research report

Investigation of Bolted Connections in Cold-Formed Steel Members using SAE J429 Bolts

RESEARCH REPORT RP20-8

November 2020

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

American Iron and Steel Institute

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UNIVERSITY OF NORTH TEXAS

2018 AISI Small Fellowship Project

Investigation of Bolted Connections in Cold-Formed Steel Members using SAE J429 Bolts

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Updated November 9, 2020

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ABSTRACT

The report presents a research project aimed at comparing ASTM and SAE J429 bolts. The research includes comparison of those two bolt standards in terms of tensile strength, chemical and mechanical properties, shanks length, head size, thread profile and bolt styles. The research shows that the overall dimension, tensile strength, head and shank size for both standards are the same and no considerable difference is observed.

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1 RESEARCH OBJECTIVES

The purpose of this research is to compare two types of bolts with different grades: SAE J429 and ASTM bolts, and determine if any of those two types of bolts are equivalent and exchangeable in cold-formed steel applications. The ASTM bolts included in this study are the A307, A325, and A490.

The research first reviews the relevant standards, and then compares the materials and properties, dimensions and tolerances of bolts in the relevant standards. Finally, it shows that some grades of bolts in SAE J429, ASTM A307 and ASTM F3125 can be replaced with each other.

2 INTRODUCTION

SAE J429 (2014) bolts and screws are normally available in Grades 1, 2, 5, 5.2, 8, and 8.2. Studs are normally available only in Grades 1, 2, 4, 5, 8, and 8.1.

ASTM bolts include A182, A193, A194, A307, A320, A325 (Type 1 Medium carbon, carbon boron, or medium carbon alloy steel, Type 2 Withdrawn in November 1991 and Type 3 Weathering steel), A449, A453 and A490. In this study, the focus is on A307 and F3125 bolts as those are commonly used in cold-formed steel structures. Fig. 2.1 shows the style of bolt's head and some terminologies.

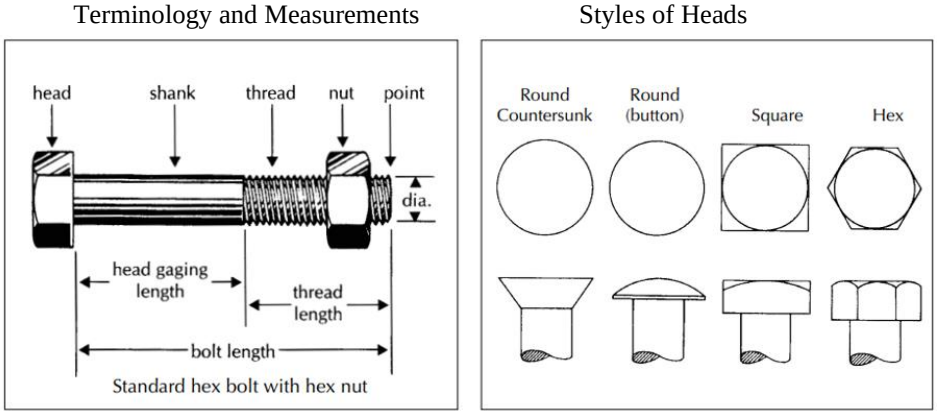

Figure 2. 1: Style of Bolt's Head and Terminology

2-1 Basic Fastener Types

A bolt is a device with a head on one end of a shank or body and a thread on the other end. Designed for insertion through holes in assembly parts, it is mated with a tapped nut (see Fig. 2.2). Tension is normally induced in the bolt to compress the assembly by rotating the nut. This may also be done by rotation of the bolt head.

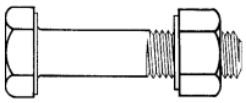

Figure 2. 2: Bolt and Nut

A screw is a headed and threaded bolt used without a nut (see Fig. 2.3). It is inserted into an internally tapped hole and tension is induced by rotation of the screw head.

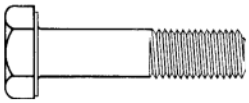

Figure 2. 3: Screw

A stud is a fastener with no head, but it has threads at both ends of the shank (see Fig. 2.4). It, like a screw, has one end that screws into a tapped hole. A nut is used on the other end to create tension.

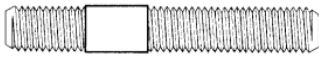

Figure 2. 4: Stud threads at both ends

If a stud is threaded its entire shank length and a nut used on both ends to create tension, it serves the function of a bolt and is then classified as a Stud Bolt (see Fig. 2.5).

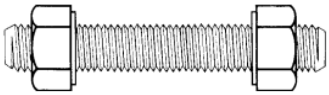

Figure 2. 5: Stud, threads entire shank length

A set screw is a type of screw generally used to secure an object within or against another object, normally not using a nut (see bolts compared with screws). If a set screw has a head, the thread will extend all the way to the head (whereas a bolt might have an unthreaded shank between the head and thread).

Self-drilling screws are usually used for the connection of thin metal plates. When the self-drilling screw is screwed into the connecting plate, it can be tightened without nut, and the connected plate does not need to process the prefabricated hole, thus reducing the assembly cost.

The washer is generally a flat metal ring, which is used to protect the surface of the connected part from the friction force of the nut, evenly distribute the nut pressure on the connector, and protect the bolt thread and the surface of the connector. Neoprene washers are often used in the connection of self-drilling screws, and larger washer can help to increase the splitting load (delay splitting) in pull-through failure.

Twist-off-type tension control structural bolts are constructed by the corresponding wrench. When the torque is applied to gather the internal tensile stress of the material to reach the design value (tightening axial force), the shear strength corresponding to the bolt material can weaken the cross section of the bolt's plum head and cut it off.

2-2 Classes of Thread

Classes of thread are distinguished from each other by the amounts of tolerance specified in two categories, external and internal threads, the class for each category is as below:

Classes 1A, 2A, and 3A apply to external threads,

Classes 1B, 2B and 3B, to internal threads.

Most standard fasteners are produced with a Class 2A fit for bolts and a Class 2B fit for nuts. The Class 2A allowance assures easier assembly of mating parts, minimizes galling and seizing in high-cycle wrench assembly, and can be used to accommodate commercial electroplated finishes. Classes 1A and 1B are shown in ANSI B1.1-1982 but are rarely used.

Classes 3A and 3B afford no allowance or clearance for mating parts and are used chiefly for applications where a close tolerance fit is important.

Threading requirements are designated as follow:

The number of threads per inch applied to a specific diameter,

The initial letters of the thread standard (UNR or UN),

The letters C, F, or numeral 8 to indicate coarse-, fine-, or 8-thread series,

The thread fit.

The coarse-thread series (UNRC or UNC) is used on the vast majority of bolts and nuts. Number of threads per inch ranges from 20 threads for a 1/4-in. diameter bolt to 4 threads for a 4-in. diameter bolt. The fine-thread series (UNRF or UNF) is found mostly in automotive and aeronautical work. Threads per inch range from 28 threads for a 1/4-in. diameter bolt to 12 threads for a 1-1/2-in. diameter bolt. There is no fine-thread standard for fasteners over 1-1/2 in. The 8-thread series (8UNR or 8UN) is used only for sizes over 1inch in diameter, usually in high temperature, high pressure service.

Example: A bolt 1/2 in. -13 UNRC-2A is interpreted as: 1/2 in. nominal diameter of thread, 13 means number of threads per inch, UNR means thread from standard (Unified National Radius-Root) and C means coarse-thread series 2A means class of thread fit.

2-3 Industry Standards

Most industrial fasteners are covered by two basic standards:

Materials and properties,

Dimensions and tolerances.

Specifications for materials and properties (ASTM A307-2014, ASTM A563-2015, SAE J 429-2014, ASTM A354-2017) are published by the American Society for Testing and Materials (ASTM). The Society of Automotive Engineers (SAE) also publishes specifications covering these same requirements.

Standards for dimensions and tolerances (ANSI/ASME B18.2.1-2012, ANSI/ASME B18.5.2.3M-1998, IFI-128-2000, IFI-136-2002) are issued by the American National Standards Institute (ANSI) in cooperation with the American Society of Mechanical Engineers (ASME) and the Industrial Fasteners Institute (IFI).

Standard fasteners include square and hex bolts, cap screws, carriage bolts, plow bolts, lag screws, studs, self-tapping screws and rivets.

3 SAE J429 SPECIFICATION

The SAE standard (SAE J429, 2014) covers the mechanical and material requirements for inch-series steel bolts, studs, screws for sems (screw and washer assemblies), and U-bolts in sizes to 1-1/2 in. inclusive, these bolts are intended for use in the automotive industry and similar industries. Fig. 3.1 shows the SAE J429 Grade identification.

Table 3.1 lists mechanical requirements and identification marking for bolts, screws, studs, sems (screw and washer assemblies) and U-Bolts, based on SAE J 429. SAE bolts and screws are normally available in Grades 1, 2, 5, 5.2, 8 and 8.2. Studs are normally available in Grades 1, 2, 4, 5, 8 and 8.1. Grade 5.1 is applicable to sems (screw and washer assemblies) which can be heat treated following assembly of the washer on the screw, and to products without assembled washer.

In Table 3.2, proof load and tensile strength requirements are indicated based on bolt numbers in different grades.

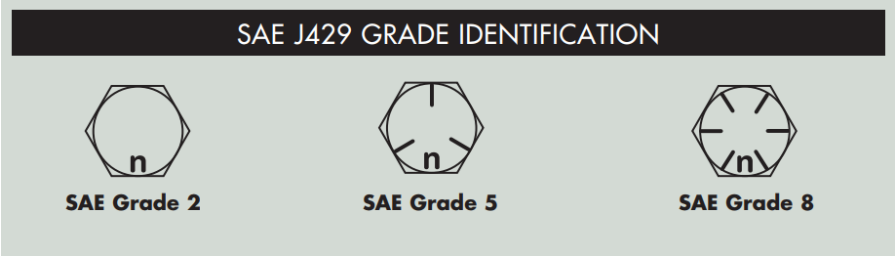

Figure 3. 1: J429 Grade Identification

(www.Nucor-Fastener.com)

Table 3.3 shows the summary of J429 mechanical properties for each grade based on nominal size. As per one of the research objectives Grade 1 with 60,000 psi tensile strength, Grade 2 with 60,000 and 74,000 psi based on bolt size, Grade 5 with 105,000 and 120,000 psi based on bolt size, Grade 5.1 and 5.2 with 120,000 psi and Grade 8, 8.1 and 8.2 with 150,000 psi is considered for comparison. Table 3.2 shows the proof load and minimum tensile strength (lb) for each SAE J429 grade, moreover it is significant that J429 is produced with two types of threads, the unified coarse thread (UNC) and the unified fine thread (UNF).

Table 3. 1 Mechanical Requirements and Identification Marking for Bolts, Screws, Studs and U-bolts (SAE J429, 2014)

Grade Designation	Products	Nominal Size Dia - In	Full Size<7l Bolts, Screws, Studs, Sems, Proof Load (Stress), psi	Full Size<7l Bolts, Screws, Studs, Sems, Tensile Strength (Stress) Min, psi	Machine Test Specimens of Bolts, Screws, and Studs Yield<2l Strength (Stress) Min, psi	Machine Test Specimens of Bolts, Screws, and Studs Tensile Strength (Stress) Min, psi	Machine Test Specimens of Bolts, Screws, and Studs Elongation Min,%	Machine Test Specimens of Bolts, Screws, and Studs Reduction of Area Min,%	Surface Hardness Rockwell 30N Max	Core Hardness Rockwell Min	Core Hardness Rockwell Max	Grade Identification Marking<
1	Bolts, Screws, Studs	1/4 thru 1-1/2	33,0001	60,000	36,000	60,000	18	35	-	B70	B100	None
2	Bolts, Screws, Studs	1/4 thru 3/4!5)	55,0001	74,000	57,000	74,000	18	35	-	B80	B100	None
		Over 3/4 thru 1-1/2	33,000	60,000	36,000	60,000	18	35		B70	B100	None
4	Studs	1/4 thru 1-1/2	65,000	115,000	100,000	115,000	10	35	-	C22	C32	None
5	Bolts, Screws, Studs	1/4 thru 1	85,000	120,000	92,000	120,000	14	35	54	C25	C34	
		Over 1 thru 1-1/2	74,000	105,000	81,000	105,000	14	35	50	C19	C30	
5.11	SEMS	No. 4 thru 5/8	85,000	120,000	-	-	-	-	59.5	C25	C40	
5.2	Bolts, Screws	1/4 thru 1	85,000	120,000	92,000	120,000	14	35	56	C26	C36	
8	Bolts, Screws, Studs	1/4 thru 1-1/2	120,000	150,000	130,000	150,000	12	35	58.6	C33	C39	
8.1	Studs	1/4 thru 1-1/2	120,000	150,000	130,000	150,000	10	35	58.6	C33	C39	None
8.2	Bolts, Screws	1/4 thru 1	120,000	150,000	130,000	150,000	10	35	58.6	C33	C39	

Note: 1-Yield Strength is stress at which a permanent set of 0.2% of gage length occurs
2- Full size means a tension test specimen consisting of a completed fastener for testing in the ready to use condition without alteration

Table 3. 2 Proof Load and Tensile Strength Requirements (SAE J429, 2014)

	Stress Area, in²	Grade 1		Grade 2		Grade 4		Grade 5 & 5.2[2]		Grade 5.1		Grade 8, 8.1, 8.2[2]	
		Proof Load, lbf	Tensile Load Min, lbf	Proof Load, lbf	Tensile Load Min, lbf	Proof Load, lbf	Tensile Load Min, lbf	Proof Load, lbf	Tensile Load Min, lbf	Proof Load, lbf	Tensile Load Min, lbf	Proof Load, lbf	Tensile Load Min, lbf
Coarse Thread Series UNC													
No. 6-32	0.00909	-	-	-	-	-	-	-	-	750	1,100	-	-
8-32	0.0140	-	-	-	-	-	-	-	-	1,200	1,700	-	-
10-24	0.0175	-	-	-	-	-	-	-	-	1,500	2,100	-	-
12-24	0.0242	-	-	-	-	-	-	-	-	2,050	2,900	-	-
1/4-20	0.0318	1,050	1,900	1,750	2,350	2,050	3,650	2,700	3,800	2,700	3,800	3,800	4,750
5/16-18	0.0524	1,750	3,150	2,900	3,900	3,400	6,000	4,450	6,300	4,450	6,300	6,300	7,850
3/8-16	0.0775	2,550	4,650	4,250	5,750	5,050	8,400	6,600	9,300	6,600	9,300	9,300	11,600
7/16-14	0.1063	3,500	6,400	5,850	7,850	6,900	12,200	9,050	12,800	9,050	12,800	12,800	15,900
1/2-13	0.1419	4,700	8,500	7,800	10,500	9,200	18,300	12,100	17,000	12,100	17,000	17,000	21,300
9/16-12	0.182	6,000	10,900	10,000	13,500	11,800	20,900	15,500	21,800	15,500	21,800	21,800	27,300
5/8-11	0.226	7,450	13,600	12,400	16,700	14,700	25,400	19,200	27,100	19,200	27,100	27,100	33,900
3/4-10	0.334	11,000	20,000	18,400	24,700	21,700	38,400	28,400	40,100	-	-	40,100	50,100
7/8-9	0.462	15,200	27,700	15,200	27,700	30,000	53,100	39,300	55,400	-	-	55,400	69,300
1-8	0.606	20,000	36,400	20,000	36,400	39,400	69,700	51,500	72,700	-	-	72,700	90,900
1-1/8-7	0.763	25,200	45,800	25,200	45,800	49,600	87,700	56,500	80,100	-	-	91,600	114,400
1-1/4-7	0.969	32,000	58,100	32,000	58,100	63,000	111,400	71,700	101,700	-	-	116,300	145,400
1-3/8-6	1.155	38,100	69,300	38,100	69,300	75,100	132,800	85,500	121,300	-	-	138,600	173,200
1-1/2-6	1.405	46,400	84,300	46,400	84,300	91,300	161,600	104,000	147,500	-	-	168,600	210,800
Fine Thread Series UNF													
No. 6-40	0.01015	-	-	-	-	-	-	-	-	850	1,200	-	-
8-36	0.01474	-	-	-	-	-	-	-	-	1,250	1,750	-	-
10-32	0.0200	-	-	-	-	-	-	-	-	1,700	2,400	-	-
12-28	0.0258	-	-	-	-	-	-	-	-	2,200	3,100	-	-
1/4-28	0.0364	1,200	2,200	2,000	2,700	2,350	4,200	3,100	4,350	3,100	4,350	4,350	5,450
5/16-24	0.0580	1,900	3,500	3,200	4,300	3,750	6,700	4,900	6,950	4,900	6,950	6,950	8,700
3/8-24	0.0878	2,900	5,250	4,800	6,500	5,700	10,100	7,450	10,500	7,450	10,500	10,500	13,200
7/16-20	0.1187	3,900	7,100	6,550	8,800	7,700	13,650	10,100	14,200	10,100	14,200	14,200	17,800
1/2-20	0.1599	5,300	9,600	8,800	11,800	10,400	18,400	13,600	19,200	13,600	19,200	19,200	24,000
9/16-18	0.203	6,700	12,200	11,200	15,000	13,200	23,300	17,300	24,400	17,300	24,400	24,400	30,400
5/8-18	0.256	8,450	15,400	14,100	18,900	16,600	29,400	21,800	30,700	21,800	30,700	30,700	38,400
3/4-16	0.373	12,300	22,400	20,500	27,600	24,200	42,900	31,700	44,800	-	-	44,800	56,000
7/8-14	0.509	16,800	30,500	16,800	30,500	33,100	58,500	43,300	61,100	-	-	61,100	76,400
1-12	0.663	21,900	39,800	21,900	39,800	43,100	76,200	56,400	79,600	-	-	79,600	99,400
1 - 14 UNS	0.679	22,400	40,700	22,400	40,700	44,100	78,100	57,700	81,500	-	-	81,500	101,900
1-1/8-12	0.856	28,200	51,400	28,200	51,400	55,600	98,400	63,300	89,900	-	-	102,700	128,400
1-1/4-12	1.073	35,400	64,400	35,400	64,400	69,700	123,400	79,400	112,700	-	-	128,800	161,000
1-3/8-12	1.315	43,400	78,900	43,400	78,900	85,500	151,200	97,300	138,100	-	-	157,800	197,200
1-1/2-12	1.581	52,200	94,900	52,200	94,900	102,800	181,800	117,000	166,000	-	-	189,700	237,200

Table 3. 3 Mechanical Properties of J429 Bolts

Grade Designation	Products	Nominal Size Diameter, in.	Full size Bolts, Screws, Studs, Sems, Tensile Strength Min, psi
1	Bolt, Screws, Studs	1/4 thru 1 -1/2	60,000
2	Bolt, Screws, Studs	1/4 thru 3/4 Over 3/4 thru 1-1/2	74,000 60,000
4	Studs	1/4 thru 1-1/2	115,000
5	Bolt, Screws, Studs	1/4 thru 1 Over 1 thru 1 - 1/2	120,000 105,000
5.1	Sems	No .4 thru 5/8	120,000
5.2	Bolt, Screw	1/4 thru 1	120,000
8	Bolt, Screws, Studs	1/4 thru 1 -1/2	150,000
8.1	Studs	1/4 thru 1- 1/2	150,000
8.2	Bolt, Screw	1/4 thru 1	150,000

Note: Sems- screw and washer assemblies.

4 ASTM A307 SPECIFICATION

The ASTM A307 specification covers carbon steel bolts and studs from size ¼ in. through 4 in. diameter. These series of bolts include three Grades A, B, and C which denote tensile strength, configuration, and application. Tensile requirements based on bolt size for Grade A and Grade B is listed in Table 4.1. Chemical and hardness requirements are based on Tables 4.2 and 4.3.

The fasteners are designated by "Grade" denoting tensile strength and intended use as follows:

Grade A: Bolts, studs, and threaded rod having a minimum tensile strength of 60 ksi and intended for general applications.

Grade B: Bolts, studs, and threaded rod having a tensile strength of 60 to 100 ksi and intended for flanged joints in piping systems with cast iron flanges.

Grade C: Replaced by Specification ASTM F1554 (2018) Gr. 36.

Specification:

Threads on ASTM A307 bolts and studs shall be the Coarse Thread Series as specified in the latest standard of ASME B1.1 (2003), and shall have a Class 2A tolerance. Unless otherwise specified, threads on threaded rod shall be per the requirements of the latest issue of ASME B18.31.3 (2014).

Unless otherwise specified, Grade A bolts shall be hex bolts with dimensions as given in the latest standard of ASME B18.2.1 (2012).

Grade B bolts shall be heavy hex bolts with dimensions as given in the latest issue of ASME B18.2.1 (2012). Threads on threaded rod shall be per the requirements of the latest issue of ASME B18.31.3 (2014).

Unless otherwise specified, bolts, studs, and threaded rod to be used with nuts or tapped holes which have been tapped oversize, in accordance with ASTM A563 (2015).

Table 4. 1 Mechanical Properties of A307 Bolts (ASTM A307, 2014)

Bolt Size, in.	Stress Area [A], in. [2]	Tensile Strength, lbf [B]			Tensile Strength (psi) Tensile Strength (lbf)/ Stress Area (in.^{2})		
		Grade A, min [C]	Grade B		Grade A, min [C]	Grade B	
			min [D]	max [D]		min [D]	max [D]
1/4	0.0318	1,900	1,900	3,180	59,748	59,748	100,000
5/16	0.0524	3,100	3,100	5,240	59,160	59,160	100,000
3/8	0.0775	4,650	4,650	7,750	60,000	60,000	100,000
7/16	0.1063	6,350	6,350	10,630	59,737	59,737	100,000
1/2	0.1419	8,500	8,500	14,190	59,901	59,901	100,000
9/16	0.182	11,000	11,000	18,200	60,440	60,440	100,000
5/8	0.226	13,550	13,550	22,600	59,956	59,956	100,000
3/4	0.334	20,050	20,050	33,400	60,030	60,030	100,000
7/8	0.462	27,700	27,700	46,200	59,957	59,957	100,000
1	0.606	36,350	36,350	60,600	59,983	59,983	100,000
1 1/8	0.763	45,800	45,800	76,300	60,026	60,026	100,000
1 1/4	0.969	58,150	58,150	96,900	60,010	60,010	100,000
1 3/8	1.155	69,300	69,300	115,500	60,000	60,000	100,000
1 1/2	1.405	84,300	84,300	140,500	60,000	60,000	100,000
1 3/4	1.9	114,000	114,000	190,000	60,000	60,000	100,000
2	2.50	150,000	150,000	250,000	60,000	60,000	100,000
2 1/4	3.25	195,000	195,000	325,000	60,000	60,000	100,000
2 1/2	4.00	240,000	240,000	400,000	60,000	60,000	100,000
2 3/4	4.93	295,800	295,800	493,000	60,000	60,000	100,000
3	5.97	358,200	358,200	597,000	60,000	60,000	100,000
3 1/4	7.10	426,000	426,000	710,000	60,000	60,000	100,000
3 1/2	8.33	499,800	499,800	833,000	60,000	60,000	100,000
3 3/4	9.66	579,600	579,600	966,000	60,000	60,000	100,000
4	11.08	664,800	664,800	1,108,000	60,000	60,000	100,000

Note：A- Area calculated from the equation: $A_s = 0.7854\ [\ D - (0.9743 / n)]^2$
where: As = stress area, D = nominal diameter of bolt, and n = threads per inch.
B- 1 lbf = 4.448 N.
C- Based on 60 ksi (414 MPa).
D- Based on 60-100 ksi (414-690 MPa).

Table 4. 2 Chemical Requirements for Bolt A307 Grade A and B (ASTM A307, 2014)

	Heat Analysis	Product Analysis
Carbon - max	0.29	0.33
Manganese, max	1.2	1.25
Phosphorus, max	0.04	0.041
Sulfur, max		
Grade A	0.15	See Note
Grade B	0.05	0.051

Note: Re-sulfurized steel is not subject to rejection based on product analysis for sulfur.

Table 4. 3 Hardness Requirement for Bolt A307 Grade A and B (ASTM A307, 2014)

Grade	Nominal Length, in.	Hardness [a]			
		Brinell		Rockwell B	
		Min	Max	Min	Max
A	Less than 3x dia [b]	121	241	69	100
	3x dia and longer	-	241	-	100
B	Less than 3x dia [b]	121	212	69	95
	3x dia and longer	-	212	-	95

Note: a- as measured anywhere on the surface or through the cross section.

b-Also bolts with drilled or undersized heads. These sizes and bolts with modified heads shall meet the minimum hardness as hardness is the only requirement.

5 ASTM F3125 GRADE A325 SPECIFICATION

This type of bolt is recognized as ASTM A325 commonly and the applicable standard for ASTM 325 bolts is consolidated and replaced by ASTM F3125 (2015). Based on this standard, Table 5.1 shows the tensile load requirements, for bolt sizes ranging from ½ in. through 1½ in., stress area and tensile load requirements. Based on Table 5.1, the bolt's tensile strength is calculated and presented in Table 5.2. As per Table 5.2 the tensile strength for ASTM A325 bolts is 120,000 PSI. The thread types for ASTM A325 bolts is UNC.

Table 5. 1 Tensile Load Requirements for Bolts Tested Full-Size (ASTM F3152, 2018)

120 ksi - A325 – F1852					
Bolt Size, in.	Threads per inch	Stress Area [A], in [2]	Tensile Load, min, lbf	Proof Load, Length Measurement min, lbf	Alternative Proof Load, Yield Strength Method, min, lbf
1/2	13 UNC	0.142	17, 050	12, 050	13,050
5/8	11 UNC	0.226	27 ,100	19 ,200	20,800
3/4	10 UNC	0.334	40 ,100	28 ,400	30,700
7/8	9 UNC	0.462	55 ,450	39 ,250	42,500
1	8 UNC	0.606	72 ,700	51, 500	55,750
1 1/8	7 UNC	0.763	80 ,100 [B]	64 ,900[B]	70,250 [B]
1 1/4	7 UNC	0.969	101 ,700 [B]	82 ,400[B]	89,200 [B]
1 3/8	6 UNC	1.155	121 ,300 [B]	98, 200[B]	106,300 [B]
1 1/2	6 UNC	1.405	147, 500 [B]	119 ,500[B]	129,300 [B]
Above values based on			120 ksi	85 ksi	92 ksi

Note: A- The stress area is calculated as follows for inch: $A_s = 0.7854\ [\ D - (0.9743 / n)]^2$; for Metric: $A_s = 0.7854(D - 0.9382P)^2$; where: As = Stress Area, D = Nominal Bolt Size, and n = thread pitch.

B- Previous versions of ASTM A325 and F1852 required tensile testing based on 105 ksi min. tensile strength for larger diameters, and proof load testing of 74 ksi (length measurement method) and 81 ksi (yield strength method). This specification was changed to align with AISC/RCSC design and installation values and metric equivalent strength levels.

Table 5. 2 Tensile Strength for Bolt Grade A325

Bolt Size, in.	Threads per inch	Stress Area [A], in. [2]	Tensile min lbf	Tensile Strength [B] (psi) Tensile: Strength (lbf)/ Stress Area (in.[2])
1/2	13	0.142	17,050	120,070
5/8	11	0.226	27,100	119,912
3/4	10	0.334	40,100	120,060
7/8	9	0.462	55,450	120,022
1	8	0.606	72,700	119,967
1 1/8	7	0.763	91,600	120,052
1 1/4	7	0.969	116,300	120,021
1 3/8	6	1.155	138,600	120,000
1 1/2	6	1.405	168,600	120,000

Note: A- The stress area is calculated as follows for inch: $A_s = 0.7854\ [\ D - (0.9743 / n)]^2$; for Metric: $A_s = 0.7854(D - 0.9382P)^2$; where: As = Stress Area, D = Nominal Bolt Size, and n = thread pitch.

B- Tensile Strength (psi) was calculated as Strength (lbf) divided by Stress Area (in.[2])

6 ASTM F3125 GRADE A490 Specification

This type of bolt is recognized as A490 commonly and the applicable standard for ASTM 490 is consolidated and replaced by ASTM F3125 (2015). The thread type for ASTM A490 bolts is UNT.

Table 6.1 shows the tensile load requirements, for bolt sizes ranging from ½ in. through 1½ in., stress area and tensile load requirements is indicated in columns 3 and 4 in Table 6.1. Based on Table 6.1, the tensile strength is calculated which presented in Table 6.2. Column 6 in Table 6.2 indicates that that tensile strength for bolt A490 is 150,000 psi.

Table 6. 1 Tensile Load Requirements for Bolts Tested Full-Size – (ASTM F3152, 2018)

150ksi- A490 –F2280						
Bolt Size, in.	Threads per inch	Stress Area [A], in. [2]	Tensile Load, lbf		Proof Load , lbf, Length Measurement Method	Alternative Proof Load, lbf, Yield Strength Method
			min	max		
1/2	13 UNC	0.142	21,300	24,600	17,050	18,500
5/8	11 UNC	0.226	33,900	39,100	27,100	29,400
3/4	10 UNC	0.334	50,100	57,800	40,100	43,400
7/8	9 UNC	0.462	69,300	79,950	55,450	60,100
1	8 UNC	0.606	90,900	104,850	72,700	78,800
1 1/8	7 UNC	0.763	114,450	132,000	91,550	99,200
1 1/4	7 UNC	0.969	145,350	167,650	116,300	126,000
1 3/8	6 UNC	1.155	173,250	199,850	138,600	150,200
1 1/2	6 UNC	1.405	210,750	243,100	168,600	182,600
Above values based on			150 ksi	173 ksi	120 ksi	130 ksi

Note: A- The stress area is calculated as follows for inch: $A_s = 0.7854\ [\ D - (0.9743 / n)]^2$; for Metric: $A_s = 0.7854(D - 0.9382P)^2$; where: As = Stress Area, D = Nominal Bolt Size, and n = thread pitch.

Table 6. 2 Tensile Strength for Bolt Grade A490

Bolt Size, in.	Threads per inch	Stress Area [A,] In.^{2}	Tensile Min, lbf	Tensile Max, lbf	Tensile Strength (psi) Tensile: Strength min (lbf)/ Stress Area(in.^{2})	Tensile Strength [B] (psi) Tensile: Strength max (lbf)/ Stress Area(in.^{2})
1/2	13	0.142	21,300	24,600	150,000	173,239
5/8	11	0.226	33,900	39,100	150,000	173,009
3/4	10	0.334	50,100	57,800	150,000	173,054
7/8	9	0.462	69,300	79,950	150,000	173,052
1	8	0.606	90,900	104,850	150,000	173,020
1 1/8	7	0.763	114,450	132,000	150,000	173,001
1 1/4	7	0.969	145,350	167,650	150,000	173,013
1 3/8	6	1.155	173,250	199,850	150,000	173,030
1 1/2	6	1.405	210,750	243,100	150,000	173,025
Above values based on			150 ksi	173 ksi	-	-

Note: A- The stress area is calculated as follows for inch: $A_s = 0.7854\ [\ D - (0.9743 / n)]^2$; for Metric: $A_s = 0.7854(D - 0.9382P)^2$; where: As = Stress Area, D = Nominal Bolt Size, and n = thread pitch.

B- Tensile Strength (psi) was calculated as Strength (lbf) divided by Stress Area (in.^{2})

7 DIMENSIONAL COMPARISON

According to the relevant standards, each bolt has the specified minimum strength and bolt head shape. In this section, the head styles of each type of bolt are compared and identified. Table 7.1 shows the comparison of head styles in different standards. For ASTM A307 bolts, two head styles are applicable, depending on the grade. For ASTM A325 and A490 bolts, only the heavy hex head style is applicable.

Heading practice for SAE J429 is as follows:

Primary operation for bolt and screw manufacturing other than upsetting or extrusion are permitted only by special agreement purchaser and supplier.

Grade 1 bolts and screws shall be hot or cold headed, at option of the manufacturer.

Grade 2, 5, 5.2, 8 and 8.2 bolts and screws in sizes up to ¾ in., inclusive, and in lengths up to 6 in., inclusive shall be cold headed, except that by special agreement they may be hot headed. Larger sizes and longer lengths shall be hot or cold headed, at option of the manufacturer.

Grade 5.1 sems (screw and washer assemblies) screws shall be cold headed.

Product making for ASTM A307 is as follows:

Grade A and B bolts and studs:

Bolt heads and one end of studs shall be marked with a unique identifier by the manufacturer to identify the manufacturer or private label distributor, as appropriate. Additional marking required by the manufacturer for his own use shall be at the option of the manufacturer.

All bolt heads, one end of studs 3/8 in. and larger, and whenever feasible studs less than 3/8 in. shall be marked with a grade marking as follows:

the marking of Grade A is 307A; the marking of Grade B is 307B.

Table 7. 1 Head Type Comparison

Grade	Min	Type		Style
A 307	60 ksi	Grade A		Hex Bolt
	60-100 ksi	Grade B		Heavy Hex Bolt
A325	120 ksi	1	3	Heavy Hex Head
A325M	830 MPa	1	3	Heavy Hex Head
F1852	120 ksi	1	3	Twist -Off
A490	150 ksi	1	3	Heavy Hex Head
A490M	1040 MPa	1	3	Heavy Hex Head
F2280	150 ksi	1	3	Twist -Off

Dimension:

According to ASME B18.2.1-2012, the dimension of hex boltis indicated in Table 7.2, main parameters as diameter (E), width across flats (F), width across corners (G) and head height (H) are shown in Figure 7.1.

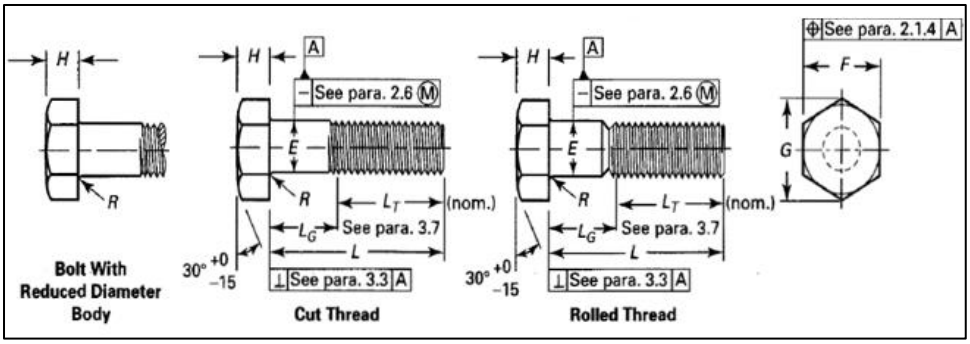

Figure 7. 1: ASME B18.2.1-2012

Table 7. 2 Hex Bolt Dimension (ASME B18.2.1-2012)

Nominal Size of Basic Product Diameter		Full-Size Body Diameter, *E*		Width Across Flats, *F*			Width Across Corners, *G*		Head Height, *H*			Radius of Fillet, *R*		Nominal Thread Length for Bolt Length, L_T	
		Max.	Min.	Basic	Max.	Min.	Max.	Min.	Basic	Max.	Min.	Max.	Min.	≤6in.	>6in.
1/4	0.2500	0.260	0.237	7/16	0.438	0.425	0.505	0.484	11/64	0.188	0.150	0.03	0.01	0.750	1.000
5/16	0.3125	0.324	0.298	1/2	0.500	0.484	0.577	0.552	7/32	0.235	0.195	0.03	0.01	0.875	1.125
3/8	0.3750	0.388	0.360	9/16	0.562	0.544	0.650	0.620	1/4	0.268	0.226	0.03	0.01	1.000	1.250
7/16	0.4375	0.452	0.421	5/8	0.625	0.603	0.722	0.687	19/64	0.316	0.272	0.03	0.01	1.125	1.375
1/2	0.5000	0.515	0.482	3/4	0.750	0.725	0.866	0.826	11/32	0.364	0.302	0.03	0.01	1.250	1.500
5/8	0.6250	0.642	0.605	15/16	0.938	0.906	1.083	1.033	27/64	0.444	0.378	0.06	0.02	1.500	1.750
3/4	0.7500	0.768	0.729	1 1/8	1.125	1.088	1.299	1.240	1/2	0.524	0.455	0.06	0.02	1.750	2.000
7/8	0.8750	0.895	0.852	1 5/16	1.312	1.269	1.516	1.447	37/64	0.604	0.531	0.06	0.02	2.000	2.250
1	1.0000	1.022	0.976	1 1/2	1.500	1.450	1.732	1.653	43/64	0.700	0.591	0.09	0.03	2.250	2.500
1 1/8	1.1250	1.149	1.098	1 11/16	1.688	1.631	1.949	1.859	3/4	0.780	0.658	0.09	0.03	2.500	2.750
1 1/4	1.2500	1.277	1.223	1 7/8	1.875	1.812	2.165	2.066	27/32	0.876	0.749	0.09	0.03	2.750	3.000
1 3/8	1.3750	1.404	1.345	2 1/16	2.062	1.994	2.382	2.273	29/32	0.940	0.810	0.09	0.03	3.000	3.250
1 1/2	1.5000	1.531	1.470	2 1/4	2.250	2.175	2.598	2.480	1	1.036	0.902	0.09	0.03	3.250	3.500
1 5/8	1.6250	1.658	1.591	2 7/16	2.438	2.356	2.815	2.616	1 3/32	1.116	0.978	0.09	0.03	3.500	3.750
1 3/4	1.7500	1.785	1.716	2 5/8	2.625	2.538	3.031	2.893	1 5/32	1.196	1.054	0.12	0.04	3.750	4.000
1 7/8	1.8750	1.912	1.839	2 13/16	2.812	2.719	3.248	3.099	1 1/4	1.276	1.130	0.12	0.04	4.000	4.250
2	2.0000	2.039	1.964	3	3.000	2.900	3.464	3.306	1 11/32	1.388	1.175	0.12	0.04	4.250	4.500
2 1/4	2.2500	2.305	2.214	3 3/8	3.375	3.262	3.897	3.719	1 1/2	1.548	1.327	0.19	0.06	4.750	5.000
2 1/2	2.5000	2.559	2.461	3 3/4	3.750	3.625	4.330	4.133	1 21/32	1.708	1.479	0.19	0.06	5.250	5.500
2 3/4	2.7500	2.827	2.711	4 1/8	4.125	3.988	4.763	4.546	1 13/16	1.869	1.632	0.19	0.06	5.750	6.000
3	3.0000	3.081	2.961	4 1/2	4.500	4.350	5.196	4.959	2	2.060	1.815	0.19	0.06	6.250	6.500
3 1/4	3.2500	3.335	3.210	4 7/8	4.875	4.712	5.629	5.372	2 3/16	2.251	1.936	0.19	0.06	6.750	7.000
3 1/2	3.5000	3.589	3.461	5 1/4	5.250	5.075	6.062	5.786	2 5/16	2.380	2.057	0.19	0.06	7.250	7.500
3 3/4	3.7500	3.858	3.726	5 5/8	5.625	5.437	6.495	6.198	2 1/2	2.572	2.241	0.19	0.06	7.750	8.000
4	4.0000	4.111	3.975	6	6.000	5.800	6.928	6.612	2 11/16	2.764	2.424	0.19	0.06	8.250	8.500

Based on four parameters (bolt length, head height, width across flat and width across corner), a comparison between hex head bolt and heavy hex head bolt is made (see Fig. 7.3-7.6), and the results are as follows:

Refer to Table 7.3, hex bolt and heavy hex bolt as per standard ASME B18.2.1 has the same total shank length.

Refer to Table 7.4, hex bolt and heavy hex bolt as per standard ASME B18.2.1 has the same head height. Refer to Table 7.5, it shows that width across flats (*F*) has difference for hex and heavy hex bolts. The width across flats (*F*) of heavy hex bolt is about 0.125-in. larger than that of hex bolt.

Refer to Table 7.6, it indicates that width across corner (*G*) has difference for hex and heavy hex bolts. The width across corner (*G*) of heavy hex bolt is 0.144-in. larger than that of hex bolt.

In conclusion Hex and Heavy Hex bolts have the same total shank length and head height but the width across flats and width across corner of heavy hex bolts are 0.125in. and 0.144-in. larger than those of hex bolt respectively, which indicates that the main difference in dimension between the two kinds of bolts is that the cross-sectional area of the head of heavy hex bolt is larger.

It is noteworthy that in both standard ASTM A307 and SAE J429, for bolt dimension referred to standard ASME B18.2.1 as referenced document, which indicates that the dimension requirements of hex head bolt and heavy hex bolt in ASME B18.2.1 are also applicable to standard ASTM A307 and SAE j429.

Regarding the thread type comparison, for ASTM A307, threads on bolts shall be the coarse thread series as specified in ASME B1.1. Based on first part of Table 3.2, SAE J429 bolt's thread profile is UNC for the nominal diameter sizes 6-32 up to 1-1/2-6. Refer to Table 5.1 for ASTM A325 and Table 3.2 for J429, the thread profile for the matching sizes are UNC. Based on Table 6.1, ASTM A490 thread type is UNC for bolt sizes 1/2 up to 1-1/2 and the same thread profile is observed for SAE J429, refer to Table 3.2.

Regarding the thread type comparison, for ASTM A307, A325, and A490, threads on bolts shall be the coarse thread series (UNC) as specified in the ASME B1.1. As mentioned in Section 3, SAE J429 bolts include two type of threads UNC and UNF. This research focuses on ASTM bolts and SAE J429 bolts with the UNC thread configuration.

Table 7. 3 Dimension Comparison for Hex and Heavy Hex bolt Head (E and L_T) (ASME B18.2.1-2012)

Dimension of Hex Bolt					Dimension of Heavy Hex Bolt				
Nominal Size of basic product Diameter	Full-Size body Diameter, E		Nominal Thread Length for Bolt Lengths, L_T		Nominal Size of basic product Diameter	Full-Size body Diameter, E		Nominal Thread Length for Bolt Lengths, L_T	
	Max.	Min.	6 in. and shorter	Over 6 in.		Max.	Min.	6 in. and shorter	Over 6 in.
1/4	0.2500	0.260	0.750	1.000	-	-	-	-	-
5/16	0.3125	0.324	0.875	1.125	-	-	-	-	-
3/8	0.3750	0.388	1.000	1.250	3/8	0.3750	0.388	1.000	1.250
7/16	0.4375	0.452	1.125	1.375	-	-	-	-	-
1/2	0.5000	0.515	1.250	1.500	1/2	0.5000	0.515	1.250	1.500
5/8	0.6250	0.642	1.500	1.750	5/8	0.6250	0.642	1.500	1.750
3/4	0.7500	0.768	1.750	2.000	3/4	0.7500	0.768	1.750	2.000
7/8	0.8750	0.895	2.000	2.250	7/8	0.8750	0.895	2.000	2.250
1	1.0000	1.022	2.250	2.500	1	1.0000	1.022	2.250	2.500
1 1/8	1.1250	1.149	2.500	2.750	1 1/8	1.1250	1.149	2.500	2.750
1 1/4	1.2500	1.277	2.750	3.000	1 1/4	1.2500	1.277	2.750	3.000
1 3/8	1.3750	1.404	3.000	3.250	1 3/8	1.3750	1.404	3.000	3.250
1 1/2	1.5000	1.531	3.250	3.500	1 1/2	1.5000	1.531	3.250	3.500
1 5/8	1.6250	1.658	3.500	3.750	1 5/8	1.6250	1.658	3.500	3.750
1 3/4	1.7500	1.785	3.750	4.000	1 3/4	1.7500	1.785	3.750	4.000
1 7/8	1.8750	1.912	4.000	4.250	1 7/8	1.8750	1.912	4.000	4.250
2	2.0000	2.039	4.250	4.500	2	2.0000	2.039	4.250	4.500
2 1/4	2.2500	2.305	4.750	5.000	2 1/4	2.2500	2.305	4.750	5.000
2 1/2	2.5000	2.559	5.250	5.500	2 1/2	2.5000	2.559	5.250	5.500
2 3/4	2.7500	2.827	5.750	6.000	2 3/4	2.7500	2.827	5.750	6.000
3	3.0000	3.081	6.250	6.500	3	3.0000	3.081	6.250	6.500
3 1/4	3.2500	3.335	6.750	7.000	-	-	-	-	-
3 1/2	3.5000	3.589	7.250	7.500	-	-	-	-	-
3 3/4	3.7500	3.858	7.750	8.000	-	-	-	-	-
4	4.0000	4.111	8.250	8.500	-	-	-	-	-

Note: The Unfilled cells (-) means there is no data or equivalent size exists.

Table 7. 4 Dimension Comparison for Hex and Heavy Hex Head Height (*H*) (ASME B18.2.1-2012)

Dimension of Hex Bolt				Dimension of Heavy Hex			
Nominal Size of basic product Diameter	Head Height, *H*			Nominal Size of basic product Diameter	Head Height, *H*		
	Basic	Max.	Min.		Basic	Max.	Min.
1/4	11/64	0.188	0.150	-	-	-	-
5/16	7/32	0.235	0.195	-	-	-	-
3/8	1/4	0.268	0.226	3/8	1/4	0.268	0.226
7/16	19/64	0.316	0.272	-	-	-	-
1/2	11/32	0.364	0.302	1/2	11/32	0.364	0.302
5/8	27/64	0.444	0.738	5/8	27/64	0.444	0.738
3/4	1/2	0.524	0.455	3/4	1/2	0.524	0.455
7/8	37/64	0.604	0.531	7/8	37/64	0.604	0.531
1	43/64	0.700	0.591	1	43/64	0.700	0.591
1 1/8	3/4	0.780	0.658	1 1/8	3/4	0.780	0.658
1 1/4	27/32	0.876	0.749	1 1/4	27/32	0.876	0.749
1 3/8	29/32	0.940	0.810	1 3/8	29/32	0.940	0.810
1 1/2	1	1.036	0.902	1 1/2	1	1.036	0.902
1 5/8	1 3/32	1.116	0.978	1 5/8	1 3/32	1.116	0.978
1 3/4	1 5/32	1.196	1.054	1 3/4	1 5/32	1.196	1.054
1 7/8	1 1/4	1.276	1.130	1 7/8	1 1/4	1.276	1.130
2	1 11/32	1.388	1.175	2	1 11/32	1.388	1.175
2 1/4	1 1/2	1.548	1.327	2 1/4	1 1/2	1.548	1.327
2 1/2	1 21/32	1.708	1.479	2 1/2	1 21/32	1.708	1.479
2 3/4	1 13/16	1.869	1.632	2 3/4	1 13/16	1.869	1.632
3	2	2.060	1.815	3	2	2.060	1.815
3 1/4	2 3/16	2.251	1.936	-	-	-	-
3 1/2	2 5/16	2.380	2.057	-	-	-	-
3 3/4	2 1/2	2.572	2.241	-	-	-	-
4	2 11/16	2.764	2.424	-	-	-	-

Note: The Unfilled cells (-) means there is no data or equivalent size exists.

Table 7. 5 Dimension Comparison for Hex and Heavy Hex Head -Cross Flat (*F*) (ASME B18.2.1-2012)

Hex Bolt				Heavy Hex Bolt			
Nominal Size of basic product Diameter	Width across flats, *F*			Nominal Size of basic product Diameter	Width across flats, *F*		
	Basic	Max.	Min.		Basic	Max.	Min.
1/4	7/16	0.438	0.425	-	-	-	-
5/16	1/2	0.500	0.484	-	-	-	-
3/8	9/16	0.562	0.544	3/8	11/16	0.688	0.669
7/16	5/8	0.625	0.603	-	-	-	-
1/2	3/4	0.750	0.725	1/2	7/8	0.875	0.850
5/8	15/16	0.938	0.906	5/8	1 1/16	1.062	1.031
3/4	1 1/8	1.125	1.088	3/4	1 1/4	1.250	1.212
7/8	1 5/16	1.312	1.269	7/8	1 7/16	1.438	1.394
1	1 1/2	1.500	1.450	1	1 5/8	1.625	1.575
1 1/8	1 11/16	1.688	1.631	1 1/8	1 13/16	1.812	1.756
1 1/4	1 7/8	1.875	1.812	1 1/4	2	2.000	1.938
1 3/8	2 1/16	2.062	1.994	1 3/8	2 3/16	2.188	2.119
1 1/2	2 1/4	2.250	2.175	1 1/2	2 3/8	2.375	2.300
1 5/8	2 7/16	2.438	2.356	1 5/8	2 9/16	2.562	2.481
1 3/4	2 5/8	2.625	2.538	1 3/4	2 3/4	2.750	2.662
1 7/8	2 13/16	2.812	2.719	1 7/8	2 15/16	2.938	2.844
2	3	3.000	2.900	2	3 1/8	3.125	3.025
2 1/4	3 3/8	3.375	3.262	2 1/4	3 1/2	3.500	3.388
2 1/2	3 3/4	3.750	3.625	2 1/2	3 7/8	3.875	3.750
2 3/4	4 1/8	4.125	3.988	2 3/4	4 1/4	4.250	4.112
3	4 1/2	4.500	4.350	3	4 5/8	4.625	4.475
3 1/4	4 7/8	4.875	4.712	-	-	-	-
3 1/2	5 1/4	5.250	5.075	-	-	-	-
3 3/4	5 5/8	5.625	5.437	-	-	-	-
4	6	6.000	5.800	-	-	-	-

Note: The Unfilled cells (-) means there is no data or equivalent size exists.

Table 7. 6 Dimension Comparison for Hex and Heavy Hex Head - Width across Corners (*G*)

(ASME B18.2.1-2012)

Hex Bolt			Heavy Hex Bolt		
Nominal Size of basic product Diameter	Width Across Corners, *G*		Nominal Size of basic product Diameter	Width Across Corners, *G*	
	Max.	Min.		Max.	Min.
1/4	0.505	0.484	-	-	-
5/16	0.577	0.552	-	-	-
3/8	0.650	0.620	3/8	0.794	0.763
7/16	0.722	0.987	-	-	-
1/2	0.866	0.826	1/2	1.010	0.969
5/8	1.083	1.330	5/8	1.227	1.175
3/4	1.299	1.240	3/4	1.443	1.383
7/8	1.516	1.447	7/8	1.660	1.589
1	1.732	1.653	1	1.876	1.796
1 1/8	1.949	1.859	1 1/8	2.093	2.002
1 1/4	2.165	2.066	1 1/4	2.309	2.209
1 3/8	2.382	2.273	1 3/8	2.526	2.416
1 1/2	2.598	2.480	1 1/2	2.742	2.622
1 5/8	2.815	2.616	1 5/8	2.959	2.829
1 3/4	3.031	2.893	1 3/4	3.175	3.035
1 7/8	3.248	3.099	1 7/8	3.392	3.242
2	3.464	3.306	2	3.608	3.449
2 1/4	3.897	3.179	2 1/4	4.041	3.862
2 1/2	4.330	4.133	2 1/2	4.474	4.275
2 3/4	4.763	4.546	2 3/4	4.907	4.688
3	5.196	4.959	3	5.340	5.102
3 1/4	5.629	5.372	-	-	-
3 1/2	6.062	5.786	-	-	-
3 3/4	6.495	6.198	-	-	-
4	6.928	6.612	-	-	-

Note: The Unfilled cells (-) means there is no data or equivalent size exists.

8 MECHANICAL PROPERTIES COMPARISON

ASTM A307 and SAE J429 bolts can be compared based on mechanical requirements as per Tables 3.3 and 4.1. Table 4.1 lists the mechanical requirements for ASTM A307 bolts. Table 4.1 shows that A307 bolt's size ranges from ¼ to 4 in. Tensile strength is calculated based on Tensile Strength (lbf) divided by Stress Area (in^2). As per calculation it is observed that tensile strength for Grade A and minimum for Grade B is 60,000 psi as well as the maximum tensile strength for Grade B is 100,000 psi.

Table 3.3 presents the mechanical requirements for SAE J429 bolts in relevant grade designation 1 to 8.2. Tensile strength for Grade 1 is 60,000 psi, for Grade 2 is 74,000 psi for size ¼ through ¾ and 60,000 psi for size over ¾ through 1-1/2. For Grades 8, 8.1 and 8.2 tensile strength is 150,000 psi.

Bolts ASTM A325 and J429 are compared based on mechanical properties as per Table 3.3 and 5.2, as the two tables illustrate tensile strength for SAE J429 grade 5 and 5.2 and ASTM A325 are 120,000 psi.

Bolts ASTM A490 and J429 are compared based on mechanical requirements as per Table 3.3 and Table 6.2, for SAE J429 grades 8, 8.1 and 8.2 and ASTM A490 tensile strength is 150,000 psi.

Therefore, ASTM A 307 Grade A and SAE J429 Grade 1 have 60,000 psi tensile strength , ASTM A325 and J429 Grade 5 and 5.2 has 120,000 psi tensile Strength and ASTM A490 and SAE J429 Grades 8,8.1,8.2 has 150,000 psi tensile strength.

9 CONCLUSIONS

ASTM A307 and SAE J429 (Grades 1 and 2)

Table 9.1 shows that ASTM A307 (Grade A and B) have a minimum tensile strength (60,000 psi), and SAE J429 Grade 1 has the same tensile strength, therefore ASTM A307 Grade A and B and SAE J429 Grade 1 have the same tensile strength equal to 60,000 psi. The threads per inch and stress area of bolt sizes between 1/4 to 1 ½ are the same, and the tensile bearing capacity is almost equal, which means Grade 1 (SAE J429) and Grade A and B (ASTM A307) can be replaced each other. Moreover, ASTM A307 Grade A and B has the equal tensile strength to SAE J429 Grade 2 for sizes 7/8 in. through 1 ½ in. Therefore, when the screw sizes are between 7/8 to 1 ½, bolts in ASTM A307 Grade A and B and SAE J429 Grade 1 and 2 are exchangeable.

Table 9. 1 Comparison for Tensile Load between SAE J429 Grades 1 & 2 and ASTM A307 Grades A & B

SAE J429					ASTM A307			
Bolt Size in.	Threads per inch	Stress Area, [A], in.^{2}	Tensile Load Min, lbf		Bolt Size in.	Threads per inch	Stress Area, [A], in.^{2}	Tensile Load Min, lbf [B]
			1 [C]	2 [C]				A & B [D]
1/4	20	0.0318	1900	2350	1/4	20	0.0318	1900
5/16	18	0.0524	3150	3900	5/16	18	0.0524	3100
3/8	16	0.0775	4600	5750	3/8	16	0.0775	4650
7/16	14	0.1063	6400	7850	7/16	14	0.1063	6350
1/2	13	0.1419	8500	10500	1/2	13	0.1419	8500
9/16	12	0.182	10900	13500	9/16	12	0.182	11000
5/8	11	0.226	13600	16700	5/8	11	0.226	13550
3/4	10	0.334	20000	24700	3/4	10	0.334	20050
7/8	9	0.462	27700	27700	7/8	9	0.462	27700
1	8	0.606	36400	36400	1	8	0.606	36350
1 1/8	7	0.763	45800	45800	1 1/8	7	0.763	45800
1 1/4	7	0.969	58100	58100	1 1/4	7	0.969	58150
1 3/8	6	1.155	69300	69300	1 3/8	6	1.155	69300
1 1/2	6	1.405	84300	84300	1 1/2	6	1.405	84300

Note: A- The stress area is calculated as follows for inch: $A_s = 0.7854\ [\ D - (0.9743 / n)]^2$; for Metric: $A_s = 0.7854(D - 0.9382P)^2$; where: As = Stress Area, D = Nominal Bolt Size, and n = thread pitch.

B- Based on 60 ksi (414MPa).

C- Grade 1 and Grade 2.

D- Grade A and Grade B.

It is noteworthy that SAE J429 has bolt size range from ¼ in. to 1 ½ in., but ASTM A307 has bolt range from ¼ in. to 4 in., so for the same bolt range we get the same value for tensile strength.

Also, for ASTM A307, threads on bolts shall be the Coarse Thread Series (UNC) as specified in the ASME B1.1. Based on Table 3.2, SAE J429 bolt's thread profile could be UNC for nominal diameter sizes 6-32 up to size 1-1/2-6, and UNF for nominal diameter sizes 6-40 up to size 1-1/2-12

ASTM F3125 Grade A325 and SAE J429 (Grade 5 and 5.2)

ASTM F3125 Grade A325 bolts are produced with a heavy hex head but SAE J429 Grade 5 and 8 bolts are produced to standard hex cap screw configuration. In standards ASTM F3125/F3125M − 15a, heads for ASTM F3125 Grade A325 indicated as heavy hex head, refer to Table 7.1. Therefore, ASTM F3125 Grade A325 and SAE J429 have the same thread shape and profile.

Table 9. 2 Comparison for Tensile Load between SAE J429 Grades 5 & 5.2 and ASTM F3125 Grades A325

SAE J429 Grades 5 & 5.2				ASTM F3125 Grade A325			
Bolt Size in.	Threads per inch	Stress Area, [A], $in.^2$	Tensile Load Min, lbf	Bolt Size in.	Threads per inch	Stress Area, [A], $in.^2$	Tensile Load Min, lbf [B]
1/2	13	0.1419	17000	1/2	13	0.142	17050
5/8	11	0.226	27100	5/8	11	0.226	27100
3/4	10	0.334	40100	3/4	10	0.334	40100
7/8	9	0.462	55400	7/8	9	0.462	55450
1	8	0.606	72700	1	8	0.606	72700
1 1/8	7	0.763	80100	1 1/8	7	0.763	91600
1 1/4	7	0.969	101700	1 1/4	7	0.969	116300
1 3/8	6	1.155	121300	1 3/8	6	1.155	138600
1 1/2	6	1.405	147500	1 1/2	6	1.405	168600

Table 9.2 shows that tensile strength for bolts ASTM F3125 Grade A325 is the same as for SAE J429 Grade 5 and Grade 5.2 between the bolt size of 1/2 in. to 1 in.. However, when the bolt size exceeds 1 inch, ASTM F3125 Grade A325 has a larger tensile load, which is 14.3% higher than that of SAE J429 Grade 5 & 5.2 bolt. The reason is that when the bolt size is less than 1 in., the bolt yield strength and tensile strength in SAE J429 Grades 5 & 5.2 and ASTM F3125 Grades A325 are the same (92 ksi & 120 ksi), but when the bolt size is over 1 in. through 1½ in., yield strength and tensile strength in SAE J429 Grade 5 dropped to 81 ksi and 105 ksi respectively. So, the bolts are replaceable in terms of the connection strength between the bolt size of 1/2 in. to 1 in..

It is noteworthy that SAE J429 Grades 5 & 5.2 have bolt size range from ¼ in. to 1 ½ in., which means that some smaller screws can be selected.

ASTM F3125 Grade A490 and SAE J429 (Grade 8, 8.1, 8.2)

Yield strength and Tensile strength for bolts ASTM F3125 Grade A490 and SAE J429 Grade 8 & 8.1 & 8.2 are same (130 ksi, 150 ksi). Table 9.3 shows that the two kinds of bolts exhibit the same tensile strength.

It is noteworthy that SAE J429 Grades 8 & 8.1 & 8.2 have bolt size range from ¼ in. to 1 ½ in., which means that some smaller screws can be selected.

Table 9. 3 Comparison for Tensile Load between SAE J429 Grades 8 & 8.1 & 8.2 and ASTM F3125 Grades A490

SAE J429 Grades 8 & 8.1 & 8.2				ASTM F3125 Grade A490			
Bolt Size in.	Threads per inch	Stress Area, [A], $in.^2$	Tensile Load Min, lbf	Bolt Size in.	Threads per inch	Stress Area, [A], $in.^2$	Tensile Load Min, lbf [B]
1/2	13	0.1419	21300	1/2	13	0.142	21300
5/8	11	0.226	33900	5/8	11	0.226	33900
3/4	10	0.334	50100	3/4	10	0.334	50100
7/8	9	0.462	69300	7/8	9	0.462	69300
1	8	0.606	90900	1	8	0.606	90900
1 1/8	7	0.763	114400	1 1/8	7	0.763	114450
1 1/4	7	0.969	145400	1 1/4	7	0.969	145350
1 3/8	6	1.155	173200	1 3/8	6	1.155	173250
1 1/2	6	1.405	210800	1 1/2	6	1.405	210750

Heads for ASTM F3125 Grade A490 indicated as heavy hex head. Therefore, the bolts are replaceable in terms of tensile strength. Regarding thread shape ASTM F3125 Grade A490 has UNC threads.

Table 9.4 summarizes the equivalent grades for both ASTM and SAE bolts. The material properties and bolt's dimensions are identical in each pair.

Table 9. 4 Equivalent Bolts

ASTM	SAE (UNC threads)
A307 Grade A and B	J429 Grade 1
A307 Grade A and B	J429 Grade 2 for size 7/8" to 1-1/2"
F3125 Grade A325	J 429 Grade 5 and 5.2
F3125 Grade A490	J 429 Grade 8, 8.1 , 8.2

ACKNOWLEDGEMENTS

The sponsorship of American Iron and Steel Institute is gratefully acknowledged. The technical advising provided by the industrial advisors, Linfeng Chen, Perry Green, and Patrick Bodwell, is highly appreciated.

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Research Report RP-20-8