



Standard Test Method for Measuring Force Reduction, Vertical Deformation, and Energy Restitution of Synthetic Turf Systems Using the Advanced Artificial Athlete¹

This standard is issued under the fixed designation F3189; 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 specifies a method for measuring force reduction, vertical deformation, and energy restitution of synthetic turf surfaces.

1.2 This method is used to characterize properties of synthetic turf systems including the turf fabric, infill material, and shock pad (if applicable).

1.3 It can be used for characterizing synthetic turf systems in laboratory environment or in the field.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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 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

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

¹ This test method is under the jurisdiction of ASTM Committee F08 on Sports Equipment, Playing Surfaces, and Facilities and is the direct responsibility of Subcommittee F08.65 on Artificial Turf Surfaces and Systems.

Current edition approved Nov. 1, 2020. Published December 2020. Originally approved in 2017. Last previous edition approved in 2017 as F3189 – 17. DOI: 10.1520/F3189-20.

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. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *energy restitution (ER), n*—a measure of the energy returned by the synthetic turf surface after the impact force has been applied.

3.1.2 *energy restitution coefficient, n*—the ratio of the dynamic load energy applied to the surface to the energy returned by the surface.

3.1.3 *force reduction (FR), n*—the ability of a synthetic turf sports surface to reduce the impact force of a mass falling onto that surface.

3.1.3.1 *Discussion*—The reduction in impact force for this test method is expressed as a percentage reduction when compared to a reference force of 6760 N. The reference force is the theoretical maximum impact force that occurs when the test is performed on a rigid surface (concrete).

3.1.4 *synthetic turf system, n*—all components of the synthetic turf surface and subsurface that have the potential to influence the dynamic properties of the surface.

3.1.4.1 *Discussion*—These include any shock pads or dynamic base constructions installed as part of the synthetic turf system.

3.1.5 *vertical deformation (Def), n*—a measure of the distance a test foot penetrates into the surface when a standard impact force is applied.

3.2 *Symbols:*

3.2.1 *A*—acceleration in m/s^2 .

3.2.2 *Def*—deformation in millimeters.

3.2.3 *E*—energy in Joules.

3.2.4 *ER*—energy restitution.

3.2.5 *F*—force in Newtons.

3.2.6 *FR*—force reduction in %.

3.2.7 *g*—acceleration due to gravity.

3.2.8 *R*—coefficient of restitution.

3.2.9 *t*—time in seconds.

4. Summary of Test Method

4.1 A mass with a spring attached is allowed to fall onto the test surface. The acceleration of the mass is recorded from the moment of release until after its impact with the turf surface. Force Reduction is the percentage reduction in the measured maximum force (F_{max}) relative to the reference force (F_{max}).

4.2 Deformation is calculated by double integration of the record of acceleration versus time. Energy restitution is calculated from the force versus deformation curve.

5. Significance and Use

5.1 The dynamic interaction between the athlete and the synthetic turf surface affects the comfort and the performance of the athlete. Interaction with a surface that has low amounts of deformation and shock absorption allows the player to run fast and turn quickly, but has the potential to cause discomfort and damage to the lower extremity joints. Synthetic turf surfaces having high deformation have lower energy restitution. Less of the energy exerted by the athlete returns from the surface, possibly increasing the fatigue for the performing athlete.

6. Test Conditions

6.1 Laboratory Test Conditions:

6.1.1 Laboratory tests shall be conducted on samples of the complete turf system. The test sample shall have nominal dimensions of 1 m by 1 m. The turf samples shall be prepared in accordance with the manufacturers stated method.

6.1.2 *Characteristics of the Laboratory Floor*—The laboratory floor shall be concrete with a minimum thickness of 100 mm.

6.1.3 *Conditioning and Test Temperature*—The test piece shall be conditioned at laboratory temperature ($23 \pm 2^\circ\text{C}$) for 24 ± 0.5 h.

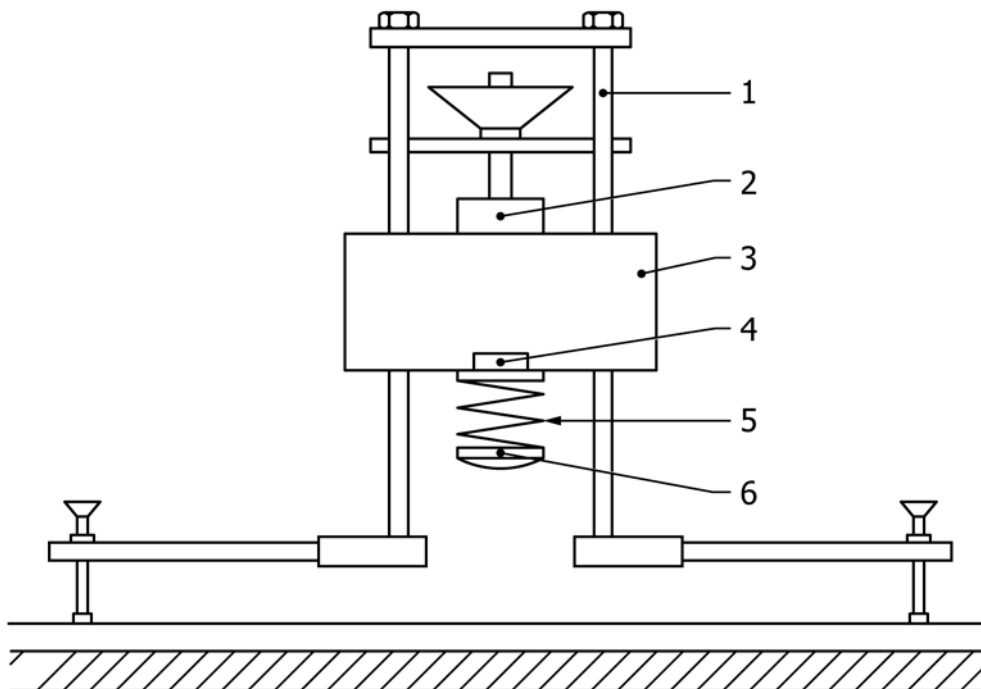
6.2 *Field Test Conditions*—Testing in the field shall be performed at ambient temperature and humidity which shall be recorded and reported.

7. Test Apparatus

7.1 The principle of the test apparatus is shown in Fig. 1 and consists of the following essential components specified in 7.2 – 7.7.

7.2 Falling mass (3), incorporating a helical metal spring (5) and steel foot (6) and fitted with an accelerometer (4), having a total mass of 20.0 ± 0.1 kg.

7.3 Helical steel spring (5), whose characteristic is linear (measured with maximum increments of 1000 N) with a spring rate of 2000 ± 60 N/mm over the range of 0.1 to 7.5 kN. The



- Keys:
- 1 guide for the falling mass
 - 2 electric magnet
 - 3 falling mass
 - 4 accelerometer
 - 5 spring
 - 6 test foot

FIG. 1 Test Apparatus

axis of the spring shall be vertical and shall be directly below the center of gravity of the falling mass. The spring shall have three coaxial coils that shall be rigidly fixed together at their ends. The mass of the spring shall be 0.80 ± 0.05 kg.

7.4 Steel test foot (6) having a lower side rounded to a radius of 500 ± 50 mm; an edge radius of 1 mm; a diameter of 70 ± 1 mm and a minimum thickness of 10 mm. The mass of the test foot shall be 400 ± 50 g.

7.5 Test frame with minimum of three adjustable supporting feet, no less than 250 mm from the point of application of the load. The design of the supporting feet shall insure the weight of the test apparatus is equally distributed on all of the feet.

7.5.1 The pressure (with the mass) on each foot shall be <0.020 N/mm² and the pressure (without the mass) on each foot shall be >0.003 N/mm².

7.5.2 The complete system will have a mass of ≤ 50 kg.

7.6 A piezo-resistive accelerometer (4) with the following characteristics:

- (1) measuring range: ± 50 g;
- (2) 3 dB upper frequency response: ≥ 1 kHz;
- (3) linearity error $< 2\%$.

7.6.1 The accelerometer shall be firmly attached to avoid natural filtering and the generation of spurious signals.

7.7 Means of supporting the mass (2) that allows the falling height to be set with an uncertainty of no greater than 0.25 mm.

7.8 Means of conditioning and recording the signal from the acceleration sensing device and a means of displaying the recorded signal (see Fig. 2).

7.8.1 Sampling rate minimum: 9600 Hz;

7.8.2 Electronic A-D converter with a resolution giving 1 bit equal to a maximum 0.005 g acceleration;

7.8.3 Signal from the acceleration sensing device shall be filtered with a 2nd order low-pass Butterworth filter with a cut-off frequency of 600 Hz.

7.9 Means of calculating the speed and displacement of the falling weight during the course of impact by integration and double integration of the acceleration signal. To be verified in accordance with 8.4 and 8.5.

8. Verification of Impact Speed

8.1 *General*—The verification is carried out to ensure the correct impact speed (or energy, because the mass is fixed) and the correct functioning of the apparatus. The checking procedure shall consist of three steps and shall be carried out on a stable and rigid floor (no significant deflection under a 5 kg/cm² pressure) as follows:

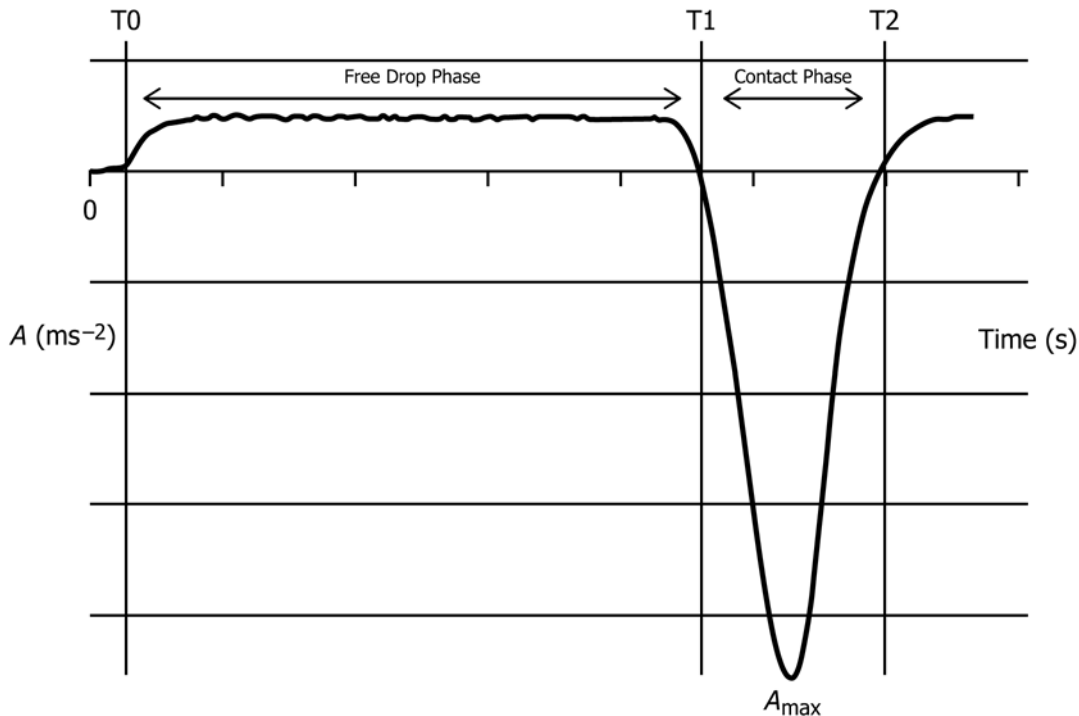


FIG. 2 Example of Falling Mass Acceleration Versus Time Curve

where:

T_0 = time when the mass starts to fall.

T_1 = time when the test foot makes initial contact with the surface (determined on the Velocity/time curve – V_{max}^*)

T_2 = time (determined on the Velocity/time curve – V_{min}^*) corresponding to the maximum velocity when the mass rebounds after the impact.

NOTE 1— V_{min} can be a minimum or maximum value depending on the sensor's direction.