*The Ohio Department of Transportation*
*Office of Statewide Planning & Research*
*Research Section*
*Executive Summary Report*

# Nighttime Visibility of 3M AWP and 3M 380WR ES Durable Tape under Dry, Wet, and Rainy Conditions

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## Problem Statement

Pavement markings play an important role in providing visual guidance to motorists. They are used to delineate the intended travel path and guide drivers regarding their location on the road. In order to function properly, pavement markings must be visible under all weather conditions. In general, most pavement markings provide satisfactory performance under dry conditions. However, under wet night conditions, the visibility of these materials degrades significantly as the marking surface becomes flooded with water, leading to partial or complete disappearance of the marking. There are two reasons for this phenomenon. First, the accumulated water over the pavement marking scatters the light away before it reaches the marking surface, resulting in a specular reflection rather than retroreflection. Second, the accumulated layer of water changes the efficiency of the reflective media in the pavement markings, resulting in a shorter detection distance for the drivers. Therefore, under wet night conditions, driving becomes more challenging because less guidance is provided to the drivers by the pavement markings.

Snow plowable raised pavement markers (RPMs) are typically used in Ohio to provide visual guidance to road users under inclement weather conditions. In recent years, due to the extended pavement resurfacing cycle employed by the Ohio Department of Transportation (ODOT), rare incidents have occurred where the aged pavement surface failed to provide adequate support to the RPM castings. As a result, ODOT has adopted a rigorous plan to identify and replace loose RPMs. In addition, ODOT initiated this study to evaluate the performance of alternative marking materials and determine whether they can provide equivalent or better delineation than the existing system.

## Study Objective

The primary objective of this study is to evaluate the wet night performance of several pavement markings and determine the feasibility of using them as a replacement for RPMs in Ohio.

## Test Site

This study was conducted in Licking County, Ohio, along Interstate 70, at a location where the interstate has two lanes per direction. The average annual daily traffic (AADT) at the test site is approximately 44,000 vehicles per day, equally divided between the eastbound and westbound directions, with about 30% truck traffic. This region of Ohio receives an average annual snow fall of 20 to 30 inches. Snow removal practices involve using deicing salt and front-mounted snow plows. ODOT employs a bare pavement surface policy in its snow removal activities, where the plow blade runs on the pavement surface, leaving little to no snow/ice behind.

## Pavement Marking Materials

Three pavement markings were evaluated in this study. These materials included 3M all weather paint (AWP), 3M 380 wet reflective (WR) extended season (ES) durable tape, and extruded thermoplastic. The 3M AWP consisted of a traditional fast dry waterborne traffic paint mixed with standard glass beads and wet-reflective elements. Each element comprises of a silicon core topped with microcrystalline ceramic beads. The ceramic beads are a mixture of 80% wet reflective beads, with a refraction index of 2.4, and 20% dry reflective beads, with a refraction index of 1.9. The 2.4 refraction index ceramic beads are not effective under dry conditions. However, in the presence of water that has a refraction index of 1.33, the overall refraction of the element-water system becomes ideal for pavement marking retroreflectivity. The 3M 380WR ES durable tape consisted of a base bead-filled pliant polymer layer topped with polyurethane coating intermixed with microcrystalline ceramic beads. It utilizes specially designed optics to improve wet-night visibility. In addition, it has a patterned structure with raised near vertical surfaces to improve retroreflectivity under wet weather conditions. The extruded thermoplastic was the standard alkyd thermoplastic that is commonly used by ODOT on new asphalt surfaces.

As can be seen in Table 1, these materials were applied in six different treatments. All materials were installed on a new asphalt surface, i.e., following an asphalt resurfacing project. The 3M AWP was installed on rumble strips and on the surface, while the 3M 380WR ES durable tape and the extruded thermoplastic were installed in groove and on the surface. The 3M AWP was applied at a thickness of 20 mil (0.51 mm), the 3M 380WR ES durable tape was about 90 mil (2.3 mm) thick at the raised profile, and the extruded thermoplastic was applied at a thickness of 125 mil (3.2 mm). Where applicable, a groove depth of 90±10 mil was used for the 3M 380WR ES durable tape and a groove depth of 125±10 mil was used for the extruded thermoplastic. The groove depth was selected the same as the pavement marking thickness to protect them from snow plowing during winter. In addition, RPMs were installed on the lane lines where 3M AWP and extruded thermoplastic were used, but not where the 3M 380WR ES durable tape was used.

## Performance Evaluation

The performance of the pavement markings was evaluated on a semi-annual basis for a period of 1.5 years. The performance evaluations were conducted in September 2008, April 2009, September 2009, and April 2010. This allowed for evaluating the performance of these materials for two winter seasons. All evaluations were conducted at night between midnight and dawn.

**Table 1. Pavement Marking Materials**

| Treatment No. | Mile Marker | Line Type | Treatment Type |
|---|---|---|---|
| 1[a] | 138-139 (EB) | Yellow Edge Line | 3M AWP on Rumple Strips |
| | | White Lane Line | 3M AWP on Surface |
| | | White Edge Line | 3M AWP on Rumple Strips |
| 2[b] | 139-140 (EB) | Yellow Edge Line | 3M 380WR ES on Surface |
| | | White Lane Line | 3M 380WR ES on Surface |
| | | White Edge Line | 3M 380WR ES on Surface |
| 3[b] | 140-141 (EB) | Yellow Edge Line | 3M 380WR ES in Groove |
| | | White Lane Line | 3M 380WR ES in Groove |
| | | White Edge Line | 3M 380WR ES in Groove |
| 4[a] | 141-142 (EB) | Yellow Edge Line | Thermoplastic in Groove |
| | | White Lane Line | Thermoplastic in Groove |
| | | White Edge Line | Thermoplastic in Groove |
| 5[a] | 142-143 (EB) | Yellow Edge Line | 3M AWP on Surface |
| | | White Lane Line | Thermoplastic on Surface |
| | | White Edge Line | 3M AWP on Surface |
| Control[a] | 138-143 (WB) | Yellow Edge Line | Thermoplastic on Surface |
| | | White Lane Line | Thermoplastic on Surface |
| | | White Edge Line | Thermoplastic on Surface |

[a] RPMs were installed at 120 ft along the lane line.
[b] No RPMs were used.

Each treatment was evaluated in two locations. Key performance attributes that were taken into consideration include dry and wet retro-reflectivity, dry and wet night visibility, color, and durability.

The dry and wet retroreflectivity of the pavement markings were measured in accordance with ASTM E1710 and E2177, respectively, using a Delta LTL-X handheld retroreflectometer. This device employs the 30-m geometry in simulating the roadway being illuminated by the headlights of a car. This device was calibrated prior to taking any retroreflectivity measurements and outfitted with a base plate and two wet night feet before being used to measure wet retroreflectivity. At each location, an effort was made to collect ten dry and five wet retroreflectivity readings per line per evaluation.

The dry and wet retroreflectivity measurements were made by placing the LTL-X device on the surface of the pavement marking in a stationary mode. For rumble stripes, the device was placed 14 inches away from the highest point on the rumble strip to take the reading. Wet retroreflectivity measurements were made 45 ± 5 seconds after 2 to 5 liters of water were applied to the surface. This waiting period allows some water to drain leaving a surface in a wet condition.

The dry and wet night visibility evaluations involved observing the pavement markings as well as the RPMs from a stationary vehicle under low beam headlight illumination to determine the longest visible distance. The distances were estimated by counting the number of RPMs that were visible and multiplying by 120 ft (36.6 m) or by counting the number of lane lines that were visible and multiplying by 40 ft (12.2 m).

Color was measured using a MiniScan XE Plus (Model 4500L) spectrocolorimeter. This model employs the 45°/0° geometry in measuring daytime color, where the system illuminates the sample at an angle of 45° and measures its color at an angle of 0° (perpendicular to the surface). This model has a relatively large view area, over which color is measured, with 31.8 mm measurement port. Color readings are provided in the Commission Internationale de l'Eclairage (CIE) color units. In this study, color was measured every 6 months. An effort was made to collect five color readings per line per evaluation.

Durability was rated by a group of experienced evaluators who visually examined the percentage of pavement marking remaining on a 10 ft line segment. This evaluation was conducted in the most deteriorated location for each treatment. The durability rating was reported as an integer on a scale of 0 (the material is completely lost) to 10 (more than 95% of the material remaining).

In general, six to eight evaluators were present during the evaluations. The evaluation team consisted primarily of engineers from ODOT District 5 and ODOT Central Office who were familiar with the performance evaluation procedures.

## Results and Discussion

Figures 1 and 2 present the average dry and wet retroreflectivity values obtained during the periodic evaluations for all six treatments. Only results for the white right edge lines that are typically subjected to higher traffic volumes are presented. As can be seen from these figures, the 3M 380WR ES durable tape had the highest initial dry and wet retroreflectivity values. This was expected since these tapes contain specially designed optics to improve their dry and wet performance. This material also had the highest retained dry and wet retroreflectivity values even after 1.5 years. Nevertheless, the wet retro-reflectivity of this material dropped significantly during the first and second winter seasons.

The initial dry retroreflectivity of the 3M AWP was comparable to that of the extruded thermoplastic. However, the 3M AWP had significantly higher initial wet retro-reflectivity, which was anticipated since this material contains wet-reflective elements to improve their

wet visibility. Similar to the 3M 380WR ES durable tape, the wet retroreflectivity of the 3M AWP dropped significantly during the winter. This material lost most of its wet retroreflectivity though during the first winter season, which was the case for both 3M AWP installed on rumble strips and on the surface.

The extruded thermoplastic had moderately high dry retroreflectivity, with the lowest retroreflectivity deterioration rate (year to year drop in retroreflectivity). This was especially the case for the lines that were installed in groove, which probably had a better glass bead retention. This material, however, had the lowest wet retroreflectivity values of all materials. This was expected since this material uses standard glass beads that are not designed for wet conditions.

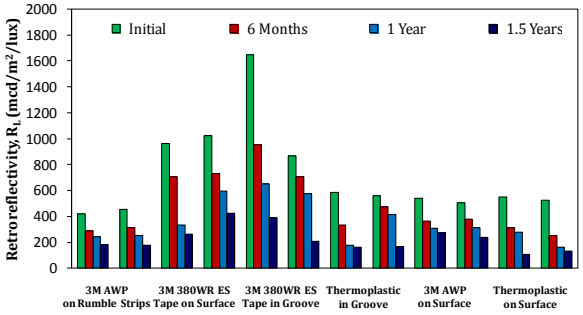


**Figure 1. Dry Retroreflectivity**

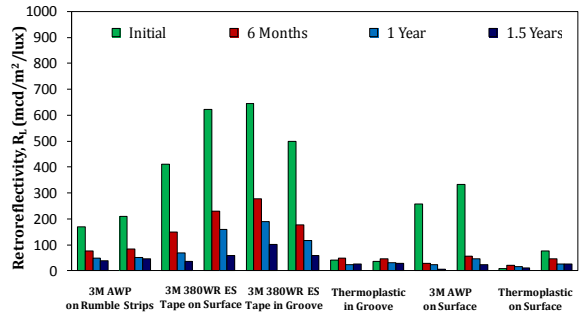


**Figure 2. Wet Retroreflectivity**

Figures 3 and 4 present the wet night visibility distances obtained during the periodic evaluations for the pavement markings on the white right edge line and the RPMs along the lane lines, respectively. As can be observed from these figures, the RPMs exhibited the longest wet night visibility distance, followed by the AWP on rumble strips, then the AWP on the surface, and finally the extruded thermoplastic.

It is noted that in some instances, the wet visibility distance of some of the pavement markings increased rather than decreased over time. These variations are expected since ratings are subjective and may vary from one person to another. Another factor that might have contributed to such variations is the rainfall intensity during the evaluations. This study was not conducted under a controlled environment. Therefore, it was not possible to apply the same rainfall rate during the evaluations.

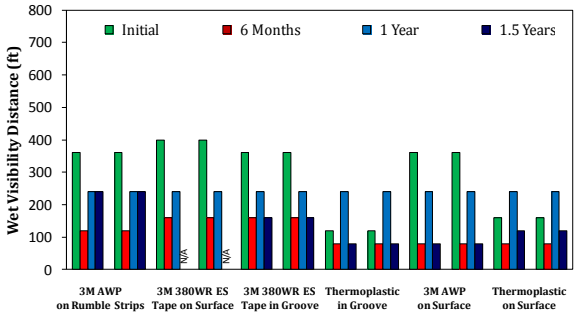


**Figure 3. Wet Night Visibility of Markings**

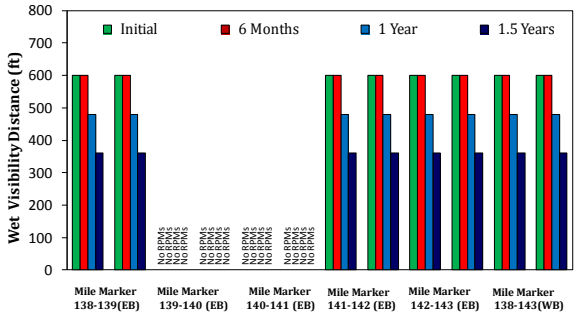


**Figure 4. Wet Night Visibility of RPMs**

The color readings obtained using the MiniScan XE Plus colorimeter were compared to ODOT color specifications for both yellow and white markings. A set of formulas were developed in Microsoft Excel to determine

whether or not the readings met these specifications. This was visually verified by superimposing the color readings and the specifications on a CIE color chromaticity diagram. It was observed that all materials met ODOT color specifications for both white and yellow markings, except for 3M AWP on rumble strips that met ODOT specifications for white markings at all times as well as yellow markings for both initial and 6-month evaluations. However, it did not meet ODOT color specifications for yellow markings after 1 and 1.5 years, as can be seen in Figure 5.

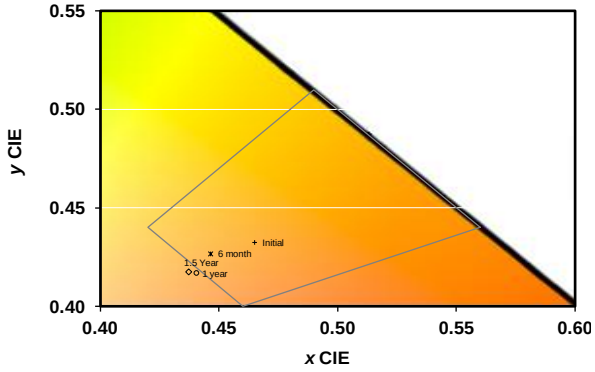


**Figure 5. Comparison between Color Readings of Yellow 3M AWP on Rumble Strips and ODOT Color Specifications**

In terms of durability, almost all materials performed satisfactory throughout the first year of evaluation. The only material that showed a drop in durability was the 3M AWP installed on the surface. After the second winter season, the 3M 380WR ES durable tape installed on the surface was caught by snowplows in many locations, and was striped with fast dry traffic paint in the following summer.

## Conclusions

The following conclusions were drawn based on the periodic performance evaluation results:

- The 3M AWP had relatively high initial dry and wet retroreflectivity. However, it lost most of its wet retroreflectivity during the first winter season. This was the case for both 3M AWP installed on the surface and on rumble strips. Therefore, this product would require regular restriping to maintain a reasonable level of wet visibility, which may not be cost effective.
- The 3M 380WR ES durable tape lost most of its wet visibility during the first and second winter seasons. Therefore, it would not be cost effective to use this relatively expensive material as a replacement for RPMs to guide motorists under inclement weather conditions.
- When installed on the surface, the 3M 380WR ES durable tape was caught by snowplows. Therefore, this material must be installed in groove to protect it from snow plowing activities.
- RPMs provided the longest dry and wet night visibility distances throughout this study. Hence, they are more effective in providing guidance to drivers at night under both dry and wet conditions than the alternative marking materials evaluated in this study.

## Recommendations for Implementation

Based on the conclusions above, it is recommended that ODOT continues to use RPMs in Ohio to provide wet night visibility until a reasonable replacement is found. However, ODOT is advised to continue checking the condition of the RPMs from time to time, especially on aged asphalt pavements, to ensure proper adhesion to the pavement surface. RPMs not only guide motorists under inclement weather conditions, but also help snowplow truck drivers detect the center of the roadway when roads are covered with snow. While there have been rare incidents where RPMs have detached from the aged pavement surface, it is believed that RPMs prevent countless crashes during inclement weather conditions.