Designation: D6459 − 19

Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion[1]

This standard is issued under the fixed designation D6459; 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 This test method covers the guidelines, requirements and procedures for evaluating the ability of Rolled Erosion Control Products (RECPs) to protect hillslopes from rainfall-induced erosion. Critical elements of this protection are the ability of the RECP to:

1.1.1 Absorb the impact force of raindrops, thereby reducing soil particle loosening through "splash" mechanisms;

1.1.2 Slow runoff and encourage infiltration, thereby reducing soil particle displacement and transport through "overland flow" mechanisms;

1.1.3 Absorb shear forces of overland flow; and,

1.1.4 Trap soil particles beneath.

1.2 This test method utilizes full-scale testing procedures, rather than reduced-scale (bench-scale) simulation, and is patterned after conditions typically found on construction sites at the conclusion of earthwork operations, but prior to the start of revegetation work. Therefore this considers only unvegetated conditions.

1.3 This test method provides a comparative evaluation of an RECP-to baseline bare soil conditions under controlled and documented conditions.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units, which are provided for information only and are not considered standard.

1.5 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this standard.

1.5.1 The procedures used to specify how data are collected/recorded or calculated, in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for 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 analytical methods for engineering design.

1.6 *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.* Also, the user must comply with prevalent regulatory codes, such as OSHA (Occupational Health and Safety Administration) guidelines, while using the test method.

1.7 *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]

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))

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D6026 Practice for Using Significant Digits in Geotechnical Data

D6475 Test Method for Measuring Mass per Unit Area of Erosion Control Blankets

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock; Subcommittee D18.25 on Erosion and Sediment Control Technology; and is the direct responsibility of Section .02 on Erosion Control Blankets (ECBs).

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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.

***A Summary of Changes section appears at the end of this standard**

D6525 Test Method for Measuring Nominal Thickness of Rolled Erosion Control Products
D6566 Test Method for Measuring Mass Per Unit Area of Turf Reinforcement Mats
D6567 Test Method for Measuring the Light Penetration of a Rolled Erosion Control Product (RECP)
D6818 Test Method for Ultimate Tensile Properties of Rolled Erosion Control Products
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 For common definitions of terms in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *erosion control blanket (ECB) in erosion control, n*—a degradable material, composed primarily of processed natural organic materials, manufactured or fabricated into rolls designed to reduce soil erosion and assist in the growth, establishment and protection of vegetation.

3.2.2 *rolled erosion control product (RECP) in erosion control, n*—a temporary degradable or long-term non-degradable material manufactured or fabricated into rolls designed to reduce soil erosion and assist in the growth, establishment, and protection of vegetation.

3.2.3 *turf reinforcement mat (TRM), in erosion control, n*—a non-degradable geosynthetic or geocomposite processed into a matrix sufficient to increase the stability threshold of otherwise unreinforced established vegetation.

3.2.3.1 *Discussion*—Products in this category may incorporate ancillary degradable components to enhance the germination and establishment of vegetation.

4. Summary of Test Method

4.1 The performance of a rolled erosion control product in reducing rainfall-induced erosion is determined by subjecting the material to simulated rainfall in a controlled and documented environment.

4.2 Key elements of the testing process include:

4.2.1 Calibration of the rainfall simulation equipment;
4.2.2 Preparation of the test plot;
4.2.3 Documentation of the RECP to be tested;
4.2.4 Installation of the RECP;
4.2.5 Performance of the test;
4.2.6 Collection of runoff and associated sediment yield data;
4.2.7 Analysis of the resultant data, and;
4.2.8 Reporting.

5. Significance and Use

5.1 This test method evaluates RECPs and their means of installation to:

5.1.1 Reduce soil loss and sediment concentrations in stormwater runoff under conditions of varying rainfall intensity and soil type, and;

5.1.2 Improve water quality exiting the area disturbed by earthwork activity by reducing suspended solids.

5.2 This test method models and examines conditions typically found on construction sites involving earthwork activities including: highway and roads; airports; residential, commercial and industrial developments; pipelines, mines, and landfills; golf courses; etc.

5.3 This test method is a performance test, but can be used for quality control to determine product conformance to project specifications. Caution is advised since information regarding laboratory specific precision is incomplete. For project specific conformance, unique project-specific conditions should be taken into consideration.

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 the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspections/etc. Users of this standard are cautioned that compliance with Practice D3740 does not itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Rainfall Simulators*—Rainfall simulators shall include sprinkler heads, sprinkler risers, valves and pressure gauges. The sprinkler heads should be selected on their ability to model natural raindrop size and distribution (no more than 10 % greater than 6 mm (0.24 in.) and no more than 10 % smaller than 1 mm (0.04 in.)). To approximate the kinetic energy of natural rainfall, the sprinkler riser shall be constructed to position the sprinkler heads to achieve a minimum fall height (peak vertical trajectory) of 4.3 m (14 ft). A flow control valve and a pressure gauge capable of maintaining a uniform operating pressure shall be located on each riser. Fig. 1 shows an example of a rainfall simulator.

6.2 *Water Source*—Any water source shall be suitable for this use provided that it does not contain deleterious materials which could impair the operation of the rainfall simulators.

6.3 *Runoff and Sediment Collection System*—The runoff and sediment collection system includes flashing, collection apparatus and a holding tank. Flashing shall be fabricated to direct runoff from the plot into the collection apparatus. Once the runoff is on the flashing, it may be desirable to divert the flow to a single collection point. The flashing shall be continuous across the entire bottom edge of the plot. A holding tank(s) capable of temporarily containing all runoff shall be connected to the collection apparatus.

6.4 *Vegetative Stand Quantification Equipment*—A calibrated template used to ensure height of vegetation and counting box are necessary for vegetated testing. Vegetation is cut to a specific, uniform stand height by placing a template on the soil surface and trimming blades/stems at the top of the template. An open, square box is used to count vegetation stems and blades to determine stand density. The box may be constructed of metal or wood with an internal opening measure 76.2 mm (3 in.) square and 25.4 to 50.8 mm (1 to 2 in.) in height.

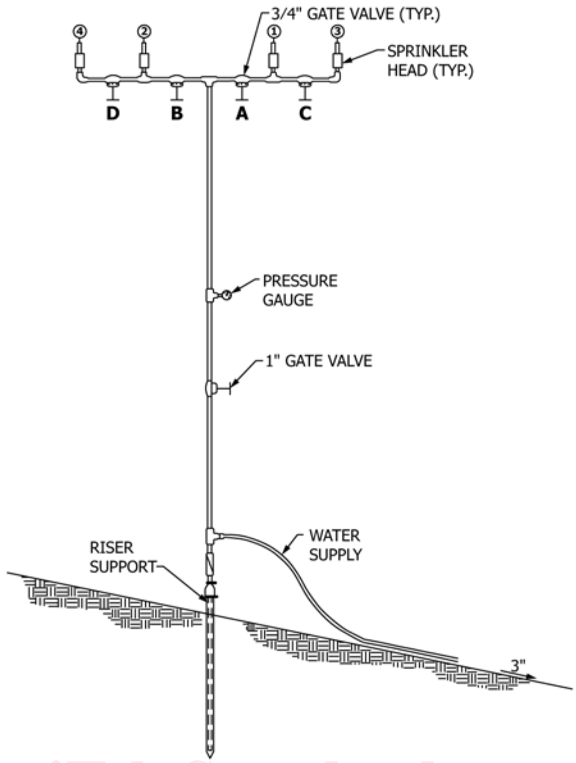

FIG. 1 Typical Rainfall Simulator

6.5 *Miscellaneous*—Other miscellaneous equipment includes: rain gauges (20), pie pans (3), sieve set (standard US sieves), evaporating dishes, a drying oven or microwave oven, balances, meteorological equipment (wind speed, temperature, precipitation), a surveyor's rod, sample bottles and bags, cooler and camera or video recorder.

7. Procedure

7.1 *Test Plot Preparation:*

7.1.1 Construct an earthen embankment using conventional earthwork placement techniques. Perform compaction of the embankment to create a geotechnically (structurally) stable embankment with a surface slope of 3H:1V having a slope length of 12 m (40 ft). Fig. 2 shows a typical embankment cross-section.

NOTE 2—The effect of variations in test plot width, length, gradient, and drainage conditions are currently being evaluated.

7.1.2 Plate the top surface of the embarkment with a minimum 30 cm (12 in.) thick veneer of soil. General soil types to be used for testing shall be loam, clay, and sand. Target grain sizes and plasticity indices are included in Fig. 3. Place the veneer in 15 cm (6 in.) lifts and compact to 90 ± 3 % of standard Proctor density in accordance with Test Method D698.

7.1.3 Locate test plots on the embankment using a plot size of 2.4 m (8 ft) in width (cross-slope) and of 12 m (40 ft) in length (downslope). Separate the test plots such that overspray from the rainfall simulators does not impact adjacent plots.

NOTE 3—The slope width, length and steepness were selected as being representative of conditions typically found on construction sites. This test plot configuration was chosen to assure uniformity and consistence of testing activities.

7.1.4 Isolate the top edge and sides of each test plot by a water barrier which forms the boundary of the test plot. Bury the bottom edge of the barrier approximately 10 cm (4 in.) to divert surface flow such that no intrusion of outside surface water onto the test plot ("run-on") occurs. The barrier shall be continuous such that joints do not allow outside flow to enter the plot. Commercially available lawn edging is suitable for this purpose.

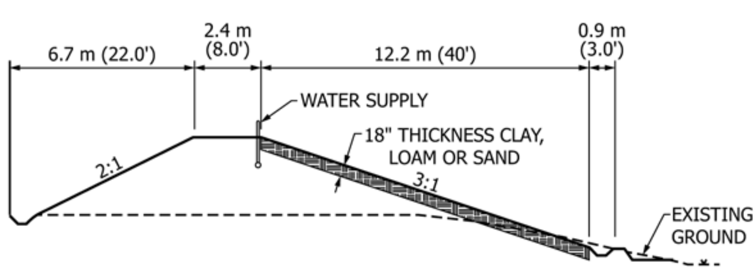

FIG. 2 Typical Embankment Cross Section

Particle size (mm)	Sand	Loam	Clay
D_{100} (mm)	25 > D_{100} > 3.0	10 > D_{100} > 0.3	3.0 > D_{100} > 0.02
D_{85} (mm)	4.0 > D_{85} > 0.8	0.8 > D_{85} > 0.08	0.08 > D_{85} > 0.003
D_{50} (mm)	0.9 > D_{50} > 0.2	0.15 > D_{50} > 0.015	0.015 > D_{50} > 0.0008
D_{15} (mm)	0.3 > D_{15} > 0.01	0.03 > D_{15} > 0.001	D_{15} < 0.002
Plasticity Index	N/A (nonplastic)	2 < PI <8	10 < PI

FIG. 3 Typical Grain Sizes and Plasticity Indices

7.1.5 Loosen the soil veneer to a depth of approximately 10 cm (4 in.) using a tiller or other appropriate tools. Rake the tilled plot smooth with a steel hand rake and lightly compact using a turf roller. Repair depressions, voids, soft, or uncompacted areas before testing commences. Also, free the plot from obstruction or protrusions, such as roots, large stones, or other foreign material. Soil preparation methods for bare soil testing utilized as a baseline, control plots for product or vegetated testing shall be identical to soil preparation methods for the protected scenario.

NOTE 4—Standarized, quantified soil compaction rate is being evaluated.

7.1.6 If the plots have been used for previous test series, discard the soil carried of the plot and obliterate any rills and gullies. Spread new soil of the same type across the plot and blend (rake or till) into the surface. If the soil loss of the control plot differs significantly from the base line calibration test reevaluate the soil properties.

7.2 *Calibration:*

7.2.1 Calibration of the rainfall simulation equipment includes:

7.2.1.1 Rainfall intensity;

7.2.1.2 Uniformity of rainfall application across the plot, and;

7.2.1.3 Drop size distribution for each intensity.

7.2.2 To ensure uniform raindrop distribution, do not conduct calibration or testing when the wind velocity is greater than 1.6 km/h (1 mph).

7.2.3 At a minimum, conduct calibration annually or following equipment maintenance work. Conduct one intensity/uniformity check every 90 days, or after no more than four test series, whichever comes first.

7.2.4 Place sprinkler risers around the perimeter of the test plot to provide uniform distribution. The precise location of the risers to provide uniform rainfall distribution will be determined by the calibration process and the nuances of any given simulator system (see Fig. 4 for typical sprinkler riser configuration).

7.2.5 Place the rain gauges on the plot surface following the pattern shown in Fig. 4. Duration of the calibration test shall be 15 min, recorded to the nearest second. Perform calibrations at uniform pressure for each intensity. Adjust riser locations until an acceptable uniform rainfall distribution pattern is achieved, as defined in Section 8.

7.2.6 Calculate the rainfall intensity uniformity using the Christiansen uniformity coefficient (see Section 8).

7.2.7 To measure drop size distribution, completely fill three labeled pie pans with sifted flour, struck off with a ruler to produce a smooth, uncompacted surface. Locate three supports approximately 20-cm (8-in.) high (for example, 1-gal cans) along the vertical centerline of the test plot, and at the horizontal quarter points. Place the filled pie pans on the supports (horizontal, not parallel to the ground) and cover. At the desired test intensity, remove the cover briefly so that drops impinge on the flour to form pellets. Recover the pans after only a few seconds and before the drops start to touch each other. Repeat this procedure at each desired intensity. Air-dry the flour pellets for a minimum of 12 h. Screen each sample of these semi-dry pellets by emptying the entire contents of the pan onto a 70 mesh sieve to carefully remove as much loose flour as possible. Then transfer the remaining pellets to evaporating dishes and heat in an oven at approximately 43°C (110°F) for 2 h. Record the total weight of the hard flour pellets. Sieve the pellets through standard soil sieves by shaking the stack for 2 min. Cull foreign matter and any double pellets from each sieve and record the total weight and pellet count for each size (**1**).[3]

7.2.8 Repeat the raindrop size calibration procedure (7.2.7) three times for each desired intensity.

7.2.9 Determine raindrop fall height by measuring the average height of the raindrop trajectory using a surveyor's rod. Hold the rod vertically in the spray of a single riser and measure the wetted height. Repeat the height measurement for each desired intensity.

7.3 *Pre-Test Documentation:*

[3] The boldface numbers given in parentheses refer to a list of references at the end of the text.

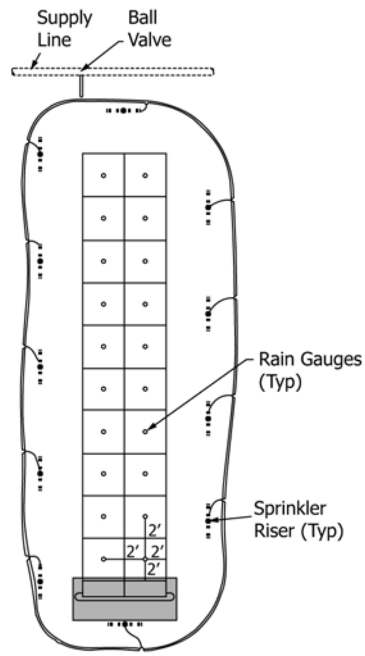

FIG. 4 Typical Sprinkler Riser Configuration

7.3.1 Maintain a test folder for each test cycle, including information on: site conditions; geotechnical and soil conditions; meteorological data; RECP product type, description and installation procedure, and; photo and/or video documentation.

7.3.2 Include the following subjective site information: general visual conditions of the plot to be tested; general meteorological information; plot treatment; photographs or videotape, or both, and any supplemental information that is not included in the following sections but is felt to be of interest to the test.

7.3.3 Include the following geotechnical and soils information: soil classification [Unified Soil Classification System (USCS) and USDA classification system.]; standard proctor moisture-density relationship; "K" factor; and; gradation (including hydrometer test for the P_{200} fraction).

7.3.4 Include the following meteorological information: all data from the on-site weather station at the time of the test (that is, ambient air temperature, wind speed and precipitation).

7.3.5 Include the following product type and description information: manufacturer name; product name; description; specifications; size; a sample of the material, if practical, and; the following index test results from subsamples of the products tested (if product test): Thickness (Test Method D6525), Mass per Unit Area (Test Method D6475 for ECBs; Test Method D6566 for TRMs), Tensile Strength (Test Method D6818), and Light Penetration (Test Method D6567).

7.4 *Test Set-Up*

7.4.1 Determine the optimum moisture content for the soil type on the given plot. Wet the plot using the rainfall simulation system until the soil reaches the optimum moisture content plus or minus 4 %. Take soil sample to determine the pretest soil moisture content within 1 h prior to the test.

7.4.2 Install the RECP on the plot after calibration has been completed and the test plot has been prepared. Permit no foot traffic on the plot, once the RECP has been installed. Document the installation methodology for the ECB including: orientation on the slope (longitudinal or lateral); placement (which side faces up); termination details; joint details, and; anchor type and installation pattern. Place the RECP so that no gaps are present along the perimeter barrier and be cut to fit, as necessary, to cover the plot.

7.4.3 Take photographs or videotapes, or both of the covered plot prior to testing.

NOTE 5—If testing an ECB or unvegetated TRM, proceed to 7.5. If testing a vegetated TRM, continue with 7.4.4.

7.4.4 It is desirable to know the performance capabilities of TRMs under both unvegetated and vegetated conditions because they are permanent products and their function continues after the establishment of vegetation. For vegetated TRM tests, prepare seed bed, apply seed as desired, and install TRM as described in 7.4.2. Provide water and fertilizer or other additives as required to establish vegetation. Record seed type, preparation methodology, watering schedule, fertilizer and additives used, and climatic variables over the entirety of the maturation period. Photograph test plot weekly. Include photographs and notes regarding vegetation establishment in log with seed type, seed source, and date of planting. If a uniform vegetation height is desired, trim vegetation using hand shears and height template.

7.4.5 Immediately prior to testing a vegetated TRM, quantify vegetative stand density using count box described in 6.4. Place count box on plot surface; count and record the number of stems and the number of blades within the opening of the box. A minimum of three vegetation stem density counts are to be performed; one located within the upper, middle, and lower third of the test plot. Minimize damage to vegetated system by limiting foot traffic and stepping carefully around vegetation stem/blade density count location. Subsequent counts during testing are to be performed in the same location as the initial count. Document condition of vegetation immediately prior to testing, recording stand height as obtained by trimming to template height, density obtained from box counts, photographs and video footage, and visual classification of vegetative stand. Classify and record condition of vegetation (**2**). If variable vegetation height is used, record description of vegetation and a range of heights and USDA classification.

7.5 *Test Operation and Data Collection:*

7.5.1 Include the following test data: operator name and title; operating pressure; sprinkler heads activated; time rainfall began; time runoff from the plot began; time rainfall stopped; time runoff stopped, and; volume readings taken at intervals ranging from 30 s to 3 min (the more frequent measurements shall be recorded at higher runoff rates).

7.5.1.1 For vegetated TRM tests, include the following test data in addition to the items listed in 7.5.1: Vegetative component variables including seed type, seed source, stand density and maturity at time of testing, stand height, visual classification of vegetation, and photo and note log from vegetation.

7.5.2 Include one control plot (bare soil) and a minimum of three product test plots in each test series. Each test series shall follow identical procedures as noted above.

7.5.3 Perform testing at sequential target intensities of 5.1, 10.2, 15.2 cm/hr (2, 4, 6 in/hr) for 20 min or until catastrophic slope erosion is observed.

7.5.4 During each target intensity, collect samples to determine the total amount of sediment produced from the test plot and the time history of sediment concentrations in runoff during the course of the event. Determine total sediment from the plot tested by allowing settlement to occur in the runoff collection tank. Siphon off excess water and discard. Make sure that the sediment in the bottom of the tank is not disturbed. Depending on the amount of sediment produced during the test, collect either the entire amount of the settled sediment, or a representative sample, in a labeled one-gallon freezer bag. Weigh, record and then discard the unsampled portion, if any. Determine the water content of the sediment by assuming that the entire sediment produced during the test exhibited the same moisture content as the sample portion.

7.5.5 During each target intensity, take grab samples at intervals of 30 s to 3 min depending on the runoff rate to determine sediment concentration. Commence sampling when runoff starts and continue until runoff stops. Take samples from the plot apron in 200 mL laboratory sample bottles and analyze for suspended sediment. To keep rainfall from entering the bottle during filling, lift the cover on the apron and collection apparatus just enough to gain access for the sampling bottle. Label each bottle and place in a cooler until the laboratory analysis can be performed.

7.5.6 Record general observations regarding the condition of the tested RECP at the conclusion of the data collection.

7.5.7 Take photographs or videotapes, or both of the covered plot after testing has been completed.

7.5.8 Carefully remove the RECP from the plot with as little disturbance of the soil as possible. Note general observations regarding the condition and erosion patterns (rills, etc.). Take photograph or videotape, or both to record the condition of the soil. Markers may be used to identify any rilling patterns for the pictorial documentation.

8. Calculation

8.1 *Calibration Data:*

8.1.1 Calculate the Christiansen uniformity coefficient (C_u) using a network of rain gauges (20 min) each of which represents an equal area of the test plot. Calculate the C_u as follows:

$$C_u = 100\left[1.00 - \sum|d| \div n\bar{X}\right] \tag{1}$$

where:

C_u = Christiansen uniformity coefficient,
d = $X_i - \bar{X}$,
n = number of observations (20 in this case),
X = average depth caught, and
X_i = depth caught in each rain gauge, i.

NOTE 6—Distribution of rain drop size and intensity over the plot may affect results and need to be evaluated on a case-specific basis.

8.1.2 The average rainfall intensity over the entire test plot is the average depth of rainfall collected in the rain gauges (see 7.2.5 and Fig. 4) divided by the elapsed time of the test. The formula to calculate intensity (in centimeters per hour) is:

$$i = 60\left[\sum_{j=1}^{J} P_j \div Jt\right] \tag{2}$$

where:

i = rainfall intensity (cm / h),
P_j = depth of rainfall (cm),
J = number of rain gauges (20 in this case), and
t = time of test (minutes).

8.1.3 Plot the raindrop size distribution for each intensity. Fig. 5 shows example raindrop size distribution curves.

8.1.4 Determine the kinetic energy imparted by the rainfall simulators at the soil surface by summing the kinetic energy of each drop size class multiplied by the relative percentage of that drop size, as determined by the distribution data. The kinetic energy represented by each size class is:

$$KE_{total} = \sum 0.5\, m\, v^2 \tag{3}$$

where:

KE = kinetic energy of drop size class,
m = mass of drop, and
v = velocity of drop at the soil surface.

Figs. 6 and 7 show velocity of fall of seven sizes of water drops after heights of fall from 0.5 to 20.0 m (**2**), and terminal velocity of distilled water droplets in still air, respectively (**3**).

8.1.5 As described in Refs (**4**) and (**5**), calculate the Erosion Index (EI) for the rainfall simulators as:

$$EI = I \times 1099 \times \left[1 - 0.72\exp(-1.27 \times I)\right] \tag{4}$$

where:

EI = erosion index, and
I = rainfall intensity, in./h.

Calculate the EI value for the desired intensities and corrected for the kinetic energy of drops at less than terminal velocity.