Maintaining Pavement Marking Retroreflectivity for Nighttime Safety

Over 30 years ago, Congress required the FHWA to produce a standard that agencies can use to determine when pavement markings need to be maintained. On August 5, 2022, the FHWA published a Final Rule on minimum pavement marking retroreflectivity, with an effective date just 30 days later. The Final Rule has been incorporated into the Manual on Uniform Traffic Control Devices (MUTCD), which is recognized as the national standard for traffic control devices on all streets, highways, bikeways and private roads open to public travel. The Final Rule was officially incorporated into the Revision 3 of the 2009 MUTCD and is expected to be the same in the 11th Edition. The release of that edition is imminent.

One of the primary reasons for establishing a threshold to maintain retroreflective pavement markings is to improve nighttime safety and driver visibility. According to the FHWA, the U.S. nighttime fatal crash rate is approximately three times than the daytime crash fatal crash rate, but the threshold levels that FHWA has established in the final rule are not directly based on improved safety—rather, they are mostly based on the nighttime visibility needs of older drivers. This theory is tied to safety but evidence-based research has shown that in order to improve nighttime safety for all motorists, different thresholds of retroreflectivity should be considered to drive down nighttime crash rates.

While exceptions and other factors apply, the required MUTCD minimum retroreflectivity level has been set to 50 mcd/m^2/lx for longitudinal markings on roadways with speed limits of 35 mph or greater. This applies to both white and yellow longitudinal markings. For roadways with speeds limits of 70 mph and greater, a higher level of 100 mcd/m^2/lx is suggested but not required. These conditions are based on an older driver being able to see nighttime markings with about 2.2 seconds of preview time. They do not include adverse conditions such as weather, oncoming vehicles, other glare sources, or complex backgrounds. While the MUTCD minimum pavement marking retroreflectivity levels provide some possible relief when continuous lighting is present, they do not provide relief when retroreflective pavement markers are used. The FHWA has posted reports and other additional resources for agencies on their nighttime visibility website. https://highways.dot.gov/safety/other/visibility/nighttime-visibility.

To better understand the safety impact of pavement marking retroreflectivity, researchers studied the retroreflectivity of yellow center lines on Michigan highways using nighttime crashes and single-vehicle nighttime crashes. When the yellow retroreflectivity levels were below 150 mcd/m^2/lx, nighttime crashes were found to increase at a statistically significant rate. The findings also showed that the expected crash frequency decreases as the yellow center line retroreflectivity approaches the 150 mcd/m^2/lx level. A follow-up study using the same data but by using more advanced analysis techniques, was able to establish a safety-derived minimum threshold value for the maintenance of yellow center line markings on rural two-lane highways of 175 mcd/m^2/lx.

Like most of the physical roadway features such as signs, signals, guardrails and even pavements, pavement markings wear out over time, typically faster than any other physical roadway feature on our nation's roadways. Because of this and to ensure quality, some transportation agencies specify two thresholds for retroreflective markings. The first is typically called "initial retroreflectivity requirements" and help agencies understand that they have on-hand the quality of retroreflective marking that they paid for. The second is typically called "maintenance retroreflectivity requirements" and they help agencies determine when the markings need to be restriped. Both of the initial and maintenance thresholds play a role in nighttime safety. Data from two-lane highways in Michigan and North Carolina are examples of how nighttime safety can be dramatically improved.

Example	Initial Retroreflectivity Level (mcd/m^2/lx)		Maintained Retroreflectivity Level (mcd/m^2/lx)		Estimated Average Yearly Reduction of Nighttime Crashes
	White Edge	Yellow Center	White Edge	Yellow Center	
Example A	350	225	175	175	14.8%
Example B	500	350	250	175	28.3%

In both examples, 175 mcd/m^2/lx was used to set the minimum for the yellow center line. In Example B, the white retroreflectivity levels were set brighter than yellow because everything else being equal, white markings are brighter than yellow because they do not absorb as much light. Example B also includes higher initial retroreflectivity levels than Example A.

As usual, there are many factors to consider developing a cost-effective pavement marking program. For instance, setting initial and maintenance levels for retroreflectivity is only part of the equation. Selecting the right binder material such as paint or thermoplastic as well as the correct retroreflective optic bead. Not all binder and optics wear at the same rate, therefore, measuring your markings can also be an important consideration. Measurement equipment falls in two general categories: handheld, (where a lane closure is often required to ensure worker safety) and mobile, which keeps traffic and the project moving.

Pavement markings have been successfully used on our roadways for over 100 years to help drivers navigate the roadway and they will become even more important as vehicle cameras and other sensors provide automated vehicle features. Efforts are underway now to understand how agencies can better prepare and maintain their roadways for these new technologies, which promise to improve mobility and safety, relieve congestion and save lives.

Right now, the U.S. is focused on retroreflectivity levels for markings (i.e., nighttime performance). While the automotive machine vision systems require markings night and day, there appears to be some early research showing a need for maintaining daytime visibility of markings to improve the detection of automotive machine vision systems. There is generally little attention paid to characterizing the daytime performance of markings expect their presence and sometimes their color. But as we learn more about the interaction between markings and automotive machine vision systems, we are starting to understand that we might also be looking at a daytime performance metric in addition to the nighttime performance metric we use so much today and that's retroreflectivity. Follow TMMA to learn more about the future of pavement markings.

Paul Carlson, written for Roads & Bridges, May 30, 2023

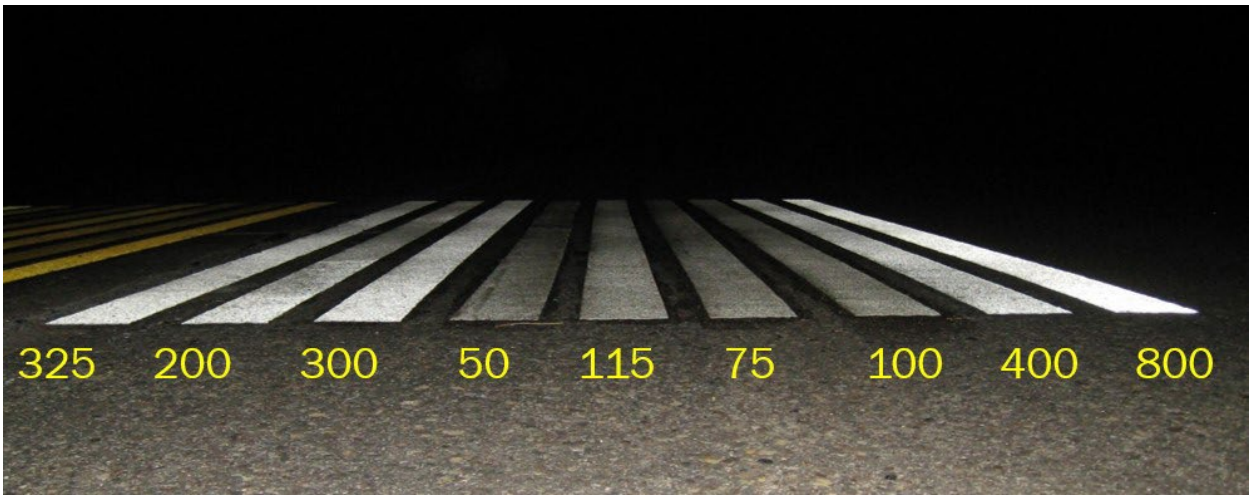

Figure 1. A nighttime photo of various levels of retroreflectivity levels

Figure 1 shows a photo of different levels of retroreflectivity for white markings. This photo is the property of Texas A&M Transportation Institute. Various factors impact the perceived brightness of markings, including retroreflectivity levels. Imagine if the lighting was half or double of that used for this photo. If enough lighting is used, a very low retroreflectivity can appear bright. Photos to show retroreflectivity can be misleading and the photo in Figure 1 should be used with care.

Figure 2. Mobile retroreflectivity equipment

Figure 2 shows a photo of measurement equipment that can be used to assess the retroreflectivity of pavement markings while traveling at highway speed (no need for lane closures or other safety vehicles). This equipment can be used day or night and measures the retroreflectivity of both adjacent lanes, including symbols, word messages, crosswalks, or other in-lane retroreflective markings.