

Elastomeric Bearing Guidance Document

Introduction

The purpose of this document is to provide Michigan Department of Transportation (MDOT) designers, inspectors, and consultants with guidance on elastomeric bearing pads. It provides a single source for AASHTO and MDOT policy information related to the design, fabrication, material, and testing of elastomeric bearings (plain and reinforced) used on MDOT projects. Information presented in this document is taken from the following references:

- AASHTO LRFD Bridge Design Specifications, 7th Edition w/2015 Interims (AASHTO Design);
- AASHTO LRFD Bridge Construction Specifications, 3rd Edition w/2015 Interims (AASHTO Construction);
- AASHTO M 251 Standard Specifications for Plain and Laminated Elastomeric Bridge Bearings, 2015 Ed. (AASHTO M 251);
- MDOT Bridge Design Manual (MDOT BDM); and
- MDOT 2012 Standard Specifications for Construction [including 12SS001(A) – Errata] (MDOT SSC).

Design Methods

AASHTO Design allows elastomeric bearings to be designed based on one of two methods. These methods along with their respective use criteria are provided below:

- Method A (AASHTO Design subsection 14.7.6):
 - Applicable to the design of plain elastomeric pads;
 - Applicable to the design of steel-reinforced elastomeric bearings if **all** of the following are true:
 - The shape factor (S) for an interior layer of elastomer divided by the total number of interior layers is less than:
 - 22 for square/rectangular bearings with 2 or fewer interior layers;
 - 20 for square/rectangular bearing with 3 or more interior layers; and
 - 16 for circular or nearly square bearings.
 - The primary rotation is about the axis of the bearing parallel to the transverse axis of the bridge;
 - Total thickness of the bearing is less than or equal to 8"; and
 - The plan area of the bearing is less than 1,000 square inches.
- Method B (AASHTO Design subsection 14.7.5):
 - Applicable to the design of steel-reinforced elastomeric bearings only;
 - Must be used for all steel-reinforced elastomeric bearings if any of the following is true:
 - Total thickness of the bearing is greater than 8"; or
 - The plan area of the bearing is 1,000 square inches or greater.

The equations used in Method B permit higher stress limits resulting in a higher capacity bearing than those designed using Method A, thus reducing the bearing size. As a result, Method B requires higher sampling frequency and more extensive testing. This leads to higher material quality control, which results in higher fabrication cost and longer lead time. The fabrication requirements for elastomeric bearings do not change depending on the design method used and are specified in section 5 of AASHTO M 251.

MDOT Policy on Design Methods

MDOT utilizes both plain and steel-reinforced elastomeric bearing pads. Fiber and cotton-duck reinforced bearings are not permitted to be used on MDOT projects without **approval** by the *MDOT Bridge Design Section Manager* and *MDOT Structural Fabrication Engineer*. Subsection 7.02.05.C of the MDOT BDM addresses the design of elastomeric bearings and specifies that steel-reinforced elastomeric bearings are to be designed using Method A. The MDOT BDM doesn't discuss design requirements for plain elastomeric pads; however, AASHTO Design states plain bearings must be designed using Method A so MDOT defaults to AASHTO for plain pads.

Design Method B is not permitted to be used on MDOT projects without **approval** by the *MDOT Bridge Design Section Manager* and *MDOT Structural Fabrication Engineer*. Approval is needed due to the additional project cost, potential schedule impact, required specification changes, and potential fabrication inspection. Note fabrication inspection is not required as the basis of acceptance for elastomeric bearings, but it might be utilized as a quality assurance measure for bearings designed using Method B. If Method B is approved for the design of steel-reinforced elastomeric bearings, then a special provision will be required to provide the following specifications:

- Specify that the bearings be tested and accepted in accordance with section 8 of AASHTO M 251; and
- Fabrication inspection specifications (notification, facilities for inspector, basis of acceptance, etc.).

Material Properties

Regardless of the bearing design method, the elastomer and reinforcement materials must conform to AASHTO Construction and AASHTO M 251, except as modified by MDOT project specifications. Listed below are the different material parameters used to specify elastomer for bearings that should be verified as part of the shop drawing review process:

- Shear modulus;
- Polymer type; and
- Minimum low-temperature grade.

The shear modulus, polymer type, and minimum low-temperature grade should be specified in the contract documents for a project (see AASHTO Design subsection 14.7.5.2 and T14.7.5.2-1). Shear modulus increases as elastomer cools, therefore it is important to specify a material with low-temperature properties appropriate for the bridge site. The increased shear modulus results in higher lateral superstructure loads being transmitted into the substructure that must be accounted for in the substructure design. AASHTO

Construction states that unless otherwise specified in the contract documents the contractor is required to provide bearings with a hardness of 60, low-temperature Grade 3, and steel reinforced. As specified in Table 14.7.5.2-1 of AASHTO Design a low-temperature grade 3 corresponds to zone C (without special force provisions), which would be the correct specification for only the lower 1/3 of the lower peninsula of Michigan. A hardness of 60 has a correlated shear modulus of 130 to 200 psi per Table 14.7.6.2-1 of AASHTO Design.

AASHTO Design subsection 14.7.5.2 commentary states that the shear modulus “is the most important material property for design, and it is, therefore, the primary means of specifying the elastomer”. As will be discussed later in this document, specifying elastomer by shear modulus requires more extensive testing, which results in higher bearing costs and longer lead times. While AASTHO Design clearly acknowledges the importance of the shear modulus of an elastomer, AASHTO does permit the use of hardness for specifying elastomer when using design Method A. A summary of the permissible material properties for the two design methods is shown below:

- Method A – Shear modulus or hardness (Shore A scale) must be specified; and
- Method B – Shear modulus must be specified.

AASHTO permits Method A designed bearings to be specified by hardness because the stress in the bearing is limited by the design equations. The testing required to determine hardness is quick and simple, but the AASHTO Design commentary cautions that the results of the hardness test “are variable and correlate only loosely with shear modulus”.

While AASHTO Design permits the use of hardness to specify the elastomer, the design equations used in Method A are still based on the shear modulus. The correlation between hardness and shear modulus is summarized in Table 14.7.6.2-1 of AASHTO Design. Figures 1 and 2 below illustrate how the correlated material values for shear modulus overlay with the as-designed shear modulus required by the MDOT SSC and MDOT BDM for steel-reinforced and plain elastomeric bearings, respectively. AASHTO M 251 requires testing and acceptance per section 8 or testing and acceptance per Appendix X1 at the owner’s discretion provided bearings are designed per Method A and a hardness is specified.



Figure 1. Chart depicting steel-reinforced elastomer shear modulus overlap between as-designed bearing (MDOT SSC) and material provided based on hardness (Shore A 50 durometer) testing (correlated value).

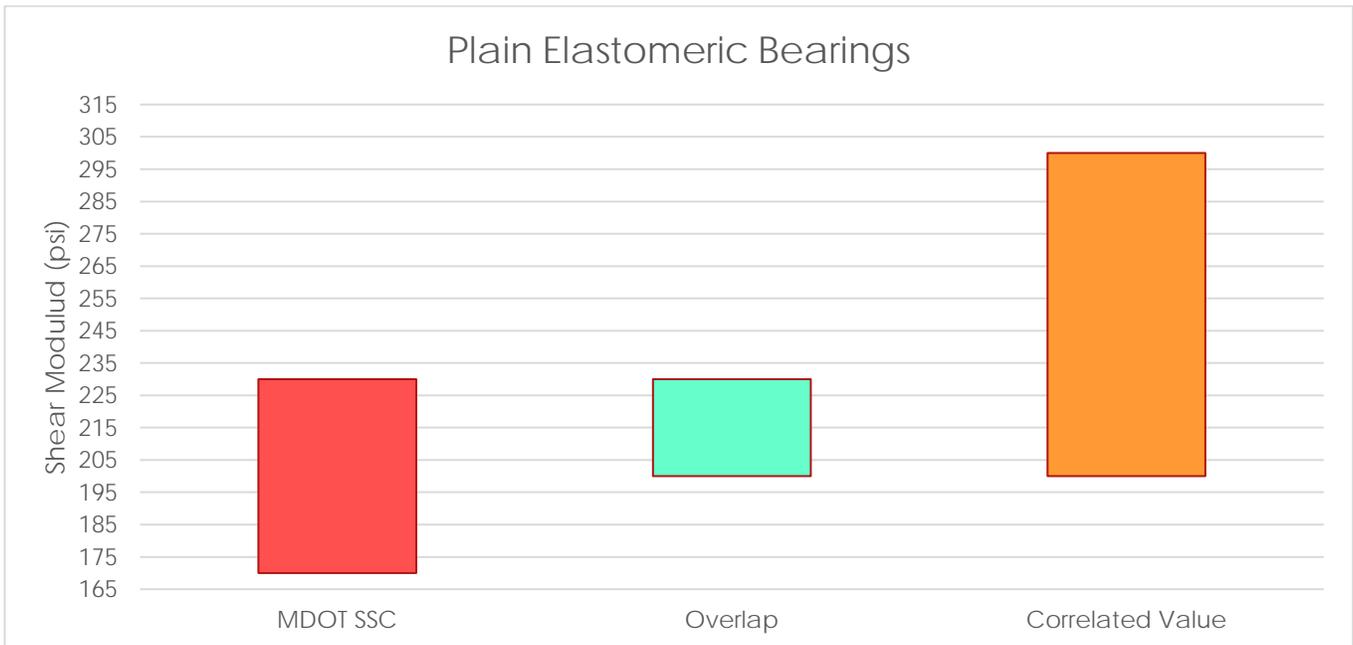


Figure 2. Chart depicting plain elastomer shear modulus overlap between as-designed bearing (MDOT SSC) and material provided based on hardness (Shore A 70 durometer) testing (correlated value).

MDOT Policy on Material Properties

Subsection 914.12 of the MDOT SSC specifies the following criteria for steel-reinforced and plain elastomeric bearing pads:

- Elastomeric bearings must meet the requirements of subsection 18.2 of the AASHTO Construction;
- Material must be 100 percent virgin polychloroprene (neoprene) or virgin polyisoprene (natural rubber);
- Steel-reinforced bearings must have a shear modulus (G) of 100 psi \pm 15 psi;
- Plain bearings must have a shear modulus (G) of 200 psi \pm 30 psi;
- The elastomer used in the bearings must have a minimum low-temperature grade of 4 or better; and
- Steel sheet laminates must meet ASTM A36 or ASTM A1011, Gr 36 or Gr 40.

Elastomer with a minimum low temperature grade of 4 or higher cannot be fabricated economically for all bearing sizes using neoprene. Because of this, MDOT now permits the use of natural rubber.

MDOT doesn't permit the use of cotton-duck or other fiber reinforcement without the approval of the *MDOT Bridge Design Section Manager* and *MDOT Structural Fabrication Engineer*.

For design purposes, the shear modulus must be taken as the least favorable (minimum or maximum) of the values in the ranges described above for each design check.

MDOT material property requirements for elastomer used in bearings has varied over time. A summary of the history of these requirements is included below:

- Prior to the 1996 MDOT SSC: Hardness of the elastomer was specified;
- 1996 MDOT SSC through today: Shear modulus of the elastomer is specified; and
- At the time this document was prepared records were not located stating why MDOT selected shear modulus over hardness for the 1996 MDOT SSC.

Material Testing and Fabrication

Material testing and fabrication requirements for elastomeric bearings are specified in AASHTO M 251 per subsection 18.2.4 of AASHTO Construction. Section 3.4 of AASHTO M 251 stipulates that the cost of providing additional bearings for testing purposes should be "borne by the supplier".

Subsection 4.1.1 of AASHTO M 251 requires the elastomer to meet the testing requirements in Table 1. The properties specified include:

- Physical Properties:
 - Minimum shear modulus;
 - Minimum tensile strength; and
 - Minimum ultimate elongation.
- Low-temperature brittleness.

The testing and acceptance criteria for elastomeric bearings is specified in section 8 of AASHTO M 251. Highlights from this section are included below.

1. All sampling, testing, and acceptance will be based on a lot, which cannot exceed 100 bearings.
2. All of the bearings in a lot must be manufactured "in a reasonably continuous manner from the same batch of elastomer, cured under the same conditions, and are all the same size and type".
3. Sampling rates are:
 - a. Plain bearings = two (2) full size bearings per lot.
 - b. Steel-reinforced bearings = one (1) full size bearing per every ten per lot, with a minimum of two (2).
4. If a sample fails the entire lot is to be rejected.
5. If testing is done by the manufacturer or an independent laboratory certified test results are to be provided to the Owner.
6. Tests to be completed, as a minimum, include:
 - a. Determine compressive strain at the maximum design dead load plus live load at the service limit state in accordance with section 9.1 of AASHTO M 251.
 - b. Material defects under a compressive load equal to 1.5 times the maximum design dead load plus live load at the service limit state.
 - c. Determine the creep and shear bond strength in accordance with Annex A2 of AASHTO M 251.
 - d. Determine the shear modulus of the elastomer. The test method used depends on the design method used.

For elastomeric bearings designed using Method A and specified by hardness, subsection 3.5 of AASHTO M 251 permits, at the owner's discretion, for elastomeric bearings to be tested in accordance with Appendix X1 instead of section 8.

Section 6 of AASHTO M 251 outlines the dimensional tolerances for elastomeric bearings. The designer should be aware of these limits, and verify that the dimensions included on the submitted shop drawings are within the limits specified. Shop drawings must either list dimensional tolerances or reference subsection 6 of AASHTO M 251 for dimensional tolerances.

MDOT Policy on Material Testing and Fabrication

MDOT specifies the shear modulus requirement for elastomeric bearings in subsection 914.12 of the MDOT SSC. For elastomeric bearings designed using Method A and specified by shear modulus, MDOT requires the bearings to be tested and accepted in accordance with section 8 of AASHTO M 251, except the definition of a lot specified in subsection 8.2 of AASHTO M 251 is revised as follows:

Sampling, testing, and acceptance consideration will be made on a lot basis. A lot of bearings shall be considered to be a group of bearings that are manufactured over a 4 month period from the same elastomer recipe, cured under the same conditions, and of the same type (plain or steel-laminated).

The sampling rate for testing specified in subsection 8.5 of AASHTO M251 is revised as follows:

The purchaser may select sample bearings from the lot for testing in accordance with this specification. Sampling rate shall be as follows:

- ***Plain Bearings – Two full-size bearings per lot.***
- ***Laminated Bearings – Two full-size bearings per lot.***

If Method B is approved for the design of elastomeric bearings then a special provision will be required to modify the MDOT SSC to specify that the bearings must be tested and accepted in accordance with section 8 of AASHTO M 251 without the above noted revision.