RAISED-AGGREGATE, LANE-DELINEATION STRIPE
[East Main Street Widening, US 60; Franklin County; SP 37-65; EHST 3005(4)]

J.G. Pigman

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MEMO TO: G. F. Kemper
State Highway Engineer
Chairman, Research Committee

SUBJECT: Research Report 462; "Raised-Aggregate, Lane-Delineation Stripe"; KYP-73-48;
HPR-PL-1(12), Part III B.

Southland Drive in Lexington has operated for several years with a two-way, center, left-turn lane. Its seeming success has dismayed traffic engineers somewhat. When US 60, from Lyons Avenue in Frankfort eastward to US 421, was to be improved, all types of barrier medians, mountable medians, and exclusive left-turn storage lanes seemed unnecessarily complicating and confounding for drivers desiring to access midblock business entrances or minor streets. It was decided that existing medians would be abandoned and replaced with a two-way flush lane similar to the one on Southland Drive. Some expressed concern about delineation if it were not raised above the inner, traffic lanes and (or) coarsely textured. Eventually, it was decided to merely paint lines through a portion of the project but to specify a raised, knobby, rough, lane-separation line on the remaining portion. This would require eventual comparison and analysis. In that way, this particular feature of the project achieved experimental status.

Relatively large limestone chips were specified to be set in asphalt cement. It was thought that limestone might suffice without painting if a white, dashed line were admissible as on Southland Drive -- and certainly could be whitened and brightened with paint as desired. Later, the 1971, color coding and marking standard -- requiring both a yellow, dashed line and a yellow, solid line -- was invoked. A typical marking is shown in Figure 3-4a, page 185, of the Manual.... Since color had not been specified in the project contract, the lines were, later, painted yellow by state forces. The only surviving, experimental feature was the texturing of the dashed, yellow lines.

It will be noted that the delineation was compounded by later addition of reflective, raised markers. Turn arrows have been added also.

Respectfully submitted,

Jas. H. Havens
Director of Research

gd
Enclosure
cc's: Research Committee
Experimental raised-aggregate (1/2 inch (13 mm) to 1 inch (25 mm)) traffic stripes were installed on approximately 0.4 mile (644 m) of US 60 just north of the intersection with US 421 in Franklin County. Installation was during June 1974. Aggregate stripes were painted yellow and used as skip lines inside the continuous channelization stripes to indicate no crossing into the two-way, left-turn lane except for turning movements.

Observations indicated that the raised-aggregate stripes had good durability after being exposed to 2 years of wear. During dry, nighttime conditions, the paint stripes were slightly more effective than the aggregate stripes; but raised, pavement markers simulating a paint stripe were superior to either method of delineation. Aggregate stripes provided a substantial improvement over paint stripes during wet, nighttime conditions; but raised, pavement markers were most effective.

The aggregate stripes produced an increase of approximately 3 dBA in the noise level compared to an increase of 5 dBA when driving over raised, pavement markers arranged to simulate paint stripes.

Raised-aggregate stripes were uneconomical when compared to regular paint stripes, thermoplastic striping, and raised, pavement markers. The cost of aggregate stripes would most likely decrease if installation were on a larger scale.
Research Report

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KYP-73-48, HPR-PL-1(12), Part III B

by

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

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INTRODUCTION

Experimental, raised-aggregate, lane-delineation stripes were installed on approximately 0.4 mile (644 m) of US 60 just west of the intersection with US 421 in Franklin County. Installation was during June 1974. This section of US 60 has four lanes with access controlled by permit and with a two-way, left-turn center lane. Aggregate stripes, painted yellow, were used for the skip lanes on the inside of the continuous, yellow channelization stripes to indicate no crossing movements and for the turn lane except for left-turn movements and for the turn lane (1). The extension controlled center lane. Install on the inside of the continuous, yellow channelization stripes to indicate no crossing movements and for the turn lane (1).

A total of 1545 lineal feet (471 m) of 6-inch (0.15-m) wide, raised-aggregate stripe was constructed. The installation consisted of 1020 feet (311 m) of skip line and 525 feet (160 m) of solid line. The cross section of the highway where skip lines were constructed is shown in Figure 1.

Gradation requirements are given in Table 1. Special notes for construction of the stripe stated that the area was to be broomed and forms 3/4 inch (19 mm) to 1 inch (25 mm) thick be used. Specifications called for the stripe to be 6 inches (0.15 m) wide. Caulking was required between the forms and pavement to prevent leaking of the asphalt cement (tack coat). The material specified for the tack coat was either PAC-3 or AC-20 applied at the appropriate temperature. The hot tack coat was to be applied at a rate which would adequately tack and bond the aggregate together as well as bond the aggregate to the pavement (Figure 2). The aggregate was heated to between 240-325 F (116-163 C). The hot aggregate was then placed between the forms onto the hot asphalt cement (Figure 3). While both were hot, the aggregate was rolled and set with a light-weight roller (Figure 4). After cooling slightly, the forms were removed and any loose aggregate was removed (Figure 5). No bituminous tack-coat material was to be left on the exposed surface. The required thickness was between 3/4 inch (19 mm) and 1 inch (25 mm).

A portion of the project prior to painting is shown in Figure 6. Close observation of one of the stripes shows that the cement had flowed out along the edges of stripes (Figure 7). A photograph of the painted stripe a few days after construction shows that the tack-coat material had spread farther (Figure 8) and presented an unsightly appearance.

DURABILITY

After 2 years in service, the aggregate stripe had demonstrated good durability. The aggregate has hardened into the asphalt very well and can not be easily dislodged. The proudness of the stripe has been maintained -- that is, the aggregate has not been pushed into the pavement. The average height of the aggregate above the road surface was about 1.1/4 inches (32 mm). As shown in Figure 9, only a very small percentage of the aggregate is missing. The width of the line was approximately 8 inches (0.20 m) compared to a 6-inch (0.15-m) width when installed.

There was a problem associated with the installation. Evidently, an excessive amount of tack-coat material was used because this material had spread beyond the area of original placement. As shown in Figure 9, the tack material has covered part of the adjacent paint stripe in many instances. The material did not leak under the forms to this extent during installation. The spreading occurred over a period of time after installation. Obviously, a non-sagging grade of roofing asphalt should have been specified.

DELINEATION

Both daytime and nighttime observations were made of the aggregate stripe under dry and wet pavement conditions. Two types of comparisons were made of the delineation provided by the regular paint striping, the aggregate stripe, and raised, pavement markers. First, a comparison was made with simulated paint stripe composed of raised, pavement markers. The pattern for lane-line marking in areas without high ambient light levels was used (2). During dry, daytime conditions, all three were effective (Figure 10); but when the pavement was wet, the aggregate delineation and raised, pavement markers were best (Figure 11). The aggregate delineation appeared to be the most effective during wet, daytime conditions. The big difference in delineation occurred at night (Figure 12) when it was demonstrated that raised, pavement markers were superior to either paint or aggregate stripes.

Another type of comparison was also possible since raised, pavement markers were later installed on this section of road as a supplement to the existing delineation. Inasmuch as the raised markers were installed only as a supplement, they would not provide a significant improvement in delineation during dry days (Figure 13). Even during wet, daytime conditions, the
raised markers did not provide an improvement (Figure 14), unless headlights were used (Figure 15). A strobe light was used to simulate headlights. The effectiveness of the raised, pavement markers became evident during darkness. For dry, nighttime conditions, the paint striping provided better delineation than the aggregate stripe (Figure 16). However, for wet, nighttime conditions the aggregate stripe was more effective than the paint striping (Figure 17). The raised, pavement markers were best in both instances.

Of course, the increased height above the road surface resulted in better delineation under wet conditions by the aggregate stripe and raised, pavement markers. While a paint stripe with beads gives a thickness 25 or 30 mils (0.64 or 0.77 mm), the average height of the aggregate stripe was 1 1/4 inches (32 mm); and raised, pavement markers are about 0.7 inches (18 mm) high. Thermoplastic striping has been placed elsewhere at a thickness of 90 mils (2.3 mm).

When a vehicle is driven across the aggregate stripe, the driver can detect an obvious bump and an increased noise level. Measurements indicated that driving across the aggregate stripe results in an increase of approximately 3 dBA in the noise level. A 10-dBA change in noise level is equivalent in doubling or halving the loudness of a sound; a 3-dBA change results in a perceptible change in relative loudness. Noise readings taken while driving over a stripe simulated with raised, pavement markers resulted in an increase of approximately 5 dBA.

**ECONOMIC ANALYSIS**

Cost comparisons between aggregate stripes and other methods of delineation were made. Costs of using regular paint striping, thermoplastic striping, and raised, pavement markers were compared to the cost of the aggregate stripes. Also, the cost of supplementing paint lines with raised markers was calculated. In an earlier report, the costs of thermoplastic striping and paint striping were compared (3).

The traffic volume on this section of highway was 12,360 vehicles per day. Results from a previous report (4) were used to determine the annual paint striping cost of 2.47 cents per lineal foot (8.10 cents per meter). Also, the total cost of thermoplastic striping was 32 cents per lineal foot (104.92 cents per meter). Total cost of the aggregate stripe during its service life would be its installation cost of $5.00 per lineal foot ($16.39 per meter) plus the annual paint striping cost. Cost of the raised, pavement markers would depend on the pattern used. For the sections where a skip line must be simulated, the pattern for lane-line marking in areas without high ambient light levels was used (2). For simulation of a solid line, the same spacing between nonreflective (Type I) markers was used with highly reflectorized (Type III) markers placed on 20-foot (6.1-m) centers. From past estimate and actual contract prices, an installed price of $1.25, $1.75, and $2.00 per marker was used for Type I, Type II, and Type III markers, respectively. Using these costs and patterns, the installation cost for raised markers would have been $790. Assuming 20-percent replacement over the 8-year period yielded a total cost of $948. The pattern for supplementing the paint striping, which was used for the cost calculations, was actually used when raised markers were installed on the study section of highway. The pattern for supplementing paint striping was a raised marker between each skip line and at 20-foot (6.1-m) centers adjacent to solid lines. The cost of the raised markers would be $216 (assuming 20-percent replacement), in addition to the cost of the paint striping. The total cost for this delineation treatment would be $521. The total costs of each delineation treatment over an 8-year period are summarized in Table 2.

As expected, normal paint striping had the lowest cost. Thermoplastic striping would have cost about 60 percent more in the long run than paint striping but would have provided better delineation. Raised, pavement markers were found to provide the best delineation during poor visibility conditions; this could offset their higher cost (about two times the cost of thermoplastic striping). The cost of the aggregate stripe was extremely high (over eight times the cost of raised, pavement markers). Of course, the cost for the aggregate stripe might decrease to some extent if it were installed on a larger scale. The delineation treatment consisting of paint striping supplemented by raised markers may be the most cost-effective. Its cost was about 70 percent above paint striping alone, but it was a much more effective delineation technique.

**ACCIDENT ANALYSES**

Accident statistics presented in Table 3 were collected before and after installation of the raised-aggregate stripes. The before period was from August 1, 1971, to August 1, 1972, and the after period was from July 1, 1974, to July 1, 1975.

Raised-aggregate stripes were experimental and were part of a TOPICS improvement project. The TOPICS project covered approximately 1 mile (1600 m) and included the entire aggregate stripe study section. The TOPICS project involved removal of a raised median on the four-lane, uncontrolled-access section of US 60.
and installation of a two-way, left-turn lane. Accident statistics associated with the median removal and left-turn installation could not be separated from accident statistics associated with the aggregate-stripe installation. However, the improvements under the 1-mile (1600-m) TOPICS project were the same throughout the section, and any change in accident statistics from that of the 0.4-mile (644-m) aggregate-stripe section was assumed to be attributable to the aggregate stripe.

As shown in Table 3, there was a 40.4-percent reduction in the total number of accidents after the TOPICS project. Since the primary purpose of the project was installation of a two-way, left-turn lane, it is interesting to note that there was an 83-percent reduction in the rear-end accidents associated with left-turns. On the aggregate-stripe section and on the section with other delineation treatments, there were 47.6- and 34.6-percent reductions in accidents, respectively. Accidents occurring at night on the section with aggregate stripes decreased from 12 to 3 while those on the section with other delineation treatments decreased from 5 to 2. During wet times, there was a reduction from 4 to 2 accidents on the section with aggregate stripes and a reduction from 6 to 5 on the other section.

At night, when the pavement was wet, the number of accidents occurring was not sufficient to permit valid comparisons between the before and after periods. Only two accidents occurred under wet, nighttime conditions on the section with aggregate stripes during the before period and none after. Likewise, no accidents were recorded during either the before or after periods on the section with other delineation treatments.

**SUMMARY AND CONCLUSIONS**

The study was limited by the fact that only 1545 lineal feet (471 m) of raised-aggregate stripe were available for evaluation over a 0.4-mile (644-m) section. Primary emphasis was placed on the visual and photographic evaluation under various light and weather conditions. Findings from the study are as follows:

1. After 2 years in service, the raised aggregate stripes have demonstrated good durability.

2. During dry, daylight conditions, all three types of delineation (aggregate stripe, raised, pavement markers simulating a paint stripe, and paint stripes) were effective.

3. During wet, daylight conditions, the aggregate stripe and raised, pavement markers simulating a paint stripe were better than paint stripes. The aggregate stripe appeared to provide the best visibility.

4. During dry, nighttime conditions, the paint striping was slightly more visible than the aggregate stripe, but raised, pavement markers were superior to either treatment.

5. During wet, nighttime conditions, the aggregate stripe provided a substantial improvement over paint striping alone; but raised, pavement markers were still the most visible.

6. Raised, pavement markers supplementing paint striping did not provide a significant improvement in delineation during the day.

7. In addition to visual delineation, the aggregate stripe also provided audible stimuli. Driving over the aggregate stripes resulted in a 3-dBA increase in the noise level as compared to an increase of 5 dBA when driving over raised, pavement markers which were arranged to simulate paint stripes.

8. An economic comparison of various delineation techniques indicated that regular paint striping was the least expensive. Thermoplastic striping costs about 60 percent more than paint striping. Raised, pavement markers were about twice as expensive as thermoplastic stripes, and aggregate stripes cost over eight times as much as raised, pavement markers. The cost of aggregate stripes would most likely decrease if installation was on a larger scale. The cost of paint striping supplemented by raised, pavement markers would be about 70 percent above paint striping alone.

9. A 40.4-percent reduction in the total number of accidents occurred over the TOPICS improvement section (a 1-mile (1600-m) improvement section which included the 0.4 mile (644 m) of raised aggregate). On the aggregate-stripe section, there was a 47.6-percent reduction in accidents as compared to a 34.6-percent reduction on the section without aggregate stripes.

10. It was found that accidents occurring at night on the section with aggregate stripes decreased from 12 to 3 while those on the section with other delineation treatments decreased from 5 to 2. During wet-pavement conditions, there was a reduction from 4 to 2 accidents on the section with aggregate stripes and a reduction from 6 to 5 on the other section. Sufficient data were not available to compare accidents during wet, nighttime conditions.

**RECOMMENDATION**

Under certain conditions, the aggregate stripes were superior to other types of delineation; the cost of the aggregate stripes, however, was exorbitant. Raised, pavement markers provide a more cost-effective delineation. A delineation treatment consisting of paint striping supplemented by raised, pavement markers would provide the more cost-effective treatment for the type of location evaluated in this study.
### TABLE 1. GRADATION REQUIREMENTS FOR CRUSHED LIMESTONE

<table>
<thead>
<tr>
<th>SIEVE SIZE (SQUARE OPENINGS)</th>
<th>PERCENT PASSING</th>
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<tbody>
<tr>
<td>1 inch (25 mm)</td>
<td>100</td>
</tr>
<tr>
<td>3/4 inch (19 mm)</td>
<td>65-100</td>
</tr>
<tr>
<td>1/2 inch (13 mm)</td>
<td>0-10</td>
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### TABLE 2. ECONOMIC COMPARISON OF VARIOUS DELINEATION TREATMENTS

<table>
<thead>
<tr>
<th>DELINEATION TREATMENT</th>
<th>TOTAL COST(^a)</th>
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<tbody>
<tr>
<td>Paint Striping</td>
<td>$305</td>
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<tr>
<td>Thermoplastic Striping</td>
<td>$494</td>
</tr>
<tr>
<td>Aggregate Stripe (Painted)</td>
<td>$8030</td>
</tr>
<tr>
<td>Raised Pavement Markers</td>
<td>$948</td>
</tr>
<tr>
<td>Paint Striping Supplemented with Raised, Pavement Markers</td>
<td>$521</td>
</tr>
</tbody>
</table>

\(^a\) Total cost over an 8-year period, which is the service life for aggregate and thermoplastic striping.

### TABLE 3. ACCIDENT SUMMARY

<table>
<thead>
<tr>
<th></th>
<th>BEFORE</th>
<th>AFTER</th>
<th>PERCENT REDUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Accidents</td>
<td>47</td>
<td>28</td>
<td>40.4</td>
</tr>
<tr>
<td>Rear-End and Left-Turn Accidents</td>
<td>18</td>
<td>3</td>
<td>83.3</td>
</tr>
<tr>
<td>Accidents on Section with Aggregate Stripes</td>
<td>21</td>
<td>11</td>
<td>47.6</td>
</tr>
<tr>
<td>Accidents on Section with other Delineation Treatments</td>
<td>26</td>
<td>17</td>
<td>34.6</td>
</tr>
<tr>
<td>Nighttime Accidents on Section with Aggregate Stripes</td>
<td>12</td>
<td>3</td>
<td>75.0</td>
</tr>
<tr>
<td>Accidents on Section with other Delineation Treatments</td>
<td>5</td>
<td>2</td>
<td>60.0</td>
</tr>
<tr>
<td>Wet Pavement Conditions Accidents on Section with Aggregate Stripes</td>
<td>4</td>
<td>2</td>
<td>50.0</td>
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<tr>
<td>Accidents on Section with Other Delineation Treatments</td>
<td>6</td>
<td>5</td>
<td>16.7</td>
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<tr>
<td>Wet Nighttime Conditions Accidents on Section with Aggregate Stripes</td>
<td>2</td>
<td>0</td>
<td>100.0</td>
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<tr>
<td>Accidents on Section with other Delineation Treatments</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 1. Cross Section of Flush Median Delineation.

12 feet (3.7 m) to 19 feet (5.8 m)
VARIABLE WIDTH FLUSH MEDIAN

9.8 feet (3.0 m) to 16.8 feet (5.1 m)
VARIABLE

1. 4 inch (0.1 m) YELLOW PAINT STRIPE
2. 6 inch (0.15 m) AGGREGATE STRIPE

Figure 2. Application of Hot Asphalt.
Figure 3. Application of Hot Aggregate.

Figure 4. Rolling the Aggregate.
Figure 5. Aggregate Stripe Immediately after Removal of Forms.

Figure 6. Portion of Completed Project before Stripes Were Painted.
Figure 7. Aggregate Stripe before It Was Painted.

Figure 8. Painted Aggregate Stripe a Few Days after Construction.
Figure 9. Aggregate Stripe Approximately 2 Years after Installation.

Figure 10. Comparison of Aggregate Stripe, Paint Stripe, and Raised, Pavement Markers during Dry, Daytime Conditions.
Figure 11. Comparison of Aggregate Stripe, Paint Stripe, and Raised, Pavement Markers during Wet, Daytime Conditions.

Figure 12. Comparison of Aggregate Stripe, Paint Stripe, and Raised, Pavement Markers during Dry, Nighttime Conditions.
Figure 13. Comparison of Aggregate Stripe, Paint Stripe, and Raised Pavement Markers during Dry, Daytime Conditions.

Figure 14. Comparison of Aggregate Stripe, Paint Stripe, and Raised Pavement Markers during Wet, Daytime Conditions.
Figure 15. Comparison of Aggregate Stripe, Paint Stripe, and Raised, Pavement Markers during Wet, Daytime Conditions (Using Strobe Light To Simulate Headlights).

Figure 16. Comparison of Aggregate Stripe, Paint Stripe, and Raised, Pavement Markers during Dry, Nighttime Conditions.
Figure 17. Comparison of Aggregate Stripe, Paint Stripe, and Raised, Pavement Markers during Wet, Nighttime Conditions.

REFERENCES


