AMERICAN NATIONAL STANDARDS INSTITUTE/ STEEL DECK INSTITUTE

ANSI/SDI AISI S903-2020 (R2024)

Test Standard for Determining the Uniform and Local Ductility of Carbon and Low-Alloy Steels

DISCLAIMER

First Printing, December 2024

PREFACE

(This Preface is not part of the ANSI/SDI AISI S903-2020 (R2024), *Test Standard for Determining the Uniform and Local Ductility of Carbon and Low-Alloy Steels*, but is included for informational purposes only.)

This Standard is a reaffirmation of ANSI/AISI S903-2020.

This Standard has been developed as a consensus document for the design of cold-formed steel members and structures. The intention is to provide criteria for routine use and not to provide specific criteria for infrequently encountered problems, which occur in the full range of structural design. The Symbols and Appendices to this Standard are an integral part of the Standard. A non-mandatory Commentary has been prepared to provide background for the Standard provisions and the user is encouraged to consult it. Additionally, non-mandatory User Notes may be interspersed throughout the Standard to provide concise and practical guidance in the application of the provisions. The user is cautioned that professional judgment must be exercised when data or recommendations in the Standard are applied, as described more fully in the disclaimer notice preceding this Preface.

AISI S903-20

American Iron and Steel Institute

AISI STANDARD

Test Standard for Determining the Uniform and Local Ductility of Carbon and Low-Alloy Steels

2020 Edition

Approved by
the AISI Committee on Specifications for the Design of
Cold-Formed Steel Structural Members

DISCLAIMER

The material contained herein has been developed by the American Iron and Steel Institute Committee on Specifications for the Design of Cold-Formed Steel Structural Members. The organization and the Committee have made a diligent effort to present accurate, reliable, and useful information on testing of cold-formed steel members, components, or structures. The Committee acknowledges and is grateful for the contributions of the numerous researchers, engineers, and others who have contributed to the body of knowledge on the subject. With anticipated improvements in understanding of the behavior of cold-formed steel and the continuing development of new technology, this material will become dated. It is anticipated that future editions of this test procedure will update this material as new information becomes available, but this cannot be guaranteed.

The materials set forth herein are for general information only. They are not a substitute for competent professional advice. Application of this information to a specific project should be reviewed by a registered professional engineer. Indeed, in most jurisdictions, such review is required by law. Anyone making use of the information set forth herein does so at their own risk and assumes any and all resulting liability arising therefrom.

1st Printing – December 2020

Produced by American Iron and Steel Institute

PREFACE

The American Iron and Steel Institute Committee on Specifications developed this *Standard* to provide test methods for determination of uniform and local ductility of carbon and low-alloy steels from a tension test.

The Committee acknowledges and is grateful for the contribution of the numerous engineers, researchers, producers and others who have contributed to the body of knowledge on this subject.

Commentaries and User Notes are non-mandatory and copyrightable portions of this *Standard*.

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AISI S903-20
TEST STANDARD FOR DETERMINING
UNIFORM AND LOCAL DUCTILITY OF CARBON AND LOW-ALLOY STEELS

1. Scope

This *Standard* provides methods to determine uniform and local ductility of carbon and low-alloy steels from a tension test.

2. Referenced Documents

The following documents or portions thereof are referenced within this *Standard* and shall be considered as part of the requirements of this document.

a. American Iron and Steel Institute (AISI), Washington, DC:

S100-16 (2020) w/S2-20, *North American Specification for the Design of Cold-Formed Steel Structural Members* With Supplement 2

b. ASTM International (ASTM), West Conshohocken, PA:

A370-20, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM E6 - 15e3, *Standard Terminology Relating to Methods of Mechanical Testing*
IEEE/ASTM SI10-16, *American National Standard for Metric Practice*

3. Terminology

Terms not defined in Section 3 of this *Standard*, AISI S100 or ASTM E6 shall have the ordinary accepted meaning for the context for which they are intended.

4. Symbols

e_1 = Linear elongation, in., in 1-in. (25.4-mm) gauge length
e_3 = Linear elongation, in., in 3-in. (76.2-mm) gauge length
e_{3e} = Linear elongation, in., in 2-in. (50.8 mm) gauge length not containing 1-in. (25.4-mm) length of fractured portion
e_u = Linear elongation, in., in 2-in. (50.8 mm) gauge length at ultimate load in standard tension coupon test
ε_3 = Percent elongation in 3-in. (76.2-mm) gauge length
ε_{3e} = Percent elongation in 2-in. (50.8-mm) gauge length not containing 1-in. (25.4 mm) length of fractured portion
ε_f = Percent elongation at fracture in 2-in. (50.8 mm) gauge length of standard tension coupon
ε_u = Percent elongation at ultimate load in standard tension coupon test
$\varepsilon_{uniform}$ = Uniform percent elongation
ε_{local} = Local percent elongation in ½-in. (12.7-mm) gauge length
$\varepsilon_{1/2}$ = Percent elongation in ½-in. (12.7-mm) gauge length

5. Units of Symbols and Terms

Any compatible system of measurement units is permitted to be used in this *Standard*, except where explicitly stated otherwise. The unit systems considered in this *Standard* shall include

U.S. Customary units (force in kips and length in inches) and SI units (force in Newtons and length in millimeters) in accordance with IEEE/ASTM SI10.

6. Measurement Precision

6.1 Loads shall be recorded to a precision of ±1 percent of the full range of the measuring device.

User Note:
The capacity (range) of the load-measuring device should be appropriate to the expected maximum tested load. The use of a measuring device with a calibrated capacity greatly exceeding the anticipated load is inappropriate. A target ratio of the load-measuring device capacity to specimen strength of no greater than three is recommended.

The tests should be conducted on a testing machine that complies with the requirements of ASTM E4-20, *Standard Practices for Force Verification of Testing Machines*.

6.2 Deformation shall be recorded to a precision of 0.001 in. (0.025 mm).

6.3 Strains, if measured directly, shall be recorded to a precision of 0.1%.

7. Test Procedure

7.1 A tension coupon shall be prepared in accordance with ASTM A370 except that the central length of ½-in. (12.7-mm) uniform width of the coupon shall be at least 3½-in. (88.9-mm) long.

7.2 Gauge lines shall be scribed at ½-in. (12.7-mm) intervals along the entire length of the coupon.

7.3 After completion of the coupon test, the following two permanent plastic deformations shall be measured: (a) the linear elongation in a 3-in. (76.2-mm) gauge length, e_3, such that the fractured portion is included; and (b) the linear elongation in a 1-in. (25.4-mm) gauge length, e_1, containing the fracture.

User Note:
In item (a) of Section 7.3, the linear elongation, e_3, is preferably measured near the middle third of the 3-in. (76.2-mm) gauge length.

7.4 The linear elongation, e_{3e}, shall be calculated in accordance with Equation (1), where e_{3e} equals linear elongation in a 2-in. (50.8-mm) gauge length not containing the 1-in. (25.4-mm) length of the fractured portion.

$$e_{3e} = e_3 - e_1 \quad (1)$$

7.5 From the two preceding elongation measurements, e_3 and e_{3e}, the percentage elongations shall be calculated as follows:

$$\varepsilon_3 = (e_3/3.00) \times 100 \quad \text{where } e_3 \text{ is in inches} \quad (2a)$$

$$= (e_3/76.2) \times 100 \quad \text{where } e_3 \text{ is in millimeters} \quad (2b)$$

$$\varepsilon_{3e} = (e_{3e}/2.00) \times 100 \quad \text{where } e_{3e} \text{ is in inches} \quad (3a)$$

$$= (e_{3e}/50.8) \times 100 \quad \text{where } e_{3e} \text{ is in millimeters} \quad (3b)$$

From these percentage elongations, the uniform and local ductility parameters shall be obtained in accordance with Sections 7.6 and 7.7.

7.6 Since the fractured portion which includes local elongation is eliminated from ε_{3e}, it shall be a measure of the uniform ductility of the material. Thus:

$$\varepsilon_{uniform} = \varepsilon_{3e} \quad (4)$$

7.7 The local elongation shall be determined over a small length which includes the fractured portion. For simplicity, this length is permitted to be assumed to be ½ in. (12.7 mm), which is large enough to include the necked portion of most thicknesses and types of sheet steels used, and is small enough to give valid comparison for different types of steels. Thus:

$$\varepsilon_{local} = \varepsilon_{1/2} = 6\ (\varepsilon_3 - \varepsilon_{3e}) + \varepsilon_{3e} \quad (5)$$

in which constant 6 is the multiplication factor which converts the local elongation (ε_3 - ε_{3e}) measured in 3-in. (76.2-mm) to local elongation in the ½-in. (12.7-mm) gauge length.

8. Alternative Test Procedure A

The alternative test procedure provided in this section is permitted to be used in lieu of the test procedure provided in Section 7 for determining the local elongation.

8.1 A standard tension coupon shall be prepared in accordance with ASTM A370 with a standard 2-in. (50.8 mm) gauge length.

8.2 The linear elongation, e_u, at the peak of the stress-strain curve (ultimate stress) shall be measured. The percentage elongation, ε_u, at ultimate stress shall then be calculated as:

$$\varepsilon_u = (e_u/2.00) \times 100 \qquad \text{where } e_u \text{ is in inches} \quad (6a)$$

$$= (e_u/50.8) \times 100 \qquad \text{where } e_u \text{ is in millimeters} \quad (6b)$$

8.3 To obtain a measure of the local ductility, percentage elongation at fracture ε_f, also in a 2-in. (50.8 mm) gauge length, shall be measured. Equation (7) shall then be used to convert (ε_f - ε_u) into the percentage elongation in a ½-in. (12.7-mm) gauge length:

$$\varepsilon_{local} = \varepsilon_{1/2} = \varepsilon_u + 4\ (\varepsilon_f - \varepsilon_u) \quad (7)$$

in which 4 is the multiplication factor to convert the 2-in. (50.8-mm) gauge length local elongation to the ½-in. (12.7-mm) gauge length.

9. Alternative Test Procedure B

The alternative test procedure provided in this section is permitted to be used in lieu of the test procedure provided in Section 7 for determining the local elongation. Strain fields are permitted to be provided by a non-contact sensor (for example, using digital image correlation, DIC) or through dense placement of strain gauges. To achieve a dense gauge field, a fully-populated grid of three gauges across the flat width of the specimen and six gauges within the gauge length shall be installed.

9.1 A standard tension coupon shall be prepared in accordance with ASTM A370 with a standard 2-in. (50.8 mm) gauge length.

9.2 The percentage elongation at ultimate load, ε_u, shall be measured at the peak of the stress-strain curve.

9.3 To obtain a measure of the local ductility, percentage elongation at fracture ε_f, also in a 2-in. (50.8 mm) gauge length shall be measured. Equation (7) shall then be used to convert (ε_f - ε_u) into the percentage elongation in a ½-in. (12.7-mm) gauge length.

In lieu of Equation 7, the local percent elongation, ε_{local}, at fracture is permitted to be taken directly from a strain field provided the ½-in gauge length is captured.

10. Test Report

10.1 The report shall include a record of the material type, measurements and elongation calculations.

AISI S903-20-C
COMMENTARY ON TEST STANDARD FOR DETERMINING UNIFORM AND LOCAL DUCTILITY OF CARBON AND LOW-ALLOY STEELS

This *Standard* is developed to determine uniform and local ductility from a tension test. This test *Standard* is based on the method suggested by Dhalla and Winter (1974). The test *Standard* also provides alternative methods of determining if steel has adequate ductility as defined in AISI S100, *North American Specification for the Design of Cold-Formed Steel Structural Members*.

In the *Standard*, three test procedures are provided. In the first test procedure provided in *Standard* Section 7, linear elongation in a 3-in. (76.2 mm) gauge length, e_3, and linear elongation in a 1-in. (50.8 mm) gauge length, e_1, are measured. Both elongations contain the fractured portion. The difference of e_3 and e_1 gives the linear elongation, e_{3e}, in a 2-in. (50.8 mm) gauge length not containing the 1-in. (25.4 mm) length of the fracture. ε_{3e} is used to measure the uniform ductility. The local elongation, which should include the fractured portion, is determined using *Standard* Equation (5).

In the alternative test procedure provided in *Standard* Section 8, the strain at the tensile strength (i.e., percentage strain ε_u at the peak of the stress-strain curve) is a measure of uniform ductility, because up to this strain, no necking or local elongation has taken place. Therefore, to obtain the uniform ductility, the stress-strain curve is plotted at least up to the maximum load or the linear elongation, e_u, at maximum load is measured directly, so that ε_u is obtained by *Standard* Equation (6a) or (6b).

To obtain a measure of the local ductility, it is necessary to measure the percentage strain at fracture ε_f, also in a 2-in. (50.8 mm) gauge length. However, the strain which occurs after the maximum load has been passed (descending branch) is the necking strain, and is localized at the eventual fracture zone, thus (ε_f - ε_u) is the local percentage elongation referred to in a 2-in. (50.4 mm) gauge length. *Standard* Equation (7) converts this (ε_f - ε_u) into the percentage elongation in a ½-in. (12.7-mm) gauge length.

In 2020, Alternative Procedure B was added into Section 9. This alternative method enables more advanced measurement methods to be used in determining the percent elongations. In using a strain gauge field or digital image correlation (DIC) measuring system, strains throughout the tensile coupon are measured. Prior to the maximum load, strains will be uniform and thus best characterized by a mean of the measured strains within the gauge length. However, after the maximum load is achieved and necking begins to occur in the coupon, strains localize at the eventual fracture point and the maximum strain in the coupon becomes a more appropriate measure of strain.

Reference

Dhalla, A. K. and G. Winter (1974), "Steel Ductility Measurements," *Journal of Structural Division, Proceedings ASCE*, Vol. 100, No. ST2, February 1974.