A Procedure for Determining Bicycle Braking Performance

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Washington, D. C. 20234

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Prepared for
Office of Consumer Product Safety
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A PROCEDURE FOR DETERMINING BICYCLE
BRAKING PERFORMANCE

Donald E. Marlowe

ABSTRACT

A procedure which could be used to determine bicycle braking performance for compliance with the Federal Bicycle Safety Regulation, Requirements for Bicycles, has been developed. The procedure includes tests for brake system integrity and stopping distance performance. Sample data collection sheets and calculations are given.

Key Words: Bicycles, braking, consumer safety, handbrakes, testing.

1. SCOPE

1.1 General

This procedure was used for the testing of bicycles in accordance with paragraph 1512.18(d)(2)(i) Loading Test, paragraph 1512.18(d)(2)(iii) Rocking Test, and paragraph 1512.18(d)(2)(v) Performance Test of the Federal Bicycle Safety Regulation, Requirements for Bicycles, Federal Register, July 16, 1974, and its amendments.

1.2 Test Samples

Bicycles which are proposed for sale on the retail market were tested for brake performance using the test procedure with the equipment outlined below or its equivalent.

1.3 Test Flow

The flow of procedures which were followed in the tests is shown in Figure 1.

2. APPLICABLE DOCUMENTS

The documents which are applicable to these tests are:

Bicycle Assembly
   According to
   Manufacturers
   Instructions

   Set Up
   Interval
   Timer

   Installation
   and Adjustment
   of Test
   Equipment

   Familiarization
   Ride
   for Test
   Rider

   Measure the
   Coefficient of
   Friction Between
   The Test Tire
   And Pavement

   Familiarization
   Ride for Test
   Rider

   Clean Tire
   Rims and
   Photograph
   the Bicycle

   Perform Brake
   Loading Test
   (1512.18(d)(2)(i))

   Perform Rocking
   Test
   (1512.18(d)(2)(iii))

   Final Brake
   Adjustment

   Readjust
   Force Gage Stops
   and Switches

   Load the
   Ground Marker System

   Perform Performance
   Test
   (1512.18(d)(2)(v))

   Compute the
   Bicycle Speed
   and Stopping
   Distance

Fig. 1  Flow Diagram of Test Procedures
3. TEST EQUIPMENT

Tests were performed using the test equipment listed in Table 1 or its equivalent.

4. PRECAUTIONS

4.1 Environment

(1) All testing was performed on a dry, clean, smooth paved surface free from protruding aggregate. The coefficient of friction between the tire and test surface was always less than 1.0 as determined on the bicycle being tested (see section 4.3). The pavement had a slope of less than one percent.

(2) The wind velocity during the tests did not exceed 11 km/hr (7 mph).

4.2 Rider Safety

(1) All riders were equipped with a riding helmet and clothing to limit the degree of injury should an accident occur during testing. Suitable clothing should include abrasion resistant pants, jacket and gloves similar to those used by professional motorcycle riders.

(2) The rider was encouraged to gain familiarity with the performance characteristics of the test bicycle. The familiarization took place with the bicycle equipped for testing. Several test runs, similar to the performance test run, but at lesser speeds, were made.

4.3 Equipment Check-out

(1) The coefficient of static friction between the bicycle and test surface was measured. A weight of 68.1 kg (150 lb) was placed on the bicycle seat. The weight distribution of the bicycle was determined by placing a platform scale or load cell weighing system under each wheel. The rear wheel of the bicycle was locked to prevent its rotation. A force gage was attached to the locked wheel near the tire-pavement interface. Steadily increasing forces were applied to the wheel in a direction parallel to the test surface until the wheel began to slide on the surface. The coefficient of friction between the tire and pavement is the ratio of the maximum tractive force parallel to the surface to the load distributed onto the rear wheel.
Table 1 - Test Equipment for Bicycle Braking Tests

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tire inflation pressure gage, $7 \times 10^5$ N/m$^2$, (100 psi) capacity.</td>
</tr>
<tr>
<td>2.</td>
<td>Steel tape measure.</td>
</tr>
<tr>
<td>3.</td>
<td>Scales-91 kg (200 lb) capacity.</td>
</tr>
<tr>
<td>4.</td>
<td>68.1 kg (150 lb) mass (rider dummy)</td>
</tr>
<tr>
<td>5.</td>
<td>Force gage - 900 N (200 lbf) capacity.</td>
</tr>
<tr>
<td>6.</td>
<td>Rear wheel loading fixture.</td>
</tr>
<tr>
<td>7.</td>
<td>Rear wheel locking pin.</td>
</tr>
<tr>
<td>8.</td>
<td>Electronic timer.</td>
</tr>
<tr>
<td>9.</td>
<td>Tape switch, 2 m (6 ft) length.</td>
</tr>
<tr>
<td>10.</td>
<td>12 volt rechargeable battery, (2), with charger.</td>
</tr>
<tr>
<td>11.</td>
<td>Force gage assembly with marker system firing switches.</td>
</tr>
<tr>
<td>12.</td>
<td>Force gage - 450 N (100 lbf) capacity, (2).</td>
</tr>
<tr>
<td>15.</td>
<td>Extension lever stops.</td>
</tr>
<tr>
<td>16.</td>
<td>Tape switch, 5 cm (2 in) length for actuating marker gun.</td>
</tr>
<tr>
<td>17.</td>
<td>Firing switch for coaster brakes.</td>
</tr>
<tr>
<td>18.</td>
<td>Riding helmet.</td>
</tr>
<tr>
<td>20.</td>
<td>Riding coveralls.</td>
</tr>
<tr>
<td>21.</td>
<td>Alcohol and rag.</td>
</tr>
<tr>
<td>22.</td>
<td>Camera.</td>
</tr>
</tbody>
</table>
(2) **Batteries** for the ground marker system and velocity timer were fully charged at the start of testing.

(3) **Bicycle tires** were inflated to the pressure recommended by the tire manufacturer and molded into the tire sidewall.

## 5. PROCEDURE

The test procedures described in the following sections are not unique and were determined somewhat by the equipment available at the time the tests were conducted. These tests were designed to evaluate the structural integrity of the braking system (Loading Test and Rocking Test), to insure that the coefficient of static friction between the tire and test pavement is within acceptable limits, and to evaluate the dynamic stopping capability of the bicycle (Performance Test). The braking systems to be tested using these procedures include those actuated from primary hand brake levers, from auxiliary or extension hand lines, and from foot pedals.

### 5.1 Preliminary Checks and Measurements

<table>
<thead>
<tr>
<th>STEP</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fully assemble the bicycle using the instructions provided by its manufacturer.</td>
</tr>
<tr>
<td>2.</td>
<td>Adjust all brake and shift linkages in accordance with the instructions.</td>
</tr>
<tr>
<td>3.</td>
<td>Inflate the tires to the maximum pressure recommended by their manufacturer.</td>
</tr>
<tr>
<td>4.</td>
<td>Ride the bicycle to insure that all adjustments are properly made.</td>
</tr>
<tr>
<td>5.</td>
<td>Measure the wheel base of the bicycle. This measurement is made from the center of the front axle to the center of the rear axle to the nearest 0.1 cm (0.05 in). Record the wheel base on the data sheet (Table 2).</td>
</tr>
<tr>
<td>6.</td>
<td>Weigh the test equipment. Record the weight (Table 2).</td>
</tr>
<tr>
<td>7.</td>
<td>Weigh the rider. Record the weight (Table 2).</td>
</tr>
<tr>
<td>8.</td>
<td>Affix a 68.1 kg (150 lb) mass to the bicycle seat.</td>
</tr>
<tr>
<td>9.</td>
<td>With the bicycle level and upright, measure the ground force at the rear wheel. Record the weight (Table 2).</td>
</tr>
<tr>
<td>10.</td>
<td>Position the bicycle on the test pavement in the vicinity of the expected stopping tests.</td>
</tr>
</tbody>
</table>
11. Attach the force gage to the rear wheel of the bicycle near the ground (Fig. 2).

12. Lock the rear wheel to prevent its rotation (Fig. 2). The front wheel must be free to rotate.

13. Using the force gage, apply steadily increasing forces to the wheel, parallel to the test pavement and in the plane of the wheel. Continue loading until the tire slides on the pavement. Record the maximum force (Table 2).

14. Compute the coefficient of friction for the particular tire-pavement combination as the ratio of the maximum applied force (item 13) to the weight on the rear wheel (item 9).

15. Verify that the above coefficient of friction is less than 1.0 (1512.18(d)(2)(v)(i)).

16. Remove the test mass from the bicycle.

17. Connect the external power plug to the electronic interval timer.

18. Connect the triggering tape switch to the battery (Fig. 3).

19. Connect the battery package to the timer.

20. Position the triggering tape switch across the test pavement.

5.2 Test Equipment Setup

5.2.1 Caliper Brake System

5.2.1(a) Primary Brake System

STEP DESCRIPTION

1. Remove all handgrips, wrapping tape, end plugs, etc., from the handlebars.

2. Position the force gage assembly on the handlebars and fasten with the friction clamp (Fig. 4).

3. Attach the lever clamp to the brake lever so that the center of the clamp is 25 mm (1 in) from the lever end (Fig. 5).

4. Adjust the position of the brake lever on the handlebar such that the line of action of the force gage will be straight when the lever is fully depressed (Fig. 6).

5. Using the force gage assembly, apply 445 N (100 lbf) to the hand brake lever.
Table 2 - Braking Test Data Sheet

a) Bicycle Manufacturer
   Serial No. 
   Model No. 

d) Bicycle Information
   Wheel Size__________in
   Max Gear Ratio
   Brake Type
   Brake Mfg.
   Frame Size_________lbf

e) Test Information
   Wheel Base__________in
   Equip. Weight_______lbf
   Rider Weight_______lbf

g) Rocking Test
   Pass-Fail

f) Loading Test
   Load on Force Gage_________lbf
   Lever Hit Bar
   Pass-Fail

h) Performance Test

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Elapsed Time for Speed Measurement</th>
<th>Stopping Distance from Rear Most Marker</th>
<th>Distance Between Markers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sec</td>
<td>sec</td>
<td>ft</td>
</tr>
<tr>
<td></td>
<td>sec</td>
<td>ft</td>
<td>ft</td>
</tr>
</tbody>
</table>

i) Coefficient of Friction
   Bicycle weight_______lbf
   Force applied to wheel_________lbf
Fig. 2  Test setup for measurement of coefficient of friction

Fig. 3  Velocity timer setup
Fig. 5  Lever clamp of force gage prior to actuation
Fig. 6  Force shall be applied along the line of action of the force gage after actuation.
6. Adjust the stops (Fig. 7) on the force gage assembly to limit the applied force to a maximum of 445 N (100 lbf).

7. If the clamp bottoms against the handlebar at a load less than 445 N (100 lbf), readjust the position of the clamp (Fig. 8).

8. Remove the 445 N (100 lbf) load from the brake system.

9. Adjust the length of the force gage clamp linkage to insure that the brake system is fully unloaded and no braking forces are being applied to the braking system.

10. Install the ground marker gun on the front fork of the bicycle (Fig. 9).

11. Strap or tape the ground marker system battery to the bicycle in any convenient location (Fig. 4).

12. Connect the wiring to the battery, gun and firing switches on the force gage assembly (Fig. 10).

13. Connect the ground wire from the marker gun to the battery.

5.2.1(b) Extension Lever System

STEP DESCRIPTION

1. Install the extension lever stops on the handlebar.

2. Adjust the position of these stops so that the extension lever travel beyond the top surface of the handlebar is prevented (Fig. 11).

3. Install the ground marker gun on the front part of the bicycle (Fig. 9).

4. Strap or tape the ground marker system battery to the bicycle in any convenient location (Figs. 4 & 11).

5. Install the firing switch on the extension level (Fig. 11).

6. Connect the battery to the switch and gun (Fig. 10).

7. Connect the ground wire from the gun to the battery.

5.2.2 Coaster Brake System

STEP DESCRIPTION

1. Install the ground marker gun on the front fork of the bicycle (Fig. 9).

2. Strap or tape the ground marker system battery to the bicycle in any convenient location (Figs. 4 & 11).
Fig. 7 Limit stops and switches on the force gage

Fig. 8 Lever clamp adjusted to allow the lever to bottom against the handlebar
Fig. 9  Ground marker gun
Fig. 10 Schematic of marker gun firing circuit

NOTE: Solenoid ground circuit completed through the bicycle fork.
Fig. 11  Test setup for extension lever
3. Install the firing switch on the seat tube (Fig. 12) so that any rearward motion of the chain causes the switch to close.

4. Connect the battery through the switch to the gun.

5. Connect the ground wire from the battery to the gun.

5.2.3 Caliper-Coaster Brake Combinations

To conduct tests on these systems, use procedures discussed above in sections 5.2.1 and 5.2.2 of the procedure. Both systems must be tested simultaneously.

5.3 Final Checks and Adjustments

<table>
<thead>
<tr>
<th>STEP</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Check the rider's safety equipment. The rider shall wear a riding helmet and leather gloves plus a pair of durable coveralls or other riding attire.</td>
</tr>
<tr>
<td>2.</td>
<td>Familiarize the rider with the behavior characteristics of the bicycle as it is equipped for the performance tests. This shall include several stops similar to those needed in the performance test but from lower speeds.</td>
</tr>
<tr>
<td>3.</td>
<td>Adjust all brake system linkages and clearances in accordance with the manufacturer's instructions. This is the final adjustment which is permitted under the regulation (1512.18(d)(2)).</td>
</tr>
<tr>
<td>4.</td>
<td>Wipe the tire rims of the bicycle using a clean cloth dampened with alcohol to remove any residue from earlier bicycle use.</td>
</tr>
<tr>
<td>5.</td>
<td>Photograph the bicycle as it is set up for testing.</td>
</tr>
<tr>
<td>6.</td>
<td>Turn on AC power to the interval timer.</td>
</tr>
</tbody>
</table>

5.4 Compliance Test Procedure

5.4.1 Loading Test

All bicycles equipped with hand brakes (primary and/or extension levers) are to be tested in accordance with the Hand Brake Loading Test (1512.18(d)(2)(i)) of the regulation using the procedure as follows:

<table>
<thead>
<tr>
<th>STEP</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Using the force gage loading apparatus, apply load to the hand brake lever to a maximum of 445 N (100 lbf) or until the hand brake bottoms against the handlebar, whichever occurs first. Release the load.</td>
</tr>
</tbody>
</table>
Fig. 12  Test setup for coaster brake
2. Repeat for a total of ten tests.

3. Repeat steps 1 and 2 for the extension lever system, if any.

4. Visually inspect the braking system after testing for fractures, failures, or misalignments which result from the test.

5. Record the results (Table 2).

5.4.2 Rocking Test

All bicycles equipped with hand brakes (primary and/or extension lever) are to be tested in accordance with the Rocking Test (1512.18(d)(2)(iii)) of the regulation using the procedure as follows:

<table>
<thead>
<tr>
<th>STEP</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Affix a 68.1 kg (150 lb) mass to the bicycle seat.</td>
</tr>
<tr>
<td>2</td>
<td>Position the bicycle on the test surface.</td>
</tr>
<tr>
<td>3</td>
<td>Using the force gage loading apparatus, apply load to the hand brake lever to a maximum of 445 N (100 lbf) as in the loading test above (section 5.4.1, step 1).</td>
</tr>
<tr>
<td>4</td>
<td>Drag the bicycle forward and rearward over the test surface for a total distance of 8 cm (3 in) in each direction.</td>
</tr>
<tr>
<td>5</td>
<td>Repeat for a total of 6 tests.</td>
</tr>
<tr>
<td>6</td>
<td>Visually inspect the braking system after testing for loosening of the brake pads, pad holder, or cable and hand-lever securing devices.</td>
</tr>
<tr>
<td>7</td>
<td>Remove the 68.1 kg (150 lb) mass from the bicycle.</td>
</tr>
<tr>
<td>8</td>
<td>Record the results (Table 2).</td>
</tr>
</tbody>
</table>

5.4.3 Performance Test

All bicycles are to be tested in accordance with the Performance Test (1512.18(d)(2)(v)) of the regulation using the procedure as follows:

<table>
<thead>
<tr>
<th>STEP</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>On bicycles equipped with hand brakes adjust the stops on the force gage assembly (Fig. 7) or the extension lever (Fig. 11) to limit the applied force to a maximum of 180 N (40 lbf).</td>
</tr>
<tr>
<td>2</td>
<td>Adjust the position of the firing switches (Fig. 7) so that the marker guns fire upon first actuation of the brake lever.</td>
</tr>
</tbody>
</table>
3. Load the ground marker guns with the paint cartridges.

4. Set the elapsed timer to zero.

5. Accelerate the bicycle to the specified test speed. Insure that the bicycle is traveling in a straight line at the test speed as it crosses the timing tape switch, and that the test rider is in the normal riding position. The test rider must remain in the normal riding position throughout the test.

6. Using the brake system(s) under test, stop the bicycle as rapidly as possible.

7. Note the presence of front wheel lockup, if any. A test run is invalid if front wheel lockup occurs.

8. Measure the stopping distance from the center of the rearmost ground marker along the original line of travel of the bicycle to the point opposite the center of the ground marker guns, disregarding changes in path which occur during the test. Record the distance (Table 2).

9. Record the elapsed time of the bicycle from the interval timer (Table 2).

10. Repeat steps 3 through 8 for a minimum of 4 test runs.

11. Compute the bicycle speed and corrected stopping distance using the equations and following the example shown in Fig. 13. Corrections for velocity at the initiation of braking may be made. The corrected braking distance shall be computed as follows:

\[ S_c = \left( \frac{V_a}{V_m} \right)^2 S_m \]

where:

- \( S_c \) = Corrected braking distance,
- \( V_a \) = Specified test velocity,
- \( V_m \) = Measured test velocity,
- \( S_m \) = Measured braking distance.

The test run is invalid if at the commencement of the test, the measured test speed of the bicycle is not less than nor greater than the test speed required by this Part 1512 by 1.5 km/h (0.9 mph).

The stopping distances specified are based on a rider weight of at least 68.1 g (150 lb) and a maximum rider and weight combination of 91 kg (200 lb). Greater stopping distances are allowable for heavier riders and test equipment weights at the rate of 0.30 m per 4.5 kg (1.0 ft per 10 lb).
Figure 13. Bicycle performance test sample calculation.

For all tests in which valid stopping runs were made, average distance = arithmetic average of the load corrected stopping distance (col. G) computed for every 10-1/2 ft over 150-1/2 ft.

Distance, corrected for load = distance + 0.30 m for every 0.5 kg over 68.1 kg.

Stopping distance, corrected for velocity = \( \frac{m}{w} \) x stopping distance

Where:
- \( m \) = measured test velocity
- \( w \) = velocity required for test

Specified test velocity, \( v = \) velocity required for test, PR 1572, January 28, 1976.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Bicycle Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Distance</td>
<td>Average</td>
</tr>
<tr>
<td>Ft</td>
<td>Ft/Sec</td>
</tr>
</tbody>
</table>
5.4.4 Rider Coordination

On bicycles equipped with hand brake systems, it may be desirable to measure the actuation time of the braking system, i.e., the time from first actuation of the brake to the time the applied lever force equals 178 N (40 lbf). Similarly, it may be desirable to measure the rider coordination in actuating the brake levers, or for bicycles equipped with a single hand brake and coaster brakes, the time difference between actuation of these two systems. In these cases, the second chamber of the ground marker gun can be wired to the battery (see Fig. 10), and the firing switch adjusted to measure the desired parameter. A second ground marker gun can be mounted on the bicycle to permit various measurements to be made during a single test. For these measurements, assume a constant bicycle speed between the ground marks and calculate the resulting elapsed time. Record the distance between ground marks in Table 2.
A procedure which could be used to determine bicycle braking performance for compliance with the Federal Bicycle Safety Regulation, Requirements for Bicycles, has been developed. The procedure includes tests for brake system integrity and stopping distance performance. Sample data collection sheets and calculations are given.