2J-3 Porous Asphalt Pavement


Porous Asphalt Parking (Lot 121 – Iowa State University)

Pollutant Removal Low = <30% Medium = 30-65% High = 65-100%			
	Low	Med	High
Suspended Solids		■	
Nitrogen		■	■
Phosphorous		■	
Metals			■
Bacteriological		■	
Hydrocarbons		■	■

Description: Porous asphalt concrete is the term for a mixture of coarse aggregate and asphalt binder materials. An aggregate subbase reservoir provides temporary storage as runoff infiltrates into underlying permeable soils and/or out through an underdrain system. Provide water quality capture volume (WQv) and some stormwater quantity management for smaller storms (channel protection volume, CPv).

Typical Uses: Intended for low traffic areas, recreational trails, pedestrian paths, or for residential or overflow parking applications in higher density residential areas, high-density ultra urban areas, and commercial areas. Good general application for parking areas to reduce impervious area. Aggregate layer can accept roof runoff from adjoining buildings.

Advantages:
- High level of pollutant removal.
- Provides reduction in runoff volume and some peak rate control (CPv).
- Suitable for cold climates with modified pervious mix.
- Fewer problems with icing in the winter.

Limitations:
- Soil infiltration rate of 0.5 inches per hour or greater required
- Higher cost compared to conventional pavements
- Increased maintenance requirements over standard PCC.
- Potential for high failure rate if not adequately maintained or used in unstabilized areas
- Potential for groundwater contamination

Maintenance Requirements:
- Prevent run-on of sediment in runoff from adjoining areas.
- Sweep/vacuum one to two times per year.
- Avoid (“prevent”) application of sand in winter.

A. General description

Porous asphalt consists of standard bituminous asphalt in which the fines have been screened and reduced, creating void space to make it highly permeable to water. The void space of porous asphalt is approximately 16%, as opposed to two to three percent for conventional asphalt. Porous asphalt pavement consists of a porous asphalt surface layer, a top filter base course of 1/2 inch open graded aggregate, an aggregate subbase layer to provide temporary water storage and structural support, a geotextile filter fabric, and the existing subgrade soil. Porous asphalt surface course is also called Open Graded Friction Course (OGFC). The number of porous asphalt installations in Iowa is increasing at a steady pace since the initial full scale applications began in 2006.

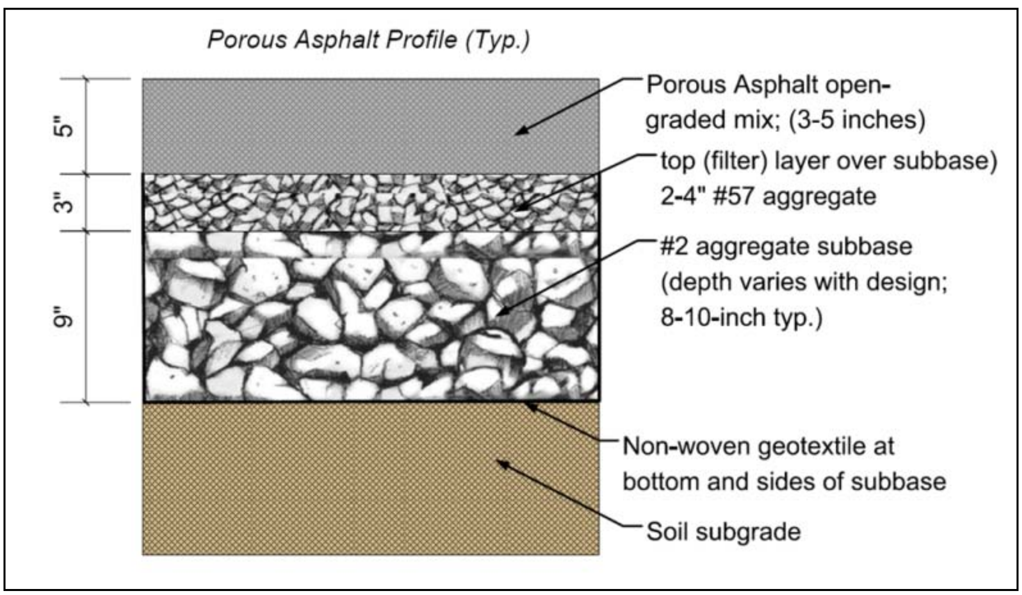
Porous asphalt has the positive characteristics of an ability to blend into the normal urban landscape relatively unnoticed. It will typically allow a reduction in the cost of other stormwater detention infrastructure by increasing the time of concentration and reducing the peak discharge rates for the larger storms. This can offset the somewhat greater placement cost over traditional impervious pavements.

A drawback is the cost and complexity of porous asphalt systems compared to conventional pavements. Porous asphalt systems require a modified construction protocol for equipment and placement than is typical for regular asphalt pavements. The level of construction workmanship is not necessarily more difficult, just different. As with other pavement systems, pervious pavements can experience an increased failure rate if they are not designed, constructed, and maintained properly.

B. Design criteria and specifications

For the purpose of sizing downstream conveyance and structural control system, porous asphalt surface areas can be assumed to 20% impervious. An approximate curve number for pervious pavement area would be in the range of 30 to 35 (i.e. meadow/pasture/grassland on hydrologic soils group A soils). In addition, credit can be taken for the runoff volume infiltrated from other impervious areas conveyed onto the pervious pavement system. The cross-section typically consists of four layers, as shown in Figure 1. A description of each of the layers is presented below:

Figure 1: Typical cross-section for porous asphalt pavement



- ***Porous asphalt layer.*** The porous asphalt layer consists of an open-graded asphalt mixture usually ranging from depths of 3 to 5 inches depending on the required bearing strength and pavement design requirements (3 inches is the recommended minimum for mostly all parking applications). Porous asphalt can be assumed to contain 16% voids (porosity = 0.16) for design purposes. For example, a 6 inch thick pervious concrete layer would hold 0.96 inches of rainfall. The reduction in the quantity of fine aggregate provides the porosity of the porous pavement. To provide a smooth riding surface and to enhance handling and placement a coarse aggregate of #4 to 3/8 inch maximum size is normally used.
- ***Top filter layer.*** For an aggregate subbase layer size of AASHTO #2, a 0.5 inch diameter crushed stone to a depth of 2 inches (minimum) is placed to provide a more uniform compacted surface for placement of the porous asphalt mix. When a #57 aggregate is used, the porous asphalt surface course should be placed directly on top of the aggregate. The filter course layer can be lightly compacted with a vibratory roller or plate compactor to provide a level and firm paving surface. A typical thickness for this upper filter layer is 2 to 4 inches.
- ***Subbase reservoir layer.*** This subbase layer provides the bulk of the aggregate storage capacity for water. The typical base aggregate will be an AASHTO #2 that provides a nominal size of 2.5 to 1.5 inches. The minimum thickness of this layer will depend on the type of subgrade soils, the design subgrade infiltration rate, and the minimum depth required for the storage of the design storm event (i.e. WQv, CPv, 2 year, etc.). A nominal thickness of at least 8 to 10 inches is used. Porous asphalt is a flexible pavement and the #2 base layers provide additional structural support for the pavement system. Guidance on minimum aggregate thickness for structural support based on traffic load (ESALs) and soil conditions is presented in Section 2J-1, Table 2. The gradation for the #2 aggregate will provide a nominal porosity of 0.4. A subbase layer of #2 aggregate 12 inches in depth will provide 0.4 cubic feet of storage for each cubic foot of material. Aggregate gradations based on ASTM D 448 are presented in Section 2J-1, Table 3 and Table 4. Standard sizes of coarse aggregate can also be obtained in Table 4, AASHTO Specifications, Part I, 13th Ed., 1982 or later.
- ***Filter fabric layer.*** A non-woven geotextile fabric provided a separation layer between the subgrade soil and the base course. Selection criteria for the geotextile are provided in Section 2J-1, Figure 4. The geotextile prevents the migration of soil fines into the base course and some additional structural support for weaker soils.

Porous asphalt materials. General design criteria for conventional HMA pavement mix selection design is provided in SUDAS Design Manual, Chapter 5D-1, including guidance on determination of traffic load (ESALs) and material properties for asphalt binder and aggregate. For porous asphalt design, the National Asphalt Paving Association (NAPA) provides a design procedure for Open-graded Friction Courses (1). A summary of the mix design procedure for the porous asphalt surface layer follows:

Coarse aggregates:
- L.A. Abrasion $\leq$ 30 %
- Fractured faces $\geq$ 90% two fractured faces; 100% one of more fractured faces
- Flat and Elongated $\leq$ 5% 5:1 ratio; $\leq$ 20% 2:1 ratio

Fine aggregate:
- Fine Aggregate Angularity (FAA) $\geq$ 45

Asphalt binder:
- High stiffness binder generally two grades stiffer (high temperature designation) than normally used for the local climate.
- Asphalt grade - AASHTO Designation M 20-70 (1996) for 65-80 penetration graded asphalt cement as binder. A performance or PG 64-22 PG 70-22 is acceptable.

- The asphalt binder is the same as used for conventional HMA pavement in Iowa. Since the porous asphalt pavement is more susceptible to scuffing, a stiffer binder should be considered (1). The use of fibers may prevent drain down.
- When using the PG grading system, the high temperature designation is increased one to two grades (1).
- Polymer modifies binder, asphalt rubber binder, or fiber may be used.
- The asphalt content will normally be in the range of 6.0 to 6.5% based on the total weight of the mix. The lower limit assures an adequate coating around the aggregate for durability and the upper limit to prevent an over asphalted mix. The optimum binder content is for the mix design will be based on the local aggregate gradation and determined previously described.

Selection of design gradation:

Table 1: Recommended Gradation for Porous Asphalt (OGFC) (1)

Sieve	Percent Passing
3/4 inch	100
1/2 inch	85 to 100
3/8 inch	55 to 75
No. 4	10 to 25
No. 8	5 to 10
No. 200	2 to 4

- Blend selected aggregate stockpiles to produce three trial blends.
  - One near the coarse side of the gradation band
  - One near the fine side of the gradation band
  - One near the middle of the gradation band
- Determine the dry-rodded voids in the coarse aggregate fraction (VCA_{DRC}) where coarse aggregate fraction is that retained on the No. 4 sieve.
  - Compact the coarse aggregate IAW AASHTO T 19.
  - Calculate the VCA_{DRC}.

  $$VCA_{DRC} = [VCA_{DRC} (\gamma_w - \gamma_s)] \times 100 / G_{CA}\ \gamma_w$$

  Where:
  - G_{CA} = bulk specific gravity of the coarse aggregate (AASHTO T 85)
  - γ_s = unit weight of the coarse aggregate fraction in the dry condition (kg/m^3)
  - γ_w = unit weight of water (998 kg/m^3)

- For each trial gradation prepare three batches at between 6.0 and 6.5 % asphalt binder. Include polymer modifier if used.
- Compact two specimens from each trial gradation using 50 gyrations of the Superpave gyratory compactor.
  - Determine the bulk specific gravity (G) of each specimen.
  - Determine the VCA_{MIX} of each compacted specimen.

  $$VCA_{MIX} = 100 - [\ G_{MB}/G_{CA} \times P_{CA}]$$

  Where:
  - G_{MB} = bulk specific gravity of compacted OGFC specimens
  - G_{CA} = bulk specific gravity of compacted coarse aggregate

P_{CA} = percent coarse aggregate in the total mixture

- Use the remaining sample from each trial gradation to determine the theoretical maximum specific gravity (G_{mm}) of each trial.
- Compare VCA_{MIX} to VCA_{DRC} for each trial gradation.
- The design gradation is the trial gradation with the highest air voids $VCA_{MIX} < VCA_{DRC}$.

Optimum asphalt content:
- Using the selected design gradation, prepare porous asphalt (OGFC) mixes at three binder contents in increments of 0.5%.
- Conduct draindown test (ASTM D 63900 on loose mix at a temperature 15° higher than anticipated production temperature.
- Compact mix using 50 gyrations of a Superpave gyratory compactor and determine air void contents.
- Conduct the Cantabro abrasion test on un-aged and aged (7-d @ 140° F) samples.
- The asphalt content that meets the following criteria is selected as optimum asphalt content.
  - Air voids $\geq$ 18%
  - Cantabro Abrasion Test (un-aged) $\leq$ 20%
  - Cantabro Abrasion Test (aged) $\leq$ 30%
  - Draindown $\leq$ 0.3%

Evaluate mix for moisture susceptibility:
- Test final mix for moisture susceptibility using the modified Lottman method (AASHTO T 2830).
  - Compact using 50 gyrations of Superpave gyratory compactor.
  - Apply partial vacuum of 26 inches Hg for 10 minutes to whatever saturation is achieved.
  - Use five freeze-thaw cycles in lieu of one cycle.
  - Keep specimens submerged in water during freeze cycles.
- Retained tensile strength (TSR) $\geq$ 80%.

Porous asphalt pavement construction. The construction of a porous asphalt pavement system consists of the following procedures:
1. Complete site soils testing as outlined above and in Section 2J-1.
2. Conduct a pre-construction meeting with the contractor to review the design elements and emphasize the importance of avoiding soil compaction on the subgrade and installation of erosion and sediment control BMPs. Review the installation process with the contractor.
3. Prepare the subgrade to design elevation and place geotextile material. Keep wheeled vehicles off of the pervious subgrade.
4. Install the geotextile filter fabric; as an option, several inches of #57 aggregate can be placed as a bottom lower filter course.
5. Place a clean AASHTO #2 (2.5 to 1.5 inch) aggregate base layer in lifts to the *design* thickness and lightly compact. A 5 ton vibratory roller or plate compactor can be used. This operation is to provide light to moderate compaction of the subbase aggregate and will provide a more stable surface for the porous asphalt placement operations. (DO NOT COMPACT THE SUBGRADE).
6. The AASHTO #2 gradation calls for a 0% to 5% passing the 3/4 inch sieve. Most of the material passing the 3/4 inch sieve could be fines that could lead to clogging of the filter fabric. An additional gradation requirement of no more than 0% to 2% passing the No. 100 sieve can be added to the specification to prevent future problems.
7. If subdrain piping is used in the system, place and make the piping connections prior to placing the aggregate. Place the subdrain piping in the aggregate layer to the design elevations.
8. Place a 2 to 4 inch top filter layer of #57 aggregate on top of the subbase layer. When compacted, this layer provides a level and solid base layer to support the installation of the porous asphalt surface layer.

9. Complete the construction of the perimeter PCC curb if used. The PCC curb section provides a stable edge surface for the pervious concrete and a visual and definitive stop for parking of vehicles. (See Figure 4).
10. The porous asphalt layer is placed to a depth of 4 to 6 inches following guidelines for construction of open-graded asphalt mixes (1). (See Figure 4).
11. The asphalt is rolled with two to three passes with a 10 ton roller. (See Figure 5). More frequent rolling may lead to over compaction and reduced infiltration rate of the open-graded mix.

Maintenance

- Protect pavement from vehicular traffic for at least two days after installation.
- Post signs to prevent vehicles with muddy tires from entering area.
- Potholes and cracks may be patched with traditional patching mix, unless more than 10% of porous surface area needs to be repaired.
- Inspect one to two times per month after construction and then a minimum of once annually.
- Check for surface ponding after large storms (> 3.5 inches).
- The porous asphalt surface can be flushed or pressure washed to maintain surface porosity.
- Maintain effective erosion and sediment control on contributing catchment areas.
- Do not allow the use of sand or salt/sand mixtures in the winter for ice control. Liquid de-icer can be used in small amounts in severe conditions, but generally will not be needed.
- Conventional removal of snow with plowing and/or power brushes should not damage the pavement since porous asphalt pavements will accumulate less compacted snow and ice than traditional pavements because of the porous structure and infiltration of melting snow/ice prior to re-freezing.

Figure 2: Placement of geotextile and aggregate subbase on subgrade
(Lot 121, Iowa State University, 2007)

Figure 3: Placement of porous asphalt material over aggregate top layer
(Lot 121, Iowa State University, 2007)

Figure 4: Placement of porous asphalt material
(Lot 121, Iowa State University, 2007)

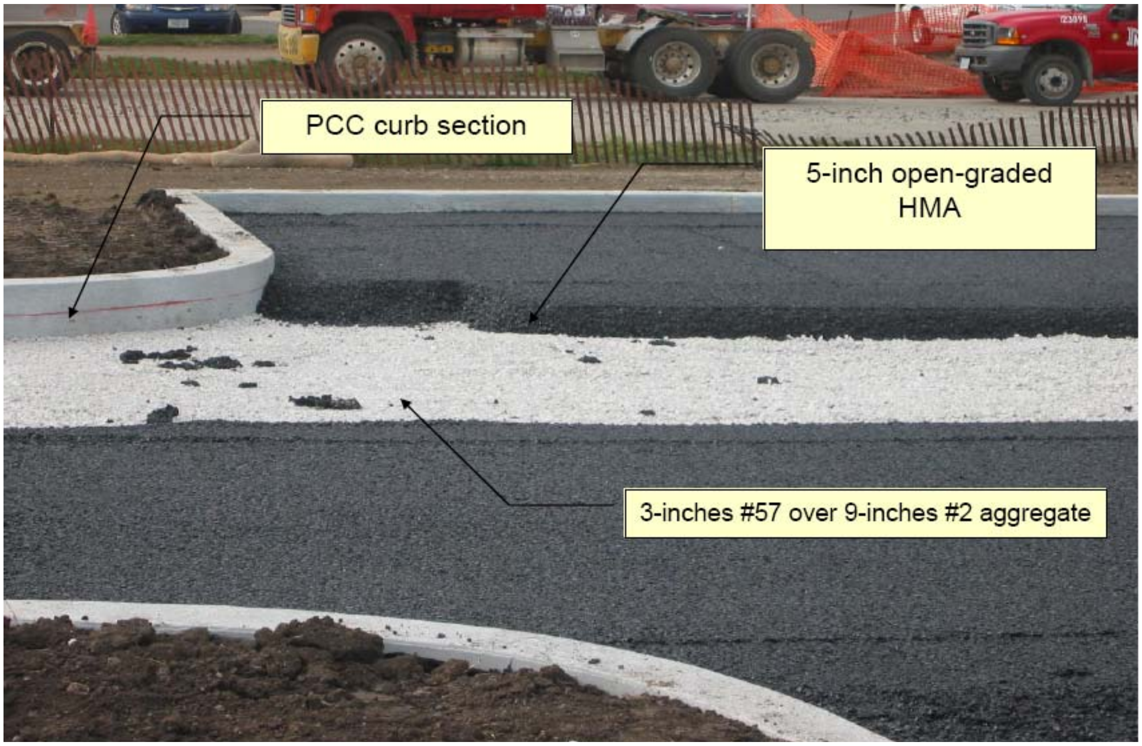


Figure 5: Finish rolling of porous asphalt surface
(Lot 121, Iowa State University, 2007)

Figure 6: Finished porous asphalt surface (18% porosity, PG 82-22)
(Lot 121, Iowa State University, 2007)

Figure 7: Lot 121, Iowa State University - Second winter of operation (2009)

References

1. National Asphalt Pavement Association, "*Design, Construction, and Maintenance of Open-Graded Asphalt Friction Courses,*" NAPA IS-115, Latham, MD, 2003.
2. Center for Transportation Research and Education, "*SUDAS Design Manual,*" Iowa State University, Ames, IA, 2008.
3. U.S. Environmental Protection Agency, Office of Water, Washington D.C., "*Storm Water Technology Fact Sheets Porous Pavement,*" EPA 832-F-99-023, 1999.