Specification for Structural Joints Using ASTM A325 or A490 Bolts

June 30, 2004

Supersedes the June 23, 2000 *Specification for Structural Joints Using ASTM A325 or A490 Bolts.*

Prepared by RCSC Committee A.1—Specifications and approved by the Research Council on Structural Connections.

RESEARCH COUNCIL ON STRUCTURAL CONNECTIONS
www.boltcouncil.org

c/o American Institute of Steel Construction, Inc.
One East Wacker Drive, Suite 3100, Chicago, Illinois 60601-2001

AVA Documents
Document Sharing Hub

Full document details: AISC S334L 2004

Copyright © 2004

by

Research Council on Structural Connections

All rights reserved. This book or any part thereof
must not be reproduced in any form without
the written permission of the publisher.

The information presented in this publication has been prepared in accordance with recognized engineering principles and is for general information only. While it is believed to be accurate, this information should not be used or relied upon for any specific application without competent professional examination and verification of its accuracy, suitability, and applicability by a licensed engineer, architect or other design professional. The publication of the material contained herein is not intended as a representation or warranty on the part of the Research Council on Structural Connections or of any other person named herein, that this information is suitable for any general or particular use or of freedom from infringement of any patent or patents. Anyone making use of this information assumes all liability arising from such use.

Caution must be exercised when relying upon other specifications and codes developed by other bodies and incorporated by reference herein since such material may be modified or amended from time to time subsequent to the printing of this edition. The Research Council on Structural Connections bears no responsibility for such material other than to refer to it and incorporate it by reference at the time of the initial publication of this edition.

Printed in the United States of America

Documents
Document Sharing Hub

Full document details: AISC S334L 2004

PREFACE

The purpose of the Research Council on Structural Connections (RCSC) is:

(1) To stimulate and support such investigation as may be deemed necessary and valuable to determine the suitability, strength and behavior of various types of structural connections;
(2) To promote the knowledge of economical and efficient practices relating to such structural connections; and,
(3) To prepare and publish related standards and such other documents as necessary to achieving its purpose.

The Council membership consists of qualified structural engineers from academic and research institutions, practicing design engineers, suppliers and manufacturers of fastener components, fabricators, erectors and code-writing authorities.

The first Specification approved by the Council, called the *Specification for Assembly of Structural Joints Using High Tensile Steel Bolts*, was published in January 1951. Since that time the Council has published fifteen successive editions. Each was developed through the deliberations and approval of the full Council membership and based upon past successful usage, advances in the state of knowledge and changes in engineering design practice. This edition of the Council's *Specification for Structural Joints Using ASTM A325 or A490 Bolts* continues the tradition of earlier editions. The major changes are:

- Sections 5.1, 5.2, and 5.3 were editorially revised to clarify strength requirements of slip critical connections.
- Section 6.2.1 was modified to permit the use of A490 type bolts, with round heads equal or larger in diameter than ASTM F1852 heads, without F436 hardened washers.
- Table 6.1, footnote d, was added to clarify use of non-hardened plate washer to be used in conjunction with an ASTM F436 hardened washer.
- Commentary Table C-2.1 bolt head and nut dimension locations F and W as shown in the artwork Figure C-2.2 was corrected.

In addition, typographical changes have been made throughout this Specification.

By the Research Council on Structural Connections,

Raymond H. R. Tide Chairman	Geoffrey L. Kulak Vice Chairman	Emile W. J. Troup Secretary/Treasurer
Abolhassan Astaneh-Asl Joseph G. Bahadrian Peter C. Birkemoe	David W. Bogaty Charles J. Carter Helen Chen	Robert J. Connor Nick E. Deal Robert J. Dexter

Continued on page iv.

AVA Documents
Document Sharing Hub
Full document details: AISC S334L 2004

Robert O. Disque
James M. Doyle
G. Dean Droddy
Edward R. Estes, Jr.
John W. Fisher
Karl H. Frank
Michael C. Friel
Rodney D. Gibble
Michael I. Gilmor
Gilbert Y. Grondin
Roger D. Hamilton
Allen J. Harrold
Ian C. Hodgson
Mark V. Holland
Donald L. Johnson
Charles E. Hundley
Kaushik A. Iyer
Peter F. Kasper
Lawrence A. Kloiber
Peter Kneen
Richard F. Knoblock
Chad M. Larson
Daeyong Lee
Jean-Claude Legault
Kenneth B. Lohr
Richard W. Marshall
Jonathan C. McGormley
David L. McKenzie
Greg Miazga
William A. Milek, Jr.
Eugene R. Mitchell
Heath E. Mitchell
William H. Munse
Thomas M. Murray
Rex V. Owen
Frederick J. Palmer
Andrew E. Pfeifer
Thomas J. Schlafly
Gerald E. Schroeder
David F. Sharp
Robert E. Shaw, Jr.
W. Lee Shoemaker
James A. Swanson
Arun A. Syam
Thomas S. Tarpy, Jr.
William A. Thornton
Floyd J. Vissat
I. Wayne Wallace
Charles J. Wilson
Ted W. Winneberger
Joseph A. Yura

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

TABLE OF CONTENTS

SYMBOLS . . . . . **vii**
GLOSSARY . . . . . **ix**

SECTION 1. GENERAL REQUIREMENTS **1**
1.1. Scope 1
1.2. Loads, Load Factors and Load Combinations 1
1.3. Referenced Standards and Specifications 2
1.4. Drawing Information 3

SECTION 2. FASTENER COMPONENTS **5**
2.1. Manufacturer Certification of Fastener Components 5
2.2. Storage of Fastener Components 5
2.3. Heavy-Hex Structural Bolts 6
2.4. Heavy-Hex Nuts 12
2.5. Washers 13
2.6. Washer-Type Indicating Devices 13
2.7. Twist-Off-Type Tension-Control Bolt Assemblies 14
2.8. Alternative-Design Fasteners 14

SECTION 3. BOLTED PARTS **16**
3.1. Connected Plies 16
3.2. Faying Surfaces 16
3.3. Bolt Holes 20
3.4. Burrs 22

SECTION 4. JOINT TYPE **23**
4.1. Snug-Tightened Joints 25
4.2. Pretensioned Joints 25
4.3. Slip-Critical Joints 26

SECTION 5. LIMIT STATES IN BOLTED JOINTS **28**
5.1. Design Shear and Tensile Strengths 29
5.2. Combined Shear and Tension 32
5.3. Design Bearing Strength at Bolt Holes 32
5.4. Design Slip Resistance 34
5.5. Tensile Fatigue 38

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

SECTION 6. USE OF WASHERS 40
6.1. Snug-Tightened Joints 40
6.2. Pretensioned Joints and Slip-Critical Joints 40

SECTION 7. PRE-INSTALLATION VERIFICATION 43
7.1. Tension Calibrator 43
7.2. Required Testing 43

SECTION 8. INSTALLATION 46
8.1. Snug-Tightened Joints 46
8.2. Pretensioned Joints 46

SECTION 9. INSPECTION 53
9.1. Snug-Tightened Joints 53
9.2. Pretensioned Joints 53
9.3. Slip-Critical Joints 56

SECTION 10. ARBITRATION 57

APPENDIX A. TESTING METHOD TO DETERMINE THE SLIP COEFFICIENT FOR COATINGS USED IN BOLTED JOINTS 59

APPENDIX B. ALLOWABLE STRESS DESIGN (ASD) ALTERNATIVE 70

REFERENCES 75

INDEX 77

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

SYMBOLS

The following symbols are used in this Specification.

A_b Cross-sectional area based upon the nominal diameter of bolt, in.^{2}

D Slip probability factor as described in Section 5.4.2

D_u Multiplier that reflects the ratio of the mean installed bolt pretension to the specified minimum bolt pretension T_m as described in Section 5.4.1

F_n Nominal strength (per unit area), ksi

F_u Specified minimum tensile strength (per unit area), ksi

I Moment of inertia of the built-up member about the axis of buckling (see the Commentary to Section 5.4), in.^{4}

L Total length of the built-up member (see the Commentary to Section 5.4), in.

L_c Clear distance, in the direction of load, between the edge of the hole and the edge of the adjacent hole or the edge of the material, in.

N_b Number of bolts in the joint

P_u Required strength in compression, kips; Axial compressive force in the built-up member (see the Commentary to Section 5.4), kips

Q First moment of area of one component about the axis of buckling of the built-up member (see the Commentary to Section 5.4), in.^{3}

R_n Nominal strength, kips

R_s Service-load slip resistance, kips

T Applied service load in tension, kips

T_m Specified minimum bolt pretension (for pretensioned joints as specified in Table 8.1), kips

T_u Required strength in tension (factored tensile load), kips

V_u Required strength in shear (factored shear load), kips

d_b Nominal diameter of bolt, in.

t Thickness of the connected material, in.

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

t' Total thickness of fillers or shims (see Section 5.1), in.

k_s Slip coefficient for an individual specimen determined in accordance with Appendix A

ϕ Resistance factor

ϕR_n Design strength, kips

μ Mean slip coefficient

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

GLOSSARY

The following terms are used in this Specification. Where used, they are italicized to alert the user that the term is defined in this Glossary.

Coated Faying Surface. A *faying surface* that has been primed, primed and painted or protected against corrosion, except by hot-dip galvanizing.

Connection. An assembly of one or more *joints* that is used to transmit forces between two or more members.

Contractor. The party or parties responsible to provide, prepare and assemble the fastener components and connected parts described in this Specification.

Design Strength. ϕR_n, the resistance provided by an element or *connection*; the product of the *nominal strength* R_n and the resistance factor ϕ.

Engineer of Record. The party responsible for the design of the structure and for the approvals that are required in this Specification (see Section 1.4 and the corresponding Commentary).

Fastener Assembly. An assembly of fastener components that is supplied, tested and installed as a unit.

Faying Surface. The plane of contact between two plies of a *joint*.

Firm Contact. The condition that exists on a *faying surface* when the plies are solidly seated against each other, but not necessarily in continuous contact.

Galvanized Faying Surface. A *faying surface* that has been hot-dip galvanized.

Grip. The total thickness of the plies of a *joint* through which the bolt passes, exclusive of washers or direct-tension indicators.

Guide. The *Guide to Design Criteria for Bolted and Riveted Joints*, 2nd Edition (Kulak et al., 1987).

High-Strength Bolt. An ASTM A325 or A490 bolt, an ASTM F1852 twist-off-type tension-control bolt or an alternative-design fastener that meets the requirements in Section 2.8.

Inspector. The party responsible to ensure that the *contractor* has satisfied the provisions of this Specification in the work.

Joint. A bolted assembly with or without collateral materials that is used to join two structural elements.

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

Lot. In this Specification, the term *lot* shall be taken as that given in the ASTM Standard as follows:

Product	ASTM Standard	See Lot Definition in Section
Bolts	A325	9.4
	A490	11.3.2 or 11.4.2
Twist-off-type tension control bolt assemblies	F1852	13.4
Nuts	A563	9.2
Washers	F436	9.2
Compressible-washer-type direct tension indicators	F959	10.2.2

Manufacturer. The party or parties that produce the components of the *fastener assembly*.

Mean Slip Coefficient. μ, the ratio of the frictional shear load at the *faying surface* to the total normal force when slip occurs.

Nominal Strength. The capacity of a structure or component to resist the effects of loads, as determined by computations using the specified material strengths and dimensions and equations derived from accepted principles of structural mechanics or by field tests or laboratory tests of scaled models, allowing for modeling effects and differences between laboratory and field conditions.

Pretensioned Joint. A *joint* that transmits shear and/or tensile loads in which the bolts have been installed in accordance with Section 8.2 to provide a pretension in the installed bolt.

Protected Storage. The continuous protection of fastener components in closed containers in a protected shelter as described in the Commentary to Section 2.2.

Prying Action. Lever action that exists in *connections* in which the line of application of the applied load is eccentric to the axis of the bolt, causing deformation of the fitting and an amplification of the axial tension in the bolt.

Required Strength. The load effect acting on an element or *connection* determined by structural analysis from the factored loads using the most appropriate critical load combination.

Routine Observation. Periodic monitoring of the work in progress.

Shear/Bearing Joint. A *snug-tightened joint* or *pretensioned joint* with bolts that transmit shear loads and for which the design criteria are based upon the shear strength of the bolts and the bearing strength of the connected materials.

Slip-Critical Joint. A *joint* that transmits shear loads or shear loads in combination with tensile loads in which the bolts have been installed in accordance with Section 8.2 to

AVA Documents
Document Sharing Hub

Full document details: AISC S334L 2004

provide a pretension in the installed bolt (clamping force on the *faying surfaces*), and with *faying surfaces* that have been prepared to provide a calculable resistance against slip.

Snug-Tightened Joint. A *joint* in which the bolts have been installed in accordance with Section 8.1. The snug-tightened condition is the tightness that is attained with a few impacts of an impact wrench or the full effort of an ironworker using an ordinary spud wrench to bring the plies into *firm contact*.

Start of Work. Any time prior to the installation of *high-strength bolts* in structural *connections* in accordance with Section 8.

Sufficient Thread Engagement. Having the end of the bolt extending beyond or at least flush with the outer face of the nut; a condition that develops the strength of the bolt.

Supplier. The party that sells the fastener components to the party that will install them in the work.

Tension Calibrator. A calibrated tension-indicating device that is used to verify the acceptability of the pretensioning method when a *pretensioned joint* or *slip-critical joint* is specified.

Uncoated Faying Surface. A *faying surface* that has neither been primed, painted, nor galvanized and is free of loose scale, dirt and other foreign material.

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

NOTES

Documents
Document Sharing Hub

Full document details: AISC S334L 2004

SPECIFICATION FOR STRUCTURAL JOINTS USING ASTM A325 OR A490 BOLTS
June 30, 2004

SECTION 1. GENERAL REQUIREMENTS

1.1. Scope

This Specification covers the design of bolted *joints* and the installation and inspection of the assemblies of fastener components listed in Section 1.3, the use of alternative-design fasteners as permitted in Section 2.8 and alternative washer-type indicating devices as permitted in Section 2.6.2, in structural steel *joints*. This Specification relates only to those aspects of the connected materials that bear upon the performance of the fastener components. The Symbols, Glossary and Appendices are a part of this Specification.

Commentary:
This Specification deals principally with two strength grades of *high-strength bolts*, ASTM A325 and A490, and with their design, installation and inspection in structural steel *joints*. Equivalent fasteners, however, such as ASTM F1852 (equivalent to ASTM A325) twist-off-type tension-control bolt assemblies, are also covered. These provisions may not be relied upon for high-strength fasteners of other chemical composition, mechanical properties, or size. These provisions do not apply when material other than steel is included in the *grip*; nor are they applicable to anchor rods.

This Specification relates only to the performance of fasteners in structural steel *joints* and those few aspects of the connected material that affect this performance. Many other aspects of *connection* design and fabrication are of equal importance and must not be overlooked. For more general information on design and issues relating to *high-strength bolting* and the connected material, refer to current steel design textbooks and the *Guide to Design Criteria for Bolted and Riveted Joints*, 2nd Edition (Kulak et al., 1987).

1.2. Loads, Load Factors and Load Combinations

The design and construction of the structure shall conform to an applicable load and resistance factor design specification for steel structures. Because factored load combinations account for the reduced probabilities of maximum loads acting concurrently, the *design strengths* given in this Specification shall not be increased. Appendix B is included as an alternative approach.

Commentary:
This Specification is written in the load and resistance factor design (LRFD) format, which provides a method of proportioning structural components such that no applicable limit state is exceeded when the structure is subject to all appropriate load combinations. When a structure or structural component ceases to fulfill the intended purpose in some way, it is said to have exceeded a limit state. Strength limit states concern maximum load-carrying capability, and are related to

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

safety. Serviceability limit states are usually related to performance under normal service conditions, and usually are not related to strength or safety. The term "resistance" includes both strength limit states and serviceability limit states.

The *design strength* ϕR_n is the *nominal strength* R_n multiplied by the resistance factor ϕ. The factored load is the sum of the nominal loads multiplied by load factors, with due recognition of load combinations that account for the improbability of simultaneous occurrence of multiple transient load effects at their respective maximum values. The *design strength* ϕR_n of each structural component or assemblage must equal or exceed the *required strength* (V_u, T_u, etc.).

Although loads, load factors and load combinations are not explicitly specified in this Specification, the resistance factors herein are based upon those specified in ASCE 7. When the design is governed by other load criteria, the resistance factors specified herein should be adjusted as appropriate.

1.3. Referenced Standards and Specifications

The following standards and specifications are referenced herein:

American Institute of Steel Construction
Load and Resistance Factor Design Specification for Structural Steel Buildings, December 27,1999

American National Standards Institute
ANSI/ASME B18.2.6-96 *Fasteners for Use in Structural Applications*

American Society for Testing and Materials
ASTM A123-97a *Standard Specification for Zinc* (*Hot-Dip Galvanized*) *Coatings on Iron and Steel Products*

ASTM A153-98 *Standard Specification for Zinc Coating* (*Hot-Dip*) *on Iron and Steel Hardware*

ASTM A194-98b *Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High-Temperature Service, or Both*

ASTM A325-97 *Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength*

ASTM A490-97 *Standard Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength*

ASTM A563-97 *Standard Specification for Carbon and Alloy Steel Nuts*

ASTM B695-91[1] *Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel*

[1] Reapproved 1997.

Documents
Document Sharing Hub

Full document details: AISC S334L 2004

ASTM F436-93 *Standard Specification for Hardened Steel Washers*

ASTM F959-99a *Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners*

ASTM F1852-98 "*Twist off*" *Type Tension Control Structural Bolt/Nut/Washer Assemblies, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength*

American Society of Civil Engineers
ASCE 7-98 *Minimum Design Loads for Buildings and Other Structures*

SSPC: The Society for Protective Coatings
SSPC-PA2-96 *Measurement of Dry Coating Thickness With Magnetic Gages*

Commentary:
Familiarity with the referenced AISC, ASCE, ASME, ASTM and SSPC specification requirements is necessary for the proper application of this Specification. The discussion of referenced specifications in this Commentary is limited to only a few frequently overlooked or misunderstood items.

1.4. Drawing Information

The *Engineer of Record* shall specify the following information in the contract documents

(1) The ASTM designation and type (Section 2) of bolt to be used;
(2) The *joint* type (Section 4);
(3) The required class of slip resistance if *slip-critical joints* are specified (Section 4); and,
(4) Whether slip is checked at the factored-load level or the service-load level, if *slip-critical joints* are specified (Section 5).

Commentary:
A summary of the information that the *Engineer of Record* is required to provide in the contract documents is provided in this Section. The parenthetical reference after each listed item indicates the location of the actual requirement in this Specification. In addition, the approval of the *Engineer of Record* is required in this Specification in the following cases:

(1) For the reuse of non-galvanized ASTM A325 bolts (Section 2.3.3);
(2) For the use of alternative washer-type indicating devices that differ from those that meet the requirements of ASTM F959, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.6.2);
(3) For the use of alternative-design fasteners, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.8);

Documents
Document Sharing Hub

Full document details: AISC S334L 2004

(4) For the use of faying-surface coatings in *slip-critical joints* that provide a *mean slip coefficient* determined per Appendix A, but differing from Class A or Class B (Section 3.2.2(b));
(5) For the use of thermal cutting in the production of bolt holes (Section 3.3);
(6) For the use of oversized (Section 3.3.2), short-slotted (Section 3.3.3) or long slotted holes (Section 3.3.4) in lieu of standard holes;
(7) For the use of a value of D_u other than 1.13 (Section 5.4.1); and,
(8) For the use of a value of D other than 0.80 (Section 5.4.2).

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

SECTION 2. FASTENER COMPONENTS

2.1. Manufacturer Certification of Fastener Components

Manufacturer certifications documenting conformance to the applicable specifications required in Sections 2.3 through 2.8 for all fastener components used in the *fastener assemblies* shall be available to the *Engineer of Record* and *inspector* prior to assembly or erection of structural steel.

Commentary:
Certification by the *manufacturer* or *supplier* of *high-strength bolts*, nuts, washers and other components of the *fastener assembly* is required to ensure that the components to be used are identifiable and meet the requirements of the applicable ASTM Specifications.

2.2. Storage of Fastener Components

Fastener components shall be protected from dirt and moisture in closed containers at the site of installation. Only as many fastener components as are anticipated to be installed during the work shift shall be taken from *protected storage*. Fastener components that are not incorporated into the work shall be returned to *protected storage* at the end of the work shift. Fastener components shall not be cleaned or modified from the as-delivered condition.

Fastener components that accumulate rust or dirt shall not be incorporated into the work unless they are requalified as specified in Section 7. ASTM F1852 twist-off-type tension-control bolt assemblies and alternative-design fasteners that meet the requirements in Section 2.8 shall not be relubricated, except by the *manufacturer*.

Commentary:
Protected storage requirements are specified for *high-strength bolts*, nuts, washers and other fastener components with the intent that the condition of the components be maintained as nearly as possible to the as-manufactured condition until they are installed in the work. This involves:

(1) The storage of the fastener components in closed containers to protect from dirt and corrosion;
(2) The storage of the closed containers in a protected shelter;
(3) The removal of fastener components from *protected storage* only as necessary; and,
(4) The prompt return of unused fastener components to *protected storage*.

To facilitate manufacture, prevent corrosion and facilitate installation, the *manufacturer* may apply various coatings and oils that are present in the as manufactured condition. As such, the condition of supplied fastener components or the *fastener assembly* should not be altered to make them unsuitable for pre-tensioned installation.

If fastener components become dirty, rusty, or otherwise have their as received condition altered, they may be unsuitable for pre-tensioned installation.

AVA Documents
Document Sharing Hub
Full document details: AISC S334L 2004

It is also possible that a *fastener assembly* may not pass the pre-installation verification requirements of Section 7. Except for ASTM F1852 twist-off-type tension-control bolt assemblies (Section 2.7) and some alternative-design fasteners (Section 2.8), fastener components can be cleaned and lubricated by the fabricator or the erector. Because the acceptability of their installation is dependent upon specific lubrication, ASTM F1852 twist-off-type tension-control bolt assemblies and some alternative-design fasteners are suitable only if the *manufacturer* lubricates them.

2.3. Heavy-Hex Structural Bolts

2.3.1. Specifications: Heavy-hex structural bolts shall meet the requirements of ASTM A325 or ASTM A490. The *Engineer of Record* shall specify the ASTM designation and type of bolt (see Table 2.1) to be used.

2.3.2. Geometry: Heavy-hex structural bolt dimensions shall meet the requirements of ANSI/ASME B18.2.6. The bolt length used shall be such that the end of the bolt extends beyond or is at least flush with the outer face of the nut when properly installed.

Table 2.1. Acceptable ASTM A563 Nut Grade and Finish and ASTM F436 Washer Type and Finish

ASTM Desig.	Bolt Type	Bolt Finish[d]	ASTM A563 nut grade and finish[d]	ASTM F436 washer type and finish [a,d]
A325	1	Plain (uncoated)	C, C3, D, DH [c] and DH3; plain	1; plain
		Galvanized	DH [c]; galvanized And lubricated	1; galvanized
	3	Plain	C3 and DH3; plain	3; plain
F1852	1	Plain (uncoated)	C, C3, DH [c] and DH3; plain	1; plain [b]
		Mechanically Galvanized	DH [c]; mechanically galvanized and lubricated	1; mechanically galvanized [b]
	3	Plain	C3 and DH3; plain	3; plain [b]
A490	1	Plain	DH [c] and DH3; plain	1; plain
	3	Plain	DH3; plain	3; plain

[a] Applicable only if washer is required in Section 6.
[b] Required in all cases under nut per Section 6.
[c] The substitution of ASTM A194 grade 2H nuts in place of ASTM A563 grade DH nuts is permitted.
[d] "Galvanized" as used in this table refers to hot-dip galvanizing in accordance with ASTM A153 or mechanical galvanizing in accordance with ASTM B695.

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

2.3.3. Reuse: ASTM A490 bolts and galvanized ASTM A325 bolts shall not be reused. When approved by the *Engineer of Record*, black ASTM A325 bolts are permitted to be reused. Touching up or re-tightening bolts that may have been loosened by the installation of adjacent bolts shall not be considered to be a reuse.

Commentary:
ASTM A325 and ASTM A490 currently provide for two types (according to metallurgical classification) of *high-strength bolts*, supplied in diameters from ½ in. to 1½ in. inclusive. Type 1 covers medium carbon steel for ASTM A325 bolts and alloy steel for ASTM A490 bolts. Type 3 covers *high-strength bolts* that have improved atmospheric corrosion resistance and weathering characteristics. (Reference to Type 2 ASTM A325 and Type 2 A490 bolts, which appeared in previous editions of this Specification, has been removed following the removal of similar reference within the ASTM A325 and A490 Specifications). When the bolt type is not specified, either Type 1 or Type 3 may be supplied at the option of the *manufacturer*. Note that ASTM F1852 twist-off-type tension-control bolt assemblies may be manufactured with a button head or hexagonal head; other requirements for these *fastener assemblies* are found in Section 2.7.

Regular heavy-hex structural bolts and twist-off-type tension-control bolt assemblies are required by ASTM Specifications to be distinctively marked. Certain markings are mandatory. In addition to the mandatory markings, the *manufacturer* may apply additional distinguishing markings. The mandatory and sample optional markings are illustrated in Figure C-2.1.

ASTM Specifications permit the galvanizing of ASTM A325 bolts but not ASTM A490 bolts. Similarly, the application of zinc to ASTM A490 bolts by metallizing or mechanical coating is not permitted because the effect of mechanical galvanizing on embrittlement and delayed cracking of ASTM A490 bolts has not been fully investigated to date.

Galvanized *high-strength bolts* and nuts must be considered as a manufactured *fastener assembly*. Insofar as the hot-dip galvanized bolt and nut assembly is concerned, four principal factors must be considered so that the provisions of this Specification are understood and properly applied. These are:

(1) The effect of the hot-dip galvanizing process on the mechanical properties of high-strength steels;
(2) The effect of over-tapping for hot-dip galvanized coatings on the nut stripping strength;
(3) The effect of galvanizing and lubrication on the torque required for pretensioning; and,
(4) Shipping requirements.

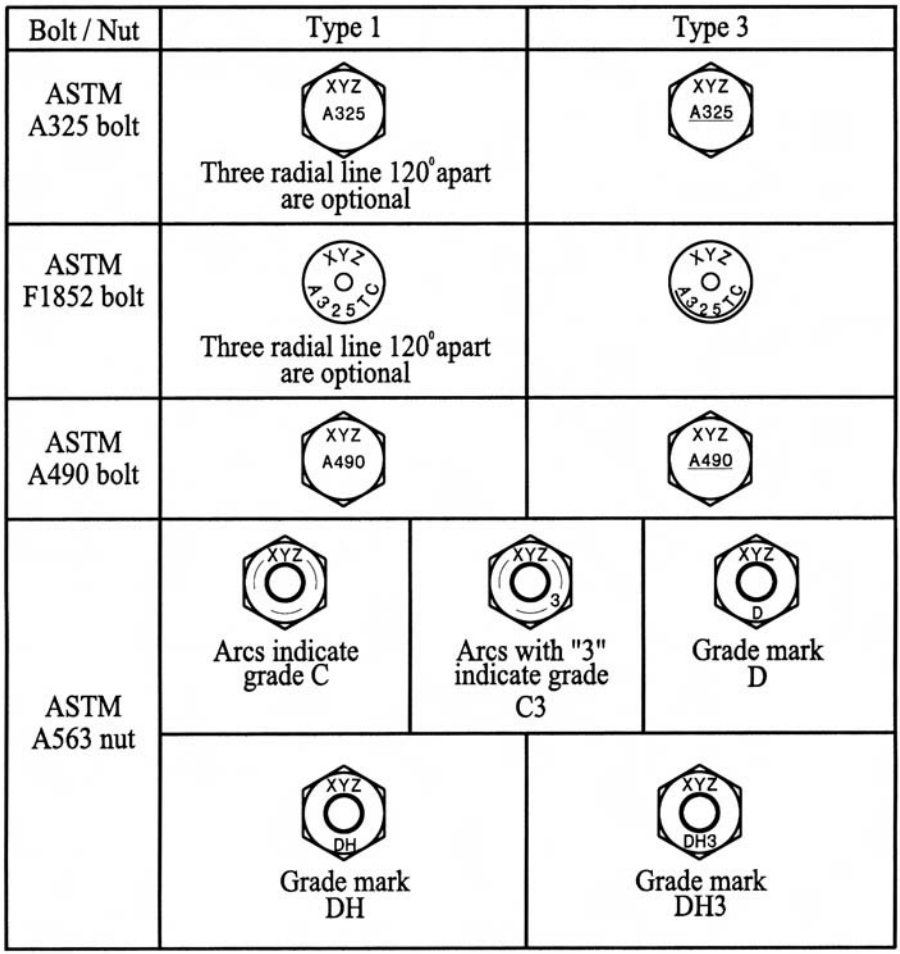
Birkemoe and Herrschaft (1970) showed that, in the as-galvanized condition, galvanizing increases the friction between the bolt and nut threads as well as the variability of the torque-induced pretension. A lower required torque and more consistent results are obtained if the nuts are lubricated. Thus, it is required in ASTM A325 that a galvanized bolt and lubricated galvanized nut be assembled in a steel *joint* with a galvanized washer and tested by the *supplier* prior

AVA Documents
Document Sharing Hub

Full document details: AISC S334L 2004

to shipment. This testing must show that the galvanized nut with the lubricant provided may be rotated from the snug-tight condition well in excess of the rotation required for pretensioned installation without stripping. This requirement applies to both hot-dip and mechanically galvanized fasteners. The above requirements clearly indicate that:

(1) Galvanized *high-strength bolts* and nuts must be treated as a *fastener assembly*;
(2) The *supplier* must supply nuts that have been lubricated and tested with the supplied *high-strength bolts*;



Notes:
1. XYZ represents the manufacturer's identification mark.
2. ASTM F1852 twist-off-type tension-control bolt assemblies are also produced with heavy-hex head that has similar markings.

Figure C-2.1. Required marks for acceptable bolt and nut assemblies.

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

(3) Nuts and *high-strength bolts* must be shipped together in the same shipping container; and,

(4) The purchase of galvanized *high-strength bolts* and galvanized nuts from separate *suppliers* is not in accordance with the intent of the ASTM Specifications because the control of over-tapping, the testing and application of lubricant and the *supplier* responsibility for the performance of the assembly would clearly not have been provided as required.

Because some of the lubricants used to meet the requirements of ASTM Specifications are water soluble, it is advisable that galvanized *high-strength bolts* and nuts be shipped and stored in plastic bags or in sealed wood or metal containers. Containers of fasteners with hot-wax-type lubricants should not be subjected to heat that would cause depletion or change in the properties of the lubricant.

Both the hot-dip galvanizing process (ASTM A153) and the mechanical galvanizing process (ASTM B695) are recognized in ASTM A325. The effects of the two processes upon the performance characteristics and requirements for proper installation are distinctly different. Therefore, distinction between the two must be noted in the comments that follow. In accordance with ASTM A325, all threaded components of the *fastener assembly* must be galvanized by the same process and the *supplier's* option is limited to one process per item with no mixed processes in a *lot*. Mixing *high-strength bolts* that are galvanized by one process with nuts that are galvanized by the other may result in an unworkable assembly.

Steels in the 200 ksi and higher tensile-strength range are subject to embrittlement if hydrogen is permitted to remain in the steel and the steel is subjected to high tensile stress. The minimum tensile strength of ASTM A325 bolts is 105 ksi or 120 ksi, depending upon the diameter, and maximum hardness limits result in production tensile strengths well below the critical range. The maximum tensile strength for ASTM A490 bolts was set at 170 ksi to provide a little more than a ten-percent margin below 200 ksi. However, because *manufacturers* must target their production slightly higher than the required minimum, ASTM A490 bolts close to the critical range of tensile strength must be anticipated. For black *high-strength bolts*, this is not a cause for concern. However, if the bolt is hot-dip galvanized, delayed brittle fracture in service is a concern because of the possibility of the introduction of hydrogen during the pickling operation of the hot-dip galvanizing process and the subsequent "sealing-in" of the hydrogen by the zinc coating. There also exists the possibility of cathodic hydrogen absorption arising from the corrosion process in certain aggressive environments.

ASTM A325 and A490 bolts are manufactured to dimensions as specified in ANSI/ASME B18.2.6. The basic dimensions, as defined in Figure C-2.2, are shown in Table C-2.1.

The principal geometric features of heavy-hex structural bolts that distinguish them from bolts for general application are the size of the head and the unthreaded body length. The head of the heavy-hex structural bolt is specified to be the same size as a heavy-hex nut of the same nominal diameter so that the ironworker may use the same wrench or socket either on the bolt head and/or on the nut. With the specific exception of fully threaded ASTM A325T bolts as

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

discussed below, heavy-hex structural bolts have shorter threaded lengths than bolts for general applications. By making the body length of the bolt the control dimension, it has been possible to exclude the thread from all shear planes when desirable, except for the case of thin outside parts adjacent to the nut.

The shorter threaded lengths provided with heavy-hex structural bolts tend to minimize the threaded portion of the bolt within the *grip*. Accordingly, care must also be exercised to provide adequate threaded length between the nut and the bolt head to enable appropriate installation without jamming the nut on the thread run-out.

Depending upon the increments of supplied bolt lengths, the full thread may extend into the *grip* for an assembly without washers by as much as 3/8 in. for 1/2, 5/8, 3/4, 7/8, 1 1/4, and 1 1/2 in. diameter *high-strength bolts* and as much as 1/2 in. for 1,

Table C-2.1. Bolt and Nut Dimensions

Nominal Bolt Diameter d_b, in.	Heavy Hex Structural Bolt Dimensions			Heavy Hex Nut Dimensions	
	Width across flats *F*, in.	Height H_1, in.	Thread Length *T*, in.	Width across flats *W*, in.	Height H_2, in.
1/2	7/8	5/16	1	7/8	31/64
5/8	1 1/16	25/64	1 1/4	1 1/16	39/64
3/4	1 1/4	15/32	1 3/8	1 1/4	47/64
7/8	1 7/16	35/64	1 1/2	1 7/16	55/64
1	1 5/8	39/64	1 3/4	1 5/8	63/64
1 1/8	1 13/16	11/16	2	1 13/16	1 7/64
1 1/4	2	25/32	2	2	1 7/32
1 3/8	2 3/16	27/32	2 1/4	2 3/16	1 11/32
1 1/2	2 3/8	15/16	2 1/4	2 3/8	1 15/32

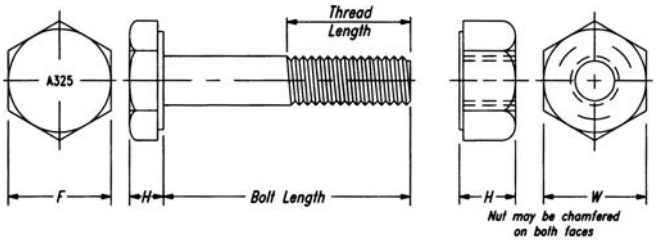


Figure C-2.2. Heavy-hex structural bolt and heavy-hex nut.

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

1⅛, and 1⅜ in. diameter *high-strength bolts*. When the thickness of the ply closest to the nut is less than the ⅜ in. or ½ in. dimensions given above, it may still be possible to exclude the threads from the shear plane, when required, depending upon the specific combination of bolt length, *grip* and number of washers used under the nut (Carter, 1996). If necessary, the next increment of bolt length can be specified with ASTM F436 washers in sufficient number to both exclude the threads from the shear plane and ensure that the assembly can be installed with adequate threads included in the *grip* for proper installation.

At maximum accumulation of tolerances from all components in the *fastener assembly*, the thread run-out will cross the shear plane for the critical combination of bolt length and *grip* used to select the foregoing rules of thumb for ply thickness required to exclude the threads. This condition is not of concern, however, for two reasons. First, it is too unlikely that all component tolerances will accumulate at their maximum values to warrant consideration. Second, even if the maximum accumulation were to occur, the small reduction in shear strength due to the presence of the thread run-out (not a full thread) would be negligible.

There is an exception to the foregoing thread length requirements for ASTM A325 bolts but not for ASTM A490 bolts nor ASTM F1852 twist-off-type tension-control bolt assemblies. Supplementary requirements in ASTM A325 permit the purchaser to specify a bolt that is threaded for the full length of the shank, when the bolt length is equal to or less than four times the nominal diameter. This exception is provided to increase economy through simplified ordering and inventory control in the fabrication and erection of some structures. It is particularly useful in those structures in which the strength of the *connection* is dependent upon the bearing strength of relatively thin connected material rather than the shear strength of the bolt, whether with threads in the shear plane or not. As required in ASTM A325, *high-strength bolts* ordered to such supplementary requirements must be marked with the symbol A325T.

To determine the required bolt length, the value shown in Table C-2.2 should be added to the *grip* (i.e., the total thickness of all connected material, exclusive of washers). For each ASTM F436 washer that is used, add 5/32 in.; for each beveled washer, add 5/16 in. The tabulated values provide appropriate allowances for manufacturing tolerances and also provide *sufficient thread engagement* with an installed heavy-hex nut. The length determined by the use of Table C-2.2 should be adjusted to the next longer ¼-in. length increment (½-in. length increment for lengths exceeding 6 in.). A more extensive table for bolt length selection based upon these rules is available (Carter, 1996).

Pretensioned installation involves the inelastic elongation of the portion of the threaded length between the nut and the thread run-out. ASTM A490 bolts and galvanized ASTM A325 bolts possess sufficient ductility to undergo one pretensioned installation, but are not consistently ductile enough to undergo a second pretensioned installation. Black ASTM A325 bolts, however, possess sufficient ductility to undergo more than one pretensioned installation as suggested in the *Guide* (Kulak et al., 1987). As a simple rule of thumb, a black ASTM A325 bolt is suitable for reuse if the nut can be run up the threads by hand.

Documents
Document Sharing Hub

Full document details: AISC S334L 2004

Table C- 2.2. Bolt Length Selection Increment

Nominal Bolt Diameter d_b, in.	To Determine the Required Bolt Length, Add to Grip, in.
1/2	11/16
5/8	7/8
3/4	1
7/8	1 1/8
1	1 1/4
1 1/8	1 1/2
1 1/4	1 5/8
1 3/8	1 3/4
1 1/2	1 7/8

2.4. Heavy-Hex Nuts

2.4.1. Specifications: Heavy-hex nuts shall meet the requirements of ASTM A563. The grade and finish of such nuts shall be as given in Table 2.1.

2.4.2. Geometry: Heavy-hex nut dimensions shall meet the requirements of ANSI/ASME B18.2.6.

Commentary:
Heavy-hex nuts are required by ASTM Specifications to be distinctively marked. Certain markings are mandatory. In addition to the mandatory markings, the *manufacturer* may apply additional distinguishing markings. The mandatory markings and sample optional markings are illustrated in Figure C-2.1.

Hot-dip galvanizing affects the stripping strength of the bolt-nut assembly because, to accommodate the relatively thick zinc coatings of non-uniform thickness on bolt threads, it is usual practice to hot-dip galvanize the blank nut and then to tap the nut over-size. This results in a reduction of thread engagement with a consequent reduction of the stripping strength. Only the stronger hardened nuts have adequate strength to meet ASTM thread strength requirements after over-tapping. Therefore, as specified in ASTM A325, only ASTM A563 grade DH are suitable for use as galvanized nuts. This requirement should not be overlooked if non-galvanized nuts are purchased and then sent to a local galvanizer for hot-dip galvanizing. Because the mechanical galvanizing process results in a more uniformly distributed and smooth zinc coating, nuts may be tapped over-size before galvanizing by an amount that is less than that required for the hot-dip process before galvanizing.

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

In earlier editions, this Specification permitted the use of ASTM A194 grade 2H nuts in the same finish as that permitted for ASTM A563 nuts in the following cases: with ASTM A325 Type 1 plain, Type 1 galvanized and Type 3 plain bolts and with ASTM A490 Type 1 plain bolts. Reference to ASTM A194 grade 2H nuts has been removed following the removal of similar reference within the ASTM A325 and A490 Specifications. However, it should be noted that ASTM A194 grade 2H nuts remain acceptable in these applications as indicated by footnote in Table 2.1, should they be available.

ASTM A563 nuts are manufactured to dimensions as specified in ANSI/ASME B18.2.6. The basic dimensions, as defined in Figure C-2.2, are shown in Table C-2.1.

2.5. Washers

Flat circular washers and square or rectangular beveled washers shall meet the requirements of ASTM F436, except as provided in Table 6.1. The type and finish of such washers shall be as given in Table 2.1.

2.6. Washer-Type Indicating Devices

The use of washer-type indicating devices is permitted as described in Sections 2.6.1 and 2.6.2.

2.6.1. Compressible-Washer-Type Direct Tension Indicators: Compressible-washer-type direct tension indicators shall meet the requirements of ASTM F959.

2.6.2. Alternative Washer-Type Indicating Devices: When approved by the *Engineer of Record*, the use of alternative washer-type indicating devices that differ from those that meet the requirements of ASTM F959 is permitted.

Detailed installation instructions shall be prepared by the *manufacturer* in a supplemental specification that is approved by the *Engineer of Record* and shall provide for:

(1) The required character and frequency of pre-installation verification;
(2) The alignment of bolt holes to permit insertion of the bolt without undue damage to the threads;
(3) The placement of *fastener assemblies* in all types and sizes of holes, including placement and orientation of the alternative and regular washers;
(4) The systematic assembly of the *joint*, progressing from the most rigid part of the *joint* until the connected plies are in *firm contact*; and;
(5) The subsequent systematic pretensioning of all bolts in the *joint*, progressing from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts.

Detailed inspection instructions shall be prepared by the *manufacturer* in a supplemental specification that is approved by the *Engineer of Record* and shall provide for:

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

(1) Observation of the required pre-installation verification testing; and,
(2) Subsequent *routine observation* to ensure the proper use of the alternative washer-type indicating device.

2.7. Twist-Off-Type Tension-Control Bolt Assemblies

2.7.1. Specifications: Twist-off-type tension-control bolt assemblies shall meet the requirements of ASTM F1852. The *Engineer of Record* shall specify the type of bolt (Table 2.1) to be used.

2.7.2. Geometry: Twist-off-type tension-control bolt assembly dimensions shall meet the requirements of ASTM F1852. The bolt length used shall be such that the end of the bolt extends beyond or is at least flush with the outer face of the nut when properly installed.

Commentary:
It is the policy of the Research Council on Structural Connections to directly recognize only those fastener components that are manufactured to meet the requirements in an approved ASTM specification. Prior to this edition, the RCSC Specification provided for the use of ASTM A325 and A490 bolts directly and alternative-design fasteners meeting detailed requirements similar to those in Section 2.8 when approved by the *Engineer of Record*. With this edition, ASTM F1852 twist-off-type tension-control bolt assemblies are now recognized directly. Essentially, ASTM F1852 relates an ASTM A325-equivalent product to a specific method of installation that is suitable for use in all *joint* types as described in Section 8. Provision has also been retained for approval by the *Engineer of Record* of other alternative-design fasteners that meet the detailed requirements in 2.8. As an example of one such approval, the use of twist-off-type tension-control bolt assemblies with ASTM A490 mechanical properties is usually deemed acceptable.

If galvanized, ASTM F1852 twist-off-type tension-control bolt assemblies are required in ASTM F1852 to be mechanically galvanized.

While specific provisions for reuse of ASTM F1852 twist-off-type tension control bolts have not been included in this Specification, those given in Section 2.3.3 for reuse of heavy-hex structural bolts are equally applicable if the use of an alternative pretensioning method, such as the turn-of-nut pretensioning method, is practical. It is assumed that rotation of the non-turned element can be restrained.

2.8. Alternative-Design Fasteners

When approved by the *Engineer of Record*, the use of alternative-design fasteners is permitted if they:

(1) Meet the materials, manufacturing and chemical composition requirements of ASTM A325 or ASTM A490, as applicable;
(2) Meet the mechanical property requirements of ASTM A325 or ASTM A490 in full-size tests;
(3) Have a body diameter and bearing area under the bolt head and nut that is equal to or greater than those provided by a bolt and nut of the same nomi-

AVA Documents
Document Sharing Hub

Full document details: AISC S334L 2004

nal dimensions specified in Sections 2.3 and 2.4; and,

(4) Are supplied and used in the work as a *fastener assembly*.

Such alternative-design fasteners are permitted to differ in other dimensions from those of the specified *high-strength bolts* and nuts.

Detailed installation instructions shall be prepared by the *manufacturer* in a supplemental specification that is approved by the *Engineer of Record* and shall provide for:

(1) The required character and frequency of pre-installation verification;
(2) The alignment of bolt holes to permit insertion of the alternative-design fastener without undue damage;
(3) The placement of *fastener assemblies* in all holes, including any washer requirements as appropriate;
(4) The systematic assembly of the *joint*, progressing from the most rigid part of the *joint* until the connected plies are in *firm contact*; and,
(5) The subsequent systematic pretensioning of all *fastener assemblies* in the *joint*, progressing from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts.

Detailed inspection instructions shall be prepared by the *manufacturer* in a supplemental specification that is approved by the *Engineer of Record* and shall provide for:

(1) Observation of the required pre-installation verification testing; and,
(2) Subsequent *routine observation* to ensure the proper use of the alternative-design fastener.

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

SECTION 3. BOLTED PARTS

3.1. Connected Plies

All connected plies that are within the *grip* of the bolt and any materials that are used under the head or nut shall be steel (uncoated, coated or galvanized) as defined in Section 3.2. Compressible materials shall not be placed within the *grip* of the bolt. The slope of the surfaces of parts in contact with the bolt head and nut shall be equal to or less than 1:20 with respect to a plane that is normal to the bolt axis.

Commentary:
The presence of gaskets, insulation or any compressible materials other than the specified coatings within the *grip* would preclude the development and/or retention of the installed pretensions in the bolts, when required.

ASTM A325, F1852 and A490 bolt assemblies are ductile enough to deform to a surface with a slope that is less than or equal to 1:20 with respect to a plane normal to the bolt axis. Greater slopes are undesirable because the resultant localized bending decreases both the strength and the ductility of the bolt.

3.2. Faying Surfaces

Faying surfaces and surfaces adjacent to the bolt head and nut shall be free of dirt and other foreign material. Additionally, *faying surfaces* shall meet the requirements in Sections 3.2.1 or 3.2.2.

3.2.1. *Snug-Tightened Joints* and *Pretensioned Joints*: The *faying surfaces* of *snug-tightened joints* and *pretensioned joints* as defined in Sections 4.1 and 4.2 are permitted to be uncoated, coated with coatings of any formulation or galvanized.

Commentary:
In both *snug-tightened joints* and *pretensioned joints*, the ultimate strength is dependent upon shear transmitted by the bolts and bearing of the bolts against the connected material. It is independent of any frictional resistance that may exist on the *faying surfaces*. Consequently, since slip resistance is not an issue, the *faying surfaces* are permitted to be uncoated, coated, or galvanized without regard to the resulting slip coefficient obtained.

3.2.2. *Slip-Critical Joints*: The *faying surfaces* of *slip-critical joints* as defined in Section 4.3, including those of filler plates and finger shims, shall meet the following requirements:

(a) *Uncoated Faying Surfaces*: *Uncoated faying surfaces* shall be free of scale, except tight mill scale, and free of coatings, including inadvertent overspray, in areas closer than one bolt diameter but not less than 1 in. from the edge of any hole and in all areas within the bolt pattern.

(b) *Coated Faying Surfaces*: *Coated faying surfaces* shall first be blast cleaned and subsequently coated with a coating that is qualified in accordance with the requirements in Appendix A as a Class A or Class B coating as defined

Documents
Document Sharing Hub
Full document details: AISC S334L 2004

in Section 5.4. Alternatively, when approved by the *Engineer of Record*, coatings that provide a *mean slip coefficient* that differs from Class A or Class B are permitted when:

(1) The *mean slip coefficient* μ is established by testing in accordance with the requirements in Appendix A; and,
(2) The design slip resistance is determined in accordance with Section 5.4 using this coefficient, except that, for design purposes, a value of μ greater than 0.50 shall not be used.

The plies of *slip-critical joints* with *coated faying surfaces* shall not be assembled before the coating has cured for the minimum time that was used in the qualifying tests.

(c) *Galvanized Faying Surfaces*: *Galvanized faying surfaces* shall first be hot-dip galvanized in accordance with the requirements of ASTM A123 and subsequently roughened by means of hand wire brushing. Power wire brushing is not permitted. When prepared by roughening, the *galvanized faying surface* is designated as Class C for design.

Commentary:
Slip-critical joints are those *joints* that have specified *faying surface* conditions that, in the presence of the clamping force provided by pretensioned fasteners, resist a design load solely by friction and without displacement at the *faying surfaces*. Consequently, it is necessary to prepare the *faying surfaces* in a manner so that the desired slip performance is achieved.

Clean mill scale steel surfaces (Class A, see Section 5.4.1) and blast-cleaned steel surfaces (Class B, see Section 5.4.1) can be used within *slip-critical joints*. When used, it is necessary to keep the *faying surfaces* free of coatings, including inadvertent overspray.

Corrosion often occurs on uncoated blast-cleaned steel surfaces (Class B, see Section 5.4.1) due to exposure between the time of fabrication and subsequent erection. In normal atmospheric exposures, this corrosion is not detrimental and may actually increase the slip resistance of the *joint*. Yura et al. (1981) found that the Class B slip coefficient could be maintained for up to one year prior to *joint* assembly.

Polyzois and Frank (1986) demonstrated that, for plate material with thickness in the range of ⅜ in. to ¾ in., the contact pressure caused by bolt pretension is concentrated on the *faying surfaces* in annular rings around and close to the bolts. In this study, unqualified paint on the *faying surfaces* away from the edge of the bolt hole by not less than 1 in. nor the bolt diameter did not reduce the slip resistance. However, this would not likely be the case for *joints* involving thicker material, particularly those with a large number of bolts on multiple gage lines; the Table 8.1 minimum bolt pretension might not be adequate to completely flatten and pull thicker material into tight contact around every bolt. Instead, the bolt pretension would be balanced by contact pressure on the regions of the *faying surfaces* that are in contact. To account for both possibilities, it is

Documents
Document Sharing Hub
Full document details: AISC S334L 2004