Max. allowable RAP and/or RAS percentage, Wear /Non Wear	0/0

Mixture Requirements

Gyratory Mixture Requirements	Porous Asphalt
Gyrations for $\mathbf{N_{design}}$	50
Air Voids, % -- Wear	≥ 16%
Tensile Strength Ratio, min% at mix design	Not applicable
Fines/Effective Asphalt	≤ 1.2
Draindown - based on a 1 hour reading at the anticipated production temperature	≤ 0.3 %
Stabilizer by weight of total mix, %	0.2 – 0.4
VCA Ratio	$VCA_{MIX} < VCA_{DRC}$

The recommendation for minimum percent asphalt binder is approximately 5.5 percent by weight of mix.

Using the selected design gradation, prepare mixes at the three binder contents in increments of 0.5 percent. Conduct draindown test (AASHTO T305 or ASTM D6390) on loose mix at a temperature 15°C higher than anticipated production temperature. Compact mix using 50 gyrations of a Superpave gyratory compactor and determine air void contents.

Tensile strength (TSR) testing is not applicable to porous asphalt pavements.

Documentation, Additional Documentation for Gyratory Design:

- For the trial blend(s), determine the Voids in the Coarse Aggregate-Dry Rodded Condition (VCA_{DRC}) according to AASHTO T19. The VCA ratio (VCA_{mix}/VCA_{DRC}) shall be less than 1.0, i.e. $VCA_{mix} < VCA_{DRC}$.
- The design number of gyrations at N_{design}.
- Evidence that the completed mixture will conform to all specified physical requirements as follows: asphalt content and densification $\%G_{mm}$ at N_{design}, design air voids (V_a), Fines/Effective Asphalt, draindown, percent Stabilizer by weight of total mix, and VCA ratio.

- Percent and manufacturer's data for type of stabilizer used.

The tests for mixture properties shall be conducted on representative portions of the mix, quartered from a larger sample of mixture taken from the truck box. The mixture shall be sampled from the truck box at the plant site after the truck has been fully loaded. The procedure for truck box sampling is contained on the Mn/DOT Bituminous Office Web site at www.dot.state.mn.us/materials/bituminous.html

Production Testing Rates

Production Test	Minimum Testing Rates	Test Reference
Bulk Specific Gravity	1 test per 500 tons	ASTM D6752 Mn/DOT modified
Maximum Specific Gravity	1 test per 500 tons	AASHTO T209 MnDOT modified
Air Voids (calculated)	1 test per 500 tons	AASHTO T269, T312
Asphalt Content	1 test per 500 tons	Bit & Lab Manual
Gradation	1 test per 500 tons	AASHTO T11 & T27
Coarse Aggregate Angularity	1 test per 500 tons	ASTM D5821
VCA Ratio (calculation)	1 test per 500 tons	AASHTO T19
Draindown	1 test per 500 tons	AASHTO T305 or ASTM D6390

Draindown Test **AASHTO T305**

Draindown that exceeds 0.3% is unacceptable. The Contractor shall take appropriate action to bring draindown values into specification. This action may include checking to determine if the stabilizer is being added, if the rate of adding stabilizer is correct and checking if the mixing temperature is excessive. The draindown test shall be performed at the production plant mixing temperature.

Voids in Coarse Aggregate (VCA) Ratio Calculation **AASHTO PP41-02**

To select gradation, choose the gradation with the $VCA_{MIX}<VCA_{DRC}$ with high air voids.

JMF Limits (N=4)

Item	JMF Limits
% G_{mm} @ N_{design} / Production Air Void	+3.0
Asphalt Binder Content, Percent	±0.4
Sieve - % Passing*	
3/4", 1/2", 3/8"	± 4
No. 4 , No. 8	± 3
No. 200	± 2.0

* JMF target values are not allowed outside the broadband requirements in Table 2360.2-E.

Storage of the mix will be allowed during production at the risk of the Contractor.

Porous asphalt shall be placed with a track paver.

All compaction shall be by the Ordinary Compaction Method. Compaction of the asphalt pavement shall take place when the surface is cool enough to resist a 10-ton steel-wheeled roller. **Typically, one or two passes is all that is required for proper compaction. Excessive rolling will cause a reduction in the surface porosity which is unacceptable.** Pneumatic-tired rollers are not allowed. Unless directed by the Engineer in writing, placement of porous asphalt mixtures will be allowed only when the ambient air temperatures are at least 50°F when measured away from artificial heat.

For multiple lift construction, the Engineer and Contractor may elect to mutually agree to criss-cross the previously placed strip (lift) prior to placement operations.

Transporting of mix to the site shall be in vehicles with smooth, clean dump beds that have been sprayed with a non-petroleum release agent.

After final rolling, no vehicular traffic of any kind shall be permitted on the surface until cooling and hardening has taken place, and in no case within the first 24 hours.

Transition to adjacent impervious bituminous paving shall be merged neatly with flush, clean line. Finished paving shall be even, without pockets, and graded to elevations shown on drawing.

Porous pavement beds shall not be used for equipment or materials storage during construction, and under no circumstances shall vehicles be allowed to deposit soil on paved porous surfaces. Nor should the porous asphalt be allowed for storage of construction materials unless protected.

Establish and maintain required lines and elevations. The Engineer shall be notified for review and approval of final stake lines for the work before construction work is to begin. Finished surfaces shall be true to grade and even, free of roller marks and free of low spots to form puddles. All areas must drain.

Appendix A - Table 1 Design Criteria for porous Pavements, portions from the Minnesota Stormwater Manual and the EPA Storm Water Technology Fact Sheet, EPA 832-F-99-023.

Design Criterion	Guidelines
Site Evaluation	• Take soil boring to a depth of at least 4 feet below bottom of stone reservoir to check for soil permeability, porosity, depth of seasonally high water table, and depth to bedrock. • Consider designing the parking spaces in tiers for slopes greater than 5 percent. Minimum 1 percent slope required. • Minimum depth to bedrock and seasonally high water table: 3 feet. • Minimum setback from water supply wells: variable, typically 50 feet. • Minimum setback from building foundations: 10 feet downgradient, 100 feet upgradient. • Not recommended in areas where wind erosion supplies significant amounts of windblown sediment. • Drainable area should be less than 15 acres.
Traffic Conditions	• Use for low-volume automobile parking areas and lightly used access roads. • Avoid moderate to high traffic areas and significant truck traffic. • Avoid sanding operations; post with signs to restrict the use of sand with snow cleaning activities or other materials that may clog the surface.
Design Storm Storage Volume	• Highly variable; depends upon regulatory requirements. Typically design for storm water runoff volume produced in the tributary watershed by the 6-month, 24-hour duration storm event.
Drainage Time for Design Storm	• Minimum: 12 hours. • Maximum: 72 hours. • Recommended: 24 hours.
Construction	• Excavate and grade with light equipment with tracks or oversized tires to prevent soil compaction. • As needed, divert storm water runoff away from planed pavement area before and during construction. • A typical porous pavement cross-section consists of the following layers: 1) porous asphalt course, 2 to 4 inches thick; 2) filter aggregate course, about one inch thick; 3) reservoir course of 1.5 to 3 inch sized stone; and 4) non-woven filter fabric.
Porous Pavement Placement	• Minimum air temperature: 50^{o}F. • Compact with one or two passes of a 10-ton roller in static mode. • Prevent any vehicular traffic on pavement for at least one day.
Pretreatment	• Pretreatment recommended to treat runoff from off-site areas. For example, place a 25-foot wide vegetative filter strip around the perimeter of the porous pavement where drainage flows onto the pavement surface. • If adjacent dense-graded asphalt pavement is sanded in the winter, design the porous asphalt pavement accordingly to prevent clogging.