



# Standard Specification for Plain and Steel-Laminated Elastomeric Bearings for Bridges<sup>1</sup>

This standard is issued under the fixed designation D 4014; 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 bearings, which consist of all elastomer or of alternate laminates of elastomer and steel, when the function of the bearings is to transfer loads or accommodate relative movement between a bridge superstructure and its supporting structure, or both.

1.2 The values stated in SI units are to be regarded as the standard.

NOTE 1—The words “elastomer” or “elastomeric” will be used interchangeably with the word “rubber” in this specification.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section B, 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>
- D 395 Test Methods for Rubber Property—Compression Set<sup>3</sup>
- D 412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension<sup>3</sup>
- D 518 Test Method for Rubber Deterioration—Surface Cracking<sup>3</sup>
- D 573 Test Method for Rubber—Deterioration in an Air Oven<sup>3</sup>
- D 832 Practice for Rubber Conditioning for Low-Temperature Testing<sup>3</sup>
- D 1149 Test Method for Rubber Deterioration Surface Ozone Cracking in a Chamber<sup>3</sup>
- D 1415 Test Method for Rubber Property—International Hardness<sup>3</sup>

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

<sup>3</sup> Annual Book of ASTM Standards, Vol 09.01.

- D 1418 Practice for Rubber and Rubber Latices—Nomenclature<sup>3</sup>
- D 2000 Classification System for Rubber Products in Automotive Applications<sup>4</sup>
- D 2137 Test Methods for Rubber Property—Brittleness Point of Flexible Polymers and Coated Fabrics<sup>3</sup>
- D 2240 Test Method for Rubber Property—Durometer Hardness<sup>3</sup>
- D 3183 Practice for Rubber—Preparation of Pieces for Test Purposes from Products<sup>3</sup>
- E 4 Practices for Force Verification of Testing Machines<sup>5</sup>

## 3. Terminology

### 3.1 Definitions:

- 3.1.1 *design load*—the mean compressive stress applied to the area of the steel laminate.
- 3.1.2 *external load plate*—a steel plate bonded to the top or bottom elastomeric surface of a bearing, or both.
- 3.1.3 *lot*—unless otherwise specified in the contract or purchase order, a lot shall consist of a single type of bearing, of the same design and material, submitted for inspection at the same time.
- 3.1.4 *plain elastomeric bearing pad*—a bearing that consists only of elastomeric material.
- 3.1.5 *plain elastomeric sandwich bearing*—a bearing that consists of a single layer of elastomeric material bonded to one or two external load plates (3.1.2).
- 3.1.6 *steel-laminated elastomeric bearing*—a bearing molded of elastomeric material with one or more steel laminates embedded in and bonded to it, and to which one or two external load plates (3.1.2) may be bonded.

## 4. Classification

- 4.1 The bearings are furnished in four types as follows:
  - 4.1.1 Plain Elastomeric Bearing Pad.
  - 4.1.2 Plain Elastomeric Sandwich Bearing.
  - 4.1.3 Steel-Laminated Elastomeric Bearing.
  - 4.1.4 Steel-Laminated Elastomeric Bearing with External Load Plate(s).

<sup>4</sup> Annual Book of ASTM Standards, Vol 09.02.

<sup>5</sup> Annual Book of ASTM Standards, Vol 03.01.

NOTE 2—Examples of the types of elastomeric bearing construction are given in Fig. 1.

NOTE 3—The adjective elastomeric is omitted in this specification when referring to bearing types.

4.2 The elastomer for the manufacture of the bearing is furnished in two types as follows:

4.2.1 Type CR—Chloroprene rubber.

4.2.2 Type NR—Natural rubber.

4.2.3 If none is specified then the manufacturer shall use one of those types.

NOTE 4—Appendix X1 relates to elastomeric materials which do not have fully documented in-service records or sufficiently widespread use or both.

NOTE 5—The abbreviations for the elastomer types are taken from Practice D 1418.

4.3 The elastomer for the manufacture of the bearing is furnished in four grades of low-temperature properties. The grades and typical operating temperature conditions for each grade are as follows:

4.3.1 Grade 0—Suitable for continuous use down to + 5°C.

4.3.2 Grade 2—Sub-zero temperatures occur at night and occasionally persist for no more than 1 or 2 days.

4.3.3 Grade 3—Same as 2 but occasional periods of up to 2 weeks continuously below zero.

4.3.4 Grade 5—Sub-zero temperatures down to - 40°C persisting for several months each year with up to 2 months continuously below - 15°C.

4.3.5 If a grade is not specified Grade 0 shall be furnished. An elastomer of a higher grade number may be substituted for any lower grade.

NOTE 6—A discussion of low-temperature properties of elastomeric materials is given in Practice D 832.

NOTE 7—The grade numbers for the low-temperature properties correspond to those in Table 5 of Classification D 2000.

5. Ordering Information

5.1 Orders for each type of bearing under this specification shall include the following:

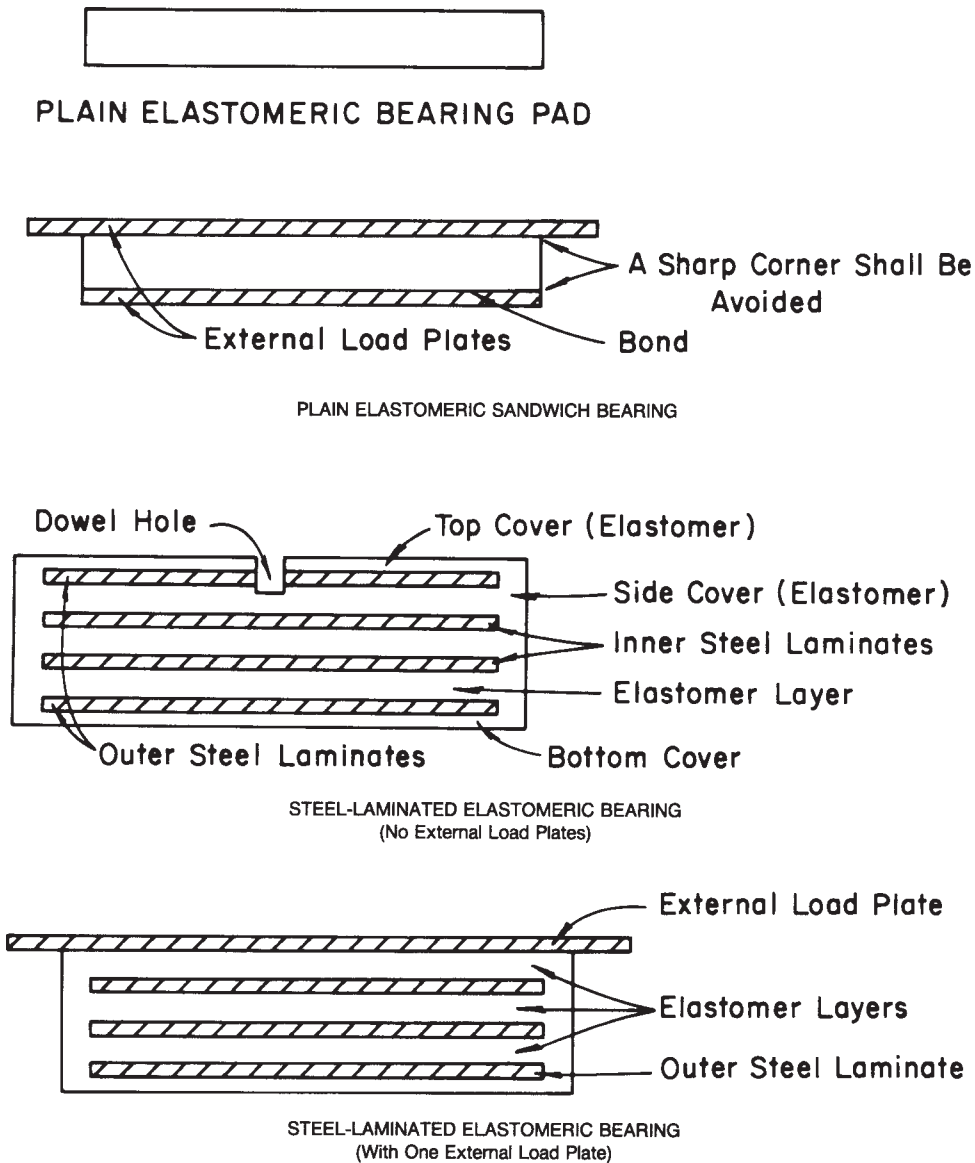


FIG. 1 Examples of the Construction of Elastomeric Bearings

- 5.1.1 Quantity,
- 5.1.2 Bearing design,

NOTE 8—An example of the design information required is given in Appendix X2. Working drawings may be substituted.

- 5.1.3 Design load,
- 5.1.4 Shear modulus of the elastomer,
- 5.1.5 Rubber type,
- 5.1.6 Rubber grade,
- 5.1.7 Ozone test partial pressure, if higher than 50 mPa (formerly referred to as a concentration of 50 parts per hundred million (pphm)).

## 6. Materials and Manufacture

6.1 The elastomeric compound used in the construction of a bearing shall contain only either natural rubber or chloroprene rubber as the raw polymer. No reclaimed rubber shall be used.

6.2 Internal steel laminates shall be of rolled mild steel.

6.3 External load plates shall conform to the requirements of Specification A 36/A 36M unless otherwise specified in the contract or purchase order.

6.4 Plain bearing pads shall be molded individually, or cut from previously molded strips or slabs, or extruded and cut to length. Cutting shall produce a smooth surface and no heating of the elastomer.

6.5 A steel-laminated bearing or a plain sandwich bearing shall be molded as a single unit under pressure and heat.

6.6 All bonding of elastomer to steel laminates and to external load plates shall be carried out during molding. The elastomer at the outer edges of bonds to external load plates shall be shaped to avoid serious stress concentrations (see Fig. 1).

6.7 Internal steel laminates shall be free of sharp edges.

6.8 External load plates shall be protected from rusting when supplied by the manufacturer.

6.9 All molds shall have a standard shop-practice mold finish.

## 7. Dimensions and Permissible Variations

7.1 All elastomeric layers, for example, plain-bearing pads, laminates, and covers, shall be of uniform thickness unless otherwise specified in the contract or purchase order.

7.2 All internal steel laminates shall be of uniform thickness. When specified in the contract or purchase order, the thickness of the outer steel laminates may differ if not adjacent to an external load plate (see Fig. 1).

7.3 The minimum thickness of internal steel laminates shall be 1.5 mm or 0.060 in. (16 gage) when the greater of the length or width of a rectangular bearing or the diameter of a circular bearing is less than 450 mm or 18 in. In all other cases, the minimum thickness shall be 2 mm or 0.075 in. (14 gage).

7.4 External load plates shall be of uniform thickness unless otherwise specified in the contract or purchase order.

7.5 Bearing dimensions and elastomer layer thicknesses shall satisfy the tolerances in Table 1, in which  $D$  is the length, width or diameter as appropriate, and  $T$  is the total elastomer thickness.

**TABLE 1 Tolerances for Bearing Dimensions and Elastomer Layer Thicknesses**

| Dimension                                      | Tolerance             |                     |
|--|-----------------------|---------------------|
|  | minimum               | maximum             |
| Length, width or diameter of bearing, mm (in.) | 0                     | 5 (0.2) + 0.005 $D$ |
| Height of bearing, mm (in.)                    | 0                     | 2 (0.1) + 0.04 $T$  |
| Thickness of elastomer cover                   | 0                     | 3 (0.1)             |
| at top, bottom or side, mm (in.)               |                       |                     |
| Thickness of internal elastomer laminate, %    | ±20 % of design value |                     |

7.6 Variation from a plane parallel to a design surface shall not exceed an average slope of 0.005 for the upper surface and 0.006 for a side surface.

## 8. Test Methods and Acceptance Requirements

8.1 *Bearing Compression Tests*—All bearings sampled from a lot shall be subjected to the compression tests. The cost of replacement bearings and of testing them shall be borne by the supplier.

8.1.1 The bearings shall be brought to a temperature of  $23 \pm 6^\circ\text{C}$  and shall be tested at this temperature.

8.1.2 *Compression Stiffness*—Load the bearing to the design load (3.1.1) by increments of one fifth of the design load. For each load increment, the loading time shall be within the range of 1.4 to 2.6 min. When the increment has been applied the load or deflection (depending on the type of testing machine) shall be maintained constant for 30 s then the load and deflection measured. From a plot of load against deflection, the compression stiffness shall be determined as the slope of the best straight line through the points, ignoring the first point at zero load. Record the compressive stiffness for each bearing.

8.1.3 *Visual Inspection*—Increase the load to 1.5 times the design load then maintain either load or deflection constant while the bearing is inspected for visual faults, as follows:

8.1.3.1 If lack of elastomer to steel bond is indicated, the bearing shall be rejected.

8.1.3.2 If laminate placement faults are observed which result in elastomer layer thickness that exceed the tolerances in 7.5, the bearing shall be rejected.

8.1.3.3 If there are at least three separate surface cracks which are each at least 2 mm wide and 2 mm deep, the bearing shall be rejected.

8.1.4 Record the median compressive stiffness ( $K$ ) of the bearing of median stiffness. The compressive stiffness of each bearing tested shall not differ from ( $K$ ) by more than 10 %.

8.1.5 For each bearing that fails to meet the requirements in 8.1, two additional bearings may be sampled and shall meet all the requirements in 8.1 or the lot shall be rejected.

8.1.6 If the lot is not rejected, the bearing of median stiffness ( $K$ ) shall be subjected to the elastomeric material tests in 8.2.

### 8.2 Elastomeric Material Tests:

8.2.1 All test specimens used for the determination of the properties of the vulcanized elastomeric material shall be taken from bearings (see Practice D 3183). Tensile and hardness

specimens for the quality control tests in 8.2.3, specimens for the ozone resistance test in 8.2.5, and strips for the low-temperature brittleness test in 8.2.6.1, if applicable, shall include an outer surface of a bearing. All other specimens shall be taken from within the middle one third of a bearing. Compression set specimens shall be as specified in Test Methods D 395, Method B, Type 1.

8.2.2 The temperature at which the tests shall be carried out shall be  $23 \pm 2^\circ\text{C}$  except where otherwise specified in this specification.

8.2.3 *Quality Control Properties*—The quality control properties of the elastomer shall meet the requirements of Table 2 for the hardness and type of rubber used.

8.2.4 *Shear Modulus*—The shear modulus of the elastomer determined in accordance with Annex A1 shall not differ by more than  $\pm 15\%$  from the required shear modulus of the elastomer.

8.2.5 *Ozone Resistance*—An ozone resistance test shall be carried out on test strips mounted in accordance with procedure A of Test Method D 518. The test shall be carried out in accordance with Test Method D 1149 at 20 % strain and at  $40 \pm 2^\circ\text{C}$  for 100 h. The ozone test partial pressure shall be  $50 \pm 5$  mPa formerly referred to as a concentration of  $50 \pm 5$  ppm unless a higher test partial pressure has been specified. The test strips shall be examined for cracks using a  $7\times$  magnification lens. The elastomer has adequate ozone resistance if no perpendicular cracks are observed on that surface of the strip corresponding to the outer surface of the bearing.

8.2.6 *Low-Temperature Grade Tests*:

8.2.6.1 When Low-Temperature Grade 2, 3 or 5 is specified, a low-temperature brittleness test shall be carried out in accordance with Test Methods D 2137, Method A using five test strips. The temperature at which the strips shall be conditioned and tested shall be  $-10^\circ\text{C}$  for Grade 2,  $-25^\circ\text{C}$  for Grade 3 and  $-40^\circ\text{C}$  for Grade 5. To meet the requirements of this specification, none shall fail.

**TABLE 2 Quality Control Properties of Elastomer**

| Rubber   | NR          | CR          |
|--|-------------|-------------|
| Hardness limits (Test Methods D 1415 or D 2240)  | 45 to 75    | 45 to 75    |
| Physical properties (Test Methods D 412):        |             |             |
| Tensile strength, min, MPa (psi)                 | 15.5 (2250) | 15.5 (2250) |
| Ultimate elongation:                             |             |             |
| 45 to 55   | 400         | 400         |
| hardness, min, %                                 |             |             |
| 56 to 65   | 400         | 350         |
| hardness, min, %                                 |             |             |
| 66 to 75   | 300         | 300         |
| hardness, min, %                                 |             |             |
| High-temperature resistance (Test Methods D 573) |             |             |
| Aging time, h                                    | 168         | 70          |
| Aging temperature, $^\circ\text{C}$              | 70          | 100         |
| Change in hardness, max, %                       | + 10        | + 15        |
| Change in tensile strength, max, %               | -25         | -15         |
| Change in ultimate elongation, max, %            | -25         | -40         |
| Compression set (Test Methods D 395 Method B)    |             |             |
| After 22 h at $70^\circ\text{C}$ , max, %        | 25          | ...         |
| After 22 h at $100^\circ\text{C}$ , max, %       | ...         | 35          |

## 9. Sampling

9.1 Unless otherwise specified in the contract or purchase order, sampling shall consist of the following.

9.1.1 For acceptance purposes, bearing from within the lot shall be selected at random as samples for inspection and testing.

9.1.2 A minimum of three bearings shall be taken from the lot for testing. If the number of bearings in the lot exceeds 50 then for each 50, or part thereof, one additional bearing shall be taken for testing.

## 10. Product Marking

10.1 Every bearing shall be marked in indelible ink or flexible paint. The marking shall consist of the order number, lot number, bearing identification number and elastomer type and grade reference number.

10.2 Unless otherwise specified in the contract or purchase order, the marking should be on a side face visible after erection of the bridge.

## 11. Precision and Bias

11.1 No user is currently interested in participating in a round robin test to verify precision and bias. As an alternative, two producers have agreed to run repeatability in their own laboratories.

(Mandatory Information)

**A1. DETERMINATION OF SHEAR MODULUS**

**A1.1 Scope**

A1.1.1 This method determines the shear modulus of the bearing elastomer from the shear force-extension curve after five conditioning cycles to 50 % strain as four times the stress at 25 % strain.

NOTE A1.1—If the shear stress-strain curve is assumed to be linear for design purposes, then the use of the chord modulus from 0 to 25 % strain may overestimate the stress at higher strains. The overestimate will be small for elastomers of up to about 55 hardness but will increase as the volume fraction of carbon-black filler in the elastomer increases.

**A1.2 Apparatus**

A1.2.1 A tension testing machine shall be used that conforms to the requirements of Practices E 4 and is fitted with a force-deformation recording device.

A1.2.2 The fixtures for holding the specimen in the testing machine shall be provided with ball seats to permit proper centering of the load during the test.

**A1.3 Test Specimen**

A1.3.1 The quadruple shear test specimen, Fig. A1.1, shall consist of four identical blocks of elastomer bonded to rigid plates.

A1.3.2 The elastomer blocks shall be of uniform thickness, preferably not less than 6 mm or 1/4 in. and of square or rectangular cross-section, the length and width each being not less than four times the thickness.

A1.3.3 The rigid plates shall be of rectangular section, the same width as the elastomer blocks, and may be of mild steel. Suitable plate dimensions for use with 6 mm thick blocks are a thickness of 5 mm or 3/16 in. and a width of 25 mm or 1 in.

A1.3.4 Measure the length, width and thickness of the blocks and determine the average cross-sectional area (*A*) and average thickness (*T*) of a block.

A1.3.5 The blocks shall be bonded to the rigid plates using a suitable bonding system which does not require curing at a temperature greater than 40°C. Care should be taken to prevent excess bonding cement from adhering to the sides of the elastomer blocks.

**A1.4 Test Procedure**

A1.4.1 After allowing time for the bonds to achieve adequate strength, condition the specimen at the test temperature of  $23 \pm 2^\circ\text{C}$  for at least 16 h immediately prior to testing.

A1.4.2 The test specimen shall be attached to the tension testing machine using the appropriate fixtures or grips.

A1.4.3 Carry out six successive loading and release cycles to a deformation equal to the average block thickness, *T*, and at such a rate that the time per cycle is within the range of 30 to 60 s.

NOTE A1.2—The first five cycles are carried out in order to reach a stabilized stress-strain behavior of the elastomer. If significant softening occurs during these cycles, an upturn in the curves may be observed as the maximum deformation is approached.

A1.4.4 If there is any indication of slip of the blocks relative to the rigid plates or of bond failure during the test, prepare a new specimen and repeat the test.

NOTE A1.3—Slip may show as excessive set on the force-deformation loops and bond failure as a marked reduction in slope of one or more of the force-extension curves. The latter should be confirmed by visual examination of the bonds.

**A1.5 Calculation**

A1.5.1 The shear modulus shall be determined from the extension curve on the sixth cycle, Fig. A1.2.

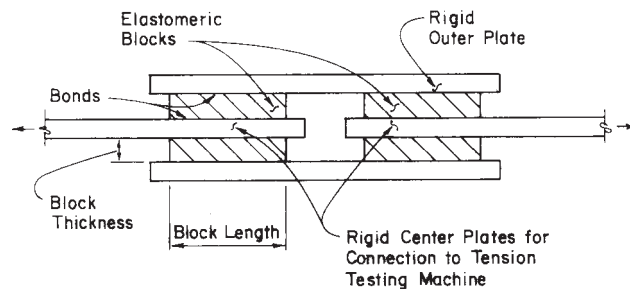
A1.5.2 Take an effective origin at force *F*<sub>1</sub>, extension *X*<sub>1</sub> where *F*<sub>1</sub> is 2 % of the maximum force on the sixth cycle. Determine the force *F*<sub>2</sub> at an extension *X*<sub>2</sub> given by *X*<sub>1</sub> + 0.5*T*, where *T* is the average block thickness (A1.3.4).

NOTE A1.4—From force *F* and extension *X*, stress = *F*/2*A* and strain = *X*/2*T*; *X*<sub>2</sub> - *X*<sub>1</sub> thus corresponds to 25 % strain.

A1.5.3 The shear modulus is calculated as follows:

$$\text{Shear modulus} = 2(F_2 - F_1)/A \quad (\text{A1.1})$$

where: *A* is the average cross-sectional area of a block (A1.3.4).



**FIG. A1.1 Shear Test Specimen**

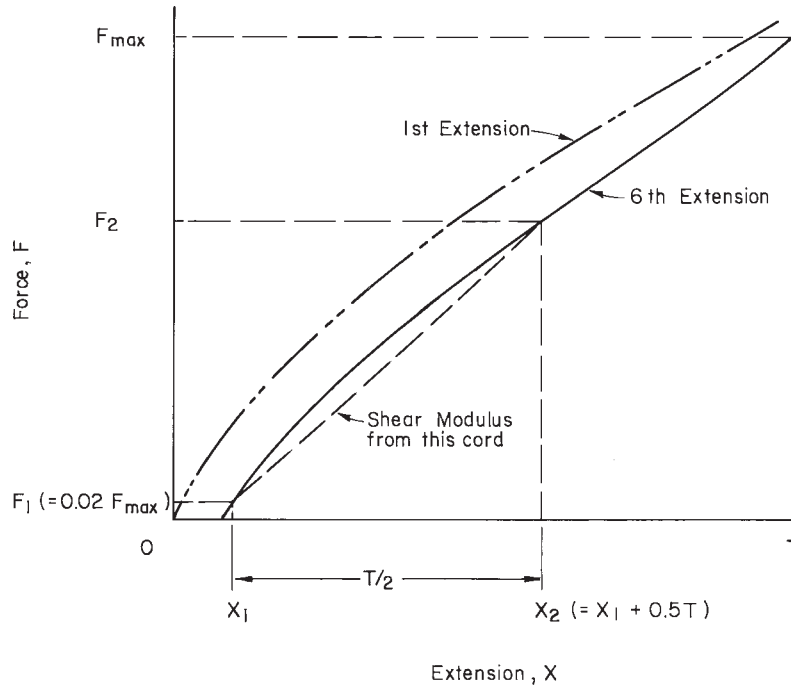


FIG. A1.2 Shear Test Force-Extension Curves

## APPENDIXES

### (Nonmandatory Information)

#### X1. ALTERNATIVE ELASTOMERIC MATERIALS

X1.1 Elastomers based on the following rubbers are now in limited use in bridge bearings in various parts of the world:

- Ethylene propylene rubber (EPDM)
- Butyl rubber (IIR)
- Chlorobutyl rubber (CIIR)

X1.2 The quality control properties of elastomers based on these rubbers are given in Table X1.1. The values relate to tests carried out on specimens specifically molded for test purposes and not on specimens prepared from bearings.

**TABLE X1.1 Quality Control Properties of Alternative Elastomers**

| Rubber   | EPDM        | IIR         | CIIR        |
|--|-------------|-------------|-------------|
| Hardness range (Test Methods D 1415 or D 2240)   | 60 to 75    | 55 to 65    | 55 to 65    |
| Physical properties (Test Methods D 412):        |             |             |             |
| Tensile strength, min, MPa (psi)                 | 15.2 (2200) | 16.6 (2400) | 16.6 (2400) |
| Ultimate elongation                              |             |             |             |
| 55 hardness, min, %                              | ...         | 600         | 500         |
| 60 hardness, min, %                              | 400         | 550         | 450         |
| 65 hardness, min, %                              | 350         | 500         | 400         |
| 70 hardness, min, %                              | 300         | ...         | ...         |
| High temperature resistance (Test Method D 573): |             |             |             |
| Aging time, h                                    | 70          | 70          | 70          |
| Aging temperature, °C                            | 100         | 100         | 100         |
| Change in hardness, max                          | + 10        | + 10        | + 10        |
| Change in tensile strength, max, %               | -15         | -25         | -15         |
| Change in ultimate elongation, max, %            | -40         | -25         | -25         |
| Compression set (Test Methods D 395 Method B)    |             |             |             |
| After 22 h at 70°C, max, %                       | 25          | 25          | 20          |

## X2. EXAMPLE OF BEARING DESIGN INFORMATION

### X2.1 *Steel-laminated bearing with 1 external load plate (at top):*

|   |               |
|---|---------------|
| Overall dimensions, mm:                               |               |
| Length (in direction of main expansion movement)      | 300           |
| Width   | 400           |
| Height  | 52.5          |
| Total elastomer thickness, mm                         | 46            |
| Internal steel laminates (4 in number), mm:           |               |
| Length  | 288           |
| Width   | 388           |
| Thickness of outer (bottom) laminate with dowel holes | 2 (14 gage)   |
| Thickness of other three internal laminates           | 1.5 (16 gage) |

|   |               |
|---|---------------|
| Elastomer layers bonded to steel on both faces:   | (4 in number) |
| Thickness, mm   | 10            |
| Bottom cover (elastomer layer bonded to steel on one face only):                            |               |
| Thickness, mm   | 6             |
| Side cover (elastomer layer bonded to steel edges in both the length and width directions): |               |
| Thickness, mm   | 6             |

X2.2 The bottom steel laminate has two 30-mm diameter dowel holes, 10 mm deep, centered on the length, and 120 mm from the center. The external (top) load plate, length 300 mm, width 500 mm, thickness 25 mm, to be fitted by manufacturer.

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