EVALUATION OF TRAFFIC MARKING BEADS AND PAINT

by

Frank D. Shepard
Highway Research Engineer

Virginia Highway Research Council
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SUMMARY

Traffic markings that retain high reflective properties under adverse lighting and weather conditions are clearly of utmost importance in traffic safety. It was the intent of this study to investigate optimum traffic striping procedures and materials by evaluating such variables as:

(1) Certain characteristics of glass beads, namely their gradation and flotation properties;

(2) Rate of bead application; and

(3) Type of paint, including fast and slow drying paints.

As a consequence of problems encountered with the control of the bead and paint application rates, the evaluation of the striping procedure and materials was limited. However, based on the results the following conclusions are presented:

(1) Insufficient evidence was obtained to indicate that any one of the three bead types used was superior to the other in brightness under dry night conditions; however, it appears that the floating bead has an advantage over the non-floating bead under wet night conditions as the stripes with the floating bead were visible for further distances.

(2) No clear advantage was noted for either of the two bead application rates used.

(3) The fast drying paint used seemed to compare favorably with the slow drying paint, which supports the Department's decision for more extensive use of fast drying pavement marking paint in the immediate future.

It is suggested that before additional in-depth studies are considered the results of a 1971 NCHRP Project entitled "Development of Optimum Specifications for Glass beads in Pavement Markings" be awaited, as many of the objectives of this NCHRP project should touch upon many of the unanswered questions in this report.

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BACKGROUND

Traffic markings that retain high reflecting properties under adverse lighting and weather conditions are clearly of utmost importance to traffic safety. The Virginia Department of Highways, seeking information on new materials and techniques employed for pavement markings, requested the Research Council to conduct a preliminary investigation of various aspects of traffic markings, the more important of which are discussed in a general way in the following subsections.

Paint Film Thickness

It has become general practice in most state highway departments to use a wet paint film thickness of 15 mils (0.015 inch). This thickness was selected primarily on the basis of field experience. Several years ago the Michigan Department of State Highways conducted field tests on various paint film thicknesses and found that above 16 mils additional thickness did yield additional durability, but the added durability was not proportional to the additional thickness of the film. For this reason it was decided by Michigan that the use of a wet paint film thickness in excess of 16 mils was uneconomical. For the purposes of this study, a wet film thickness of 15 mils is considered adequate and will be used as a standard reference base in comparing the other variables.

Bead Gradation

Glass beads are applied to traffic markings in a somewhat indiscriminate, random fashion. Past and present practices utilize a gradation specification nearly identical to the production gradation: the "specifications" largely coincide with what is produced. Pocock and Rhodes long ago pointed out:

> Most users have assumed thus far that the glass beads should be uniformly graded from coarse to fine, the theory being that the smaller beads would be successively exposed for effective reflection as the paint wore down. Although the theory is logical and plausible, there are no published data to show exactly the relation between gradation and continuing optimum reflectivity. (1)

Recent studies, notably one by the Colorado Department of Highways,[2] seem to show considerable improvements in night reflectivity for more uniform bead gradations. It should be noted that the Colorado tests were performed on flotation-type beads, which may or may not have influenced the results.

Bead gradations in the different state specifications vary considerably. Generally, the beads range in size from the No. 30 mesh down to the No. 100 mesh. As mentioned above, this size distribution seems to have been adopted more for convenience than any other reason, and research into the performance and economic qualities of other gradations is necessary.

Bead Type and Application Rate

The standard rate of application of glass beads is 6 pounds of drop-on beads per gallon of paint. In the previously mentioned Colorado report it was noted that when using the newly developed flotation-type bead with a uniform gradation, an application rate of 4 pounds per gallon was found to be satisfactory.[2]

The amount of beads applied to the striping is of fundamental importance. Too few beads will fail to provide sufficient reflectorization and too many beads may contribute to the premature failure of the marking through abrasion. Additionally, only so many beads can be "held" by the paint. A high application rate could result in substantial waste. The significance of this aspect of the Colorado report is thus highly evident: though the flotation-type bead is slightly more expensive than the regular glass bead, only two-thirds as much by weight is required. The economic savings accruing from the use of this new type of bead could be very high.

Paint Type

Much research recently has been directed to developing fast drying paints for traffic markings. The drying time of regular paint is in the range of 30 to 50 minutes. This presents the painting crew with the problem of directing traffic away from the freshly applied markings for a considerable period of time. Cones must be placed and removed; the crews must be trained in safety techniques; and the operation is very time-consuming.

The New York State Department of Transportation uses a paint that dries in less than 90 seconds after application. The use of this type paint eliminates the need to set out cones, which often are hazardous; two follow-up trucks clear traffic away from the fresh striping for a distance of 900-1,500 feet behind the paint truck, which allows the binder sufficient time to dry if the trucks travel at 9 mph. The fast drying paints cost about the same as the regular paint.

The Florida Department of Transportation is using paints with drying times of between 20 and 50 seconds. At 20 seconds, the follow-up truck need clear traffic for only 230 feet, a distance easily protected. Even with the higher cost of these paints, Florida has found them economically superior to the regular paints.

What needs to be determined is how readily the glass beads adhere to these new paints. With the short drying times, beads may have to be applied with a pressure gun to become adequately imbedded in the wet binder.

PURPOSE AND SCOPE

The purpose of this study was to determine optimum pavement striping procedures and materials with respect to the following variables:

(1) Bead type
   (a) Flotation properties with uniform gradation
   (b) Non-flotation properties with uniform gradation
   (c) Virginia standard with wide gradation

(2) Bead application rate — the standard rate of 6 pounds per gallon versus a rate of 4 pounds per gallon

(3) Binder type — quick drying paint versus conventional, or slow drying, paint

The scope of the project was limited to investigations of center line pavement markings on a rural interstate highway with a traffic volume in the 5,000 vehicles per day range.

APPLICATION OF TEST STRIPES

Experimental pavement markings were applied on a 12-mile section of I-64 near Zion Crossroads — 6 miles of concrete and 6 miles of bituminous pavement. Test lines were painted over existing lines, which had no significant paint build up as a result of the highway being only one year old. This scheme is considered ideal, since the two comparative sites are subjected to nearly identical traffic flow and weather conditions.

At each site, test sections approximately one-half mile in length (about 66 stripes) were applied. Three bead types were employed: the Virginia standard, well graded bead; a uniformly graded bead with flotation properties; and a uniformly graded bead with non-flotation properties. (See Table 1.) An attempt was made to apply the beads at two different rates — 4 and 6 pounds per gallon of paint. Examples of bead application rates in the 6 lb./gal. range are shown in Figures 1 and 2 for the Virginia standard, well graded bead and the uniformly graded bead. As noted in Figure 1, the well graded beads have a wider gradation as compared with those shown in Figure 2 which are within a smaller gradation range. Finally, both the Virginia standard paint and a quick drying paint that is used in Florida were used with a desired wet thickness of 15 mils. Table 2 shows the combination of variables desired for each test section. In all cases where a slow drying paint was used, beads were dropped under gravity flow, whereas, for the fast drying paint, beads were applied under pressure because of the rapid surface hardening of the fast drying paint requiring pressure for proper bead embedment and retention.

TABLE 1

Bead Type Specifications

Sieve No.	Virginia Standard	Floating*	Non-Floating
30	91.2	100.0	100.0
40	55.6	98.8	98.0
60	12.6	67.0	67.0
80	2.1	25.8	26.0
100	0.5	0.9	1.0
200	0.15	0.0	0.0

* A maximum of 90% by weight of the glass beads shall float on xylol when tested.

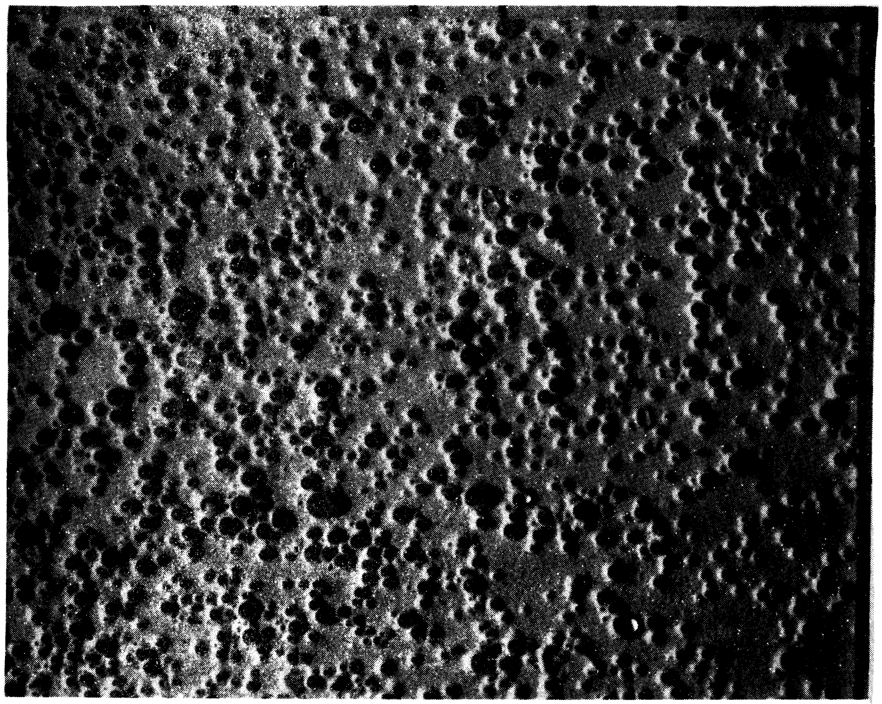


Figure 1. Close-up of Virginia standard, well graded beads — 5.6 lb./gal.

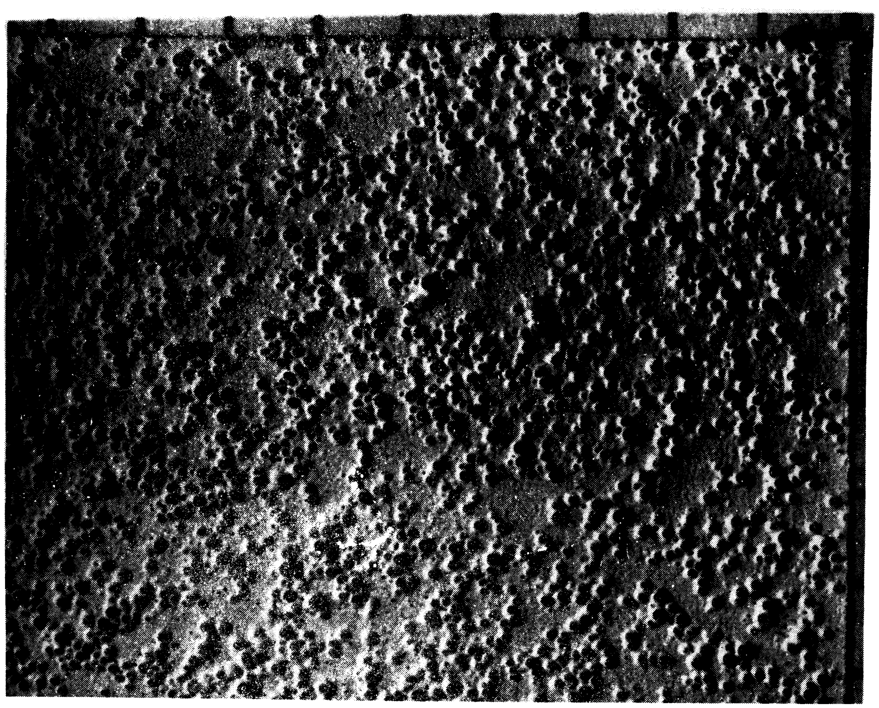


Figure 2. Close-up of uniformly graded beads — 5.6 lb./gal.

TABLE 2

Summary of Variables Desired for Each Test Section

Test Section	Pavement Type	Paint Type	Bead Type	Bead Rate (lb./gal).	Bead Flow
1	Bituminous	Fast[a]	Std.[b]	4	press.[c]
2	"	Fast	Std.	6	press.
3	"	Fast	Unif.[d]	6	press.
4	"	Fast	Unif.	4	press.
5	"	Fast	Fl.[e]	4	press.
6	"	Fast	Fl.	6	press.
7	"	Slow[f]	Std.	6	grav.[g]
8	"	Slow	Std.	4	grav.
9	"	Slow	Fl.	6	grav.
10	"	Slow	Fl.	4	grav.
11	"	Slow	Unif.	6	grav.
12	"	Slow	Unif.	4	grav.
13	Concrete	Fast	Std.	6	press.
14	"	Slow	Fl.	4	grav.
15	"	Slow	Fl.	6	grav.
16	"	Fast	Std.	4	press.
17	"	Fast	Unif.	4	press.
18	"	Fast	Unif.	6	press.
19	"	Fast	Std.-Ct.[h]	6	press.
20	"	---[i]	---	-	----
21	"	Slow	Unif.	6	grav.
22	"	Slow	Unif.	4	grav.
23	"	Slow	Std.	6	grav.
24	"	Slow	Std.	4	grav.
25	"	Fast	Fl.	6	press.
26	"	Fast	Fl.	4	press.
27	"	Slow	Fl.	6	grav.

(a) Fast drying — less than 2 min.
(b) Standard Virginia bead
(c) Beads applied under pressure
(d) Non-floating bead with same gradation as floating bead
(e) Floating bead
(f) Slow drying — 1/2 hour
(g) Beads applied under gravity flow
(h) Virginia standard bead with flotation properties
(i) Existing pavement marking from previous year

INSTRUMENTATION AND EVALUATION

Paint Thickness

Samples of paint and bead application rates were obtained by placing 4 in. x 4 in. metal plates on the road surface prior to striping. Dry paint thickness was determined by focusing a microscope on the paint surface and then on the plate surface, the difference in readings being the paint thickness. Eight readings were taken for each plate; the high and low were omitted and the remaining six were averaged. Two sample plates were obtained from each test section.

Bead Application Rate

An indication of the rate of bead application was obtained by counting the number of beads per unit area on the sample plates taken from each test section. The number of beads per unit area was then converted to pounds of beads per gallon of paint by using the conversion chart shown in Figure 3, which was developed by Colorado. (2)

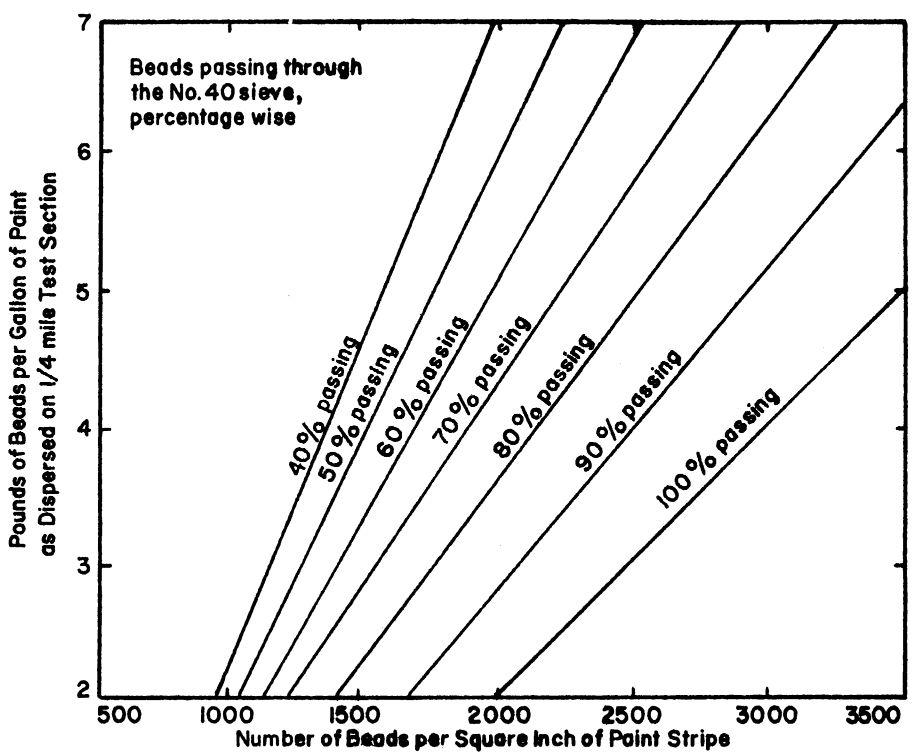


Figure 3. Bead conversion chart from reference 2.

Dry Night Visibility

The relative retroflection under dry night conditions was measured using a photocell device similar to that developed in New Jersey for the Department of Transportation. As noted on the diagram in Figure 4 the components used in the apparatus are a spotlight, battery, inverter, recording electrometer, photocell, and convex lens. Reflected light from a single traffic stripe is admitted through a slot in the end of a cylinder and is focused onto a photocell.

The photocell sensing device was mounted on a van at a height of 3 feet above the pavement as shown in Figure 5. The spotlight was focused at a point on the pavement ten feet in front of the van (approximately an 18 degree angle). The van was driven at a speed of approximately 5 mph with the spotlight centered over the stripes.

Reflected light from each stripe is recorded on the electrometer in terms of a resistance value, with the indicated resistance being inversely proportional to stripe brightness. A typical record of photocell data is shown in Figure 6 with all stripes showing similar brightness.

After elimination of all brightness values for nonrepresentative lines (lines obviously missed by the focused light, etc.) a single value was obtained by averaging the remaining individual lines comprising a section. This brightness value was then corrected for temperature variation using the charts shown in Figure 7, as furnished by the photocell manufacturer.

To ensure against possible variations in instrument response, a photocell brightness reading was obtained from a reference standard at various intervals within each section. This reference standard consisted of an 8-foot piece of reflective tape applied to the center of a 3-foot wide piece of plywood painted with flat black paint.

It should be noted that the values of brightness obtained here are relative brightnesses of the traffic stripes and do not represent absolute stripe brightness.

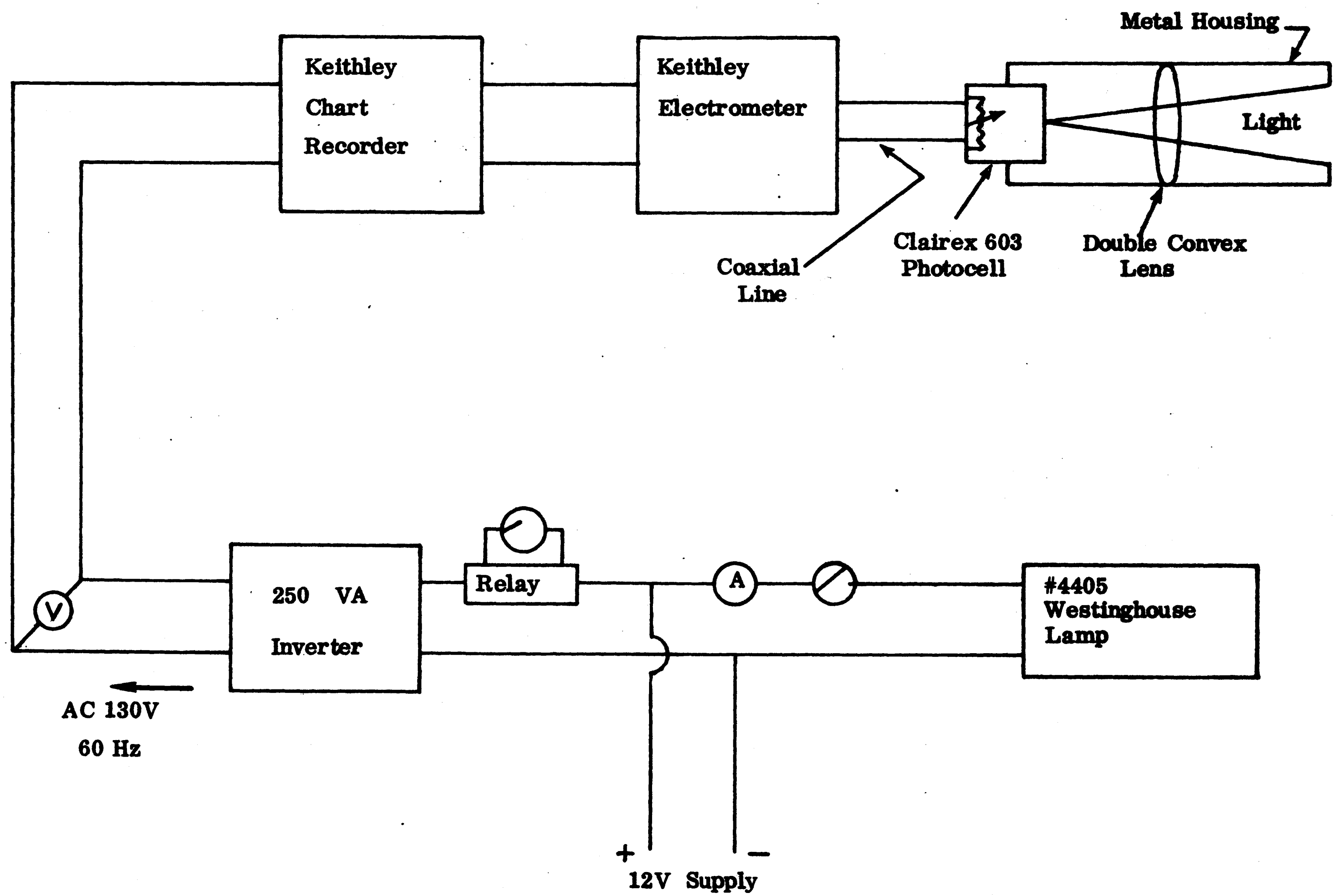


Figure 4. Diagram of photocell apparatus electrical circuit.

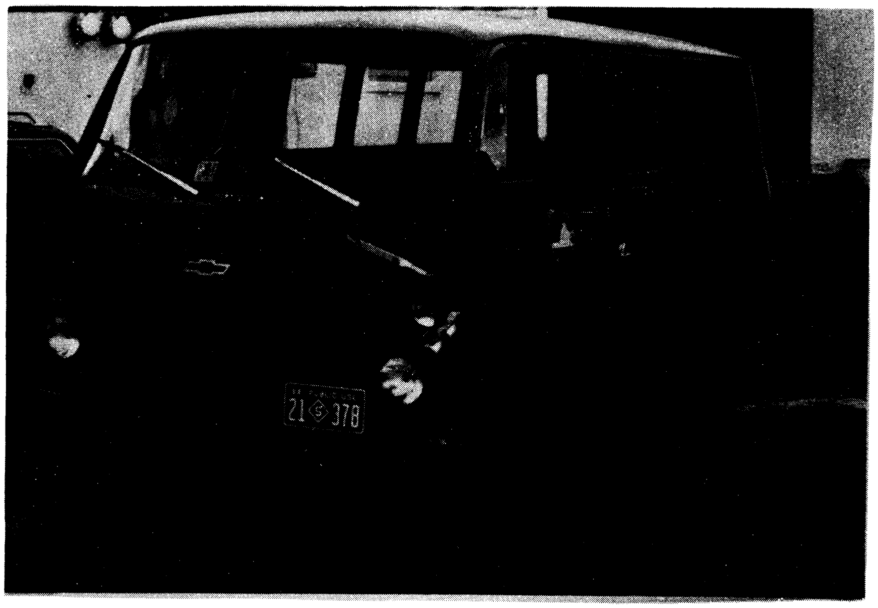


Figure 5. Photocell sensing device and spotlight mounted on van.

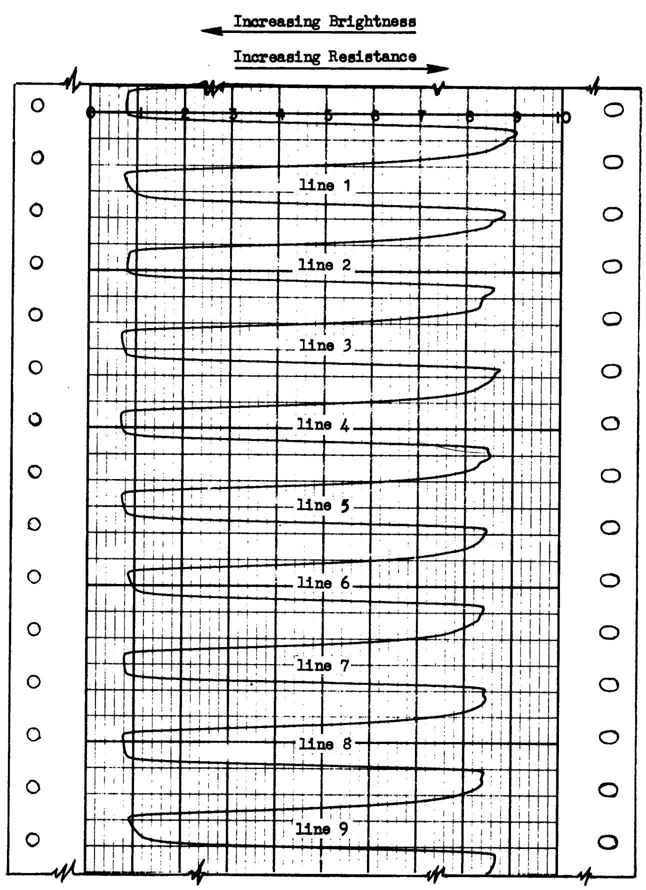
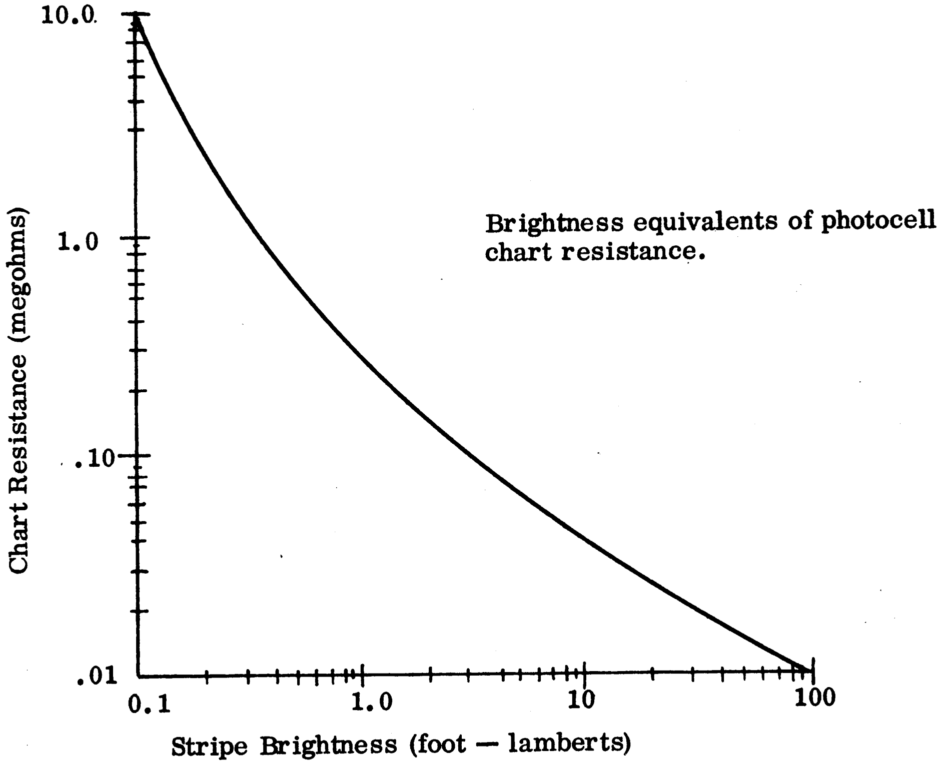


Figure 6. Typical record of photocell data.



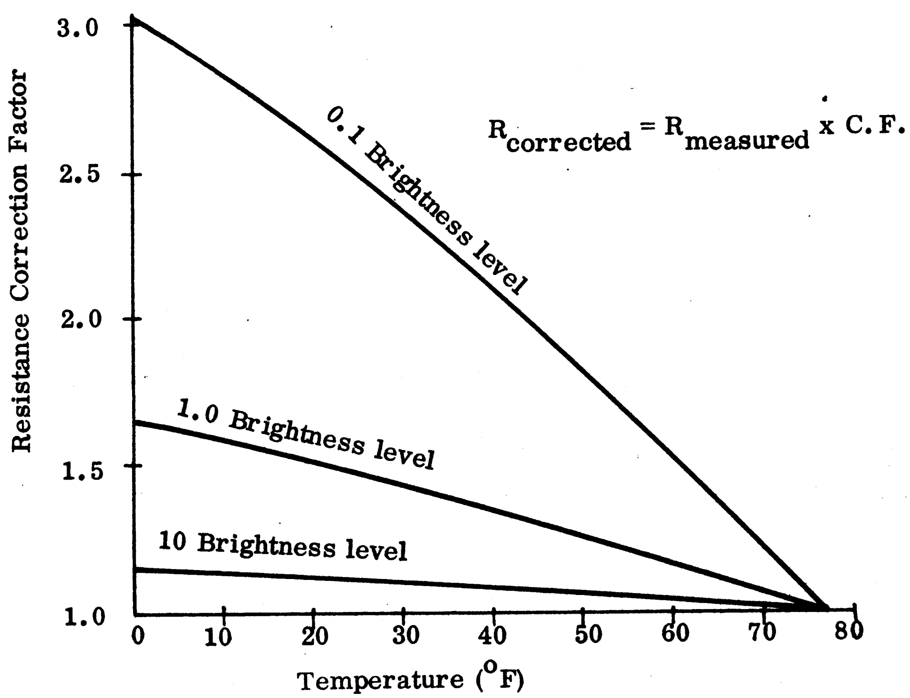


Figure 7. Temperature correction charts for photocell chart resistance.

Wet Night Visibility

An evaluation of the test sections under wet night conditions was made by an ovservation panel as the photocell apparatus could not be used in rainy weather. The panel, consisting of two engineers and one technician, drove over the test sections at normal driving speeds and independently ranked each section from 1 to 10, with 1 denoting the least bright section and 10 the brightest.

Two separate evaluations were made with each consisting of two runs through all sections. An individual brightness rating for each section was obtained by averaging the panel's rating for the section.

Bead Retention

Photographs were taken at a designated spot in each section the day after the site had been tested with the photocell apparatus. The number of beads and the number of voids were counted from these photographs and the percent bead retention was calculated.

RESULTS

The results of the study are based primarily on the photocell brightness values, taking into consideration actual bead application rates, wet ratings, and paint thickness. It should be noted that as a result of the many variables involved, and the problems associated with the control of bead and paint application rates with the striping machine, the results are erratic and in many cases inconclusive.

The photocell brightness values (resistance) along with actual bead application rates, wet ratings, dry paint thickness and percent bead retention are shown in Table 3 for bituminous and concrete pavements. As noted, there was a large discrepancy between the desired and actual bead application rates. Also, the dry paint thickness varies from 2.6 mils to 17.6 mils, which deviates somewhat from the desired 10 mils dry thickness. Again, it should be noted that the brightness values are in terms of resistance and are inversely proportional to actual brightness, i.e., the higher resistance values denote decreased brightness.

TABLE 3

Summary of Data for Each Test Section

Test Section	Pavement Type	Bead Application Rate		Photocell Values					Wet Rating		Dry Paint Thickness	% Bead Retention
		Desired	Actual	11/16/71	11/30/71	1/24/72	4/10/72	8/1/72	1	2	(Mils)	8/1/72
1	Bit.	4	4.7	.102	.116	.176	.228	.949	7.7	6.8	3.9	69
2	Bit.	6	9.1	.110	.111	.169	.175	.371	6.0	4.6	4.6	--
3	Bit.	6	3.8	.107	.106	.171	.180	.441	4.0	4.0	4.0	63
4	Bit.	4	0.6	.138	.146	.188	.188	.336	6.4	6.3	5.0	49
5	Bit.	4	0.2	.166	.159	.199	.219	.278	6.6	6.9	2.8	62
6	Bit.	6	3.7	.110	.105	.160	.195	.394	3.0	3.4	2.6	40
7	Bit.	6	2.8	.110	.110	.168	.198	.348	5.6	5.8	11.4	34
8	Bit.	4	14.1	.064	.084	.115	.091	.140	9.6	10.0	13,6	72
9	Bit.	6	7.1	.067	.090	.120	.128	.227	9.0	9.2	11.5	70
10	Bit.	4	5.0	.075	.106	.143	.169	.272	8.3	9.0	12.7	86
11	Bit.	6	11.0	.088	.110	.148	.140	.201	8.4	9.2	13.8	92
12	Bit.	4	3.0	.137	.144	.210	.271	.389	6.2	6.1	12.0	62
13	Conc.	6	12.6	.096	.082	.134	.136	.321	4.3	4.1	3.5	--
14	Conc.	4	5.1	.095	.102	.163	.198	.535	4.3	2.9	10.8	61
15	Conc.	6	11.6	.058	.074	.107	.101	.181	4.3	3.1	12.7	50
16	Conc.	4	5.6	.121	.102	.151	.192	.212	2.8	2.6	4.1	--
17	Conc.	4	1.2	.183	.126	.173	.203	.213	4.6	2.9	5.0	41
18	Conc.	6	5.7	.131	.110	.138	.126	.166	4.5	2.9	4.8	38
19	Conc.	6	8.6	.093	.084	.143	.170	.188	4.1	3.6	4.7	43
20	Conc.	-	---	.080	.090	.147	.190	.260	2.4	1.9	---	--
21	Conc.	6	11.1	.075	.076	.124	.127	.121	3.6	3.1	15.2	47
22	Conc.	4	1.8	.156	.126	.190	.199	.255	4.7	2.8	10.6	--
23	Conc.	6	8.1	.093	.101	.136	.127	.151	4.9	2.9	12.4	76
24	Conc.	4	3.3	.106	.105	.170	.167	.204	6.2	3.1	11.2	66
25	Conc.	6	5.6	.093	.090	.148	.155	.168	4.7	2.7	3.4	39
26	Conc.	4	0.2	.172	.131	.195	.246	.225	3.1	3.4	3.0	67
27	Conc.	6	12.0	.118	.097	.152	.136	.094	5.2	---	17.6	72

Effect of Bead Type on Brightness

An evaluation of the Virginia standard well graded bead, the uniformly graded floating bead, and uniformly graded non-floating bead was attempted by plotting photocell brightness values against time. Only those bead types which had application rates and paint thicknesses in the same range were compared.

Figure 8 shows a comparison of the floating and non-floating beads applied under pressure to a fast drying paint. There is obviously no difference in the two types as both show almost identical photocell values for each time period. This would be expected as both types have the same gradation in addition to being applied under pressure, which would counteract the floating properties of the flotation bead. It should be noted that in cases where the dry paint thicknesses were less than 5 mils , the 9-month evaluation period was not included. It has been indicated from the study of close-up photographs that 5 mils may be worn away by traffic prior to the expiration of the 9-month period.

A comparison of the non-floating bead with the standard, well graded bead is shown in Figure 9 for slow drying paint applied under gravity flow. The standard bead is superior in brightness for all observation periods. It is felt that this finding results from the smaller non-floating beads being submerged below the paint surface whereas with the standard beads, although they do not possess flotation properties, a small percentage of the larger ones are not initially submerged.

Results for all the bead types are shown in Figure 10, with the beads being applied under pressure to fast drying paint. There is very little difference in the bead types for the first three observation periods, however, after the last observation period the non-floating, uniform beads are slightly brighter than the floating and standard bead types. This is a reversal of the comparison in Figure 9, however, the difference could be a result of a below normal paint thickness that would allow the smaller uniform beads to be exposed. The larger standard beads may have raveled off because of the inadequate adhesive properties of the thinner paint film.

Based on the limited bead type comparisons shown above, it cannot be stated with any degree of certainty that one bead type or gradation is superior to another.

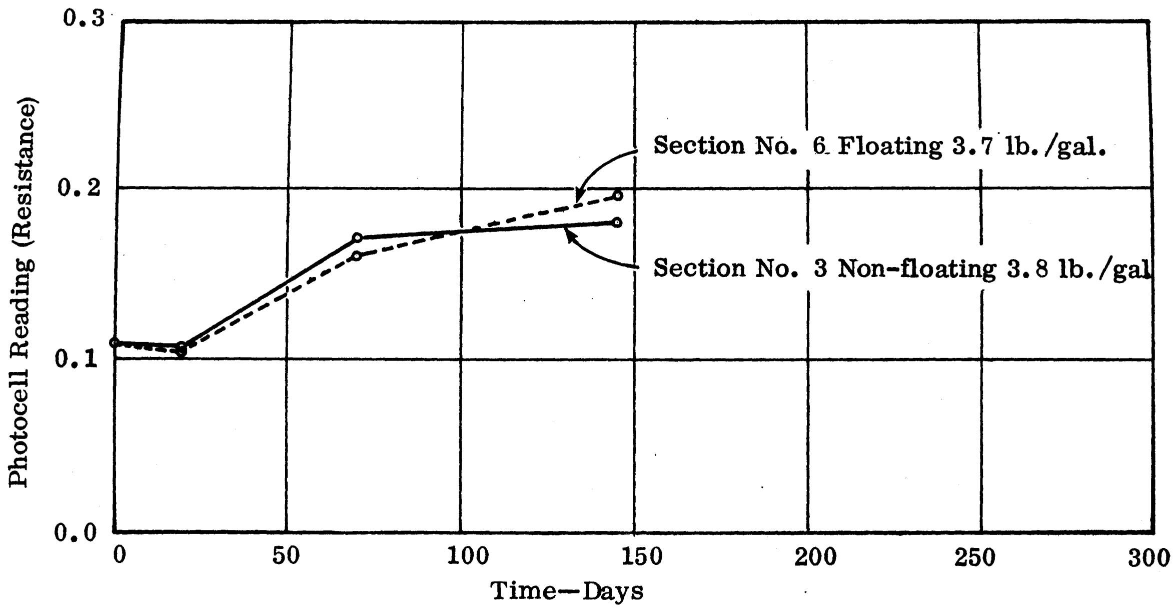


Figure 8. Comparison of bead type — pressure flow on fast drying paint.

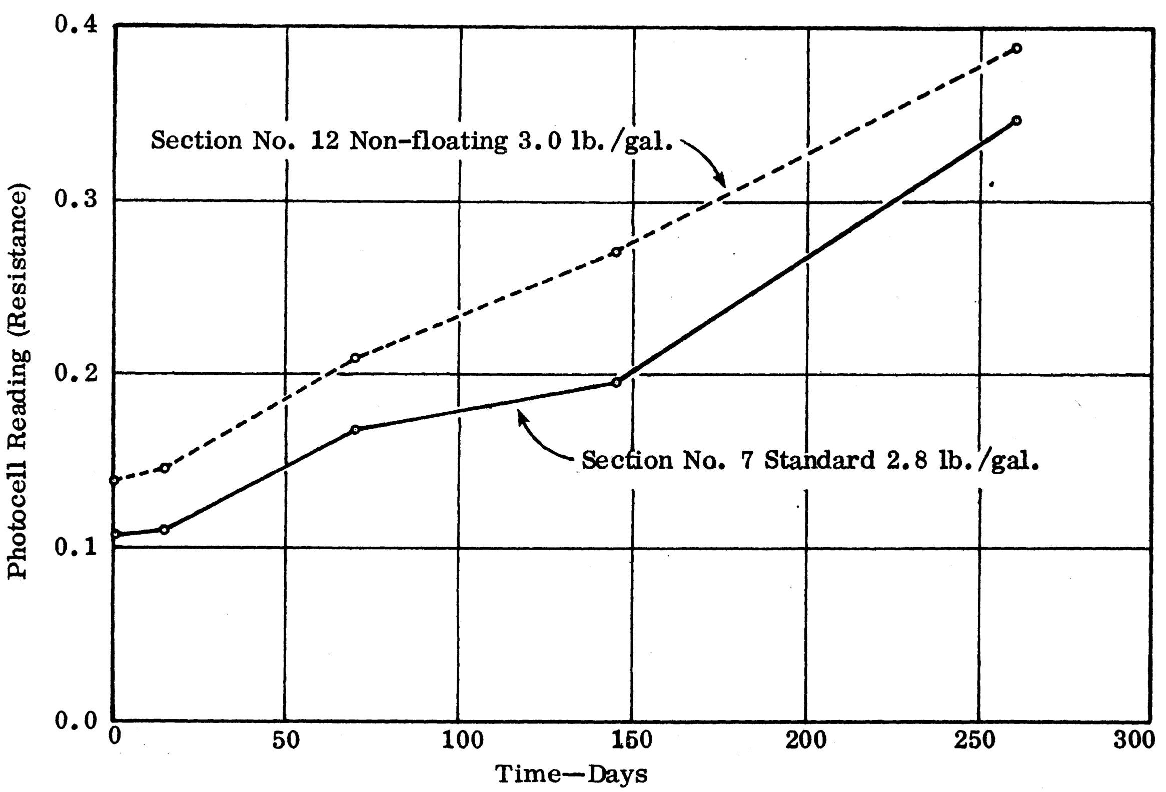


Figure 9. Comparison of bead type — gravity flow on slow drying paint.

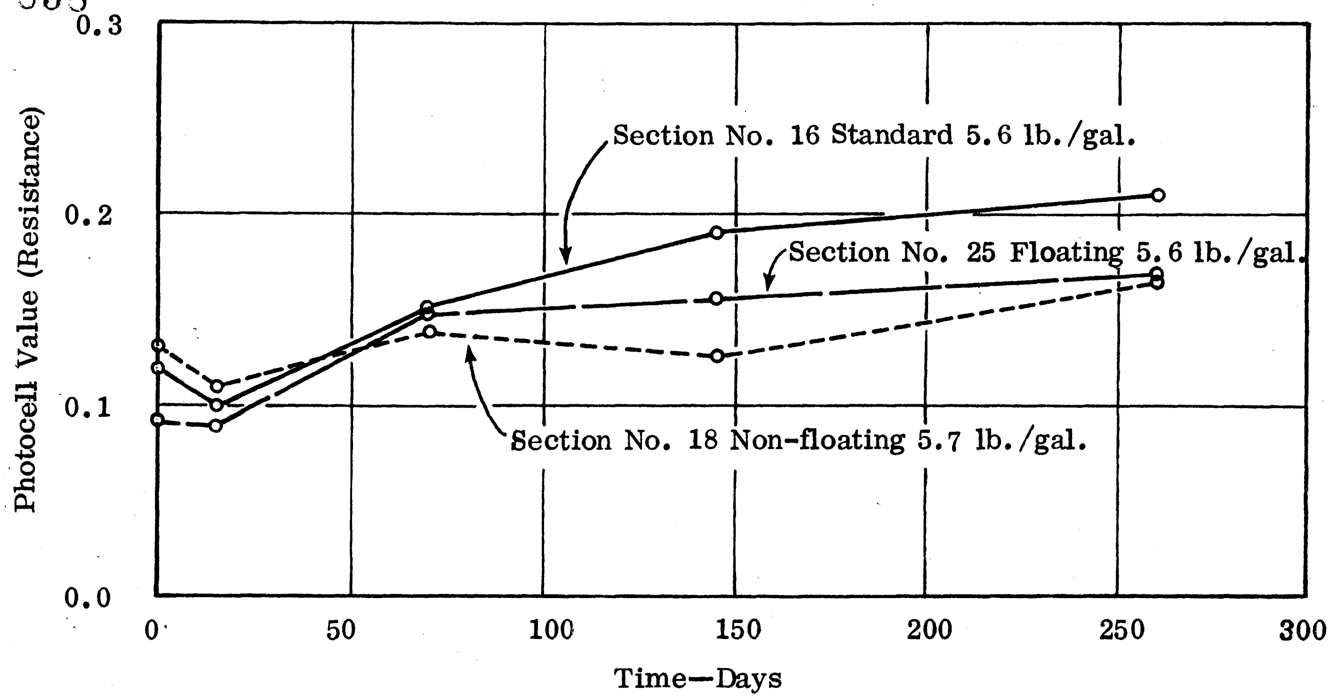


Figure 10. Comparison of bead types — pressure flow on fast drying paint.

Effect of Rate of Bead Application on Brightness

Referring to Table 3, it is seen that the actual rate of bead application varies from 0.2 lb./gal. to 14.1 lb./gal., which made it difficult to compare bead rates in the 4 - 6 lb./gal. range as desired. Therefore, only those plates are presented which involved bead rates in the 3 - 8 lb./gal. range.

As mentioned earlier, there does not seem to be any significant difference in brightness among the bead types which have similar application rates based on the observations in Figures 8, 9, and 10.

A comparison of different bead rates for the standard bead applied under gravity flow to slow drying paint is shown in Figure 11. As may be expected, the higher bead rates of 8.1 lb./gal. of paint gave brighter values for each observation period as opposed to the 3.3 lb./gal. rate. This is also true for the floating beads as shown in Figure 12. Here 7.1 lb./gal. is brighter for all observation periods than 5.0 lb./gal.

Based on the results of bead rate comparisons there is insufficient evidence to equate relative brightness for the floating beads at 4 lb./gal. with that of the standard beads at 6 lb./gal.

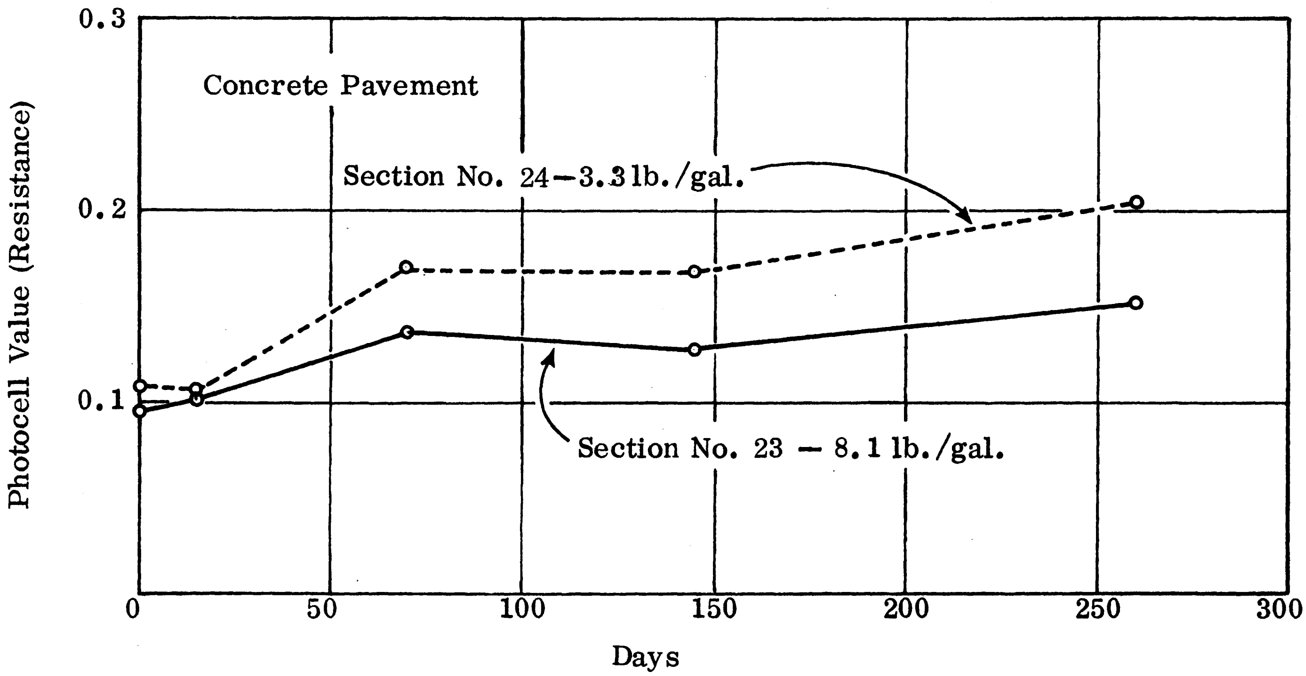


Figure 11. Bead application rate for standard bead — gravity flow on slow drying paint.

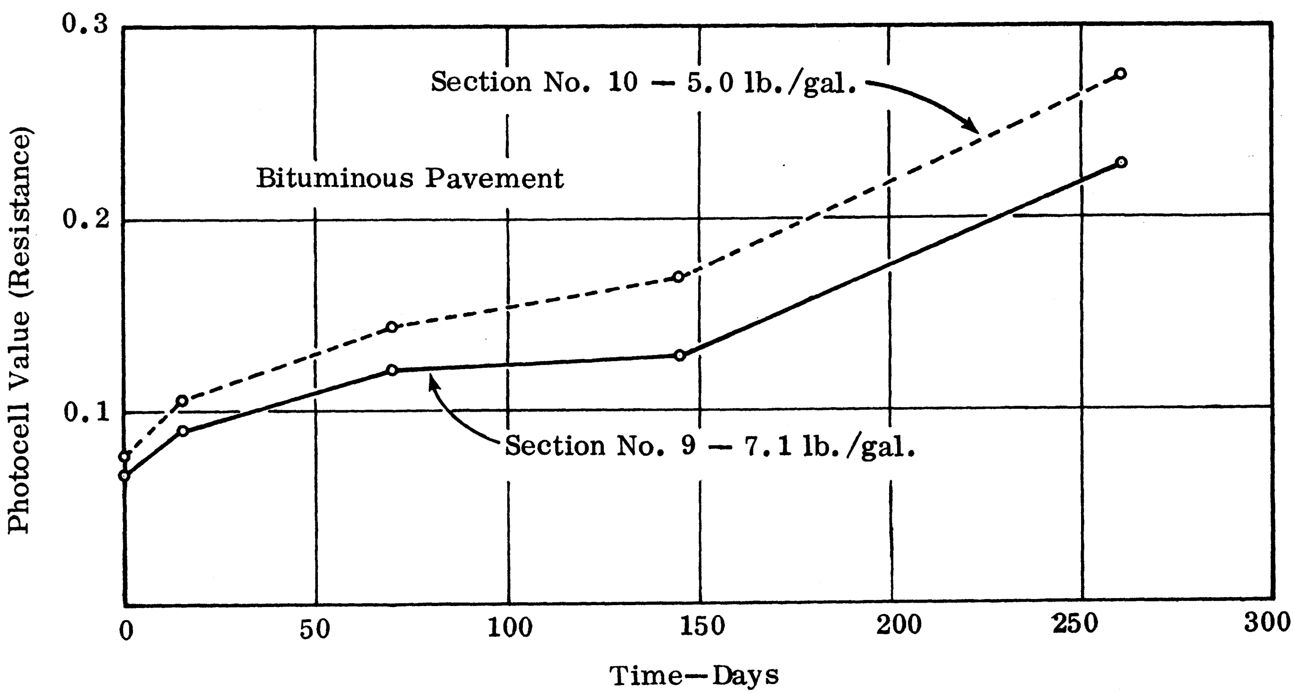


Figure 12. Bead application rate for floating beads — gravity flow on slow drying paint.

Effect of Paint Type on Brightness

It was difficult to compare fast and slow drying paints because of the wide variations in paint thicknesses. As noted in Table 3, the paint thicknesses are substantially lower for the fast drying paints than for the slow drying ones. This, coupled with the difference in bead application, i.e., beads were applied under gravity flow for the slow drying paints and pressure for the fast drying paints, did not allow for a proper evaluation of the paint type. However, there are no indications that the fast drying paint cannot be used when beads are applied under pressure.

Wet Night Visibility

The relative ranking of the four brightest test sections under wet night conditions is shown in Table 4. It does not appear that one bead type is superior to another as all three types considered are included. It is interesting to note that of the top four, two are flotating bead types which have bead application rates well below the remaining two. This is thought to be a result of the flotation properties of the bead. Although the number one ranked bead does not have flotation properties, the high application rate accounts for the relatively high brightness.

TABLE 4

Ranking for Wet Night Conditions

Rank	Bead Type	Paint	Bead Rate (lb./gal.)	Paint Thickness (mils)	Pavement Type	Panel Rating
1	Standard	Slow	14.1	13.6	Bituminous	9.8
2	Floating	Slow	7.1	11.5	Bituminous	9.1
3	Non-floating	Slow	11.0	13.8	Bituminous	8.8
4	Floating	Slow	5.0	12.7	Bituminous	8.7

The fact that all four test sections had slow drying paint should not be considered significant here as the paint thicknesses for all sections with slow drying paint were at least twice the thickness of the fast drying sections. The thicker lines allow a portion of the beads to protrude above the water film and result in increased brightness.

It may have been expected that all four sections would have been on bituminous pavement because the darker background of the bituminous pavement would result in better contrast.

CONCLUSIONS

As mentioned earlier, problems were encountered with the control of the bead and paint application rates with the pavement striping machine, which considerably limited the evaluation of the variables considered. However, based on the results included in this report the following conclusions are presented:

(1) There seems to be no significant difference in the relative brightness for the three types of beads considered.

(2) For both the standard and floating beads, the higher bead application rates yielded brighter photocell values.

(3) The limited data produced are insufficient evidence to permit a valid comparison of the relative brightness of the floating beads at 4 lb./gal. with that of the standard beads at 6 lb./gal.

(4) There does not appear to be any disparity in brightness levels between bead types placed at similar application rates.

(5) There was no evidence to indicate that the fast drying paint was inferior to the slow drying paint when the beads were applied under pressure.

(6) It appears that the floating bead has an advantage over the non-floating bead under wet night conditions as a result of the high ranking and significantly lower application rates. This is considered to be important because of the hazard involved in night driving during rainy conditions.

(7) Test sections on bituminous pavements exhibited brighter lines than those on concrete because of the contrast in pavement background color.

RECOMMENDATIONS

Considering the above conclusions and the importance attached to any recommendations relating to traffic markings, it is felt that no specific suggestions should be made at this time. However, it should be mentioned that the fast drying paint used for this project seemed to compare favorably with the slow drying paint, which supports the Virginia Department of Highways' decision for more extensive use of fast drying pavement marking paint in the immediate future.

It is suggested that before additional in-depth studies are considered, the results of 1971 NCHRP Project 5-5A entitled "Development of Optimum Specifications for Glass Beads in Pavement Markings" be awaited. As noted in the objectives listed below, the report on this project should touch upon many of the unanswered questions in this present report.

NCHRP Objectives:

(1) Review and analyze world wide research and practices involving the use and manufacture of traffic marking beads.

(2) Identify those variables that markedly influence the effective utilization of glass beads in pavement markings. Evaluate these variables by laboratory and field tests as required in order to rate them in terms of their influence on the effectiveness and serviceability of delineation under actual traffic conditions. Field tests shall include measurements of wet-nighttime reflectivity.

(3) Determine the capability and economics of producing glass beads of specified gradation, composition, shape, flow properties, color, etc.

(4) Develop practical specifications and criteria for the selection and use of beads for reflectorizing traffic paint markings.

(5) Evaluate for one or more states the probable benefits that would accrue should the proposed specifications be adopted in place of current specifications.

REFERENCES

1. Pocock, B. W., and C. C. Rhodes, "Principles of Glass-Bead Reflectorization," HRB Bulletin 56, pp. 32-48, 1952.

2. Colorado Department of Highways, "Reflective Traffic Bead Study," May 1970.