

DRAFT 09/08/2022

**APPENDIX A**  
**PERVIOUS CONCRETE MIX DESIGN VARIATIONS**

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## Pervious Concrete Mix Design Variations

Component	Information From 2013				Illinois Ready Mixed Concrete Association	National Ready Mixed Concrete Association	Wingra Concrete
	Ohio Ready Mix Concrete Association	Kentucky Ready Mix Concrete Association	American Concrete Pavement Association	Indiana Ready Mixed Concrete Association			
Aggregate/cementitious ratio	4:1 to 5:1					4:1 to 4.5:1	Contact manufacturer for local mix design information
Unit Weight (lb/ft <sup>3</sup> )	115 - 135	Results for mix by ASTM C 1668 Method shall not vary by more than +/- 5 lbs/ft <sup>3</sup> from target C 1668 submitted test result	ASTM C29 Paragraph 11, jiggling method (105-130)	ASTM C29 Paragraph 11, jiggling method (105-130)	Gravimetric plastic unit weight at time of placement shall be +/- 8 lbs of design mixture unit weight.	100-130 lbs/ft <sup>3</sup>	
Void Content	13% - 30%	15% - 20%	ASTM C138 Gravimetric Air Determination: 15% ideal, the higher the voids the less durable the mix is to freeze/thaw cycle.	ASTM C138 Gravimetric Air Determination: 15% to 25%	ASTM C138 Gravimetric Air Determination: 15% to 25%	15%-30%	
Cementitious Content (lb/yd <sup>3</sup> )	450 - 600	520 - 600	580-620	300 - 520	400 - 600	450-550	
Supplementary Cementitious Content	<25% Fly Ash, <25% Slag, <35% combined supplementary content		Maximum 20% replacement	Fly Ash: 25% max. Slag: 25% max. Combined: 50% max.	Fly Ash: 25% max. Slag: 25% max. Combined: 60% max.	Silica Fume (5-12%), Fly Ash (5-65%), Slag (20-70%)	
Water-Cementitious Ratio	0.28 - 0.35	0.35 (usually, batch at 0.30-0.32)	0.27 - 0.32	0.26 - 0.40	0.27 - 0.35	0.27-0.36	
Fiber Reinforcement	Synthetic polypropylene: 1-1.5 lb/yd <sup>3</sup> , Cellulose: 1.5-3 lb/yd <sup>3</sup>		Fibrillated variable length polypropylene or equivalent		If used, shall be in accordance with manufacturers' instructions and recommendations		
Aggregate		Limestone or gravel permitted, 100% passing 1/2 inch sieve	Coarse: 1/2" minus, larger aggregate increase porosity but decrease strength/workability. Sand: 7% of total aggregate content.	Coarse: Complies with ASTM C33, use Nos. 6, 7, 8, 9, 9, 11, or 12. Fine: Complies with ASTM C33, shall not exceed 3 ft <sup>3</sup> per yd <sup>3</sup> .	Crushed stone or gravel complying with ASTM C33. Gradation choice limited to sizes 3/8" or 1/2" with min. 9% retained on #4 sieve. Combine grading must have measurable voids of 38% or greater (ASTM C29).	2000-2500 (lb/yd <sup>3</sup> )	
Admixtures	Air-entraining admixture shall be a minimum of 2 oz /cwt	Air Entraining required to entrain 6.0% air. Hydration Control Stabilizer required 6 - 10oz. per cementitious hundred weight, optional: Water reducer, Viscosity Modifier	Air entrainment, water reducer, viscosity modifier, hydration stabilizer	Mid-range water reducer, high range permitted due to low water-cement ratios. Hydration stabilizing admixtures are REQUIRED.	Air entraining admixtures (ASTM C260), Mid-range water reducer Type A or High-range Type F or G permitted. Hydration stabilizers (ASTM C494 Type B Retarding or Type D Water Reducing/Retarding) shall be used. Viscosity modifying admixtures permitted.		
Filter Fabric			Non-woven geotextile (Mirafix 140N or Typar 3341, or equal). Woven geotextile along sides of excavation in order to prevent infiltration into adjacent subgrades if required.	Mirafix 140N or Typar fabric, style 3341, or equal	Non-woven: Mirafix 140N or Typar fabric, style 3341, or equal		
Curing Materials				Primary: Polyethylene sheeting, minimum 6 mil. Other: soybean oil based sealer/water repellent; liquid membrane compounds (must meet ASTM C-309, Type 1, Class A); Monomolecular film (evaporation retardant).	Primary: Polyethylene sheeting, minimum 6 mil, in conjunction with one of below methods. Other: soybean oil based sealer/water repellent; liquid membrane compounds (must meet ASTM C-309, Type 1, Class A); Monomolecular film (evaporation retardant).		
Website:							





## Porous Asphalt Mix Design

Component	Flexible Pavements of Ohio: Porous Asphalt Pavement Surface Course	Porous Pavement: Edmund Thelen and L. Fielding Howe - Open Graded Asphalt Concrete	Wisconsin Asphalt Pavement Association	Illinois Department of Transportation (Open-Graded Asphalt Friction Course (BDE) Special Provision)	Rock Roads (from Brett Williams, City of Rockford job in 2009)	National Asphalt Pavement Association	Payne and Dolan (formerly DRS)
Asphalt Binder	ODOT 702.01, PG 64-22 Modified with 5 percent SBR Latex or PG 76-22M(ER80)		WisDOT PG 64-22: 5.5% recommended. 5.2% to 6.0% recommended	Asphaltic cement shall meet requirements of PG 76-22 as specified in AASHTO MP 1. Elastomers shall be added and shall be either styrene-butadiene diblock or triblock copolymer without oil extension or a styrene-butadiene rubber.	Seneca 64-22 modified with 10-12% ground tire rubber (grade equivalent = PG76-22GTR)		Contact manufacturer for local mix design information
Aggregates	Coarse aggregate angularity, percent fractured (two or more faces, ASTM D5821, 100%	No. 8 screen for coarse aggregate		Coarse: OGAF C (D mix) shall be Class B quality crushed gravel/stone (other than limestone)/sandstone/slag/steel slag. OGAF C (E mix) shall be Class B quality crushed sandstone/slag/steel slag. Fine: Class B quality, max 20%.	12.5mm NSD Pervious HMA Sieve Gradation Bands: 1/2" = 85-100% passing; 3/8" = 55-75% passing; #4 = 10-25% passing; #8 = 5-10% passing; #200 = 2-4% passing	Reference State APA	
Mineral Filler	ODOT 703.07: Limestone dust, portland cement, or other inert mineral matter. Sieve Analysis: No. 30 - 100% pass, No. 50 95 to 100% pass, No. 200 - 65 to 100 % pass.			Article 1011.01 of the Standard Specifications shall apply.			
Rubber Compound	ODOT 702.14				Ground Tire Rubber		
Fiber Stabilizer	Use cellulose fiber in loose or pellet form meeting the properties in Table 1 below		5.5-6%	Mineral fiber additive shall be included into OGAF C mixture. Added at dosage rate between 0.0% and 0.4% by weight of total OGAF C mix. 0.25" max length. 0.0002" max thickness. 90-100% passing No. 60 sieve. 65-100% passing No. 230 sieve.			
Air voids	16 to 22 percent (ASTM D3203)	16% by volume	16-22 percent		24.2%	Air Voids (AASHTO T 269-11/ASTM D3203M-11) > 16%	
Permeability rates		>170 inches/hour over 2.5 inch thick pavement surface					
Asphalt Grade		AASHTO Spec M-20 for 85-100 concentration road asphalt	Minimum high temperature of 64-C is recommended. PG 64-28 or PG 70-28 modified binders can be specified in an effort to provide improved		PG76-22GTR		
Website:							





## Permeable Pavers

Component	County Materials H2O Pro or Harmony Pavers	Unilock Eco-Optilock	Belgard Anjalina Series	Pavedrain
Length	8"	9 7/8"	9"	12"
Width	4"	9 7/8"	4 1/2"	12"
Thickness	3 1/8"	3 1/8"	3 1/8"	5.65"
Shapes	Rectangle, square (8" x 8" x 3 1/8"), Large rectangle (16" x 8" x 3 1/8")	L Shape	Rectangle or L shape	Rectangle
Angles		90 Degree	90 Degree	
Patterns	Multiple patterns, see attachment	Hatch pattern	Basket weave pattern, herringbone pattern, running bond pattern	
Colors	Standard or Tumbled, Majestic, Reflection, Timeless	River	Ashbury Haze, Colswold Mist, Charcoal, Foundry, Gascony Tan, Pewter	Grey, Charcoal, Tan, Rose, Brown and more
ADA Compliant	Harmony Pavers		Smooth surface with micro-chamfer to reduce vibration which can provide an ADA-compliant pavement.	Yes, 1/4" gap between each individual Pave Drain block
Strength (If Found)				
Other Useful information		Special spacer bars create a 12mm gap between units which results in excellent infiltration rates when installed on an open graded base with fine stone chip between the joints. A heavy duty industrial paver that is one of the best solutions for vehicular pavements.		0.25" spacer tabs on each side of the block initial infiltration: 1,600 in/hr (ASTM C1701)
Interlocking?	Interlocks	Tri-axis locking principle	Interlocking blind space bars for increased structural performance and aesthetics	interlocked with 6 neighboring units
Strand Project Locations	Monona, WI and Dubuque, IA			
Sources:	<a href="https://www.countymaterials.com/en/products/h2opro/h2opro-permeable-interlocking-pavers/#?p=per-pavers#pvc-tab-0">https://www.countymaterials.com/en/products/h2opro/h2opro-permeable-interlocking-pavers/#?p=per-pavers#pvc-tab-0</a>	<a href="http://www.eco-optilock.com/permeable-pavers-1-unilock-chicago">http://www.eco-optilock.com/permeable-pavers-1-unilock-chicago</a>	<a href="https://www.belgard.com/products/permeable-pavers/beljalina-series/">https://www.belgard.com/products/permeable-pavers/beljalina-series/</a>	<a href="https://www.pavedrain.com/">https://www.pavedrain.com/</a>

<http://www.flexiblepavements.org/node/1037>



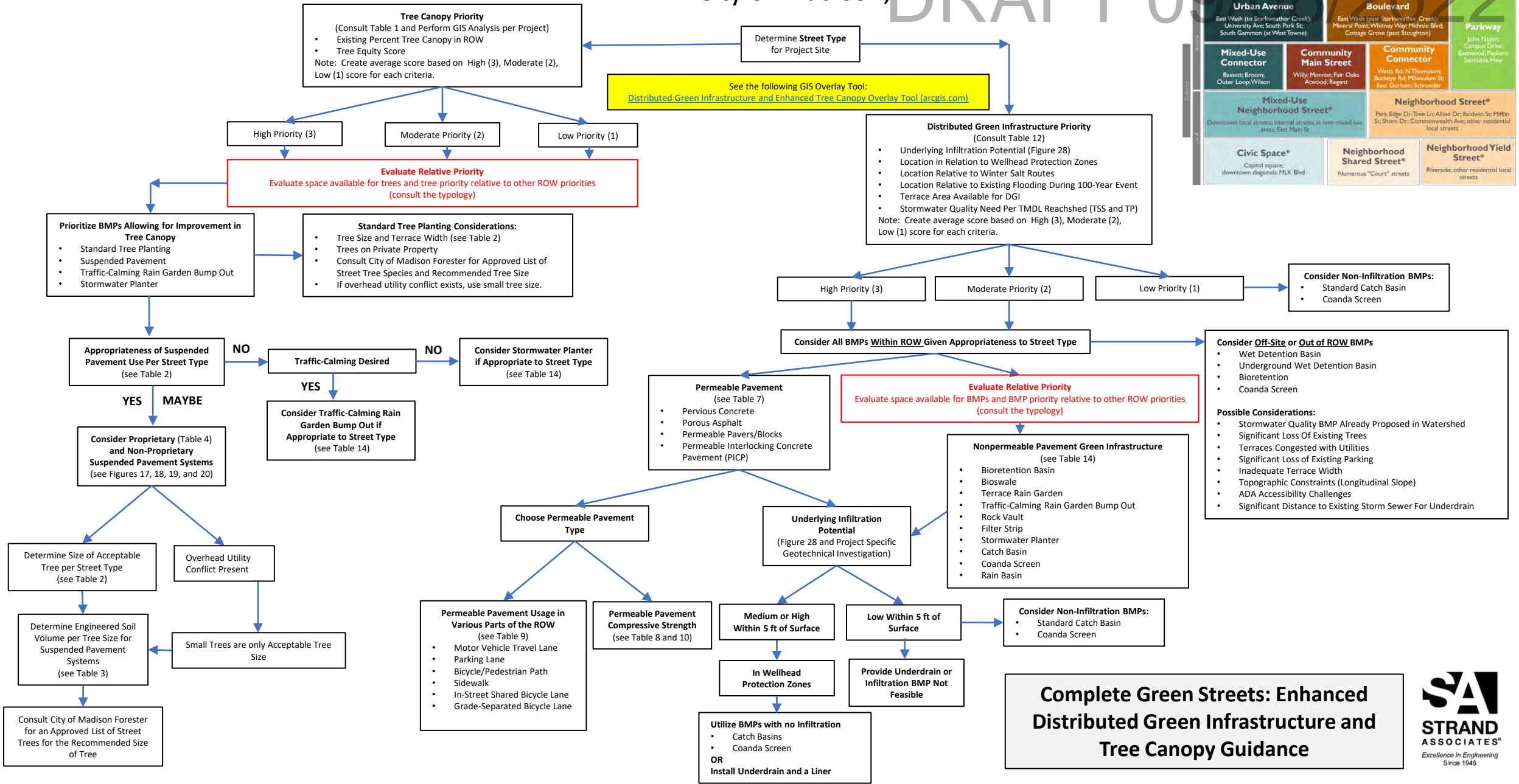


# Distributed Green Infrastructure and Tree Canopy Decision-Making Flow Chart

City of Madison, WI

DRAFT 09/09/2022

<b>Urban Avenue</b> East Wash (to Starkweather Creek); University Ave; South Park St; South Gammon (at West Towne)	<b>Boulevard</b> East Wash (past Starkweather Creek); Mineral Point; Whitney Way; Midvale Blvd; Cottage Grove (past Stoughton)	<b>Parkway</b> John Nolan; Gansole Drive; Eastwood Parkers; Sarnsible Hwy
<b>Mixed-Use Connector</b> Bassett; Broom; Outer Loop; Wilson	<b>Community Main Street</b> Willy; Monroe; Fair Oaks; Atwood; Regent	<b>Community Connector</b> Wicks Rd; N Thompson; Buckeye Rd; Milwaukee St; East Gorham; Schroeder
<b>Mixed-Use Neighborhood Street*</b> Downtown local streets; internal streets in new mixed-use areas; East Main St	<b>Neighborhood Street*</b> Park Edge Dr; Tree Ln; Allied Dr; Baldwin St; Millin St; Shore Dr; Commonwealth Ave; other residential local streets	
<b>Civic Space*</b> Capital square; downtown; diagonal; MLK Blvd	<b>Neighborhood Shared Street*</b> Numerous "Court" streets	<b>Neighborhood Yield Street*</b> Riverside; other residential local streets



**Complete Green Streets: Enhanced Distributed Green Infrastructure and Tree Canopy Guidance**







02839 POROUS PAVEMENT GREEN INFRASTRUCTURE STRATEGY

[NTS: The specification is considered to be a technical guidance document to assist users with the design of green infrastructure strategies. It is the responsibility of the design engineer to make revisions to the specification as needed for specific design projects. It is recommended the documents are reviewed by a licensed professional engineer before releasing for construction. Note that the specification was last updated by the City in 2022.]

A. SCOPE

This Section covers the work necessary to furnish and install porous pavement green infrastructure strategies, including the porous pavement surface, bedding aggregate layer, base course aggregate layer, stormwater storage aggregate layer, underdrain piping, cleanouts, and observation wells.

1. GENERAL

[NTS: Update language of this Section as necessary based on applicable references to front-end specifications.]

See CONDITIONS OF THE CONTRACT, and Division 1, GENERAL REQUIREMENTS, which contain information and requirements that apply to the work specified herein and are mandatory for this project.

2. RELATED WORK

[NTS: The list below may not be fully inclusive depending upon the specifics of each individual project. Update language of this Section as necessary based on applicable references to other technical specification sections.]

The applicable requirements, materials and workmanship specified in the following Sections are included by reference in this Section. The list below is from the Wisconsin Department of Transportation (WisDOT) Standards and Specifications for Highway and Structure Construction, latest edition.

- Section 201 Clearing and Grubbing
- Section 205 Roadway and Drainage Excavation
- Section 301 General Requirements for Base Aggregates
- Section 501 Concrete
- Section 601 Concrete Curb and Gutter
- Section 612 Underdrains
- Section 628 Erosion Control
- Section 645 Geotextile Fabrics

In addition to the WisDOT Standards and Specifications for Highway and Structure Construction, latest edition, the American Concrete Institute (ACI) Specification for

Pervious Concrete Pavement (ACI 522.1-08) is also included by reference.

### 3. SUBMITTALS

#### a. SUBMITTALS REQUIRED PRIOR TO BID OPENING

Prebid approval of materials is not required. Suppliers and products have been identified as a means of establishing quality, but not for purposes of limiting competition.

#### b. SUBMITTALS DURING CONSTRUCTION

[NTS: Update language of this Section as necessary based on applicable references to front-end specifications.]

Submittals during construction shall be made in accordance with Section 01300 in Division 1, GENERAL REQUIREMENTS. In addition, the following specific information shall be provided:

1. **CONTRACTOR's Qualifications:** CONTRACTOR shall submit information showing conformance with qualification requirements listed in specifications. Submit CONTRACTOR Qualifications to OWNER for review prior Notice to Proceed.
2. **Porous Pavement Surface:** CONTRACTOR shall submit drawings and documentation for the porous pavement surface in accordance with the respective industry standards, including:
  - a. ACI Specification for Pervious Concrete or the recommendations of the Wisconsin or National Ready Mixed Concrete Associations for pervious concrete. Only one test panel, as described in ACI 522.1-1.5.3.4, shall be required to be placed. If total proposed pervious concrete area is less than the required 225 square feet for a test panel, the test panel shall be the entire proposed pervious concrete area;
  - b. Wisconsin or National Asphalt Pavement Associations for porous asphalt;
  - c. Concrete Pavement Institute, Brick Industry Association, or National Concrete Masonry Association for permeable interlocking pavers and permeable blocks.

CONTRACTOR may submit drawings and documentation conforming to other industry standard sources for review by

OWNER. OWNER will review and inform CONTRACTOR in writing that drawings and documentation conforming to industry standards not specifically mentioned here are either approved or not approved. Only those approved in writing by OWNER will be accepted.

Submit shop drawings to OWNER for review and approval prior to installation.

3. Bedding Aggregate Layer, Base Course Aggregate Layer, Stormwater Storage Aggregate Layer: CONTRACTOR shall submit sieve analysis by a qualified testing laboratory and other documentation necessary showing conformance with specifications for each aggregate layer. Submit sieve analysis and other documentation to OWNER for review and approval prior to installation.
4. Underdrain Piping: CONTRACTOR shall submit shop drawings of underdrain piping showing conformance with specifications. Submit shop drawings to OWNER for review and approval prior to installation.
5. Porous Pavement Surface Performance Infiltration Testing: CONTRACTOR shall submit results of surface infiltration testing completed in accordance with applicable standards to OWNER for review and approval prior to final acceptance.

#### 4. SUBSTITUTION OF MATERIALS

The use of manufacturer's name and model or catalog number is for the purpose of establishing the standard of quality and general configuration desired only. Products of other manufacturers will be considered in accordance with GENERAL CONDITIONS.

#### 5. SHOP DRAWINGS, MATERIAL REVIEW AND SAMPLES

- a. Porous Pavement Surface
- b. Bedding Aggregate Layer
- c. Base Course Aggregate Layer
- d. Stormwater Storage Aggregate Layer
- e. Underdrain Piping

6. CONTRACTOR QUALIFICATIONS

The CONTRACTOR shall have five years' experience (minimum) and shall have completed green infrastructure work similar in material, design, and extent to that indicated for this Project. CONTRACTOR must provide five or more successful installations of green infrastructure projects.

7. TOLERANCES

Tolerances for porous pavement green infrastructure strategy construction and materials shall conform to the requirements hereinafter specified. The finished surface elevation of the porous pavement green infrastructure strategy shall be as required by the respective industry standards referenced in the specification. If tolerance for surface elevations are not discussed in industry standard specifications, elevations shall be within 0.06 feet (+/-) of the finished elevations as specified in the drawings. Subgrade elevations shall be within 0.12 feet (+/-) of the finished elevations as specified in the drawings.

B. MATERIALS

1. GENERAL

All porous pavement green infrastructure strategies shall meet the requirements of the following specifications. The OWNER reserves the right to take samples of materials whenever deemed necessary.

2. POROUS PAVEMENT SURFACE

The porous pavement surface shall conform to the following specifications:

- a. Pervious concrete shall conform with all requirements of ACI 522.1, "Specification for Pervious Concrete Pavement," published by the ACI, Farmington Hills, Michigan, except as modified by these Specifications
- b. Porous asphalt shall conform with all requirements of the Wisconsin or National Asphalt Pavement Associations, except as modified by these Specifications.
- c. Permeable interlocking pavers and permeable blocks shall conform with all requirements of the Concrete Pavement Institute, Brick Industry Association, or National Concrete Masonry Association, except as modified by these Specifications.
- d. All porous pavement green infrastructure strategy surface treatments shall have a percent voids less than 25 percent and meet the porous pavement surface performance requirements listed in Section C.1 of this

specification.

### 3. BEDDING AGGREGATE LAYER/JOINT FILL AGGREGATE

Bedding aggregate layer is intended to provide a suitable surface on which to place the permeable interlocking pavers and permeable blocks. The bedding aggregate layer is not required for pervious concrete or porous asphalt. The minimum depth of the bedding aggregate layer shall be 5 inches for permeable interlocking pavers and permeable blocks. Aggregate shall be provided in accordance with ASTM C-33 and size No. 8, 89, 9, or 57 aggregate. Aggregate shall be kept sediment-free during storage and handling and placed to avoid segregation of aggregate.

If required by drawings, joint fill aggregate shall be provided between the joints of the permeable interlocking pavers and permeable blocks. Joint fill material depth can be included to meet the total depth for bedding aggregate layer for the permeable interlocking pavers or permeable blocks so long as the total combined depth of the two layers is 5 inches. Aggregate shall be provided in accordance with ASTM C-33 and size No. 8, 89, 9, or 57 aggregate. Aggregate shall be kept sediment-free during storage and handling and placed to avoid segregation of aggregate.

### 4. BASE COURSE LAYER

Base course layer is required for permeable interlocking pavers. Base course layer shall be installed to depth shown on the drawings and a minimum of 4 inches in depth. Aggregate shall be provided in accordance with ASTM C-33 and size No. 57 aggregate. Base course aggregate conforming to these specifications may be considered part of the aggregate storage depth. Aggregate shall be kept sediment-free during storage and handling and placed to avoid segregation of aggregate.

### 5. STORAGE LAYER

The storage layer below the porous pavement surface is intended for temporary storage of stormwater runoff. Storage layer shall be installed to depth shown on the drawings and a minimum of 12 inches in depth. The storage layer shall consist of aggregate that shall conform to the following specifications:

- a. The aggregate shall be open graded consisting of crushed stone or crushed gravel with no greater than 5 percent passing the No. 200 sieve.
- b. Aggregate shall have a minimum porosity of 30 percent in accordance with ASTM C29 Standard Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate.
- c. Aggregate shall be in accordance with soundness, wear, and fracture requirements listed in WisDOT Standards and Specifications for Highway and Structure Construction Section 301.2.4.5 - Aggregate Base

Physical Properties.

- d. Aggregate shall be kept sediment-free during storage and handling and placed to avoid segregation of aggregate.

6. UNDERDRAIN PIPING

The underdrain pipe shall conform to the following specifications:

- a. The underdrain pipe shall have a minimum diameter of 4 inches and be made of SDR-35 PVC or other material approved by the OWNER. The pipe shall be capable of withstanding expected traffic loads over portions of the pipe extending beyond the soil planting bed.
- b. The underdrain orifice shall be restricted as necessary so that the design infiltration rate plus the underdrain rate equals the design draw down rate. The restriction shall be achieved by using an adjustable restrictor plate or valve. The restriction device shall be accessible for adjustment.
- c. The total opening area of all perforation holes combined shall be sufficient to allow the underdrain pipe to discharge at full capacity, as would occur if there were no orifice restriction. The amount of perforations shall be increased to provide a margin of safety but shall not be so great as to compromise structural integrity of the pipe material. The size of the perforations shall be small enough to prevent surrounding aggregate material from traveling through the perforations. A minimum of three rows of perforations shall be used.
- d. The underdrain pipe shall be protected from clogging by use of a cover of pea gravel. The pea gravel shall conform to the following specifications:
  - 1. Pea gravel - The pea gravel layer shall be at least 4 inches thick on all sides of the underdrain. Pea gravel shall be washed. Pea gravel shall be large enough to prevent its falling through the perforations of the underdrain pipe. The pea gravel shall be sized in accordance with AASHTO No. 8 aggregate (size number according to AASHTO M43) to meet the following gradation requirements:

Sieve Size	Percent Passing by Weight
1/2-inch	100
3/8-inch	85 to 100
No. 4	10 to 30
No. 8	0 to 10
No. 16	0 to 5