Mechanical and physical properties of screws

according to ISO 898, part 1

The mechanical properties are given for tests at room temperature.

No.	Mechanical or physical property		Property class									
			4.6	4.8	5.6	5.8	6.8	8.8 d ≤ 16 mm[a]	8.8 d > 16 mm[b]	9.8 d ≤ 16 mm	10.9	12.9/12.9
1	Tensile strength, R_m, MPa, [N/mm²]	nom.[c]	400	400	500	500	600	800	800	900	1000	1200
		min.	400	420	500	520	600	800	830	900	1040	1220
2	Lower yield strength, R_{eL}[d], MPa, [N/mm²]	nom.[c]	240	–	300	–	–	–	–	–	–	–
		min.	240	–	300	–	–	–	–	–	–	–
3	Stress at 0,2 % non-proportional elongation $R_{p0,2}$, MPa, [N/mm²]	nom.[c]	–	–	–	–	–	640	640	720	900	1080
		min.	–	–	–	–	–	640	660	720	940	1100
4	Stress at 0,0048 d non-proportional elongation for full-size fasteners R_{pf}, MPa, [N/mm²]	nom.[c]	–	320	–	400	480	–	–	–	–	–
		min.	–	340[e]	–	420[e]	480[e]	–	–	–	–	–
5	Stress under proof load, S_p[f], MPa, [N/mm²]	nom.	225	310	280	380	440	580	600	650	830	970
	Proof strength ratio $S_{p,\,nom}/R_{eL\,min}$ or $S_{p,\,nom}/R_{p0,2\,min}$ or $S_{p,\,nom}/R_{pf\,min}$		0,94	0,91	0,93	0,90	0,92	0,91	0,91	0,90	0,88	0,88
6	Percentage elongation after fracture for machined test pieces, A, %	min.	22	–	20	–	–	12	12	10	9	8
7	Percentage reduction of area after fracture for machined test pieces, Z, %	min.	–	–	–	–	–	52	52	48	48	44
8	Elongation after fracture for full-size fasteners, A_f (see also ISO 898-1 Annex C)	min.	–	0,24	–	0,22	0,20	–	–	–	–	–
9	Head soundness		no fracture									
10	Vickers hardness, HV F ≥ 98 N	min.	120	130	155	160	190	250	255	290	320	385
		max.	220[g]	220[g]	220[g]	220[g]	250	320	335	360	380	435
11	Brinell hardness, HBW F = 30 D²	min.	114	124	147	152	181	238	242	276	304	366
		max.	209[g]	209[g]	209[g]	209[g]	238	304	318	342	361	414
12	Rockwell hardness, HRB	min.	67	71	79	82	89	–	–	–	–	–
		max.	95,0[g]	95,0[g]	95,0[g]	95,0[g]	99,5	–	–	–	–	–
	Rockwell hardness, HRC	min.	–	–	–	–	–	22	23	28	32	39
		max.	–	–	–	–	–	32	34	37	39	44
13	Surface hardness, HV 0,3	max.	–	–	–	–	–	[h]	[h]	[h]	[h,i]	[h,j]
14	Height of non-decarburized thread zone, E, mm	min.	–	–	–	–	–	$^1/_2\,H_1$	$^1/_2\,H_1$	$^1/_2\,H_1$	$^2/_3\,H_1$	$^3/_4\,H_1$
	Depth of complete decarburization in the thread, G, mm	max.	–	–	–	–	–	0,015	0,015	0,015	0,015	0,015
15	Reduction of hardness after retempering, HV	max.	–	–	–	–	–	20	20	20	20	20
16	Breaking torque, M_B Nm	min.	–	–	–	–	–	in accordance with ISO 898-7				
17	Impact strength K_V[k, l], J	min.	–	–	27	–	–	27	27	27	27	m
18	Surface integrity in accordance with		ISO 6157-1[n]									ISO 6157-3

[a] Values do not apply for structural bolting.
[b] For structural bolting d ≥ M12.
[c] Nominal values are specified only for the purpose of the desigation system for property classes. See clause 5.
[d] In cases where the lower yield strength R_{eL} cannot be determined, it is permissible to measure the stress at 0,2 % non-proportional elongation $R_{p0,2}$.
[e] For the property classes 4.8, 5.8 and 6.8 the values for $R_{pf\,min}$ are under investigation. The present values are given for calculation of the proof stress ratio only. They are not test values.
[f] Proof loads are specified in tables F.006.
[g] Hardness determined at the end of a fastener shall be 250 HV, 238 HB or 99,5 HRB maximum.
[h] Surface hardness shall not be more than 30 Vickers points above the measured core hardness of the fastener when determination of both surface hardness and core hardness are carried out with HV 0,3.
[i] Any increase in hardness at the surface which indicates that the surface hardness exceeds 390 HV is not acceptable.
[j] Any increase in hardness at the surface which indicates that the surface hardness exceeds 435 HV is not acceptable.
[k] Values are determined at a test temperature of –20 °C.
[l] Applies to d ≥ 16 mm.
[m] Value for K_V is under investigation.
[n] Instead of ISO 6157-1, ISO 6157-3 may apply by agreement between the manufacturer and the purchaser.

Minimum ultimate tensile loads

according to ISO 898, part 1

Minimum ultimate tensile loads – ISO metric coarse pitch thread

Thread[1)] d	Nominal stress area $A_{s, nom}$ [mm²]	Minimum ultimate tensile load $F_{m\ min}$ ($A_{s, nom}$ x $R_{m, min}$) [N]								
		Property class								
		4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9/12.9
M3	5,03	2 010	2 110	2 510	2 620	3 020	4 020	4 530	5 230	6 140
M3,5	6,78	2 710	2 850	3 390	3 530	4 070	5 420	6 100	7 050	8 270
M4	8,78	3 510	3 690	4 390	4 570	5 270	7 020	7 900	9 130	10 700
M5	14,2	5 680	5 960	7 100	7 380	8 520	11 350	12 800	14 800	17 300
M6	20,1	8 040	8 440	10 000	10 400	12 100	16 100	18 100	20 900	24 500
M7	28,9	11 600	12 100	14 400	15 000	17 300	23 100	26 000	30 100	35 300
M8	36,6	14 600[2)]	15 400	18 300[2)]	19 000	22 000	29 200[2)]	32 900	38 100[2)]	44 600
M10	58,0	23 200[2)]	24 400	29 000[2)]	30 200	34 800	46 400[2)]	52 200	60 300[2)]	70 800
M12	84,3	33 700	35 400	42 200	43 800	50 600	67 400[3)]	75 900	87 700	103 000
M14	115	46 000	48 300	57 500	59 800	69 000	92 000[3)]	104 000	120 000	140 000
M16	157	62 800	65 900	78 500	81 600	94 000	125 000[3)]	141 000	163 000	192 000
M18	192	76 800	80 600	96 000	99 800	115 000	159 000	–	200 000	234 000
M20	245	98 000	103 000	122 000	127 000	147 000	203 000	–	255 000	299 000
M22	303	121 000	127 000	152 000	158 000	182 000	252 000	–	315 000	370 000
M24	353	141 000	148 000	176 000	184 000	212 000	293 000	–	367 000	431 000
M27	459	184 000	193 000	230 000	239 000	275 000	381 000	–	477 000	560 000
M30	561	224 000	236 000	280 000	292 000	337 000	466 000	–	583 000	684 000
M33	694	278 000	292 000	347 000	361 000	416 000	576 000	–	722 000	847 000
M36	817	327 000	343 000	408 000	425 000	490 000	678 000	–	850 000	997 000
M39	976	390 000	410 000	488 000	508 000	586 000	810 000	–	1 020 000	1 200 000

1) Where no thread pitch is indicated in a thread designation, coarse pitch is specified.
2) For fasteners with thread tolerance 6az according to ISO 965-4 subject to hot dip galvanizing, reduced values in accordance with ISO 10684.
3) For structural bolting 70 000 N (for M12), 95 500 N (for M14) and 130 000 N (for M16).

To calculate the nominal stress area $A_{s, nom}$
Page F.046

Minimum ultimate tensile loads – ISO metric fine pitch thread

Thread d x P	Nominal stress area $A_{s, nom}$ [mm²]	Minimum ultimate tensile load $F_{m\ min}$ ($A_{s, nom}$ x $R_{m, min}$) [N]								
		Property class								
		4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9/12.9
M8x1	39,2	15 700	16 500	19 600	20 400	23 500	31 360	35 300	40 800	47 800
M10x1	64,5	25 800	27 100	32 300	33 500	38 700	51 600	58 100	67 100	78 700
M10x1,25	61,2	24 500	25 700	30 600	31 800	36 700	49 000	55 100	63 600	74 700
M12x1,25	92,1	36 800	38 700	46 100	47 900	55 300	73 700	82 900	95 800	112 000
M12x1,5	88,1	35 200	37 000	44 100	45 800	52 900	70 500	79 300	91 600	107 000
M14x1,5	125	50 000	52 500	62 500	65 000	75 000	100 000	112 000	130 000	152 000
M16x1,5	167	66 800	70 100	83 500	86 800	100 000	134 000	150 000	174 000	204 000
M18x1,5	216	86 400	90 700	108 000	112 000	130 000	179 000	–	225 000	264 000
M20x1,5	272	109 000	114 000	136 000	141 000	163 000	226 000	–	283 000	332 000
M22x1,5	333	133 000	140 000	166 000	173 000	200 000	276 000	–	346 000	406 000
M24x2	384	154 000	161 000	192 000	200 000	230 000	319 000	–	399 000	469 000
M27x2	496	198 000	208 000	248 000	258 000	298 000	412 000	–	516 000	605 000
M30x2	621	248 000	261 000	310 000	323 000	373 000	515 000	–	646 000	758 000
M33x2	761	304 000	320 000	380 000	396 000	457 000	632 000	–	791 000	928 000
M36x3	865	346 000	363 000	432 000	450 000	519 000	718 000	–	900 000	1 055 000
M39x3	1 030	412 000	433 000	515 000	536 000	618 000	855 000	–	1 070 000	1 260 000

Proof loads of screws

according to ISO 898, part 1

Proof loads – ISO metric coarse pitch thread

Thread[1] d	Nominal stress area $A_{s, nom}$ [mm^2]	Proof load F_p ($A_{s, nom}$ x $S_{p, nom}$[4]) [N] Property class 4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9/12.9
M3	5,03	1 130	1 560	1 410	1 910	2 210	2 920	3 270	4 180	4 880
M3,5	6,78	1 530	2 100	1 900	2 580	2 980	3 940	4 410	5 630	6 580
M4	8,78	1 980	2 720	2 460	3 340	3 860	5 100	5 710	7 290	8 520
M5	14,2	3 200	4 400	3 980	5 400	6 250	8 230	9 230	11 800	13 800
M6	20,1	4 520	6 230	5 630	7 640	8 840	11 600	13 100	16 700	19 500
M7	28,9	6 500	8 960	8 090	11 000	12 700	16 800	18 800	24 000	28 000
M8	36,6	8 240[2]	11 400	10 200[2]	13 900	16 100	21 200[2]	23 800	30 400[2]	35 500
M10	58,0	13 000[2]	18 000	16 200[2]	22 000	25 500	33 700[2]	37 700	48 100[2]	56 300
M12	84,3	19 000	26 100	23 600	32 000	37 100	48 900[3]	54 800	70 000	81 800
M14	115	25 900	35 600	32 200	43 700	50 600	66 700[3]	74 800	95 500	112 000
M16	157	35 300	48 700	44 000	59 700	69 100	91 000[3]	102 000	130 000	152 000
M18	192	43 200	59 500	53 800	73 000	84 500	115 000	–	159 000	186 000
M20	245	55 100	76 000	68 600	93 100	108 000	147 000	–	203 000	238 000
M22	303	68 200	93 900	84 800	115 000	133 000	182 000	–	252 000	294 000
M24	353	79 400	109 000	98 800	134 000	155 000	212 000	–	293 000	342 000
M27	459	103 000	142 000	128 000	174 000	202 000	275 000	–	381 000	445 000
M30	561	126 000	174 000	157 000	213 000	247 000	337 000	–	466 000	544 000
M33	694	156 000	215 000	194 000	264 000	305 000	416 000	–	576 000	673 000
M36	817	184 000	253 000	229 000	310 000	359 000	490 000	–	678 000	792 000
M39	976	220 000	303 000	273 000	371 000	429 000	586 000	–	810 000	947 000

1) Where no thread pitch is indicated in a thread designation, coarse pitch is specified.
2) For fasteners with thread tolerance 6az according to ISO 965-4 subject to hot dip galvanizing, reduced values in accordance with ISO 10684.
3) For structural bolting 50 700 N (for M12), 68 800 N (for M14) and 94 500 N (for M16).
4) Value for stress under proof load $S_{p, nom}$ and their relation to stress at non-proportional elongation see page F.004, No. 5 in table.

To calculate the nominal stress area $A_{s, nom}$
Page F.046

Proof loads – ISO metric fine pitch thread

Thread d x P	Nominal stress area $A_{s, nom}$ [mm^2]	Proof load F_p ($A_{s, nom}$ x $S_{p, nom}$) [N] Property class 4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9/12.9
M8x1	39,2	8 820	12 200	11 000	14 900	17 200	22 700	25 500	32 500	38 000
M10x1,25	61,2	13 800	19 000	17 100	23 300	26 900	35 500	39 800	50 800	59 400
M10x1	64,5	14 500	20 000	18 100	24 500	28 400	37 400	41 900	53 500	62 700
M12x1,25	92,1	20 700	28 600	25 800	35 000	40 500	53 400	59 900	76 400	89 300
M12x1,5	88,1	19 800	27 300	24 700	33 500	38 800	51 100	57 300	73 100	85 500
M14x1,5	125	28 100	38 800	35 000	47 500	55 000	72 500	81 200	104 000	121 000
M16x1,5	167	37 600	51 800	46 800	63 500	73 500	96 900	109 000	139 000	162 000
M18x1,5	216	48 600	67 000	60 500	82 100	95 000	130 000	–	179 000	210 000
M20x1,5	272	61 200	84 300	76 200	103 000	120 000	163 000	–	226 000	264 000
M22x1,5	333	74 900	103 000	93 200	126 000	146 000	200 000	–	276 000	323 000
M24x2	384	86 400	119 000	108 000	146 000	169 000	230 000	–	319 000	372 000
M27x2	496	112 000	154 000	139 000	188 000	218 000	298 000	–	412 000	481 000
M30x2	621	140 000	192 000	174 000	236 000	273 000	373 000	–	515 000	602 000
M33x2	761	171 000	236 000	213 000	289 000	335 000	457 000	–	632 000	738 000
M36x3	865	195 000	268 000	242 000	329 000	381 000	519 000	–	718 000	839 000
M39x3	1 030	232 000	319 000	288 000	391 000	453 000	618 000	–	855 000	999 000

Materials, heat treatment, chemical compositions

according to ISO 898, part 1

Steels

Property class	Material and heat treatment	Chemical composition limits (cast analysis, %)[1)]					Tempering temperature
		C		P	S	B[2)]	°C
		min.	max.	max.	max.	max.	min.
4.6[3), 4)]	Carbon steel or carbon steel with additives	–	0,55	0,05	0,06	not specified	–
4.8[4)]							
5.6[3)]		0,13	0,55	0,05	0,06		
5.8[4)]		–	0,55	0,05	0,06		
6.8[4)]		0,15	0,55	0,05	0,06		
8.8[6)]	Carbon steel with additives (e.g. Boron or Mn or Cr), quenched and tempered	0,15[5)]	0,40	0,025	0,025	0,003	425
	or Carbon steel, quenched and tempered	0,25	0,55	0,025	0,025		
	or Alloyed steel, quenched and tempered[7)]	0,20	0,55	0,025	0,025		
9.8[6)]	Carbon steel with additives (e.g. Boron or Mn or Cr), quenched and tempered	0,15[5)]	0,40	0,025	0,025	0,003	425
	or Carbon steel, quenched and tempered	0,25	0,55	0,025	0,025		
	or Alloyed steel, quenched and tempered[7)]	0,20	0,55	0,025	0,025		
10.9[6)]	Carbon steel with additives (e.g. Boron, Mn or Cr), quenched and tempered	0,20[5)]	0,55	0,025	0,025	0,003	425
	or Carbon steel, quenched and tempered	0,25	0,55	0,025	0,025		
	or Alloyed steel, quenched and tempered[7)]	0,20	0,55	0,025	0,025		
12.9[6), 8), 9)]	Alloyed steel, quenched and tempered[7)]	0,30	0,50	0,025	0,025	0,003	425
12.9[6), 8), 9)]	Carbon steel with additives (e.g. Boron, Mn or Cr or Molybdenum), quenched and tempered	0,28	0,50	0,025	0,025	0,003	380

1) In case of dispute, the product analysis applies.
2) Boron content can reach 0,005 %, provided that non-effective boron is controlled by addition of titanium and / or aluminum.
3) For cold forged fasteners of property classes 4.6 and 5.6, heat treatment of the wire used for cold forging or of the cold forged fastener itself may be necessary to achieve required ductility.
4) Free cutting steel is allowed for these property classes with the following maximum sulphur, phosphorus and lead contents: sulphur 0,34 %; phosphorus 0,11 %; lead 0,35 %.
5) In case of plain carbon boron steel with a carbon content below 0,25 % (cast analysis), the minimum manganese content shall be 0,6 % for property class 8.8 and 0,7 % for 9.8 and 10.9.
6) For the materials of these property classes, there shall be a sufficient hardenabiltity to ensure a structure consisting of approximately 90 % martensite in the core of the threaded sections for the fasteners in the «as-hardened» condition before tempering.
7) This alloy steel shall contain at least one of the following elements in the minimum quantity given: chromium 0,3 %, nickel 0,3 %, molybdenum 0,2 %, vanadium 0,1 %. Where elements are specified in combinations of two, three or four and have alloy contents less than those given above, the limit value to be applied for class determination is 70 % of the sum of the individual limit values shown above for the two, three or four elements concerned.
8) A metallographically detectable white phosphorous enriched layer is not permitted for property class 12.9/12.9. It shall be detected by a suitable test method.
9) Caution is advised when the use of property class 12.9/12.9 is considered. The capability of the fastener manufacturer, the service conditions and the wrenching methods should be considered. Environments may cause stress corrosion cracking of fasteners as processed as well as those coated.

Characteristics at elevated temperatures

according to ISO 898, part 1

Influence of elevated temperatures on mechanical properties of fasteners

Elevated temperatures can cause changes in the mechanical properties and in the functional performance of a fastener.

Up to typical service temperatures of 150 °C, no detrimental effects due to a change of mechanical properties of fasteners are known. At temperatures over 150 °C and up to a maximum temperature of 300 °C, the functional performance of fasteners should be ensured by careful examination.

With encreasing temperatures, a progressive
– reduction of lower yield strength or stress at 0,2 % non-proportional elongation or stress at 0,0048 d non-proportional elongation for finished fasteners, and
– reduction of tensile strength can be experienced. The continuous operating of fasteners at elevated service temperatures can result in stress relaxation, which increases with higher temperatures. Stress relaxation accompanies a loss of clamp force.

Work-hardened fasteners (property classes 4.8, 5.8, 6.8) are more sensitive with regard to stress relaxation compared with quenched and tempered or stress-relieved fasteners.

Care should be taken when lead-containing steels are used for fasteners at elevated temperatures. For such fasteners, a risk of liquid metal embrittlement (LME) should be taken into consideration when the service temperature is in the range of the melting point of lead.

Information for example, in EN 10269 and in ASTM F2281.

Characteristics at higher strength (if ≥ 1000 N/mm²)

Influence of higher screw property class under comprehension of the mechanical stress and environmental conditions.

Risk of hydrogen embrittlement
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