

**Benefits of Including SAE
Bolts, Nuts, and Washers in
the AISI STANDARD S100**

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for the Design of Cold-Formed
Steel Structural Members



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Final Report

**Benefits of Including SAE Bolts, Nuts, and Washers
in the
AISI STANDARD S100**

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Table of Contents

1.0	Overview	2
2.0	Bolt Geometry	2
3.0	Nuts and Washers	6
4.0	Bolted Connections	8
4.1	Design of Bearing Connections	8
4.2	Design of Bolts for Shear and Tension	10
5.0	Quality Assurance	11
6.0	Observations of AISI STANDARD S100 for Bolted Connections Beyond the Comparison of ASTM to SAE Bolts	13
7.0	Proposal	15
7.1	Other Recommendations	16
8.0	References	17

1.0 Overview

The addition of SAE J429 bolts along with their associated nuts and washers into the AISI STANDARD S100, **North American Specification for the Design of Cold-Formed Members**, would be a significant enhancement to the specification by providing practitioners the opportunity to use a broader range of fasteners for the design of cold-formed steel structures. The design of bolted connections using SAE J429 bolts would be advantageous for many types of structures including mechanical support structures, storage rack systems, photovoltaic support structures, carport structures, and conventional repetitive frame structures that all utilize cold-formed steel members. These structures would benefit by having a more robust range of smaller diameter fasteners available that are not found in ASTM A307 common bolts or ASTM F3125 Grades A325 or A490 high-strength structural bolts. Many industries that require small diameter fasteners already use SAE J429 bolts or have attempted to use SAE bolts in their designs without any specification guidance.

Incorporation of SAE J429 bolts into AISI STANDARD S100 requires a comparison between the ASTM bolts currently recognized in the Standard with those SAE bolts looking to be included in the specification. This comparison would need to cover:

- 1) Geometry of the bolt, nut, and washer,
- 2) Bearing strength of connections,
- 3) Shear strength of SAE bolts,
- 4) Tension strength of SAE bolts, and
- 5) Assurance of quality.

This comparison would also need to demonstrate that SAE J429 bolted connections will provide designs with an equivalent level of safety or resistance as do ASTM bolts. The following sections address these issues and provide the reasons or benefits for their proposed inclusion in the next edition of the AISI Standard.

2.0 Bolt Geometry

The first step in determining the suitability of SAE J429 bolts to perform equally or better than ASTM A307 bolts or F3125 Grades A325 or A490 bolts is to compare their geometry. The primary characteristics for comparison are: head size, thread form, and thread length. The AISI STANDARD S100 Section J3 *Bolted Connections* specifies the most common ASTM A307 and F3125 Grades A325 and A490 bolts in addition to several other bolt specifications and threaded parts (see AISI S100-16 w/S18 pages

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

105 and 106). This research report will only focus on comparing SAE J429 bolts to the most common ASTM A307 and ASTM F3125 Grades A325 and A490 specified bolts.

The hex head size of the specified bolts includes both standard hex heads and heavy hex head bolts. ASTM A307 Type A has a standard hex head and Type B has a heavy hex head. ASTM F3125 Grades A325 and A490 have heavy hex heads. SAE J429 bolts are available with either a common standard hex head or a heavy hex head. Both the ASTM and SAE bolt heads are manufactured in accordance with ASME B18.2.1 dimensions. Table 2-1 provides a summary of hex head sizes for ASTM and SAE bolts.

The thread size of the specified ASTM A307, A325, and A490 bolts is the Unified National Coarse (UNC) thread. SAE J429 bolts are available with either UNC or Unified National Fine (UNF) thread. UNC thread is more common for construction applications than UNF thread. The primary difference between UNC and UNF is the root diameter of the threads. UNC thread has a smaller root diameter than UNF thread due to its deeper thread cut.

The thread length on the shank of the bolt varies based on the specified bolt's requirements. ASTM A307 Type A conform to hex bolt dimensions, ASTM A307 Type B conform to heavy hex bolt dimensions, and ASTM F3125 Grades A325 and A490 conform to heavy hex structural bolt dimensions. SAE J429 bolts are commonly manufactured to hex bolt dimensions and are also available in heavy hex dimensions, but not in heavy hex structural bolt dimensions. Heavy hex structural bolts have a shorter thread length than heavy hex bolts to reduce the occurrence of the threads being in the shear plane for hot rolled steel construction. This is generally not a significant consideration for cold-formed steel connections since member thickness is 3/16 inch or less and the short length bolts are typically fully threaded. See Table 2-2A for an overall comparison of ASTM and SAE bolts that shows the nominal head size, tensile strength, and thread length by bolt size for hex, heavy hex, and heavy hex structural bolts while Table 2-2B highlights only a tensile strength comparison between ASTM A307 bolts and SAE J429 Grade 2 bolts.

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

Table 2-1 Comparison of Bolt Specification and Hex Head Size

		Nominal Bolt Head (in.)				
		ASME Dimensional Requirements B18.2.1				
Bolt Type					Heavy Hex Bolt	
Specification(s)		SAE J429		ASTM A307 Type A		ASTM A307 Type B F3125 Grades A325, A490
Bolt Diameter (in.)	1/4	7/16	=	7/16		---
	5/16	1/2	=	1/2		---
	3/8	9/16	=	9/16		---
	7/16	5/8	=	5/8		---
	1/2	3/4	=	3/4	<	7/8
	9/16	13/16	=	13/16		---
	5/8	15/16	=	15/16	<	1 1/16
	3/4	1 1/8	=	1 1/8	<	1 1/4
	7/8	1 5/16	=	1 5/16	<	1 7/16
	1	1 1/2	=	1 1/2	<	1 5/8
	1 1/8	1 11/16	=	1 11/16	<	1 3/4
	1 1/4	1 7/8	=	1 7/8	<	2
	1 3/8	---		---		2 3/16
	1 1/2	2 1/4	=	2 1/4	<	2 3/8
	1 3/4	2 3/4	=	2 3/4	=	2 3/4
	2	3 1/8	=	3 1/8	=	3 1/8
	2 1/4	N/A	<	3 1/2	=	3 1/2
	2 1/2	N/A	<	3 7/8	=	3 7/8
	2 3/4	N/A	<	4 1/4	=	4 1/4
	3	N/A	<	4 5/8	=	4 5/8

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

Table 2-2A Overall Comparison of ASTM and SAE Bolts

Bolt Size	Nominal Bolt Head (in)					Tensile Strength (ksi)							Thread Length ASME B18.2.1						
	ASME Dimensional Requirements B18.2.1					SAE J429 Grade 2	A307 Type A or Type B	SAE J429 Grade 5	A325	SAE J429 Grade 8	A490	Hex Bolt	Heavy Hex Bolt	Heavy Hex Structural Bolt					
	Hex Bolt		Heavy Hex Bolt																
	SAE J429	A307 Type A	% Less	A307 Type B A325, or A490															
1/4	7/16	=	7/16		-	74	>	60	120	=	120	150	=	150	3/4	=	-	-	
5/16	1/2	=	1/2		-	74	>	60	120	=	120	150	=	150	7/8	=	-	-	
3/8	9/16	=	9/16		-	74	>	60	120	=	120	150	=	150	1	=	-	-	
7/16	5/8	=	5/8		-	74	>	60	120	=	120	150	=	150	1 1/8	=	-	-	
1/2	3/4	=	3/4	14% <	7/8	74	>	60	120	=	120	150	=	150	1 1/4	=	1 1/4	>	1
9/16	13/16	=	13/16		-	74	>	60	120	=	120	150	=	150	-	=	-	-	-
5/8	15/16	=	15/16	12% <	1 1/16	74	>	60	120	=	120	150	=	150	1 1/2	=	1 1/2	>	1 1/4
3/4	1 1/8	=	1 1/8	10% <	1 1/4	74	>	60	120	=	120	150	=	150	1 3/4	=	1 3/4	>	1 3/8
7/8	1 5/16	=	1 5/16	9% <	1 7/16	70	>	60	120	=	120	150	=	150	2	=	2	>	1 1/2
1	1 1/2	=	1 1/2	8% <	1 5/8	70	>	60	120	=	120	150	=	150	2 1/4	=	2 1/4	>	1 3/4
1 1/8	1 11/16	=	1 11/16	4% <	1 3/4	70	>	60	105	=	105	150	=	150	2 1/2	=	2 1/2	>	2
1 1/4	1 7/8	=	1 7/8	6% <	2	70	>	60	105	=	105	150	=	150	2 3/4	=	2 3/4	>	2
1 3/8	-		-		2 3/16	70	>	60	105	=	105	150	=	150	3	=	3	>	2 1/4
1 1/2	2 1/4	=	2 1/4	5% <	2 3/8	70	>	60	105	=	105	150	=	150	3 1/4	=	3 1/4	>	2 1/4
1 3/4	2 3/4	=	2 3/4	0% =	2 3/4	n/a	>	60	n/a		n/a	n/a		n/a	3 3/4	=	3 3/4		n/a
2	3 1/8	=	3 1/8	0% =	3 1/8	n/a	>	60	n/a		n/a	n/a		n/a	4 1/4	=	4 1/4		n/a
2 1/4	n/a		3 1/2	0% =	3 1/2	n/a		60	n/a		n/a	n/a		n/a	4 3/4	=	4 3/4		n/a
2 1/2	n/a		3 7/8	0% =	3 7/8	n/a		60	n/a		n/a	n/a		n/a	5 1/4	=	5 1/4		n/a
2 3/4	n/a		4 1/4	0% =	4 1/4	n/a		60	n/a		n/a	n/a		n/a	5 3/4	=	5 3/4		n/a
3	n/a		4 5/8	0% =	4 5/8	n/a		60	n/a		n/a	n/a		n/a	6 1/4	=	6 1/4		n/a

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

Table 2-2B Comparison of Tensile Strength for Only
ASTM A307 and SAE J429 Grade 2 Bolts

Bolt Type		Wedge Tensile Strength (ksi)		
		SAE J429 Grade 2	Hex Bolt	
Specification(s)			A307 Type A	A307 Type B
Bolt Diameter (in.)	1/4	74	>	60
	5/16	74	>	60
	3/8	74	>	60
	7/16	74	>	60
	1/2	74	>	60
	9/16	74	>	60
	5/8	74	>	60
	3/4	74	>	60
	7/8	70	>	60
	1	70	>	60
	1 1/8	70	>	60
	1 1/4	70	>	60
	1 3/8	70	>	60
	1 1/2	70	>	60
	1 3/4	70	>	60
	2	70	>	60
	2 1/4	70	>	60
	2 1/2	70	>	60
	2 3/4	70	>	60
	3	70	>	60

3.0 Nuts and Washers

The nut grades recognized in AISI STANDARD S100 J3.4 include ASTM A563 and ASTM A194. This section does not specify the nut to be used however the applicable ASTM bolt standard recommends the appropriate nut standard to be used with the grade of the specified bolt. The following standard specifications summarize the appropriate nut to be used for a given bolt:

- ASTM A563 is recommended in the standard for A307 bolts.
- ASTM A563 is recommended or alternately ASTM A194 H2 is also in the standard for ASTM F3125 Grades A325 or A490 bolts.

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

- SAE J995 is listed as a related standard in SAE J429, but is not included as the recommended standard for compatible nuts. Therefore, for compatibility, SAE J995 nuts should be added as a suitable option for SAE J429 bolts.

The washers specified in AISI STANDARD S100 J3.4 include ASTM F436 and ASTM F844. These are the recommended washers that are referenced in the ASTM F3125 standard specification for Grades A325 and A490 bolts. The following standard specifications summarize the appropriate washers to be used for a given bolt:

- ASTM F436 “hardened steel washers” are the recommended washer for use with A325 or A490 bolts.
- ASTM F844 “unhardened or soft washers” are not referenced or recommended for use in the corresponding A307, A325, or A490 bolt standards, however they are allowed for use in bolted connections in AISI STANDARD S100.
- SAE J429 contains no reference to suitable washers. It would be reasonable to include an applicable SAE standard such as J2655 for washers that are allowed under the provisions of ASTM F844.
- SAE J2486 is the suitable equivalent tension indicating washer standard for SAE J429 bolts and is comparable to ASTM F959 for ASTM F3125 Grades A325 and A490 bolts.

The SAE standard for washers and lock washers are in accordance J2655. This is a suitable standard to reference however, for use in cold-formed steel bolted connections it should be limited to washers, and lock washers should be excluded. SAE washers conform to ASME B18.22.1 Type A, Narrow Plain Washers. ASTM F844 specifies the standard washer dimensions are to be in accordance with ASME B18.22.1, Tables 1A and 1B for Type A, Narrow Plain Washers. ASTM F844 continues to allow non-standard washers including USS and SAE series washers. Based on this review of standards and washer dimensions it is appropriate to include SAE J2655 washers in the standard. See Table 3-1 for a comparison of ASTM and SAE Washers.

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

Table 3-1 Comparison of ASTM and SAE Washers

Nominal Size		ASTM F844 "soft washers"								ASTM F436 "hard washers"					
		USS				SAE				Circular, Clipped Circular, and Extra Thick		Thickness (T), in.			
		ASME B18.21.1, Type A, Wide Plain Washers				ASME B18.21.1, Type A, Narrow Plain Washers									
		Nominal Diameter		Thickness		Nominal Diameter		Thickness		Nominal Diameter		Circular and Clipped		Extra Thick	
OD (in.)	ID (in.)	min (in)	max (in)	OD (in.)	ID (in.)	min (in)	max (in)	OD (in.)	ID (in.)	min (in)	max (in)	min (in)	max (in)		
1/8	#6	-	-	-	-	0.375	0.156	.036	.065	-	-	-	-	-	-
5/32	#8	-	-	-	-	0.438	0.188	.036	.065	-	-	-	-	-	-
3/16	#10	0.56	0.25	.036	.065	0.5	0.22	.036	.065	-	-	-	-	-	-
7/32	#12	-	-	-	-	0.562	0.25	.051	.080	-	-	-	-	-	-
1/4	#14	0.734	0.312	.051	.080	0.625	0.281	.051	.080	0.625	0.281	0.051	0.08	-	-
5/16		0.875	0.375	.064	.104	0.688	0.344	.051	.080	0.688	0.344	0.051	0.08	-	-
3/8		1	0.438	.064	.104	0.812	0.406	.051	.080	0.813	0.406	0.051	0.08	-	-
7/16		1.25	0.5	.064	.104	0.922	0.469	.051	.080	0.922	0.469	0.051	0.08	-	-
1/2		1.375	0.562	.086	.132	1.062	0.531	.074	.121	1.063	0.531	0.097	0.177	0.305	0.375
9/16		1.469	0.625	.086	.132	1.156	0.594	.074	.121	1.188	0.625	0.11	0.177	0.305	0.375
5/8		1.75	0.688	.108	.160	1.312	0.656	.074	.121	1.313	0.688	0.122	0.177	0.305	0.375
3/4		2	0.812	.122	.177	1.469	0.812	.108	.160	1.468	0.813	0.122	0.177	0.305	0.375
7/8		2.25	0.938	.136	.192	1.75	0.938	.108	.160	1.75	0.938	0.136	0.177	0.305	0.375
1		2.5	1.062	.136	.192	2	1.062	.108	.160	2	1.063	0.136	0.177	0.305	0.375
1 1/8		2.75	1.25	.136	.192	2.25	1.25	.108	.160	2.25	1.188	0.136	0.177	0.305	0.375
1 1/4		3	1.375	.136	.192	2.5	1.375	.136	.192	2.5	1.375	0.136	0.177	0.305	0.375
1 3/8		3.25	1.5	.153	.213	2.75	1.5	.136	.213	2.75	1.5	0.136	0.177	0.305	0.375
1 1/2		3.5	1.625	.153	.213	3	1.625	.153	.213	3	1.625	0.136	0.177	0.305	0.375

4.0 Bolted Connections

The design of cold-formed steel bolted connections is specified in AISI STANDARD S100 Chapter J, *Connections and Joints*, Section J3. The specification section is broken down into the following subsections:

- J3.1 *Minimum Spacing*
- J3.2 *Minimum Edge and End Distances*
- J3.3 *Bearing*
- J3.4 *Shear and Tension in Bolts*

Only Sections J3.3 and J3.4 are germane to this research report looking into the benefits of adding SAE J429 Bolts into the AISI STANDARD S100. The nominal tensile and shear strengths of these bolts are summarized in Table 4-1.

4.1 Design of Bearing Connections

Section J3.3 *Bearing* is the condition where the bolt does not yield and the strength limit state is the bearing of the cold-formed steel member(s) against the bolt. A more

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

rigorous description can be found in the AISI STANDARD S100 Commentary Section J3.3 where it states:

“... *bearing* strength of bolted *connections* depends on: (1) the *tensile strength*, F_u , of the connected parts, (2) the *thickness* of connected parts, (3) the diameter of the bolt, (4) *joints* with single shear and double shear conditions, (5) the F_u/F_y ratio, and (6) the use of washers ...”

Therefore, if the diameter of the ASTM bolt is the same as that of the SAE bolt and the use of washers is the same, there should be no difference when specifying either type of bolt.

Section J3.3 is further broken down into subsections J3.3.1 *Bearing Strength Without Consideration of Bolt Hole Deformation* and J3.3.2 *Bearing Strength With Consideration of Bolt Hole Deformation*. The provisions in Section J3.3.1 are applicable to:

- Standard hex bolt head size (ASTM A307 Type A) or heavy hex bolt head size (ASTM A307 Type B, and ASTM F3125 Grades A325 and A490) are allowed without restriction on the use of standard hex or heavy hex head size.
- All standard, oversize, and slotted hole sizes are allowed without restriction on the use of standard hex or heavy hex bolt head size.
- ASTM F844 “soft” washers or ASTM F436 “hard” washers are allowed without restriction on the use of standard hex or heavy hex bolt head size.
- Both connections with or without a washer under the hex head or hex head nut are allowed without restriction on the use of standard hex or heavy hex bolt head size.

The provisions in Section J3.3.2 are applicable to:

- All connections covered in Section J3.3.1.
- Not to exceed the strength of the connecting part(s) in accordance with Section J3.3.1.
- Bearing strength is limited to address bolt hole deformation without restriction on the use of standard hex or heavy hex bolt head size.

Based on this review of the methods in J3.3.1 *Bearing Strength Without Consideration of Bolt Hole Deformation* and J3.3.2 *Bearing Strength With Consideration of Bolt Hole Deformation*, SAE J429 bolts with a standard hex head size, that is the same size as an ASTM A307 Type A, are acceptable for use with this section as well as ASTM A307 Type B heavy hex head that is the same as ASTM F3125 Grades A325 or A490 structural bolts.

4.2 Design of Bolts for Shear and Tension

Section J3.4 *Shear and Tension in Bolts* specifies the design of the bolt body to resist shear and tension based on the tensile strength of the bolt. This section provides design provisions for the U.S. and Mexico in Appendix A and Canada in Appendix B.

Appendices A and B Section J3.4 *Shear and Tension in Bolts* are influenced by:

- The controlling shear plane of failure for both shear and tension is the narrowest section of the bolt shank, the root diameter of the threaded section. ASTM A307 and ASTM F3125 Grades A325 and A490 bolts all use a Unified National Coarse (UNC) thread which is the same thread form used for SAE J429 bolts with UNC thread. Therefore, the narrowest cross section at the root of the threads is the same for both ASTM and SAE bolts.
- SAE J429 bolts allow for both UNC and Unified National Fine (UNF) thread. Fine thread bolts have a shallower thread depth than coarse thread bolts, therefore if UNF bolts are used the narrowest cross section at the root of the threads will be larger than UNC threads making the design based on UNC thread conservative.
- The range of tensile strengths for SAE J429 bolts is 70 ksi to 150 ksi which is within the same range of tensile strengths that are defined for ASTM bolts which is 60 ksi to 150 ksi. Again, see Tables 2-2A and 2-2B that summarize the strength of ASTM and SAE bolts.

Based on the thread form and grade of steel, SAE J429 bolts are acceptable within the methods given in Section J3.4 of Appendix A or B.

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

Table 4-1 Nominal Tensile and Shear Strengths for SAE J429 Bolts

Bolt Type	Nominal Tensile Strength F_{nt} , ksi (MPa)		Nominal Shear Strength F_{nv} , ksi (MPa) ^a	
	1/4 in. \leq d < 1/2 in. (6.4 mm \leq d < 12 mm)	d \geq 1/2 in. (12 mm)	1/4 in. \leq d < 1/2 in. (6.4 mm \leq d < 12 mm)	d \geq 1/2 in. (12 mm)
Grade 2 Bolts: <ul style="list-style-type: none"> • When threads are not excluded from shear planes • When threads are excluded from shear planes 	50 (345)	56 (386)	30 (207) 42 (290)	33 (228) 42 (290)
Grade 5 Bolts: <ul style="list-style-type: none"> • When threads are not excluded from shear planes • When threads are excluded from shear planes 	81 (558)	90 (621)	48 (331) 68 (469)	54 (372) 68 (469)
Grade 8 Bolts: <ul style="list-style-type: none"> • When threads are not excluded from shear planes • When threads are excluded from shear planes 	101 (696)	113 (779)	60 (414) 84 (579)	68 (469) 84 (579)

5.0 Quality Assurance

SAE J429 bolts are inspected to the same quality standards as their counterpart ASTM F3125 Grades A325 and A490 bolts. All of these bolts are inspected in accordance with ASME B18.18.1 *Inspection and Quality Assurance for General Purpose Fasteners* (see Table 5-1, Comparison of Quality Control Standards). ASTM F3125 has additional sampling requirements that are defined in ASTM F1470 *Standard Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection*. SAE J429 specifies that for in-process inspection the applicable ASME, ASTM, or SAE quality system consensus standard be applied which would then point back to ASTM F1470 as the applicable standard for sampling. Figure 5.1 provides a flowchart for both ASTM and SAE Bolt Quality Sampling Requirements. Based on the use of the same quality

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

standard, ASME B18.18.1, the use of SAE J429 bolts are equally suited for use in AISI STANDARD S100 as the listed ASTM bolts from a quality assurance perspective.

Table 5-1 Comparison of Quality Control Standards

Grade	Size	Hardness, HRb		Wedge Tensile Strength, ksi		Quality Standard
		min	max	min	max	
SAE J429 Grade 2	To 3/4"	80	100	74	-	ASME B18.18.1
	Over 3/4"	70	100	60	-	
A307A	Less Than 3D	69	100	60	-	Test per ASTM A370 Sampling per ASTM A307
	3D and Longer	-	100	60	-	
A307B	All Sizes	69	95	60	100	

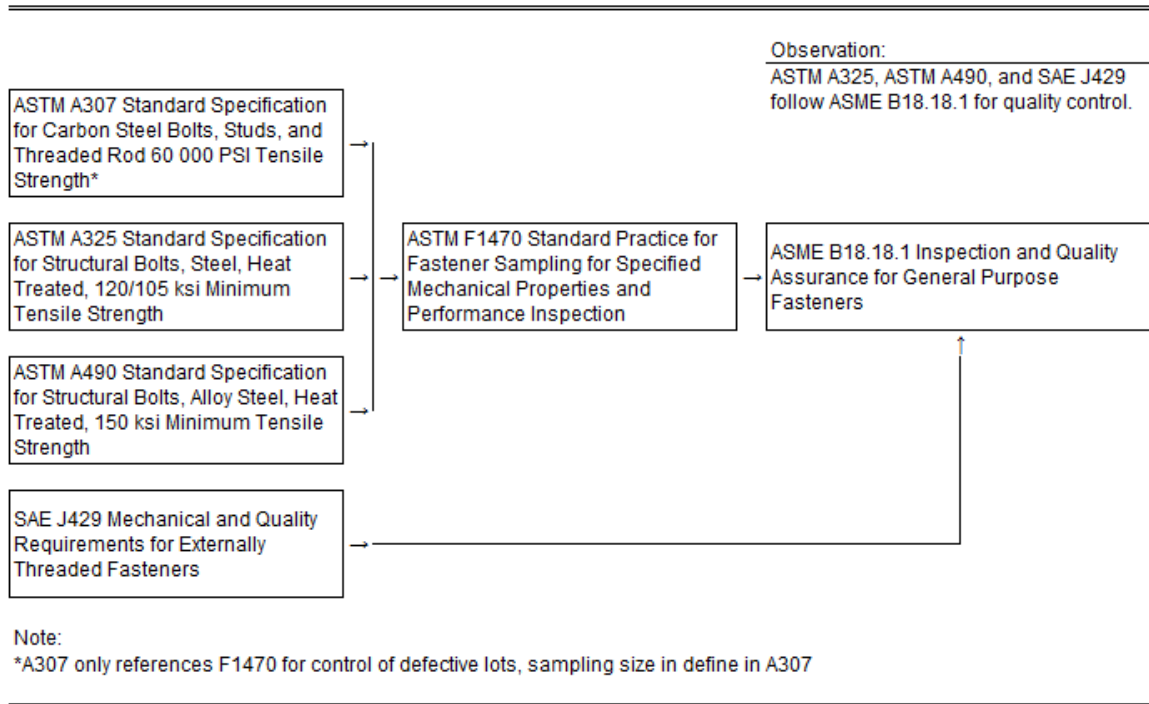


Figure 5.1 - ASTM and SAE Bolt Quality Sampling Requirements

6.0 Observations of AISI STANDARD S100 for Bolted Connections Beyond the Comparison of ASTM to SAE Bolts

Pull-over of bolted connections is not addressed well in AISI STANDARD S100. Section J3.4 *Shear and Tension in Bolts* does not address pull-over of the sheet steel relative to the bolt head size or washer size as is provided for screws in Section J4 Screw Connections. The only design provisions are found in Section J3.4 of Appendix A or B where it is specified that tension pull-over strength of the connected sheet at the bolt head, nut, or washer shall be considered where bolt tension is involved. AISI STANDARD S100 Section J6.2 *Tension Rupture* does not mention pull-over even though in concept pull-over is a rupture limit state that likely involves tension effects. The AISI Standard is essentially silent on how to address pull-over without restriction on bolt head size. Since ASTM A307 Type A, standard hex head size, bolts are allowed then there is no basis to restrict the use of SAE bolts with the same standard hex head size. It may be worth noting in the AISI STANDARD S100 Commentary that if SAE bolts with standard hex heads are being substituted for heavy hex head bolts the impact of the smaller head size on pull-over should be considered.

Matching the appropriate grade of nut with the bolt is not addressed directly in AISI STANDARD S100. Section J3.4 *Shear and Tension in Bolts* allows for ASTM A307 and ASTM F3125 Grades A325 and A490 bolts along with either ASTM A194 or ASTM A563 for nuts. The standard is silent on requiring that the appropriate grade nut be matched with the selected bolt for a given application. The ASTM standards do provide recommended nut grades. The SAE J429 standard lists SAE J995 *Mechanical and Material Requirements for Steel Nuts* as a reference document but is silent on selecting the appropriate nut for the grade of bolt selected. It is recommended that AISI STANDARD S100 specify the appropriate grade of nut be selected for the bolt.

The AISI STANDARD S100 Commentary can remind users that those requirements are in the appropriate [applicable] bolt standards. The RCSC **Specification for Structural Joints Using High-Strength Bolts** (2019) specifies the appropriate nut relative to the selected bolt in Figure C-2.1, Bolt and Nut Dimensions and provided in Table 6-1 while the bolt selection grip length is given in Figure C-2.2, Bolt Length Selection Increment and shown in Table 6-2 along with Figure 6.1.

Finally, the authors think that a new table either be added to AISI STANDARD S100 as a User Note or in the Commentary that correlates the appropriate nut with the specified bolt or provided in AISI D100.

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

Table 6-1 Bolt and Nut Dimensions,
(taken from RCSC Specification Figure C-2.1. Bolt and Nut Dimensions)

Nominal Bolt Diameter, d_b , in.	Heavy- Hex Bolt Dimensions, in.			Heavy-Hex Nut Dimensions., in.	
	Width across flats, F	Height, H_1	Thread Length, T	Width across flats, W	Height, H_2
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

Table 6-2 Bolt Selection Grip Length, (taken from RCSC Specification Figure 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

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

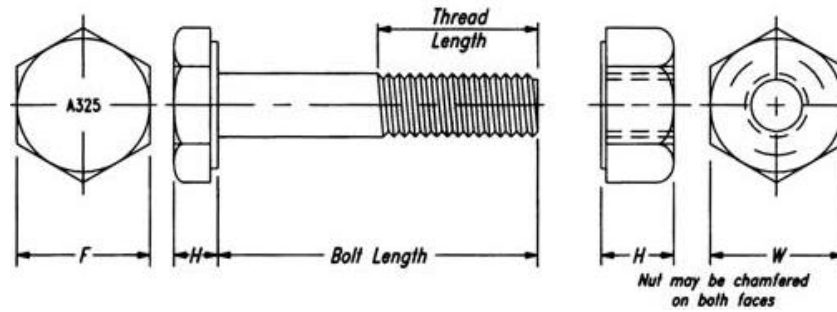


Figure 6.1 – Bolt Dimensions F , H , W Illustrated (taken from RCSC Specification Figure C-2.2. Heavy-hex structural bolt and heavy-hex nut)

7.0 Proposal

Based on the information assembled it is appropriate to add SAE J429 bolts into the AISI STANDARD S100 for use in the design of cold-formed steel structures based on the review of the existing bolt geometry, bearing strength provisions, bolt shear strength provisions and bolt tension strength provisions.

In addition to the SAE J429 bolts the corresponding recommended nuts detailed in Table 3-1 which is based on ASME B18.21.1, *Washers: Helical Spring-Lock, Tooth Lock, and Plain Washers (Inch Series)* should be added to help enable the proper use of these bolts. The table describes either USS or SAE washers based on ASTM F844, *Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use*. The ASME Standard has the following note that tries to explain the differences between SAE and USS washers, “Sometimes Type A narrow washers are referred to as SAE and Type A wide washers are referred to as USS washers even though they are not covered by SAE or USS standards.”

The specific SAE washer designations J995, *Mechanical and Material Requirements for Steel Nuts* and J2655, *Fastener Part Standard - Washers and Lockwashers (Inch Dimensioned)* should be added to the AISI STANDARD S100.

To enable this, the following additions should be made to the AISI Standard:

1. ADD SAE J429 Grade 2, 3, and 5 bolts to AISI STANDARD S100 Appendix A Table J3.4-1 and Appendix B Table J3.4-1;
2. ADD references to SAE J429 bolts, SAE J995 nuts, and SAE J2655 washers and SAE J2486 tension indicating washers;

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

3. ADD mandatory language that the appropriate grade of nut needs to be selected based on the grade of bolt chosen; and
4. ADD Commentary language that discusses issues that could occur when substituting SAE bolts, nuts, and washers for designs initially based on ASTM bolts, nuts, and washers. The language will address differences such as bolt thread length and head size.

7.1 Other Recommendations

Additions to the AISI STANDARD S100 beyond the scope of adding SAE bolts, nuts, and washers.

1. The U.S., Mexico, and Canadian provisions in Appendix A and B for fastener strength and combined shear and tension could be reconciled to provide a single method in the main body of the Standard. This would be a significant improvement for the practitioner to have one set of provisions in the main body of the Standard.
2. Provide a new table correlating the appropriate nut with the specified bolt grade. This might fit well into an updated section of AISI D100 that addresses fastener types, nuts, and washer selection.
3. Develop provision(s) in AISI S905 to test pull-over of bolted connections similar to that of screws.

8.0 References

AISI S100-16 w/S1-18, *North American Specification for the Design of Cold-Formed Steel Structural Members*, 2016 Edition with Supplement 1

From AISI Standard

Bolts, nuts, and washers conforming to one of the following ASTM specifications are approved for use under this Specification:

ASTM A194/A194M-20a, Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

ASTM A307-14e1, Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength

ASTM A354-17e2, Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

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

ASTM A449-14, Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use

ASTM A563-15, Standard Specification for Carbon and Alloy Steel Nuts

ASTM A563M-07(Reapproved 2013), Standard Specification for Carbon and Alloy Steel Nuts (Metric)

ASTM F436/F436M-19, Standard Specification for Hardened Steel Washers Inch and Metric Dimensions

ASTM F844-07a (Reapproved 2013), Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use

ASTM F959/F959M-17a, Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners, Inch and Metric Series

ASTM F1470-19, Standard Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

ASTM F3125/F3125M-19e1, Standard Specification for High Strength Structural Bolts and Assemblies, Steel and Alloy Steel, Heat Treated, Inch Dimensions 120 ksi and 150 ksi Minimum Tensile Strength, and Metric Dimensions 830 MPa and 1040 MPa Minimum Tensile Strength

Benefits of Including SAE Bolts, Nuts, and Washers in the AISI STANDARD S100

Recommended SAE Standards

SAE J429-2014, Mechanical and Material Requirements for Externally Threaded Fasteners

SAE J995-2017, Mechanical and Material Requirements for Steel Nuts

SAE J1701-2017, Torque-Tension Tightening for Inch Series Fasteners

SAE J1701M-2017, Torque-Tension Tightening for Metric Series Fasteners

SAE J2486-2018, Tension Indicating Washer Tightening Method for Fasteners

SAE J2655-2015, Fastener Part Standard - Washers and Lockwashers (Inch Dimensioned)

From ASME

ASME B18.2.1-2012 (Errata 2013), Square, Hex, Heavy Hex, and Askew Head Bolts, and Hex, Heavy Hex, Hex Flange, Lobed Head, and Lag Screws (Inch Series)

ASME B18.2.6-2019, Fasteners for Use in Structural Applications

ASME B18.2.6M-2012, Metric Fasteners for Use in Structural Applications

ASME B18.18-2017, Quality Assurance for Fasteners

ASME B18.21.1-2009 (R2016), Washers: Helical Spring-Lock, Tooth Lock, and Plain Washers (Inch Series), (Revision and consolidation of ASME B18.21.1 and ASME B18.22.1)

ASME B18.22.1, Note: see ASME B18.21.1-2009 (R2016)

Other

Specification for Structural Joints Using High-Strength Bolts, Research Council on Structural Connections, RCSC, 2014



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