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Effect of Polymer Additives on Permeability of Asphalt Concrete Mixtures

Abstract- *The presence of water in the pavement structure causes early deterioration and leads to less pavement durability as a result of loss of bond between aggregate and binder and may causes loss of strength and stability in mixture, The main goal of this study was to investigate the effect of various polymer additives on permeability of asphalt concrete mixture. The surface wearing coarse type IIIA was chosen in this study. Three types of polymer additives were used in this study; (7% Latex Emulsion (LE), 7% Poly Vinyl Acetate with 4% Styrene Butadiene Styrene (PVA + SBS) and 8% Ethylene Diamine (ED)). The results appeared that the permeability average of all mixtures were (27.745, 17.18, 7.773 and 11.409 * 10* $^{-5}$ *cm/s) for (control blend, LE, PVA+SBS and ED) and the percent of decreasing in permeability were (48.52%, 74.547% and 58.312%) for (LE, (PVA + SBS) and ED) respectively.*

Keywords- *Permeability, Superpave, Polymers, Asphalt Content, Air Voids.*

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1. Introduction

Generally, the presence of water in pavement surface, "specially in winter season" has many harmful effects such as pumping, degradation of paving materials and stripping because of loss of bond between aggregate and binder, Moisture damage of asphalt concrete can be defined as the loss of strength and stability caused by the assemble of moisture on the pavement surface [1]. The presence of water in the pavement for extended periods of time is directly linked to early deterioration [2]. The Adhesion between asphalt mixtures components are usually characterized by their resistance to moisture [3]. One of the most influential factor in permeability is air voids content [4].The gradation and nominal maximum aggregate size (NMAS) are influenced by permeability [5]. Therefore, polymers (in liquid or solid state) has significant effect on pavement. The additives/polymers can be defined as a material liquid or solid which would normally be added to mix with the asphalt or the aggregate mixture before or during mix production, to improve the properties and performance of the resulting mix [6]. It may repair many pavement deteriorations such as rutting, permanent deformations and permeability. It can be classified to different types according to their chemical compositions and usage such as (elastomer, plastomer and anti-stripping polymers). This study indicate anti-stripping and some types of polymers that may reduce the hydraulic conductivity of pavements. Reference [7] stated that the hydraulic conductivity can be measured by computing the coefficient of permeability (K value). Therefore, this research has been conducted to reduce or to produce a HMA mixture with controlled permeability by adding the polymers in order to resist the striping failure or reduce any other underlying layer default caused by interring of excessive water due to poor drainage. Various polymers are used to improve the performance of asphalt mixtures However, some of these polymers may repair the moisture damage of the asphaltic mixtures [1]. Many research included these polymers such as: in reference [8] stated that if a polymer (modifier) or additive is used to confirm moisture resistance, the main factors should be taken into a consideration cost, dosage, and other economic factors, and influence of some mixture properties and modification on adhesive. Therefore, this thesis includes the use of some polymers such as poly amines (Ethylene Diamine) (8% ED), Poly Vinyl Acetate (7% PVA) with Styrene Butadiene Styrene (4% SBS) and latex emulsion (7% LE). This study indicated the use of Superpave design method as amended by the strategic highway research program (SHRP) in a (HMA) mixture design method. The

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new design method (superpave design system) has improved the quality of HMA mixtures [9].

2. Laboratory Testing

I. Materials

To compass the most realistic emulation of HMA mixtures paved in Iraq, conjoint local asphalt binder in addition to aggregates have been selected for fabricating laboratory specimens. Specimens that have polymers (LE, PVA with SBS and ED) have also been prepared by superpave gyratory compactor and test its permeability. The next items will be devoted to demonstrate the physical properties of these materials and some physical and chemical properties of polymers. The penetration grade of asphalt binder used were (40–50) and (60 –70) from Daurah refinery chosen for the experimental work in this study. The coarse aggregate (crushed gravel) used in this study was from Al-Nibaie quarry. This type of aggregate has been vastly used in local asphalt paving. The sizes of coarse aggregate used in the study ranged from (19 mm) to No.4 sieve size (4.75 mm). Crushed gravel and screened sand were used in this study as fine aggregate. The fine aggregate is between No.4 sieve size (4.75 mm) and No.200 sieve size (0.075 mm). The lime stone dust has been used as a filler. Its source is the lime factory in Karbala governorate. Al-Mass Cement from Sulaimaniya government factory in north of Iraq has been also used as a filler.

The chemical composition and (physical and chemical) properties of polymers are given in Tables 2 to 5.

Table 1: Physical Properties of Limestone Dust

Properties	Test results
%Passing No 200 (0.075 mm)	96 %
Specific gravity	2.92
Plasticity index	N.P.

Table 2: Physical Properties of (LE) [1]

No.	Properties	
1	Total solid content%	61
٢	dry rubber content%	60
٣	Non rubber content%	1.5
4	PH	10
٥	Mechanical stability time (s)	122 7

Table 3: Physical and Chemical Properties of PVA [10]

No.	Properties	
1	Chemical formula	$(C_4H_6O_2)_n$
2	Molar mass	86.09 g/mol/unit
3	Density	1.19 g/cm^3 at 25 ^oC
4	Boiling point	112 ^oC
5	PH	6.6

Table 4: Physical and Chemical Properties of SBS [11]

Results	Items	Results	Items
Molecular Weight Avg.	353.164	Elongation at break (%)	660
Polydispersity	1.08	Permanent deformation (MPa)	≤55
Diblock content (%)	14	Hardness shore (A) ASTM D 2240	82 Radial
Styrene (%)	30.1	Oil-Extended	10
Tensile strength (MPa)	16.5	Melt flow index (g/10min) ASTM D1238	0.1-0.5

Table 5: Physical and Chemical Properties of ED [12]

No.	Properties	
١	chemical formula	C2H8N2
٢	Molar mass	60.10 g.mol^-1
٣	order	ammonia Cal
٤	density	0.9g/cm^3
٥	boiling point	116 ^oC
٦	solubility in water	miscible
٧	Log P	-2.057
٨	vapor pressure	1.3kpa(at 20 ^oC)
٩	henry, slaw constant (Kh)	5.8 mol pa^-1kg^-1
١٠	refractive index (n0)	1.4565

II. Mixture Design

The mixture design was done to meet the demands of the Superpave mixture design specifications for a traffic level of 10-30 million Equivalent Single Axle Loads (ESAL). Reference [13] and reference [14] have been used as shown in Table (6). Table 7 clarifies the restricted zone restrictions for 12.5 mm nominal maximum sieve sizes according to superpave aggregate gradation requirements [15]. About 4800 grams of materials required to produce a hot mix asphalt HMA to prepare the test specimens. This HMA will result in a compacted specimen 115 (±5) mm in height [16]. The optimum binder content of mixture was determined by using the Superpave mixture design method, elected on the basis of 4 % voids in the total mixture (VTM), in specimens compacted with 160 gyrations of the Superpave Gyratory Compactor (SGC). Three blends were selected under the restricted zone numbered from (1-3) as shown in Figure (5) clarify the selected gradations used in this work of surface (wearing) course type IIIA. The results appeared that blend1 was the best one.

Table 6: Selected Gradation Used for Surface Course Type IIIA (Below Restricted Zone)

Sieve Size		Selected Grade % Pass.	Iraqi Spec. Req.	AASHTO-SP2 2010
Sieve Opening (mm)	Sieve Size			
19	3/4"	100	100	100
12.5	1/2"	93	90-100	90-100
9.5	3/8"	80	76-90	MIN.90
4.75	No.4	45	44-74	-
2.36	No.8	30	25-58	39.1
1.18	No.16	23	-	25.6-31.6
o.6	No.30	18	-	19.1-23.1
0.3	No.50	12	5-21	15.5
0.150	No.100	7	-	-
0.075	No.200	4	4-10	2-10

Table 7: Restricted Zone Limitations [15].

No.	Sieve Size		Percent Passing Criteria (control points)
	Sieve Opening (mm)	Sieve Size	12.5 mm
1	4.75	No.4	
2	2.36	No.8	39.1
3	1.18	No.16	25.6 - 31.6
4	0.60	No.30	19.1 - 23.1
5	0.3	No.50	15.5

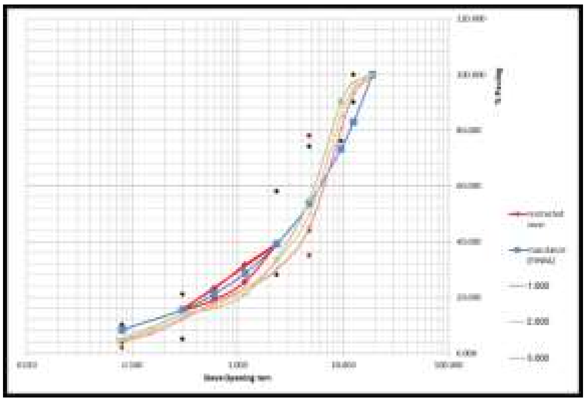


Figure 5: Selected Gradation Used for Surface (wearing) Course Type IIIA.

The optimum binder content for asphalt with penetration grade (40-50) and (60-70) and tensile strength ratio according to Superpave system were indicated in Tables (8) and (9) below.

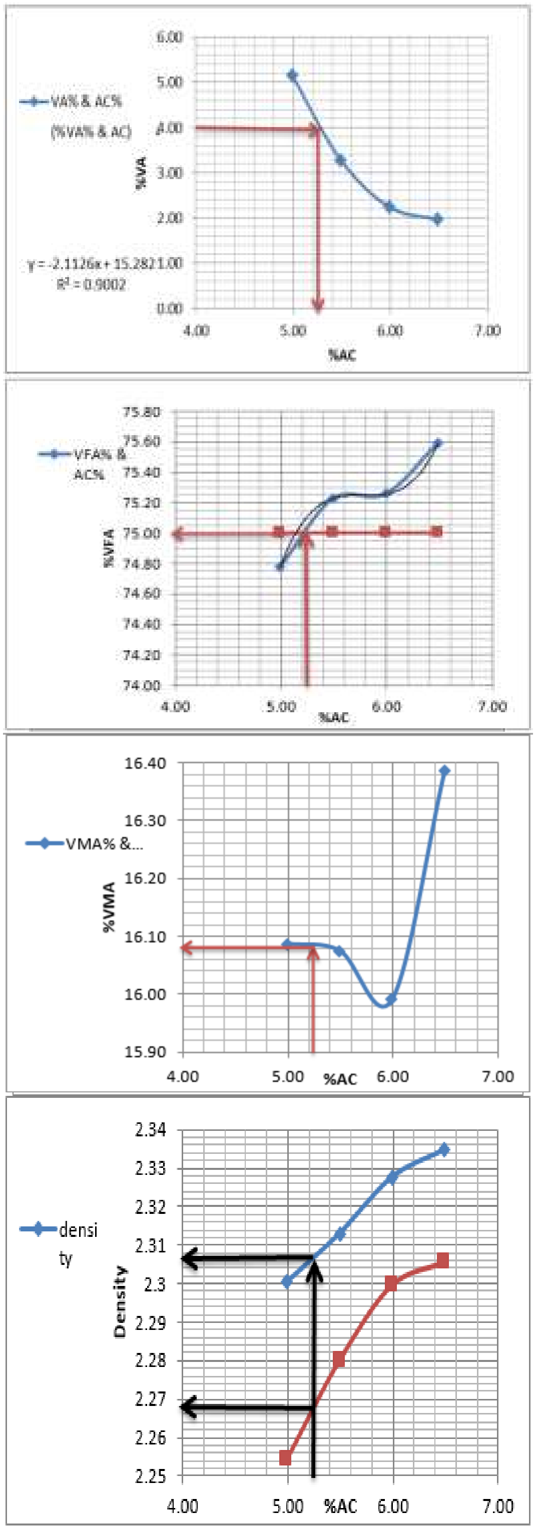


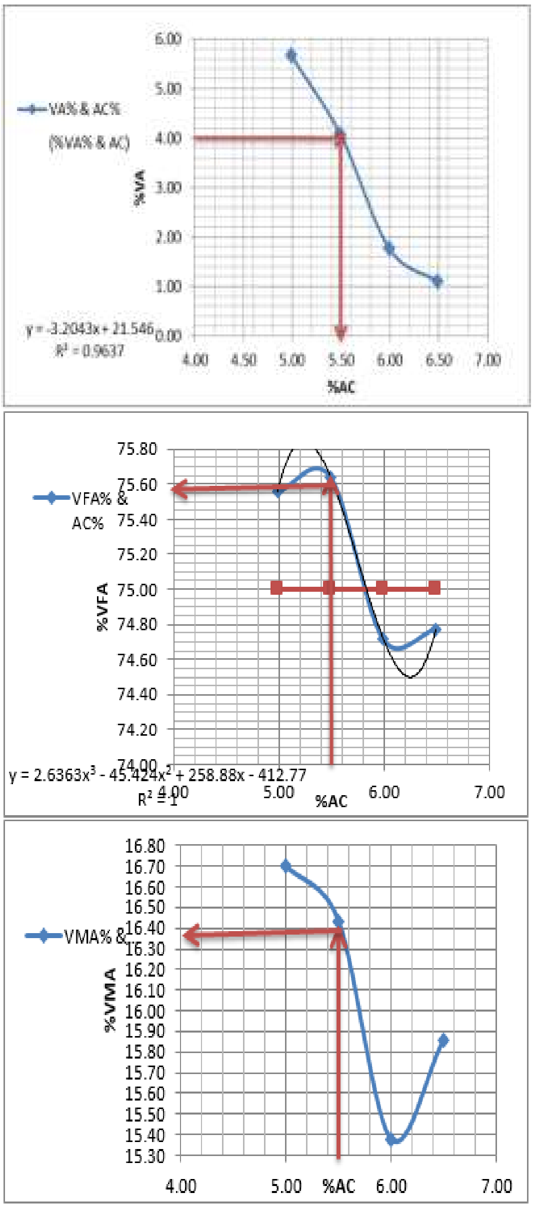
Figure 6: Selected Design Asphalt Binder Content (ABC) by Superpave Gyratory Compactor for Asphalt Penetration Grade (40-50)

Table 8: Optimum Binder Content (OBC) Results for Asphalt Penetration Grade (40-50)

Pavement Layer	Gradation	Optimum Binder Content (%)	Tensile Strength Ratio (%)
Wearing Course Blend1	Below restricted zone	5.22	91

Table 9: Design Binder Content (OBC) Results for Asphalt Penetration Grade (60-70)

Pavement Layer	Gradation	Optimum Binder Content (%)	Tensile Strength Ratio (%)
Wearing Course Blend 1	Below restricted zone	5.5	88.4



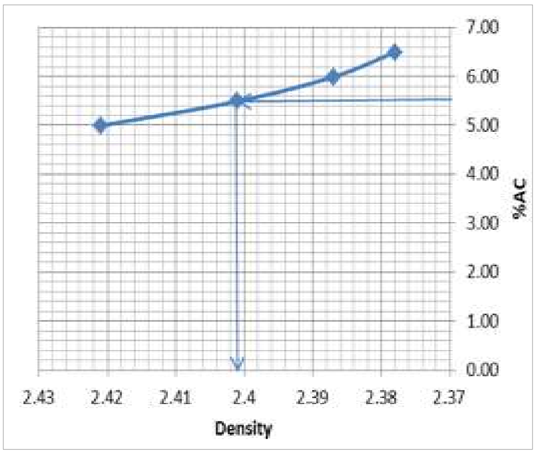


Figure 7: Selected Design Asphalt Binder Content (ABC) by Superpave Gyratory Compactor for Asphalt Penetration Grade (60-70).

II. Permeability Test

To evaluate the permeability (compute the coefficient of permeability K) of HMA mixtures, device was used as shown in plate (1) According to Virginia test method-120 and using falling head method, the time required for a sample to perish a head of water was sized and employed to set the permeability (hydraulic conductivity). For this tactic, the following equation can be used depending on darcy's law [17].

$$K = \frac{aL}{A\,\Delta t} ln\left(\frac{h1}{h2}\right)$$

(1)

Where:

k = Coefficient of Water Permeability, (cm/s).

a = Inside Cross-Sectional Area of the Inlet Standpipe, (cm^2).

h1 = Hydraulic Head on Specimen at Time t1, (cm).

h2 = Hydraulic Head on Specimen at Time t2, (cm).

Δt = Average Elapsed Time of Water Flow between Timing Marks, (s).

L = Thickness of Test Specimen, (cm).

A = Cross-Sectional Area of Test Specimen.

Table 10 clarifies the samples height for each mixture [18]. Table (10) shows that for 12.5 mm nominal maximum aggregate size (NMAS) mixtures, the required height is (38.1±2) mm.

Plate 1: The Assembled Falling Head Permeameter.

Table 10: Specimens Height for Permeability Test Requirements [18].

Nominal Maximum Aggregate Size, in. (mm)	Specimen Height, in.(mm)
3/8″ (9.5)	1.5 ± 0.1 in. (38.1 ± 2)
1/2″ (12.5)	1.5 ± 0.1 in. (38.1 ± 2)
3/4″ (19)	2.0 ± 0.1 in. (50.8 ± 2)
1″ (25)	2.5 ± 0.1 in. (63.5 ± 2)

The Falling Head Permeameter is used to measure the permeability and the test desired for mensuration the time necessary for water to flow from upper to lower mark points. The lower mark was beholden as the point of water at that time, if this time overtakes10 minutes [18]. Using these information, permeability values were computed using Eq. (1). The test was repeated for each specimen until the latest three permeability values diverse by less than 10 percent. The average of these three values represented the permeability of the specimen. The computed hydraulic conductivity was corrected to that (20 ^oC) 68 ^oF this is called K20 and done by multiplying computed permeability K by the ratio of the viscosity of water at the test temperature to the temperature of water at 68^o F (20 ^{o} C), the ratio is known as R_T. Thus, the corrected permeability is calculated from the equation below [17, 18].

$$K_{20} = R_T K \quad (2)$$

Where:

K_{20}= Permeability at 20^o C.

R_T= the Ratio of the Viscosity of Water at the Test Temperature to the Temperature of Water at 68^o F (20 ^{o} C).

K= Computed Permeability.

3. Results

The number of specimens prepared for computing the permeability were (48) specimens and results of permeability test for all mixtures (with and without adding polymers) were indicated in Figure (8) and permeability with air voids relationship was indicated in Figure (9) for asphalt penetration grade (40-50) and results of permeability for all mixtures (with and without adding polymers) were indicated in Figure (10) below as well as permeability air voids relationship for asphalt penetration grade (60-70) were indicated in Figure 11. All mixtures were prepared using Superpave gyratory compacter and the permeability of these specimens was tested using falling head permeameter.

The permeability values indicated on Figure (8) and Table (11) above for asphalt penetration grade (40-50) Blend1with NMAS 12.5 mm are plotted with air voids, it appears that the maximum permeability is 66.251 × 10^{-5} cm/s at a maximum air void 7.645 % using cement as a filler content in control (without adding polymers) and the maximum values of permeability in polymers equal to (59.04 × 10^{-5} cm/s, 22.1 × 10^{-5} cm/s and 38.718 × 10^{-5} cm/s) for (LE, PVA+ SBS and ED) respectively, while the maximum permeability of above mixtures are (64.948 × 10^{-5} cm/s, 23.198 × 10^{-5} cm/s, 19.575 × 10^{-5} cm/s and 31.041 × 10^{-5} cm/s) in case of using limestone dust as a filler content and a minimum values of permeability equal to (7.078 × 10^{-5} cm/s, 1.282 × 10^{-5} cm/s, 1.16 × 10^{-5} cm/s and 2.05 × 10^{-5} cm/s) for (Control, LE, PVA+SBS and ED) respectively. The control mixture with other polymers has a permeability average of (34.332 × 10^{-5} cm/s, 22.05 × 10^{-5} cm/s, 11.651 × 10^{-5} cm/s and 15.663 × 10^{-5} cm/s) respectively, as shown in Figure (8) above. It appears that the percent of decreasing in permeability values are (35.774, 66.065 and 54.379) for (LE, PVA+ SBS and ED) respectively. It appears that all mixtures have the same trend of permeability as shown in Figure (9) and it is appears that the permeability increase with increase air voids.

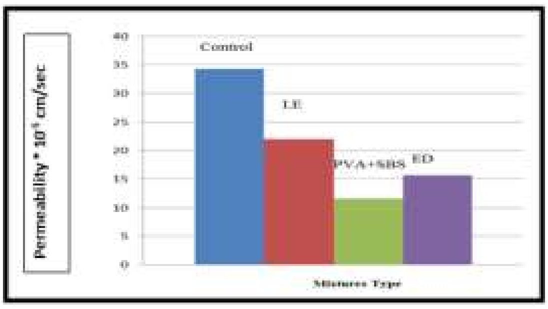


Figure 8: Average Permeability of All Mixtures Contain Asphalt Penetration Grade (40-50).

Table 11: Hydraulic Conductivity Results for Asphalt Penetration Grade (40-50) and NMAS (12.5mm).

Specimens No.	Blend No. With filer type	%Va	%Gmm	K(10¯5 cm/sec)
Control				
1	Blend1 lime stone dust at OBC	5.413	94.587	8.971
2	cement at OBC	6.983	93.017	58.745
3	lime stone dust at -0.5 OBC	7.273	92.727	64.948
4	cement at -0.5 OBC	7.645	92.355	66.251
5	lime stone dust at +0.5 OBC	5.165	94.835	7.078
6	cement at + 0.5 OBC	5.496	94.504	13.457
LE				
7	Blend1 lime stone dust at OBC	5.868	94.132	23.198
8	cement at OBC	6.871	93.129	59.04
9	lime stone dust at -0.5 OBC	5.041	94.959	6.058
10	cement at -0.5 OBC	6.322	93.678	37.958
11	lime stone dust at +0.5 OBC	4.752	95.248	4.765
12	cement at + 0.5 OBC	4.008	95.992	1.282
PVA+SBS				
13	Blend1 lime stone dust at OBC	5.992	94.008	19.575
14	cement at OBC	6.488	93.512	22.1
15	lime stone dust at -0.5 OBC	5	95	5.631
16	cement at -0.5 OBC	5.992	94.008	18.77
17	lime stone dust at +0.5 OBC	4.323	95.677	2.667
18	cement at + 0.5 OBC	4.298	95.702	1.16
ED				
19	Blend1 lime stone dust at OBC	6.488	93.512	31.041
20	cement at OBC	6.99	93.01	38.718
21	lime stone dust at -0.5 OBC	5.331	94.669	8.32
22	cement at -0.5 OBC	5.496	94.504	8.983
23	lime stone dust at +0.5 OBC	4.421	95.579	2.05
24	cement at + 0.5 OBC	4.835	95.165	4.864

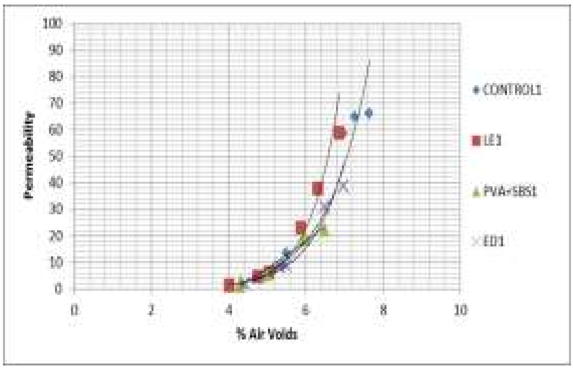


Figure 9: Trend of Permeability of All Mixtures Contain Asphalt Penetration Grade (40 – 50)

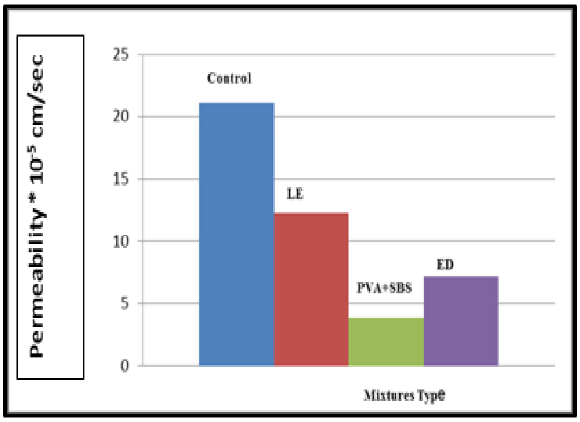


Figure 10: Average Permeability of All Mixtures Contain Asphalt Penetration Grade (60-70)

Table 12: Hydraulic Conductivity Results for Asphalt Penetration Grade (60-70) and NMAS (12.5mm).

Specimens No.	Blend No. With filer type	%Va	%Gmm	K(105cm/sec)
Control				
1	Blend 1 time stone dust at OBO	6.68	93.32	36.464
2	cement at OBC	7.054	92.946	61.523
3	time stone dust at -0.5 OBC	5.145	94.855	6-69
4	cement at -0.5 OBC	5-436	94-564	9.859
5	time stone dust at +0.5 OBC	4.647	95.353	4.504
6	cement at +0.5 OBC	4.938	95-062	7.908
LE				
7	Blend 1 lime stone dust at OBO	6.224	93.776	23 OO2
8	cement at OBC	6.556	93.444	34 OO6
9	limestone dust at -0.5 OBC	5-104	94.896	4.943
10	cement at -0.5 OBC	5.021	94-979	5.177
11	limestone dust at --O.5 OBC	4.523	95.477	4.323
12	cement at -- 0.5 OBC	4.274	95.726	2.403
PVA+SBS				
13	Blend1 ime stone dust at OBC	4398	95.6O2	2.305
14	cement at OBC	5.987	94.013	14.101
15	time stone dust at -0.5 OBC	4.025	95.975	1.064
16	cement at -0.5 OBC	4.772	95.228	4.814
17	time stone dust at +0.5 OBC	3.776	96.224	O
18	cement at -- 0.5 OBC	4.025	95.975	1.091
ED				
19	Blend1 lime stone dust at OBO	5.394	94.606	9.053
20	cement at OBC	5.602	94-398	13.332
21	time stone dust at -0.5 OBC	4.855	95.145	5.497
22	cement at -0.5 OBC	5.145	94.855	6.429
23	time stone dust at +0.5 OBC	4.315	95.685	3-806
24	cement at +0.5 OBC	4.647	95.353	4.819

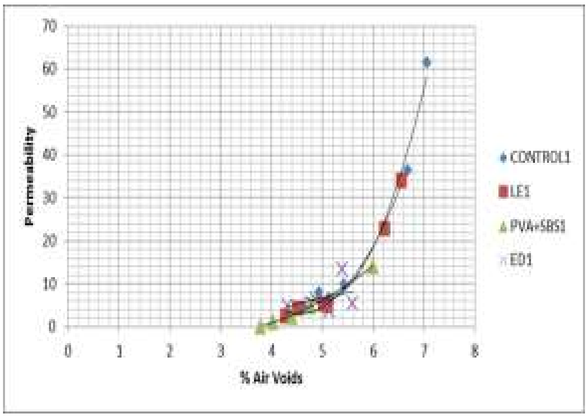


Figure 11: The Trend of Permeability of All Mixtures Contain Asphalt Penetration Grade (60-70).

In the Figures 10 and11 and Table 12 above The permeability values were indicated for asphalt penetration grade (60-70) below restricted zone with NMAS 12.5 mm are plotted with air voids, it appears that the maximum permeability is 61.523 × 10^{-5} cm/s at a maximum air void 7.054 using cement as a filer content in control and the maximum values of permeability in polymers equal to (34.006 × 10^{-5} cm/s, 14.101 × 10^{-5} cm/s and 13.332 × 10^{-5} cm/s) for (LE, PVA+ SBS and ED) respectively, while the maximum permeability of above mixtures is (36.464 × 10^{-5} cm/s, 23.002 × 10^{-5} cm/s, 2.305 × 10^{-5} cm/s and 9.053 × 10^{-5} cm/s) in case of using lime stone dust as a filer content and a minimum values of permeability equal to (4.504 × 10^{-5} cm/s, 2.403 × 10^{-5} cm/s, 0 cm/s and 3.806 × 10^{-5} cm/s) for (Control, LE, PVA+SBS and ED) respectively. The permeability average of control mixture with other polymers were (21.158 × 10^{-5} cm/s, 12.309 × 10^{-5} cm/s, 3.869 × 10^{-5} cm/s and 7.156 × 10^{-5} cm/s) respectively as shown in Figure (10) above. The percent of decreasing in permeability values is (41.832, 81.587 and 66.178) for (LE, PVA+ SBS and ED) respectively. It seems that all mixtures have the same trend of permeability as shown in Figure 11.

4. Conclusions

The following conclusions are limited to the materials used and test conditions under which the tests were conducted:

1. For all blends and mixtures the permeability ranged between (0 to 66.251 × 10^{-5} cm/s).
2. Depending on the aggregate gradation under restricted zone with different asphalt penetration grade the permeability average for all mixture types was (20.924 × 10^{-5} cm/s) content.
3. Mixtures with the asphalt penetration grade (60-70) has less permeability than that with asphalt penetration grade (40-50).
4. The results appeared that the permeability average of all mixtures were (27.745, 17.18, 7.773 and 11.409 × 10 $^{-5}$ cm/s) for (control blend, LE, PVA+SBS and ED)
5. The percent of decreasing in permeability were (38.799%, 73.826% and 60.279%) for mixtures contains (LE, PVA+ SBS and ED) respectively, it's appeared that mixture contain (PVA+ SBS) has a higher percent of decreasing in permeability.

5. References

[1] I. A. Ibrahim M. Abu awad, H. Dhasmana, A. R. Coenen, "Effect of Various Asphalt Binder Additives/Modifiers on Moisture-Susceptible Asphaltic Mixtures", Civil Engineering Studies Illinois Center for Transportation, 2014.

[2] C. H. Harris, "Hot Mix Asphalt Permeability Tester Size Effects and Anisotropy", Thesis Submitted Faculty of the Virginia Polytechnic Institute and State University in Partial Fulfillment of the Requirements for the Degree of Master, 2007.

[3] J.V. Martin (Innophos) and G. Orange (Rhodia Recherches), "Chemical Modified Asphalt Properties: Influence of Polyphosphoric on Asphalt Mixes Granulates Adhesion", Petersen Asphalt Research Conference, 2005.

[4] K.K. Bahia, H.U., Benson C.H.,and Wang X, "Measuring and Predicting Hydraulic Conductivity (Permeability) of compacted Asphalt Mixtures in the Laboratory", Presented at 82nd Annual Meeting of the Transportation Research Board, Washington, 2003.

[5] C.L.A. Brown E.R., and Maghsoodloo S, "Development of Critical Field Permeability and Pavement Density Values for Coarse-Graded Superpave Mixtures Pavements", NCAT Report No. 01-03. Auburn University. National Center for Asphalt Technology, 2001.

[6] J.W. Button And D.N. Little, "Asphalt Additiev For Increased Pavement Flexibility", Research No.471-2f, Report No. FHWA/TX-87/471-2f, Taxes State Department Of Highways And Public Transportation Planning Division P.O. Box 5051, Austin, Texas 78763, Texas Transportation Institute The Texas A&M University System College Station, 1986.

[7] S. Thornton. and C. Toh. "Permeability of Pavement Base Course ", Final Report, Submitted to Arkansas Highway and Transportation Department, Mack-Blackwell National Rural Transportation Study Center, University of Arkansas, Fayetteville, 1995.

[8] Expert. Task. Group. Federal Highway Administration. Moisture Damage in Asphalt Mixtures—A State-of-the-Art Report. Publication FHWA-RD-90-019. FHWA, U.S. Department of Transportation, 1990.

[9] A. G. M. Hossain, S. Romanoschi, and G. A. Fager, "Correlation between the Laboratory and Field

DOI: https://doi.org/10.30684/etj.2018.136780
2412-0758/University of Technology-Iraq, Baghdad, Iraq

Permeability Values for the Superpave Pavements", Proceedings of the Mid-Continent Transportation Research Symposium, Ames, Iowa, 2003.

[10] **https://en.wikipedia.org/wiki/Polyvinyl_acetate.**

[11] S. M, M. Nejad F and K. Fard Polymer modified bitumen production based on the degree of efficiency indifferent areas of Iran. Iranian Journal of Polymer Science and Technology 24(6) 467-479, 2012.

[12]http://pubchem.ncbi.nlm.nih.gov/compound/ethylenediamine#section=Other-Identifiers.

[13] General Specification for Roads and Bridges – Section R9" Hot-Mix Asphalt Concrete Pavement ", Department of Planning and Studies, Iraq, 2003.

[14] AASHTO PP-28, "Standard practice for designing superpave hot mix asphalt", 2010.

[15] T. H. J. D'Angelo, and J. Bukowski, "Superpave Asphalt Mixture Design Workshop", Workbook, Version 8.0, U.S. Department of Transportation, Federal Highway Administration, 2002.

[16] Iowa Department of Transportation, "Method of Test for Determining the Density of Hot Mix Asphalt (HMA) by Means of the Superpave Gyratory Compactor (SGC) ", Project Development Division – Office of Materials, 2002.

[17] ASTM–PS 129 – 01, "Standard Provisional Test Method for Measurement of Permeability of Bituminous Paving Mixtures Using a Flexible Wall Permeameter", 2003.

[18] Virginia Test Method – 120, "Method of Test for Measurement of Permeability of Bituminous Paving Mixtures Using a Flexible Wall Permeameter", 2009.

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