PAINT MARKING DURABILITY

Project Number ST-2019-5

Summary Report

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Sponsored by
The State of Alabama Highway Department

March 1988

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ABSTRACT

Two laboratory tests were developed to evaluate properties of pavement marking paints that could be used to predict durability of the stripes in the field. Tensile tests of free film specimens of paint yielded several properties derived from the stress-strain curves. Abrasion tests provided results for paint specimens tested both dry and submerged in distilled water. The tests produced consistent results and repeatability.

Ten paint samples representing five different vehicles were evaluated using the laboratory tests developed. The paints were quite different as reflected in the tensile properties. The water base paints were considerably more ductile than the solvent base and alkyd resin paints. The load rate used for the test had significant effect on the results due to increased viscous creep introduced at slower load rates. The effect of temperature and humidity during the curing of the paints is also reported.

The ten paint samples tested in the laboratory were applied to two asphalt surfaces of different ages in the form of transverse stripes. None of the stripes showed significant abrasion wear during the 42 weeks that they were monitored. There was a definite correlation between the tensile properties recorded in the laboratory and observed cracking in the stripes. The paints that were the most brittle and stiff all developed transverse cracks at approximately 8 weeks and continued to worsen over the observation period. These same paints also caused the asphalt surface to crack around the periphery of the stripes. Two of the water base paints that were the most ductile underwent a premature chipping failure due to a lack of adhesion to the asphalt surface. The paints that exhibited average ductility in the laboratory have performed the best to date.

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1 INTRODUCTION

1.1 Statement of Problem

Highway pavement markings are subjected to traffic and environmental forces that combine to wear them away and therefore require a continuous remarking effort. Pavement markings that become unacceptable due to deterioration are safety and operational hazards. Any improvements in durability, or evaluating durability, to increase the life of pavement markings will reduce maintenance costs.

Field tests have been utilized in the past to evaluate durability, reflectivity, and other characteristics of pavement marking materials. However, the rapid introduction of new materials are not conducive to lengthy and less controllable field evaluations.

A laboratory testing procedure that predicts durability in the field will be useful to highway officials in selecting pavement marking materials. The tests can also be used in quality control procedures to ensure that the delivered and applied product will provide expected performance.

1.2 Objectives

The overall objective of this research effort was to improve the durability and cost-effectiveness of highway pavement markings. Specific objectives of the research presented herein were:

- Review current and past efforts to develop laboratory tests to predict field service of pavement markings.
- Develop a laboratory test to be used to evaluate relative durability of highway pavement marking materials.

- Demonstrate and evaluate the procedure identified above by testing a spectrum of materials including currently used materials by the Alabama Highway Department.
- Provide guidelines to help in acceptance testing of new products and for quality control testing.

1.3 Scope

A laboratory test program was developed and carried out on ten different traffic paint samples. Paint from the same sample batches was applied to a road surface in the form of transverse stripes and observed over a 42 week period.

This project was concerned only with durability and did not consider reflectivity or bead retention of the paint stripes. In fact, only two of the paints contained beads which were premixed into the paint. Tests were conducted that relate to chipping and abrasion failures, but not to general loss of adhesion.

The following considerations were given to the five factors that affect paint performance:

- paint formulation - five different paint vehicles were represented in the samples (water base, modified alkyd-chlorinated rubber, alkyd resin, solvent base, and modified alkyd resin).
- substrate - no laboratory tests were conducted to evaluate the effect of substrate, but for the field tests, two different asphalt surfaces were used (1 year old surface and 3 year old surface).

- surface preparation - the paints in the field were applied to the surfaces with no preparation.

- humidity and temperature - for the tensile tests, the samples were cured for 48 hours at four different humidity and temperature conditions (room conditions, 50% humidity and 50° F, 50% humidity and 90° F, 90% humidity and 90° F) and for the abrasion tests, the samples were tested dry and submerged in distilled water.

- traffic volume - the site selected for the field tests was on U.S. Highway 29 (South College St.) in Auburn, Alabama. This site was selected because there were contiguous asphalt surfaces of different ages. The traffic volume over all four lanes is approximately 12,500 ADT at the test site.

- striping equipment - unfortunately, a walk-behind striping unit had to be used due to the difficulty in using a truck-mounted heated paint striper for the small quantities of paint obtained for the test stripes.

2 LABORATORY TESTS

Two testing methods were selected based on (1) the findings and recommendations of the literature review, (2) types of failure modes expected of paint, and (3) tests most likely to predict susceptibility to these different failures. Tensile tests of free film samples were used to quantify susceptibility to chipping and abrasion tests were used to quantify susceptibility to normal wear. It was also felt that these tests would be relatively simple and fast.

Free film tensile tests involve applying the paint to a backing material from which the paint can be separated after drying. Cut into the shape of a normal tensile coupon (bone shape), the sample can then be tested while load-deformation data is recorded for later evaluation of several tensile properties.

Abrasion tests performed on paints are typically either a test using an abrading rotating wheel, or a falling sand test where sand free falls onto a painted surface. A Taber Abraser, of the former variety, was selected due to its wide use in other highway departments and studies. ASTM Standard D-4060-81 and Federal Test Method Standard No. 141a provide testing procedures for using the Taber Abraser.

A list of various paint manufacturers that respond to solicitations for bids for maintenance striping paint was furnished by the AHD. The list contained 16 paint companies, 8 of which were contacted with regard to furnishing samples for this study. Three companies consented to sending a total of 5 different paints for the study. The paints received were as follows:

- water base (white) [WB-1-W]
- modified alkyd-chlorinated rubber (white) [CR-1-W]
- modified alkyd-chlorinated rubber (yellow) [CR-2-Y]
- alkyd resin (yellow) [AR-1-Y]
- modified alkyd resin (white) [MAR-1-W]

In addition, for an extreme data point, a sample of white latex (water base) house paint [HP-1-W] was purchased and tested. This provided a total of ten different paints utilizing five different vehicles.

3 RESULTS

3.1 Tensile Tests

The load rate tests performed on a typical water base paint demonstrated the visco-elastic nature of the material. Figures 3.1 and 3.2 clearly show the dramatic effect that the load rate has on this type of material. The slower the load rate, the more time the material has to undergo viscous creep. A load rate of 0.5 in/min was selected for subsequent tensile testing as it provided the greatest consistency in the measured data.

For discussion purposes, the 10 paints evaluated in this study were categorized according to their ductility, or percent elongation, recorded at room condition curing and a load rate of 0.5 in/min. This classification was given as ductile (% elongation > 50%), brittle (% elongation < 10%), or average ductility as shown in Table 3.1.

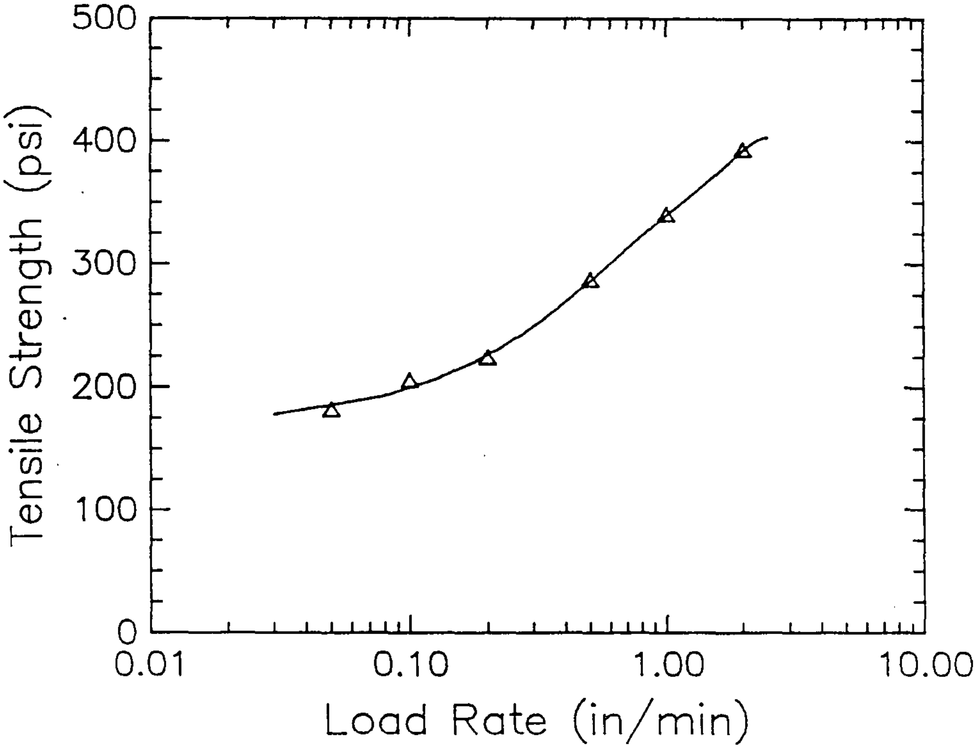

Figure 3.1 Effect of Load Rate on Ultimate Tensile Strength (Water Base)

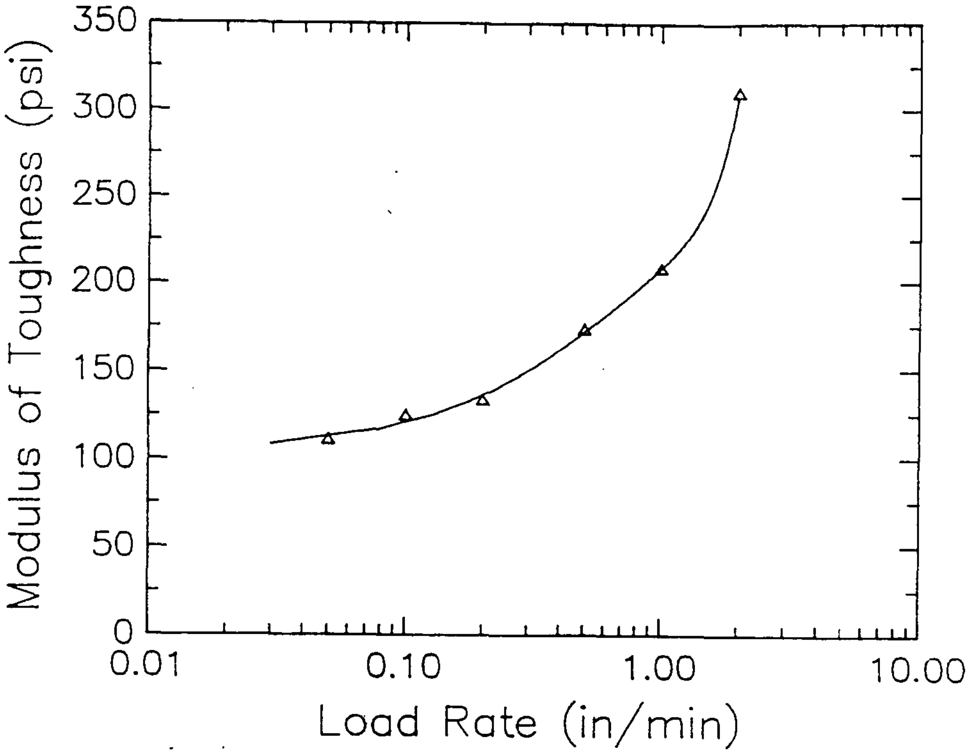

Figure 3.2 Effect of Load Rate on Toughness (Water Base)

Table 3.1 Ductility Classifications

Brittle	Average	Ductile
[CR-1-W]	[HP-1-W]	[WB-2-W]
[CR-1-Y]	[WB-1-W]	[WB-3-Y]
[AR-1-Y]	[MAR-1-W]	
[SB-1-W]		
[SB-2-Y]		

The effect of the temperature/humidity curing condition on the tensile properties was very substantial and of interest due to the extreme environmental conditions to which the paints will be exposed in service. Increased temperature during curing caused the ultimate strength, ultimate modulus of toughness, and breaking strength to all increase to varying degrees. The percent elongation and initial elastic modulus were erratic and showed no pattern with regard to paint type or vehicle.

Increased humidity during curing caused the ultimate strength, ultimate modulus of toughness (with one exception), and breaking strength of all of the paints to decrease. All of the water base paints had an increase in percent elongation with the increased humidity. This is readily explained since the water base paints cured at the higher humidity would not dry properly and remain more ductile.

The significance of these results in predicting whether a paint will be more durable in the field depends on which properties are determined to be the key indicators in this respect. If the ultimate strength or breaking strength are key predictors, then stripes placed during warmer or less humid conditions should attain a higher strength based on the results of this study. On the other hand, if percent elongation is determined to be a key indicator, then the effect of environmental factors is less clear.

3.2 Abrasion Tests

The relative rankings of the 10 paints with regard to the abrasion tests are shown in Table 3.2.

Table 3.2 Abrasion Rating Summary

Rating	Dry Test	Wet Test
1	[WB-1-W]	[AR-1-Y]
2	[WB-2-W]	[CR-1-W]
3	[AR-1-Y]	[SB-2-Y]
4	[CR-1-W]	[SB-1-W]
5	[WB-3-Y]	[WB-2-W]
6	[CR-2-Y]	[WB-1-W]
7	[HP-1-W]	[CR-2-Y]
8	[MAR-1-W]	[WB-3-Y]
9	[SB-1-W]	[MAR-1-W]
10	[SB-2-Y]	[HP-1-W]

The most significant results of these tests were the relatively poor performance of the water base paints when submerged in water. This would indicate that a water base paint would be a poor choice in an area susceptible to ponding. If the abrasion tests are eventually deemed significant with respect to predicting durability, the alkyd resin paint was the best performer overall considering both conditions. The solvent base paints performed poorly in the dry test while doing better in the submerged test. The modified alkyd resin paint tested performed poorly in both abrasion test conditions.

3.3 Field Stripes

The following observations were recorded for the transverse field stripes:

1) The five brittle paints exhibited very similar characteristics in the field. At 16 weeks, a few small transverse cracks appeared and at 42 weeks, the cracks had grown in size and number. These cracks penetrated the asphalt surface. In addition, cracks formed in the asphalt around the periphery of the stripes. Aside from this cracking, the stripes showed no signs of failure due to abrasion or chipping.

2) Not counting the house paint, whose formulation was not compatible with the asphalt surface, the average ductility paints exhibited the best wear characteristics to date. No cracking has appeared and no other wear has been observed.

3) The two water base paints, that were much more ductile than the other paints tested, have not performed well in the field. Both of these paints started chipping at two weeks. However, the chipping had not worsened at 42 weeks. The ductility and toughness of these paints probably held the chipping down to the levels shown at two weeks. The inherent problem of getting water base paints to adhere to asphalt is the likely reason that the chipping initiated very soon after placement of the stripes. The chipping of paint [WB-1-W] was much more severe than [WB-2-W].

Two properties of the brittle paints caused the cracking noted; low elongation at failure (brittleness) and high initial modulus (stiffness).

Paints [CR-1-W], [AR-1-Y], [SB-1-W], and [SB-2-Y] have much lower failure elongation and higher initial modulus. Tensile test specimens for [CR-1-Y] could not be prepared due to brittleness. Brittleness is primarily responsible for the transverse cracking. As the paint dries and shrinks and as the pavement/paint expands and contracts with temperature, shear stresses at the paint-pavement interface induce tensile stresses in the paint film that cause cracking. The more ductile paints are able to tolerate the tensile stresses.

The large stiffness of the brittle paints is primarily responsible for the periphery cracking. As the pavement expands and contracts in response to average temperature changes and flexes in response to temperature gradients through the asphalt, the stiff paint stripe confines the asphalt preventing conformity. This results in stress concentrations around the periphery of the stripe leading to cracking. The more flexible and ductile paints are better able to conform to pavement movements.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Two laboratory tests were developed to evaluate properties of pavement marking paints that could be used to predict durability of the stripes in the field. Tensile tests of free film specimens of paint yielded several properties derived from the stress-strain curves. Abrasion tests provided results for both wet and dry paint specimens. The tests produced consistent and repeatable results that varied widely for the different types of paints tested. These are positive indications that the tests will prove valuable for controlling paint quality.

Ten paint samples representing five different vehicles were evaluated using the laboratory tests developed. The paints were quite different as reflected in the tensile properties. The water base paints were considerably more ductile than the solvent base and alkyd resin paints. The load rate used for the test had significant effect on the results due to increased viscous creep introduced at slower load rates. On the average, paints cured at a higher humidity exhibited a 38% lower ultimate strength. Water base traffic paints cured at a higher humidity were more ductile and averaged a 23% higher percent of elongation. Paints cured at a higher temperature averaged a 55% higher ultimate strength. The effect of these different curing conditions on the tensile properties indicates the influence environmental factors have on the performance of traffic paints and one of the reasons why different geographic regions report different service from the various paints.

The abrasion tests also produced a wide variation of results among the ten paints tested. Water base paints performed poorly when tested wet, indicating that they would not be a good choice in a location where there is a ponding potential. The relevance of abrasion tests in predicting durability in the field is questionable for longitudinal stripes where traffic volume has little effect on the service life of the paint. The alkyd resin paint tested had the highest abrasion resistance considering both wet and dry test results.

The ten paint samples tested in the laboratory were applied to two asphalt surfaces of different ages in the form of transverse stripes. The stripes were monitored for 42 weeks as to their performance. None of the stripes showed significant abrasion wear. There was a definite correlation between the tensile properties recorded in the laboratory and observed cracking in the stripes. The paints that were the most brittle and stiff all developed transverse cracks at approximately 8 weeks and continued to worsen over the observation period. These same paints also caused the asphalt surface to crack around the periphery of the stripes. Two of the water base paints that were the most ductile underwent a premature chipping failure due to a lack of adhesion to the asphalt surface. The paints that exhibited average ductility in the laboratory have performed the best to date.

4.2 Recommendations

This study has provided significant insight into measuring properties of paint in the laboratory that can be used to predict the service life of the paint in the field. However, the field stripes that were applied and monitored failed to provide enough data with respect to correlating the laboratory results to the prediction of durability.

It is recommended that an ongoing project be implemented in which paint samples from AHD striping projects be tested in the manner described in this report and the laboratory results correlated with the observed performance of the marking materials. With sufficient data, obtained from stripes that are placed using normal techniques and application machinery, it is felt that a correlation can be made to determine which properties are the key predictors in evaluating durability.