

Evaluation of Temporary Day-Night Visible Raised Pavement Marker Adequacy

THOMAS D. DAVIS

Compared to paint, day-night visible raised pavement markers improve construction-zone traffic performance significantly. However, there is a need to find temporary markers that can withstand construction-zone traffic. After initial screening, six marker types were tested further for visibility and durability. The features that met the criteria for an adequate day-night visible temporary marker installed with butyl on primer are a streamlined profile, a microscopic cube-corner, sealed prismatic air cell, cube-corner reflex, or multiple-glass lens reflector, and a balance between the reflector area and casing area exposed to the driver. Two marker systems met these requirements: (a) a hollow acrylic marker with a sealed prismatic air cell reflector such as the Stimsonite 66B by the Amerace Corporation; and (b) a combination of a domed-shaped polyester marker such as the Titan TM-40 by the Traffic Safety Supply Company for day visibility, and a filled ABS shell marker with a cube-corner reflex reflector such as the Ray-o-Lite by I.T.L. Industries, Inc., or equivalent for night visibility.

Compared to paint, day-night visible raised pavement markers improve construction-zone traffic performance significantly. However, until recently, the only day-night visible marker available was the ceramic marker. Ceramic markers are designed for permanent installation with epoxy adhesives. In construction zones, a butyl adhesive is used for pavement markers to permit easy removal. However, the combination of heavy, weaving traffic and butyl adhesives caused the markers to break up, especially on concrete pavements. Even when panel adhesives were used, the results were much the same: the ceramics broke up or came off.

BACKGROUND

A recent report by Davis (1) showed that raised reflective ceramic markers proved to be day visible and provided night and wet-pavement lane delineation superior to that provided by paint. The markers decreased lane changes and night lane encroachments. Unfortunately, 25 percent of the markers were lost or damaged within 6 days while under traffic. The markers were attached to the pavement with butyl adhesives. Losses were probably due to a combination of heavy, weaving traffic and the butyl adhesives. Another experiment in the same report showed that ceramic marker losses were 2 times higher on concrete than on asphalt pavements. Also, a commonly used plastic marker (not day visible) experienced a 29 percent failure rate, but the ceramic marker experienced a 79 percent failure rate, even with other one-step, panel-type adhesives.

Other reports related similar experiences with ceramic markers.

Niessner reported: "On one project nearly 80 percent of the ceramic markers placed with the butyl pads were missing or damaged in 4.5 months. The contractor had used this detour to bring all of his heavy equipment onto and off of the construction site. Combined with the narrow 9-ft lanes on the detour, this may partly explain the poor performance of the ceramic markers. The damage and loss record for this location seems to indicate that a butyl pad does not afford the ceramic markers with the support and adhesive properties it requires" (2).

Lanz reported on a permanent (nonconstruction) installation of ceramic markers. Although the 5 to 10 percent overall annual loss may seem relatively small, he noted that: "Many of these markers failed because of poor bond. Traffic is detrimental to ceramic markers in curves and in areas with much lane crossing. Replacement of ceramic markers is necessary in several locations where up to 50 percent are missing in 0.5-mi stretches" (3). The markers were installed with epoxy adhesives.

This project described here was designed to select a durable temporary day-night visible marker system compatible with butyl adhesives that hold the marker in place during construction and permit easy removal once construction is complete.

PROCEDURE

A review of the various procedures and criteria used to select adequate day-night markers follows:

1. Fourteen manufacturers were solicited for samples of day-night visible raised pavement markers. The markers had to be easy to install and present no hazard to drivers. A night reflective marker was assumed to also be wet-night reflective. The six marker types given in Table 1 and shown in Figures 1 through 6 were judged acceptable for further testing.

2. In April 1984, the six marker types were installed in a parking lot for approximately 1 month and run over at random. They did not crack, turn, or fall off, and they were removable with a shovel. Five marker types were attached with butyl, and the Swareflex type was installed with a thermoplastic.

3. The new candidate markers were tested for visibility on an unopened section of I-78, which was asphalt, and on I-295, which was concrete. Thirty-three of each type of marker were installed at 6-ft intervals side by side as shown in Figures 7 and 8. Eight observers independently judged the visibility of the markers from a car with the sun behind, the sun in front, and at night and recorded their opinions on a questionnaire as to the distance from which they could detect each marker.

4. Following the visibility study, the markers were installed at six sites with various pavement and traffic characteristics given in Table 2. In late May and early June, the six marker types were

TABLE 1 MARKER DESCRIPTION

Company	Model	Body	Reflector
Ferro Corporation	P-15	Ceramic	Microscopic cube-corner
Amerace Corporation	Stimsonite 66B	Hollow acrylic shell	Sealed prismatic air cell
I.T.L. Industries, Inc.	Ray-o-Lite	High-impact ABS	Cube-corner reflex
Traffic Safety Supply Company	Titan TM-40	Polyester	None
D. Swarovski and Company	Swareflex 3557	ABS shell	43 glass reflectors
Olympic Machines, Inc.	44C	Polymer	Single-glass lens

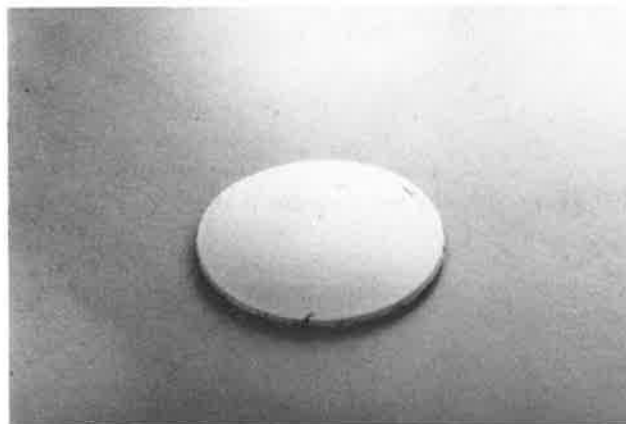
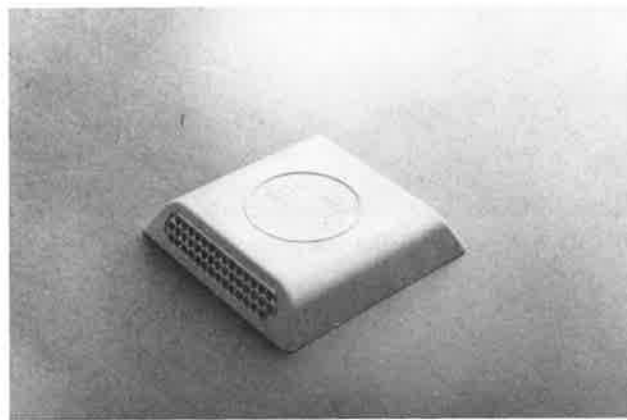
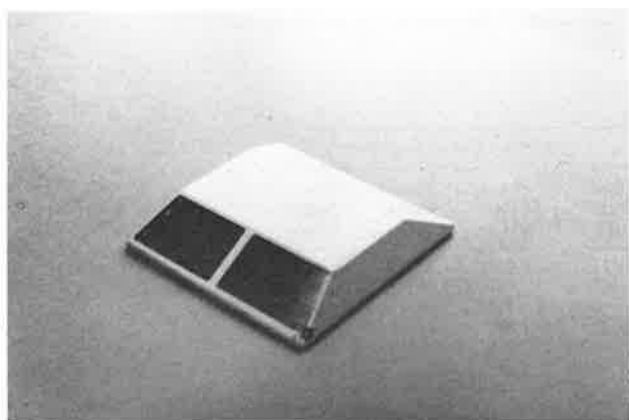
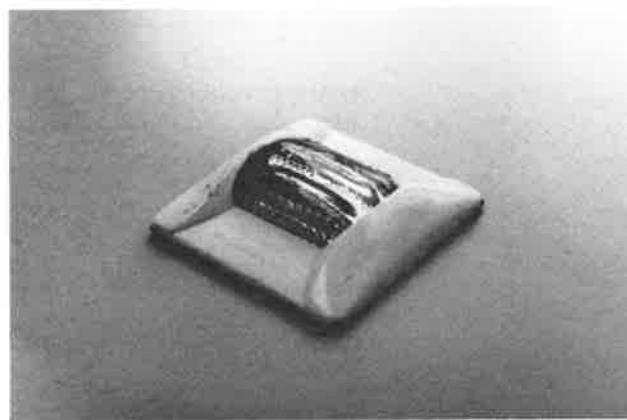
**FIGURE 1 Ferro Corporation P-15.****FIGURE 4 Traffic Safety Supply Company Titan TM-40.****FIGURE 2 Amerace Corporation Stimsonite 66B.****FIGURE 5 D. Swarovski and Company Swareflex 3557.****FIGURE 3 I.T.L. Industries, Inc., Ray-o-Lite.****FIGURE 6 Olympic Machines, Inc., 44C.**



FIGURE 7 Visibility test from 200 ft away.

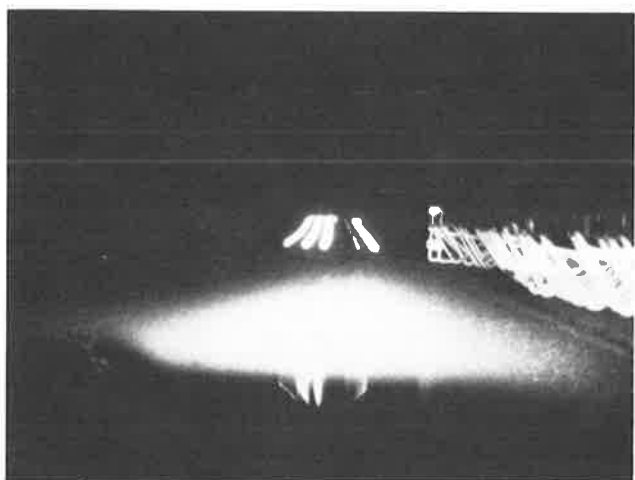


FIGURE 8 Night visibility test from 200 ft away.

randomly installed between skip lines at each site. For 6 months, the markers were monitored at 12 periodic intervals for cracks, losses, turns, slips, and dirt.

5. Following the 6-month durability test, the markers were completely removed with snowplows without noticeable damage to the pavement.

6. Finally, the worn markers were judged for visibility in the same manner as in Step 3.

RESULTS

Tables 3 and 4 summarize the results of the visibility and durability tests applied to the six candidate markers. The Ferro Corporation's P-15 ceramic marker was the control used in the experiment. The recommended system should equal or surpass the ceramic's visibility and exceed the ceramic's durability.

In Table 3, eight observers made independent decisions on the distance from which they could detect each marker array under various light conditions and with asphalt and concrete pavements. The asphalt and concrete site data were combined. The 16 observations were averaged to produce the distances in the table. After 6 months of wear, the markers were removed from the durability test locations. Unfortunately, the Stimsonite markers came off the pavement in fragments. Therefore, nine of each marker type were used in the final visibility survey. The fact that the Stimsonite markers had to be fitted together again no doubt lowered the visibility results from what they would have been had the markers remained intact on removal. The other markers were removed intact from the pavement. Significant changes were detected with the paired t-test with a 95 percent level of confidence. There was no noticeable damage to the pavement from any of the markers.

CONCLUSIONS

During the experiment, it was noted that the ideal marker should incorporate certain features and avoid others. Although the plastic

TABLE 2 SITE DESCRIPTION

Name	Location	Pavement	Traffic Pattern	AADT (1,000)	Marker Type	Test Section	Total Markers
US-1 North	I-287	Asphalt	Weave	28	6	21	126
I-287 North	US-1	Concrete	Weave	39	6	8	48
I-287 North	Route 18	Asphalt	Exit	35	6	14	84
I-287 North	Mt. Airy Road	Concrete	Exit	24	6	5	30
I-78 East	I-287	Asphalt	Split	19	6	15	90
I-287 North	I-78	Concrete	Split	19	6	15	90

TABLE 3 VISIBILITY RESULTS

Type	New Markers			After 6 Months of Wear		
	Sun in Face (ft)	Face in Shade (ft)	Dry Night (ft)	Sun in Face (ft)	Face in Shade (ft)	Dry Night (ft)
Ferro P-15 (control)	1,075	1,063	1,110	1,045	816	419
Stimsonite 66B	1,175	1,050	1,025	1,048	— ^a	— ^a
Ray-o-Lite	737 ^b	645 ^b	1,100	849 ^b	565 ^b	385
Titan TM-40	1,175	1,063	NA ^c	1,048	781	NA
Swareflex 3557	1,088	800 ^b	1,100	1,045	585 ^b	1,041 ^b
Olympic Machines 44C	1,172	1,063	457 ^b	1,045	746	246 ^b

^aFigures were biased because the Stimsonite markers broke up on removal. Face in shade = 613 ft, and dry

^bnight = 271 ft.

^cSignificant change from ceramic at the 95 percent level of confidence.

^dNot applicable.

TABLE 4 DURABILITY AFTER 6 MONTHS

Type	Marker on Asphalt			Marker on Concrete		
	No. Installed	No. Left	Percent Left	No. Installed	No. Left	Percent Left
Ferro P-15 (control)	51	29	57	28	15	54
Stimsonite 66B	50	47	94	28	23	82
Ray-o-Lite	50	43	86	28	24	86
Titan TM-40	50	50	100	28	28	100
Swareflex 3557	37	14	38	28	12	43
Olympic Machines 44C	49	43	88	28	12	43

cube-corner-type reflectors proved adequate, they lost over one-half of their visibility after 6 months of wear (Table 3). The Swareflex (Figure 5) multiple-glass lens reflector was the only one that retained 1,000 ft of dry-night visibility after 6 months.

Also, the more vertical and nonstreamlined the marker casing and reflector facing the driver, the less likely motorists would be able to see the marker in the day with the sun behind the visible face, and the more likely the marker would come off the pavement from tire impacts. The face of the Swareflex marker toward the driver sloped 60 degrees from the pavement causing the visible face to go into a shadow and lose visibility (Table 3). The Swareflex also experienced the highest losses, no doubt from tire impacts on its nonstreamlined surface (Table 4).

The ideal marker should also avoid dedicating too much visible surface to the reflector because the reflector has low visibility in the day. The Ray-o-Lite (Figure 3) visible surface is mostly reflector and is the least visible marker in the day (Table 3).

An adequate day-night, construction-zone marker should have the following features:

1. A streamlined profile;
2. A microscopic cube-corner, sealed prismatic air cell, cube-corner reflex, or multiple-glass lens reflector; and
3. A balance between the reflector and casing area exposed to the driver.

The systems that met the aforementioned criteria are (Table 5):

1. The hollow acrylic marker with a sealed prismatic air cell reflector (Amerace Corporation Stimsonite 66B), and
2. The combination of the dome-shaped polyester marker (Traffic Safety Supply Company Titan TM-40) for day visibility and the filled ABS shell marker with a cube-corner reflex reflector (I.T.L. Industries, Inc. Ray-o-Lite or equivalent) for night visibility.

Both systems used butyl adhesives on a primed surface, and both systems were removed from the pavement without any noticeable damage to the pavement.

The Titan TM-40/Ray-o-Lite system and the Stimsonite 66B were installed in an actual construction zone by contract forces during the 1985 construction season. The markers were used to delineate lane diversion through an I-78 bridge-deck restoration project in New Jersey. There were three lanes of traffic in each direction, the pavement was concrete, and the annual average daily traffic (AADT) was over 40. After the 1 month that the diversions were in effect, 100 percent of the Ray-o-Lite, 98 percent of the Titans, and 87 percent of the Stimsonites were in place.

FUTURE RESEARCH

Further research is needed to find an adhesive better than the butyl pad for temporary markers. The butyl requires a primer that must be allowed to dry, and a vehicle must then be driven over the marker. In practice, these steps may not be followed and the marker may fall off the pavement. There are also problems with cold temperatures, rough pavement, and incompatibility with some markers.

Hot-melt adhesives should be investigated because in comparison to butyl, they (a) require no primer, (b) can conform to pavement irregularities, and (c) can be used in a wide range of temperatures. This ensures fast, durable and economical installations without compromising removability.

There is also a need to enhance raised marker visibility by adjusting spacing and placement to account for special geometric situations such as reconstructed ramps.

ACKNOWLEDGMENTS

This research was done in cooperation with the FHWA, U.S. Department of Transportation.

Appreciation is expressed to William Mullowney for his direction and guidance in all phases of the project; Arthur W. Roberts and Eugene F. Reilly, for their administrative assistance; and the

TABLE 5 DAY-NIGHT VISIBLE MARKER ADEQUACY

Type	Visibility			Percent Remaining		Overall Adequacy
	Sun in Face	Face in Shade	Night	Bitumin	Concrete	
Ferro P-15	Control	Control	Control	Control	Control	Control
Stimsonite 66B	Equal ^a	Equal	Equal	Better ^b	Better	Pass
Ray-o-Lite	Worse ^c	Worse	Equal	Better	Better	Pass, night
Titan TM-40	Equal	Equal	NA ^d	Better	Better	Pass, day
Swareflex 3557	Equal	Worse	Equal	Worse	Worse	Fail
Olympic Machines 44C	Equal	Equal	Worse	Better	Worse	Fail

^aEqual to ceramic.

^bBetter than ceramic.

^cWorse than ceramic.

^dNot applicable.

Division of Research staff, for the collection of data at inconvenient locations and times of day.

REFERENCES

1. T. D. Davis. *Construction Zone Safety and Delineation Study*. Report FHWA/NJ-83/005. FHWA, U.S. Department of Transportation, 1983.
2. C. W. Niessner. *Construction Zone Delineation (RPM)*. Report FHWA-TS-78-222. FHWA, U.S. Department of Transportation, 1978.

3. L. J. Lanz. *Road Marking Material, Second Interim Report*. Mississippi State Highway Department, Jackson, 1973.

The contents of this paper reflect the views of the author, who is responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the New Jersey Department of Transportation or the Federal Highway Administration. This paper does not constitute a standard, specification, or regulation.

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

Evaluation of Temporary Pavement Marking Patterns in Work Zones: Proving-Ground Studies

CONRAD L. DUDEK, R. DALE HUCHINGSON, AND DONALD L. WOODS

Results of proving-ground studies for evaluation of temporary pavement markings for work zones are summarized. The objective was to investigate 10 candidate temporary marking treatments: one base treatment consisted of 4-ft stripes with 36-ft gaps, and nine other candidate marking treatments employed variations in stripe length, gap length, and reflective and nonreflective raised pavement markers (RPMs). The initial studies were conducted during dry-weather, daytime conditions. Based on the findings of the daytime studies, the base treatment and the best six of the nine other marking treatments were evaluated during nighttime, dry-weather conditions employing the same procedures and experimental design. The studies were conducted on the test track at the Texas A&M Research and Extension Center, with a demographically balanced sample of drivers individually driving an instrumented test vehicle. Measures of effectiveness included speed and distance data, erratic maneuver data, and subjective evaluations of treatment effectiveness. The nighttime studies aimed to determine whether the daytime findings were applicable to dry-weather, nighttime driving conditions. The approach was to essentially replicate the daytime study procedures with a matched, but different sample of drivers. The six markings selected were three with striping patterns and three RPM configurations. Daytime treatments deleted were those with 1- and 2-ft stripes, long (48- and 38-ft) gaps, or both.

In highway work zones traffic is often required to use different parts of the roadway for short periods of time, which necessitates changes in path delineation. For example, a significant portion of highway maintenance activities involves pavement overlay work. This type of work frequently requires more than one layer of pavement, and traffic is permitted to operate on the roadway

between the times the first and last layers are laid. Therefore, there is a need to delineate pathways (lanes) through work zones for motorists, particularly for nighttime and adverse weather driving conditions.

There are basically two schools of thought: (a) to simply use the Manual on Uniform Traffic Control Devices (MUTCD) standard markings, resulting in the expenditure of considerable time and materials, which seems impractical for conditions where the marking would be in use for a short period of time, and (b) to use temporary and possibly an abbreviated marking pattern. Research is needed to develop a cost-effective temporary pavement-marking pattern for use in highway work zones.

Proving-ground studies were conducted to evaluate 10 candidate temporary pavement marking treatments: one base treatment consisting of 4-ft stripes with 36-ft gaps, and nine other candidate marking treatments. Studies were first conducted during daytime, dry weather conditions. The six best or most promising treatments, along with the base treatment, were then studied during nighttime, dry weather conditions.

APPROACH FOR DAYTIME STUDIES

Objectives and Scope

The objective of this series of studies was to investigate 10 candidate temporary pavement marking treatments for use at work zones by determining the effects of each on various measures of driving effectiveness during daytime, dry weather conditions. The markings consisted of a set of low-profile markings (LPMs) and raised pavement markings (RPMs) applicable to work zones.