Evaluation of Construction-Zone Pavement Marking Materials

Kenneth R. Agent*    Jerry G. Pigman†

*University of Kentucky, ken.agent@uky.edu
†University of Kentucky, jerry.pigman@uky.edu
This paper is posted at UKnowledge.
https://uknowledge.uky.edu/ktc_researchreports/729
Research Report
UKTRP-87-11

EVALUATION OF CONSTRUCTION-ZONE
PAVEMENT MARKING MATERIALS

by

Kenneth R. Agent
Transportation Research Engineer

and

Jerry G. Pigman
Transportation Research Engineer

May 1987
### Abstract

The objectives of this study were to evaluate available foil-back and removable tapes as well as construction-zone raised pavement markers and to recommend materials that should be included on approved lists for use by the Kentucky Department of Highways. Tapes and markers were placed on transverse test sections and the reflectivity, durability, and appearance were observed.

Tapes to be included on the approved lists for foil-back and removable tapes were recommended. Tapes manufactured by 3M, Flex-O-Lite, Cataphote, and Swarolite were included on the list of acceptable foil-back tapes. Recommended removable tapes were the 3M and Cataphote removable tapes. Stimsonite 66 and Flex-O-Lite construction-zone markers were included on the approved list for construction-zone raised pavement markers.

More specific guidelines were developed to use in future evaluations of construction-zone preformed tape and markers.
EVALUATION OF CONSTRUCTION-ZONE PAVEMENT MARKING MATERIALS

by

Kenneth R. Agent
Transportation Research Engineer

and

Jerry G. Pigman
Transportation Research Engineer

Kentucky Transportation Research Program
College of Engineering
University of Kentucky
Lexington, Kentucky

in cooperation with

Kentucky Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
US Department of Transportation

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 of policies of the University of Kentucky, the Kentucky Transportation Cabinet, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. The inclusion of manufacturer names and tradenames are for identification purposes and are not to be considered as endorsements.

May 1987
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Procedure</td>
<td>1</td>
</tr>
<tr>
<td>Preformed Tape</td>
<td>1</td>
</tr>
<tr>
<td>Construction-Zone Markers</td>
<td>1</td>
</tr>
<tr>
<td>Results</td>
<td>1</td>
</tr>
<tr>
<td>Preformed Tape</td>
<td>1</td>
</tr>
<tr>
<td>Construction-Zone Markers</td>
<td>3</td>
</tr>
<tr>
<td>Summary and Conclusions</td>
<td>4</td>
</tr>
<tr>
<td>Preformed Tape</td>
<td>4</td>
</tr>
<tr>
<td>Construction-Zone Markers</td>
<td>4</td>
</tr>
<tr>
<td>Test Procedure</td>
<td>5</td>
</tr>
<tr>
<td>Implementation</td>
<td>6</td>
</tr>
<tr>
<td>References</td>
<td>6</td>
</tr>
</tbody>
</table>
An alternative to typical paint striping as traffic control during construction and maintenance activities is the use of preformed tapes or, more recently, construction-zone raised pavement markers. The objectives of this study were to evaluate available foil-back and removable preformed tapes as well as construction-zone raised pavement markers and to recommend materials that should be included on approved lists.

Reflectivity, durability, and appearance of the tapes were observed periodically. Transverse test sections of the tape were placed on both bituminous and concrete surfaces. Reflectivities of the tapes were rated using the Mirolux 12 portable retroreflectometer (PRR). The durability and appearance of the tapes also were observed during each site visit. Also, the removability of the removable tape was tested during each site visit.

The reflectivity and durability evaluation revealed that none of the foil-back tapes could be classified as a failure. The 3M tapes performed best followed by the Cataphote and the Flex-O-Lite tapes. The Swarolite tapes sustained the earliest loss in reflectivity and the most wear in the wheelpaths. The various engineering and construction grade tapes of each manufacturer performed similarly. The 3M and Cataphote removable tapes performed adequately while the Swarolite and Prismo tapes experienced durability problems.

Of the five construction-zone markers tested, all experienced durability problems. The Davidson, 3M, and Swarolite markers had durability problems of the marker body while the Stimsonite and Flex-O-Lite problems were related to the bond between the adhesive pad and pavement.

The following tapes are recommended to be included on the approved list for foil-back construction tape:

1. 3M Engineering Grade (5360 and 5361)
2. Flex-O-Lite Wet-Reflective
3. Cataphote Catatape
4. Swarolite Engineering Grade

The construction-grade tapes do not meet the thickness requirement of Kentucky's specifications. Consideration should be given to replacing the laboratory durability test with a field performance test.

The two tapes recommended to be included on the approved list for removable construction tape are the 3M Removable (5710 and 5711) and Cataphote Removable.

Stimsonite 66 and Flex-O-Lite markers are the only two markers recommended for the approved list for construction-zone raised pavement markers. These markers should be used only as edge line markers, not as lane
line or centerline markers. They should be used only when provision is made in the contract that the adhesive be completely removed along with the marker. For the most effective delineation in construction zones, construction tape should be used in conjunction with construction-zone markers.

More specific guidelines were developed to use in future evaluations of construction-zone preformed tape and markers.
INTRODUCTION

Pavement marking is a vital component of traffic control during construction and maintenance activities. An alternative to typical paint striping is the use of preformed tapes or, more recently, construction-zone raised pavement markers. When the stripe must be removed, removable tape or markers provide an advantage over traffic paint.

The objectives of this study were to evaluate available foil-back and removable preformed tapes as well as construction zone raised pavement markers and to recommend materials that should be included on approved lists. A similar study was completed in 1985 (1).

PROCEDURE

PREFORMED TAPE

The reflectivity, durability, and appearance of the tapes were observed periodically at a test location. Transverse test sections of the tapes were placed on US 421 (ADT of 11,000) in Frankfort on October 9, 1986, on both bituminous and portland cement concrete surfaces. The tape was placed across the shoulder lane. Three white and three yellow stripes were placed on both the bituminous and concrete pavements, so 12 stripes of each material were placed. Each stripe was approximately 11 feet in length.

Reflectivities of the tapes were rated using a portable retroreflectometer (PRR). The Mirolux 12 PRR was used to collect reflectivity data. The first sets of data obtained with the PRR were dimensionless, but the PRR was later modified to provide data in terms of millicandelas per square foot per footcandle (will be referred to as millicandelas). The durability and appearance of the tapes also were observed during each visit. Also, the removability of the removable tape was tested during each visit. Eight sets of data were collected at the test location over an approximate 6-month period.

An effort was made to contact all manufacturers of construction-zone preformed tape. Samples from 3M, Flex-O-Lite, Swarolite, Prismo, and Cataphote were received and evaluated.

CONSTRUCTION ZONE MARKERS

The reflectivity, durability, and appearance of the construction zone markers were evaluated at a test section placed adjacent to the construction tapes on US 421 in Frankfort. Samples from Stimsonite, 3M, Flex-O-Lite, Swarolite, and Davidson Plastics were received and evaluated. The markers were placed in a transverse orientation across the shoulder lane. A total of 84 markers of each type was placed.

RESULTS

PREFORMED TAPE

Summaries of the PRR measurements for the foil-back and removable tapes at the transverse-stripe test location are shown in Tables 1 and 2, respectively. Measurements indicated that all tapes sustained a significant
loss in reflectivity over the evaluation period. However, some tapes lost reflectivity more rapidly than others. Reflectivity data were collected in the wheel path.

Considering both white and yellow foil-back tapes, the 3M, Flex-O-Lite, and Cataphote tapes maintained reflectivity better than the Swarolite tape (Table 1). The Swarolite tapes lost reflectivity sooner than any other tape. Although the 3M Engineering and Flex-O-Lite Wet-Reflective tapes initially had substantially higher reflectivity than their construction-grade tapes, within two months the reflectivities of the construction-grade tapes were similar. The 3M construction-grade tape maintained reflectivity better than any other single tape.

PRR measurements of the removable tapes (Table 2) show that the Cataphote tape maintained the highest reflectivity for both yellow and white tapes. The Swarolite tape sustained the earliest loss of reflectivity. The 3M tape also suffered considerable loss in reflectivity. The Prismo tape maintained reflectivity better than the Swarolite and 3M tapes but not as well as the Cataphote tape.

During each inspection, the durability and appearance of the tapes were noted. Although some tapes experienced durability problems, the appearance of the remaining tape was adequately maintained. That is, the white or yellow colors of the tapes were maintained.

None of the foil-back tapes experienced durability problems that would be termed failures. Durability was evaluated in two ways: 1) failure of the bond between the tape and the pavement and 2) wear in the wheel path. The 3M tapes provided good durability with only slight wear (there was little difference between the construction-grade and the thicker engineering-grade tapes). The Cataphote tape had no major durability problem but did experience some wear in wheel paths. The Swarolite tapes sustained the most wear in wheel paths. This was also shown in loss of reflectivity; however, there was no major loss of tape. Flex-O-Lite tapes did not sustain any significant wear in the wheel path, but the Flex-O-Lite Wet-Reflective tape sustained the greatest loss of tape due to failure of bond between the tape and the pavement. Within 2 months, about two feet of some of the stripes were missing and by the end of the evaluation period, up to 4 feet of some of the stripes were missing.

Of the removable tapes, only the 3M and Cataphote tapes provided acceptable durability. After 188 days in service at the transverse stripe location, both of these tapes had sustained only slight wear and their appearance was good. The problem with the Swarolite and Prismo tapes was a failure in bonding between the adhesive and the pavement. Within 1 month in service, most white tapes from both manufacturers on both the bituminous and the concrete pavements were missing. This problem was not observed for the yellow tapes, although the yellow Swarolite tape did experience some problems on the bituminous pavement.

The ease of removal for the four removable tapes was investigated along with the length of time necessary for the stain or mark left after removing the tapes to disappear. One stripe of each tape was removed during each inspection. All removable tapes were removed fairly easily in the first few months. The exception was when the tapes were removed on a very cold day. During cold weather, the tapes were brittle and had to be removed in small
pieces. The Prismo and Swarolite tapes became more difficult to remove after several months in service. By the end of the evaluation period, the Prismo and Swarolite tapes were very hard to remove, especially in the wheel paths. The 3M and Cataphote tapes could still be removed easily at the end of the evaluation period.

The adhesive marks remaining on the pavement after removal of the tapes disappeared within 1 to 2 months. The Prismo tape adhesive remained longer than the other tape adhesives, but none of the adhesives left a permanent mark.

CONSTRUCTION-ZONE MARKERS

A test section that included the Stimsonite 66, Davidson, Flex-O-Lite, Swarolite, and 3M markers was placed at the transverse test location in October 1986 and monitored for approximately 4 months until the few remaining markers were snowplowed. Stimsonite 66 markers were received after the other markers and were placed 3 weeks after placement of the markers. The markers were placed on 2-foot centers across the shoulder lane so that 7 markers were in each set. Six sets of markers were placed on both bituminous and concrete pavement with half being white and half yellow. This required a total of 84 of each marker. Problems with either the durability of the marker or bond between the adhesive and the pavement were observed for all markers. All markers provided good reflectivity.

The Davidson markers sustained loss in durability after a short time in service. This marker is constructed with a plastic material and consists of a base with an adhesive and a flap with the reflective tape. The adhesive adhered the marker to the pavement but there was rapid failure that involved the top flap splitting. After 1 month, only 29 percent of the markers were usable and, after 2 months, only 17 percent were usable. Only three markers (which were on the edge of the road) were usable after 3 months. The manufacturer states that this marker is meant for short duration resurfacing projects as an interim measure before the road can be restriped. It is evident these markers are not suited for long-term use.

The 3M marker has been proposed to be used in conjunction with the 3M removable tape to provide additional wet-nighttime delineation. This marker is black, provides no daytime delineation, and is made of a foam material with an adhesive on the base and a reflective tape on the flap. After 1 month in service, only 7 percent were damaged. However, the percentage having substantial damage increased to 62 percent after 2 months, 67 percent after 3 months, and 75 percent after 4 months. After 4 months, the only undamaged markers were either on the edge line or between wheel paths. Damage to these markers was to the flaps. As with the Davidson marker, there was no failure observed with the adhesive holding the marker to the pavement.

The Swarolite marker sustained considerable loss due to failure of the adhesive pad to hold the marker on the pavement and due to breaking of the marker body. Within 2 weeks, 30 of the 84 markers were missing and five of the remaining markers were damaged. After 1 month, only 32 percent of the markers were usable and that percentage decreased to 14 percent after 2 months.
The Flex-O-Lite marker also experienced considerable loss on the bituminous pavement due to loss of adhesion between the adhesive pad and the pavement. There was no such loss on the concrete pavement. However, the markers that remained had no significant durability problem until being snow plowed. After 1 month, 86 percent of the markers placed on the bituminous pavement were missing compared to 14 percent of those placed on concrete. After 3 months, 93 percent of those placed on bituminous were missing compared to 31 percent of those placed on concrete.

Stimsonite markers also experienced substantial loss due to lack of bond between the adhesive pad and the pavement. The Stimsonite marker had been the only construction-zone marker approved in Kentucky and has been used extensively without having this problem. After about 2 weeks, 44 percent of the markers were missing, and that percentage increased to 88 percent after 6 weeks.

The Stimsonite marker was placed about 2 weeks after the other markers. All of the markers were placed in October but were placed on warm days when the pavement temperature was well in excess of the minimum temperature of 50 degrees Fahrenheit.

SUMMARY AND CONCLUSIONS

PREFORMED TAPE

The reflectivity and durability evaluations revealed that none of the foil-back tapes could be classified as failures. Specifically, tapes from 3M, Flex-O-Lite, Cataphote, and Swarolite performed adequately. The 3M tapes performed best followed by the Cataphote and Flex-O-Lite tapes. The Swarolite tapes sustained the earliest loss in reflectivity and the most wear in the wheel paths. There was not a significant difference in performance of the engineering- and construction-grade tapes from 3M and Swarolite. Also, the two Flex-O-Lite tapes (Wet-Reflective and Construction Grade) had similar performances.

Removable tapes that performed adequately were the 3M and Cataphote tapes. The Swarolite and Prismo tapes experienced durability problems.

CONSTRUCTION ZONE MARKERS

All construction zone markers tested experienced durability problems while they all had adequate reflectivity. The Davision, 3M, and Swarolite markers had problems with durability of the marker body. The Stimsonite and Flex-O-Lite markers had problems related to the bond between the adhesive pad and the pavement. Prior experience with the Stimsonite marker has not indicated a problem with the pad providing adequate adhesion to the pavement. The Stimsonite, Flex-O-Lite, and Swarolite markers all use separate pads for adhesion to the pavement and all sustained adhesion problems.

The most effective delineation would be a combination of temporary tape and construction-zone markers. The tape provides better daytime delineation while the markers provide better nighttime delineation, especially during hazardous rainy, nighttime conditions. When used as a supplement, the markers should be placed at 40-foot intervals for a skip line and at 10-foot intervals for a solid line (1). If used as a replacement for temporary tape, the
markers should be placed at 5-foot intervals to represent a solid line, and a set of four markers placed at 3 1/3-foot intervals should be used to represent a 10-foot skip line (1).

TEST PROCEDURE

It is evident that more specific guidelines are needed to evaluate construction-zone tapes and markers. For example, minimum reflectivity levels should be specified. The following evaluation criteria is recommended for future tests:

Preformed Tape

1. Reflectivity — must maintain a minimum reflectivity level of 70 millicanndelas per square foot per footcandle after 6 months in service (measured in the wheel path of a transverse line).

2. Durability — after 6 months in service, must not wear in the wheel paths such that any pavement can be seen and not more than 25 percent of the total length of stripes may be missing.

3. Appearance — must not discolor to an unacceptable level.

4. Removability — to be accepted as a removable tape, the tape must be capable of being easily removed by hand each month over a 6-month test period without the use of heat, grinder, etc. and leave no adhesive and no visible pavement scar within 1 month of removal.

Construction-Zone Markers

1. Reflectivity — nighttime inspection must prove that the reflectivity will be maintained over a 6-month test period.

2. Durability — after the 6-month test period, not more than 25 percent of the markers should be rated as failed (either missing as a result of failure of the bond between the pavement and the adhesive or have sufficient damage to the body of the marker such that over 50 percent of the reflective face is not functional).

3. Appearance — the marker must provide sufficient daytime visibility such that a series of markers placed at 5-foot intervals would represent a solid line.

4. Removability — the marker must be capable of being easily removed manually and leave no objectionable pavement scar or adhesive.

The test for the preformed tape will consist of placing six yellow and six white transverse lines (half on bituminous and half on concrete pavement) on a transverse test section across the right or shoulder lane. This will require 100 feet of white and yellow 4-inch tape to be submitted by a manufacturer. The test for construction-zone markers will involve markers placed in longitudinal test sections such that 100 yellow and 100 white markers must be submitted by the manufacturer.
The performance tests will be conducted annually. The six-month test period will last from May to November. All available preformed tapes and construction-zone markers will be included in the initial test using this test procedure. After the initial tests, the annual test will include any new tapes or markers along with previously approved material that has been modified. Also included would be any tapes or markers that did not pass the previous test that the manufacturer desires to resubmit.

IMPLEMENTATION

The following tapes are recommended to be included on the approved list for foil-back construction tape:

1. 3M Engineering Grade (5360 and 5361),
2. Flex-O-Lite Wet-Reflective,
3. Cataphote Catatape, and
4. Swarolite Engineering Grade.

The construction-grade tapes do not meet specification requirements of Section 831 of Kentucky's Standard Specifications for Road and Bridge Construction (1985 Edition). This specification could be revised by modifying the thickness requirement and replacing the laboratory durability test with a field performance test.

The two tapes recommended to be included on the approved list are

1. 3M Removable (5710 and 5711) and
2. Cataphote Removable.

The two construction-zone markers recommended to be included on the approved list are

1. Stimsonite 66 and
2. Flex-O-Lite construction-zone marker.

These markers should be used only when provision is made in the contract that the adhesive be completely removed along with the marker. None of the construction-zone markers have been shown to be sufficiently durable when used as lane lines or centerlines, so it is recommended that their use be limited to edge lines. For the most effective daytime and nighttime delineation in construction zones during both dry and wet pavement conditions, construction tape should be used in conjunction with construction-zone markers. For example, the 3M marker is provided with the 3M removable tape by the manufacturer and should be used along with the tape.

REFERENCES

<table>
<thead>
<tr>
<th>COLOR</th>
<th>MANUFACTURER AND BRAND</th>
<th>PRR MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DAYS IN SERVICE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NEW</td>
</tr>
<tr>
<td>White</td>
<td>3M Engineering (5360)</td>
<td>760</td>
</tr>
<tr>
<td></td>
<td>3M Construction (5160)</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td>Flex-O-Lite Wet-Reflective</td>
<td>910</td>
</tr>
<tr>
<td></td>
<td>Flex-O-Lite Construction</td>
<td>650</td>
</tr>
<tr>
<td></td>
<td>Swarolite Engineering</td>
<td>570</td>
</tr>
<tr>
<td></td>
<td>Swarolite Construction</td>
<td>510</td>
</tr>
<tr>
<td></td>
<td>Cataphote (Catatape)</td>
<td>600</td>
</tr>
<tr>
<td>Yellow</td>
<td>3M Engineering (5361)</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>3M Construction (5161)</td>
<td>380</td>
</tr>
<tr>
<td></td>
<td>Flex-O-Lite Wet-Reflective</td>
<td>710</td>
</tr>
<tr>
<td></td>
<td>Flex-O-Lite Construction</td>
<td>440</td>
</tr>
<tr>
<td></td>
<td>Swarolite Engineering</td>
<td>570</td>
</tr>
<tr>
<td></td>
<td>Swarolite Construction</td>
<td>430</td>
</tr>
<tr>
<td></td>
<td>Cataphote (Catatape)</td>
<td>730</td>
</tr>
</tbody>
</table>

* Millicandelas per square foot per footcandle.
TABLE 2. PRR MEASUREMENTS FOR REMOVABLE TAPE

<table>
<thead>
<tr>
<th>COLOR</th>
<th>MANUFACTURER AND BRAND</th>
<th>PRR MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DAYS IN SERVICE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New 14 32 62 89 119* 147* 188*</td>
</tr>
<tr>
<td>White</td>
<td>3M Removable (5710)</td>
<td>530 500 470 350 120 80 80 80</td>
</tr>
<tr>
<td></td>
<td>Swarolite Removable</td>
<td>380 310 320 240 80 ** ** **</td>
</tr>
<tr>
<td></td>
<td>Cataphote</td>
<td>460 530 560 470 320 210 190 120</td>
</tr>
<tr>
<td></td>
<td>Prismo</td>
<td>410 310 370 350 210 160 ** **</td>
</tr>
<tr>
<td>Yellow</td>
<td>3M Removable (5711)</td>
<td>200 180 160 110 60 60 50 50</td>
</tr>
<tr>
<td></td>
<td>Swarolite Removable</td>
<td>160 120 120 100 60 60 60 60</td>
</tr>
<tr>
<td></td>
<td>Cataphote</td>
<td>230 380 360 290 170 130 100 90</td>
</tr>
<tr>
<td></td>
<td>Prismo</td>
<td>240 180 200 190 120 110 80 70</td>
</tr>
</tbody>
</table>

* Millicandela per square foot per footcandle.
** No tape remaining.