Porous Asphalt: A New Pavement Technology in Palestine

Shafik Jendia[1], Ziad AlDahdooh[2] Mohammed AbuRahma[2],
Mahmoud AbuJayyab[2], AbdElkarim ElDahdouh[2].

1, Professor of Highway Engineering, Islamic University of Gaza, Palestine
2, Faculty of Engineering, Islamic University of Gaza, Palestine

Abstract—Porous Asphalt (PA) is researched and produced in Europe and the United States of America to increase the skid resistance of the asphalt surface. This can be caused when storm water infiltrate directly in the ground through the porous surface layer. So far, in Palestine this type of pavement has not been used. If PA is used in Palestine, it may contribute to solving many of the local problems especially groundwater deficit. Therefore, this research deals with studying the possibility of producing Porous Asphalt as new pavement technology in Palestine. Based on several international researches, a proposal for the limits of aggregate gradation was determined. To investigate the applicability of using local material and the proposed gradation limits, several tests were conducted, including sieve analysis, specific gravity, absorption, abrasion, impact and crushing value. Bitumen tests were also conducted such as, penetration test, softening point, ductility and specific gravity. Also, asphalt mixtures were prepared in accordance with the proposed gradation curves, followed by testing of 24 PA- specimens to determine the mechanical properties, especially stability, flow, and bulk density. The results showed that any aggregate blending curve lie between the limits of proposed gradation can be used to produce PA. Marshall test results showed that the optimal bitumen content was approximately 4% by the weight of total mixture, and the void ratio obtained was approximately 21% for the produced asphalt.

Index Terms— Porous Asphalt, Marshall, void ratio, aggregate gradation.

I. INTRODUCTION

Porous Asphalt (PA) is a new pavement technology. It has been researched and produced in several sites worldwide, especially in Europe and the United States. The surface permeability and high porosity of PA allow water to pass vertically through the pavement to the subgrade below to naturally recharging groundwater levels. The water in the base is stored temporarily in stone reservoir consisting of uniformly graded layer thick enough to allow sufficient water storage during anticipated rain events, clean crushed stone with around 40% voids, often allowed to infiltrate into permeable subgrade soils, and can recharge the groundwater directly [1, 2, 3, 4].

Unlike conventional pavements, PA is typically built over an uncompacted subgrade to maximize infiltration water into the soil. Above the uncompacted subgrade is a geotextile fabric, which prevents the migration of fines from the subgrade into the stone recharge bed while still allowing for water to pass through, as shown in Figure (1).

PA has not been used in Palestine despite its potential benefits like reducing runoff, which leads to increasing the skid resistance and improving surface water quality which infiltrate directly in the ground through the porous surface layer. PA can in Palestine due to its advantages (mentioned below) contribute to solving many of local problems.

The objectives of this study are:

a) to determine a suitable aggregate gradation for local aggregates used in the asphalt mix.
b) to determine the highest void ratio that can be reached using the local material.

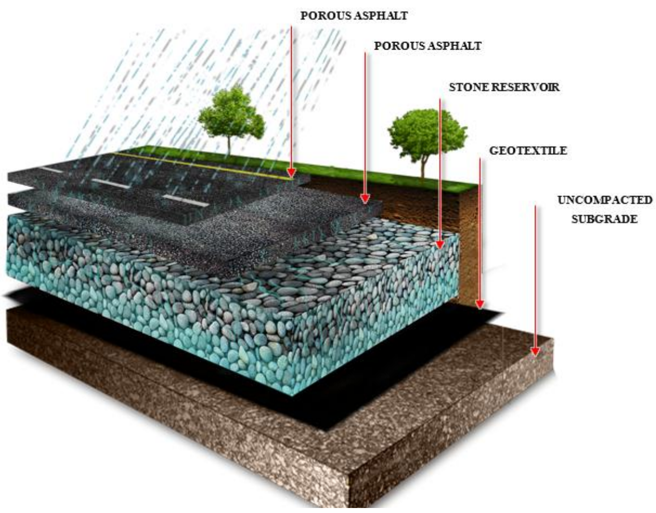

Figure 1: Typical section of Porous Asphalt pavement.

II. ADVANTAGES

There are several advantages for the Porous Asphalt pavement [1 – 8]. Some of them are summarized below:

1. Removing the pollutants and improving water quality.
2. Melting snow and ice fast and reducing the need for deicing salt.
3. Recharging groundwater to underlying aquifers and providing flood control.
4. Increasing permeability, potentially improving the water quality through filtering capabilities.
5. Improving water and oxygen transfer to nearby plant roots.
6. Improving skid resistance, splash, and spray, and driving speed.
7. Reducing hydroplanes on pavement surfaces by reducing glare on the road surfaces specifically during wet night conditions.
8. Absorption of noise from tires and engines (sound is not reflected but absorbed by the porous layer).
9. Reducing fuel consumption due to enhanced smoothness.
10. Reducing tires wear on the asphalt.
11. Extending pavement life due to well drained base.

III. MATERIALS AND TEST RESULTS

A. Materials properties

In this study, all important laboratory tests were conducted to evaluate the properties of the used bitumen. Table (1) illustrates the test results.

Table 1: Bitumen properties and specifications.

Bitumen Tests			
Test	Standard Specification	Test Result	Specification Values
Density (g/cm^3)	AASHTO T 228-94 ASTM D 70 – 03	1.03	1.01-1.06
Penetration 1/10 mm	AASHTO T 49-96 ASTM D 5 – 97	68.33	60-70
Ductility (cm)	AASHTO T 51-94 ASTM D 113 – 99	150	Min 100
Softening Point (°C)	AASHTO T 53-96 ASTM D 36 – 95	49.6	Min 48 Max 56
Flash and Fire points	AASHTO T 48-96 ASTM D 92 – 02 b	286 +326	Min 230 Max 330

Also, laboratory tests were conducted on the aggregate to determine their properties. Table (2) illustrates the tests results.

Table 2: Aggregates test results according to ASTM specifications.

Aggregates Tests	
Specification	Test result
Specific Gravity (g/cm^3)	2.58-2.61
Water Absorption (%)	1.87-3.0
Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion in the Los Angeles Machine (%)	19.2
Sieve Analysis of Fine and Coarse Aggregates	See Appendix [B]
Materials Finer than (No. 200) Sieve in Mineral Aggregates by Washing	See Appendix [B]

B. Blending of aggregates

Several specifications and researches [1-10] were studied to determine the best aggregate gradation as shown in Appendix [A]. The result is presented in Figure (A-1) which illustrates the gradation limits in comparison with the international gradations. The suggested limits and the result of the aggregates blending process followed for this purpose is illustrated in in Figure (2) and in Table (3). The blending procedure [9] of all aggregate types are presented in Table (B-1). For this purpose, all aggregates were brought from the stockpiles available in the asphalt factories in the Gaza Strip. From Table (B-1) is clear that the part of filler (particles size less than 0.075 mm) is approximately 4%. The maximum percentage (5.0 %) of filler is relatively to that for dense asphalt is small. This means that in order to produce a large void ratio in the PA the amount of mortar (bitumen + filler) should be relative small.

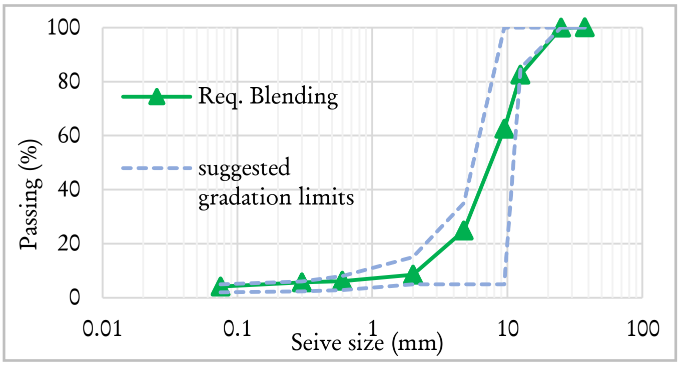

Figure 2: Aggregate gradation curve in comparison with suggested limit curves

Table 3: Blending of stockpile aggregates.

Aggregate Size (mm)	Blending (%)
Simsimia (0/12.5)	50
Adasia (0/25)	45
Folia (0/37.5)	5

C. Mechanical test results

In order to study the mechanical properties (stability, flow, bulk density ρ_A, air voids V_a, volumetric part of bitumen content V_b , voids in mineral aggregates VMA and Voids filled with bitumen VFB) of the mixture of Porous Asphalt (PA), Marshall method was used in this research. Accordingly, the selected aggregates with the determined gradation were mixed carefully with three different percentages of bitumen content in the laboratory. Eight Marshal specimens were produced for each bitumen content (24 specimens). The results of mechanical properties are given in Table (4).

Table 4: Marshall test results.

m_b (%)	Stability (KN)	Flow (mm)	ρ_A (g/cm³)	V_a (%)	V_b (%)	VMA (%)	VFB (%)
3.50	6.57	2.85	1.90	20.90	6.45	27.37	23.64
4.00	4.97	2.88	1.91	20.19	8.59	27.60	26.85
4.50	5.38	2.90	1.91	19.42	8.34	27.78	30.09

From Table (4), it is obvious that the reached air void ratio in the produced PA- specimens is relatively large (approximately 20%) comparatively to that in dense asphalt (maximum 8%). This ratio lies in the acceptable range discussed in references, mentioned above [1- 10].

D. Optimum bitumen content m_b%

Based on the specimen testing, the main relationships between bitumen content and the obtained values of Marshall stability, flow, bulk density and air void content were presented in Table (4). The optimum bitumen content of the mixture is the numerical average of the three values as it is described in the following equation [9]:

$$m_b = (a + b + c) / 3$$

where
m_b = optimum bitumen content (%).
a = bitumen content at maximum bulk density (%).
b = bitumen content at maximum stability (%).
c = bitumen content at minimum air void content (%).

Table (5) illustrates the bitumen content for each property.

Table 5: Mechanical properties of PA and bitumen contents

Property	Value	m_b%
Maximum stability	6.75 KN	3.50 %
Maximum bulk density	1.91 g/cm³	4.50 %
V_a Required	20.9 %	3.50 %

$$\textbf{Optimum } m_b\% = \frac{3.5 + 4.5 + 3.5}{3} = \mathbf{3.83} \approx \mathbf{4}\%$$

Figure (3) presents the water permeability through one of the produced specimen with v_a = 20.9 %.

Figure 3: Porous Asphalt specimen while permeability test

IV. CONCLUSIONS AND RECOMMENDATIONS

1. Porous Asphalt (PA) can be produced successfully with local material in Palestine, provided the gradation of the selected aggregate should lie within the limits suggested in Table (6).

Table 6: Sieve Size Passing Percent for the limit Curves.

Sieve Size (mm)	Percent Passing (%)	
	Min	Max
22.4	100	100
16	93	100
12.5	85	100
11.2	70	100
9.5	5	100
4.75	5	35
2	5	15
0.075	2	5

2. The effective bitumen content obtained using Marshall method should be approximately 4%. Bitumen content much less than 4% increases the possibility of causing surface raveling.
3. The maximum air void ratio can be reached using local material approximately 21%.
4. Marshall stability and bulk density of PA- specimen are lower than that for the dense asphalt concrete.
5. The values of Marshall flow are suitable, they lie in the acceptable range (2- 4) mm.

V. REFERENCES

[1] Environmental Protection Agency (EPA), *"Porous Pavement. National Pollutant Discharge Elimination System"* 2007. [Online]. Available: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm. [Accessed on 1 November 2016].

[2] Lebens, M. *"Porous Asphalt Pavement Performance in Cold Regions"*, Minnesota Department of Transportation, Minnesota 2012.

[3] Wisconsin Asphalt Pavement Association, (WAPA) *"Tech Bulletin Porous Asphalt Pavements"*
Wisconsin, 2015.

[4] U.S. Federal Highway Administration, (FHWA) *"Porous Asphalt Pavements with Stone Reservoirs"* 2015.

[5] Lori, K. S. *"Porous Asphalt Pavement Designs: Proactive Design for Cold Climate"*, University of Waterloo, Canada, 2007.

[6] The UNH storm water center, *"Porous Asphalt Pavement for Storm Water Management"* 2009.

[7] Cahill H., Michele, A., Courtney. M. *"Stormwater Management with Porous Pavements"* 2005.

[8] Quantao, L. *"Induction Healing of Porous Asphalt Concrete"*, University of Technology, P.R. China, 2012.

[9] Jendia, S. *"Highway Engineering Structural design"*, Dar al Manara, Gaza, 2000.

[10] Velske, S., Mentlein, H., Eymann, P. Strassenbau, "*Strassenbautechnick*", Germany, 2008.

APPENDIX A

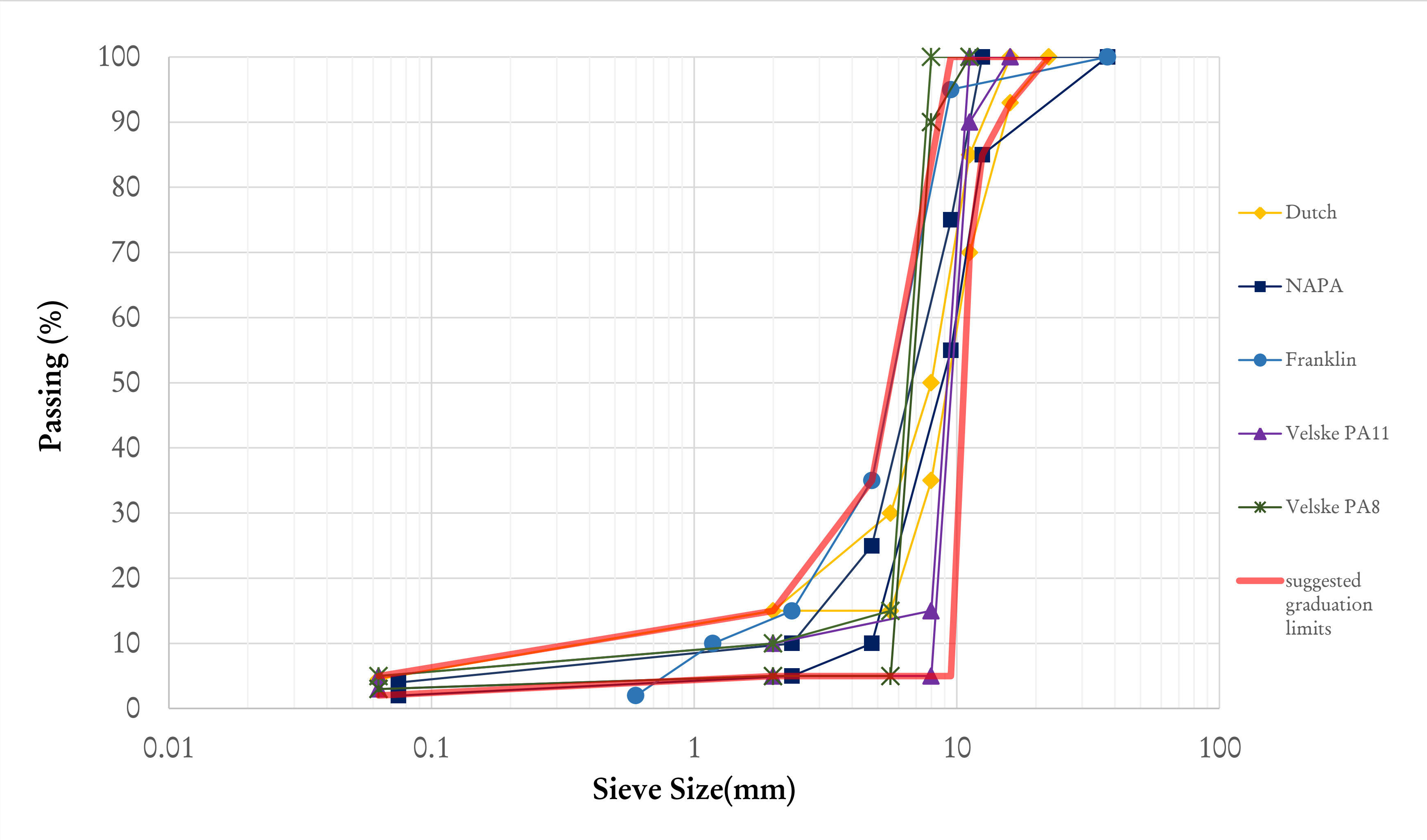

Figure A-1: The proposed gradation limits in comparison with the international gradations

Appendix B

Table B-1: Local aggregate blending procedure.

Aggregate Mix	Aggregate Size(mm)									Blending %
	0-0.075	0.075-0.3	0.3-0.6	0.6-2	2-4.75	4.75-9.5	9.5-12.5	12.5-25	25-37.5	
Simsimia (12.5)	5.58	1.82	0.88	4.31	31.53	55.45	0.42			50
	2.79	0.91	0.44	2.15	15.76	27.73	0.21	0.00	0.00	
Adasia (25)	2.72	1.31	0.21	0.31	1.22	21.18	42.31	30.73		45
	1.22	0.59	0.10	0.14	0.55	9.53	19.04	13.83	0.00	
Folia (37.5)	1.50	0.50	0.10	0.21	1.01	7.84	16.60	69.71	2.54	5
	0.07	0.02	0.01	0.01	0.05	0.39	0.83	3.49	0.13	
Total	4.09	1.52	0.54	2.31	16.36	37.65	20.08	17.32	0.13	100
Req. Blending	4.09	5.61	6.16	8.46	24.83	62.48	82.56	99.87	100	100
Min. of the proposed aggregate Gradation	2	2.3	2.8	5	5	5	85	100	100	
Max. of the proposed aggregate Gradation	5	6	8	15	35	100	100	100	100	