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Research Summary Report

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AN EVALUATION OF RAISED PAVEMENT MARKER REFLECTIVITY

PROBLEM STATEMENT

Millions of raised pavement markers (RPMs) have been installed along Texas highways to delineate lanes and intersections. They also guide motorists while driving under adverse conditions, like wet pavements, where painted lines may not be effective. In recent years, problems associated with marker retention have mostly been solved, but maintaining acceptable levels of raised pavement marker (RPM) reflectivity still remains a challenge.

OBJECTIVES

The Texas Transportation Institute (TTI) conducted study 1151, *Raised Pavement Marker Reflectivity*, in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA) to accomplish the following.

- using representative drivers, establish the minimum effective retroreflector performance levels based on visual detection thresholds under nighttime and simulated wet pavement conditions;
- develop some alternative approaches for fabricating and bonding retro-reflective elements;
- develop a cost-effective method for measuring and evaluating marker retroreflectivity;
- determine the relative durability of different types and colors of RPMs when exposed to vehicle traffic and temperature extremes; and
- determine the feasibility of restoring degraded RPMs.

FINDINGS

To effectively delineate the path over extended time periods, raised pavement markers must maintain a minimum level of retroreflectivity. Commercially available markers vary widely in cost and performance effectiveness. The majority of RPMs used in Texas are marketed under the names Stimsonite and Ray-O-Lite. Both manufacturers make standard and low profile RPMs with reflective surfaces on one or both sides. Available in a variety of color combinations, they are designed to reflect light back in the direction of the light source. This reflex- or retro-reflective property is accomplished by a small molded cube-corner prism array.

The surface treatment of the reflective element is the primary difference among RPMs. The base surface of all commercially available markers is methyl methacrylate. It has a low fabrication cost and excellent performance in extreme heat and sun exposure. Stimsonite is the only RPM manufacturer, however, using a patented process to laminate a thin glass face onto the plastic lens surface. All other RPMs use plastic lens surfaces only.

Measurement Technologies

A method for measuring RPM retroreflectivity in place (i.e., installed on the highway) was developed. This vehicle-installed measuring system uses an externally mounted infrared source and receiver with an in-vehicle logic circuit, display, and recorder. The system can be used at highway speeds, but as it is currently configured, requires multiple passes of the vehicle tires over each RPM to be measured and the application of statistical techniques to enhance measurement accuracy.

Driver Visual Thresholds

Specific Intensity (SI) is a measure of the photometric performance of an RPM. It is based on the ratio of the luminous intensity of the retroreflector to the luminous intensity incident on the reflector, i.e., SI= candle power per footcandle.

There is no one value for minimum SI that can be specified independent of the required sight distance, roadway geometrics and traffic conditions. A highway marker visible on a dark night without opposing traffic headlamps may become completely invisible to even the youngest, keenest-sighted driver under urban glare conditions. Older drivers may have great difficulty seeing brand new RPMs under routine city traffic conditions.

Sight distances also differ for amber, red, and crystal retroreflectors. Threshold detection of amber RPMs (as a point of light, not as the color amber), requires lower specific intensity than either crystal or red. The value tables developed in the study for various conditions of weather, sight distance, and opposing traffic conditions can help determine minimum SI thresholds for RPM replacement.

Raised Pavement Marker Durability

Studies of otherwise comparable glass- and plastic-faced RPMs removed from highways after known amounts of exposure to highway conditions show that glass-faced RPMs demonstrate a significant superiority in retaining SI. Although abraded plastic-faced RPMs improve in SI when wet, they do so only if they are reasonably clean. Abraded RPMs do not improve when wet *and dirty*.

For testing and evaluation, a sample was gathered of in-service RPMs that had been subjected to real-life operating conditions for known periods of time. The specific intensity was measured for each RPM under four conditions; (1) as received but contaminated with dirt, (2) as received but wet; (3) after cleaning but dried; and (4) after cleaning but wet. Both plastic and glass models were examined. The results of these tests are illustrated in ***Figures 1 and 2.***

Heat/cold thermal cycling affects the retroreflectivity of both glass-faced and plastic-only RPMs, but glass-faced RPMs tend to improve by a significant margin, as much as 34 percent, after being subjected to elevated temperatures. Plastic-faced RPMs decline somewhat under temperature stress. No explanation for this behavior was available from the RPM manufacturers, who also have noted this phenomenon. The thermal shock that each RPM is subjected to when being installed using 340 to 370 degree F bituminous mastic is not significantly detrimental to any of the RPMs that TxDOT currently installs on Texas highways.

In both laboratory tests and controlled access field tests in which RPMs were subjected to run-over by a test vehicle, glass-faced RPMs were far superior to plastic-faced RPMs. Whereas 10 passes of a weighted garnet cloth abrader effectively eliminated the retroreflective performance of any plastic-faced RPM, as many as 100 passes on glass-faced RPMs produced very little degradation. These results were replicated with an actual vehicle in the run-over tests. The tests indicated that the most durable RPM is the Model 948 Stimsonite.

On plastic-faced RPMs subjected to abrasion, myriads of scratches in the outer surface scatter light rather than transmit it directly to the reflective curb-corner prism array underneath. The greatly reduced light that does get to the reflective surface is scattered yet again as it leaves the retroreflector through the scratched outer surface. Plastic faced RPMs, after installation, degrade rather quickly to some low asymptotic level, then decline rather slowly thereafter unless broken.

Glass-faced reflectors are far more abrasion resistant, with the RPM staying bright unless damaged in such a way that the glass face shatters over the reflective surface but stays in place. Under these conditions, they "go out" abruptly. If the glass face cracks away, the plastic face directly underneath acts just like an all-plastic RPM. Although a glass-faced RPM may have broken or chipped areas on it, and look much more damaged than a plastic-faced RPM installed near it on the roadway, it may still perform better than an apparently undamaged, all-plastic RPM with the same exposure to the elements.

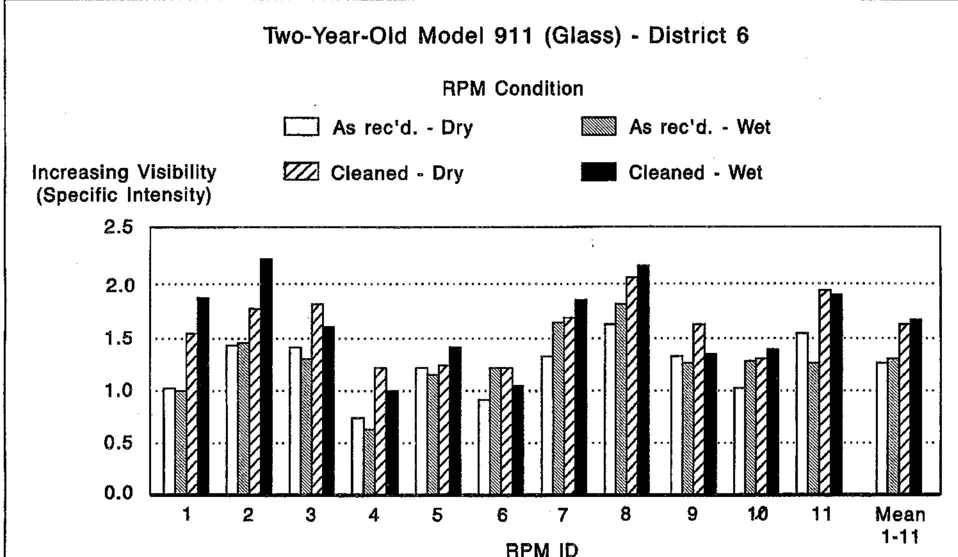

Figure 1. Dry and Wet Measurements of Glass RPMs

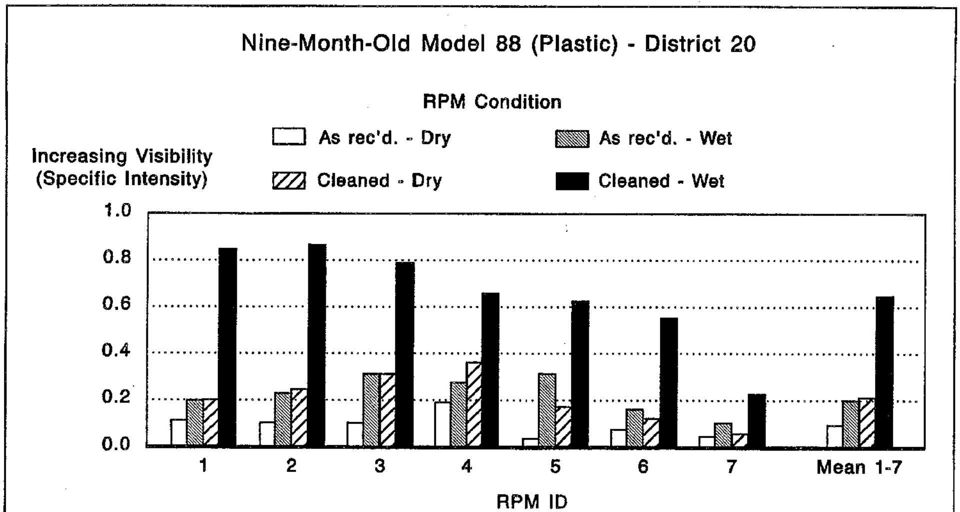

Figure 2. Dry and Wet Measurements of Plastic RPMs

Glass-faced RPMs tend to improve by a significant margin, as much as 34%, after being subjected to elevated temperatures, while plastic-faced RPMs decline somewhat under temperature stress.

Feasibility of RPM Restoration

Clean but abraded plastic-faced RPMs can be temporarily restored to some of their original retroreflective performance by wetting the surface, thus "filling in" the scratches. TTI conducted a preliminary study to see if a clear coating of some kind would produce more lasting results. Although these restoration tests showed that using an acrylic and epoxy coating more than *doubled* the effective SI of a sample group of abraded plastic-faced RPMs and produced positive results under tire abrasion tests and under brief exposure to harsh December temperature extremes, the restored RPMs exhibited SIs of only about 15% of their original new values.

Experience of Other States With Retroreflective RPMs

Three states with weather conditions similar to Texas were contacted: California, Florida and Georgia. All three reported adhesion problems that have improved since adopting a bituminous mastic. Although some quality control problems have occurred in the past with glass-faced RPMs, all three states use them because of their superior retroreflective durability and cost.

CONCLUSIONS

Based on these findings, the following recommendations are made:

1. The SI threshold tables developed in this study should be adopted by TxDOT to help determine when to replace RPMs. Until the onroad RPM measurement system is fully developed and available, samples of RPMs suspected of performing below acceptable levels should be removed from the roadway for laboratory measurement. A procedure could be developed to temporarily install RPMs

with known acceptable SI levels adjacent to suspect in-service RPMs.

2. TxDOT maintenance supervisors should be advised that although part of a RPM face is cracked or broken, it does not necessarily mean the RPM will no longer function. Threshold and durability studies indicate that even if more than half the surface is badly damaged, the SI of the remaining portion may be sufficient to provide adequate reflectivity (especially with glass- faced units). However, if it cracks through the prism layer, to the aluminum, moisture may detach or corrode the coating and warrant precautionary removal.

3. Plastic-faced RPMs work well in protected areas or for short-term installations, but otherwise they degrade to unacceptable levels of performance too rapidly when compared to glass-faced RPMs. For most applications, glass-faced RPMs are recommended.

4. Further study of clear coating suitable for restoration application on plastic-faced RPMs is warranted, based on the positive results obtained in this study. Methods of application, which include cleaning the RPMs, should also be developed. The cost/benefit of such an approach, and when it would be used, also needs to be studied.

5. TxDOT should consider replacing its Tex-842-B SI standard with the *ASTM E 809-81 Standard Practice for Measuring Photometric Characteristics of Retroreflectors* to place Texas in conformance with national photometric test standards.

6. The Infrared Field Measurement System developed by TTI under this project is in prototype form. A brief informational videotape on this system was prepared.

--Prepared by Sandra Parsons, Research Associate, Texas Transportation Institute.

The information described in this summary is reported in Research Report 1151-1, *Raised Pavement Market Reflectivity*, V.J. Pezoldt, R.J. Koppa, A.T. Perry, and H.W. Milsap, November 1990. The contents of this summary do not necessarily reflect the official views of the Federal Highway Administration or the Texas Department of Transportation.