Designation: D7277 − 16 (Reapproved 2023)

Standard Test Method for Performance Testing of Articulating Concrete Block (ACB) Revetment Systems for Hydraulic Stability in Open Channel Flow[1]

This standard is issued under the fixed designation D7277; 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.

1. Scope

1.1 The purpose of this test method is to provide specifications for the hydraulic testing of full-scale articulating concrete block (ACB) revetment systems under controlled laboratory conditions for purposes of identifying stability performance in steep slope, high-velocity flows. The testing protocols, including system installation, test procedures, measurement techniques, analysis techniques, and reporting requirements are described in this test method.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard. Reporting or use of units other than inch-pound shall not be considered non-conformance as long as the selected parameters described regarding flume construction by the inch-pound system used in this method are met as a minimum.

1.2.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The rationalized slug unit is not given, unless dynamic (F = ma) calculations are involved.

1.3 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.3.1 The procedures used to specify how data are collected, recorded and calculated in this Guide are regarded as the industry standard. In addition they are representative of the significant digits that generally be retained. The procedures used do not consider material variation, purpose of obtaining the data, special purpose studies or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering design.

1.4 *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 determine the applicability of regulatory limitations prior to use.*

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors and Practice D3740 provides a means of evaluating some of these factors.

1.5 *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]

D422 Test Method for Particle-Size Analysis of Soils (Withdrawn 2016)[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))

D1556/D1556M Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.25 on Erosion and Sediment Control Technology.

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[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.

D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D5195 Test Method for Density of Soil and Rock In-Place at Depths Below Surface by Nuclear Methods
D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of technical terms in this test method, refer to Terminology D653.

3.1.2 *articulating concrete block (ACB) revetment system, n—in erosion control*, a matrix of interconnected concrete block units for erosion protection. Units are typically connected by geometric interlock, cables, ropes, geotextile, geogrids or a combination thereof and typically include a geotextile underlayment.

3.1.3 *depth of flow, y_o,* (**L**), *n—in hydraulics*, the distance from the channel thalweg to the water surface, measured normal to the direction of flow, for a given discharge.

3.1.4 *design discharge, Q_d,* (**L^{3}T^{-1}**), *n—in erosion control*, the volumetric quantity of water flow within a channel which is typically used in determining required channel dimensions and suitable lining materials for ensuring adequate channel capacity and stability.

3.1.4.1 *Discussion*—The discharge associated with a specified frequency of recurrence, for example, an *n*-year flood. The *n*-year flood event has a probability of 1/*n* of being equaled or exceeded in any given year.

3.1.5 *discharge, Q,* (**L^{3}T^{-1}**), *n—in channel flow*, the volume of water flowing through a cross-section in a unit of time, including sediment or other solids that may be dissolved in or mixed with the water; usually cubic feet per second (ft^3/s) or cubic meters per second (m^3/s).

3.1.6 *hydraulic radius,* (**L**), *n—in channel flow*, the cross-sectional area of flow divided by the wetted perimeter.

3.1.7 *local velocity,* (**L^{3}T^{-1}**), *n—in channel flow*, the velocity at a specific point in the flow region. May be defined as a direction-dependent quantity with components V_x, V_y, or V_z.

3.1.8 *mean velocity,* (**LT^{-1}**), *n—in hydraulics*, the average velocity throughout a channel cross section. Defined as the discharge divided by the cross-sectional area of flow usually expressed in meters per second (m/s) or feet per second (ft/s).

3.1.9 *subcritical flow,* (**LT^{-1}**), *n—in channel flow*, a characteristic of flowing water whereby gravitational forces dominate over inertial forces, quantified by a Froude Number less than 1.

3.1.10 *supercritical flow,* (**LT^{-1}**), *n—in channel flow*, a characteristic of flowing water whereby inertial forces dominate over gravitational forces, quantified by a Froude Number greater than 1.

3.1.11 *uniform flow,* (**LT^{-1}**), *n—in hydraulics*, the condition of flow where the rate of energy loss due to frictional and form resistance is equal to the bed slope of the channel.

3.1.11.1 *Discussion*—Where uniform flow exists, the slopes of the energy grade line, the water surface, and the channel bed are identical. Cross-sectional area and velocity of flow do not change from cross section to cross section in uniform flow.

3.1.12 *velocity, V,* (**LT^{-1}**), *n—in channel flow*, time rate of linear motion in a given direction.

4. Summary of Test Method

4.1 The test method is designed to determine the stability threshold values of shear stress and velocity of articulating concrete block (ACB) revetment systems under controlled laboratory conditions of steep-slope, high-velocity flow (flume test). Systems are tested as full-scale production units.

4.2 The procedures associated with test set-up, testing, data collection, and reporting are provided in this test method.

5. Significance and Use

5.1 An articulating concrete block revetment system is comprised of a matrix of individual concrete blocks placed together to form an erosion-resistant revetment with specific hydraulic performance characteristics. The system includes a filter layer compatible with the subsoil which allows infiltration and exfiltration to occur while providing particle retention. The filter layer may be comprised of a geotextile, properly graded granular media, or both. The concrete blocks within the matrix shall be dense and durable, and the matrix shall be flexible and porous.

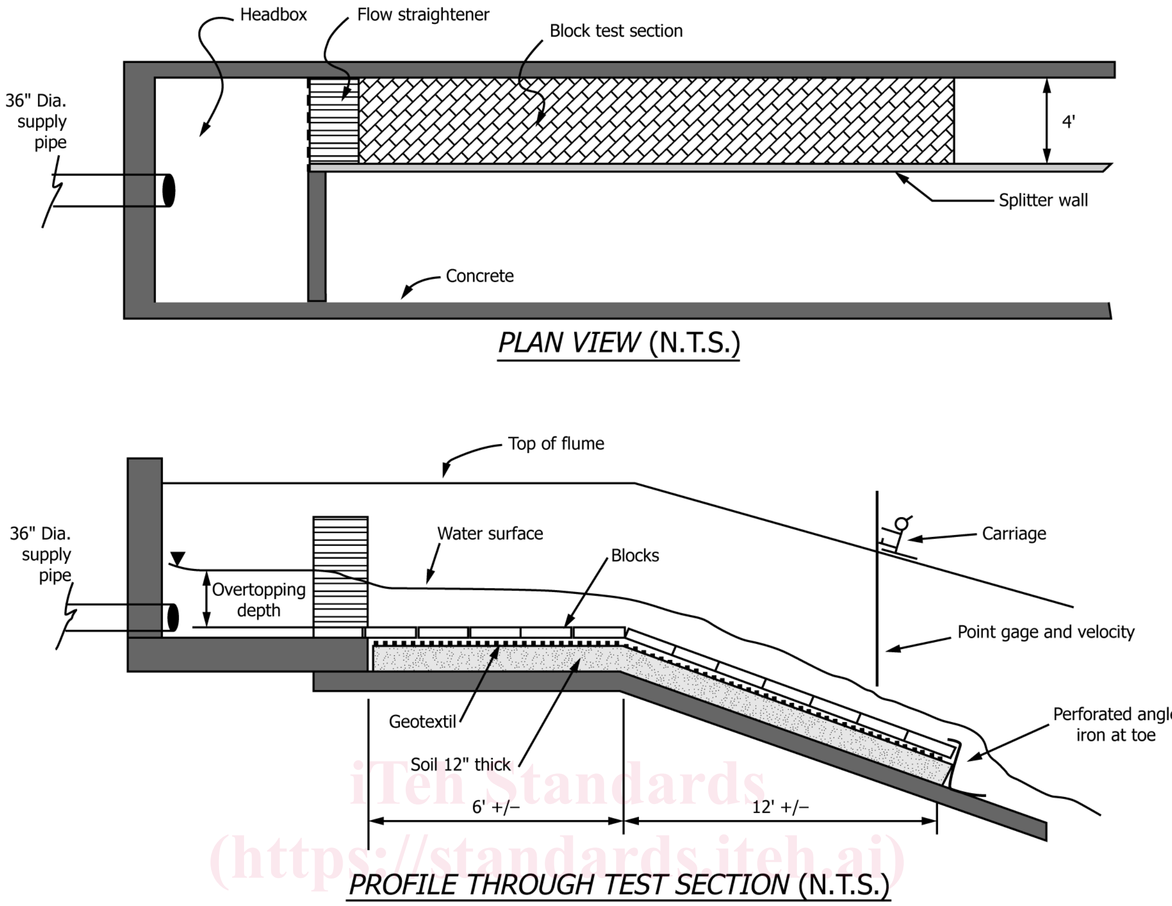
5.2 ACB revetment system are used to provide erosion protection to underlying soil materials from the forces of flowing water. The term "articulating," as used in this standard, implies the ability of individual concrete blocks of the system to conform to changes in subgrade while remaining interconnected by virtue of geometric interlock, cables, ropes, geotextiles, geogrids, or combination thereof.

5.3 The definition of ACB revetment system does not distinguish between interlocking and non-interlocking block geometries, between cable-tied and non-cable-tied systems, between vegetated and non-vegetated systems or between methods of manufacturing or placement. Furthermore, the definition does not restrict or limit the block size, shape, strength, or longevity; however, guidelines and recommendations regarding these factors are incorporated into this standard. Blocks are available in either open-cell or closed-cell configurations.

6. Preparation of Test Section

6.1 *Soil Subgrade Construction:*

6.1.1 The testing program includes the construction of an earthen test subgrade compacted between vertical walls of the testing flume (Fig. 1). The soil subgrade shall be placed and compacted in horizontal lifts of 4 to 6 in. (100 to 150 mm) in thickness to a minimum subgrade thickness of 12 in. (300 mm). The distance between the walls shall be a minimum of 4.0 ft (1.2 m); installation shall be reflective of standard field usage



NOTE 1—Drawing not to scale, and slope, as shown, is not 2H:1V.

NOTE 2—1 ft = 0.305 m.

FIG. 1 Schematic Profile of Typical Testing Flume

and shall accommodate full-scale block units such that at least one block is not adjacent to a sidewall, at least every other row of the revetment matrix.

6.1.2 The soil subgrade shall consist of a silty sand with a plasticity index (PI) in the range of 2 to 6 %, and will be compacted at optimum water content to between 90 and 95 % of Standard Effort density (Test Methods D698). The embankment shall be constructed to a height such that the finished surface of the revetment consists of a horizontal crest section at least 6 ft (1.8 m) in length followed by a downstream slope angle typically set at 2H:1V.

NOTE 2—Test conditions may incorporate slopes other that the 2H:1V identified as the benchmark. Variations from the procedures identified must be included in the report. Additionally, engineering judgment must accompany utilizing and interpreting the results from tests varying from the proposed test method.

6.1.3 Soil information to be determined and documented prior to and during test embankment construction includes, as applicable:

6.1.3.1 Standard Effort moisture-density curve, Test Methods D698.

6.1.3.2 Soil textural classification, Practice D2487.

6.1.3.3 Particle size distribution curve (including hydrometer fraction), Test Method D422, and

6.1.3.4 Atterberg Limits (liquid limit, plastic limit), Test Methods D4318.

6.1.4 Following the preparation of the soil subgrade, the following information is determined within 24 h prior to installation of the revetment system. This information shall include as a minimum the soil water (moisture) content (Test Methods D2216) and density/unit weight determined by sand cone (Test Method D1556/D1556M) or nuclear gauge (Test Method D5195) at a minimum of two locations along the centerline of the test embankment.

6.2 *Installation of ACB Revetment System:*

6.2.1 A properly designed filter (geotextile, granular filter, or both), properly engineered or selected for the soil subgrade utilized for testing, and the ACBs shall be placed on the crest and downstream slope in accordance with the manufacturer's recommendations. Potential artificially induced scour along the sidewalls will be prevented by placing geotextile wadding, protective flashing, loose grout or a combination, along the edge of the ACB revetment system (Fig. 2). The chosen side protection shall allow nominal block movement and not press the block onto the subgrade. Side protection shall permit a gap a above the blocks a minimum of 0.25 in. (6.4 mm) and a maximum of 0.75 in. (19 mm) in the vertical direction.

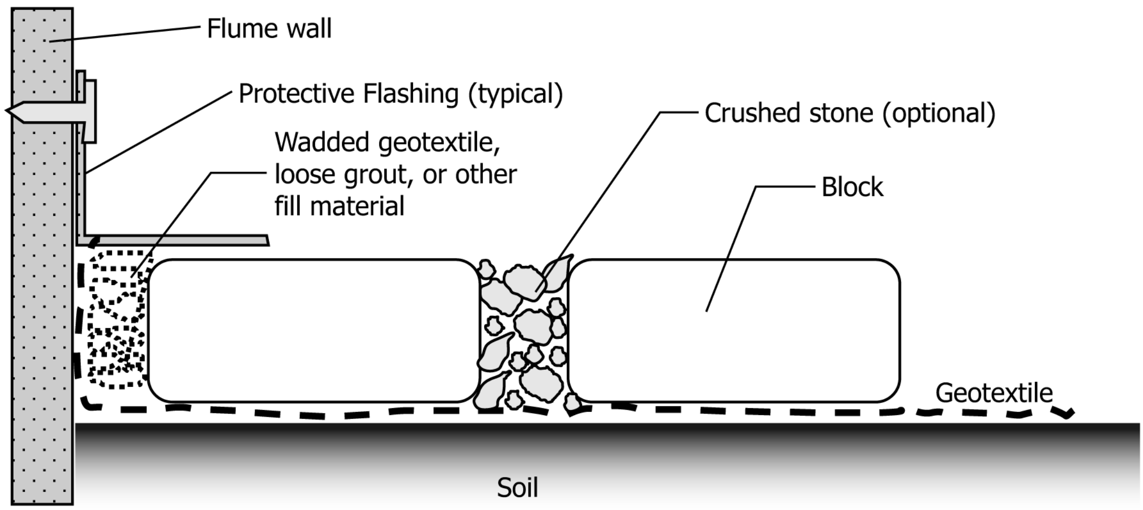


FIG. 2 Recommended Sidewall Detail (Cross Section View)

Horizontal projection of the side protection shall extend a minimum of 0.5 in. (13 mm) and a maximum of 2.5 in. (64 mm) into the flume. The ACB revetment system will be secured at the embankment toe by means of a bolted or welded toe retention system designed for the specific system to be tested (Fig. 3). Depending on the geometry of the system being tested, void spaces next to the sidewalls greater than 3 in. (75 mm) should be filled with partial blocks specially cut with a masonry saw to fill the void, while maintaining the proper geometric relationship of the matrix. Under no circumstances should the void spaces against the sidewall be filled any compound that bonds the block to the sidewall or prevents the system from its inherent ability to articulate. As shown in Fig. 1, a joint between the ACBs shall occur at the crest (top) of the slope.

7. Procedure

7.1 *Definition of Test*—A test consists of a continuous four-hour flow over the ACB revetment system at a uniform discharge. Providing that the ACB revetment system successfully survives the four-hour flow without deformation, soil loss, or loss of solid contact with the soil subgrade, the procedure is repeated at the next higher target discharge or until the flow capacity of the testing facility is reached. Typically, target discharges correspond to predetermined overtopping depths above the revetment system's crest elevation (for example, 1 ft (0.3 m), 2 ft (0.6 m), etc.), although any discharge may be utilized provided proper measurement and reporting procedures are followed as described in this document. Even if minor system deformation occurs during the test, hourly data collection shall be maintained for the entire four-hour test duration, unless catastrophic ACB revetment system failure occurs.

7.2 *Water Surface and Bed Elevation Profiles*—Hourly measurements of water surface elevation will be made at 2-ft (0.6-m) intervals (stations) along the centerline of the embankment during each test. Bed elevations (top of ACB revetment surface) shall be established prior to each test and again after the cessation of each test, at the same measurement stations as the water surface readings. When testing ACBs that exhibit a staggered layout pattern such that there may not be a block at the centerline location at every measurement station, an adjacent block to the left or right of the centerline may be selected as the measurement point. Those ACBs should be identified with a paint mark to ensure consistency in measurement. Measurements should be made to the nearest 0.01 ft (0.003 m) using point gauge, survey level, or other suitable elevation-measuring device. Suitable stationing positions should be established so that the horizontal location of each measurement station does not vary between subsequent measurements.

7.3 *Water Velocity Measurements*—Hourly measurements of point velocity shall be made at two-tenths, six-tenths, and eight-tenths depth of flow, measured from the water surface down, at 4-ft (1.2-m) intervals along the centerline stationing, and shall correspond to every other water surface measurement station. In areas where depth is insufficient to provide velocity measurements at these three depths, one measurement at six-tenths depth shall be made. The velocity measurements shall be made with an electromagnetic current meter, Price-type pygmy (mini) current meter ("spinning cup"), or pitot tube flow meter. The axis of the device shall be maintained at an angle normal to the plane of the embankment while the measurement is made.

7.4 *Total Discharge Determination*—The total discharge, Q_t, shall be determined independently of the measurements