RECOMMENDED MATERIALS

Numerous BMPs in this manual have similar material needs. These BMPs are listed in the table below. Detailed information on each material requirement follows. In addition, Porous Pavement and Vegetated Roofs have significant material requirements that are listed according to their individual needs.

	Constructed Filters	Dry Well	Infiltration Trench	Planter Boxes	Porous Pavement	Subsurface Infiltration	Vegetated Filter Strip	Vegetated Swale
Check dams							X	X
Non-Woven Geotextile	X	X	X	X	X	X	X	
Pea Gravel							X	
Peat	X			X				
Pervious Berms							X	
Pipe – 8”	X	X	X	X	X	X	X	
Sand	X			X				X
Stone/Gravel	X			X				
Stone – 30%							X	
Stone – 40%			X		X			

Check dams (Vegetated Filter Strip, Vegetated Swale)

An earthen check dam shall be constructed of sand, gravel, and sandy loam to encourage grass cover. (Sand: ASTM C-33 fine aggregate concrete sand 0.02 in to 0.04 in, Gravel: AASHTO M-43 0.5 in to 1.0 in). A stone check dam shall be constructed of R-4 rip rap, or equivalent.

Non-Woven Geotextile (Constructed Filter, Dry Well, Infiltration Trench, Planter Boxes, Vegetated Filter Strip)

Should consist of needled nonwoven polypropylene fibers and meet the following properties:

a. Grab Tensile Strength (ASTM-D4632) 120 lbs minimum
b. Mullen Burst Strength (ASTM-D3786) 225 psi minimum
c. Flow Rate (ASTM-D4491) 110 gal/min/ft^2 minimum
d. UV Resistance after 500 hrs (ASTM-D4355) 70% minimum
e. Puncture strength (ASTM D-4833-00) 90 lbs minimum
f. Apparent opening size (ASTM D-4751-99A) 60-70 US Sieve

Heat-set or heat-calendared fabrics are not permitted. Acceptable types include Mirafi 140N, Amoco 4547, Geotex 451, or approved others.

Pea Gravel (Vegetated Filter Strip)

Clean bank-run gravel may also be used and should meet ASTM D 448 and be sized as per No.6 or 1/8” to 3/8”.

Peat (Constructed Filter, Planter Boxes)
Should have ash content <15%, pH range 3.3-5.2, loose bulk density range 0.12-0.14 g/cc.

Pervious Berms (Vegetated Filter Strip)
The berm shall have a height of 6-12 inches and be constructed of sand, gravel, and sandy loam to encourage grass cover. (Sand: ASTM C-33 fine aggregate concrete sand 0.02”-0.04”, Gravel: AASHTO M-43, ½” to 1”)

Pipe - (Dry Well, Porous Pavement, Subsurface Infiltration, Constructed Filter, Infiltration Trench, Planter Boxes, Vegetated Filter Strip)
Should be continuously perforated, double-wall, smooth interior (smooth bore), with a minimum inside diameter as required. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or M294, Type S (12-gauge aluminum or pipe may also be used in seepage pits).

Sand (Constructed Filter, Planter Boxes, Vegetated Swale)
Should be ASTM-C-33 (or AASHTO M-6) size (0.02” – 0.04”), concrete sand, clean, medium to fine sand.

Soil Testing (all BMPs)
Should be completed in accordance to the Purdue University Cooperative Extension Service Department of Horticulture “Collecting Soil Samples for Testing” HO-71-W” http://www.hort.purdue.edu/ext/HO-71.pdf

Stone/Gravel (Constructed Filter, Planter Boxes):
Should be uniformly graded coarse aggregate, 1-inch to ½-inch with a wash loss of no more than 0.5%, AASHTO size number 5 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and have voids of 40% as measured by ASTM-C29.

Stone – 40% voids (Infiltration Trench, Porous Pavement, Subsurface Infiltration Bed,)
Infiltration trenches should have stone 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29.

Porous Pavement

General
Choker base course aggregate for beds shall be 3/8 inch to 3/4 inch clean, uniformly-graded, coarse, crushed aggregate AASHTO size number 57 per Table 4, AASHTO Specifications, Part I, 19th Ed., 1998 (p. 47).

Porous Asphalt
Bituminous surface course for porous paving shall be 2.5 to 3 inches thick with a bituminous mix of 5.75% to 6.75% by total weight as determined by testing below. Use neat asphalt binder modified with an elastomeric polymer to produce a binder meeting the requirements of PG 76-22P as specified in AASHTO MP-1. The composite materials shall be thoroughly blended at the asphalt refinery or terminal prior to being loaded into the transport vehicle. The polymer modified asphalt binder shall be heat and storage stable.

Determination of optimal asphalt content should be determined according the following tests:

- Draindown Test (ASTM Method D6390)
- Moisture Susceptibility Test using the Modifed Lottman Method (AASHTO T283) with the following:
    - Compact using 50 gyrations of Superpave gyratory compactor
    - Apply partial vacuum of 26 inches of Hg for 10 minutes to whatever saturation is achieved.
    - Keep specimens submerged in water during freeze cycle.
    - Required retained tensile strength (TSR) ≥ 80%

- Air Voids Test (AASHTO T269/ASTM D3203)

Hydrated lime, if required, shall meet the requirements of AASHTO M 303 Type 1 and shall be blended with the damp aggregate at a rate of 1.0% by weight of the total dry aggregate. The additive must be able to prevent the separation of the asphalt binder from the aggregate and achieve a required tensile strength ratio (TSR) of at least 80% on the asphalt mix.

Fibers, if used, shall consist of either cellulose fibers or mineral fibers which are to be treated with a cationic sizing agent to enhance dispersement of the fiber as well as increase cohesion of the fiber to the bitumen. Fiber is to be added at a dosage rate between 0.2% and 0.4% by weight of total mix.

- Mineral fibers shall be from virgin, basalt, diabase, or slag with a maximum average fiber length of 6.35 mm and a maximum average fiber thickness of 0.005 mm.
- Cellulose fiber – Fiber length shall be 6.4 mm (max), Ash Content 18% non-volatiles (±5%), pH 7.5 (± 1), Oil absorption (times fiber weight) 5.0 (± 1), Moisture Content 5.0 (max).

Porous Concrete

The use of Installers or Craftsmen who have been certified by the NRMCA's Pervious Concrete Contractor Certification Program is strongly recommended. Contractor shall furnish a proposed mix design with all applicable information to the Engineer prior to commencement of work. Critical mix characteristics typically include the following:

- Cement Content: 550 to 650 lb/yd^3
- Fine aggregate, if used: maximum 3 cubic feet per cubic yard
- Admixtures: use in accordance with the manufacturer's instructions and recommendations
- An aggregate/cement (A/C) ratio: 4:1 to 4.5:1
- Water/cement (W/C) ratio: 0.27 to 0.34
- Curing: shall begin within 15 minutes after placement and continue for 7 days

The data shall include unit weights determined in accordance with ASTM C29 paragraph 11, jigging procedure.

Cement: Portland Cement Type II or V conforming to ASTM C150 or Portland Cement Type IP or IS conforming to ASTM C595. The total cementitious material shall be between 550 and 650 lb/yd^3.

Aggregate: Use No 8 coarse aggregate (3/8 to No. 16) per ASTM C33 or No. 89 coarse aggregate (3/8 to No. 50) per ASTM D 448. If other gradation of aggregate is to be used, submit data on proposed material to owner for approval. The volume of aggregate per cubic yard shall be equal to 27 cubic feet when calculated as a function of the unit weight determined in accordance with ASTM C29 jigging procedure. Fine aggregate, if used, should not exceed 3 cubic feet and shall be included in the total aggregate volume.

Air Entraining Agent: Shall comply with ASTM C 260 and shall be used to improve workability and resistance to freeze/thaw cycles.

Admixtures: The following admixtures shall be used:

- Type D Water Reducing/Retarding – ASTM C 494.
- A hydration stabilizer that also meets the requirements of ASTM C 494 Type B Retarding or Type D Water Reducing/Retarding admixtures may be used. This stabilizer suspends cement hydration by forming a protective barrier around the cementitious particles, which delays the particles from achieving initial set.

Water: Potable shall be used and shall comply with ASTM C1602. Mix water shall be such that the cement paste displays a wet metallic sheen without causing the paste to flow from the aggregate. (Mix water yielding a cement paste with a dull-dry appearance has insufficient water for hydration).

- Insufficient water results in inconsistency in the mix and poor bond strength.
- High water content results in the paste sealing the void system primarily at the bottom and poor surface bond.

An aggregate/cement (A/C) ratio range of 4:1 to 4.5:1 and a water/cement (W/C) ratio range of 0.27 to 0.34 should produce pervious pavement of satisfactory properties in regard to permeability, load carrying capacity, and durability characteristics.

Vegetated roofs

Some key components and associated performance-related properties are as follows:

Root-barriers should be thermoplastic membranes with a thickness of at least 30 mils. Thermoplastic sheets can be bonded using hot-air fusion methods, rendering the seams safe from root penetration. Membranes that have been certified for use as root-barriers are recommended. At present only FLL offers a recognized test for root-barriers. Several FLL-certified materials are available in the United States. Interested American manufactures can submit products for testing to FLL-certified labs.

Granular drainage media should be a non-carbonate mineral aggregate conforming to the following specifications:

- Saturated Hydraulic Conductivity ≥ 25 in/min
- Total Organic Matter, by Wet Combustion (MSA) ≤ 1%
- Abrasion Resistance (ASTM-C131-96) ≤ 25% loss
- Soundness (ASTM-C88 or T103 or T103-91) ≤ 5% loss
- Porosity (ASTM-C29) ≥ 25%
- Alkalinity, $CaCO_3$ equivalents (MSA) ≤ 1%
- Grain-Size Distribution (ASTM-C136)
  - Percentage Passing US#18 sieve ≤ 1%
  - Percentage Passing ¼-inch sieve ≤ 30%
  - Percentage Passing 3/8-inch sieve ≤ 80%

Growth media should be a soil-like mixture containing not more than 15% organic content (wet combustion or loss on ignition methods). The appropriate grain-size distribution is essential for achieving the proper moisture content, permeability, nutrient management, and non-capillary porosity, and 'soil' structure. The grain-size guidelines vary

- Non-capillary Pore Space at Field Capacity, 0.333 bar (TMECC 03.01, A) ≥ 15% (vol)
- Moisture Content at Field Capacity (TMECC 03.01, A) ≥ 12% (vol)
- Maximum Media Water Retention (FLL) ≥ 30% (vol)
- Alkalinity, Ca CO3 equivalents (MSA) ≤ 2.5%
- Total Organic Matter by Wet Combustion (MSA) 3-15% (dry wt.)
- pH (RCSTP) 6.5 - 8.0
- Soluble Salts (DTPA saturated media extraction)"(RCSTP) ≤ 6 mmhos/cm
- Cation exchange capacity (MSA) ≥ 10 meq/100g

- Saturated Hydraulic Conductivity for Single Media Assemblies (FLL) ≥ 0.05 in/min
- Saturated Hydraulic Conductivity for Dual Media Assemblies (FLL) ≥ 0.30 in/min

Grain-size Distribution of the Mineral Fraction (ASTM-D422)

- Single Media Assemblies:
  - Clay fraction (2 micron) 0
  - Pct. Passing US#200 sieve (i.e., silt fraction) ≤ 5%
  - Pct. Passing US#60 sieve ≤ 10%
  - Pct. Passing US#18 sieve 5 - 50%
  - Pct. Passing 1/8-inch sieve 0 - 70%
  - Pct. Passing 3/8-inch sieve 75 -100%

- Dual Media Assemblies:
  - Clay fraction (2 micron) 0
  - Pct. Passing US#200 sieve (i.e., silt fraction) 5 - 15%
  - Pct. Passing US#60 sieve 10 - 25%
  - Pct. Passing US#18 sieve 20 - 50%
  - Pct. Passing 1/8-inch sieve 55 - 95%
  - Pct. Passing 3/8-inch sieve 90 - 100%

Macro- and micro-nutrients shall be incorporated in the formulation in initial proportions suitable for support the specified planting.

Separation fabric should be readily penetrated by roots, but provide a durable separation between the drainage and growth media layers (Only lightweight nonwoven geotextiles are recommended for this function.

- Unit Weight (ASTM-D3776) ≤ 4.25 oz/yd^2
- Grab tensile (ASTM-D4632) ≤ 90 lb
- Mullen Burst Strength (ASTM-D4632) ≥ 135 lb/in
- Permittivity (ASTM-D4491) ≥ 2 per second

Credits and Acknowledgments

This Appendix has been developed by Christopher B. Burke Engineering, LLC, and is primarily based upon similar segments contained in “Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers” published in 2009 by the Southeast Michigan Council of Governments (SEMCOG). A selection of material contained in the noted SEMCOG publication has been modified to reflect conditions in Indiana and used, with permission, for development of this Appendix. The valuable contribution of SEMCOG through sharing of this material for use in this Appendix is hereby acknowledged.

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