ICC EVALUATION SERVICE®

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March 1, 2024

TO: PARTIES INTERESTED IN BLIND BOLTS IN STRUCTURAL STEEL CONNECTIONS

SUBJECT: Proposed Revisions to the Acceptance Criteria for Blind Bolts in Structural Steel Connections – AC437-0324-R1 (MG/MC)

Dear Colleague:

We are seeking your comments on proposed revisions to the subject acceptance criteria, AC437, as presented in the enclosed draft. The revisions, which are being posted on the ICC-ES web site for 30 days of public comment, may be summarized as follows:

ICC-ES has an applicant who is interested in an evaluation report for reverse expansion blind bolts that can be used in structural steel and cold-formed steel under the 2021 IBC. The criteria currently doesn't address reverse expansion blind bolts and only address connections in structural steel. The following revisions are proposed:

1. Include Reverse Expansion Bolts as new type of blind bolts.
2. Include the evaluation of blind bolts in cold-formed steel connections.
3. Minor editorial revision to include the 2024 IBC and the 2024 IRC

The evaluation of the reverse expansion bolt in structural steel will follow the existing requirements in AC437 in accordance with AISC 360. For the cold-formed steel connections, the evaluation will be in accordance with the requirements of AISI S100 and AISI S240. The testing requirements of cold-formed steel connection will be in accordance with AISI S905. For the inclusion of the 2024 IBC and the 2024 IRC, there were no technical changes required.

Should the Evaluation Committee approve the proposed revisions to the criteria, no mandatory compliance date will be required.

While the Evaluation Committee will be voting on the revised criteria during the 30-day comment period, we will seriously consider all comments from the public and will pull the criteria back for reconsideration if public comments raise major issues. In that case, we would seek a new committee vote; further revise the draft and post it for a new round of public comments; or put the revised criteria on the agenda for a future Evaluation Committee hearing.

If they are of interest, please review the proposed revisions and send us your comments at the earliest opportunity.

To submit your comments, please use the form on the web site and attach any letters or other materials. If you would like an explanation of the “alternate criteria process,” under which we are soliciting comments, this too is available on the ICC-ES web site.

Please do not try to communicate directly with any Evaluation Committee member about a criteria under consideration, as committee members cannot accept such communications.

Thank you for your interest and your contributions. If you have any questions, please contact me at (800) 423-6587, extension 5698, or Manuel Chan, P.E., S.E., Principal Structural Engineer, at extension 3288. You may also reach us by e-mail at es@icc-es.org.

Yours very truly,

Moneeb Genedy, Ph.D.
Evaluation Specialist

MG/ls

Encl.

cc: Evaluation Committee

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ACCEPTANCE CRITERIA FOR BLIND BOLTS IN STRUCTURAL STEEL AND COLD-FORMED STEEL CONNECTIONS

AC437

Proposed March 2024

Previously approved June 2022, December 2019, February 2019, October 2014, October 2011

(Previously editorially revised March 2018, December 2016)

PREFACE

Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes, and may include other codes, as applicable. For alternative materials, design and methods of construction and equipment, see Section 104.2.3 of the 2024 *International Building Code®* (IBC), Section R104.2.2 of the 2024 International Residential Code (IRC), Section 104.11 of the 2021 IBC and earlier editions, and Section R104.11 of the 2021 IRC and earlier editions.

ICC-ES may consider alternate criteria for report approval, provided the report applicant submits data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. ICC-ES retains the right to refuse to issue or renew any evaluation report, if the applicable product, material, or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause injury or unreasonable damage.

Acceptance criteria are developed for use solely by ICC-ES for purposes of issuing ICC-ES evaluation reports

ACCEPTANCE CRITERIA FOR BLIND BOLTS IN STRUCTURAL STEEL AND COLD-FORMED STEEL CONNECTIONS (AC437)

1.0 INTRODUCTION

1.1 Purpose: The purpose of this acceptance criteria is to establish requirements for issuance of ICC Evaluation Service, LLC (ICC-ES) evaluation reports on blind bolts for structural steel and cold-formed steel connections under the 2024, 2021, 2018, 2015, 2012 and 2009 *International Building Code*® (IBC) and the 2024, 2021, 2018, 2015, 2012 and 2009 *International Residential Code*® (IRC). Bases of evaluation are ~~IBC~~ Section 104.2.3 of 2024 IBC (Section 104.11 of 2021, 2018, 2015, 2012, and 2009 IBC) and ~~IRC~~ Section R104.2.2 of 2024 IRC (Section R104.11 of 2021, 2018, 2015, 2012, and 2009 IRC).

The reason for the development of this acceptance criteria is to provide guidelines for evaluating blind bolts for ~~structural~~ steel connections, since the codes do not specify procedures for qualifying or installing such products.

1.2 Scope: This criteria applies to blind bolts used to resist loads in structural steel and cold-formed steel connections. The criteria calls for assessment of strength and deformation capacity, service conditions, design procedures, and quality control.

The blind bolts are alternatives to through bolts prescribed in Section J3 of AISC 360 and Section J3 of AISI S100 and are permitted to be installed in accordance with AISC 360, AISC 341, AISC 348, AISI S100, AISI S240 and additional requirements specified in the report holder's installation instructions, if applicable. There are ~~two~~ three versions of blind bolts covered by this acceptance criteria: gravity or spring-operated bolts, ~~and~~ expansion bolts, and reverse expansion bolts. ~~The gravity or spring-operated~~Blind bolts are installed in holes sized per manufacturer installation instructions but not larger than standard holes~~,~~ as defined in AISC 360 for structural steel and AISI S100 for cold formed steel.~~, with a hole diameter no greater than the bolt's diameter plus $^{1}/_{16}$ inch (1.6 mm). In the case of expansion bolts, the hole is to be a standard hole, sized to accommodate the expansion shell of the bolt, with the hole diameter no greater than the bolt's expansion shell diameter plus $^{1}/_{16}$ inch (1.6 mm).~~

This criteria is limited to only the blind bolt product and assumes that affected elements of members and connecting elements (non-bolt elements) are designed and specified in accordance with the IBC and its referenced standards including AISC 360, AISC 341, ~~and~~ AISC 348, AISI S100, and AISI S240. Report holder's design and installation instructions shall inform blind bolt users that the design of affected elements of members and connecting elements shall be analyzed and designed in accordance with the IBC and its referenced standards including AISC 360, AISC 341, ~~and~~ AISC 348, AISI S100, and AISI S240. For example, bearing capacity at bolt holes or plate net section tensile rupture, shall be designed in accordance with AISC 360.

At a minimum, test data in accordance with Sections 3.0, 4.1, 4.3 and 4.5 of this criteria shall be submitted in order to establish blind bolt strengths in bearing-type connections for resisting static dominant loads, including gravity, wind and seismic loads for structures assigned to Seismic Design Category (SDC) A, B or C. Table 2 provides a summary of the required testing and additional testing requirements for optional evaluations.

1.3 Codes and Referenced Standards:

1.3.1 Where multiple editions of standards are referenced in this criteria, these standards shall be applied consistently with the code upon which compliance is based, per Table 1.

1.3.2 2024, 2021, 2018, 2015, 2012 and 2009 *International Building Code*® (IBC), International Code Council.

1.3.3 2024, 2021, 2018, 2015, 2012 and 2009 *International Residential Code*® (IRC), International Code Council.

1.3.4 AISC 341, Seismic Provisions for Structural Steel Buildings, American Institute of Steel Construction.

1.3.5 AISC 348, Specification for Structural Joints using High-strength Bolts, Research Council on Structural Connections.

1.3.6 AISC 360, Specification for Structural Steel Buildings, American Institute of Steel Construction.

1.3.7 AISI S100, North American Specification for the Design of Cold-Formed Steel Structural Members, American Iron and Steel Institute.

1.3.8 AISI S240, North American Standard for Cold-Formed Steel Structural Framing, American Iron and Steel Institute.

1.3.9 AISI S905, Test Standards for Cold-formed Steel Connections, American Iron and Steel Institute.

1.3.10 ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers.

1.3.11 ASTM A370, Test Methods and Definitions for Mechanical Testing of Steel Products, ASTM International.

1.3.12 ASTM F606, Test Methods for Determining the Mechanical Properties of Externally and Internally Threated Fasteners, Washers, Direct Tension Indicators, and Rivets, ASTM International.

1.3.13 ATC 24, Guidelines for Cyclic Seismic Testing of Components of Steel Structures, Krawinkler, H., Applied Technology Council, 1992.

1.3.14 EN 1993-1-9 Eurocode 3: Design of Steel Structures Part 1-9: Fatigue, May 2005, European Committee for Standardization.

1.3.15 ISO 21930-2017 Sustainability in Buildings and Civil Engineering Works - Core Rules for Environmental Product Declarations of Construction Products and Services, International Organization for Standardization (ISO).

1.3.16 NCHRP Report 402, Fatigue Design of Modular Bridge Expansion Joints, March 1998, National Cooperative Highway Research Program.

1.4 Definitions:

1.4.1 Blind Bolt: Blind bolts are bolts in ~~structural~~ steel connections that eliminate the need for access to install a nut.

The bolts' primary use is to provide a blind-side connection solution for attachments of steel members to hollow-section structural steel and other ~~structural~~ steel framing where access is restricted to one side only.

1.4.2 Cold-Formed Steel Connection: Cold-formed steel connection is a bolted connection of cold-formed steel members or elements as specified in AISI S100.

Exception: Bolted connection of cold-formed steel members or elements of 1/8 inch (3.18 mm) or more in thickness could be evaluated as structural steel connection in accordance with AISC 360.

1.4.3 Standard Hole: Standard hole is a hole sized as defined in AISC 360 for structural steel and AISI S100 for cold formed steel. For gravity or spring-operated blind bolts, a standard hole has a diameter no greater than the bolt's diameter plus 1/16 inch (1.6 mm) for structural steel and no greater than the bolt's diameter plus 1/32 inch (0.8 mm) for cold-formed steel. For expansion and reverse expansion bolts, a standard hole has a diameter no greater than bolt's expansion shell diameter plus 1/16 inch (1.6 mm) for structural steel and no greater than bolt's expansion shell diameter plus 1/32 inch (0.8 mm) for cold-formed steel.

1.4.4 Expansion Bolt: Blind bolts that are similar in appearance to concrete expansion anchors, but are instead used to connect two steel components. It consists of a bolt in a ~~sleeve~~ shell that expands as the bolt is tightened, preventing the bolt from pulling out of the connection.

In this connection solution, a hole is drilled into both steel parts, the parts are mated together, and the bolt is inserted into the hole and tightened from one side. As the bolt core is tightened, it expands a ~~sleeve~~shell, fixing the bolt on the blind side of the attachment. A torque wrench is used to tighten the bolt to produce controlled tension forces on the bolt, resulting in a pretensioned connection similar to pretensioned joints prescribed in AISC 348, designed and installed in accordance with the AISC 360 and AISC 348 specifications.

The bolts are typically an assembly of three main steel components as shown in Figure 1: (1) a core, (2) a shell, and (3) a nut. The core is the solid portion of the bolt, ~~usually~~ a high-strength bolt with full-length threads along its shank, and is typically used to identify the bolt size. The shell is a hollow tubular element that surrounds the core and is designed to expand in order to lock the bolt in place during installation, thereby acting as a substitute for a washer commonly used in standard threaded bolts. The nut is a conical device that expands the shell as the bolt is tightened. Other assembly configurations are possible, with approval from the ICC-ES staff.

1.4.5 Reverse Expansion Bolt: During tightening, the shell of the reverse expansion bolt expands on the inaccessible side of the joint from the side facing the connected steel parts, clamping the plates together.

In this connection type, a hole is drilled into both steel parts, the parts are mated together, and the bolt is inserted into the hole with the central screw tightened whilst holding the outer ferrule to prevent rotation. As the screw is tightened, the shell is forced over the ferrule, expanding and engaging with the inaccessible side of the joint.

The bolts are typically an assembly of three main steel components as shown in Figure 2: (1) a core, (2) a ferrule, and (3) a threaded shell. The core is the solid portion of the bolt, a high-strength bolt with full-length threads along its shank, and is typically used to identify the bolt size. The shell is a hollow tubular element that surrounds the core and is designed to expand through inner side threads at the end, in order to lock the bolt in place during installation, thereby acting as a substitute for a washer and nut commonly used in standard threaded bolts. The ferrule is a conical device that expands the shell as the bolt is tightened. Other assembly configurations are possible, with approval from the ICC-ES staff.

1.4.6 Gravity or Spring-operated Bolt: Gravity-operated bolts in ~~structural~~ steel connections are blind bolts with a gravity-operated toggle on the inaccessible (blind) end of the bolt. Spring-operated bolts in ~~structural~~ steel connections are blind bolts that engage with expansion blades by an internal spring automatically after the bolt is inserted into the connection. Expansion blades are steel slender pieces that are released with a certain angle from the bolt.

In the connection solution for gravity operated bolts, a hole is drilled into both steel parts, the parts are mated together, and the toggle end of the bolt is inserted into the hole. The bolt is initially oriented in such a way that the toggle lines up with the bolt. After inserting the bolt in the hole, the bolt is rotated such that the toggle rotates, due to gravity, to a position that is perpendicular to the bolt. The bolt can then be tightened from one side. The nut is tightened in the normal manner. A gravity-operated bolt is not designed to be used as a pre-tensioned assembly or for slip-critical connections. See Figure ~~2a~~ 3a for an illustration of a gravity-operated blind bolt.

In the connecting solution for spring-operated bolts, a hole is drilled into both steel parts, the steel parts are mated together, and the open end of the bolt is inserted into the hole. The bolt is considered engaged when the head of the bolt is in contact with the outer steel ply to be connected. A spring-operated bolt is not designed to be used as a pre-tensioned assembly or for slip-critical connections. See Figure ~~2b~~ 3b for an illustration of a spring-operated bolt.

1.5 Symbols: Symbols used in this criteria are defined in AISC 360 and as indicated below:

- A_{nc} Effective tensile cross-sectional area of the core of expansion bolts or the bolt of gravity or spring-operated blind bolts, as applicable, in.^{2} (mm^2)
- A_{vc} Effective shear cross-sectional area of the core of expansion bolts or the bolt of gravity or spring-operated blind bolts, as applicable, in.^{2} (mm^2)
- A_{vs} Effective shear cross-sectional area of the shell, in.^{2} (mm^2)
- $A_{v,t}$ Total effective shear cross-sectional area for expansion bolts, equal to the sum of A_{vc} and A_{vs}, in.^{2} (mm^2)
- D_c Diameter of core of expansion bolts or the bolt of gravity or spring-operated blind bolts, as applicable, in. (mm)
- D_{s1} Inner diameter of shell, in. (mm)
- D_{s2} Outer diameter of shell, in. (mm)
- F_y The yield strength of the bolt material, psi (MPa)
- F_{yc} Yield strength of the core of expansion bolts or the bolt of gravity or spring-operated blind bolts, as applicable, psi (MPa)

F_{ys} Yield strength of the shell, psi (MPa)

F_{uc} Ultimate stress of the core of expansion bolts or the bolt of gravity or spring-operated blind bolts, as applicable, psi (MPa)

F_{us} Ultimate stress of the shell, psi (MPa)

R_n Nominal strength for each bolt diameter of the same specified strength, derived per Section 3.4, lbf (N)

S_V Shear stress range, ksi (MPa)

S_T Tension stress range, ksi (MPa)

T_s Nominal static tension strength determined in accordance with Sections 4.3 and 3.5, lbf (N)

T_{UT} Target ultimate tension strength for each bolt diameter and each bolt length for cyclic tension tests per Section 4.4.3.1, lbf (N)

T_{YT} Target yield tension strength for cyclic shear (bearing) tests per Section 4.4.3.2, lbf (N)

V_{FT} Target slip-friction shear strength for each bolt diameter and each bolt length for cyclic shear test (for slip critical connection) per Section 4.4.2.1, lbf (N)

$V_{S,b}$ Nominal static shear (bearing-type connection) strength determined in accordance with Sections 4.1 and 3.5, lbf (N)

$V_{s,F}$ Nominal static shear (slip-critical or friction-type connection) strength determined in accordance with Sections 4.2 and 3.5, lbf (N)

V_{UT} Target ultimate shear (bearing-type connection) strength for each bolt diameter and each bolt length for cyclic shear (bearing) test per Section 4.4.1.1, lbf (N)

V_{YT} Target yield shear strength for cyclic shear (bearing) test per Section 4.4.1.2, lbf (N)

α_v Adjustment factor for shear nominal capacity to account for the difference between the actual and specified material and diameters

α_t Adjustment factor for tension nominal capacity to account for the difference between the actual and specified material and diameters

ΔF Tested capacity or load level set for fatigue resistance, lbf (N)

ϕ Resistance factor used in Load and Resistance Factor Design (LRFD) formulations

Ω Factor of safety used in Allowable Strength Design (ASD) formulations

2.0 BASIC INFORMATION

2.1 General: The following information shall be submitted with ICC-ES evaluation report applications:

2.1.1 Blind bolts shall be described as to:

1. Generic or trade name.
2. Manufacturer's catalog number.
3. Nominal thread size (as applicable) and specification.
4. Nominal bolt or ~~sleeve~~ shell diameters.
5. Length.
6. Permitted manufacturing tolerances.
7. Material specifications (physical and chemical) for all parts, including metallic and nonmetallic coatings.
8. Dimensions for all parts as shown in Figures 1 or 2, as applicable.
9. Manufacturing process.

2.1.2 Installation Instructions: Manufacturer's published installation instructions shall be submitted and shall include procedures for typical blind bolt products as follows:

1. Holes shall be drilled into the ~~sections to be fixed~~members or elements to be connected, ensuring that the resulting holes have the correct diameter and spacing according to the manufacturer's published specifications, and the correct design requirements for the connection. Hole sizes shall be sized per manufacturer installation instructions but not larger than standard holes~~be standard diameter holes conforming to AISC 360, where the bolt hole diameters shall be no greater than the bolt diameter plus 1/16 inch (1.6 mm), or in the case of an expansion bolt, shell diameter plus 1/16 inch (1.6 mm)~~.

2. Burrs in the holes shall be removed before inserting blind bolts.

3. The ~~structural~~ steel elements to be fastened adjacent to each other shall be positioned to ensure:

a. That the two ~~sections~~ elements are lined up and rest one against the other without any gap. Clamps shall be used as necessary to hold the two ~~sections~~ elements together and prevent formation of gaps.

b. That the holes are aligned, using a mandrel if necessary.

4. The bolts shall be positioned in the holes. For expansion bolts, the shell shall rest flat against the section with no gap.

5. For reverse expansion bolts, the ferrule shall be held in position using a suitable open-ended wrench and then the core shall be tightened to snug tight.

6. For expansion bolts, the shell shall be held in position using a suitable open-ended wrench and then the bolt shall be tightened to the specified torque.

7. The tightening tool (as applicable) shall be removed and the tightening torque (as applicable) on the bolt shall be verified. If necessary, the tightening torque shall be corrected.

8. Manufacturer's inspection procedures to verify proper installation of the blind bolts, including verification of applied torque and/or pretension, as applicable.

2.1.3 Packaging and Identification: Identification provisions shall include product part number, batch number, the report holder's name, and the evaluation report number. Packaging shall include the following information: installation instructions, minimum and maximum fixing ranges (thickness of connected elements), installation torque, and special inspection requirements.

2.2 Testing Laboratories: Testing laboratories shall comply with Section 2.0 of the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation Reports.

2.3 Test Reports: Test reports shall comply with AC85.

2.4 Product Sampling: Sampling of the blind bolts for tests under this criteria shall comply with Section 3.1 of AC85.

2.5 Qualification Test Plan: A qualification test plan shall be submitted to and approved by ICC-ES staff prior to any testing being conducted.

3.0 TEST AND PERFORMANCE REQUIREMENTS

3.1 General: Blind bolts shall be qualified for design using strength values (or available strengths) derived from tested samples. See Table 2 for required and optional qualifications and applicable testing requirements.

3.2 Number of specimens:

3.2.1 Diameters: Each bolt diameter shall be tested to establish strength values to be used in design.

3.2.2 Lengths: For each bolt diameter, the longest length and shortest length shall be tested, as a minimum.

3.2.3 Static Load Testing: A minimum of three replicate tests are required for each test sample. If the deviation of any single tested capacity from the mean of all replicate tested capacities exceeds 15 percent, then additional tests shall be performed until the deviation of any single tested capacity from the mean value is less than or equal to 15 percent. The maximum number of replicate tests need not exceed six.

3.2.4 Cyclic Load Testing: For evaluation for use in Seismic Design Category (SDC) D, E or F, three replicate tests are required for each test sample.

3.2.5 Fatigue Testing: For evaluation for fatigue resistance, see Section 4.6.1.1.

3.2.6 Multiple Finishes: Additional tests in accordance with Sections 3.2.3, 3.2.4 and 3.2.5 shall be conducted on expansion bolts supplied with multiple available finishes. (Not required for gravity or spring-operated bolts.)

3.3 Loading Conditions: Each of the selected bolt diameters and lengths shall be tested as required by Table 2.

3.4 Nominal Strength: The nominal strength of each bolt diameter size, R_n, shall be the least of the adjusted tested capacity of the longest tested length and the adjusted tested capacity of the shortest tested length for the particular bolt diameter of the same specified strength, respectively, for each limit state (shear-bearing, shear-friction and tension) of the loading conditions (static and seismic loading). The adjusted tested capacity shall be derived in accordance with Section 3.5. The nominal strength of the blind bolt shall not exceed the nominal strength of a standard threaded bolt as computed in accordance with Section J3 of AISC 360 and/or Section J3 of AISI S100 with, in the case of an expansion bolt and reverse expansion bolt, a diameter equal to that of the core of the expansion bolt. In the case on an expansion bolt and reverse expansion bolt, the value of F_u used in the calculation for standard threaded bolt shall be equal to the specified ultimate tensile strength of the steel core, F_{uc}, used in the expansion bolt.

3.5 Tested Capacity Adjustment: The tested capacity of each test specimen shall be the maximum (peak) strength determined per testing in accordance with Section 4.0. The tested capacity of each test specimen shall be adjusted downward considering any difference between the actual measured material ultimate strengths and cross-sectional areas of the blind bolt test specimens, as determined in accordance with Section 4.5, and the minimum specified tensile strengths and the specified cross-sectional area(s), specified by the product specifications. The adjusted tested capacity for each bolt diameter and for each bolt length from each test protocol shall be the average of the adjusted tested capacities of the replicate tested specimens. The adjusted tested capacities shall be computed as follows:

Adjusted Tested Shear Capacity = Tested Shear Capacity times α_v

Adjusted Tested Tension Capacity = Tested Tension Capacity times α_t

where:

Expansion or reverse expansion bolts:

α_v = Adjustment factor for shear =

$$\frac{\left[D_c^2F_{uc} + \left(D_{s2}^2 - D_{s1}^2\right)F_{us}\right]_{Specified}}{\left[D_c^2F_{uc} + \left(D_{s2}^2 - D_{s1}^2\right)F_{us}\right]_{Actual}} \leq 1.0$$

α_t = Adjustment factor for tension =

$$\frac{\left[D_c^2F_{uc}\right]_{Specified}}{\left[D_c^2F_{uc}\right]_{Actual}} \leq 1.0$$

Gravity or spring-operated bolts:

α_v = Adjustment factor for shear =

$$\frac{\left[D_c^2F_y\right]_{Specified}}{\left[D_c^2F_y\right]_{Actual}} \leq 1.0$$

α_t = Adjustment factor for tension =

$$\frac{\left[D_c^2F_y\right]_{Specified}}{\left[D_c^2F_y\right]_{Actual}} \leq 1.0$$

3.6 Strength of Testing Apparatus: All components of the apparatus shall have capacities that exceed the ultimate capacity of the bolt for the test type in question (i.e., shear, tension, etc.). No component of the testing apparatus including connecting plates, welds, bolts, load cells, actuators, etc., shall limit the load applied in the test.

3.7 Resistance Factor for LRFD: The resistance factor, Φ, shall be applied to the nominal strength determined in accordance with Section 3.4, for determining the LRFD design strength. For each set of replicate specimens tested for the same loading condition, the LRFD resistance factor shall be computed in accordance with Chapter K of AISI S100-16 (Chapter F of AISI S100-12, S100-07/S2-10, S100-07) as follows:

$$\phi = 1.672e^{-3.5\sqrt{0.053+C_pV_p^2}}$$

where,

V_p = Coefficient of variation of tested maximum strengths based on replicate specimens (e.g. a minimum of 3 tests) ≥ 0.065

C_p = $(1+1/n)m/(m-2)$, if $n \geq 4$

= *5.7 if n = 3*

n = Number of replicate tests, for each series of tests (a minimum of 3)

m = $n-1$

3.8 LRFD Design Strength: The LRFD design strength shall be determined as follows:

LRFD design strength = ϕR_n

Where: ϕ used for determining the LRFD design strength (ϕR_n), for each limit state (shear-bearing, shear-friction and tension) related to each load condition (i.e., static and seismic loading), must be the lowest value of all tested blind bolts that have the same specified strength and are tested for the same limit state and same loading condition.

3.9 Factor of Safety for ASD: A factor of safety, Ω, shall be applied to the nominal strength determined in accordance with Section 3.4, for determining the ASD allowable strength. The ASD factor of safety shall be determined in accordance with Chapter K of AISI S100-16 (Chapter F of AISI S100-12, S100-07/S2-10, S100-07) as follows:

$$\Omega = \frac{1.6}{\phi}$$

Where: ϕ is determined per Section 3.8, for each limit state (shear-bearing, shear-friction and tension) related to each load condition (i.e., static and seismic loading).

3.10 ASD Design Strength: The ASD allowable strength shall be determined as follows:

ASD allowable strength = R_n/Ω

Where: Ω is determined per Section 3.9, for each limit state (shear-bearing, shear-friction and tension) related to each load condition (i.e., static and seismic loading).

3.11 Combined Loading: Combined static shear-bearing and static tension loading shall be considered for LRFD and ASD in accordance with the following equation:

$$\left(\frac{\text{Tension Demand}}{\text{Tension Capacity}}\right)^2 + \left(\frac{\text{Shear Demand}}{\text{Shear Capacity}}\right)^2 \leq 1.0$$

Bolts in slip-critical applications shall not be used in combined shear and tension loading.

3.12 Fatigue Resistance (Optional):

3.12.1 General: Design for fatigue resistance in accordance with Appendix 3 of AISC 360 for structural steel and Chapter M of AISI S100 for cold-formed steel shall apply when the blind bolt connections are expected to be subjected to 10,000 or more cycles of application of live load. Fatigue resistance shall be evaluated separately for shear (bearing) and tension connections made with expansion bolts. Fatigue resistance of expansion bolts subject to combined shear and tension loading is outside the scope of this criteria.

3.12.2 Design for Fatigue: When connections made with expansion bolts are subject to fatigue, they shall be designed in accordance with Appendix 3 of AISC 360. The applicable Stress Category for design shall be determined in accordance with Sections 3.12.4 through 3.12.6.

3.12.3 Stress Categories: Stress Categories are described by S-N curves shown in Figure C-A-3.1 of the Commentary to Section 3.1 of Appendix 3 of AISC 360. Each curve consists of a sloping line of variable resistance (finite life), followed by a horizontal line representing the constant amplitude fatigue threshold (infinite life).

3.12.4 Required Testing: Testing shall be performed in accordance with Section 4.6. For each bolt type, the minimum bolt diameter and one other bolt diameter shall be tested.

3.12.5 Determination of Representative S-N Curve: The results of the fatigue testing shall be statistically evaluated for the derivation of an S-N curve for shear (bearing) and for tension in order to determine the appropriate stress category in accordance with Figure C-A-3.1 of the Commentary to Section 3.1 of Appendix 3 of AISC 360.

The tested capacity ΔF, from each test shall be divided by the nominal stress area to determine the stress ranges in both shear (bearing) and tension as follows:

$$S_V = \Delta F / (2^*(A_{v,t}))$$

$$S_T = \Delta F / (2^*A_{nc})$$

The stress ranges S_V and S_T shall be plotted separately. For all tested bolt diameters, stress ranges shall be plotted on a log-log scale with a mean regression line plotted through the data, representing the average value of the fatigue strength curve. A normal distribution with a 95% confidence limit shall be used. The mean regression line shall be offset by two standard deviations below and to the left. This offset line shall be considered the representative S-N curve for the blind bolt. See Figure ~~13~~ 14 for and example of a log-log scale, mean regression line and a representative S-N curve.

3.12.6 Determination of Applicable Stress Category: The representative S-N curve shall be compared to the fatigue resistance curves illustrated in Figure C-A-3.1 of the Commentary to Section 3.1 of Appendix 3 of AISC 360 and the next lower curve in the figure shall be considered the applicable fatigue resistance curve. From this, the applicable Stress Category is determined. The applicable values of C_f and F_{TH} shall be determined from Table A-3.1 of AISC 360.

4.0 TEST METHODS

4.1 Static Shear (Bearing) Test: Each blind bolt shall be tested (ultimate (peak) load) for shear (bearing-connection) in an assembly in order to determine its static shear (bearing-type connection) strength, $V_{S,b}$. For gravity or spring-operated bolts, submitted documentation shall indicate whether or not the bolt threads and/or bolt toggle/spring slot are to be included in the shear plane. If the bolt threads and/or bolt toggle/spring slot are to be included in the shear plane, then testing shall be set up to reflect the inclusion of the threads and/or bolt toggle/spring slot. The testing shall satisfy the following minimum criteria:

4.1.1 Test Setup:

4.1.1.1 Structural Steel Connection: The bolt shall be installed in a two-bolt, single shear lap joint assembly with load applied to the outer plates, resulting in a tension loading configuration as shown in Figure ~~3~~4. The plate adjacent to the nut of the expansion bolt, the shell of the reverse expansion bolt, or toggle or expansion blades of the gravity or spring-operated bolt shall be the minimum thickness for which the bolt is to be qualified. In the case of gravity-operated bolts, test plan shall indicate the toggle orientation with respect to the applied shear test load. For tests of the shortest length bolt for a particular bolt diameter, both plates shall be of the minimum thickness for which the bolt is to be qualified.

4.1.1.2 Cold-Formed Steel Connection: The bolt shall be installed in a lap-joint shear test setup in accordance with section 7.1 of AISI S905. The blind bolt shall be tested at its minimum fixing thickness (clamping range for reverse expansion bolts) and the plate adjacent to the nut of the expansion bolt, the shell of the reverse expansion bolt, or toggle or expansion blades of the gravity or spring-operated bolt shall be the minimum thickness for which the bolt is to be qualified.

4.1.2 Edge Distances: Minimum distances in accordance with Chapter J3 of AISC 360 or S100, as applicable, between the ~~sleeve~~ shell ~~or nut~~ of the expansion bolt, and reverse expansion bolt, or bolt of the gravity or spring-operated bolts, to the edges of its connecting elements shall be provided in all directions. In the case of expansion bolts and reverse expansion bolts, the minimum distance shall be determined based on the outer diameter of the ~~sleeve~~shell. The configuration of the test assemblies shall be coordinated such that the load direction engages the least edge distance to be loaded as shown in Figure ~~3~~4 for structural steel, section 7.1 of AISI S905 for cold-formed steel.

4.1.3 Displacement Measurement: A displacement measuring device shall be positioned to permit determination of the shear displacement between the inner and outer plates of the assembly in the direction of applied load as shown in Figure ~~3~~4 for structural steel, section 7.1 of AISI S905 for cold-formed steel.

4.1.4 Expected Ultimate Capacity: An expected ultimate shear (bearing) capacity shall be determined. In the case of expansion and reverse expansion bolts, for purposes of approximating a maximum possible load to be applied in this testing protocol, the expansion bolt shall be assumed to be a single solid dowel with a nominal diameter equal to the outer diameter of the shell, and with an ultimate tensile strength equal to the larger of the ultimate tensile strength of either the shell or the core.

4.1.5 Bolt Installation: The expansion blind bolt and reverse expansion blind bolt shall be fastened snug-tight in accordance with Section 8.1 of AISC 348 for structural steel connections and~~.~~ in accordance with Section J3 of AISI S100 for cold-formed steel connections.

4.1.6 Initial Load: An initial load of five percent of the expected ultimate shear capacity of the bolt shall be applied in order to bring all members into full bearing.

4.1.7 Loading Protocols: A continuous monotonic load shall be increasingly applied at a rate ranging from 25 percent to 100 percent of the expected ultimate shear strength of the bolt (based on previous test results), per minute until either of the following occurs:

1. There is a sudden failure or zero load resistance measurement.

2. There is a 20 percent reduction in load resistance measurement. This reduction shall not be due to slip or a sudden loss in friction strength and shall be verified during the test. Loading shall continue to be applied if reduction in load resistance measurement is due to slip. Slip shall be determined to be a measurable displacement without increase in load, followed by an increase in load with further displacement.

The total test time shall not be less than one minute.

4.2 Static Shear Test for Slip-Critical Connections with Expansion Bolts (Optional): Each bolt shall be tested for slip friction shear resistance in an assembly in order to determine its static shear (slip-critical or friction-type connection) strength, $V_{s,F}$. The testing shall satisfy the following minimum criteria:

4.2.1 Test Setup: The bolt shall be installed in a two-bolt, single shear lap joint assembly with load applied to the outer plates, resulting in a tension loading configuration as shown in Figure ~~3~~4. The test plates shall have Class A faying surfaces in accordance with AISC 360 Section J3.8, consisting of "unpainted clean mill scale steel surfaces or surfaces with Class A coatings on blast-cleaned steel or hot-dipped galvanized and roughened surfaces." The plate adjacent to the nut shall be of the minimum thickness for which the bolt is to be qualified. For tests of the shortest length bolt for a particular bolt diameter, both plates shall be of the minimum thickness for which the bolt is to be qualified.

4.2.2 Edge Distances: A minimum distance in accordance with AISC specifications between the blind bolt and the edges of its connecting elements shall be provided in all directions.

In the case of expansion bolts, a minimum distance in accordance with AISC specifications between the ~~sleeve~~ shell of the bolt and the edges of its connecting elements shall be provided in all directions. Minimum distance shall be determined based on the outer diameter of the ~~sleeve~~shell.

4.2.3 Displacement Measurement: A displacement measuring device shall be positioned to permit determination of the shear displacement between the inner and outer plates of the assembly in the direction of applied load.

4.2.4 Bolt Installation: The bolt shall be pretensioned in accordance with the manufacturer's standard installation procedure. A tension calibrator shall be used to verify the pretension force. Pretension can be verified by using any of the methods in accordance with Section 8.2 of AISC 348.

4.2.5 Expected Ultimate Capacity: An expected ultimate shear (slip-critical) capacity shall be computed in accordance with Section J3.8 of AISC 360 using the factors associated with the applicable edition of AISC 360. Expansion bolt strength shall be assumed to be controlled by the properties of the core component.

4.2.6 Conditioning: A minimum of five days shall lapse between pretensioning of the installed bolt and testing to allow for pretension relaxation.

4.2.7 Loading Protocols: A continuous monotonic load shall be increasingly applied at a rate equal to the lesser of 25 kips (111 kN) per minute or 0.003 inch (0.076 mm) of slip displacement per minute until any of the following occurs:

1. There is 0.05 inch (1.27 mm) of displacement.

2. There is a 20 percent reduction in load resistance measurement.

3. There is a sudden failure or zero load resistance measurement.

The total test time shall be at least one minute.

4.2.8 Condition Of Acceptance: The ultimate shear (slip-critical) strength shall exceed 40 percent of the nominal shear strength of the bolt core material.

4.3 Static Tension Test: Each blind bolt shall be tested for tension in an assembly in order to determine its static tension strength, T_s. The testing shall satisfy the following minimum criteria:

4.3.1 Test Setup:

4.3.1.1 Structural Steel Connection: The blind bolt shall be installed such that it fastens to two plates: a face plate and a back plate. The face plate shall be attached to a rigid assembly allowing it to be pulled away from the back plate as shown in Figure 45. The back plate shall be fastened to a rigid assembly anchored to a permanent fixture such as the ground. The face and back plates along with the rigid assemblies shall be sufficiently rigid such that any deformation contributed by these elements is less than one percent of the total deflection measured at the load cell or actuator.

4.3.1.2 Cold-Formed Steel Connection: The bolt shall be installed and tested in standard tension test setup in accordance with section 7.2 of AISI S905.

4.3.2 Displacement Measurement: A displacement measuring device shall be positioned to measure the displacement between each of the base assemblies.

4.3.3 Expected Ultimate Capacity: An expected ultimate tension capacity of the bolt shall be computed in accordance with Section J3.6 of AISC 360 for structural steel and Section J3 of AISI S100 for cold-formed steel connections. For expansion and reverse expansion bolts, assume only the contribution of the bolt core without the contribution of the ~~sleeve~~shell.

4.3.4 Loading Protocols: The bolt shall be fastened snug-tight (as applicable) in accordance with Section 8.2 of AISC 348. A continuous monotonic load shall be increasingly applied at a rate ranging from 25 percent to 100 percent of the expected ultimate tension capacity of the bolt per minute until either of the following occurs:

1. There is a 20 percent reduction in load resistance measurement.

2. There is a sudden failure or zero load resistance measurement.

The total test time shall be at least one minute.

4.4 Cyclic Testing (Optional): Cyclic testing shall be performed to determine shear-bearing, slip-friction, and tension capacities to be used in seismic design for SDC of D, E or F. The approach outlined here is based on the testing method described in ATC-24 for cyclic seismic testing of steel components. Since blind bolts are intended to be used as force-controlled components and are not expected to undergo significant inelastic deformations where they would serve as the primary yielding mechanism in a lateral force-resisting system, the procedure outlined here is based on force-controlled behavior as opposed to deformation-controlled behavior. Therefore, the method for cyclic loading described in ATC-24 has been modified here to be based on forces instead of deformations.

4.4.1 Cyclic Shear (Bearing) Test (Optional):

4.4.1.1 Target Ultimate Shear Strength, V_{UT}: A target ultimate shear strength, V_{UT}, for each bolt diameter and for each bolt length, shall be determined by the evaluation report applicant, which shall be larger than the target yield shear strength determined per Section 4.4.1.2 of this criteria, and shall be smaller than the static shear (bearing-type connection) strength, which shall be the average of the unadjusted tested capacities of the replicate bolt specimens with the same bolt length, determined from the static shear tests in accordance with Section 4.1.

The target ultimate shear strength, V_{UT}, determined by the evaluation report applicant, as noted above, must be used as N5 in Figure ~~6~~ 7 and declared as the pass criteria. However, if there is failure at N5, then a lower value of V_{UT} must be chosen that can pass all the required cycles. This value is then used to determine LRFD and ASD values for seismic resistance under SDC D, E or F in accordance with Sections 3.4 and 3.5.

4.4.1.2 Target Yield Shear Strength, V_{YT}: A target yield shear strength, V_{YT}, shall be set equal to the observed yield strength, V_y, obtained from the force-displacement plot in the static tests in accordance with Section 4.1 as shown in Figure 56. The observed shear yield strength shall be associated with significant shear yielding observed in the critical region of the test specimen, which should be reflected by a clear nonlinearity in the control force-deformation relationship. If a clear transition point from linearity to nonlinearity cannot be determined, then the target shear yield strength shall be computed as follows:

For expansion bolts:

$$V_{yt} = (V_{yt})_{Core} + (V_{yt})_{Shell}$$

$$(V_{yt})_{Core} = A_{vc}\,(0.6F_{yc})$$

$$(V_{yt})_{Shell} = A_{vs}\,(0.6F_{ys})$$

where: A_{vc} and A_{vs} are the effective cross-sectional areas of core and shell, respectively, based on specified dimensions; and F_{yc} and F_{ys} are the specified yield strengths *of* the core and the shell, respectively.

For gravity or spring-operated bolts:

$$V_{yt} = A_{vc}(0.6F_{yc})$$

Submitted documentation shall indicate whether or not the bolt threads and/or bolt toggle or spring slot are to be included in the shear plane. If the bolt threads and/or bolt toggle or spring slot are to be included in the shear plane, then A_{vc} shall be adjusted accordingly.

4.4.1.3 Test Setup: The testing apparatus and setup shall be in accordance with the requirements set forth in Section 4.1 for the static testing protocol except that the thickness of all plates shall be sufficient to preclude plate buckling under compression loading. A load cell actuator shall be provided that is capable of inducing cyclic motion on the test assembly such that forces can be applied continuously in a positive (support plates are loaded in compression) and negative (support plates are loaded in tension) direction.

4.4.1.4 Loading Protocols: Loading cycles for shear testing shall be determined and applied in accordance with the cyclic pattern shown in Figure 67. Each cycle consists of a positive and negative excursion, where an excursion is defined by a load or deformation history unit that starts and finishes at zero load, and contains a loading and unloading branch.

4.4.1.5 Conditions of Acceptance: Each test shall successfully complete the cyclic loading sequence described in Figure 67, including the final three cycles at the target ultimate shear strength determined per Section 4.4.1.1, which shall be reported as the unadjusted tested cyclic shear (bearing) capacity of the replicate bolt specimens. No test shall be eliminated unless a rationale for its exclusion is given.

4.4.1.6 Reporting: The deflection at peak load of each excursion shall be reported.

4.4.2 Cyclic Shear Test for Slip-Critical Connections with Expansion Bolts (Optional):

4.4.2.1 Target Slip-Friction Shear Strength, V_{FT}: A target slip-friction shear strength, V_{FT}, for each bolt diameter and for each bolt length, shall be equal to the average value of the unadjusted tested shear friction strengths of replicate specimens, derived from the static slip friction tests in accordance with Section 4.2.

The target slip-friction shear strength, V_{FT}, determined by the evaluation report applicant, as noted above, must be used as N3 in Figure 78 and declared as the pass criteria. However, if there is failure at N3, then a lower value of V_{FT} must be chosen that can pass all the required cycles. This value is then used to determine LRFD and ASD values for seismic resistance under SDC D, E or F in accordance with Sections 3.4 and 3.5.

4.4.2.2 Test Setup: The testing apparatus and setup shall be in accordance with the requirements stated in Section 4.2 for the static testing protocol except that the thickness of all plates shall be sufficient to preclude plate buckling under compression loading. A load cell actuator shall be provided that is capable of inducing cyclic motion on the test assembly such that forces can be applied continuously in a positive (support plates are loaded in compression) and negative (support plates are loaded in tension) direction.

4.4.2.3 Loading Protocol: Loading cycles for slip-friction testing shall be determined and applied in accordance with the cyclic pattern shown in Figure 78. Each cycle consists of a positive and negative excursion, where an excursion is defined by a load or deformation history unit that starts and finishes at zero load, and contains a loading and unloading branch.

4.4.2.4 Condition of Acceptance: Each test shall successfully complete the cyclic loading sequence described in Figure 78, including the final three cycles at the target slip-friction shear strength determined per Section 4.4.2.1, which shall be reported as the unadjusted tested cyclic slip-friction shear capacity of the replicate bolt specimens. No test shall be eliminated unless a rationale for its exclusion is given.

4.4.2.5 Reporting: The deflection at peak load of each excursion shall be reported.

4.4.3 Cyclic Tension Test (Optional):

4.4.3.1 Target Ultimate Tension Strength, T_{UT}: A target ultimate tension strength, T_{UT}, for each bolt diameter and for each bolt length, shall be determined by the evaluation report applicant, which shall be larger than the target yield tension strength determined per Section 4.4.3.2 of this criteria, and shall be smaller than the static tension strength, which shall be the average of the unadjusted tested capacities of the replicate bolt specimens with the same bolt length, determined from the static tests in accordance with Section 4.3.

The target ultimate tension strength, $T_{UT,}$ determined by the evaluation report applicant, as noted above, must be used as N5 in Figure 8 9 and declared as the pass criteria. However, if there is failure at N5, then a lower value of T_{UT} must be chosen that can pass all the required cycles. This value is then used to determine LRFD and ASD values for seismic resistance under SDC D, E or F in accordance with Sections 3.4 and 3.5.

4.4.3.2 Target Yield Tension Strength, T_{YT}: A target yield tension strength, T_{yt}, shall be set equal to the observed yield tension strength, T_y, obtained from the force-displacement plot in the static test as shown in Figure 56. The observed tension yield strength shall be associated with significant tension yielding observed in the critical region of the test specimen, which should be reflected by a clear nonlinearity in the control force-deformation relationship. If a clear transition point from linearity to nonlinearity cannot be determined, then the target tension yield strength shall be computed as follows:

$$T_{yt} = A_{nc}F_{yc}$$

where: A_{nc} is the effective tensile cross-sectional area of the core of expansion bolt or the bolt of the gravity or spring-operated blind bolt based on specified dimensions, and F_{yc} is the specified yield strength of the core of the expansion bolt or the bolt of the gravity or spring-operated blind bolt.

4.4.3.3 Test Setup: The testing apparatus and setup shall be in accordance with the requirements set forth in Section 4.3 for the static testing protocol. A load cell actuator shall be provided that is capable of inducing cyclic motion on the test assembly such that forces can be applied continuously in the tension loading and unloading directions.

4.4.3.4 Loading Protocol: Loading cycles for tension testing shall be determined and applied in accordance with the cyclic pattern shown in Figure 89. Each cycle consists of a positive excursion, where an excursion is defined by a load or deformation history unit that starts and finishes at zero load, and contains a loading and unloading branch.

4.4.3.5 Condition of Acceptance: Each test shall successfully complete the cyclic loading sequence described in Figure 89, including the final three cycles at the target ultimate tension strength determined per Section 4.4.3.1, which shall be reported as the unadjusted tested cyclic tension capacity of the replicate bolt specimens. No test shall be eliminated unless a rationale for its exclusion is given.

4.4.3.6 Reporting: The deflection at peak load of each excursion shall be reported.

4.5 Product Identification:

4.5.1 The following characteristics shall be checked by the independent testing laboratory for conformance to the drawings and specifications:

- Critical dimensions
- Surface finishes
- Coatings
- Fabrication techniques
- Markings

4.5.2 Constituent Materials: Critical constituent materials shall be checked by the testing laboratory for conformance to mechanical and chemical specifications using testing conducted in accordance with applicable procedures such as ASTM A370 and ASTM F606. The results shall be used to adjust tested capacities in accordance with Section 3.5 of this criteria.

4.6 Fatigue Resistance Test (Optional): Fatigue testing shall be conducted as outlined in NCHRP Report 402 and EN 1993-1-9 and this section.

4.6.1 General:

4.6.1.1 Number of Tests: A minimum of ten tests for each bolt diameter shall be tested and statistically evaluated and for each applicable loading condition. The load levels for each test shall vary, but shall not be less than 10,000 load cycles. The intended load levels shall be described in the approved qualification test plan.

4.6.1.2 Test Setup: See Section 4.6.2 or 4.6.3, as applicable, and the following: A load cell actuator shall be provided that is capable of inducing cyclic loading on the test assembly such that forces can be applied continuously in a positive and negative direction.

4.6.1.3 Edge Distances: Minimum distances from the ~~sleeve~~ shell of the expansion bolt to the edges of the connected elements shall be in accordance with Section J3 of AISC 360 for structural steel and Section J3 of AISI S100 for cold-formed steel.

4.6.1.4 Bolt Installation: Bolt installation shall be in accordance with the applicant's installation instructions.

4.6.1.5 Loading Protocols: See Sections 4.6.2 and 4.6.3 and the following:

1. All tests shall be performed as force controlled constant amplitude fatigue tests at a fixed stress ratio R=0.1. The frequency shall be set on the basis of speed of testing and optimization of the laboratory testing machine's hydraulic system.
2. Each test shall start and continue without interruption until fatigue failure of at least one of the bolts in the assembly is recorded or the required number of load cycles is exceeded (runout).

4.6.1.6 Reporting: The applied load range, number of cycles to failure or runout, failure mode and any loosening of the bolts shall be reported for each test.

4.6.2 Shear (Bearing) Fatigue Resistance Test: The bolt shall be installed in a two bolt, double shear joint assembly with load applied to the central plates as shown in Figure ~~9~~ 10 to ensure that secondary bending is excluded from the test. The plates shall be sufficiently rigid to preclude plate buckling under compression loading. The bolt length shall be selected accordingly, based on the required clamping dimension.

Strain gauges shall be placed on the centroid of the external test plates to measure any bending in the steel plates. This will give an indication of the test specimen behavior with respect to the elastic/inelastic region and crack initiation and shall be documented in the test report.

The load level for each shear (bearing) test shall be in accordance with the approved qualification test plan. Each cycle shall consist of a of a positive and negative excursion that starts and finishes at zero as shown in Figure ~~11~~12.

4.6.3 Tension Fatigue Resistance Test: The blind bolts shall be installed in a two-bolt assembly consisting of two T-stubs connected with two blind bolts, each one placed in the centroid of each T-stub flange as shown in Figure ~~10~~11. The symmetry of the test set up shall exclude any secondary bending.

Strain gauges shall be positioned on the two sides of the upper T-stub web to measure any bending in the steel plates. This will give an indication of the test specimen behavior with respect to the elastic/inelastic region and crack initiation and will be documented in the test report.

The load level for each tension test shall be in accordance with the approved qualification test plan. Each cycle shall consist of a zero to positive and positive to zero excursion as shown in Figure ~~12~~13.

5.0 QUALITY CONTROL

5.1 Manufacturing: The blind bolts shall be manufactured under an approved quality control program with inspections by ICC-ES or by a properly accredited inspection agency that has a contractual relationship with ICC-ES. A qualifying inspection shall be conducted at each manufacturing facility when required by the ICC-ES Acceptance Criteria for Inspections and Inspection Agencies (AC304).

5.2 Quality Control Documentation: Quality control documentation complying with the ICC-ES Acceptance Criteria for Quality Documentation (AC10) shall be submitted.

5.3 Special Inspection: Special inspection is required in accordance with IBC Sections 1704.3, 1705.1.1 and 1705.2 (2009 IBC Sections 1704.3, 1704.15 and 1705, as applicable). Where bolts are used for seismic or wind load resistance, special inspection shall comply with 2021 IBC Sections 1705.12, 1705.13 and 1705.14 (2018 and 2015 IBC Sections 1705.11, 1705.12 and 1705.13, 2012 IBC Sections 1705.10, 1705.11 and 1705.12; 2009 IBC Sections 1706, 1707 and 1708) as applicable~~)~~.

6.0 EVALUATION REPORT REQUIREMENTS

6.1 The evaluation report shall address only tested products and identify the nominal or available strength for each tested blind bolt diameter and bolt strength.

6.2 The evaluation report shall include the following information:

6.2.1 Information described in Section 2.1 of this criteria.

6.2.2 ASD allowable strengths or LRFD design strengths in bearing-type connections for resisting static dominant loads including gravity, wind and seismic loads in structures assigned to SDC of A, B or C, as determined in accordance with Sections 3.0, 4.1, 4.3 and 4.5 of this criteria, and available strengths in slip-critical connections or available strengths for seismic resistance in structures assigned to SDC D, E or F, if additional data in accordance with Table 2 of this criteria justifying the corresponding additional evaluation is submitted.

6.2.3 Steel structures utilizing blind bolts addressed in the evaluation report must be designed in accordance with the IBC including its referenced standards (such as AISC 360 ~~and~~, AISC 341, and AISI S100), and the evaluation report, and must be installed in accordance with the evaluation report and the report holder's installation instructions. In case of a conflict between the evaluation report and the report holder's installation instructions, the most restrictive requirement governs.

6.2.4 Calculations and details, justifying the use of blind bolts is in compliance with the applicable code and the evaluation report, including showing that the blind bolts, the connected steel base materials and the connecting steel elements are adequate to resist the applied loads, must be submitted to the code official for approval. The calculations and details must be signed and sealed by a registered design professional, when required by the statutes of the jurisdiction in which the project is to be constructed.

6.2.5 Fire-resistive Construction: Where not otherwise prohibited in the code, blind bolts are permitted for use with fire-resistance rated construction provided that at least one of the following conditions is fulfilled:

- Blind bolts are used to resist wind, seismic or fatigue loads only.
- Blind bolts that support a fire-resistance-rated envelope or a fire-resistance-rated membrane, are protected by approved fire-resistance-rated materials, or have been evaluated for resistance to fire exposure in accordance with recognized standards.
- Blind bolts are used to support nonstructural elements.

6.2.6 Special Inspection: Special inspection requirements as described in Section 5.3 of this criteria shall be included in the evaluation report.

6.2.7 Information on combined loading as described in Section 3.11 of this criteria shall be noted in the evaluation report.

6.2.8 If a blind bolt of specific diameter is qualified for application in SDCs of D, E and F, in accordance with Sections 3.0 and 4.4 of this criteria, the evaluation report shall state that the blind bolt is intended to be used as a force-controlled component and is not expected to undergo significant inelastic deformation, and the registered design professional shall consider this forced-controlled behavior in his design.

6.3 When fatigue resistance is evaluated in accordance with Sections 3.0 and 4.6, the evaluation report shall include the following:

6.3.1 A requirement that the design for fatigue be in accordance with Appendix 3 of AISC 360 (Chapter M of AISI S100 for cold-formed steel connections) when the expected number of cycles of application of live load exceeds 10,000.

6.3.2 The applicable Stress Category and associated C_f and F_{TH} values needed to determine the allowable stress range, F_{SR}, in accordance with Section 3.4 of Appendix 3 of AISC 360 (Chapter M of AISI S100 for cold-formed steel connections). At the applicant's option, values of F_{SR} may be reported for specific values of n_{SR}, based on the applicable Stress Category.

7.0 ENVIRONMENTAL PRODUCT DECLARATION (Optional):

Environmental impacts shall be assessed via an Environmental Product Declaration (EPD) based on a Life Cycle Assessment (LCA). The LCA and EPD shall be conducted in accordance with ISO 21930 and the appropriate Product Category Rule(s) for the product type.■

TABLE 1—APPLICABLE EDITIONS OF REFERENCED STANDARDS

REFERENCED STANDARD	STANDARD EDITION					
	2024 IBC	2021 IBC	2018 IBC	2015 IBC	2012 IBC	2009 IBC
AISC 341	-22	-16	-16	-10	-10	-05
AISC 348	-20	-14	-14	-09	-09	-04
AISC 360	-22	-16	-16	-10	-10	-05
AISI S100	-16(2020)/S2-20	-16(2020)/S2-20	-16	-12	-07/S2-10	-07
AISI S240	-20	-20	-15	N/A	N/A	N/A
AISI S905	-17	-17	-17	-13	-08	-08
ASCE/SEI 7	-16 with Supplement 1	-16 with Supplement 1	-16	-10 with Supplement 1	-10	-05
ASTM A370	-23	-15	-15	-12a	-12a	-12a
ASTM F606	-21	-14a	-14a	-11a	-11a	-11a

TABLE 2—REQUIRED AND OPTIONAL QUALIFICATIONS AND ASSOCIATED TESTING REQUIREMENTS[1]

REQUIRED TESTING (SECTION NUMBERS)[~~5~~]	OPTIONAL TESTING (SECTION NUMBERS)[~~5~~]	EXTENT OF REPORTED VALUES
4.1 – Static shear (bearing)[1] 4.3 – Static tension[1] 4.5 – Component Properties		Blind bolt strengths in bearing-type connections for resisting static dominant loads [gravity, wind and seismic loads in structures assigned to Seismic Design Category (SDC) A, B or C].
	4.2 – Static shear (slip-critical)[~~2~~3]	Blind bolt strengths in slip-critical connections for resisting static dominant loads.
	4.4.3 – Cyclic tension	Blind bolt strengths in bearing-type or slip-critical type connections for resisting seismic loads in structures assigned to SDC D, E or F.
	4.4.1 – Cyclic shear (bearing)	Blind bolt strengths in bearing-type connections for resisting seismic loads in structures assigned to SDC D, E or F.
	4.4.2 – Cyclic shear (slip-critical)[~~1,~~2,3]	Blind bolt strengths in slip-critical connections for resisting seismic loads in structures assigned to SDC D, E or F.
	4.6 – Fatigue[~~2~~4]	Blind bolt strengths in bearing-type connections subject to fatigue.

[1]Static shear (bearing) and static tension can be tested in structural steel connections or cold-formed steel connections.
[~~1~~]~~Only~~ [2]Only available for blind bolts that have been evaluated for static slip-critical shear connections.
[~~2~~]~~Available~~ [3]Available for expansion bolts only. Gravity, ~~or~~ spring-operated, or reverse expansion bolts ~~bolts~~ are not eligible for qualification of slip-critical connections. ~~or for qualification of bearing connections subject to fatigue loading~~.
[4]Available for expansion and reverse expansion bolts only. Gravity or spring-operated bolts are not eligible for qualification of bearing connections subject to fatigue loading.

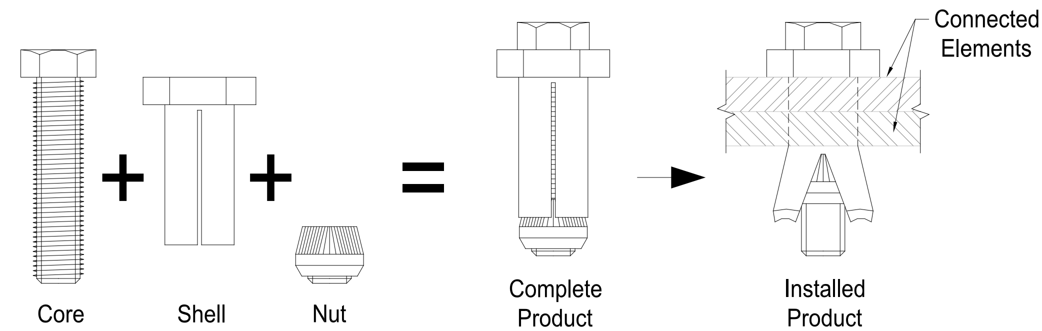


FIGURE 1—EXPANSION BOLT TYPICAL COMPONENTS

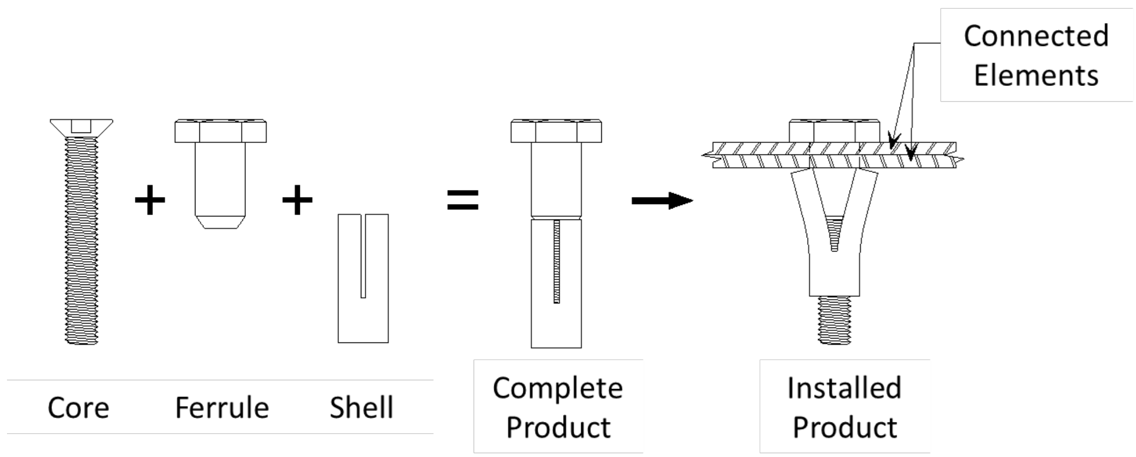


FIGURE 2—REVERSE EXPANSION BOLT TYPICAL COMPONENTS

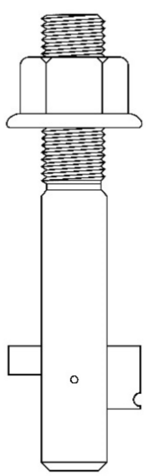


FIGURE ~~2a~~3a—GRAVITY OPERATED BOLT

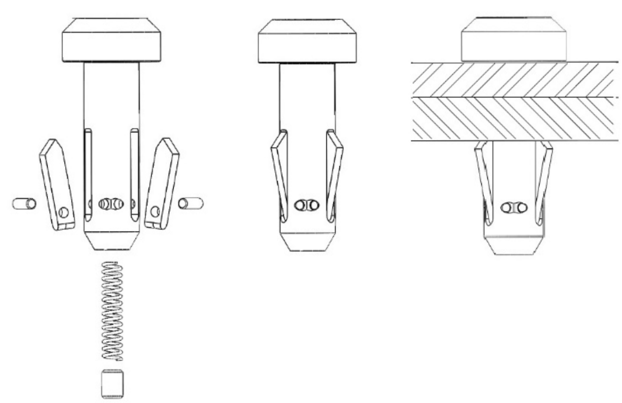


FIGURE ~~2b~~3b—SPRING-OPERATED BOLT

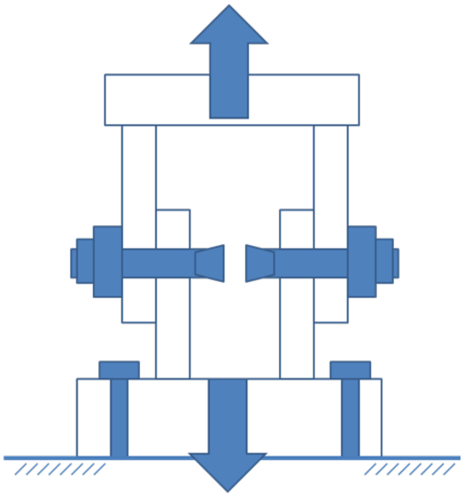


FIGURE ~~3~~4—STATIC SHEAR TEST ASSEMBLY

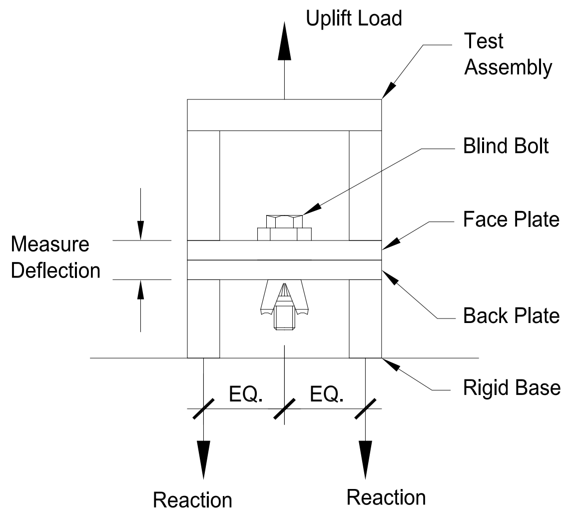


FIGURE ~~4~~5—STATIC TENSION TEST ASSEMBLY

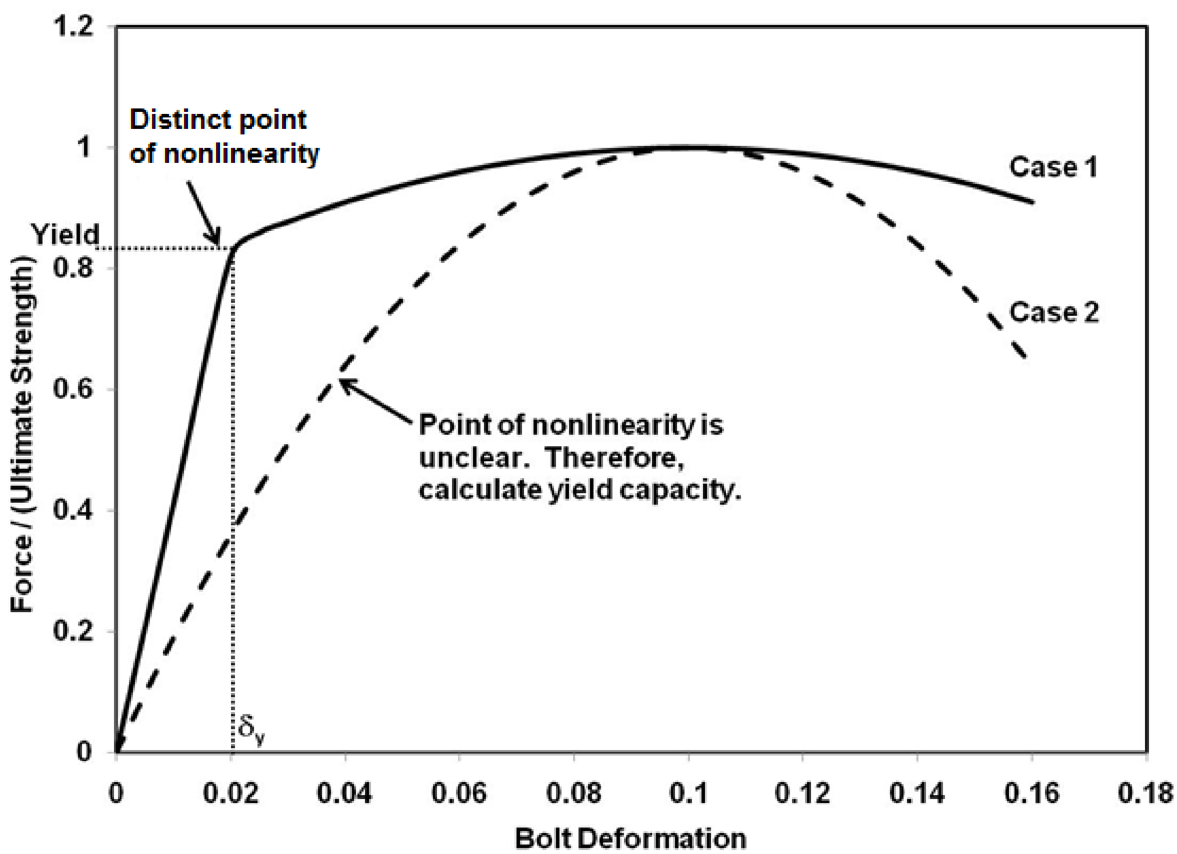
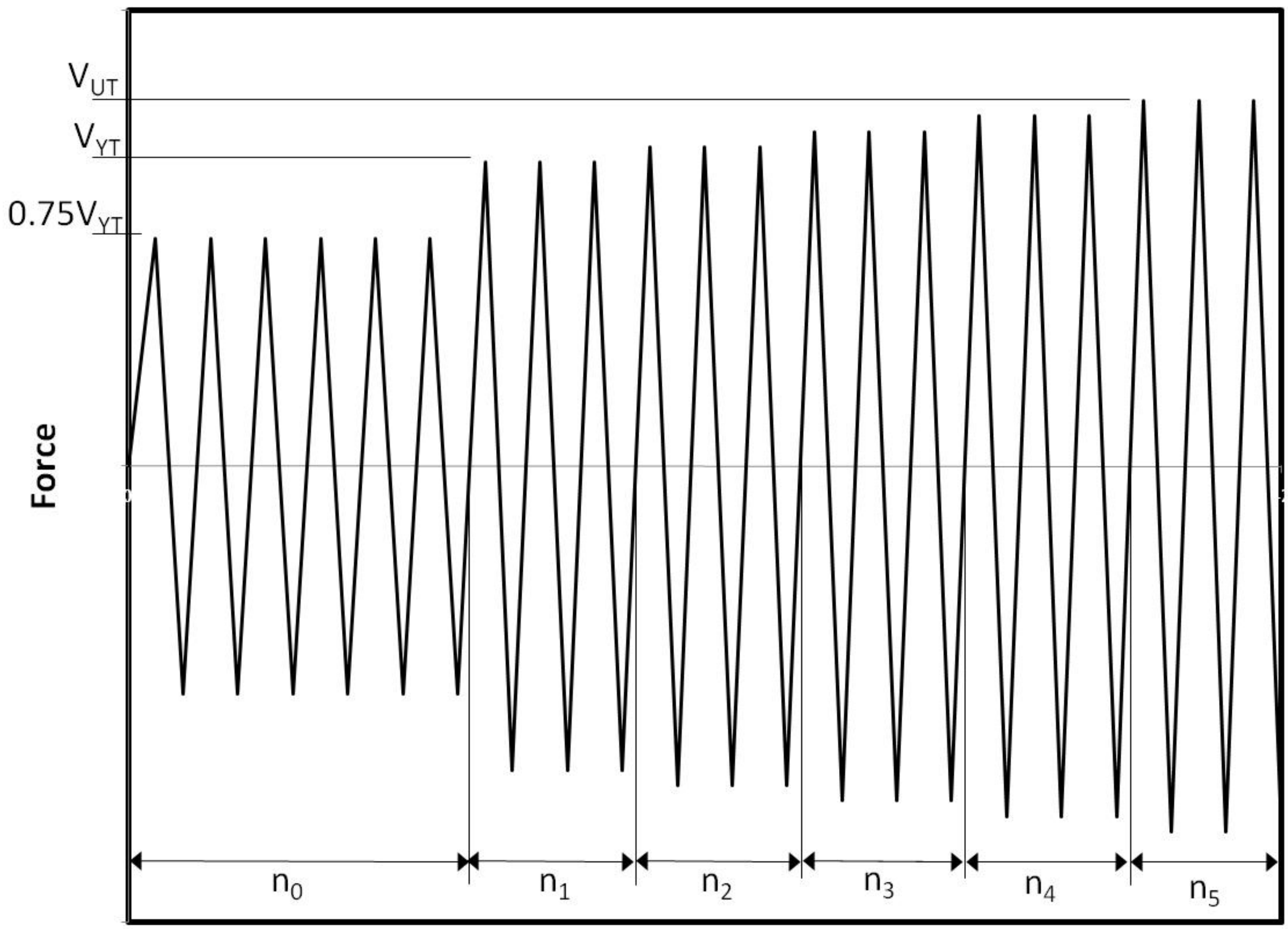
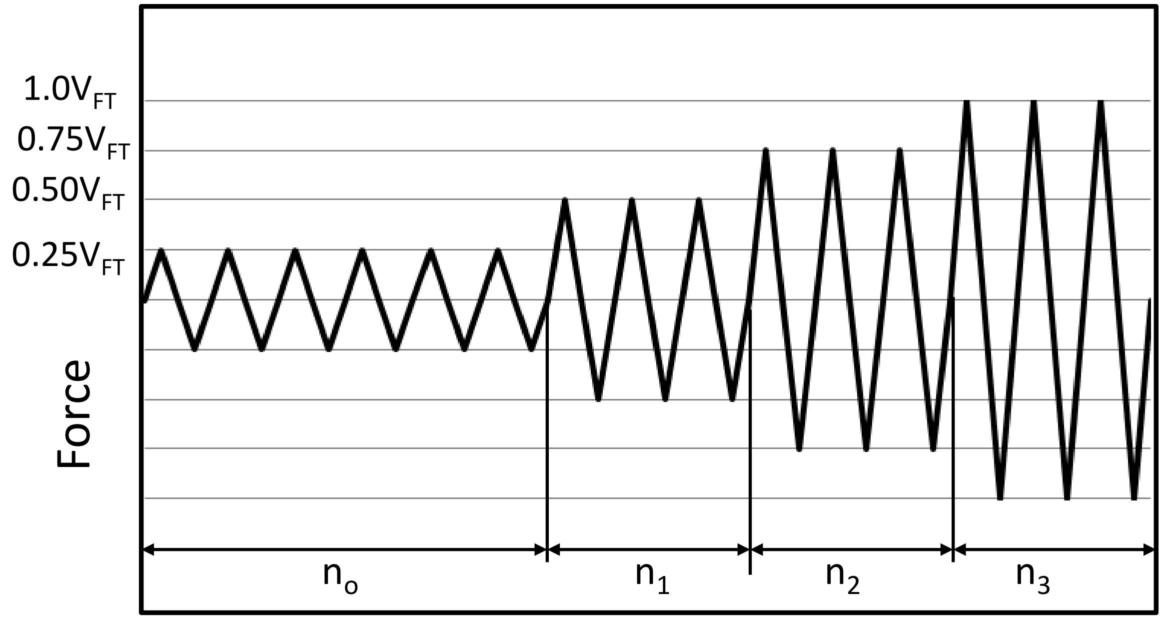


FIGURE ~~5~~6—EXAMPLE CASES OF FORCE-DEFORMATION PLOTS ILLUSTRATING CLEAR AND UNCLEAR POINTS OF NON-LINEARITY



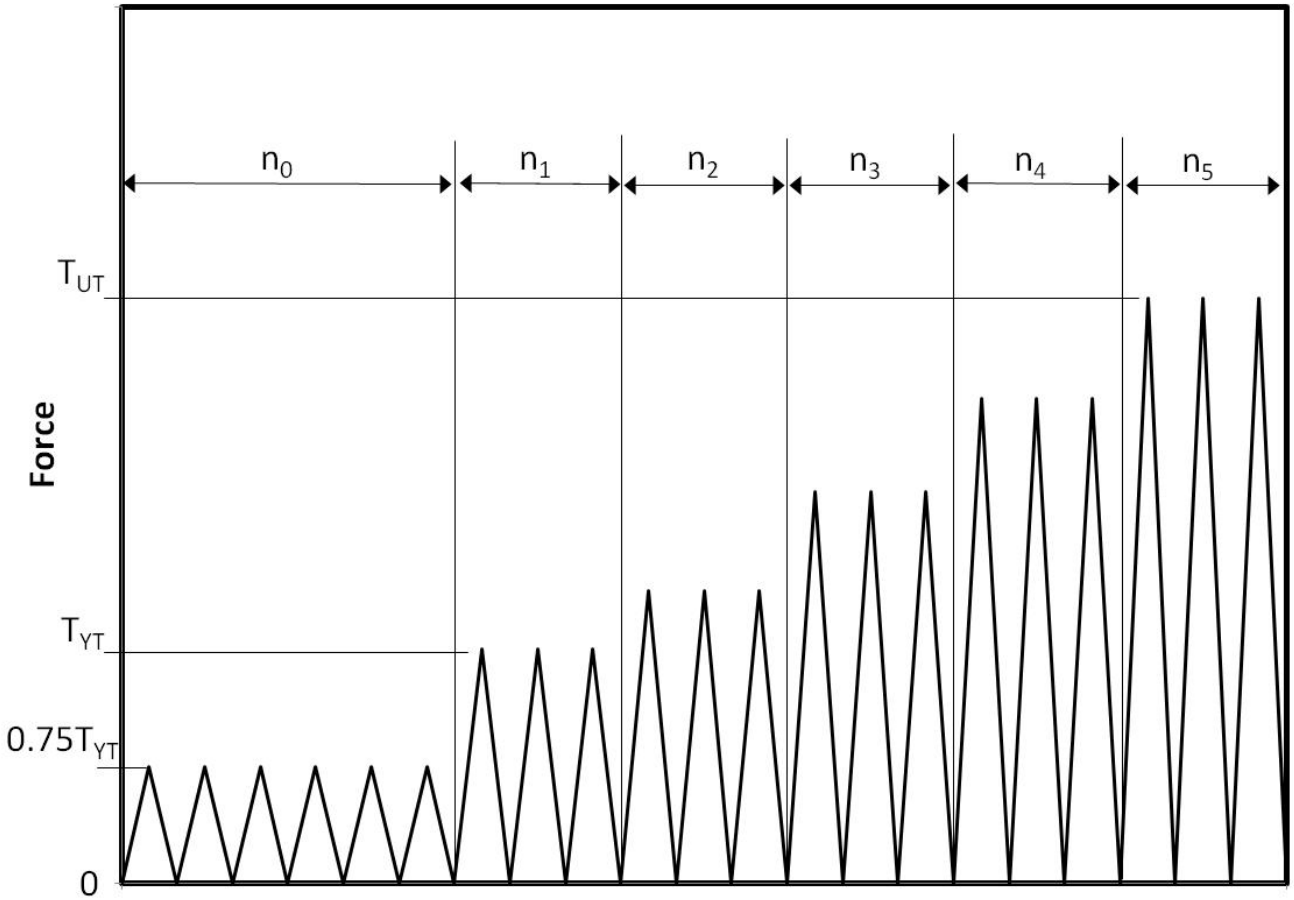
Load Pattern	Number of Cycles	Applied Shear Load
N0	6	$0.75V_{YT}$
N1	3	$1.0V_{YT}$
N2	3	$V_{YT} + 0.25(V_{UT} - V_{YT})$
N3	3	$V_{YT} + 0.50(V_{UT} - V_{YT})$
N4	3	$V_{YT} + 0.75(V_{UT} - V_{YT})$
N5	3	V_{UT}

FIGURE 67—CYCLIC LOADING PATTERN FOR SHEAR (BEARING) TESTING



Load Pattern	Number of Cycles	Applied Slip Friction Shear Load
n_0	6	$0.25V_{FT}$
n_1	3	$0.50V_{FT}$
n_2	3	$0.75V_{FT}$
n_3	3	$1.0V_{FT}$

FIGURE ~~7~~8—CYCLIC LOADING PATTERN FOR SLIP-FRICTION SHEAR TESTING



Load Pattern	Number of Cycles	Applied Tension Load
n_0	6	$0.75T_{YT}$
n_1	3	$1.0T_{YT}$
n_2	3	$T_{YT} + 0.25(T_{UT} - T_{YT})$
n_3	3	$T_{YT} + 0.50(T_{UT} - T_{YT})$
n_4	3	$T_{YT} + 0.75(T_{UT} - T_{YT})$
n_5	3	T_{UT}

FIGURE ~~8~~9—CYCLIC LOADING PATTERN FOR TENSION TESTING

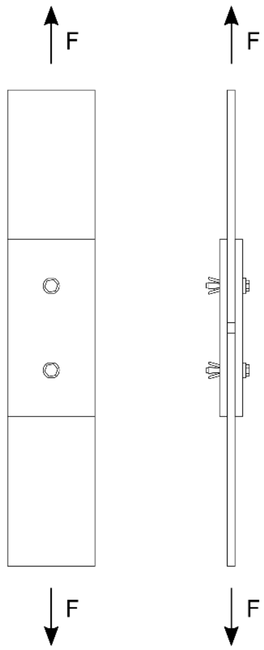


FIGURE ~~9~~10—FATIGUE SHEAR TEST ASSEMBLY

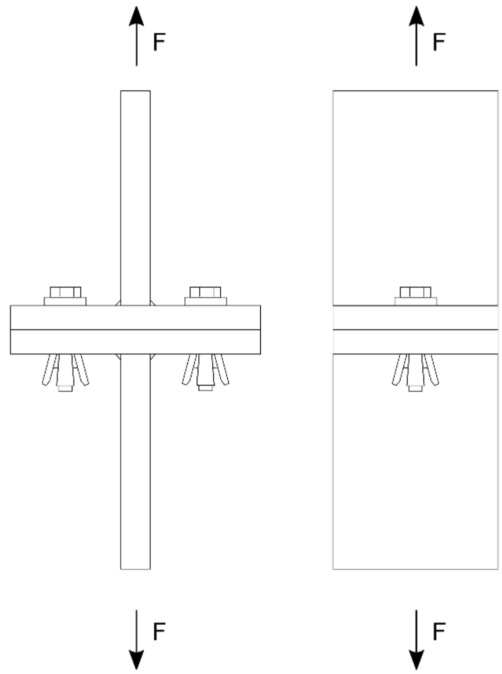


FIGURE ~~10~~9— FATIGUE TENSION TEST ASSEMBLY

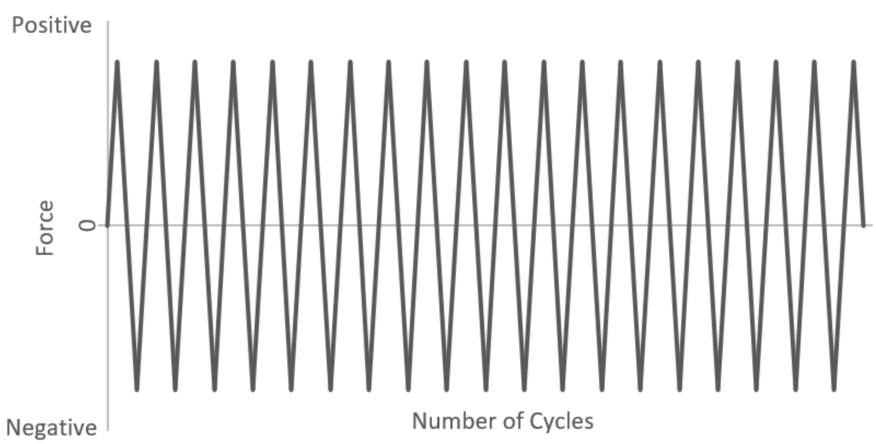


FIGURE ~~11~~12—FATIGUE LOADING PATTERN FOR SHEAR TESTING

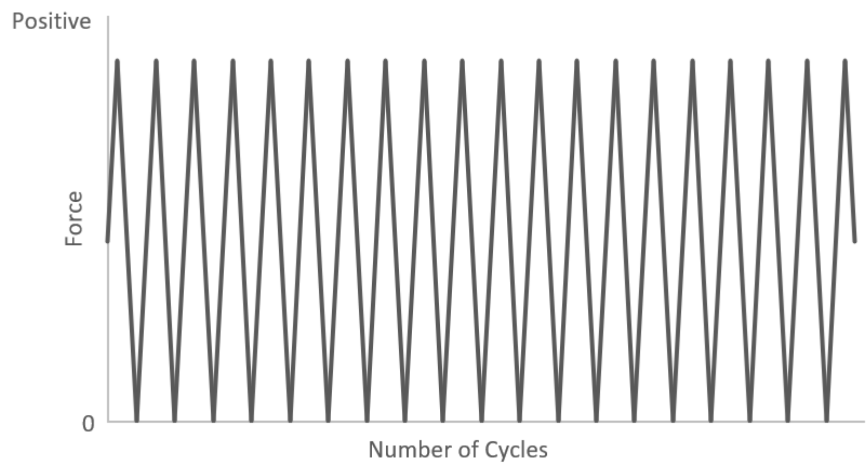


FIGURE ~~12~~13—FATIGUE LOADING PATTERN FOR TENSION TESTING

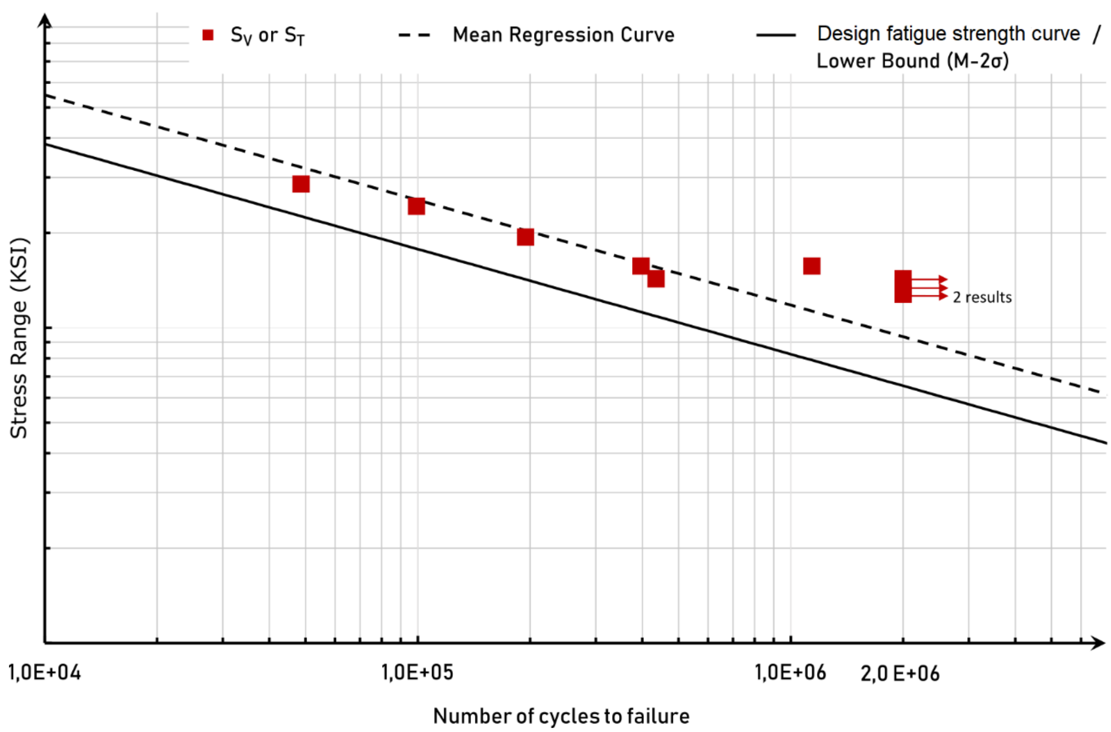


FIGURE ~~13~~14—EXAMPLE OF A LOG-LOG SCALE, MEAN REGRESSION LINE AND REPRESENTATIVE S-N CURVE