Evaluation of Sign Sheeting Service Life in Wyoming

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ABSTRACT

The minimum retroreflectivity standard for traffic signs in the Manual on Uniform Traffic Control Devices (MUTCD) requires that transportation agencies replace signs before they deteriorate beyond a prescribed minimum level of retroreflectivity. The objective of this research was to measure the retroreflectivity of in-service signs in Wyoming and to determine the expected service life of the sign sheeting materials that have been used in the state.

The research team measured 525 in-service signs resulting in a total of 783 different sign sheeting samples being measured. The majority of signs evaluated were installed within the last 13 years. Of the 525 signs evaluated 21.5 percent of the signs had been shot, vandalized, damaged, or were notably dirty. The majority of sign sheeting materials evaluated were ASTM Type III or IV material. The ASTM Type III materials were each found to have at least 13 or 14 years of service life with no clear end of service life based on retroreflectivity. The ASTM Type IV material was found to have a range of expected service lives of 15 years to no clear end of service life based on retroreflectivity, depending on the retroreflectivity degradation, sheeting color, sheeting orientation, and the minimum retroreflectivity level as required by the MUTCD. Based on the findings of this research it appears that the sign sheeting materials evaluated would not need to be replaced any sooner than on a 15 year cycle for retroreflectivity purposes, and that retroreflectivity may not be the primary reason for sign replacement.
INTRODUCTION

The minimum retroreflectivity standard for traffic signs in the Manual on Uniform Traffic Control Devices (MUTCD) requires that transportation agencies replace signs before they deteriorate beyond a prescribed minimum level of retroreflectivity (1). According to a recent NCHRP study (2), the most popular way agencies are maintaining their sign retroreflectivity is managing their sign age and using estimated sign sheeting service life values. The NCHRP study showed that agencies tend to rely on the sign sheeting warranty period in lieu of actual sign sheeting service life values. While this may be a conservative and compliant practice, it is typically not cost effective because most materials have a service life longer than their warranty periods (2). Actual sign sheeting service life values are needed so that agencies can manage their traffic signs in a more cost effective manner.

The intent of this study is to take advantage of the practice used by Wyoming DOT where they include, on each sign, the year of fabrication, which is typically the same as the installation date. Since Wyoming has been implementing this method for over 20 years, it is possible to measure sign retroreflectivity of in-service signs and determine their age. It is also possible to determine the type of sheeting on each sign. Combined, these pieces of information can be used to estimate sign sheeting service life values.

Previous Research

In an effort to determine the expected life of in-service sign sheeting materials numerous state and national research projects have been conducted (3,4,5,6,7,8,9). Unfortunately, the nationwide sign sheeting service life study is over 20 years old (3). In the past 20 years sign sheeting types, materials, quality, and production practices have changed, limiting the usefulness of the estimates of sign sheeting life. The results from state based research studies may be limited to local conditions and local sign maintenance practices. This would limit the ability of other states to convey those research results and apply them to their own state.

A recent paper presented at the 92nd Annual Transportation Research Board Meeting evaluated previous research on sign sheeting service life estimation (10). The paper noted limitations of past studies including the following, sign sheeting materials changing over time (new materials released, changes to current materials), age distribution of in-service signs, signs with poor retroreflectivity being replaced and thus not being included in degradation modeling, not accounting for initial retroreflectivity of signs, and sign age being the only consistent factor found to influence degradation. The authors expressed a need for a controlled study to evaluate the retroreflectivity degradation of sign sheeting materials.

OBJECTIVES

The objective of this research was to measure the retroreflectivity value of in-service signs in Wyoming and to determine the expected service life of the various sign sheeting materials that have been used in the state. There is a need to develop estimates of sign sheeting service life values to aid in life-cycle cost analysis and to help determine the best replacement schedule of signs so that signs are always maintained above the minimum retroreflectivity requirements,
while not replacing signs that have years of service life remaining. This information can then be used by WYDOT and surrounding areas to better manage their sign assets.

**METHODOLOGY**

The research team developed a data collection plan to obtain sign retroreflectivity measurements in various regions of Wyoming. The specific data collected, and the determination of where to collect data are described below.

**Data to Collect**

The focus of the data collection was to collect retroreflectivity measurements on various signs in the State of Wyoming. This was accomplished by using a portable handheld retroreflectometer capable of measuring at an observation angle of 0.2° and an entrance angle of -4.0° (11). This measurement geometry is the geometry noted in the minimum maintained retroreflectivity levels in the 2009 MUTCD (1). The retroreflectometer had recently been serviced to ensure it was in proper operation condition prior to the data collection. The output retroreflectivity values are in units of cd/lx/m². Four measurements were taken and recorded from various locations on background and legend sheeting materials. All measurements were taken with the retroreflectometer in the vertical position and the sheeting material was left as is, i.e. the signs were not washed prior to measurement.

In addition to the retroreflectivity measurements several other factors were collected to assist in analyzing the sign sheeting retroreflectivity degradation. The year of manufacture of the sign, which was considered the installation year, was recorded for every sign measured (See Figure 1 indicating a sign from 2005). The sign sheeting material type was recorded based on experience and the FHWA 2011 Traffic Sign Reflective Sheeting Identification Guide (12). Other information was also recorded such as sign type (warning, regulatory, guide), a description of the sign (stop, chevron, destination, etc.), the color of the signs background and legend, the cardinal direction the sign is facing (north, south, east or west), a general visual assessment of the sign, and the GPS location of the sign. The researchers attempted to balance the study while in the field by measuring a representative sample of signs with a focus on acquiring varying sheeting material types and colors across a range of ages.

Each sign was visually assessed by the research team during the daytime data collection. The researchers rated the signs daytime visual appearance based on the following categories. 1) Good – the signs color and appearance show no damage, weathering, or vandalism. 2) Adequate - the signs color and appearance show some signs of damage, weathering or vandalism. 3) Poor – the signs color and appearance show significant signs of damage, weathering or vandalism. Any vandalized signs will also be specifically noted during the data collection process. The researchers also collected digital images of each sign measured for reference later if needed. Knowing the exact location of the sign may also assist in modeling retroreflectivity degradation between signs in different areas. The researchers recorded the road the sign was on and the location (rural, or urban). In addition, latitude and longitude coordinates and elevation of the sign will be recorded. The information was collected with a handheld GPS unit.
Locations to Conduct Data Collection

The state of Wyoming has greatly varying terrain and weather conditions. The state itself is broken up into 5 districts by the state department of transportation. The state maintains nearly 6,900 miles of road with over 6,400 being considered rural. The districts in Wyoming were not selected based on conditions that may influence the degradation of sign retroreflectivity, so for the most part were ignored when selecting areas to measure signs.

A factor the researchers wanted to explore that may influence sign sheeting retroreflectivity degradation is average precipitation. The annual precipitation (rain and snow), in Wyoming is influenced by the elevation of the area. The lower elevations have less precipitation than the higher elevations. Based on the relationship between elevation and precipitation the research team focused their data collection efforts in areas of differing elevation levels.

Data were collected in two types of situations, 1) on a single section of roadway, and 2) at highway intersections. Data on single sections of roadway were collected as the researchers drove the roads in the areas of interest and measured signs that fit the need of data necessary to meet the objective of the research. The researchers measured a representative sample of signs (based on sign age, type, color, direction) and collected as many as possible during the data collection period. Only signs that could be safely accessed and have a convenient and safe location to park the data collection vehicle were considered for measurement. Collecting data at highway intersections allowed for comparisons of sign degradation based on the direction the sign is facing easier. All legs of the intersections had signs measured so that similar sign sheeting materials in a single area will only differ by the direction they are facing. The goal was to be able to measure signs on each leg of the intersection that are the same type, with the same material, and are the same age.
DATA ANALYSIS

The research team measured 525 in-service signs in the State of Wyoming. The manufacture date of these signs ranged from 1983 to 2012. The 525 signs resulted in a total of 783 different sign sheeting samples being measured. Three different types of sign sheeting materials were measured, ASTM Type I (engineering grade), ASTM Type III (high intensity), and ASTM Type IV (high intensity prismatic). Figure 2 provides a histogram of the types of frequency of the materials measured based on year installed and material type. From the figure it can be seen that the majority of the signs evaluated were installed since 1999, meaning the signs were 14 years old or newer. It is clear that the usage of the ASTM Type I material was being phased out of usage at the end of the 90’s. The ASTM Type III material began to see limited usage in 2006, and appeared to be phased out by 2011. The ASTM Type IV material started seeing increased usage in 2005, after initially being used in 2003, and was the only material type measured on signs installed the last two years.

![Histogram of sign sheeting material](image)

**FIGURE 2** Type, quantity, and installation year of sign sheeting material measured.

The research team took notes on every sign measured. Other than the ASTM Type I signs, there were no notes on noticeable fading/discoloring of any of the white, green, yellow, or red signs, other than slight discolorations around the edges of the cut ASTM Type III material. The research team took specific notes on signs shot with bullets or shotguns, signs that were vandalized with paint or stickers, signs that were damaged by being hit, bent, or damage from...
abrasion from falling or from passing snow plows, and signs that had a noticeable dirt or other material build up on the surface. Table 1 provides a summary of the number of signs noted with these deficiencies. Overall 21.5 percent of the signs assessed had some form of deficiency that was not related to the retroreflectivity of the sign. In addition to these deficiencies some signs also had varying amounts of their sheeting material peeling, typically around the edges, and some signs had fading ink or peeling electro cut (ec) film black legends.

**TABLE 1 Summary of Notes on Signs**

<table>
<thead>
<tr>
<th>Notes</th>
<th>Number of Signs (Out of 525)</th>
<th>Percent of Signs Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shot with bullet or shotgun</td>
<td>47</td>
<td>9</td>
</tr>
<tr>
<td>Vandalism</td>
<td>12</td>
<td>2.3</td>
</tr>
<tr>
<td>Shot and/or Vandalized</td>
<td>58</td>
<td>11</td>
</tr>
<tr>
<td>Damaged</td>
<td>40</td>
<td>7.6</td>
</tr>
<tr>
<td>Dirty</td>
<td>19</td>
<td>3.6</td>
</tr>
<tr>
<td>Damaged and/or Dirty</td>
<td>58</td>
<td>11</td>
</tr>
<tr>
<td>Shot, Vandalized, Damage, and/or Dirty</td>
<td>113</td>
<td>21.5</td>
</tr>
</tbody>
</table>

All signs noted as being dirty were removed from the retroreflectivity analysis. The retroreflectivity analysis was based on sheeting type, color, and age. There was not enough data to support a strong statistical analysis of the other factors. The other factors were looked at with simple descriptive statistics and plotted in charts but no strong associations between retroreflectivity degradation and elevation, sign direction, location, or film vs ink for red signs could be determined. The following sections look at the results of the ASTM Type III and IV retroreflectivity analysis for white, yellow, green and red sheeting materials.

**ASTM Type III Material**

The ASTM Type III material evaluated by the research team in Wyoming ranged in age from 3 to 14 years old. The majority of the signs evaluated were 7 to 13 years old. The MUTCD requirements have different levels of retroreflectivity based on sheeting type and usage. The following values are a summary of the applicable values for ASTM Type III beaded material, white ($\geq 35, 50$ or 120), yellow ($\geq 50$ or 75), green ($\geq 15$ or 25), and red ($\geq 7$). Overall, not a single ASTM Type III sign included in the retroreflectivity evaluation was below the MUTCD retroreflectivity requirements.

Figure 3 and Figure 4 provide plots of the retroreflectivity and age of the white ASTM Type III sheeting material. Figure 3 provides the results of all of the data. Figure 4 breaks the data down by rural or urban locations of the signs. Wyoming’s urban areas are relatively small and do not have the levels of passing traffic or pollution that may be found in an area with a larger population. The rural signs appear to have a slightly higher retroreflectivity than the urban signs, but the difference is not much and the regression slopes are similar. The most interesting thing about the plots is the lack of degradation. The slopes of the regression lines are all around positive one, which means the signs are actually slightly increasing in retroreflectivity with age, although the increase is very little, assuming a linear trend. The expected service life of the white material would be at least 14 years with no clear end of service life based on retroreflectivity.
Other studies have found Type III material with indefinite service lives, or service lives that were unrealistic at over a hundred year (4,7,8).

![Graph showing retroreflectivity vs age for Type III material](image)

**FIGURE 3** ASTM Type III white.

![Graph showing retroreflectivity vs age for Type III material in rural and urban areas](image)

**FIGURE 4** ASTM Type III white rural/urban.
Figures 5 through 7 provide plots of the retroreflectivity and age of the yellow, green, and red ASTM Type III sheeting material. Like the white ASTM Type III material plots show a lack of degradation. The slopes of the regression lines are again all around positive one, which means the signs are actually slightly increasing in retroreflectivity with age, although the increase is very little, assuming a linear trend. The expected service life of the yellow, green and red material would be at least 13 years with no clear end of service life based on retroreflectivity. There are a couple possible explanations for the increasing retroreflectivity that will be discussed at the end of this paper.

![Figure 5: ASTM Type III yellow](image-url)
**FIGURE 6** ASTM Type III green.

\[ y = 1.4328x + 30.66 \]
\[ R^2 = 0.1746 \]

**FIGURE 7** ASTM Type III red.

\[ y = 0.4731x + 49.324 \]
\[ R^2 = 0.0042 \]
ASTM Type IV Material

The ASTM Type IV material evaluated by the research team in Wyoming ranged in age from 0 (new) to 7 years old. The ASTM Type IV materials installed in 2003 and 2004 were not included in the analysis for this paper because they were a different style and from a different manufacturer than the majority of the signs measured in the other years. The MUTCD requirements have different levels of retroreflectivity based on sheeting type and usage. The following values are a summary of the applicable minimum maintained retroreflectivity values for ASTM Type IV prismatic material, white ($\geq 35, 50, 120$ or $250$), yellow ($\geq 50$ or $75$), green ($\geq 15$ or $25$), and red ($\geq 7$). Overall, not a single ASTM Type IV sign included in the retroreflectivity evaluation was below the MUTCD retroreflectivity requirements.

The predominate ASTM Type IV material used in Wyoming is directionally sensitive, although not all Type IV materials are directionally sensitive. The research team noted the orientation of the sheeting material on each sign measured since the retroreflectivity readings can vary depending on the application direction. Figure 8 provides an example of the sheeting material. This particular sample is orientated vertically as can be seen by the alternating dark and light striations of the material. All measurements for vertical or horizontal material application were taken with the retroreflectometer held vertically to the sign at a zero degree orientation. To maintain consistency and to account for the difference between the retroreflectometers aperture and the spacing of the striations of the sheeting materials, the research team always positioned the retroreflectometer in a consistent position when taking readings. The edge of the retroreflectometers aperture was positioned at the edge of a dark striation for two readings and at the edge of a light striation for two readings. Figure 8 provides a scaled example of each of these readings with the larger circle representing the full aperture and the smaller circle representing the reduced aperture used when measuring legends.

FIGURE 8  Measurements on directional Type IV material (vertical orientation).
Figure 9 provides plots of the retroreflectivity and age of the white ASTM Type IV sheeting material. The horizontal orientation shows lower retroreflectivity levels but also shows a much slower degradation rate than the vertical orientation, assuming a linear trend. The expected service life of the white material considering the minimum maintained values listed above would be 143, 139, 119, and 81 years for the horizontal application and 23, 22, 20, and 17 years for the vertical application.

![Image](image-url)

**FIGURE 9** ASTM Type IV white.
Figure 10 provides plots of the retroreflectivity and age of the yellow ASTM Type IV sheeting material. The horizontal orientation shows lower retroreflectivity levels but also shows a much slower degradation rate than the vertical orientation, assuming a linear trend. The expected service life of the yellow material considering the minimum maintained values listed above would be 226 and 212 years for the horizontal application and 16 and 15 years for the vertical application.

![Graph of retroreflectivity vs age for horizontal orientation](image1)

\[ y = -1.7863x + 453.93 \]
\[ R^2 = 0.0041 \]

![Graph of retroreflectivity vs age for vertical orientation](image2)

\[ y = -44.437x + 762.64 \]
\[ R^2 = 0.4436 \]

**FIGURE 10** ASTM Type IV yellow.
Figure 11 provides plots of the retroreflectivity and age of the green ASTM Type IV sheeting material. The horizontal orientation shows slightly lower retroreflectivity levels but also shows no degradation compared to the vertical orientation which shows degradation. The expected service life of the green material considering the minimum maintained values listed above would be at least 7 years with no clear end of service life based on retroreflectivity for the horizontal application and 21 and 19 years for the vertical application.

**FIGURE 11  ASTM Type IV green.**

![Graphs showing retroreflectivity vs. age for horizontal and vertical orientations.](image-url)
Figure 12 provides plots of the retroreflectivity and age of the red ASTM Type IV sheeting material. The horizontal orientation shows lower retroreflectivity levels but also shows no degradation compared to the vertical orientation which shows degradation. The expected service life of the red material considering the minimum maintained values listed above would be at least 7 years with no clear end of service life based on retroreflectivity for the horizontal application and 21 years for the vertical application.

![Graphs showing retroreflectivity vs age for horizontal and vertical orientations.](image)

**FIGURE 12** ASTM Type IV red.
FINDINGS AND RECOMMENDATIONS

The majority of signs evaluated in Wyoming were installed within the last 13 years. Of the 525 signs evaluated 21.5 percent of the signs had been shot, vandalized, damaged, or were notably dirty. The majority of sign sheeting materials evaluated were either ASTM Type III or ASTM Type IV material. None of the ASTM Type III or IV sign sheeting materials evaluated for retroreflectivity were below any of the MUTCD minimum maintained retroreflectivity levels. Due to the number of factors evaluated it was difficult to statistically assess the impacts of elevation (weather conditions), cardinal direction, or ec film vs ink. General analysis of these factors did not appear to show any noticeable impacts on the retroreflectivity degradation of the sign sheeting materials.

The white, yellow, green and red ASTM Type III material evaluated were each found to have at least 13 or 14 years of service life with no clear end of service life based on retroreflectivity. There are several possible reasons for not seeing degradation in the retroreflectivity of the sheeting material. The replacement schedule of the signs may be too frequent and the signs are being replaced before their retroreflectivity actually begins to degrade. The signs may be deteriorating but the lower retroreflectivity signs are being replaced only leaving in place signs with good and similar retroreflectivity. The sheeting materials may be slightly changing in color/fading resulting in higher retroreflectivity as the sheeting ages. It should be noted that fading was not obvious on the signs evaluated for retroreflectivity performance, but color measurements we not recorded to verify this. There also could have been changes to the sheeting material formulation or manufacturing process resulting in changes to initial retroreflectivity levels or degradation rates from year to year. It is most likely that the slight upward trend is indicative of color fading as other studies have shown similar findings (J3).

The ASTM Type IV material was found to have a range of expected service lives, based on retroreflectivity degradation, depending on the color of the material, the orientation of the material, and the minimum retroreflectivity level as required by the MUTCD. The white material ranged from 17 to 143 years of service life. The yellow material ranged from 15 to 226 years of service life. The green material ranged from 19 year to no clear end of service life based on retroreflectivity. The red material ranged from 21 years to no clear end of service life based on retroreflectivity. Even though the Type IV material has much higher initial retroreflectivity levels compared to the Type III material, it may not have a longer service life based on retroreflectivity degradation.

Based on the findings of this research it appears that the sign sheeting materials evaluated would not need to be replaced any sooner than on a 15 year cycle for retroreflectivity purposes in an environment like Wyoming’s. Based on the degradation of the ASTM Type III material it is likely that the signs will need to be replaced due to being shot, vandalized, damaged or being dirty (cleaning the sign may extend its life instead of replacement) instead of replacement due to retroreflectivity. The ASTM Type IV material was only on signs that had been installed within the last 7 years so the actual long term degradation is unknown, but again retroreflectivity may not be the primary reason for sign replacement in an environment like Wyoming’s.
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