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Test Standard for Determining the Uniform and Local Ductility of Carbon and Low-Alloy Steels, 2017 Edition

American Iron and Steel Institute

Approved American National Standard

ANSI

AISI S903-17

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

2017 Edition

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

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.

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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.

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AISI S903-17
TEST STANDARD FOR DETERMINING
UNIFORM AND LOCAL DUCTILITY OF CARBON AND LOW-ALLOY STEELS

1. Scope

This Standard provides method 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, *North American Specification for the Design of Cold-Formed Steel Structural Members*

b. ASTM International (ASTM), West Conshohocken, PA:
   A370-16, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*
   IEEE/ASTM SI10-10, *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) gage length
e_3 = Linear elongation, in., in 3-in. (76.2-mm) gage length
e_{3e} = Linear elongation, in., in 2-in. (50.8 mm) gage length not containing 1-in. (25.4-mm) length of fractured portion
e_u = Linear elongation, in., at ultimate load in standard tension coupon test
ε_3 = Percent elongation in 3-in. (76.2-mm) gage length
ε_{3e} = Percent elongation in 2-in. (50.8-mm) gage length not containing 1-in. (25.4 mm) length of fractured portion
ε_f = Percent elongation at fracture in 2-in. (50.8 mm) gage 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) gage length
$\varepsilon_{1/2}$ = Percent elongation in ½-in. (12.7-mm) gage 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 E4-16, *Standard Practices for Force Verification of Testing Machines*.

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

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 Gage 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) gage length, e_3, such that the fractured portion is included (preferably near the middle third of this 3-in. (76.2-mm) gage length); and (b) the linear elongation in a 1-in. (25.4-mm) gage length, e_1, containing the fracture.

7.4 The linear elongation, e_{3e}, shall be calculated in accordance with Equation (1), where e_{3e} = linear elongation in a 2-in. (50.8-mm) gage 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}, calculate the percentage elongations as follows:

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

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

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

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

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 ($\varepsilon_3 - \varepsilon_{3e}$) measured in 3-in. (76.2-mm) to local elongation in ½-in. (12.7-mm) gage length.

8. Alternative Test Procedure

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) gage length.

8.2 The strain at the tensile strength, i.e., percentage strain ε_u at the peak of the stress-strain curve, shall be measured. The percentage elongation, ε_u, at ultimate load shall then be calculated as

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

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

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

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

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

9. Test Report

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

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AISI S903-17-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. The test Standard provides an alternative method of determining if a steel has adequate ductility as defined in AISI S100, *North American Specification for the Design of Cold-Formed Steel Structural Members*. This test Standard is based on the method suggested by Dhalla and Winter (1974).

In the Standard, two test procedures are provided. In the first test procedure provided in Standard Section 7, linear elongation in a 3-in. (76.2 mm) gage length, e_3, and linear elongation in a 2-in. (50.8 mm) gage 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) gage 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 the 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) gage 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) gage length. The Standard Equation (7) converts this (ε_f - ε_u) into the percentage elongation in a ½-in. (12.7-mm) gage length.

Reference

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

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