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DURABILITY OF POROUS ASPHALT PAVEMENT

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Abstract: This work describes a research study for evaluating the durability performance of open-graded asphalt materials in terms of accelerated aging, moisture damage and permanent deformation. Such asphalt mixes have high porosity, which offers significantly better drainage properties than normal mix designs. However, these materials also exhibit poor durability and strength limiting their use in pavement application, to remedy this, fiber and/or polymer binder modifiers have been proposed. samples were prepared with and without the modifiers using Marshall mix procedures and slabs (approximately 1000 samples for Marshall test with 20 slabs for wheel track test (*Dyna-Track*) and were experimentally tested using various conditions (short and long term aging) and standardized testing procedures including wheel track test for rutting, falling-head test for permeability , cantabro abrasion test for particle loss resistance and indirect tensile test for strength. In general, the results indicate that the introduction of fiber modifiers leads to minor improvement in strength characteristics of the samples, while contributing to significant reduction in permeability. On the other hand, the introduction of polymer modifiers nearly doubled both the strength and permeability and also increased the air voids. However, when polymer fiber is used (6% is the best percent of polymer modifiers), additional strength improvement is observed of 39,17and 8% for Control, short and long term aging respectively at 60C, but the permeability increase is not as large as that with polymer modifier alone of 10,12and 19% for Control, short and long term aging respectively. Consequently, the results indicate that, the best strength and permeability characteristics can be achieved by introducing only polymer modifier in the mix. Also, the effects of elevated temperature are investigated and it is found to have significant influence on the strength and permeability characteristics of the mixture.The second approach is testing the slabs as the same as the previous testing conditions. The resulting increase in the polypropylene additive increases the number of passes which reaches the same value of rutting (11.75mm of rutting at1000 passes). In case of long and short term aging increase. the number of passes which reach the same value of rutting (value in the case of the control) is increased and increases in the asphalt content decreases the number of passes which reach the same value of rutting (11.35,9.4mm of rutting at1000 passes) for short and long term aging for CM model.

Keywords: *Porous Asphalt, Permeability, Open Graded Fraction Courses, Rutting, Durability*

ديمومة التبليط الأسفلتي المسامي

الخلاصة: دراسة بحثية لتقييم أداء متانة الخلطه الأسفلتيه مفتوحة التدرج من حيث تقادم العمر، ضرر الرطوبة والتشوه الدائم. هذه الخلطات الإسفلتية لها مسامية عاليه، والتي تقدم خصائص تصريف أفضل بكثير من تصاميم المزجه العادية. ومع ذلك، فإن هذه المواد أيضا ضعيفة من ناحية قابلية التحمل والمتانة والتي تحد من استخدامها في تطبيقات الرصف، ولغرض زيادة قابليتها لاستخدامها في الرصف تم استخدام الياف لبولمر، وقد تم استخدام نسب مختلفة من البولمر(3,6,9)% وتم التحقق من آثار هذه النسب باستخدام عينات بمزجات قياسية، تم إعداد العينات

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ا مع وبدون مضافات البولمر باستخدام إجراءات مزيج مارشال والبلاطات الاسفلتيه (حوالي ١٠٠٠ عينة فحص مارشال مع ٢٠ بلاطه لفحص (Wheel Tracking Test.) وتم فحص جميع العينات مختبريا باستخدام مختلف ظروف التقادم السريع (تقادم قصير الامد) و (تقادم طويل الامد) ، وإجراء بعض الفحوصات وتشمل: فحص (Wheel Tracking Test)، فحص مقاومة الشد الغير مباشر، فحص النفاذيه وفحص مقاومة النموذج للكشط وتطاير الركام abrasion loss. بشكل عام، فإن النتائج تشير إلى أن استخدام الياف أدى إلى تحسن طفيف في خصائص القوة مع المساهمة في زيادة في النفاذية من ناحية أخرى عند استخدام البوليمر تضاعفت تقريبا كل من المقاومه والنفاذية وأيضا زيادة فراغات الهواء. ومع ذلك، عندما استخدمت الياف البوليمر بمقدار ٦٪ تمثل النسبة الافضل والمتوازنة وقد لوحظ تحسن المقاومه بمقدار ٣٩،١٧،٨ % لكل من التقادم الطويل الامد ،التقادم قصير الامد والخلطة القياسيه على التوالي في درجة حرارة ٦٠ درجة مؤيه ، لكن حدثت زيادة بمقدار النفاذيه لكن بصوره قليله ١٠،١٢،١٩% لكل من التقادم الطويل الامد ،التقادم قصير الامد والخلطة القياسيه على التوالي. ونتيجة لذلك، النتائج تشير إلى أن أفضل خصائص قوة و نفاذية يمكن أن تتحقق عن طريق إدخال البوليمر بنسبه ٦ بالمائة ، تم التحقيق في الآثار المترتبة على درجات الحرارة المرتفعه وتبين أن لها تأثير كبير على المقاومه والنفاذية . القسم الثاني هو اختبار البلاطات الاسفلتيه بنفس ظروف الاختبارات السابقة، لوحظ بان اي زيادة بمحتوى البوليمر يزيد من عدد مرات مرور عجلة الاختبار فوق النموذج لتحقيق الفشل المطلوب يحصل هبوط بمقدار ١١,٧٥ ملم عند نهايه الفحص عند ١٠٠٠ دوره، في حاله التقادم الطويل الامد وفي حالة التقادم القصير الامد تزداد عدد مرات مرور عجلة الاختبار لحين الحصول على الفشل المطلوب وعند زيادة نسبة الاسفلت تقل عدد مرات مرور عجلة الاختبار لحين الحصول على الفشل المطلوب (١١,٣٥،٩،٤) ملم عند ١٠٠٠ دوره للخلطة طويلة الامد ، والخلطة القصيرة الامد والخلطة القياسيه

1. Introduction

Open-graded asphalt is an infiltration system where storm water runoff is infiltrated into the ground through a permeable layer of pavement or other stabilized permeable surface. These systems can include porous asphalt concrete (PAC), porous concrete, modular perforated concrete block, cobble pavers with porous joints or gaps or reinforced/stabilized turf [1].

Open-graded asphalt has been in use as a wearing surface since the 1950s. Its first major use in Australia was about 1973 and it is known under a wide range of names in different parts of the world, such as: (Open-graded asphalt ,Porous friction mix , Open-textured asphalt , Friction course, Drainage asphalt, Whisper asphalt , Porous asphalt , Pervious macadam). [2].

Open graded friction course (OG) asphalt is widely used for water drainage and noise reduction in order to improve traffic safety and comfort for both drivers and residents living in the vicinity of roads. the composition of porous asphalt differs completely from conventional dense mixes. It consists mainly of coarse aggregate with small amounts of sand and filler, thus creating an open texture and a permeable structure with high porosity, and mixture design methodologies for OG and PA used by different local and foreign agencies and institutions.

First, an overview of the design procedures for OGFC applied by some local agencies is introduced. Next, to provide a short, historical background, the design method proposed in the 1990s by FHWA is introduced. After that, the methodologies suggested by NCAT and the current method of design applied by TxDOT are described. These methodologies provide a general idea about the current design approach in the United States. However, one should keep in mind that there are variants in the design processes applied by different state DOTs.

2. General

Open grade asphalt concrete mixture is a gap graded mix with intermediate sized and fine aggregate fractions omitted from the grading while dense-graded asphalt has a more continuous grading. Air voids are more inter-connected in OG compared to dense-graded mixes where the voids are often occluded [2]

Durability of asphalt concrete paving mixtures is the ability of the materials comprising the mixture to resist the effects of age hardening of asphalt , damage due to moisture , temperature variations and deterioration resulting from traffic loading (cracking and permanent deformation), through it is service life, [3]. This is due to the open structure of the layer therefore environmental forces such as moisture and binder oxidation (due to the ingress of water, heat and ultra-violet radiation) have an adverse effect on durability [4]. The service life of porous asphalt has been generally considered to be shorter than that of traditional dense graded asphalt. This is possibly caused by the clogging of the pores and drainage paths while under construction and also during the service life of the road [5].

3. Objectives and Scope of Work

The objectives of this paper are:

1- Study the durability performance of open grade asphalt concrete mixture in terms of accelerated aging, moisture damage, permanent deformation.
2- Explore the effect of accelerated aging methods (Short-Term Aging), (Long –Term Aging) and additives (PPF) on mechanical properties of open grade asphalt concrete.
3- Evaluate the effect of asphalt content on durability performance of open grade asphalt concrete mixture.

Explore the effect of one type of additives (PPF) on aging behavior of open grade asphalt concrete mixture.

3.1 Scope of Work

The scope of this paper is to evaluate the effect of:

1- Two accelerated aging methods (Short-Term Aging) and (Long – Term Aging) as per superpave procedure on open grade asphalt concrete .specimens have been prepared and tested for the following properties:
   - Marshall test
   - Cantabro abrasion test
   - Indirect tensile strength test at 25˚C, 40˚C, and 60˚C, and temperature susceptibility
   - Wheel track test (*Dyna-Track*)
2- Two accelerated aging methods (Short-Term Aging) and (Long – Term Aging) for slab specimen on open grade asphalt concrete.
3- One type of additives (polypropylene fiber) is used.

4. Materials

The materials used in this study are widely used in asphalt paving industry in Iraq and they are described in the following sections.

4.1. Asphalt Cement

One type of asphalt cement (40-50) penetration graded was used in this study. It is obtained from (Dourah refinery), South-West of Baghdad. Tests conducted on asphalt cement confirmed that its properties complied with the specifications of State Corporation for Roads and Bridges [6], The physical properties of the asphalt cement are presented in Table (1).

Table 1. The Physical Properties of the Asphalt (Daurah refinery).

Test	*Unit*	*Penetration-Grade (40-50)*	*S.C.R.B Spec .for (40-50) pen. Grade*
Penetration (25˚C, 100g, 5sec) ASTM D5	1/10 mm	45	40-50
Softening Point (ring & ball). ASTM D 36	˚C	54	50-60
Ductility (25˚C, 5 cm/min). ASTM D 113	cm	119	100>
Flash Point (cleave land open cup) ASTM D 92	˚C	255	232>
Solubility in Trichloroethylene	%	100	>99
*After Thin-Film Oven Test ASTM D 1754			
Penetration of Residue	1/10 mm	38	<55
Ductility of Residue	cm	109	>100
Loss in Weight (163˚C, 50 gm, 5h),%	%	0.3	>0.75

The test was done in cooperation with National Center for Construction and Laboratories.

4.2. *Aggregate*

4.2.1 Coarse Aggregate

The coarse aggregate (crushed) is brought from Al-Nibaee quarry. It consists hard, strong, durable pieces, free of coherent coatings. The gradation of coarse aggregate ranges between 3/4 in. (19.0 mm) and No.4 sieve (4.75 mm) according to [6]. The physical and chemical composition of the coarse aggregate are shown in Tables (2) and (3) respectively.

4.2.2 Fine Aggregate

Two types of fine aggregate are used in this study. These are crushed and river sand. The gradation of fine aggregates ranges between passing 4.75mm (No.4) sieve and retains on 0.075mm (No.200) sieve [6]. It consists of tough grains, free of amount of clay, loam or other deleterious substance. The physical properties and the chemical composition of the fine aggregate are shown in Tables (2) and (3) respectively.

Table 2. Physical Properties of Nibaee Aggregates.

Property	*Coarse Aggregate*	*Fine Aggregate*
Bulk Specific Gravity (ASTMC127 and C128).	2.6802	2.6303
Apparent Specific Gravity (ASTMC127 and C128).	2.602	2.46
Percent Water Absorption (ASTMC127 and C128).	0.423	0.542
Percent Wear (Los Angeles Abrasion) (ASTMC131) *	20.10	……

Table 3. Chemical Composition of Nibaee Aggregates *

Chemical Compound	*%Content*
Silica,Sio2	82.52
Lime, CaO	5.37
Magnesia, MgO	0.78
Sulfuric Anhydride, SO3	2.7
Alumina, Al2O3	0.48
Ferric Oxide, Fe2O3	0.69
Loss on Ignition	6.55
Total	99.09
Mineral Composition	
Quartz	80.3
Calcite	10.92

The test was done in cooperation with National Center for Construction and Laboratories.

4.2.3 Mineral Filler

One type of mineral filler which is (ordinary Portland cement) is used. It is thoroughly dry and free from lumps or aggregations of fine particles. The chemical composition and physical properties are shown in Table (4).

Table 4. Physical Properties of Portland cement

Chemical Compound	*%Content*
Silica,Sio2	21.51
Lime, CaO	62.52
Sulfuric Anhydride, SO3	1.58
Alumina, Al2O3	5.64
Magnesia (MgO)	3.77
Ferric Oxide, Fe2O3	3.35
Loss on Ignition (L.O.I)	1.34
Total	99.44
Physical properties	
%Passing Sieve No. 200	98
Bulk specific gravity	3.14
Specific Surface Area(m^2/kg)	356

4.3 Additives

4.3.1 Polypropylene Fiber

Description:

Grace cemfiber is ahigh performance micro polypropylene fiber developed as a crack controlling additive for cementitious materials. It is available in two grades, designated by its fiber length, 12 to 6mm for concrete and 6mm for mortar Polypropylene fibers have a number of advantages over polyethylene fibers in the field of textile applications. The degree of crystallinity, 72 to 75%, results in a fiber that is strong and resilient, and does not fibrillate like high-density polyethylene. The melting point of polypropylene is 165°C, which is low by comparison with nylon or polyester, but is high enough to make it suitable for most textile applications. So light that it actually floats, polypropylene fiber provides greater coverage per pound than any other fiber. It is highly resistant to mechanical abuse and chemical attack **[7].**

(a) Shape Propylene fiber (b) Box Propylene fiber

Figure (1.a,b):Polypropylene Fiber.

Table 5. Physical Properties of Polypropylene Fibers. (Tests manufacturer- Grace Cemfiber).

Fiber length	*12mm*
Specific weight	0.91 (g/cm³)
Alkali content	Nil
Sulphate content	Nil
Chloride content	Nil
Constituents	polypropylene fiberC3 H6,
Fiber thickness	18 micron 2denier
Specific surface area	244 m^{2-}/kg

<u>*Uses:*</u> Polypropylene fibers are widely used in industrial, carpet, and geotextile applications. They have found important uses in fishing gear, in ropes, and for filter cloths, laundry bags and dye bags. The excellent chemical resistance of polypropylene fiber is of advantage in the filtration and protective clothing fields. Fibrillated polypropylene yarns are widely used in indoor-outdoor carpets. Staple fiber finds application in blankets, pile fabrics, underwear, and industrial fabrics; it is being developed for carpets, candlewicks, knitted outerwear, hand-knitting yarns, and upholstery [7].

4.4 Aggregate Gradation

The selected gradation follows National Asphalt Pavement Association **[8],** for porous asphalt paving mixtures for (19 mm) aggregate maximum sizes and go outside of specifications that increase the percent of fine aggregate (sieve size 4.75mm and 2.36mm) for three gradation (A,B and C). Table (6): and Figure (2) show the gradation for wearing layer.

Table 6. Gradation Selected.

Sieve Size	*National Asphalt Pavement Association[8]*	*Gradation (A)*	*Gradation (B)*	*Gradation (C)*
19	100	100	100	100
12.5	85-100	92.5	92.5	92.5
9.5	55-75	65	65	65
4.75	10-25	15	20	25
2.36	5-10	10	15	20
o.o75	2-4	3	3	3

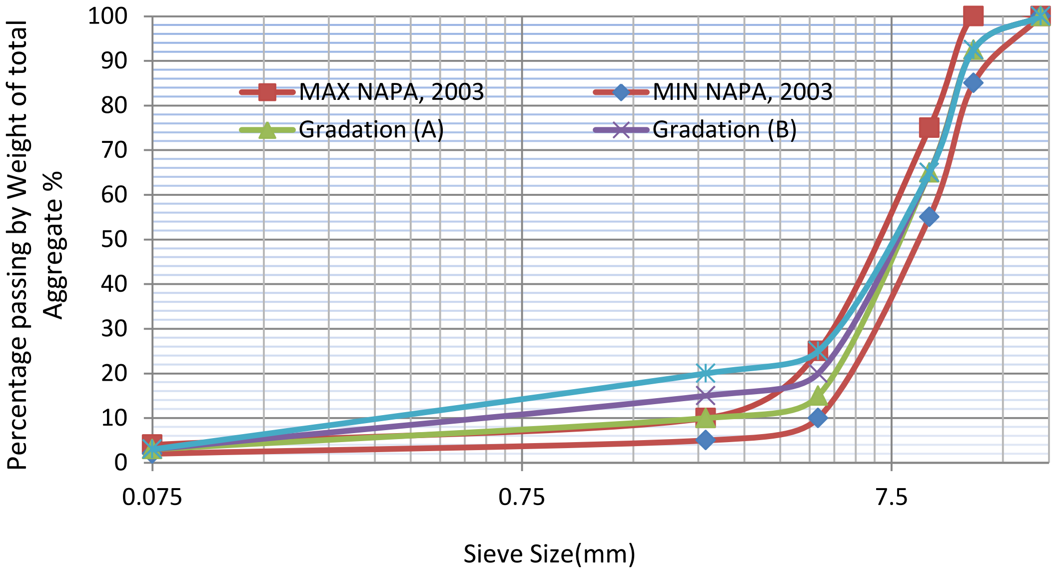


Figure 2.The Aggregate Gradation.

5. Testing Program

Selected three aggregate gradation .and determine the optimum binder content for each gradation using asphalt contents limit from 3.5 to 6.5 % [9]. The whole testing program was conducted on specimens constructed at optimum asphalt content and at asphalt contents 0.5 percent above, and 0.5 percent below. The preparation of asphalt concrete mixture was scheduled as below:

1- Select one aggregate gradation.

2- Preparation of asphalt concrete mixtures, asphalt content 4, 4.5 and 5% (Reference mixture).

3- Preparation of asphalt concrete mixtures, asphalt content (4, 4.5 and 5%) and polymer content (3, 6 and 9%) for each asphalt content (Reference mixture).

4- Preparation of three groups of Marshall specimens for hydraulic honductivity test with polymer additives bases on concept of Darcy’s law. Including (short, long term aging) and moisture condition.

5- Preparation of three groups of Marshall specimens. First group was prepared to abrasion loss test (unaging). Second group was prepared by subjecting the loose asphalt concrete mix to one cycle of accelerated aging (short and long term aging) for Abrasion Loss test (aging).. The third group of specimens was prepared by cycle of freeze-thaw and examined by Abrasion Loss test [10].

6- Prepare groups of Marshall Specimens to study the effect of temperature susceptibility and tested by indirect tensile test.

7- Prepare groups of slab specimen with different binder, polymer content and different test condition to study the rutting effect.

6. Process for the Selection of Optimum Binder Content

The general process for the selection of optimum binder content for open grade asphalt mixes is illustrated in Figure 3 below [9]:

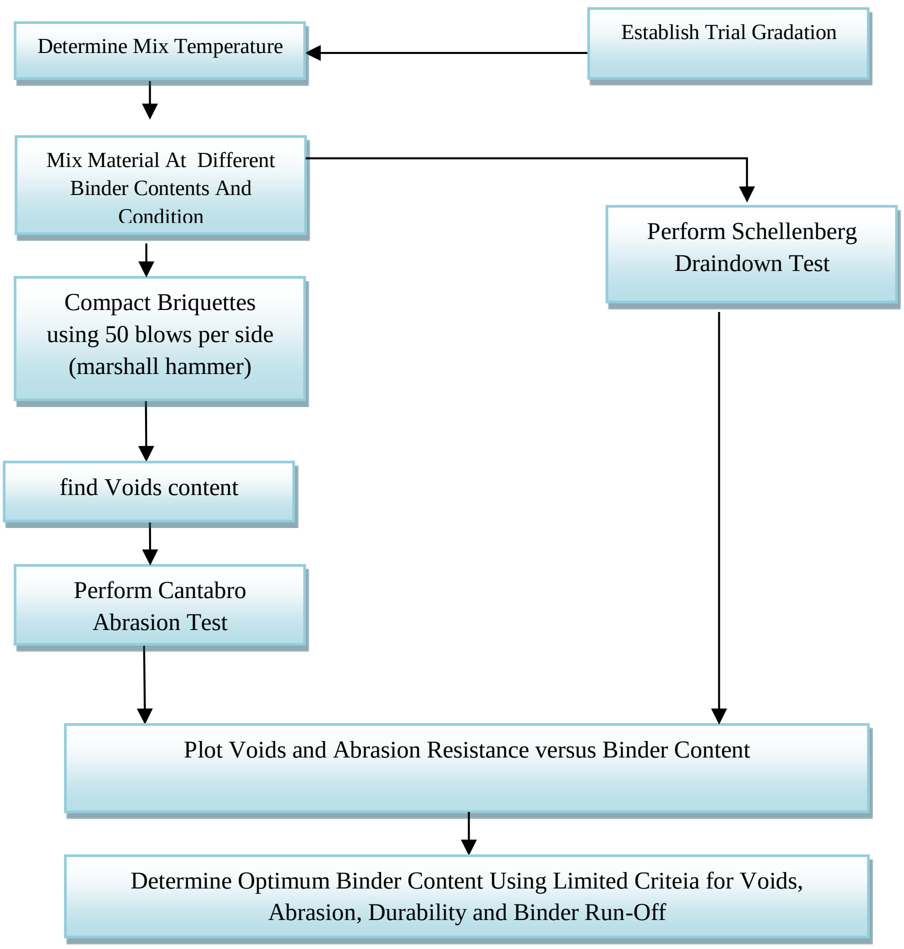


Figure 3: The general process for the selection of optimum binder content for OG asphalt mixes.

7. Preparation of Asphalt Concrete Mixtures

7.1 Preparation of Slab Specimens

Preparation a rectangular specimen of (400 mm) in length,(50mm) in height and (300mm) in width. Steel mold rectangular mold of (400 mm) in length,(120mm) in height

and (300mm) [11] mold and spatula, were heated on a hot plate to a temperature between (120-150ºC). Adding the polymer is heated to a temperature polymer 165ºC and then add asphalt is complete mixing process According to [12], A piece of non-absorbent paper, cut to size, was placed in the bottom and around of the mold before the mixture was introduced. The asphalt mixture was placed in the preheated mold. Another piece of non-absorbent paper cut to size was placed on the top of the mix. The temperature of mixture immediately prior to compaction temperature was (150ºC) The mold assembly was placed on the compaction Machine and compaction the specimen at constant force, (5.1)KN load, Pass through the monitoring arm (arm convex) on the form several times to get to the density ratio and the desired height. Compaction Machine Consists of chamber to save the temperature during the compaction process and the digital screen to control by density and high final model left the slap to cool at room temperature to extract the sample from the mold after 24 hours, then the sample is encapsulated aluminum foil until the examination.
Presently, AASHTO and Superpave have adopted methods to achieve short and long term aging designated as [13-14]. The short and long term procedures of asphalt mixes include:

1. Mixture conditioning for short –term aging

The short –term conditioning for the mixture mechanical property testing procedure is applied to laboratory –prepared, loose mix only. The brief description of procedure is to place the mixture in a pan, and spread it to an even thickness ranging between 25 and 50 mm .The pan is then placed in a forced air draft oven for 2 or 4 h±5 min. at a temperature of 135 ± 3 ^{o}C .The mixture is stirred every 60±5 min to maintain uniform conditioning.

2. Mixture conditioning for long –term aging

The long term mixture conditioning procedure can be applied to laboratory –prepared samples following short term aging , to plant –mixed HMA , or to compact roadway samples when needed to simulate long term aging effects. This mixture conditioning step is used when samples will be tested for mechanical properties such as indirect tensile creep or strength. The compacted specimens are stored in a forced air draft oven for five days at 85˚C.

8. Result and Conclusions

The main objective of this study is to study open grade asphalt layer and determine the durability of this layer, type of materials its constituent and effect of polymer additive on the strength and durability of this layer, which is reflected on the pavement as whole system. In addition, predict the allowable number of load repetitions to prevent limit rutting of pavement.

8.1 *Effect of Control Mixture, Short and Long Term Aging Time on Permeability Coefficient Rate*

A standard procedure, FM 5-565 for falling head permeability test was developed by Florida Department of Transportation in 2000 and revised in 2006. The permeability cell consists of a 300 mm long acrylic tube with an inner diameter of 92 mm. A 50 mm diameter valve connects the bottom part of the tube to a vertical pipe through which water can drain out. A graduated acrylic cylinder of 300 mm length is attached to the top of the specimen assembly and clamped tightly using a rubber sleeve. This is used to monitor the water level during the test. The specimen is enclosed in a latex membrane (as is done for the electrical property measurements), and is inserted into the test set up. Water is added to the graduated cylinder to fill the specimen cell and the draining pipe. The specimen is preconditioned by allowing water to drain out through the pipe until the level in the graduated cylinder is the same as the top of the drain pipe. This eliminates any air pockets in the specimen and ensures that the specimen is completely saturated. With the valve closed, the graduated cylinder is filled with water. The valve is then open, and the time in seconds (t) is required for water to fall from an initial head of 290 mm (h1) to a final head of 70 mm (h2) noted. This procedure is repeated three times, and the average value of t is use. The coefficient of permeability (K) is calculated according to Darcy's law as Equation (1).

$$K = \frac{A_1 l}{A_2 t} log\left(\frac{h_2}{h_1}\right) \tag{1}$$

Where A1 and A2 are the areas of the cross-section of the sample and the tube respectively and l is the length of the specimen.

Following the permeability measurements, the same specimens are tested to evaluate their clogging potential. The permeability coefficients are shown in Figure (٤) which shows that at any specific PPF content in the mix, the permeability coefficient decreased as the binder content increase. This happens due to the excess bitumen filling the air voids and clogging of some of the interconnected pores, short and long term aging lead to increase the permeability coefficient, to a maximum value (284m/day) and increases with PPF% content, because of the lack of compensation from the asphalt by PPF.

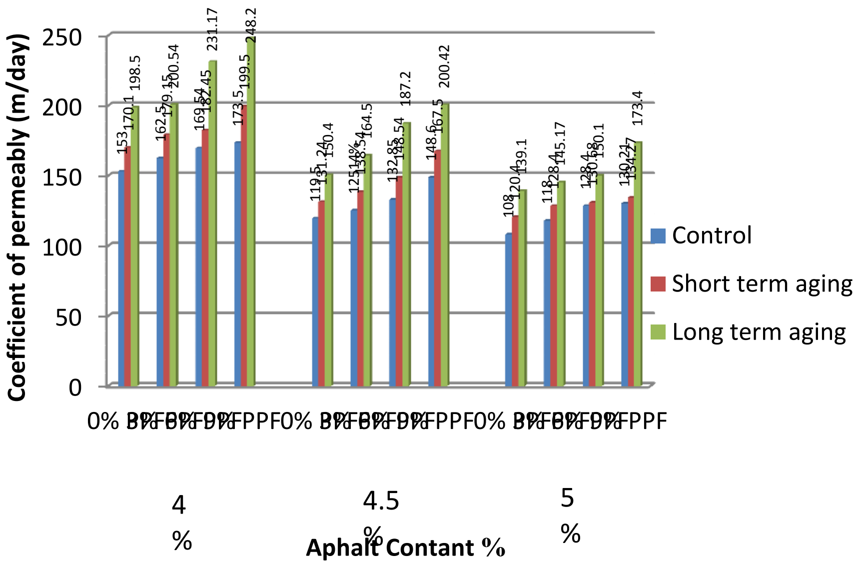


Figure 4 Coefficient of permeably Results For Control Mixture , Short And Long Term Aging.

8.2 *Effect of Short and Long Term Aging Time Temperature Susceptibility*

The temperature susceptibility is calculated using the following equation (2), *(Husham1999)*:

$$TS = \frac{(ITS)t1-(ITS)t2}{(t2-t1)} \quad (2)$$

Where:

TS = temperature susceptibility (Kpa/C°)

(ITS) t1 = indirect tensile strength at t1
(ITS) t2 = indirect tensile strength at t2
t1 = 25C°, t2 = 40C°

Figure (5) the result of temperature susceptibility by indirect tensile strength test , show that long term aging at asphalt content 4% and PPF 0% show less effect of temperature change by 8.8% and short term aging by 4.2%, and when increased PPF to reach 9% show less effect of temperature change by 14% and short term aging by 4% : A long term aging at asphalt content 4.5% and PPF 0% show less effect of temperature change by 10.8% and short term aging by 6.3%, and when increased PPF to reach 9% show less effect of temperature change by 11.9% and short term aging by 4.2%, a long term aging at asphalt content 5% and PPF 0% show less effect due to temperature change by 5.5% and short term aging by 4.7%, and when is increased PPF to reach 9% show less effect due temperature change by 7% and short term aging by 4.3%.

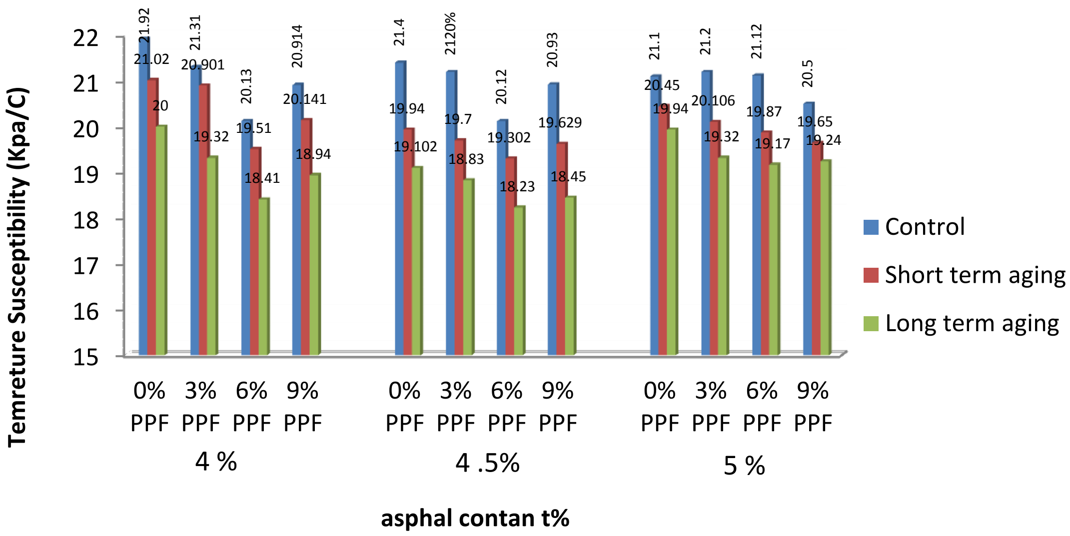


Figure 5. Temperature Susceptibility For Control Mixture , Short And Long Term Aging.

8.3 Cantabro Abrasion Test (Particle Loss Resistance)

The Cantabro test is conducted to evaluate the resistance to particle loss of the mixtures according to [15]. The compacted specimens are individually put in the Los Angeles testing machine without steel balls. After Los Angeles drum has been rotated for 300 revolutions at a speed of 30–33 revolutions per minute, the loose material broken off from surface of the test specimen is discarded. The masses of the specimens before and after the test are recorded. The percentage loss by weight of original specimen is calculated as the Cantabro abrasion. This test can be conducted on unaged specimens, aged specimens, and wet conditioned specimens and the corresponding abrasion losses are termed as Unaged Abrasion Loss (UAL), Aged Abrasion Loss (AAL), and Wet Abrasion Loss (WAL) as shown in Figures (6, 7, 8 and 9) respectively.

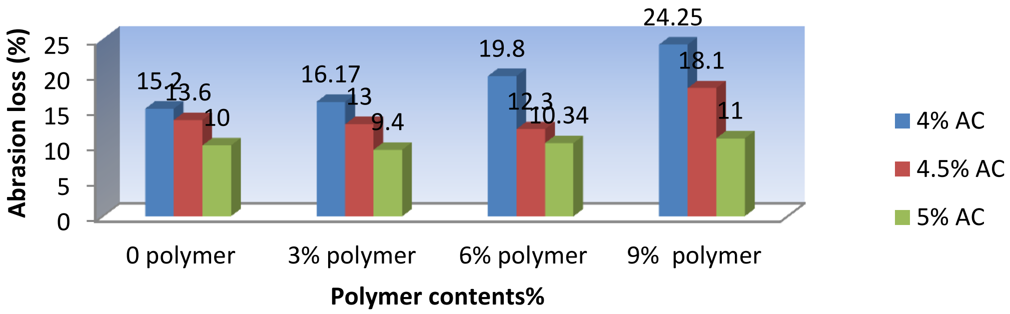


Figure .6 Unaged Abrasion Loss Result at 300 Revolutions and 25C° for Different Polymer Contents.

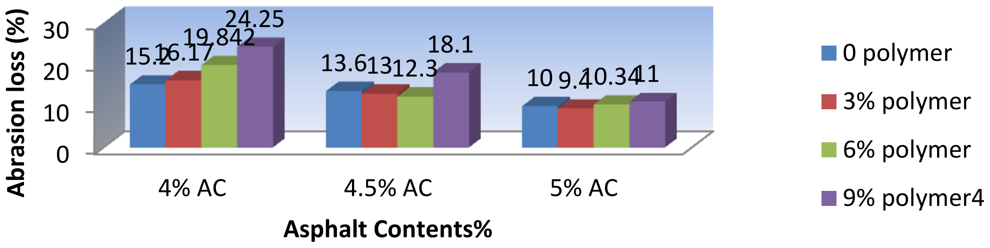


Figure 7 .Unaged Abrasion Loss Result at 300 Revolutions and 25C° for Different asphalt Contents.

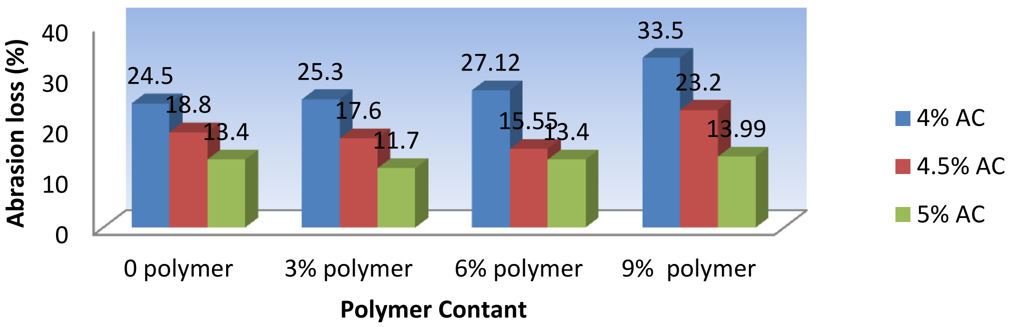


Figure 8. Aged Abrasion Loss Result at 300 Revolutions and 25C° for Different Polymer Contents.

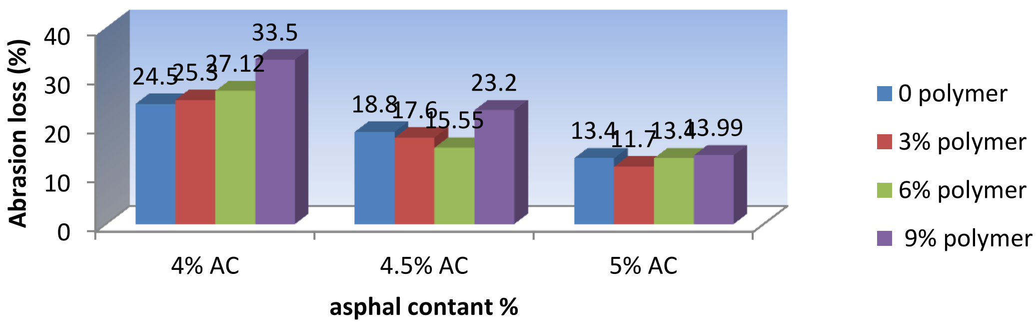


Figure 9. Aged Abrasion Loss Result at 300 Revolutions and 25C° for Different asphalt Contents.

8.4 Effect of Control Mixture, Short and Long Term Aging and PPF on Rutting

The rutting profiles measurements were taken after 500,1000,1500,2000 to 10000 axle loads relative to the profile measurement (0) before, These results have been summarized and are represented in Figure (10),(11),(12),(13),(14),(15) and (16), which shows the cumulative average maximum rutting as a function of increased axle loading.

Figure(10) These figures show that increasing asphalt content shows an increase in the deformation rate and a decrease in number of cycles to failure. Figure (12) and Figure (12), these figures show that the rutting decreased at short and long term aging, short term aging have rutting result less than rutting for long term aging because fundamental factors caused hardening in asphalt materials *(Read and Whiteoak 2003).* Figure (12) have higher value for rut depth 13.25mm at asphalt content 4.5% rutting result at the highest level equal 11.75mm. Figure (13) and Figure (14) show rutting result, decreased When adding PPF additive 10.8mm at asphalt content 4.5% and 11.2mm at asphalt content 5%, polymer additives improve the rutting results *(kandal 2006).*

When in increasing PPF percentage to 6% improve the rutting result and improve short and long term aging Figure (15) and Figure (16), show rut depth value 7.7mm for asphalt content 4.5% and 8mm at asphalt content 5%

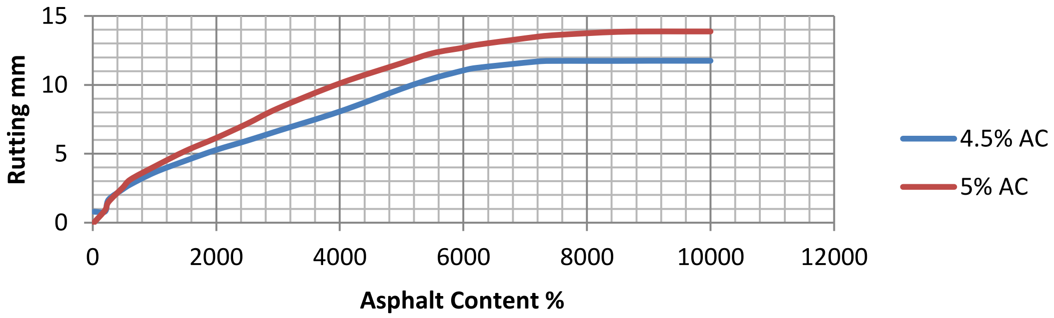
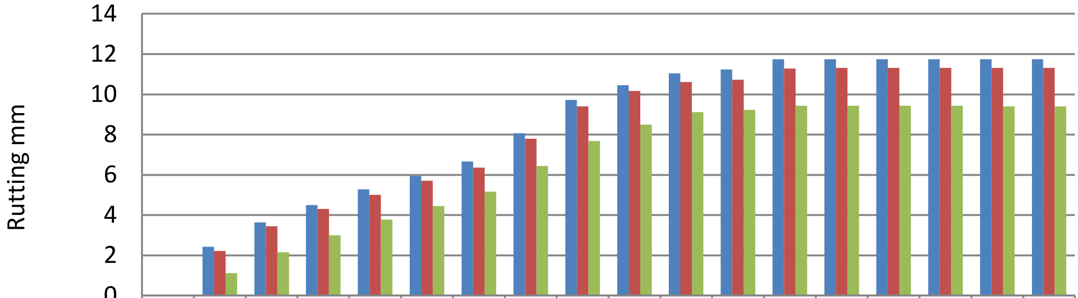


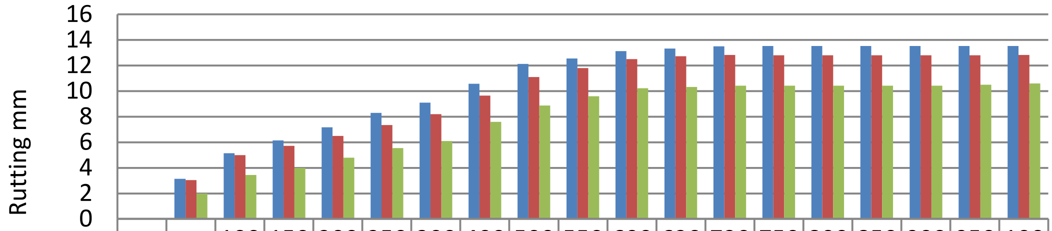
Figure 10. Effect of Asphalt Content on Rutting.



	0	500	1000	1500	2000	2500	3000	4000	5000	5500	6000	6500	7500	8000	8500	9000	9500	10000
Control	0	2.42	3.64	4.49	5.28	5.95	6.66	8.07	9.72	10.5	11.1	11.2	11.7	11.7	11.7	11.8	11.8	11.8
Short Term	0	2.22	3.44	4.31	5	5.71	6.36	7.8	9.41	10.2	10.6	10.7	11.3	11.3	11.3	11.3	11.3	11.3
Long Term	0	1.12	2.15	3	3.78	4.45	5.17	6.44	7.68	8.49	9.12	9.22	9.43	9.44	9.43	9.43	9.41	9.41

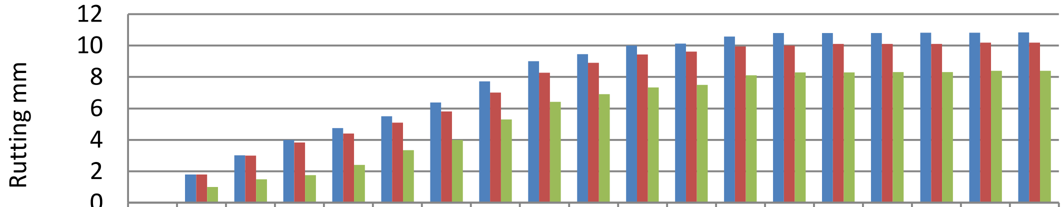
No of Cycle

Figure 11. (4.5% AC) Effect of Control Mixture, Short and Long Term Aging Time on Rutting.



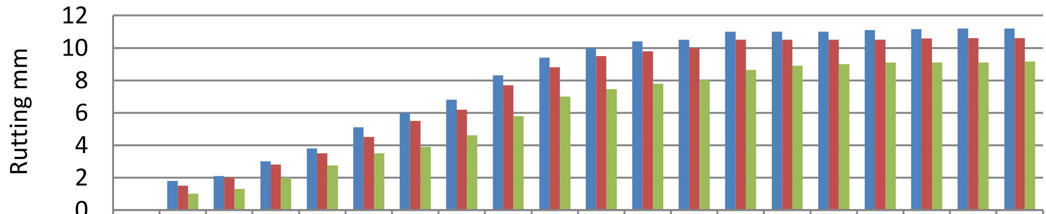
	0	500	1000	1500	2000	2500	3000	4000	5000	5500	6000	6200	7200	7500	8000	8500	9000	9500	10000
Control	0	3.13	5.14	6.15	7.18	8.3	9.11	10.6	12.1	12.6	13.1	13.3	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Short Term	0	3.03	5	5.72	6.5	7.34	8.2	9.64	11.1	11.8	12.5	12.7	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long Term	0	2	3.45	4	4.78	5.55	6.1	7.6	8.88	9.59	10.2	10.3	10.4	10.4	10.4	10.4	10.4	10.5	10.6

Figure 12. (5% AC) Effect of Control Mixture, Short and Long Term Aging Time on Rutting.



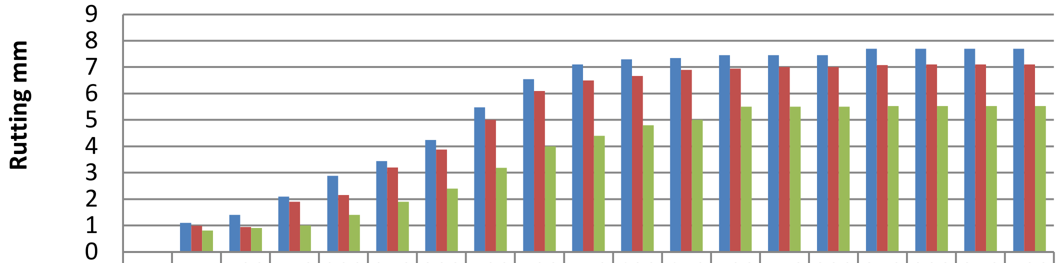
	0	500	1000	1500	2000	2500	3000	4000	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000
Control	0	1.8	3.01	4	4.74	5.5	6.38	7.73	9	9.45	10	10.1	10.6	10.8	10.8	10.8	10.8	10.8	10.8
Short Term	0	1.8	2.99	3.83	4.4	5.1	5.8	7	8.28	8.91	9.44	9.61	9.95	10	10.1	10.1	10.1	10.2	10.2
Long Term	0	1	1.5	1.75	2.41	3.35	4	5.3	6.42	6.9	7.34	7.5	8.1	8.3	8.3	8.32	8.32	8.4	8.4

Figure 13. (4.5%AC,3%PPF)Effect of Control Mixture, Short and Long Term Aging Time on Rutting.



	0	500	611	1000	1500	2000	2500	3000	4000	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000
Control	0	1.8	2.1	3	3.8	5.1	6	6.8	8.3	9.4	10	10	11	11	11	11	11	11	11	11
Short Term	0	1.5	2	2.8	3.5	4.5	5.5	6.2	7.7	8.8	9.5	9.8	10	11	11	11	11	11	11	11
Long Term	0	1	1.3	2	2.8	3.5	3.9	4.6	5.8	7	7.5	7.8	8	8.6	8.9	9	9.1	9.1	9.1	9.2

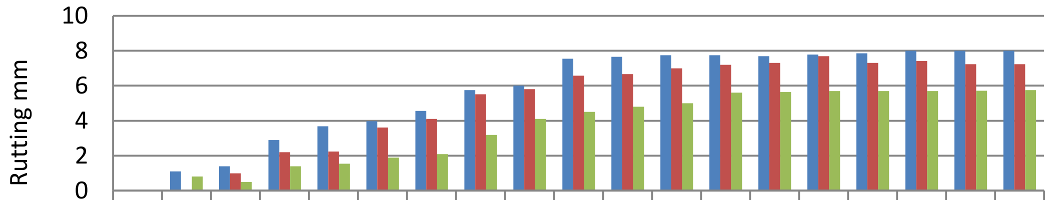
Figure 14. (5%AC,3%PPF)Effect of Control Mixture, Short and Long Term Aging Time on Rutting.



No of Cycle	0	500	1000	1500	2000	2500	3000	4000	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000
Control	0	1.1	1.4	2.1	2.88	3.44	4.24	5.48	6.54	7.1	7.3	7.35	7.45	7.45	7.46	7.7	7.7	7.7	7.7
Short Term	0	0.99	0.94	1.9	2.15	3.2	3.88	5	6.1	6.5	6.67	6.9	6.95	7	7	7.08	7.1	7.1	7.1
Long Term	0	0.81	0.9	1	1.4	1.9	2.4	3.18	4	4.4	4.8	5	5.5	5.5	5.5	5.52	5.52	5.53	5.53

No of Cycle

Figure 15. (4.5%AC,6%PPF)Effect of Control Mixture, Short and Long Term Aging Time on Rutting.



No of Cycle	0	500	1000	1500	2000	2500	3000	4000	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000
Control	0	1.1	1.4	2.9	3.68	3.98	4.57	5.75	6	7.54	7.66	7.75	7.75	7.7	7.78	7.85	8	8	8
Short Term	0	0	1	2.2	2.24	3.62	4.1	5.51	5.81	6.58	6.66	7	7.2	7.3	7.7	7.31	7.42	7.24	7.24
Long Term	0	0.81	0.5	1.4	1.54	1.9	2.1	3.2	4.1	4.5	4.8	5	5.6	5.64	5.7	5.7	5.7	5.71	5.76

No of Cycle

Figure 16. (5%AC,6%PPF)Effect of Control Mixture, Short and Long Term Aging Time on Rutting

9. Conclusions

Based on the testing results and limitations, the following conclusions can be addressed:

1-Abrasion loss result was noticed for unaged mixtures properties compared to aged mixture ,at 4.5% and 6% asphalt and polymer content respectively, the percent of improvement was (9.55%,5.39%,32%,) for (0%,3% and 9% polymer content respectively. and for aged mixture at 4.5% and 6% of asphalt and polymer content respectively, the percent of improvement was (17.29%,11.65% and 34%,) for (0% ,3% and 9%) polymer content respectively.

2- Open grade is more effected by change in temperature during indirect tensile strength , at 4.5% and 6% asphalt and polymer content respectively, the percent of decrease for control mixture was (-43.7%,-86%,) at (40°C 60°C) respectively of indirect tensile strength at temperature 25°C , and percent of descries for short term aging mixture was (-44.15%,-88%,) at (40°C 60°C) respectively of indirect tensile strength at temperature 25°C, also percent of decrease for long term aging was (-38%,-81%,) at (40°C 60°C) respectively of indirect tensile strength at temperature 25°C

3- Temperature susceptibility, at asphalt content 4.5% and PPF 0% shows less effect due temperature change by (10.8,6.3)% short and long term aging respectively, and when increased PPF to reach 9% shows less effect due temperature change by (11.9,4.2)% short and long term aging respectively ,increased asphalt content 5% and PPF 0% show less effect of temperature change by (5.5, 4.7)% short and long term aging respectively, and when increasing PPF to reach 9% show less effect due temperature change by (7,4.3)% short and long term aging respectively.

4- In increasing of added PPF permeability coefficient has been increased , The study was conducted on three AC% and PPF%, The effective influence for permeability coefficient was 4%AC and 9% PPF the results were (173,199 and 248) m/day for control, short and long term aging respectively. any increase in the asphalt content and without an increase PPF% permeability coefficient is decreased, shows this effect at AC5% and PPF0%, the results were (108,120 and 139) m/day for control, short and long term aging respectively.

7-The increase in the polypropylene additive increases the number of passes which reaches the same value of rutting (value in the case of the control).

8- In case long term aging increase the number of passes which reaches the same value of rutting (value in the case of the control).and in case short term aging increases the number of passes which reaches the same value of rutting but no more in number of passes in case long term aging (value in the case of the control).

9- Increasing the asphalt content decreases the number of passes which reaches the same value of rutting.

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