

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 135°C and at two period of time varying between two and four days. Marshall Specimens were compacted by a mechanical compactor at temperature of 138°C to 142°C.

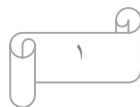
Six mix types of high-density polyethylene including the control at optimum asphalt content were used throughout the investigation. The asphaltic concrete was of dense-graded aggregate type for surface course confirming to gradation limits of ASTM highway commission specifications.

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.

INTRUCTION

The use of additives in road construction for both surfaces and base courses was initiated in 1981 under the Roads and Transportation Association of Canada (RTAC) research program⁽¹⁾. 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⁽²⁾ 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:

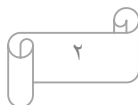
(Al-Khazer) aggregate was utilized in the preparation of asphaltic concrete specimens. Table (١) show the results of the physical properties of this aggregate. Portland cement from the (Senjar) cement factory was used as mineral filler. It had (٨٧ percent) passing No. ٢٠٠ sieve and a specific gravity of ٣.١٥ by ASTM^(٢) 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- $\epsilon 123$)⁽³⁾.
- Percent of swelling acc. To super pave SP- γ ⁽⁴⁾.
- Bulk density (ASTM D- $\gamma\gamma\gamma$)⁽³⁾.

SAMPLES PREPARATION AND TESTING

Composition and size of specimens:

The mix design conformed to ASTM specification D- $\gamma\gamma\gamma$ dense graded type with $\frac{3}{4}$ inch maximum size aggregate. Mix characteristics and proportions are summarized in Tables γ and ϵ . 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 ϵ inch in diameter and $\gamma.\gamma$ inch in high.

Specimen fabrication:

Two groups of samples are mixed at optimum asphalt content of $\gamma\%$ (by weight of total aggregate and filler) and at the appropriate mixing temperature of 150°C to 160°C for selected $\epsilon\gamma\gamma$ penetration graded binder and additive by hand for γ min. in a mixing bowl acc. to the asphalt institute method ⁽⁵⁾. The first group is then aged by placing the loose mix in a flat pan and into a forced draft oven at 130°C for γ -days, while the second group are aged at 130°C for ϵ -days according to super pave ⁽⁶⁾. The samples are then brought to compaction temperature range (130 - 140°C) by placing them in another oven for a short time (generally less than 30 minutes). A mechanical compactor of Marshall was used to consolidate the hot mix. The specimens were compacted in one layer with $\gamma\gamma$ blows for each face, which simulate a tire pressure of 200 psi. The specimens were then removed from the mold according to the method described in ASTM D- 1009 , and left them to cure in air for $\gamma\epsilon$ -hr. to subject them for laboratory tests.



INDIRECT TENSILE STRENGTH PROCEDURE

Before testing, the specimens were allowed to conditioned for 2-hr at the test temperature of 20°C according to ASTM D-1123⁽⁷⁾ using laboratory oven. Then the specimens were tested at constant rate of deformation of (3.8 mm/min) as recommended by Lottman^(7, 8) 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 (0.1 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^(7, 8) and as illustrates below:

$$St = \frac{S_{10} \times P_{max}}{10000 \times L}$$

Where:

St = Tensile Strength (psi).

S₁₀ = Maximum Tensile Strength (psi) produces in (1-in) diameter solid cylinder

by a load (10000 pound per thickness of 1 in.) obtained by calculating:

$$S_{10} = 1091 + 437a - 1889a^2 + 2804a^3 - 2474a^4 + 880a^5$$

In which: a = amount of core or specimen flattening in inch under P_{max}.

$$(0 < a < 1 \text{ inch})$$

P_{max} = Maximum Compressive Load on core specimen in lb, and

L = Thickness of core specimen in inches.

While:

$$\text{TSM} = [P_{\text{max}} * (\nu + 0.273 \epsilon) / L * \Delta]$$

Where:

TSM = Tensile Stiffness Modulus in (psi).

Pmax = Load at failure in (lb).

L = Sample thickness in inches.

Δ = Total horizontal deformation of sample in inches.

ν = Poison's ratio assumed between (0.30-0.40) for asphaltic concrete mixtures.

Table (6) 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 20°C for 2-hrs and the other at 20°C for 24-hrs then; the percent swelling of HDPE/Asphalt concrete mixtures was calculated according to superpave (4) using the following relationship:

$$\% \text{Swell} = 100 * (E - E) / E$$

Where:

E = Volume of specimen in cm³ conditioning at 20°C for 2-hrs = (B - C)

B = SSD mass gm. After 2-hrs of conditioning at 20°C

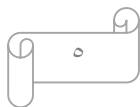
C = Mass in water gm. After 2-hrs of conditioning at 20°C

E = Volume of specimen in cm³ conditioning at 20°C for 24-hrs = (B - C)

B = SSD mass gm. After 24-hrs of conditioning at 20°C

C = Mass in water gm. After 24-hrs of conditioning at 20°C

Fig (7) and Table (7) 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 (Δ) increased with H addition of HDPE, except for the pyrolysis types specially at 2% H, which makes the horizontal deformation to decreased by (-17%) & (-20%) for 2-days and 4-days aging period respectively, and resulted in an increasing in tensile stiffness modulus by (82%) for 4-days aging period, this reduction in the horizontal deformation at (2%) may be related to the increasing in evaporation of liquid gases (LPG) from pyrolysis polyethylene which resulted in changing the modified binder from “sol” to “gel” structure, therefore behave as “Newtonian flow”.

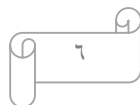
Bulk Density:

Fig (1) 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 (1), it can be seen that the percent swell of the aged mixes modified with HDPE additive reduced rapidly, except for (4% H pyrolysis HDPE) that the inverse is true, as shown in fig (2), this may be related to the reduction in bulk density of modified mixes with HDPE.

It was found that the percent of swell reached to (0.267 and 0.112) at (2% H) of HDPE additive for 2 and 4-days aging period, respectively which is less than the maximum value of swell (1%) as recommended by SCRB (A) specification for asphaltic concrete mixtures.



CONCLUSIONS AND RECOMMENDATIONS

The following tentative conclusions are based on 7-days and 14-days periods of aging asphalt concrete modified with HDPE additive:

1. Indirect tensile strength and tensile stiffness modulus decreased as a result of adding HDPE while the horizontal deformation tends to increase.
2. The tensile stiffness modulus increased by (12%), while the horizontal deformation decreased by (-0.5%) for (7% H) pyrolysis polyethylene at 14-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.
3. The aging was performed above 96-hrs and at 130°C, therefore, it's called "**long term aging**" which simulate the aging of the asphalt binder through the pressure-aging vessel.
4. The Results indicated that achieved of flexible pavement with high performance and more economize can be obtained with (7% H) pyrolysis HDPE.
5. The reduction in tensile stiffness modulus referred that using of HDPE as additive result to making asphalt concrete less susceptible to thermal cracking.
6. The increasing in aging time was less susceptible on indirect tensile parameters of HDPE modified asphalt concrete mixtures.

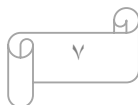


Table (1) Physical Properties of Al-Kazer Aggregate

Property	ASTM Designation No.	Coarse Agg.	Fine Agg.	ASTM Limits
% Water	D-121	18.1	-	ε· max.
Bulk Specific Gravity	D-127	2.704	2.770	-
Apparent Specific Gravity	D-128	2.744	2.796	-
Apparent Specific Gravity Filler	D-128	-	3.10	-

Table (2a) Physical Properties of HDPE before and after Pyrolysis

	Before Pyrolysis Process	
Property	Result	Unit
Density	0.94	gm/cm ³
Chemical Unit	CH	
Thermal Degradation Temp.	407	°C
Colour	Yellow	
	After Pyrolysis Process	
Density	0.86	gm/cm ³
Melting Point	108 – 164	°C
Decomposed	141	°C
Colour	Kaki	

Table (۲b) Physical Properties of Wire Mesh HDPE

Property	Result	Unit
Density	۰.۹۴	gm/cm ^۳
Chemical Unit	-(CH _۲ - CH _۲)-	
Thermal Degradation Temp.	۴۰۷	°C
Colour	White	
Grid Opening	۱۲ x ۸	mm x mm

Table (۳) Aggregate Gradation

Sieve Size	%Passing	Job Mix Formula	Tolerance
½ inch	۱۰۰	۱۰۰	۶%
۳/۸ inch	۹۰ - ۱۰۰	۹۰	۰%
No. ۴	۰۰ - ۸۰	۷۰	۰%
No. ۸	۳۲ - ۶۷	۴۹.۰	۴%
No. ۲۰	۷ - ۲۳	۱۰	۳%
No. ۴۰	۲ - ۱۰	۶	۱.۰%

Table (۴) Mix Proportion

Component %Wt	Mix Type					
	Control	۲%H	۴%H	۱M	۲M	۲%G
Coarse agg.	۲۸.۰	۲۸.۰	۲۸.۰	۲۸.۰	۲۸.۰	۲۸.۰
Fine agg.	۶۱	۶۱	۶۱	۶۱	۶۱	۶۱
Filler	۰.۷	۰.۷	۰.۷	۰.۷	۰.۷	۰.۷
Asphalt	۴.۸	۴.۷	۴.۶	۴.۸	۴.۸	۴.۷
Additive	۰	۰.۰۱	۰.۰۲	-	-	۰.۰۱

Table (٥) Indirect Tensile Strength Test

Mix Type	٢-Days			٤-Days		
	St kg/cm ^٢	TSM kg/cm ^٢	Δ mm	St kg/cm ^٢	TSM kg/cm ^٢	Δ mm
Control	٢٤.٨٧	١١.٠٠	٠.٢٥٤	٢٣	٨٤٩٣	٠.٣٠٥
١M	١٨.٢	٥٩٩١	٠.٣٥٦	١٩	٦٦٨٥	٠.٣٠٥
٢M	١٨.٢	٥.٣٣	٠.٤٠٤	١٨.٥	٦٣.٧	٠.٣٣
٢%H	١٩.٧	١.٨٩٩	٠.٢٠٤	٢٠.٩	١٥٤٢١	٠.١٥٣
٤%H	١٣.٨	٢.٤٠	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

Mix Type	٢-Days		٤-days	
	Bulk Density kg/cm ^٣	% Swell	Bulk Density kg/cm ^٣	% 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

REFERENCES

١. Ralph C.G. Haas, Elaine Thompson, Frank Neyer and G. Robert Tessier. (١٩٨٣) **“The Role of Additives in Asphalt Paving Technology”**. The Asphalt paving Technology (AAPT) Vol. ٥٢.
٢. Ayman A. Abdul-Mawjoud (٢٠٠٣) **“Effect of High Density Polyethylene on Performance of Hot – Mix Asphalt”**. Unpublished Research.
٣. ASTM Standard Specification (١٩٨٨) Section Vol. ٠٤ – ٠٣.
٤. Superior Performing Pavements (٢٠٠٢), **“Mix Design Series No.٢”** (SP-٢).
٥. Asphalt Institute (١٩٨٤), **“Mix Design Method for Asphalt Concrete and other Hot – Mix Types”** (MS-٢).
٦. Lottman R. and Dennis L. G. (١٩٧٠). **“Pressure – Induced Stripping in Asphalt Concrete”** TRB. ٣٤٠, pp. ١٣ – ٢٥.
٧. Lottman R. (١٩٧٨). **“Predicting Moisture – Induced Damage to Asphaltic Concrete”** NCHRP, Report No. ١٩٢ – TRB.
٨. State Cooperation of Road and Bridges (١٩٩٩) **“Hot Mix Asphaltic Concrete Pavements”** Iraqi Standard Specifications, Ministry of Housing and Construction. Department of Design and Study, Section R٩.

*The Effects of Aging on
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٢٩/٠٣/٢٠١٢

