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An American National Standard

Standard Test Method for Characterization of Gymnastic Landing Mats and Floor Exercise Surfaces[1]

This standard is issued under the fixed designation F 1931; 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 measurement of shock absorption characteristics and rebound properties of landing mats and floor exercise surfaces used in the sport of gymnastics. It defines quantitative parameters for these characteristics.

1.2 This test method is performed under laboratory conditions and requires use of an impact-testing device.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.4 *This standard may involve hazardous materials, operations, and equipment. 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]

F 355 Test Method for Shock-Absorbing Properties of Playing Surface Systems and Materials

F 1292 Specification for Impact Attenuation of Surface Systems Under and Around Playground Equipment

2.2 *SAE Standards:*[3]

SAE J211 Instrumentation for Impact Test

3. Terminology

3.1 *Definitions:*

3.1.1 *acceleration*, *n*—instantaneous time rate of change of velocity, which may be positive or negative.

3.1.2 *base line*, *n*—starting reference height of the mat or floor exercise surface from which penetration and rebound are measured; this is the top surface of the mat in its undeformed state.

3.1.3 *depth of penetration*, *n*—maximum deformation of test specimen at impact of missile that is dropped with a predetermined impact velocity; measurement is the differential of maximally compressed surface and base line height.

3.1.4 *floor exercise surface*, *n*—structure generally consisting of a deck surface with foam or spring supports and one or more layers of cushioning material on top, designed for use in competitive gymnastics floor exercises.

3.1.5 *impact velocity*, *n*—velocity of the missile as it crosses the base line on impact.

3.1.6 *landing mat*, *n*—structure designed for cushioning falls or landing dismounts, or both, from gymnastic routines.

3.1.7 *low impact use*, *n*—usage of a mat for cushioning landings that are from heights below the surface of the apparatus and do not involve somersaulting dismounts, for example, pommel horse mats.

3.1.8 *mat system*, *n*—two-mat system such as a base landing mat and a supplemental mat.

3.1.9 *maximum force*, *n*—peak force exerted on the testing missile by the equipment surface; that is equal to the peak acceleration times the mass of the missile.

3.1.10 *rebound height*, *n*—theoretical maximum rebound distance of the missile from the base line of the apparatus after impact and under ideal (frictionless) conditions.

3.1.11 *rebound velocity*, *n*—velocity of the missile as it crosses the base line on rebound.

3.2 *Symbols:*

3.2.1 F_{ave}—weighted average of maximum force for a mat; the values for 8 drops on each of four defined points are averaged, with weighting to simulate dropping on nine points.

3.2.2 *G*—ratio of the magnitude of missile acceleration during impact to the acceleration due to gravity, expressed in the same units.

3.2.3 G_{max}—maximum value of *G* encountered during impact.

[1] This test method is under the jurisdiction of ASTM Committee F08 on Sports Equipment and Facilities and is the direct responsibility of Subcommittee F08.12 on Gymnastics and Wrestling Equipment.

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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 Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

3.2.4 P_{ave}—weighted average of depth of penetration for a mat; the values for eight drops on each of four defined points are averaged, with weighting to simulate dropping on nine points.

3.2.5 R_{ave}—weighted average of rebound height for a mat; the values for eight drops on each of four defined points are averaged, with weighing to simulate dropping on nine points.

4. Summary of Test Method

4.1 *Impact Test*—A test specimen of mat, mat system, or floor exercise surface is impacted at a specified velocity with a cylindrical missile of specified mass and geometry. The velocity, acceleration, and displacement of the missile are monitored and the depth of penetration, rebound height, and maximum force are recorded.

5. Significance and Use

5.1 Data obtained from this test method is indicative of the energy absorption and elasticity of the test specimen.

5.2 The results of the test method may be used by the consumer to determine the suitability of a mat, mat system, or floor exercise surface for its intended application. This test method is intended to provide data similar to tests conducted under the authorization of the Fédération Internationale de Gymnastique (FIG).[4]

6. Apparatus

6.1 *Impact testing machine*, consisting of a stand that allows vertical impacting of a specimen up to 1.2 by 2.4 m (4 by 8 ft) in size over any point of the test specimen. The legs of the test machine shall not touch the test specimen at any point. The drop height must be adjustable. The test machine and missile system must be designed to minimize friction and to minimize undesirable vibrations in the apparatus that might be recorded on the acceleration-time curve. In order to do this, the machine must be able to obtain the desired impact velocity within 5 cm (1.97 in.) of the theoretical drop height for this velocity. In addition, the apparatus should not contain resonant frequencies below 2000 Hz.

6.1.1 *Base*, of at least 500 kg (1100 lb), which is fixed to a rigid foundation such as a concrete slab or floor. The test specimen is to be placed on this impact base.

6.2 *Missile*, constructed of a rigid cylindrical steel body. The mass of the missile shall be 10 kg (22 lb) or 20 kg (44 lb), depending upon the type of mat being tested. The area that contacts the test specimen shall be 10 cm (3.94 in.) in diameter. The circumference of the missile shall have a 0.1 cm (0.039 in.) radius to relieve sharp edges.

6.2.1 *Alignment of Missile in Impact Testing Machine*—The missile shall be aligned so that the drop is within 0.5° of vertical.

6.3 *Recording Equipment*, meeting the following criteria:

6.3.1 *Acceleration-Time*—An accelerometer shall be mounted on the missile at a point on the surface that is on a vertical line through the center of gravity of the missile. Equipment must record vertical acceleration of missile during all contact phases of the drop. The recording system shall measure the peak acceleration value to an accuracy of ±5 % of the true value. The total system, detection and recording, shall be capable of measuring impulses up to 200 *g* (200 × acceleration due to gravity) at sampling frequencies of at least 8 kHz to an accuracy of ±5 %. The recording system should have a flat frequency response to beyond 3000 Hz. The recording system should conform with SAE J211.

6.3.2 *Velocity*—The velocity recording equipment, at a minimum, must measure and record impact and rebound velocities to an accuracy of ±5 % of the true value, with a sampling frequency of at least 8 kHz. Any method that does not physically interfere with the impact and give erroneous acceleration-time results is acceptable.

6.3.3 *Displacement*—The displacement must be recorded during the contact phase of the impact, with a sampling frequency of at least 8 kHz. If accuracy can be validated, it is acceptable to determine displacement data from the integral of the velocity data.

7. Test Specimen

7.1 For landing mats and mat systems, the test specimen must be 1 by 1 m (39 by 40 in.) and the same thickness as the mat or mat system as used in actual practice. A 1-cm (0.39-in.) tolerance in thickness and a 2-cm (0.79 in.) tolerance in length and width is permitted.

7.2 For floor exercise surfaces, the test specimen must be at least 1 by 1 m (39 by 39 in.) and is generally one section of a multi-section floor exercise surface. A 2-cm tolerance in each dimension is permitted. The dimensions may not exceed 1.2 by 2.4 m (4 by 8 ft). It must be constructed with the same materials and support geometry/layout as competitive floor exercise surface. The test specimen must include all components of the floor exercise surface including deck, supports, padding material, and top surface material.

7.3 This test method may be used for other size specimens of mats, as specified by the individual requesting the test.

8. Number of Specimens

8.1 A minimum of two samples must be tested for each set of conditions.

9. Conditioning

9.1 The test specimens should be preconditioned at 20 ± 2°C (68 ± 3.6°F) and at a humidity of 50 ± 10 % for a minimum of 4 h before testing. Do not stack test specimens during conditioning. Testing should take place under these same conditions.

10. Procedure

10.1 *Calibration*—Completely calibrate all test equipment within 30 days prior to testing.

10.2 Prewarm the recording equipment as recommended by the manufacturer. Calibrate acceleration, velocity and displacement recorders as necessary, following the procedures recommended by the equipment manufacturer.

[4] Available from Fédération Internationale de Gymnastique (FIG) Testing Procedures for Landing Mats, Surfaces for Floor Exercises and Vaulting Boards, 10, Rue Des Oeuches, P.O. Box 359, 2740 Moutier 1, Switzerland.

10.3 After recording equipment has been prewarmed and calibrated, perform ten drops on a control object whose acceleration response is known. Check to ensure that the results from the system are accurate. If they are not, check the system set-up for errors and repeat this step. Do not proceed with tests until the system results are acceptable. Repeat this test after the entire mat has been tested to verify that the performance of the testing system has not changed over the course of the test.

10.4 Mark the test specimen at the points to be impacted at four of the nine points shown in Fig. 1. The points must include the center (Point 5), one corner (any of Points 1, 3, 7 or 9), and two sides (Points 2 or 8 and 4 or 6). The sides should not be opposite each other. In addition, mark one random drop location, at least 10 cm (3.94 in.) away from any of the previous sites used for drop testing.

10.5 Orient the specimen under the missile so that one of the marked target spots is directly beneath the missile.

10.6 Determine the base line by fixing the face of the missile at the top surface of the mat. Adjust the displacement recorder to read zero penetration.

10.7 Use a 10-kg (22-lb) mass for testing mats intended for low impact use (for example, mats used with men's pommel horse). Test all other mats, systems and floor exercise surfaces with a 20-kg (44 lb) mass.

10.8 Test mats intended for low impact use at an impact velocity equivalent to a free-fall drop from 40-cm (15.75-in.), 2.80 +0, -0.2 m/s (117.0 in./s). Test all other mats, systems and floor exercise surfaces at an impact velocity equivalent to an 80-cm (31.50 in.) free-fall, 3.96 + 0, -0.2 m/s (155.90 in./s).

10.9 Adjust the drop height to obtain the desired impact velocity.

10.10 Release the missile and record acceleration, velocity and displacement data in accordance with the recommended procedures of the equipment manufacturer(s).

10.11 Make ten consecutive drops at intervals of less than 2 min between drops. Keep the missile aligned with the target spot on the test specimen.

10.12 Repeat the drop procedure for each of the five target spots.

11. Calculation

11.1 *Filtering of Acceleration Data*—Acceleration data should be filtered in accordance with Class 1000 as given in SAE J211. Use a 4th order high-pass Butterworth filter with a cut-off frequency of 1000 Hz and a rolloff rate such that the -3 dB point is at 1650 Hz. Filtering may be done during data collection or numerically after the signal has been stored.

11.2 All calculations should be done using values that are the average of the last eight of ten drops for each variable.

11.3 *Depth of Penetration*—Determine the average depth of penetration for each target point by using the following equation:

$$P_{ave} = 1/9(4\cdot\text{corneravg} + 2\cdot\text{edge1avg} + 2\cdot\text{edge2avg} + \text{centeravg}) \quad (1)$$

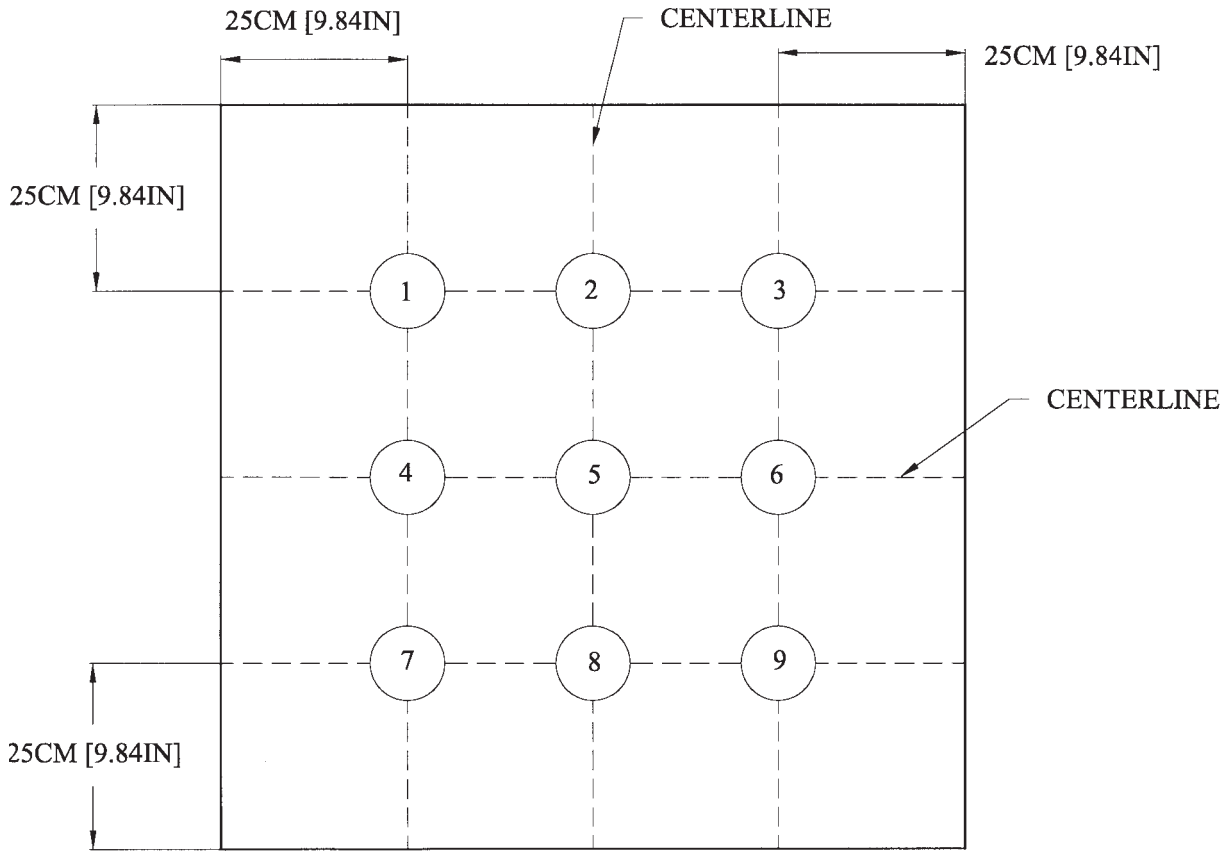

FIG. 1 Example Marking Points For Test Specimen

where:
corneravg = the average depth of penetration of eight drops at the corner target (Point 1, 3, 7 or 9),
edge1avg = the average of eight drops at one edge target (Point 2 or 8),
edge2avg = the average of eight drops at the second edge target (Point 4 or 6), and
centeravg = the average of eight drops on the center target (Point 5).

11.4 *Rebound Height*—Determine the rebound height from the average rebound velocity using the principle of conservation of energy:

$$\text{height} = 1/2(v^2/g) \quad (2)$$

where:
g = the acceleration due to gravity, and
v = the average rebound velocity.

An overall value for the test specimen may be obtained using the same weighting as shown above.

$$R_{ave} = 1/9(4\cdot\text{corneravg} + 2\cdot\text{edge1avg} + 2\cdot\text{edge2avg} + \text{centeravg} \quad (3)$$

where: corneravg, edge1avg, edge2avg and centeravg are the average rebound heights at each target spot.

11.5 *Maximum Force*—The maximum force is calculated from the acceleration data:

$$F_{max} = a_{max}\cdot\text{mass}_{missile} \quad (4)$$

and the overall value for the mat is calculated by weighting the average maximum forces from each of the target points:

$$F_{ave} = 1/9(4\cdot\text{corneravg} + 2\cdot\text{edge1avg} + 2\cdot\text{edge2avg} + \text{centeravg} \quad (5)$$

where: corneravg, edge1avg, edge2avg and centeravg are the average F_{max} at each target spot.

11.6 *Random Point Averages of F_{max}, P, and R*—These should be within the range of the values found for the four target points used in the above calculations.

NOTE 1—If the values for the random point are more than 2 % higher than the highest values for the other points or more than 2 % lower than the lowest values for the other points, the mat should be rejected and an alternate sample tested.

11.7 *G_{max}, Severity Index, Head Injury Coefficient, or Dynamic Hardness Index*, or a combination thereof, may optionally be calculated from the impact data gathered in this test procedure. Refer to Test Method F 335 and F 1292 for determination of these values.

11.8 At the request of the person contracting for the test, or if product specifications require, additional drops may be done to assess longer-term performance of the mat.

12. Report

12.1 The report shall include the following:

12.1.1 Complete identification of mat, mat system, or floor exercise surface tested, including manufacturer, thickness, materials used or other identification/model information, and any other pertinent information,

12.1.2 Date of test,

12.1.3 Description of the test apparatus used and the methods used to measure acceleration, velocity and displacement,

12.1.4 Depth of penetration, rebound height and maximum force for each drop at each point,

12.1.5 Average values of the last eight of ten drops at each impact point for depth of penetration, rebound height and maximum force,

12.1.6 P_{ave}, R_{ave} and F_{ave} for the test specimen, and

12.1.7 Results of optional calculations detailed in 11.6 and 11.7

13. Precision and Bias

13.1 *Precision and Bias*—Precision and bias for this test method shall be determined through round-robin testing, which will be completed on or before Nov. 1, 2003.

14. Keywords

14.1 floor exercise surface; gymnastics; mat