

PRELIMINARY RESULTS OF THE ACCELERATED AGEING OF MODIFIED AND UNMODIFIED BITUMINOUS BINDERS USING THE PRESSURE AGEING VESSEL

W. G. Ford

Transport Research Laboratory, United Kingdom

H. R. Smith

Transport Research Laboratory, United Kingdom

R. C. Asis

Bureau of Research and Standards, DPWH, Philippines

A. S. Idabaga

Ministry of Works, Tanzania

B. St. Cyr

Ministry of Communications, Works and Transport, St. Lucia

W.G. Ford is a Highway Engineering Researcher in the International Division of TRL. He is the Principal Researcher in a project that is investigating the effect of different polymers in increasing the durability of both asphaltic concrete surfacings and surface dressings. He has considerable experience in the design and construction of surface dressings and has supervised the construction of two major road trials in Malaysia

H.R. Smith MPhil (Eng) FIHT is a Project Manager in the International Division of TRL with specific responsibilities for the development of specifications for bituminous road surfacings for countries with tropical and sub-tropical climates. He has over 30 years of experience in road pavement research in developing countries and has played a pivotal role in research programmes that have established the fundamental causes of failure of bituminous materials in severe climates. He was awarded a MPhil by the University of Birmingham for a thesis based on his research.

R.C. Asis is the Director of the Bureau of Research and Standards of the Department of Public Works and Highways in the Philippines. The Bureau was formed in 1987 to ensure the safety of all infrastructure facilities and secure the highest efficiency and the most appropriate quality in construction by continuously developing its technology. Director Asis leads the Bureau in its dual role of introducing new technologies and implementing them to the required standards.

A.S. Idabaga B. Eng. is an Executive Engineer working for the Central Materials Laboratory of the Ministry of Works, Tanzania. His responsibilities include the supervision of quality control, investigation and research for road construction materials and also geotechnical investigation for infrastructure and road construction materials.

B.St. Cyr has worked on road construction projects in St Lucia and has had experience in the testing and assessment of a wide range of road building materials including soils, asphaltic concrete and bitumen. He is currently in charge of the Materials Testing Laboratory in St Lucia and is responsible for ensuring the quality of testing for on-going construction projects.

ABSTRACT

The Transport Research Laboratory in collaboration with road authorities in a number of developing countries is currently developing recommendations for the use of bitumen modifiers in both hot mixed asphalt (HMA) and surface dressings. This project forms part of an extensive programme of research, funded by the Department for International Development (DFID), which has the final objective of producing a guide to design and construction of bituminous surfacings in tropical climates. A specific aim, is to identify modified and unmodified bitumens which may have improved resistance to environmentally induced degradation.

The effect of natural weathering on a range of modified and unmodified bitumens has been assessed in trials constructed in four tropical countries. The change in viscosity of bitumens used in these trials has been monitored over a two year period, to establish rates of hardening.

Ever increasing numbers of bitumen modifiers are being introduced and it would be advantageous to have an accelerated laboratory technique for testing the effect of ageing on new products without the need for laborious field-testing. To do this a Pressure Ageing Vessel (PAV), as used during the Strategic Highway Research Programme (SHRP, 1996), has been used to simulate long-term weathering using the standard and two extended ageing procedures. Early results indicate that, under controlled laboratory conditions, the PAV can be used to estimate the rate of ageing of bitumens used for surface dressing.

1. Introduction

The objective of this DFID funded project is to develop recommendations for the selection of bitumen modifiers which inhibit premature age-hardening and cracking in surface dressings and 'top-down' cracking in HMA. This latter type of cracking is very common in countries with tropical or temperate climates (Rolt et al., 1986), (TRL, 1993) and leads to a need for early and unplanned maintenance. The need for such maintenance imposes severe financial difficulties for many developing countries and failure to implement such work often results in premature failure of the road itself and consequent increases in road user costs. It is very important that optimum durability is obtained for all bituminous surfacings if maintenance and user costs are to be reduced. This paper describes the early results obtained from trials to test the durability of surface dressing bitumens.

Seven bitumens have been tested to determine their penetration and viscosity characteristics both before and after natural and artificial weathering. This has enabled a laboratory testing procedure to be developed which simulates the rate of hardening of bitumens in a road surface.

2. Field Trials

A number of surface dressings have been subject to natural weathering, with no trafficking, at exposure sites constructed in three countries.

Two exposure sites were installed in Tanzania and one each in the Philippines and St. Lucia. Each bitumen sample was prepared by spreading a film of the binder on a tile at spread rates which are typical of normal surface dressings (TRL, 1982). Five imported

bitumens were used at each of the four trial sites in addition to a locally available penetration grade bitumen. Each trial comprised an equal numbers of tiles of the test bitumens which were either left uncovered or covered by a single layer of chippings which had been obtained in the UK or locally. Details of the trials are given in Table 1.

Table 1. Surface Dressing Trial Locations and Bitumens Used

Sample	Type	Dar es Salaam	Dodoma	Philippines	St. Lucia
Tanzania 80/100 penetration grade	Unmodified	✓	✓		
Philippines 85/100 penetration grade	Unmodified			✓	
St. Lucia 60/70 penetration grade	Unmodified				✓
UK 100 penetration grade	Unmodified	✓	✓	✓	✓
Hydrated lime-bitumen	Modified laboratory blended	✓	✓	✓	✓
Thermoplastic rubber modified bitumen.	Modified, proprietary, laboratory blended	✓	✓	✓	✓
Natural latex rubber modified bitumen	Modified, proprietary, laboratory blended	✓	✓	✓	✓
Polymer modified cut-back	Modified, proprietary	✓	✓	✓	✓

The unmodified bitumens consisted of nominal 100 penetration grade bitumens obtained in the United Kingdom, The Philippines and Tanzania. In St. Lucia only a 60/70 penetration grade bitumen was available. The modified bitumens comprised proprietary binders supplied by a manufacturer or were blended in the laboratory with 100 penetration grade bitumen obtained in the UK.

Samples have been tested after intervals of natural weathering and the changes in penetration and viscosity determined after 6, 12 and 20 months exposure.

3. Laboratory Ageing

Artificial weathering was achieved in the laboratory by using a PAV and Rolling Thin Film Oven (RTFO) in accordance with SHRP procedures (SHRP, 1996).

Each test bitumen was pre-aged in the RTFO by placing 35 grams of binder in each glass vessel and ageing the material for 85 minutes at a temperature of 163°C. The bitumen was then recombined and mixed before being subjected to ageing in the PAV. Pre-conditioning in this manner removed virtually all solvent from the polymer modified cut-back bitumen.

The bitumens were then placed in the PAV for 20 hours at 105°C at a maintained pressure of 2.1 Mpa. In addition, two further extended tests of 40 and 100 hours were carried out.

4. Determination of Bitumen Characteristics

Unaged and aged field and laboratory test samples were subjected to standard tests to determine the rate of change in the properties of the bitumens.

Measurements of penetration were made at 25°C and 35°C and the viscosity was measured at 105°C, 135°C and 160°C in a Brookfield Viscometer. The Penetration readings at the two temperatures enabled the calculation of Penetration Index (PI). Normally the Softening Point (SP) is assumed to be the temperature, under standard test conditions, at which the penetration of a bitumen is 800. However, this relationship may not be reliable either for modified bitumens or after ageing has taken place. The equivalent SP and PI have, therefore, been determined from measurements of penetration at two temperatures.

4.1 Penetration Ageing Index

To compare the relative performance of the various bitumens, the Penetration Ageing Index (PAI_{25}) was calculated. It is defined as the ratio of the penetration after ageing, measured at 25°C, and the penetration before ageing.

Figure 1 shows the effect of increased time in the PAV on the PAI_{25} of the test bitumens. It is immediately apparent that the polymer modified cut-back bitumen has aged the least and indeed is statistically significantly better than the other six bitumens. However, all modified bitumens aged at a somewhat slower rate than the unmodified penetration grades. The thermoplastic rubber and natural rubber latex modified bitumens recorded similar ageing properties. The hydrated lime modified bitumen, was initially effective but, after 100 hours PAV ageing, finally deteriorated to the same degree as the penetration grade bitumens. The Tanzanian penetration grade bitumen aged at twice the rate of the modified cut-back and the other two penetration grade bitumens aged at a similar rate.

Figure 2 shows the rate of natural ageing of the bitumens, covered with UK chippings, at the exposure site in The Philippines. PAI_{25} data plotted against exposure time, gave similar forms of curves to those produced in the laboratory for PAV aged samples.

A comparison of Figures 1 and 2 shows, therefore that it is possible to predict the PAV treatment time required to reach any particular stage of ageing in terms of PAI_{25} , from the trendline of each bitumen or group of bitumens. Penetration grade bitumens age to an index of 0.25, (25 per cent of their original penetration) after approximately 34 hours of PAV ageing. Bitumens modified by either synthetic or natural rubber would need 53 hours and Hydrated lime modified bitumen, 44 hours of PAV ageing to reach the same PAI_{25} . The corresponding time required for polymer modified cut-back used in the study would be 73 hours.

A comparison between the rates of hardening under laboratory and field ageing conditions to reach a fixed value of PAI_{25} is shown in Table 2.

Table 2. Comparison of Laboratory and Field Trial Results

Exposure Site (Samples covered by UK chippings)	Period* to reach PAI ₂₅ of 0.25			
	Penetration Grade Bitumens		Polymer Modified Cut-back	
	PAV (hrs)	Field Trial (months)	PAV (hrs)	Field Trial (months)
Dar es Salaam	34	13	73	50
Dodoma		18		56
The Philippines		14		39
St. Lucia		19		28

* Derived and extrapolated from trendline equations.

Analysis of PAI₂₅ results after 20 months natural weathering at the exposure sites showed that:

- The bitumens not covered with chippings aged approximately three times faster than the same bitumens covered with aggregate. The slower rate of ageing is the result of the chippings 'protecting' the bitumen from 'weathering' effects including oxidation, evaporation of volatile oils and ultra violet radiation.
- There was no significant difference in the rate of hardening between those bitumens covered with either UK or local chippings at any of the sites.
- The polymer modified cut-back bitumen covered with either UK or local chippings, aged at a significantly slower rate than the other binders at all sites. All other binders hardened at approximately similar rates.

4.2 Softening Point

The changes in the calculated softening point, after 20 months weathering, showed that for any given bitumen;

- Samples without aggregate cover exhibited significant differences in softening point between the three countries. However, there was no significant difference between uncovered samples recovered from the two sites in Tanzania.
- Samples having UK or local chipping cover exhibited no significant difference in the change in softening point regardless of location.

5. Conclusions

This study has demonstrated a laboratory test method for estimating the resistance of surface dressing bitumens to the hardening effect of natural weathering in a road. While conditions in the laboratory are closely controlled, many variables will effect the ageing properties of bitumens in road surfacings. However, the indications are that under PAV artificial ageing most conventional penetration grade bitumens age at a faster rate than modified bitumens in a given environment. The modified cut-back bitumen however

showed a significantly higher resistance to weathering effects, both in the laboratory tests and in the field trials.

Analysis of each of the indices used to measure ageing effects has confirmed the important protective effect of closely spaced and good quality surface dressing chippings. Their effect in reducing the rate of ageing has been clearly demonstrated.

Although the majority of modified bitumens did not show a high resistance to weathering it must be remembered that they have important advantages over conventional penetration grade binders. For example, those incorporating some form of rubber allow the use of higher application rates, because they are less susceptible to bleeding, are more flexible and give strong early adhesion with the chippings.

The identification of only one bitumen amongst those tested, which shows a significantly greater resistance to ageing is rather disappointing but reflects how difficult is the underlying problem. However, it is encouraging that predictive modelling of bitumen performance in the field may be carried out under controlled laboratory conditions and that the PAV may be used in the future to develop bitumens with improved resistance to ageing.

6. Future Work

Recently the test bitumens have been incorporated into small-scale surface dressing trials on heavily trafficked roads. Early results show that ageing trends are similar to those found in the study described above. The changes in the hardness of the binders will continue to be monitored together with assessments of the physical performance of the binders under traffic.

7. Acknowledgements

The work described in this report was carried out under a cooperative research programme between the Ministry of Works, Tanzania; Department of Public Works and Highways, The Philippines; Ministry of Communications, Works and Transport, St. Lucia and The Transport Research Laboratory (TRL) of the United Kingdom.

The work described forms part of a programme of research, funded by the Department for International Development (DFID), carried out by the Infrastructure and Transportation Department, of TRL's International Division (Department Head T. Toole). Any views expressed are not necessarily those of DFID; Ministry of Works, Tanzania; Department of Public Works and Highways, The Philippines; Ministry of Communications, Works and Transport, St. Lucia. The paper is published by permission of the Chief Executive of the TRL.

8. References

Rolt, J.R., Smith, H.R., Jones, C.R. 1986. The design and performance of bituminous overlays in tropical environments. Proc. 2nd Int. Conf. On Bearing Capacity of Roads and Airfields. Plymouth, United Kingdom.

Strategic Highway Research Program (1996). Performance graded asphalt binder specification and testing. Asphalt Institute Superpave Series No. 1 (SP-1), (1996).

TRL, 1982. Overseas Road Note 3, A guide to surface dressing in tropical and sub-tropical countries. Department of the Environment, Department of Transport, Overseas Development Administration, Crowthorne, 1982. Transport and Road Research Laboratory Overseas Unit.

TRL, 1993. Overseas Road Note 31. A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical countries. , Department of Transport, Overseas Development Administration, Crowthorne, 1993. Transport and Road Research Laboratory Overseas Unit.

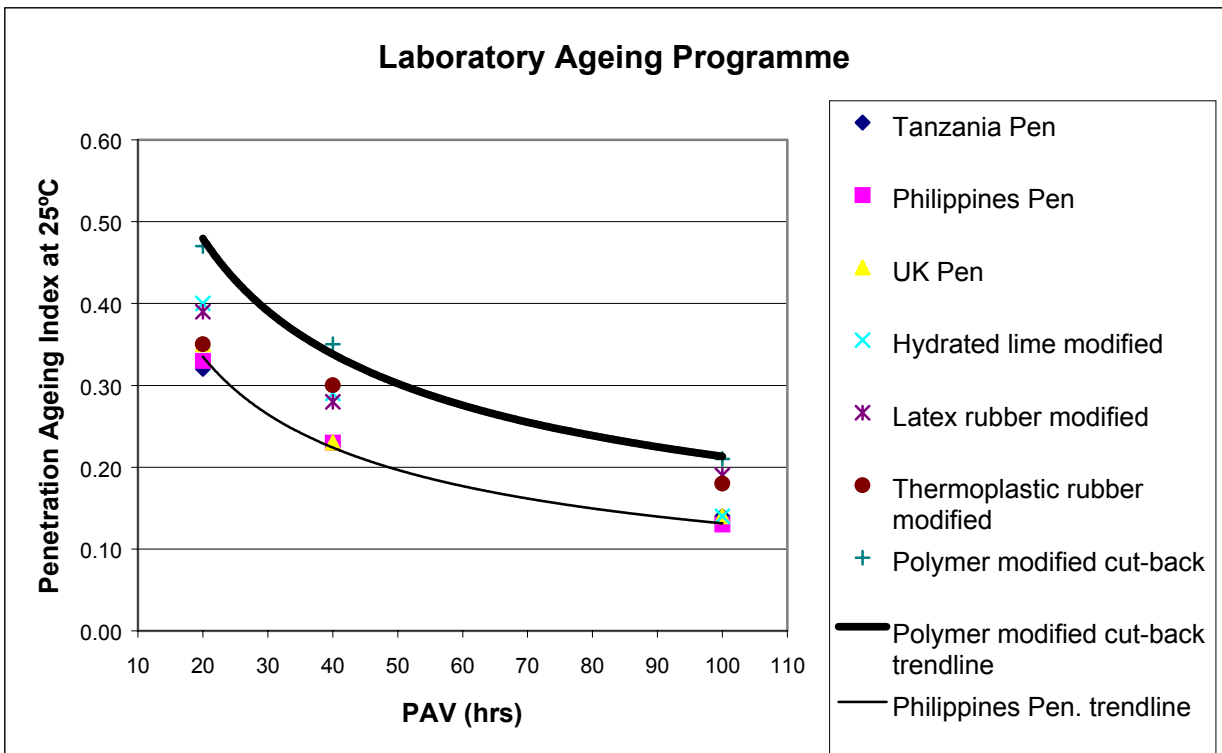


Figure 1: Laboratory Ageing

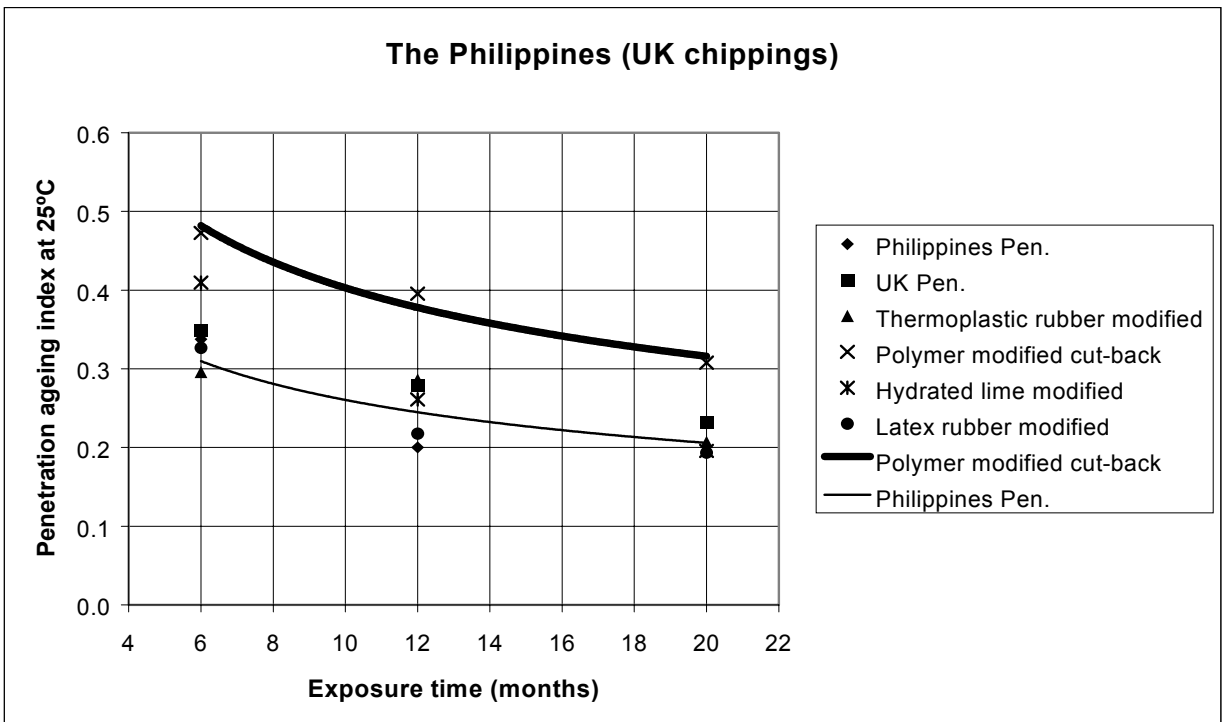


Figure 2: Field Study Ageing