Reflectivity and Durability of Epoxy Pavement Markings

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Epoxy pavement markings on 16 projects were surveyed to determine durability and reflectivity. These markings were up to 6-years old and were installed on both portland cement and asphalt concrete pavements. Most projects were in good condition and providing acceptable daytime delineation. Although most markings also had fair or good reflectivity, some were not providing acceptable reflectivity. However, most of the poor reflectivity occurred on a few recent projects. It was not possible to relate differences in condition or reflectivity to roadway characteristics, traffic, striping contractor, or material supplier, and it appears that these differences are attributable to particular characteristics of each installation.

In 1979, the New York State Department of Transportation (NYSDOT) adopted a policy requiring inclusion of durable pavement markings on most capital construction projects. Over the next few years, interpretation of this policy was broadened to include contract application of durable markings on highways not otherwise involved in capital work. These projects generally included high-volume Interstates, expressways, and other arterials where it was difficult to maintain year-round markings using traffic paints, as well as remote areas where it was not efficient to schedule periodic repainting. New York's striping policies and practices are explained at length in NYSDOT'S Research Report 112 *(1)*.

Performance of the first few major striping projects using durable materials (e.g., thermoplastic, two-component epoxy, and preformed tape) was described in Research Report 114 *(2)*. Over the first few years of this policy, about 15,000 mi of durable pavement markings were let to contract, with thermoplastic comprising about two-thirds of the total. Performance surveys on the thermoplastic markings were completed in 1981 and 1982, and the results published in Research Report 120 *(3)*.

By mid-1984 about 3,500 mi of epoxy lines had been let to contract, and more were anticipated. Therefore it became desirable to inspect a larger sample of epoxy markings installed over the past few years to determine performance characteristics of the material. Results of a survey conducted by personnel of the Engineering Research and Development Bureau during the summer of 1984 are summarized in this paper.

PROJECT DESCRIPTIONS AND METHODS OF EVALUATION

NYSDOT construction records were searched to identify projects including epoxy pavement markings completed by 1983. A total of 15 projects were selected for the survey, all striped between 1978 and 1983, including one additional contract striped in early summer of 1984. The 16 projects, summarized in Table 1, included about 1,100 mi of epoxy striping, about one-third of the total that had been let to contract by mid-1984.

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Projects selected were located throughout the state, and included a wide range of highway and pavement types, traffic volumes, and environments. Four different striping contractors were employed, and material from three different suppliers was used. Project sizes ranged from about 8 mi to nearly 200 mi of striping. Some were limited to a single route, others included a large number of routes over a wide area.

Each project was inspected by a research team experienced in rating pavement-marking performance. Markings were subdivided by type (e.g., edge line, solid lane line, skip line, centerline, and median line) as well as by color and route. On projects including no more than a few routes, each combination of marking type, color, and route was inspected as an individual sample. On projects including several routes, several locations were selected for the survey. The number of samples ranged from as few as 2 to as many as 28 per project, with a total of 145 samples on the 16 projects.

The same set of observations was made for each of the 145 samples. Durability was noted based on subjective evaluations, and reflectivity was measured. The percentage of material remaining was estimated for each sample, and a subjective condition rating of good, fair, or poor was assigned:

1. Good: marking essentially new, with no more than minor imperfections or discolorations noticeable, and small areas of missing line.
2. Fair: marking still visually effective, but imperfections, discoloration, and worn or missing areas readily apparent.
3. Poor: marking marginally effective or ineffective, widespread imperfections, badly discolored, large areas missing.

Because each sample included a large quantity of marking material—sometimes over a long length of pavement—the range of percent remaining and condition was recorded, as well as the estimated overall percent remaining for the entire sample. Examples of various levels of percent remaining are shown in Figure 1.

Reflectivity was measured at 10 locations for each sample using a retroreflectometer built by the Engineering Research and Development Bureau and patterned after one built by the Michigan Department of State Highways and Transportation *(4)*. The instrument includes an internal light source and photocell, and provides a digital readout representing the brightness of a few square inches of line. It has been used to measure a number of lines at various levels of brightness to relate them to subjective visual readings. Typical brightness readings for sample plates constructed using several materials follow:

- New white Stamark reflective tape, 350;
- New yellow Stamark reflective tape, 260;
- White unbeaded paint, 80; and
- Yellow unbeaded paint, 50.

A panel of new white tape is used as a calibration reference to keep the instrument adjusted in the field. Instrument measurement

TABLE 1 SUMMARY OF PROJECTS SURVEYED

Project No.	Contract	NYSDOT Region	Year Striped	Contractor Code	Material Supplier Code	Pavement Type[a]	Total Samples	Length, 1,000 linear ft
1	D095864	1	1978-1979	1	1	P/A	7	166
2	D096536	1	1980	1	1	P	3	130
3	D096902	1	1982	2	2	P	12	708
4	D250238	8	1982	2	2	A	2	203
5	D250239	8	1982	2	2	A	10	302
6	D250240	8	1982	2	2	A	10	512
7	D250402	8	1982	2	2	A	3	85
8	D250482	1	1983	3	2	P	12	890
9	D250656	1	1983	4	3	P/A	28	795
10	D250501	2	1983	2	2	P/A	17	1,000
11	D250474	3	1983	4	2	P/A	4	457
12	D250197	5	1983	2	2	P	3	44
13	D250557	7	1983	2	2	A	2	127
14	D250500	9	1983	2	2	A	26	74
15	D000000	9	1983	2	2	P	3	100
16	D250159	5	1984	2	2	P	3	232

[a]P = Portland cement concrete pavement; A = asphalt concrete pavement.

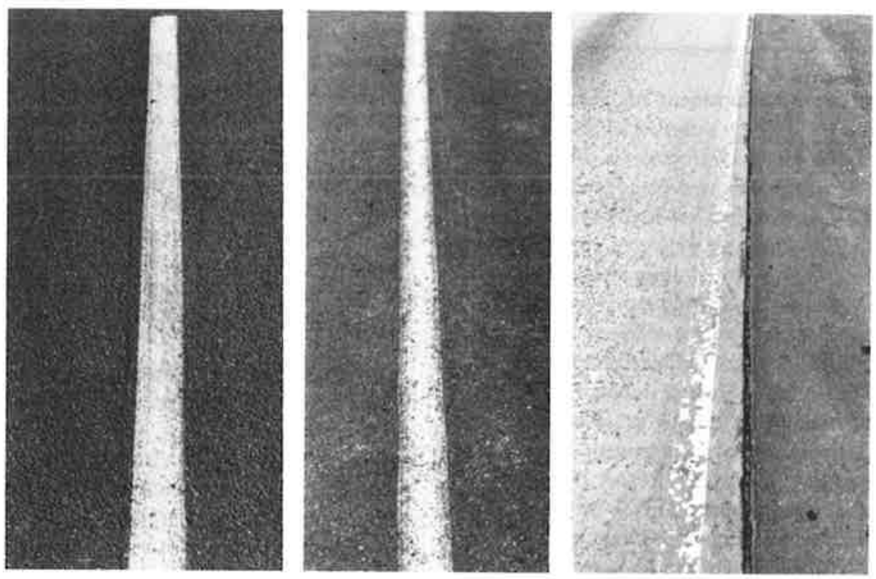

FIGURE 1 Epoxy markings rated 95 percent remaining (left), 65 percent (center), and 25 percent (right).

and subjective ratings have not been formally correlated, but based on several years of experience in subjectively rating marking materials, and 4 years of experience with the instrument, the following approximate relationships have been established:

	White	*Yellow*
Excellent	Over 300	Over 250
Good	225 to 300	175 to 250
Fair	140 to 225	110 to 175
Poor	Below 140	Below 110

More work is needed to define the relationship between measured brightness and a driver's perception of the pavement marking. However, during the interim period, these relationships provide a useful rule-of-thumb for assessing the adequacy of pavement markings, and for comparing alternative materials. Adequacy in terms of nighttime visibility also depends on pavement brightness (stripe-pavement contrast), roadway lighting, highway geometry, traffic speed and volume, and other factors. The measurements provided here are intended only as an assessment of the inherent visibility of the material. In some situations (such as lighted highways or on pavements providing dark background contrast), a white stripe with a brightness measurement of 125 may be adequate, and in others 175 may be required.

Survey data were computerized for subsequent tabulation and analysis. Summaries were generated to examine the overall condition of the markings, and various parameters (e.g., roadway, traffic, environment, etc.) were related to performance. Appropriate statistical tests were used in some cases to determine whether perceived differences in performance were statistically significant.

RESULTS

Observations for each of the 145 samples included in this survey are given in Table 2 and summarized in Table 3. Overall, most markings were in fair to good condition, and were providing good

TABLE 2 SUMMARY OF SURVEY RESULTS

Project No.	Route[a]	Lane Width and Pavement Type[a]	Shoulder Width[c]	AADT 1,000	Mark Type	Measured Brightness Average	Measured Brightness Low	Measured Brightness High	Percent Remaining Average	Percent Remaining Low	Percent Remaining High	Subject Rate	Failure Mode[d]
1	WA	4-12C	10	17.4	WEdge	213	125	358	20	2	50	11	CP
	WA	4-12C	10	17.4	YMed	247	191	309	85	70	90	33	CP
	WA	4-12C	10	17.4	WSkip	256	147	326	75	60	70	32	CA
	FR	4-10C	0	23	YCent	136	112	161	85	80	90	32	C
	20	4-12A	0	20.2	WEdge	262	222	288	65	60	80	22	CA
	20	4-12A	0	20.2	WSkip	163	136	190	75	50	70	32	CA
	20	4-12A	0	20.2	YCent	149	140	156	80	70	80	33	CA
2	188	4-12C	6	5.9	WEdge	345	238	435	80	70	90	32	CP
	188	4-12C	6	5.9	WSkip	378	235	462	75	70	80	32	CP
	188	4-12C	6	5.9	YMed	230	183	270	85	70	90	33	CP
3	I90	6-12C	10	49.7	WEdge	219	171	316	80	70	80	32	C
	I90	6-12C	10	49.7	WSkip	250	216	286	75	60	80	32	C
	I90	6-12C	10	49.7	YMed	222	202	299	85	70	90	33	C
	I787	6-12C	10	28.3	WEdge	428	373	465	80	70	80	32	C
	I787	6-12C	10	28.3	WSkip	266	252	282	70	50	80	32	C
	I787	6-12C	10	28.3	YMed	147	128	169	85	70	90	33	C
	9	4-12C	10	15.3	WEdge	358	293	423	80	70	90	33	C
	9	4-12C	10	15.8	WSkip	394	365	458	75	70	80	32	C
	9	4-12C	10	15.8	YMed	297	258	323	85	70	90	33	C
	85	4-12C	10	19.3	WEdge	289	156	484	80	70	80	32	C
	85	4-12C	10	19.3	WSkip	333	290	400	75	70	80	32	C
	85	4-12C	10	19.3	YMed	269	246	298	85	70	90	33	C
4	9H	2-12A	3	3.3	WEdge	318	232	436	85	70	90	33	AP
	9H	2-12A	3	3.3	YCent	142	93	231	75	60	80	32	AP
5	17A	2-12A	4	4.1	WEdge	209	129	290	80	60	80	32	AP
	17A	2-12A	4	4.1	YCent	172	160	193	80	70	80	32	AP
	17	4-12A	4	16.2	WEdge	205	132	245	75	60	80	32	A
	17	4-12A	4	16.2	WSkip	157	128	188	65	50	70	22	A
	17	4-12A	4	16.2	YCent	166	143	190	80	60	80	32	A
	59	2-12A	0	18.6	YCent	91	80	106	70	50	70	22	A
	94	2-12A	4	4.5	WEdge	199	147	255	80	60	80	32	A
	94	2-12A	4	4.5	YCent	127	90	155	75	60	80	32	A
	218	2-11A	3	3.7	WEdge	285	226	353	80	60	90	32	A
	218	2-11A	3	3.7	YCent	192	155	226	75	50	80	32	A
6	32	2-11A	2	5.6	WEdge	190	120	274	65	50	70	21	AP
	32	2-11A	2	5.6	YCent	91	62	108	65	50	70	21	AP
	32	2-11A	2	5.6	WEdge	161	140	219	70	50	70	22	AP
	32	2-11A	2	5.6	YCent	147	130	177	80	70	80	32	AP
	209	2-12A	6	6.1	WEdge	204	121	325	75	60	80	32	A
	209	2-12A	6	6.1	YCent	131	106	158	80	70	90	33	A
	17K	2-11A	4	7.9	WEdge	150	114	207	70	60	70	22	A
	17K	2-11A	4	7.9	YCent	181	156	210	80	70	80	33	A
	17K	2-11A	9	3.1	WEdge	204	143	302	80	70	80	33	A
	17K	2-11A	9	3.1	YCent	147	122	198	80	70	80	33	A
7	295	2-12A	2	2.6	WEdge	391	286	467	80	70	80	33	A
	295	2-12A	2	2.6	WSkip	248	228	268	75	70	80	32	A
	295	2-12A	2	2.6	YCent	228	184	260	80	70	80	33	A
8	I787	6-12C	10	28.3	WEdge	260	202	310	80	70	90	33	CA
	I787	6-12C	10	28.3	WSkip	301	244	352	75	60	80	32	CA
	I787	6-12C	10	28.3	YMed	203	164	244	85	80	90	33	CA
	I90	6-12C	10	26.2	WEdge	294	203	330	80	70	80	32	C
	I90	6-12C	10	26.2	WSkip	295	253	367	70	60	80	32	C
	I90	6-12C	10	26.2	YMed	175	155	202	85	70	90	33	C
	I87	6-12C	10	39.8	WEdge	211	189	264	75	70	80	32	CA
	I87	6-12C	10	39.8	WSkip	266	209	313	65	50	80	22	CA
	I87	6-12C	10	39.8	YMed	218	148	255	80	70	90	33	CA
	I890	4-12C	6	8.9	WEdge	322	245	376	85	70	90	33	C
	I890	4-12C	6	8.9	WSkip	267	163	414	75	60	90	32	C
	I890	4-12C	6	8.9	YMed	179	101	289	85	70	90	33	C
9	5	4-12A	0	28.9	WLane	173	136	253	75	60	80	32	A
	5	4-12A	0	28.9	YMed	126	98	158	85	70	90	33	A
	20	4-12A	0	16.9	WEdge	232	187	262	85	70	90	33	A
	20	4-12A	0	16.9	WSkip	175	140	202	75	60	80	32	A
	20	4-12A	0	16.9	YCent	160	103	225	85	70	90	33	A
	WR	4-14A	0	24.5	WLane	186	144	209	70	60	70	22	A
	WR	4-14A	0	24.5	WSkip	153	127	191	70	60	80	32	A
	WR	4-14A	0	24.5	YMed	155	97	248	80	70	80	33	A
	5	4-12A	4	6	WEdge	301	261	340	80	70	90	33	A
	5	4-12A	4	6	WSkip	282	190	352	70	60	80	32	A
	5	4-12A	4	6	YMed	240	174	295	80	70	90	33	A
	9	4-12A	0	18.3	WEdge	249	204	301	80	70	80	33	A
	9	4-12A	0	18.3	WSkip	215	163	260	70	50	70	32	A
	9	4-12A	0	18.3	YCent	169	141	205	80	70	80	33	A
	378	4-12C	4	11.1	WEdge	319	212	383	30	0	80	31	C
	378	4-12C	4	11.1	WSkip	247	171	350	20	0	70	31	C
	378	4-12C	4	11.1	YMed	227	186	280	60	0	80	31	C
	377	4-12A	8	6.7	WEdge	340	252	428	85	70	90	33	A
	377	4-12A	8	6.7	WSkip	266	242	296	85	70	80	33	A
	377	4-12A	8	6.7	YCent	259	201	294	85	70	80	33	A
	32	4-12A	0	10.6	WSkip	171	134	212	75	60	80	32	A
	32	4-12A	0	10.6	YCent	111	92	230	80	70	80	33	A
	GIBR	4-12C	0	–[e]	WEdge	280	218	324	85	80	90	33	A
	GIBR	4-12C	0	–[e]	WSkip	187	160	231	80	80	90	33	A

TABLE 2 (continued)

Project No.	Route[a]	Lane Width and Pavement Type[b]	Shoulder Width[c]	AADT 1,000	Mark Type	Measured Brightness Average	Measured Brightness Low	Measured Brightness High	Percent Remaining Average	Percent Remaining Low	Percent Remaining High	Subject Rate	Failure Mode[d]
	GIBR	4-12C	0	–[e]	YMed	170	151	191	85	80	90	33	A
	32	4-12C	10	6.5	WEdge	496	456	532	75	60	80	31	C
	32	4-12C	10	6.5	WSkip	284	262	363	70	60	80	21	C
	32	4-12C	10	6.5	YMed	168	122	211	75	70	80	31	C
10	173	2-10A	6	2	WEdge	209	127	350	75	60	80	32	CP
	173	2-10A	6	2	YCent	107	75	164	80	70	80	32	CP
	13	2-12A	5	4.3	WEdge	252	182	358	85	70	80	33	A
	13	2-12A	5	4.3	YCent	118	68	182	80	70	80	33	A
	5S	2-12C	6	4.6	WEdge	336	221	423	75	60	80	32	C
	5S	2-12C	6	4.6	YCent	177	103	211	80	70	80	32	C
	49	2-10A	3	1.8	WEdge	227	164	281	80	70	80	33	AP
	49	2-10A	3	1.8	YCent	115	85	166	80	70	80	33	AP
	12	2-11A	5	3.4	WEdge	204	114	398	80	70	80	33	A
	12	2-11A	5	3.4	YCent	80	65	105	80	70	80	33	A
	92	2-12A	10	5.6	WEdge	226	187	278	80	70	90	33	A
	12	2-12A	10	5.6	WSkip	145	138	155	75	60	80	32	A
	92	2-12A	10	5.6	YCent	133	100	167	85	70	90	33	A
	30	2-11A	5	1.2	WEdge	263	213	301	80	70	80	33	AP
	30	2-11A	5	1.2	YCent	121	96	176	75	60	80	32	AP
	8	2-10A	2	.4	WEdge	354	307	392	80	70	90	33	AP
	8	2-10A	2	.4	YCent	140	115	166	75	40	80	32	AP
11	3	2-12C	10	4.1	WEdge	289	175	414	80	70	90	33	C
	3	2-12C	10	4.1	YCent	115	100	140	85	80	90	33	C
	370	2-12A	6	3	WEdge	255	171	383	80	70	90	33	A
	370	2-12A	6	3	YCent	149	106	196	85	80	90	33	A
12	I990	6-12C	10	5	WEdge	379	221	545	80	60	90	33	CP
	I990	6-12C	10	5	WSkip	371	242	446	80	60	90	32	CP
	I990	6-12C	10	5	YMed	214	159	266	85	70	90	33	CP
13	12	2-12A	8	3.4	WEdge	340	314	377	85	80	90	33	A
	12	2-12A	8	3.4	YCent	109	97	117	85	70	90	33	A
14	17	2-12A	5	12.6	WEdge	156	126	179	80	70	90	33	A
	17	2-12A	5	12.6	YCent	99	80	117	80	70	90	33	A
	MCLO	2-12A	0	–[e]	WEdge	213	163	275	80	70	80	33	A
	MCLO	2-12A	0	–[e]	YCent	110	100	126	80	70	80	33	A
	MCLO	2-14A	0	–[e]	WEdge	220	185	269	80	70	80	32	A
	MCLO	2-14A	0	–[e]	YCent	80	74	89	75	60	80	32	A
	VSTL	2-14A	0	–[e]	WEdge	304	208	350	80	70	80	33	A
	VSTL	2-14A	0	–[e]	YCent	91	73	109	75	60	80	32	A
	VSTL	2-13A	0	–[e]	YCent	62	57	69	75	60	80	22	A
	UNON	2-12A	0	–[e]	WLane	202	181	235	70	60	80	22	A
	UNON	2-12A	0	–[e]	YCent	87	78	94	75	60	80	22	A
	UNON	2-12A	0	–[e]	WLane	111	106	117	75	60	80	22	A
	UNON	2-12A	0	–[e]	YCent	64	58	69	75	60	80	22	A
	JONC	4-12A	0	–[e]	WLane	159	139	194	75	60	80	22	A
	JONC	4-12A	0	–[e]	WSkip	192	173	207	70	50	80	22	A
	JONC	4-12A	0	–[e]	YMed	90	79	114	80	70	80	32	A
	JONC	4-12A	0	–[e]	YCent	97	87	107	80	60	80	32	A
	BING	2-12A	0	–[e]	WLane	130	118	137	80	70	80	32	A
	BING	2-12A	0	–[e]	YCent	77	57	108	75	50	80	22	A
	BING	2-12A	0	–[e]	YCent	89	79	101	80	60	90	32	A
	ONTA	2-12A	0	–[e]	WLane	101	91	112	70	50	70	22	A
	ONTA	2-12A	0	–[e]	WSkip	79	70	97	70	50	70	22	A
	ONTA	2-12A	0	–[e]	WLane	74	70	79	70	50	70	22	A
	ONTA	2-12A	0	–[e]	YCent	50	46	54	70	50	70	22	A
	NOWH	2-13A	0	–[e]	YCent	78	65	86	60	0	70	21	A
	NOWH	2-12A	0	–[e]	YCent	103	81	131	80	70	80	32	A
15	I88	4-12C	12	4.7	WEdge	391	277	464	80	70	80	33	AP
	I88	4-12C	12	4.7	WSkip	360	227	448	75	70	80	32	AP
	I88	4-12C	12	4.7	YMed	312	280	358	80	70	90	33	AP
16	I290	6-12C	10	50	WEdge	315	233	378	80	70	90	33	CP
	I290	6-12C	10	50	WSkip	220	185	260	80	60	90	32	CP
	I290	6-12C	10	50	YMed	238	184	274	85	70	90	33	CP

[a]Striping areas that are not numbered state routes were located on: Washington Avenue (WA), Fuller Road (FR), Wolf Road (WR), Green Island Bridge (GIBR), Vestal (VSTL), Monticello (MCLO), Union (UNON), Johnson City (JONC), Binghamton (BING), Oneonta (ONTA), and Norwich (NOWH).
[b]Shows number of lanes, width, and type of pavement (C = concrete, A = asphalt).
[c]0 = curbed section without shoulder.
[d]C = chipping, A = abrasion, P = pavement deterioration.
[e]No data.

daytime delineation as shown in Figure 2. All 145 samples experienced some material loss, with most in the range of 70 to 90 percent intact. Only 26 samples were less than 70 percent intact. Most failure was in the form of small areas of missing line, with only occasional areas of more widespread failure. Abrasion failure caused by traffic and snowplow wear was the prevalent failure mode encountered, although chipping failures (loss of adhesion) were observed in a few cases. Some striping failure was also caused by failure of the pavement itself, either by deterioration of the pavement along joints and cracks, or by loss of peaks on rough-textured pavements (Figure 3) probably caused by snowplowing. Typical examples of marking failure are shown in Figure 1.

Only one sample was rated poor overall for appearance, with nine more rated poor to fair or poor to good. Therefore, nearly all the samples were in the fair and good ranges and provided adequate daytime delineation. Some graying of white markings was apparent on most projects, but the markings were still considered adequate for daytime delineation.

TABLE 3 MARKING CONDITION RELATED TO PAVEMENT TYPE

		Number of Samples for Each Marking Type				
Variable	Total Samples	Right Edge (White)	Skip (White)	Solid Lane (White)	Center-line (Yellow)	Median Edge (Yellow)
Percent remaining						
50 or less	3	2	1	0	0	0
51-70	23	4	10	4	4	1
71-90	119	41	17	4	38	19
Over 90	0	0	0	0	0	0
Total	145	47	28	8	42	20
Condition						
Poor	1	1	0	0	0	0
Poor-fair	4	1	1	0	2	0
Poor-good	5	2	1	0	0	2
Fair	19	3	4	6	6	0
Fair-good	53	14	20	2	16	1
Good	63	26	2	0	18	17
Total	145	47	28	8	42	20
Reflectivity						
Poor	24	0	1	4	18	1
Fair	55	16	10	4	19	6
Good	39	14	11	0	4	10
Excellent	27	17	6	0	1	3
Total	145	47	28	8	42	20

FIGURE 2 Typical epoxy markings in good condition.

Marking reflectivity was generally not as good as overall durability. Less than half the average brightness values were good or excellent, with 24 samples in the poor range and 55 more only fair. Considering the range of reflectivity values often observed within samples, even more had some unacceptable brightness values. In all, 55 of 145 samples had one or more poor reflectivity measurements. However, most samples with poor reflectivity were concentrated on a few projects, and most remaining projects had few or no samples with areas of poor reflectivity.

Table 3 also relates condition to marking type; skip lines and solid lane lines experienced substantially more material loss than edge lines and centerlines. Because these stripes are more exposed to traffic forces, it is expected that they would experience greater wear. The solid lane lines again were rated somewhat below the others in terms of subjective condition ratings, with 6 of 8 samples rated only fair. In terms of reflectivity, solid lane lines and centerlines performed much poorer than the others. Only 5 of 42 centerline samples and no solid lane-line samples had good or excellent reflectivity, but about two-thirds of the other types had good or excellent reflectivity. However, most of the poor and fair reflectivity ratings occurred on a few projects that consisted primarily of centerlines and solid lane lines, with no lines of the other three types. If these few projects were disregarded, it does not appear that any marking type performed very differently from others in terms of reflectivity.

Table 4 relates condition to marking color and pavement type. Because marking color and type are interdependent, trends observed for marking types would also be expected when the data are stratified by color. White markings experienced significantly more material loss than the yellow, but in terms of subjective condition, yellow markings were rated only slightly better than the white, and the difference is not significant. This same trend was seen when results were stratified by marking type, the skip lines and solid edge lines, both white, experienced the most material loss. Reflectivity of white lines was significantly better than

FIGURE 3 Loss of epoxy striping caused by chipping of peaks on tine-textured concrete pavement.

TABLE 4 MARKING CONDITION RELATED TO PAINT COLOR AND PAVEMENT TYPE

Variable	Marking Color		Pavement Type	
	White	Yellow	Asphalt	Concrete
Percent remaining				
50 or less	3	0	0	3
51-70	18	5	18	5
71-90	62	57	74	45
Over 90	0	0	0	0
Condition				
Poor	1	0	0	1
Poor-fair	2	2	3	1
Poor-good	3	2	0	5
Fair	13	6	18	1
Fair-good	36	17	32	21
Good	28	35	39	24
Reflectivity				
Poor	5	19	24	0
Fair	30	25	44	11
Good	25	14	16	11
Excellent	23	4	8	19
Total	83	62	92	41

yellow; this trend was apparent on most projects and not limited to a few worst cases.

No significant differences in percent remaining or subjective condition were found between pavement types; the minor differences apparent in Table 4 are not statistically significant. However, markings on concrete pavement had significantly better reflectivity, on the whole, than those on asphalt. About 80 percent of the markings on concrete had good or excellent reflectivity, compared to only about 25 percent on asphalt.

Epoxy is considered a long-life marking material, and these markings are expected to provide several years of satisfactory service before gradually failing through traffic wear. Accordingly, newer projects would be expected to be in better condition and to have better reflectivity than older ones. Table 5 relates marking condition to age. When samples striped in 1983 and 1984 are compared to older samples, no advantage is seen for the new markings either in terms of percent remaining or reflectivity. The older samples—up to 6-years old when inspected—are in as good condition as those 1-year old.

Individual project results reveal that highest line loss on the 1983-1984 projects is concentrated primarily on two of the nine projects (9 and 14). However, on the older projects, four of seven projects have some samples with high loss. Therefore, heavy wear is more widespread on older projects than on newer ones. Disregarding those two projects with high losses, the 1983 and 1984 projects actually have significantly less material loss than the older ones. The 1983 Project 14 is similarly responsible for nearly all of the poor average reflectivity ratings encountered on newer projects. However, some individual measurements in the poor range were encountered on five of nine 1983 and 1984 projects, even though average values for all but Project 14 were fair or better.

Material supplier and striping contractor were examined to determine whether differences in durability and reflectivity might be related to these variables. No significant differences were found among the three material suppliers in terms of either percent remaining or reflectivity. One contractor had significantly more low reflectivity values than the other three, but most of those poor and fair ratings were recorded on two 1983 projects, and several other projects striped by the same contractor had acceptable reflectivity. No significant differences in percent remaining were seen among the four contractors.

In addition to pavement age, traffic volume also has a direct effect on total wear experienced by a pavement marking. Traffic volumes were available for most of the 145 samples and were examined to determine whether they related to marking condition. However, no trends were apparent relating traffic volume to marking condition or reflectivity. Total annual average daily traffic (AADT), lane AADT, and total lane traffic over the life of the markings were all examined, but none showed a significant relationship to marking condition. In general, samples that had low total traffic exposure were in no better condition than markings exposed to high total traffic volumes.

Pavement and shoulder widths affect lateral vehicle placement, thereby affecting the number of vehicles actually crossing over the markings. These two parameters were examined to determine whether they related to marking durability. Unfortunately, only 21 of 145 samples had pavement widths less than 12 ft, and the total range was only 10 to 14 ft. Samples on pavement widths narrower than 12 ft performed almost exactly the same as those on wider pavements in terms of percent of material remaining. The narrower pavements had slightly more markings with poor and fair reflectivity values, but the small difference was not statistically significant.

The effects of shoulder width are summarized in Table 6. Samples with shoulder widths of 5 ft or less had significantly more low ratings—in terms of both percent remaining and reflectivity—than samples with wider shoulders. In terms of percent remaining, the narrow-shoulder group had about 25 percent rated poor or fair, compared to less than 10 percent for the wide-shoulder group. In terms of reflectivity, the difference was even greater; only about one-third of the narrow-shoulder group had good reflectivity, compared to about two-thirds for the wide-shoulder group. However, this cannot be interpreted as a cause-effect relationship. Even though there is a significant association between narrow shoulders and lower reflectivity, most low-reflectivity values were concentrated on a few projects that also had several samples with narrow shoulders.

TABLE 5 MARKING CONDITION RELATED TO AGE

Year Striped	Total Samples	Number of Samples							
		Percent Remaining				Reflectivity			
		≤50	51-70	71-90	>90	Poor	Fair	Good	Excellent
1978	2	1	0	1	0	0	1	1	0
1979	5	0	1	4	0	0	2	3	0
1980	3	0	0	3	0	0	0	1	2
1982	37	0	7	30	0	2	18	9	8
1983	95	2	15	78	0	22	32	25	16
1984	3	0	0	3	0	0	1	1	1

TABLE 6 MARKING CONDITION RELATED TO SHOULDER WIDTH

Shoulder Width, ft	Total Samples							
	Average Brightness				Percent Remaining			
	Poor	Fair	Good	Excellent	≤50	51-70	71-90	>90
0-2	2	18	5	3	0	7	21	0
3-5	2	14	10	3	2	4	23	0
6-9	2	8	6	7	0	1	22	0
10-12	0	10	17	18	1	4	36	0

DISCUSSION AND FINDINGS

Most of the 16 projects surveyed appear to be providing adequate service in terms of durability and reflectivity. However, considerable material loss and reduced reflectivity were experienced on several projects, and a few projects were performing poorly. Table 7 summarizes overall performance for each of the 16 projects. Twelve of 16 were rated in mostly good physical condition, but 10 are not providing good overall reflectivity.

TABLE 7 SUMMARY OF MARKING CONDITION

Project No.	Year Striped	Overall Rating[a]	
		Condition	Reflectivity
1	1978-1979	2	2
2	1980	3	3
3	1982	3	3
4	1982	3	2
5	1982	3	1
6	1982	1	1
7	1982	3	3
8	1983	3	3
9	1983	2	2
10	1983	3	1
11	1983	3	2
12	1983	3	3
13	1983	3	1
14	1983	2	0
15	1983	3	3
16	1984	3	2

[a]3 = mostly good ratings, 2 = less than half fair or poor ratings, 1 = mostly fair, poor ratings or both, and 0 = many poor ratings.

Several parameters were examined to determine whether possible causes of poor performance could be identified. A few trends were found that were statistically significant, but most appear to be related to poor performance on a small number of projects rather than being causal in nature. Thus, more projects must be surveyed to determine relationships that may be useful in predicting performance of epoxy pavement markings on a long-term basis. If the poor performance observed on a few projects in this survey can be related to construction practices or other parameters, it is important to identify those causes so that they can be remedied on future epoxy striping contracts.

Based on this survey of 16 epoxy striping projects, the findings that follow appear to be warranted:

1. Most projects inspected were in fair to good condition. While some striping material has been lost, most still provide an acceptable level of daytime delineation.
2. Most projects surveyed provide fair to good reflectivity, but about one-third provided marginal or unacceptable reflectivity. Most markings with marginal or unacceptable reflectivity were located on only a few projects, some only 1-year old.
3. Several parameters appeared to be associated with increased wear or lower reflectivity, but these apparent trends may be related to poor performance noted on a few projects, which introduced bias into the analysis.
4. A larger survey of epoxy markings in service over a longer period is needed to identify causes of the marginal performance noted on a few projects.

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