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Standard Test Method for Determining Impact Attenuation of Playground Surfaces Within the Use Zone of Playground Equipment as Tested in the Field[1]

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INTRODUCTION

Surveys by the United States Consumer Product Safety Commission (CPSC)[2] and others have shown that falls from playground equipment onto the underlying surface are a significant cause of injuries to children. While entanglement is the leading cause of deaths in playground, severe head injuries are the most frequently implicated cause of death in playground equipment-related falls. Falls are 79 % of playground injuries. Use of appropriate impact-attenuating surfacing materials in the use zone of playground equipment can reduce the severity of fall-related injuries. In particular, there is evidence from automotive industry research testing that lowering impact values reduces head injury severity. Lower impact values also reduced the severity of all injuries when appropriate surfacing materials are installed based on reasonable foreseeable use of the play structures associated with the surface.

This test method provides a means of determining impact attenuation performance of a playground using a test method that simulates the impact of a child's head with the playground surfaces. The test method quantifies impact in terms of *g*-max and Head Injury Criterion (HIC) scores. *G*-max is the measure of the maximum acceleration (shock) produced by an impact. The Head Injury Criterion or HIC score is an empirical measure of impact severity based on published research describing the relationship between the magnitude and duration of impact accelerations and the risk of head trauma.

The purpose of this test method is to reduce the frequency and severity of fall-related head injuries to children by establishing a uniform and reliable means of comparing and specifying the impact attenuation of playground surfaces. Although the focus is on head injury, lower values for impact attenuation should lower the severity of other impact related injuries. Its use will give designers, manufacturers, installers, specifiers, prospective purchasers, owners, and operators of playgrounds a means of objectively assessing the performance of surfacing materials under and around playground equipment and hence of evaluating the associated injury risk.

1. Scope

1.1 This test method provides a means of determining impact attenuation performance of a playground using a test method that simulates the impact of a child's head with the playground surfaces.

[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 F08.63 on Playground Surfacing Systems.

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[2] U.S. CPSC Special Study. Injuries and Deaths Associated with Children's Playground Equipment, April 2001. US Consumer Product Safety Commission, Washington DC.

1.2 This test method is specific to surfacing materials used in conjunction with playground equipment, such as that described in Specifications F1148, F1487, F1918, CSA Z614 (Canada), and SS457 (Singapore).

1.3 This test method establishes procedures for determining the impact attenuation value of playground surfaces as tested in the field and for comparison with the test performed under laboratory conditions in Specification F1292 and contract and warranty requirements. This test method does not establish the critical fall height for an installed playground surface.

1.4 The field test required by this test method addresses the performance of playground surfaces as they are found in the field during a time when play by children 2-12 is anticipated.

1.5 The impact attenuation test method and test methods established in this test method are specific to the risk of head injury. There is evidence that lowering impact attenuation values can reduce the risk of other kinds of serious injury (for example, long bone fractures).

1.6 This test method relates only to the impact attenuation properties of playground surfacing materials and does not address other factors that contribute to fall-related injuries. While it is believed that conformance with the requirements of this test method will reduce the risk of severe injury and death from falls, adherence to this test method will not prevent all injuries and deaths.

1.7 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.

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

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:*[3]

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

F355 Test Method for Impact Attenuation of Playing Surface Systems, Other Protective Sport Systems, and Materials Used for Athletics, Recreation and Play

F1148 Consumer Safety Performance Specification for Home Playground Equipment

F1292 Specification for Impact Attenuation of Surfacing Materials Within the Use Zone of Playground Equipment

F1487 Consumer Safety Performance Specification for Playground Equipment for Public Use

F1918 Safety Performance Specification for Soft Contained Play Equipment

2.2 *Federal Documents:*

U.S. Consumer Product Safety Commission, Publication 325 Handbook for Public Playground Safety

U.S. Consumer Product Safety Commission Special Study: Injuries and Deaths Associated with Children's Playground Equipment. April 2002

U.S. Department of Justice – 2010 Standard for Accessible Design

2.3 *Other Documents:*

CSA Z614 Children's Playspaces and Equipment

ISO TC83 Technical Report on and Thresholds to the Used in Standards

SS457 Specification for Playground Equipment for Public Use

3. Terminology

3.1 *Definitions of Terms Related to Playgrounds:*

3.1.1 *critical fall height (CFH), n*—a measure of the impact attenuation performance of a playground surface or surfacing

[3] 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.

materials; defined as the highest theoretical drop height from which a surface meets the impact attenuation performance criterion specified by this test method. The critical fall height approximates the maximum fall height from which a life-threatening head injury would not be expected to occur.

3.1.2 *designated play surface, n*—any elevated surface for standing, walking, sitting, or climbing, or a flat surface larger than 2.0 in. (51 mm) wide by 2.0 in. (51 mm) long having less than 30° angle from horizontal.

3.1.3 *fall height, n*—the vertical distance between a designated play surface and the playground surface beneath it.

3.1.3.1 *Discussion—*

Fall heights for specific types of play structure are defined in Specifications F1148, F1487, F1918, CSA Z614, and SS457.

3.1.4 *playground equipment, n*—any fixed physical structure installed in a designated play area that is accessible to children for activities such as climbing, swinging, sliding, rocking, spinning, crawling, creeping, or combinations thereof.

3.1.5 *playground surface, n*—a manufactured or natural material used to cover the ground below playground equipment, including foundations, substrates, and any compliant surfacing materials intended to attenuate impact.

3.1.6 *play structure, n*—a free-standing structure with one or more components and their supporting members.

3.1.7 *public use playground equipment, n*—a play structure anchored to the ground or not intended to be moved, for use in play areas of schools, parks, child-care facilities, institutions, multiple-family dwellings, private resorts and recreation developments, restaurants, and other areas of public use.

3.1.8 *specifier, n*—person or entity responsible for specifying the performance requirements of a playground surface. (For example an architect, or the prospective purchaser, owner, or operator of a playground.)

3.1.9 *surfacing materials, n*—materials used to cover the surface of the playground use zone.

3.1.9.1 *loose-fill surface, n*—a compliant top layer of small, independently, movable components; for example, wood fiber, bark mulch, wood chips, shredded foam, shredded rubber, sand, gravel, and so forth.

3.1.9.2 *aggregate surface, n*—a loose fill surface in which the compliant top layer is made of particulate materials (for example, sand, gravel, crushed marble, slag, cinders, calcined materials).

3.1.9.3 *unitary surface, n*—a compliant top layer of one or more material components bound together to form a continuous surface; for example, urethane and rubber composites, molded foam, molded rubber mats.

3.1.10 *use zone, n*—the area beneath and immediately adjacent to a play structure or playground equipment that is designated for unrestricted circulation around the equipment and on whose surface it is predicted that a user would land when falling from or exiting the equipment.

3.2 *Definitions of Terms Related to Impact Testing:*

3.2.1 *acceleration, n*—the rate of change of velocity with time, expressed in units of ft s^{-2} (m s^{-2}).

3.2.2 *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.

3.2.3 *g, n*—common notation for accelerations expressed in units of *standard gravity*, where 1 g = 1 standard gravity.

3.2.4 *g-max, n*—the maximum acceleration of a missile during an impact, expressed in g units.

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

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

3.2.7 *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.

3.2.8 *impact attenuation, n*—property of a playground surface that, through localized deformation or displacement, absorbs the energy of an impact in a way that reduces the magnitudes of peak impact force and peak acceleration.

3.2.9 *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.

3.2.9.1 *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.

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

3.2.9.3 *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.

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

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

3.2.12 *missile, n*—a rigid object of specified mass having a hemispherical surface of specified radius; used to impart an impact to a surface.

3.2.13 *qualified personnel, n*—those with current knowledge, training, skill, education and experience who have successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work through the application of professional judgement.

3.2.14 *reference pad, n*—an elastomeric pad with consistent and known impact attenuation properties that is used to verify proper functioning of the impact test equipment.

3.2.15 *standard gravity, n*—the nominal value of the acceleration due to gravity at sea level having an international standard value of exactly 9.806 65 m s^{-2} (approximately 32.174 ft s^{-2}).

3.2.15.1 *Discussion*—
Accelerations may be expressed in units of standard gravity.

3.2.16 *surface test point, n*—point on the playground surface selected as the target of an impact test.

3.2.17 *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).

3.2.17.1 *Discussion*—
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.

4. Performance Requirements

4.1 *Surface Performance Parameters*—The average g-max and average Head Injury Criterion (HIC) scores calculated from the last two of a series of three impact tests shall be used as measures of playground surface performance.

4.2 *Performance Measure*—The linear acceleration in g for each drop is recorded and reported as is the HIC calculated, recorded and reported. The value for each test location is the average of the last 2 of three drops.

4.3 *Performance of Installed Playground Surfaces:*

4.3.1 When an installed playground surface is tested in accordance with the requirements of Sections 10 – 14, the surface performance parameters at every tested location in the use zone shall meet the performance criteria of Specification F1292. The drop height shall be the greater of *(1)* the height specified by the owner/operator prior to purchase, or *(2)* the equipment fall height, as defined in the applicable equipment specification(s).

NOTE 1—When an installed playground surface is tested in accordance with this section, if the impact test scores at any tested location in the use zone of a play structure do not meet the performance criterion, the entity requesting tests shall be informed that the surface is not in compliance with existing performance standards.

4.3.2 *More Stringent Test Methods*—The specifier is permitted to specify additional impact attenuation performance requirements, providing that such additional performance requirements are more stringent than the performance requirements of this test method.

5. Summary of Test Method

5.1 *Installed Surface Performance Test*—To test whether a playground surface installed within the use zone of a play structure meets the performance criterion of Specification F1292, an impact test is performed in accordance with Sections 10 – 14 using a theoretical drop height equal to or greater than the equipment fall height of the structure as specified by the owner/operator. The test is performed under ambient conditions and the results reported.

6. Significance and Use

6.1 The purpose of this test method is to establish impact attenuation for the installed playground surface at the time of testing.

6.2 This test method provides a uniform means of quantifying the impact attenuation performance of installed playground surfaces.

6.3 This test method is to be used as a reference for specifying the impact attenuation performance of an installed playground surface.

6.4 This test method provides a uniform means of comparing the impact attenuation performance of installed playground surfaces with the performance requirements of this test method and with other performance requirements expressed in terms of drop height. Consequently, the test method is appropriately used to determine the actual impact attenuation performance of installed playground surfaces under ambient conditions of use.

6.5 In combination with data relating impact test scores to head injury, the information generated by application of this test method is suitable to estimate the relative risk of a severe head injury due to a fall.

6.6 Performance of this test does not satisfy the requirements to certify surfaces to the specification Specification F1292.

7. Equipment Operator Qualifications

7.1 Impact tests shall be conducted by qualified personnel.

8. Test Apparatus

8.1 *Temperature Measuring Device*—A thermometer, digital temperature gage, or other sensor used to measure surface temperature shall have a functional range of at least from 20 to +130°F (-7 to +54°C), a resolution of 1.0°F (0.6°C), and an accuracy of ±1.0°F (0.6°C). The temperature sensor shall be capable of penetrating the playground surface to a depth of at least 1 in. (25 mm).

8.2 *Impact Test System*—A device or system as described as missile E in Test Method F355. Missile E is used for performing an impact test in which it is dropped onto a playground surface from a drop height as determined in 4.3.1. Missile E suspended in a fixed location for free fall testing and ensure consistency of the drop height, velocity measurement and impact location.

8.2.1 It is acceptable to rigidly attach a supporting assembly (for example, a handle or ball arm) to the missile as a means of

connecting it to an external guidance system. The total mass of the drop assembly, which is the combined mass of the missile, accelerometer, and supporting assembly shall be 10.1 ± 0.05 lb (4.6 ± 0.02 kg). The mass of the supporting assembly alone shall not exceed 3.0 lb (1.4 kg).

8.2.2 *Guidance Mechanism for Guided Impact Tests*—For guided impact tests, it is acceptable for the missile to be connected to low-friction guides (such as monorail, dual rails, or guide wires) using a follower or other mechanism in order to constrain the fall trajectory of the missile to a vertically downward path. The guidance system must allow the missile to be leveled prior to a drop and must maintain the missile in a level (±5°) attitude during the drop. The guidance mechanism shall be constructed in a manner that does not impede the trajectory of the missile during its fall or during its contact with the surface being tested; other than necessary impedance caused by friction in the guidance mechanism.

8.2.3 *Support Structure for Free-Fall Impact Tests*—For free-fall impact tests, a support structure (for example, a tripod) shall be used to ensure repeatable drop height and location. The support structure shall be sufficiently rigid to support the weight of the missile without visible deformation. The support structure shall be erected in a manner that does not impede the trajectory of the missile during its fall or during its contact with the surface being tested.

8.2.4 *Drop Height Control Mechanism*—The guidance mechanism of 8.2.2 or the support structure of 8.2.3 shall incorporate a means of repeatedly positioning the missile at a predetermined drop height.

8.2.5 *Release Mechanism*—A manual or electronically operated quick-release mechanism shall be provided as a means of initiating a drop of the missile. The operation of the release mechanism shall not influence the fall trajectory of the missile following release.

9. Instrumentation Check

9.1 Check the proper operation of the test apparatus by performing a series of impact tests on a reference pad immediately prior to the start of testing and within 24 h of completion of the tests.

9.2 The reference pad shall be provided by the equipment manufacturer or by another agency capable of ensuring reproducible reference pads and shall have been assigned a reference drop height and a nominal *g*-max score.

9.3 Perform three impact tests on the reference pad from the reference drop height with an interval of 1.5 ± 0.5 min between impacts.

9.4 Determine the average *g*-max score by averaging the *g*-max scores from the second and third drops.

9.5 Compare the average *g*-max score to the nominal *g*-max score provided with the reference pad.

9.6 If the difference between the recorded *g*-max score and the nominal *g*-max score exceeds 5 % of the nominal *g*-max score, the equipment does not conform to the requirements of this test method and shall not be used.

10. Impact Test Procedure

10.1 *Data Recording:*

10.1.1 Determine the test point of the surface within the equipment use zone(s).

NOTE 2—For surfaces that are non-uniform, the test point shall include areas that may contain uneven thickness, seams, fasteners, and other factors (such as: surface temperature sensitivity, density, areas with high traffic, partitions, corners, anchors and contamination.)

NOTE 3—For further guidance, the equipment operator may request, or elect to reference Specification F1292 laboratory test report(s) for documented "Least Favorable Impact location data & description," as per Specification F1292. The equipment operator shall assure themselves that the test report specifically describes the product(s) being tested.

10.1.2 Align the sample test point with the point of impact of the missile for each drop in the test.

10.1.3 Before the first drop in any series, elevate the missile to the drop height as determined in 4.3.1. For subsequent drops in

a series, the missile shall be elevated to the same point, notwithstanding the formation of cavities or other elevation changes in the surface being tested. Each of the three drops shall be from the same height to the same location.

10.1.4 Before the first drop in any series, measure and record the drop height.

10.1.5 Release the missile and record the outputs of the acceleration measuring system and the drop height measuring system. If the trajectory of the missile prior to and during impact is impeded by any fixtures, human intervention, or other means, data from the trial shall be discarded and the drop repeated.

10.1.6 Record the depth of any cavity in the surface formed by the impact.

NOTE 4—The depth is conveniently determined by measuring the distance between the lowest point of the elevated missile and the surface under test. The cavity depth is the difference between this measurement and the originally measured drop height.

10.2 *Data Check:*

10.2.1 Examine the acceleration display following each drop. The recorded acceleration pulse shall conform to the following requirements:

10.2.1.1 The acceleration pulse shall consist of a single primary impact event.

10.2.1.2 Prior to the onset of impact, the recorded acceleration value needs to be 0 ± 2 *g*.

10.2.1.3 The acceleration waveform needs to descend from its maximum value to a stable value of 0 ± 2 *g* without overshooting the zero baseline by more than 2 *g*.

NOTE 5—Excessive overshoot of the acceleration signal after an impact is indicative of transducer or signal processing error. Overshoot is frequently symptomatic of inadequate low frequency response in the accelerometer data channel(s).

10.2.2 If the recorded acceleration pulse does not conform to the specifications of 10.2, the test shall be restarted using a new test location consistent with 10.2.1.1 or 10.2.1.2.

10.3 *Data Analysis:*

10.3.1 Calculate and record the *g*-max and HIC scores.

10.3.2 Calculate and record the theoretical drop height. If the calculated theoretical drop height differs from the measured drop height by more than ±3.0 in. (±76 mm) or by more than ±2.5 % of the measured drop height, data from the trial shall be discarded.

NOTE 6—A difference between theoretical drop height and actual drop height that is greater than the specified margin may indicate an error in measurement of impact velocity, an error in the measurement of fall time, or that the fall of the missile was retarded by excessive friction in the guidance mechanism.

10.3.3 If a free-fall impact test is used, calculate the missile angle at the onset of impact and at the instant of maximum resultant acceleration. If the calculated missile angle at either point exceeds 20° (that is, the cosine of the missile angle is less than 0.9397), data from the trial shall be reviewed for anomalies and if there is an anomaly, the data shall be discarded.

11. Test Site Selection

11.1 To determine whether an installed playground surface meets the requirements of this test method, a minimum of three different impact test sites in the use zone of each play structure shall be tested using the impact test procedure described in Sections 12 – 14.

NOTE 7—Functionally linked play structures shall be considered to be one structure.