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An American National Standard

Standard Test Method for Evaluating the Force Reduction Properties of Surfaces for Athletic Use[1]

This standard is issued under the fixed designation F2569; 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 quantitative measurement and normalization of impact forces generated through a mechanical impact test on an athletic surface. The impact forces simulated in this test method are intended to represent those produced by lower extremities of an athlete during landing events on sport or athletic surfaces.

1.2 This test method may be applied to any surface where athletic activity may be conducted.

1.3 The test methods described are applicable in both laboratory and field settings.

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

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

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

2.2 *DIN Standard:*[3]

DIN 18032-2 Halls for Gymnastics, Games and Multipurpose Use, Part 2: Sports Floors, Requirements, Testing

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *force reduction, n*—ability of a surface to reduce impact forces as compared to a rigid surface using a specified impact. Force reduction expresses the difference between the impact forces generated on the test and rigid surfaces as the percentage of the impact force from the rigid surface.

3.1.2 *rigid surface, n*—concrete surface covered by a steel plate used as the basis for measuring force reduction.

3.1.3 *test surface, n*—athletic surface upon which force reduction testing is conducted (for example, indoor wood courts, poured urethane courts, walk/jog tracks, and so forth).

4. Summary of Test Method

4.1 The dynamic interaction between the athlete and the surface is significant to the performance, comfort, and possibly the safety of the athlete. Therefore, the ability of the surface to reduce impact forces is important. This test method provides a non-destructive means for evaluating the force reduction properties of a surface in both laboratory and field settings. Impact forces are recorded by releasing a 20 kg mass and allowing it to impact a spring resting on a test foot resting on the surface. The force reduction of the surface is presented as a percentage of the reduction in the impact forces produced on the test surface, compared to the impact force generated on a rigid surface. This test method is more closely associated with the impacts generated by the lower extremities, and is not an indication of the ability of the test surface to prevent head injury trauma.

5. Significance and Use

5.1 The force reduction property is just one of the important properties of a surface used for athletic activity. It may be an indicator of the performance, safety, comfort, or suitability of the surface.

5.2 Manufacturers of athletic surfaces may use this test method to evaluate the effects of design changes on the impact forces generated on the surface.

5.3 Facility owners may use this standard to evaluate the performance of existing sport/athletic surfaces. Results may be

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[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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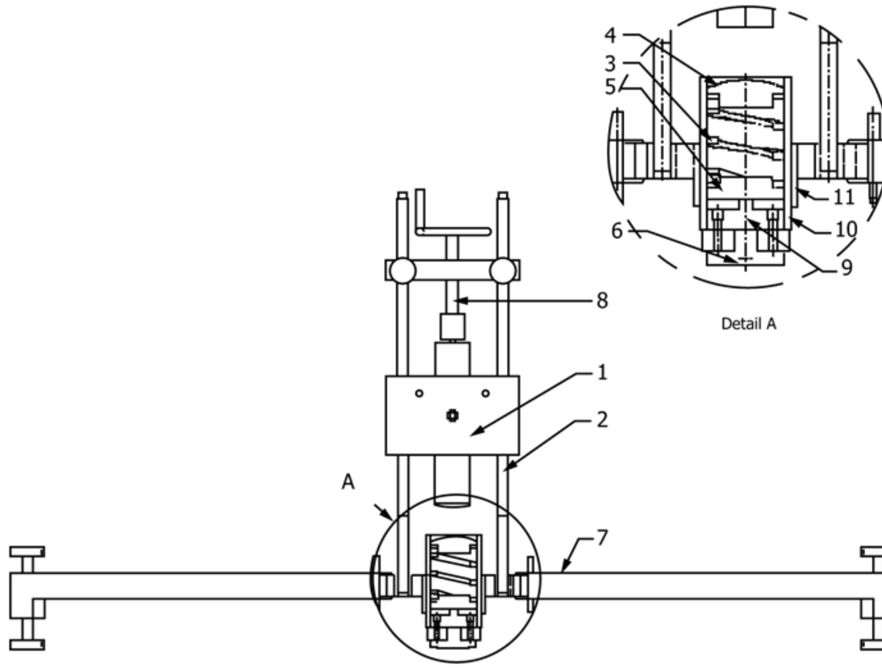
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Beuth Verlag GmbH (DIN-- DIN Deutsches Institut fur Normung e.V.), Burggrafenstrasse 6, 10787, Berlin, Germany, http://www.en.din.de.



1	=	drop mass and striker
2	=	guide rod
3	=	spring
4	=	upper end-cap
5	=	bottom end-cap
6	=	test foot
7	=	adjustable support
8	=	height adjustment and release mechanism
9	=	load cell
10	=	housing sleeve
11	=	guide hole

FIG. 1 Force Reduction Test Apparatus

useful during the selection process for a replacement surface, or for an additional athletic surface being added to the facility.

5.4 Facility owners may also use this test method to verify that newly installed surfaces perform at or near the levels included in project specifications.

6. Apparatus

6.1 *Force Reduction Test Apparatus*—This test method utilizes a force reduction test device similar to the one outlined in DIN 18032-2. The force reduction device is shown in Fig. 1. A mass of 20 kg is allowed to fall onto an anvil, which transmits the load via a spring to a test foot resting on the surface. The foot is fitted with a force transducer that enables the peak force during the impact event to be recorded. The peak force is compared with the result obtained on a rigid floor, and the percentage of force reduction calculated for the test surface.

6.1.1 The apparatus shall conform to the following requirements:

6.1.1.1 Falling mass with a striker screwed into the bottom side of the mass. The striker has a diameter of 50 ± 10 mm (2.0 ± 0.4 in.) and a length of 75 ± 25 mm (3 ± 1 in.). The total mass of the falling weight and the striker is 20 ± 0.05 kg (44 ± 0.1 lb);

6.1.1.2 Ensure the drop mass travels in a vertical path from release to impact, such as by using guide rods;

6.1.1.3 Spring[4] with a spring rate 2000 ± 100 kN/m (11 420 ± 571 lb/in.), an outside diameter of 70.0 ± 0.1 mm (2.75 ± 0.004 in.), a free length of 75 ± 10 mm (3.95 ± 0.39 in.);

(1) Spring rate shall be determined by linear regression through force-deflection data recorded the following loads; 200 N, 2000 N, 4000 N, 6000 N, 8000 N, and 10 000 N (45 lb, 448 lb, 897 lb, 1346 lb, 1794 lb, and 2243 lb).

6.1.1.4 Upper spring end-cap made of hardened steel with a diameter of 70.0 ± 0.1 mm (2.75 ± 0.004 in.).

6.1.1.5 Bottom spring end-cap made of hardened steel to contact the load-cell with a diameter of 70.0 ± 0.1 mm (2.75 ± 0.004 in.). The face of this end-cap that contacts the load cell may be made flat, or it may have a recess milled into it to fit a load-button on the load cell.

6.1.1.6 Test foot diameter 70.0 ± 0.1 mm (2.75 ± 0.004 in.), thickness 12 ± 1 mm (0.47 ± 0.04 in.) with a radius of

[4] The sole source of supply of the apparatus known to the committee at this time is Rein Kratmessegerate, D-89150 Laichingen, Gottlieb-Diamler-Str. 62 Germany. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

500 ± 50 mm (20 ± 2.0 in.) and filleted edges with a radius of 1 ± 1 mm (0.004 ± 0.004 in.);

6.1.1.7 Adjustable support with three contact points (spaced 120 ± 5°) to set apparatus vertical (±2°), such as by using a pair of calibrated levels with a minimum distance of 600 mm (24 in.) between the falling axis and the axis of the contact points;

6.1.1.8 Capable of producing a drop height between 22.0 mm (0.87 in.) and 88.0 mm (3.46 in.) with a lifting facility to hold and release the drop mass and to adjust the drop height between bottom of the striker and the upper spring end-cap to an accuracy of 0.25 mm (0.01 in.);

6.1.1.9 Mass of test foot and load cell and spring, end-caps and any other attached components shall be 3.0 ± 0.5 kg (6.6 ± 1.1 lb);

6.1.1.10 Housing sleeve that ensures the axis of the spring and the load-cell are collinear. Housing sleeve length sufficient to extend below the spring over the load-cell and cover a minimum of 90 % of the free length of the spring. The housing sleeve must have an inside diameter of 71 ± 0.1 mm (2.80 ± 0.004 in.) and a minimum thickness of 4 mm (0.25 in.). The housing sleeve shall not be attached to the test foot, load-cell, or spring in any fashion. The inside and outside shall ensure smooth uninterrupted travel of the spring during impact, such as by polishing the surfaces.

6.1.1.11 The housing sleeve shall fit through a guide hole with a clearance of 0.5 ± 0.05 mm (0.019 ± 0.002 in.). The inside of the guide hole shall allow smooth uninterrupted travel of the housing sleeve during impact, such as by polishing the surface.

6.2 *Rigid Surface*—Concrete, 15 cm (5.9 in.) minimum thickness with a 10 mm (0.39 in.) thick steel plate fully glued to the concrete using an adhesive with a Young's modulus ≥ 10 kN/mm^2 (1.45 Mpsi).

6.3 *Data Collection and Analysis System:*

6.3.1 Sampling frequency of at least 2000 Hz;

6.3.2 Butterworth filter 120 Hz, 2-pole for collecting data on both the rigid and the test surface;

6.3.3 Electronic load-cell with amplifier, with a loading capacity of at least 10 000 N (2242 lb) and an accuracy of 1 % or better, and

6.3.4 Recording equipment capable of storing enough force data to calculate data, display readings and graph impact force-time curves.

6.4 *Appropriate Devices for Determining Surface/Air Temperatures and Relative Humidity:*

6.4.1 Measurements may be obtained using hand-held commercially available devices.

7. Testing Conditions

7.1 The following general testing conditions shall be recorded and included in the test report for information purposes only.

7.1.1 *All Surfaces:*

7.1.1.1 Testing is to be conducted at 23 ± 2°C (72 ± 4°F) when possible. Record surface and air temperature (to the nearest 1°C (2°F)) and relative humidity (to the nearest 1 %). Surface temperature measurements should be taken in manner appropriate to the test surface. Other ASTM guides and specifications may also require testing at additional temperatures.

7.1.1.2 The force reduction shall be tested using the missile drop height specified by the test procedure/standard named in the test report. If no specific drop height is specified therein, the standard drop height of 55 mm (2.2 in.) shall be used. Additional drop heights may be tested and should be agreed on by the purchaser and the seller. Other ASTM guides and specifications may also require testing at additional drop heights.

7.1.2 *Laboratory Sample Sizes*—Standards that reference this method shall ensure that the sample size is sufficiently large and that test points are sufficiently far from the edge of the sample that edge effects are prevented from altering the outcome of the tests.

8. Procedure

8.1 Because of the definition of the rigid surface, testing of the rigid surface can not be conducted on-site. Documentation of the rigid surface will refer to the rigid surface present at the testing person's/company's laboratory.

8.2 Locate and document all points to be tested. This includes points on the athletic surface and the rigid surface when applicable.

8.3 Set the axis of the falling mass to vertical (±2°), and adjust the drop height to the desired height (±0.25 mm (±0.01 in.)). The sports system shall be evaluated using a drop height of 55.0 ± 0.25 mm (2.2 ± 0.01 in.) and any additional drop heights considered useful.

8.4 *Rigid Surface Testing:*

8.4.1 Evaluate the impact force from the rigid floor by conducting 11 drops, rotating the spring by 70 ± 15° and allowing 30 ± 15 s between drops, and use the Butterworth 120 Hz, 2-pole low pass filter to condition the data and record the maximum impact force in Newtons. Calculate the average impact force for the rigid surface $\left(\overline{Fc}\right)$ using the final 10 drops. Check and adjust release height as necessary between every drop.

8.4.2 The value of $\overline{Fc}$ shall be 6.60 ± 0.25 kN (1480 ± 56 lb) for the results to be considered valid.

8.4.3 The time between rigid surface testing and test surface testing must be less than three months.

8.5 *Test Surface*—Evaluate the impact force from each point of interest on the test surface by conducting three drops allowing 60 ± 15 s between drops; use the Butterworth 120 Hz, 2-pole low pass filter to condition the data, and record and present the maximum impact force in Newtons for all three drops, calculate the average impact force for each point of the test surface (*Fs*) using the result from the final two drops at each point. Check and adjust release height as necessary between every drop.

9. Calculation

9.1 Compute the average maximum impact force generated on the rigid surface $\left(\overline{Fc}\right)$.

$$\overline{Fc} = \frac{\sum_{i=2}^{11} Fc_i}{10} \quad (1)$$

9.2 Compute the average maximum impact force generated at each test surface test point (Fs_i). The results of the first drop are not be included in the analysis because it often produces results significantly different from the second ($Fs_{i,2}$). and third ($Fs_{i,3}$). impacts, where i represents an individual test point.

$$Fs_i = \frac{Fs_{i,2} + Fs_{i,3}}{2} \quad (2)$$

9.3 Compute the force reduction to the nearest 1% for each test surface test point $\left(\overline{FR_i}\right)$.

$$\overline{FR_i}(\%) = \left(1 - \frac{Fs_i}{\overline{Fc}}\right) * 100 \quad (3)$$

9.4 Compute the average force reduction property for the entire system to the nearest 1 % $\left(\overline{FR}\right)$.

$$\overline{FR}(\%) = \frac{\sum_{i=1}^{n} \left(\overline{FR_i}\right)}{n} \quad (4)$$

9.5 When appropriate calculate the standard deviation of the force reduction to the nearest 0.1 % of the entire test surface (σFR).

$$\sigma FR = \frac{\sqrt{\sum_{i=1}^{n} \left(\left(\overline{FR_i}\right)^2 - \left(\overline{FR}\right)^2\right)}}{n-1} \quad (5)$$

10. Submissions for Suitability Testing

10.1 *All Systems:*

10.1.1 All system components and construction methods shall be identified.

10.1.2 Description of the system including composition, structures, textures, and thicknesses of all material layers in the system.

11. Report

11.1 Date of the test.

11.2 Test location.

11.3 Temperature and humidity of each test.

11.4 Name of person or laboratory, or both, performing the test.

11.5 Average impact force from rigid surface.

11.6 Date of rigid surface testing.

11.7 Average force reduction values for each point tested.

11.8 Average force reduction for the test surface, including the range of force reduction values from the individual test points.

11.9 Name of client/company.

11.10 Description of system (name and description of product, materials, and components) to the extent possible.

11.11 Name of surface manufacturer, if possible.

11.12 Name of surface installer, if possible.

TABLE 1 Shock Absorption – 2nd Impact (%)

Sample	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	sr	sR	r	R
SS1	36.05	0.559	1.958	1.57	5.48
SS2	39.83	1.527	1.763	4.28	4.94
ST3	62.30	0.491	1.188	1.38	3.33

TABLE 2 Shock Absorption – 3rd Impact (%)

Sample	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	sr	sR	r	R
SS1	35.85	0.509	1.841	1.42	5.16
SS2	39.69	1.589	1.894	4.45	5.30
ST3	61.16	1.296	1.722	3.63	4.82

11.13 Record of the delivery of the samples (date, amount, size, delivered by) if possible.

11.14 Diagram illustrating system construction features and test point locations relevant to those construction features to the extent possible.

11.14.1 When testing under laboratory conditions, include a description of the overall system construction and descriptions and drawings of the construction details present at all test points.

11.15 Diagram, site plan, or description of the test surface identifying the locations of test points and when possible describe the construction and surface conditions present.

12. Precision and Bias[5]

12.1 The precision of this test method is based on an interlaboratory study conducted by the International Association for Sports Surface Sciences (ISSS) in 2010. Twenty laboratories participated in this study, evaluating three different surfaces, each at two points. Each lab reported two individual results per surface. Every "test result" reported represents an individual determination. Practice E691 was followed for the design and analysis of the data.

12.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

12.1.1.1 Repeatability limits are listed in Table 1 and Table 2.

12.1.2 *Reproducibility Limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F08-1011.

12.1.2.1 Reproducibility limits are listed in Table 1 and Table 2.

12.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

12.1.4 Any judgment in accordance with these two statements would have an approximate 95 % probability of being correct.

12.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

12.3 The precision statement was determined through statistical examination of 262 results, on three surfaces. These three surfaces were described as the following:

SS1:	12 mm solid rubber running track flooring
SS2:	12 mm crumb rubber matrix pad from recycled rubber
ST3:	Padded Carpet with 10 mm resilient underlayment and 10 mm pile depth (no infill)

13. Keywords

13.1 impact test; sports surface force reduction; test surface