WORLD CUP 2010 TRAFFIC SIMULATION LONG-TERM AGING OF POLYPROPYLENE ASPHALT PAVING MIXTURES

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ABSTRACT

This study investigated the influence of accelerated weathering (aging) on the engineering properties of modified asphalt mixtures with pyrolysis polypropylene (PP). The accelerated weathering was done at a temperature of 85 °C and over two periods of time, namely between two and four days. Marshall specimens were compacted with a mechanical compactor at a temperature of 135 to 142 °C. Five pyrolysis polypropylene mixtures, including the control, which had an optimum asphalt content, were investigated. The asphalt concrete was of a dense-graded aggregate type of surface course conforming to the gradation limits of ASTM highway commission specifications. The results showed that variations in age change the physical properties of modified mixtures.

KEYWORDS: Aging, polypropylene, asphalt, indirect tensile strength, modifiers.

1. INTRODUCTION

Polymers have been used for a number of years for the modification of asphalt concrete mixtures because most of them have implications for performance and economy. Certain polymers may help to a certain extent to minimise asphalt pavement problems, such as permanent deformation, flushing, thermal cracking, etc. Pyrolysis polypropylene has been used as an additive to improve the performance of asphalt concrete mixtures. This type of polymer satisfactorily improves the Marshall properties and the results of the indirect tensile strength test (Al-Hadidy, 2006).

In this study we investigated the influence of accelerated weathering on the characteristics of pyrolysis polypropylene/asphalt paving mixture, because pavement age is an important factor for two reasons: the first is that the hardening effect increases the stiffness of the asphalt with age, and the second is that the probability of obtaining a low critical temperature increases with time (Ralph et al., 1983).

The additives studied were chemically modified experimental pyrolysis polypropylene (PP) proprietary materials. The polymer concentrations were 1% up to 4%.

2. PURPOSE AND SCOPE OF THE INVESTIGATION

The purpose of this investigation was:

- To study the effects of different aging times on the physical properties of modified asphalt concrete mixtures with PP additives measured by the Marshall, indirect tensile strength and compressive strength tests.
- To determine the percentage of additive that affects the results obtained.
- To produce a dense graded mixture which can be utilised for military airfield pavements.

3. SELECTION OF MATERIALS

3.1 Aggregates

Al-Khazer aggregates were used in the preparation of the asphalt concrete specimens. Table 1 shows the result of the physical properties of the aggregates. Portland cement was used as a mineral filler. It was passed through a 200 µm sieve and had a specific gravity of 3.15 according to ASTM designation D854 (ASTM, 1988).

Table 1. Results of the physical properties of aggregates

Property	ASTM Designation No.	Coarse aggregate	Fine aggregate	ASTM limits
L.A. abrasion	D-131	17.76	-	40 max.
Bulk SG	D-127	2.634	2.561	-
Apparent SG	D-128	2.669	2.584	-
Apparent SG (filler)	D-128	-	3.15	-
% water absorption	-	0.503	2.354	4.0 max.

3.2 Asphalt cement

The asphalt cement was a 40-50 penetration grade as produced by the Baiji refinery. At 25 °C it has a specific gravity of 1.053 and a ductility of 100+ cm.

3.3 Polypropylene

Pyrolysis polypropylene (PP) was used in the testing programme. It has a density of 0.6 gm/cm^3 and a melting point of 156 - 161 °C.

4. LABORATORY TESTING

A series of tests were carried out on aged PP/asphalt mixtures for different percentages of PP as an additive. The following tests were used:

- Marshall test (ASTM D-1559) (ASTM, 1988)
- Indirect tensile strength test (ASTM D-4123) (ASTM, 1988)
- Compressive strength test (ASTM D-1074) (ASTM, 1988).

4.1 Indirect tensile strength procedure

Before testing, the specimens were allowed to condition for 2 h at the test temperature of 25 °C according to ASTM D-4123 (ASTM, 1988) using the laboratory oven. The specimens were then tested at a constant rate of deformation of 3.8 mm/min as recommended by Lottman and Dennis (1970) and Lottman (1978) using a universal testing machine which provides a record of load and deformation.

4.2 Compressive strength procedure

At 25 °C, the specimens were taken out of the curing oven for 2 h according to ASTM D-1074 (ASTM, 1988) and tested in an axial compression machine at a uniform rate of vertical deformation at 0.05 mm/min of height or 3.2 mm/min for Marshall specimens.

5. SPECIMEN PREPARATION

The optimum asphalt content chosen was 4.8% to achieve 4% air voids using the aggregate gradation given in Figure 1 with 40-50 penetration grade Baiji asphalt cement. Two groups of samples were then mixed for 2 minutes in a mechanical mixer at this asphalt ratio at the appropriate mixing temperature of 150 to 160 °C for the selected additive (Asphalt Institute, 1984). The first group was then aged by placing the loose mix in a flat pan in a forced draft oven at 85 °C for two days. The second group was aged at 85 °C for four days (Asphalt Institute, 2002: Superior Performing Asphalt Pavement).

The samples were then brought to a compaction temperature of 135 to 142 °C by placing them in another oven for about 30 minutes. A Marshall mechanical compactor was used to consolidate the hot mixtures. The specimens were compacted for heavy duty use of 75 Marshall blows to each face at a tire pressure of 1 379 KPa. The specimens were then removed from the mould (ASTM, 1988) and left to cure in air for 24 hours.

Nine samples of each percentage of PP that had been aged at 85 °C for two and four days were tested. Three samples were subjected to the Marshall stability test at 60 °C for 35 minutes, three underwent an indirect tensile strength test at 25 °C, and three samples were tested for compressive strength at 25 °C. From these, the tensile stiffness modulus, tensile strain and elasticity modulus were determined.

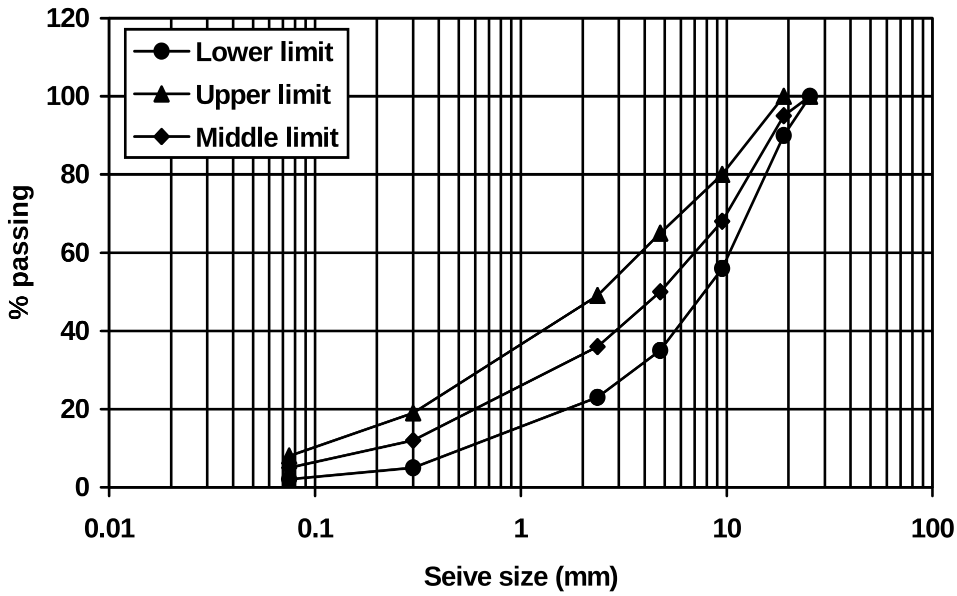

Figure 1. Aggregate gradation

6. DETERMINATION OF TENSILE AND COMPRESSIVE STRENGTH

The compressive load at failure and the horizontal deformation of compacted specimens were recorded. The load was decreased to zero and the specimen was then removed. Side flattening was measured to the nearest 1 mm by painting the top and bottom of the flattened side with a yellow marker. Three measurements of the width were made to find the average flattening width. The indirect tensile strength (St) and the tensile stiffness modulus (TSM) parameters were calculated according to equations described by Lottman (1970, 1978):

The modulus of elasticity (Ec) at 25 °C was determined using the equation:

$$Ec = 483 \times Ms \ (lb/in^2) \qquad (1)$$

where

Ms = Marshall stability in kg at 60 °C.

The tensile strain ($\in_t$) was calculated from equation (2):

$$\in_t = \frac{\sigma_t}{Ec} \qquad (2)$$

where

σ_t = maximum tensile strength (stress)

The compressive strength for each percentage of aged PP/asphalt concrete mixture was determined by dividing the recorded compressive load at failure by the area of the specimen. Figures 2, 3 and 4 show the results of these variables.

7. RESULTS AND DISCUSSION

7.1 Marshall test

Figure 2 gives the Marshall test data for aged PP/A mixtures. In this case, all PP percentages significantly affect the Marshall stability and air voids values. It can be seen from this figure that the maximum stability value was reached at 3% PP for both aging periods, while the air voids were reduced. The increase in stability values may be attributed to the increased interlocking offered by the PP additive. The reduction in the air voids value may be related to the reduction in the asphaltene percentage, which causes a reduction in the bulk density of the modified mixtures with the PP additive.

From the results in Figure 2, it was found that the stability value increased by 70% and 86% at 3% PP content for 2-day and 4-day aging periods respectively.

7.2 Indirect tensile strength

Tensile strength data for aged PP/A concrete mixture are given in Figure 3. The results indicate that tensile strength, tensile stiffness modulus, tensile strain and elasticity modulus were increased with the addition of PP for two aging periods. This may be due to the transition of PP from “polymer” to “monomer” and to the bonding that occurs between the C-H chain in PP and the asphaltene component in asphalt cement binder. In addition to these reasons, the increase in the tensile stiffness modulus and the elasticity modulus may be attributed to the increase in evaporation of liquid propane gases (LPG) from pyrolysis polypropylene which resulted in a change in the modified binder from a “sol” to a “gel” structure, which therefore behaves as a “Newtonian flow”.

However, for 3% PP content, the indirect tensile strength increases by 3 and 4 times for 2-day and 4-day aging periods respectively, whereas the elasticity modulus increases by 69% and 86% for 2-day and 4-day aging periods respectively.

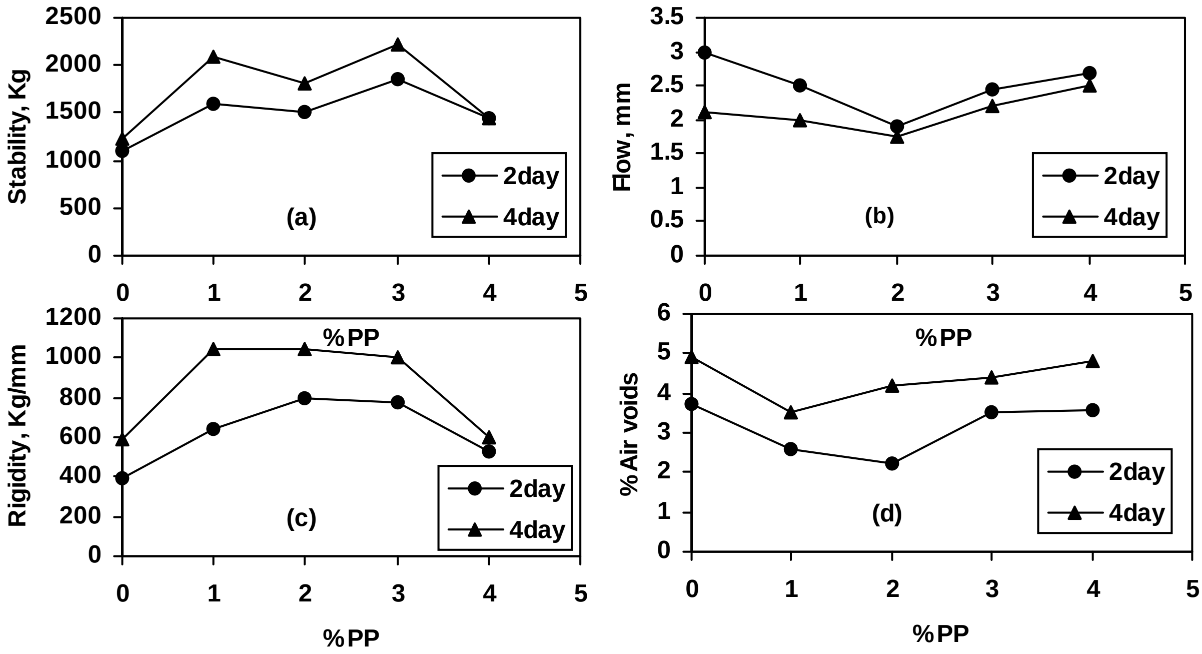

Figure 2. Effect of aging on Marshall properties

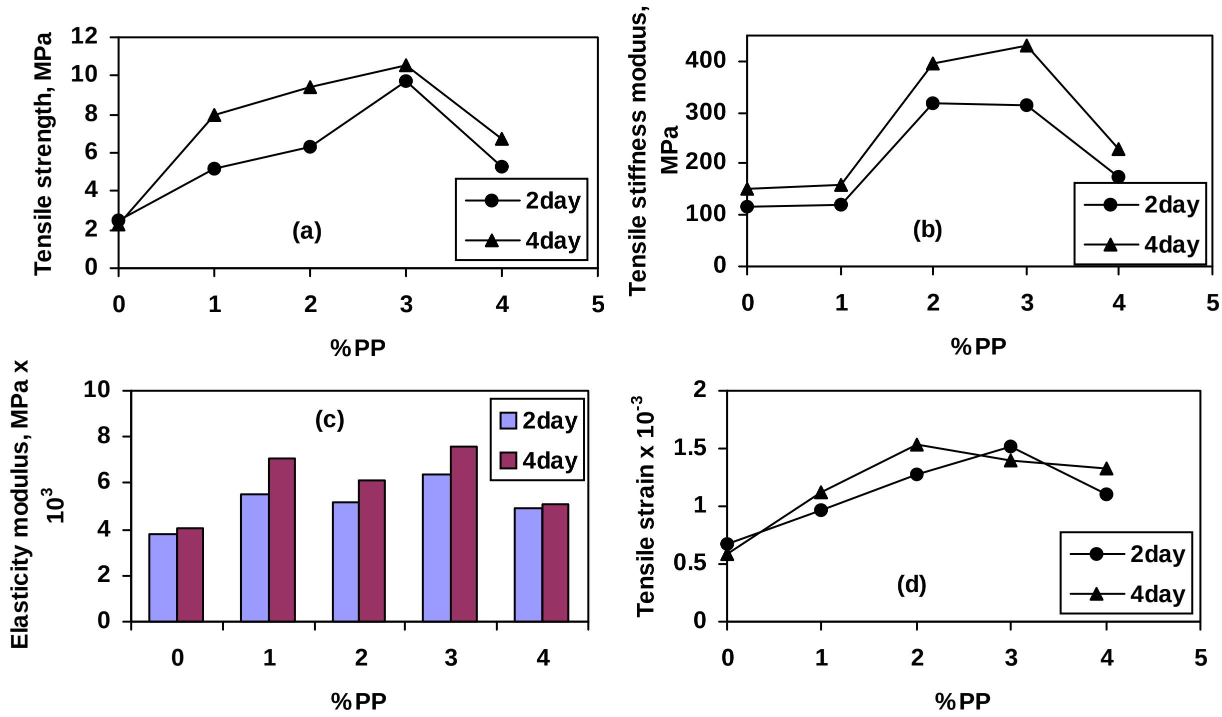

Figure 3. Effect of aging on tensile strength properties

7.3 Compressive strength

From the results in Figure 4 it can be seen that the compressive strength of an aged mixture modified with PP additive increased rapidly with a increase of PP content, while the horizontal deformation due to axial load decreased. This may be related to a reduction in air voids content of the modified mixtures.

It was found that the compressive strength was increased by two times at 3% PP additive for both aging periods, while the horizontal deformation at this percentage of PP was decreased by 76% and 62% for 2-day and 4-day aging periods respectively. The drop in compressive strength at 4% PP for the 4-day period is related to the breaking of the bonds between PP and asphalt with the increase of aging time.

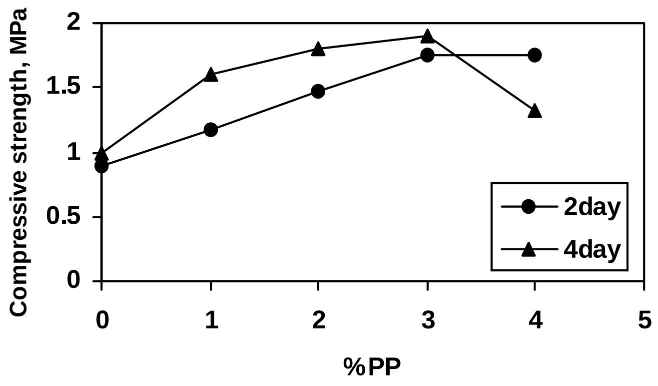

Figure 4. Effect of aging on compressive strength

8. CONCLUSIONS

The following conclusions are based on the testing and analysis:

- The Marshall stability and rigidity ratio increases with an increase in aging time, while the Marshall flow decreases.
- The tensile strengths of the mixtures varied from 2.49 MPa to 9.6 MPa and from 2.3 MPa to 10.6 MPa at 3% PP content for 2-day and 4-day aging periods respectively.
- The tensile stiffness modulus, the elasticity modulus and the compressive strength increase for both aging periods. These results indicate that these mixtures resist heavy loads and could therefore be used in military airfield pavements where a stiff asphalt mixture and low asphalt content are required.
- The addition of pyrolysis polypropylene to asphalt concrete mixtures improves resistance to permanent deformation, fatigue, cracking and aging.
- The aging was carried out for more than 5 h at 85 °C, in a procedure known as “long term aging”, which simulates the aging of the asphalt binder, by means of a pressure aging vessel (PAV).
- Increasing aging time significantly affects the test performed on PP-modified asphalt concrete mixtures.
- A flexible pavement with high performance and durability and which is more economical can be obtained with 3% pyrolysis polypropylene.

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