In a previous evaluation of paint-stripe beads (Research Report No. 439), a determination was made that none of several types of beads could be evaluated because proper embedment was not obtained in quick-drying paints. We proceeded, therefore, to determine the necessary consistency of paints to assure embedment. This involved progressive thinning with solvent and consequent extensions of drying time. These findings were included in the referenced report along with recommendations for the 1977 paint-stripping season. Among the recommendations were proposals for experimental applications of three types of beads for further evaluation.

Two of the three bead types were applied on sections of the Old Frankfort Pike, Newtown Pike, and I 75 in September of 1976. One type was a well-graded, 1.65 refractive-index glass which was applied on center lines. The other was a large-gradation, 1.52 refractive-index, non-floating, glass bead which was applied at the rate of four pounds per gallon. The third type was never purchased because of failure of the beads to meet moisture resistance requirements. Inspections were made at the time of application and on two occasions within six months after application. From samples of paint and beads taken up on plates during application, it was obvious that proper embedment of beads was not being obtained. Visual inspections at night revealed that the stripes were generally reflective immediately after installation, but most of the reflectivity was lost within a few weeks. When it became apparent that the stripes had lost their reflectivity, observations were discontinued. More detailed analyses of the data, including photographs of the test stripes and bead embedment, are in the attached report.

Limited tests of paint obtained from the California Department of Transportation were generally unsuccessful in achieving proper embedment of beads.

A survey of other states was made to determine if Kentucky's problem with bead embedment was unique. Responses were received from 42 states, and a summary of the results is included in the report.
Almost half of the states responding to the survey indicated that they were experiencing bead embedment problems, primarily with quick-drying paints. A copy of the questionnaire and summaries of responses with a brief commentary are appended to the report.

As we view the status of the paint-striping program in Kentucky, it appears that the quality of stripes is very poor; and the likelihood of improvement is not good as long as we use ultra-quick-drying paints. We must initiate changes in the paint specifications to insure better embedment of beads. Another consideration might be more widespread application of a preformed, marking tape such as the "Stamark" which was placed on US 60 in Frankfort.

By memorandum, September 15, 1978, we recommended the following changes in Special Provision No. 31. The purpose and intent is to remove any implication that instant-drying paints are sought or desired. Section D., Requirements, page 1, shall read as follows:

5. Application Rates -- The paint shall be applied at the rates specified in Table 1. Although any acceptable method of determining wet film thickness may be used or suggested by the manufacturer for the purpose of adjusting the equipment, an Alcometer wet film gauge will be used for officially determining the wet film thickness for all lines.

For measurement of wet film thickness, specimens of unbeaded material shall be deposited on a steel plate by the striping machine while it is moving at a normal striping speed. Immediately after the material is deposited on the plate, it will be gauged to determine its wet film thickness. The record specimen will be obtained on the immediate approach to the test line area and on the same striper pass that produces the test line.

Dry film thickness readings will be taken on the final calibration specimen and the record specimen to ensure that a similar application rate was used on each.

Beads shall be applied at the rate of approximately four (4) pounds per gallon of paint.

(Note: Subsection 6, Paint Temperature, will be deleted.)

6. Drying Characteristics: Both types of paint, A and B, upon actual application to the pavement surfaces, shall dry to no-tracking condition for the intervals, spray orifice paint temperature, and application rates listed below in Table 1. The no-tracking condition shall be determined by passing over the applied line with a passenger vehicle. A line showing no visual deposition of the paint to the pavement surface when viewed from a distance of 50 feet shall be considered as non-tracking and conforming to the requirement for field drying condition.

<table>
<thead>
<tr>
<th>Spray Orifice Paint Temperature and Maximum Allowable No-Tracking Time</th>
<th>Paint Types A and B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient 120° F</td>
<td>180 seconds and over</td>
</tr>
<tr>
<td>140° F</td>
<td>90 seconds</td>
</tr>
<tr>
<td>160° F</td>
<td>60 seconds</td>
</tr>
<tr>
<td>Wet Film Application Rate</td>
<td>45 seconds</td>
</tr>
<tr>
<td>Pavement Surface Temperature</td>
<td>15 ± 2 mils</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>Ambient to 140° F</td>
</tr>
<tr>
<td></td>
<td>85% or less</td>
</tr>
</tbody>
</table>
7. Packaging (No Change)

Special Provision No. 31 is attached for convenient reference.

Whereas the FHWA in a letter of August 23 recommended 6 pounds of glass beads per gallon of paint, we persist and persevere in our recommendation as stated in Research Report 439 (of which the FHWA disclaimed knowledge) that the application be nominally 4 pounds per gallon. Contrary to their Report No. FHWA-TS-78-213 by the Potters Glass Company, we adjudge 6 pounds to be an "over-kill." Heavy dosages of beads (and the coverage obtained) improve reflectivity under some conditions but are detrimental to drainage and proudness of beads during the most adverse times – that is during rain and near-total darkness.

Respectfully submitted,

Jas. H. Havens  
Director of Research

kb  
cc's: Research Committee

Attachments:
1) Special Provision No. 31.
2) Research Report No. 504.
I. PURPOSE

The purpose of the work described herein is to determine by service test (1) materials of various types producing the best performance in terms of lowest-cost-per-mile per day of useful life; (2) that the material applied for test does not rate excessively low on any one of the following factors: general appearance, including color; film condition; and reflectorization; and (3) that it meets requirements for other physical properties as specified.

II. MATERIALS

A. General -- The successful bidder will be required to furnish under contract material identical to the material tested in the laboratory in accordance with the manufacturer's application rate. At least five gallons of drop-on beads will be deposited on a steel plate by the Bureau purchased on Bureau specifications. Such statements shall be for the confidential use of the Bureau and the information therein will not be revealed by the Bureau.

Each manufacturer shall complete the attached "Statement of Identification and Paint Characteristics," and "Statement of Characteristics, Pavement Marking Materials, (Quick-Dry)". Any sample which, upon testing by the Bureau, does not coincide with the Statement of Characteristics will not be considered. Such statements shall be for the confidential use of the Bureau and the information therein will not be revealed by the Bureau.

Unless the required statements are received by the hour and date fixed in the inquiry, the Bureau will not be obliged to include the samples in the testing nor consider them for purchase. Samples received after the hour and date fixed in the inquiry will not be considered.

B. Types of Material -- This Special Provision covers the following types of material:

TYPE A -- White quick-dry traffic paint for use with drop-on beads

TYPE B -- Yellow quick-dry traffic paint for use with drop-on beads

C. Samples -- Each manufacturer may submit no more than one sample of each type of material. A sample shall consist of one 5 gallon bucket of material for use at the manufacturer's recommended solvent; with labeled packaging samples shall be contained in a 5 gallon, open-head type bucket. The bucket shall carry the manufacturer's label which shall specify the type and color of material. All samples called for by these specifications shall be for the purpose of adjusting the equipment, and the manufacturer's recommended solvent, with labeled packaging samples shall be for the purpose of adjusting the equipment.

D. Requirements

1. Viscosity -- The consistency of the pigmented binder shall not exceed 100 KU at 25 degrees C, when all paint furnished is of the same formulation as the original sample. The Bureau reserves the right to make or have made analyses of both test samples and samples from shipments made under contract to determine whether such samples are in fact identical. Samples will be extracted immediately after placement of test lines and will be retained by the Bureau.

2. Packaging Stability -- The paint shall not cake, thicken, curdle, settle badly or show any objectionable properties after periods of storage not to exceed 12 months.

3. Color -- The diffused daylight color of yellow paint after drying shall conform to the Color Tolerance Chart issued by the Federal Highway Administration and referred to as Highway Yellow (PR Color F1). The diffused daylight color of white paint after drying shall be within the following Munsell color limits:

| Munsell Notation - Glossy Collection |
|-----------|---|---|---|
| Hue       | Value | Chroma |
| N          | 8.75 min. | -- |

4. Quality -- The composition and quality of the paint shall be such as to be a suitable binder for the glass spheres and produce a satisfactory lane marker.

5. Application Rates -- Paint application rates shall be specified by the manufacturer in terms of wet film thickness for paint within the limits imposed by the installation equipment. Lines will be placed to within ± 10 percent of the wet film thickness requested by the manufacturer insofar as practicable. Application rate ranges or dry film thickness will not be accepted. Although any acceptable method of determining wet film thickness may be used or suggested by the manufacturer for the purpose of adjusting the equipment, an Electron wet film gauge shall be used for officially determining the wet film thickness for all lines.

For measurement of wet film thickness, specimens of unheated material shall be deposited on a steel plate by the Bureau while it is moving at a normal striping speed. Immediately after the material is deposited on the plate, it will be gauged to determine its wet film thickness. The record specimen will be obtained from within the test line area and on the same striping pass that produces the test line.

Dry film thickness readings will be taken on the final calibration specimen and the record specimen to ensure that a similar application rate was used on each.

6. Paint Temperature -- Within the limits imposed by the installation equipment every effort will be made to heat the material to the temperature specified by the manufacturer while it is moving at a normal striping speed. After the material is deposited on the plate, it will be gauged to determine its wet film thickness. The record specimen will be obtained from within the test line area and on the same striping pass that produces the test line.

A vehicle will be driven over the test line approximately 50 seconds after it has been installed. A line showing no visual deposition of the paint to the pavement surface when viewed from a distance of 50 feet shall be considered as showing no-tracking and conforming to the requirements for field drying conditions.

7. Packaging -- Paint samples shall be contained in a 5 gallon, open-head type bucket. The bucket shall carry the manufacturer's label which shall specify the type and color of material. All samples called for by these specifications and used in these performance tests shall be delivered to Bureau of Highways, Division of Traffic, Traffic Barn, Wilkinson Boulevard, Frankfort, Kentucky 40601. Transportation charges shall be fully prepaid.

III. APPLICATION

A. Equipment -- The equipment used to apply test samples on the pavement will be owned and operated by the Kentucky Bureau of Highways.

B. Equipment Limitations (See Note) --
   a. Pumping pressures shall not exceed 80 pounds per square inch.
   b. Paint heating temperatures shall be between 110 degrees F and 160 degrees F at the spray orifice.
NOTE: Materials requiring higher pressures or temperatures than those indicated above to obtain recommended application rates will not be applied.

B. Position of Marking -- Materials will be applied on a high type bituminous pavement, on sections of highway which are subjected to hard wear. Areas where the traffic wear is relatively uniform will be selected; they will be areas where the traffic is free moving, with no wide streets and free of loose material or any other factors which might cause lack of uniformity. The test stripes will be applied transversely across the traffic lanes. Lines will be 4 inches wide. At least two lines of each test sample will be applied. The application of all samples will be positioned in such a manner as to cancel out any non-uniformity in traffic pattern insofar as practicable. Spray guns will start to operate in advance of the edge of the test line area.

C. Day of Application -- The sample materials will be applied on a day in which the condition of the pavement is substantially uniform throughout the period of application of all samples. Records of temperature and humidity will be made at the time of each application. The samples will be applied under normal field conditions at the required rate.

IV. EVALUATION

A. General -- Manufacturer's labels will be removed from samples by the Division of Purchases, Department of Transportation, who will substitute a code identification for each sample.

Each manufacturer whose product fails at the time of application will be notified thereof as soon as practicable; no further test of these materials will be allowed until the next time that samples are requested.

Installation of the test lines will be performed under the supervision of the Division of Research. Subsequent evaluations and ratings will be made by representatives of the Division of Materials, who will have no knowledge of the manufacturer of the coded test lines.

Periodic inspection will be made and early loss in durability appropriately recorded as to time and extent for comparison against more durable lines. Final evaluation will be made after sufficient time has elapsed to indicate superiority by any of the samples. Final evaluation will be made by representatives of the Division of Materials. Four evaluations will be made during the test period including the final evaluation, if practicable. Each of these will include both daytime and nighttime evaluations of general appearance and film condition, and reflectivity, respectively.

B. Quantitative Factors of Evaluation -- The test lines shall be rated according to the following numerical scales:

10) Perfect or absence of failure
9) Good or slight failure
8) Fair or intermediate failure
7) Poor or bad failure
6) Very poor, or complete failure.

The following factors shall be considered of equal weight in evaluating lines:

1. General appearance
2. Film Condition

3. Reflectorization

If any one of the above factors shall be excessively low (3 or lower) on 2 successive evaluations or on the final evaluation, the sample shall be rejected, regardless of the performance on the other factors.

C. Definitions -- Terms applicable to the detailed inspection and ratings of the paint surface are as follows:

1. General Appearance -- General appearance is the complete impression conveyed to the observer when the material's surface is viewed from a distance of no less than ten feet and before any detailed inspection has been made and is measured purely in terms of satisfactory or unsatisfactory appeal to the observer. This is to include a comparison of color of the surface under consideration with that of the original color specified.

2. Film Condition -- The factor used in rating film condition will be numerical rating of the area of pavement still covered by the material when estimated upon close observation by the unaided eye.

3. Reflectorization -- Samples will be rated by the same method that the test lines are rated under Paragraph IV.B, Quantitative Factors of Evaluation. Actual photometric readings may be substituted for the visual comparison figures by again rating a perfect sample "10" and complete failure "0".

4. Final Evaluation -- At the time of final evaluation of the materials tested in terms of cost-per-mile per day-of-useful-life the average of three factors will be used to obtain the rating.

The following formula will apply at the time bids are received:

\[ U = \frac{GM \times GM + CA}{R_p - R_f} \]

where:

- \( U \) = Cost per mile per day of useful life
- \( GM \) = Cost of material per gallon
- \( CA \) = Cost of application per mile of highway (from past cost records)
- \( R_p \) = Rating of a perfect line (10)
- \( R_f \) = Rating of line needing replacement (3)
- \( D \) = Days of test

For the purpose of this Special Provision, "Manufacturer" means any corporation, company, association, partnership or person who converts raw material, at a factory or plant, into a finished product, complete and ready for final use for which intended, or so completed that in ordinary course of business it is ready to be put upon the open market for sale to anyone wishing to buy it.

It does not, for the purpose of this Special Provision, include partially or wholly owned subsidiaries, holding companies, "dummy corporations", or any other enterprise by whatever designation which would enable interested persons or entities to submit more than one sample of each type of material.
V. ACCEPTANCE

Paint furnished under the contract shall be identical with the sample submitted for performance tests and shall comply with the requirements herein set forth. In the event that the traffic paint does not comply with this Special Provision or is not identical with the sample submitted, the vendor will be required to replace all such paint at his own expense, including all handling and transportation charges, with paint that does comply.

APPROVED 2-7-76

G. F. Kemper, P. E.
STATE HIGHWAY ENGINEER
This report presents another phase of a study on evaluation of paint stripes and glass beads. The results from the previous phases of this study indicated that large-scale, experimental evaluation of a 1.65 refractive-index bead and a large-gradation, 1.52 refractive-index bead was warranted. Poor embedment of beads, however, precluded the evaluation because the quick-drying paint used did not allow beads to be properly embedded. After progressive thinning of the paint with solvent, adequate bead embedment was obtained. Drying time, of course, was longer.

Attempts were made to obtain good embedment without extending the drying time. This included testing of a paint having a lower viscosity and by trials at lower temperatures and thinner applications. These efforts were not successful. A survey of other states indicated that over half of the 42 respondents were having a problem similar to that being experienced in Kentucky.
Research Report
504

EVALUATION OF PAINT-STRIPE BEADS
KYP-73-48; HPR-PL-1(14), Part III-B

by

Jerry G. Pigman
Research Engineer Chief

and

Kenneth R. Agent
Research Engineer Principal

Division of Research
Bureau of Highways
DEPARTMENT OF TRANSPORTATION
Commonwealth of Kentucky

The contents of this report reflect the views of
the authors who are responsible for the facts and the
accuracy of the data presented herein. The contents
do not necessarily reflect the official views or policies
of the Bureau of Highways. The report does not represent
a standard, specification, or regulation.

September 1978
INTRODUCTION

This report covers another phase of a study on evaluation and application of roadway delineation techniques. Past studies have dealt with raised markers for pavements, paint-stripe beads, thermoplastic striping, and a raised-aggregate lane-delineation stripe (1, 2, 3, 4, 5).

A previous study of paint-stripe beads involved an evaluation of several types of beads, but poor embedment of the beads in the paint precluded any recommendation of a specific bead type (3). The quick-drying traffic paint used would not allow the beads to be embedded properly. As a result, an attempt was made to determine the necessary consistency of paint to assure embedment of beads. After progressively thinning with solvent, adequate bead embedment was obtained. The drying time, however, was extended.

Results from the study warranted a larger, experimental evaluation. For this study, paint was applied with standard striping equipment. The objective was to compare various types of paint-stripe beads. Applications were controlled closely to determine if proper bead embedment could be obtained under these conditions. As recommended in the previous report, the beads were applied at a rate of 4 pounds per gallon (479 kg/m³). A wet-film paint thickness of 15 mils (0.38 mm) was obtained.

Since the Kentucky trials in 1976, the California Department of Transportation reported similar bead embedment problems (6). Through experimentation there, an improvement in paint-stripe reflectivity was achieved. Their efforts involved a change in the chemical composition and a reduction in viscosity of the paint. The drying time, however, remained at less than one minute. After discussions with a representative of the California Department of Transportation, samples of paint were obtained for application with a small striper.

PROCEDURE

The following paint-stripe beads were applied by District 7 personnel in September 1976:

1. Standard glass bead (Special Provision No. 62-C); well-graded, non-floating, 1.52 refractive-index glass bead.
2. Well-graded, 1.65 refractive-index glass bead.
3. Large, 1.52 refractive-index, non-floating glass bead (on edgelines). Gradation specifications for this bead type were as follows:

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 16</td>
<td>100</td>
</tr>
<tr>
<td>No. 30</td>
<td>15-35</td>
</tr>
<tr>
<td>No. 50</td>
<td>5-15</td>
</tr>
<tr>
<td>No. 100</td>
<td>0-5</td>
</tr>
</tbody>
</table>

A recommendation had been made that a uniformly graded, floating, 1.52 refractive-index glass bead also be evaluated (3). However, this type of bead was not purchased because the beads failed to meet moisture resistance requirements.

Evaluations were conducted on a section of rural interstate road and two sections of rural two-lane roads. A 34.2-mile (55.0-km) section of I 75 (AADT ~ 22,000) between US 60 in Fayette County and KY 21 in Madison County was selected. The two-lane sites were 7.3 miles (11.7 km) of KY 922 (AADT = 1,000) in Fayette County and 17.9 miles (28.8 km) of KY 1631 (AADT = 1,000) in Fayette and Woodford Counties. The test sections permitted a comparison of the standard and high refractive-index beads under different volume conditions. The standard beads and the 1.65 refractive-index beads were used with both yellow and white paint on centerlines, lane lines, and edgelines. Large-gradation beads were used only as edgelines on I 75.

Pick-up panels were used to obtain specimens of the stripe. Tests of paint-stripe thickness were also made periodically. Nighttime, visual observations were conducted approximately one month and six months after the applications. Close-up photographs of the stripes were made a few days after application (Figures 1 through 6). Also, nighttime photographs of the test sections were made a few weeks after the applications (Figures 7 through 10).

The Department's small test striper was used to apply samples of the California paint in the parking lot at the Division of Research. These test applications were made in June of 1978. Photographs of the stripes are shown in Figures 11 and 12.
Figure 1. Well-Graded, 1.65 Refractive-Index Beads; Specimen of Line Preserved on Pick-up Panel; Applied to Centerline of Low-Volume Road; September 1976.
Figure 2. Well-Graded, 1.65 Refractive-Index Beads; Specimen of Line Preserved on Pick-up Panel; Applied to Edgeline Interstate; September 1976.
Figure 3. Large-Gradation Beads; Specimen of Line Preserved on Pick-up Panel; Applied to Edgeline of Interstate; September 1976.
Figure 4. Large-Gradation Beads; Specimen of Line Preserved on Pick-up Panel; Applied to Edgeline of Interstate; 20 mils (0.51 mm); September 1976.
Figure 5. Well-Graded, 1.65 Refractive-Index Beads; Applied to Centerline of Low-Volume Road; After a Few Days in Service; September 1976.
Figure 6. Standard Glass Beads; Applied to Centerline of Low-Volume Road; After a Few Days in Service; September 1976.
Figure 7. Nighttime Photograph; Low-Volume Road with 1.65 Refractive-Index Beads; October 1976.
Figure 8. Nighttime Photograph; Low-Volume Road with Standard, Glass Beads; October 1976.
Figure 9. Nighttime Photograph; Interstate with 1.65 Refractive-Index Beads, Applied to Centerline and Right Edgeline and Large-Gradation Beads Applied to Left-Edgeline; October 1976.
Figure 10. Nighttime Photograph; Interstate with Standard Glass Beads Applied to Centerline and Large-Gradation Beads Applied to Right Edgeline; October 1976.
RESULTS

Even though paint-stripe thickness and bead application pressure were closely controlled, proper bead embedment was not obtained by the District 7 striping crew. Photographs of the pick-up panels (Figures 1, 2, and 3) show that bead embedment was very poor (10 percent or less). The beads should be embedded to a depth of about 50 percent of their diameter to provide a maximum retro-reflectivity and adequate adhesion to the paint film. When the wet-film thickness was increased to 20 mils (0.51 mm) for a short length, bead embedment was improved for the large-gradation beads (Figure 4).

As stated earlier, poor bead embedment will lead to poor bead retention. Photographs taken of centerline stripes on the low-volume roads (Figures 5 and 6) showed the large loss of beads. These photographs were taken a few days after application. Only a small percentage of the beads remained, a condition which existed for all the bead types.

Although failure to attain proper bead embedment made specific recommendations impossible, visual observations and ratings at nighttime were conducted one month and six months after application (Table 1). Subjective ratings of reflectivity were based on a scale from 0 to 10. The best rating was "10" and complete failure was "0". In general, the ratings did not show any type-of bead to be substantially better than any other. The test beads did not have higher ratings than the presently used beads in most instances. The only exception was the 1.65 refractive-index bead; better results were obtained when these beads were used on the edgeline. Other studies have found high refractive-index beads to be superior immediately after application. However, after a period of wear, they were not any better, and possibly were worse, than the regular 1.52 refractive-index beads. Use on the edgeline where abrasion is not significant may be a better application of the 1.65 refractive-index glass bead.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>BEAD TYPE</th>
<th>AVERAGE RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 MONTH</td>
<td>6 MONTHS</td>
</tr>
<tr>
<td>LOW VOLUME (CENTERLINE)</td>
<td>1.65&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.1</td>
</tr>
<tr>
<td>LOW VOLUME (CENTERLINE)</td>
<td>STANDARD&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.6</td>
</tr>
<tr>
<td>INTERSTATE (RIGHT EDGELINE)</td>
<td>1.65</td>
<td>8.1</td>
</tr>
<tr>
<td>INTERSTATE (CENTERLINE)</td>
<td>1.65</td>
<td>5.8</td>
</tr>
<tr>
<td>INTERSTATE (LEFT EDGELINE)</td>
<td>LARGE&lt;sup&gt;d&lt;/sup&gt;</td>
<td>7.1</td>
</tr>
<tr>
<td>INTERSTATE (RIGHT EDGELINE)</td>
<td>LARGE</td>
<td>6.9</td>
</tr>
<tr>
<td>INTERSTATE (CENTERLINE)</td>
<td>STANDARD</td>
<td>7.9</td>
</tr>
<tr>
<td>INTERSTATE (LEFT EDGELINE)</td>
<td>STANDARD</td>
<td>7.1</td>
</tr>
</tbody>
</table>

<sup>a</sup>Subjective ratings based on a scale of 0 to 10; 10 represents highest rating.

<sup>b</sup>Well-graded, 1.65 refractive-index glass bead

<sup>c</sup>Standard glass bead (well-graded, non-floating, 1.52 refractive index)

<sup>d</sup>Large gradation (as previously listed), 1.52 refractive-index, non-floating glass bead
Applications of the California paint were also unsuccessful. Even though the drying was supposed to be only slightly slower than Kentucky specifications require, the difference in viscosity was expected to result in better embedment. The Kentucky specifications require the viscosity to not exceed 110 kreb units at 25° C (77° F). California requires that the viscosity be 69 to 75 kreb units. As recommended by California, the application temperature was lowered to the 120-130° F (48-54° C) range. Attempts were also made to obtain specimens of line reducing the wet-film paint thickness from 15 mils (0.38 mm) to 13 mils (0.33 mm). Apparently none of these changes made any difference; the photographs of pick-up panels failed to show any improvement in bead embedment. Presented in Figures 11 and 12 are photographs of bead embedment obtained with the California paint.

After trials with the California paint, a survey was made of other states to determine if Kentucky's problem with bead embedment was unique. Responses were received from 42 states, and a summary of the results is presented in the APPENDIX. Almost half of the states responding to the survey indicated that they were experiencing problems, primarily with the use of quick-drying paints.

Figure 11. Kentucky Specification Beads; California Paint; Specimen of Line Preserved on Pick-up Panel; Applied on Division of Research Parking Area; June 1978.
Figure 12. Kentucky Specification Beads; California Paint; Specimen of Line Preserved on Pick-up Panel; Applied on Division of Research Parking Area; June 1978.
SUMMARY

Even under controlled conditions, proper embedment of beads could not be obtained. This prevented formulation of any specific conclusion regarding type of beads. However, results indicated that the 1.65 refractive-index beads may be suitable for edgelines. Meaningful evaluations of performance of glass beads cannot be performed until specifications for paint are improved to assure adequate embedment of the beads. The problem of embedment and retention in quick-drying traffic paints has been documented by the Research Division (3) and others (6, 7).

The California Department of Transportation gave encouragement to the possibility of improved embedment without a significant increase in drying time. These expectations were not verified in our trials of the California paint.

From the survey of striping procedures in other states, it was noted that over half of the 42 respondents have problems similar to those being experienced in Kentucky. Many of the states use both quick-dry and conventional paint; about one-third use paints with drying times or no-track times less than one minute. Practically all of the states which use a quick-dry paint reported that they were experiencing a problem with bead embedment. The problem was attributed most often to instantaneous formation of a film when or before the paint touched the pavement. The only action taken as a solution to this problem was aiming the bead gun closer to the paint gun so that the beads and paint touched the pavement simultaneously. In some instances, the beads contacted the paint before the paint touched the pavement. In order to protect the stripe while it was drying, cones were generally used with conventional paint; truck caravans were trailed behind quick-dry paints.

The survey indicated that 60 percent of the states specify a paint thickness of 15 mils (0.38 mm), and almost 50 percent apply beads at a rate of 6 pounds per gallon (719 kg/m²). Viscosity levels specified were wide, but 59 percent were in the range of 65-85 kreb units.

RECOMMENDATIONS

1. The present striping procedures and paints should be altered to insure proper embedment of beads.

2. As recommended in a previous report, the application rate of glass beads should be 4 pounds per gallon (479 kg/m³) (3). Field observations indicated that an excessive amount of beads were being used in some instances.

3. After proper bead embedment is assured, a large-scale evaluation of glass beads should be conducted. This would include the bead types listed in the previous report (3) as well as the gradations suggested by the California Department of Transportation.

4. Serious consideration should be given to more widespread application of a preformed marking tape (60 mils (1.52 mm) or greater in thickness) such as the "Stamark" tape. Nighttime photographs of the "Stamark" tape are presented in Figures 13, 14, and 15.
"Stamark" Tape Placed on US 60 in Frankfort in July 1978; Bituminous Concrete Surface; Photographed in September 1978.
"Stamark" Tape Placed on US 60 in Frankfort in July 1978; Portland Cement Concrete Surface; Photographed in September 1978.
"Stamark" Tape Placed on US 60 in Frankfort in July 1978; Bituminous Concrete Surface; Photographed in September 1978.
REFERENCES

1. J. G. Pigman and K. R. Agent; *Raised Pavement Markers as a Traffic Control Measure at Lane Drops*; Division of Research, Kentucky Department of Transportation, February 1974.


4. J. G. Pigman and K. R. Agent; *Evaluation of Thermoplastic Pavement-Striping Materials* (Louisville and Jefferson County); Division of Research, Kentucky Department of Transportation, May 1976.

5. J. G. Pigman and K. R. Agent; *Raised-Aggregate, Lane-Delineations Stripe [East Main Street Widening, US 60; Franklin County; SP 37-65; EHST 3005(4)]*; Division of Research, Kentucky Department of Transportation, December 1976.


APPENDIX

SUMMARY OF PAINT STRIPING PROCEDURES IN OTHER STATES
MEMO TO: Jas. H. Havens, Director
Division of Research

FROM: Vernon Azevedo, P.E.
Civil Engineer, Senior

SUBJECT: Paint and Bead Survey

September 22, 1978

H.3.48
P.2.3.1

On July 11, 1978, a paint and bead survey was sent to all state transportation agencies. The purpose of the survey was to review the specifications and application methods of other states in an effort to develop and implement an improved striping procedure for Kentucky. To date there have been 42 responses.

Of the 42 states responding, 45% experience bead-retention problems similar to those experienced in Kentucky. The problem was most often related to beads failing to be embedded because an almost instantaneous film formed when the paint contacted the pavement. Ten percent of the states having bead-retention problems have a drying time of less than one minute, and 42% of those states having problems have a "no-track" time of less than one minute. Of those states experiencing bead-retention problems, 63% indicated the problem has been improved or solved by aiming the bead gun so that the beads and paint strike the pavement simultaneously or in some cases the beads are sprayed into the paint before it strikes the pavement. Thirty-one percent of the states indicated that no problems existed in their striping procedures.

Other results indicate that 60% of the respondents specify a wet-film thickness of 15 mils (0.38 mm) and 33% specify a dry-film thickness of 5-10 mils (0.13-0.25 mm). Fifty-nine percent indicated a paint viscosity in the range of 65-85 kreb units. Forty-seven percent specified a drying time of greater than 5 minutes. Thirty percent specified a no-track time of greater than 5 minutes while 29% specified a no-track time of one minute or less.

Bead gradation was generally between the No. 20 and No. 80 (0.850 mm and 0.180 mm) sieve sizes, but ranged from the No. 16 (1.18 mm) to the No. 230 (0.063 mm). Fifty-three percent specified a refractive index in the range 1.50-1.65. Forty-eight percent indicated a bead application rate of 6 lb/gal (719 kg/m³) and 43% apply their beads at 20-40 psi (138-276 kPa).

A copy of the survey mailed to each transportation agency, a detailed summary, and the state-by-state results are attached. Kentucky is included in the state-by-state results but is not included in the percentages stated.

Attachment

kb
Dear Mr. 

The Division of Research of the Kentucky Department of Transportation is conducting a research study with the objective of achieving proper bead embedment and reflectivity in traffic paint. A survey is being made of other states to determine their policy in this area. In order to accomplish this, we request that you complete the attached questionnaire.

If requested, we will supply you with a copy of the research report when it is published.

Very truly yours,

Vernon Azevedo
Civil Engineer

gd
Attachment
Traffic Paint and Bead Questionnaire
Kentucky DOT

1. Does your state have a specification for paint and bead type and application method? If yes, please attach a copy.

2. What wet-film and dry-film thicknesses are used?

3. What paint application temperature is used?

4. What is the viscosity of the paint?

5. What drying time is used?

6. What no-track time is used?

7. Is paint-line protection used? If yes, describe method (i.e. cones, following trucks).

8. Does bead application involve drop-on beads or is premix used?

9. What bead gradation is used?

10. Are floating or high refractive beads used?

11. What bead application rate (lb/gal) is used?

12. What pressure is used to apply the beads?

13. How is the bead delivery system arranged for the drop-on beads; that is, what is the distance between paint and bead guns?

14. What type of solvent is used in the paint?

15. What bead embedment problems have been encountered and what improvements have been implemented?
SUMMARIZED SURVEY RESULTS

1. State Specification
   Yes  98%
   No   2%

2. Wet-Film Thickness
   less than 10 mils (0.25 mm) - 0
   10-12 mils (0.25-0.30 mm) - 9%
   12-15 mils (0.30-0.38 mm) - 12%
   15 mils (0.38 mm) - 60%
   greater than 15 mils (0.38 mm) - 16%
   not specified - 2%

   Dry-Film Thickness
   less than 5 mils (0.13 mm) - 0
   5-10 mils (0.13-0.25 mm) - 33%
   greater than 10 mils (0.25 mm) - 12%
   not specified - 56%

3. Application Temperature
   less than 100° F (38° C) - 4%
   100°-120° F (38°-49° C) - 6%
   120°-140° F (49°-60° C) - 16%
   140°-160° F (60°-71° C) - 14%
   greater than 160° F (71° C) - 31%
   ambient - 27%
   not specified - 2%

4. Viscosity
   less than 65 ku - 0
   65-85 ku - 59%
   85-110 ku - 29%
   110-130 ku - 8%
   greater than 130 ku - 0
   not specified - 3%

5. Drying Time
   less than 1 minute - 10%
   1-3 minutes - 8%
   3-5 minutes - 16%
   greater than 5 minutes - 47%
   not specified - 20%

6. No-track Time
   less than 1 minute - 29%
   1-3 minutes - 20%
   3-5 minutes - 7%
   greater than 5 minutes - 30%
   not specified - 14%
7. **Paint-Line Protection**
   - cones: 12%
   - trucks: 19%
   - both: 36%
   - other--none: 21%
   - not specified: 7%

8. **Drop-on or Premix**
   - drop-on: 86%
   - premix: 5%
   - both: 10%

9. **Bead Gradation**
   - generally #20 to #80 (0.850-0.180 mm) sieve
   - range #16 to #230 (1.18-0.063 mm) sieve
   - not specified -- one state

10. **Floating or High Refractive**
    - floating: 16%
    - refractive index 1.50-1.65: 53%
    - refractive index -- other: 0
    - not specified: 30%

11. **Bead Rate**
    - less than or equal 5 lb/gal (599 kg/m³): 29%
    - 5-6 lb/gal (599-719 kg/m³): 21%
    - 6 lb/gal (719 kg/m³): 48%
    - greater than 6 lb/gal (719 kg/m³): 2%

12. **Bead Pressure**
    - less than 20 psi (138 kPa): 14%
    - 20-40 psi (138-276 kPa): 43%
    - 40-60 psi (276-414 kPa): 14%
    - greater than 60 psi (414 kPa): 7%
    - varies: 7%
    - not specified: 14%

13. **Distance between Bead and Paint Guns**
    - less than 3 inches (76 mm): 21%
    - 3-6 inches (76-152 mm): 33%
    - greater than 6 inches (152 mm): 26%
    - varies: 7%
    - not specified: 12%
14. Solvent
- toluene, toluol - 26%
- MEK, methylene chloride, xylol - 12%
- other - 10%
- varies as to manufacturer - 36%
- not specified - 17%

15. Drying Times of States Experiencing Bead Embedment Problems
- less than 1 minute - 10%
- 1-3 minutes - 37%
- greater than 3 minutes - 16%
- not specified - 37%

16. No-track Times of States Experiencing Bead Embedment Problems
- less than 1 minute - 42%
- 1-3 minutes - 32%
- greater than 3 minutes - 5%
- not specified - 16%
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Notes:
- **IL cane TRANSPORTATION**: No satisfactory method of eliminating the bad problem has been found.
- **WEATHER**: When thinner paint film was used, a problem of bead retention arises.
- **THICKNESS**: Beads are used a problem of bead retention arises.
- **TOOL**: No embedding problems if beads are immersed in paint immediately.
- **Nylon**: No embedding problems if beads are bonded in paint immediately.
- **TOWEL**: No problems with bead embedding as long as paint application is not decreased.
- **MANUFACTURER**: Prior bad retention has been experienced due to drying time being too fast. This problem has been partially resolved by spraying the glass beads into the paint spray prior to hitting the paint tank pressure.
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<td>32-195</td>
<td>Conv</td>
<td>40-120</td>
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### Tennessee

<table>
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<th>Application</th>
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</thead>
<tbody>
<tr>
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<td>15</td>
<td>NS</td>
<td>Conv</td>
<td>90-120</td>
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### Utah

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<tbody>
<tr>
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<td>Varies</td>
<td>PD</td>
<td>DF</td>
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### Washington

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### West Virginia

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### Wisconsin

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<tr>
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</table>

### Key
- NS: Not Specified
- Conv: Conventional
- DF: Fast Dry
- PD: Partial Dry
- HI: High Reflective Index

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Problems experienced with Dead END spray in Essex Paint. If the dead end gun does not apply the dead directly behind the paint spray gun, the paint drips before the beads adhere to the paint. This causes problems with the bead spray as close as possible to the paint gun.

**New Sparge System**

The dead end gun needs to be applied in a fast dry paint. Fast dry paint is poor. Rapid dry paint works before beads are wetted properly.

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The pressure dead system tends to drive the beads into the wet lane. Dusters are used to slow the rate of fall of the beads. They are not perfect but work reasonably well.