Traffic Engineering and Highway Safety Bulletin 18-05
September 2018

Passive Barrier Systems

In This Issue...

The Function of Passive Barrier...... 1
Passive Barrier Requirements 2
Passive Barrier Testing Standards.. 2
Certified and DoD Approved Passive Barriers 4
Non-Proprietary Modified Midwest Guardrail System 5

MILITARY SURFACE DEPLOYMENT AND DISTRIBUTION COMMAND, TRANSPORTATION ENGINEERING AGENCY (SDDCTEA)

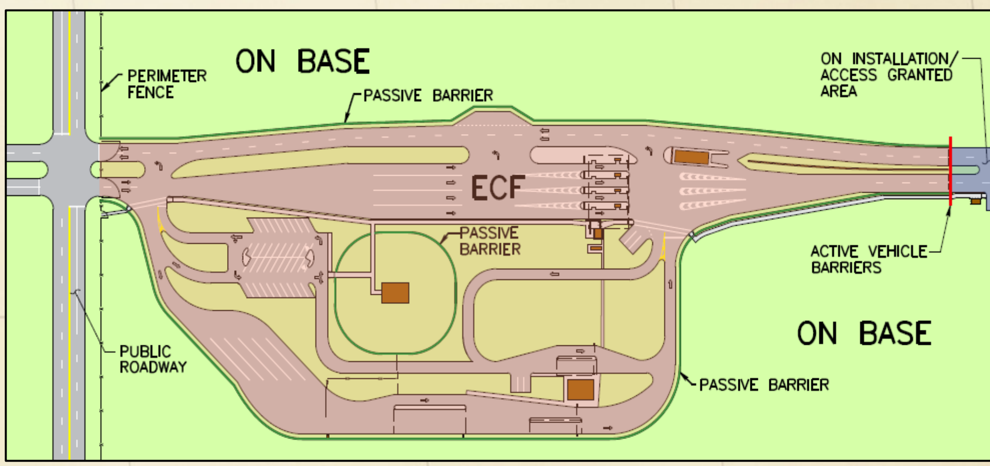
1 Soldier Way
Scott Air Force Base, Illinois
62225-5006
http://www.sddc.army.mil/sites/TEA

Scan Here to Quickly Visit Us Online!

The Function of Passive Barrier

A passive vehicle barrier system is a static or non-moving system designed to effectively stop and/or disable vehicles that pose a threat, including explosive laden vehicles, of breaching the perimeter of a protected area (UFC 4-022-02 *Selection and Application of Vehicle Barriers*). A passive barrier is typically used to form a contiguous perimeter around an entry control facility (ECF) [or, in Army terminology, an Access Control Point (ACP)] for full threat containment. Vehicle containment within the roadway is necessary to prevent inbound vehicles from unauthorized access and must extend from the installation perimeter to the final denial active vehicle barriers (AVBs) to be effective. Passive vehicle barriers must be arranged to ensure that a vehicle will not circumvent the barrier once the vehicle has entered the ECF. The perimeter of the ECF will consist of both passive and active vehicle barriers arranged to form a continuous barrier to pedestrians and/or vehicles.

Figure 1 – ECF Area



Source: SDDCTEA Pamphlet 55-15

A passive barrier has other applications at ECFs as well. It can be used to form a perimeter around a visitor control center (VCC) in order to provide setback from the building to meet standoff distance. To assist in meeting response time requirements, it is also used to limit the paths available to a threat vehicle. Additionally, passive barrier protection must be provided for facilities located less than 3 feet behind the face of curb when adjacent to a curbed roadway section or less than 7 feet from the traveled lane when adjacent to a shouldered roadway section.

Passive Barrier Requirements

According to Section 5-2.1.2.1 of the UFC 4-022-01 *Entry Control Facilities / Access Control Points*:

- Passive vehicle barriers utilized must be tested products listed on the DoD Anti-Ram Vehicle Barrier List. *(this listing is maintained by the US Army Corps of Engineers Protective Design Center (USACE PDC) and housed on their website at: https://pdc.usace.army.mil/library/BarrierCertification)*
- Breaks in the passive vehicle barrier system of the ECF must not exceed 3 feet in width for traffic having a 90-degree approach and 4 feet in width for traffic paralleling the barrier.
- The location and installation of passive vehicle barriers must conform to the requirements of the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide* for objects placed near roadways. *(Refer to Figure 2 below for clear zone requirements for a given set of conditions. A barrier installed beyond the requirement stated is considered to have met the clear zone requirement and is installed outside the clear zone area. For additional information concerning the clear zone distance, see SDDCTEA Pamphlet 55-17, Chapter 11.)*
- If passive vehicle barriers must be installed within the clear zone area, the barriers must meet the requirements of the AASHTO *Manual for Assessing Safety Hardware (MASH)*. MASH presents uniform guidelines for crash testing permanent and temporary highway safety features and recommends evaluation criteria to assess test results. MASH-compliant hardware is crash-tested and approved for crash safety.

Figure 2 – Clear Zone Requirements

Design Speed	Deign ADT	Fill Slopes			Cut Slopes		
		6:1 or Flatter	5:1 to 4:1	3:1	3:1	5:1 to 4:1	6:1 or Flatter
40 mph or Less	Under 750	7 - 10 ft	7 - 10 ft	*	7 - 10 ft	7 - 10 ft	7 - 10 ft
	750 - 1,500	10 - 12 ft	12 - 14 ft	*	12 - 14 ft	12 - 14 ft	12 - 14 ft
	1,500 - 6,000	12 - 14 ft	14 - 16 ft	*	14 - 16 ft	14 - 16 ft	14 - 16 ft
	Over 6,000	14 - 16 ft	16 - 18 ft	*	16 - 18 ft	16 - 18 ft	16 - 18 ft
45-50 mph	Under 750	10 - 12 ft	12 - 14 ft	*	8 - 10 ft	8 - 10 ft	10 - 12 ft
	750 - 1,500	14 - 16 ft	16 - 20 ft	*	10 - 12 ft	12 - 14 ft	14 - 16 ft
	1,500 - 6,000	16 - 18 ft	20 - 26 ft	*	12 - 14 ft	14 - 16 ft	16 - 18 ft
	Over 6,000	20 - 22 ft	24 - 28 ft	*	14 - 16 ft	18 - 20 ft	20 - 22 ft

Source: *AASHTO Roadside Design Guide*

* Note: Since recovery is less likely on unshielded, traversable 3:1 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Determination of the width of the recovery area at the toe of the slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories.

Passive Barrier Testing Standards

When planning and selecting passive vehicle barriers to be used for facility perimeter protection, the first step is to determine the design basis threat (DBT) for any given location in the facility. The two main factors to consider are the amount of kinetic energy absorbed and the vehicle penetration distance. The appropriate penetration distance for a given facility is determined by the threat and risk assessments and physical security survey results as indicated by the process outlined in UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual,* UFC 4-020-02FA*, Concept Design,* and 4-020-03FA, *Security Engineering: Final Design.*

The list of passive barrier systems approved by the Department of Defense (DoD) is contained within the DoD Anti-Ram Vehicle Barrier List that is mentioned above. The USACE PDC maintains and updates the listing on a quarterly basis. According to the DoD Anti-Ram Vehicle Barrier List: “The list does not represent an overall endorsement of any product or design or address its operational suitability or maintainability. The list merely verifies that particular vehicle barriers have been certified in accordance with the performance standards in ASTM F2656/F2656M-18a, or previously tested to the U.S. Department of State (DoS) SD-STD-02.01 standard, and that the appropriate test reports have been submitted to, and validated by, the Protective Design Center." **Note that the DOS SD-STD-02.01 has been superseded by ASTM F2656/F2656M-18a Crash Testing of Vehicle Security Barriers**.

Each type of passive barrier system has a condition designation and a penetration rating. The condition designation is the maximum kinetic energy the system can absorb for a given vehicle type, mass and velocity. The penetration ratings categorize the range of allowable penetration for the barrier system.

In the ASTM F2656/F2656M-18a test standards, condition designation is based on a combination of test vehicle classes and nominal test velocities and is associated with three penetration ratings beginning with the letter "P". In the DoS SD-STD-02.01 standards, kinetic energy rating has a "K" label and the penetration rating has an "L" label. A table showing the different ratings used in the DoD Anti-Ram Vehicle Barrier List is shown below. Note that the condition designations and penetration ratings from the DoS SD-STD-02.01 standards are still used in the DoD Anti-Ram Vehicle Barrier List but are being phased-out since they have been superseded by ASTM F2656/F2656M-18a test standards.

Standard	Condition Designation	Vehicle Weight (lbs)	Vehicle Speed (mph)
DoS SD-STD-02.01	K4	15,000	30
	K8	15,000	40
	K12	15,000	50
ASTM F2656/F2656M-18a	SC30, SC40, SC50, SC60	2,430	30, 40, 50, 60
	FS30, FS40, FS50, FS60	4,630	30, 40, 50, 60
	PU30, PU40, PU50, PU60	5,000	30, 40, 50, 60
	M30, M40, M50	15,000	30, 40, 50
	C730, C740, C750	15,000	30, 40, 50
	H30, H40, H50	65,000	30, 40, 50
	U30, U40, U50	User-defined*	30, 40, 50

Standard	Penetration Rating	Allowable Penetration (ft)
DoS SD-STD-02.01	L1	20 – 50
	L2	3 – 20
	L3	Less than 3
ASTM F2656/F2656M-18a	P3	23.1 – 98.4
	P2	3.31 – 23
	P1	Less than 3.3

* Any specific vehicle type as per end user's requirements to accommodate interests of various U.S. agencies

The abbreviations for the various vehicle classes used to create the condition designations are shown below.

Designation	SC	FS	PU	M	C7	H
Vehicle Type	Small passenger car	Full-size sedan	Pickup truck	Standard test truck	Class 7 Cabover	Heavy goods vehicle
Vehicle Weight (lbm)	2,430	4,630	5,000	15,000	15,000	65,000

Certified and DoD Approved Passive Barrier

According to the *Army Standard for Access Control Points* (April 2012), page 6 and UFC 4-022-01, Section 5-2.1.2.1; only passive barriers from the DoD approved list can be used on Army installations. The various types of passive barrier systems on the DoD approved list are shown below.

Type	Kinetic Energy Ratings	Penetration Ratings	Example
Bollards	PU50, M30-M50, K4-K12	P1-P3, L3	
Cable	M30-M50	P1-P3	
Portable Modular	M30	P2	
Portable Bollards	M30	P3	
Post and Beam*	M30-M50, FS30	P1-P2	
Reinforced Fence	M50, K8-K12	P1-P2, L1-L3	
Inertial	M50, K12	P1, L3	

*New, non-proprietary W-beam barrier, discussed on page 5

Recent Addition to Listing: Non-Proprietary Modified Midwest Guardrail System

The passive barrier systems on the DoD approved list can be costly due to their proprietary design and costly components. A typical M30- through M50-rated triple cable system with fence costs $200 - $300 per linear foot and an M50-rated concrete barrier system with fence costs approximately $750 per linear foot *[ACP Facility Costs as found on the USACE Military Construction Requirements and Standardization Integration (MRSI) website]*. Installations have sought after low-cost options such as a standard highway guardrail system to avoid these expensive barrier systems. Components for a standard highway guardrail system are inexpensive, abundant, and readily available; this is in stark contrast to the certified passive barrier systems which use proprietary designs and can only be purchased from select vendors.

These guardrail systems were acceptable as passive barriers in certain instances under UFC 04-022-02 and the previous UFC 04-022-01 (2005 version), but they are no longer acceptable under the latest version of UFC 4-022-01 (dated July 2017) where only passive barriers from the DoD approved list can be used on installations. In an effort to provide installations with a low-cost, non-proprietary passive barrier system, SDDCTEA sponsored a research study at the University of Nebraska-Lincoln (UNL) with the Nebraska Transportation Center (NTC) and the Midwest Roadside Safety Facility (MwRSF).

The objective of the study was to develop and full-scale crash test a new, non-proprietary barrier by modifying the MwRSF's non-proprietary W-beam barrier, the Midwest Guardrail System (MGS), to satisfy ASTM F2656-15 M30 P2 designation and also evaluate the MGS at 45-degree impact angles. Note that the ASTM F2656-18a was not yet available for the M30 P2 testing requirements at the time of the study.

The sponsors of the study developed a set of design requirements for the modified MGS:

- Must meet ASTM F2656-15 criteria for the M30 P2 and FS30 P2 designation
- Must be a non-proprietary design
- Should meet the Manual for Assessing Safety Hardware (MASH) TL-1*
    - MASH TL-1 impact conditions consist of a ½-ton, 5,000-lb (2,268-kg) pickup truck (2270P) and 2,425-lb (1,100-kg) small car (1100C) impacting at 31 mph (50 km/h) and 25 degrees
- Target an installation cost of $150/ft or less
    - The installation cost would include all system components and construction labor
- Utilize standard hardware wherever practical
    - The term "standard hardware" was defined to mean readily-available, off-the-shelf, and/or prefabricated structural sections

* Not a design requirement, but stakeholders included it as an important criterion since barriers must be MASH-certified to be installed within the clear zone.

Final Design, Testing Results, and Costs

The existing guardrail system (unmodified) failed the M30 P2 test due primarily to a splice failure. The final (as-tested) design of the modified MGS consisted of a nested, 12-gauge thrie-beam rail mounted on 84-in. long, W6x9 steel posts with 8-in. deep blockouts and higher strength bolts, nuts and washers. In addition, an end anchor was selected consisting of a reinforced concrete block-and-shaft soil foundation and an A-frame steel terminal post with thrie-beam terminal connectors to attach to thrie-beam rails. Example photos of the final MGS design are shown in figure 3.

Why was MGS chosen over other guardrail systems?

The MGS is a non-proprietary W-beam guardrail system that was specifically designed for today's vehicles which have a high center of gravity and is recommended by the Federal Highway Administration for its superior performance over other guardrail systems at little to no additional cost. It is widely available and has proven to be very versatile in a number of demanding applications, including at high flare rates (5:1), adjacent to steep 2:1 slopes, over long-span culverts, on bridges as bridge rails, and as attachments to temporary concrete barriers.

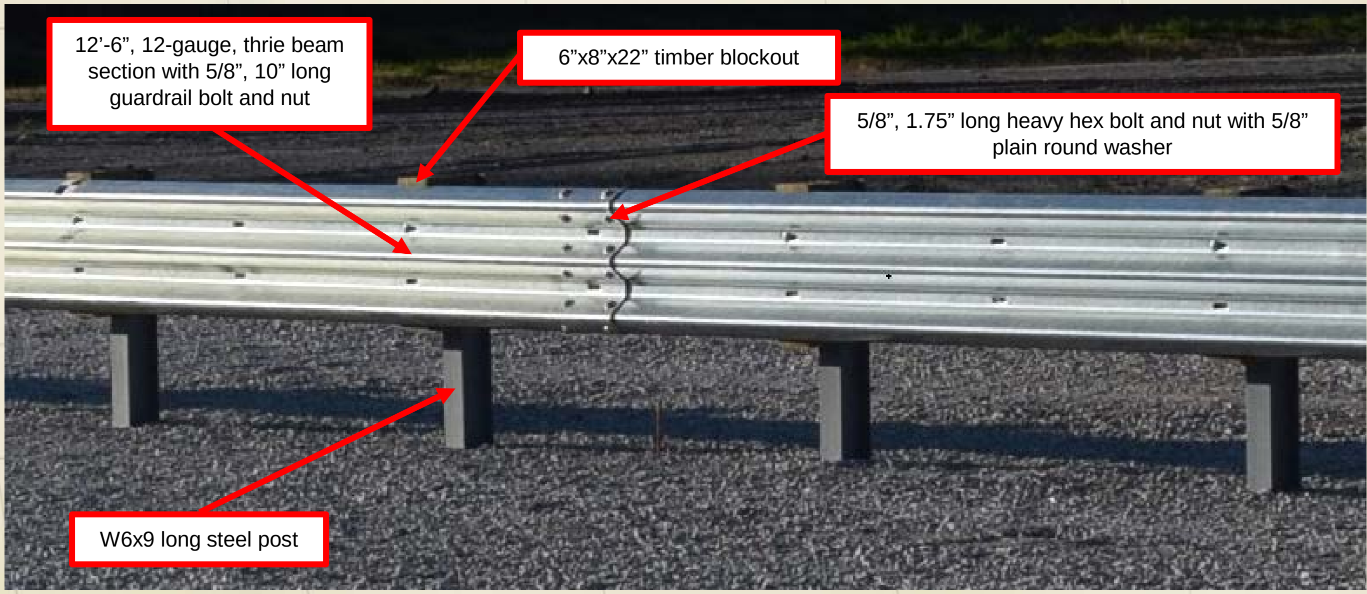
In addition to computer simulation testing, full-scale testing was conducted using an M-class vehicle (2005 International 4300) and an FS-class vehicle (2010 Ford Crown Victoria) for an impact angle at 90 degrees. Photos showing the results of the full-scale testing are shown in figure 4. The modified guardrail system was determined to pass criteria according to ASTM F2656-15 M30 P1 and FS30 P1 designations. Note that this exceeded the original goal of the M30 P2 and FS30 P2 designations.

Figure 3 – Final Design

Front View of End Anchor

Rear View of End Anchor

Front View of Guardrail Section



For more component details, request the drawing files from SDDCTEA by emailing army.sddc.safb.traffic@mail.mil

Figure 4 – Test Results

FS30 Test Results (90-degree Impact Angle)

M30 Test Results (90-degree Impact Angle)

The end anchorage system estimated cost is $15,400 which includes both end anchors (one upstream and one downstream). The guardrail section (in-between the end anchors) cost is estimated at $62.00 per foot. A 600-foot section of guardrail, to include end anchors, is estimated at $52,600 [($15,400 + ($62/ft x 600 ft)] which equates to approximately $88 per foot. Shorter guardrail sections will cost more per foot and longer guardrail sections will costs less per foot due to the initial costs for the end anchors.

The non-proprietary barrier system was designed to be relatively easy and inexpensive to maintain and install. However, during some impacts, the end anchorages may displace toward impact resulting in end anchorage permanent set. In these situations, it may be necessary to reset the end anchorages to ensure that the system can be repaired and re-assembled. Researchers recommend evaluation, design, and possibly retesting of the end anchorage to allow for precision adjustments in barrier length to ensure that maintenance is quick, easy, and minimizes repair labor costs.

Conclusions

The modified MGS was recently approved by the USACE PDC to be added to the DoD Anti-Ram Vehicle Barriers listing, under the passive barrier description 'Non-Proprietary M30 P1 Barrier'. Being DoD approved for use on all installations, **SDDCTEA believes that the modified MGS (as designed) provides a solution for installations seeking a low-cost, non-proprietary, and safe passive barrier system that meets the M30 P1 or FS30 P1 designations**. Researchers have stated that minor modifications can be made to the modified guardrail system to achieve the M40 or FS40 designations with increased costs of approximately 20%. **Note that this system is not MASH-certified and is not authorized for use within the clear zone according to the UFC 4-022-01**. Although the test was not conducted according to MASH impact conditions, test results would have been satisfactory according to MASH TL-1 occupant risk evaluation criteria. Certified MASH testing is needed to verify this if the system is to be used within the clear zone.

Mr. Bruce A. Busler, SES
Director, Transportation Engineering Agency

Contact Us

MILITARY SURFACE DEPLOYMENT AND DISTRIBUTION COMMAND

TRANSPORTATION ENGINEERING AGENCY (SDDCTEA)

1 Soldier Way
Scott Air Force Base, Illinois
62225-5006

DSN: 770-5252

FAX: 618-220-5125

EMAIL: army.sddc.safb.traffic@mail.mil

WEBSITE: http://www.sddc.army.mil/sites/tea for pamphlets, bulletins and studies

Reference List

- ☑ TEA Home: http://www.sddc.army.mil/sites/tea
- ☑ Unified Facilities Criteria 4-022-01. *Entry Control Facilities Access Control Points,* 2009. https://www.wbdg.org/FFC/DOD/UFC/ufc_4_022_01_2017.pdf
- ☑ Unified Facilities Criteria 4-022-02. *Selection and Application of Vehicle Barriers,* 2009, Change 1, 2010. https://www.wbdg.org/FFC/DOD/UFC/ufc_4_022_02_2009_c1.pdf
- ☑ Department of Defense Anti-Ram Vehicle Barriers List*, United States Army Corps of Engineers Protective Design Center, 2018.* https://pdc.usace.army.mil/library/BarrierCertification
- ☑ ASTM F2656 / F2656M-15, Standard Test Method for Crash Testing of Vehicle Security Barriers. *ASTM International, West Conshohocken, PA, 2015.* www.astm.org
- ☑ ASTM F2656 / F2656M-18a, Standard Test Method for Crash Testing of Vehicle Security Barriers. *ASTM International, West Conshohocken, PA, 2018.* www.astm.org
- ☑ Phase 3 Final Report: Design of Low-Cost Guardrail System for Threat Mitigation*. Midwest Roadside Safety, February 1, 2018. Prepared for SDDCTEA. MwRSF Report No. TRP-03-381-17*
- ☑ The Army Standard for Access Control Points (ACPs). *Department of Army, April 2012.* https://pdc.usace.army.mil/library/drawings/acp
- ☑ Roadside Design Guide. *American Association of State Highway and Transportation Officials*. 2011, Fourth Edition. https://store.transportation.org/item/collectiondetail/105
- ☑ Manual for Assessing Safety Hardware (MASH). *American Association of State Highway and Transportation Officials*. *2016, Second Edition.* https://store.transportation.org/item/publicationdetail/2707
- ☑ ACP Facility Costs (2015, Adjusted for Inflation), *Military Construction Requirements and Standardization Integration (MRSI),* https://mrsi.erdc.dren.mil/system/folder-view?folderId=3379