



SURFACE VEHICLE RECOMMENDED PRACTICE

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Active Safety Roadside Concrete Divider Surrogate Recommendation

RATIONALE

Reducing road departure crashes is key for active safety systems since road departure crashes contribute to many road fatalities in the U.S. As more active safety systems—especially road departure mitigation systems (RDMS)—are introduced to the market, standard roadside object surrogates are needed for the automotive industry to test and evaluate RDMS systems. SAE International created an Active Safety Roadside Object Surrogate Target Task Force under the Active Safety Systems Standards Committee to study this topic and recommend roadside object surrogate design guidelines. The Roadside Object Surrogate Task Force aims to develop design specifications/recommendations for roadside object surrogates. The surrogates should represent real roadside objects to the sensors used in RDMS. They can be used for the performance assessment of such in-vehicle sensing systems in simulating real-world test scenarios/conditions. This document summarizes the findings and recommendations from the Roadside Object Surrogate Task Force.

INTRODUCTION

Reducing road departure crashes is one of the primary goals of active safety systems. As more active safety systems—especially road departure mitigation systems (RDMS)—are introduced, standard roadside object surrogates are needed for the automotive industry to test and evaluate RDMS systems. SAE International created an Active Safety Roadside Object Surrogate Task Force under the Active Safety Systems Standards Committee to study this topic and recommend design specifications for roadside object surrogates. All task force members are from industry, academia, and government agencies. Many members had experience using, testing, and/or developing roadside object surrogates. In addition, the task force gathered information about concrete divider surrogates known to the members and the state-of-the-art features of these surrogates. This document summarizes the findings and recommendations from the Roadside Object Surrogate Task Force.

Since the radar characteristics of concrete dividers depend on their shapes and supporting posts/blocks that vary in different countries, this task force adopts the concrete divider in the United States of America to develop the design recommendations of the surrogate concrete divider. These SAE concrete divider surrogate design recommendations are representative of 180-degree approach angles. Concrete divider surrogates for other countries may be developed similarly.

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1. SCOPE

The scope of this document is to provide the design specifications/requirements/guidelines for concrete divider surrogates that represent actual concrete dividers to the in-vehicle sensors and can be used for performance assessment of such in-vehicle sensing systems in real-world test scenarios/conditions. Therefore, this document only includes the recommended concrete divider surrogate characteristics for automotive cameras, LiDARs, and/or radars. Concrete dividers are also known as concrete barriers [1].

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J3063 Active Safety Systems Terms and Definitions

SAE J3157 Active Safety Bicyclist Test Targets Recommendation

2.1.2 Other Publications

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3. DEFINITIONS

ACTIVE SAFETY SYSTEM: Vehicle safety systems that sense and monitor conditions inside and outside the vehicle; identify perceived present and potential dangers to the vehicle, occupants, and other roadway users; and then automatically react to help avoid or mitigate crashes via various methods, including alerts, vehicle system adjustments, and active control of the vehicle motion subsystems (brakes, throttle, suspension, etc.). (SAE J3157.)

AUTOMATIC EMERGENCY BRAKING (AEB): Detects potential collisions with a vehicle ahead, provides forward collision warning, and automatically brakes to avoid a collision or lessen the severity of impact. Some systems also detect pedestrians or other objects. (SAE J3063.)

INFRARED: Have a wavelength higher than that of the red end of the visible light spectrum but less than that of microwaves. In this document, infrared refers to near-infrared radiation with a wavelength from about 800 nm to 1 mm. (SAE J3157.)

LiDAR: An active sensing technology that can measure the distance to, or other properties of, targets by illuminating the target with light and analyzing the backscattered light. (SAE J3157.)

4. SYMBOLS AND ABBREVIATIONS

AEB	Automatic Emergency Braking
CSRC	Collaborative Safety Research Center
IIHS	Insurance Institute for Highway Safety
IUPUI	Indiana University-Purdue University Indianapolis
LiDAR	Light Detection and Ranging
NHTSA	National Highway Traffic Safety Administration
OSU	Ohio State University
Radar	Radio Detection and Ranging
RCS	Radar Cross Section
TASI	Transportation Autonomous Systems Institute

5. CONCRETE DIVIDER SURROGATE RECOMMENDED SPECIFICATIONS

The concrete divider surrogate should provide sufficient details of the concrete divider characteristics to satisfy the need of all state-of-the-art detection sensors. Table 1 shows the concrete divider characteristics that potentially affect the sensing outcome. Therefore, they should be considered in the design specifications of concrete divider surrogates.

Table 1 - Concrete divider characteristics versus detection sensors

Sensor Type	Concrete Divider Characteristics			Infrared Reflectivity
	Size and Shape	Viewing Angle	Radar Reflectivity	
Camera	X	X		
76-78 GHz Radar	X	X	X	
Lidar/Active Infrared	X	X		X

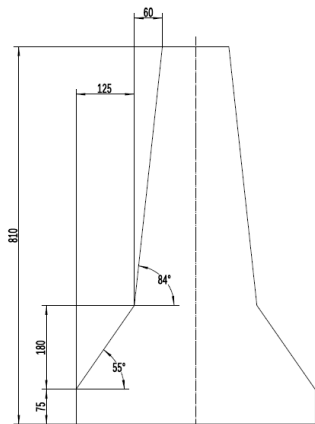
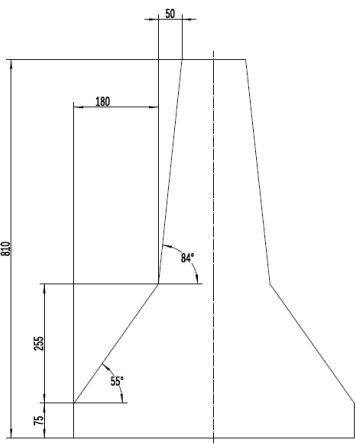
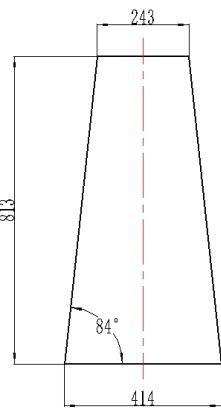
The size and shape of concrete divider surrogates affect all automotive sensors currently used for road departure mitigation. Concrete dividers have many shapes and sizes, as specified in various standards in different countries. The concrete divider has a fixed height and is continuous in length in the U.S. Some concrete dividers are coated with various surface treatment materials to improve their lifetime and appearance. Except for the concrete's thickness, all variations affect the concrete divider's camera (visual), LiDAR, or radar signatures.

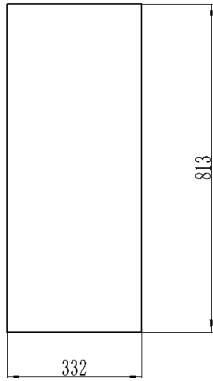
During naturalistic driving, the detection sensors are frequently exposed to concrete dividers from different horizontal and vertical angles. Assuming that the vehicle is always on the road and the roadside object is always on the roadside, the standard concrete divider surrogate must represent the characteristics of the concrete divider from all 180-degree horizontal viewing angles and -90 to 90 degrees vertical viewing angles.

5.1 Size and Shape

This document uses the most commonly seen concrete divider in the U.S. as an example for specifying the design specifications of the surrogate concrete divider. Concrete divider surrogates for other countries may be developed similarly. The concrete dividers in the U.S. are F-shape, New Jersey shape, and single-slope shape (see Table 2) [2]. The most common shapes are the F-shape and the New Jersey shape. The dimensions of the concrete divider for the standard crash test are described in Chapter 6 of NCHRP Report 350 (see Figure 1) [3].

Table 2 - The types and distribution of concrete dividers were observed in 856 locations in the U.S.

Types	Example	Number and Percentage of Random Samples in the U.S.	Dimensions (in mm)
Type 1 (F-Shape) New Generation		185 (21.61%)	
Type 2 (New Jersey Shape) Old Generation		208 (24.30%)	
Type 3 (Single- Slope)		174 (20.33%)	

Types	Example	Number and Percentage of Random Samples in the U.S.	Dimensions (in mm)
Type 4 (Vertical Shape)		249 (29.09%)	
Other Types	 	40 (4.68%)	

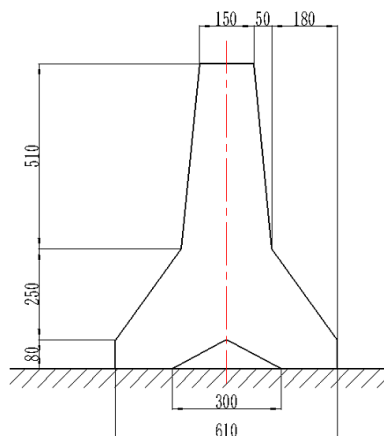


Figure 1 - NCHRP recommended concrete divider dimensions for the safety performance evaluation of highway features

5.2 Color

The goal of specifying the color of the concrete divider surrogate is to test the performance of the automotive cameras commonly used in active safety systems. The surface of the concrete divider can be bare concrete or painted. In North America, most concrete dividers are bare concrete. According to the study of 881 concrete divider images sampled all over the U.S. from Google street view [4], the representative color is gray with an RGB range from (203, 195, 182) to (137, 131, 120) (Table 3, Figure 2).

Table 3 - The representative color of concrete dividers is based on samples from all over the U.S.

Cluster	RGB	Number of Locations	Range (±10% Brightness)	
1	193, 187, 176	558	233, 226, 214	157, 151, 142
2	129, 122, 108	323	155, 147, 132	105, 98, 86
Central color	168, 161, 149	881	203, 195, 182	137, 131, 120

**Figure 2 - New built (left, cluster 1) and old concrete divider (right, cluster 2)**

5.3 Infrared Reflection Characteristics of Concrete Divider

The actual 3D image mapping capability has made LiDAR a popular active safety system sensor for vehicles. Modern automotive LiDAR can provide details about the target's speed, direction, and location (spherical coordinates). The goal of specifying the IR reflectance of the concrete divider surrogate is to ensure the surrogate provides the same LiDAR reflectance as the actual concrete divider at various viewing distances and angles. The infrared discussed here is near-infrared (800 to 1600 nm), but not far-infrared (5 to 1000 μ m) used in temperature measurement. Most automotive LiDAR uses laser beams between 800 nm and 1100 nm. More recently, vendors are in the process of developing a new generation of LiDAR operating at wavelength 1550 nm. Since IR's penetration depth is at the micrometer level, the IR reflectivity is only contributed by the surface of the concrete divider.

5.3.1 The Operating Principle of the LiDAR

The LiDAR emits laser pulse signals to a target and measures each pulse's time to bounce back from the target [5]. Since the light speed is a constant, a LiDAR can calculate the distance between itself and the target based on the light traveling time. Therefore, the detectability of an object by a LiDAR depends on the reflected signal power from the object, i.e., the received power [6]. The reflected signal power is proportional to the IR reflectivity of the object's surface and inversely proportional to the square of the distance between the LiDAR and the object.

The LiDAR reflectivity of an object is a function of the wavelength of the laser emitted by the LiDAR. It is also a function of the surface texture of the object. When the surface is smooth like a mirror, all emitted light is reflected in one direction, and the laser reflection is defined as the specular reflection. When the surface is rough, the LiDAR emitted light is reflected in many directions, and the laser reflection is defined as the diffuse reflection (see Figure 3). For automotive LiDAR, the illumination and measurement angles are the same. Therefore, the reflectivity of an object's surface changes as the measurement angle changes. The reflected light is strongest for a specular object surface when the LiDAR is perpendicular to the surface, and almost none when the LiDAR is not perpendicular to the surface. For a diffuse object surface, the power of the reflected light is a function of the object's viewing angle. It should be noted that this function is different for different surface materials and textures of objects.