ABSTRACT

This laboratory study investigated the effects of aging on the physical properties of modified asphaltic concrete mixtures with high density polyethylene as measured by indirect tensile strengths, percent of swell, and bulk density. The aging was performed at temperature of ١٣٥°C and at two period of time varying between two and four days. Marshall Specimens were compacted by a mechanical compactor at temperature of ١٣٨°C to ١٤٢°C.

Six mix types of high-density polyethylene including the control at optimum asphalt content were used throughout the investigation. The asphaltic concrete was of dense-graded aggregate type for surface course confirming to gradation limits of ASTM highway commission specifications.

The results showed that variations in the aging time produced changes in the physical properties of modified mixes also the results showed that changes in the additive type affect on these properties.

INTRUDUCTION

The use of additives in road construction for both surfaces and base courses was initiated in ١٩٨١ under the Roads and Transportation Association of Canada (RTAC) research program [١]. Because most of them have significant performance and economic implications and because certain additives may offer some help in alleviating the asphalt pavement problems such as rutting, stripping, flushing, thermal cracking… etc. Al-Mawajood and Al-Hadidy [٢] were used high-density polyethylene as additive in improving the performance of asphalt concrete mixtures they illustrates that this type of additive has give a satisfactory results in improving Marshall properties and compression test.

In this research we tried to completion the study of aging effect on the characteristics of high-density polyethylene / Asphalt paving mixtures, because pavement age is an important factor for the stiffness of the asphalt with age, making the material more susceptible to thermal cracking. Second, the probability of obtaining a low critical temperature increases with time.

PURPOSE AND SCOPE

The purpose of this investigation is:

١. To study the effects of variations in aging time on physical properties of modified asphaltic concrete mixtures with high density polyethylene (HDPE) additive by indirect tensile strength, percent swell and bulk density tests.

٢. To determine the effects of additive type on the results obtained.

٣. To establish the better type of additive for the asphaltic concrete mixtures investigated.

SELECTION OF MATERIALS

Aggregate:

(Al-Khazer) aggregate was utilized in the preparation of asphaltic concrete specimens. Table (١) show the results of the physical properties of this aggregate. Portland cement from the (Senjar) cement factory was used as mineral filler. It had (٨٧ percent) passing No. ٢٠٠ sieve and a specific gravity of ٣.١٥ by ASTM [٣] designation D٨٥٤.

Asphalt cement:

The asphalt cement was ٤٠-٥٠ penetration grade produced by the Baiji refinery. At ٢٥°C, it has a specific gravity of ١.٠٥٣ and ductility of ١٠٠$^{+}$ cm.

High Density Polyethylene:

The high-density polyethylene (HDPE) was obtained from one private factory for jugs production, while the wire mesh of (HDPE) was brought from Al-Kornesh market in Mosul city. It has physical and chemical properties as shown in Table (٢ a & b), respectively.

LABORATORY TESTING

A series of tests were carried out on aged HDPE/Asphalt mixtures according to ASTM methods to characterize the mixes designed for different type of (HDPE) as additive. The tests that were conducted include the:

- Indirect tensile strength test (ASTM D-٤١٢٣) [٣].
- Percent of swelling acc. To super pave SP-٢[٤].
- Bulk density (ASTM D-٢٧٢٦) [٣].

SAMPLES PREPARATION AND TESTING

Composition and size of specimens:

The mix design conformed to ASTM specification D-٣٥١٥ dense graded type with ¾ inch maximum size aggregate. Mix characteristics and proportions are summarized in Tables ٣ and ٤. This mix has been used extensively by the civil engineering materials research laboratory at Mosul University for indirect tensile strength testing program. The specimen used was ٤ inch in diameter and ٢.٥ inch in high.

Specimen fabrication:

Two groups of samples are mixed at optimum asphalt content of ٥% (by weight of total aggregate and filler) and at the appropriate mixing temperature of ١٥٠°C to ١٦٠°C for selected ٤٠-٥٠ penetration graded binder and additive by hand for ٢min. in a mixing bowel acc. to the asphalt institute method [٥]. The first group is then aged by placing the loose mix in a flat pan and into a forced draft oven at ١٣٥°C for ٢-days, while the second group are aged at ١٣٥°C for ٤-days according to super pave [٥]. The samples are then brought to compaction temperature range (١٣٥-١٤٢°C) by placing them in another oven for a short time (generally less than ٣٠ minutes). A mechanical compactor of Marshall was used to consolidate the hot mix. The specimens were compacted in one layer with ٧٥ blows for each face, which simulate a tire pressure of ٢٠٠ psi. The specimens were then removed from the mold according to the method described in ASTM D-١٥٥٩, and left them to cure in air for ٢٤-hr. to subject them for laboratory tests.

INDIRECT TENSILE STRENGTH PROCEDURE

Before testing, the specimens were allowed to conditioned for ٢-hr at the test temperature of ٢٥°C according to ASTM d-٤١٢٣ [٣] using laboratory oven. Then the specimens were tested at constant rate of deformation of (٣.٨ mm/min) as recommended by Lottman [٦, ٧] by a universal testing machine which provides a record of load and deformation.

DETERMINATION OF INDIRECT TENSILE STRENGTH AND TENSILE STIFFNESS MODULUS

The compressive load at failure and the horizontal deformation of compacted specimens were recorded. The load decreased to zero and the specimen was then removed. The side flattening was measured to nearest (١ mm) by painting the top and bottom flattened side with powder of white colour. Then three measurements of the width were done by scale to find the average width of flattening. The indirect tensile strength (St) and tensile stiffness modulus (TSM) parameters were calculated according to equations described by Lottman [٦, ٧] and as illustrates below:

$$\mathbf{St = \frac{S١٠}{١٠٠٠٠} \times \frac{Pmax}{L}}$$

Where:

St = Tensile Strength (psi).

S١٠ = Maximum Tensile Strength (psi) produces in (٤-in) diameter solid cylinder

by a load (١٠٠٠٠ pound per thickness of ١ in.) obtained by calculating:

$$\mathbf{S١٠ = ١٥٩١ + ٤٣٧a - ١٨٨٩a^{٢} + ٢٨٥٤a^{٣} - ٢٤٧٤a^{٤} + ٨٨٥a^{٥}}$$

In which: a = amount of core or specimen flattening in inch under Pmax.

(٠ < a < ١ inch)

Pmax = Maximum Compressive Load on core specimen in Ib, and

L = Thickness of core specimen in inches.

While:

TSM = [Pmax * (v + ٠.٢٧٣٤) / L * △]

Where:

TSM = Tensile Stiffness Modulus in (psi).

Pmax = Load at failure in (Ib).

L = Sample thickness in inches.

△ = Total horizontal deformation of sample in inches.

v = Poison’s ratio assumed between (٠.٣٥-٠.٤٥) for asphaltic concrete mixtures.

Table (٥) illustrates the data of tensile strength, tensile stiffness modulus, and horizontal deformation, respectively.

DETERMINATION THE PERCENT OF SWELLING

Two groups of aged samples were submerged in the water, one of them at ٢٥°C for ٢-hrs and the other at ٢٥°C for ٢٤-hrs then; the percent swelling of HDPE/Asphalt concrete mixtures was calculated according to superpave [٤] using the following relationship:

%Swell = ١٠٠ * (E – E)/E

Where:

E = Volume of specimen in $cm^{٣}$ conditioning at ٢٥°C for ٢-hrs = (B – C)

B = SSD mass gm. After ٢-hrs of conditioning at ٢٥°C

C = Mass in water gm. After ٢-hrs of conditioning at ٢٥°C

E = Volume of specimen in $cm^{٣}$ conditioning at ٢٥°C for ٢٤-hrs = (B – C)

B = SSD mass gm. After ٢٤-hrs of conditioning at ٢٥°C

C = Mass in water gm. After ٢٤-hrs of conditioning at ٢٥°C

Fig (٢) and Table (٦) shows the data of swell percent of aged mixes modified with HDPE.

DISCUSSION OF TEST RESULTS

Indirect Tensile Strength:

The indirect tensile strength (St) and tensile stiffness modulus (TSM) of the aged HDPE modified mixes decreased with the addition of HDPE for the two periods of aging, this may be related to the transition of HDPE from "polymer" to "monomer" and to the de-bonding failure happened between (C – H) chain in HDPE and the asphalt component in asphalt cement binder. While the horizontal deformation (∆) increased with H addition of HDPE, except for the pyrolisis types specially at ٢%H, which makes the horizontal deformation to decreased by (-١٧%) & (-٥٠%) for ٢-days and ٤-days aging period respectively, and resulted in an increasing in tensile stiffness modulus by (٨٢%) for ٤-days aging period, this reduction in the horizontal deformation at (٢%) may be related to the increasing in evaporation of liquid gases (LPG) from pyrolisis polyethylene which resulted in changing the modified binder from "sol" to "gel" structure, therefore behave as "Newtonian flow".

Bulk Density:

Fig (١) shows that the bulk density of the aged HDPE modified mixes decreased with the addition of HDPE for the two aging period, this may be due to the reduction in specific gravity of the modified binder with HDPE.

Percent Swell:

From the sited results in Table (٦), it can be seen that the percent swell of the aged mixes modified with HDPE additive reduced rapidly, except for (٤% H pyrolisis HDPE) that the inverse is true, as shown in fig (٢), this may be related to the reduction in bulk density of modified mixes with HDPE.

It was fond that the percent of swell reached to (٠.٣٦٧ and ٠.١١٢) at (٢% H) of HDPE additive for ٢ and ٤-days aging period, respectively which is less than the maximum value of swell (١%) as recommended by SCRB [٨] specification for asphaltic concrete mixtures.

CONCLUSIONS AND RECOMMENDATIONS

The following tentative conclusions are based on ٢-days and ٤-days periods of aging asphalt concrete modified with HDPE additive:

١. Indirect tensile strength and tensile stiffness modulus decreased as a result of adding HDPE while the horizontal deformation tends to increase.

٢. The tensile stiffness modulus increased by (٨٢%), while the horizontal deformation decreased by (-٥٠%) for (٢% H) pyrolisis polyethylene at ٤-days aging period. These results indicated that these mixtures resist pavement deformation forces, rutting and shoving, therefore, it should be used at busy intersections or truck stops and parking lots where standing loads which cause extended periods of such deformation.

٣. The aging was performed above ٥-hrs and at ١٣٥˚C, therefore, it's called **"long term aging"** which simulate the aging of the asphalt binder through the pressure-aging vessel.

٤. The Results indicated that achieved of flexible pavement with high performance and more economize can be obtained with (٢% H) pyrolisis HDPE.

٥. The reduction in tensile stiffness modulus referred that using of HDPE as additive result to making asphalt concrete less susceptible to thermal cracking.

٦. The increasing in aging time was less susceptible on indirect tensile parameters of HDPE modified asphalt concrete mixtures.

Table (١) Physical Properties of Al-Kazer Aggrgate

Property	ASTM Designation No.	Coarse Agg.	Fine Agg.	ASTM Limits
% Water	D-١٣١	١٨.١	-	٤٠ max.
Bulk Specific Gravity	D-١٢٧	٢.٧٠٤	٢.٦٧٥	-
Apparent Specific Gravity	D-١٢٨	٢.٧٤٤	٢.٦٩٦	-
Apparent Specific Gravity Filler	D-١٢٨	-	٣.١٥	-

Table (٢a) Physical Properties of HDPE before and after Pyrolysis

	Before Pyrolysis Process	
Property	**Result**	**Unit**
Density	٠.٩٤	gm/cm^{٣}
Chemical Unit	CH	
Thermal Degradation Temp.	٤٠٧	^{o}C
Colour	Yellow	
	After Pyrolysis Process	
Density	٠.٨٦	gm/cm^{٣}
Melting Point	١٥٨ – ١٦٤	^{o}C
Decomposed	١٤١	^{o}C
Colour	Kaki	

Table (٢b) Physical Properties of Wire Mesh HDPE

Property	Result	Unit
Density	٠.٩٤	gm/cm^{٣}
Chemical Unit	-(-CH٢ – CH٢-)-	
Thermal Degradation Temp.	٤٠٧	^{o}C
Colour	White	
Grid Opening	١٢ x ٨	mm x mm

Table (٣) Aggregate Gradation

Sieve Size	%Passing	Job Mix Formula	Tolerance
½ inch	١٠٠	١٠٠	٦%
٣/٨ inch	٩٠ – ١٠٠	٩٥	٥%
No.٤	٥٥ – ٨٥	٧٠	٥%
No.٨	٣٢ – ٦٧	٤٩.٥	٤%
No.٥٠	٧ – ٢٣	١٥	٣%
No. ٢٠٠	٢ - ١٠	٦	١.٥%

Table (٤) Mix Proportion

	Mix Type					
Component %Wt	**Control**	**٢%H**	**٤%H**	**١M**	**٢M**	**٢%G**
Coarse agg.	٢٨.٥	٢٨.٥	٢٨.٥	٢٨.٥	٢٨.٥	٢٨.٥
Fine agg.	٦١	٦١	٦١	٦١	٦١	٦١
Filler	٥.٧	٥.٧	٥.٧	٥.٧	٥.٧	٥.٧
Asphalt	٤.٨	٤.٧	٤.٦	٤.٨	٤.٨	٤.٧
Additive	٠	٠.٠١	٠.٠٢	-	-	٠.٠١

Table (٥) Indirect Tensile Strength Test

	٢-Days			٤-Days		
Mix Type	St kg/cm٢	TSM kg/cm٢	∆ mm	St kg/cm٢	TSM kg/cm٢	∆mm
Control	٢٤.٨٧	١١٠٠٥	٠.٢٥٤	٢٣	٨٤٩٣	٠.٣٠٥
١M	١٨.٢	٥٩٩١	٠.٣٥٦	١٩	٦٦٨٥	٠.٣٠٥
٢M	١٨.٢	٥٠٣٣	٠.٤٠٤	١٨.٥	٦٣٠٧	٠.٣٣
٢%H	١٩.٧	١٠٨٩٩	٠.٢٠٤	٢٠.٩	١٥٤٢١	٠.١٥٣
٤%H	١٣.٨	٢٠٤٠	٠.٧٦٢	١٦.٦	٧٣٥٤	٠.٣٣
٢%G	١٧.٥	٣٥٨٩	٠.٥٥٩	١٧.٨	٧٧٣٨	٠.٢٥٤

Table (٦) Bulk Density and Swell Percent

	٢-Days		٤-days	
Mix Type	Bulk Density kg/cm٣	% Swell	Bulk Density kg/cm٣	% Swell
Control	٢٣٧٥	١.٥٠٦	٢٣٤٦	٠.٧٥١
١M	٢٣٤٣	٠.٧٨٤	٢٢٨٢	٠.١٨١
٢M	٢٣١٣	٠.٥٥٨	٢٢٨٢	٠.٣٦١
٢%H	٢٣٥٠	٠.٣٦٧	٢٣٢٢	٠.١١٢
٤%H	٢٢٩٤	١.١٢٤	٢٢٧٧	٠.٩٢١
٢%G	٢٣٣٥	٠.١٨٥	٢٣٠١	٠.١٠٢

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The Effects of Aging on the Physical Properties of Modified Asphaltic Concrete Mixtures with High Density Polyethylene

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