An Asset Management Framework for Addressing the New MUTCD Traffic Sign Retroreflectivity Standards

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A model with sample calculations that reflect sign costs and life expectancy is developed to assist agencies in evaluating the implications of selecting alternative sheeting types and corresponding replacement schedules. The paper concludes that based on the longer warranty, the larger proportion of signs meeting the MUTCD minimums at their warranty age, and the annual cost over the warranty period that Type III High Intensity Beaded sheeting performs better than Type I Engineering Grade Beaded sheeting and has an overall lower annual cost to the agency. The paper documents the cost data and survival assumption so that local agencies can apply the model with local cost data to determine if our conclusions are consistent with local data.

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ABSTRACT

The 2009 Manual on Uniform Traffic Control Devices (MUTCD) requires that all agencies implement traffic sign management programs by January 8th, 2012. Most agencies are expected to adopt some type of systematic replacement policy based on life expectancy, augmented by visual inspection to identify signs with obvious damage.

Several previous efforts have developed models based on average degradation of the retroreflective sheeting as the signs age. This paper develops a series of survival curves characterizing the percent of signs that pass the retroreflectivity standards for signs ranging from 0 to 20 years. The curves representing expected conformance with the retroreflectivity standards (survival curves) are believed of greater use than previous degradation curves of average retroreflectivity. A framework for using these survival curves for red, white, and yellow backgrounds, in conjunction with local cost information, is presented to aid in the development of sign management programs.

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INTRODUCTION

The 2009 Manual on Uniform Traffic Control Devices (MUTCD) requires that all agencies implement traffic sign management programs by January 8th, 2012, and meet the minimum retroreflectivity standards shown in Table 1 by January 2015 (1).

TABLE 1 Federal Minimum Retroreflectivity Standards

Sign Color	Retroreflectivity Standard by Sheeting Type (cd/lx/m^2)		Additional Criteria	Study Survival Curves
	I	III, IV, VI, VII, VIII, IX, X		
White on Green	W* G ≥ 7	W ≥ 120 G ≥ 15	Ground-Mounted	
Black on White	B = 0 W ≥ 50			Figure 4
Black on Yellow	B = 0 Y*	B = 0 Y ≥ 75	Text and fine symbols measuring less than 48 inches	Figure 5
White on Red	W ≥ 35 R ≥ 7		Minimum contrast ratio (White : Red) ≥ 3:1	Figure 6
* This sheeting type is not to be used for this color.				

Table Adapted from Reference (1), Table 2A-3.

These standards reinforce the need to replace inadequate traffic signs in a timely manner. As agencies prepare to meet the requirements there are many maintenance decisions that an agency must make (2, 3, 4, 5, 6). These decisions include the selection of sheeting materials for signs, planning and budgeting for systematic sign replacement and how to implement a systematic method of identifying premature failures, such as those illustrated in Figure 1.

(a) Speed limit sign beyond the end of useful life.

(b) Stop sign beyond useful life.

(c) Peeling of sheeting material.

(d) Bleeding ink.

(e) Vandalism.

(f) Damage from graffiti cleaning solvent.

(g) Bending from attempted theft.

(h) Damage to sign from crash.

FIGURE 1 Systematic identification of premature failures.

Traffic Sign Management

Local agency engineers and sign managers must implement traffic sign management programs for compliance with the retroreflectivity standards outlined in the MUTCD. Previous research has been conducted on conceptual and data management techniques for managing sign inventories. A 2010 Federal Highway Administration (FHWA) report provides an overview of fundamental programs for sign management systems and techniques for implementing a management system (6). A 2009 study suggests how to implement information technology infrastructure for the development and implementation of a sign management program, and includes selected technology infrastructure costs (4).

Retroreflectivity of Traffic Signs

Previous efforts have focused on developing degradation and durability curves for Type III sheeting materials. A FHWA study produced a set of conceptual durability curves for the expected life of Type I, Type II, and Type III sheeting materials, as shown in Figure 2 (7). While conceptually useful, this figure does not differentiate between the performances of the various background colors. Degradation curves have been developed for Type I and Type III signs in previous studies (8, 9, 10).

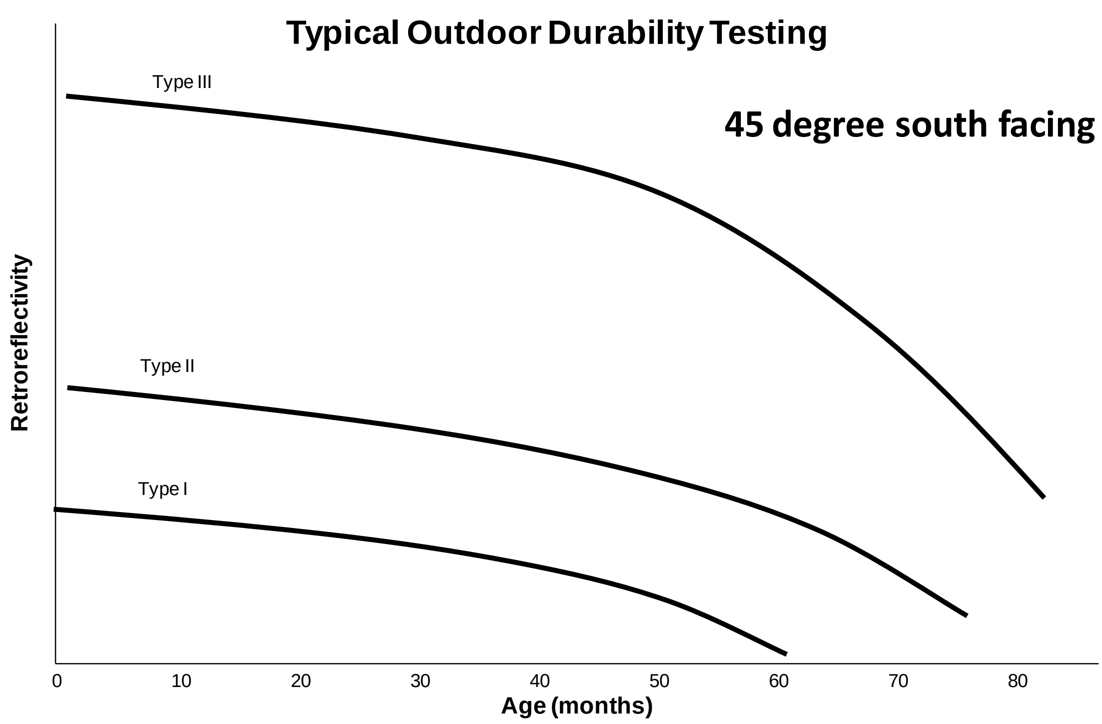


FIGURE 2 Typical outdoor durability testing (7).

In 2001, Purdue University compared the emerging minimum retroreflectivity standards to Type III signs that had recently been removed from service or were currently deployed on state highways (8, 9). This study produced a set of degradation curves for Type III red, white, and yellow background signs. It was determined that less than 5-percent of the Type III signs removed at 10 years of service fell below the minimum retroreflectivity standards; the study recommended that as a result of these findings, a new lifecycle of 12 years should be considered for Type III white and yellow background signs. A recent Purdue University study highlights the reliability and repeatability of sign retroreflectivity measurements (13). This study demonstrated that even measurements conducted under closely controlled laboratory conditions there is substantial variation that is important to understand when creating degradation curves.

In 2009, North Carolina State University (NCSU) synthesized information from six previous studies to develop degradation curves for Type I and Type III green, red, white, and yellow background signs (10). This study resulted in "best-fit" degradation curves for each color and sheeting type. This study also estimated the age at which the average retroreflectivity of each color and sheeting type will reach the respective minimum retroreflectivity standard, as shown in Table 2. However, a concern with this approach is that even if signs, on average, may not meet the standard, there is some proportion that is likely to fall below the minimum standard. While the study suggested the concept of survival plots for further research, no survival plots were developed.

TABLE 2 North Carolina State University (NCSU) Life Expectancy of Signs by Sheeting Type and Color

Sign Type and Color	Data Source	Age at FHWA minimum retroreflectivity level (years)
Type I White	FHWA	10
Type I Yellow	FHWA	7
Type I Red	NCSU	10
Type III White	FHWA	53
Type III Yellow	Purdue	22
Type III Red	NCSU	20

Table Adapted from Reference (10), Table 8.

Agency Costs

While sources exist to aid agencies in determining the costs associated with installing new signs to meet the minimum retroreflectivity standards, the sources are geared towards the perspective of a state department of transportation and not a local agency. There is also limited information regarding localized unit costs local agencies may use for annual cost estimation, budgeting activities, and to assist in making decisions regarding the most appropriate sheeting type.

FHWA has provided two methodologies for estimating sign costs (5). The first method may be used if the agency has a known quantity of signs, and the second method estimates the number of signs that will be needed based on the centerline miles of roadway that the agency is responsible for. Both methods assume a unit cost of $150 per installed sign, and do not differentiate between Type I and Type III sign sheeting.

Case studies have been developed for local agencies that provide more detailed values for sign quantities and costs. One study performed in 2005 estimated the percent of signs in each category (regulatory, school, stop, and warning) that did not meet the minimum retroreflectivity standards for a county in Florida (11). These percentages were used to determine the cost of replacing the sub-standard signs at a variety of unit costs to estimate the cost of having all signs in compliance with the retroreflectivity standard. As with other case studies involving cost, the focus of this study was on the initial cost of compliance and it did not consider the on-going or annual cost of a compliant sign management program

OBJECTIVE

The objective of this paper is to develop an asset management framework to address the new MUTCD traffic sign retroreflectivity standards. This paper presents a systematic approach for sign management based on expected sign life from the perspective of a local agency. This paper also presents data that a local agency can use to balance the competing needs of minimizing the probability of deployed signs that do not conform to the minimum retroreflectivity standards, and minimizing the annual cost of sign replacement.

The following sections describe the data collection procedure used to obtain retroreflectivity data from local agency signs, develop survival curves that characterize the percent of signs that are expected to meet the MUTCD standard in each year of the sign life, and present an asset management framework, including an economic analysis, to estimate annual sign replacement costs as illustrated in a case study.

DATA COLLECTION

It was desirable to collect data representative of current sign deployments maintained by local agencies in 2010. Data was collected for Type I Engineering Grade Beaded and Type III High Intensity Beaded traffic signs having red, white and yellow backgrounds on local roads in Indiana. The retroreflectivity levels of 800 traffic signs were measured. Information about the quantities of signs measured, including the sign type, background color, and sign age, is shown in Table 3.

TABLE 3 Distribution of Signs Measured by Sheeting Type, Background Color and Age

(a) Distribution of Type I Signs

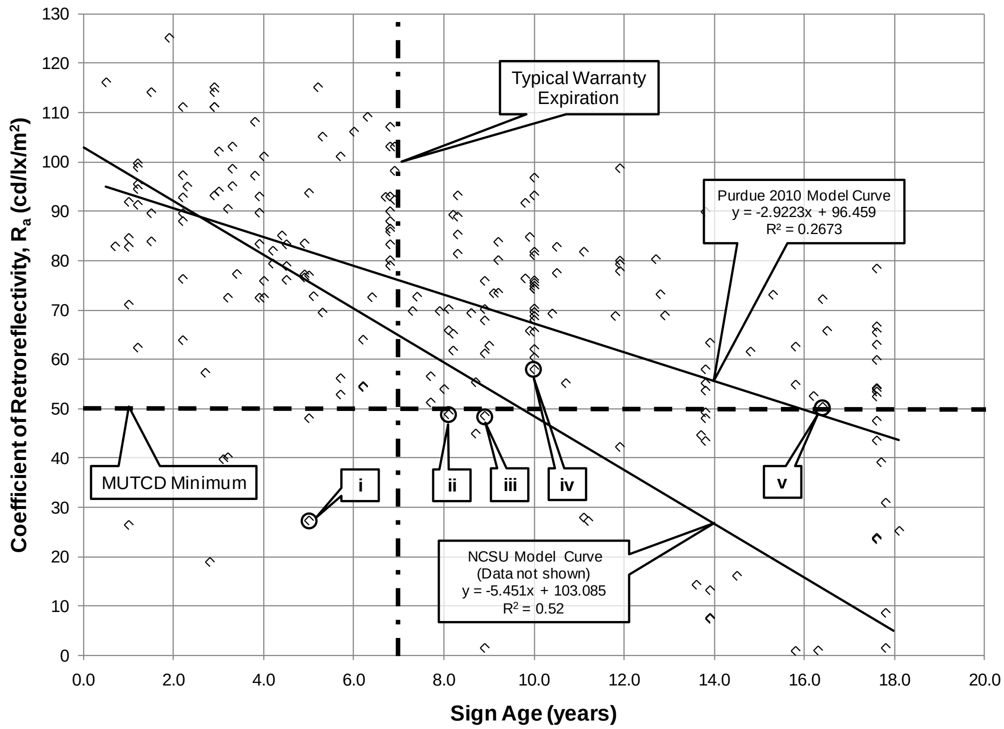
	Sign Age (years)																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	**Totals**
Red	3	6	3	1	12	2	13	9	24	10	14	7	1	3	4	1	1		1			**115**
White	9	10	17	14	12	11	20	5	21	10	20	9	3	13	2	4	8	21	3			**212**
Yellow	14	13	12	7	13	32	24	19	13	10	2	8	4	7	4	10	6	4	4			**206**
Totals	**26**	**29**	**32**	**22**	**37**	**45**	**57**	**33**	**58**	**30**	**36**	**24**	**8**	**23**	**10**	**15**	**15**	**25**	**8**			**533**

(b) Distribution of Type III Signs

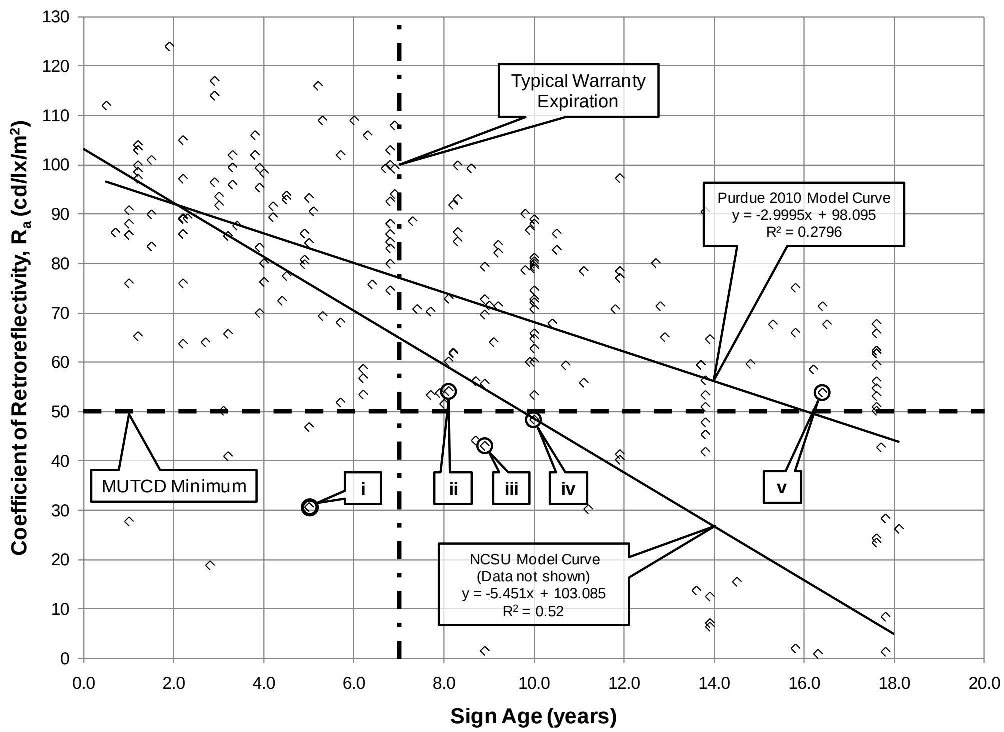
	Sign Age (years)																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	**Totals**
Red		2	2	9	3	17	9	10	10	9	5	4	4	1		6			2			**93**
White		11		3	6	3	10	10	15	2		1										**61**
Yellow	2	8	9	15	14	8	20	8	10	3	1	3	1			5	5				1	**113**
Totals	**2**	**21**	**11**	**27**	**23**	**28**	**39**	**28**	**35**	**13**	**6**	**8**	**5**	**1**		**11**	**5**		**2**		**1**	**267**

Retroreflectivity measurements were taken using the methodology described in American Society for Testing and Materials (ASTM) E 1709-08 (12). Four measurements were taken of a sign's legend (if not black) and four measurements taken of a sign's background using a RoadVista 922 retroreflectometer at an entrance angle of -4.0° and an observation angle of +0.2°. The four readings for each legend and background were averaged by the retroreflectometer to provide a retroreflectivity level for the sign. Sign measurements were taken both before the sign was cleaned, designated "unwiped condition" (Figure 3a), and after the sign was cleaned with water and a cloth towel, designated "wiped conditions" (Figure 3b). Measurements of wiped and unwiped were compared to assess the impact of cleaning signs on the retroreflectivity levels. As can be seen in Figure 3, cleaning the signs did not have a substantial impact on the overall retroreflectivity levels, though it did have a minor impact the readings for some individual signs as indicated by the callouts for signs i through v in Figure 3a and Figure 3b.

The following information was recorded for each sign: unique sign identification number, jurisdiction, location using street name and GPS coordinates, MUTCD sign designation, color of legend and background, sheeting type, direction of the sign face, weather conditions during data collection, unwiped retroreflectivity level, and wiped retroreflectivity level. The installation date of each sign was from the installation date sticker, engraving, or sign inventory. GPS coordinates were taken using the GPS receiver built in to the retroreflectometer.



(a) Unwiped signs.



(b) Wiped signs.

FIGURE 3 Type I white background retroreflectivity levels.

ASSET MANAGEMENT

An important component of the new MUTCD requirements is that agencies are expected to implement a sign management system to meet the minimum retroreflectivity standard. A management system will allow agencies to prioritize signs that need replacing; effectively budget time, money, and resources; and minimize agency exposure to tort liability by reducing the number of signs that do not meet the minimum retroreflectivity levels (6). As part of the standard, Section 2A.08 of the MUTCD outlines six accepted practices for sign management (1):

- Visual nighttime inspection
- Measured sign retroreflectivity
- Expected sign life
- Blanket replacement
- Control signs
- Other methods, based on engineering studies

The expected sign life was selected as the method of choice for the proposed sign management program presented in this paper. Expected sign life may be based on the warranty period, local data, or other models, and should be augmented with visual inspections of signs to assure that signs that require replacement due to obsolescence or premature failures are also addressed (as illustrated in Figure 1).

Measured Sign Retroreflectivity

Using the kind of data shown in Figure 3, degradation curves have been developed for Type I and Type III signs in previous studies (8, 9, 10). The R^2 values for degradation curves in previous studies range from 0.01 to 0.52 (8, 9, 10). The sign life expectancy based on previous studies is shown in Table 2 (10).

The curves shown in Figure 3 represent degradation curves for Type I white background signs. The curve labeled "Purdue 2010 Model Curve" is the best-fit curve for the data collected in this study and does not include any of the data collected by the Purdue 2001 study. The "NC State Model Curve" shows the best-fit curve reported by the NCSU synthesis of previous retroreflectivity studies, which is from a FHWA study (10). These curves show that on average, in year seven Type I white background signs will exceed the minimum threshold (as determined by the manufacturers' warranty) by 52.0-percent (Purdue 2010) and 29.9-percent (NCSU). It should be noted that the NCSU curve is based on data collected approximately 10 years ago on state highways, whereas the Purdue 2010 curve is based upon data collected in 2010 from signs on local and county roads. The data in Figure 3 illustrates that there is a non-zero probability of signs failing as early as year one.

There is a noticeable difference between the R^2 values of the degradation curves for the Purdue 2010 and NCSU, which may account for the difference in geographic locations of the data sets. The Purdue 2010 signs were collected across the State of Indiana in both urban and rural locations, which could perhaps account for the higher variance (lesser R^2) for this degradation regression model.

SURVIVAL CURVES

A survival curve characterizes the percent of signs expected to pass the minimum standards at a given age. These curves provide engineers and decision makers with a better understanding of the risk of sign failure for each sheeting material.

The percent of signs passing was determined by comparing the measured retroreflectivity levels of each sign collected to the minimum retroreflectivity standards (and minimum contrast ratio for white on red) shown in Table 1. The quantity of signs passing the standard for each year was tabulated, and a linear regression equation was calculated for each sign type. Survival curves for white, yellow and red background signs are shown in Figures 4, 5 and 6.

Interpretation of Survival Curves

Survival curves provide an assessment of the expected risk that signs do not meet the minimum standards for each sheeting type. Agencies can use the survival curves to assess the implied failure rate for a proposed replacement cycle, and can use this information in a formal risk assessment program, if desired. Additional details for each sign type are discussed below.

White Background Signs

A comparison of survival curves for Type I and Type III white background signs (Figure 4) illustrates that Type III signs have 100-percent of the signs passing the minimum standard at years seven and 10. The less expensive Type I signs also perform fairly well with 86-percent of signs passing the minimum retroreflectivity standards at year seven and 77-percent passing the minimum standard at year 10.

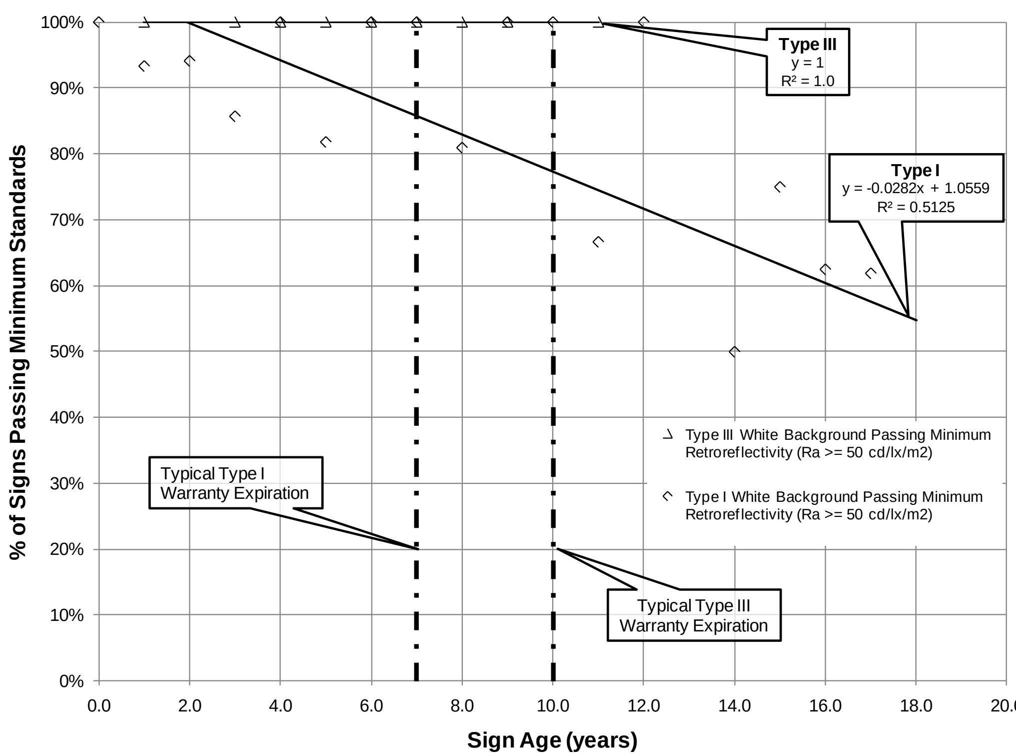


FIGURE 4 Percentage of white background signs passing retroreflectivity standard by year (unwiped).

Yellow Background Signs

A comparison of survival curves for Type I and Type III yellow background signs (Figure 5) illustrates why Type I sheeting is no longer acceptable for yellow background signs. Only 20-percent of Type I yellow signs pass the minimum retroreflectivity standard by the fourth year. On the other hand, Type III yellow signs have a very high survival rate of 91-percent and 81-percent at years seven and 10, respectively.

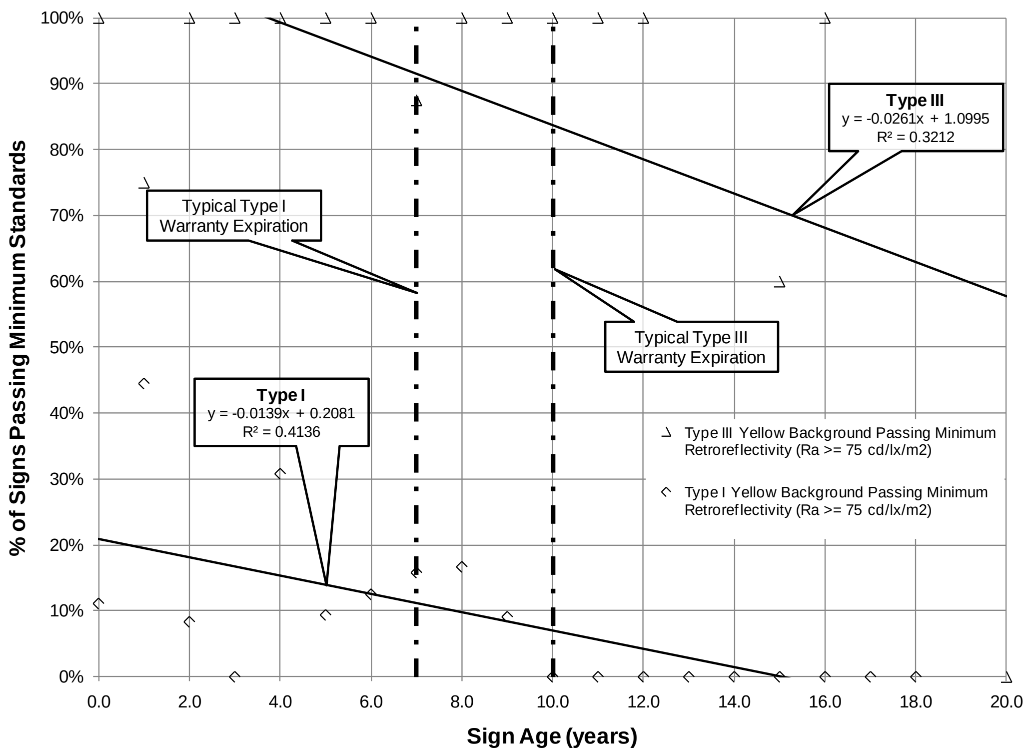


FIGURE 5 Percentage of yellow background signs passing retroreflectivity standard by year (unwiped).

Red Background Signs

Assessment of red background signs must consider not only retroreflectivity level, but also contrast ratio: the retroreflectivity level of the white legend must be at least three times the level of the red background. The comparison of Type I and Type III red background signs (Figure 6) takes into account both the retroreflectivity level and the contrast ratio, and illustrates the higher performance of Type III sheeting for red background signs. The Type III signs demonstrated a few premature failures (two failing signs of six total signs) in year five, but in most years, 100-percent of the Type III signs passed the standard. Although the regression line for Type III signs has an increasing slope, the passing rate is not expected to increase with time. The positive slope is due to the overall very low failure rate for Type III red background signs and the small sample size. Clearly, the life expectancy for red Type III signs exceeds the age of the signs included in this study.

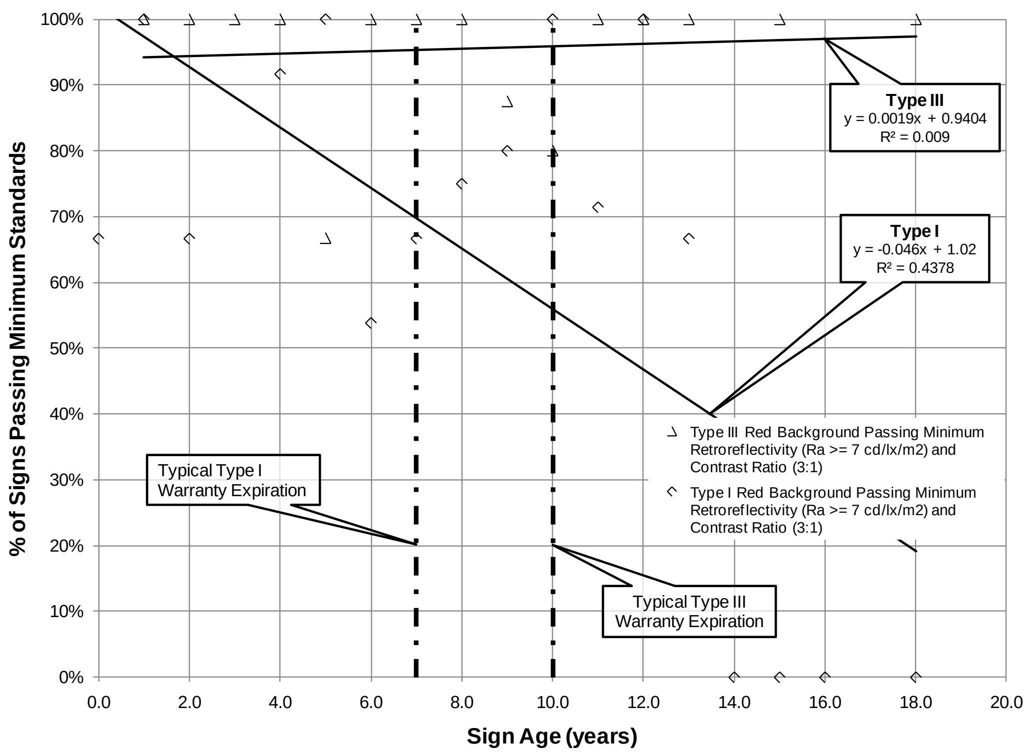


FIGURE 6 Percentage of red background signs passing retroreflectivity and contrast ratio standard by year (unwiped).

CASE STUDY

A local agency's sign infrastructure represents a significant investment in both capital and maintenance costs, which are important components of a sign management program. This case study presents an asset management framework for sign replacement for a local agency that considers sign cost, replacement cycle and expected failure rate for the replacement cycle chosen. Local agencies may use this example to assess alternatives and guide program decisions. The values shown can be replaced with local values, including local sign unit costs, current interest rates, and the life cycle of the material under consideration. Furthermore, agencies will need to determine a method to assess premature failures of signs (as illustrated in Figure 1).

This case study is illustrated for a town with 10,000 signs. The distribution of signs by background colors is based on sign category (regulatory, warning and guide) data for towns from the FHWA *Sign Retroreflectivity Manual* (5), as shown below:

- Stop (and other red background signs): 45% of all signs 4,410 signs
- Speed Limit (and other white background signs): 30% of all signs 2,940 signs
- Warning (and other yellow background signs): 20% of all signs 1,960 signs
- Guide (and other green background signs): 5% of all signs 690 signs

Although this case study focuses on stop, speed limit, and warning signs, and does not consider guide signs, the framework could be expanded to include guide signs. Similarly, this case study provides a comparison of costs for an agency considering Type I and Type III sheeting, though the framework could be expanded to include additional sheeting types. The unit costs in the framework are based on local agency data in Indiana.

Equivalent Annual Cost

Calculations to determine an equivalent annual cost for each type of sign and sheeting material are shown in Table 4. It is assumed that the new signs can be mounted on existing sign poles and the sign poles do not require replacement. The present cost (*P*) for each sign (Table 4, column c) is calculated as the sign unit cost (Table 4, column a) plus the installation unit cost (Table 4, column b). The present cost (*P*) is multiplied by a Capital Recovery Factor (CRF) to determine the equivalent annual cost (*A*). The CRF is conventionally referred to by the notation (*A/P*, *i*, *n*), based on a given interest rate (*i*) and the life cycle in years (*n*). In this example, the interest rate used is 4-percent per year, which accounts for expected losses due to inflation. The current manufacturers' warranty for the sheeting material was used as the life cycle for each sign type. The CRF is calculated using Equation 1, or may be looked up in reference tables.

Equation 1

The resulting annual cost (Table 4, column g) allows the agency to predict how much a single sign will cost the agency per year of service assuming the sign remains in the field for the duration of the service life, and is not replaced due to vandalism, crashes or other sources of premature failure. Based on the cost information, Table 4, column g indicates the annual cost for Type III signs is lower than the annual cost of Type I signs for all background colors, despite the higher initial cost.

TABLE 4 Sample Unit Costs and Lifecycle Estimates for Sheeting Materials

	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Type of Sign	Sign Unit Cost	Installation Unit Cost	Total Cost (*P*)	Warranty Life or Replacement Cycle in years (*n*)	Interest (*i*)	Capital Recovery Factor (*A/P*, *i*, *n*)	Equivalent Annual Cost
Type I Speed (White)	$25	$50	$75	7	4%	0.1666	$12.50
Type I Warning (Yellow)	$35	$50	$85	7	4%	0.1666	$14.16
Type I Stop (Red)	$30	$50	$80	7	4%	0.1666	$13.33
Type III Speed (White)	$35	$50	$85	10	4%	0.1233	$10.48
Type III Warning (Yellow)	$45	$50	$95	10	4%	0.1233	$11.71
Type III Stop (Red)	$40	$50	$90	10	4%	0.1233	$11.10

Assumed Sign Sizes: *Speed* = 24" x 30"; *Warning* = 36" x 36"; and *Stop* = 30" x 30"

Sign Inventory Cost

Calculations to estimate the total cost for an agency's entire inventory are shown in Table 5. This information may be used to budget for sign expenditures, and it may be presented to decision makers to justify higher initial costs for better sheeting grades. It is also appropriate to budget funds to replace signs damaged due to crashes, vandalism and premature failures. However, these values vary substantially for different agencies and are not included in this example for simplicity.

TABLE 5 Alternatives Analysis of Sheeting Material for Sign Maintenance Program

	(a)	(b)	(c)	(d)	(e)	(f)
			Programmed Sign Replacement			
Type of Sign	Number of Signs in Inventory (S)	Life of Sign in years (n)	Percent of signs (1/n)	Number of signs (S/n)	Equivalent Annual Cost per Sign	Total Annual Cost for Signs
Type I Speed (White)	2,940	7	14.29%	420	$12.50	$5,250
Type I Warning (Yellow)	1,960	7	14.29%	280	$14.16	$3,965
Type I Stop (Red)	4,410	7	14.29%	630	$13.33	$3,398
Type III Speed (White)	2,940	10	10%	294	$10.48	$3,081
Type III Warning (Yellow)	1,960	10	10%	196	$11.71	$2,295
Type III Stop (Red)	4,410	10	10%	441	$11.10	$4,985

To illustrate the values in Table 5, consider Type I speed limit signs. There are 2,940 signs in the inventory, and the manufacturers' warranty of seven years is used as the replacement cycle. It is assumed that each year the agency will replace $1/7^{th}$, or 14.3-percent of the speed limit signs, which amounts to 420 signs per year. Using the equivalent annual cost of $12.50 per year for a Type I speed limit sign from Table 4, the total annual cost for speed limit signs is $5,250. Note that for budgeting purposes, any planning for future expenditures should consider inflation.

Expected Failure Rate

In addition to the consideration of equivalent annual cost, it is important for agencies to have an idea of the risk exposure associated with the type of sheeting selected. The risk exposure is based on the estimated quantity of signs that may not meet the minimum retroreflectivity standard in a given year. This quantity will vary depending on the type of sheeting selected and the replacement cycle used. Calculations that illustrate risk exposure and expected failure are shown in Table 6. The expected failures expressed as a percent for each type of sign were derived from the survival curves shown in Figures 4, 5, and 6 for white, yellow, and red signs, respectively. However, as noted by footnote 1 in Table 6, the survival curve for the Type III red signs was neglected due to small pool of signs measured, resulting in positive slope for the curve. The number of signs that are expected to fail is based on the number of signs in the inventory in each age category, multiplied by the percent of failures for signs that age.

TABLE 6 Analysis of Expected Failures for Sign Management Program

(a) Expected Failures by Percentage of Signs

Type of Sign	Signs in Each Age Category	Age of Sign in Years										Avg.
		1	2	3	4	5	6	7	8	9	10	
Type I Speed (White)	420	0%	0%	3%	6%	9%	11%	14%				6%
Type I Warning (Yellow)	280	81%	82%	83%	85%	86%	88%	89%				85%
Type I Stop (Red)	630	3%	7%	12%	16%	21%	26%	30%				16%
Type III Speed (White)	294	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Type III Warning (Yellow)	196	0%	0%	0%	0%	3%	6%	8%	11%	14%	16%	6%
Type III Stop (Red)[1]	441	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%

(b) Expected Failures by Sign Quantities

Type of Sign	Signs in Each Age Category	Age of Sign in Years										Total
		1	2	3	4	5	6	7	8	9	10	
Type I Speed (White)	420	0	0	12	24	36	48	59				179
Type I Warning (Yellow)	280	226	230	233	237	241	245	249				1,661
Type I Stop (Red)	630	16	45	74	103	132	161	190				721
Type III Speed (White)	294	0	0	0	0	0	0	0	0	0	0	0
Type III Warning (Yellow)	196	0	0	0	1	6	11	16	21	27	32	114
Type III Stop (Red)[1]	441	25	25	25	25	25	25	25	25	25	25	250

1 Small pool of signs, coefficient from survival model was neglected

To illustrate the values in Table 6, consider Type I speed limit signs. If an equal number of signs are replaced each year (Table 5, column d), then there are 420 signs that are one year old, 420 signs that are two years old, 420 signs that are three years old, and so on through the 420 signs that are seven years old. Using the percent failures from the survival curves, as expressed in the survival model (2.8-percent) or the rounded value in Table 6a (3-percent), the number of signs expected to fail each year can be calculated, as illustrated for year three below:

The total number of white speed limit signs in the inventory that may be expected to fail is the sum of the failures in each age category, as illustrated below:

These calculations illustrate there is an expectancy that 179 (6-perecent) of the 2,490 Type I white speed limit signs are expected to be below the minimum retroreflectivity standard over their seven year lifecycle. As shown in Table 6, Type III white speed limit signs had the lowest lower risk of signs below the retroreflectivity threshold (0-percent).

Based on the assumed costs, it is clear that Type III sheeting is the economical choice for all sign types analyzed, despite the higher initial cost. The $10 increase in initial cost (per Table 4) is recouped during the longer expected life, as illustrated by a comparison of the equivalent annual cost per sign (Table 5, column e). Moreover, the expected failure rate is substantially lower for Type III signs than for Type I signs (Table 6).

CONCLUSIONS

This study evaluates how to calculate the equivalent annual cost, determine an appropriate replacement cycle, and assess the expected failure rate based on local agency data in Indiana. Local agencies can use this information to calculate the annual cost of alternative sign sheeting materials, to estimate budget requirements for their sign program, and to estimate the failure rate associated with the selection of Type I Engineering Grade Beaded or Type III High Intensity Beaded sheeting. This information may be useful for internal decision making, as well as to communicate the needs of their sign program with decision makers, such as city and county councils. This information may also be helpful to communicate that failure to provide an adequate budget for sign replacement implies acceptance of a higher failure rate for signs, and a subsequent increase in potential liability. It also may be helpful in determining the service life an agency is willing to accept for a particular type of sign.

Based on the assumptions used in this case study and analysis based on the costs and survival rates of signs from local agencies in Indiana, Type III signs are superior to Type I signs considering both the annual cost of the signs and the expected risk associated with signs failing to meet the new MUTCD retroreflectivity standards. The framework presented for the determination of equivalent annual costs and the use of the survival curves to determine expected sign failure allow local agencies to use their own data to confirm the applicability of these recommendations to their jurisdiction.

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APPENDIX A:

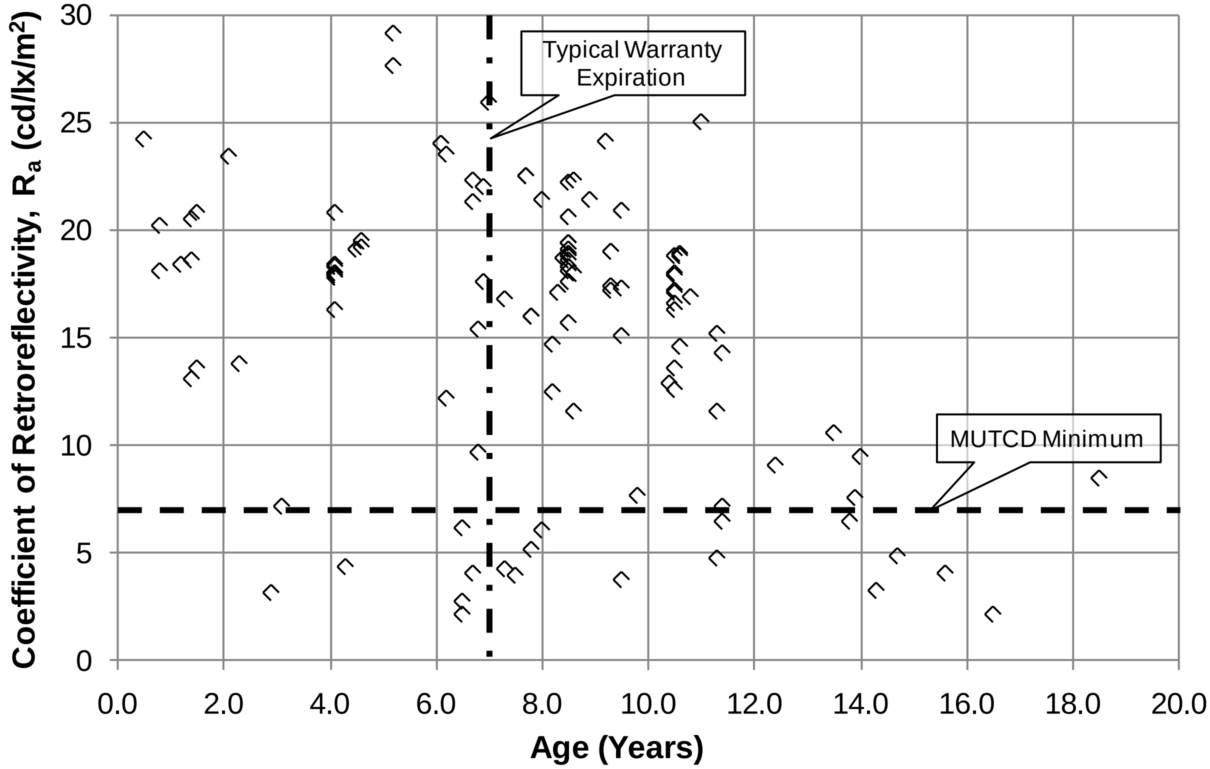
RETROREFLECTIVITY FIELD DATA BY SHEETING TYPE AND COLOR AND AGE

Table 1 of the accompanying technical report defines the new MUTCD thresholds for retroreflectivity and Figure 2 conceptually shows how retroreflectivity is expected to decline with age. However, the stochastic impact of subtle differences in manufacturing, handling, weather, and other environmental impacts result in signs that have significant variation in retroreflectivity for a specific age. Figure 3 in the technical report illustrates this scatter quite well, as well as the opportunity for differing perspectives on what is the appropriate line (or other model) to fit to the data. Table 2 in the technical report illustrates that depending upon the model applied, different studies have suggested different target replacement age thresholds.

For the sake of brevity, the accompanying technical report does not contain the complete field data. Appendix A contains the entire set of retroreflectivity scatter plots from field observations collected from approximately 800 signs (Table 1) throughout Indiana in 2010.

As the technical report explains, there are many factors besides retroreflectivity that influence the decision to replace a sign (Figure 1 illustrates some of those). Although there is opportunity for informed professionals to disagree on the life expectancy of a sign, there is broad consensus in the industry to develop a scheduled replacement plan where a certain proportion of signs are replaced on an annual basis. Such a maintenance plan provides a framework for developing good budgeting practices and selection of the sheeting material with the lowest life cycle costs.

Based upon the data presented in the following tables, an agency may make a decision to select a different life cycle and update the life cycle cost values in Tables 4 and 5. However, this should be done with caution and with consideration of the stated warranty of the sign material.



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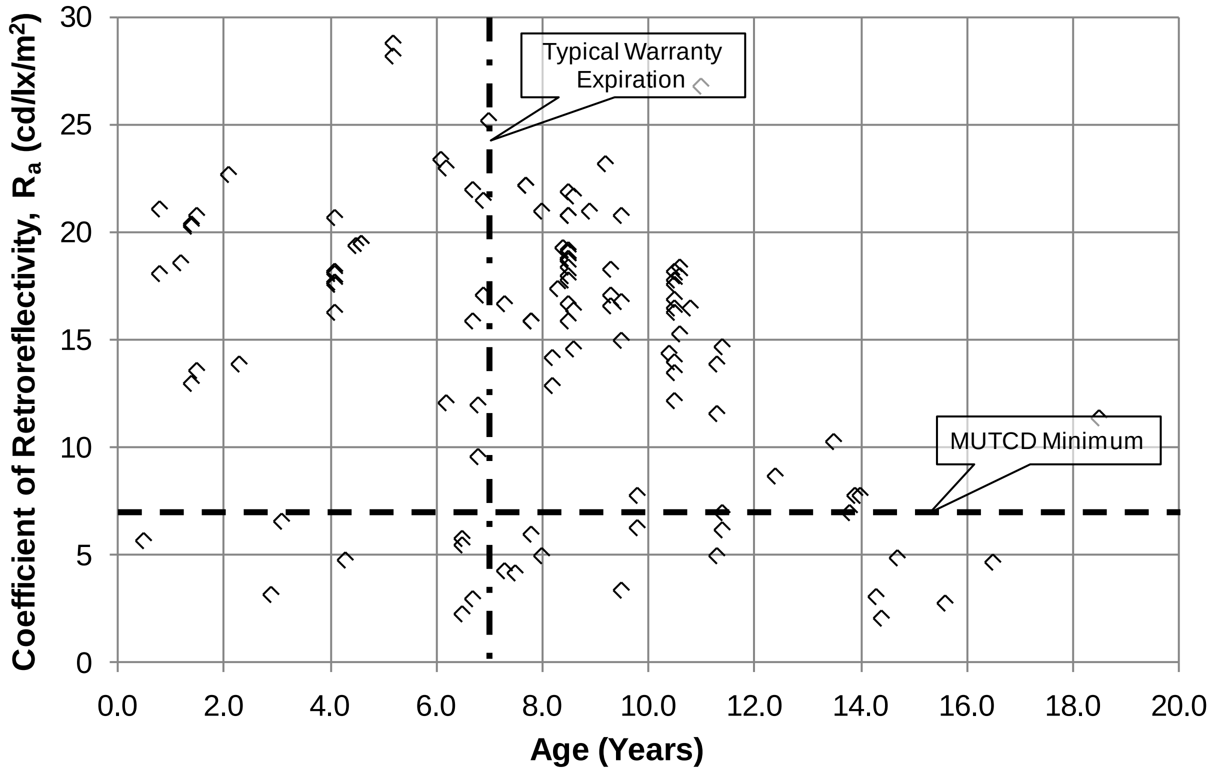
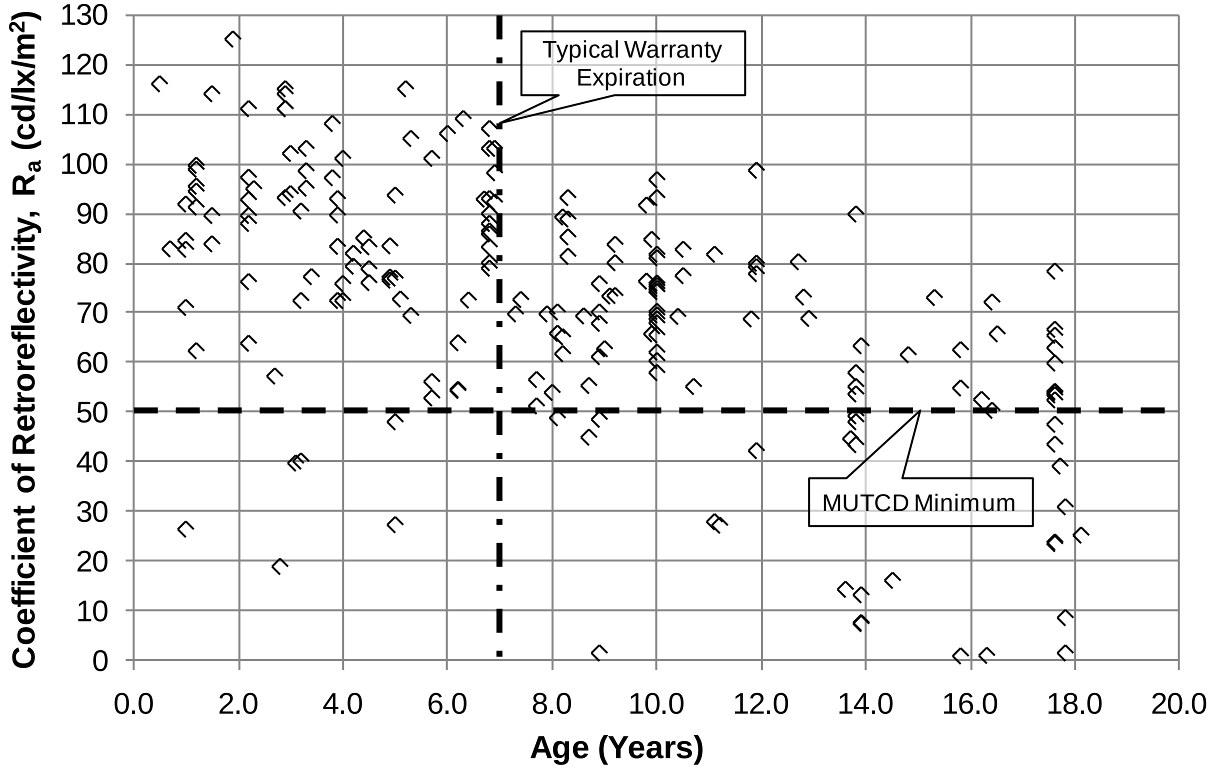


b) Wiped

Figure A7. Type I Red Background



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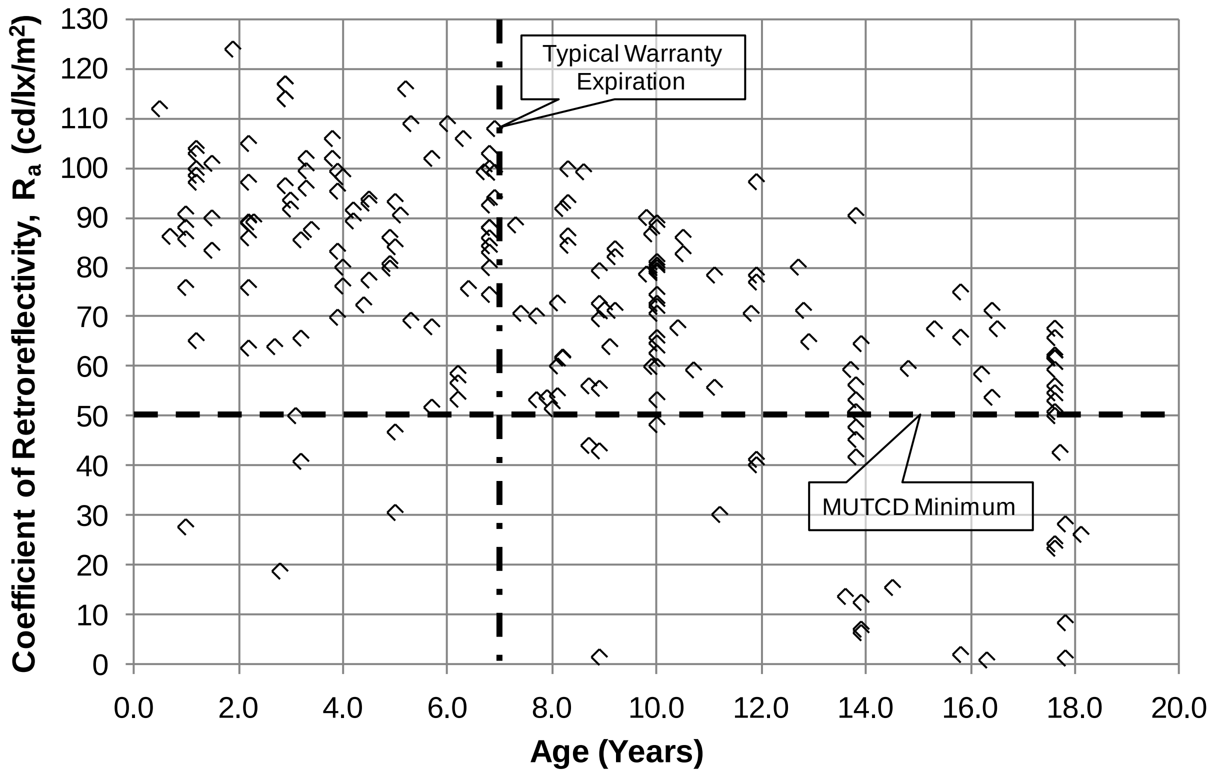
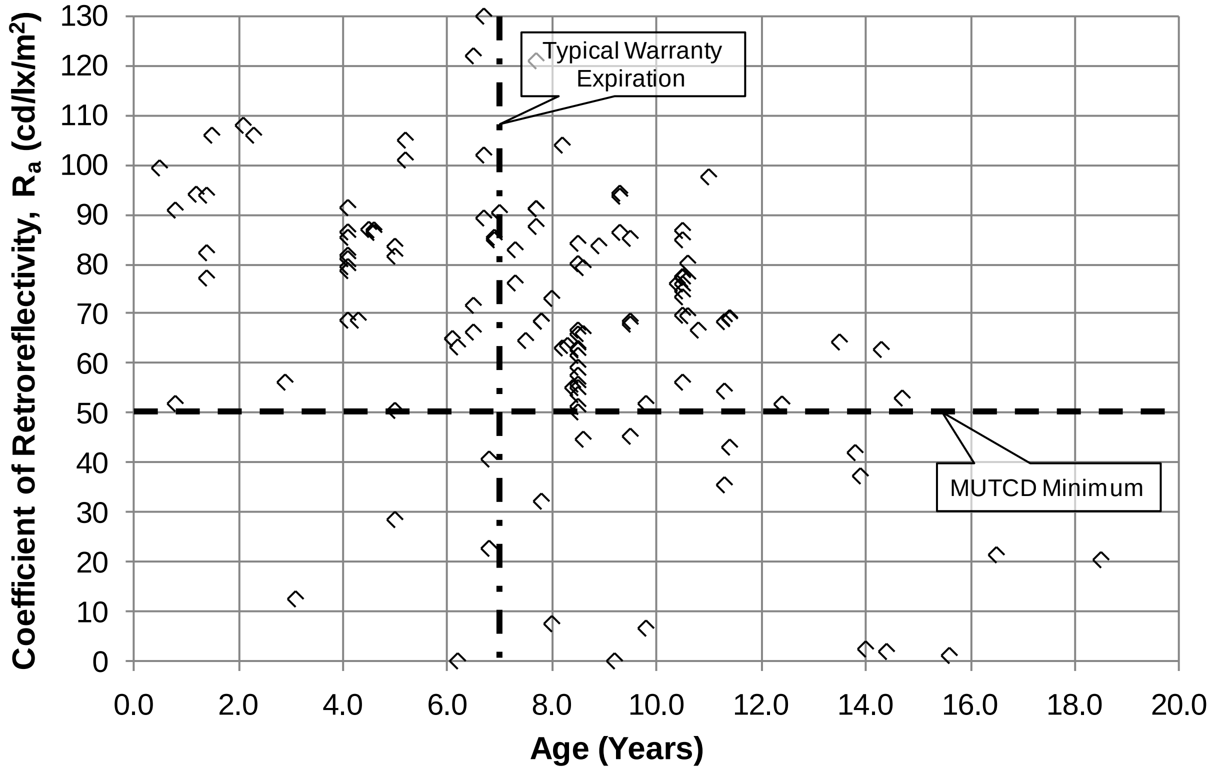


b) Wiped

Figure A8. Type I White Background



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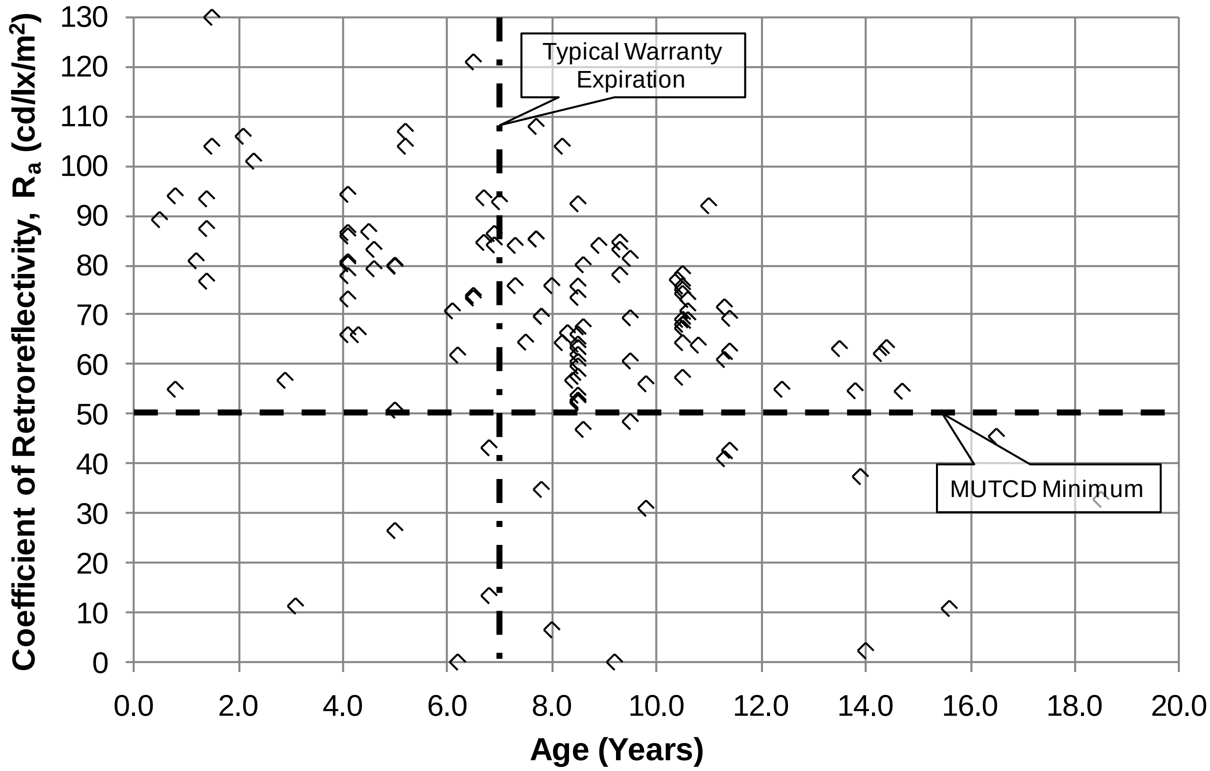

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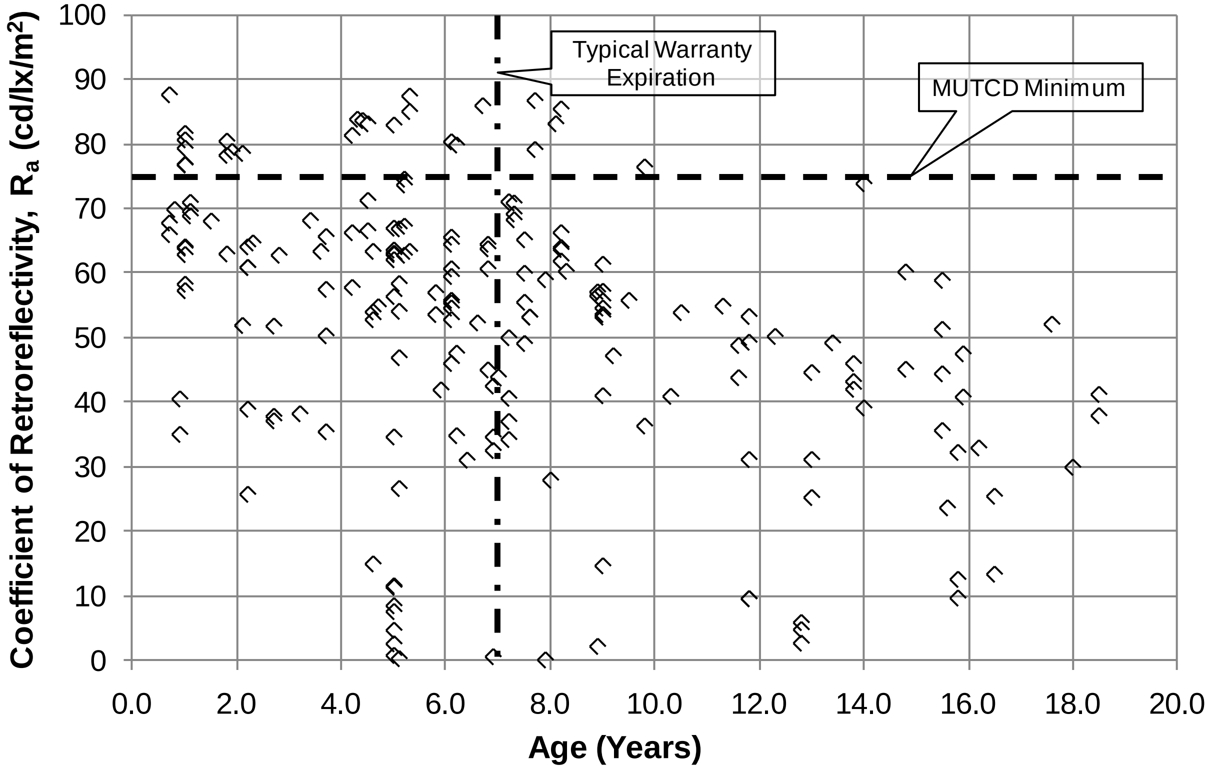
Figure A9. Type I White Legend



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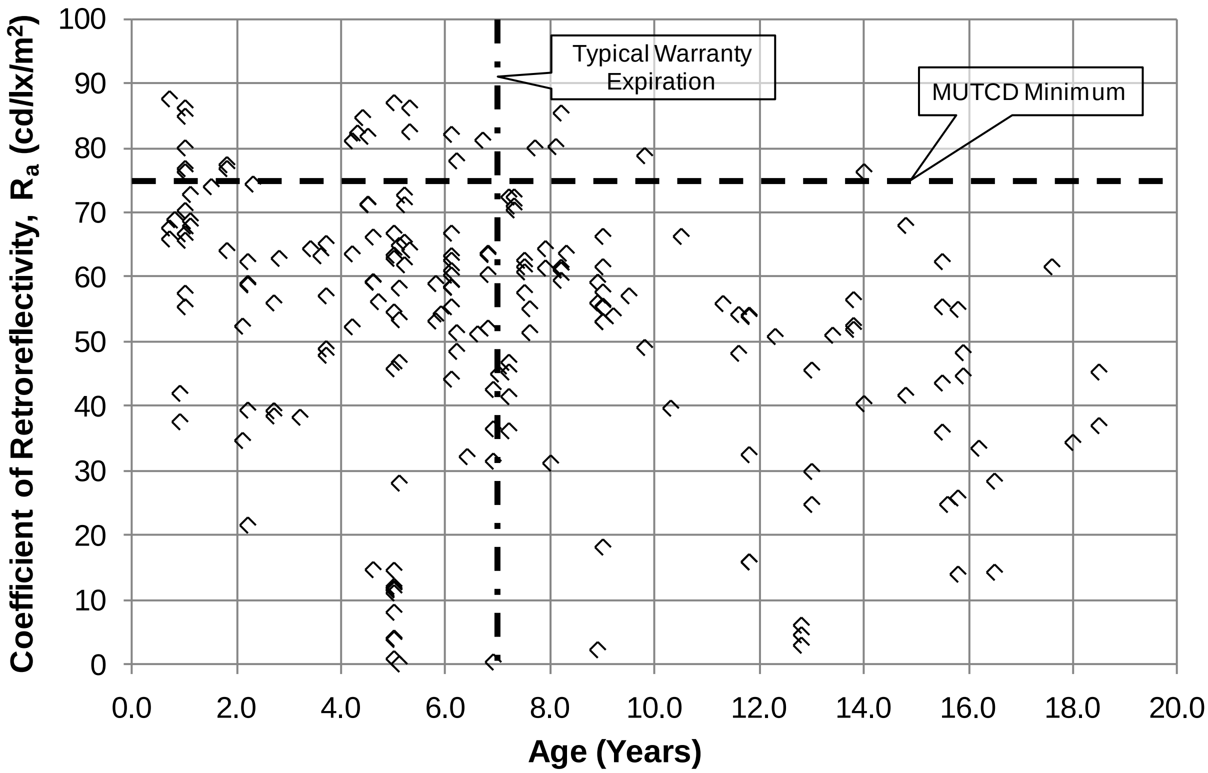
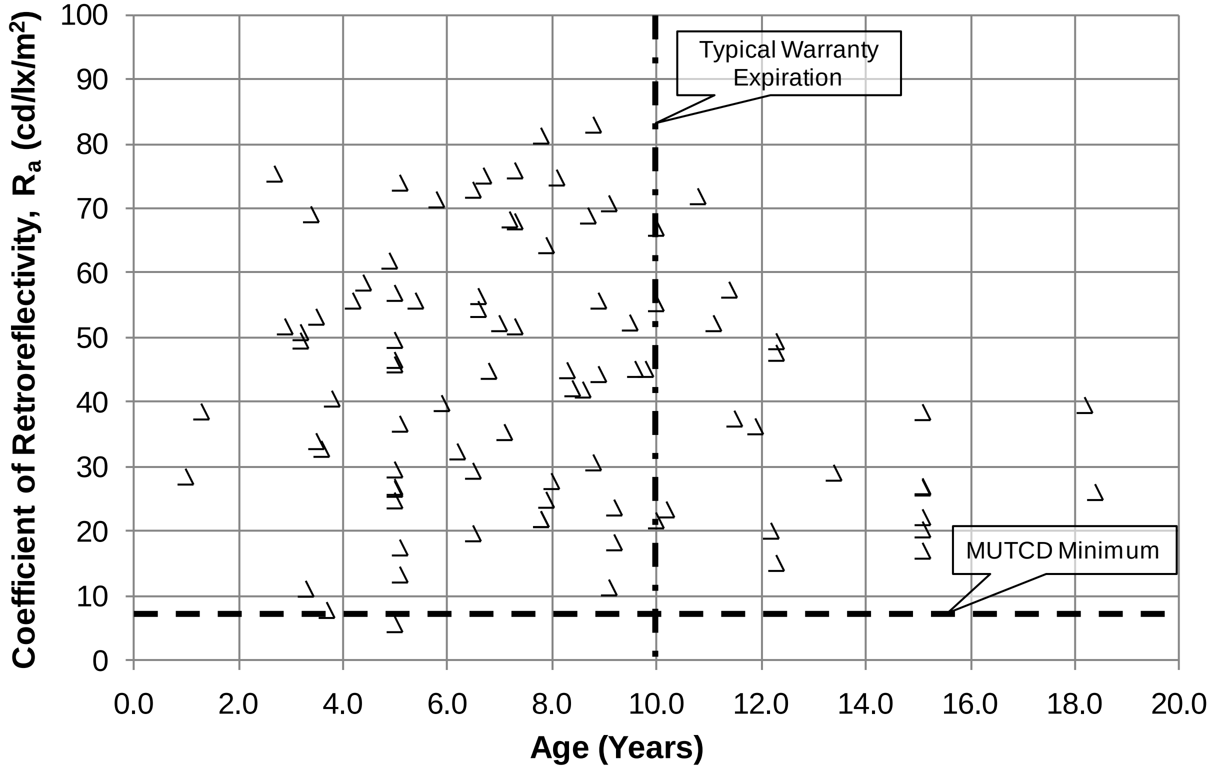


b) Wiped

Figure A10. Type I Yellow Background



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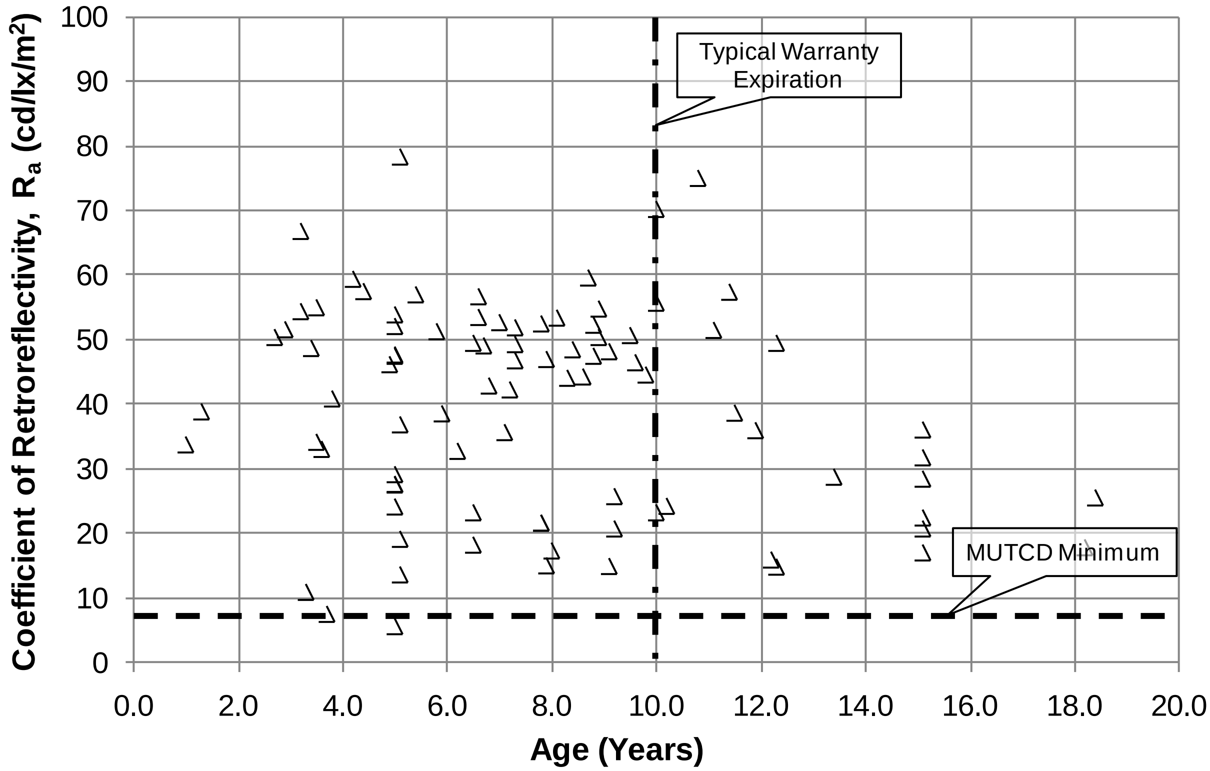

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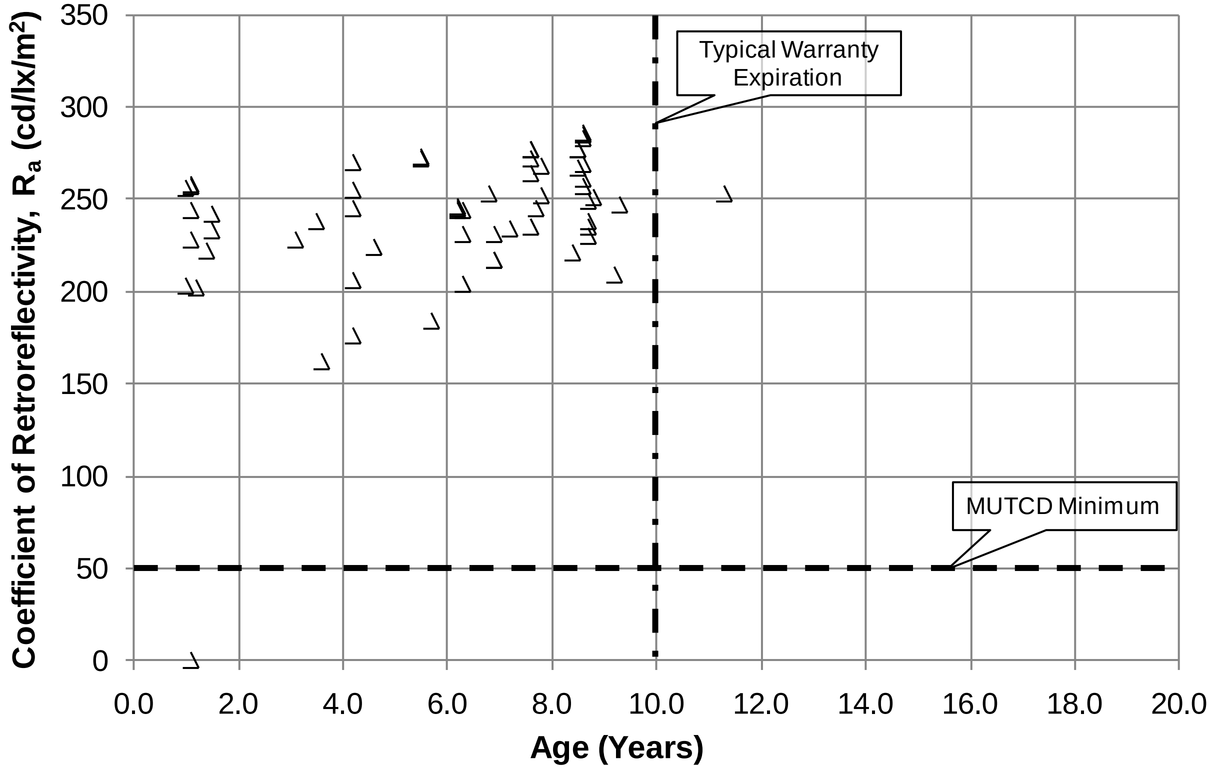
Figure A11. Type III Red Background



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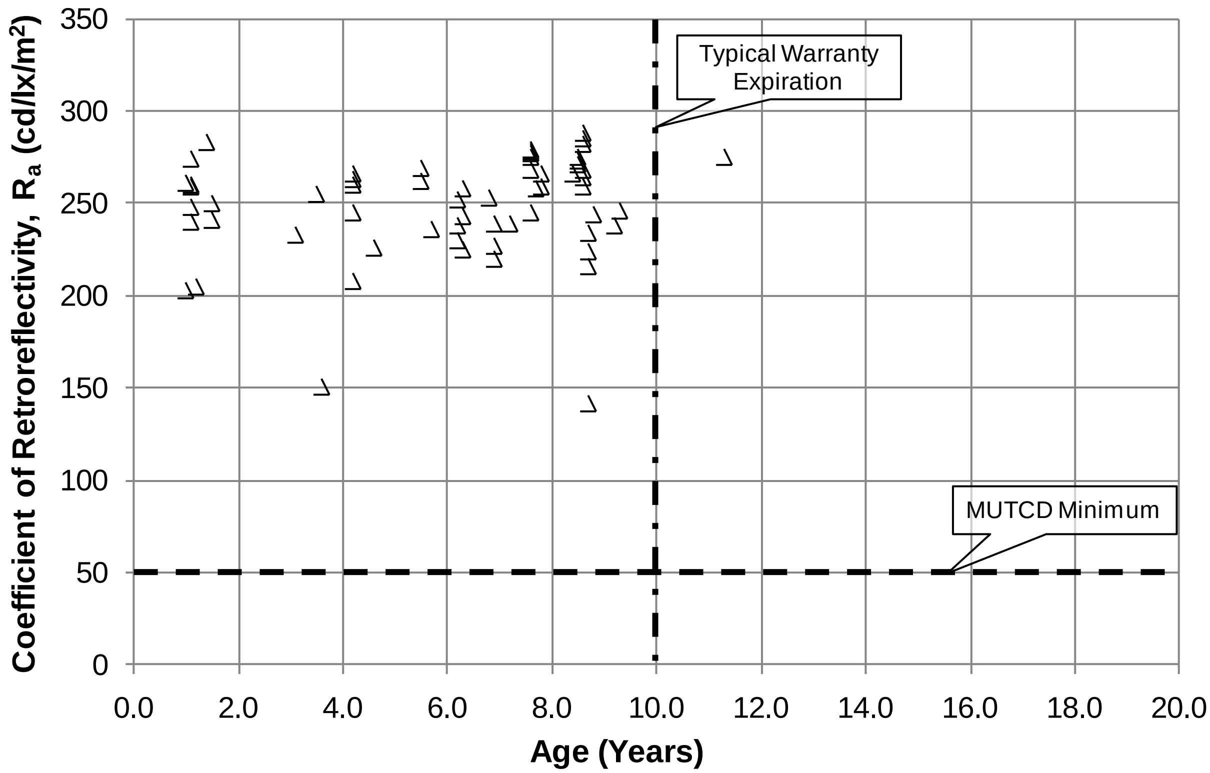

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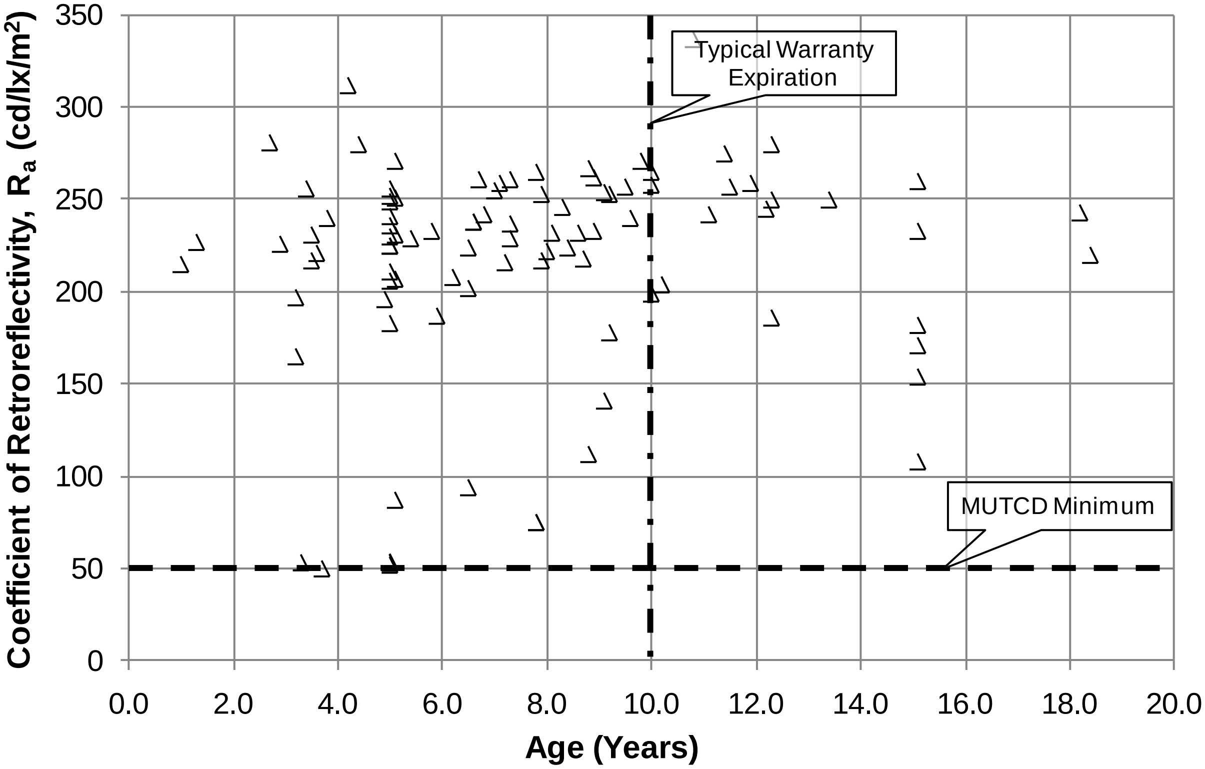
Figure A12. Type III White Background



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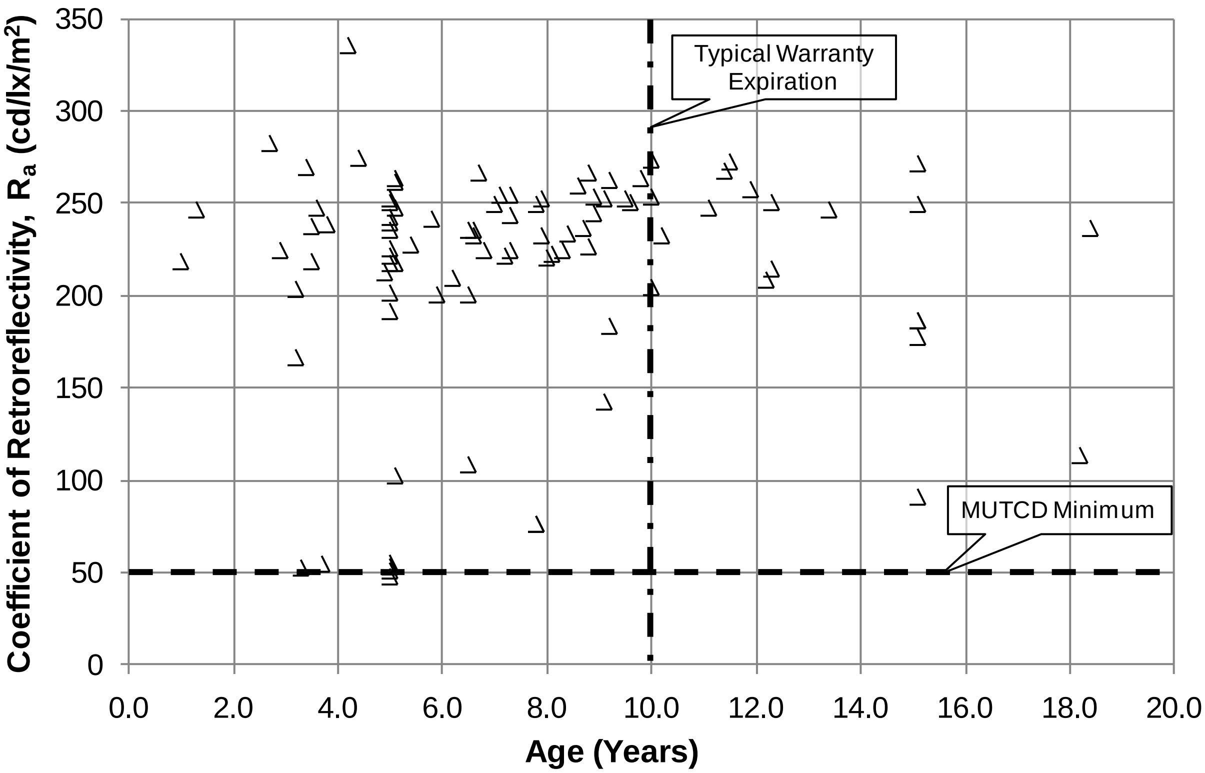

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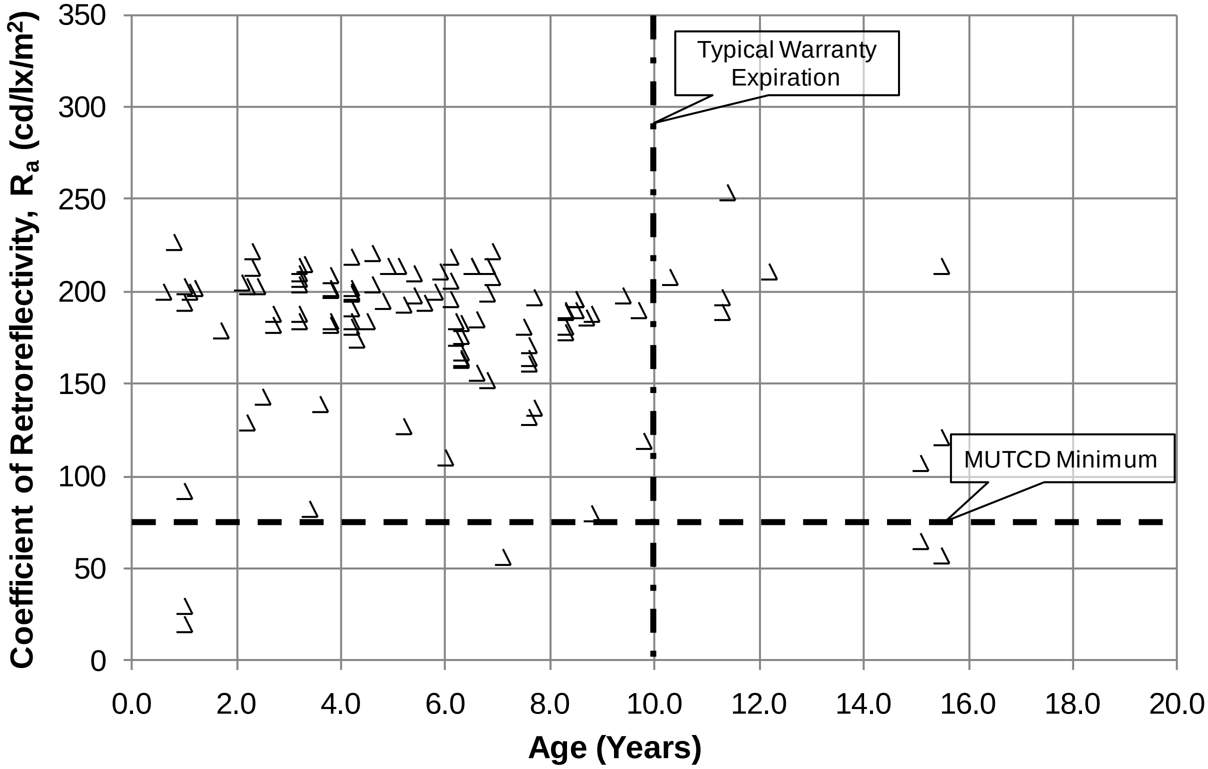
Figure A13. Type III White Legend



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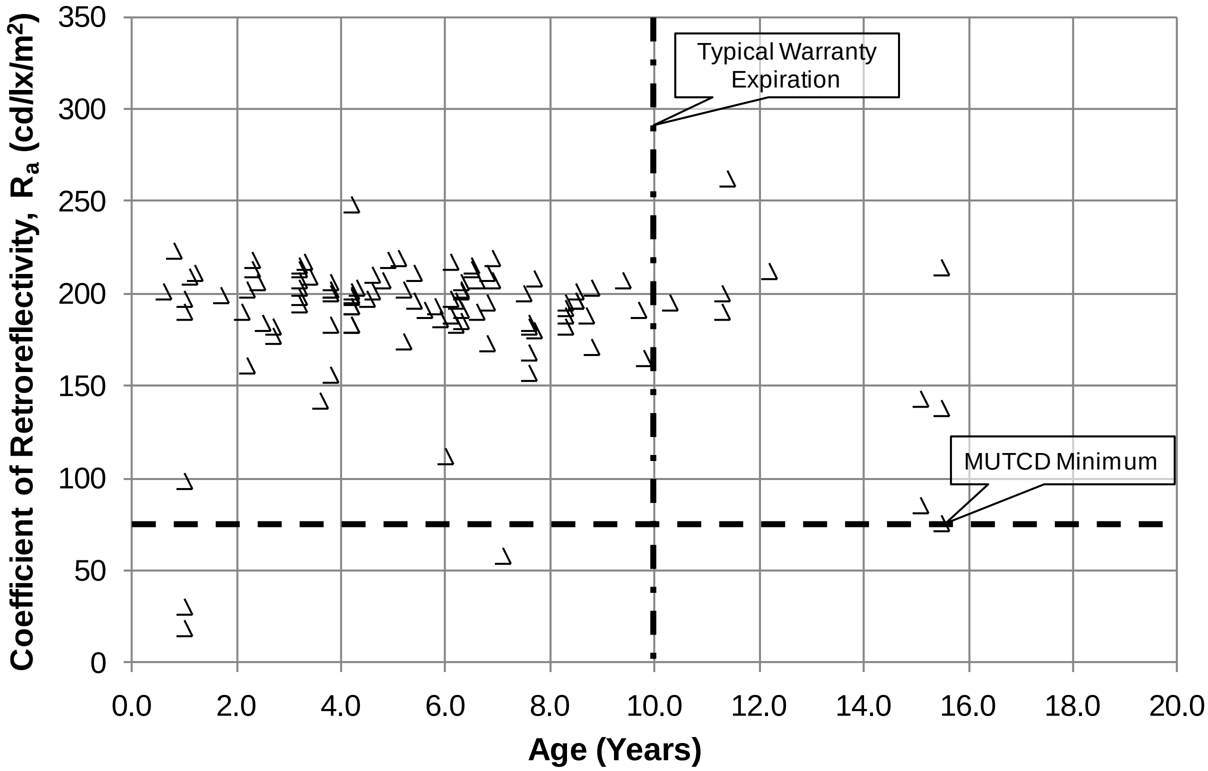

b) Wiped

Figure A14. Type III Yellow Background