Designation: ~~F2656/F2656M – 18~~ F2656/F2656M – 18a

Standard Test Method for Crash Testing of Vehicle Security Barriers[1]

This standard is issued under the fixed designation F2656/F2656M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Original perimeter barrier test methods were first published in 1985 by the Bureau of Diplomatic Security to assess the crash performance of perimeter barriers and gates. Since that time, the frequency and scale of attacks using vehicles with or without an explosive payload have increased both internationally and domestically. Therefore, there is a need to address a broad spectrum of possible incident conditions such as credible threat vehicle types for the locale, attack velocities of the different vehicles, and different acceptable penetration limitations. Also, there are different evaluation criteria for different agencies that fulfill their unique access control operations, aesthetics, and other organizational requirements. This test method was originally developed to expand the previous Department of State, Bureau of Diplomatic Security's crash testing standard to meet the broader needs of multiple organizations responsible for the protection of U.S. assets domestically and abroad.

Published test standards for vehicle perimeter security devices have previously been maintained by the U.S. State Department, Bureau of Diplomatic Security. The Specification for Vehicle Crash Test of Perimeter Barriers and Gates was first published in 1985 as SD-STD-02.01. In that standard, the test vehicle was specified as a medium-duty truck weighing 6800 kg [15 000 lb]. The payload was to be securely attached to the frame and nominal impact velocities were 50, 65, and 80 km/h [30, 40, and 50 mph]. Penetration limits were 1, 6, and 15 m [3, 20, and 50 ft] and were measured from the attack face of the perimeter security device to the final resting position of the front of the frame rails of the test vehicle.

In 2003, the U.S. State Department, Bureau of Diplomatic Security issued an updated standard (SD-STD-02.01, Revision A) for the testing of perimeter barriers. This update was done for several reasons. The foremost reason for change was limited setback distances precluded the use of any devices at their facilities or compounds that did not meet the highest test level, that is, those allowing more than 1-m [3-ft] penetration distance. Therefore, the revised standard only uses a 1-m [3-ft] penetration distance. Secondly, the method of rigid attachment of the ballast to the test vehicle was not simulating likely payload configurations and was altering the structural integrity of the test vehicle. Consequently, the updated standard requires a payload consisting of 208-L [55-gal] steel drums strapped together that have been filled with soil. This assembly is then strapped to the vehicle load platform. The third reason for change was based on the observation that the cargo bed of trucks could effectively penetrate certain types of barriers. Accordingly, the penetration distance is now measured from the inside face or non-impact surface of the barrier to the front of the cargo bed when the vehicle has reached its final position. Lastly, it was determined that the trucks used different platforms within a given class affecting result consistency. The revised test standard required the use of very specific diesel-powered medium-duty trucks.

In 2007, ASTM first published Test Method F2656 for Vehicle Crash Testing of Perimeter Barriers. It included the same test vehicle as specified in the 2003 SD-STD-02.01, Revision A, but additional test vehicles were added. They were the small passenger car, a ½-ton regular cab pickup, and a tandem axle dump truck. In addition, penetration ratings were reestablished and included the highest rating established by the 2003 SD-STD-02.01. Occupant risk values as established in NCHRP Report 350

[1] This test method is under the jurisdiction of ASTM Committee F12 on Security Systems and Equipment and is the direct responsibility of Subcommittee F12.10 on Systems Products and Services.

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were also added.

This latest version of Test Method F2656 incorporates two additional vehicles, the large passenger sedan and a Class 7 cab-over with a single rear axle. Additionally, the small car and pickup have been updated to match the latest AASHTO *Manual for Assessing Safety Hardware* (MASH), the update to NCHRP Report 350. Class 7 cab-over is compatible with European standards and is designated C7. Additional definitions and recommendations have also been added and the word "perimeter" has been deleted from the title to reflect more accurately all barriers tested under this test method. Since it was determined that the P4 rating did not have substantial relevance, this rating has been eliminated. To keep up with current terminology, the term "reduced risk" is discussed in this version of Test Method F2656.

~~Test Method F2656/F2656M – 18 has incorporated two major changes from F2656/F2656M – 15. The first and most significant change is all penetration ratings are referenced to the leading edge of the barrier being tested. This serves to remove any ambiguity relating to barrier size or footprint and the previous determination of reference points on trailing edges. It also serves to harmonize with the standard employed by the European Union. Secondly, because the previous bed attachment requirement has been shown to be inadequate by loss of bed attachment, so the number of shear plates has been increased to three. Since the leading edge of the bed is the vehicle reference point on the Standard Test Truck, keeping the bed attached to the truck imparts the greatest load into the barrier and yields more valid test results for penetration.~~

1. Scope

1.1 This test method provides a range of vehicle impact conditions, designations, and penetration performance levels. This will allow an agency to select passive perimeter barriers and active entry point barriers appropriate for use at facilities with a defined moving vehicle threat. Agencies may adopt and specify those condition designations and performance levels in this test method that satisfy their specific needs. Agencies may also assign certification ratings for active and passive perimeter barriers based on the tests and test methodologies described herein. Many test parameters are standardized to arrive at a common vehicle type and mass, enhance test realism and replication, and produce uniform rating designations.

1.2 Compliance with these test procedures establishes a measure of performance but does not render any vehicle perimeter barrier invulnerable to vehicle penetration. Caution should be exercised in interpreting test findings and in extrapolating results to other than test conditions. While computer simulations are powerful tools that are useful in the development of new and improved barriers or in estimating performance under differing conditions, use of only the results from computer simulation for fielding a product is strongly discouraged. When performing a test, developers and users are encouraged to address specific or unusual site conditions as needed. Often local terrain features, soil conditions, climate, or other items will dictate special needs at specific locations. Therefore, if site conditions are likely to degrade a barrier's performance, the agency in need of a vehicle perimeter barrier should require testing with the specific site conditions replicated for full-scale crash testing.

1.3 Product/design certification under this test method only addresses the ability of the barrier to withstand the impact of the test vehicle. It does not represent an endorsement of the product/design or address its operational suitability.

1.4 The values in stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This standard 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, health, and environmental practices and to determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

~~C39/C39M~~C39 Test Method for Compressive Strength of Cylindrical Concrete Specimens
~~D1556/D1556M~~D1556 Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
D4429 Test Method for CBR (California Bearing Ratio) of Soils in Place (Withdrawn 2018)[3]
D6938 Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

2.2 *AASHTO Standards* [4]

M147-65 Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Table 1 Grading Requirements for Soil-Aggregate Materials, Grading B

T099 Standard Method of Test for Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop

2.3 *ISO Standard* [5]

ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories

2.4 *SAE Standard* [6]

J211-1 Instrumentation for Impact Test – Part 1: Electronic Instrumentation

J211-2 Instrumentation for Impact Test – Part 2: Photographic Instrumentation

2.5 *U.S. Army Corps of Engineers – PDC Standard* [7]

List of DOD Certified Anti-Ram Vehicle Barriers[8]

2.6 *U.S. Department of State – DS* [9]

SD-STD-02.01 Specification for Vehicle Crash Test of Perimeter Barriers and Gates, 1985

SD-STD-02.01, Revision A Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates, 2003

3. Terminology

3.1 *Definitions:*

3.1.1 *"A" pillar, n*—structural member forming the forward corner of the cab or passenger compartment.

3.1.2 *accredited independent testing laboratory, n*—testing laboratory accredited to perform the referenced testing procedures by a nationally recognized accrediting agency in accordance with ISO/IEC 17025 and led by a test director.

3.1.2.1 *Discussion*—

Accredited independent testing laboratories may have no financial interest in or otherwise be affiliated with companies or individuals for which they perform accreditation testing. Hereinafter, accredited independent testing laboratories are referred to as either accredited facilities or testing laboratories. Other independent testing agencies actively pursuing accreditation and whose testing protocols are accepted by a federal agency may also conduct tests for a period of one year after performing the first test using this test method.

3.1.3 *agency, n*—specifier, responsible party, or owner.

3.1.4 *barrier, n*—gate, bollard, wedges, drop arms, walls, wire ropes, net, planter, other structure, or topographic feature (that is, berms, rocks, or trenches) that provides protection against a vehicle trying to gain access overtly to a compound or facility.

3.1.4.1 *Discussion*—

Active barriers can be deployed to serve as a security device and can be stored to allow traffic passage while passive barriers are essentially permanent and do not move. The perimeter is typically the outermost boundary over which the facility has control and is normally defined by the property line.

3.1.5 *berm, n*—mounded section of available material such as soil, gravel, rock, and so forth.

3.1.6 *bollard, n*—hollow or solid section posts or series of posts, usually metal, concrete, wood, or combinations of same, used to channel or restrict vehicular traffic which includes fixed, removable, and operable/retractable posts.

3.1.7 *condition designation, n*—relates vehicle type and vehicle velocity to the kinetic energy for which testing is conducted.

3.1.8 *continuous barrier, n*—any barrier that relies on a continuous foundation or a continuous structural element to resist penetration by vehicles.

3.1.9 *debris, n*—post-impact barrier, ballast, and vehicle components dispersed as a result of impact.

3.1.10 *disabled, adj*—used in conjunction with the vehicle and barrier description after impact.

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[4] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

[5] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.

[6] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

[7] Available from the U.S. Army Corps of Engineers, Protective Design Center, 12565 W. Center Rd., Omaha, NE 68144-3869, https://pdc.usace.army.mil/library/BarrierCertification. Maintains 1985 list for penetration purposes.

[8] Available from the U.S. Army Corps of Engineers, Protective Design Center, 1616 Capital Avenue, Ste 9000, ATTN: CENWO ED S. Omaha, NE 68102-9000, https://pdc.usace.army.mil/library/BarrierCertification.

[9] Available from U.S. Department of State, Bureau of Diplomatic Security, Office of Physical Security Programs, Physical Security Division, Washington, D.C. 20520-1403

3.1.10.1 *Discussion—*

Disabled barrier pertains to an active barrier that is not operable after impact as a result of damage caused by the test impact. Disabled barrier also pertains to the post-test barrier conditions if it is no longer in a deployed position. Disabled vehicle pertains to the vehicle being unable to proceed under its own power immediately after impact as a result of damage caused by the test impact. It is appropriate and necessary to discuss the level of damage to the vehicle in determining what extent the vehicle is disabled, for example, the radiator or the oil pan or both may be ruptured that would ultimately render the vehicle inoperable but would not immediately prevent the vehicle from proceeding under its own power, thus not being defined as disabled for the purposes of this test method. However, the vehicle is determined to be disabled if it is unable to move under its own power immediately after impact, for example, the motor is ejected or the axle is dislodged from the vehicle.

3.1.11 *ditch, n—*excavation into existing grade with varying cross sections such as "V" or "U" shaped.

3.1.12 *dynamic penetration distance, n—*during the crash event, the maximum horizontal penetration distance of the reference point on the test vehicle, as defined in 7.5.1, to the pre-test location of the barrier reference point.

3.1.12.1 *Discussion—*

See Annex A1 for barrier reference point locations.

3.1.13 *final resting point, n—*distance from the pre-impact reference point on a barrier to the portion of the protective barrier that is furthest away from the original reference point at final rest.

3.1.13.1 *Discussion—*

Additionally, it is the distance from the pre-impact reference point on a barrier to the defined vehicle reference point at final rest. This distance may be negative if the vehicle reference point did not pass the pre-impact reference point on a perimeter barrier.

3.1.14 *override, n—*type of crash in which a portion of a vehicle goes over a barrier.

3.1.15 *penetration rating, n—*rating achieved by a barrier based on maximum dynamic penetration distance for a given condition designation.

3.1.15.1 *Discussion—*

Maximum dynamic penetration distance is defined in 3.1.12, final resting position is also recorded and will sometimes be ~~referenceed~~reference as the static penetration distance.

3.1.16 *rated-ASTM barrier, n—*vehicle security barrier tested in accordance with this test standard by an accredited facility that achieves a given Condition Designation and Penetration Rating based on the distance traveled after impact.

3.1.17 *reduced occupant risk, n—*computed values for indicators of severe injury, the lateral and longitudinal occupant impact velocity is less than 12.20 m/s, and the ridedown acceleration is less than 20.49 g[10] as recommended by MASH.

3.1.17.1 *Discussion—*

There is a minimum of two tests required. The first test is with the desired impact vehicle for rating the barrier and the second test is with the small passenger car (SC) impacting at the same location and angle as the first test with the SC traveling 100 km/h [60 mph]. No other changes are permitted for the second test.

3.1.18 *setback, n—*horizontal distance from the barrier reference point to the nearest surface of the asset being protected.

3.1.18.1 *Discussion—*

Loss of setback is equivalent to the original setback minus the penetration distance as defined by 7.5.2 for the respective vehicles.

3.1.19 *static penetration distance, n—*horizontal distance measurement to the respective test vehicle reference point from the barrier reference point at final rest post-test.

3.1.19.1 *Discussion—*

[10] *Manual for Assessing Safety Hardware* (MASH), American Association of State Highway and Transportation Officials, Washington, DC, 2009.

See Annex A1 for barrier reference point locations.

3.1.20 *supplier, n*—manufacturer, distributor, designer, or constructor of the barrier system that is to be tested and can include contractors, engineers, and architects.

3.1.21 *test director, n*—employee of the testing laboratory responsible for all aspects of a test.

3.1.22 *test vehicle, n*—designated vehicle for specific crash testing.

3.1.23 *underride, n*—a type of crash in which a portion of a vehicle goes under a barrier.

3.1.24 *variable width barrier, n*—perimeter security devices such as gates, nets, wedges, and modular units that will likely be deployed with different functional widths.

3.1.25 *vehicle security barrier, n*—gate, bollard, wedges, drop arms, walls, wire ropes, net, planter, other structure, or topographic feature (that is, berms, rocks, or trenches) that provides protection against a vehicle trying to gain access overtly to a compound or facility.

3.2 *Acronyms:*

3.2.1 *AASHTO*—American Association of State Highway Transportation Officials

3.2.2 *DHS*—U.S. Department of Homeland Security

3.2.3 *DOD*—U.S. Department of Defense

3.2.4 *DOE*—U.S. Department of Energy

3.2.5 *DOS*—U.S. Department of State

3.2.6 *DOS-DS*—Department of State-Bureau of Diplomatic Security

3.2.7 *DOT*—U.S. Department of Transportation

3.2.8 *GSA*—General Services Administration

3.2.9 *ISO*—International Standards Organization

3.2.10 *MASH*—Manual for Assessing Safety Hardware[10]

3.2.11 *NCHRP*—National Cooperative Highway Research Program

3.2.12 *OBO*—Overseas Building Operations

3.2.13 *USACE-PDC*—United States Army Corps of Engineers-Protective Design Center

3.3 *Abbreviations:*

3.3.1 *fps*—frames per second

3.3.2 *ft/s*—feet per second

3.3.3 *g*—measure of acceleration referenced to gravity

3.3.4 *km/h*—kilometres per hour

3.3.5 *lbm*—pounds mass

3.3.6 *m/s*—metres per second

3.3.7 *mph*—miles per hour

4. Summary of Test Method

4.1 The complete, comprehensive set of engineering drawings and specifications for a barrier that is to be tested shall be submitted by the supplier to the testing laboratory at least 14 days before testing. These documents shall become part of the permanent test record and report. If a supplier desires to obtain listing of their barrier by one of several agencies that maintain such lists, then see Appendix X3 for additional information.

4.2 Before testing, an approved test vehicle, test velocity, and desired penetration rating is selected by the supplier in coordination with the test director and others who might be involved. The test is then conducted at the chosen velocity using the defined test vehicle and ballast conforming to this test method. Required test data shall be captured and reported.

4.3 The test director shall determine the validity of the test and, if found valid, shall assign a penetration rating for the barrier. The vehicle security barrier shall then become a rated ASTM vehicle perimeter barrier with a Condition Designation and Penetration Rating.

5. Significance and Use

5.1 This test method provides a structured procedure to establish a penetration rating for vehicle perimeter barriers subjected to a vehicle impact. Knowing the penetration rating provides the ability to select an appropriate barrier for site-specific conditions around a facility.

5.2 The barrier penetration rating does not imply that a barrier will perform as rated in all site conditions, approach routes, and topography. Also, only single-specimen tests at a specified impact location are required by this test method, and therefore, not all points of impact can be tested and validated for the penetration rating. Other impact locations may respond differently.

6. Apparatus

6.1 Appendix X1 provides recommendations on methods of data acquisition that are required by this test method and Appendix X2 provides example forms that may be used for parameters to be measured before, during, and after collision, including measurement tolerances and techniques.

6.2 Pre-test data acquisition shall document the as-built, untested barrier and test vehicle configuration. Documentation includes as-built specifications and drawings for the test article, measurements, and photography. Survey points for elevation of any base slab, columns, bollards, barrier, or barrier support elements that may define deformation, translation, rotation, and uplift should be recorded in pre-test and post-test states.

6.3 During the test, vehicle impact velocity shall be measured. Video documentation, with perpendicular (profile) view shall be provided. Overhead and oblique views are recommended. Photographic instrumentation specifications shall be in accordance with SAE Standard J211-2. The lens error as referenced by Section 3.1.1 of SEA J11-2 shall not exceed 3 % for lenses <50-mm [2-in.] focal length and shall not exceed 1 % for lenses equal to or greater than 50-mm [2-in.] focal length. Minimum high-speed film or video shall be 400 fps or greater. Determination of impact time = 0 s shall be established by the use of a contact ribbon switch mounted to the front face of the barrier or vehicle bumper triggering a strobe flash that can be recorded on the video documentation for cross-referencing between video sources.

TABLE 1 Impact Condition Designations

Test Vehicle/Minimum Test Inertial Vehicle, kg [lbm]	Nominal Minimum Test Velocity, km/h [mph]	Permissible Speed Range, km/h [mph]	Kinetic Energy, KJ [ft-kips]	Condition Designation
Small passenger car (SC) 1100 [2430]	50 [30]	45.0-60.0 [28.0-37.9]	106 [78]	SC30
1100 + 25 [2420 + 55]	65 [40]	60.1-75.0 [38.0-46.9]	179 [131]	SC40
	80 [50]	75.1-90.0 [47.0-56.9]	271 [205]	SC50
	100 [60]	90.1- above [57.0-above]	424 [295]	SC60
Full-size Sedan (FS) 2100 [4630]	50 [30]	45.0-60.0 [28.0-37.9]	203 [37]	FS30
2100 + 50 [4630 + 110]	65 [40]	60.1-75.0 [38.0-46.9]	342 [247]	FS40
	80 [50]	75.1-90.0 [47.0-56.9]	519 [387]	FS50
	100 [60]	90.1-above [57.0-above]	810 [557]	FS60
Pickup truck (PU) 2300 [5070]	50 [30]	45.0-60.0 [28.0-37.9]	222 [164]	PU30
	65 [40]	60.1-75.0 [38.0-46.9]	375 [273]	PU40
	80 [50]	75.1-90.0 [47.0-56.9]	568 [426]	PU50
	100 [60]	90.1- above [57.0-above]	887 [613]	PU60
Standard Test Truck (M) 6800 [15 000]	50 [30]	45.0-60.0 [28.0-37.9]	656 [451]	M30
11 800-14 970 [26 000-33 000]	65 [40]	60.1-75.0 [38.0-46.9]	1110 [802]	M40
	80 [50]	75.1-above [47.0-above]	1680 [1250]	M50
Class 7 Cabover (C7) 7200 [15873]	50 [30]	45.0-60.0 [28.0-37.9]	673 [497]	C730
11 800-14 970 [26 000-33 000]	65 [40]	60.1-75.0 [38.0-46.9]	1199 [884]	C740
	80 [50]	75.1-above [47.0-above]	1872 [1381]	C750
Heavy goods vehicle (H) 29 500 [65 000]	50 [30]	45.0-60.0 [28.0-37.9]	2850 [1950]	H30
27 000 [60 000	65 [40]	60.1-75.0 [38.0-46.9]	4810 [3470]	H40
	80 [50]	75.1-above [47.0-above]	7280 [5430]	H50

6.4 Vehicle acceleration shall be measured. Accelerometer location is shown in Figs. X2.1-X2.4 in Appendix X2. Electronic instrumentation specifications shall be in accordance with SAE Standard J211-1. Occupant risk values are to be computed per the method of A5.3 "Occupant Risk" in MASH from the acceleration data. Reported occupant risk values only pertain to the system and vehicle as tested.

6.5 After the test, barrier deformation, vehicle penetration, and damage of both test article and vehicle shall be documented with measurements, data recordings, and photography. See 6.2 for suggested data collection points. Other parameters peculiar to a barrier may entail additional documentation. For instance, a gate may be shown to be operational after the collision, even though this is not a requirement of this test method. The maximum horizontal distance between two barriers measured above the finished ground surface shall be recorded.

7. Test Criteria

7.1 *Impact Performance:*

7.1.1 The level of impact kinetic energy that a barrier is to withstand shall be established by the supplier in consultation with the test director and others who might be involved. This level is then compared with the kinetic energy levels shown in Table 1 to select a test vehicle and associated test impact velocity. Actual test velocity shall be within the permissible range indicated to receive the condition designation. During the test, the amount of vehicle penetration of the test barrier at the required impact velocity determines the dynamic penetration rating for the condition designation. Test vehicle dynamic penetration shall be referenced to the base of the "A" pillar on the small passenger car (SC) and the full-size passenger sedan (FS), the front leading lower edge of the pickup truck bed (PU), the pre-impact location of the intersection of the leading lower vertical edge of the cargo bed and the frame rail on the standard test truck (M), and the pre-impact location of the intersection of the leading lower vertical edge of the cargo bed and the frame rail on the Class 7 Cabover (C7), and the pre-impact location of the intersection of the leading lower vertical edge of the cargo bed and the frame rail on the heavy goods vehicle (H).

7.1.2 There are four nominal vehicle test velocities in this test method. These nominal velocities are 50, 65, 80, and 100 km/h [30, 40, 50, and 60 mph]. The velocity and associated vehicle determine the condition designation (see last column in Table 1).

7.2 *Test Site:*

7.2.1 Tests shall be conducted at an accredited facility. These facilities shall have adequate space to accelerate the test vehicle to the desired impact velocity and have 30 m [98 ft] minimum behind the barrier reference point, as shown in Annex A1, in accordance with Table 2. In general, the space needs to be level with unobstructed impact regions and not contain curbs, dikes, or ditches in front of the test article installation except where test requirements specify such features as part of the barrier system. Lateral clearance to adjacent objects shall be a minimum of 3 m [10 ft]. The surface shall replicate anticipated field deployed conditions.

7.2.2 Unless otherwise required, in test barriers requiring embedment in soil, including concrete footings, the soil shall be low-cohesive, well-graded crushed stone or broken gravel of a particle size distribution comparable to Table 3. The low-cohesive soil shall have a depth equal to the bottom of the foundation and a width equal to 1.5 times the foundation depth behind the test barrier or 0.6 m [2 ft], whichever is greater up to a maximum of 1.8 m [6 ft]. The low-cohesive soil shall be compacted fill to a density of not less than 90 % maximum dry density in accordance with Test Methods ~~D1556/D1556M~~D1556 and D6938 and AASHTO Method of Test T099 and meet Table 3 for gradation. If testing for site-specific soil conditions is being conducted, then testing may be performed in replicated site soil conditions and reported in the test report. The lateral bearing pressure and moisture content shall be recorded and reported. These values shall be determined from standard test methods. It is recommended that Test Method D4429 be used to determine the lateral bearing ~~pressure (if lateral loads are expected, the low-cohesive soil shall extend the same distance laterally).~~pressure.

7.2.3 For test barriers that are surface mounted, testing shall be on a surface established by the supplier in consultation with the test director and any others who might be involved. Regardless of the surface on which the barrier is mounted, the profile of the test bed to a depth of 0.6 m [2 ft] shall be determined and documented in the test report.

7.3 *Test Article*—The test barrier shall be constructed and erected in a manner representative of the proposed actual service installation and conform to supplier specifications and drawings. Any deviations from fabrication, specification, or erection details shall be noted in the test report.

7.4 *Test Vehicle*—The test vehicle shall be structurally sound (no major rust or structural weakness), have an unmodified bumper, and not have any structural additions or modifications that may enhance test performance. Tires shall be of the size and type recommended by the manufacturer and inflated to recommended pressure. Note that there might be agency-specific vehicle requirements to which the test must comply to enable the barrier's inclusion on the agency's approved barrier list.

TABLE 2 Penetration Ratings

Designation	Dynamic Penetration Rating
P1	≤1 m [3.3 ft]
P2	1.01 to 7 m [3.31 to 23.0 ft]
P3	7.01 to 30 m [23.1 to 98.4 ft]

TABLE 3 Recommended Soil Foundation Material (from AASHTO M147-65)

Sieve Size, mm [in.]	Mass % Passing
50.0 [2]	100
25.0 [1]	75-95
9.5 [⅜]	40-75
4.75 [No. 4]	30-60
2.00 [No. 10]	20-45
0.425 [No. 40]	15-30
0.075 [No. 200]	5-20

TABLE 4 Typical U.S. Small Passenger Car

Make	Model	GVW, kg [lb]	Curb Weight, kg [lb]
Kia	Rio	1560 [3438]	1125 [2480]
Toyota	Yaris	1061 [2340]	1041 [2295]

TABLE 5 Typical U.S. Full Size Passenger Sedan

Make	Model	GVW, kg [lb]	Curb Weight, kg [lb]
Ford	Taurus	2440 [5379]	1831 [4037]
Dodge	Charger	2313 [5100]	1797 [3961]
Kia	Cadenza	1985 [4376]	1664 [3668]

TABLE 6 Typical U.S. ½ Ton Pickup Trucks

Make	Model	GVW, kg [lb]	Curb Weight, kg [lb]
Chevrolet	1500 Crew Cab 4 Door	3084 [6800]	2313 [5100]
Ford	F150	2926-3720 [6450-8200]	2125 [4685]
Dodge	Ram 1500 Quad Cab	2722-3084 [6000-6800]	2263 [4990]

7.4.1 *Small Passenger Car (SC)*—The small passenger car shall be manufactured within ten years of the test date and should be selected based on sales information for the applicable years. The vehicle may be a sedan or coupe configuration. The gross vehicle test mass shall be 1100 ± 25 kg [2420 ± 55 lb]. If ballasting is required, water may be added to the fuel tank or weights evenly distributed and securely anchored to the occupant compartment floor. Care should be taken to distribute the ballast uniformly.

7.4.2 *Full-Size Passenger Sedan (FC)*—The full-size passenger sedan shall be manufactured within ten years of the test date and should be selected based on sales information for the applicable years. The gross vehicle test mass shall be 2100 ± 50 kg [4630 ± 110 lb]. If ballasting is required, water may be added to the fuel tank or weights evenly distributed and securely anchored to the occupant compartment floor. Care should be taken to distribute the ballast uniformly.

7.4.3 *Pickup Truck (PU)*—The pickup truck shall be a ½-ton-rated body style and manufactured within ten years of the test date and should be selected based on sales information for the applicable years. Four-door, crew cab pickups shall be used. The ½-ton crew cab pickup has been shown to be a good surrogate for the sport utility vehicle. The gross vehicle test mass shall be 2270 ± 50 kg [5000 ± 110 lb]. If ballasting is required, care should be taken to distribute the ballast uniformly.

7.4.4 *Standard Test Truck (M)*—The standard test truck will be equipped with a conventional cab. The conventional M vehicle shall be equipped with a diesel engine and tested at a test inertial vehicle mass of 6800 ± 140 kg ~~[15~~(15 000 ± 309 lb]. U.S. standard test trucks have gross vehicle mass ratings of ~~11 801 to 14 970 kg [26 001 to 33 000~~ 11 801 to 14 970 kg [26 001 to 33 000 lb] and a wheelbase of 6.0 ± 1.25 m [236 ± 50 in.]. A commercially manufactured flat bed, 6.1 ± 1.5 m [20 ft ± 60 in.] long shall be installed per the vehicle manufacturer's specifications. "U" bolts shall be spaced at 1.0 ± 0.2 m [3 ft ± 8 in.] on center, unless otherwise specified by the vehicle manufacturer and shear plate connections shall be provided on the front and rear of the flat bed as specified by vehicle manufacturer. Ballast material shall be soil-filled, 208-L [55-gal] steel drums attached to the vehicle cargo bed, as described in 7.4.4.3.

7.4.4.1 Illustrative U.S. manufactured standard test trucks are given in Table 7.

7.4.4.2 Table 7 is not all inclusive; comparable vehicles may be acceptable as a test vehicle.

7.4.4.3 The ballast will be standard, round, "open top" (removable top, secured with ring and nut/bolt, or level-lock mechanism), 208-L [55-gal] metal drums filled with soil. The 208 L [55-gal] drums are nominally 610 ± 51 mm [24 ± 2 in.] in diameter and 914 ± 51 mm [36 ± 2 in.] in outside height. (ISO "containerizable" steel drums may also be used. These are

TABLE 7 Typical U.S. Standard Test Trucks (Conventional Cab)

Make	Model	GVW, kg [lb]
Ford	650	8850-13 1360 [19 500-29 000]
Ford	750	8850-14 970 [19 500-33 000]
Freightliner	M2 106	8850-14 970 [19 500-33 000]
International	4300	8850-14 970 [19 500-33 000]
International	4400	8850-14 970 [19 500-33 000]

nominally 595 mm [23 7⁄16 in.] with the same inside diameter as the standard 208-L [55-gal] drum. Three horizontal cargo straps and a minimum of one cargo strap over the top of each row of steel drums are required. Photos of a typical test vehicle configuration and ballast attachment using 4540 kg [10 000-lb] ultimate capacity cargo straps are shown in Figs. 1 and 2.

FIG. 1 Typical Text vehicle Configuration, Side View

FIG. 2 Typical Ballast Attachment, Rear View