Traffic Paint Performance in Accelerated-Wear Tests

JAMES E. BRYDEN AND RONALD A. LORINI

Accelerated-wear tests of traffic paints on portland cement concrete and asphalt-concrete pavements are described. Installation and performance of several paints, including chlorinated rubber and chlorinated rubber-alkyd, alkyd, acrylic and alkyd-acrylic, epoxy, and water-based paints, are discussed. Durability and appearance ratings provided reliable indications of paint performance, but reflectivity ratings were extremely variable. Chlorinated rubber paint provided the best service life, but also had the longest drying time, averaging more than 3 min.

In 1981 the New York State Department of Transportation initiated a study to compare the durability of candidate pavement-marking materials—both paints and more durable materials—through accelerated-wear tests. In this paper the performance of 125 sets of traffic paint stripes installed between 1981 and 1983 is described. The performance of the more durable markings evaluated in this project will be reported separately. The purpose of this evaluation was to identify traffic paints that offer improved durability compared with that of New York State standard traffic paints. The general goal was to select for in-field evaluation paints that could provide year-round delineation on at least part of the state highway system.

INVESTIGATION

Test Sites and Test Section Layout

Two test sites were used in this study—the Washington Avenue Extension in the city of Albany and Wolf Road in the town of Colonie. The former is a four-lane divided portland cement concrete pavement (PCCP) with a 10-ft shoulder on the right and a raised curbed median. Lane widths are 12 ft, and the 1984 two-way annual average daily traffic (AADT) was 17,400 vehicles. This highway has partial access control, with signalized intersections and no midblock access. The test site was located in a long tangent section of the eastbound driving lane.

Wolf Road is a four-lane highway with asphalt-concrete pavement (ACP), a 16-ft flush median, and a curb adjacent to the driving lane. Lane widths are 15 ft for the driving lane and 12 ft for the passing lane. This highway has unlimited access, with numerous commercial driveways and intersections. The 1984 two-way AADT was 24,500 vehicles. Test stripes were installed in several tangent sections of the southbound driving lane, again located to eliminate the effects of turning and slowing traffic. Both pavements were constructed in 1970 and were in good condition at the time of this test.

Seven lines were installed for each set of test stripes—six 10-ft long longitudinal and one transverse stripe across the lane at the upstream end of the longitudinal lines (Figure 1). Two lines of each set were located in the apparent wheelpath; the other four were spaced across the lane. This layout was thought to offer several advantages over a test layout consisting of transverse stripes:

1. The longitudinal orientation of the test stripes was similar to that for normal pavement markings, so that wear patterns would more directly reflect those of in-service markings. This is especially critical because in winter months, snowplow use may cause abnormal wear on the leading edges of transverse stripes.
2. The 10-ft test stripes provide a much larger sample on which to base durability observations. Wheelpath wear zones on transverse stripes are limited to a few inches of the line.
3. The different locations of the longitudinal lines within the lane provide multiple exposure levels within each set of test stripes. This was considered desirable to compare the effects of abnormally high wear in the wheelpath during the winter months with those of more typical wear outside the wheelpath.

For most paints, both white and yellow were used on both PCCP and ACP. In some cases, duplicate test stripes were installed because the first set was not considered satisfactory. In addition, several sets of the standard state traffic paints were installed as controls each year by the various participants in the program.

FIGURE 1 Typical completed stripe sets.

Engineering Research and Development Bureau, New York State Depanment of Transportation, State Campus, Albany, N.Y. 12232.

Installation Procedures

Most test stripes were installed during July and August 1981, 1982, and 1983 by several paint and paint component manufacturers and by state personnel. Most stripes were installed with portable walk-behind stripers, but a few sets were installed with a state truck-mounted striper. Adequate work areas were available alongside each test area on which practice lines could be laid on tar paper or similar material to obtain the desired adjustments in wet-film thickness, bead-application rates, material temperature, and line appearance. Once the desired line quality had been achieved, the seven test lines were placed on the pavement.

Installation of all test lines was monitored by research personnel to obtain information on handling characteristics of the various materials and to ensure uniformity among the test stripes to the greatest extent possible. Information obtained during installation included application rate, material temperature and climatic condition, material drying time, and initial reflectivity.

Evaluation Procedures

In periodic surveys, stripes were rated for durability, appearance, and reflectivity. During good weather, evaluations were conducted monthly, but during the winter the interval varied, depending on snow, ice, and dirt accumulation on the pavement and on air temperature. The following procedures were used to evaluate stripe condition:

1. Durability was evaluated with ASTM D 821-47 (Evaluating Degree of Abrasion, Erosion, or a Combination of Both, in Road Service Tests of Traffic Paints) and D 913-51 (Evaluating Degree of Chipping of Traffic Paint). A single rating on a scale of 0 to 10 (10 is perfect and 0 is complete line loss) was assigned to each of the six longitudinal stripes. The lower of the abrasion or chipping ratings was used to indicate condition, and the controlling wear mode was noted. Typical ratings are shown in Figures 2–5.

2. ASTM D 713-69 (Conducting Road Service Tests on Traffic Paint) was used to rate appearance. A separate rating was assigned to each longitudinal line.

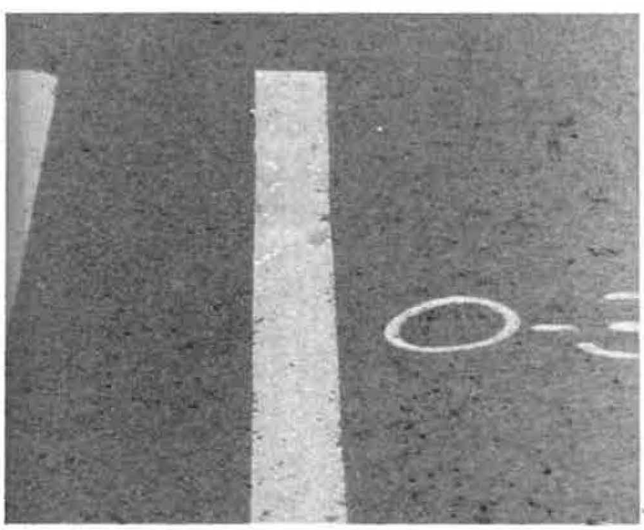

FIGURE 2 Paint stripe rated 9.

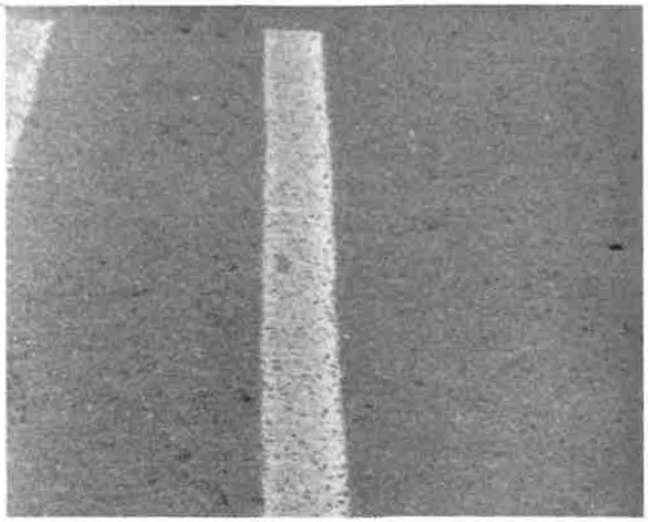

FIGURE 3 Paint stripe rated 6.

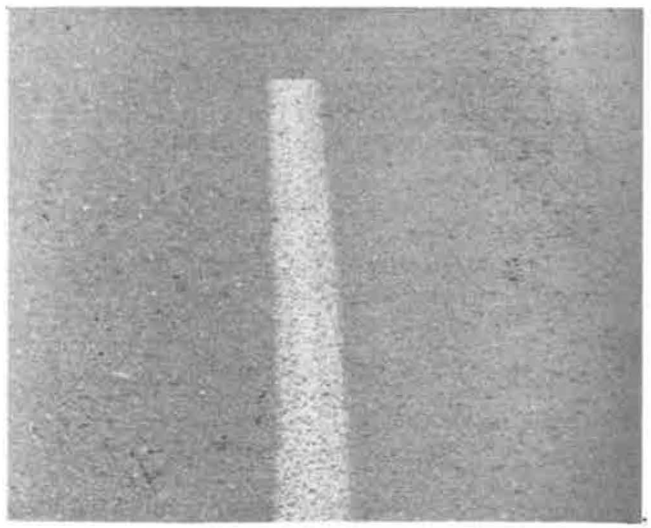

FIGURE 4 Paint stripe rated 4.

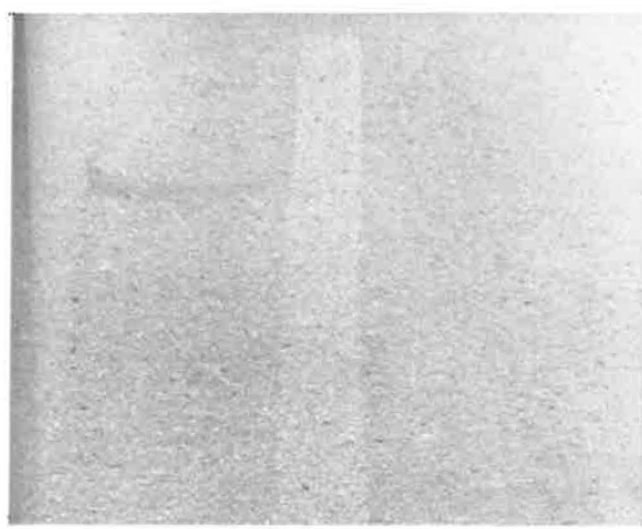

FIGURE 5 Paint stripe rated 1.

3. A reflectometer patterned after a device developed by the Michigan Department of Transportation and described in detail in an earlier research report *(1)* measured reflectivity. Five reflectivity measurements were made along the length of each longitudinal line, and six measurements were made on each transverse line where it intersected the longitudinal lines. An average brightness value was then computed for each line.

4. On the basis of results of the periodic surveys, service life was determined for each of the six longitudinal stripes in terms of each of the three evaluation criteria—durability, appearance, and reflectivity. For durability and appearance, the failure level was set at a rating of 5. For reflectivity, the failure level was 140 for white and 110 for yellow. To determine the exact length of service life in days, a straight-line interpolation was performed between the two surveys on either side of the failure point.

Materials Evaluated

A total of 125 sets of test stripes were installed; 29 formulas from 7 resin types were used. The control plants were New York State standard modified-alkyd paints with nominal drying times of 20 or 60 sec when applied at 140°F. Table 1 gives a description of the 29 paint formulas. Selection of traffic paints for this evaluation was based on recommendations of the suppliers and manufacturers participating. A total of 17 firms were solicited for participation. The criterion used to select materials for inclusion was either that a paint be commercially available (i.e., operational) at the time of installation or that the manufacturer consider the product to offer improved performance compared with paints then commercially available and that it become operational in the immediate future.

RESULTS

One of the earliest decisions necessary in analysis of the study results was the grouping of the six longitudinal stripes into wear-severity levels. Examination of the raw survey data revealed that the PCCP site fell into three levels—Stripes 2 and 5 experienced the most rapid wear, which was termed the "wheelpath" severity level; Stripes 3 and 6 experienced an intermediate wear rate; and Stripes 1 and 4 experienced the "nonwheelpath" wear rate. On the ACP site, the wheelpath was less clearly defined, and Stripes 2, 3, 5, and 6 all experienced essentially equal wear rates, termed the "wheelpath" rate. Stripes 1 and 4 wore at a slower rate, termed the "nonwheelpath" rate. Table 2 summarizes the effect of lane position on service life for each of the three evaluation criteria. A paired *t*-test was used to compare differences among lane positions (wear severity levels), and all the differences among severity levels in Table 2 were found to be significant at the 95 percent

TABLE 2 EFFECT OF LANE POSITION OF STRIPE ON SERVICE LIFE

	PCCP*			ACP*	
Evaluation Criteria	WP	INT	NWP	WP	NWP
Durability					
Average Life, days	129	146	264	155	205
Std Deviation, days	29	33	150	60	132
Sample Size	60	60	60	65	65
Appearance					
Average Life, days	126	139	226	148	179
Std Deviation, days	27	30	127	65	108
Sample Size	60	60	60	65	65
Reflectivity					
Average Life, days	124	129	158	96	102
Std Deviation, days	34	36	57	44	51
Sample Size	60	60	60	65	65

*WP = wheelpath (Stripes 2 and 3 in Fig. 1), INT = intermediate (Stripes 3 and 6), NWP = non-wheelpath (Stripes 1 and 4).

NOTE: All differences among wheelpath means are statistically significant at 95-percent confidence when tested using paired comparison.

TABLE 1 DESCRIPTION OF PAINTS TESTED

Formula	Resin Type	Mfr	Appl	Derivation	Solvent
1	Acrylic	3	3	Experimental	Toluene
2	Acrylic	3	3	Experimental	Toluene
3	Alkyd	3	2,3	NY 20-Second	Toluene
4	Alkyd	8	2	Ind. Standard	Toluene
5	Alkyd	8	2	Md. Standard	Toluene
6	Alkyd	3	3	Experimental	Toluene
7	Alkyd	8	8	Ky. Standard	Toluene
8	Alkyd	3	9,2	NY 60-Second	Toluene
9	Alkyd	3	1	NY Cold-Applied	Toluene
10	Alkyd	8	2,3	NY 60-Second	Toluene
11	Alkyd-Acrylic	5	2	Calif. Standard	Toluene
12	Chlorinated Rubber-Alkyd	8	8	Penn. Standard	MEK
13	Chlorinated Rubber-Alkyd	2	2	NJ Modified	Toluene
14	Epoxy	9	9	Commercial	MEK
15	Epoxy	7	1	Commercial	MEK
16	Chlorinated Rubber	4	2	Texas Standard	MEK
17	Chlorinated Rubber	4	2	Ill. Standard	MEK
18	Chlorinated Rubber	4	2	NJ Standard	MEK
19	Chlorinated Rubber	3	3	Experimental	MEK
20	Chlorinated Rubber	2	2	Wyo. Standard	MEK
21	Chlorinated Rubber	2	2	NJ Modified	MEK
22	Chlorinated Rubber	2	2	NJ Modified	MEK
23	Chlorinated Rubber	3	3	Experimental	MEK
24	Chlorinated Rubber	2	2	NJ High-Viscosity	MEK
25	Chlorinated Rubber	2	2	Ill. Modified	MEK
26	Water-Based	3	3	Experimental	Water
27	Water-Based	3	3	Experimental	Water
28	Water-Based	3	3	Experimental	Water
29	Water-Based	3	3	Experimental	Water

confidence level. Service life in terms of reflectivity varied only slightly between the wheelpath and nonwheelpath positions of the stripes. The differences in appearance were somewhat more pronounced, and in durability, the nonwheelpath stripes lasted much longer than those in the wheelpath. It is also apparent that differences in service lives were greater on PCCP than on ACP.

Service lives for all 125 sets of stripes are summarized in Figure 6 for each of the three evaluation criteria and wear severity levels. For the wheelpath and intermediate severity levels, most paints tested provided service lives between 90 and 180 days (3 to 6 months) regardless of the evaluation criterion used, and only a small number of paints survived beyond 6 months. For the nonwheelpath severity level, average service lives were somewhat higher, and the service lives of several paints were considerably longer than 6 months. However, these extended service lives were experienced primarily in durability and appearance, whereas in reflectivity, service lives for the nonwheelpath severity level were only slightly longer than those for the wheelpath and intermediate levels.

Figure 7 demonstrates typical differences between service lives observed for wheelpath and nonwheelpath severity levels. The durability ratings for three typical paints are shown over the entire evaluation period; ratings for wheelpath and nonwheelpath positions shown separately. Two important concepts are demonstrated in this figure. First, wear rates accelerated dramatically at the beginning of winter for all three paints at both wheelpath and nonwheelpath severity levels. Second, wheelpath stripes were more affected by the onset of winter weather than were nonwheelpath stripes.

Although substantial differences in service life were observed in these wear tests, the differences observed were highly dependent on the evaluation criteria used to measure service life and severity of wear. It is hoped that much of the difference in service life relates to the material formulas tested, but a number of other parameters could also affect service life. These must be examined to assess the observed service life differences. The effects of these parameters, as well as the differences among paint formulas, are discussed in the following sections.

Winter Severity and Repeatability of Service-Life Estimates

A total of 29 paints of different formulas were installed during the 3 years of this evaluation, but only 7 were installed in more than one year, and the other 22 were installed in the same year. Any effects of differences in severity of weather during winter would be reflected in observed performance differences among paints installed in different years. Table 3 summarizes weather severity over the three winter evaluation periods. Total snowfall accumulation each winter is presented as well as the number of storms with measurable accumulation. The application of salt and abrasives to the pavement during winter maintenance activities affects pavement marking wear. Thus, several small storms may result in more severe wear than one large storm, because more abrasives are applied over a longer period. Likewise, timing of the storms may also affect service life, because storms occurring early in the winter result in rapid

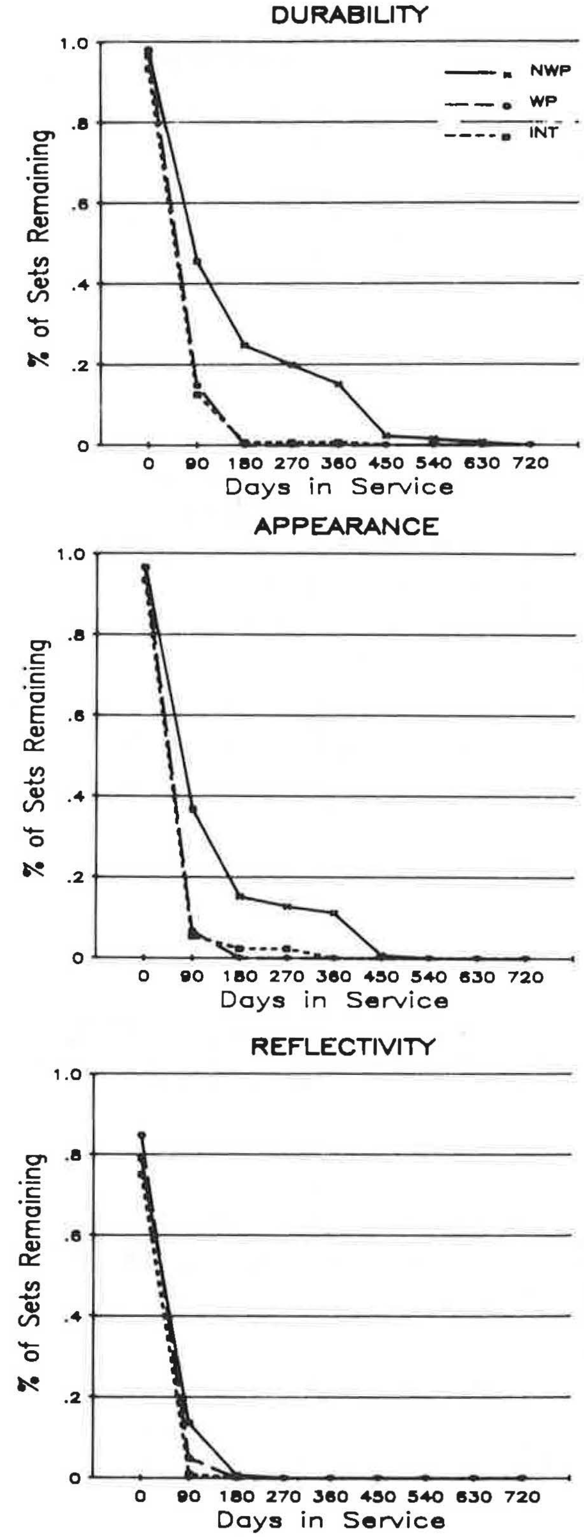

FIGURE 6 Service lives provided at various wear severity levels.

wear earlier in the life of the marking. Thus Table 3 presents storm data for November and December as well as for the entire season.

Examination of Table 3 reveals that weather severity varied greatly among the three winters. The first winter was the most severe, with more frequent storms, higher total accumulation of

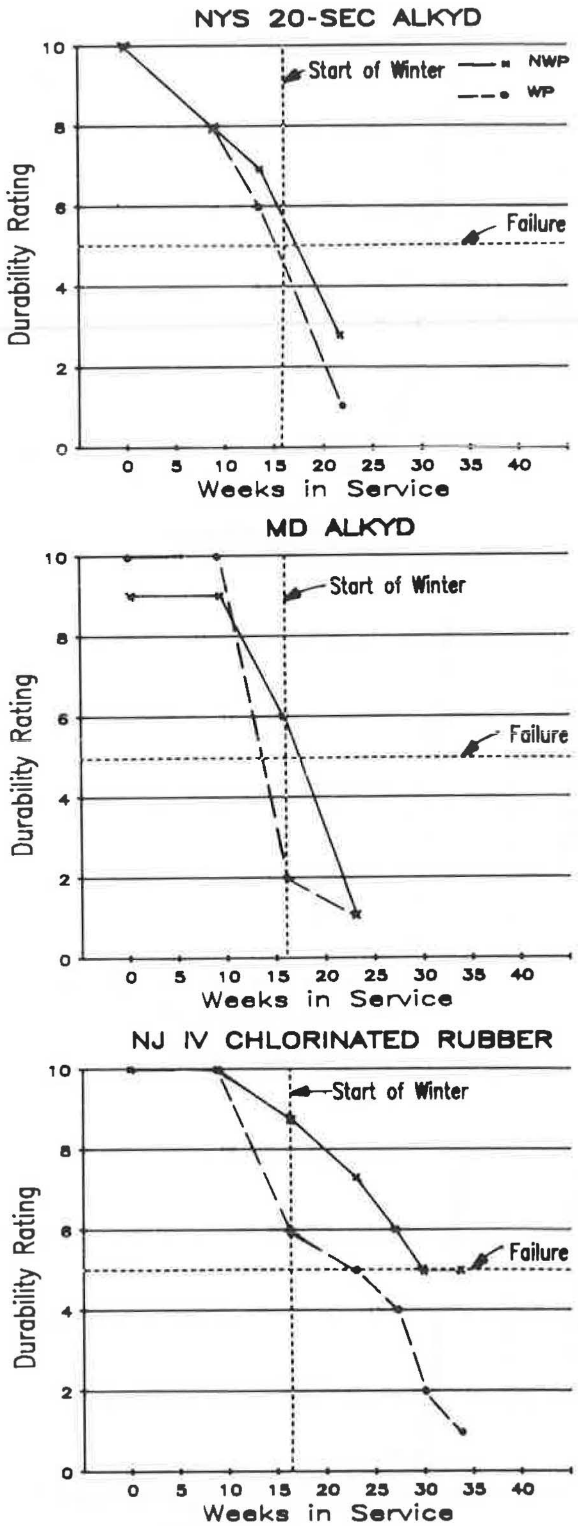

FIGURE 7 Condition of typical stripe sets.

snow, and more storms during the early part of the season. The second winter (1982–1983) appears the least severe. Although total accumulation of snow was greater than in 1983–1984, most of that accumulation resulted from a few major storms occurring late in the season. November and December 1982 were relatively mild, with few storms and little accumulation.

On the basis Table 3, it would be expected that the longest service lives would result for materials installed in 1982 and the shortest for those installed in 1981. The data in Table 4, which gives average service lives of materials installed in each of the three years, can be seen to support this trend in terms of material durability and appearance. Most differences between the years are statistically significant. The trend for reflectivity is less pronounced and relates to differences in weather severity only in the nonwheelpath positions.

TABLE 3 SUMMARY OF SEASONAL SNOWFALL

	Snow Accumulation, in.		Total Storms		Total Storms >6 in.	
Season	Nov. -Dec.	Entire Season	Nov. -Dec.	Entire Season	Nov. -Dec.	Entire Season
1981–82	32.5	96.9	16	44	1	5
1982–83	6.1	75.0	6	24	–	5
1983–84	13.4	65.2	11	38	–	2

TABLE 4 SERVICE LIVES OVER 3 YEARS

	Service Life, days								
	1981			1982			1983		
Evaluation Criteria	x̄	σ	n	x̄	σ	n	x̄	σ	n
Durability									
Wheelpath	128	24	57	163✓	73	44	141✓	20	24
Intermediate	135	26	28	159✓	41	23	143	21	9
Non-Wheelpath	159	65	57	328✓	174	44	235✓*	117	24
Appearance									
Wheelpath	126	23	57	153✓	79	44	136	20	24
Intermediate	134	20	28	146	40	23	140	24	9
Non-Wheelpath	144	31	57	260✓	155	44	231✓	115	24
Reflectivity									
Wheelpath	105	38	57	105	45	44	127✓*	39	24
Intermediate	129	31	28	130	45	23	125	31	9
Non-Wheelpath	111	43	57	139✓	77	44	153✓	52	24

✓ = Significant difference compared to 1981 (95%).
* = Signifieant difference, 1982-83 (95%).

Table 4 thus shows an apparent trend relating observed service lives to winter weather severity. However, different material formulas were used in each of the three years, and the observed differences may thus be related to material properties as well as to weather severity. Consequently, it is necessary to examine observed differences in performance for materials installed in more than one year or for multiple installations within the same year. Comparison of those results would provide a measure of repeatability of the evaluation process. Seven of the 29 formulas were installed in two different years; a total of 20 stripe sets were replicated. Examination of service lives for those 20 pairs reveals considerable variability between years. The variability between repeated stripe sets is summarized in Table 5, which provides the average range (difference in service life between repeated samples) and the relative range (average range divided by average service life for repeated samples) in service life between years and within years. Depending on evaluation criterion and severity level, average range in service life between years varied from as little as 31 to as much as 117 days, or about 1 to 4 months. Of more interest is the relative range. These values ranged from 0.21 to 0.53. In other words, the average difference in service life between years ranged from about one-fifth to over one-half of the mean of the two years.

Within-year repeatability was much better than that between years. Based on 12 duplicate sets of stripes placed in the same

TABLE 5 BETWEEN-YEAR AND WITHIN-YEAR SERVICE-LIFE VARIABILITY FOR REPLICATE SAMPLES

	Between Years (n = 20)		Within Years (n = 12)	
Evaluation Criteria	Average Range*	Relative Range*	Average Range*	Relative Range*
Durability				
Wheelpath	50	0.34	16	0.12
Intermediate	34	0.21	--	--
Non-Wheelpath	117	0.46	42	0.23
Appearance				
Wheelpath	47	0.38	12	0.09
Intermediate	31	0.22	--	--
Non-Wheelpath	74	0.37	37	0.19
Reflectivity				
Wheelpath	36	0.51	32	0.24
Intermediate	42	0.37	--	--
Non-Wheelpath	53	0.53	34	0.28

*Average range = difference in service life between repeat samples; relative range = average range divided by average service life for repeat samples.

year, the range in service life averaged 12 to 42 days for the various severity levels and evaluation criteria. The relative ranges were also lower, averaging from about one-tenth to one-quarter of the mean values for the duplicate sets.

The data in Table 5 thus show that estimates of service life from accelerated-wear tests are subject to considerable annual variation. Repeated samples tested within the same year typically resulted in differences of 2 to 6 weeks in service life, and repeated samples between years resulted in average differences of up to 4 months. Considering the wide range observed between repeated samples, the results of these tests cannot be used to identify differences of less than several months between paints installed in different years. For paints installed in the same year, differences of less than several weeks are probably not reliable.

Further examination of the data used to compile Table 5 reveals that for 14 of the 20 repeated stripe sets, installation included 1982, which had the mildest winter. For these 14 pairs of stripe sets, those installed in 1982 showed markedly improved service lives compared with those installed in 1981 or 1983. For four sets there was less improvement in service life for those installed in either 1981 or 1983, and for one set there was little difference in service life between the two years. Although this sample is small, it provides a strong indication that the milder winter of 1982–1983 substantially affected service life.

Paint Color and Pavement Type

Because most paint formulas were applied in both colors and on both pavement types, paired comparisons were used to examine differences in service lives related to paint color and pavement type. In durability and appearance, yellow performed better than white; service life ranged from a few days in the wheelpath and intermediate positions to nearly 2 months for the nonwheelpath position. In reflectivity, white performed better than yellow, but the differences represent only a few days of service life. In the wheelpath, stripes on ACP provided nearly a month's longer service than those on PCCP in durability and appearance. However, outside the wheelpath, stripes on PCCP lasted nearly 2 months longer than those on ACP. In reflectivity, stripes on PCCP lasted longer than those on ACP for both wheelpath and nonwheelpath positions.

Effects of Installation Parameters

Dry-film thicknesses of plate samples obtained during installation, with and without beads, were measured as well as initial reflectivity on beaded plate samples. Wet-film thickness was adjusted by the installers to 15 mils, which was verified by measurements with a wet-film-thickness gauge. Dry-film thicknesses corresponding to 15 mils wet are dependent on solvent content of the paint as well as on actual applied wet-film thickness. For 15 mils wet, typical dry-film thickness is expected to range from about 8 to 12 mils. Most plate samples had dry-film thicknesses within that range. For 20 samples of the 125 sets placed, thickness was between 6 and 8 mils, for 15 it was between 12 and 15 mils, for 3 it exceeded 15 mils. In view of the variety of materials installed, considerable variation in dry-film thickness was to be expected. In addition, normal variation encountered during application would be expected to result in some differences along the length of a line. Thus, the dry-film thicknesses observed, although exceeding the theoretical range by a few mils, indicate that most test materials were installed close to the desired 15-mil wet-film thickness.

Beaded thickness is more difficult to assess, because it depends on paint and bead application rates, solvent content, bead gradation, embedment depths, and other factors. Thickness of the beaded plate samples showed a wide range, but was generally within what was expected.

Reflectivity of the sample plates as measured with the retroreflectometer was also examined. A wide range of brightness values was observed, ranging from poor in a few cases to excellent in a few others. Service lives of pavement markings obviously depend at least partially on initial thickness and brightness. A simple regression analysis was used to determine these relations for the test stripes, and it was found that there was very little correlation between service life and initial thickness and brightness values. Initial thickness and brightness were mostly within the expected ranges. In addition, a number of other parameters—weather, paint formula and color, pavement type, and others—also exhibited varying degrees of influence on service life. Thus this lack of correlation between service life and initial brightness and thickness is not surprising.

Drying times measured for the test stripes ranged from less than 1 min to longer than 6 min. Those of a minute or less are desirable from the standpoint of traffic control during placement. However, few paints could achieve such short times. The two New York State alkyds—20- and 60-sec—had drying times of 1 min or less for 12 of the 20 sets placed; three more sets had times between 1 and 2 min. Several other paints were also characterized by 1- to 3-min drying times. Drying times are summarized by paint type in Table 6.

Paint Formulas

Table 6 lists average service lives of each paint formula, presented separately for each of the 3 years. The paints are listed in descending order of service life measured in the nonwheelpath position, because this parameter was earlier shown to provide the clearest indication of difference between paints.

TABLE 6 SUMMARY OF SERVICE LIFE

					Days of Service						
					Durability		Appearance		Reflectivity		
Formula	Resin Type	Derivation	Ranked by Durability	Ranked by Reflectivity	WP	NWP	WP	NWP	WP	NWP	n
1981 TEST STRIPES											
12	Chlorinated Rubber-Alkyd	Penn. Standard	1	7	133	278	127	161	113	122	3
18	Chlorinated Rubber	NJ Standard	2	5	179	232	171	189	93	128	4
16	Chlorinated Rubber	Texas Standard	3	1	154	200	158	181	124	139	4
17	Chlorinated Rubber	Ill. Standard	4	9	150	184	143	170	111	118	4
5	Alkyd	Md. Standard	5	13	138	185	130	159	75	82	2
19	Chlorinated Rubber	Experimental	6	2	125	154	124	144	122	132	4
1	Acrylic	Experimental	7	4	130	152	124	144	129	128	4
7	Alkyd-Acrylic	Ky. Standard	8	10	110	152	109	132	108	108	4
14	Epoxy	Commercial	9	14	129	151	128	138	70	82	2
11	Alkyd	Calif. Standard	10	15	129	148	124	140	36	36	4
6	Alkyd	Experimental	11	3	120	135	115	128	130	128	4
26	Waterbase	Experimental	12	6	112	133	95	123	115	123	4
4	Alkyd	Ind. Standard	13	11	114	126	128	141	94	91	2
8	Alkyd	NY 60-Sec	14	12	101	118	109	117	78	85	4
3	Alkyd	NY 20-Sec	15	8	109	113	117	122	120	120	3
1982 TEST STRIPES											
21	Chlorinated Rubber	NJ Modified	1	2	258	549	233	488	133	194	4
23	Chlorinated Rubber	Experimental	2	1	194	495	159	337	151	198	2
22	Chlorinated Rubber	NJ Modified	3	4	218	458	283	443	130	188	4
20	Chlorinated Rubber	Wyo. Standard	4	10	208	428	188	275	92	126	4
13	Chlorinated Rubber-Alkyd	NJ Modified	5	5	203	418	185	350	118	179	4
25	Chlorinated Rubber	Ill. Modified	6	11	175	366	189	331	86	110	4
2	Acrylic	Experimental	7	7	178	338	148	211	143	182	2
14	Epoxy	Commercial	8	15	69	266	58	122	26	40	2
18	Chlorinated Rubber	NJ Standard	9	14	74	238	67	132	64	82	2
28	Waterbase	Experimental	10	3	150	238	140	194	138	192	2
15	Epoxy	Commercial	11	16	68	213	68	122	36	61	2
29	Waterbase	Experimental	12	6	156	207	128	164	138	168	2
27	Waterbase	Experimental	13	8	129	177	115	162	122	145	3
9	Alkyd	NY Cold Applied	14	12	57	161	49	144	29	87	1
28	Waterbase	Experimental	15	9	110	148	108	136	126	138	2
10	Alkyd	NY 60-Sec	16	13	122	148	117	131	85	84	4
1983 TEST STRIPES											
24	Chlorinated Rubber	NJ High Viscosity	1	1	160	372	157	361	152	214	4
13	Chlorinated Rubber-Alkyd	NJ Modified	2	3	144	211	138	203	142	163	7
5	Alkyd	Md. Standard	3	4	144	185	140	183	94	107	3
20	Chlorinated Rubber	Wyo. Standard	4	2	144	184	135	255	147	173	6
8	Alkyd	NY 60-Sec	5	5	111	137	109	135	72	80	4

Note: WP = wheelpath, NWP = non-wheelpath, n = number of stripe sets.

This table shows that several chlorinated rubber paints and a chlorinated rubber-alkyd were the best performers, with average service lives considerably above those of the department's standard paints. Performance of each paint type can be summarized as follows:

1. Chlorinated rubber and chlorinated rubber-alkyd: These paints were consistently the best performers, with average durabilities considerably better than those of the department's alkyd paints and other paint types. All the various state standard chlorinated rubbers and chlorinated rubber-alkyds performed well, as did several variations of the New Jersey IV formula. In all these formulas, methyl ethyl ketone (MEK) was used as the solvent. In one—the NJ Modified (NJ IV with Cellolyn 604), a chlorinated rubber-alkyd (formula 13)—toluene was substituted. Although formula 13 did not perform quite as well as the others in this group did, it performed better than most paints from the other groups and much better than the New York State alkyds. With the exception of formula 13 most of these paints also had slow drying times.

2. Alkyds: The New York State alkyd paints were consistently the poorest performers. Of the four other alkyds, all performed better than the New York State paints, but none lasted more than a few weeks longer than the New York State paints. None of the alkyds had service lives that approached those of most of the chlorinated-rubber and chlorinated-rubber-alkyd paints.

3. Acrylic and alkyd-acrylic: An acrylic paint installed in 1982 performed nearly as well as the chlorinated-rubber paints, but the other two in this group were only slightly better than the New York State alkyds.

4. Epoxy: Two epoxy paints were installed. Both performed somewhat better than the New York State paints, but neither was outstanding.

5. Water based: Four water-based paints were installed. Their performance ranged from a little better than to about the same as that of the New York State alkyds.

Although nonwheelpath durability provided the best distinction among paints, appearance and reflectivity were also important. Paints that ranked well in durability also did generally well in appearance and to a lesser extent in reflectivity. The relationship among the three criteria is explored further in Table 7, which presents a correlation matrix for the three criteria and durability levels. Correlation coefficients between durability and appearance were high for all three positions—

TABLE 7 MATRIX OF CORRELATION COEFFICIENTS RELATING SERVICE LIFE TO VARIOUS DURABILITY LEVELS AND EVALUATION CRITERIA

	Durability		
Evaluation Criteria	Wheelpath	Intermediate	Non-Wheelpath
Durability			
Wheelpath	1.00	0.94	0.55
Intermediate	0.94	1.00	0.63
Non-Wheelpath	0.55	0.63	1.00
Appearance			
Wheelpath	0.92	—	--
Intermediate	—	0.91	--
Non-Wheelpath	—	—	0.87
Reflectivity			
Wheelpath	0.44	—	--
Intermediate	—	0.37	--
Non-Wheelpath	—	—	0.57

Note: Correlation coefficients based on linear regression of service lives for 125 stripe sets.

wheelpath, intermediate and nonwheelpath—about 0.9. Although the correlation with reflectivity was not high, most paints that rated well on durability also generally tended to rate well in reflectivity, and those lower in durability generally rated low in reflectivity. A notable exception are the water-based paints, which generally rated somewhat better in terms of reflectivity than durability, and the epoxies, which had reflectivity ratings lower than durability ratings.

Examination of performance data for individual sets of stripes revealed that there was considerable performance variability between stripe sets, even for the best paints. Although some paint groups were clearly superior to others, performance variations among formulas within paint groups, combined with the effects of differences in installation, climate, and traffic, resulted in wide variations in performance within paint groups.

Failure Modes

When the durability ratings were determined, separate values were assigned for abrasion and chipping. When a stripe set reached failure, the controlling failure mode was noted. Overall, slightly more than half the sets failed by abrasion, about one-fourth through chipping, and the remaining sets failed in both modes simultaneously. It is desirable for traffic paints to fail by abrasion (i.e., to wear out) rather than through chipping, which represents a premature separation from the pavement substrate. Thus it is encouraging that only about one-fourth of the paints tested failed through chipping. The acrylic, alkyd-acrylic, and epoxy paints generally had the lowest rate of chipping failure, whereas the alkyds failed predominately by abrasion. About half the chlorinated rubbers and chlorinated rubber-alkyds experienced abrasion failure, but the other half failed through chipping or in both modes simultaneously. Most water-based paints failed through chipping.

DISCUSSION AND RESULTS

Results of these accelerated-wear tests demonstrated that there are considerable differences in the service lives of various traffic paints. In general, similar estimates of service life were obtained for durability and appearance, but for reflectivity service lives were much shorter.

Variability in service life was quite large between duplicate stripe sets installed in the same year or in more than 1 year. Within-year differences were generally no more than a few weeks for duplicate sets of paint stripes, but, between years, differences between duplicate sets averaged a few months. Thus, the results of these accelerated-wear tests should not be used to evaluate small differences in performance between paints, especially if those paints were installed in different years.

In spite of the sizable variability in performance experienced between duplicate stripe sets and the relatively small differences in performance experienced in the wheelpath stripes, some large differences in performance were found among paints used in the nonwheelpath stripes. The range in performance among paints was much larger than the differences between repeated tests with the same paint; thus the range appears to be a valid measure of performance. It also appears that differences in winter weather severity among years affected the wear rates observed. However, the relative ranking of the various paints and paint groups was very similar in each of the three annual evaluation periods, even though the service lives actually observed varied from year to year.

Performance was also closely related to paint group. All the best-performing paints were chlorinated rubbers or chlorinated rubber-alkyds, and the poorest were alkyds and water-based paints. However, most paint groups exhibited a range in performance, so identification of a paint group does not necessarily indicate the performance capability of that particular paint.

Finally, the best-performing paints provided satisfactory durability and appearance for a year or more in nonwheelpath positions and acceptable reflectivity for as long as 7 months. Considering the high traffic volumes on the test sites and the location of the test stripes, which were closer to the wheelpath than the normal location of longitudinal paint lines, these tests indicate that some traffic paints can provide year-round delineation on a sizable portion of the state highway system. On the basis of the results and their discussion in this paper, the following findings can be stated:

1. Service lives of the standard New York State alkyd traffic paints were the lowest of all paints tested.
2. The best-performing paints were several formulas of chlorinated rubber and chlorinated rubber-alkyd. Service lives of the best paints were more than three times as long as those of the state standard traffic paints.
3. Some formulas of other paint types—including alkyds, acrylics, epoxies, and water-based paints—provided improved service lives over those of the state standard paints. However, these improvements were generally of 50 percent or less.
4. Duplicate stripe sets installed in the same year generally varied in service life by several weeks, and those installed in more than one year varied by a few months. Thus, small differences in service life observed in these accelerated-wear tests are not reliable, especially if the paints were not installed in the same year.
5. The very rapid wear experienced by wheelpath stripes after the onset of winter tends to mask differences among paints. Thus, nonwheelpath stripes provided the clearest measure of performance differences among paints.
6. Durability and appearance ratings provided good measures of differences among paints, but reflectivity measurements were less reliable.

7. Nearly all the best-performing chlorinated-rubber and chlorinated-rubber-alkyd paints contained MEK as a solvent, but one chlorinated rubber-alkyd that contained toluene also performed well.

8. Several paints provided drying times in the range of a minute or less, but these were generally the poorest performers. Most paints providing good performance had drying times of more than 2 min, but the toluene-based chlorinated rubber-alkyd had a drying time generally of less than 2 min.

9. A number of traffic paints appear capable of providing year-round delineation on a substantial portion of the New York State highway system with only one application per year.

ACKNOWLEDGMENTS

This work was conducted in cooperation with FHWA under the supervision of James E. Bryden. Installation documentation and performance surveys were conducted by current and former research engineers Ronald A. Lorini, Peter D. Kelly, and Gary F. Gurney. Research technicians assisting with the study included David J. Leininger, Robert P. Murray, William P. Nolan, Steve L. Roden, William G. Roth, and Alan W. Rowley. The cooperation of Region 1 highway maintenance personnel (the Hudson Falls striping crew) and the manufacturers who participated is truly appreciated. Their assistance was essential for the successful installation of the materials evaluated in this study.

REFERENCE

1. J. E. Bryden and G. F. Gurney. *Pavement Marking Materials: New York's Experience*. Research Report 112. Engineering Research and Development Bureau, New York State Department of Transportation, Albany, March 1984.

Publication of this paper sponsored by Committee on Coatings, Signing and Marking Materials.