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16. Abstract

This report is the fourth and final of research project 2-18-82-322, "A Study of Raised Reflective Pavement Markers." This report contains an executive summary of the project which includes the research methodology, significant conclusions and suggested future research in the area. This report also contains several tests and procedures which once used will result in a more useful and effective route guidance system. These tests and procedures include (1) installation guidelines, (2) a polyethelene test for pavement moisture, (3) a maintenance evaluation procedure, and (4) suggested guidelines for pavement marker placement.

The other published reports in this series include:

Research Report 322-1, "State-of-the-Art and Objectives of Reflective Raised Pavement Markers,"

Research Report 322-2, "Reflectivity Retention of Reflective Raised Pavement Markers," and

Research Report 322-3, "Retention of Reflective Raised Pavement Markers."

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EXECUTIVE SUMMARY, SIGNIFICANT RESULTS AND ASSORTED TESTS AND PROCEDURES FOR REFLECTIVE RAISED PAVEMENT MARKERS

By

Roger W. McNees

and

James S. Noel

FINAL
Research Report 322-4F
Research Study Number 2-18-82-322

Sponsored by
Texas State Department of Highways and Public Transportation
In Cooperation with
U.S. Department of Transportation
Federal Highway Administration

October 1986

Texas Transportation Institute
Texas A&M University
College Station, Texas 77843

METRIC CONVERSION FACTORS

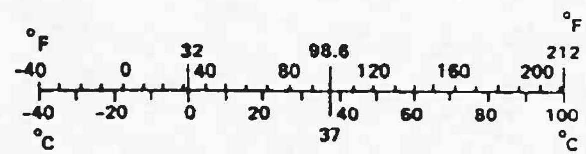
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



SUMMARY

This report is the fourth and final of a research project 2-18-82-322 "A Study of Raised Reflective Pavement Markers". This report contains an executive summary of the project which includes the research methodology, significant conclusions and suggested future research in the area. This report also contains several tests and procedures which once used will result in a more useful and effective route guidance system. These test and procedures include (1) installation guidelines (2) a polyethelene test for pavement moisture, (3) a maintenance evaluation procedure, and (4) suggested guidelines for pavement marker placement.

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Research Report 322-2 "Reflectivity Retention of Reflective Raised Pavement Markers", and

Research Report 322-3, "Retention of Reflective Raised Pavement Markers".

Implementation

This research project addressed two very critical problems related to reflective raised pavement markers, namely loss of reflectivity and retention of markers on the road. Many factors which contributes to both of these problems have been developed and should be used by installation contractors and SDHPT inspectors. A test has been developed to determine whether the pavement is too wet for installation. A maintenance evaluation procedure has been developed which is simple and safe to use. A set of standard photographs are utilized in the evaluation and will result in a more uniform maintenance practice for RPMs and RTBs in the state.

Disclaimer

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 Federal Highway Administration. This report does not constitute a standard, specification or regulation.

Acknowledgement

The authors wish to thank the members of the technical advisory committee for their guidance and support throughout the project. Special thanks are extended to Mr. Richard H. Oliver (D-18T), Mr. Randall Keir (D-18T) and Mr. H. Dexter Jones (District 12) for their continued technical guidance and moral support during the project. Special interest was shown by Mr. Raymond Stotzer (District 15), Mr. Lawrence Jester (District 19) and Mr. Franklin Young (District 20) for which the authors are extremely thankful.

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EXECUTIVE SUMMARY

OVERVIEW

The scope of this study was to determine the causes and possible reasons for the loss of reflectivity and physical loss of markers. The effectiveness of the markers with respect to both reflectivity and marker loss was related to service life, pattern, amount of truck traffic, average daily traffic (ADT), tensile strength of pavement and other pertinent factors. Installation procedures, current maintenance procedures, and initial brightness levels necessary for purchase were reviewed, and new procedures and specifications were determined from this study. Appropriate laboratory and field studies were conducted to obtain the desired goals and objectives of this study. A set of 35 mm slides were assembled for the Departments use in evaluating maintenance requirements. A new type of adhesive and several epoxies were evaluated with respect to marker retention. A new bituminous material named "bitumen" is the most appropriate to use where marker retention is a problem.

RESEARCH METHODOLOGY

A photographic technique was developed and used to determine the effectiveness of various reflective raised pavement marking systems. A panel of experts consisting of the technical advisory committee of the project and the SDHPT project contact personnel evaluated slides of each site with respect to the effectiveness of the markers reflectivity to present positive route guidance to the driver. These levels of effectiveness were related to (1) service life, (2) level of specific intensity, (3) number of missing markers, (4) color of marker, (5) two types of patterns, (6) percentage of trucks and (7) average daily traffic (ADT). The results of this study was documented in research report 322-2 "Reflectivity Retention of Reflective Raised Pavement Markers".

A study utilizing twenty-three drivers from College Station and Austin viewed four sites in Austin, Texas. These test drivers were used to (1) determine the accuracy of the slides, (2) validate the judgement of the panel of experts and (3) determine whether the set of photograph standards were useful for maintenance purposes. The results of this study were documented in research report 322-2.

Physical counts of markers around the state were made for several reasons. The first was to determine the magnitude of the reflectivity and retention problem. These results were documented in research report 322-1 "State-of-the-Art, Research Methodology, and Annotated Bibliography of Reflective Raised Pavement Markers". The second was the physical count of the loss of reflectivity. Both reflector damage and structural damage were noted and quantified. These results were documented in research report 322-2. And thirdly, physical counts were conducted to determine the reasons for the rapid rate of loss of the markers. These counts also allowed determination of the service life of the markers. These results were documented in research report 322-3.

A controlled field study was conducted at the Texas A&M University Research Center. The controlled field study was conducted to evaluate a test File D-9 suggested to determine the moisture content of the pavement prior to installation. The results of this study were documented in research report 322-3.

MARKERS PERFORMANCE CURVES

Figures 1A and 1B present the retention properties of both RPMs and RTBs on both portland cement concrete and asphalt concrete, respectively. RPMs performance on PCC is good, however, the performance on AC is very poor. Virtually all of the RPMs will be removed from the road surface with 50 million vehicles using the facility. The data used to develop these figures were the counts of RPMs and RTBs made during the study period and did not take into account the 1976-77 study performed by the Texas SDHPT. These figures categorize effctiveness by retention and reflectivity. The reflectivity curve was developed using sites in which photometric readings were obtained. The PCC sites were to be in the Houston area however it was not possible to stop traffic to obtain the photographs or photometric readings. The effectiveness levels used were those developed during the study. Figure 1A when compared to figure 1B points out the relatively poorer performance of the RPMs than RTBs on both PCC and ACC pavements.

The RTB curves indicate that on both PCC and ACC the RTBs remain effecive longer than RPMs. The length of time is based on the total volume of traffic passing the markers. In both figures it becomes apparent that markers remain

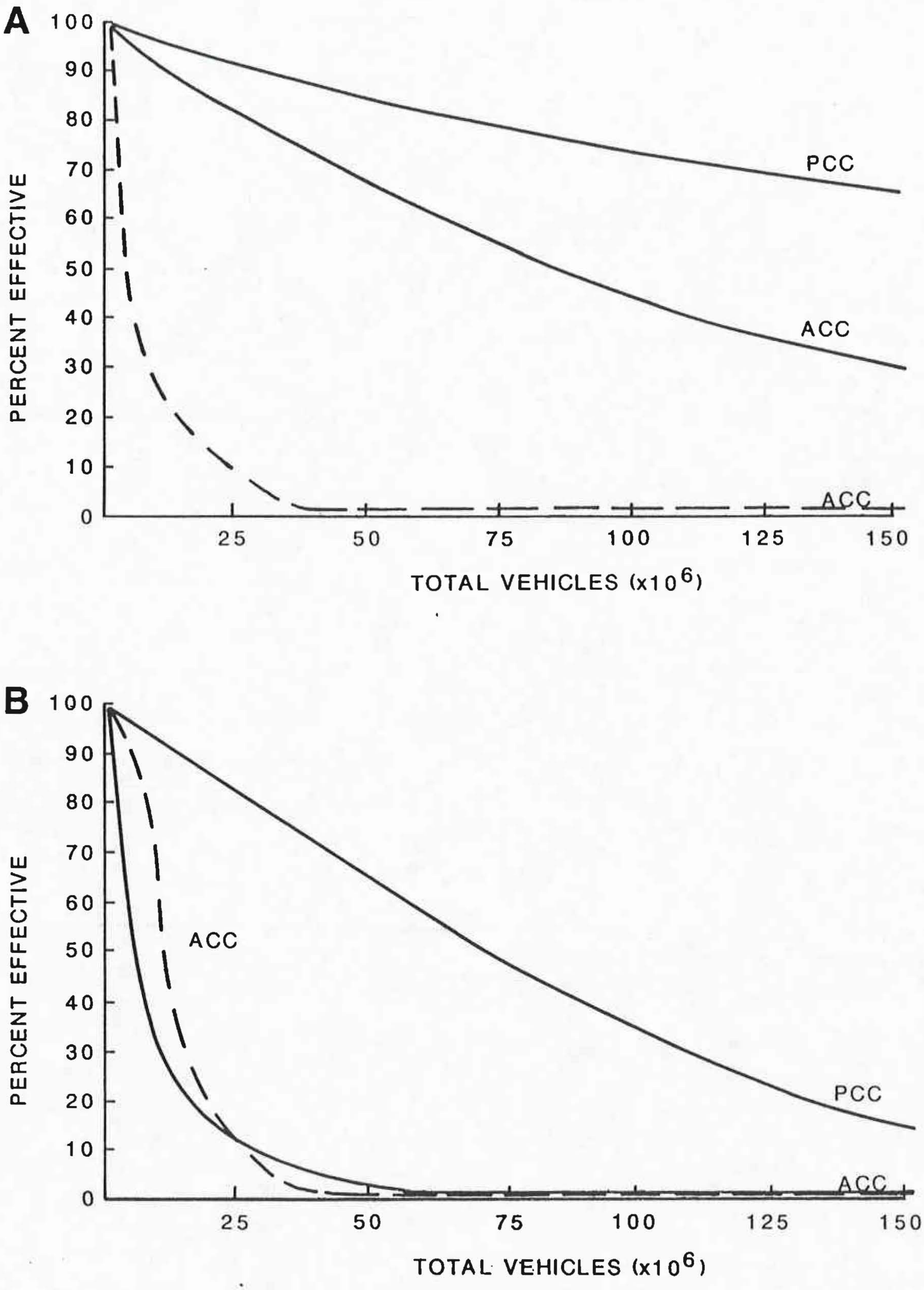


Figure 1. Effectiveness of Both Reflective Traffic Buttons (a) and Pavement Markers (b) on Portland Cement Concrete (PCC) and Asphaltic Concrete (ACC), with respect to both marker retention and retroreflectivity.

effective longer than those on ACC. The reflectivity curve for RTBs point out most appropriately the loss of effectiveness of that marker being the low level of reflectivity initially and some loss of buttons at a later time. The RPM curve indicates that the markers initial loss of effectiveness is not due to reflecivity but to marker loss.

FAILURE MODES OF MARKERS AND CAUSES OF FAILURES

The type of marker failure is generally related to (1) the type of marker and (2) the type of road surface material. In most cases, the plastic reflective pavement marker (RPM) is characterized by short retention life and high reflectivity whereas the ceramic reflective traffic button (RTB) is characterized by longer retention and lower levels of reflectivity, initially. The type of road surface has a major effect on the markers retention. Asphaltic concrete (AC) surfaces tend to reduce the retention of RPMs by at least one-half. Large sections of AC pavement fracture and pull-up with the RPM intact. This condition will usually occur within the first 18 months of service depending on when the RPMs were installed. If the RPMs survive the first 18 months their normal retention life will be 3-5 years. Portland cement concrete (PC) surfaces are not characterized by this type of failure. All types of markers had satisfactory retention on this surface. A period of 3-5 years is expected. During the course of this project, it was determined that the service life of Texas Type II-M epoxy is 7-8 years. The markers will not survive 7-8 years with high traffic levels.

The second major cause of marker failure is the reduction in reflectivity levels. Ceramic RTBs are initially lower in reflectivity levels than plastic RPMs; however, after 2-3 years in service the reflectivity levels of both marker types are approximately the same (.15 Candlepower/Foot-Candle (CP/FT-C)). The major cause of this reduction in reflectivity for the plastic RPMs is abrasion to the reflector surface and dirt accumulation in the front of the reflector of ceramic RTBs. Plastic RPMs which crack or break on the reflector face, due to improper installation, allowing moisture to seep in between the reflector and the acrylic shell reducing reflectivity. Ceramic markers generally lose their reflective rod due to improper gluing or the reflector breaks due to weak reflector rods or improper ramp design. Table 1 lists all possible failure types and causes of these failures.

SIGNIFICANT RESULTS OF RESEARCH

The following are the significant results obtained from this research project. These results are given in sequence of reports.

A. Results from reflectivity analysis:

1. The results of the effectiveness study:

   a. RPMs and RTBs lose a significant amount of their initial specific intensity within two years. Over two-thirds of effectiveness when high beams are used.

   c. The overall reduction of brightness appears to be unrelated to (1) the type of marker and (2) their initial brightness level.

   d. The markers reflective retention is approximately 2.5 years. The markers will remain effective and semi-effective during this time.

   e. The marker system is effective if 75-80 percent or more of the markers on the road are effective. The markers are semi-effective as long as 50-75 percent of the markers are on the road and are ineffective when less than 50 percent of the markers are on the road regardless of the specific intensity level.

   f. Trucks have a more significant effect on marker retention than on reduction of reflectivity.

   g. Markers with S.I.'s of 0.15 CP/FT-C or higher are effective providing 75 percent of the markers are in place. Markers with SIs between .15 and .10 CP/FT-C are semi-effective providing over 50 percent of the markers are remaining. Markers with S.I.'s of less than .10 CP/FT-C are ineffective. These values must be obtained from a representative number of markers at any particular site. A system is not ineffective if only one marker has an S.I. of .10 CP/FT-C or less.

   h. The color of the marker has a significant effect on the amount of reflectivity for any specific effectiveness level. Yellow makers were consistently higher in

Table 1. Observed Failure Modes With Most Important Independent Variables And Parameters.

Type Failure	Pavement Surface	Parameters	Independent Variables
Marker Loss (in pavement)	Asphalt	Season (maybe temperature) Moisture Type of Marker Green Asphalt Asphalt Properties Epoxy Pad Size	Impacts Truck Impacts Time
	Portland	Moisture Type of Marker Epoxy Pad Size PCC Properties Green PCC	Impacts Truck Impacts Time
Epoxy-to-Pavement Failure	PCC and Asphalt	Faulty Installation Type of Epoxy	Impacts Truck Impacts
Epoxy Failure	Rarely Observed		
Epoxy-to-Marker Failure	Immaterial	Faulty Installation Cleats Type of Epoxy Type of Marker Wet Porcelain	Impacts Truck Impacts
Marker Fracture	Asphalt	Type of Marker Temperature Type II CR Epoxy	Impacts Truck Impacts
	Portland Cement Concrete	Type of Marker Temperature Type of Epoxy Type II CR Epoxy	Impacts Truck Impacts
Marker Wearout	Immaterial	Type of Marker Marker Shape	Impacts Truck Impacts

Table 1 (Continued). Observed Failure Modes With Most Important Independent Variables And Parameters.

Type Failure	Marker Type	Parameters	Independent Variables
Abrasion to Reflector Face Impacts	Plastic RPMs		Location of Markers Number of
		Material Used to Cover Reflector	
Accumulation of Road Dirt and Tar		Material Used to Cover Reflector Face Improper Drainage of Road Surface	Scuffing by Tires
Moisture Seeps Into Reflector		Weak Reflector Rod Impacts Not Protected by Ramp Faulty Rod Gluing	Impact Time
Accumulation of Road Dirt and Tar	Ceramic Button	Ramp Design Improper Drainage of Road Surface	Location of Marker
Broken Reflector Rods		Weak Reflector Rod Impacts Not Protected By Ramp Faulty Rod Gluing	Impact Time
Abrasion to Reflector Rod		Inadequate Ramp Protection	

reflectivity than crystal markers for each level of effectiveness.

2. The results of the reliability study

   a. The procedure used to obtain the slides resulted in accurate representation of sites with low ambient light. ASA 400 film was used with (camera settings of 1/60 of a second with a f-stop of 1.4 or 1.30 of a second with an f-stop of 1.8. The film was pushed two full stops during development.

   b. The color balance was slightly off. This is normal in low ambient light environments.

   c. The standard set of photographs is a useful tool for determining when maintenance should be performed.

   d. The team approach for evaluating sites is a useful and safe tool. The maintenance engineer may use it in determining when maintenance should take place. Thirty five millimeter slides of the site can be evaluated in the safety of the office during normal business hours, not on the road at night.

   e. When maintenance is necessary, all markers in the pattern should be replaced. This will avoid the occurrence of the driver's misunderstanding a pattern because of faulty visual aids.

B. Results from retention analysis:

   a. Installation procedures in most cases are not the major cause of maker loss in Texas.

   b. The markers must be installed on clean, dry pavement.

   c. The markers must be installed on a portland cement concrete and asphaltic concrete over 3-months old.

   d. When retention is of major concern, RTBs are superior to the RPMs. The modified (2x4) RPM is inferior to all other types of markers.

   e. Retention is a function of the number of hits a marker sustains. This is the most important single factor affecting retention.

   f. A marker shape appears to be the primary variable in reducing the stress between the pavement and the marker, thus increasing marker retention.

g. Lane lines receive twice as many hits as centerlines.

h. Any type of installation procedure which protects the marker will aid in retention; for example, centerline markers being placed inside the painted centerline.

i. The number of hits, amount of truck traffic, moisture, temperature and location of markers all have an effect on marker retention.

j. The polyethelene (CLEAR PLASTIC FOOD WRAP) test is a simple and quick test to determine the presence of moisture in the pavement.

k. The bituminous adhesive material currently being tested in Districts 15 and 16 resulted in less than 2 percent of the markers and buttons being dislodged.

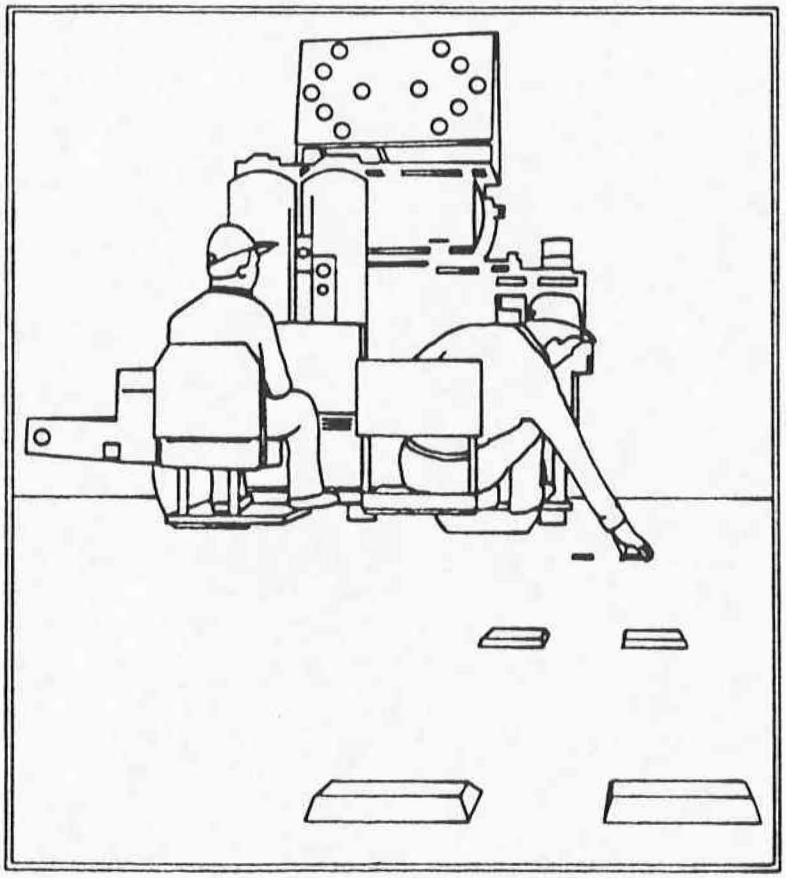
CONCLUSIONS AND ADDITIONAL RESEARCH

The general conclusion obtained from this study indicate that the markers rapidly lose both reflectivity and retention. The service life of any marker cannot extend beyond 2-3 years. The problem of retention is asphalt related. Until a suitable asphalt can be developed that will retain the markers, they are not a cost beneficial system on asphaltic concrete surface. Shape contributed the most to retaining the markers on the road. The initial brightness level can be reduced to 2.0 CP/FT-C.

In order to increase the effectiveness of the markers the following research should be undertaken:

1. Establish test sections to study specific asphalt properties affecting retention.
2. Determine the optimal shape for the markers which will work in unison with the pavement to retain the markers.
3. Set-up an effective cost accounting system, so accurate maintenance costs of markers can be obtained.
4. Determine the truck equivalency factor by road type and vehicle weight.
5. Modify the photographic technique to include selecting a higher speed film and obtaining more accurate color reproduction.

PAVEMENT MARKER INSTALLATION GUIDE



Raised pavement markers stay longer and perform better if they are installed correctly. These installation guidelines will help make the markers last as long as possible on any pavement.

Be safety conscious. Keep alert for erratic traffic at all times. Use barricades, signs, caution lights, shadow vehicles, and flagmen as the traffic requires. The life you save may be yours.

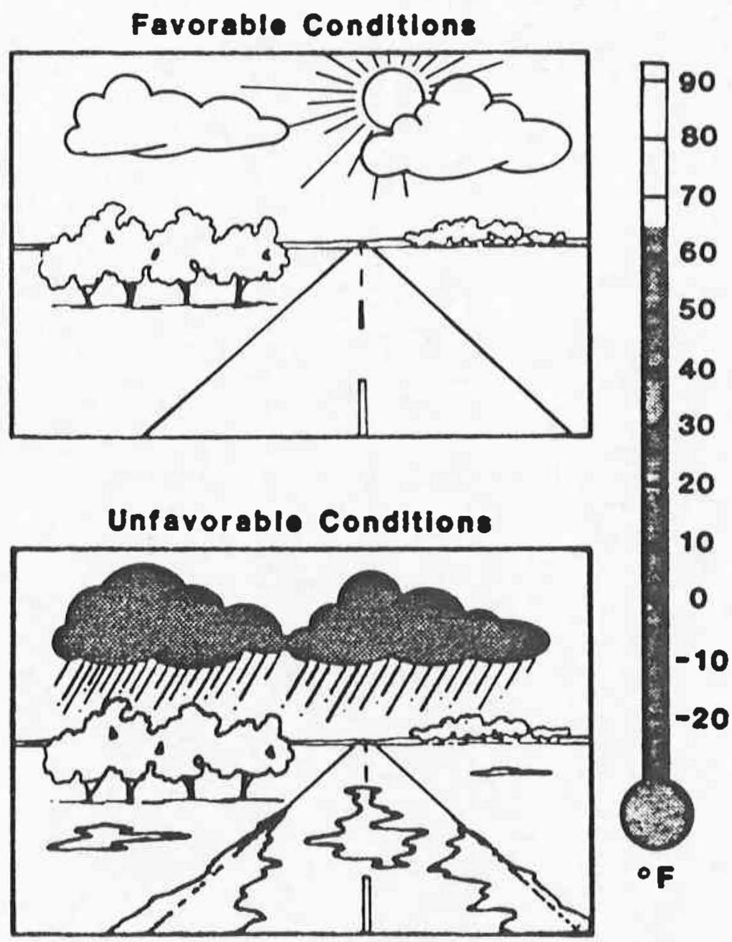
Procedures to follow to insure proper installation include:

1. Make sure that pavement surface and weather conditions permit placement operations.
   a. Best installations require dry pavement; the drier the better. Never install where visible moisture is present. Best installations result where moisture will not collect under the marker or button, as moisture weakens the bond with the pavement. The Polyethelene Film Moisture test should be used to determine moisture content of pavement surface. Cover a small area of pavement (1' X 1') with a polyethelene film (clear plastic food wrap) and taped firmly down on all four sides. If visible moisture is drawn to the film, in 15 minutes in sunshine, do not proceed with installing the marker.

b. Never install when temperatures are below 40°F or forecast to go below 40°F during adhesive cure time. Best curing results when temperatures are above 80°F.

c. Avoid installations on all road surfaces less than 30 days old; 90 days is preferred. If asphalt rejuvenation chemicals are used allow a year cure time.

d. Avoid cracks and joint seams either on surface or in pavements underneath overlays.

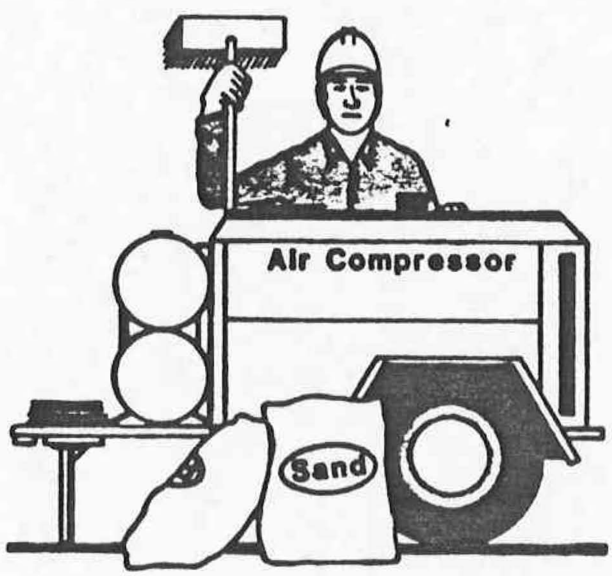


2. Prepare surface of roadway and marker.

   a. Clean surface of oil, grease, dirt, etc. that may adversely affect the ability of the adhesive to perform. This can be done by wirebrushing, sand-blasting or grinding the surface. Air-blowing or broomsweeping is also acceptable if contaminants are loose. Air compressors should have oil and moisture traps to remove oil and moisture from the air stream so as not to contaminate the pavement surface.

   b. Make sure plastic markers and ceramic buttons are clean and dry. Ceramic buttons must be stored in dry conditions. If ceramic buttons are placed with excessive moisture they will not be retained on the road surface. This applies to both AC and PCC surfaces.

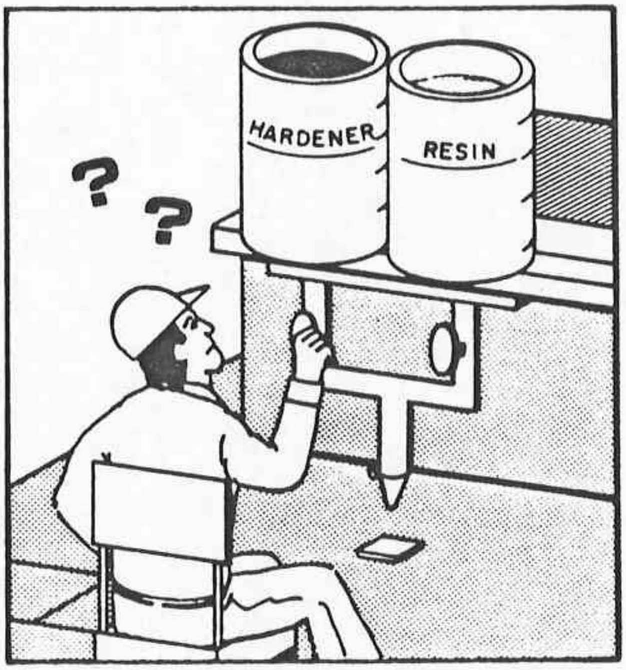
CLEAN!



3. Properly mix epoxy

   a. Mix epoxy in proper ratios according to epoxy specifications.

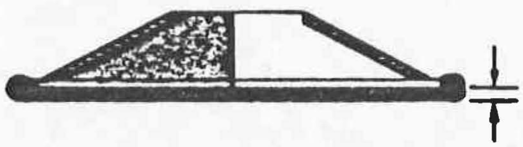
   b. Darkening of adhesive indicates improper mix ratio. Streaking indicates that the adhesive is not mixed properly. Do not use darkened or streaked adhesive.



4. Apply epoxy evenly.

   a. Apply epoxy to the button or marker not the pavement so that complete coverage, including the corners, will be achieved when the marker is properly placed.

   b. Apply epoxy evenly so that it is 1/8" to 1/4" thick after placement on road surface.



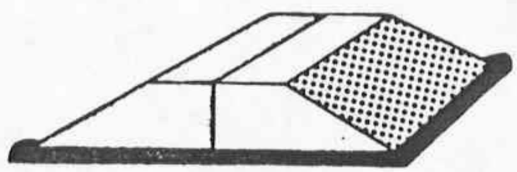
Epoxy - 1/8 to 1/4 inch thick in place

5. Place marker.

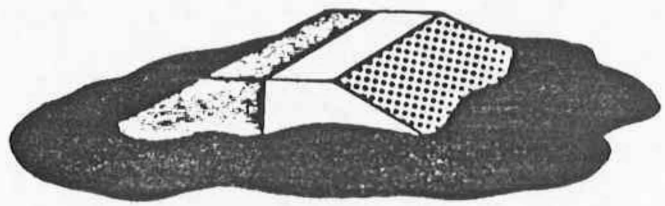
   a. Place marker on previously determined location, applying a slight twisting pressure to force small epoxy bead around the marker.

   b. Do not allow roll of epoxy to obscure the reflector lens.

   c. Do not apply too much pressure so as to cause marker/pavement contact.



RIGHT

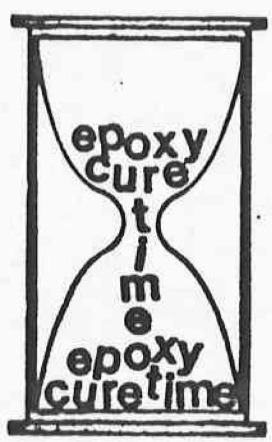


WRONG

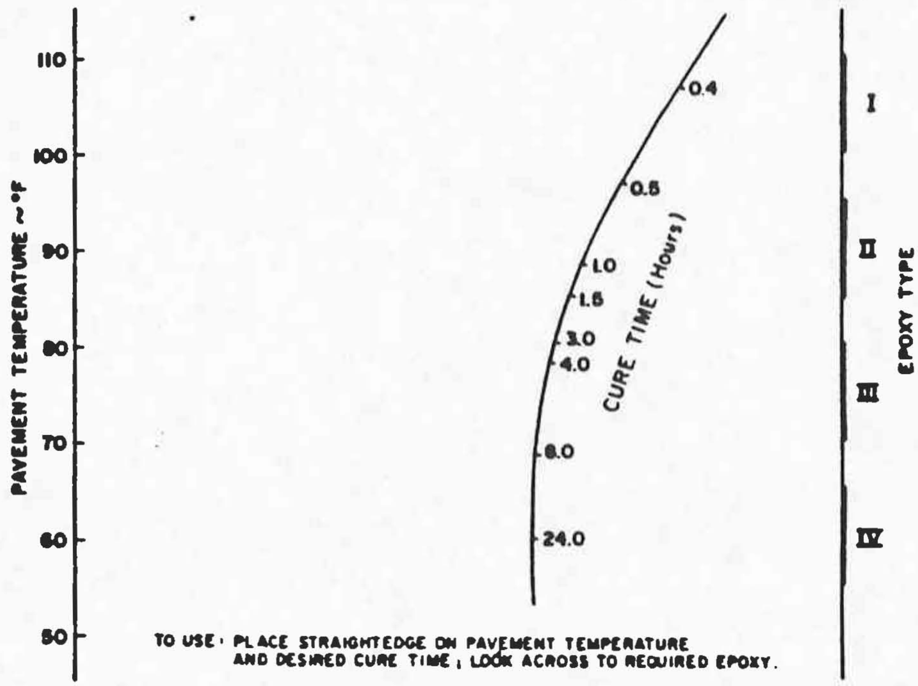
6. Epoxy cure time.

   a. The marker should be protected from traffic until the epoxy has properly cured.

   b. See chart (next page) for required cure time.



PAVEMENT TEMPERATURE, CURE TIME AND EPOXY TYPE RELATIONSHIP



TO USE: PLACE STRAIGHTEDGE ON PAVEMENT TEMPERATURE AND DESIRED CURE TIME; LOOK ACROSS TO REQUIRED EPOXY.

DO's and DON'Ts

DO's

1. Read and be familiar with the Texas SDHPT specifications for applying markers and adhesives.
2. Prepare surface properly.
3. Mix adhesive in proper ratios.
4. Assure 100% coverage of bond area with adhesive.
5. Set up a procedure for application and make sure installers and inspectors are familiar with procedure prior to marker application.
6. Use the proper equipment.

DON'Ts

1. Do not install when temperatures go below 40°F or are forecast to go below 40°F during adhesive cure time. Best curing time is when temperatures are above 80°F (roadbed as well as ambient air temperature; ambient air = 80°F; roadbed = 120°F preferably).
2. Never install where visible moisture is present. Perform the Polyethelene Film test. If moisture appears after 15 minutes do not place marker.
3. Avoid installations on pavements less than 30 days old; 90 days preferred.
4. Avoid cracks, joints, seams either on surface or underlying pavements on overlays.
5. Do not allow roll of epoxy to obscure the RPM lens.
6. Do not exceed pot life of adhesive.
7. Do not use RPM's that have been exposed to moisture for long periods of time as they tend to absorb moisture.
8. Do not allow traffic on the RPM's and RTB's before required time has expired.

BITUMINOUS INSTALLATION ADHESIVE

Besides the adhesives being evaluated in Bryan/College Station, a bituminous adhesive distributed by Southwestern Materials is being evaluated in Districts 15 (San Antonio) and 16 (Corpus Christi). This new material appears to be the solution to the RPM retention problem. The loss rate in Corpus Christi has been less than 2 percent with the bituminous adhesive.

As with any material product there are favorable and unfavorable characteristics which should be considered in its use. The favorable characteristics are:

1. The material is not affected by humidity, temperature, mixing or placement,
2. There is no cleanup after use of the melter/applicator machine,
3. The machine has very little maintenance because it has few mechanical parts,
4. When applied on asphalt surfaces, the material will not leave shadow markings when markers are removed.

The unfavorable material characteristics are:

1. The melter/extruder must be hand pushed, requiring both operator and installer to walk,
2. The adhesive is heated and applied at temperatures between 400-425 . Severe burns could occur if workers come into contact with the adhesive,
3. Depending on ambient temperatures, heating time may be as long as 2 hours, and
4. The material will leave shadow markings on concrete pavements. The standard two part epoxy performs satisfactorily on concrete, therefore it is at the discretion of the department as to which adhesive to use on concrete.

POLYETHYLENE (CLEAR PLASTIC FOOD WRAP) MOISTURE TYPE

A simple test to determine the moisture properties of the roadway surface prior to installation of RPMs and RTBs was developed. It can be used on both asphaltic concrete and portland cement concrete roadways. The test will not determine how much water is present in the material, only whether there is sufficient moisture to prevent the markers from remaining satisfactorily on the roadway surface.

The test procedure consists of placing a one foot by one foot piece of polyethylene on the road surface in full sunlight. At no time should the polyethylene be placed in the shade. Duct tape should be used to attach the polyethylene to the surface. Make sure all of the sides and corners are taped to the surface to prevent any moisture from escaping. At the end of a ten minute period, if any moisture appears, the road surface contains too much moisture to install the markers. Wait several hours and repeat the above test. This procedure should be continued until no moisture appears under the polyethylene test section.

MAINTENANCE PROCEDURES

These maintenance standards are proposed to aid in evaluating a marker system with respect to effectiveness and reflectivity. To evaluate the effectiveness of the markers the following procedure is suggested:

1. Photograph Inventory

   Sites to be evaluated should be photographically inventoried. This photographic inventory may be made from a vehicle. The appropriate camera setting to use should be either (1) 1/60 of a second with an f-stop of 1.8 or (2) 1/30 of a second with an f-stop of 1.4. A high speed 35 mm film such as ASA 400 pushed 2 stops or a night 8 mm movie film such as Type G may be used.

2. Evaluation of the Site

   A panel of individuals, selected within the district, may evaluate the photographs from the sites to be evaluated. This panel may consist of 5, 7, or 9 individuals. A panel consisting of this number is large enough to adequately evaluate a site but not too large that the members cannot adjust their schedule to evaluate the sites. The odd number is to prevent a tie from occurring.

3. The evaluation With Respect to Effectiveness

   The subject sites will be evaluated with respect to its effectiveness. An acceptable rule of thumb is that if 50 percent of the markers are missing the system is ineffective. A system is semi-effective when 20-30 percent of the markers are missing. Markers become ineffective when their specific intensity is .05 CP/FT-C or less for 75 percent of the remaining markers. A system is semi-effective when 75 percent of the remaining markers have a specific intensity between 0.2 and .05 CP/FT-C. At present the only way in which to determine the S.I. of the markers is to (1) remove several randomly selected markers for adnalysis in a laboratory or (2) use a photometric van. Figure 1 illustrates the reflective and retention properties of markers with different levels of effectiveness.

4. Maintenance Photographic Set

   When the panel cannot decide the effectiveness of the markers based on the physical properties, the maintenance slides can be used. A

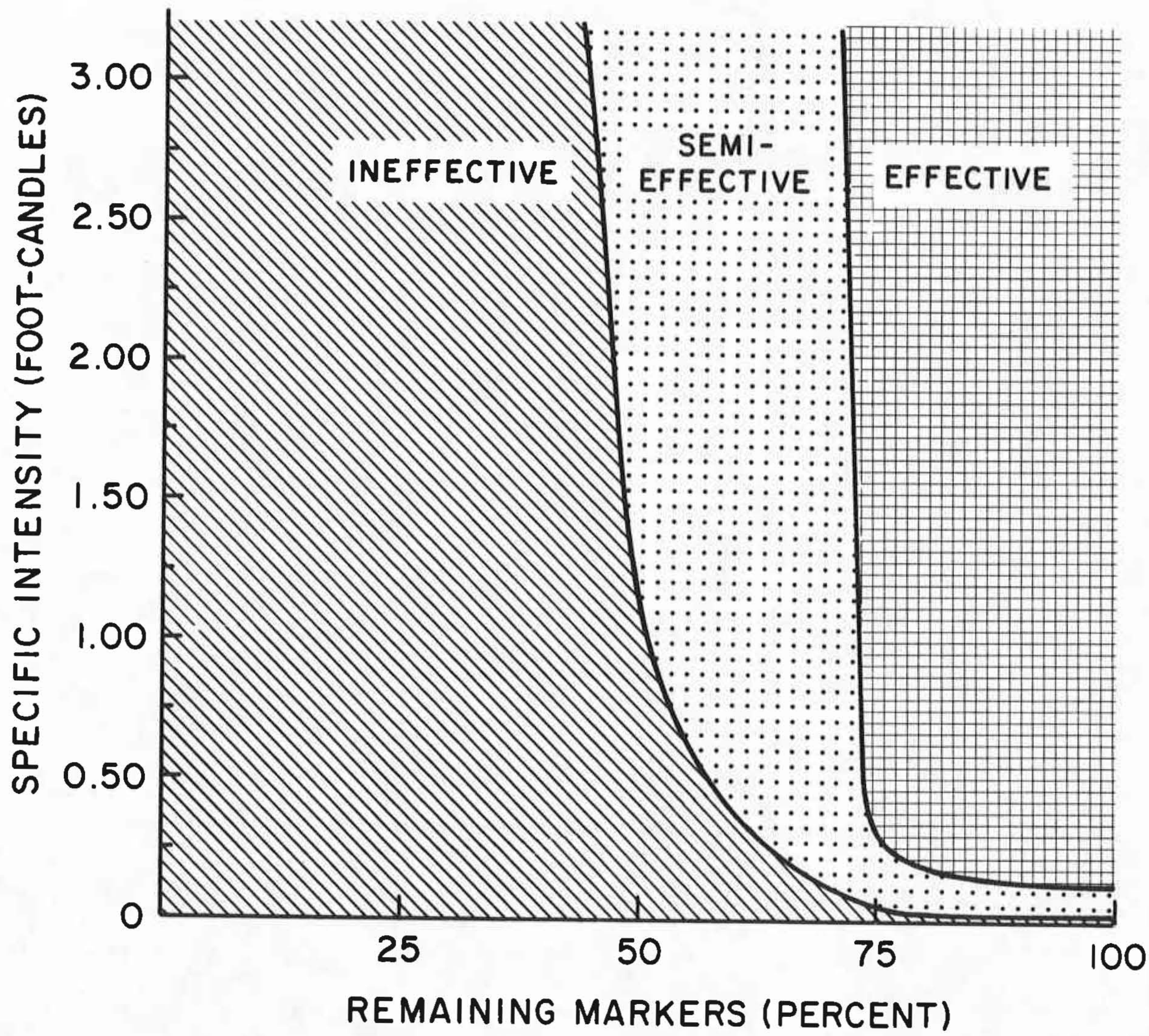


Figure 2. Relationship Between Specific Intensity And Remaining Markers With Respect To Level Of Effectiveness.

suggested procedure would be for each member of the panel to individually view the slide of the site in question and view the set of standards. After each member has selected the most appropriate standard the panel would reconvene. By use of the standard set of 35 mm slides a decision may be reached.

5. Take Appropriate Action

If the site is judged to be semi-effective or ineffective, appropriate action would be taken. The maintenance activity decided by the evaluation panel would begin.

SUGGESTED GUIDELINES FOR PLACEMENT OF MARKERS

1. Markers may be placed at 120 foot spacings on tangent sections of roadway. Maintenance becomes critical at 120 foot spacings. One missing marker destroys the positive route guidance (1).
2. Use markers for centerlines and left edgelines. DO NOT use markers for lanelines. Markers used for centerlines and left edgelines on divided multi-lane facilities should be protected by being placed either on or behind the painted stripe.
3. DO NOT use markers in weaving areas of 30 percent of the vehicles or greater. Markers sustaining a large number of hits on asphaltic concrete fail the pavement.
4. DO NOT use markers on routes when the percentage of trucks exceed 20%. Heavily loaded trucks with few axles (80,000 GVW with 3 axles) are more damaging than heavily loaded trucks with many axles (80,000 GVW with 5 axles).
5. DO NOT place markers in areas where water tends to accumulate (low water crossings) and does not dry within a few hours (4-6 hours) after normal rainfall.
6. DO NOT place markers closer than 15 feet to intersections. Centerline and laneline markers fail when vehicles cut corners at intersections.
7. Two-way left turn markers near large shopping centers are extremely susceptible to failure due to turning vehicles. The ceramic markers would be preferred at these locations.
8. No-passing zone markers quickly lose their information ability with the loss of markers (4 missing markers/depending on their location). These patterns should continue to be marked. However, maintenance becomes critical. Ceramic markers could be used to prolong the useful life of the no-passing zone markings.

REFERENCES

1. Zwahlen, Helmut T., "Optimal Spacings and Placements of Snowplowable Raised Pavement Markers", U.S. Department of Transportation, Federal Highway Administration, Ohio University, (Unpublished Study Results), 1984.