Designation: ~~F355 – 16ε1~~ F355 – 23

An American National Standard

Standard Test Method for Impact Attenuation of Playing Surface Systems, Other Protective Sport Systems, and Materials Used for Athletics, Recreation and Play[1]

This standard is issued under the fixed designation F355; 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.

~~ε[1] NOTE—Editorially corrected A1.9 in December 2016.~~

1. Scope

1.1 This test method measures the impact attenuation of surface systems and materials, specifically the peak impact acceleration ("impact shock") and calculates the Head Injury Criteria produced under prescribed impact conditions.

1.2 This test method is applicable to ~~natural and artificial~~ surface systems intended to provide impact attenuation, ~~including natural and artificial turf sports fields.~~made of naturally occurring or synthetic materials.

1.3 This test method is applicable to impact attenuating mats and padding used in sports facilities, ~~including~~ including, but not limited to: stadium wall padding, gymnastic mats, wrestling mats, turf playing systems, pole vault landing systems, and playground protective ~~surfacing, and other systems.~~surfacing.

1.4 This test method is used to measure the impact attenuation of materials and components used as protective padding on trampoline frames, goal posts, etc., provided the material or component can be tested separately from the equipment to which it is attached.

1.5 Without modifications, this test method shall not be used to test materials and components that are attached to structures or equipment or finished products, unless the impact attenuation of the whole system is of interest.

1.6 While it is widely believed that ~~appropriate~~ lower values for impact attenuation can reduce the ~~risk~~severity of impact-related injuries, the relationships between the results of this test method and specific injury risk ~~and outcomes have not been determined.~~are within automotive testing data.

1.7 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.8 *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 and health~~safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

[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 F08.52 on Miscellaneous Playing Surfaces.

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1.9 *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]

D1596D5874 Test Method for Dynamic Shock Cushioning Characteristics of Packaging MaterialMethods for Determination of the Impact Value (IV) of a Soil

E105 Guide for Probability Sampling of Materials

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

F1292F1702 Specification for Impact Attenuation of Surfacing Materials Within the Use Zone of Playground EquipmentTest Method for Measuring Impact-Attenuation Characteristics of Natural Playing Surface Systems Using a Lightweight Portable Apparatus

F2650 Terminology Relating to Impact Testing of Sports Surfaces and Equipment

2.2 *SAE Standard:*

SAE J211/1 Instrumentation for Impact Tests - Part 1 - Electronic Instrumentation (rev. July 2007)[3]

3. Terminology

3.1 Definitions of terms related to impact testing of sports surfaces equipment ~~can be~~ are found in Terminology F2650, except as noted.

3.2 *Definitions:*

3.2.1 *drop height, n*—height from which the missile is dropped during an impact test, measured as the vertical distance between the lowest point of the elevated missile and surface under test.

3.2.2 *head injury criterion (HIC), n*—a specific integral of the acceleration-time history of an impact, used to determine relative risk of head injury. See Appendix X1.

3.2.3 *HIC interval, n*—the time interval within the acceleration-time history of an impact over which the HIC integral is evaluated.

3.2.4 *impact, n*—contact caused by a moving object (for example, an impact test missile) striking another object (for example, a surface) and during which one or both bodies are subject to high accelerations.

3.2.5 *impact test, n*—a procedure in which the impact attenuation of a playground surface or surfacing materials is determined by measuring the acceleration of a missile dropped onto the surface.

3.2.6 *free-fall impact test, n*—an impact test in which the trajectory of the missile is not restrained by rails, wires, or mechanisms or structures of any type.

~~3.2.5 *guided impact test, n*—an impact test in which the trajectory of the missile is restrained by rails, wires, or other mechanism or structure.~~

3.2.7 *impact test results, n*—one or more measured or calculated values from one or more impact tests used to define the impact attenuation of a playground surface or surfacing materials.

3.2.8 *impact test site, n*—point on the surface of an installed playground surface that is selected as the target of an impact test.

3.2.9 *impact velocity, n*—the velocity (V_0) of a falling body (for example, a missile) at the instant of impact.

[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] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

3.2.10 *missile, n*—a rigid object of specified mass and dimensions; used to impart an impact to a surface.

3.2.11 *impact test system, n*—a device or system for performing an impact test in which an instrumented missile ~~as described in Annex A1 and Annex A2~~is used to impact the surface or surfacing materials as specified in the appropriate specification or test procedure.

3.2.12 *missile reference plane, n*—the plane of the flat circular face of the hemispherical missile.

3.2.13 *reference drop height, n*—a specification of the ~~theoretical~~ drop height of an impact test.

3.2.14 *reference MEP pad, n*—a modular elastomer programmer pad with consistent and known impact attenuation properties that is used to verify proper functioning of the impact test equipment.

~~3.2.14 *theoretical drop height, n*—the drop height (h) that, under standard conditions, would result in an impact velocity equal to a missile's measured impact velocity (V_0). The standard conditions assume that friction and air resistance do not affect the acceleration of the missile and that the acceleration due to gravity is equal to the standard value of g at sea level. In a free-fall impact test, the actual drop height will approximate the theoretical drop height. In a guided impact test, the theoretical drop height will be less than the actual drop height, due to the effects of friction in the guidance mechanism.~~

3.3 *Definitions of Terms Related to the Measurement of Acceleration Used in Annexes:*

3.3.1 *accelerometer, n*—a transducer for measuring acceleration.

3.3.1.1 *sensor, n*—alternative term for accelerometer.

3.3.1.2 *transducer, n*—the first device in data channel, used to convert a physical quantity to be measured into a second quantity (such as an electrical voltage) which ~~can be~~ is processed by the remainder of the channel.

3.3.1.3 *triaxial accelerometer, n*—a transducer or combination of transducers used for measuring the three vector components of acceleration in three dimensions, relative to three orthogonal spatial axes.

~~3.3.1.3 *uniaxial accelerometer, n*—a transducer used to measure the component of acceleration relative to a single spatial axis.~~

3.3.2 *accelerometer data channel, n*—all of the instrumentation used to communicate information about the physical quantity of acceleration from its origin to the point of presentation. ~~The data channel includes all transducers, signal conditioners, amplifiers, filters, digitizers, recording devices, cables and interconnectors through which the information passes and also includes the analytical software or procedures that may change the frequency, amplitude, or timing of the data.~~

3.3.2.1 *Discussion—*

The data channel includes all transducers, signal conditioners, amplifiers, filters, digitizers, recording devices, cables and interconnectors through which the information passes and also includes the analytical software or procedures that affect the frequency, amplitude, or timing of the data.

3.3.3 *Z axis, n*—axis of motion (fall) perpendicular to a horizontal surface.

3.3.4 *Y axis, n*—one of two axes forming a plane parallel to a horizontal surface.

3.3.5 *X axis, n*—one of two axes forming a plane parallel to a horizontal surface.

4. Summary of Test Method

4.1 A test specimen or installed surface system is impacted at a specified velocity or from a specified height with a specific missile of given mass and geometry as stipulated in a specification or test method. An accelerometer mounted in the missile is used to record the acceleration-time history of the ~~impact and the peak acceleration is~~ impact. The peak acceleration and duration are used as a measure of impact severity. ~~Optionally, the displacement history of the impact may also be recorded.~~

4.2 This test method defines ~~three~~two missiles for use in playing surface impact tests:

4.2.1 ~~*Missiles A and D*~~ *Missile A* ~~are both cylindrical,~~ has a cylindrical impacting surface, with specified mass and geometry and a circular, flat, metal impacting surface. ~~These missiles are~~This missile is used with a ~~guidance mechanism.~~friction free guidance tube.

4.2.2 *Missile E* has a hemispherical impacting surface of specified mass and geometry and is used with a ~~guidance system or, if equipped with a triaxial accelerometer, without guidance~~ support structure and without a guidance system ("free-fall").

4.2.3 Both missiles shall be fitted with triaxial accelerometers.

4.2.4 The specific masses and geometries of the missiles are detailed in Annex A1.

5. Significance and Use

5.1 The results of this method quantify the impact attenuation of playing surface and system specimens under the specific test ~~conditions.~~conditions, either within a laboratory or the location the surface system is installed for use.

5.2 The test method measures the outcome of impacts performed under specific conditions. It does not quantify the intrinsic material properties of the tested specimens.

5.3 Test results from different specimens obtained under the same conditions (that is, the same missile mass and geometry, drop height, etc.) are used to compare impact attenuation under those conditions.

5.4 Test results obtained under different conditions are not comparable. Specifically obtained with different missiles are not equivalent and cannot be directly compared. Similarly, test results obtained using the same missile, but using different drop heights, are not directly comparable.

6. Apparatus

6.1 The user is to select the appropriate apparatus as called for in the test method or specification for the testing.

NOTE 1—The apparatus is detailed in Annex A1.

7. Test Specimen

7.1 Test specimens shall represent the surface system or protective padding as it is intended to be used. The minimum distance between the outer dimension of the missile and the edge of the specimen shall be at least 25.4 mm (1 in.) and no less than the thickness of the specimen.

7.2 Where the sample is to be tested in a controlled laboratory a method of confinement for the sample is required when specified in the appropriate standard.

7.3 Where the test is to be performed on an installed surface or in a location where it is to be used, there will be a testing protocol in the system specifications that will state the test procedure. The procedure ~~can include, the theoretical~~ typically includes the impact velocity or drop height, test locations, surface preparation, temperature and requirements for the collection, ~~recording~~ recording, preservation, and reporting of data.

7.4 Where the missiles ~~and~~of Annex A1 ~~and Annex A2~~are used in the testing of surface systems, the appropriate specification shall provide any reference or confirmation procedures required.

8. Number of Specimens

8.1 The number of specimens tested as a sample ~~can vary~~often varies widely, depending upon the intended use of the data. It is recommended that at least two specimens be tested for each set of conditions. To obtain a specific quality assurance level, the sampling procedures of Practices E105 and E122 shall be followed.

8.2 The appropriate specification will have requirements for number and size of samples required for laboratory testing.

8.3 Where the testing is to take place at the site of installation or use, the appropriate standard ~~will provide~~ provides direction to the person performing the testing as to the number of test locations and how they are determined.

9. Conditioning ~~Laboratory Testing~~

9.1 ~~Do~~ In a laboratory, do not stack the specimens during any conditioning. They shall be under the intended use condition or preconditioned at 50 ± 2 % relative humidity and 23 ± 2°C for a minimum of 4 h, or until desired temperature is attained. ~~Samples to be tested at other than these conditions shall be stored in the desired environment for at least 4 h, or until they reach the desired temperature, before testing. Samples shall be tested (that is, impacted) within 10 s after removal from the environmental chamber. Samples shall be returned to the environmental chamber within 20 s after impact and stored for at least 2 h between drops. Testing at other than ambient precludes conducting successive drops at short time intervals.~~The specification to which the sample is being tested outlines all requirements for conditioning of laboratory test samples.

~~9.2 The specification to which the sample is being tested will outline all requirements for conditioning of laboratory test samples.~~

9.2 The specification to which the surface system is being tested in the field ~~will outline~~ outlines all requirements of conditioning or preparation requirements for the surface or the selection of the test location.

NOTE 2—Due to differing thermal conductivities and the extreme time dependence of temperature profiles in most materials exposed to extreme surface temperature changes, there may be variability introduced by this type of testing.

10. Procedure

10.1 Perform an instrument check as described for the appropriate instrument in ~~Annex A1~~A1.21 ~~and Annex A2~~. Reference drops are performed appropriate to the test.

10.2 Place the specimen under the missile, or orient the dynamic test equipment over the playing surface system.

10.3 ~~Determine the baseline by preloading the test specimen to 6.8 kPa (1.0 psi) for Procedure A and adjusting the recorder to read zero penetration. When testing at other than ambient conditions, determine the baseline with the sample at the desired test temperature.~~*Drop Height Control:*

10.3.1 For “A” missile tests the guidance tube used shall have a release mechanism located to provide the drop height as required by the specification to which the tests are being performed.

10.3.2 For “E” missile tests the missile shall be supported at the specified drop height above the surface by a structure such as a tripod with the missile elevated to the drop height as required by the specification to which the tests are being performed.

NOTE 3—For test specifications where an impact velocity rather than a drop height is specified, the drop height shall be calculated as:

$$h = v^2/2g \quad (1)$$

where:

h = drop height cm (in.)
v = velocity cm/s (in./s)
g = acceleration due to gravity 981 cm/s^2 (386 in/s^2)

~~10.4 Set the theoretical drop height to obtain the desired impact velocity.~~

10.4 Release the missile, and record the results in accordance with the recommended procedures of the equipment manufacturers.

10.5 Make three consecutive drops at intervals of 1 ± 0.5 min, unless otherwise ~~specified (see~~ specified.~~Annex A1).~~

10.6 Ensure the measured drop height corresponds with the ~~theoretical drop height.~~drop height measured by the test instrument.

11. Evaluation of the Data

11.1 Select the appropriate calculations as the relevant specification.

11.2 G_{max}—Determine the maximum deceleration in the time-deceleration history to the closest *G*.

11.3 The drop test data shall be reviewed at the time of testing and evaluated for G_{max}, velocity, and anomalies in the data, for example large variation in peak from one drop to the other for the same location, that could affect the validity of the data. The actual measured drop height shall be compared to the calculated drop height reported by the instrument (A1.19.1) to ensure the missile trajectory was not impeded in any way.

11.3.1 Where an anomaly is found, the testing shall be terminated and the device brought into compliance prior to proceeding.

12. Report

12.1 Report the following information:

12.1.1 Complete identification of material tested, including type, source, manufacturer's lot number (if appropriate), thickness (if ~~measureable),~~measurable), and any other pertinent information,

12.1.2 Conditions of test, including temperatures, humidity, and any other pertinent data,

12.1.3 Date of test,

12.1.4 ~~Procedure used and missile description, including mass and geometry,~~Missile used (A or E), manufacturer, model and serial number,

12.1.5 ~~Method of determining the baseline,~~Measured impact velocity or drop height as provided by impact test instrument,

~~12.1.6 Impact velocity,~~

12.1.6 ~~Average~~ Impact data for each drop and average values of last two of three impacts or as specified,

12.1.7 G_{max}, ~~and~~

12.1.8 Head Injury Criterion (HIC) depending on ~~specification.~~specification,

12.1.9 Date of most recent reference drops, and

12.1.10 Date of most recent calibration certificate of the test instrument.

12.2 Where additional reporting requirements are called for ~~in~~by the standard ~~that~~ to which the test is being ~~performed to,~~ performed, this shall be added to that report.

13. Precision and Bias

13.1 *Precision Procedure A*—The ~~reproducibiltiy~~reproducibility is estimated to be ±15 % between laboratories and ±2.5 % within a laboratory.

NOTE 4—This precision statement is based on a series of round-robin tests. The data were analyzed in accordance with Practice E691.

13.2 *Precision Procedure E*—In a preliminary inter-laboratory study, three samples (two reference MEP pads and a unitary surface sample) were tested by five laboratories, using a total of seven different impact test systems. Based on this study the