Designation: D8511/D8511M – 23

Standard Guide for Design and Analysis of Local Buckling and Crippling Test Specimens[1]

This standard is issued under the fixed designation D8511/D8511M; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers designing local buckling and crippling test specimens to obtain empirical strength data for one-edge-free and no-edge-free cross section configurations using solid laminate composite material construction. This guide also discusses data analysis procedures for these test specimens. Test procedures for local buckling and crippling specimens are covered in Test Method D8510/D8510M. This guide is intended to be used by persons requesting these test types.

1.2 Local buckling and crippling tests require careful specimen design, instrumentation, data measurement and data analysis. Test requestors designing these specimen need to be familiar with Test Method D8510/D8510M, CMH-17 Volume 3 Chapter 9 (**1**)[2], and the stress analysis methods that will use the resulting local buckling and crippling design data.

1.3 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.3.1 Within the text the inch-pound units are shown in brackets.

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D883 Terminology Relating to Plastics
D3878 Terminology for Composite Materials
D8510/D8510M

3. Terminology

3.1 *Definitions:*

3.1.1 Terminology D3878 defines terms relating to high-modulus fibers and their composites. Terminology D883 defines terms relating to plastics. In the event of a conflict between terms, Terminology D3878 shall have precedence.

NOTE 1—If the term represents a physical quantity, its analytical dimensions are stated immediately following the term (or letter symbol) in fundamental dimension form, using the following ASTM standard symbology for fundamental dimensions, shown within square brackets: [M] for mass, [L] for length, [T] for time, [θ] for thermodynamic temperature, and [nd] for non-dimensional quantities. Use of these symbols is restricted to analytical dimensions when used with square brackets, as the symbols may have other definitions when used without the brackets.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *crippling force, P^{cc} [MLT^{-2}], n*—the applied compressive force at or above the local buckling force at which specimen failure occurs.

3.2.2 *crippling stress, F^{cc} [$ML^{-1}T^{-2}$], n*—the average stress in the test specimen cross-section at failure.

3.2.3 *local buckling force, P^{lcr} [MLT^{-2}], n*—the applied compressive force at which buckling initiates.

3.2.4 *local buckling stress, F^{lcr} [$ML^{-1}T^{-2}$], n*—the average stress in the test specimen cross-section at which buckling of a compression element within the cross-section initiates.

3.2.5 *slenderness ratio, L'/ρ [nd], n*—the ratio of the specimen length adjusted for end boundary condition effects divided by the minimum radius of gyration of the specimen cross-section.

[1] This guide is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.05 on Structural Test Methods.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.6 *width to thickness ratio, b/t [nd], n*—the ratio of the width of the buckling critical section of the specimen cross-section to the specimen thickness.

3.2.6.1 *Discussion*—The width to thickness ratio may be either a nominal value determined from nominal thickness or an actual value determined from measured thickness.

3.3 *Symbols:*

3.3.1 *A*—cross-sectional area, mm^2 [$in.^2$].

3.3.2 *b*—width of buckling critical segment of specimen cross-section, relative to laminate centerline, mm [in.].

3.3.3 *c*—specimen end boundary condition factor (= 1.0 for both ends pinned; = 4 for both ends fully fixed).

3.3.4 F^{lcr}—local buckling stress, MPa [psi].

3.3.5 F^{cc}—crippling stress, MPa [psi].

3.3.6 *L1*—specimen length between end potting or fixture inner surfaces, mm [in.].

3.3.7 *L2*—total specimen length, mm [in.].

3.3.8 *L'* —specimen length adjusted for end boundary condition (= $L/\sqrt{c}$), mm [in.].

3.3.9 *P*—total compressive force applied to specimen, N [lbf].

3.3.10 P^{lcr}—applied compressive force at which buckling initiates, N [lbf].

3.3.11 P^{cc}—maximum applied compressive force, N [lbf].

3.3.12 ρ—minimum cross-section radius of gyration.

3.3.13 *t*—specimen thickness (nominal or actual, as specified), mm [in.].

3.3.14 *w*—overall width of buckling critical segment of specimen cross-section, mm [in.].

4. Summary of Guide

4.1 This guide provides information for designing test specimens to determine the local instability (buckling) force in one or more cross-section segments and the maximum post-buckled force sustained by a composite specimen. The test involves applying an axial compressive force to an unsupported specimen until local buckling and subsequent catastrophic failure ("crippling") occurs. Users of this guide should be familiar with the stress analysis methods that will use the resulting local buckling and crippling design data. The following references discuss these methods and associated test data for metallic and composite structures:

4.1.1 CMH-17, Volume 3 Chapter 9 (**1**),

4.1.2 Esp, Chapter 17 (**2**),

4.1.3 Peery, Chapter 14 (**3**),

4.1.4 Peery and Azar, Chapter 11 (**4**),

4.1.5 Niu, Chapter 10 (**5**), and

4.1.6 Ziemian (**6**).

5. Background

5.1 When beams or stiffened panels are loaded in compression, force is shared between skin and stiffener cross section elements in proportion to their respective stiffnesses. After initial buckling of an element of the cross section, the effective tangent stiffness of the buckled element is reduced sharply; the unbuckled elements will carry additional force as the overall structural force is increased.

5.2 Prior to any buckling, an axially loaded stiffener or structural member will have a uniformly distributed compressive stress as shown in Fig. 1(a). At some force one or more flat elements of the section begin to buckle, with additional force carried by unbuckled portions (for example, corners, Fig. 1(b)). Metallic structures can exhibit local yielding in the buckled cross-section prior to reaching maximum force ("crippling" failure). In composite structure sections the onset of local failure occurring anywhere in the cross-section typically results in complete section failure. The failure onset can occur in compression in the unbuckled areas or in bending in the buckled areas. In some cases ultimate failure may be preceded by delaminations induced by the post-buckled deformations. This ultimate failure mode is also referred to as "crippling" (or sometimes as "post-buckling failure") even though the failure mechanisms are different from those of metallic structure. Similar to metals, composite crippling failure stress can be significantly higher than the initial local buckling stress.

5.3 The analysis of sections or stiffened panels loaded in the post-buckling range becomes a geometrically nonlinear problem and, therefore, "conventional" plate buckling linear analysis cannot be used to estimate the crippling strength of

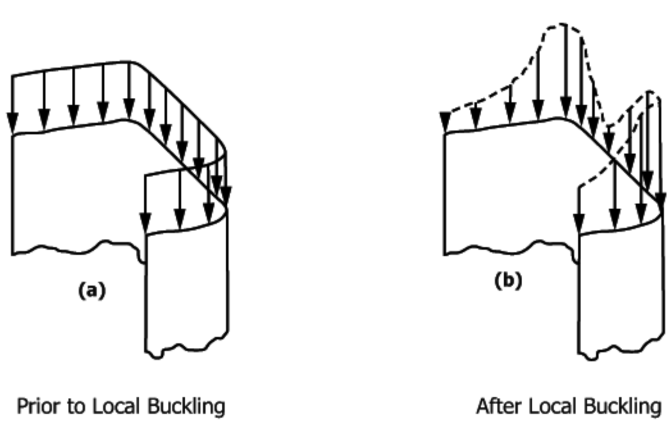

FIG. 1 Typical Stiffener Stress Distribution Prior and After Local Buckling