

Field Measurements of New Retroreflective Highway Sign Materials

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Introduction

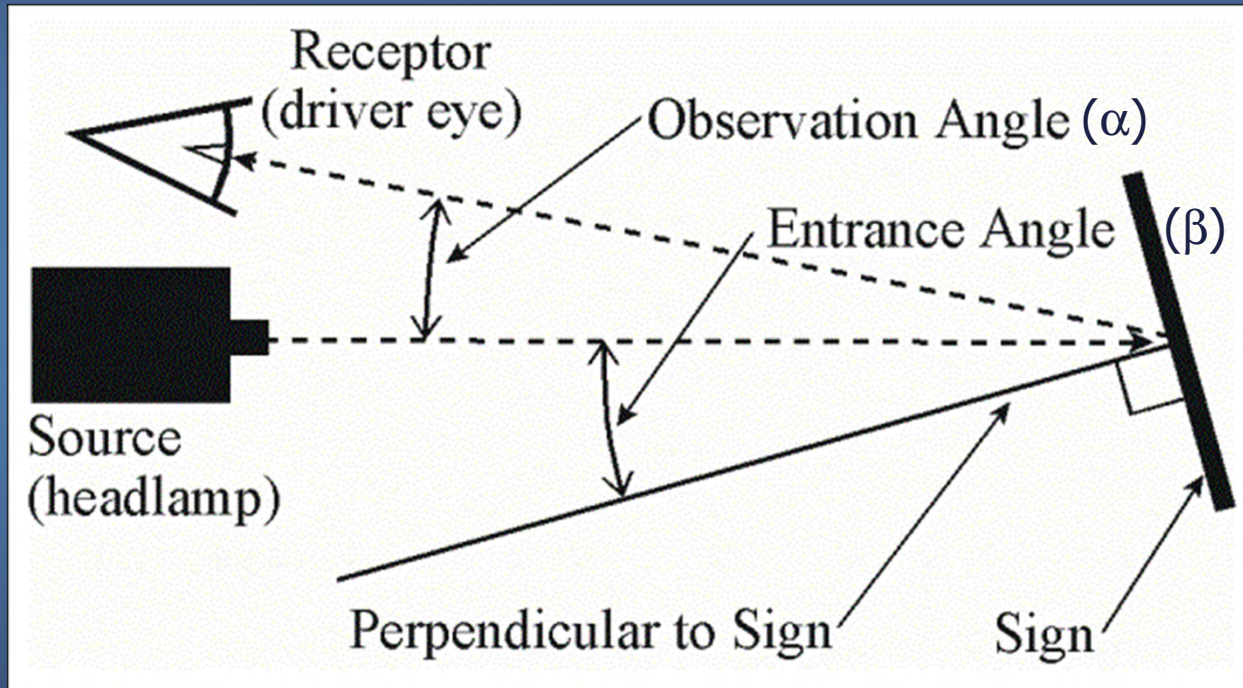


- ◆ According to AASHTO (2005) highway signs are required to be illuminated or retroreflective to ensure visibility
- ◆ External illumination systems are difficult to maintain and potentially contribute to light pollution
- ◆ New retroreflective materials are being developed that increase efficiency of headlight illumination reflected toward drivers

Retroreflective material types

- ◆ ASTM D4956: Multiple sign sheeting types designated by Roman numerals (I-XI)
- ◆ AASHTO M268: Reduced number of sheeting types designated by letters (A-D)
 - Lower type numbers/letters refer to glass bead materials, higher to prismatic/cube structures
- ◆ Retroreflectivity is specified for 3-4 **observation angles** (0.1° - 1°) and two **entrance angles** (4° , 30°)
 - Unit is cd/lx/m^2 indicating the luminance in a given direction for a given amount of incident illuminance from another given direction

Basic retroreflectivity geometry



<http://safety.fhwa.dot.gov>

Alpha (α): Observation angle
Beta (β): Entrance angle

Example type specifications

Type A

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

Type C

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

(AASHTO 2010)

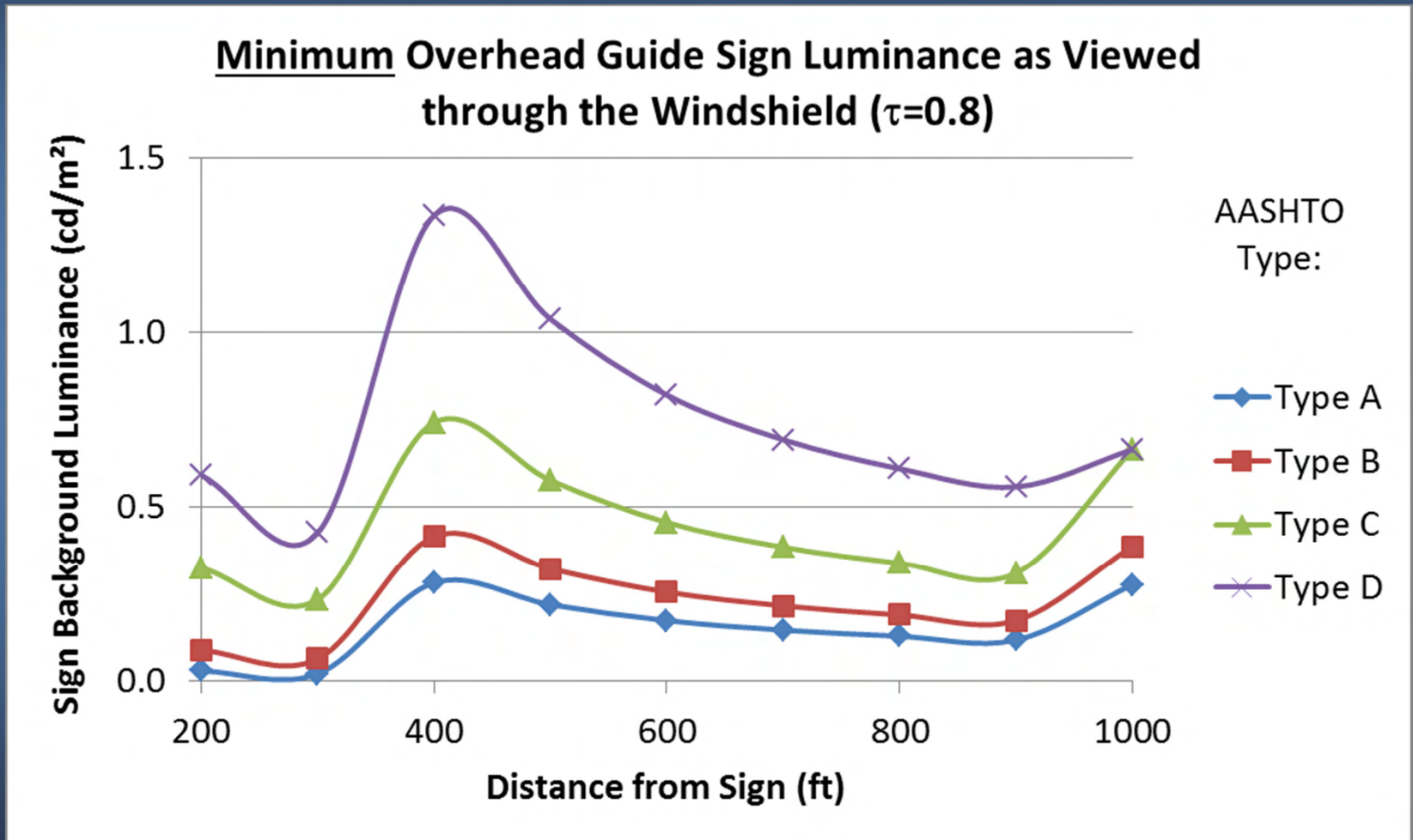
Overhead highway sign geometry and illumination

Distance (ft)	Average Observation Angle (deg)	Average Entrance Angle (deg)	Intensity Toward Sign (cd)	Illum. on Sign (lx)
200	1.00	2.40	275	0.0740
300	0.65	0.70	446	0.0533
400	0.47	0.40	552	0.0371
500	0.37	0.90	670	0.0288
600	0.31	1.20	763	0.0228
700	0.26	1.45	877	0.0193
800	0.23	1.70	1008	0.0170
900	0.20	1.83	1167	0.0155
1000	0.18	1.95	1288	0.0139

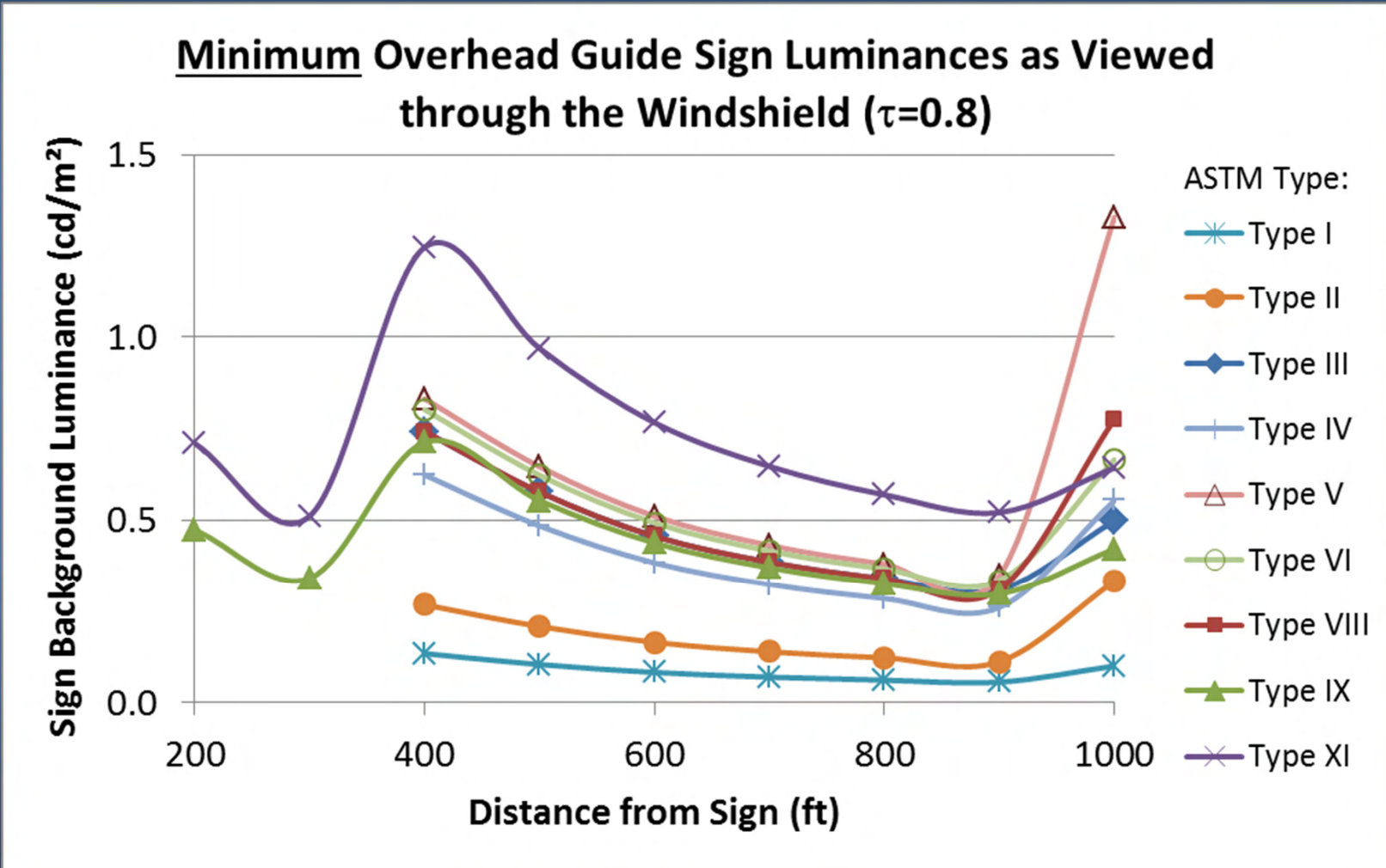
Observation Angle	Entrance Angle
≤ 0.2 degrees	≤ 4 degrees
$0.2 < x \leq 0.5$ degrees	$4 < x \leq 30$ degrees
$0.5 < x \leq 1$ degrees	

Assumes “market-weighted average” passenger vehicle dimensions (Carlson et al. 2009), 21.5 ft sign height tilted forward 3° along a straight highway section, low beam halogen headlamps (average of driver and passenger side [Schoettle et al. 2004])

Minimum overhead (green) sign luminances for different material types

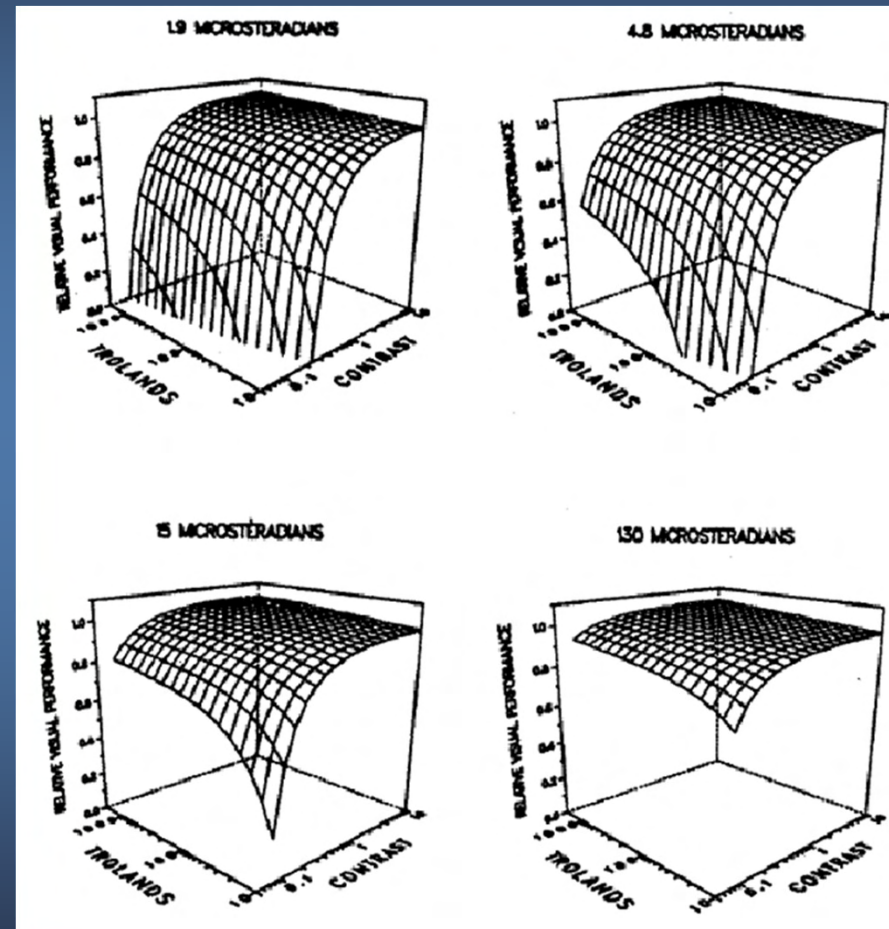


Minimum overhead (green) sign luminances for different material types



How much luminance is “enough?”

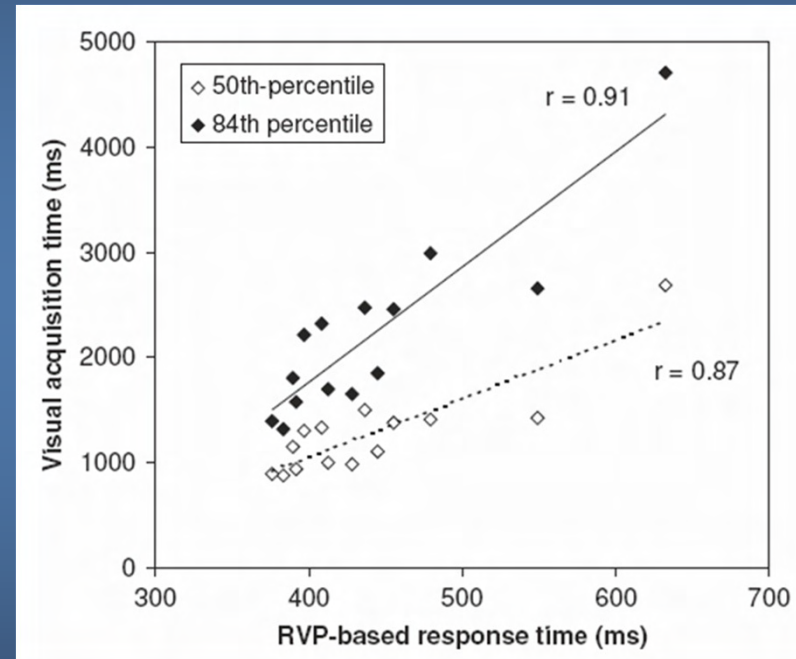
- ◆ Luminance alone cannot predict visibility
 - Contrast and size are also factors
- ◆ Relative visual performance (RVP; Rea and Ouellette 1991) indicates the relative speed and accuracy of visual processing
 - RVP=0 at legibility threshold
 - RVP=1 for a reference visual task
- ◆ RVP exhibits a plateau characteristic
 - On the plateau (RVP \geq 0.8), increased luminance, contrast or size do not substantially improve visibility



(Rea and Ouellette 1991)

Relevance of RVP to sign visibility

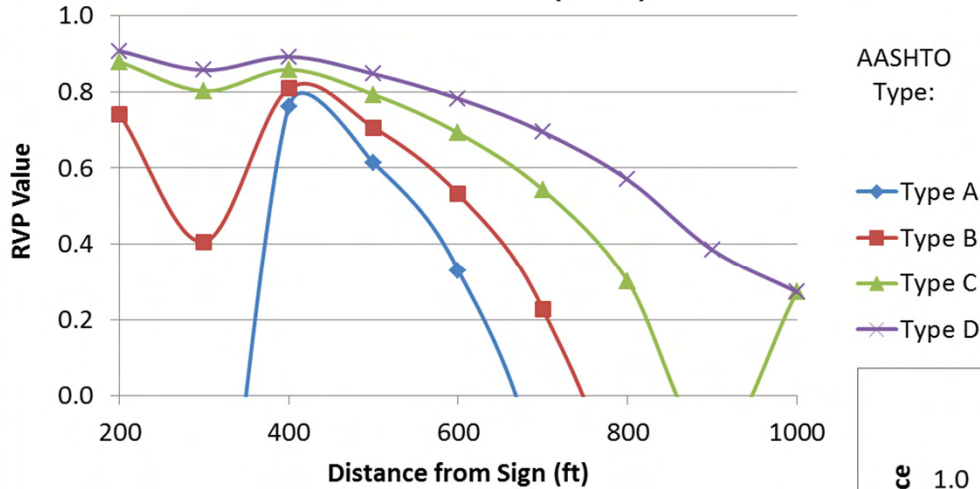
- ◆ Bailey et al. (1993) demonstrated relationship between reading speed and RVP
- ◆ Goodspeed and Rea (1999) showed RVP was directly correlated to symbol recognition times for simulated highway signs
- ◆ Visual acquisition times for signs varying in contrast and luminance (Schnell et al. 2009) were strongly correlated to RVP-based quantities



(Schnell et al. 2009)

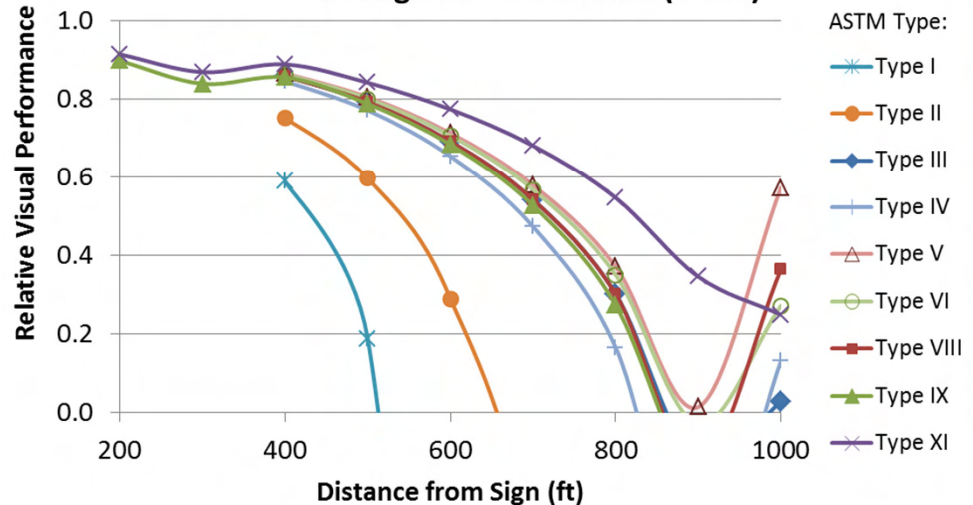
What visual performance levels do different sign material types provide?

Minimum Overhead Guide Sign RVP as Viewed through the Windshield ($\tau=0.8$)



All calculations assume a 60-year-old driver and green-white luminance contrast of 0.8

Minimum Overhead Guide Sign RVP as Viewed through the Windshield ($\tau=0.8$)



Field measurement of overhead signs

- ◆ New York State Department of Transportation (NYSDOT) installed several signs along the Bruckner/Cross-Bronx Expressways
- ◆ With traffic control provided by NYSDOT, sign background luminances were measured from within a passenger car with low beam headlamps located within the rightmost traffic lane

Location number	Sign number(s)	Direction	Mounting	Distance	Viewing Station	Comments
8	9	NB	Arm	150	8+840	
4	40, 5	NB	OH Structure	150	8+140	
1	1, 1	NB	OH Structure	200	7+695	
24	25, 42	SB	Bridge	130	9+280	
30	34, 32, 30	SB	OH Structure	200	8+490	Best view from LEFT Lane
33	34, 32, 43	SB	OH Structure	200	8+095	
36	34, 32, 37	SB	OH Structure	200*	7+850	* View at 150 m also, 7+800
38A	44, 45	SB	OH Structure	135	7+650	

distances in meters

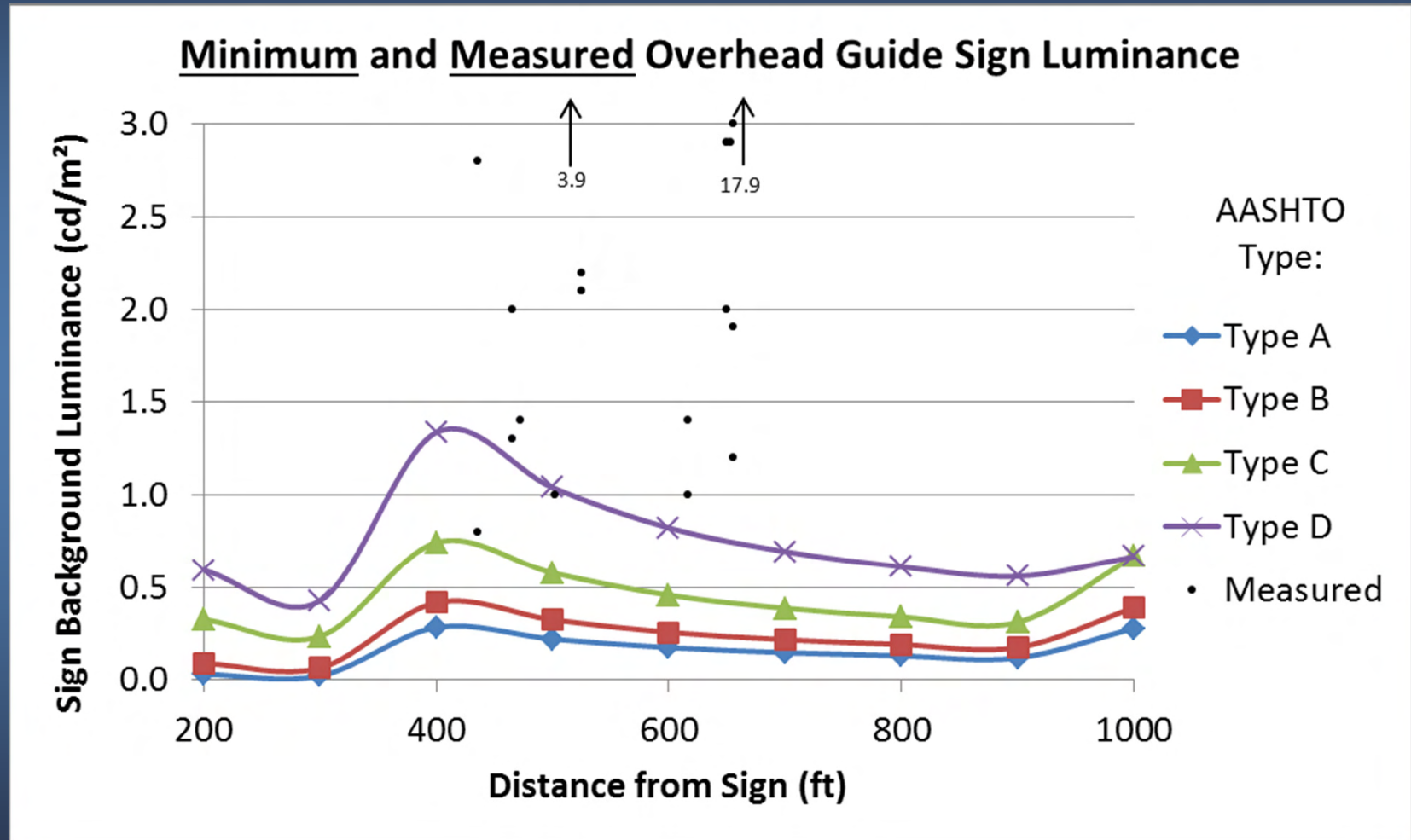
- > With headlights of test vehicle switched on and off (and traffic control vehicle headlights off) in order to estimate luminance from retroreflection
- > Signs used a variety of ASTM Type IX and XI materials (very approximately corresponding to AASHTO Type C and D, respectively)

Field measurement analysis

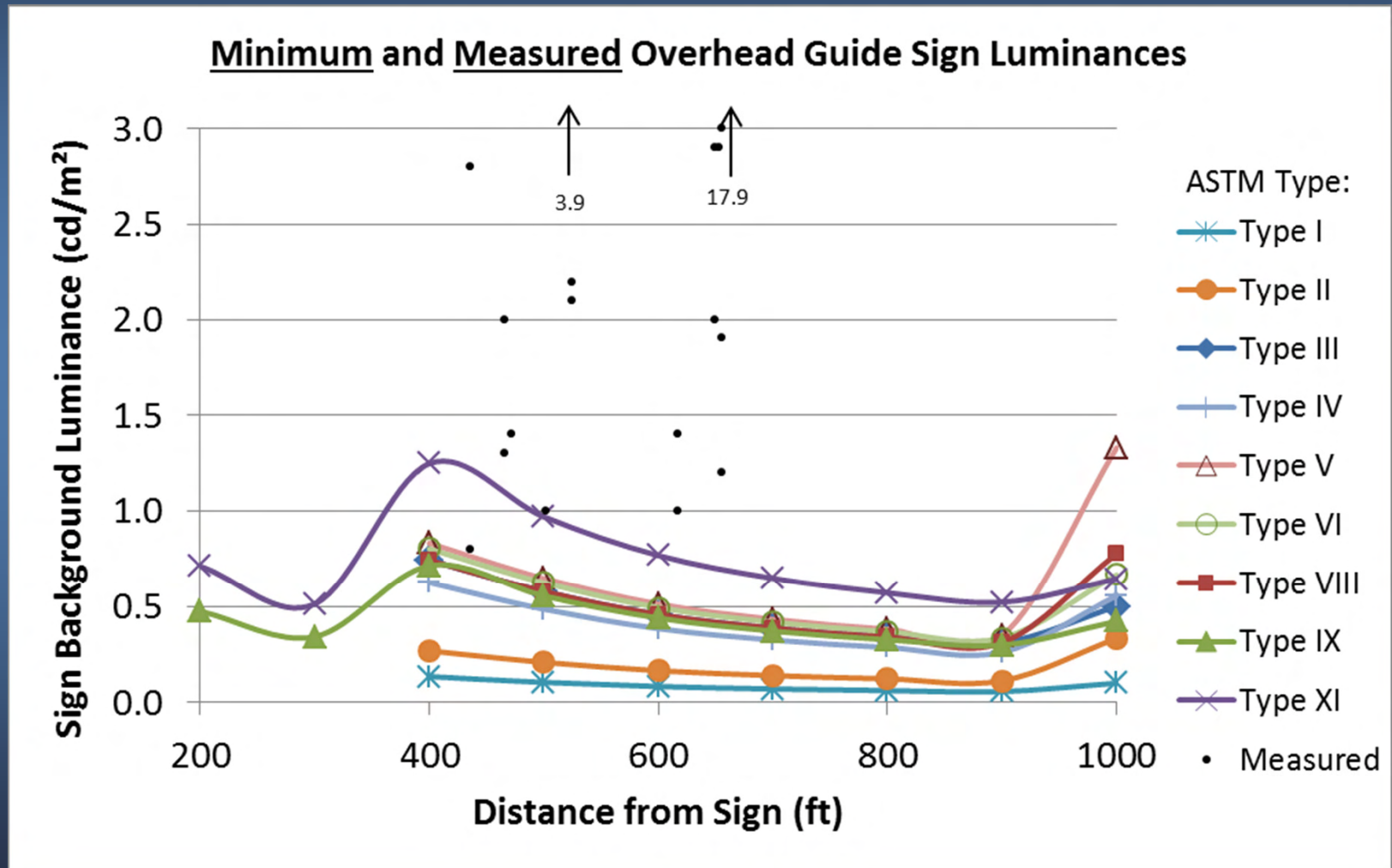
- ◆ Ambient light from other vehicles' headlights and/or adjacent streetlights contributed 0.9-4.4 cd/m² to sign luminances
- ◆ Subtracting ambient light, retroreflective luminances ranged from 0.8-17.9 cd/m²
- ◆ Data were compared to minimum levels and RVP values achieved with different material types

Northbound			
Location	Luminance (headlights on, cd/m ²)	Luminance (headlamps off, cd/m ²)	Difference (cd/m ²)
1	6.0	4.0	2.0
1	7.3	4.4	2.9
4 & 30	2.8	1.8	1.0
4 & 30	6.3	2.4	3.9
8	3.2	1.8	1.4
Southbound			
Location	Luminance (headlights on, cd/m ²)	Luminance (headlamps off, cd/m ²)	Difference (cd/m ²)
24	2.2	0.9	1.3
24	3.5	1.5	2.0
4 & 30	2.5	1.1	1.4
4 & 30	2.1	1.1	1.0
33	4.1	1.1	3.0
33	2.7	1.5	1.2
33	4.1	2.2	1.9
36 (199 m)	6.4	3.5	2.9
36 (199 m)	22.3	4.4	17.9
36 (160 m)	3.9	1.7	2.2
36 (160 m)	5.9	3.8	2.1
38A	1.7	0.9	0.8
38A	3.9	1.1	2.8

Luminances compared to AASHTO types

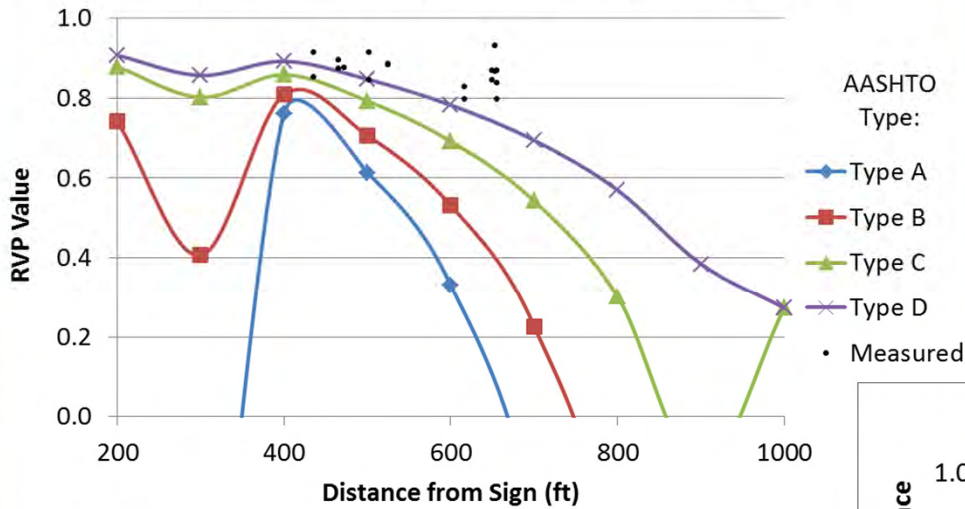


Luminances compared to ASTM types



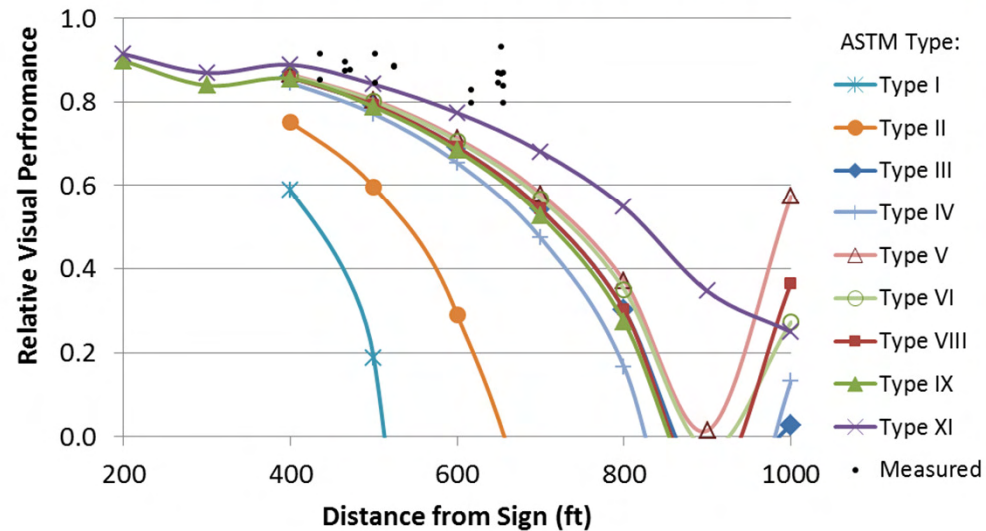
RVP values compared to different sign material types

Minimum and Measured Overhead Guide Sign RVP



All calculations assume a 60-year-old driver and green-white luminance contrast of 0.8

Minimum and Measured Overhead Guide Sign RVP



Caveats

- ◆ All field measurements made from the rightmost traffic lane
- ◆ Several signs were located 1-2 lanes to the left (minimum luminance calculations assume sign above the driving lane) and would have had higher luminances if located within the driving lane
- ◆ Variations in roadway elevation, roadway curvature, misalignment of signs are not considered at present



Discussion

- ◆ The signs measured generally met/exceeded retroreflectivity criteria for the specified sign materials
- ◆ Relative visual performance analyses indicate plateau (≥ 0.8) levels of visibility even without ambient light
 - In comparison, an externally-illuminated sign viewed between 200-1000 ft also results in an RVP value ≥ 0.8
 - This suggests that the use of new reflective material types can under certain conditions reduce the need for external illumination while maintaining visibility
- ◆ Preliminary results suggest a specification procedure based on visual performance could be practical

Acknowledgments

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