CIVIL ENGINEERING STUDIES
Illinois Center for Transportation Series No. 10-065
UILU-ENG-2010-2005
ISSN: 0197-9191

TEXAS - AASHTO RETROREFLECTIVE SIGN SHEETING SPECIFICATIONS

Prepared By
Liang Y. Liu
University of Illinois at Urbana-Champaign

Research Report ICT-10-065

A report of the findings of
ICT-R27-SP14
AASHTO Retroreflective Sign Sheeting Specifications

Illinois Center for Transportation

March 2010

Technical Report Documentation Page

1. Report No.
FHWA-ICT-10-065

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Texas - AASHTO Retroreflective Sign Sheeting Specifications

5. Report Date
March 2010

6. Performing Organization Code

7. Author(s)
Liang Y. Liu

8. Performing Organization Report N o.
ICT-10-065
UILU-ENG-2010-2005

9. Performing Organization Name and Address
Illinois Center for Transportation
Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign
205 N. Mathews Ave., MC-250
Urbana, IL 61801

10. Work Unit (TRAIS)

11. Contract or Grant No.
ICT-R27-SP14

12. Sponsoring Agency Name and Address
Illinois Department of Transportation
Bureau of Materials and Physical Research
126 East Ash Street
Springfield, IL 62704

13. Type of Report and Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The Illinois Department of Transportation (IDOT) was appointed to chair an American Association of State Highway and Transportation Officials' (AASHTO) effort to develop a specification that will simplify and improve how sign sheeting materials will be specified for state DOTs. At the same time, ASTM began efforts to modify their specifications which over the years have expanded to the point that each type that is specified is unique to a single producer. To address the true differences in the performance of these materials TxDOT and TTI (Texas Transportation Institute) conducted a sign sheeting research demonstration, "Standard Specification for Retroreflective Sheeting for Traffic Control," held on May 21-22, 2009, in College Station, Texas. The two entities hosted the event in which manufacturers, industry, and end users joined forces to attempt to resolve questions regarding how drivers perceive retroreflective sign materials. This report contains the proceedings of the field trip experience from the May demonstration in Texas and summarizes the discussions leading to a final draft specification (7/25/09) that was distributed to the AASHTO Subcommittee on Materials Tech Section 4d Sign Sheeting Task Force. This effort led to a new AASHTO Standard Specification for Retroreflective Sheeting for Traffic Control (M 268-09).

17. Key Words
Sign sheeting; retroreflective materials; traffic control

18. Distribution Statement
No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

ACKNOWLEDGMENT, DISCLAIMER, MANUFACTURERS' NAMES

This publication is based on the results of ICT-R27-SP14, Texas - AASHTO Retroreflective Sign Sheeting Specifications. ICT-R27-SP14 was conducted in cooperation with the Illinois Center for Transportation; the Illinois Department of Transportation; and the U.S. Department of Transportation, Federal Highway Administration.

The Technical Review Panel consists of one member, Ms. Kelly Morse of the Illinois Department of Transportation. The author would like to thank (1) Ms. Morse for her insight and assistance during the research and (2) Mr. David Lippert, who led the American Association of State Highway and Transportation Officials' (AASHTO) effort to develop a specification that will simplify and improve how sign sheeting materials will be specified for state DOTs.

The contents of this report reflect the view of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Illinois Center for Transportation, the Illinois Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Trademark or manufacturers' names appear in this report only because they are considered essential to the object of this document and do not constitute an endorsement of product by the Federal Highway Administration, the Illinois Department of Transportation, or the Illinois Center for Transportation.

EXECUTIVE SUMMARY

Illinois DOT, under the leadership of David Lippert, was appointed chair of an American Association of State Highway and Transportation Officials (AASHTO) effort to develop a specification that will simplify and improve how sign sheeting materials will be specified for state DOTs. At the same time, ASTM has started efforts to modify their specifications which over the years have expanded to the point that each type that is specified is unique to a single producer. To address the true differences in the performance of these materials TxDOT and TTI (Texas Transportation Institute) conducted a sign sheeting research demonstration, "Standard Specification for Retroreflective Sheeting for Traffic Control," held on May 21-22, 2009, in College Station, Texas. The two entities hosted an event in which manufacturers, industry, and end users joined forces to attempt to resolve some questions regarding how humans perceive retroreflective sign materials.

Kelly Morse (IDOT) and Liang Liu (ICT researcher) attended the demonstration which evaluated various retroreflective sign sheeting materials. The demonstration helps solidify components of the specification based upon human factors and field performance data. Additionally, the demonstration allows both government agencies and manufacturers the opportunity to address any remaining questions regarding the specification criteria and the validity of the proposed standard specification. Specifications were drafted for balloting through AASHTO's Subcommittee on Materials regarding performance factors of retroreflective sign sheeting as a result of this work. Technical input was needed to aid in simplifying the specifications with considerations gained from the demonstration effort. Development and adoption of improved specifications from this effort would then be seen on the roadways in Illinois and nationally by improved signing and delineation that would better meet the drivers' needs while providing the greatest amount of competition between vendors and value to the public.

The objective of this project is for ICT to provide support in reviewing the TXDOT/TTI demonstration and provide input into the proposed sign sheeting specifications modifications for AASHTO and Illinois DOT.

This report presents (1) the proceedings of the field demonstration and (2) description of efforts and discussions among committee members leading to a draft AASHTO sign sheeting specification (dated 7/25/09). This draft specification was sent to the AASHTO Subcommittee on Materials Tech Section 4d Sign Sheeting Task Force for wider distribution and comments on July 30, 2009, and this effort led to a new Standard Specification for Retroreflective Sheeting for Traffic Control (AASHTO Designation: M268-09).

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

1. 1 BACKGROUND

IDOT was appointed to chair an American Association of State Highway and Transportation Officials (AASHTO) effort to develop a specification that will simplify and improve how sign sheeting materials will be specified for state DOTs. At the same time, ASTM has started efforts to modify their specifications which over the years have expanded to the point that each specified type is unique to a single producer. To address the true differences in the performance of these materials TXDOT and TTI conducted a sign sheeting research demonstration, "Standard Specification for Retroreflective Sheeting for Traffic Control," held on May 21-22, 2009, in College Station, Texas. The two entities hosted an event in which manufacturers, industry and end users worked together to attempt to resolve some questions regarding how humans perceive retroreflective sign materials.

1.2 RESEARCH NEEDS

Attending the May 21-22 demonstration provided IDOT personnel with a better understanding of the variety of signs installed with different properties. The demonstration solidified components of the specification based upon human factor information and field performance data. Furthermore, the demonstration allows both government agencies and manufacturers the opportunity to answer any remaining questions regarding the specification criteria and the validity of the proposed standard specification. Kelly Morse (IDOT) served as the key writer for an AASHTO Task Force that was addressing many specification items and procedures. Specifications were drafted for balloting through AASHTO's Sub-committee on Materials regarding performance factors of retroreflective sign sheeting as a result of this work. Technical input was needed to aid in simplifying the specifications with considerations gained from the demonstration effort.

Support at this demonstration enhances the current Illinois specification by answering performance and human perception questions that are typically difficult to understand and interpret into specification requirement values. Development and adoption of improved specifications from this effort would then be seen on the roadways in Illinois and nationally by improved signing and delineation that would better meet the drivers' needs while providing the greatest amount of competition among venders and value to the public.

1.3 RESEARCH OBJECTIVE

The objective of this project is for ICT to provide support in reviewing the TXDOT/TTI demonstration and provide input into the proposed sign sheeting specifications modifications for AASHTO and Illinois DOT.

1.4 RESEARCH TEAM

This research was carried out by Liang Y. Liu, Associate Professor, Department of Civil and Environmental Engineering via an ICT (Illinois Center for Transportation) contract. Ms. Kelly Morse of IDOT chairs the Technical Review Panel. Liu and Morse attended the field tests on May 21 and 22 in College Station, Texas conducted by researchers from TTI (Texas Transportation Institute).

1.5 ORGANIZATION OF REPORT

Chapter 1 contains information on background, research needs, objectives, and the research team. Chapter 2 presents the proceedings of the field trip experience and the results from the tests. Chapter 3 concludes with the creation of the (last) 7^{th} AASHTO draft specification for retroreflective sign sheeting materials and subsequent reviews leading to a final specification. Also included in the chapter are broader impact and areas for future research. The final AASHTO Standard Specification for Retroreflective Sheeting for Traffic Control (AASHTO Designation: M 268-09) is included in the Appendix.

CHAPTER 2 TTI RETROFLECTIVE SIGN SHEETING FIELD TESTS

2.1 MEETING DATE AND AGENDA

The field tests were carried out on May 21 - 22, 2009, with the following activities:

May 21, 2009

3:50 p.m. - Meet at the TTI Riverside Campus for a refresher of the AASHTO draft specification and the test procedures

6:00 p.m. - Leave for a Tex-Mex dinner at Papa Perez

8:00 p.m. - Depart for TTI Riverside to get organized for the demo

9:00 p.m. - Field tests starts

11:20 p.m. - Field test ends

11:30 p.m.- Discussion starts

May 22, 2009

12:40 a.m. - Discussion ends and meeting adjourned

2.2 PARTICIPANTS

Iindividuals who participated in the field tests include Bernie Arseneau (MnDOT), Charlie Wicker (TxDOT), Arturo Perez (TxDOT), Darren Hazlett (TxDOT), Johnnie Miller (TxDOT), Henry Lacinak (AASHTO), Karl Janak (TxDOT), Greg Schertz (FHWA), Carl K. Andersen (FHWA), Jeff Seiders (TxDOT), Michael Chacon (TxDOT), Meg Moore (TxDOT), Kelly Morse (IDOT), Liang Liu (University of Illinois at Urbana-Champaign), Paul Carlson (TTI), and Wade Odell (TxDOT).

2.3 TEST SITE

The field tests were conducted at the runways of a World War II era airport which is used by TTI for transportation research. TTI is located at 3100 State Highway 47, Building 709, Bryan, TX 77807 on the Texas A& M University, Riverside campus.

Figure 2.1. Texas Transportation Institute

Figure 2.2. Field Tests at Old Airport Runways

2.4 FIELD TEST OBJECTIVES

The field tests were a joint effort by AASHTO and TxDOT; they share common objectives with slight variations in focus areas.

ASHTO Demo Objectives:

1. Preview TxDOT sign sheeting study
2. Evaluate proposed AASHTO sheeting classification table

TxDOT Sign Sheeting Study Objectives:

1. Validate proposed AASHTO sheeting classification table
2. Study orientation to establish criteria for AASHTO specification
   a. Orientation of signs on same post (e.g., route marker assembly tree)
   b. Orientation of nested letters on guide signs
3. Assess over brightness to determine need for ceiling in retro tables

According to Paul Carlson, principal investigator of the TxDOT research, the AASHTO demo is essentially a preview of the TxDOT study. The main difference is that in the TxDOT study, the test signs are shown one at a time. In the AASHTO demo, side-by-side comparisons are used to help demonstrate the differences in the materials. The side-by-side technique helps show the similarities and differences in a qualitative manner where the user's impression will give researchers a baseline input for further study and refinement.

For the AASHTO demo, drivers and passengers drove by individually placed sign posts with test signs as shown in Figure 2.3. They were asked: Considering nighttime performance:

- is the LEFT sign better,
- is the RIGHT sign better
- or are they approximately EQUAL

There were multiple locations of the test signs and the participants drove by all the locations in one lap. Between laps, the test signs were changed and another lap was driven. This process was repeated several times. For the AASHTO demo, the qualitative responses of sign materials were grouped so that the results can be compared to the proposed AASHTO sheeting classification table. The results provide some indication of whether the sheeting table needs to be adjusted.

2.5 SIGNS AND MATERIALS

24-in square signs with border were used, as shown in Figure 2.3. Sign hardware was fabricated so that signs were easily changed and rotated as needed during the tests.

Materials used in the field tests include:

- Beaded HI (any manufacturer)
- 3M 3930 (HIP)
- 3M DG3
- AD 6500
- AD 7500
- AD 9500
- NCI 92000
- NCI 95000

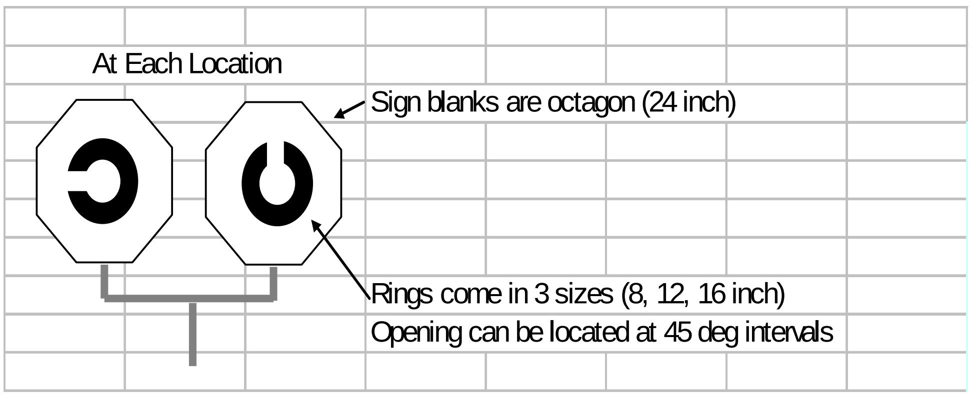


Figure 2.3. Example of sign location and test signs for AASHTO demo.

2.6 TARGETS

A Landolt C is an optotype or a standardized symbol used for testing vision. It consists of a ring that has a gap, thus looking similar to the letter C. The gap can be at various positions (usually left, right, bottom, top and the 45° positions in between). The stroke width is 1/5 of the diameter, and the gap width is the same, which is identical to the letter C from a Snellen chart. The Landolt C rings was fabricated so that signs could be easily changed and rotated as needed.

2.7 PROCEEDINGS OF THE FIELD TESTS

A total of five vehicles were used for the field tests, including two pickup trucks, an SUV, a 4-door full-size sedan, and a semi truck (no trailer). The semi carried one evaluator at a time only and the other vehicles carried three evaluators each time. All vehicles first stopped at a check point to have the high and low beam light intensity measured. On both sides of the runways, student assistants changed the types and settings of the signs with side-by-side tests in four observation stations without artificial light nearby. A total of 12 raters driving through the test zones in eight runs, five in low beam, two in high beam, and one semi (low beam). All vehicles drove by the signs at the speed of approximately 40 miles per hour. The tests lasted 2 hours 20 minutes, from 9 p.m. to 11:20 p.m.

All raters were asked to rank the signs based on their initial reaction when they viewed the signs as they drove by. They wrote down “left” sign better, “right” sign better, or “equal” on the evaluation sheet. After the field tests, all participants went back to TTI’s conference room for further discussion. The summary of the discussion is presented in

Section 2.8, and the rankings from the participants were compiled by researcher Paul Carlson of TTI and are included in Section 2.9.

2.8 DISCUSSIONS AFTER FIELD TESTS

The drive-by side-by-side comparisons of signs provided participants with the opportunities to give qualitative responses to the sign sheeting classes. Participants received hands-on experience in comparing the visibility of these signs in terms of legibility, brightness, contrast, and glare. These comparisons also served the purpose of assessing whether the differences in visibility justify different classes in defining the new specification.

After the drive-by tests, the participants gathered at the TTI conference room for a short discussion of their experience. The following is a summary of items that were discussed:

- Some participants reported halo effects on some of the signs.
- The visibility of the signs varied due to distance to the sign and vehicle type and high/low beams.
- Some signs seem sensitive to orientation.
- Was sign nesting a factor?
- Was sign geometry a factor?

The group adjourned at approximately 12:40 a.m. on May 22 and agreed to have a conference call on June 10 to further discuss the field test results and potential modifications to the draft specification.

2.9 FIELD TEST RESULTS

After the May 21 - 22 field tests, Paul Carlson compiled and reported the following results to all field test participants. The official report from the field tests, written by Paul Carlson, is currently under review by TxDOT, and is expected to be published by TxDOT and TTI in 2009 or 2010.

Carlson reported, "*We do not have much distinction between Class B and C. Class B is roughly equivalent to ASTM D4956 Types IV, VII, VIII, and X. Class C is roughly equivalent to ASTM D4956 Type IX. The results are similar to those summarized in FHWA's letter regarding sign sheeting proprietary products from 2006. We might want to consider having fewer than 4 Classes in the AASHTO spec.*"

He further summarized a comparison table with the materials used in the May 21/22 field tests with the AASHTO Draft 4 retroreflectivity tables, as listed below.

AASHTO CLASS	MATERIAL TYPE
A	AD HIB
B	3M HIP
B	AD 6500
B	AD 7500
C	AD 9500
D	3M DG3

The following are narratives of the field test report from Paul Carlson:

Headlamp: Lowbeam
Sheeting: White with 10-inch black landolt C
These results include all vehicle types unless otherwise indicated.

When A was compared to B, 96% of responses (n=28) rated B as better than A.
When A was compared to C, 86% of responses (n=14) rated C as better than A.

When A was compared to D, 93% of responses (n=26) rated D as better than A.

When B was compared to C, 18% of responses (n=28) rated C as better than B.

- *50% of responses rated the materials as equal*
- *32% of responses rated B better than C*
    - *B and C combinations were shown twice. Once with HIP and 9500 and once with 7500 and 9500.*
        - *HIP and 9500 results: equal (8), HIP (5), 9500 (1)*
        - *7500 and 9500 results: equal (6), 7500 (4), 9500 (4)*
- *Considering all the B pairings (4 combinations resulting in n=56), 63% rated them equal, 37% unequal.*
    - *Problem occurs when HIP was compared to 6500 and 7500*
        - *In three pairings of HIP versus either 6500 or 7500 (n=42), they were rated equal 57% of the time but when they were rated different, the 6500 or 7500 were rated better than HIP 83% of the time (n=18)*
        - *When 6500 and 7500 were paired, they were rated as equal 78% of the time*

When B was compared to D, 43% of responses (n=28) rated D as better than B.

- *43% of responses rated the materials as equal*

When C was compared to D, 52% of responses (n=27) rated D as better than C.

- *48% of responses rated the materials as equal*

The low "percent correct response" of 18% for the comparison of B to C may be acceptable since a key difference between grades B and C in the AASHTO Draft 4 spec is the observation angle requirements. Grades C and D can be distinguished from Grades A and B by having substantially higher observation angle requirements at 1.0 degree. In theory, the need for this distinction would be demonstrated by the evaluations from the large truck. However, the responses from the large truck when B and C materials were paired are not as expected. Three observations were made with these pairs, and they were rated equal twice and C was chosen better B once. Grades D and B were seen by 6 observers from the large truck. In this case, they were rated equal twice, D was rated better than B twice, and B was rated better than D twice. All the observations from the large truck were made with the headlamps on the lowbeam position.

Under highbeam illumination, the signs with black legend on white background were rated as being equal or at least undistinguishable more often than under lowbeam illumination. At the greatest extreme, the A-D combination had mixed results. While none of the nine participants viewed the signs as equal, 5 preferred D and 4 preferred A (all 4 commenting that Class D was too bright or too glaring). In an A-C combination, 7 participants preferred C (AD9500), while 3 preferred A, and 2 reported them as equal. Again, over brightness or glare was often cited in the remark column. There were two combinations of B-D and most of the participants felt these were equal (15 of 24) with 4 preferring D and 5 preferring B. Finally, in the case of B-B combinations, there were 18 of 24 that thought they were equal and still a fair amount of remarks concerning over-brightness.

For every 3 pairs of black-on-white signs shown, there was one white-on-green sign. Therefore, there is much less data to make inferences from. Under lowbeam illumination, the B or the A-B combination was preferred 11 of 14 times (equal was chosen once). The C of the A-C combination was preferred 11 of 14 times (equal was *chosen twice). When a C-D combination was shown, participants chose equal 10 times, and both C and D twice (n=14).*

The remaining combinations were shown with mixed sheeting. In one, a A-on-C was paired with a D-on-D. In this case, the signs were rated as equal 9 times (D-on-D was chosen twice). In another, a B-on-C was paired with a B-on-D. In this case, the signs were rated as equal 3 times (B-on-D was chosen eight times).

2.10 PHONE CONFERENCE ON JUNE 10, 2009

After the field tests on May 21 - 22, all committee members participated in a 5-location telephone conference to discuss the results from the May field tests and to further refine/modify the draft specification (Draft # 5 at the time). Paul Carlson presented the findings from the field tests, and the participants further discussed whether the performance of type B and C justify separate classifications, font size, driver age and demographic factors, viewing angles, different color and material combinations, and material quality variations.

2.11 E-MAIL EXCHANGES, DISCUSSIONS AND BALLOTS

Between June 10 and July 25, 2009, committee members exchanged e-mails and engaged in active discussions in developing a new draft specification. The committee discussed various aspects of the draft specification including (1) the types of materials, (2) daylight reflection, (3) rotation angles, (4) years of weathering, (5) coefficient of retroreflection, (6) manufacturer's choices, (7) font sizes, and (8) sign luminance. A balloting process was conducted among the committee members on Draft #6 and the comments were incorporated into the final (#7) draft specification on July 25, 2009.

CHAPTER 3 CONCLUSION

3.1 New AASHTO Draft Specification

The effort of the AASHTO committee led by David Lippert of IDOT has produced a new AASHTO sign sheeting specification. This draft specification (July 25, 2009) was sent to the AASHTO Subcommittee on Materials Tech Section 4d Sign Sheeting Task Force for wider distribution and comments on July 30, 2009. This effort led to a new Standard Specification for Retroreflective Sheeting for Traffic Control (AASHTO designation: M268-09), which is included in the appendix of this report.

3.2 Broader Impact

The broader impacts of the effort of the AASHTO committee include the following:

a. enhancement of public safety
b. promotion of innovation among sign sheeting material suppliers
c. better design specifications for highways and roads
d. uniformity in sign sheeting specification among different states

3.3 Future Research

Future research areas related to retroreflective sign sheeting include:

a. performance-based specifications
b. material improvements
c. responses from various demographic groups
d. new materials and technologies
e. degradation and performance of traffic sign materials
f. maintainability of traffic signs
g. cost effectiveness of materials
h. performance under different weather conditions
i. a drive-by vehicle-mounted inspection system to measure traffic sign retroreflectivity in real time

CHAPTER 4 REFERENCES

Bible, R.C. and N. Johnson, “Retroreflective Material Specifications and On-Road Sign Performance,” Transportation Research Record, *Journal of the Transportation Research Board*, No 1801, Paper No. 02-2788, Transportation Board of the National Academies, Washington, D.C., 2002, pp. 61-72.

Nuber, L. and D. Bullock, “Comparison of Observed Retroreflectivity Values with Proposed FHWA Minimums,” Transportation Research Record, *Journal of the Transportation Research Board*, No 1794, Transportation Board of the National Academies, Washington, D.C., 2002, pp. 29-37.

Carlson, P.J. and A. Holick, “Maximizing Legibility of Unlit Freeway Guide Signs with Clearview Font and Combinations of Retroreflective Sheeting Materials,” Transportation Research Record, *Journal of the Transportation Research Board*, No 1918, Transportation Board of the National Academies, Washington, D.C., 2005, pp. 26-34.

Carlson, P.J. and T. Urbanik II, “Validation of Photometric Modeling Techniques for Retroreflective Traffic Signs,” Transportation Research Record, *Journal of the Transportation Research Board*, No 1862, TRB, National Research Council, Washington, D.C., 2004, pp. 109-118.

Manual of Uniform Traffic Control Devices (MUTCD), 2003 Edition with Revision Numbers 1 and 2 Incorporated, U.S. Department of Transportation, Federal Highway Administration, 2007.

“Manual of Traffic Signs-Sign Sheetings,” *Traffic Sign*, www.trafficsign.us/signsheet.html, accessed May 15, 2009.

APPENDIX

Standard Specification for

Retroreflective Sheeting for Traffic Control

AASHTO Designation: M 268-09

Standard Specification for

Retroreflective Sheeting for Traffic Control

AASHTO Designation: M 268-09

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Specification for

Retroreflective Sheeting for Traffic Control

AASHTO Designation: M 268-09

1. SCOPE

1.1. This specification covers retroreflective sheeting and translucent overlay films intended for use on traffic control signs, delineators, barricades and other devices. The sheeting serves as the reflectorized background for sign messages and legends and symbols applied to the reflectorized background. Messages may be applied in opaque black or transparent colors.

1.2. All material furnished under this specification shall have been manufactured within 18 months of the delivery date. All material shall be supplied by the same manufacturer.

1.3. The values stated in inch-pound units are to be regarded as the standard.

1.4. This specification does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1. *ASTM Standards*:

- B 209, Specification for Aluminum and Aluminum-Alloy Sheet and Plate
- B 449, Specification for Chromates on Aluminum
- D 523, Test Method for Specular Gloss
- E 308, Practice for Computing the Colors of Objects by Using the CIE System
- E 810, Test Method for Coefficient of Retroreflection of Retroreflective Sheeting Utilizing the Coplanar Geometry
- E 811, Practice for Measuring Colorimetric Characteristics of Retroreflectors Under Nighttime Conditions
- E 991, Practice for Color Measurement of Fluorescent Specimens Using the One-Monochromator Method
- E 1164, Practice for Obtaining Spectrometric Data for Object-Color Evaluation
- E 1347, Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry
- E 1349, Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional (45°:0° or 0°:45°) Geometry
- E 2152, Practice for Computing the Colors of Fluorescent Objects from Bispectral Photometric Data
- E 2153, Practice for Obtaining Bispectral Photometric Data for Evaluation of Fluorescent Color
- E 2301, Test Method for Daytime Colorimetric Properties of Fluorescent Retroreflective Sheeting and Marking Materials for High Visibility Traffic Control and Personal Safety Applications Using 45°:Normal Geometry
- G 151, Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources

2.2. *Federal Standards:*

- U. S. Department of Transportation, Federal Highway Administration, Standard Color Tolerance Charts

3. DISCUSSION

3.1. The retroreflective sheeting classifications established in this specification are not intended to describe any specific materials, but are instead intended to establish meaningful minimum retroreflectivity intervals. These intervals are correlated with human performance factors by which sheeting may be classified.

3.2. Classifications are provided as a means for differentiating functional performance based on minimum retroreflectivity levels at standard combinations of entrance and observation angles. The combinations of entrance and observation angles shown in this specification provide a mechanism to categorize retroreflective sheeting materials into Type classifications. It should be recognized that performance characteristics outside these standard geometries cannot always be reasonably predicted, especially for retroreflective sheeting of microprismatic construction, and may vary between particular products meeting the same Type. It is the responsibility of the user of this specification to determine the suitability of any reflective sheeting material for its intended application.

3.3. When tested in accordance with ASTM E 810, the average coefficient of retroreflection (R_A) for a set of three samples taken from the same roll must not vary more than 20 percent between R_A measured at 0, 45, 90 and 120 degrees of rotation in order to be considered rotationally insensitive. Other rotational angles can be specified for testing by the user. The test shall be conducted at an observation angle of 0.5 degrees and an entrance angle of -4.0 degrees. Other combinations of observation and entrance angle can be specified for testing by the user. Calculate the percent difference by dividing the absolute difference between R_A (0) and R_A (45) by R_A (0). Repeat the calculation replacing R_A (45) with R_A (90) and R_A (120). R_A (0) is established with the sheeting aligned in its optimum rotation.

3.3.1. For sheeting not meeting the 20% maximum rotational sensitivity requirement, the manufacturer must provide identification marks or other features (such as a datum mark, tiles, or distinct seal pattern) in or on the sheeting face denoting the optimum orientation of the sheeting. The markings or features must be visible from a minimum distance of 2 ft. and must be arrayed in such a manner that they will be readily distinguishable on cut-out legends, symbols, or borders. The manufacturer must provide fabrication guidelines outlining optimum sheeting orientation upon user request.

3.3.2. When utilizing sheeting (for permanent signs) that does not meet the 20% maximum rotational requirement, fabricate signs by applying white sheeting for cut-out legends, symbols, borders, and route marker attachments within the parent sign face in the optimum rotation according to the identification markings; and apply all background sheeting uniformly oriented.

3.4. Delineators – Retroreflective sheeting materials suitable for use on delineators are typically of microprismatic construction. The Type of retroreflective sheeting shall be specified by the user.

3.5. Reboundable – Reboundable retroreflective sheeting materials are typically of encapsulated microscopic glass bead lens or unmetallized microprismatic construction. These materials are suitable for use on flexible impact resistant plastic devices, such as traffic drum-like channelizing devices and tubular markers, and would typically be used on all classes of rural roads, highways and urban streets. This characteristic may be specified by the user.

4. CLASSIFICATIONS

4.1. This specification establishes four Types of retroreflective sheeting, with successively increasing minimum coefficients of retroreflection. Retroreflective sheeting materials shall meet all of the performance requirements in Section 5 to qualify as a particular Type under this specification. Minimum coefficients of retroreflection are shown in Tables 6, 7, 8 and 9 for retroreflective sheeting Type A, Type B, Type C and Type D respectively. The designated Type is exclusive to the highest specified minimum R_A satisfied at observation angle of 0.5 degrees and an entrance angle of -4.0 degrees. Using higher retroreflectivity sheeting to manufacture signs where lower retroreflectivity sheeting Types are specified must be approved by the end user.

4.2. The following are general descriptions of the Types of retroreflective sheeting established by this specification. These are provided for descriptive information only and are not intended to be limitations or recommendations.

Note 1-The Manual on Uniform Traffic Control Devices (MUTCD) requires that traffic control signs, unless illuminated, be retroreflective to show the same shape and similar color both day and night. Therefore, any retroreflective sheeting materials meeting this specification would satisfy that requirement. However, when determining the appropriateness of a particular Type of sheeting for a particular application, consideration should be given to the pertinent highway characteristics where the materials will be installed, such as traffic volumes, traffic speeds, and roadway geometrics, as well as available resources. Brighter materials (meeting Type B, C or D) should be considered for use on complex roadway environments where the driving task may be more involved.

4.2.1. Type A – Retroreflective sheeting materials meeting Type A are typically constructed of encapsulated microscopic glass bead lens construction.

4.2.2. Type B – Retroreflective sheeting materials meeting Type B are typically constructed of unmetallized microprismatic optics. These triangular microprismatic materials do not have a significant 1 degree observation angle performance.

4.2.3. Type C – Retroreflective sheeting materials meeting Type C are typically constructed of unmetallized microprismatic optics. These triangular microprismatic materials have a significant 1 degree observation angle performance.

4.2.4. Type D – Retroreflective sheeting materials meeting Type D are typically constructed of unmetallized microprismatic optics. These materials have 0.5 and 1 degree observation angle performance two times greater than Type C materials.

4.3. Adhesive Backing Classes – The adhesive backing classes shall be classified as follows:

4.3.1. Class 1 – The adhesive backing shall be pressure-sensitive and require no heat, solvent, or other preparation for adhesion to smooth, clean surfaces.

4.3.2. Class 2 – The adhesive backing shall be activated by applying heat and pressure to the material. The temperature necessary to form a durable permanent bond shall be a minimum of 66°C (150°F). Reflective sheeting materials with Class 2 adhesive shall be repositionable under normal shop conditions and at substrate temperatures up to 38°C (100°F) without damage to the sheeting. Reflective sheeting materials with Class 2 adhesive may be perforated to facilitate removal of air in heat-vacuum laminators, but the perforations must be of a size and frequency such that they do not cause objectionable blemishes in the finished sign.

4.3.3. Class 3 – The adhesive backing shall be a positionable low-tack pressure-sensitive adhesive that requires no heat, solvent, or other preparation for adhesion to smooth, clean surfaces. Reflective sheeting materials with Class 3 adhesive shall be repositionable up to a temperature of 38°C (100°F) without damage to the sheeting.

4.3.4. Class 4 – The adhesive backing shall be a low-temperature pressure-sensitive adhesive that permits sheeting applications down to -7°C (+20°F) without the aid of heat, solvent, or other preparation for adhesion to smooth, dry, and clean surfaces.

5. SHEETING PROPERTIES

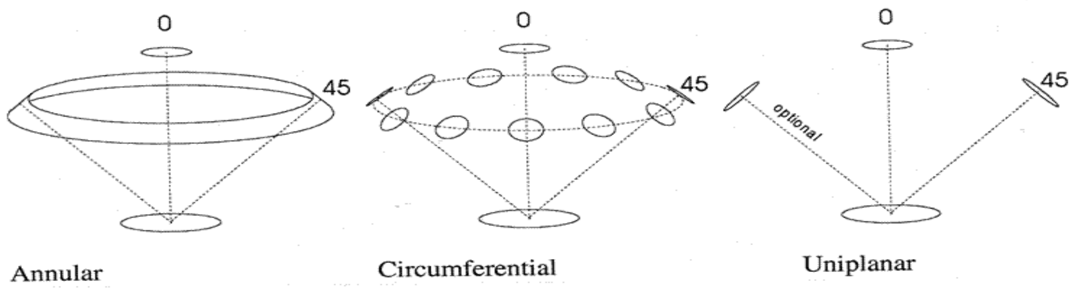
5.1. Test Conditions. Unless otherwise specified in this specification, condition all adhesively bonded and unbonded test samples and specimens at a temperature of 73 ± 3°F (23 ± 2°C) and 50 ± 5 % relative humidity for 24 hours prior to testing.

5.2. Panel Preparation. Unless otherwise specified in this specification, when tests are to be performed using test panels, apply the specimens of retroreflective material to smooth aluminum cut from Alloy 6061-T6 or 5052-H38, in accordance with Specification ASTM B 209 or ASTM B 209M. The sheets shall be 0.020 in. (0.508 mm), 0.040 in. (1.016 mm), or 0.063 in. (1.600 mm) in thickness, and a minimum of 8 by 8 in. (200 by 200 mm). Prepare the aluminum in accordance with Specification ASTM B 449, Class 2, or degrease and lightly acid etch before the specimens are applied. Apply the specimens to the panels in accordance with the recommendations of the retroreflective sheeting manufacturer.

5.3. Adhesive. The sheeting shall have a Class 1, 2, 3 or 4 adhesive as specified by the end user. For testing purposes, subject two pieces of reflective sheeting, each 2 in. by 6 in. (51 mm by 152 mm) in size, to a temperature of 160°F (71°C) and a pressure of 2.5 pounds per square inch (0.176 kg/cm^2) for 4 hours. Bring the pieces to equilibrium at standard conditions and cut one, 1 in. by 6 in. (25 mm by 152 mm) specimen from each piece and remove the liner by hand. The liner shall be removed by peeling without soaking in water or other solution, and shall not break, tear or remove any adhesive from the backing. Apply 4 in. (102 mm) of one end of each specimen to a test panel. Condition as specified in Section 5.1. Suspend the panels in a horizontal position with the specimen facing downward. The adhesive backing of the retroreflective sheeting shall produce a bond that will support a 1¾ lb (0.79kg) weight for adhesive classes 1, 2, and 3 or a 1lb (0.45kg) weight for adhesive class 4 for 5 min, without the bond peeling for a distance of more than 2 in. (51 mm). The test panel must have a minimum thickness of 0.040 in. (1.016 mm).

5.4. Liner Removal. The liner, when provided, shall be easily removed without soaking in water or other solutions, and shall not break, tear, or remove adhesive from the sheeting. The protective liner, if any, shall be easily removed following accelerated storage for 4 hours at 160°F (71°C) under a weight of 2.5 psi (17.2 kPa).

5.5. Daytime Color. Determine the chromaticity and luminance factor %Y for CIE standard illuminant D65 and the 1931 CIE 2° standard observer in accordance with Practice ASTM E 308, Test Methods ASTM E 1347, ASTM E 1349, and ASTM E 2301, and Practices ASTM E 991, ASTM E 1164, ASTM E 2152, and ASTM E 2153, as applicable. The luminance factor is the sum of the reflectance luminance factor and the fluorescence luminance factor. Bispectral measurement provides the individual factors, while measurement with simulated D65 provides their sum.



For fluorescent specimens, it is necessary either that the physical illumination of the specimen be a good approximation to illuminant D65, requiring an instrument with an appropriately filtered light source, or else that a bispectral photometer conforming to Test Method E 2301 be used.

There are three types of 45/0 (0/45) instruments: annular, circumferential and uniplanar. Measurement of prismatic sheeting with circumferential instruments may require multiple measurements. Measurement of prismatic sheeting with uniplanar instruments will require multiple measurements.

If the measurement geometry is circumferential, then the testing laboratory must verify that the apertures in the ring are sufficiently close for acceptable approximation to an annular measurement. This may depend on the optical construction of the specimen, and must be determined by the testing laboratory. Multiple measurements of the same specimen area at different rotations may be averaged to improve the approximation to an annular measurement.

If the measurement geometry is uniplanar, then a sequence of measurements shall be made on the same specimen area at incremental rotations, and the measurement values shall be taken as averages over all the rotations. The number of rotations shall be large enough for acceptable approximation to an annular measurement. The number depends on the optical construction of the specimen and must be determined by the testing laboratory.

Instruments (spectrophotometers, colorimeters) used to measure daytime color shall have 45/0 or 0/45 illumination and viewing geometry. The referee instrument shall have 10° apertures for both illumination and viewing. Use of aperture sizes deviating from these may affect the measurement results.

5.6. Nighttime color. Nighttime color shall be determined in accordance with Practice ASTM E 811 and evaluated using the CIE system in Practice ASTM E 308. (The saturation limit shall be considered to extend to the boundary of the chromaticity locus of spectral colors.) Measure using CIE Illuminant A, observation angle of 0.33 degrees, entrance angle of +5 degrees, source, and receiver apertures not exceeding 10 minutes of arc, CIE 1931 (2 degree) standard observer.

5.7. Color. When evaluated according to 5.5 and 5.6, the sheeting shall be uniform in color and devoid of streaks throughout the length of each lot or roll. Sheeting used for side by side overlay applications shall have a Hunter Lab Delta E of less than 3 units. The sheeting shall conform to the daytime and nighttime color requirements of the following tables.

TABLE 1 Daytime Luminance Factor (%*Y*)
Types A, B, C and D

Color	Minimum	Minimum for Higher Daytime Conspicuity (*)	Maximum
White	27	40	...
Yellow	15	24	45
Orange	12	14	30
Green	3.0		12
Red	2.5		15
Blue	1.0		10
Brown	1.0		9.0
Fluorescent Yellow-Green (**	60		None
Fluorescent Yellow (**)	45		None
Fluorescent Orange (**)	25		None

*Minimum values for higher daytime conspicuity are supplementary requirements that apply when specified by the end user.

**The luminance factors for fluorescent colors shown in Table 1 consist of the sum of a reflectance luminance factor and fluorescence luminance factor. The luminance factor may be determined using a good approximation to illuminant D65, requiring an instrument with an appropriately filtered light source, or a bispectral photometer conforming to Test Method ASTM E 2301 be used.

TABLE 2 Color Specification Limits (Daytime)
Types A, B, C and D

Color	1		2		3		4	
	x	y	x	y	x	y	x	y
White	0.303	0.300	0.368	0.366	0.340	0.393	0.274	0.329
Yellow	0.498	0.412	0.557	0.442	0.479	0.520	0.438	0.472
Orange	0.558	0.352	0.636	0.364	0.570	0.429	0.506	0.404
Green	0.026	0.399	0.166	0.364	0.286	0.446	0.207	0.771
Red	0.648	0.351	0.735	0.265	0.629	0.281	0.565	0.346
Blue	0.140	0.035	0.244	0.210	0.190	0.255	0.065	0.216
Brown	0.430	0.340	0.610	0.390	0.550	0.450	0.430	0.390
Fluorescent Yellow-Green	0.387	0.610	0.369	0.546	0.428	0.496	0.460	0.540
Fluorescent Yellow	0.479	0.520	0.446	0.483	0.512	0.421	0.557	0.442
Fluorescent Orange	0.583	0.416	0.535	0.400	0.595	0.351	0.645	0.355

The four pairs of chromaticity coordinates determine the acceptable color in terms of the CIE 1931 Standard Colorimetric System measured with CIE Standard Illuminant D65.

The saturation limit of green and blue may extend to the border of the CIE chromaticity locus for spectral colors.

TABLE 3 Color Specification Limits (Nighttime)
Types A, B, C and D

Color	1		2		3		4	
	x	y	x	y	x	y	x	y
White (NA)								
Yellow	0.513	0.487	0.500	0.470	0.545	0.425	0.572	0.425
Orange	0.595	0.405	0.565	0.405	0.613	0.355	0.643	0.355
Green	0.007	0.570	0.200	0.500	0.322	0.590	0.193	0.782
Red	0.650	0.348	0.620	0.348	0.712	0.255	0.735	0.265
Blue	0.033	0.370	0.180	0.370	0.230	0.240	0.091	0.133
Brown	0.595	0.405	0.540	0.405	0.570	0.365	0.643	0.355
Fluorescent Yellow-Green	0.480	0.520	0.473	0.490	0.523	0.440	0.550	0.449
Fluorescent Yellow	0.554	0.445	0.526	0.437	0.569	0.394	0.610	0.390
Fluorescent Orange	0.625	0.375	0.589	0.376	0.636	0.330	0.669	0.331

5.8. Accelerated Laboratory Weathering. Accelerated laboratory weathering will be used for provisional qualification of sheeting before the results from accelerated outdoor weathering are available. When they become available, the results from outdoor weathering take precedence over the results from laboratory-accelerated weathering tests.

5.8.1. Accelerated laboratory weathering testing will be performed for 2200 hours according to ASTM G 151 and ASTM G 155, Cycle 1. Following weathering, gently wash the panels using a soft cloth or sponge and clean water or a dilute solution of a mild detergent (1% by weight in water, maximum concentration). After washing, rinse thoroughly with clean water, and blot dry with a soft clean cloth. Following cleaning, the applied sheeting shall show no appreciable discoloration, cracking, streaking, crazing, blistering, or dimensional change. The sheeting shall exhibit a Hunter Lab Delta E of 5 or less when compared to the sample prior to exposure. In addition, the chromaticity coordinates, after exposure, must remain within the appropriate four pairs of chromaticity values listed in Tables 2 and 3. Following accelerated outdoor weathering, the sheeting shall exhibit a minimum of 80 percent of the coefficient of retroreflection for the particular Type as listed in Tables 4, 5, 6 and 7.

5.8.2. Accelerated laboratory weathering testing may be performed by an alternate method, as identified in ASTM G 151, as approved by the user.

5.9. Accelerated Outdoor Weathering. Accelerated outdoor weathering will be performed at an acceptable location as approved by the user, or by default, in climates equivalent to Phoenix, AZ and Miami, FL. Sheeting material shall be open backed and placed on an outdoor rack with a 45 degree angle facing the equator. Labeling, conditioning and handling of panels prior to exposure and during evaluation periods shall be in accordance with ASTM Practice G 147. The sheeting will be evaluated annually for three years. Following weathering, gently wash the panels using a soft cloth or sponge and clean water or a dilute solution of a mild detergent (1% by weight in water, maximum concentration). After washing, rinse thoroughly with clean water, and blot dry with a soft clean cloth. After washing and drying, condition the panels at room temperature for at least 2 hours prior to conducting any measurements. After panels have been washed, dried, and conditioned, the applied sheeting shall show no appreciable discoloration, cracking, streaking, crazing, blistering, or dimensional change. The sheeting shall exhibit a Hunter Lab Delta E of 5 or less when compared to the sample prior to exposure. In addition, the chromaticity coordinates, after exposure, must remain within the appropriate four pairs of chromaticity values listed in Tables 3 and 4. Following accelerated outdoor weathering, the sheeting shall exhibit a minimum of 80 percent of the coefficient of retroreflection for the particular Type as listed in Tables 4, 5, 6 and 7.

5.10. Shrinkage. Condition a 9 in. (230mm) by 9 in. (230mm) retroreflective sheeting specimen with liner, a minimum of 1 hour at standard conditions (see 5.1). Remove the liner and place the specimen on a flat surface with the adhesive side up. Ten minutes after the liner is removed and again after 24 hours, measure the specimen to determine the amount of dimensional change. The sheeting shall not shrink in any dimension more than 1/32 in. (0.8 mm) in ten minutes and not more than 1/8 in. (3 mm) in 24 hours.

5.11. Workability. The sheeting shall show no cracking, scaling, pitting, blistering, edge lifting, inter-film splitting, curling, or discoloration when processed and applied using mutually acceptable processing and application procedures.

5.12. Positionability. Sheeting, with Class 3 adhesive, used for manufacturing legends and borders shall provide sufficient positionability during the fabrication process to permit removal and reapplication without damage to either the legend or sign background and shall have a plastic liner suitable for use on bed cutting machines. Thereafter, all other adhesive and bond requirements contained in the specification shall apply.

Positionability shall be verified by cutting 4 in. (100 mm) letters E, I, K, M, S, W, and Y out of the positionable material. The letters shall then be applied to a sheeted aluminum blank using a single pass of a two pound roller. The letters shall sit for five minutes and then a putty knife shall be used to lift a corner. The thumb and fore finger shall be used to slowly pull the lifted corner to lift letters away from the sheeted aluminum. The letters shall not tear or distort when removed.

5.13. Thickness. The thickness of the sheeting without the protective liner shall be less than or equal to 0.015 in. (0.4 mm), or 0.025 in. (0.6 mm) for prismatic material.

5.14. Processing. The sheeting shall permit cutting and color processing according to the sheeting manufacturer's specifications at temperatures of 60 to 100 °F (15 to 38 °C) and within a relative humidity range of 20 to 80 percent. The sheeting shall be heat resistant and permit forced curing without staining the applied or unapplied sheeting at temperatures recommended by the manufacturer. The sheeting shall be solvent resistant and capable of being cleaned with VM&P naphtha, mineral spirits, and turpentine.

5.14.1. Transparent color and opaque black inks shall be single component and low odor. The inks shall dry within eight hours and not require clear coating. After color processing on white sheeting, the sheeting shall show no appreciable discoloration, cracking, streaking, crazing, blistering, or dimensional change when tested for durability (5.9 and 5.10). The ink on the weathered, prepared panel shall exhibit a Hunter Lab Delta E of 5 or less when compared to the original.

5.14.2. Transparent color electronic cutting films shall be acrylic. After application to white sheeting, the films shall show no appreciable discoloration, cracking, streaking, crazing, blistering, or dimensional change when tested for durability (5.9 and 5.10). The films on the weathered, prepared panel shall exhibit a Hunter Lab Delta E of 5 or less when compared to the original.

5.14.3. Black screen ink, when applied to white sheeting, must be completely opaque.

5.15. Transparent colors screened, or transparent acrylic electronic cutting films, on white sheeting, shall meet the minimum coefficient of retroreflection values as listed in Tables 4, 5, 6 and 7 for the color applied. After accelerated laboratory and accelerated outdoor testing, the colors shall retain a minimum 80 percent of the coefficient of retroreflection as listed in Tables 4, 5, 6 and 7.

5.16. Identification. The sheeting shall have a distinctive overall pattern in the sheeting unique to the manufacturer. If material orientation is required for optimum retroreflectivity, permanent orientation marks shall be incorporated into the face of the sheeting. Neither the overall pattern nor the orientation marks shall interfere with the reflectivity of the sheeting.

5.17. Packaging. Both ends of each box shall be clearly labeled with the sheeting type, color, adhesive type, manufacturer's lot number, date of manufacture, and supplier's name. Material Safety Data Sheets and technical bulletins for all materials shall be furnished to the Agency with each shipment.

5.18. Coefficient of Retroreflection. The coefficient of retroreflection (R_A) is expressed using the units of cd/lux/m^2 (cd/fc/ft^2) and determined in accordance with ASTM E 810. When no rotation angle is specified, measurements are taken at 0 and 90 degrees and then averaged. Compliance with the minimum coefficient of retroreflection for the 1.0° observation angle is required for Types C and D. Compliance with the minimum coefficient of retroreflection for the 1.0° observation angle is required for Types A and B when specified by the end user.

Table 4 - Minimum Coefficient of Retroreflection (R_A) for Type A Sheeting

Observation Angle (deg.)	Entrance Angle (deg.)	White	Yellow	Orange	Red	Green	Blue	Brown
0.2	-4	240	180	90	35	25	12	7.5
0.2	+30	120	90	45	20	12	6.0	3.5
0.5	-4	95	70	35	15	9.5	4.5	3.0
0.5	+30	50	35	20	7.0	4.5	2.5	1.5
1.0	-4	4.5	3.5	1.8	0.7	0.5	0.3	0.2
1.0	+30	2.5	2.0	1.0	0.5	0.3	0.2	0.1

Table 5 - Minimum Coefficient of Retroreflection (R_A) for Type B Sheeting

Observation Angle (deg.)	Entrance Angle (deg.)	White	Yellow	Orange	Red	Green	Blue	Brown	FYG	FY	FO
0.2	-4	335	250	125	50	35	17	10	270	200	100
0.2	+30	120	85	45	17	12	6.0	3.5	95	70	35
0.5	-4	135	100	50	20	14	6.5	4.0	110	80	40
0.5	+30	45	35	17	7.0	4.5	2.5	1.5	35	25	15
1.0	-4	15	12.5	6.5	2.5	1.5	1.0	0.5	15	10	5.0
1.0	+30	5.5	4.5	2.5	1.0	0.5	0.3	0.2	4.5	3.5	1.5

Table 6 - Minimum Coefficient of Retroreflection (R_A) for Type C Sheeting

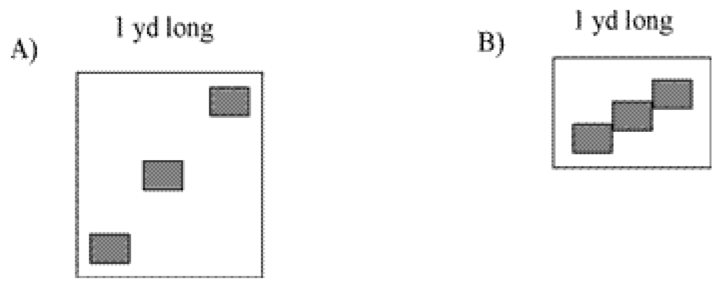
Observation Angle (deg.)	Entrance Angle (deg.)	White	Yellow	Orange	Red	Green	Blue	Brown	FYG	FY	FO
0.2	-4	580	440	220	85	60	30	17	465	350	175
0.2	+30	200	150	75	30	20	10	6.0	160	120	60
0.5	-4	235	175	85	35	25	12	7.0	190	140	70
0.5	+30	80	60	30	10	8.0	4.0	2.5	65	50	25
1.0	-4	60	45	20	8.5	5.5	3.0	1.8	45	35	17.5
1.0	+30	20	15	7.5	3.0	2.0	1.0	0.5	15	12	6.0

Table 7 - Minimum Coefficient of Retroreflection (R_A) for Type D Sheeting

Observation Angle (deg.)	Entrance Angle (deg.)	White	Yellow	Orange	Red	Green	Blue	Brown	FYG	FY	FO
0.2	-4	580	440	220	85	60	30	17	465	350	175
0.2	+30	200	150	75	30	20	10	6.0	160	120	60
0.5	-4	465	350	175	70	45	23	14	375	280	140
0.5	+30	160	120	60	25	16	8.0	5.0	130	95	50
1.0	-4	120	85	45	17	10	6.0	3.5	95	70	35
1.0	+30	40	30	15	6.0	4.0	2.0	1.0	35	25	12

6. SAMPLING

6.1. Sampling. A full width by 1 yard (0.9 m) long sample is selected at random to represent the entire sheet, roll or lot. Three samples will be taken from the selected sample. For the purpose of testing the coefficient of retroreflectivity, three samples shall be spaced evenly across (left, center and right) and spaced evenly down the specimen as shown below.



For determining conformance to all other requirements, single samples taken at random shall be tested.

For the purpose of testing, and qualification, producers shall include a physical sample with the following information:

6.1.1. Company name

6.1.2. Physical and mailing address

6.1.3. Company's material designation (product name, style number, etc.)

6.1.4. Contact person and phone number

6.1.5. AASHTO sheeting type

6.1.6. AASHTO backing class

APPENDIX

(Non-mandatory Information)

A1. *PROCEDURE FOR ESTABLISHMENT OF MINIMUM COEFFICEINTS OF RETROREFLECTION*

A1.1. *The retroreflective sheeting grades established in this specification are not intended to describe any specific materials. The following information serves to explain the theory and research applied to the creation of the values.*

A1.1.1. *White Sheeting – for white sheeting within a particular grade, the relationships for minimum coefficients of retroreflection for the various standard combinations of observation and entrance angles are shown in Table A1.1.*

A1.1.2. *Notes – The basic facts for each value listed in the tables for the coefficient of retroreflection are found in Table A1.2.*

A1.1.3. *Colored Sheeting – For colored sheeting within a particular grade, the factors shown in Table A1.3 are applied to the minimum coefficients of retroreflection obtained for white sheeting for that grade in Table A1.1.*

Table A1.1 Minimum Coefficients of Retroreflection (R_A) for White Sheeting within a Grade

Observation Angle	***Entrance Angle***	***AASHTO Sheeting Type***			
		A	***B***	***C***	***D***
0.2	*-4*	*240*	*335*	*580*	*580*
0.2	*30*	*120*	*120*	*200*	*200*
0.5	*-4*	*95*	*135*	*235*	*465*
0.5	*30*	*50*	*45*	*80*	*160*
1.0	*-4*	*4.5*	*15*	*60*	*120*
1.0	*30*	*2.5*	*5.5*	*20*	*40*

Underlying thoughts

- *Build a simple specification table that is supported through research findings-for instance, psychophysical principles of vision vetted through over a century of research have shown through such mechanisms as threshold versus intensity relationships that human visual performance is roughly approximated using Weber's Law. In other words, as the baseline condition increases (in this case, sign luminance through retroreflective materials), we need larger differences in to observe measureable changes.*
- *Maintain known alpha and beta geometries from ASTM D4956*
- *The lowest class is be based on encapsulated beaded materials*
- *Previous work has shown that of all the current ASTM D4956 alpha/beta geometries, the 0.5/-4.0 combination is best correlated with performance.*

Using geometry of 0.5/-4.0, this specification uses increasing multipliers to set thresholds for class distinctions. Research has shown that the Class B and C materials have statistically longer legibility distances than Class A materials. While Classes B and C have about the same total light return, the returned light is spread more for Class C materials than it is for Class B materials. The wider spread of returned light may be useful for signs with small letters such as street name signs. Class D materials are similar to C materials in terms of the light distribution but Class D materials are more efficient with the light returned to the driver.

Table A1.2 Specific Notes for the Development of the recommendations

Obs. Angle	***Entr. Angle***	***AASHTO Sheeting Type***			
		A	***B***	***C***	***D***
0.2	*-4*	*a * 2.5*	*b * 2.5*	*c * 2.5*	*c * 2.5*
0.2	*30*	*a * 1.25*	*b * 0.875*	*c * 0.875*	*c * 0.875*
0.5	*-4*	*a*	*b = Sq. Root 2 * a*	*c = Sq. Root 3 * b*	*d = Sq. Root 4 * c*
0.5	*30*	*a * 0.5*	*b * 0.35*	*c * 0.35*	*d * 0.35*
1.0	*-4*	*a * 0.05*	*b * 0.125*	*c * 0.25*	*d * 0.25*
1.0	*30*	*a * 0.05*	*b * 0.04375*	*c * 0.0875*	*d * 0.0875*

Table A1.2 Minimum Coefficient of Retroreflection (R_A) Factors for Colored Sheeting

Yellow	***Orange***	***Red***	***Green***	***Blue***	***Brown***	***Fluorescent Yellow-Green***	***Fluorescent Yellow***	***Fluorescent Orange***
0.75	*0.38*	*0.15*	*0.10*	*0.05*	*0.03*	*0.80*	*0.60*	*0.30*

**The above factors, when applied to the coefficients for white sheeting established in Table A1.1, establish minimum coefficients of retroreflection for colored sheeting materials.*

Illinois Department of Transportation

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN