



# Standard Specification for High Load Rotational Spherical Bearings for Bridges and Structures<sup>1</sup>

This standard is issued under the fixed designation D 5977; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers bridge bearings that consist of a spherical rotational element, where a stainless steel convex surface slides against a concave carbon steel plate covered with woven or sheet polytetrafluoroethylene (PTFE). The function of the bearing is to transfer loads and to accommodate any relative movement, including rotation between a bridge superstructure and its supporting structure, or both.

1.2 This specification covers the requirements of spherical bearings with a standard horizontal load (a maximum of 10 % of vertical).

1.3 The requirements stated in this specification are the minima necessary for the manufacture of quality bearing devices. It may be necessary to increase these minimum values due to other design conditions.

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

1.5 The following safety hazards caveat pertains only to the test method portion, Section 7, of this specification: *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:

A 36/A 36M Specification for Carbon Structural Steel<sup>2</sup>

A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip<sup>3</sup>

A 240/A 240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and General Applications<sup>3</sup>

A 572/A 572M Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel<sup>2</sup>

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in. [100 mm] Thick<sup>2</sup>

A 709/A 709M Specification for Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges<sup>2</sup>

D 638 Test Method for Tensile Properties of Plastics<sup>4</sup>

D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement<sup>4</sup>

D 1457 Specification for Polytetrafluoroethylene (PTFE) Molding and Extrusion Materials<sup>4</sup>

D 1777 Method for Measuring Thickness of Textile Materials<sup>5</sup>

D 2256 Test Method for Tensile Properties of Yarns by the Single-Strand Method<sup>5</sup>

### 2.2 AASHTO Standard:

AASHTO Standard Specifications for Highway Bridges<sup>6</sup>

### 2.3 AWS Standards:<sup>7</sup>

C.2.2-67 Metalizing with Aluminum and Zinc for Protection of Iron and Steel

D.1.5 ANSI/AASHTO/AWS Bridge Welding Code

## 3. Classification

3.1 The bearings are furnished in three types, as follows:

3.1.1 *Fixed Spherical Bearing*—Rotation only.

3.1.2 *Uni-Directional Sliding Spherical Bearing*—Rotation plus movement in one direction.

3.1.3 *Multi-Directional Sliding Spherical Bearing*—Rotation plus movement in all directions.

## 4. Material Specifications

4.1 *Steel*—The steel used for all major plates shall be structural steel conforming to Specifications A 36/A 36M, A 588/A 588M, A 572/A 572M, or A 709/A 709M, as required. All exposed surfaces shall be zinc metalized according to AWS C.2.2-67 (with no chipping), having a minimum thickness of 6

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.04.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 07.01.

<sup>6</sup> Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001.

<sup>7</sup> Available from American Welding Society, 550 N.W. Lejeune Rd., Miami, FL 33135.

mil (0.152 mm) or treated with other project-approved coating systems such as coal tar or inorganic zinc paint. The dry film thickness (DFT) of the approved paint system must be specified by the owner.

#### 4.2 Stainless Steel:

4.2.1 *Flat Sliding Surface*—The sheet stainless steel used as the mating sliding surface to the woven fabric PTFE or sheet PTFE in the sliding spherical bearings shall conform to Specification A 167 or A 240/A 240M, type 304, 20- $\mu$ m. (0.5- $\mu$ m) rms finish.

4.2.2 *Convex Surface*—The solid stainless steel plate or sheet stainless steel used as the mating rotational convex surface to the woven fabric PTFE or sheet PTFE shall conform to Specification A 167 or A 240/A 240M, type 304. The surface shall be machined to a surface finish of 20- $\mu$ m. (0.5- $\mu$ m) rms or less.

4.3 *Woven Fabric Polytetrafluoroethylene (PTFE)*—The woven fabric PTFE shall be made from virgin PTFE oriented multifilament fibers with or without a high-strength backing.

4.3.1 The thickness of the woven fabric PTFE in the free state shall be a minimum of  $\frac{3}{32}$  in. (2.38 mm) when measured in accordance with Method D 1777.

4.3.2 The thickness of the bonded woven fabric PTFE under the application of vertical load shall be a minimum of the following:

(1)  $\frac{1}{16}$  in. (1.59 mm) from 0 psi (0 N/mm<sup>2</sup>) to 3500 psi (24.1 N/mm<sup>2</sup>).

(2)  $\frac{3}{64}$  in. (1.19 mm) from 3501 psi (24.1 N/mm<sup>2</sup>) to 4500 psi (31.0 N/mm<sup>2</sup>).

4.3.3 The woven fabric PTFE shall be mechanically interlocked and epoxy-bonded to the substrate using a system that prevents migration of the epoxy through the fabric. The use of a mechanical interlock system along with the epoxy increases the bond strength, providing a redundancy for the prevention of migration of the PTFE material. Any edges, other than the selvage (woven edge), shall be oversewn so that no cut fabric edges are exposed.

4.3.4 The individual PTFE filaments used in making the woven PTFE fabric shall conform to the physical requirements of Table 1.

4.4 *Sheet Polytetrafluoroethylene (PTFE)*—The sheet PTFE shall be virgin material (not reprocessed) meeting the requirements of Specification D 1457. The PTFE shall be resistant to acids, alkalis, petroleum products, and nonabsorption of water. It shall be stable for temperatures up to 500°F (260°C) and shall be nonflammable. When used in PTFE surfaces used for guide bars only, filler material shall be composed of milled glass fibers or carbon.

4.4.1 The thickness of the sheet PTFE shall be a minimum of  $\frac{1}{8}$  in. (3.17 mm) and shall be recessed at least one-half of its thickness.

4.4.2 The PTFE for the principal slide surface and for guide bars shall conform to the physical requirements listed in Table 2.

## 5. Design Requirements

NOTE 1—*To Designer:* The bearing details shall be designed in accordance with the requirements of the current edition with interims of the AASHTO Standard Specifications for Highway Bridges or other governing design procedures.

### 5.1 Rotational Elements:

5.1.1 The spherical radius shall be determined such that the resulting geometry of the bearing is capable of withstanding the greatest ratio of the horizontal load to vertical load under all loading conditions to prevent the unseating (separation at the edges) of the convex/concave elements.

5.1.2 Unseating of the curved spherical surfaces relative to each other shall be prevented by transferring horizontal forces through specifically designed restraints or by control of the spherical radius.

5.1.3 Acceptable spherical radius control shall be given when the configuration of the woven fabric PTFE concave radius follows the following design:

$$\text{ratio} \leq \tan \alpha \quad (1)$$

where:

ratio = worst case ratio of horizontal to vertical loads.

$$\alpha = \left( \arcsin \left( \frac{d/2}{R_{\max}} \right) \right) - (\text{design rotation}) \quad (2)$$

where:

$d$  = projected diameter of the woven fabric PTFE,  
 design rotation = design rotation of the bearing (in degrees), and  
 $R_{\max}$  = maximum allowable radius to prevent uplift within the bearing during the worst horizontal to vertical load case.

5.1.4 Calculations showing determination of the radius shall be submitted for approval.

5.1.5 The radius of the convex plate shall be less than the radius calculated for the woven fabric PTFE (concave plate) by a value equal to the thickness of the PTFE.

5.1.6 The concave surface shall face down whenever the resulting center of rotation is not detrimental to the system geometry. See Fig. 1

5.1.7 The minimum thickness at the center of the concave spherical element shall be  $\frac{3}{4}$  in. (19 mm).

5.1.8 The minimum thickness at the edge of the convex spherical element shall be  $\frac{1}{2}$  in. (12.7 mm).

**TABLE 1 Physical Property Requirements for Woven PTFE**

Physical Properties	Test Method	Requirement
Ultimate tensile strength, min, psi (MPa)	D 2256	24 000 (165.4)
Ultimate elongation, min, %	D 2256	35

**TABLE 2 Physical Property Requirements for Sheet PTFE<sup>A</sup>**

Physical Properties	Test Method	Requirement
Ultimate tensile strength, min, psi (MPa)	D 638	2800 (19.3)
Ultimate elongation, min, %	D 638	200
Specific gravity, min	D 792	2.12

<sup>A</sup>15% glass-filled PTFE may be used for guide bar surfaces (Specification D 1457).

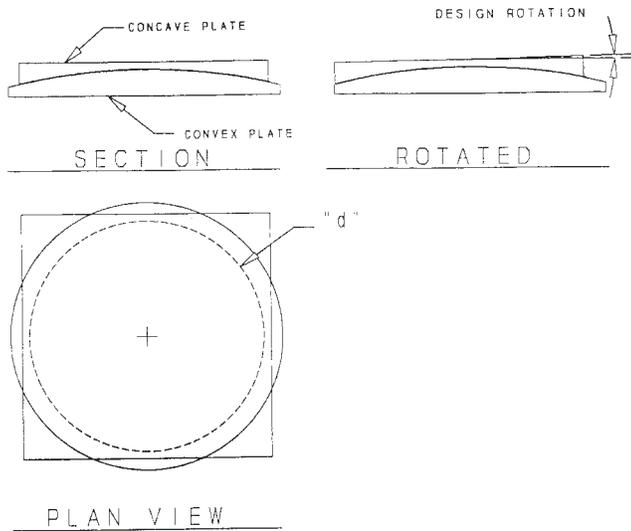


FIG. 1 Views of a Spherical Bearing

5.1.9 Vertical and horizontal clearance between the rotating (attached to the superstructure) and non-rotating (attached to the substructure) spherical bearing components, including fasteners, shall be no less than 1/8 in. (3.17 mm) when rotated to 150 % of the design rotation.

NOTE 2—To Designer: The spherical PTFE pad may be damaged at 150 % of the design rotation.

5.1.10 The concave radius shall be machined to a tolerance of  $-0.000, +0.010$  in. ( $-0, +0.25$  mm).

5.1.11 The convex radius shall be machined to a tolerance of  $-0.010, +0.000$  in. ( $-0.25, +0$  mm).

5.2 *Stainless Steel Sliding Surface:*

5.2.1 The thickness of the stainless steel sheet shall be 11 gage, with a manufacturer’s minimum thickness of 0.059 in. (1.5 mm).

5.2.2 *Fixing of the Stainless Steel Sheet*—The stainless steel sheet shall be attached to its backing plate by continuous fillet welding along its edges. It is essential that the stainless steel sheet remain in contact with the base metal throughout its service life and that interface corrosion cannot occur. The attachment of the stainless steel to its back-up plate shall be capable of resisting the frictional force set up in the bearing. Welding must be in accordance with ANSI/AASHTO/AWS D1.5.

5.2.3 The backing plate shall extend beyond the edge of the stainless steel sheet to accommodate the weld; also, the weld must not protrude above the stainless steel sheet. TIG welding of the stainless steel sheet is highly recommended to achieve this connection.

5.2.4 The flat horizontal stainless steel sliding surface shall cover the PTFE surface completely in all operations, plus one additional in. (25.4 mm) in all directions of movement. For a guided bearing with which there is no transverse movement, this requirement does not apply in the transverse direction.

5.3 *Woven Fabric PTFE Concave or Sliding Surfaces, or Both:*

5.3.1 The woven fabric PTFE shall be mechanically interlocked to the steel substrate. An epoxy bond system shall be

used for additional security. After completion of the bonding operation, the PTFE surface shall be smooth and free from blisters, bubbles, and evidence that any epoxy has migrated through the woven fabric PTFE.

5.3.2 The area of the woven fabric PTFE shall be designed for a maximum average working stress of 4500 psi (31.0 N/mm<sup>2</sup>).

5.3.3 The maximum edge pressure on the woven fabric PTFE shall not exceed 10 000 psi (68.8 N/mm<sup>2</sup>).

5.4 *Sheet PTFE on Concave or Sliding Surfaces, or Both:*

5.4.1 The sheet PTFE shall be pure virgin, unfilled, meeting the requirements of Specification D 1457. The sheet PTFE shall be recessed to one-half of its thickness and epoxy bonded to the steel substrate. The PTFE surface shall be smooth and free from blisters or bubbles after completion of the bonding operation.

5.4.2 The area of the sheet PTFE shall be designed for a maximum average working stress of 3500 psi (24.1 N/mm<sup>2</sup>).

5.4.3 The maximum edge pressure on the sheet PTFE shall not exceed 5000 psi (34.4 N/mm<sup>2</sup>).

5.4.4 The surface of the PTFE sheet to be epoxy bonded shall be etched using the sodium naphthalene or sodium ammonia etching process.

5.5 *Sheet PTFE Guiding Surfaces:*

5.5.1 Attachment of the sheet PTFE to the steel substrate of the guiding surface shall be performed by epoxy bonding and mechanical fastening. The mechanical fastening shall consist of a minimum of two stainless steel screws (Specification A 304) located on the centerline of the strip of PTFE and located 1/2 in. (12.7 mm) from each end of the PTFE strip. The top of the screws shall be recessed a minimum of 50 % of the amount of protrusion of the PTFE above the steel substrate.

5.5.2 The surface of the PTFE sheet to be epoxy bonded shall be etched using the sodium naphthalene or sodium ammonia etching process.

5.6 *Guide Bars:*

5.6.1 Each guide bar shall be manufactured from a monolithic piece of steel. Guide bars may be made integral by machining from the solid shape or fabricated from solid bars that are welded, bolted, or recessed into the guiding plate, or some combination thereof.

5.6.2 Guided surfaces shall be faced with opposing strips of stainless steel and sheet PTFE. No metal-to-metal contact shall be permitted. The sheet PTFE may be fastened to either the concave plate or guide bars, with opposing stainless steel on the guide bars or concave plate, respectively. The sheet PTFE shall be bonded as well as fastened mechanically with stainless steel screws (see 5.5.1). The maximum total gap allowed between the guiding surfaces shall be 1/16 in. (1.59 mm).

5.6.3 The guide bars and their connections to the sliding/sole plate shall be designed for the horizontal forces on the bearing but not less than 10 % of the maximum working stress load on the bearing.

5.6.4 Guiding arrangements shall be designed so that the PTFE-covered guide surface is kept parallel and always within the limits of the stainless steel-covered guides at all points of translation and rotation of the bearing. Guiding against the fixed base or any extension of it is not recommended.

5.7 *Flatness*—All bearing load carrying surfaces in contact with one another shall be flat within 0.006 in. (0.13 mm) per any 12 in. (305 mm), as determined by a precision straightedge and feeler gages or by other approved methods.

## 6. Sampling

### 6.1 Lot Size:

6.1.1 Sampling, testing, and acceptance consideration will be made on a lot basis prior to shipment by the manufacturer. A lot shall be defined as those bearings presented for inspection at a specific time and date.

6.1.2 A lot shall not exceed 25 bearings.

6.1.3 A lot shall consist of those bearings of the same type and may consist of differing vertical load capacities but not to exceed a range of capacity by more than 300 kips (1333.3 kN).

6.1.4 The tests and number of samples to perform tests shall be in accordance with the following table:

Test	Samples Required
Proof load and compression strain	one production bearing per lot
Rotation	one production bearing per lot
Coefficient of friction	one production bearing per lot (test must be completed using two identical bearings)
PTFE (woven or sheet) bond test	one production bearing per lot
Physical properties of woven fabric PTFE material	one piece of fabric PTFE per project, of a size similar to the smallest bearing in the lot
Physical properties of sheet PTFE material	one 10 by 15 in. (250 by 380 mm) piece of sheet PTFE per project

## 7. Test Method

7.1 *Proof Load*—This applies to fixed and expansion bearings.

7.1.1 Load the bearing to 150 % of the maximum design vertical load. Hold for 1 h. Note any deformations, cracks, or separations in the PTFE.

7.2 *Rotation*—This applies to fixed and expansion bearings.

7.2.1 Load the bearing to 75 % of the design load while simultaneously placing it in a rotated condition of 0.02 radians or the design rotation, whichever is greater. Hold for 1 h. Note any separation (lift-off) of plates from each other or from the PTFE surfaces.

7.3 *Coefficient of Friction*—This applies to expansion bearings only.

7.3.1 Load two bearings of identical load capacity at their design load for a minimum of 12 h, while simultaneously placing them in a rotated condition of 0.02 radians, or design rotation, whichever is greater. Determine for the first movement the average static and dynamic coefficient of friction for the two sliding surfaces at a sliding speed of less than 1 in./min (25.4 mm/min). Subject the bearing to 100 sliding cycles of 1 in. (25.4 mm) minimum movement at a speed not exceeding 12 in./min (305 mm/min). Determine for the 101<sup>st</sup> movement the average static and dynamic coefficient of friction for the two sliding surfaces as described for the first movement. Note any deformation or cold flow of the PTFE.

7.4 *PTFE (Woven or Sheet) Bond*—This applies to expansion bearings only.

7.4.1 Subject the bearing to the maximum vertical design load and simultaneously, but transversely, a load equal to 13 % of the maximum vertical design load for a period of 1 min.

Note any slip or creep of the PTFE. Any PTFE that is surface damaged by the testing shall be replaced by material of equal quality to the original PTFE material. This surface damage does not cause rejection of the bearing.

7.5 *Physical Properties of Woven Fabric PTFE*—This applies to fixed and expansion bearings.

7.5.1 Determine the physical properties in accordance with the relevant test methods called out in Table 1.

7.6 *Physical Properties of Sheet PTFE*—This applies to expansion bearings only.

7.6.1 Determine the physical properties in accordance with the relevant test methods called out in Table 2.

7.7 *Acceptance Criteria Upon Inspection After Testing:*

7.7.1 There shall be no liftoff or separation between plates during rotation. There shall also be no separation between plates and woven fabric PTFE under rotation. Woven fabric PTFE weave shall not ravel.

7.7.2 Measured static and dynamic coefficients of friction shall not exceed 4 % for bearings using woven fabric PTFE.

7.7.3 Measured static and dynamic coefficients of friction shall not exceed 3 % for bearings using sheet PTFE.

7.7.4 Slip or creep shall not exceed 1/8 in. (3.17 mm) during the woven fabric PTFE bond test.

7.7.5 Woven fabric PTFE properties shall be within the limits given in Table 1.

7.7.6 Sheet PTFE properties shall be within the limits given in Table 2.

7.7.7 There shall be no cracks, separation, or permanent deformation of the PTFE, stainless steel, other components, or welds.

## 8. Precision and Bias

8.1 *Precision*—The precision of the procedures described in 7.1.1, 7.2.1, 7.3.1, and 7.4.1 for measuring proof load, rotation, coefficient of friction, and PTFE bond are being determined. A problem exists in that users are not interested in performing these tests in house, and are relying on producers and independent laboratories for compliance. Round robin tests would not be practicable.

8.2 *Bias*—The procedures described in 7.1.1, 7.2.1, 7.3.1, and 7.4.1 for measuring proof load, rotation, coefficient of friction, and PTFE bond have no bias because the values derived are defined only in terms of these test methods.

## 9. Product Marking

9.1 Every bearing shall be marked by stamping and, unless otherwise specified in the contract or purchase order, the markings shall be on a side face visible after erection of the bridge.

9.2 The marking shall consist of the manufacturer's name or trademark, bearing identification, and placement/setting (location and orientation) details.

9.3 To establish a correct setting position for sliding plates of expansion bearings, the slide plate shall have the centerline inscribed on a side visible after erection, a graduated scale showing the limit of design movement on either side of its centerline. A mating centerline shall also be inscribed on the lower portion of the bearing.

## 10. Keywords

10.1 bearing devices; high load rotational bearings; polytetrafluoroethylene (PTFE); spherical bearings

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