VERMONT AGENCY OF TRANSPORTATION RESEARCH SECTION

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Final Report Report 2025-02

Maintenance and Performance Study of Porous Asphalt in Northern Climates at the Randolph Park & Ride

1. INTRODUCTION

Previous studies were conducted at the Randolph Park and Ride regarding the implementation and performance of porous concrete (PC) in northern climates. The studies examined field surface infiltration capacity, the effects of plowing on surface infiltration capacity and the PC implementation. The study concluded that PC surface infiltration was adequate for the predicted weather in the region. The surface infiltration deceased over time due to clogging of PC pores from fines. Plowing seemed to wear the material to the point that it reduced the surface infiltration capacity. The application of salt to the surface of the PC affected the surface infiltration in a similar fashion.

Construction on the original Randolph Park & Ride porous surface started in October 2007, PC placing began in August 2008 and construction ended in July of 2009. After seven years of use, a VTrans committee decided that deterioration to the site had reached an extent where District 4 was having difficulties safely maintaining the site. The extent of the damage to the PC surface is summarized in the site update, “Porous Concrete Deterioration Check (2015).” Deterioration depth of the PC surface ranged from 1/2” to 7”. To make winter maintenance on the site easier, the southern section was closed off and the middle section was temporarily repaved with a non-porous surface while the northern section was opened for use. In the past, the northern section was closed off during the winter months, which is why it had not sustained as much deterioration as the other sections. Due to the extent of deterioration of the PC surface, VTrans has decided to resurface the Randolph Park & Ride with porous asphalt (PA) to continue porous material infiltration research and utilize the unique drainage system on the site [1, 2].

A PA surface along with proper subbase systems can merge functionality with ecological and environmental goals. A complete system with proper design and installation would incorporate a strong PA pavement surface and subbase infiltration or storage system, with the ability to manage and treat stormwater runoff in a cost-effective way. PA has many benefits that include substantial stormwater management, effective removal of total suspended solids (TSS), and increased winter performance. Winter performance is increased due to the quick drainage of water through the porous material, which should lead to a decrease in the use of deicing chemicals. PA systems also recharge groundwater supplies, reduce the contamination of water runoff, and give credits in green construction rating systems. They may have higher initial costs, might require more design considerations for higher sloped areas, have a potential for clogging and have limited use in heavy loading areas and accommodating sharp turns [3].

The intent of this research initiative is to evaluate the performance of porous asphalt (PA) as a replacement for the deteriorated PC that was previously installed. The implementation of PA to the Randolph Park & Ride is of interest to the Agency as it would allow continued research in porous materials in northern climates and decrease the deterioration of the pavement surface while maintaining functionality. The goal of this project is to design, test, analyze, and document the performance of this Porous Asphalt Surface in Vermont's harsh northern climate.

2. CONSTRUCTION AND MATERIALS

2.1. Demolition

The existing PC, choker course, and 3" of existing subbase as illustrated in Figure 1, was excavated on August 28, 2017. Excavation was reasonably straightforward; since the PC had lost most of its structural integrity, it was easily removed by an excavator, as shown in Figure 2. After excavation, the underdrains and drainage structures were flushed to remove any construction related debris before new developed layers were added.

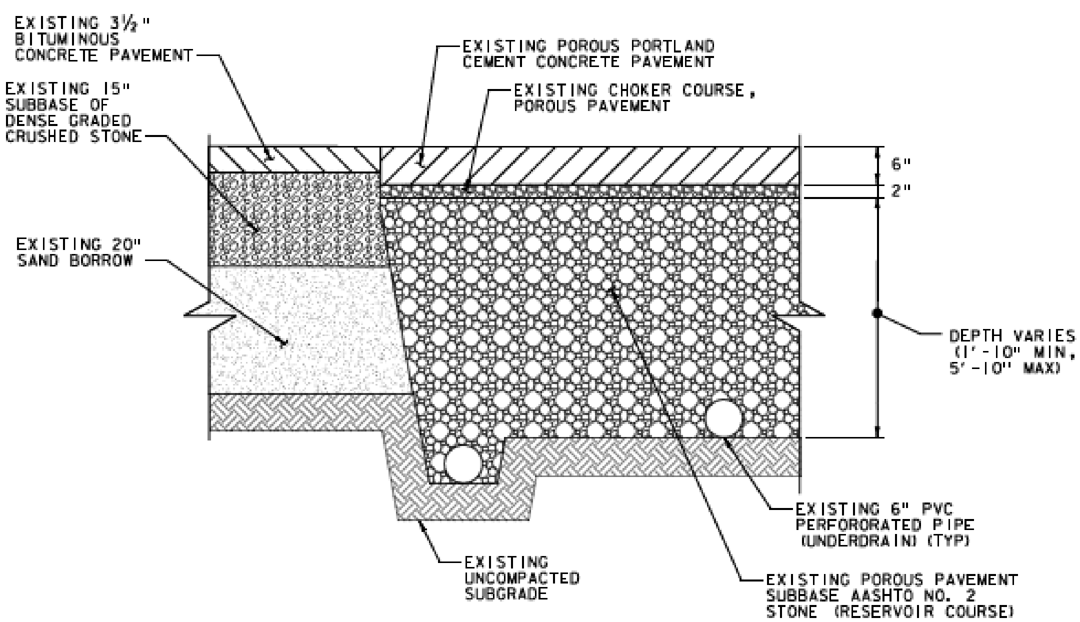

Figure 1: Prior Condition, PC as-built

Figure 2: PC removal

2.2. Asphalt Treated Permeable Base

The parking lot design included the use of an Asphalt Treated Permeable Base (ATPB) layer. The ATPB is an open voided asphalt treated aggregate mix that provides structural support and adds stormwater storage for increased capacity. Existing subbase material was removed to allow for 8" of ATPB to be installed as a new layer to function between the top PA, and the stone reservoir subbase, as shown in Figure 3: PA as-built. The ATPB was detailed and paid through a project special provision, 900.680 Special Provision (Permeable Base) [Appendix A]. ATPB covers the entire existing subbase, filling the entire parking and travel area, including underlying the conventional hot-mix asphalt (HMA) travel lanes.

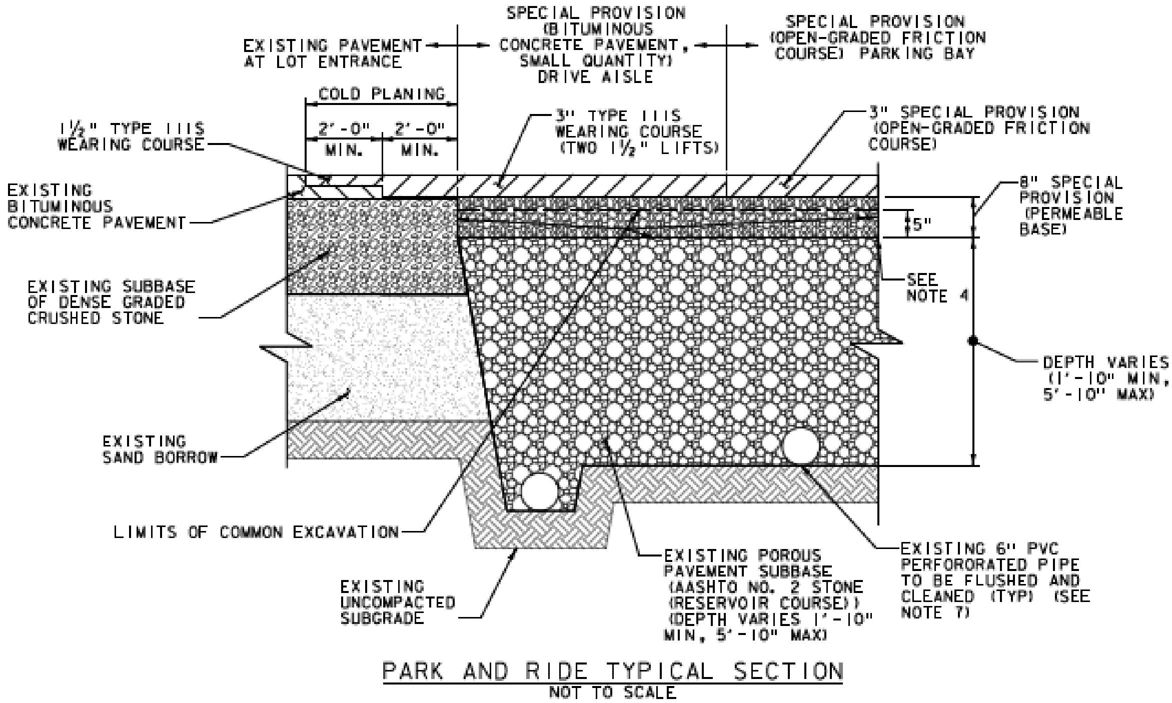

Figure 3: PA as-built

The first phase of ATPB paving began on September 12, 2017, starting with the lower lot of the park and ride. Travel lanes were then paved on the ATPB, with only the PA OGFC remaining. The ATPB, and travel lane paving are illustrated in Figure 4.

Figure 4: ATPB and Dense Mixed Paving

2.3. Porous Asphalt

PA, also referred to as Open Graded Friction Course (OGFC) in the paving industry, is an asphalt material characterized as having open and connected air voids within its structure. The open voids allow stormwater infiltration, while maintaining a useable and safe travel surface. A top layer of 3" of OGFC was applied in the areas designated for parking, matching the existing grade of the dense mixed HMA travel lanes. The OGFC was detailed and paid through a project special provision, 900.680 (Open Graded Friction Course) [Appendix B]. Paving of the OGFC started on May 16, 2018, with all paving being completed June 8, 2018. Figure 5 displays the paving of the OGFC.

2.4. Construction Summary

Construction of the Randolph Park and Ride included removal of the existing failed PC, installation of the ATPB, paving of HMA travel lanes, and finally paving of the OGFC. Work took place over two construction seasons, Fall 2017 with work up to the ATPB paving on half of the lot, Spring 2018 including the rest of the work. ATPB and OGFC is paved in a manner similar to conventional HMA, with conventional paving equipment, though it does require additional care. In contrast, PC construction is difficult and differs greatly to conventional concrete, with constructability issues potentially leading to early failure. The OGFC appeared very tacky, and caused some frustration when moving material by hand, and was difficult to clean from the delivery trucks. These difficulties did not lead to any noticeable construction deficiencies.

3. PERFORMANCE AND OBSERVATIONS

3.1. Infiltration tests 2018

Following the completion of construction of the Randolph Park and Ride, initial infiltration measurements were taken. The PA construction utilized the existing infiltration reservoir system designed previously for the PC system. Infiltration tests were conducted on June 26 and August 8, 2018 to determine a baseline permeability for the site. Sites were picked for infiltration testing and assigned letters A-L, see Figure 6 for the site plan. These test sites will be used in annual infiltration testing on the Randolph Park and Ride. The infiltration tests conducted were done using ASTM C1781/C1781M. Figure 7 shows the specific testing sites, while Figure 8 shows the results of the infiltration tests performed. Instructions on performing infiltration tests for this project are included in Appendix C. Over the first year of testing, the average site infiltration was reduced by 15.4%, but remain well above the required minimums to infiltrate expected rain events. The change in infiltration, particularly at site E, could likely be a result of inconsistences in the measurement of very high flow rates. Small time differences in the test become large variations in infiltration rate when attempting to conduct measurements of very high flow rates.

Figure 5: Open Graded Friction Course Paving

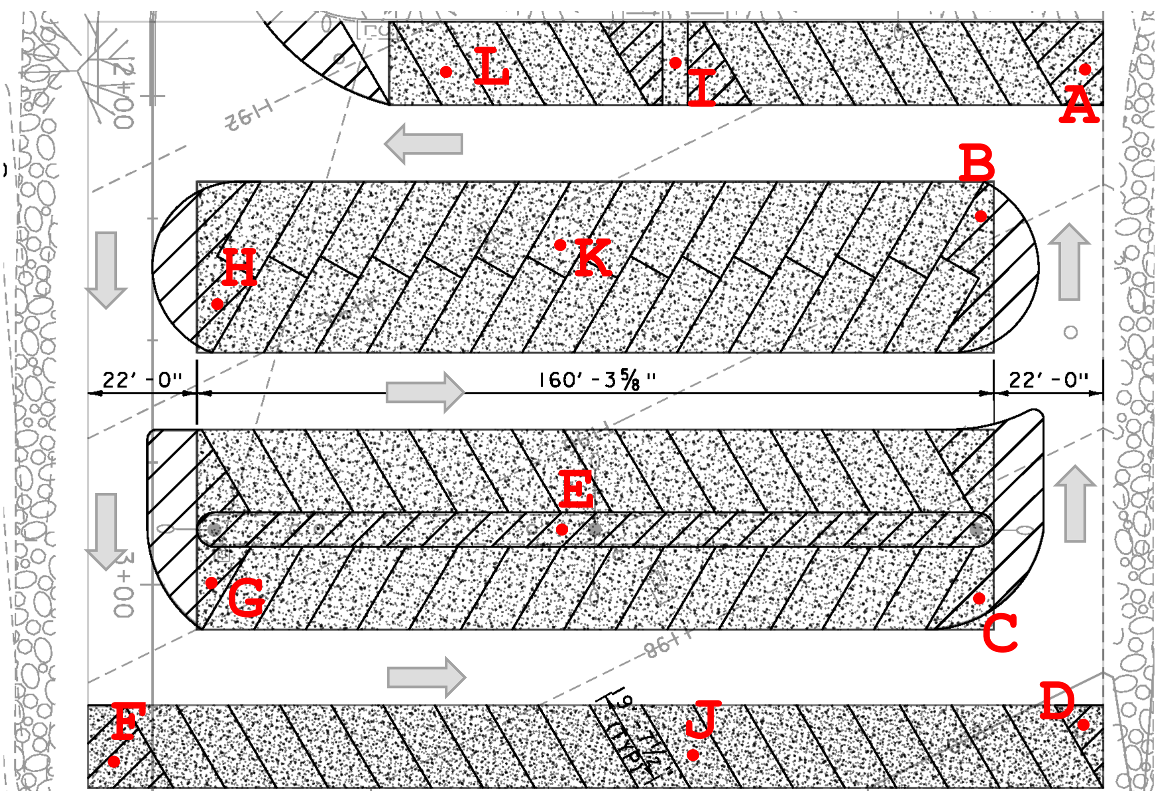

Figure 6: Test Site Layout

Figure 7: Test site locations

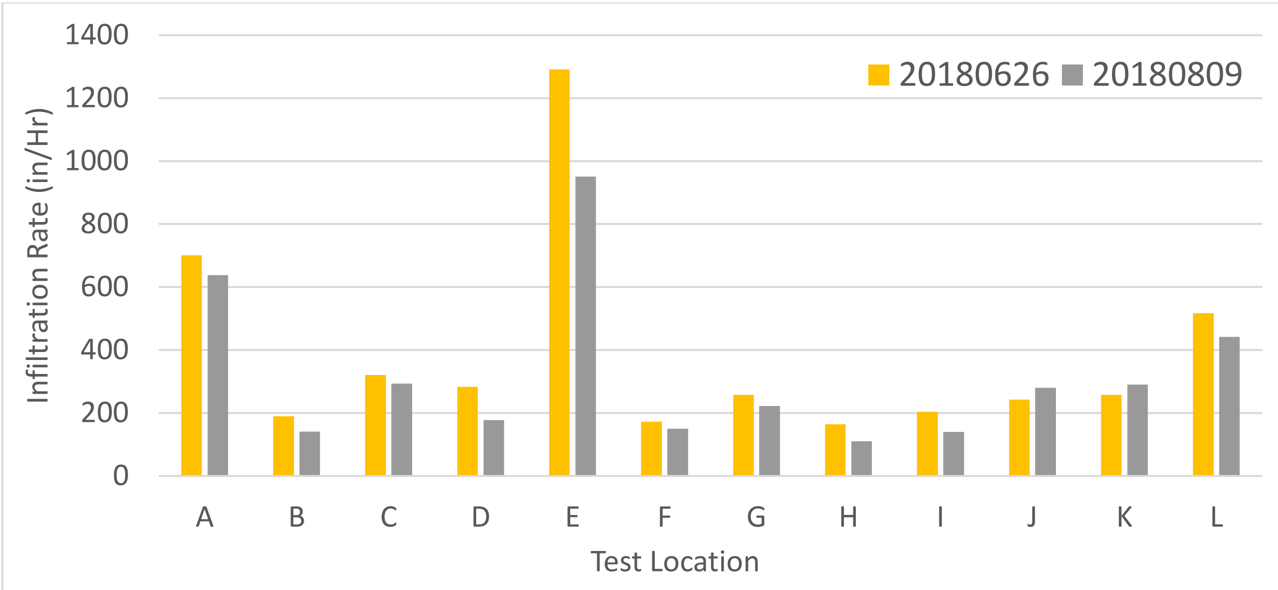

Figure 7: Infiltration Rates from first year of monitoring, average 15.4% reduction

3.2. Site Visit 2019

A site visit to the project was done on March 28, 2019, to observe its condition following the first winter. Photos collected (Figure 9) show signs of salt and winter maintenance activities that appear to be clogging the surface. Plowing marks are evident, particularly where the pavement markings have been removed from the top surface but remain in the lower voids. No damage was noted as a result of plowing, and no loose aggregate or raveling was observed.

An additional site visit was conducted on May 7, 2019 during a rain event. Figure 10 shows the relative difference in the surface moisture between the PA and HMA is easily noticed. Some localized clogging along the edge of the HMA, and in areas of high traffic can be seen, but this remains localized and should not affect the PA system infiltration overall.

Figure 9: End of Winter 2019

Figure 10: Rain event 2019

3.3. Infiltration Tests June 2021

Three years after installation infiltration testing was conducted on June 17, 2021 at the original 12 testing locations, sites A-L. See Figure 6 for the testing locations. These infiltration measurements were compared against the preliminary measurements taken on June 26 and August 8, 2018 as well as infiltration testing performed on May 20, 2019 and October 21, 2019. The testing followed ASTM C1781/C1781M. From the initial testing to the infiltration testing in June 2021 the porosity decreased on average by 26.9%. There were 4 locations (B, C, D and H) that were clogged and didn't allow the water to drain during the infiltration testing causing the test to be abandoned at those locations. These locations were not included in the calculation for the overall porosity decrease for the 12 locations. There was one location, F, which had increased porosity by 101.8%. This location is considered an outlier likely due to the geographic location being on the uphill side of the parking lot and outside of any parking spots or traffic.

3.4. Porous Asphalt Cleaning October 2021

After the infiltration testing in June 2021 showed declining porosity at many locations the Research Section worked with the Stormwater Section and Materials Section to determine the next steps. Porous pavement maintenance is generally recommended to occur every 6 months and since there had been no maintenance since installation in 2018. The group decided that cleaning the porous asphalt could give better porosity results. Research worked with the Stormwater Section to hire a consultant to power wash and vacuum the porous asphalt. Cleaning took place on October 12, 2021.

It is recommended that power washing be completed at 500 psi and at an angle of 30 degrees. ECI used a 3,200-psi power-washer at half-idle in attempt to attain the 500-psi threshold. However, they did vary the angle of power-washing between 30 and 55 degrees despite being reminded several times. After the power washing had been completed, they used a Vactor vacuum truck to pull remaining or loosened dirt and debris out of the pavement. The vacuum did visibly lift dirt from the pavement and debris could be heard entering the vacuum hose. Photos of the cleaning process can be seen in Figure 11.

Figure 11: Porous Asphalt Cleaning Procedures

3.5. Infiltration Tests October 2021

After the asphalt cleaning had been completed in June 2021, Research and Stormwater staff conducted another round of infiltration testing to confirm whether or not the cleaning improved infiltration. Testing was conducted at the original 12 locations again, but tests were only completed at 6 of the locations (E, F, G, I, J and K). This means that from June to October an additional 2 locations were unable to drain the water from the infiltration tests and tests had to be abandoned at those locations (A and L). Only 1 of the 12 locations (location E) had improved infiltration rates after the cleaning process. Overall, the porosity calculations show a decrease from June 2018 to October 2021 of 35.6% and a decrease from June 2021 to October 2021 of 11.9%, showing that the power-washing and vacuuming did not have the desired effects. Infiltration rate data is shown for all infiltration testing data in Figure 12.

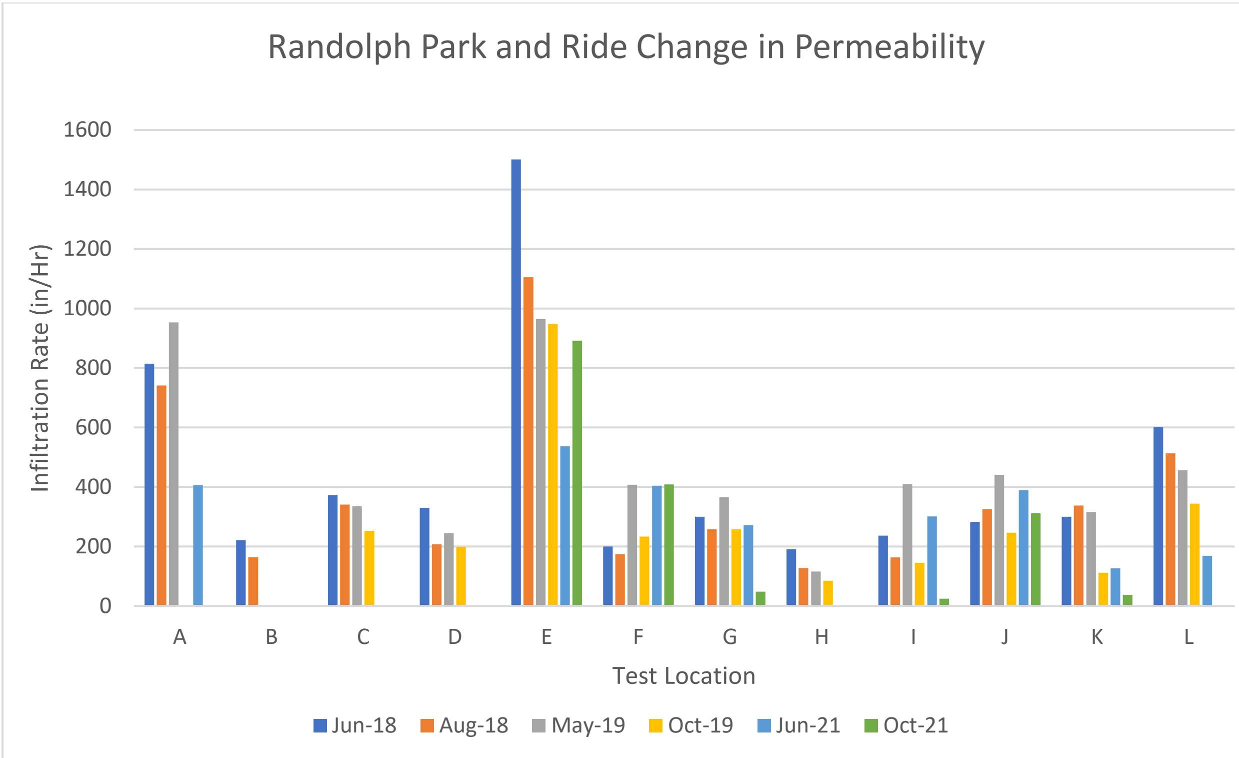

Figure 12: Infiltration Rates from every infiltration test, average 35.6% reduction

4. CORE SAMPLING

Due to the worsening infiltration performance after the asphalt cleaning, the project champions wanted to determine if there was a way to bring the porous asphalt back to its initial performance level. In order to make appropriate decision on next steps Research suggested getting core samples of the asphalt to see if there was visible clogging. If there was visible clogging, then milling the surface of the parking lot down to the clogged level could be appropriate.

Research coordinated with the Geotechnical and Materials Section to create a core sampling location and analysis plan, as seen in Appendix D. Geotech would obtain samples from an array of locations. Three control samples would be taken from location E, as it was the most porous location throughout all infiltration testing. Two samples each would be taken from locations C, G and M and would be considered "almost clogged" as they had medium values for infiltration. One sample each would be taken from locations A, D and H would be considered "clogged" as they had the lowest infiltration rate values. Infiltration rates for each location can be found in Tables 1 and 2.

Table 1: Infiltration Rates from All Infiltration Tests

	6.26.18	**8.9.18**	**5.20.19**	**10.21.19**	**6.17.21**	**10.21.21**
A	814.75	741.7846	953.7726		406.9487	
B	220.77	164.1084				
C	372.77	340.9819	335.5157	252.8774		

D	329.64	206.7752	245.441	198.451		
E	1501.36	1105.492	964.214	947.7663	536.4217	891.9295
F	200.20	174.1915	407.7212	232.6717	404.131	408.5086
G	299.99	258.2857	365.4903	257.4496	272.3622	47.67834
H	190.78	127.8046	115.8122	84.92947		
I	236.63	162.6677	409.9494	144.3651	300.9392	24.43705
J	282.57	326.1164	441.0013	246.5419	388.9543	312.2589
K	300.14	337.5006	316.5057	111.9518	126.7204	37.06442
L	601.44	513.4907	455.7977	344.1859	168.7476	

Table 2: Infiltration Ranking for Test Locations (1=Highest Infiltration Rate, Red=No Infiltration)

	6.26.18	**8.9.18**	**5.20.19**	**10.21.19**	**6.17.21**	**10.21.21**
1	E	E	E	E	E	E
2	A	A	A	L	A	F
3	L	L	L	G	F	J
4	C	C	J	C	J	G
5	D	K	I	J	I	K
6	K	J	F	F	G	I
7	G	G	G	D	L	A
8	J	D	C	I	K	B
9	I	F	K	K	B	C
10	B	B	D	H	C	D
11	F	I	H	A	D	H
12	H	H	B	B	H	L

Since it was believed that there was a layer of asphalt that was clogged Research requested tests that would determine the different in porosity between the clogged section of the core samples and the non-clogged portion. To perform these tests the core samples were visually inspected for a "visible clogging line." Only four samples (G1, C2, H and M2) were determined to have a visible clogging line and were marked to be cut at those depths. If a sample did not have a visible clogging line the sample would be cut approximately in half and the top and bottom halves would be tested for porosity. Cut depths are shown in Table 3.

Table 3: Core Sample Cut Depths

Core Number	Initial Label ID	Original Thickness (in)	First Cut Thickness (in)	% Porosity	Visible Clogged Line Depth (in)	Approximate Cut Depth (in)
1	E1	4.5	3.5	25.75		1.75
2	E2	4.75	3.8	24.701		1.9
3	E3	6	4.25	24.556		2.1
4	G1	4	3.75	15.149		1.9

5	G2	4.25	4	17.145	1	0.75
6	C1	4	3.4	18.377		1.7
7	C2	4	3.75	18.55	0.75	0.5
8	D	4	3.5	17.297		1.75
9	A	4	2.6	18.086		1.3
10	H	4.25	3.75	16.915	0.75	0.25
11	M1	3.25	2.9	21.977		1.5
12	M2	3	2.9	22.288	0.75	0.65

The Materials Section was responsible for testing the cores and determining their effective air voids, which is a measure of porosity. ASTM D7063 would be performed to determine %Effective Air Voids and AASHTO T209 would be performed to determine Total Air Voids. These values would then be used to calculate the Effective Air Voids, a measure of porosity. In order to attain these porosity values the Bulk Specific Gravity and Apparent Specific Gravity would need to be calculated for each sample. The results for the full core sample Specific Gravities and overall Porosity of the samples are shown in Table 4. Materials noted that these results suggested a design porosity value of 20%.

Table 4: Specific Gravity and Porosity for Full Core Tests

Core No.	Bulk SG Sealed Sample SG1 = A/{B-E-[(B-A)/F_T]}	Apparent Bulk SG Bag Open SG2 = A/{B-C-[(B-A)/F_{T1}]}	% Porosity = [(SG2-SG1)/SG2] x 100
I	1.918	2.583	25.750
II	1.935	2.569	24.701
III	1.926	2.552	24.556
IV	2.175	2.563	15.149
V	2.119	2.558	17.145
VI	2.075	2.542	18.377
VII	2.074	2.546	18.550
VIII	2.143	2.591	17.297
IX	2.108	2.573	18.086

X	2.136	2.571	16.915
XI	2.005	2.570	21.977
XII	1.988	2.558	22.288

The Max Specific Gravity also had to be determined for the group, which required one sample to be destroyed. One of the three control samples (Location E) was chosen to perform that test. The Max Specific Gravity for that sample was 2.531 and was used for calculations for all samples.

5. SUMMARY AND COST ANALYSIS

Construction of the PA parking surface was completed in the Spring of 2018. Construction went ahead without a problem, though it was the crews' first time working with the material. Six infiltration tests have been completed between June 2018 and October 2021, showing 35.6% reduction over the 3 years. Nevertheless, the PA surface is holding up well, showing no signs of winter maintenance damage. With these core sample results, it is not likely that any maintenance can restore the preliminary porosity performance of the asphalt as there is not any "clogged" layer of the asphalt to remove.

Ideas like drilling holes in the pavement two feet apart in order to restore the porosity of the system seem like the new holes may disrupt the integrity/structure of the pavement and the new holes would also clog eventually—even with increased power washing and vacuuming at the site.

Here we include two paragraphs related to costs of porous asphalt. In 2017, the porous asphalt cost $190.50 per ton and the adjacent conventional asphalt cost $140 per ton (small quantity), a 35% difference. The construction and design of Randolph Park and Ride with conventional in the travel lanes and porous in the parking spaces was probably an additional challenge/expense compared to all conventional. Vermont Agency of Transportation District Maintenance and Fleet staff were hoping that the porous asphalt would remain porous without special maintenance. The October 2021 power washing and maintenance of the lot cost $11,200. This was an attempt to "repair" the clogged pavements after we knew that there was low porosity and also reflective of how difficult it was to source maintenance equipment at the Randolph site. As revealed earlier, there was minimal impact with maintenance at this stage after construction.

Based on our experience with this project, the utilization of porous pavement in Vermont should be carefully considered. We need to consider the benefits from the 35% premium costs of the materials. Regular (twice a year) maintenance should be considered. Availability of power washing and heavy-duty vacuum equipment should be considered as well as the costs in personnel to perform the maintenance.

6. RECOMMENDATIONS

It is recommended that should any more porous asphalt be placed in Vermont that preventative maintenance be performed every 6 months. Maintenance work could take the form of power-washing or vacuuming the surface to remove clogged material, as it has been documented that the top inches of porous pavement is susceptible to clogging.

Additionally, it is recommended that future porous asphalt mixes potentially used in Vermont be designed for 20% air voids. This is corroborated by ASTM D3203 which states air voids should be between 16-25% for Open Bituminous Paving Mixtures.

7. REFERENCES

[1] McCain, George N., and Mandar M. Dewoolkar. *An Investigation into Porous Concrete Pavements for Northern Communities*. Burlington: The University of Vermont, July 2010. http://vtransplanning.vermont.gov/sites/aot_program_development/files/documents/materialsandresearch/completedprojects/McCain-Dewoolkar-PorousConcrete-FinalReport-06-23-10.pdf

[2] Razinger, Jonathan S. *Porous Concrete Deterioration Check*, *Randolph Park and Ride*. VTrans, 2015. https://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/Research/Research%20Field%20Report%20-%2010-19-15a.pdf

[3] Dylla, Heather L., and Kent R. Hansen. Porous Asphalt Pavements with Stone Reservoirs. U.S. Department of Transportation Federal Highway Administration, Apr. 2015. FHWAHIF-15-009

APPENDIX A - SPECIAL PROVISION - PERMEABLE BASE

1. DESCRIPTION. The Contractor shall furnish and place one or more courses of Permeable Base (PB) on an approved base in accordance with the contract documents and in reasonably close conformity with the lines, grades, thickness, and typical cross sections shown on the plans or established by the Engineer.

   The work under this section shall be performed in accordance with these provisions, the plans, and Sections 303 and Subsection 702.01, 702.02, 702.04, 702.06, 702.07, and 704.03, except as noted in this Special Provision.

2. MATERIALS.

   (a) General. This work consists of constructing an intermediate course which includes aggregate, Performance Grade Asphalt Binder (PGAB), and mineral filler if required. Materials shall meet the requirements of Subsections 702.01, 702.02, 702.04, 702.06,702.07 and 704.03, except as noted in this Special Provision.

   (b) Performance Graded Asphalt Binder. PGAB shall be 70-28, modified with SBS polymer. The PGAB shall meet the applicable requirements of AASHTO M 320 and subsection 702.02 and be from the VTrans 2017 Approved PG Binders list. The Contractor shall request approval from the Engineer for a change in PGAB supplier or source by submitting documentation stating the new supplier or source a minimum of 2 working days prior to the change. In the event that the PGAB supplier or source is changed, the Contractor shall make efforts to minimize the occurrence of PGAB co-mingling.

Table 1 – PERFORMANCE GRADED ASPHALT BINDER DESIGN CRITERIA

Mixing temperature range	290°F – 350°F Or as per PGAB supplier
PGAB Grade	PG 70-28
PGAB Content	2.0%-3.0%

   (c) Aggregate. Aggregate shall meet all of the requirements of Section 303 and Subsection 704.03 except as noted below. The use o f reclaimed asphalt pavement (RAP) shall not be permitted.

Table 2 - AGGREGATE REQUIREMENTS

GRADATION REQUIREMENTS	
Sieve Designation	Percentage by Weight Passing Square Mesh Sieves (Combined Dry Aggregate) AASHTO T 27-14
1.500 in (37.5 mm)	100
1.000 in (25 mm)	95 – 100
0.750 in (19 mm)	80 – 95
0.500 in (12.5 mm)	35 – 70
0.187 in (4.75 mm)	2 – 10

0.0937 in (2.36 mm)	0 – 5
0.0029 in (0.075 mm)	0 – 2.0
AGGREGATE QUALITIES	
AASHTO T 96 LA Abrasion	35.0 maximum
ASTM D5821 Coarse Aggregate Angularity (Minimum), % One face Two faces	 100-90
ASTM D4791 (8.4) Flat and Elongated Particles, (Maximum), % 3 to 1 5 to 1	 20 5

ASTM D5821 - Denotes that 100% of the coarse aggregate has one fractured face and 90% has two fractured faces.

ASTM 4791 - Criteria are presented as maximum percent by weight of flat and elongated particles (3:1 and 5:1 ratios).

3. COMPOSITION OF MIXTURES. The Contractor shall compose the Permeable Base with aggregate, Performance Graded Asphalt Binder (PGAB), and mineral filler if required. No Recycled Asphalt Pavement (RAP) or Recycled Asphalt Shingles (RAS) shall be used as part of this mixture. The Contractor shall size, uniformly grade, and combine the aggregate fractions in proportions that provide a mixture meeting the grading requirements specified, and the requirements in Table 1.

   The Contractor shall submit for Department approval a Job Mix Formula (JMF) to the Engineer. The JMF shall state the original source, gradation, and percentage to be used of each portion of the aggregate. It shall also state the proposed PGAB content, proposed mixing and compaction temperatures, the name and location of the refiner, the supplier, the source of PGAB submitted for approval, the type of PGAB modification if applicable, and the location of the terminal if applicable. VTrans shall then have 3 weeks in which to process the design before approval. At the time of JMF submittal, the Contractor shall identify and make available the stockpiles of all proposed aggregates at the plant site. There must be a minimum of 10 ton for stone stockpiles before VTrans will sample. VTrans may request samples for laboratory testing. The Contractor shall also make available to the Department the PGAB proposed for use in the mix in sufficient quantity to test the properties of the asphalt and to produce samples for testing of the mixture.

4. EQUIPMENT. The Permeable Base shall be produced and placed with equipment meeting the requirements of Division 300 Subsection 303, except as noted in this Special Provision.

   Rollers shall be in good mechanical condition, operated by competent personnel, capable of reversing without backlash, and operated at speeds slow enough to avoid displacement of the bituminous mixture. The mass (weight) of the rollers shall be sufficient to compact the mixture to the required density without crushing of the aggregate. Rollers shall be equipped with tanks and sprinkling bars for wetting the rolls.

   Rollers shall be two-axle tandem rollers with a gross mass (weight) of not less than 8 tons (7 metric tons) and not more than 12 tons (10 metric

tons) and shall be capable of providing a minimum compactive effort of
250 pounds per inch (44 kN/m) of width of the drive roll. All rolls shall be at least 42 inches in diameter.

5. WEATHER AND SEASONAL LIMITATIONS. The atmospheric temperature must be 16°C [60°F] or higher in the shade away from artificial heat, and the actual pavement or subbase temperature has not fallen below 10°C (50°F) for a 24-hour period leading up to start of paving. The contractor shall not pave on days when rain is forecasted for the day and night unless a change in the weather results in favorable paving conditions as determined by the Engineer. Permeable Base shall only be placed between the dates of May 1st and October 15th provided that the preceding temperature requirements are met.

6. APPLICATION OF PERMEABLE BASE.

(a) Preparation of Existing Surface. The Contractor shall thoroughly clean the surface upon which Permeable Base is to be placed of all objectionable material. When the surface of the existing base is irregular, the Contractor shall bring it to uniform grade and cross section.

No Emulsified Asphalt shall be applied on any part of the permeable pavement horizontal surface. No Emulsified Asphalt or other asphalt sealant shall be applied between layers of any porous asphalt pavement system.

(b) Preparation of Aggregates. The Contractor shall dry and heat the aggregates for the PB to the required temperature. The Contractor shall properly adjust flames to avoid physical damage to the aggregate and to avoid depositing soot on the aggregate.

(c) Mixing. The Contractor shall combine the dried aggregate in the mixer in the amount of each fraction of aggregate required to meet the JMF. The Contractor shall measure the amount of PGAB and introduce it into the mixer in the amount specified by the JMF. The Contractor shall produce the PB at the temperature established by the JMF. Once mixed, the PB must be placed as soon as possible. Storage of Permeable Base in surge hoppers or storage silos shall not be permitted. Transport may be no longer than 90 minutes.

(c) Spreading and Finishing. On areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impracticable, the Contractor shall spread, rake, and lute the PB with hand tools to provide the required compacted thickness. Solvent based agents developed to strip asphalts from aggregates will not be allowed as release agents.

Joints shall be fully coated with an approved Emulsified Asphalt just prior to the placement of the adjoining course. Areas that become contaminated or stripped of asphalt coating will be retreated with asphalt prior to placement of the adjoining course.

(e) Compaction. The actual methods and equipment utilized to compact the PB will be determined during the placement and compaction of the onsite test strip. In general, the following shall be required unless otherwise authorized by the Engineer:

Immediately after the Permeable Base has been spread, struck off, and any surface irregularities adjusted, temperatures will be taken. Surface temperature shall be between 180° to 200°F to allow for compaction and maintaining void content. The Contractor shall thoroughly and uniformly compact the PB by rolling. The PB shall be compacted by a minimum of three complete passes of a steel roller having a minimum weight of 12 tons operated in static mode, or 10 tons if equipped with oscillatory compaction and operated in low frequency, low amplitude mode, unless otherwise directed by the Engineer. When allowed by the Engineer, a light application of water may be applied to the PB during compaction. Pneumatic rollers will not be used to compact the PB.
The Contractor shall roll the surface when the mixture is in the proper condition and temperatures, such that rolling does not cause undue displacement, cracking, or shoving. The Contractor shall prevent adhesion of the PB to the rollers or vibrating compactors without the use of fuel oil or other petroleum, or solvent based release agents. Solvents designed to strip asphalt binders from aggregates will not be permitted as release agents on equipment, tools or PB surfaces. The Contractor shall immediately correct any displacement occurring as a result of the reversing of the direction of a roller or from other causes to the satisfaction of the Engineer. Any operation that results in breakdown of the aggregate shall be discontinued.

(f) Traffic. After a 48-hour minimum curing period of the PB, limited traffic may be routed over the PB surface. The preferred duration for curing without traffic shall be 7 days. Unless otherwise authorized by the Engineer, construction equipment, and traffic shall be prohibited from traveling over the PB surface until the entire pavement structure is in place, including the surface course. Damage to the PB layer caused by construction equipment or traffic shall be remedied by complete removal and replacement of the damaged area to the limits determined by the Engineer. There will be no additional payment for repairs, or associated work.

7. QUALITY ASSURANCE. Plants, testing, and testing facilities shall conform to Subsection 406.05 of except as noted below.

The use of surge bins shall not be permitted.

Sections 106, 700 and Subsections 702.01, 702.02, 702.04, 702.06, and 704.03 shall apply, with the following additions and changes:

(a) Job Mix Formula (JMF) Approval. Sufficient PGAB shall be used in the mixture such that at least 95 percent of the aggregate particles are completely coated with binder as determined by AASHTO T 195. In addition, when compacted in a superpave gyratory compactor for 50 gyrations, the resulting specimen shall be stable and must not fall apart under its own weight. Testing shall be done per AASHTO T312.

Prior to testing, the mix shall be conditioned in accordance with AASHTO R30. The mix samples, when compacted in a superpave gyratory compactor for 50 gyrations, shall result in a specimen that is porous (approx. 19% void content), and stable, and not fall apart under its own weight when removed from the superpave gyratory compactor.

The Contractor shall submit a new JMF for approval each time a change in material source or materials properties is proposed. No change in the JMF may be made without written approval of the Engineer. Once a mix design is approved the JMF is valid until the producer makes a change in aggregate source or asphalt source.

(b) Test Strip. An onsite test strip shall be constructed prior to the placement of PB on the project. The test strip will be constructed onsite to establish the proper mix design, production, placement, and compaction procedures for this contract.
The test strip shall consist of a 20-ton minimum quantity. The Contractor shall work cooperatively with the Engineer. The Construction Paving Engineer, and the Bituminous Concrete Materials Unit to develop the mix gradation and asphalt content and shall notify the Engineer within 48 hours prior to their intent to construct the test strip. The Contractor shall provide the Engineer with two mix samples from the test strip produced material for mix verification. The samples shall be tested for conformance to the contract requirements before further production. In addition to the mix samples, a minimum of three cores will be sampled from the test strip.
The cores shall be evaluated for density and asphalt coating. Testing shall be performed in accordance with AASHTO R42-06 Appendix X1 Stratified Random Sampling. Sampling shall be performed in accordance with AASHTO R42-06 Section 10.

(c) Production Testing. While production is ongoing, the contractor shall perform the tests shown in Table 3 at the indicated frequency. All testing results shall be shared with the Engineer as they become available.

Table 3 – TESTING REQUIREMENTS DURING PRODUCTION

Test	Min. Frequency	Test Method
Temperature in Truck at Plant	6 times per day	-
Gradation	Greater of either (a) 1 per 500 tons, (b) 2 per day, or (c) 3 per job	AASHTO T30
Binder Content	Greater of either (a) 1 per 500 tons, (b) 2 per day, or (c) 3 per job	AASHTO T164 or T308
Air Void Content	Greater of either (a) 1 per 500 tons, (b) 2 per day, or (c) 3 per job	AASHTO T312
Binder Drawdown	Greater of either (a) 1 per 500 tons, (b) 1 per day, or (c) 1 per job	ASTM D6390

Testing Tolerances During Production. Testing of the gradation, binder content, and draindown shall be within the limits set in Table 4.

Table 4 – CONTROL LIMITS FOR PRODUCTION

Gradation	Table 2 Limits
PGAB Content	Target ±0.5%
Draindown	ASTM D6390 limits

If an analyzed sample is outside the testing tolerances immediate corrective action will be taken. After the corrective action has been taken, the resulting mix will be sampled and tested. If the re-sampled mix test values are outside the tolerances the Engineer will be immediately informed. The Engineer may determine that it is in the best interest of the project that production is ceased. The Contractor will be responsible for all mix produced at the plant.

PB mix production will not resume unless VTrans is confident material meeting the contract requirements can be produced.

8. ACCEPTANCE. Acceptance will be based upon the permeability of the finished work as detailed below. Testing shall be conducted at random in accordance with ASTM D 3665. For the purposes of testing sublot size shall be at 100 tons, but at least 3 tests shall be conducted per job.
The full permeability of the pavement shall be tested in accordance with ASTM C1701 by applying clean water at the rate of at least 5 gpm
over the surface, using a hose or other distribution device at no extra cost to the Owner. At all test locations, all applied water shall infiltrate directly without puddle formation or surface runoff and shall be observed by the Engineer.

9. METHOD OF MEASUREMENT. The quantity of Permeable Base to be measured for payment will be the number of tons of mixture used in the complete and accepted work, as determined from the load tickets.

10. BASIS OF PAYMENT. The accepted quantity of Permeable Base will be paid for at the Contract unit price per ton. Payment will be full compensation for furnishing, mixing, hauling, and placing the material specified and for furnishing labor, tools, equipment, and incidentals necessary to complete the work, including but not limited to design of the JMF, obtaining core samples, transporting cores and samples, filling core holes, and applying emulsified asphalt to joints.

There will be no separate payment for material placed in the onsite test strip. The test strip shall be considered incidental to the Contract item unit price of Permeable Base.

The cost of furnishing testing facilities and supplies at the plant will be considered included in the Contract item unit price of Permeable Base.

The cost of obtaining, furnishing, transporting, and providing the straightedges required for Permeable Base will be paid for under the Contract item Testing Equipment, Bituminous.

Payment will be made under:

Pay Item | Pay Unit

900.680 Special Provision (Permeable Base) Ton

APPENDIX B - SPECIAL PROVISION - OPEN-GRADED FRICTION COURSE

11. DESCRIPTION. The Contractor shall furnish and place one or more courses of open-graded friction course (OGFC) on an approved base in accordance with the contract documents and in reasonably close conformity with the lines, grades, thickness, and typical cross sections shown on the plans or established by the Engineer.

The work under this provision shall be performed in accordance with these provisions, the plans, and Section 700, and Subsections 702.01, 702.02, 702.04, 702.06, and 704.11, except as noted in this Special Provision.

12. MATERIALS.

(a) General. This work consists of constructing a surface course or an intermediate course of aggregate, fiber, and bituminous-asphalt binder and additives mixed in a central plant and spread and compacted on a prepared surface. Materials shall meet the requirements of Subsections 702.01, 702.02, 702.04, 702.06, 702.07 and 704.10a, except as noted in this Special Provision.

(b) Aggregate. Aggregate shall meet all requirements Table 1 and Table 2 below. The use of reclaimed asphalt materials (RAM) shall not be permitted.

TABLE 1 - AGGREGATE REQUIREMENTS

Criteria	Test Method	Specified Minimum	Specified Maximum
Flat and Elongated, %			
3 to 1	ASTM D4791	-	20
5 to 1	ASTM D4791	-	5
Fractured Faces, %			
One face	ASTM D5821	100	-
Two faces		90	-
Sand equivalent	AASHTO T176	50	-
Uncompacted Void Content of Fine Aggregate	AASHTO T304	45	

TABLE 2 - Aggregate Gradation Control Points

Sieve Designation	Nominal Maximum Aggregate Size---Control Points - Percentage by Weight Passing Square Mesh Sieves (Combined Dry Aggregate) AASHTO T 27-14
0.750 in (19 mm)	100
0.500 in (12.5 mm)	85 – 100
0.375 in (9.5 mm)	55 – 75
0.187 in (4.75 mm)	10 – 25
0.0937 in (2.36 mm)	5 – 10
0.0029 in (0.075 mm)	2.0 – 4.0

(c) Mineral Filler. Mineral filler shall consist of finely divided mineral matter such as rock, limestone dust, or other suitable material. At the time of use, if necessary, it shall be sufficiently dry to flow freely and essentially free from agglomerations. Filler shall be free from organic impurities and have a plasticity index not greater than 4. Filler material shall meet AASHTO M17, except that the graduation requirements of M17 shall not apply.

(d) Stabilizing Additive. Stabilizing additive shall consist of an Aramid fiber stabilizer. For Aramid fibers, the dosage rate shall be approximately 0.4 percent by total mixture mass and sufficient to prevent draindown. Aramid fibers shall conform to the properties of Table 3.

Store fibers in a dry environment out of contact with moisture.

TABLE 3 – STABILIZING ADDITIVE (ARAMID FIBER) PROPERTIES

Material	Aramid
Fiber Length, inch	0.75 ± 0.13
Thickness[1], inch	0.0002 in. maximum mean test value
Crimps; ASTM D 3937	None
Tensile strength, minimum, psi; ASTM D 2256[2]	400,000
Specific gravity	1.44 ± 0.05
Melting temperature, minimum, °F	800

[1]The Aramid fiber thickness is determined by measuring at least 200 fibers in a phase contrast microscope.

[2]This data must be obtained prior to cutting of fibers.

(e) Performance Graded Asphalt Binder. PGAB shall be 70-28, modified with SBS polymer. The PGAB shall meet the applicable requirements of Subsection 702.02 and be from the VTrans 2017 Approved PG Binders list. The Contractor shall request approval from the Engineer for a change in PGAB supplier or source by submitting documentation stating the new supplier or source a minimum of 2 working days prior to the change. In the event that the PGAB supplier or source is changed, the Contractor shall make efforts to minimize the occurrence of PGAB co-mingling.

(f) Emulsified Asphalt. Emulsified Asphalt shall be RS-1, RS-1h, CRS-1, or CRS-1h and meet the requirements of Subsection 702.04.

13. COMPOSITION OF MIXTURES.

(a) General. The Contractor shall compose the open-graded friction course with aggregate, Performance Graded Asphalt Binder (PGAB), stabilizing fibers and mineral filler if required. OGFC shall conform to the requirements listed in Tables 2 and 4. The Contractor shall size, uniformly grade, and combine the aggregate fractions in proportions that provide a mixture meeting the grading requirements of the Job Mix Formula (JMF).

TABLE 4: Volumetric Design Criteria

Air Voids @ NDesign	19.0±3%
PGAB Binder Content	6.0-6.5 percent
VCA1mix	Less than VCADRC2
Draindown	0.3 percent maximum at 15° above design mix temperature (AASHTO T 305)
Gyrations @ NDesign	50

[1]Voids in coarse aggregate (per AASHTO T19)

[2]Dry-rodded condition (per AASHTO T19)

(b) Stabilizing Additive Blending Requirements. Ensure Aramid fibers are blended with 0.75 inch (19 mm) fibrillated polyolefin fibers or wax coated to ensure proper distribution in the mix. Add Aramid fibers at the rate of 1.8 to 4.0 ounces (60 to 113 g) of pure aramid fiber, not including the weight of any polyolefin fibers or coating, per ton (metric ton) of total mix.

(c) Fiber Supply System. Add treated fibers manually or through specialized equipment that can accurately proportion or meter the proper amount per batch for batch plants, or continuously and in a steady uniform manner for drum plants.

(d) Batch Plant. When a batch plant is used, add treated fibers to the aggregate before or in the weigh hopper. Ensure that the fiber is uniformly distributed with the asphalt and aggregate mixture.

(e) Drum Plant. When a drum plant is used, inject treated fibers through the RAP collar by placing fibers on the RAP belt or by feeding them through a fiber feeder. Rate the feeding of fibers with the rate the plant is producing asphalt mix. If a fiber feeder is used, it must be properly calibrated for treated aramid fiber to deliver the fiber at the correct rate.

14. TEMPERATURE REQUIREMENTS. After the JMF is established, the temperature of the mixture shall conform to the PGAB supplier’s recommended mixing and compaction temperature, with the following tolerances:

In the truck at the mixing plant +/-
10°F at the Paver +/-
10°F
The JMF and the mix subsequently produced shall meet the requirements of Tables 1, 2 and 4.

15. WEATHER AND SEASONAL LIMITATIONS. Subsection 406.04 shall apply, with the following changes: The atmospheric temperature must be 16°C [60°F] or higher in the shade away from artificial heat, and the actual pavement temperature has not fallen below 10°C (50°F) for a 24-hour

period leading up to start of paving. The contractor shall not pave on days when rain is forecasted for the day and night unless a change in the weather results in favorable paving conditions as determined by the Engineer. Open Graded Friction Course shall only be placed between the dates of May 1st and October 15th provided that the preceding temperature requirements are met.

16. ROLLERS. Rollers shall be in good mechanical condition, operated by competent personnel, capable of reversing without backlash, and operated at speeds slow enough to avoid displacement of the bituminous mixture. The mass (weight) of the rollers shall be sufficient to compact the mixture to the required density (19.0±3% voids) without crushing of the aggregate. Rollers shall be equipped with tanks and sprinkling bars for wetting the rolls.

Rollers shall be two-axle tandem rollers with a gross mass (weight) of not less than 8 tons (7 metric tons) and not more than 12 tons (10 metric tons) and shall be capable of providing a minimum compactive effort of
250 pounds per inch (44 kN/m) of width of the drive roll. All rolls shall be at least 42 inches in diameter.

17. APPLICATION OF OPEN GRADED FRICTION COURSE.

(a) Preparation of Existing Surface. The surface where the OGFC is to be placed shall be cleaned of all foreign and loose material. Immediately before beginning paving operations, ensure that the surface is dry. When precipitation has occurred within 24 hours before application, the Engineer will determine when the surface is completely dry.

An Emulsified Asphalt shall be applied to curbs, gutters, manholes, and other similar structures with vertical or horizontal surfaces to be in contact with the OGFC. Exposed surfaces of these structures shall be cleaned, and a uniform coating shall be applied to contact surfaces before paving.

No Emulsified Asphalt shall be applied on any part of the permeable pavement horizontal surface. No Emulsified Asphalt or other asphalt sealant shall be applied between layers of any porous asphalt pavement system.

Take extreme care in the application of this material to prevent splattering or staining of surfaces that will be exposed after the paving is completed. Surfaces that are stained as a result of the Contractor's operation shall be repaired or replaced by the Contractor at no additional cost.

(b) Compaction. Pneumatic rollers will not be used to compact the OGFC. The OGFC shall be compacted by a minimum of three complete passes of a steel roller operated in static mode, unless otherwise directed by the Engineer. If the OGFC is unstable during compaction, it may be allowed to cool until rolling can be completed without excessive displacement. Following compaction, no traffic will be allowed on the OGFC for a minimum of 48 hours. The preferred duration for curing without traffic shall be 7 days. If during placement there is slight unevenness have a 3 to 5-ton roller on standby to bring over pavement in a cross direction to smooth out.

18. QUALITY ASSURANCE. Plants, testing, and testing facilities shall conform to Subsection 406.05 except as noted below. The use of surge bins or silos shall not be permitted. Section 700 and Subsections 702.01, 702.02, 702.04, 702.06, and 704.10a shall apply, with the following additions and changes:

(a) Job Mix Formula (JMF) Approval. The Contractor shall submit a JMF for approval in accordance with the method described in FHWA Technical Advisory T 5040.31 for each mixture to be supplied. VTrans shall then have a minimum of 3 weeks for testing and evaluating the submitted mix design before approval. The JMF shall establish a single percentage of aggregate passing each required sieve size within the limits shown in Table 2. The general composition limits given in Table 2 indicate the control points of mixtures permissible under this specification. The JMF shall state the source, gradation, and percentage to be used of each portion of the aggregate and mineral filler if required. It shall also state the proposed PGAB content and the name of the source of PGAB. The JMF shall state the bulk density (and voids) of specimens compacted in a superpave gyratory compactor at the design number of gyrations (50).

Prior to loading the gyratory specimen, the mix shall be conditioned in accordance with AASHTO R30. The mix samples, when compacted in a superpave gyratory compactor for 50 gyrations, shall result in a specimen that is porous (19.0±3% void content), and stable, and not fall apart under its own weight when removed from the superpave gyratory compactor. Testing shall be done per AASHTO T312 and final dimensions of the specimen shall be 150 mm in diameter and 115+/-5 mm) in height.

The Contractor shall submit a new JMF for approval each time a change in material source or materials properties is proposed. The same approval process shall be followed. The cold feed percentage of any aggregate may be adjusted up to 10 percentage points from the amount listed on the JMF, however no aggregate listed on the JMF shall be eliminated. No change in the JMF may be made without written approval of the Engineer. Once a mix design is approved the JMF is valid until the producer makes a change in aggregate source or asphalt source.

The Contractor shall provide the following information with the proposed JMF:

(1) Properly completed JMF indicating all mix properties (V, Gmm, Gsb, VCA_{dry}, VCA_{mix})

(2) Stockpile Gradation Summary

(3) Design Aggregate Structure Consensus Property Summary

(4) Design Aggregate Structure

(5) Test results for the selected aggregate blend

(6) Specific Gravity and temperature/viscosity charts for the PGAB to be used

(7) Recommended mixing and compaction temperatures from the PGAB supplier

(8) Material Safety Data Sheets (MSDS) For PGAB and aramid fiber blend

(8) Test report for Contractor's Verification sample

At the time of JMF submittal, the Contractor shall identify and make available the stockpiles of all proposed aggregates at the plant site. There must be a minimum of 10 ton for stone stockpiles before VTrans will sample. VTrans may request samples for laboratory testing. The Contractor shall also make available to the Engineer the PGAB and stabilizing fibers proposed for use in the mix in sufficient quantity to test the properties of the asphalt and to produce samples for testing of the mixture. Before the start of paving, the Contractor and the Bituminous Concrete Materials Unit shall split a production sample for evaluation. The Contractor shall test its split of the sample and if the results are found to be acceptable, the Contractor will forward their results to the Engineer (within two days of receiving their results). The Bituminous Concrete Materials Unit will subsequently test their split of the sample. The results of the two split samples will be compared and shared between the Engineer, the Bituminous Concrete Materials Unit, and the Contractor. If the mixture is found to be acceptable, an approved JMF will be forwarded to the Contractor and paving may commence. The first day's production shall be monitored, and the approval may be withdrawn if the mixture exhibits undesirable characteristics such as checking, shoving or displacement. The Contractor shall be allowed to submit changes within 24 hours of receipt of the first Acceptance test result. Adjustments will be allowed of up to 2% on the percent passing the No. 8 (0.0937 in) sieve through the No. 200 (0.0029 in) and 3% on the percent passing the No. 4 (0.187 in) or larger sieves. Adjustments will be allowed on the %PGAB of up to 0.2%. Adjustments will be allowed on GMM of up to 0.010.

Sufficient PGAB shall be used in the mixture such that the aggregate particles are completely coated with binder as determined by AASHTO T 195. In the event that the cores or gyratory compacted samples do not meet the requirements set forth in this specification, mixture gradation, rolling methods and/or asphalt contents will be adjusted and new test strips will be required until the requirements are met.

OGFC mix production will not resume unless VTrans is confident material meeting the contract requirements can be produced.

(b) Test Strip. An onsite test strip shall be constructed prior to full production and the placement of OGFC on the project. The test strip shall be constructed onsite to establish the proper mix design, placement, and compaction procedures for this contract.

The test strip shall consist of a 20-ton minimum quantity. The Contractor shall provide the Engineer with two mix samples from the test strip for mix verification. The samples shall be tested for conformance to the contract requirements before further production. Testing shall be performed in accordance with AASHTO R42-06 Appendix X1 Stratified Random Sampling. Sampling shall be performed in accordance with AASHTO R42-06 Section 10.

In addition to the mix samples, permeability of the compacted in-place material shall be tested in accordance with ASTM C1701 at 3 locations selected by the Engineer, and a minimum of three cores will be sampled from the test strip and shall be evaluated for density. Coring shall be conducted in accordance with ASTM D5361/F5361M and bulk density of cores shall be tested in accordance with ASTM D6752.

The full permeability of the pavement surface shall be tested in accordance with ASTM C1701 by applying clean water at the rate of at least 5 gpm over the surface, using a hose or other distribution device at no extra cost to the Owner. All applied water shall infiltrate directly without puddle formation or surface runoff and shall be observed by the Engineer prior to and after the placement of the Open Graded Friction Course (OGFC).

Pavement cores shall exhibit an average bulk density of 81%±3% (equivalent to 19.0%±3% voids) of the average theoretical maximum density (Gmm) of the mix on the day of paving. Any modifications to the mixture shall be submitted as a change to the JMF by contract modification. The Agency will notify the Contractor in writing of satisfactory completion (or failure) of the test strip. A test strip is considered a failure if mix verification samples do not meet the control limits in Table 4, if core samples do not meet density requirements above, and if any one test location does not meet the permeability requirements above. Only after receiving notification of a satisfactory test strip will the contractor be allowed to continue with production.

(c) Production Testing. While production is ongoing, the contractor shall perform the tests shown in Table 5 at the indicated frequency. All testing results shall be shared with the Engineer as they become available.

Table 5 – TESTING REQUIREMENTS DURING PRODUCTION

Test	Min. Frequency	Test Method
Temperature in Truck at Plant	6 times per day	-
Gradation	Greater of either (a) 1 per 500 tons, (b) 2 per day, or (c) 3 per job	AASHTO T30
Binder Content	Greater of either (a) 1 per 500 tons, (b) 2 per day, or (c) 3 per job	AASHTO T164 or T308
Air Void Content	Greater of either (a) 1 per 500 tons, (b) 2 per day, or (c) 3 per job	ASTM D6752
Binder Drawdown	Greater of either (a) 1 per 500 tons,	ASTM D6390

	(b) 1 per day, or (c) 1 per job	

Testing Tolerances During Production. Testing of the gradation, binder content, and draindown shall be within the limits set in Table 6.

Table 6 – CONTROL LIMITS FOR PRODUCTION

Gradation	Table 2 Limits
PGAB Content	Target ±0.4%
Draindown	ASTM D6390 limits

If an analyzed sample is outside the testing tolerances immediate corrective action will be taken. After the corrective action has been taken the resulting mix will be sampled and tested. If the re- sampled mix test values are outside the tolerances the Engineer will be immediately informed. The Engineer may determine that it is in the best interest of the project that production is ceased. The Contractor will be responsible for all mix produced at the plant.
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.

(d) Inferior Material. Material not conforming to specification requirements shall be subject to corrective action, production suspension, rejection, removal, or reduced payment as determined by the Engineer.

The Engineer may at any time, notwithstanding previous acceptance, notify the Contractor of inferior material and recommend the rejection of any OGFC which is rendered unfit for use due to contamination, segregation, incomplete coating of aggregate, draindown, in place density or improper mix temperature. Such recommendation may be based on only visual inspection or temperature measurements.

(e) Shaping Edges. Edges shall be beveled while still hot with the back of a lute or smoothing iron and compacted by tampers or by other satisfactory methods.

(f) Paving Requirements. The contactor shall meet the following requirements during paving operations:

(1) Inspect every truck’s truck bed for pooling (draindown).

(2) Take temperature of asphalt in every truck.

(3) Take temperature of porous asphalt mix in each pull of the paver [within 6°C (10°F) of the recommended compaction temperature].

(4) Consult with the Engineer to determine locations of butt joints as needed.

(4) Test surface smoothness and positive drainage with 10’ straightedge after compaction.

(6) Consult with the Engineer to mark core locations after compaction.

19. ACCEPTANCE. Acceptance will be based on the following:

(a) Density. Open Graded Friction Course (OGFC) mixtures will be sampled via pavement cores once per sublot using a stratified random sampling procedure in accordance with ASTM D 3665 and tested by the Agency. For the purposes of acceptance testing, a lot shall consist of the total quantity of OGFC mixture compacted in-place during and one day’s production to a maximum of 24 hours. Sampling shall be performed at a rate of one sample per 100 tons, with the exception that no fewer than 3 samples be taken for any one day’s production.

Coring shall be conducted in accordance with ASTM D5361/F5361M and bulk density of cores shall be tested in accordance with ASTM D6752.

The density of the compacted OGFC shall not be less than 78% nor more than 84% of the corresponding average maximum specific gravity of the mix on the day of production.

(b) Permeability. Open Graded Friction Course (OGFC) mixtures will be tested for permeability using a stratified random sampling procedure in accordance with ASTM D 3665 and tested by the Agency. For the purposes of acceptance testing, a lot shall consist of the total quantity of OGFC mixture compacted in-place during and one day’s production to a maximum of 24 hours. Testing shall be performed at a rate of one sample per 100 tons, with the exception that no fewer than 3 samples be taken for any one day’s production.

The full permeability of the pavement surface shall be tested in accordance with ASTM C1701 by applying clean water at the rate of at least 5 gpm over the surface, using a hose or other distribution device at no extra cost to the Owner. At all test locations, all applied water shall infiltrate directly without puddle formation or surface runoff and shall be observed by the Engineer prior to and after the placement of the surface course.

(c) Grade. The finished surface of the pavement shall not vary from the gradeline elevations and cross sections shown on the plans by more than 1/2 inch; however positive drainage must be achieved. The Contractor shall remove deficient areas and replace with new material. Sufficient material shall be removed to allow at least 1.5 inches (37.5mm) of replacement OGFC to be placed. Milling or skin patching for correcting low areas shall not be permitted.

20. METHOD OF MEASUREMENT. The quantity of Special Provision (Open Graded Friction Course) to be measured for payment will be the number of tons for a lot of mixture complete in place in the accepted work as determined from the weigh tickets.

21. BASIS OF PAYMENT. The measured quantity of Special Provision (Open Graded Friction Course) will be paid for at the Contract unit price per ton. Payment shall be full compensation for furnishing, mixing, hauling, and placing the material specified and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work, including but not limited to design of the JMF, obtaining core samples, transporting cores and samples, filling core holes, and applying emulsified asphalt to joints.

There will be no separate payment for material placed in the onsite test strip. The test strip shall be considered incidental to the Contract item unit price of Open Graded Friction Course.

The costs of furnishing testing facilities and supplies at the plant will be considered included in the Contract unit price of Special Provision (Bituminous Concrete Pavement, Small Quantity).

The costs of obtaining, furnishing, transporting, and providing the straightedges required for Open Graded Friction Course will be paid for under the appropriate Section 631 pay item included in the Contract.

The costs associated with obtaining samples for acceptance testing will be incidental to the cost of Special Provision (Open Graded Friction Course).

Special Provision (Open Graded Friction Course) mixture approved by the Engineer for use in correcting deficiencies in the base course constructed as part of the Contract will not be paid for as Special Provision (Open Graded Friction Course), but will be incidental to the Contract item for the specified type of base course.

Payment will be made under:

Pay Item	Pay Unit
900.680 Open Graded Friction Course	Ton

APPENDIX C - INFILTRATION TESTING INSTRUCTIONS

Testing conducted at the Randolph Park and Ride are based on ASTM C1781/C1781M.

A tank from the Randolph Garage (stored in the lower shed) is used to transport water to the site and should be filled with water from the garage. Additional required equipment includes an Infiltration Ring, Portable Digital Scale, Plumbers Putty, Stopwatch/timer, and at least four 5-gallon buckets.

Infiltration testing follows the following process:

1. Identify test site and place the infiltration ring.
2. Seal the outer edge of the ring with a bead of plumber's putty, pushing it slightly down into the pavement to create a barrier and limit leaks.
3. Prewetting
    a. Using 8 lbs of water (record the exact weight), from a height of less than 6 in, pour the complete volume in while maintaining a water level between the two lines on the infiltration ring.
    b. Begin timing as soon as the water makes contact with the surface, and end when free water is no longer present on entire surface.
    c. Record the time to the nearest 0.1 sec.
4. Testing
    a. If the prewetting took less than 30 sec, use 40 lbs or water, and if more than 30 sec, use 8 lbs of water. Record the weight of water used.
    b. Within 2 minutes of prewetting, pour the water onto the ring at a rate sufficient to maintain a head between the two marked lines and until the measured amount of water has been used. Record the time to the nearest 0.1 sec.
    c. Repeat testing within 5 minutes for a second result, and if the first two results vary by more than 10%, conduct a third test.
5. Remove the infiltration ring, and all of the plumber's putty. Use the putty in ball to extract any remnants that are stuck in the pavement, relying on the adhesion between the putty.

APPENDIX D – CORE SAMPLE TESTING PLAN

Identifying and Sorting Samples:

1. Receive 12 samples from Geotech (organize which samples are from which locations)
    a. 3 from location E
    b. 2 each from locations G, M and C
    c. 1 each from locations A, H and D
    d. Sort samples in Clogged (C, A, H, D), Almost Clogged (G, M) and Control (E)
2. Perform level cutting on bottom of samples to square them (discard portions with non-wearing course)
3. Samples from location E:
    a. Perform Visual Analysis on the three samples. Are there any visible clogged lines? How do they compare to each other? How do they compare to the other samples? Record observations in Tables 1 and 2.
4. Samples from locations G, M, C:
    a. Perform Visual Analysis. Are there visible clogged lines? How do they compare to each other? How do they compare to samples from location E? How do they compare to clogged A, H and D samples? Record observations in Tables 1 and 2.
5. Samples from locations, A, H, D:
    a. Perform Visual Analysis. Are there visible clogged lines? How do they compare to each other? How do they compare to samples from location E? How do they compare to clogged G, M and C samples? Record observations in Tables 1 and 2.

Analysis Plan A:

1. Samples from location E:
    a. If all three samples look similar to each other:
        i. Perform ASTM D7063 to determine Effective Air Voids on two samples and keep them for Further Testing. Record Raw Data in Table 3.
        ii. Perform AASHTO T209 to determine Total Air Voids on one sample. Record Data in Table 4.
        iii. Keep other core as reserve
    b. If the three samples look different:
        i. Perform ASTM D7063 on all samples. Record Raw Data in Table 3.
2. Samples from locations G, M, C:
    a. If both samples at one location look similar to each other:
        i. Perform ASTM 7063 on one sample and keep that for Further Testing. Record Raw Data in Table 3.
    b. If two samples at one location look different:
        i. Perform ASTM 7063 on all samples. Record Raw Data in Table 3.
3. Samples from locations, A, H, D:
    a. Perform ASTM 7063 on at least one core. If possible, from all three. Record Raw Data in Table 3.
4. Further Testing (E, G, M, C, A, H, D):

a. If visible clogged line is present – use clogged line as cut line
    i. Perform Visual Analysis. After cutting, are there differences between samples? How does clogged subsample compare to other clogged subsamples? Do unclogged subsamples look like Control location E samples? Record Observations in Excel Spreadsheet Table T1.
    ii. Perform ASTM 7063 on sections above and below cut line. Record Raw Data in Excel Spreadsheet Table T2.
    iii. *Perform AASHTO 209 on sections above and below cut line from one sample from Location E. Record Raw Data in Excel Spreadsheet Table T3.*
b. If no visible clogged line is present
    i. Ideal to get three subsamples/2 cuts from each core. (Want an upper, middle, and lower layer)
    ii. Perform Visual Analysis. After cutting, are there differences between samples? How does clogged subsample compare to other clogged subsamples? Do unclogged subsamples look like Control location E samples? Record Observations in Excel Spreadsheet Table T1.
    iii. Perform ASTM 7063 on all subsamples. Record Raw Data in Excel Spreadsheet Table T2.
    iv. *Perform AASHTO 209 on sections above and below cut line from one sample from Location E. Record Raw Data in Excel Spreadsheet Table T3.*

If the ASTM D7063 test is too difficult, provides unrealistic or unexpected results, or is otherwise problem causing, please revert to Plan B. We're including Plan B because while we believe Plan A will be better, if there are problems with Plan A we want to perform AASHTO T331 and T209.

Analysis Plan B:

1. Samples from location E:
    a. If all three samples look similar to each other:
        i. Perform Bulk Specific Gravity (T331) on one sample and keep that for Further Testing. Record Raw Data in Table 6.
        ii. Perform Max Specific Gravity (T209) on one sample from Location E. Record Raw Data in Table 7.
        iii. Keep third core as reserve
    b. If the three samples look different:
        i. Perform Bulk Specific Gravity on all samples. Record Raw Data in Table 6.
        ii. Perform Max Specific Gravity on one sample from Location E. Record Raw Data in Table 7.
2. Samples from locations G, M, C:
    a. If both samples at one location look similar to each other:
        i. Perform Bulk Specific Gravity on one sample and keep that for Further Testing. Record Raw Data in Table 6.
        ii. Keep second core as reserve
    b. If two samples at one location look different:
        i. Perform Bulk Specific Gravity on all samples. Record Raw Data in Table 6
3. Samples from locations, A, H, D:
    a. Perform Bulk Specific Gravity on at least one core. If possible, from all three. Record Raw Data in Table 6.

4. Further Testing (E, G, M, C, A, H, D):
    a. If visible clogged line is present – use clogged line as cut line
        i. Perform Visual Analysis. After cutting, are there differences between samples? How does clogged subsample compare to other clogged subsamples? Do unclogged subsamples look like Control location E samples? Record Observation in Excel Spreadsheet Table. Record Observations in Excel Spreadsheet Table T1.
        ii. Perform Bulk Specific Gravity on sections above and below cut line. Record Raw Data in Excel Spreadsheet Table T5.
        iii. Perform AASHTO 209 on sections above and below cut line from one sample from Location E. Record Raw Data in Excel Spreadsheet Table T6.
    b. If no visible clogged line is present
        i. Ideal to get three subsamples/2 cuts from each core. (Want an upper, middle, and lower layer)
        ii. Perform Visual Analysis. After cutting, are there differences between samples? How does clogged subsample compare to other clogged subsamples? Do unclogged subsamples look like Control location E samples? Record Observations in Excel Spreadsheet Table T1.
        iii. Perform Bulk Specific Gravity on all subsamples. Record Raw Data in Excel Spreadsheet Table T5.
        iv. Perform AASHTO 209 on sections above and below cut line from one sample from Location E. Record Raw Data in Excel Spreadsheet Table T6.

Expected Analysis:

Visual Analysis: To be completed by Technical Expert (TE). TE will assess if there is a distinct layer of clogging in the sample. If there is that depth will be denoted in Table 1 below. If there is no distinct line that shows clogging, a measurement shall be taken to the depth at which the sample looks to be at least 50% clogged compared to samples taken at location E. The TE will also assess whether or not the samples look to be more clogged than the Control Samples taken from Location E.

Table 1- Visual Assessment: Depth of Clogging

Sample Location/Sample Number	Clogged Category	Depth of Clogging (in)	Visible Clogging Line? (Y/N)	Reserve? (Y/N)	Used for Max Density? (Y/N)
E1	Control				
E2	Control				
E3	Control				
G1	Almost Clogged				
G2	Almost Clogged				
M1	Almost Clogged				
M2	Almost Clogged				
C1	Clogged				
C2	Clogged				
A	Clogged				
H	Clogged				
D	Clogged				

Table 2- Visual Analysis: Sample Comparison

Sample Location/Sample Number	Clogged Category	Visual Assessment: More clogged than Location E samples? (Y/N)	Visual Assessment: Similarities to Which Almost Clogged Location Samples?	Visual Assessment: Similarities to Which Clogged Location Samples?
E1	Control			
E2	Control			
E3	Control			
G1	Almost Clogged			
G2	Almost Clogged			
M1	Almost Clogged			
M2	Almost Clogged			
C1	Clogged			
C2	Clogged			
A	Clogged			
H	Clogged			
D	Clogged			

Plan A Analysis: The TE will perform test as described in ASTM D7063. Bulk Specific Gravity values should be compared to Post-Construction Acceptance Test Values of XX. Effective Percent Porosity values should be compared to Post-Construction Values of 19%.

Table 3- ASTM D7063 Raw Data

Sample Location/Sample Number	Clogged Category	Oven Dry Mass, A (g)	SSD Mass, B (g)	Unsealed Mass in Water, C (g)	Mass of Sealed Specimen Underwater, E (g)	Apparent Specific Gravity of Plastic Sealing Material, F_T	Apparent Specific Gravity of Plastic Sealing Material Opened Underwater, F_{T1}
E1	Control						
E2	Control						
E3	Control						
G1	Almost Clogged						
G2	Almost Clogged						
M1	Almost Clogged						
M2	Almost Clogged						
C1	Clogged						
C2	Clogged						
A	Clogged						
H	Clogged						
D	Clogged						

Table 4- AASHTO 209 Raw Data

Sample Location/Sample Number	Clogged Category	Dry Mass, A (g)	SSD Mass, ASSD (g)	Standardized Submerged Weight of Bowl, B (g)	Submerged Weight of Sample and Bowl, C (g)
E1	Control				
E2	Control				
E3	Control				
G1	Almost Clogged				
G2	Almost Clogged				
M1	Almost Clogged				
M2	Almost Clogged				
C1	Clogged				
C2	Clogged				
A	Clogged				
H	Clogged				
D	Clogged				

Table 5- Porosity Measurements using ASTM D7063

Sample Location/Sample Number	Clogged Category	Bulk Specific Gravity (SG1)	BSG Below Post-Construction Acceptance Test Values?	Apparent Specific Gravity (SG2)	Effective Percent Air Voids (%)	Porosity Below Post-Construction Values? (Y/N)
E1	Control					
E2	Control					
E3	Control					
G1	Almost Clogged					
G2	Almost Clogged					
M1	Almost Clogged					
M2	Almost Clogged					
C1	Clogged					
C2	Clogged					
A	Clogged					
H	Clogged					
D	Clogged					

Refer to Excel for Post-Cut tables.

Plan B Analysis: The TE will perform test as described in AASHTO T331. Bulk Specific Gravity values should be compared to Post-Construction Acceptance Test Values of XX. Effective Percent Porosity values should be compared to Post-Construction Values of 19%. Max Specific Density will be measured using AASHTO T209.

Table 6- AASHTO T331 Raw Data

Sample Location/Sample Number	Clogged Category	**Dry Mass, A (g)**	**Mass of Bag in air, B (g)**	**Final Mass of Specimen after Removal from Sealed Bag, C (g)**	**Mass of Sealed Specimen Underwater, E (g)**	**Bag Correction Factor, F (g)**
E1	Control					
E2	Control					
E3	Control					
G1	Almost Clogged					
G2	Almost Clogged					
M1	Almost Clogged					
M2	Almost Clogged					
C1	Clogged					
C2	Clogged					
A	Clogged					
H	Clogged					
D	Clogged					

Table 7- AASHTO T209 Raw Data (Since T209 destroys samples, it will only be run on a few samples pre-cutting)

Sample Location/Sample Number	Clogged Category	**Dry Mass, A (g)**	**SSD Mass, A_{SSD} (g)**	**Standardized Submerged Weight of Bowl, B (g)**	**Submerged Weight of Sample and Bowl, C (g)**
E1	Control				
E2	Control				
E3	Control				
G1	Almost Clogged				
G2	Almost Clogged				
M1	Almost Clogged				
M2	Almost Clogged				
C1	Clogged				
C2	Clogged				
A	Clogged				
H	Clogged				
D	Clogged				

Table 8- Bulk Specific Gravity Values Comparison

Sample Location/Sample Number	Clogged Category	Bulk Specific Gravity, G_{mb}	BSG Below Post-Construction Acceptance Test Values? (Y/N)	Max Specific Gravity, G_{mm}	Total Percent Air Voids (%)	Porosity Above Post-Construction Values? (Y/N)	Max Density Conducted on This Sample? (Y/N)
E1	Control						
E2	Control						
E3	Control						
G1	Almost Clogged						
G2	Almost Clogged						
M1	Almost Clogged						
M2	Almost Clogged						
C1	Clogged						
C2	Clogged						
A	Clogged						
H	Clogged						
D	Clogged						

Refer to Excel for Post-Cut tables.