

Experimental Investigation Of Porous Asphalt Pavement

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ABSTRACT

Porous asphalt pavement is an open-graded pavement system intended to provide rapid surface drainage through an interconnected void structure while retaining sufficient load-carrying capacity. This study experimentally investigated the constituent materials and laboratory performance of a porous asphalt mixture prepared with crushed aggregates, Ordinary Portland Cement as mineral filler, and VG-30 bitumen. Aggregate characterization included gradation, specific gravity, water absorption, aggregate impact value, and aggregate crushing value. The binder was evaluated by penetration, softening point, ductility, and specific-gravity tests. Five Marshall specimens were assessed for stability, flow, bulk density, air void content, and permeability. The aggregate bulk dry, saturated surface-dry, and apparent specific gravities were 2.68, 2.71, and 2.75, respectively; water absorption was 1.25%, the aggregate impact value was 17.8%, and the aggregate crushing value was 21.5%. The VG-30 binder showed an average penetration of 66 dmm, softening point of 49 degrees C, ductility of 82 cm, and specific gravity of 1.02. Marshall stability averaged 8.78 kN and flow averaged 3.34 mm. The mean air void content was 19.04%, and the mean permeability coefficient was 0.260 cm/s. The reported results indicate that the tested mixture achieved the intended combination of structural response and drainage performance under the laboratory program.

Keywords: Porous Asphalt; Permeability; Marshall Stability; Air Voids; Drainage Performance; Sustainable Pavement.

1. INTRODUCTION

Effective pavement drainage is important because retained surface water can reduce wet-weather safety and can enter pavement layers through defects. Urban development also increases impervious area and stormwater runoff, creating a need for pavement systems that can remove rainfall from the surface and contribute to drainage management. Porous asphalt addresses this need through an open-graded aggregate skeleton with interconnected air voids that permit water to infiltrate through the surface layer [1,5,8,11].

The porous structure can reduce water-film formation, splash, spray, and hydroplaning while also supporting stormwater infiltration and, in suitable systems, pollutant filtration [2,10]. These benefits depend on maintaining connected voids. At the same time, high void content can reduce mixture strength and expose the binder-aggregate system to moisture, ageing, raveling, and clogging. Porous asphalt design therefore requires a balance between hydraulic conductivity and mechanical stability [4,9,12,19].

Aggregate gradation, aggregate quality, binder properties, compaction, and void connectivity govern this balance. Open-graded mixtures rely strongly on stone-on-stone contact, whereas the binder must provide cohesion without filling the drainage paths. Previous investigations have evaluated modified binders, recycled aggregates, hydraulic conductivity, durability, and the influence of gradation on porous asphalt performance [3,13-16,18].

The present investigation was conducted as a laboratory study of locally selected aggregates and VG-30 bitumen. Its objectives were to characterize the functional and structural behavior of porous asphalt and to evaluate the physical, mechanical, and rheological properties of the selected materials and mixture. The proof chain comprises material characterization, open-graded mixture preparation, Marshall testing, air-void analysis, permeability testing, and interpretation of the combined structural-hydraulic response.

2. RELATED WORK

Jiang et al. evaluated porous ultra-thin asphalt overlays across a broad air-void range and considered rutting, moisture sensitivity, hydraulic conductivity, sound absorption, and skid-related surface characteristics [1]. Jiang et al. also reported laboratory evidence that permeable pavement layers can filter suspended solids and other runoff contaminants, demonstrating that drainage and environmental functions may operate together [2].

Studies summarized in the thesis show that mixture composition and stabilization affect both durability and permeability. Akhtar et al. examined recycled coarse aggregate in porous asphalt [3], while Kandhal emphasized the combined importance of gradation, binder selection, construction quality, and maintenance for open-graded friction courses [5]. Other studies addressed the use of fibers or modified binders, rutting resistance, moisture susceptibility, ageing, and long-term performance [6-9,16].

Hydraulic performance is also influenced by pore connectivity and maintenance. Laboratory investigations have reported relationships among aggregate gradation, air void content, permeability, and mechanical response [12-15,18,19]. Clogging by fine particles can reduce permeability, and the thesis literature review therefore identifies routine maintenance as important for retaining drainage capacity [4]. The present study contributes a unified laboratory evaluation of aggregate and binder properties, Marshall response, air voids, and permeability for one open-graded porous asphalt mixture.

3. MATERIALS AND METHODS

3.1 Experimental program

The experimental program consisted of material collection, aggregate testing, VG-30 bitumen testing, selection of an open-graded aggregate gradation, porous asphalt mixture preparation, Marshall specimen preparation, Marshall stability and flow testing, air-void determination, permeability testing, and descriptive analysis of the measured results. The sequence reported in the thesis is shown in Figure 1.

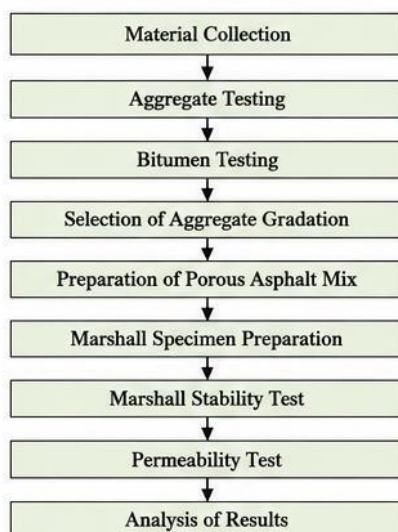


Figure 1. Experimental methodology workflow reported in the thesis.

3.2 Constituent materials

Crushed angular coarse aggregate formed the load-bearing skeleton. Fine aggregate was used in a limited proportion to preserve interconnected voids. Ordinary Portland Cement was used as mineral filler to improve the asphalt mastic, and VG-30 grade bitumen was used as the binder. The selected materials were characterized before mixture preparation.

Table 1. Selected open-graded aggregate gradation.

Sieve size (mm)	Passing (%)
19.0	100
12.5	92
9.5	78
4.75	32
2.36	15
1.18	10
0.60	8
0.30	6
0.15	4
0.075	3

Table 2. Principal aggregate and binder properties reported in the thesis.

Material/property	Reported value	Role in the investigation
Aggregate bulk dry specific gravity	2.68	Volumetric characterization
Aggregate SSD specific gravity	2.71	Volumetric characterization
Aggregate apparent specific gravity	2.75	Volumetric characterization
Aggregate water absorption	1.25%	Moisture-related material property
Aggregate impact value	17.8%	Impact resistance
Aggregate crushing value	21.5%	Crushing resistance
VG-30 penetration	66 dmm average	Binder consistency
VG-30 softening point	49 degrees C average	Thermal response
VG-30 ductility	82 cm average	Binder elongation
VG-30 specific gravity	1.02 average	Volumetric calculation

3.3 Mixture preparation and laboratory tests

Aggregates and bitumen were heated separately and mixed until the aggregate particles were uniformly coated. The mixture was placed in preheated Marshall moulds and compacted with the required blows on each face. After cooling and removal from the moulds, the specimens were inspected and conditioned for testing. For the Marshall test,

specimens were maintained in a water bath at 60 degrees C for 30-40 min and loaded at 50.8 mm/min. Maximum load was recorded as stability and the corresponding deformation as flow.

Bulk and theoretical densities were used to determine the air void content of each compacted specimen. Permeability was evaluated by placing the specimen in the permeability apparatus, introducing water under controlled conditions, recording the time for a known volume to pass through the specimen, and calculating the permeability coefficient. Five specimens were reported for Marshall response, air-void characteristics, and permeability. Figure 2 reproduces the principal laboratory operations and test setups.



Figure 2. Mixture preparation, Marshall stability apparatus, and permeability apparatus reproduced from the thesis.

3.4 Data analysis

The thesis reports specimen-level values and arithmetic averages. The analysis in this article is therefore descriptive. No inferential statistical tests, confidence intervals, or independent field validation were reported. Numerical values are reproduced without modification from the thesis tables.

4. RESULTS AND DISCUSSION

4.1 Aggregate gradation and material characterization

The selected gradation contained 100% passing the 19.0 mm sieve and only 3% passing the 0.075 mm sieve, producing the open-graded profile shown in Figure 3. The thesis interprets this reduction in fine material as favorable for forming the interconnected void network needed for drainage while retaining a coarse aggregate skeleton.

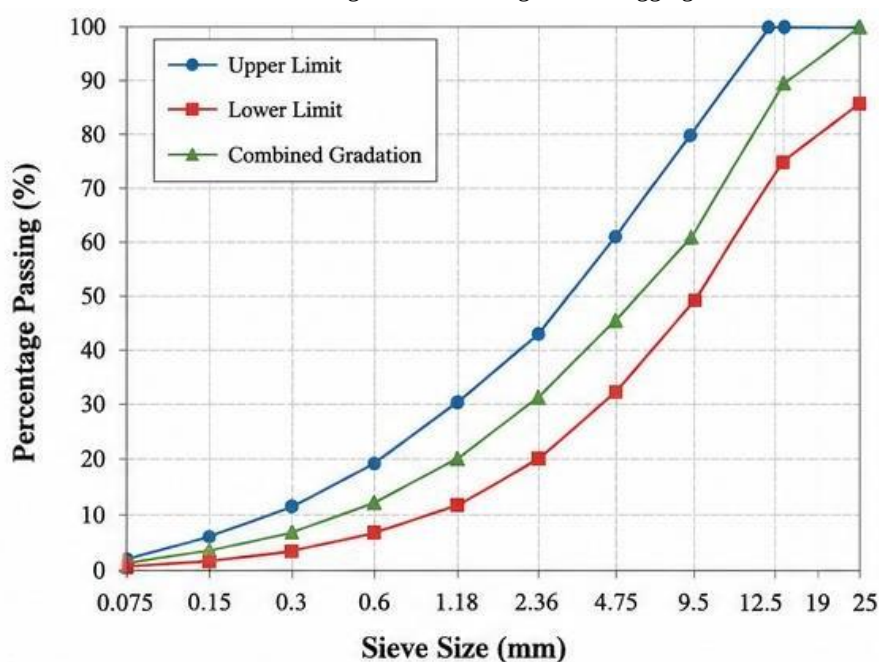


Figure 3. Aggregate gradation curve reproduced from the thesis.

Aggregate bulk dry, SSD, and apparent specific gravities were 2.68, 2.71, and 2.75. Water absorption was 1.25%, the aggregate impact value was 17.8%, and the aggregate crushing value was 21.5%. The VG-30 binder yielded average values of 66 dmm penetration, 49 degrees C softening point, 82 cm ductility, and 1.02 specific gravity. Table 3 retains the complete trial-level binder measurements reported in the thesis.

Table 3. Trial-level VG-30 bitumen test results.

Trial	Penetration (dmm)	Softening point (degrees C)	Ductility (cm)	Specific gravity
1	65	48	80	1.01
2	67	50	83	1.03
3	66	49	82	1.02
Average	66	49	82	1.02

The material results were used to support the thesis conclusion that the selected aggregate and binder were suitable for the subsequent porous asphalt mixture evaluation. The values also provided the basis for the density and air-void calculations applied to the compacted specimens.

4.2 Marshall stability and flow

Table 4. Marshall stability and flow results.

Specimen	Stability (kN)	Flow (mm)
S1	8.65	3.2
S2	8.91	3.4
S3	8.78	3.3
S4	8.84	3.5
S5	8.72	3.3
Average	8.78	3.34

Marshall stability ranged from 8.65 to 8.91 kN, with an average of 8.78 kN. Flow ranged from 3.2 to 3.5 mm, with an average of 3.34 mm. The thesis interprets the stability values as evidence of adequate aggregate interlock and the flow values as indicating a balanced deformation response. The complete specimen sequence is retained in Table 4 and the original thesis charts are reproduced in Figure 4.

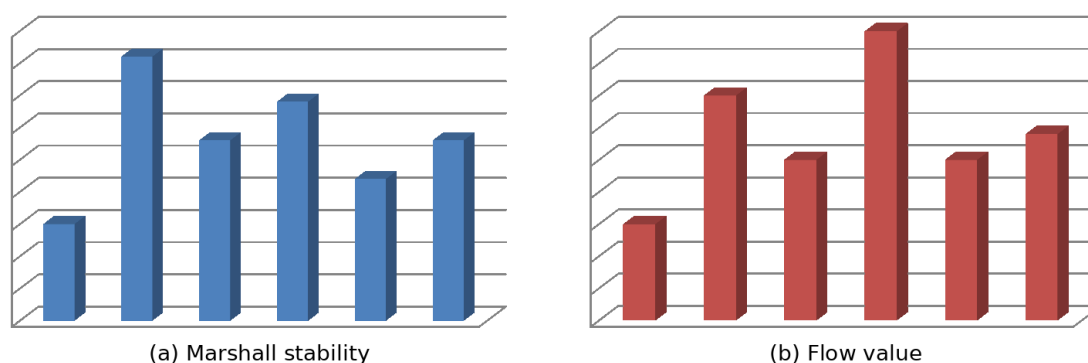


Figure 4. Marshall stability and flow charts reproduced from the thesis.

4.3 Air void characteristics

Table 5. Bulk density, theoretical density, and air void results.

Specimen	Bulk density (g/cc)	Theoretical density (g/cc)	Air voids (%)
S1	2.04	2.50	18.4
S2	2.02	2.50	19.2
S3	2.03	2.50	18.8
S4	2.01	2.50	19.6
S5	2.02	2.50	19.2
Average	2.02	2.50	19.04

Air void content ranged from 18.4% to 19.6%, with a mean of 19.04%. These values are within the 15-25% range discussed in the thesis for porous asphalt. The thesis attributes the resulting drainage capacity to the connected pore system and attributes the retained structural response to the stone-on-stone aggregate skeleton. The original air-void chart is shown in Figure 5.

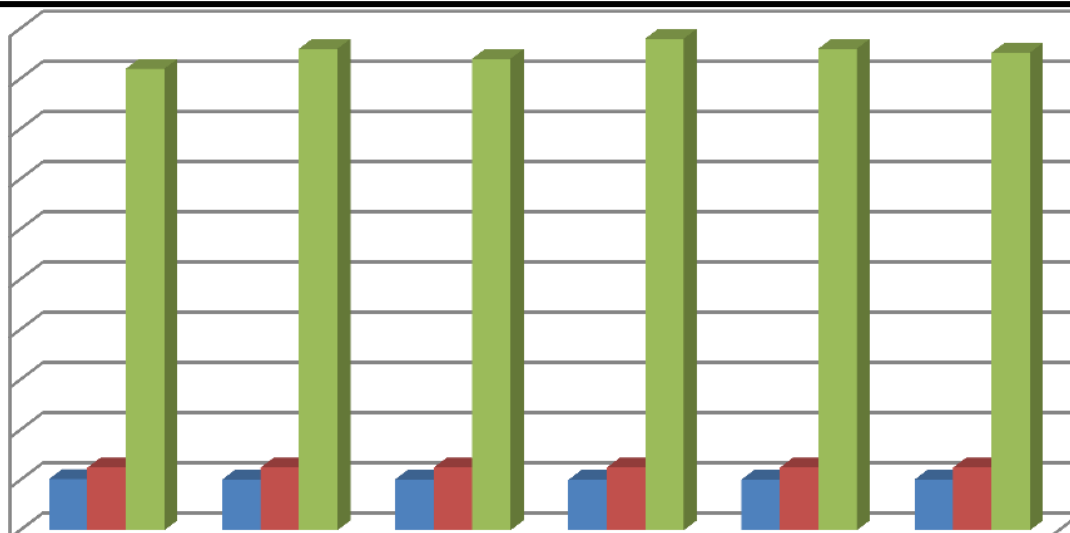


Figure 5. Air void content of the porous asphalt specimens reproduced from the thesis.

4.4 Permeability

Table 6. Permeability test results.

Specimen	Time (s)	Water flow (ml)	Permeability coefficient (cm/s)
S1	18	1000	0.245
S2	17	1000	0.262
S3	18	1000	0.251
S4	16	1000	0.275
S5	17	1000	0.266
Average	17.2	1000	0.260

The permeability coefficient ranged from 0.245 to 0.275 cm/s and averaged 0.260 cm/s. The shortest measured flow time was 16 s for S4, which also produced the highest permeability coefficient, while S1 produced the lowest coefficient. The thesis interprets the measured range as demonstrating rapid water transmission through the connected void network. Figure 6 reproduces the permeability chart.

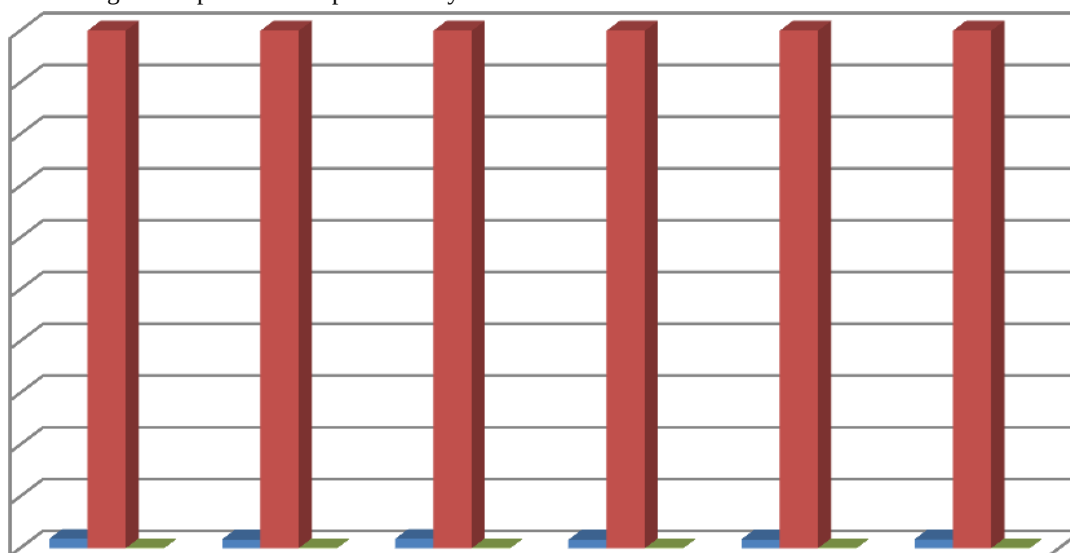


Figure 6. Permeability characteristics of the porous asphalt specimens reproduced from the thesis.

4.5 Relationship between air voids and permeability

The thesis also presented a separate trend series to illustrate the relationship between air void content and permeability. In that series, permeability increased from 0.21 to 0.32 cm/s as air void content increased from 17% to 21%. This trend is consistent with the explanation that more connected flow channels reduce resistance to water movement. The thesis also notes that excessive void content may adversely affect stability and durability, so the relationship must be considered together with the Marshall response.

Table 7. Thesis-reported relationship between air voids and permeability.

Air voids (%)	Permeability (cm/s)
17	0.21
18	0.23
19	0.26
20	0.29
21	0.32

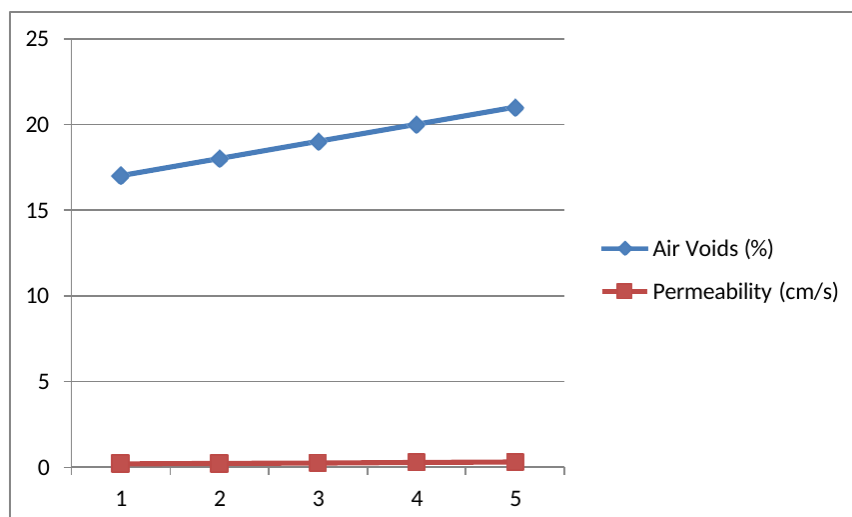


Figure 7. Air voids-versus-permeability plot reproduced from the thesis.

Taken together, the results show the intended structural-hydraulic balance: the specimens retained an average Marshall stability of 8.78 kN and an average flow of 3.34 mm while maintaining approximately 19% air voids and a mean permeability coefficient of 0.260 cm/s. Because the study is limited to one laboratory mixture and descriptive averages, the findings represent the tested program rather than a field-performance prediction.

5. CONCLUSION

- The selected open-graded aggregate distribution created the coarse skeleton and limited-fines structure required for porous asphalt.
- Aggregate characterization produced bulk dry, SSD, and apparent specific gravities of 2.68, 2.71, and 2.75; water absorption of 1.25%; an impact value of 17.8%; and a crushing value of 21.5%.
- The VG-30 binder showed average penetration, softening point, ductility, and specific-gravity values of 66 dmm, 49 degrees C, 82 cm, and 1.02, respectively.
- Marshall stability averaged 8.78 kN and flow averaged 3.34 mm, supporting the thesis interpretation of satisfactory load response and deformation characteristics.
- The mean air void content was 19.04% and the mean permeability coefficient was 0.260 cm/s, demonstrating the drainage function of the interconnected void structure in the laboratory specimens.
- The combined results support the thesis conclusion that the tested porous asphalt mixture achieved a useful balance between mechanical stability and hydraulic performance.

6. LIMITATIONS AND FUTURE WORK

The investigation was limited to laboratory preparation and testing and did not include field construction, long-term traffic monitoring, climatic exposure, or life-cycle assessment. The thesis recommends future evaluation of field performance, clogging and cleaning methods, modified binders and additives, recycled materials, noise reduction, pollutant filtration, and durability improvements that retain permeability.

DECLARATIONS

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