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OOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT **71-4**

INVESTIGATION OF PAINTS AND GLASS BEADS USED IN TRAFFIC DELINEATION MARKINGS

PHASE 2

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16. Abstract

A Missouri dispersion resin-varnish paint and a Missouri chlorinated rubber-alkyd paint were used as a guide to determine the relative wear resistance qualities of several proprietary high heat paints. The ratings were based on field evaluations of the wear resistance of transversely placed paint stripes. The results indicated a wide range of life expectancies for the various proprietary paints. One high heat paint, type "G", was equal to or better than the Missouri paints and the other high heat paints evaluated. The general appearance rating system was used to visually evaluate the transverse stripes. This rating system was used in a previous paint study and was found to correlate best with actual stripe life for pavements in the State of Missouri. Visual evaluation of abrasion and chipping, as described in ASTM, was also used.

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SYNOPSIS

A Missouri dispersion resin-varnish paint and a Missouri chlorinated rubber-alkyd paint were used as a guide to determine the relative wear resistance qualities of several proprietary high heat paints. The ratings were based on field evaluations of the wear resistance of transversely placed paint stripes. The results indicated a wide range of life expectancies for the various proprietary paints. One high heat paint, type "G", was equal to or better than the Missouri paints and the other high heat paints evaluated. The general appearance rating system was used to visually evaluate the transverse stripes. This rating system was used in a previous paint study and was found to correlate best with actual stripe life for pavements in the State of Missouri. Visual evaluation of abrasion and chipping, as described in ASTM, was also used.

CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

Figure

INTRODUCTION

With increased traffic densities on our urban and metropolitan highways, driver behavior has indicated that a fast drying paint for traffic delineation is not only desirable but often mandatory.

A joint research project, of which this study is a part, was initiated between the Divisions of Materials and Research and Maintenance and Traffic within the Missouri State Highway Department in cooperation with the Federal Highway Administration. The scope of this investigation was to study (1) cold applied paints for durability due to wear, which was reported and published in May 1970, (2) hot applied paints for durability due to wear, and (3) the compatibility of these paints with various types of glass beads.

This report covers the second phase of the investigation which was a durability study of six high heat rapid dry paints. In addition, two Missouri paints were included in the test for basis of evaluation. These paints were applied in two colors, white and yellow, to both asphalt and concrete pavements.

Evaluation was based on the same criteria as that described in the Phase 1 Report, where visual ratings of general appearances and film condition, inclusive of abrasion and chipping, were observed for each individual stripe. The general appearance rating was considered the most consistent and easiest rating to use to estimate the life expectancy of the stripes.

CONCLUSIONS

The test performed under this phase of the field evaluation of high heat paints designed specifically for use in traffic delineation markings where rapid drying is necessary, has provided sufficient data to give meaningful and just conclusions. The paints used in this phase represent several brands which were on the market at the time this investigation was conceived. Unfortunately, these high heat paints are proprietary products, therefore, the chemical formulations were not available.

Regardless of total traffic counts, the paint stripes placed on the asphalt surface generally had greater wear resistance than paint stripes placed on the concrete surface.

The failure level of 3.0 on a 10.0 to 0 rating scale as described in ASTM was used in this investigation as absolute failure by the evaluation team. However, there was a question as to whether such a value was compatible with Missouri striping procedures. Therefore, a 4.0 failure level was also included to determine possible relationships within the failure rates and between paint types. The statistical analyses generated from these observations show identical ranking of the paint types with regard to failure levels of either 3.0 or 4.0 respective of pavement type.

The paint types were found to be highly significant with respect to expected service life due to wear resistance only, however, this was complicated by the existence of an interaction involving color of paint. By breaking the statistical analyses down to one-way analyses of the kind of paint based on color, the kind of paint remains highly significant; however, there is a slight adjustment in the order of ranking of the types of paints.

The analysis provided the following conclusions of the various paints tested:

1. Regardless of the differences in ranking of the kinds of high heat paints with regard to color and pavement type, one particular paint, type "G", remained consistently high in each analysis shown. In addition, high heat paint type "G" consistently showed wear resistance qualities exceeding both the Missouri dispersion resin-varnish and chlorinated rubber-alkyd paints.
2. The Missouri chlorinated rubber-alkyd paint was always better in wear resistance than the Missouri dispersion resin-varnish paint.

3. Based on a statistical analysis of the data, the Missouri chlorinated rubber-alkyd paint generally ranked with the best of the high heat paints.
4. One high heat was the first to fail in each category of the various ratings. This fact was also noted in the first application of paints for Phase 2. This paint, type "O", is a prebeaded extremely fast dry paint. The performance of this paint in this study would indicate that the use of such paint should be limited to only those locations requiring extremely fast dry characteristics.
5. Within the limitations of this experiment, the heated chlorinated rubber-alkyd paint, with methylene chloride solvent, performed about the same as the non-heated chlorinated rubber-alkyd paint, with the methyl ethyl ketone solvent. Further evaluation of this paint may be warranted.

IMPLEMENTATION

Phase 1 of this study, based on the relative wear characteristics, indicated a chlorinated rubber-alkyd paint performed as good as or better than the Missouri dispersion resin-varnish type paints and was considerably more economical. With the exception of the purchasing of some high heat paints for striping in urban areas, the Missouri State Highway Department is now using the chlorinated rubber-alkyd paint for striping.

Phase 2 of this study, based on the relative wear characteristics, indicated that the chlorinated rubber-alkyd paint generally ranked with the best of the high heat paints. Based on the relative wear characteristics of high heat paints studied, indications are that a definite variation in quality of the high heat paints does exist.

One of the objectives of the overall study was the development of a chemical specification for high heat paints. This objective was not achieved. Even with a chemical specification, it would be most difficult to insure that the quality of the high heat paint that the Department could accept would be comparable to the paints used in this study. Therefore, at this time performance must play an important part in the selection of high heat paint and the development of specifications and acceptance procedures be considered for future laboratory research.

As a result of this research, the use of chlorinated rubber-alkyd paint will be continued in most areas of the State. In those locations where wear is not the most dominant consideration, the high traffic volume locations, fast dry, high heat paints will be used.

This study did provide valuable information on several proprietary types of paint supplied for the Phase 2 study. It was indicated in this study that a durable high heat paint can be formulated that would have better wear characteristics than any paint used to date in our normal striping operations. Due to the variations found between high heat paints, it is most important that paint companies be encouraged to develop improved high heat paint with special effort directed to the extremely fast dry paint.

SCOPE

The high heat paints purchased for this investigation included each manufacturer's recommendation as to optimum film thickness for best wear, etc. Since the Department did not own a high heat striper, a paint manufacturer was contacted to place stripes of all high heat paints to be used in the study. Unfortunately, only dry film thickness measurements were obtained and the wet film thickness, processed mathematically, indicated that all stripes placed had insufficient thickness as recommended by the various paint manufacturers. These stripes were field evaluated and some reference to the data is provided in this report. This phase of high heat paints was rescheduled and the paint thicknesses were based on wet film measurements. This report is, therefore, based primarily, unless otherwise noted, on data obtained from stripes placed according to the manufacturer's recommendation and the paint thickness based on wet film measurements.

The field evaluation was confined to the application of paint stripes four inches wide placed transverse to the direction of travel on asphaltic concrete and concrete surfaces. Evaluation of the film condition was confined to the line portion within the limits of the outer wheel path.

The asphalt and concrete test sections were located in District 6 on Route 40TR, St. Louis County, Figure 1, page 23. The same location as used in the Phase 1 test was again utilized in this test for the concrete test deck to prevent necessary relocation of the traffic counting loops. The asphalt test deck was relocated further west of the Phase 1 test site due to reconstruction. The traffic volumes actually recorded for the outside lane of both test locations showed the average number of vehicles per day to be 8,472 and 14,226 for the asphalt and concrete pavements respectively.

Each test deck was composed of six replicate stripes of each paint type and color for a total of 84 test stripes, as shown in Figure 2, page 24. All stripes of like kind and color were placed in pre-assigned areas within the test deck. Each stripe was placed at 15 mils wet film thickness with a tolerance range of ±1 mil. Glass beads were added by using a pressure assisted drop system.

Observations were made at various time intervals by a panel of four men consisting of a:

Materials Research Engineer

Maintenance and Traffic Engineer

Maintenance and Traffic Technician

District Maintenance Superintendent

ASTM D821-47, D913-51, and D713-66T were used as guidelines for rate of wear attributed to abrasion, chipping, and general appearance respectively.

MATERIALS

Materials used in this phase of our testing program were obtained by purchase order except for the Missouri dispersion resin and the Missouri chlorinated rubber-alkyd which were already in stock. The Missouri dispersion resin and chlorinated rubber-alkyd white and yellow paints were formulated from specifications similar to those shown in the Phase 1 Report, with only minor revision in the inspection and purchase procedures. Laboratory analyses of these paints, as sampled prior to use, are shown in Table 1, page 19. Laboratory analyses of the high heat paints as sampled upon receipt are shown in Table 2, page 20. The method of analysis for each of these properties is primarily based on the methods set forth in "Physical and Chemical Examination of Paints, Varnishes, Lacquers and Colors" by Henry A. Gardner and G. G. Sward. Many of these procedures are similar to those in the ASTM except for quantities of material used.

A newly formulated chlorinated rubber-alkyd paint which incorporates the use of methylene chloride rather than methyl ethyl ketone as part of the vehicle was included in this phase for exploratory results only. This formulation would safely allow some heating of the chlorinated rubber paint prior to application to decrease the time required for drying when necessary because of weather conditions.

The high heat paints were obtained by purchase order from five companies which were producing these types of paints at the time this phase of the investigation began. Conditions for application as issued by the manufacturers for the high heat paints are shown in Appendix A. Only one paint manufacturer was willing to provide the chemical formulation of the paints they supplied for this investigation.

The correlation studies made on these paints analyzed the durability of the high heat paints using the Missouri dispersion resin-varnish paint as a yardstick. The inclusion of the Missouri chlorinated rubber-alkyd paint was done for the purpose of checking the formulation and its relative durability based on the Missouri specifications. These specifications are similar to those shown in the Phase 1 Report with some minor revisions in the inspection and purchasing procedures.

Glass beads applied to the stripes were accepted for use based on the specifications as shown in the Phase 1 Report. Results of a check sample of glass beads obtained during the striping operation are shown in Table 3, page 21.

FABRICATION OF TEST SECTIONS

The Missouri dispersion resin, Missouri chlorinated rubber-alkyd, and the high heat paints, in white and yellow colors only, were placed on asphaltic concrete and concrete pavements in very high traffic areas. To identify each stripe by paint type, color, and line number, the following abbreviated identification was used:

Column 1 indicates the type of paint (B, D, F, G, ... etc.).

Column 2 indicates the color of paint being either W (white) or Y (yellow).

Columns 3 and 4 indicate the index number of each individual replicate stripe per paint (generally between 1 and 15).

Column 5 indicates the type of pavement surface being either A (asphalt) or C (concrete).

A typical identification code, such as GYO4A, would be identified as paint type "G", yellow, line number 4 and located within the asphalt test deck. The stripe sets were easily distinguishable by the paint type code painted on the pavement at the beginning of each set and by the very distinct alternating white-yellow areas within the test deck. This code for stripe identifications proved very satisfactory.

The machine used to place the stripes (Figure 3, page 25) was not capable of interrupting the bead flow, therefore, a sample could not be taken to determine the wet film thickness of the test stripes. However, the operator was required to calibrate with non-beaded lines prior to placing the first three test stripes and then required to re-calibrate prior to placing the remaining three test stripes for each paint type. During the first calibration, the line width and wet film thicknesses were checked and proper adjustments made. Stripes not meeting thickness requirements, as determined visually by comparison with the calibrating stripes or not having sufficient bead coverage, were omitted from the test.

The pavement surface, in the area where the test sections were located, showed considerable wear in the wheel paths. The concrete surface, being the same location as shown in Phase 1, was worn to an uneven exposed aggregate condition. The asphaltic concrete surface, although worn to an exposed aggregate condition, was considerably smoother than the asphaltic concrete surface which was used in Phase 1. However, as each test deck was located within an area approximately 200 feet in length by one lane in width, the pavement characteristics did not change appreciably throughout each of the test sections.

FIELD CONTROL TESTS

Weather Conditions:

The weather conditions during the application of pavement markings has a definite effect on the paint characteristics as well as a marked effect on the durability or life of the stripe. To comply with paragraph 5.1 of ASTM D713-66T, the temperatures and relative humidities were recorded hourly, as shown in Table 4, page 26. The normal working hours in these high traffic areas are 9 AM to 2 or 3 PM. During these time periods, the temperature difference was 13 to 20 degrees and the relative humidity difference was 16 to 33 percent. These small variations indicate that the weather conditions were similar throughout the experiment.

Wet Film Thickness:

Wet film thickness measurements could not be determined on the test stripes because the bead disperser on the striper could not be turned off nor could the beads be deflected during the striping operation. To provide the highest degree of accuracy possible, the operator was required to paint non-beaded stripes prior to painting any test lines to establish the striper speed and paint gun orifice setting for each specific paint type and color. After the first three test stripes of each set of six test stripes per variable were painted, a check was made for the wet film thickness of a non-beaded stripe. Corrections were made if necessary, and the remaining three test stripes were painted.

The wet film measurements taken from samples obtained as the non-beaded stripes were painted, are shown in Table 5, page 27. The samples were secured by placing metal paving plates (8 inches by 8 inches by 16 mils thick) approximately six feet from the edge of the pavement directly in the path of the stripe to be painted. The wet film measurements were taken immediately after being painted by the use of an Interchemical Wet Film Thickness Gage (ASTM D1212-54). To obtain a correct wet film thickness measurement, it was necessary to lightly coat the gage with xylol to provide the necessary pick-up of the paint on the eccentric ring of the gage.

Drying Time:

The apparatus used to evaluate the drying time required for each set of stripes is that described in ASTM D711-55 and shown in Figure 4, page 25. The apparatus described in ASTM D711-67 is designed for laboratory use only.

Since the test for drying time resulted in a delay to the striping operation, representative stripes were picked from each set of six test stripes to determine the drying time. The results of the drying time, as shown in Table 6, page 28, indicate a longer dry time period was required on concrete surfaces than on asphalt surfaces. The data also indicated a considerable variation between and within the products. However, where more than one stripe per set was observed, the difference between stripes within a set was very small. The dry times for these paints are obviously higher than the three minutes designated by most manufacturers, however, some difficulty was experienced with the dry time wheel punching through the skin film and picking up wet paint whereas an automobile tire may not. Some manufacturers suggest dry time be measured with an automobile moving at a given rate, however, for the lines placed in these test decks, this would be impossible.

Dry Film Thickness:

The samples used to measure the wet film thickness of the non-beaded stripes were allowed to air dry for approximately one week before taking the dry film thickness measurements. The dry film thickness was determined by averaging seven readings on each sample, which are shown in Table 5.

The dry film is a more realistic measure of the actual amount of paint that is resisting abrasion and wear. Therefore, it is interesting to note the variability in the percentages of reduction from the wet film condition to the dry film condition as shown in Table 5. The average reduction in film thickness for the sixteen high heat paints shown is 48 percent on asphalt and 40 percent on concrete; whereas, the average for the cold applied Missouri paints is 59 percent and 56 percent respectively. Therefore, the data infers that the difference in reduction may be proportional to the drying time, however, this will not hold true within samples between pavements. Observing the relationship between the dry time and the percent reduction of the paint film (Figure 5, page 29), it is obvious that no definite correlation exists for these samples.

EVALUATION TEST PROCEDURES

Evaluation of the paint stripes was based on the observation of two modes of failure. As discussed in the Phase 1 Report, these modes are general appearance and durability. ASTM D713-66T covers the basic mechanics of these observations; however, the general appearance rating will carry the statistical analyses to be produced in the following section. The reason for not producing the durability data within this report stems from the results of Phase 1, where it was shown that the general appearance rating was inclusive and contained basically the same significant levels as did the durability ratings.

For informational purposes only, photographs of sample individual lines for a few of the white paints on the asphaltic concrete and concrete pavements have been reproduced in Figures 8 and 9, pages 38 through 46, at the end of this report.

RESULTS AND DISCUSSION

Field observations were made on each test deck once every two weeks for the purpose of evaluating the rate of failure of each test stripe. The observations on the concrete test deck were suspended after 11 weeks of exposure and after 16 weeks of exposure on the asphalt test deck. The data obtained from these observations was tabulated and by interpolation methods was reworked into "age at failure" values shown in Tables 7 and 8, pages 31 and 32. The values shown in these tables are the ages in weeks at which time each individual stripe failed at a rating value of 3.0 or 4.0 respectively based on the ASTM recommended scale of 0 to 10.

The basis for the evaluation of the relative wear resistance of the high heat paints was initially programmed to be the Missouri dispersion resin-varnish paints. However, since the Phase 1 Report was completed, the state has discontinued the use of these paints. Therefore, the newer Missouri chlorinated rubber-alkyd paints were included as a secondary basis for evaluation. The life expectancy for the paints shown in Table 7 indicate that the chlorinated rubber paints are significantly better in wear resistance than the dispersion resin-varnish paints. Therefore, the discussion of the high heat paints will also contain the relative significance of the chlorinated rubber paints.

Within the past year, another formulation of the chlorinated rubber paint has come to our attention which can be applied cold or slightly heated. This paint was also included on an exploratory basis to determine its wear resistance characteristics. Generally, as shown in Table 7, the heated chlorinated rubber paint performs about as well as the Missouri chlorinated rubber, therefore, no further analysis of this paint will be used in this report.

The wear resistance of the high heat paints is definitely influenced by the type of pavement surface. The paints located on the asphalt surface generally performed better than the paints on the concrete surface. This evaluation is based on the total traffic count to date of failure of each paint type. The aggregate was exposed in both test decks, however, protrusion of the aggregate particles was much more pronounced in the concrete test deck. Failure of the test stripes in this test generally began on the protruding aggregate particles. Because of this difference in rates of wear per pavement type, the statistical analyses will consider the data obtained from each pavement type separately.

The reason for including both rating values of 3.0 and 4.0 was to determine if failure rates were sufficiently established at the 4.0 level to predict the time required to obtain a 3.0 rating level. By statistical analysis between the kind of paint and the rating values for each color on each pavement type, the rating values were found to be highly significant. Definition of significance and terms used in this report may be found in Table 9, page 33. When analyzing between the kind of paint and color of paint for each rating on each pavement type, as shown in Table 10, page 34, both kind and color are shown to be highly significant. The ordering of the kinds of paints for the 3.0 and 4.0 data are shown to be exactly alike within each pavement type. However, there is a color reversal between pavement types as well as a kind-color interaction within each rating. This, in essence, makes the ordering by kind very dependent upon the color and will probably not be identical.

The one-way analyses, as shown in Table 11, page 35, are a further breakdown of the data by colors for the 3.0 rating only. Comparing the ordering of the kinds of paints between colors and pavement types and also comparing with the ordering in Table 10, it is obvious that color has a definite bearing on the wear resistance of a particular brand of paint. These tendencies may be shown diagrammatically by plotting each individual paint's rate of failure as shown in Figures 6 and 7, pages 36 and 37. The abnormal fluctuation of the curves shown in Figure 6 at the 6 weeks observation can only be explained by the exceptionally dirty appearance of the lines. Preceding the observation at that time, there was a 15 day dry period with only trace amounts of precipitation recorded, thus causing a buildup of dirt. Generally, the other observations were preceded by rainfalls of sufficient magnitude to flush the pavement surfaces and cause the appearance to be rated much higher.

The curves in Figures 6 and 7 also depict the inconsistencies of the paints to retain a constant ordering with each subsequent observation, thereby causing the difference in ordering by paint type with regard to color, thus giving the kind-color interaction a value.

These results show by the use of statistics and the unbiased observation methods the following:

1. From the kind rankings shown in Table 10 and 11, pages 34 and 35, paint type "O" is consistently poor in wear quality. This paint is a very high heat paint (250°F+) and fast drying (approximately 3 seconds).
2. The Missouri standard (the dispersion resin-varnish paints) and the type "M" paints consistently rank low with very little difference between their average rate of failure. However, by comparison with the k_{01} values shown with each analysis which represents the required difference between averages before significance can occur, there does exist a small degree of significance between these paints. The slight advantage of type "M" over the Missouri standard holds for either color on the asphalt surfaces, however, the Missouri standard advantage over the type "M" paint on the concrete surface does not hold with the yellow paints.
3. The top four ranked paints, "G", "I", "K", and the Missouri chlorinated rubber (C.R.), are consistent within pavement type regardless of rating observed. However these paints are not consistent between pavement types. Considerable differences occur between these paints with regard to color on either pavement surface. In some cases the differences between the averages are very small and not significant for the asphalt pavement. However, the differences between the averages are larger and generally significant for the concrete pavement.

The above discussions are the variation displayed within each of the "Kind-of-Paint Rankings" shown in the tables; however, one paint consistently ranks high with major fluctuations in the others. Paint type "G" ranks high regardless of color or which pavement surface it is applied to.

Reference has been made that the first application of paints for Phase 2 were applied at a wet film rate much lower than recommended by the various paint manufacturers and Phase 2 was repeated to provide proper wet film thicknesses. However, the data obtained from the paints placed at an insufficient thickness indicated a lower paint thickness may achieve the same or better paint life as paints placed with thickness as recommended by the various manufacturers. This would indicate that further studies of high heat paints should be made to determine the optimum wet film thickness requirements to provide the most economical service life possible of the paints.

Appendix A

Specifications and Chemical Analysis

of Traffic Delineation Paints

The specifications for the White and Yellow Missouri dispersion resin-varnish and Missouri chlorinated rubber-alkyd paints used in this phase are identical to those published in the Phase 1 Report, except for minor changes in the procurement procedures, therefore, will not be reproduced here.

The specifications obtained for the high heat paints did not contain the information desired. Application methods and precautions, working viscosities, dry times, film thicknesses and essential bead qualities were, in essence, the information contained in many of the product specifications. Most of this information is redundant between products, therefore, will not be reproduced in this report. The following tabulated summary is the essence of the manufacturer's recommended application temperatures and wet film thicknesses.

Paint Type	Appl. Temp. (°F)	Wet Film Thickness (mils)	Dry Time No-Pick-Up (min)	Dry Time No-Track (min)	Dry Film Thickness (% Retain)	Bead Rate (lbs/gal)
B	Cold	15	-	-	-	6
D	Cold	15	-	-	-	6
F	120	15	2	-	-	6
G	120-160	12-18	-	2	65(1)	6-8
I	140-170	(2)	2	-	65(3)	8
K	140-180	15	2	-	-	6
M	165	16+1	3-5	-	44(1)	6
O	250-275	15	-	2-20 Sec.	66(1)	?

(1) Under field application.
(2) 105-115 sq. ft./gal.
(3) Under Lab. conditions, wet film thickness 18-20 mils.

For the benefit of the striper crew, all stripes to be observed were placed at 15 mils with a ±1 mil tolerance with a bead application rate of 6 pounds per gallon.

Table 1

Properties of Missouri Dispersion Resin-Varnish (Type B) and Missouri Chlorinated Rubber-Alkyd (Type D) Paints.

Paint Type	B		D	
Color of Paint	Yellow	White	Yellow	White
Laboratory No.	70-12885	70-12886	70-12887	70-12888
Percent Pigment	51.0	50.0	52.0	49.0
Percent Vehicle	49.0	50.0	48.0	51.0
Percent Non-Volatile in Vehicle	35.1	37.3	39.7	37.8
Weight Per Gallon, lbs. at 25°C.	11.22	10.76	12.59	11.93
Viscosity at 77°F, Krebs Units	63	63	70	70
Drying Time, ASTM D711-67 (Min.)	28	22	3	2½
Minimum Grind, Hegman Gage	4½	5½	4½	4½
Skinning Test, 72 Hours	Passed	Passed	Passed	Passed
Settling Test, ASTM D1309-56	1	2	7	7

Table 2

Properties of High Heat Paints and Experimental Heated Chlorinated Rubber (Type F).

Paint Type	G		I		K	
Color	Yellow	White	Yellow	White	Yellow	White
Lab. No.	70-12890	70-12891	70-12892	70-12893	70-12894	70-12895
Percent Pigment	52.4	53.4	62.4	66.0	43.4	41.6
Percent Vehicle	47.6	46.6	37.6	34.0	56.6	58.4
Percent Non-Volatile in Vehicle	30.1	34.4	42.0	46.4	30.5	31.7
Weight per gallon, lbs. at 25°C	14.29	14.33	14.45	14.71	15.30	14.91
Viscosity at 77°F, Krebs Unit	108	107	106	106	116	97
Drying Time, ASTM D711-67 (min.)	3	4½	6	3	5	5
Minimum Grind, Hegman Gage	4	3½	3	3	5	4
Skinning Test, 72 Hours	Passed	Passed	Passed	Passed	Passed	Passed
Settling Test, ASTM D1309-56	6	6	2	0	8	7

Paint Type	M		O		F
Color	Yellow	White	Yellow	White	White
Lab. No.	70-12896	70-12897	70-12898	70-12899	70-12900
Percent Pigment	60.0	62.0	58.2	57.4	45.0
Percent Vehicle	40.0	38.0	41.8	42.6	55.0
Percent Non-Volatile in Vehicle	36.1	31.0	57.9	61.5	33.3
Weight Per Gallon, lbs. at 25°C	13.54	13.59	12.49	12.33	14.03
Viscosity at 77°F, Krebs Units	115	113	-	-	90
Drying Time, ASTM D711-67 (min.)	20	12	-	-	1
Minimum Grind, Hegman Gage	4	3½	-	-	3
Skinning Test, 72 Hours	Passed	Passed	-	-	Passed
Settling Test, ASTM D1309-56	8	8	0	0	8

Table 3

Laboratory Analysis of Reflectorizing Glass Spheres

Laboratory No.	69-14032
Lot No.	24
Irregularly Shaped Particles (Percent)	20.8
Free Flowing Test	Satisfactory
Refractive Index at 25°C.	1.51
Brightness, Candle Power/ft.candle/sq.ft.	4.08

Chemical Stability:

Resistance to hydrochloric acid	Satisfactory
Resistance to sodium hydroxide	Satisfactory
Water resistance	Satisfactory
Resistance to calcium chloride	Satisfactory

Waxes or Oils	None detected

Gradation U.S. Standard Sieves:

Sieve	% Passing
No. 16	100.0
No. 20	100.0
No. 30	94.5
No. 50	26.0
No. 100	3.0
No. 200	0.0

Appendix B

Test Section Design and

Field Data

Figure 1 - Location of Test Sites

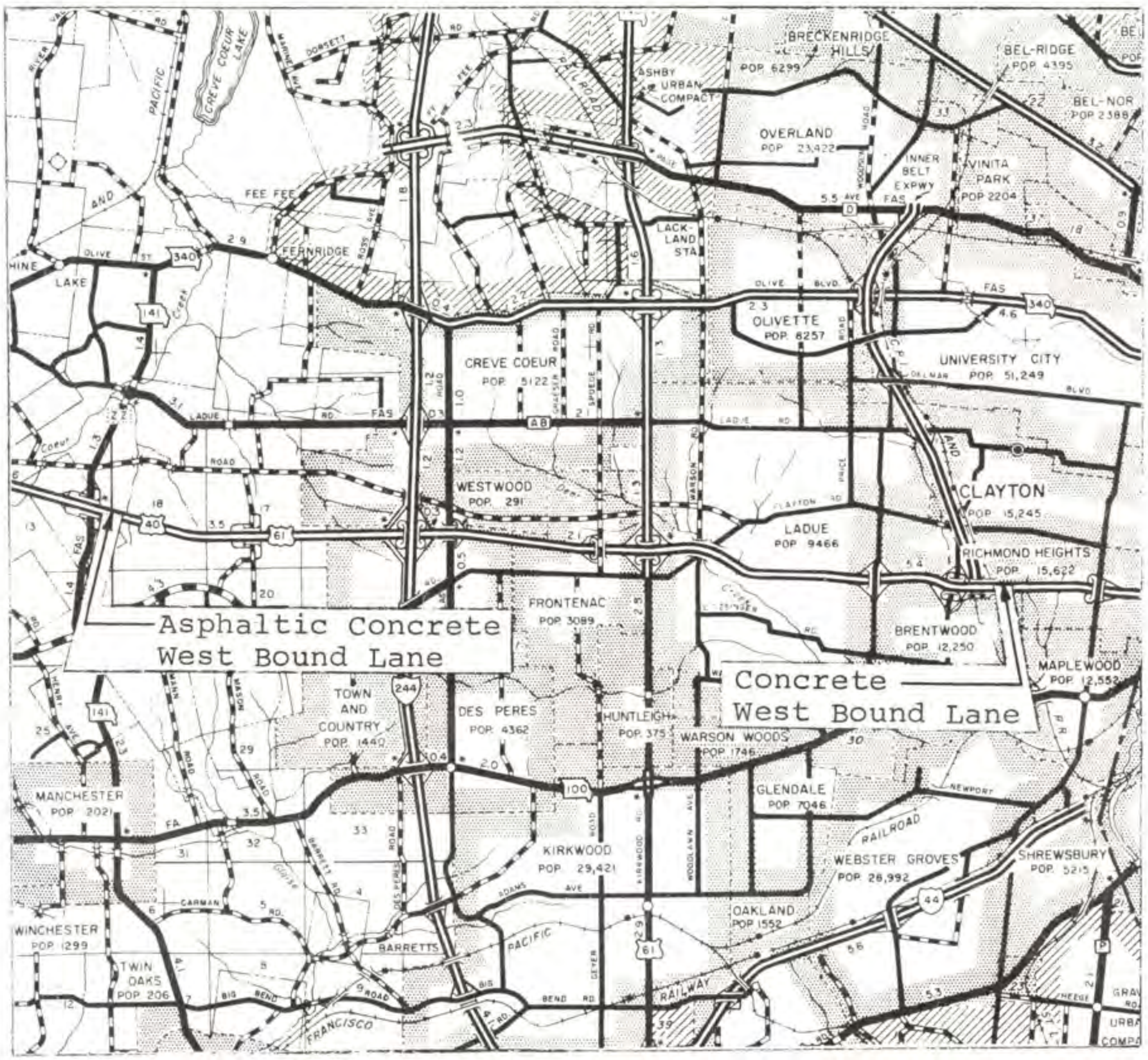
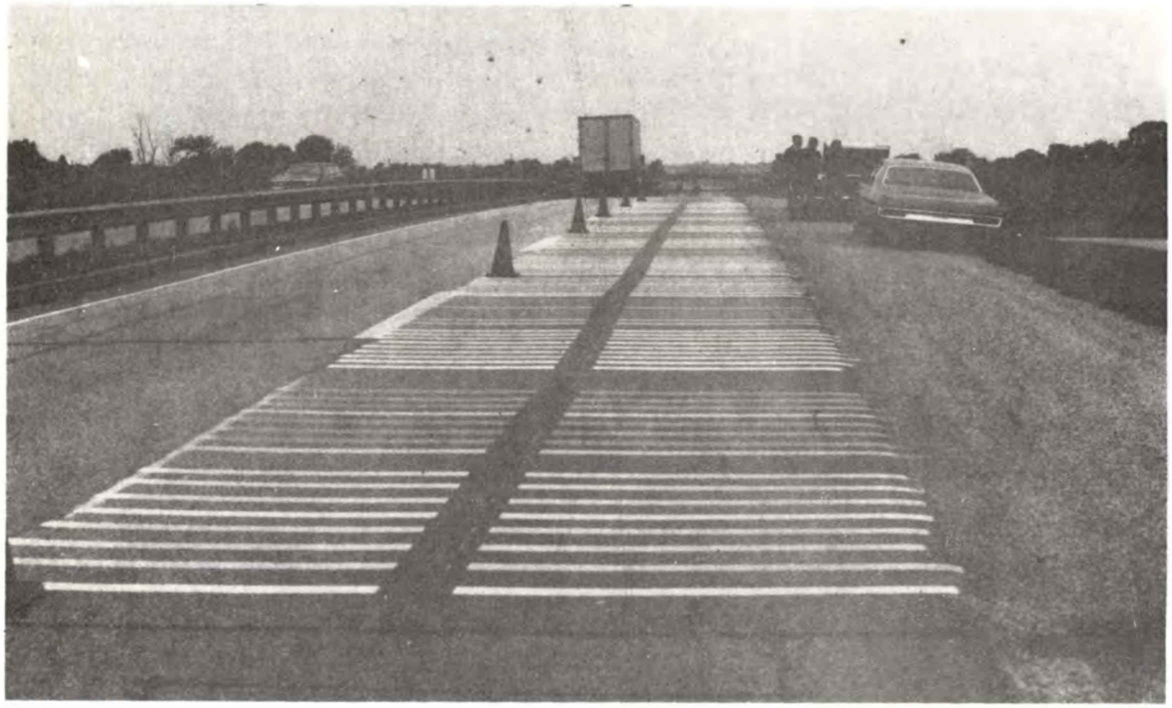
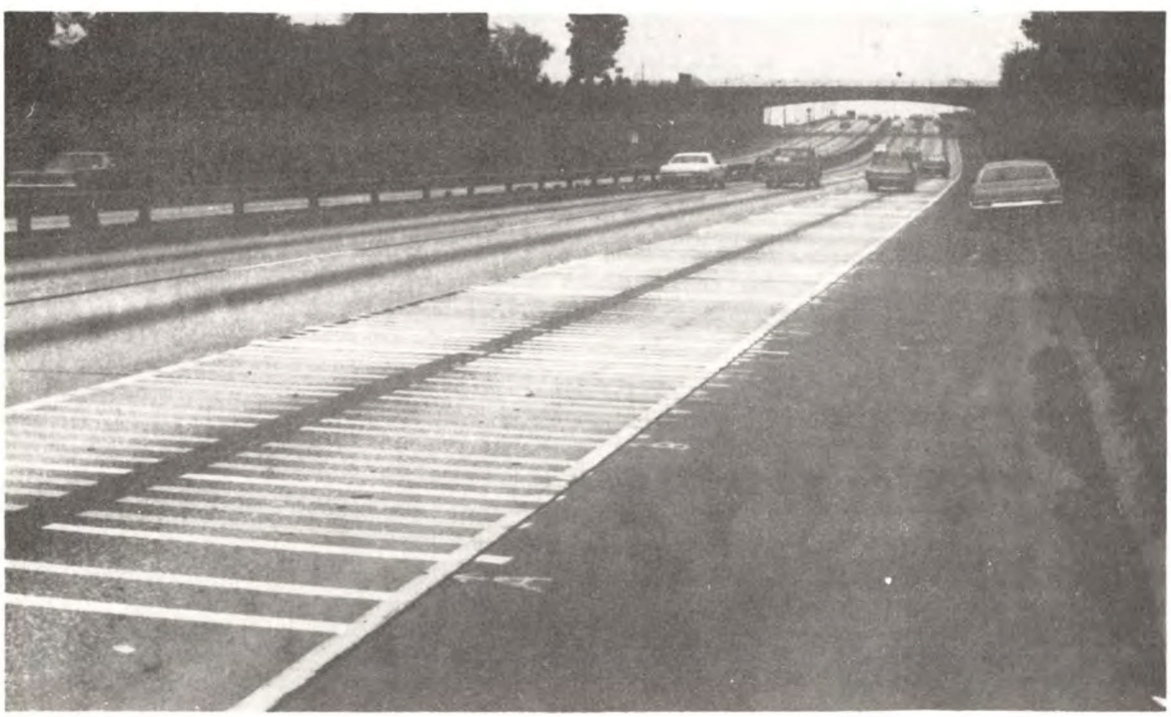


Figure 2 - Description of Test Sites



a. Asphaltic Concrete Test Deck: 4" Asphaltic Concrete, 7" Reinforced PCC Pavement, two 12' lanes, testing in outer lane only.



b. Concrete Test Deck: 9" Reinforced PCC Pavement, three 12' lanes, testing in outer lane only.

Figure 3 - High Heat Research Striper

Figure 4 - Dry Time Wheel and Weight Assembly

Table 4

Hourly Temperature and Relative Humidity Readings During Placement of the Stripes

Date	Time	Temperature Deg. F	Relative Humidity (Percent)
September 28	6:00 AM	78	79
	7:00 AM	78	79
	8:00 AM	76	88
	9:00 AM	76	88
	10:00 AM	74	93
September 29	5:00 AM	57	87
	6:00 AM	54	80
	7:00 AM	53	83
	8:00 AM	55	83
	9:00 AM	60	75
	10:00 AM	63	73
	11:00 AM	67	70
	12:00 AM	72	62
	1:00 PM	76	56
	2:00 PM	80	42
	3:00 PM	82	37
September 30	5:00 AM	58	87
	6:00 AM	57	90
	7:00 AM	57	87
	8:00 AM	59	83
	9:00 AM	62	72
	10:00 AM	67	65
	11:00 AM	70	61
	12:00 AM	72	59
	1:00 PM	74	59
	2:00 PM	76	56
	3:00 PM	77	48
October 1	9:00 AM	57	82
	10:00 AM	62	76
	11:00 AM	66	61
	12:00 AM	70	57

Table 5

Wet and Dry Film Thickness Measurements of Stripes

Line Ident No.	Asphalt Film Thickness Wet	Dry	Reduction (%)	Line Ident No.	Concrete Film Thickness Wet	Dry	Reduction (%)
			Missouri Dispersion Resin-Varnish Paints				
BY10A	14.0	6.0	57.14	BY02C	15.0	6.4	57.33
BY03A	14.0	5.5	60.71	BY06C	15.5	6.8	56.12
BW02A	14.0	6.4	54.28	BW03C	14.0	6.3	55.00
BW06A	15.0	6.8	54.66	BW07C	14.0	6.0	57.14
			Missouri Chlorinated Rubber-Alkyd Paints				
DY02A	14.0	4.8	65.71	DY01C	15.0	6.4	57.33
DY06A	15.5	5.6	63.87	DY05C	15.0	7.6	49.33
DW02A	16.0	6.4	60.00	DW02C	15.5	6.2	60.00
DW06A	14.0	5.9	57.85	DW06C	14.0	5.8	58.57
			Special Heated Chlorinated Rubber-Alkyd Paint				
FW01A*	15.0	4.5	70.00	FW02C	14.00	7.1	49.28
FW07A*	14.5	6.8	53.10	FW07C	15.00	8.3	44.66
			High Heat Paints				
GY03A	14.0	9.4	32.85	GY02C	15.0	8.3	44.66
GY07A	15.0	9.9	34.00	GY07C	15.0	9.6	36.00
GW01A	14.0	6.0	57.14	GW01C	15.0	9.4	37.33
GW07A	14.0	6.3	55.00	GW05C	16.0	10.0	37.50
IY01A	15.0	8.9	40.66	IY02C	15.0	13.2**	
IY05A	14.5	8.3	42.75	IY06C	15.0	15.6**	
IW03A	15.0	8.3	44.66	IW01C	15.0	6.4	57.33
IW07A	14.5	7.7	46.89	IW05C	15.0	7.8	48.00
KY01A	15.0	6.6	56.00	KY01C	15.0	6.6	56.00
KY05A	16.0	6.6	58.75	KY08C	15.0	6.1	59.33
KW01A	16.0	7.4	53.75	KW02C	15.0	8.4	44.00
KW05A	14.5	6.4	55.86	KW07C	16.0	9.8	38.75
MY09A	15.0	7.9	47.33	MY01C	15.0	8.4	44.00
MY03A	15.0	7.1	52.66	MY07C	15.0	9.1	39.33
MW03A	14.0	7.2	48.57	MW01C*	15.0	6.9	54.00
MW09A	14.0	7.8	44.28	MW03C*	15.0	8.8	41.33
OY--A	Premixed Beads			OY--C	Premixed Beads		
OW--A	Premixed Beads			OW--C	Premixed Beads		

* Are actually located in position Q within respective test decks.
** The dry paint film was too rough to measure accurately.

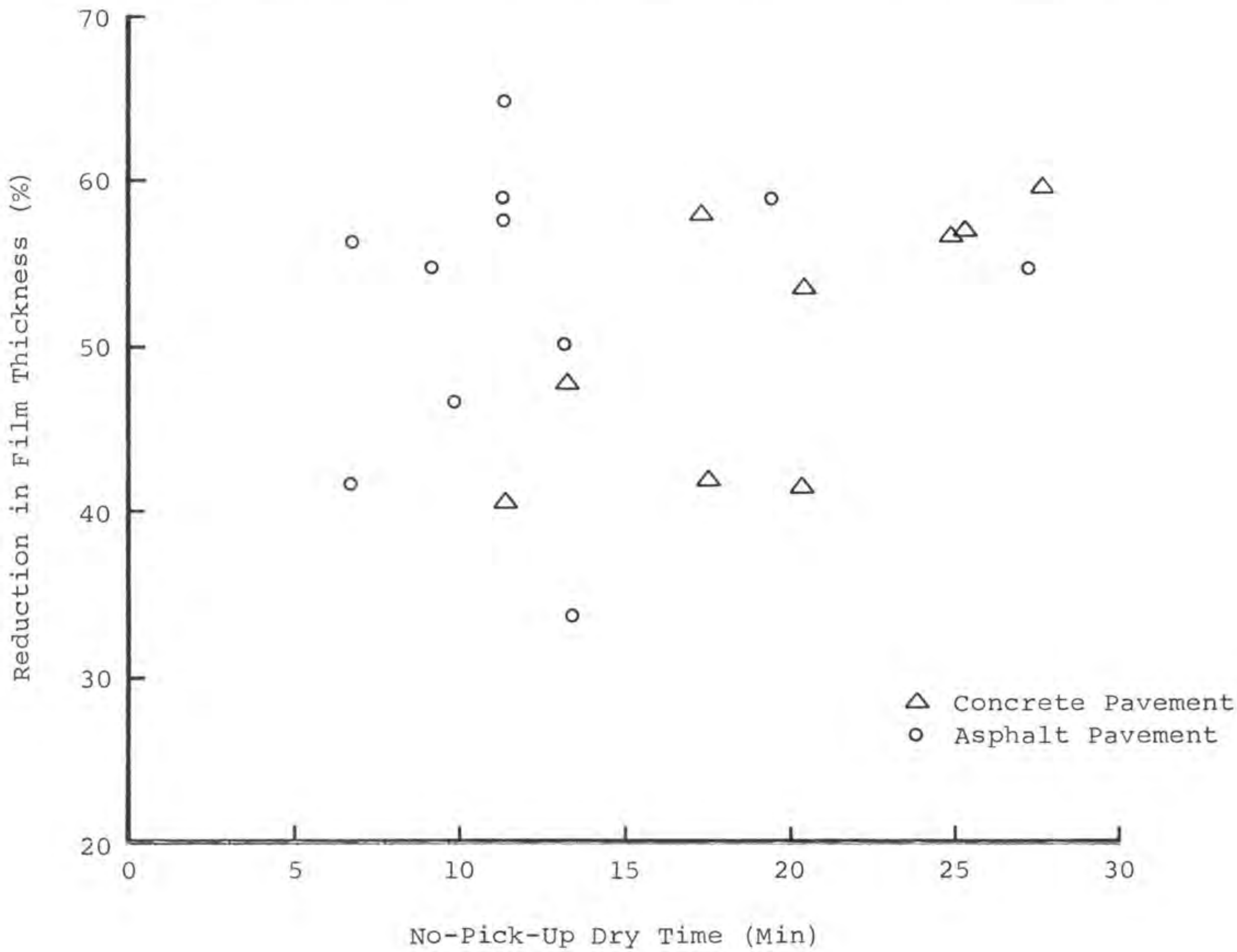
Table 6

Dry Time to No-Track and No-Pick-up

Section Ident.	No-Track Time (Min-Sec)	No-Pick-up Time (Min-Sec)
	Asphaltic Concrete Surface	
BY	- -	11-19
BW	- -	27-17
DY	- -	11-19
DW	- -	19-42
FW	3-21	4-18
GY	- -	13-28
GW	- -	6-47
IY	- -	13-20
IW	5-38	6-40
KY	- -	11-19
KW	7-30	9-02
MY	12-13	13-03
MW	- -	9-56
OY	- -	0-02
OW	- -	0-02
	Concrete Surface	
BY	23-20	25-12
BW	- -	24-59
DY	- -	20-25
DW	26-40	27-37
FW	6-58	8-54
GY	- -	11-21
GW	18-22	- -
IY	- -	4-16*
IW	16-59	- -
KY	14-45	17-17
KW	17-22	20-19
MY	- -	17-31
MW	10-10	13-11
OY	- -	0-03
OW	- -	0-04

* Paint film very rough and dry looking.

Figure 5 - Paint Film Reduction With Respect to Dry Time for No-Pick-Up.



Appendix C

Statistical Analysis and

Evaluation Data

Table 7

Data Matrix for Statistical Analysis Based on
Age at Failure Rating of 3.0 for General Appearance

Section Ident.	Line Identification 1	2	3	4	5	6	Avg.
ASPHALT							
	Missouri Dispersion Resin-Varnish Paints						
BY	11.00	11.00	11.00	11.00	11.00	11.00	11.00
BW	12.00	11.75	11.75	11.75	11.75	11.75	11.79
	Missouri Chlorinated Rubber-Alkyd Paints						
DY	14.00	14.00	14.00	14.00	14.00	14.00	14.00
DW	13.75	13.50	13.50	13.50	13.50	13.75	13.58
	Special Heated Chlorinated Rubber-Alkyd Paint						
FW	13.50	13.34	13.50	13.72	13.50	13.72	13.47
	High Heat Paints						
GY	15.33	15.20	15.33	15.33	15.33	15.33	15.31
GW	14.80	14.80	14.67	14.80	14.80	14.80	14.78
IY	15.43	15.67	15.67	15.67	15.67	15.67	15.63
IW	14.29	14.29	14.50	14.67	14.67	14.29	14.45
KY	14.40	14.22	14.22	14.22	14.00	14.22	14.21
KW	14.25	14.00	14.25	14.25	14.45	14.25	14.24
MY	12.00	12.00	13.00	13.00	13.00	13.34	12.72
MW	12.57	12.57	12.57	12.75	12.75	12.57	12.63
OY	1.52	1.60	1.52	1.52	1.56	1.52	1.54
OW	11.00	11.00	8.00	9.19	11.00	11.00	10.20
CONCRETE							
	Missouri Dispersion Resin-Varnish Paints						
BY	5.25	5.20	4.54	4.40	4.80	4.88	4.84
BW	6.40	6.40	6.22	6.22	6.22	6.22	6.28
	Missouri Chlorinated Rubber-Alkyd Paints						
DY	9.20	9.20	9.20	9.20	9.20	9.20	9.20
DW	8.35	8.35	8.35	8.35	8.35	8.35	8.35
	Special Heated Chlorinated Rubber-Alkyd Paint						
FW	9.20	9.20	9.04	9.04	9.04	9.04	9.09
	High Heat Paints						
GY	9.62	9.62	9.62	9.62	9.62	9.71	9.64
GW	10.30	10.30	10.30	11.00	11.00	11.00	10.65
IY	5.64	5.64	5.64	6.00	5.50	5.50	5.65
IW	8.00	8.00	8.00	8.00	8.00	7.45	7.91
KY	10.00	10.00	10.00	11.00	11.00	11.00	10.50
KW	8.74	8.74	5.46	5.75	5.60	4.43	6.45
MY	6.55	7.20	7.30	7.38	7.30	7.30	7.17
MW	3.10	3.10	1.65	1.65	1.65	1.56	2.12
OY	1.40	1.40	1.40	1.40	1.40	1.40	1.40
OW	1.40	1.40	1.40	1.40	1.40	1.40	1.40

Table 8

Data Matrix for Statistical Analysis Based on
Age at Failure Rating of 4.0 for General Appearance

Section Ident.	Line Identification 1	2	3	4	5	6	Avg.
ASPHALT							
	Missouri Dispersion Resin-Varnish Paints						
BY	9.50	9.50	9.50	9.50	9.50	9.50	9.50
BW	11.00	11.00	11.00	11.00	11.00	11.00	11.00
	Missouri Chlorinated Rubber-Alkyd Paints						
DY	12.80	12.80	12.80	12.80	12.80	12.80	12.80
DW	13.00	12.75	12.75	12.75	12.75	12.86	12.81
	Special Heated Chlorinated Rubber-Alkyd Paint						
FW	12.75	12.67	12.75	12.86	12.75	12.86	12.77
	High Heat Paints						
GY	14.67	14.60	14.67	14.67	14.67	14.67	14.66
GW	14.20	14.20	14.00	14.20	14.20	14.20	14.17
IY	14.57	14.67	14.67	14.67	14.67	14.67	14.65
IW	13.45	13.45	14.00	14.22	14.22	13.34	13.78
KY	13.50	13.20	13.00	13.20	12.80	13.20	13.15
KW	13.33	13.00	13.33	13.33	13.60	13.20	13.30
MY	9.19	9.19	9.19	10.00	10.00	10.00	9.60
MW	11.60	11.60	11.60	12.00	12.00	11.00	11.63
OY	1.30	1.37	1.30	1.30	1.33	1.30	1.32
OW	7.00	6.40	5.72	6.40	7.16	7.01	6.62
CONCRETE							
	Missouri Dispersion Resin-Varnish Paints						
BY	4.75	4.66	3.81	3.63	4.00	4.00	4.14
BW	5.71	5.71	5.53	5.60	5.60	5.60	5.62
	Missouri Chlorinated Rubber-Alkyd Paints						
DY	8.00	8.00	8.00	8.00	8.00	8.00	8.00
DW	6.00	6.00	6.00	5.80	5.64	5.64	5.85
	Special Heated Chlorinated Rubber-Alkyd Paint						
FW	8.48	8.48	8.26	8.26	8.26	8.26	8.33
	High Heat Paints						
GY	8.92	8.92	8.92	8.92	8.92	9.07	8.94
GW	8.93	8.93	8.93	9.20	9.50	9.50	9.22
IY	4.91	4.91	4.91	5.11	4.83	4.83	4.92
IW	7.11	7.20	7.27	7.11	7.11	6.62	7.07
KY	8.00	8.00	8.00	9.20	9.20	9.20	8.60
KW	4.72	4.72	4.73	4.75	4.80	3.86	4.60
MY	5.69	6.00	6.26	6.46	6.26	6.26	6.16
MW	2.70	2.70	1.41	1.41	1.41	1.33	1.83
OY	1.20	1.20	1.20	1.20	1.20	1.20	1.20
OW	1.20	1.20	1.20	1.20	1.20	1.20	1.20

Table 9

Notation for Statistical Tables

These symbols will be used in the following tables:

DF = Degrees of freedom

SS = Sum of squares of residuals

MS = Average mean square (SS/DF)

F = Ratio of two mean squares (two variances)

α = Probability level of significance of the test

K = Kind of paint

C = Color of paint

R = Residual or pooled effects of the individuals or duplicates

S = Significant

HS = Highly Significant

NS = Not Significant

$k_{.01} = k^*_{.01}\sqrt{MS_R \div df}$ from Engineering Statistics by Albert J. Bowker and Gerald J. Lieberman, page 298

$k^*_{.01}$ = A percentile of the Studentized Range for .01 level of significance

df = The number of observations used to compute each mean value being compared.

Significant = In testing significance a value below the 5% level will be considered not significant, a value between the 5% and 1% level of questionable significance, a value between 1% and 0.1% level as significant, and a value above 0.1% as being highly significant.

Table 10

Analysis of Variance Between Kind and Color of Paint for Each General Appearance Rating for Each Pavement Type

Source	DF	SS	MS	F	α	S	Color Ranking	Kind Ranking	Kind Avg.
a. Asphalt Pavement - Rating 3.0									
K	6	752.96	125.49	822.83	.001	HS	White	G	15.0
C	1	22.56	22.56	147.89	.001	HS	Yellow	I	15.0
KC	6	209.80	34.97	229.27	.001	HS		K	14.2
R	70	10.68	0.15					C.R.	13.8
Total	83	996.00	12.00					M	12.7
				$k_{.01} = 0.6$*				Mo.Std.	11.4
								O	5.9
b. Asphalt Pavement - Rating 4.0									
K	6	954.04	159.01	2456.92	.001	HS	White	G	14.4
C	1	24.95	24.95	385.48	.001	HS	Yellow	I	14.2
KC	6	81.56	13.59	210.04	.001	HS		K	13.2
R	70	4.53	0.06					C.R.	12.8
Total	83	1065.08	12.83					M	10.6
				$k_{.01} = 0.4$*				Mo.Std.	10.2
								O	4.0
c. Concrete Pavement - Rating 3.0									
K	6	632.98	105.50	315.42	.001	HS	Yellow	G	10.1
C	1	11.79	11.79	35.24	.001	HS	White	C.R.	8.8
KC	6	140.64	23.44	70.08	.001	HS		K	8.5
R	70	23.41	0.33					I	6.8
Total	83	808.82	9.74					Mo.Std.	5.6
				$k_{.01} = 0.8$*				M	4.6
								O	1.4
d. Concrete Pavement - Rating 4.0									
K	6	447.10	74.52	700.76	.001	HS	Yellow	G	9.1
C	1	18.83	18.83	177.07	.001	HS	White	C.R.	6.9
KC	6	120.02	20.00	188.11	.001	HS		K	6.6
R	70	7.44	0.11					I	6.0
Total	83	593.39	7.15					Mo.Std.	4.9
				$k_{.01} = 0.5$*				M	4.0
								O	1.2

* Difference in means required to indicate a significant difference.

Table 11

Analysis of Variance Between Kinds of Paint for White and Yellow Colors for Each Pavement Type for General Appearance Rating of 3.0

Source	DF	SS	MS	F	α	S	Kind Ranking	Kind Avg.
a. Asphalt Pavement - White Paints								
K	6	99.17	16.53	65.07	.001	HS	G	14.8
R	35	8.88	0.25				I	14.4
Total	41	108.05	2.64				K	14.2
							C.R.	13.6
							M	12.6
				$k_{.01} = 1.1$*			Mo.Std.	11.8
							O	10.2
b. Asphalt Pavement - Yellow Paints								
K	6	863.59	143.93	2767.90	.001	HS	I	15.6
R	35	1.80	0.05				G	15.3
Total	41	865.39	21.11				K	14.2
							C.R.	14.0
							M	12.7
				$k_{.01} = 0.5$*			Mo.Std.	11.0
							O	1.5
c. Concrete Pavement - White Paints								
K	6	402.63	67.11	113.55	.001	HS	G	10.6
R	35	20.69	0.59				C.R.	8.4
Total	41	423.32	10.32				I	7.9
							K	6.4
							Mo.Std.	6.3
				$k_{.01} = 1.7$*			M	2.1
							O	1.4
d. Concrete Pavement - Yellow Paints								
K	6	370.98	61.83	792.69	.001	HS	K	10.5
R	35	2.74	0.08				G	9.6
Total	41	373.72	9.11				C.R.	9.2
							M	7.2
							I	5.6
				$k_{.01} = 0.6$*			Mo.Std.	4.8
							O	1.4

* Difference in means required to indicate a significant difference.

Figure 6 - General Appearance of Stripes on Asphaltic Concrete Test Deck.

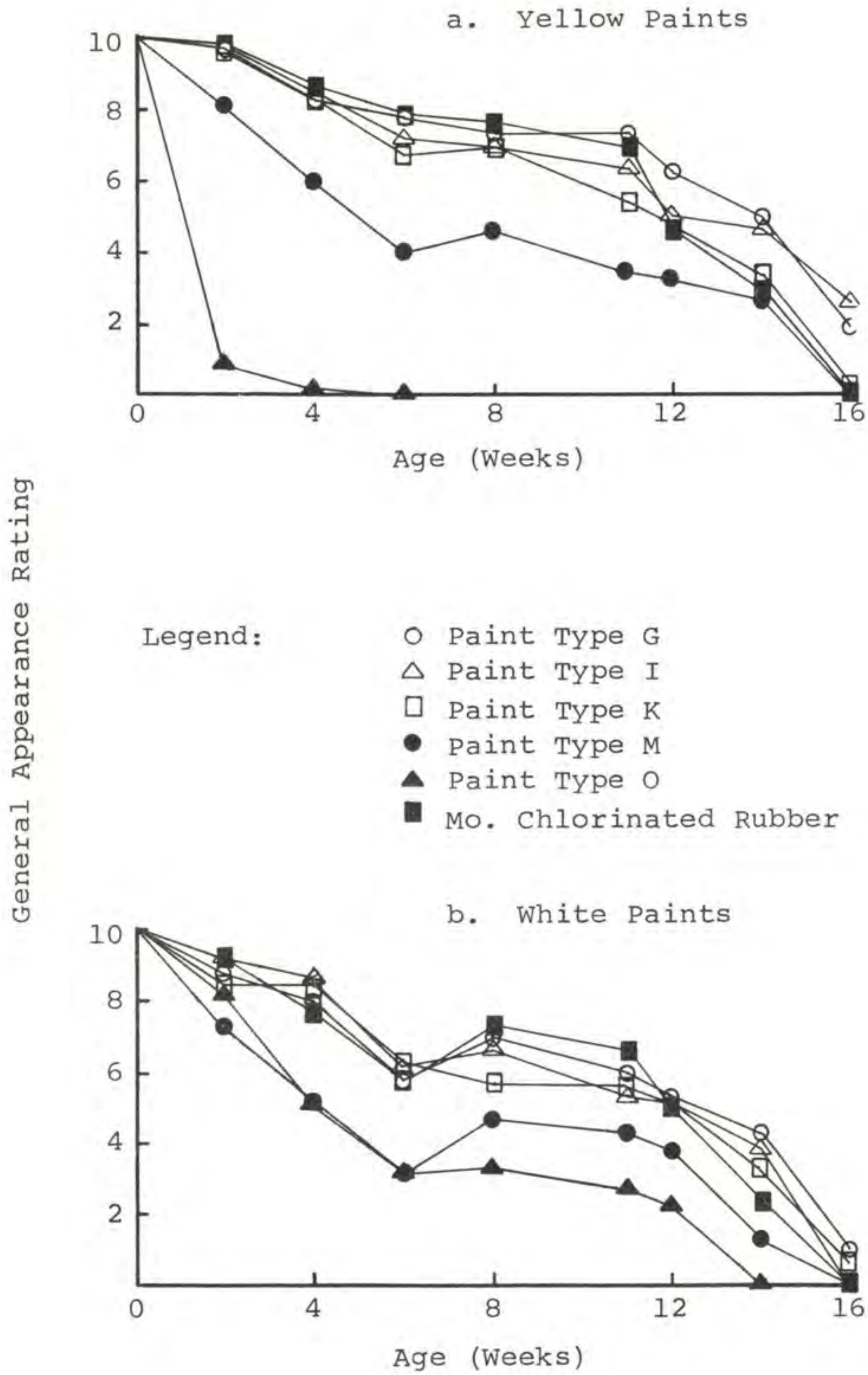


Figure 7 - General Appearance of Stripes on Concrete Test Deck.

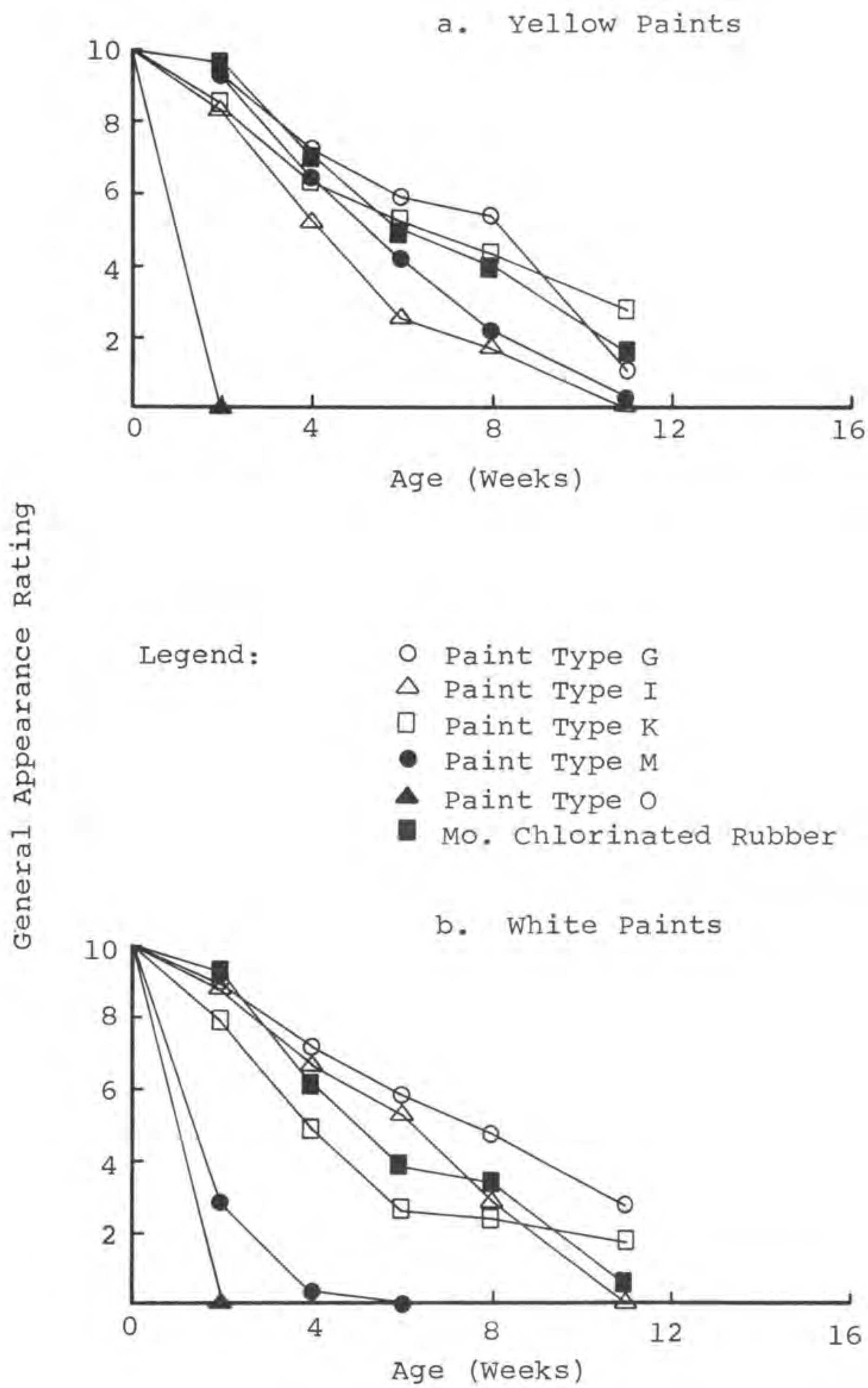
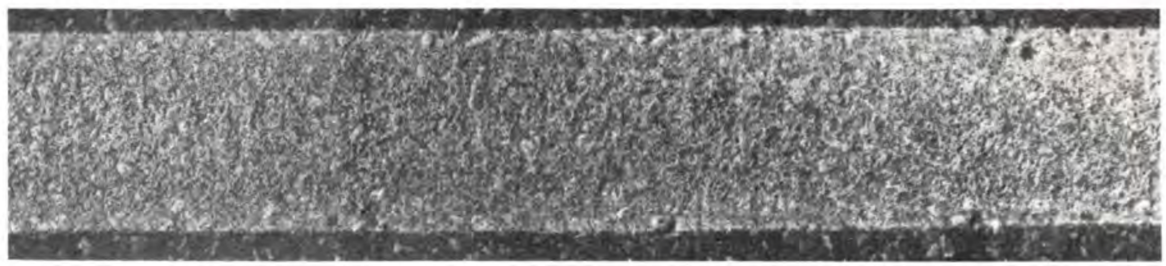


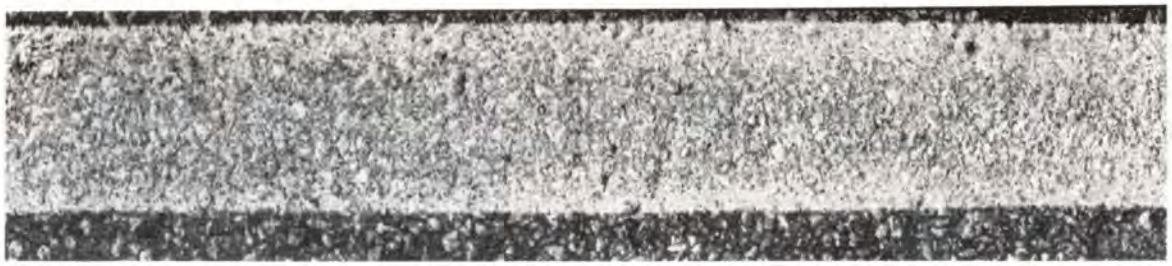
Figure 8a - Photographic Record of Missouri Dispersion Resin-Varnish, White, Paint on Asphaltic Concrete Pavement

Date: 10-14-70 Average Appearance Rating: 10.0

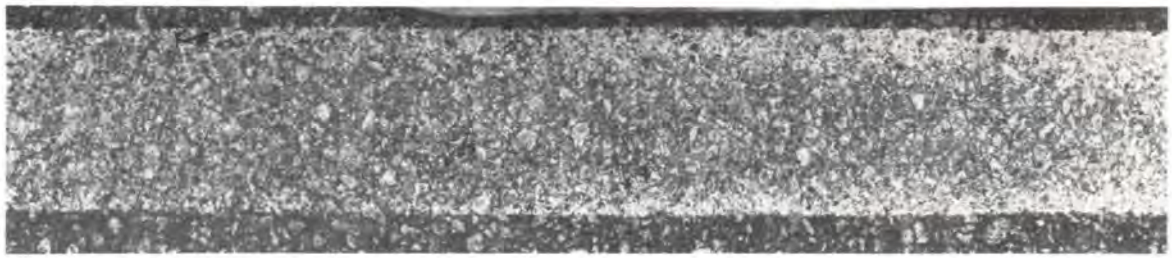


Date: 10-28-70 Average Appearance Rating: 7.7

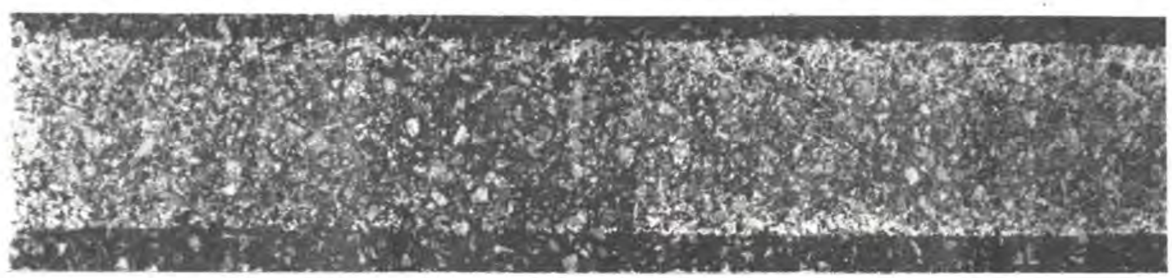
Date: 11-12-70 Average Appearance Rating: 6.1



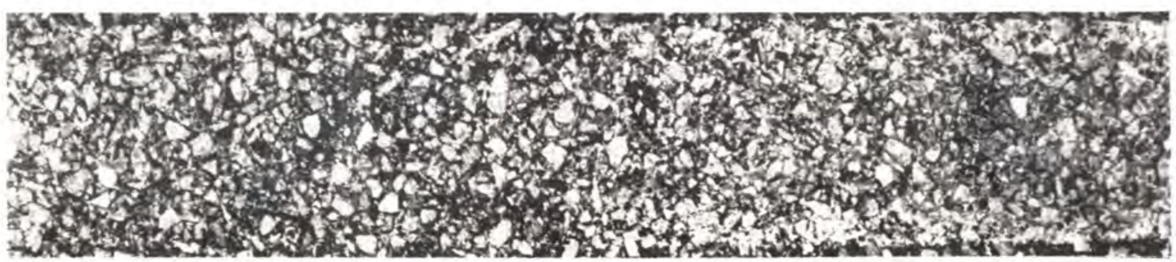
Date: 11-25-70 Average Appearance Rating: 6.0



Date: 12-16-70 Average Appearance Rating: 4.0

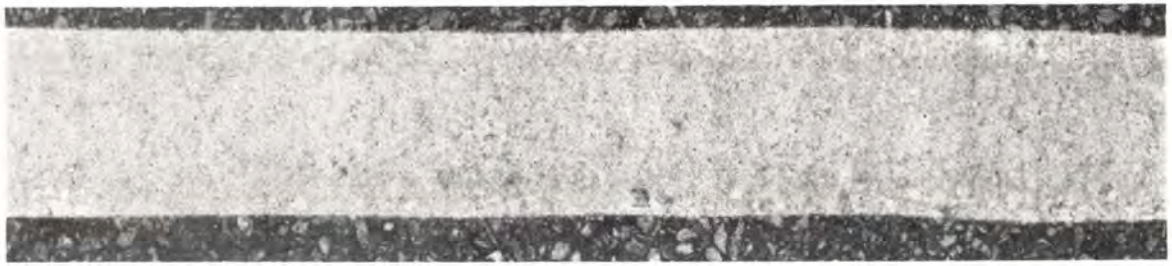


Date: 12-22-70 Average Appearance Rating: 2.7

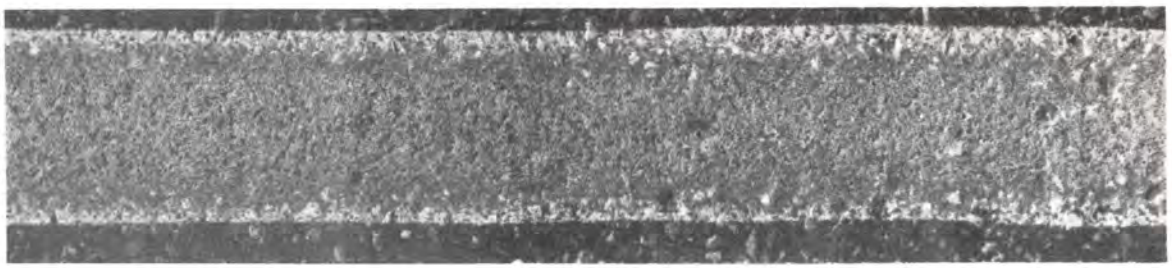


Date: 1-4-71 Average Appearance Rating: 0.7

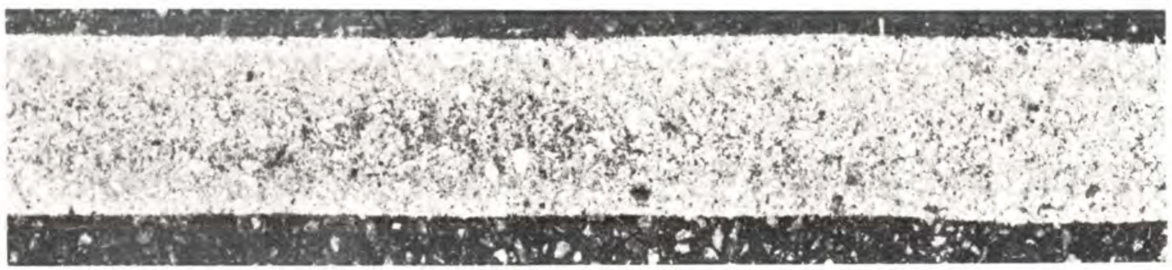
Figure 8b - Photographic Record of Missouri Chlorinated Rubber-Alkyd, White, Paint on Asphaltic Concrete Pavement



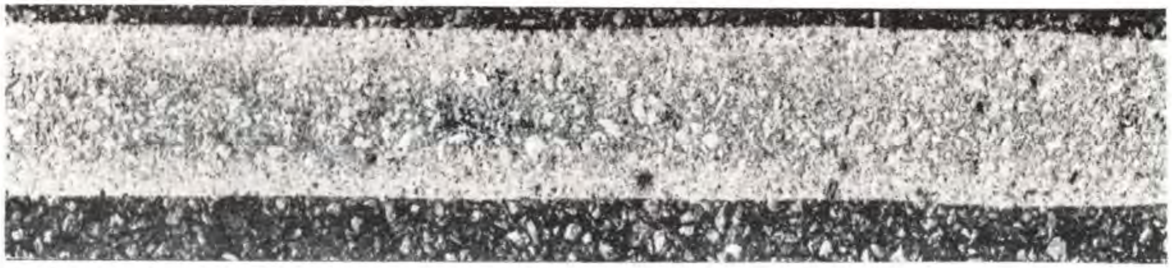
Date: 10-14-70 Average Appearance Rating: 9.2



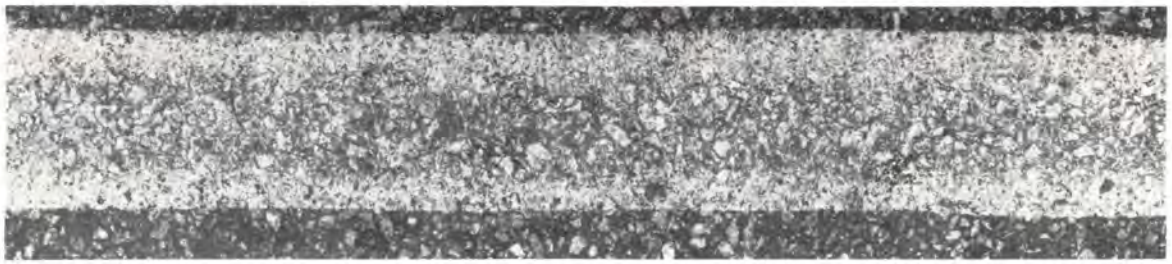
Date: 10-28-70 Average Appearance Rating: 7.8



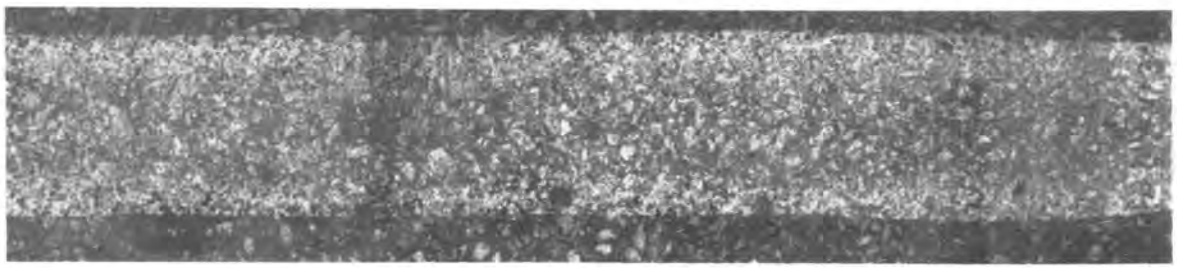
Date: 11-12-70 Average Appearance Rating: 5.8



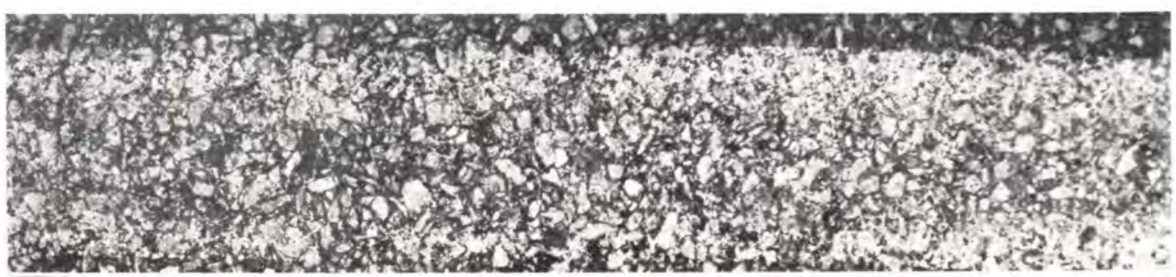
Date: 11-25-70 Average Appearance Rating: 7.3



Date: 12-16-70 Average Appearance Rating: 6.6



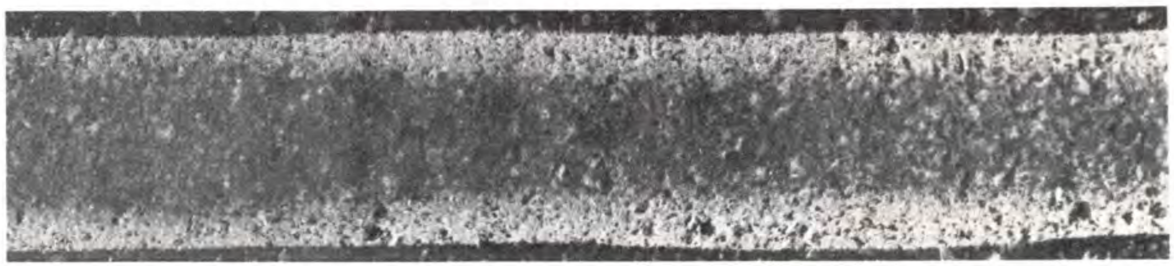
Date: 12-22-70 Average Appearance Rating: 5.0



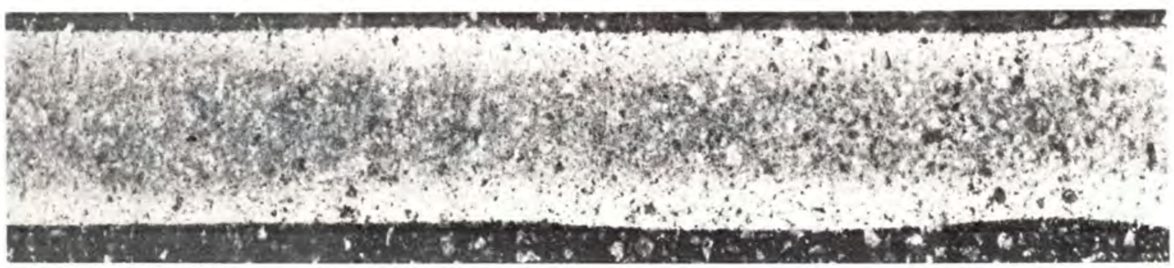
Date: 1-4-71 Average Appearance Rating: 2.4

Figure 8c - Photographic Record of High Heat Paint Type "G", White, on Asphaltic Concrete Pavement

Date: 10-14-70 Average Appearance Rating: 8.8

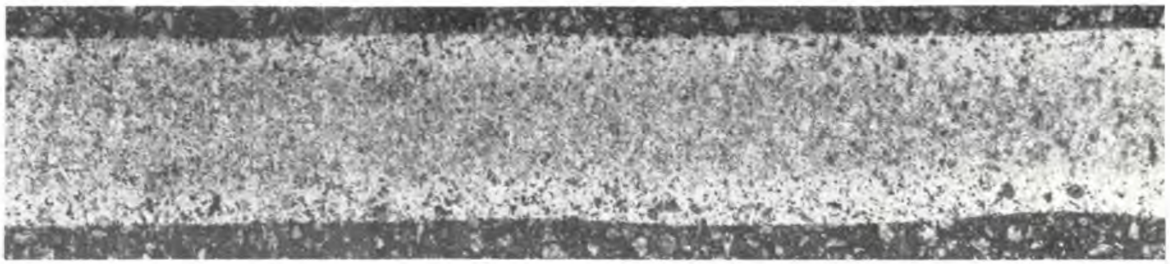


Date: 10-28-70 Average Appearance Rating: 8.0

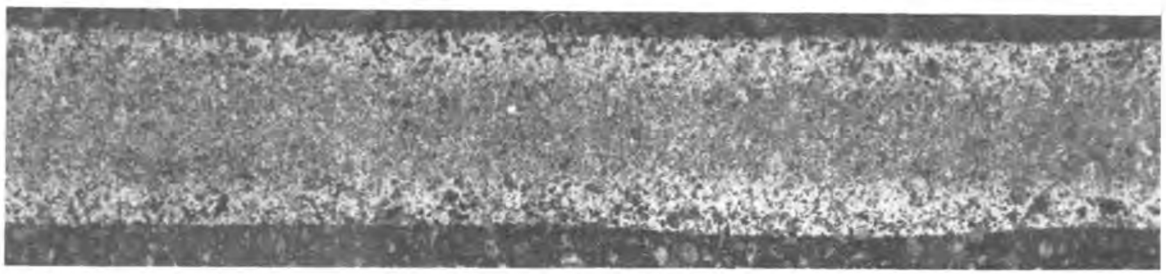


Date: 11-12-70 Average Appearance Rating: 5.8

Date: 11-25-70 Average Appearance Rating: 7.0



Date: 12-16-70 Average Appearance Rating: 6.0



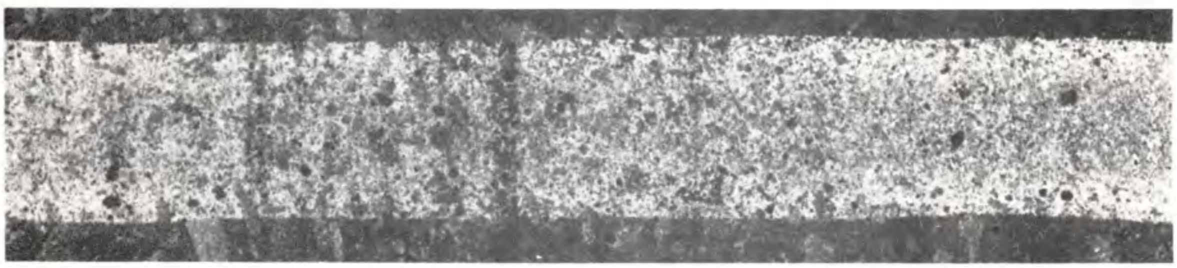
Date: 12-22-70 Average Appearance Rating: 5.3

Date: 1-4-71 Average Appearance Rating: 4.3

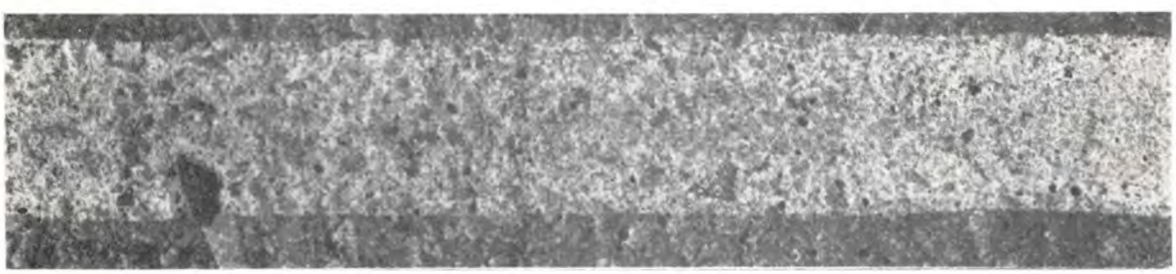
Figure 9a - Photographic Record of Missouri Dispersion Resin-Varnish, White, Paint on Concrete Pavement

Date: 10-14-70 Average Appearance Rating: 9.6

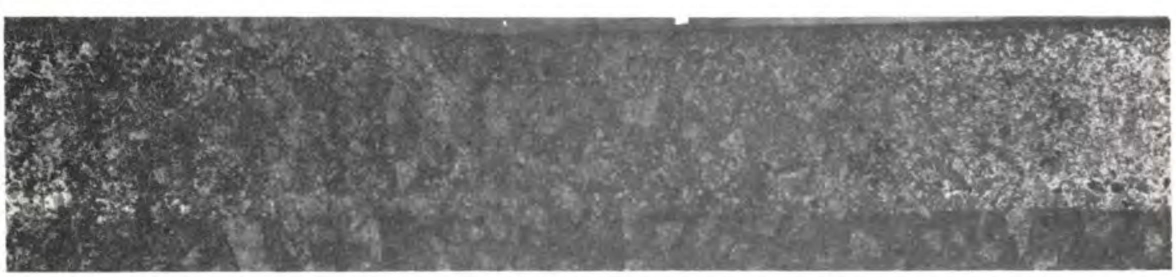
Date: 10-28-70 Average Appearance Rating: 6.9



Date: 11-12-70 Average Appearance Rating: 3.3



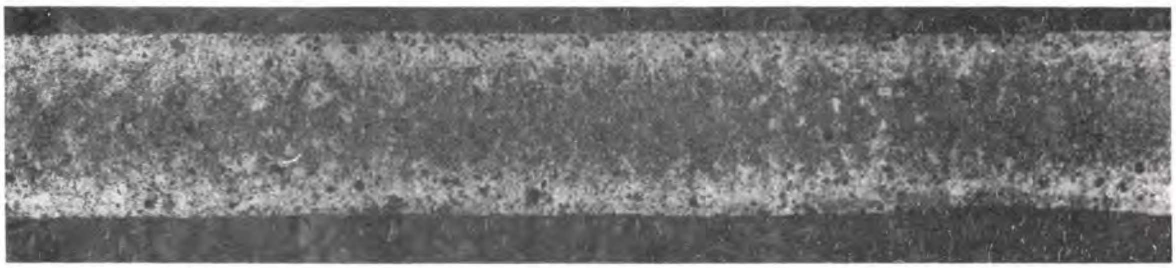
Date: 11-25-70 Average Appearance Rating: 1.0



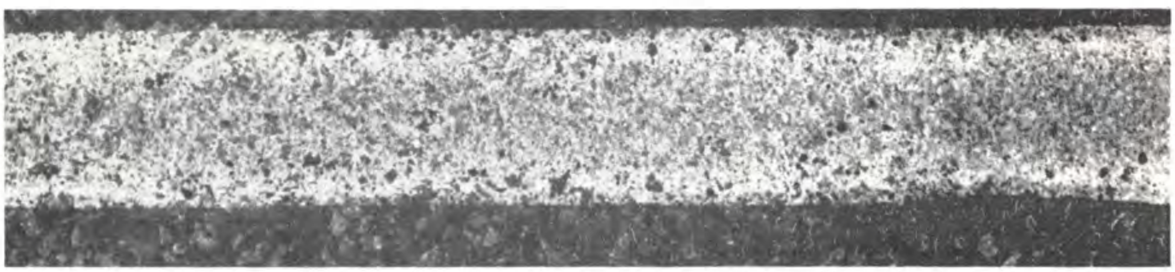
Date: 12-16-70 Average Appearance Rating: 0

Figure 9b - Photographic Record of Missouri Chlorinated Rubber-Alkyd, White, Paint on Concrete Pavement

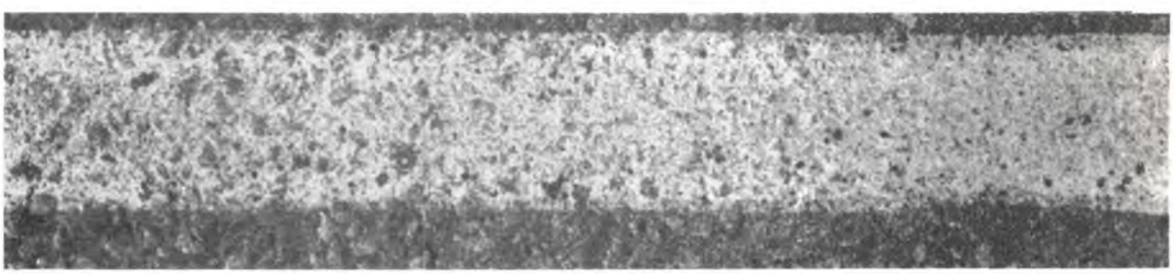
Date: 10-14-70 Average Appearance Rating: 9.3



Date: 10-28-70 Average Appearance Rating: 6.2



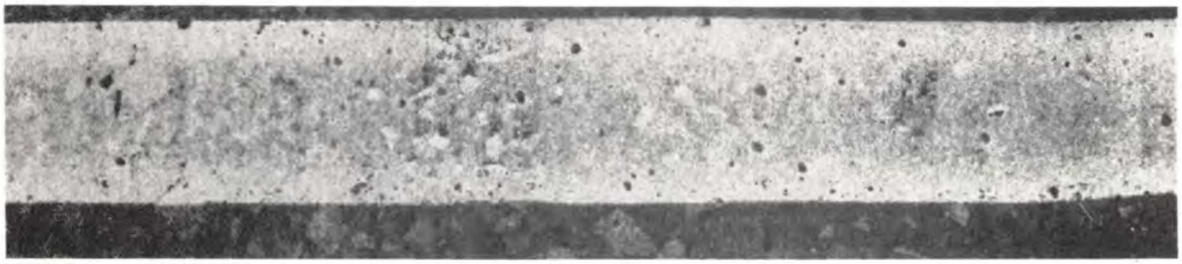
Date: 11-12-70 Average Appearance Rating: 3.8



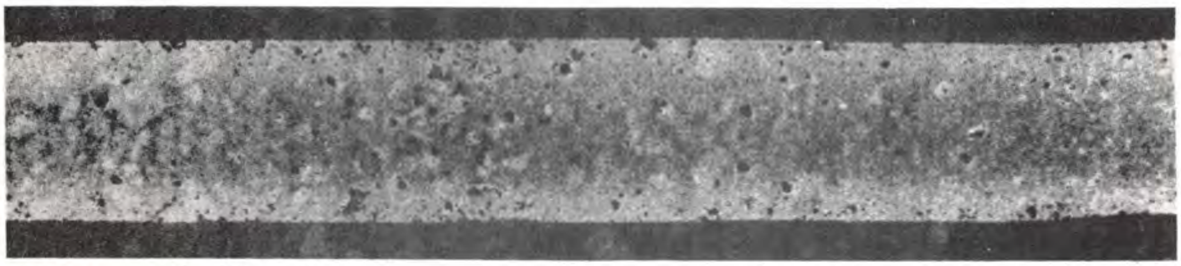
Date: 11-25-70 Average Appearance Rating: 3.3

Date: 12-16-70 Average Appearance Rating: 0.5

Figure 9c - Photographic Record of High Heat Paint Type "G", White, on Concrete Pavement

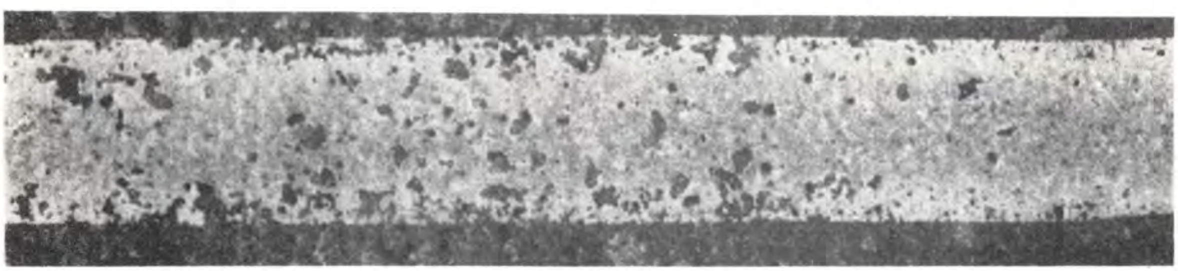


Date: 10-14-70 Average Appearance Rating: 9.0

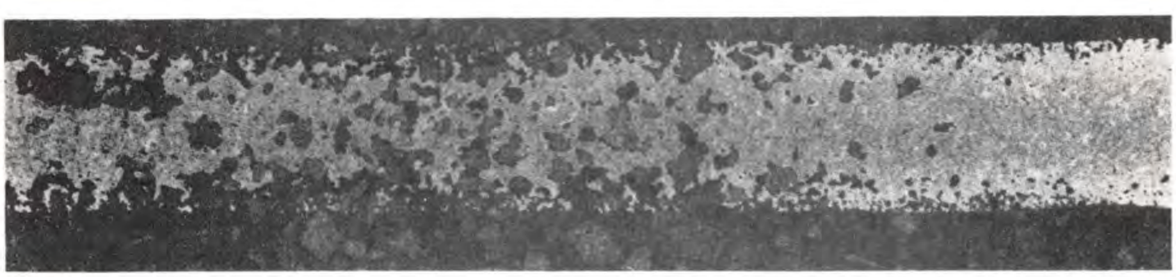


Date: 10-28-70 Average Appearance Rating: 7.2

Date: 11-12-70 Average Appearance Rating: 5.9



Date: 11-25-70 Average Appearance Rating: 4.8



Date: 12-16-70 Average Appearance Rating: 2.8

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