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 $A_{s,\,nom}$ [mm^2]	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	2010	2110	2510	2620	3020	4020	4530	5230	6140
M3,5	6,78	2710	2850	3390	3530	4070	5420	6100	7050	8270
M4	8,78	3510	3690	4390	4570	5270	7020	7900	9130	10700
M5	14,2	5680	5960	7100	7380	8520	11350	12800	14800	17300
M6	20,1	8040	8440	10000	10400	12100	16100	18100	20900	24500
M7	28,9	11600	12100	14400	15000	17300	23100	26000	30100	35300
M8	36,6	14600[2]	15400	18300[2]	19000	22000	29200[2]	32900	38100[2]	44600
M10	58,0	23200[2]	24400	29000[2]	30200	34800	46400[2]	52200	60300[2]	70800
M12	84,3	33700	35400	42200	43800	50600	67400[3]	75900	87700	103000
M14	115	46000	48300	57500	59800	69000	92000[3]	104000	120000	140000
M16	157	62800	65900	78500	81600	94000	125000[3]	141000	163000	192000
M18	192	76800	80600	96000	99800	115000	159000	–	200000	234000
M20	245	98000	103000	122000	127000	147000	203000	–	255000	299000
M22	303	121000	127000	152 000	158000	182000	252000	–	315000	370000
M24	353	141000	148000	176000	184000	212000	293000	–	367000	431000
M27	459	184000	193000	230000	239000	275000	381000	–	477000	560000
M30	561	224000	236000	280000	292000	337000	466000	–	583000	684000
M33	694	278000	292000	347000	361000	416000	576000	–	722000	847000
M36	817	327000	343000	408000	425000	490000	678000	–	850000	997000
M39	976	390000	410000	488000	508000	586000	810000	–	1020000	1200000

[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 $A_{s,\,nom}$ [mm^2]	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	15700	16500	19600	20400	23500	31360	35300	40800	47800
M10x1	64,5	25800	27100	32300	33500	38700	51600	58100	67100	78700
M10x1,25	61,2	24500	25700	30600	31800	36700	49000	55100	63600	74700
M12x1,25	92,1	36800	38700	46100	47900	55300	73700	82900	95800	112000
M12x1,5	88,1	35200	37000	44100	45800	52900	70500	79300	91600	107000
M14x1,5	125	50000	52500	62500	65000	75000	100000	112000	130000	152000
M16x1,5	167	66800	70100	83500	86800	100000	134000	150000	174000	204000
M18x1,5	216	86400	90700	108000	112000	130000	179000	–	225000	264000
M20x1,5	272	109000	114000	136000	141000	163000	226000	–	283000	332000
M22x1,5	333	133000	140000	166000	173000	200000	276000	–	346000	406000
M24x2	384	154000	161000	192000	200000	230000	319000	–	399000	469000
M27x2	496	198000	208000	248000	258000	298000	412000	–	516000	605000
M30x2	621	248000	261000	310000	323000	373000	515000	–	646000	758000
M33x2	761	304000	320000	380000	396000	457000	632000	–	791000	928000
M36x3	865	346000	363000	432000	450000	519000	718000	–	900000	1055000
M39x3	1 030	412000	433000	515000	536000	618000	855000	–	1070000	1260000

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	1130	1560	1410	1910	2210	2920	3270	4180	4880
M3,5	6,78	1530	2100	1900	2580	2980	3940	4410	5630	6580
M4	8,78	1980	2720	2460	3340	3860	5100	5710	7290	8520
M5	14,2	3200	4400	3980	5400	6250	8230	9230	11800	13800
M6	20,1	4520	6230	5630	7640	8840	11600	13100	16700	19500
M7	28,9	6500	8960	8090	11000	12700	16800	18800	24000	28000
M8	36,6	8240[2]	11400	10200[2]	13900	16100	21200[2]	23800	30400[2]	35500
M10	58,0	13000[2]	18000	16200[2]	22000	25500	33700[2]	37700	48100[2]	56300
M12	84,3	19000	26100	23600	32000	37100	48900[3]	54800	70000	81800
M14	115	25900	35600	32200	43700	50600	66700[3]	74800	95500	112000
M16	157	35300	48700	44000	59700	69100	91000[3]	102000	130000	152000
M18	192	43200	59500	53800	73000	84500	115000	–	159000	186000
M20	245	55100	76000	68600	93100	108000	147000	–	203000	238000
M22	303	68200	93900	84800	115000	133000	182000	–	252000	294000
M24	353	79400	109000	98800	134000	155000	212000	–	293000	342000
M27	459	103000	142000	128000	174000	202000	275000	–	381000	445000
M30	561	126000	174000	157000	213000	247000	337000	–	466000	544000
M33	694	156000	215000	194000	264000	305000	416000	–	576000	673000
M36	817	184000	253000	229000	310000	359000	490000	–	678000	792000
M39	976	220000	303000	273000	371000	429000	586000	–	810000	947000

[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	8820	12200	11000	14900	17200	22700	25500	32500	38000
M10x1,25	61,2	13800	19000	17100	23300	26900	35500	39800	50800	59400
M10x1	64,5	14500	20000	18100	24500	28400	37400	41900	53500	62700
M12x1,25	92,1	20700	28600	25800	35000	40500	53400	59900	76400	89300
M12x1,5	88,1	19800	27300	24700	33500	38800	51100	57300	73100	85500
M14x1,5	125	28100	38800	35000	47500	55000	72500	81200	104000	121000
M16x1,5	167	37600	51800	46800	63500	73500	96900	109000	139000	162000
M18x1,5	216	48600	67000	60500	82100	95000	130000	–	179000	210000
M20x1,5	272	61200	84300	76200	103000	120000	163000	–	226000	264000
M22x1,5	333	74900	103000	93200	126000	146000	200000	–	276000	323000
M24x2	384	86400	119000	108000	146000	169000	230000	–	319000	372000
M27x2	496	112000	154000	139000	188000	218000	298000	–	412000	481000
M30x2	621	140000	192000	174000	236000	273000	373000	–	515000	602000
M33x2	761	171000	236000	213000	289000	335000	457000	–	632000	738000
M36x3	865	195000	268000	242000	329000	381000	519000	–	718000	839000
M39x3	1 030	232000	319000	288000	391000	453000	618000	–	855000	999000

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
Page F.038