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An American National Standard

Standard Test Method for Vertical Rebound Characteristics of Sports Surface/Ball Systems; Acoustical Measurement[1]

This standard is issued under the fixed designation F2117; 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 the vertical rebound produced during impacts between athletic balls and athletic surfaces.

1.2 Measurements may be conducted on nonathletic surfaces to test the performance properties of the ball.

1.3 Measurements may be conducted using nonathletic balls to test the performance properties of the surface.

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

1.5 The values stated in metric units are to be regarded as the standard. The inch-pound units given in parentheses are for reference only.

1.6 *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.*

1.7 *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 *DIN (Deutsches Institut fur Normung):*[2]
18032 Part II, 1991 Section 5.8
2.2 *British Standards:*[3]
7044, 1990, Section 2.1
2.3 *EN (European Committee for Standardization):*[4]
EN 12235 Surfaces for sports areas - Determination of vertical ball behaviour

3. Terminology

3.1 *Definitions:*

3.1.1 *area elastic surface, n*—surfaces where the energy at impact is dispersed throughout an area significantly larger than the impact point (for example, sprung wooden basketball floors, poured urethane floors over sprung subfloor). Area elastic surfaces tend to produce a noticeable vibration when impacted.

3.1.1.1 *subfloor, n*—any structural members found between the playing surface and the underlying concrete base. Subfloor systems are typically found in sprung indoor playing surfaces and can include but are not limited to: layers consisting of sheets of plywood, layers consisting of strips of plywood, and solid-wood members.

3.1.2 *athletic surface, n*—an athletic surface appropriate for the sport(s) of interest should be selected for testing. The surface may be selected from previously installed surfaces and tested in its complete form, or smaller samples may be tested under laboratory settings.

3.1.3 *coefficient of restitution (CR), n*—the ratio of rebound height to release height. This parameter is useful for noninflated balls that are found to be damaged by impacts with a concrete reference surface. Construction differences and sensitivity to inflation pressure make this parameter inappropriate for comparing different playing surfaces based on results obtained using inflated sporting balls.

3.1.4 *point elastic surface, n*—surface where the energy at impact is dispersed throughout an area that negligibly exceeds the impact point (for example, natural turf, artificial turf, poured urethane surfaces). Point elastic surfaces do not produce noticeable vibrations when impacted.

3.1.5 *reference surface, n*—any section of a concrete slab with a smooth uniform, uncracked surface with a minimum horizontal dimension of 30 cm (12 in.) that produces a rebound with minimal horizontal movement.

3.1.6 *resting time constant (K_r), n*—a time constant that corrects for the duration that the ball is in contact with the surface.

3.1.7 *sporting ball, n*—a sporting ball appropriate for the sport(s) of interest should be selected for testing. The test ball

[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] Available from DIN, Burggrafenstrasse 6, D-10787 Berlin, Germany.

[3] Available from BSI, 389 Chiswick High Road, London W4 4AL, UK.

[4] Available from ANSI, 1819 L Street, Washington, DC 20036, USA.

should be inspected to verify that it is spherical and devoid of bulges. Bulges indicate structural damage exists within the ball, that could affect the testing results. In the case of inflated sporting balls, the pressure should conform to manufacturer's guidelines.

3.1.8 *vertical rebound height, n*—the highest height achieved by sporting ball during its first rebound after contacting the surface, as measured from the bottom of the ball to the top of the surface.

3.1.9 *vertical rebound ratio (VRR), n*—the ratio of the rebound on the test surface to the rebound on the reference surface, expressed as a percentage. This parameter may not be appropriate for all sporting balls, as some may experience damage when impacting the reference surface. When reference surface rebound measurement is found to be unrepeatable, the coefficient of restitution should be used instead.

4. Summary of Test Method

4.1 This test method provides a means for evaluating the rebound height produced by a test ball on a test surface. The procedure can be used to evaluate vertical ball rebound performance on a reference athletic surface, evaluate surface vertical rebound performance using a reference athletic ball, or to evaluate the effects of ball-surface interactions. A ball is released from a known height and allowed to impact the reference surface. The release should not impart any horizontal motion. An acoustical measurement system measures the rebound height obtained on the test surface. The ball is then released from the same height and allowed to impact the test surface, where again, the rebound height is measured. The vertical rebound ratio, presented as a percentage, is obtained from the ratio of the vertical rebound height on the sporting surface to the vertical rebound height on the reference surface.

5. Significance and Use

5.1 The ball-surface interaction is just one of the important properties of a sports surface. It may be an indicator of the playability or suitability of the surface.

5.2 Manufacturers of sporting balls may use this method to evaluate the effects of design changes on the rebound height produced.

5.3 Manufacturers of sports surfaces may use this method to evaluate the effects of design changes in the sports surface system on the rebound height produced.

5.4 The tendency of modern facilities to support multiple sports on a single surface may require that test surfaces be tested for several types of sporting balls. Examples include, but are not limited to: basketball, soccer, tennis, and baseball.

5.5 The measurement of rebound height may be affected if the temperature of the ball has not reached equilibrium with the environment.

6. Apparatus

6.1 *Ball-Release Apparatus,* capable of releasing the sporting ball from a consistent height, without imparting significant spin or horizontal motion to the sporting ball. The ball release apparatus is typically an adjustable-height tripod. The release mechanism may be mechanical, electromagnetic, vacuum, or manual.

6.2 *Sound Recording and Analysis System*—A system with the minimum requirements as follow: acoustic sampling frequency 11 000 Hz, 8-bit resolution, on a single acoustic channel. The system must be capable of determining the time of the first (t_1) and second (t_2) impacts using the peak acoustic signal generated to determine t_1 and t_2 through either the use of hardware or software.

6.2.1 *Example*—Personal computer, sound-card, and microphone have been found to produce adequate results.

7. Testing Conditions

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

7.1.1 *All Surfaces:*

7.1.1.1 Record temperature (to the nearest 1°C) and relative humidity (to the nearest 1 %) at an elevation of 30 ± 5 cm (12 ± 2 in.) above the playing surface. Measurements may be obtained using hand-held commercially available temperature and relative humidity sensors.

7.1.1.2 The vertical ball rebound should be tested using a 1.800 ± 0.005-m (71 ± 0.2-in.) drop height, as measured from the bottom of the ball to the top of the test surface. Additional drop heights may be tested and should be agreed on by the purchaser and the seller.

7.1.2 *Wood Playing Surfaces*—The wood moisture content (%) should be included. Measurements may be obtained using hand-held commercially available wood moisture sensors.

7.1.3 *Outdoor Playing Surface*—The general moisture level of the surface should be included. In general, the surface should be characterized as dry, damp, or wet.

7.1.4 *Laboratory Sample Sizes:*

7.1.4.1 Area elastic surfaces should be evaluated using a minimum sample size of 2.0 by 2.0 m (6.5 by 6.5 ft).

7.1.4.2 Point elastic surfaces should be evaluated using a minimum sample size of 1.0 by 1.0 m (3.3 by 3.3 ft).

8. Procedure

8.1 When the ball and test surface are introduced to a new environment, each should be allowed to acclimate. The ball should be allowed to acclimate to the surroundings for 1 h, and the surface should be allowed at least 4 h to acclimate to the environment.

8.2 Measure and record ambient temperature to the nearest 1°C and the relative humidity to the nearest 1 % at a height of 30 cm (12 in.) over the reference surface.

8.3 Measure and record ambient temperature to the nearest 1°C and the relative humidity to the nearest 1 % at a height of 30 cm (12 in.) over the athletic surface.

8.4 Locate and document all points to be tested. This includes points on the reference surface and on the athletic surface.

8.4.1 When testing under field conditions, include a diagram of the playing surface and its surroundings and dimensions that

allow the test points to be relocated. Effort should be made to locate and test rebound properties of the playing surface on areas representative of the surface conditions present and construction methods used in the playing surface. Tests should also be conducted on areas considered heavy-use and non-use areas. Examples include but are not limited to the following:

8.4.1.1 *Natural Turf*—Densely covered areas and skinned areas.

8.4.1.2 *Artificial Turf*—Seams in the turf layer, seams in the padding layer (if present).

8.4.1.3 *Point Elastic Surfaces*—Seams in the playing surface and seams in the padding layer (if present).

8.4.1.4 *Area Elastic Surfaces*—Joints in the playing surface, joints in the subfloor layer (if present), joints in the sleeper layer (if present), between sleepers (if present), seams in padding layer (if present), individual pads (if present).

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

8.5 Set the drop height to the nominal desired height. The actual drop height should be measured and recorded to the nearest 0.005 m (0.2 in.). The surface/ball system should be evaluated using a nominal drop height of 1.800 ± 0.005 m (71 ± 0.2 in.) and any additional drop heights considered useful.

8.6 Perform ball inspection; verify that construction is still sound. When appropriate, verify that the inflation pressure is within manufacturer's specifications and record actual pressure.

8.7 Evaluate the rebound height from the desired point on the reference surface by recording five vertical rebound heights produced from the specified testing height on the reference surface to the nearest 0.005 m (0.2 in.), calculate the time between impacts ($t_{ref\text{-}1}$) and the rebound height ($h_{ref\text{-}k}$) for all five drops and the average rebound height for the reference surface ($h_{ref\text{-}1}$). Sporting balls without inflation valves (such as golf balls, racquetballs, and so forth) are released from the drop height with a random orientation. Sporting balls with inflation valves (soccer balls, basketballs, and so forth) are released with the inflation valve pointing away from the impact surface.

8.8 Move the release apparatus to the athletic surface, and verify that the release height has not changed.

8.9 A minimum of three points should be evaluated using the methods and accuracies described in 8.7 to characterize any playing surface. Evaluate the rebound height from the desired point on the test surface by recording five vertical rebound heights produced from the specified testing height. Calculate the time between impacts ($t_{i,j}$), and the rebound height ($h_{i,j}$) from each point (i) and drop (j). For each point, calculate the average vertical rebound height from all 5 drops for each test point.

8.10 When the testing is conducted to evaluate the properties of balls on a given surface, each ball will be dropped 5 times.

8.11 Verify that the rebound height has not changed during testing by retesting the reference point every 30 min (maximum allowable time duration) and at the conclusion of every tested surface. Record five rebound measurements following the methods in 8.7 and calculate the average time between rebounds ($t_{ref\text{-}2}$) and the average rebound height for the reference surface ($h_{ref\text{-}2}$).

8.12 Record the inflation pressure of the ball, when appropriate, at the conclusion of evaluating the playing surface. The inflation pressure is for information purposes only and can be obtained using a low-pressure gage of the type available at automotive stores.

9. Calculations

9.1 Rebound height is approximated using the time duration (Δt) between the first (t_1) and second (t_2) impacts of the ball with the surface, with Δt, t_1 and t_2 measured to the nearest 0.001 s (t_1, and t_2 are obtained from the moment of maximum sound intensity generated during the impact).

$$\Delta t(s) = t_2 - t_1 \tag{1}$$

9.2 The average time between the first and second impacts excluding the maximum and minimum time differences should be computed to the nearest 0.001 s for each point *{i}* tested on the playing surface (Δt_i) and for each test *{j}* on the reference surface ($\Delta t_{ref\{j\}}$).

$$\Delta t_{\{i\}} = \frac{\Delta t_1 + \Delta t_2 + \Delta t_3 + \Delta t_4 + \Delta t_5}{5} \tag{2}$$

9.3 The average time between the first and second impacts of the ball with the playing surface is then converted to vertical rebound height for each point *{i}* and drop *{j}* on the playing surface ($h_{\{i\}}$) and for each point *{k}* and drop *{j}* on the reference surface ($h_{ref\{k,j\}}$) in metres. Calculate the average rebound height for each point *{i}* on the playing surface and for each point *{k}* on the reference surface. Apply the correct resting time constant for the ball used during testing. Select resting time constants have been supplied in Table 1. Studies using balls not included in Table 1 should consult the governing body of the respective sport for guidance.

$$h_{\{i,j\}} = 1.23(\Delta t - K_r)^2 \tag{3}$$

9.4 When appropriate, calculate the vertical rebound ratio (*VRR{i}*) to the nearest 1 % for each point *{i}* of the playing surface tested. The reference surface rebound height obtained prior to *{k}* and subsequent to *{k + 1}*, the point of interest, are used to compute the vertical rebound ratio for each point.

$$VRR_i = \frac{h_i}{(h_k + h_{k+1})/2} \times 100 \tag{4}$$

9.5 When appropriate, calculate the vertical rebound ratio to the nearest 1 % for entire surface (*VRR*) using the average.

$$VRR = \frac{\sum_{i=1}^{n} VRR_{\{i\}}}{n} \tag{5}$$

TABLE 1 Resting Time Constant (K_r) for Select Sporting Balls

Ball	Resting Time Constant, K_r (sec)
Basketball	0.025
Tennis Ball	0.005
Hockey Ball	0.038

9.6 When appropriate, calculate the standard deviation of the vertical rebound ratio (σVRR) to the nearest 0.01 % for the entire surface.

$$\sigma VRR = \sqrt{\frac{\sum_{i=1}^{n} (VRR_{\{i\}})^2 - (VRR)^2}{n-1}} \quad (6)$$

9.7 When appropriate, calculate the coefficient of restitution (CR) to the nearest 0.01 for each point of the playing surface tested, using the rebound height for each point *{i}* and the release height ($h_{release}$).

$$CR = \frac{h_{\{i\}}}{h_{release}} \quad (7)$$

9.8 When appropriate, calculate the average coefficient of restitution (CR) for the entire playing surface tested, using the average rebound height (h_i) from each point.

$$CR = \frac{\frac{\sum_{i=1}^{n} h_i}{n}}{h_{release}} \quad (8)$$

9.9 When appropriate, calculate the standard deviation of the coefficient of restitution (σCR) for the entire playing surface tested.

$$\sigma CR = \sqrt{\frac{(h_i/h_{release})^2 - CR^2}{n-1}} \quad (9)$$

10. Report

10.1 The following information is to be included in the report for general information purposes:

10.1.1 Temperature and humidity during testing.

10.1.2 Surface moisture conditions.

10.1.3 Type of test conducted:

10.1.3.1 Field Test.

10.1.3.2 Laboratory Test.

10.1.4 Description of sporting ball(s) tested. This description should include:

10.1.4.1 Manufacturer name.

10.1.4.2 Ball type (for example, baseball, tennis ball, soccer ball, basketball).

10.1.4.3 Ball surface material (for example, leather, rubber).

10.1.4.4 Rebound height recorded on the reference surface: this should be reported to provide an indication of the inflation pressure or ball condition or both.

10.1.4.5 Inflation pressure: when appropriate, the pressure in the ball should be recorded at the conclusion of the tests.

10.1.4.6 Age (when appropriate): for example, baseballs, tennis balls, racquetballs.

10.2 Laboratory tests should include a description of the construction of the entire playing surface or system or both, and a diagram illustrating system construction features and test point locations relative to those construction features.

10.3 Field test should include a diagram of the playing surface showing the locations of the test points and when possible should describe the construction and surface construction present.

10.4 Additional information specific to individual test points that may be of interest but is considered optional may include, but is not limited to:

10.4.1 *Natural Turf Surfaces*—Gravimetric soil water content; soil bulk density; description of vegetative cover, if any (for example, species, mowing height, or current height above soil surface).

10.4.2 *Artificial Turf and Point Elastic Surfaces*—Seams in playing surface; seams in padding layer, if any; description of turf conditions; infill material, if any (for example, sand, rubber).

10.4.3 *Area Elastic Surface*—Seams in playing surface; seams in padding layer, if any; subfloor moisture content; subfloor construction details.

10.5 If measurements are conducted from any drop height in addition to 1.800 m, the height should be reported and a separate report generated.

10.6 Average rebound height to the nearest 0.005 m (0.2 in.) for all points tested, including reference surfaces.

10.7 Vertical rebound ratio (VRR) to the nearest 1 % or coefficient of restitution (CR) or both to the nearest 0.01 for all points tested.

10.8 Minimum, maximum, average of the vertical rebound ratio (VRR) to the nearest 1 % and coefficient of restitution (CR) to the nearest 0.01 for the surface/ball system.

10.9 Standard deviation of the vertical rebound ratio (VRR) to the nearest 0.01 %, and the coefficient of restitution (CR) to the nearest 0.001 for the surface/ball system.

11. Precision and Bias

11.1 If rebound heights obtained on the reference surface vary by more than 2 %, inflated balls should be checked to verify their integrity, and it should be verified that the ball has been allowed to properly acclimate with the testing environment.

11.2 The time of each impact in associated with the maximum acoustic signal generated during the impact. The value obtained by taking the difference between the two time measurements includes a period of time, equal to the contact time of the ball with the surface, when the position of the ball is not defined by projectile physics. At this time there is no easy method to determine the contact time from the acoustic signatures, and the committee has decided that the errors associated with this are small. As an example, a contact time of 0.025 s would result in errors less than +1 % $VBRR$ and +0.04 CR.

11.3 A within-laboratory and between-laboratory repeatability study has not yet been completed.

12. Keywords

12.1 sports surface; vertical ball rebound; acoustic rebound

APPENDIX

(Nonmandatory Information)

X1. SAMPLE REPORT

X1.1 See Fig. X1.1.

Basic information

Test Location: _____

Test Conducted By: _____ Date _____

Environmental Conditions

Temperature: _____ Humidity _____

Surface Moisture Condition _____

Ball Moisture Condition _____

Surface Information:

Test Surface: _____ Thickness: _____ Width: _____

Subsurface Description:

_____

_____

Ball Information:

Manufacturer: _____ Model: _____

Pressure: _____

Description _____

Test Information

Reference Surface: _____ Drop Height _____(m)

FIG. X1.1 Sample Report

Results:

REFERENCE SURFACE:

Initial Test	Drop 1: _____ (m)	Average Rebound Height (m): _____
	Drop 2: _____ (m)	Time and Date of Test _____
	Drop 3: _____ (m)	Location: _____
	Drop 4: _____ (m)	Comments: _____
	Drop 5: _____ (m)	
Second Test	Drop 1: _____ (m)	Average Rebound Height (m): _____
	Drop 2: _____ (m)	% Difference from Initial Test: _____
	Drop 3: _____ (m)	Time and Date of Test _____
	Drop 4: _____ (m)	Location: _____
	Drop 5: _____ (m)	Comments: _____
	Continue as needed	

TEST SURFACE:

Point 1:	Drop 1: _____ (m)	Average Rebound Height (m): _____
	Drop 2: _____ (m)	Vertical Rebound Ratio (%): _____
	Drop 3: _____ (m)	Coefficient of Restitution: _____
	Drop 4: _____ (m)	Location: _____
	Drop 5: _____ (m)	Comments: _____
Point 2:	Drop 1: _____ (m)	Average Rebound Height (m): _____
	Drop 2: _____ (m)	Vertical Rebound Ratio (%): _____
	Drop 3: _____ (m)	Coefficient of Restitution: _____
	Drop 4: _____ (m)	Location: _____
	Drop 5: _____ (m)	Comments: _____

Continue as needed.....

Test Point Summary:

Point	VRR	CR		Point	VRR	CR
1				3		
2				4		
Continue as needed.....						

FIG. X1.1 Sample Report *(continued)*

Playing Surface Summary:

Max BRR: _____	Max CR _____
Min. BRR: _____	Min. CR _____
Avg. BRR _____	Avg CR _____
BRR Std. Dev. _____	CR Std. Dev _____

FIG. X1.1 Sample Report *(continued)*