PAINTS AND GLASS BEADS USED FOR TRAFFIC DELINEATION MARKINGS

R. J. Girard, L. T. Murray,* and R. M. Rucker,* Division of Materials and Research, Missouri State Highway Commission

This investigation was designed to study the effectiveness of Missouri's traffic delineation system on both concrete and asphalt concrete surfaces and to determine if safe and economical improvements could be made. The investigation was organized into three phases so that elimination of variables could be accomplished with a minimum of samples. Phase 1, a field evaluation of the Missouri standard dispersion resin-varnish paint and a chlorinated rubber-alkyd paint in a transverse stripe, clearly indicated the superiority of the chlorinated rubber-alkyd paint to resist wear. Phase 2, a field evaluation of several proprietary high-heat paints in a transverse stripe, indicated a wide range of life expectancies to exist. Phase 3, a field evaluation of traffic delineation stripes in the proper longitudinal configuration with various types of glass beads applied at 3, 4, and 5 lb/gal (360, 480, and 600 kg/m^3), showed the Missouri type 2 floating bead to consistently rank high in performance. This investigation has produced a superior delineation system that provides economic savings over the system previously used.

•THIS study determined the effectiveness of the Missouri State Highway Commission standards pertaining to types of paint and glass beads and application rates used in paint and traffic delineation markings. The 3-phase investigation was completed with the minimum of samples by eliminating many variables. The optimum rate of application was the first major variable to stabilize, while, at the same time, a newly formulated cold-applied paint was tested. Next, various proprietary high-heat, fast-drying paints were tested for their resistance to wear. The wear tests were based on transverse stripes. The various types and application rates of glass beads were studied by placing longitudinal centerline stripes on divided highways having loadings of either 18,000 or 30,000 average daily traffic (ADT). This investigation has produced a superior delineation system that provides economic savings over the system previously used.

TEST LAYOUT

In phase 1, test stripes placed transverse to the flow of traffic in the driving lane were used to study the optimum wet film thickness of cold-applied paints that would provide a good service life. The 4-in. (46-cm) standard stripes were randomly placed at approximately 18-in. (0.50-m) intervals. The wet film thickness of each stripe was checked with an interchemical wet film thickness gauge as described in ASTM D 1212-70. Drying time was checked with the discontinued ASTM dry-time apparatus assembly using a weighted rubber wheel as described in ASTM D 711-55. Stripes were eliminated from the test if the quality of the line did not conform to a wet film thickness range within ±1 mil (±0.025 mm) or a specified width.

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

*Mr. Murray is now with District 10 of the Missouri State Highway Commission. Mr. Rucker has since retired.

Phase 2 used high-heat paints with essentially the same test procedures as phase 1. However, because of the configuration of the small striper, the bead flow could not be obstructed or interrupted to obtain wet film thickness values for each test stripe. The placement of the stripes required nonbeaded dummy stripes to calibrate the striper so that immediately thereafter the beaded test stripes could be placed with observation acceptance. These stripes were placed side by side, rather than randomly as in phase 1, in the same relative location within the test deck.

Phase 3 was designed to test the best paints applied at optimum wet film thickness in the actual centerline position. This phase also provided the opportunity to determine what type of glass bead and concentration would give the best night reflectivity relative to each other. The test sections were located on divided highways with 2 duplicate 1,200-ft (366-m) longitudinal centerline test sections per variable placed directly adjacent to each other in the opposing travel lanes. Missouri's standard stripe sequence is 15 ft (4.6 m) of white and 25 ft (7.6 m) of black or skip for divided highways. The stripes were placed to the left of the longitudinal joints or the old stripe to eliminate the variable of the condition of the old paint film. Wet film thickness measurements were taken for each test section by manually diverting the beads from one 15-ft (4.6-m) dash mark.

In all the phases, paints were placed on both portland cement concrete and asphalt concrete pavements.

EVALUATION PROCEDURES

Evaluation of the paint stripes was based on observations by a panel of 3 or 4 men, chosen for their experience with paint or paint operations. ASTM D 713-69 covers basically the general modes of failure used for these evaluations: appearance, durability, and night visibility. Specific evaluation for durability as related to chipping and abrasion was done according to ASTM D913-51 and ASTM D821-47 respectively. In the initial testing to determine the optimum wet film thickness and the relative durability of the cold- and hot-applied paints, the night visibility observations were omitted. Basically, the performance tests were used to evaluate the portion of a transverse stripe within the limits of the inner and outer wheel paths. Even though these stripes were beaded, a meaningful reflectivity reading is almost impossible. Bead loss, however, was considered as an extra observation and was taken into account as a function of abrasion. Naturally, the glass beads provide some protection for the paint; therefore, the rate of loss of the glass beads will influence the rate of wear of the paint film.

Night visibility was incorporated into the evaluation procedures in phase 3. The effectiveness of the white paints, determined as being the most durable from phases 1 and 2, was studied to determine if they gave satisfactory delineation in daytime and at night. The test stripes were placed in the normal centerline condition on divided highways. Observation of the stripes in daylight involved the same procedures as previously mentioned for the transverse stripes. Observation at night was basically the same as that described in ASTM D 713-69. However, by knowledge gained from a previous study of several paint stripes, the ASTM rating system of these test stripes for night visibility was augmented by a point-count survey method.

TEST RESULTS

Phase 1—Cold-Applied Paints and Optimum Wet Film Thickness

Phase 1 evaluated white and yellow Missouri standard dispersion resin-varnish paint (MS) and a chlorinated rubber-alkyd paint (CR) applied at 10, 15, and 20 mils (0.25, 0.38, and 0.50 mm) of wet film thickness. Both paints were purchased in accordance with specifications of the Missouri State Highway Commission.

Field evaluation was made approximately once every 2 weeks during the initial 9 weeks, then once every 3 weeks for the remainder of the test. The observers rated both the inner and outer wheel path portion of each stripe. Each test stripe was one of a set of four replicates. Observation of the original data showed no significant difference between the rating values for wheel paths; therefore, only the data obtained for the outer wheel path were analyzed. The different modes of failure considered were hard to distinguish at times. The angle between the sun, stripe, and observer was critical. Some of the deteriorations, especially abrasion, could not be detected because of the glare or washout of the finer worn spots. The failure due to chipping was easier to evaluate early in the test, but, when the abrasion failures became more predominant (i.e., when the substrate was exposed because of full-depth abrasion), a considerable amount of interference was encountered in making the evaluation. General appearance was the easiest mode of failure to evaluate and included both the abrasion and chipping losses as well as the discoloration and dirt retention of the stripe.

The complete statistical evaluations made on each of the modes of failure show that the general appearance rating was inclusive and contained basically the same significance levels as the abrasion and chipping contained. Data from the chipping and general appearance ratings best predict the actual life expectancy of the stripes. The abrasion ratings projected the life expectancy approximately 40 percent higher than actual. Therefore, the following discussion will be based mainly on data on general appearance.

Analysis of variance indicated no significant difference between observers; however, kind of paint, wet film thickness, age, color, and pavement type were significant. Significance above the 0.1 percent level was indicated. Reorganization of the data by successive elimination of specific variables showed that the kind of paint was significant. The CR had the best wear characteristics. Table 1, which shows the magnitude of this difference, gives the life expectancies in weeks for an ASTM failure rating of 3.0. The data also show the magnitude of the significant difference between pavement types.

The effect of thickness when studied in analyses of both types of paint was significant. This does not indicate the relationship between the thickness of each paint separately. Therefore, by evaluating the 2 paints separately on each pavement type for the 3 thickness ranges indicated, significance remained at the 0.1 percent level. The thickness variables for each paint type for each pavement were subdivided into linear and quadratic components to further evaluate the nature of the thickness relationship. This analysis showed that generally there is a linear relationship with both the MS and the CR. This indicates that life expectancy does increase so that near the end of the expected life of the stripes the 20-mil (0.50-mm) thickness is significant. However, the advantage of the 20-mil (0.50-mm) thickness does seem small (Table 1), particularly for the white paints, and this was of major concern for the striping standards at that time.

This study indicates the life expectancy of the white and yellow MS was increased by 6 and 12 percent respectively on concrete and by 12 and 9 percent respectively on asphalt when the wet film thickness was increased from 10 to 20 mils (0.25 to 0.50 mm). This was an overall increase of approximately 9 percent for both colors on both test pavements. The life expectancy of the white and yellow CR was increased by 40 and 32 percent respectively on concrete and 18 and 30 percent respectively on asphalt when the wet film thickness was increased from 10 to 20 mils (0.25 to 0.50 mm). This was an overall increase of approximately 30 percent for both colors on both test pavements.

Similar comparisons were made reflecting the magnitude of the effect of paint type by the general appearance at each paint thickness. The life expectancy of the CR at 10-, 15-, and 20-mil (0.25-, 0.38-, and 0.50-mm) thickness was 16, 20, and 38 percent greater respectively than that of the MR, and there was a somewhat greater increase in life for the yellow paint than for the white.

The magnitude of the effect of pavement type was higher than expected. A comparison of pavement type regardless of paint type shows that the asphalt concrete pavement has approximately 41, 41, and 35 percent greater life expectancy than the concrete for the 10-, 15-, and 20-mil (0.25-, 0.38-, and 0.50-mm) application rates.

Phase 2—Hot-Applied Paints

Phase 2 was a field evaluation of several proprietary types of hot-applied paints and was confined to the application of paint stripes in a similar manner as described for phase 1. The test methods and evaluation of these stripes were exactly the same as those for phase 1.

The 2 cold-applied paints from phase 1 were included for standards from which durability of the heated paints could be evaluated. A newly formulated CR that incorporated methylene chloride rather than methyl ethyl ketone as part of the vehicle was included in phase 2 for exploratory results only.

The life expectancies of the paints based on general appearance were used to evaluate these results. The wear resistance of the high-heat paints was definitely influenced by the type of pavement surface. The aggregate was exposed in both test locations; however, protrusion of the aggregate particles was much more pronounced in the concrete test deck. Failure of the test stripes generally began on the protruding aggregate particles. Because of this difference in rates of wear per pavement type, the statistical analysis considered the data obtained from each pavement type separately.

Terminal rating values of 3.0 and 4.0 were included in the analysis to determine if the failure rate was sufficiently established at the 4.0 level to accurately establish significance of the same order as that given at the 3.0 level. The results of statistical analysis and the relative order of significance for the paints considered show that the same identical order persists within a pavement type. However, a color reversal that exists between the pavement type with white on asphalt and yellow on concrete gives the longer life expectancy. Tables 2 and 3 give these data by color and pavement type. Comparing the ordering of the kinds of paint shows that color has a definite bearing on the wear resistance of a particular brand of paint.

These results show that, among the various proprietary high-heat traffic paints, paint type G consistently ranked high regardless of color or pavement type. The CR retained its superiority over the MS.

The high-heat paints conformed to all the required properties as shown in their specifications; however, further tests were made for information only. Laboratory analysis of the high-heat paints was conducted by using a Beckman IR-12 spectrophotometer for the infrared spectra for the vehicle and solvent portions. An Ortec nondispersive X-ray spectrometer and an ARL microprobe were also used to determine the properties of the pigment portion of the paint. Results of this study are given in Table 4.

The infrared spectra of all the paints except type O revealed that the vehicles were all modified phthalic alkyds. The short, medium, or long oil are based on comparison with known alkyds and are considered to be more probable designations. The major and minor components of the pigments are transcribed into the most probable chemical components by the results of the X-ray and microprobe analyses.

Phase 3—Glass Beads

Phases 1 and 2 provided the data for phase 3 in which the best of the cold- and hot-applied paints tested were used to determine the quality of various glass bead types and application rates.

Each test section consisted of 1,200 ft (366 m) of centerline stripe. All systems on the striper were checked and calibrated prior to application, and the wet film thickness and dry times of each paint were taken at the time of application.

Evaluation of the paint stripes was based on the same criteria as those for phase 1 and 2 stripes; however, the night visibility test was added to test the reflectivity of the glass beads. In this test, an automobile was positioned on the shoulder of the highway so that the left tires just touched the edge of the concrete pavement or just touched the white edge stripe on the asphalt concrete pavement. The front bumper was even with the leading end of a 15-ft (4.6-m) white dash mark. This dash mark was used as the beginning of the test section and as a reference point for all observations. A point-count

Table 1. Life expectancy, in weeks, of stripes calculated from regression slope values.

	Asphalt			Concrete		
Paint Type	10 mil	15 mil	20 mil	10 mil	15 mil	20 mil
General Appearance						
MS white	13.2	13.9	14.8	9.7	9.7	10.3
CR white	13.7	14.6	16.1	10.5	12.3	14.7
MS yellow	13.7	15.2	14.9	9.2	9.0	10.0
CR yellow	17.3	17.9	22.4	11.8	12.5	15.6
Abrasion						
MS white	19.2	21.0	24.3	19.8	19.2	22.6
CR white	20.5	21.9	28.5	19.3	25.4	28.7
MS yellow	21.6	24.4	25.1	16.8	18.5	25.4
CR yellow	25.9	33.3	37.0	25.0	23.9	35.9
Chipping						
MS white	17.6	18.9	20.6	11.1	11.2	11.9
CR white	17.7	19.5	23.8	12.6	15.4	17.8
MS yellow	17.5	18.8	18.5	10.5	10.2	11.9
CR yellow	23.6	26.7	32.7	14.8	15.9	20.2

Note: 1 mil = 0.025 mm.

Table 2. Analysis of variance for white and yellow paint on concrete and asphalt pavements for general appearance rating of 3.0.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	Significance Level	Significance	$k_{0.01}$
Asphalt pavement White paint							
K	6	99.17	16.53	65.07	0.001	—[a]	1.1[b]
R	35	8.88	0.25				
Total	41	108.05	2.64				
Asphalt pavement Yellow paint							
K	6	863.59	143.93	2,767.90	0.001	—[a]	0.5[b]
R	35	1.80	0.05				
Total	41	865.39	21.11				
Concrete pavement White paint							
K	6	402.63	67.11	113.55	0.001	—[a]	1.7[b]
R	35	20.69	0.59				
Total	41	423.32	10.32				
Concrete pavement Yellow paint							
K	6	370.98	61.83	792.69	0.001	—[a]	0.6[b]
R	35	2.74	0.08				
Total	41	373.72	9.11				

[a] Highly significant. [b] Difference in means required to indicate a significant difference.

Table 3. Ranking for various high-heat, yellow and white paints on concrete and asphalt pavements.

		Ranking				Ranking	
Pavement	Paint Color	Paint Type	Average	Pavement	Paint Color	Paint Type	Average
Asphalt	White	G	14.8	Concrete	White	G	10.6
		I	14.4			CR	8.4
		K	14.2			I	7.9
		CR	13.6			K	6.4
		M	12.6			MS	6.3
		MS	11.8			M	2.1
		O	10.2			O	1.4
Asphalt	Yellow	I	15.6	Concrete	Yellow	K	10.5
		G	15.3			G	9.6
		K	14.2			CR	9.2
		CR	14.0			M	7.2
		M	12.7			I	5.6
		MS	11.0			MS	4.8
		O	1.5			O	1.4

method of testing night visibility was devised and found to be much easier to justify than the ASTM visual rating system.

The life expectancies of each set of test stripes based on ASTM method are given in Table 5 for each of the observed modes of failure.

The relationship between observers and between pavement types was nonsignificant for observers and significant for pavement types.

The night visibility rating system (Table 5) represents the ASTM method with averages computed by two methods. These data, as a whole, indicate that night visibility is the major controlling source of failure of the three modes shown. The weighted rating does, in a few instances, have a lower rating value than the night visibility. Generally, the same ordering will occur regardless of which rating is used; however, the significance between the various test sections may change. The following analyses will be based on the data shown for night visibility calculated by averaging the interpolated values between observations per observer.

The failure values for the cold-applied paints with the type 1 glass bead applied at 5 lb/gal (600 kg/m^3) indicate the following to be significant. The CR that used methylene chloride as part of the vehicle is poor in its ability to maintain a satisfactory night reflectivity. CR did maintain a respectable daytime appearance and durability rating; therefore, the probable cause of failure was an excessive loss of glass beads.

The CR did show a greater life expectancy over the MS on the asphalt concrete pavement. However, on the concrete pavement there was no difference in these 2 paints. There was a considerable difference between the life expectancy of the same paint and pavement type. The asphalt concrete provided higher values than the concrete by approximately 2 to 1. These data indicate that the possibility of selective striping by pavement types could be considered.

The failure values for the high-heat paints with the type 1 glass bead applied at 5 lb/gal (600 kg/m^3) indicate the following to be significant. The high-heat paints are the same brand of paints as those in phase 2. This analysis shows the type G paint to be the best regardless of pavement type. However, the pavement surface does not seem to have the same magnitude or ordering effect as that shown for the cold-applied paints. The concrete shows the largest life expectancies for 3 of the 4 paints. The fact that these paints are located in 30,000 ADT areas as compared with the cold-applied paints in 18,000 ADT areas may indicate that the surface characteristics are less important as traffic volume increases. The lower life of the paints placed in the higher volume locations was attributable to the loss of glass beads.

The effects of type and concentration of glass beads were studied by using 4 bead types applied at 3, 4, and 5 lb/gal (360, 480, and 600 kg/m^3). The evaluation by type consisted of placing each bead type on asphalt and concrete pavements in the 18,000 ADT and 30,000 ADT areas. This allowed all types of beads to be tested with the best of the cold- and hot-applied paints previously tested. The type 1 and 4 beads were gradation drop-on beads; type 1 conformed to the standard Missouri type 1 specification, and type 4 conformed to a gradation suggested by several manufacturers. The type 2 and 3 beads were floating beads; type 2 conformed to the standard Missouri type 2 specification, and type 3 conformed to the same gradation without the floating compound added. The application rates were evaluated by using either the concrete or the asphalt pavement as given in Table 6.

The performance of type 1, 2, 3, and 4 beads with the cold-applied paints (Table 6) for the 5-lb/gal (600-kg/m^3) application rate on US-50 and US-54 definitely indicates that types 3 and 4 are not significantly different on either pavement. Bead type 2 is significantly better relative to the other beads on concrete; however, on asphalt, the type 1 bead is best.

The performance of type 1, 2, 3, and 4 beads with the hot-applied paints (Table 6) for the 5-lb/gal (600-kg/m^3) application rate on I-55 and I-70 shows that, for concrete pavement, all types are significantly different from each other, and type 2 gives the best performance on concrete and a performance as good as any of the others on asphalt.

These results indicate that the type 2 bead, when applied in concentrations equal to the other types of beads, consistently ranks higher in performance. The type 2 bead shows the best performance on the concrete pavements and is significantly better than

Table 4. Generic composition of high-heat paints.

			Pigments	
Paint Type	Vehicle	Solvents	Major Components	Minor Components
G yellow	Oil-modified phthalic alkyd, short to medium oil	Trichloroethylene, commercial mineral spirits	Si, Pb, Ca, Cr	Al, Fe
G white	Oil-modified phthalic alkyd, medium to long oil	Trichloroethylene, commercial mineral spirits	Ti, Ca	Al, Si
I yellow	Oil-modified phthalic alkyd, medium to long oil	Methylene chloride, commercial mineral spirits	Pb, Ca, Cr, Al, Si	Fe
I white	Oil-modified phthalic alkyd, medium to long oil	Methylene chloride, commercial mineral spirits	Ca, Ti, Si	Al, Fe
K yellow	Oil-modified phthalic alkyd, medium to long oil	Trichloroethylene	Ca, Pb, Cr	Si, Zn, Fe
K white	Oil-modified phthalic alkyd, medium to long oil	Trichloroethylene	Ca, Ti, Si, Zn	Fe, Cr, Al
M yellow	Oil-modified phthalic alkyd, short to medium oil	Toluene, xylene	Ca, Si, Pb, Cr	
M white	Oil-modified phthalic alkyd, medium to long oil	Toluene, xylene	Ca, Si	Ti, Cr, Fe
O yellow	Oil-modified polyamide	Toluene	Ca, Pb, Cr, Si	Al, Fe
O white	Oil-modified polyamide	Toluene	Ca, Ti	Si, Al, Cr, Fe

Table 5. Failure values for each test section.

				Failure (weeks) at 3.0 Rating				Failure (weeks) at 4.0 Weighted Rating
						Night Visibility		
Test Section	Paint Type	Bead Code	Bead Concentration (lb/gal)	Appearance[a]	Durability[a]	$\overline{X}$[a]	$\overline{X}$[b]	
District 5, US-50, Concrete Pavement								
T-1	B	1	5	33.32	34.14	22.42	22.30	28.06
T-2	D	1	5	32.00	33.63	21.14	20.89	26.50
T-3	D	1	4	31.98	35.70	22.50	22.33	27.62
T-4	D	1	3	33.18	35.33	21.51	21.22	26.86
T-5	D	2	5	33.35	35.62	33.33	33.01	30.64
T-6	D	2	4	34.12	35.46	29.24	29.11	29.06
T-7	D	2	3	37.52	43.39[c]	21.30	21.33	25.40
T-8	D	3	5	31.22	39.21	19.73	21.78	24.11
T-9	D	4	5	30.91	37.25	20.00	19.71	23.66
T-10	F	1	5	28.27	34.76	10.00	11.37	19.98
District 5, US-54, Asphalt Concrete Pavement								
T-1	F	1	5	23.50	24.72	16.71	16.56	17.82
T-2	B	1	5	50.26[c]	50.25[c]	45.28[c]	45.28[c]	39.44
T-3	D	1	5	49.67[c]	49.13[c]	56.54[c]	56.54[c]	46.19[e]
T-4	D	2	5	35.92	38.51	34.50	33.67	33.80
T-5	D	3	5	26.44	33.77	25.14	25.17	22.40
T-6	D	4	5	23.90	29.42	25.79	26.31	20.86
District 6, I-55, Concrete Pavement								
T-1	B	1	5	26.87	28.22	15.36	15.33	19.78
T-2	O	1	5	28.22	29.25	25.81	25.67	25.67
T-3	K	1	5	32.84	35.97[d]	6.33	6.38	15.76
T-4	G	1	5	36.39[d]	40.78[d]	29.00	29.00	29.78
T-5	G	2	5	43.16[d]	49.29[d]	38.96[d]	38.96[d]	39.84[e]
T-7	G	3	5	48.92[d]	54.54[d]	32.08	32.06	32.71
T-8	G	4	5	27.06	28.41	21.57	21.53	21.22
District 6, I-70, Asphalt Concrete Pavement								
T-2	B	1	5	26.09	27.67	13.51	13.33	19.51
T-3	O	1	5	33.14	44.18[d]	11.67	10.10	25.62
T-4	G	2	5	33.65	48.37[d]	27.59	27.51	30.88
T-5	G	2	4	51.63[d]	56.41[d]	29.92	29.67	36.91[e]
T-6	G	2	3	53.92[d]	58.74[d]	27.54	27.40	33.84
T-7	G	1	5	45.94[d]	48.35[d]	27.67	27.67	31.12
T-8	K	1	5	29.21	34.66[d]	10.00	7.00	21.25
T-9	G	1	4	46.54[d]	47.83[d]	24.28	22.00	28.30
T-10	G	1	3	46.34[d]	42.81[d]	23.67	22.61	27.23
T-11	G	4	5	53.73[d]	52.21[d]	22.20	21.58	29.37
T-12	G	3	5	82.88[d]	59.92[d]	26.20	26.11	31.39

Note: 1 lb/gal = 120 kg/m^3.

[a] Determined by interpolation between average observer test section ratings of 2 or 3 observers/observation.

[b] Determined by averaging the interpolated values between observations per observer.

[c] After 40 weeks exposure, still rated higher than 3.0. Value extrapolated by regression analysis.

[d] After 34 weeks exposure, still rated higher than 3.0. Value extrapolated by regression analysis.

[e] Values computed as of termination of test did not fall below 4.0. Value extrapolated by regression analysis.

the next best bead. On the asphalt concrete pavement, the type 1 bead is significantly better than the type 2 bead when used with the cold-applied paints. However, considering the failure values, the type 2 bead shows the most consistent rate of failure.

The difference between the application rates of the type 1 bead with the cold-applied paints on US-50 (Table 6) was not significant. The maximum difference in mean failure was less than 2 weeks. The type 2 bead at 5 lb/gal (600 kg/m^3) had a significantly longer life than at 4 lb/gal (480 kg/m^3), and both of these were significantly better than at 3 lb/gal (360 kg/m^3).

The difference between the application rates of the type 1 bead with the hot-applied paints on I-70 (Table 6) shows that 5 lb/gal (600 kg/m^3) is significantly better than 4 or 3 lb/gal (480 or 360 kg/m^3), and there was no significant difference between the latter two. The type 2 bead, however, shows no significant difference based on application rates.

The results show that the type 1 bead at 5 lb/gal (600 kg/m^3) and the type 2 bead at either 5 or 4 lb/gal (600 or 480 kg/m^3) consistently rank high in significance. The most consistent results were obtained with the type 2 bead at 4 lb/gal (480 kg/m^3).

ALTERNATE METHOD FOR ESTABLISHING NIGHT VISIBILITY RATING

The method of rating traffic delineation stripes by night visibility, as stated in ASTM D 713-69, may be done with the human eye and judgment or by photographic methods in which the rating is based on a factor of 10 for the highest reading and 0 for complete failure. It was difficult for the rating team to mentally adjust from observation to observation on this type of subjective rating. Therefore, another system of night visibility rating, which had been used previously in an exploratory test, was also included.

The alternate (point-count) method of rating the stripes for night visibility was also included in this phase to provide for comparison of the 2 methods. These centerline stripes were evaluated by positioning an automobile on the shoulder of the highway so that the left tires just touched the edge of the concrete pavement or just touched the white edge stripe on the asphalt concrete pavements. The front bumper was even with the leading end of a 15-ft (4.6-m) white dash mark. This dash mark was used as the beginning of the point-count method and was established as stripe 1. However, for the point-count method, the observers positioned themselves immediately in front of the automobile, standing between the headlights rather than sitting in the front seat of the automobile. The first observation was made with the low-beam light, and the second observation was made with the high-beam light. The observer, for each light setting, made a point count of how many 15-ft (4.6-m) dashes, including the one used to place the automobile in position, could be clearly and distinctly seen. Each observer decided when to stop counting. It was accepted that this point would be when the stripe no longer gave a clear distinct white appearance and faded to dull gray. The observers consistently felt more comfortable with this rating system than that of the subjective 10 to 0 ASTM rating. Both ratings were made for all test sections in this phase of this investigation. From the number of observations made and the large number of test sections included in this phase, a large quantity of data were made available for analysis. Regression analyses made from the high-beam point-count ratings for each pavement type for the cold- and hot-applied paints versus the ASTM night visibility ratings showed good similarity. This suggested a complete regression analysis be made by using all 307 pairs of data. The resulting regression equation is shown in Figure 1. Because this equation was shown to have a standard error of estimate of only 0.59 and a coefficient of variation of only 12.5 percent, this alternate method does appear to have greater promise than was initially anticipated. From this analysis of the high-beam point-count ratings there does appear to be a less subjective method available whereby night visibility observations may be made by less experienced people who are not familiar with the ASTM method.

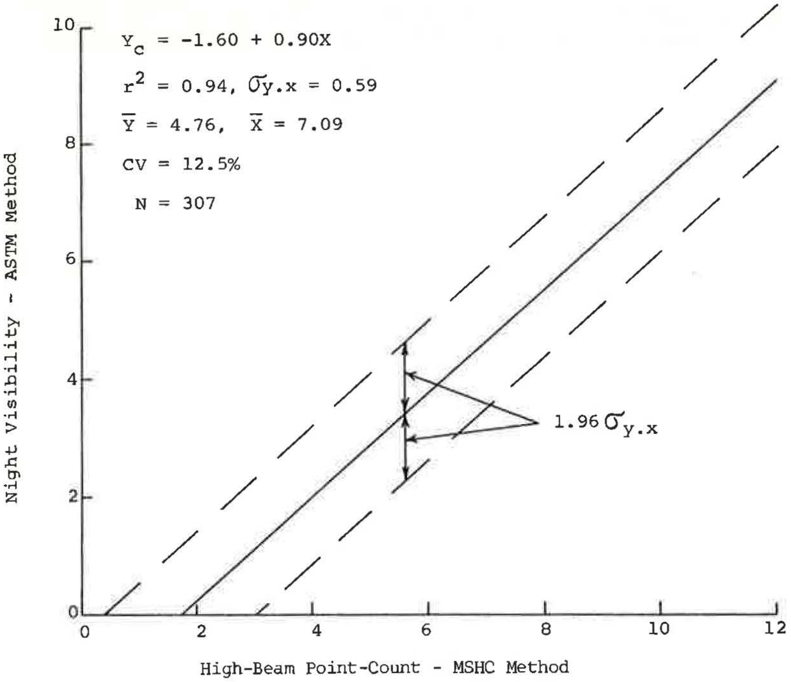
The low-beam point-count ratings were taken with each observation. It became apparent near the latter stages of the investigation, however, that a leveling off of the

Table 6. Ranking of beads and concentrations by failure in weeks and significant differences in mean failures.

Bead Type	Concentration (lb/gal)	Mean Failure (weeks)
US-50, Concrete Pavement, Paint D		
2	5	33.01
2	4	29.11
1	4	22.33
3	5	21.78
2	3	21.33
1	3	21.22
1	5	20.89
4	5	19.71
US-54, Asphalt Concrete Pavement, Paint D		
1	5	56.54
2	5	33.67
4	5	26.31
3	5	25.71
I-55, Concrete Pavement, Paint G		
2	5	38.96
3	5	32.06
1	5	29.00
4	5	21.53
I-70, Asphalt Concrete Pavement, Paint G		
2	4	29.67
1	5	27.67
2	5	27.51
2	3	27.40
3	5	26.11
1	4	24.47
1	3	22.61
4	5	21.58

Note: 1 lb/gal = 120 kg/m^3. Vertical lines connect variables for which no claim can be made for any difference in their behavior at 0.01 level.

Figure 1. Combined regression analysis of high-beam point-count and ASTM night visibility ratings.



ratings occurred around the third and fourth dash marks, and the high-beam point-count ratings continued to deteriorate. Because of this inconsistency, the low-beam point-count ratings were omitted and considered inadequate for use as a night visibility rating method.

CONCLUSIONS

Phase 1 proved that both white and yellow cold-applied CR were significantly better than MS when placed as transverse stripes on asphalt and concrete pavements. The stripes placed on the asphalt pavement had durability ratings significantly better than those placed on concrete pavement for both paints at all thickness ranges.

The significance between application rates of the paints indicates there is a linear relationship for durability for both the MS and CR. This indicates that as thickness increases the life expectancy of the stripe increases; however, the actual difference in life expectancy of the MS is only increased by 1 percent for each 1-mil (0.025-mm) increase in application rate. The CR showed a 3 percent increase in life expectancy for a 1-mil (0.025-mm) increase in application rate.

Transverse stripes placed on the asphalt surface had approximately a 40 percent increase in life expectancy over that for the concrete surface. The CR consistently showed greater life expectancy than the MS in all thickness ranges on all pavements.

Phase 2 proved that the relative durabilities of several proprietary high-heat paints were definitely a specific characteristic of the kind and color of paint and of the pavement type to which it was applied. However, one particular type of paint was consistently higher ranking than the other paints.

Phase 3 proved that the overall performance of the paint-bead system is best evaluated by the night visibility mode of failure. The cold- and hot-applied paints continued to substantiate the previous work in this study. The overall performance of the Missouri type 2 floating bead was better than the Missouri type 1 gradation bead. Glass bead types 3 and 4 had the lowest life expectancies. The type 2 bead at 4 lb/gal (480 kg/m^3) showed the most consistent results. The less subjective point-count method of rating the appearance of a stripe at night was included in phase 3 as a possible alternate method to the ASTM night visibility rating method. This method may be used by relatively inexperienced observers for determining when restriping is necessary.