Section 1

Test Method for Firmness and Stability

Contents of Section 1

ANSI/RESNA Surface/Vol. 1 Section 1 Introduction

Foreword

ANSI/RESNA is …

Introduction

The Americans with Disabilities Act Accessibility Guidelines for buildings and facilities specify that ground and floor surfaces along accessible routes and in accessible rooms be stable, firm and slip resistant. It does not specify, however, how to objectively determine the stability, firmness, or slip-resistance of the surface. This section of ANSI/RESNA Surface addresses the need for a means to objectively measure firmness and stability. This section does not address slip resistance.

With funding from the National Institute for Child Health and Human Development at the National Institutes of Health through a Small Business Innovation Research Grant, Beneficial Designs, Inc. developed a portable device, called the Rotational Penetrometer, for objectively measuring the firmness and stability of a wide variety of surface types. Through extensive research, measures obtained with the Rotational Penetrometer have been validated with human subject testing and wheelchair work measurements. The device has been shown to produce repeatable and reproducible measurements.

This standard specifies only a test method to measure firmness and stability using the Rotational Penetrometer, with no performance requirements.

This test method can be used to measure and compare the firmness and stability of trails, playground surface systems, carpet, and many other indoor and outdoor surfaces. Builders, architects and site planners will be able to use the test results to create accessible indoor and outdoor surfaces, thus facilitating access to wheelchair users and other people with disabilities. The objective surface measurements will also provide individuals with access information at specific locations.

The wheelchair work measurement method was also developed by Beneficial Designs, Inc. and is the test method specified in ASTM F 1951–99, Standard Specification for Determination of Accessibility of Surface Systems Under and Around Playground Equipment. ASTM F 1951 applies to level playground surface systems and utilizes costly equipment to perform the test. The test method and performance requirements specified in ASTM F 1951 are not suitable for other surfaces such as trails and carpet. The measurements obtained with the Rotational Penetrometer have been shown to correlate with the wheelchair work measurement values obtained with ASTM F 1951.

Section 1:
Test Method for Firmness and Stability

1 Scope

This part of ANSI/RESNA Surface specifies the test method for determining the firmness and stability of ground and floor surfaces.

2 Normative references

3 Definitions

For the purposes of this part of ANSI/RESNA Surface, the following definitions apply:

firmness
the degree to which a surface resists deformation by indentation when a person walks or wheels across it

the degree of surface resistance to deformation, especially by indentation or the movement of objects

stability
the degree to which a surface remains unchanged by contaminants or applied force, so that when the contaminant or force is removed, the surface returns to its original condition

the degree to which a surface resists change from contaminants or applied force, so that when the contaminant of force is removed, the surface returns to its original condition

loose fill surface system
a surface system consisting of individual particles that can be separated

unitary surface system
a ground or floor surface consisting of one or more components (e.g., pad and carpet)

surface
ground or floor surface or surface system

test surface
the portion of the surface to be tested

4 Principle

This test method has been developed to define a surface in terms of firmness and stability.

The test method for firmness consists of applying a specified force to a specified indentor into the test surface, and measuring the amount of vertical displacement.

The test method for stability consists of applying a specified force and then rotating a specified indentor into the test surface.

5 Test apparatus

The **rotational penetrometer** shall consist of two surface reference plates, a frame, and a penetrator assembly. The two **surface reference plates** contact the surface and distribute the weight of the operator. The **frame** is mounted to the surface reference plates and supports the penetrator assembly.

The penetrator assembly shall incorporate a **penetrator** and a means of applying a load to the penetrator. The penetrator shall displace vertically and rotate about a vertical axis relative to the surface reference plates. This allows positioning of the penetrator on the test surface at the beginning of the measurement procedure.

NOTE: This allows zeroing of the penetrator assembly relative to the test surface.

The **penetrator assembly** shall be vertically adjustable and settable relative to the surface reference plates.

NOTE: This allows the penetrator to displacement into the test surface.

NOTE: See Annex A (Informative) for a detailed description of a rotational penetrometer.

5.1 Surface reference plates

The two identical surface reference plates shall have dimensions as shown in Figure 1.

The two surface reference plates shall be constructed of **19.0 ±1 mm (0.75 in) CDX** plywood or a material with the same stiffness.

NOTE: Surface reference plates constructed of plywood should be finished with a marine grade sealer to prevent erosion and warping.

The bottom of each surface reference plate shall be planar to a tolerance of **0.25 inch**.

The nominal size of each surface reference plate shall be **203 +0/–6 mm (8.00 +0/–0.25 in)** by **610 +0/–6 mm (24.00 +0/–0.25 in)**.

The outer corners shall be curved with a radius of **25 ± 6 mm (1 ± 0.25 in).**

The inside edges of the two surface reference plates shall be parallel and spaced **203 ± 6 mm (8.0 ± 0.25 in.)** apart.

There shall be a central circular clearance area with a diameter of **292 ± 6 mm (11.5 ± 0.25 in)** and a center aligned with the central vertical axis of the penetrator assembly.

NOTE: This spacing and clearance area allow measurement of crowned surfaces, and provide sufficient clearance around the penetrator so that the test surface does not build up and interfere with the movement of the penetrator.

The total bottom surface area of both surface reference plates shall be **2260 +65/–0 sq cm (350 +10/–0 sq in)**.

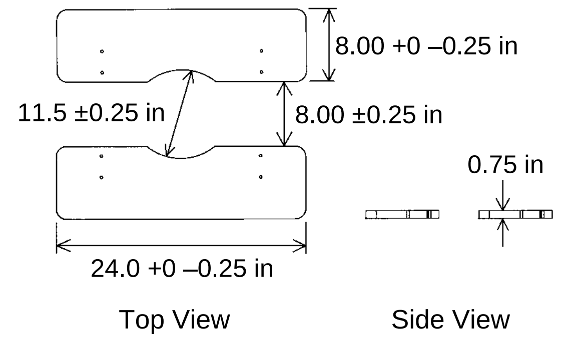


Figure 1. Surface reference plates

**** Add centerline to drawing on the left so circular area is in the center of the SRP***
**** Change orientation of drawing on the right***

5.2 Penetrator assembly

The penetrator assembly shall incorporate a penetrator which shall be a **200 x 30 mm (8 x 1.25 in)** ribbed tread pneumatic tire that is oriented vertically (upright).

The penetrator shall rotate freely **90** ± **5 degrees** about the central vertical axis of the penetrator assembly and there shall be a means to limit the extent of rotation.

The mass of the lower part of the penetrator assembly shall be evenly distributed about the central vertical axis.

There shall be a means to adjust and lock the height of the penetrator assembly relative to the surface reference plates. It shall be feasible to position the bottom of the penetrator a minimum of **25 mm (1.0 in)** above and **25 mm (1.0 in)** below the bottom of the surface reference plates to enable referencing to the test surface.

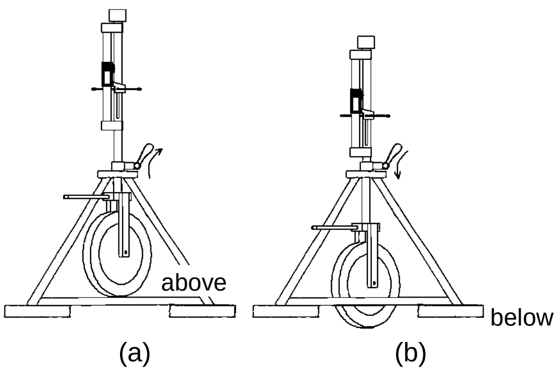


Figure 2. Height adjustability of the penetrator assembly: (a) above and (b) below the bottom of the surface reference plates

**** Remove arrow near lock handle***
**** Add up/down penetrator assembly arrow***

The resting force applied by the weight of the penetrator assembly, with no additional force applied, shall be **2.27** ± **0.045 kg (5.0** ± **0.1 lb.).**

There shall be a means to apply a spring load to the penetrator at an angle of **90** ±**1.5** degrees relative to the bottom of the surface reference plates.

With the vertical position of the penetrator assembly locked, the penetrator shall have the ability to move downward independently of the penetrator assembly and to displace at least **51 mm (2.0 in)** downward into the test surface.

There shall be a means to measure the downward vertical displacement of the penetrator into the test surface to an accuracy of 0.25 mm (0.01 in.).

At 0 in. of penetration, the calibrated spring shall apply a force of 22.0 ± 0.09 kg (48.4 ± 0.2 lb.).

There shall be a means of adjusting the spring force with a tamper-resistant method of calibration.

Note: The 22 kg (48.4 lb.) value is based on extrapolated data using 20 kg (44 lbs.) of force measured under the penetrator. The deformation of the pneumatic caster (0.4826 cm; 0.19 in) and **deflection of the scale (0.1524 cm; 0.06 in)** result in a total displacement of 0.635 cm (0.25 in). At this displacement, the device is calibrated to 19.95 ± 0.045 kg (44 ± 0.1 lb).

5.3 Force vs. displacement characteristics

The force versus displacement characteristics of the rotational penetrometer shall be characterized by one of the following equations (depending upon the units of measurement):

$Y = -18.17 X + 48.00 \pm 1.50$

Where:

X = the amount of displacement of the penetrator from the starting zero position; measured in inches (in)

Y = the amount of force applied by the penetrator; measured in pounds (lb)

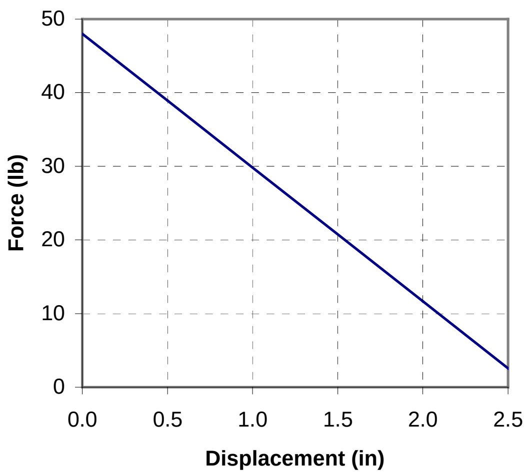


Figure 3. Force (lb) vs. displacement (in)

$Y = -3.18 X + 213.50 \pm 6.67$

Where:

X = the amount of displacement of the penetrator from the starting zero position; measured in millimeters (mm)

Y = the amount of force applied by the penetrator; measured in Newtons (N)

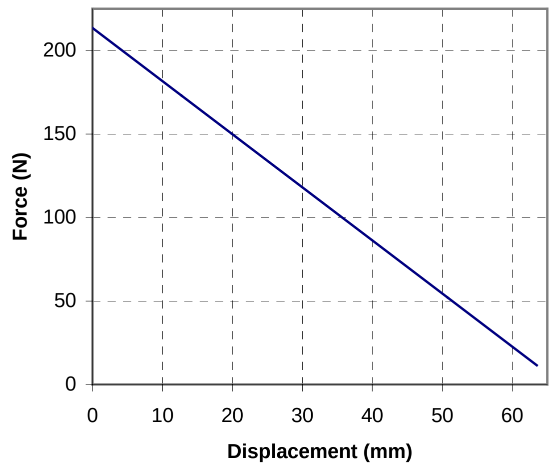


Figure 4. Force (N) vs. displacement (mm)

NOTE: A spring that meets this specification is described in Annex A (informative).

6 Calibration of rotational penetrometer

The rotational penetrometer shall have been calibrated within the previous 12 months.

6.1 Equipment

A NIST (National Institute of Standards and Technology) certified precision scale capable of measuring to the nearest **0.01 kg (0.02 lb).**

6.2 Calibration procedure

Inflate the penetrator to **248 ± 7 kpa (36 ± 1 psi).**

Secure the surface reference plates independently over, but not contacting, a precision scale which is positioned under the penetrator.

Allow the full weight of the penetrator assembly to rest on the precision scale and verify that it weighs **2.27 ± 0.045 kg (5.0 ± 0.1 lb.).**

Lock the vertical position of the penetrator assembly.

Apply the spring load to the penetrator and measure the force exerted under the penetrator at a minimum of **8** displacements, from **0 to 51 mm (2 in)** at approximately **6.3 mm (0.25 in)** intervals.

Verify that the force vs. displacement characteristics of the rotational penetrometer meet the requirements specified in 5.3.

7 Preparation of test equipment

Inflate the penetrator to **248 ± 7 kpa (36 ± 1 psi).**

8 Test procedure

8.1 Firmness test method

8.1.1 Identify test surface

Identify 5 locations that are representative of the total surface.

The test surface shall have a maximum slope of 20% (11.3 deg) and a maximum crown of 17.5% (10 deg) in each direction.

NOTE: Testing has shown that the device is repeatable under the above conditions.

8.1.2 Prepare rotational penetrometer for measurement

Raise the penetrator assembly such that the bottom of the penetrator is above the surface reference plates.

8.1.3 Position rotational penetrometer on test surface

Position the surface reference plates of the rotational penetrometer on the test surface, keeping the penetrator off of the test surface.

Settle and stabilize the surface reference plates on the test surface such that they do not slide on, lose contact with, or penetrate further into the test surface during the measurement procedure.

If the surface reference plates do not remain stabilized during the measurement procedure, discontinue testing and retest starting with 8.1.1.

NOTE: If a person's weight is used to stabilize the surface reference plates, the person should stand with one foot on each surface reference plate. To settle the surface reference plates into the test surface, lift one foot up off the surface reference plate then back down without touching the test surface; repeat with the other foot. Remain standing on the surface reference plates throughout the test without further displacing or moving them into the test surface. Stepping off of the surface reference plates during the test procedure will adversely affect the measurement.

8.1.4 Reference penetrator assembly to test surface

Slowly lower the weight of the penetrator assembly onto the test surface at a rate not to exceed **38 mm per sec (1.5 in per sec).** Allow the penetrator to rest on the test surface for a minimum of **5.0 seconds**.

8.1.5 Zero reading

Lock the vertical position of the penetrator assembly relative to the surface reference plates.

Zero the vertical displacement reading.

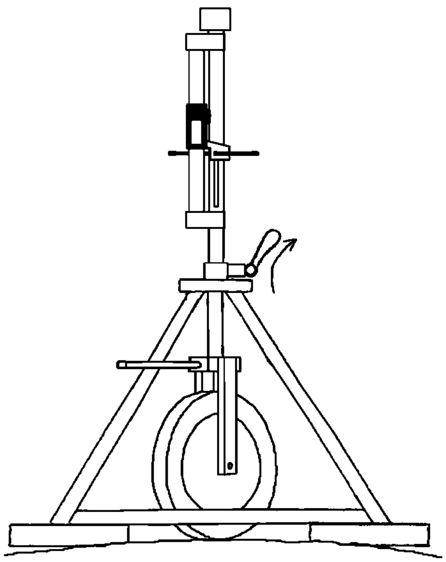


Figure 5. Rotational Penetrometer resting on the test surface with the penetrator assembly locked into position – ready to apply spring load to the penetrator

**** Remove arrow near lock handle***

8.1.6 Apply load to penetrator

Slowly apply the spring load specified in 5 to the penetrator, increasing at a slow steady rate not to exceed **8 ± 2 kg/s (17.6 ± 4.4 lb/s)** until the full load is reached.

8.1.7 Allow readings to stabilize

Wait until the rate of change of the penetrator into the test surface is less than 2.5 mm (0.01 in) per 10 seconds.

8.1.8 Record displacement

Measure and record the amount of vertical displacement of the penetrator into the test surface to the nearest **2.5 mm (0.01 in).**

8.1.9 Repeat measurements

Repeat 8.1.2 to 8.1.8 until a total of five (5) measurements have been taken.

8.1.10 Calculate firmness

Calculate firmness by averaging the five (5) measurements. Calculate the standard deviation of the five (5) measurements.

Firmness (average) = $x = \frac{(x_1 + x_2 + x_3 + x_4 + x_5)}{n}$

s (standard deviation) = √

Where:
- $n = 5$
- x = firmness (average)
- x_i = measurement i

8.2 Stability test method

8.2.1 Conduct firmness test

Conduct the firmness test method as specified in 8.1.

8.2.2 Rotate penetrator

With the spring load still applied to the penetrator, rotate the penetrator through four 90 ±5 deg rotations about a central vertical axis, alternating the direction of rotation (clockwise, counter-clockwise) after each 90 ±5 deg rotation.

8.2.3 Allow readings to stabilize

Wait until the rate of change of the penetrator into the test surface is less than 2.5 mm (0.01 in) per 10 seconds.

8.2.4 Record displacement

Measure and record the amount of vertical displacement of the penetrator into the test surface to the nearest 2.5 mm (0.01 in).

8.2.5 Repeat measurements

Repeat 8.2.1 to 8.2.4 until a total of five (5) measurements have been taken.

8.2.6 Calculate stability

Calculate stability by averaging the five (5) measurements. Calculate the standard deviation of the five (5) measurements.

Stability (average) = $y = \frac{(y_1 + y_2 + y_3 + y_4 + y_5)}{n}$

s (standard deviation) = √

Where:
n = 5
y = stability (average)
y_i = measurement i

9 Acceptance criterion

This part of ANSI/RESNA Surface does not specify acceptable performance criteria for different types of surfaces.

Acceptable performance criteria may be established by specific industries through regulatory agencies, associations, or institutes.

10 Test report

The test report shall contain the following information:

a) a reference to this part of ANSI/RESNA Surface;

b) the name and address of the institution performing the test;

c) complete identification of the test site (e.g., name and address of building and specific location, name of park and trail, name of park and playground)

d) complete identification of the test surface including manufacturer, type, manufacturer's lot number (if appropriate), thickness, and any other pertinent information;

e) for loose fill surface systems, the procedures used to install, compact and level the test surface prior to testing, if any;

f) test conditions, including atmospheric temperatures, relative humidity, and any other pertinent information;

NOTE: Additional information may include: typical or predominant environmental conditions or a photograph of the test site.

g) all details relevant to the test method (i.e. test apparatus, test apparatus manufacturer, device serial number, date of last calibration, method of stabilizing the surface reference plates)

h) date of testing;

i) the five (5) firmness measurements, average, and standard deviation; and

j) the five (5) stability measurements, average, and standard deviation.

NOTE: A sample data form is contained in Annex B.

Annex A
(Informative)

Rotational Penetrometer

The Rotational Penetrometer was developed by Beneficial Designs, Inc. in Santa Cruz, California, with funding from the National Institute of Child Health and Human Development (NICHD) at the National Institutes of Health (NIH) through Small Business Innovation Research Phase I Grant #1 R43 HD30979-01 and Phase II Grant #2 R44 HD30979-02.

The Rotational Penetrometer is available through Beneficial Designs, Inc., Santa Cruz, CA,
ph 831.429.8447, fax 831.423.8450, <surfaces@beneficialdesigns.com>.

Following are additional details and specifications for a device that meets this standard.

Main components:

- **surface reference plates** which contact the test surface and distribute the operator's body weight over a large area
- **penetrator assembly** which displaces vertically and rotates relative to the surface reference plates to measure surface firmness and stability
- **frame** which is mounted to the surface reference plates and supports the penetrator assembly

Penetrator assembly components:

- **calibration screw** that is tamper-resistant and used to calibrate the spring
- **calibration block** at the top of the penetrator assembly which contains the calibration screw and retains the spring
- **spring** which applies the load to the penetrator
  Vendor: Beneficial Designs, Inc., Santa Cruz, CA, ph 831.429.8447
  Part: Rotational penetrometer spring Price: $20.00 (approx.) (plus S&H) (as of 03/00)

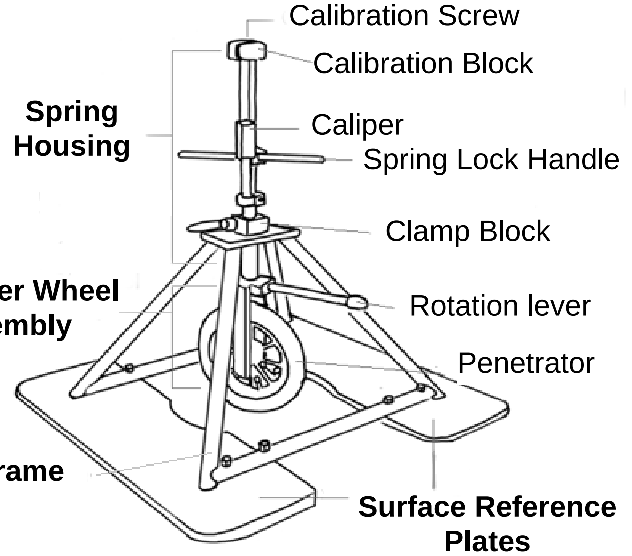
spring rate	30.65 N/cm	(17.5 lb/in)	
outside diameter	17.27 ± 1 mm	(0.680 ± 0.04in)	
length	18.288 ± ___ cm	(7.2 ± ___ in)	(after three full compressions)
number of coils	32.25		
spring constant	568.75		

- **spring housing** which contains the spring and is constructed of a tube with an inside diameter of 19.0 ± 1.0 mm (0.75 ± 0.04 in).
- **caliper** which measures the amount of vertical displacement of the penetrator:
  [RP3 caliper accuracy = 30 μm (0.0015 in); resolution = 25 μm (0.001 in)]
  Vendor: Western Tool & Supply, Santa Clara, CA, ph 408.970.9696
  Part: Fowler Euro-Cal III Model: 54-100-330 Price: $130.00
  Part: RS232 connector cable Price: $100.00 (as of 10/99)
- **spring lock handle** which locks the spring in the compressed state and prevents rotation of the spring housing
- **clamp block** which secures the vertical position of the penetrator assembly

– **clamp block lever** which tightens the clamp block

– **rotation lever** which enables rotation of the penetrator about a vertical axis during measurement of surface stability

– **penetrator** which contacts and indents into the test surface; an 8 x 1.25 in ribbed tread pneumatic tire
Vendor: The AfterMarket Group, North Ridgeville, OH, ph 888.824.8200
Model: RP365035 Price: $43.20 (as of 10/99)



Penetrator Assembly = Spring Housing + Caster Wheel Assembly

Figure 6. Rotational Penetrometer

**** Clamp block lever is on the wrong side***
**** Add penetrator assembly label to illustration***

Annex B
(Informative)

Sample Rotational Penetrometer Data Form

ANSI/RESNA Surface – Section 1: Test Method for Firmness and Stability
(Date of approval)

TEST INSTITUTION

Name ______________________
Address ______________________
____
____
Operator ______________________
Data recorder ______________________

ROTATIONAL PENETROMETER

Manufacturer ______________________
Serial number: BDRP– ______________________
Date of last calibration ______________________
☐ Tire pressure set at 36 psi. by ____________
Name ______________________
Date ______________________
Temp. °F ______________________

DATE & TIME OF TEST

Date ______________________
Time ______________________

TESTING CONDITIONS

Temperature °F ______________________
Relative Humidity % ______________________
If the temperature is more than 10 °F different than the temperature at the tire pressure check, re-inflate tire before starting to test.

TEST SURFACE

Location ______________________
Type ______________________
Depth ______________________
Slope ______________________
Manufacturer ______________________
Mfr. lot no. ______________________
Date of mfr. ______________________
Procedures used to install, compact and/or level prior to testing:

TEST RESULTS

Record readings to the nearest tenth of an inch (0.0).

Trial	Firmness	Stability
1	________	________
2	________	________
3	________	________
4	________	________
5	________	________
Average	________	________
Standard Deviation	________	________

Notes:

Annex C
(Informative)

Performance Criteria

Preliminary performance criteria for outdoor recreation access routes and trails have been developed. This information is reported in the September 1999 report by the Access Board (United States Architectural and Transportation Barriers Compliance Board) titled “Regulatory Negotiation Committee on Accessibility Guidelines for Outdoor Developed Areas Final Report.” Recommendations for accessibility guidelines for outdoor surfaces is also reported in “Accessible Exterior Surfaces Technical Report” (April 1999) which is also available through the Access Board.