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Mechanical properties of fasteners — Part I : Bolts, screws and studs

*Caractéristiques mécaniques des éléments de fixation —
Partie I : Boulons, vis et goujons*

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 898/1 was developed by Technical Committee ISO/TC 2, *Fasteners*, and was circulated to the member bodies in May 1978.

It has been approved by the member bodies of the following countries :

Australia	India	Poland
Canada	Japan	South Africa, Rep. of
Czechoslovakia	Korea, Rep. of	Sweden
Denmark	Mexico	Switzerland
Finland	Netherlands	Turkey
France	New Zealand	United Kingdom
Germany, F.R.	Norway	U.S.A.

The member body of the following country expressed disapproval of the document on technical grounds :

Italy

This International Standard cancels and replaces ISO Recommendation R 898/1-1968, of which it constitutes a technical revision.

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Mechanical properties of fasteners — Part I : Bolts, screws and studs

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the mechanical properties of bolts, screws and studs.

It applies to bolts, screws and studs

- with nominal diameters up to and including 39 mm;
- of any triangular ISO thread and with diameters and pitches according to ISO 68, ISO 261 and ISO 262;
- of any shape;
- made of carbon steel or alloy steel.

It does not apply to set screws and similar threaded fasteners.

It does not specify requirements for such properties as

- weldability;
- corrosion resistance;
- ability to withstand temperature above $+300^{\circ}\text{C}$ or below -50°C .

NOTE — The designation system of this International Standard may be used for sizes outside the limits laid down in the scope (i.e. larger sizes than 39 mm) provided that all mechanical requirements of the property classes are met.

2 REFERENCES

ISO 68, *ISO general purpose screw threads — Basic profile.*

ISO/R 79, *Brinell hardness test for steel and cast iron.*

ISO/R 80, *Rockwell hardness test (B and C scales) for steel.*

ISO/R 81, *Vickers hardness test for steel.*

ISO 82, *Steel — Tensile testing.*

ISO 83, *Steel — Charpy impact test (U-notch).*

ISO 261, *ISO general purpose metric screw threads — General plan.*

ISO 262, *ISO general purpose metric screw threads — Selected sizes for screws, bolts and nuts.*

ISO/R 273, *Clearance holes for metric bolts, 1,6 up to and including 39 mm thread diameter.*

ISO 6157/1, *Fasteners — Surface discontinuities — Part 1 : Bolts, screws and studs with thread sizes M5 to M39.*¹⁾

3 DESIGNATION SYSTEM

The designation system for property classes of bolts, screws and studs is shown in table 1. The abscissae show the nominal tensile strength values (R_m in N/mm^2) while the ordinates show those of the elongation after fracture (A_5 in %).

The symbol consists of two figures :

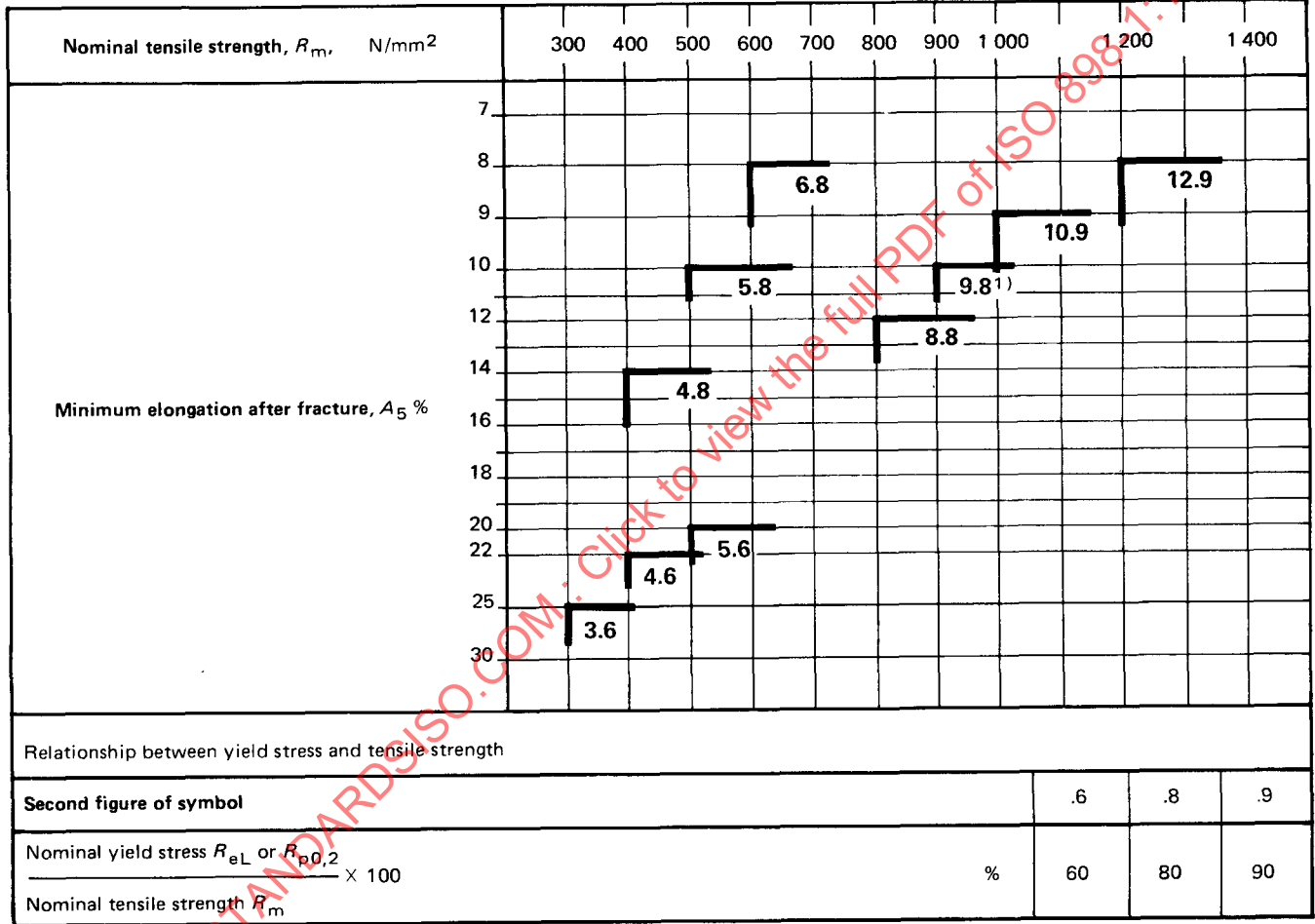
- the first indicates 1/100 of the nominal tensile strength in newtons per square millimetre (see R_m in table 3);
- the second figure indicated 10 times the ratio between nominal yield stress (R_{eL} or $R_{p0,2}$) and nominal tensile strength R_m (yield stress ratio).

The multiplication of these two figures will give 1/10 of the nominal yield stress (R_{eL} or $R_{p0,2}$) in newtons per square millimetre.

Minimum yield stress (R_{eL} or $R_{p0,2}$) and minimum tensile strength (R_m) are equal to or greater than the nominal values.

1) At present at the stage of draft.

TABLE 1 — System of co-ordinates



1) Applies only to sizes up to 16 mm thread diameter.

NOTE — Although a great number of property classes are specified in this International Standard this does not mean that all classes are appropriate for all items. Further guidance for application of the specific property classes is given in the relevant product standard. For non-standard items, it is advisable to follow as closely as possible the choice already made for similar standard items.

4 MATERIALS

Table 2 specifies steels for the different property class of bolts, screws and studs.

The minimum tempering temperatures listed in table 2 are mandatory for property classes 8.8 to 12.9 in all cases.

The chemical composition limits are mandatory only for those fasteners which are not subject to tensile testing.

Materials and heat treatments other than those listed in table 2 may be used by special agreement between purchaser and supplier when the latter can demonstrate that all mechanical properties are maintained.

TABLE 2 — Steels

Property class	Material and treatment	Chemical composition limits (check analysis) %				Tempering temperature °C ¹⁾ min.
		C min.	C max.	P max.	S max.	
3.6 ²⁾	Low carbon steel	—	0,20	0,05	0,06	—
4.6 ²⁾	Low or medium carbon steel	—	0,55	0,05	0,06	—
4.8 ²⁾						
5.6	Low or medium carbon steel	—	0,55	0,05	0,06	—
5.8 ²⁾						
6.8 ²⁾						
8.8 ⁶⁾	Low carbon steel with additives (e.g. boron or Mn or Cr), quenched and tempered	0,15	0,35	0,04	0,05	425
8.8 ³⁾	Medium carbon steel, quenched and tempered	0,25	0,55	0,04	0,05	450 ⁷⁾
9.8 ⁶⁾	Low carbon steel with additives (e.g. boron or Mn or Cr), quenched and tempered	0,15	0,35	0,04	0,05	410
9.8	Medium carbon steel, quenched and tempered	0,25	0,55	0,04	0,05	410
10.9 ⁶⁾	Low carbon steel with additives (e.g. boron or Mn or Cr), quenched and tempered	0,15	0,35	0,04	0,05	340
10.9 ⁵⁾	Medium carbon steel, quenched and tempered	0,25	0,55	0,04	0,05	425
	or — Medium carbon steel with additives (e.g. boron or Mn or Cr), quenched and tempered	0,20 ⁸⁾	0,55			
	or — Alloy steel ⁴⁾	0,20	0,55	0,035	0,035	
12.9 ⁵⁾	Alloy steel ⁴⁾	0,20	0,50	0,035	0,035	380

1) The mean of three hardness readings on a bolt tested before and after retempering shall not differ more than 20 Vickers points when retempered at a temperature 10 °C less than the specified minimum tempering temperature for 30 min.

2) Free-cutting steel is allowed for these classes with the following maximum sulphur, phosphorus and lead content :

sulphur 0,34 %; phosphorus 0,11 %; lead 0,35 %

3) For sizes above M20 the steels specified for class 10.9 may be necessary in order to achieve sufficient hardenability.

4) Alloy steel shall contain one or more of the alloying elements chromium, nickel, molybdenum or vanadium.

5) For the materials of these classes it is intended that there should be a sufficient hardenability to ensure a structure consisting of approximately 90 % martensite in the core of the threaded sections of the fasteners in the "as hardened" condition before tempering.

6) Products made of low carbon martensitic steel shall be additionally identified by underlining the symbol of the property class (see clause 9).

7) For size M20 and larger a tempering temperature of 425 °C may be used.

8) In some countries this level of carbon is classified as low carbon steel.

5 MECHANICAL PROPERTIES

When tested by the methods described in clause 8, the bolts, screws and studs shall have, at room temperature, the mechanical properties set out in table 3.

TABLE 3 – Mechanical properties of bolts, screws and studs

Sub-clause No.	Mechanical property		Property class											
			3.6	4.6	4.8	5.6	5.8	6.8	8.8 ≤ M16 > M16 ¹⁾		9.8 ²⁾	10.9	12.9	
5.1 and 5.2	Tensile strength, R_m , N/mm ²	nominal	300	400		500		600	800	800	900	1 000	1 200	
		min.	330	400	420	500	520	600	800	830	900	1 040	1 220	
5.3	Vickers hardness ³⁾ , HV, $F \geq 98$ N	min.	95	120	130	155	160	190	230	255	280	310	372	
		max.	220					250	300	336	360	382	434	
5.4	Brinell hardness ³⁾ , HB, $F = 30 D^2$	min.	90	114	124	147	152	181	219	242	266	295	353	
		max.	209					238	285	319	342	363	412	
5.5	Rockwell hardness ³⁾ , HR	min.	HRB	52	67	71	79	82	89	—	—	—	—	—
			HRC	—	—	—	—	—	—	20	23	27	31	38
		max.	HRB	95					99	—	—	—	—	—
			HRC	—			—		—	30	34	36	39	44
5.6	Surface hardness, HV 0,3	max.	—						320	356	380	402	454	
5.7	Yield stress ⁴⁾ , R_{eL} , N/mm ²	nominal	180	240	320	300	400	480	—	—	—	—	—	
		min.	190	240	340	300	420	480	—	—	—	—	—	
5.8	Stress at permanent set limit, $R_{p0,2}$, N/mm ²	nominal	—						640	640	720	900	1 080	
		min.	—						640	660	720	940	1 100	
5.9	Stress under proof load, S_p , N/mm ² S_p/R_{eL} or $R_{p0,2}$	S_p/R_{eL} or $R_{p0,2}$	0,94	0,94	0,91	0,94	0,91	0,91	0,91	0,91	0,91	0,88	0,88	
		N/mm ²	180	225	310	280	380	440	580	600	650	830	970	
5.10	Elongation after fracture, A_5 , %	min.	25	22	14	20	10	8	12	12	10	9	8	
5.11	Strength under wedge loading		The values for full size bolts and screws (not studs) should equal the minimum values for tensile strength shown in 5.2.											
5.12	Impact strength, J	min.	—			25	—		30	30	25	20	15	
5.13	Head soundness		no fracture											
5.14	Minimum height of non-decarburized thread zone, E		—						$\frac{1}{2}H_1$		$\frac{2}{3}H_1$	$\frac{3}{4}H_1$		
	Maximum depth of complete decarburization, G	mm	—						0,015					

1) For structural bolting $\geq$ M12.
2) Applies only to sizes up to 16 mm thread diameter.
3) Hardness values calculated on ISO/TC 17/SC6 N 357.
4) In a case where the yield stress, R_{eL} , cannot be determined, it is permissible to measure the stress at permanent set limit, $R_{p0,2}$.

6 MECHANICAL PROPERTIES TO BE DETERMINED

Two programmes, A and B, of tests for mechanical properties of bolts, screws and studs, using the methods described in clause 8, are set out in table 5.

Programme B shall be used wherever the capacity of available testing equipment permits.

For all cases marked with ○ in table 4, this programme is the referee method.

Programme A is suitable for machined test pieces and for bolts with a shank area less than the stress area.

For all cases marked with ● in table 4, this programme is the referee method.

TABLE 4 – Key to test programmes (table 5)

Size	Bolts and screws with thread diameters ≤ 4 mm or length < 3 d ¹⁾	Bolts and screws with thread diameters > 4 mm and length ≥ 3 d
Test decisive for acceptance	○	●

1) Also bolts and screws with special head configurations which are weaker than the threaded section.

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TABLE 5 – Test programmes A and B for acceptance purposes
These procedures apply to mechanical but not chemical properties.

Test group	Property		Test programme A				Test programme B			
			Test method		Property class		Test method		Property class	
					3.6, 4.6	8.8, 9.8			3.6, 4.6	8.8, 9.8
					4.8, 5.6	10.9			4.8, 5.6	10.9
					5.8, 6.8	12.9			5.8, 6.8	12.9
I	5.1 and 5.2	Minimum tensile strength, R_m	8.1	Tensile test	•	•	8.2	Tensile test ⁷⁾	•	•
	5.3 and 5.4	Minimum hardness ¹⁾	8.3	Hardness test ²⁾	○	○	8.3	Hardness test ²⁾	○	○
	5.5	Maximum hardness			•	•			•	•
	5.6	Maximum surface hardness			○	○			○	○
II	5.7	Minimum yield stress, R_{eL}	8.1	Tensile test	•					
	5.8	Stress at permanent set limit, $R_{p0,2}$	8.1	Tensile test		•				
	5.9	Stress under proof load, S_p					8.4	Proof load test	•	•
III	5.10	Minimum elongation after fracture, A_5	8.1	Tensile test	•	•				
	5.11	Strength under wedge loading ³⁾					8.5	Wedge loading test	•	•
IV	5.12	Minimum impact strength	8.6	Impact test ⁴⁾	• ⁵⁾	•				
	5.13	Head soundness ⁶⁾					8.7	Head soundness test	○	○
V	5.14	Maximum decarburized zone	8.8	Decarburization test		•	8.8	Decarburization test		•
	5.15	Retempering	8.8	Retempering test		•	8.8	Retempering test		•
	5.16	Surface integrity	8.9	Surface integrity test			8.9	Surface integrity test	•	•

1) Minimum hardness readings can replace tensile tests also for bolts, screws and studs with thread diameters > 4 mm and length ≥ 3 d for simplifying the procedure, but for referee purposes tensile tests are decisive.

2) Hardness may be Vickers, Brinell or Rockwell. In case of doubt the Vickers hardness test is decisive for acceptance.

3) Special head bolts and screws with configurations which are weaker than the threaded section are excluded from tensile testing requirements.

4) Only for bolts, screws and studs with thread diameters ≥ 16 mm and only if required by the purchaser.

5) Only property class 5.6.

6) Only for bolts and screws with thread diameters ≤ 16 mm and lengths too short to permit wedge load testing.

7) If the wedge loading test is applied, the axial tensile test is not required.

7 MINIMUM ULTIMATE TENSILE LOADS AND PROOF LOADS

See tables 6, 7, 8 and 9.

TABLE 6 — Minimum ultimate tensile loads — ISO metric coarse thread

Nominal thread diameter mm	Pitch of the thread mm	Nominal stress area mm ²	Property class									
			3.6	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9
			Minimum ultimate tensile load ($A_s \times R_m$), N									
3	0,5	5,03	1 660	2 010	2 110	2 510	2 620	3 020	4 020	4 530	5 230	6 140
3,5	0,6	6,78	2 240	2 710	2 850	3 390	3 530	4 070	5 420	6 100	7 050	8 270
4	0,7	8,78	2 900	3 510	3 690	4 390	4 570	5 270	7 020	7 900	9 130	10 700
5	0,8	14,2	4 690	5 680	5 960	7 100	7 380	8 520	11 350	12 800	14 800	17 300
6	1	20,1	6 630	8 040	8 440	10 000	10 400	12 100	16 100	18 100	20 900	24 500
7	1	28,9	9 540	11 600	12 100	14 400	15 000	17 300	23 100	26 000	30 100	35 300
8	1,25	36,6	12 100	14 600	15 400	18 300	19 000	22 000	29 200	32 900	38 100	44 600
10	1,5	58,0	19 100	23 200	24 400	29 000	30 200	34 800	46 400	52 200	60 300	70 800
12	1,75	84,3	27 800	33 700	35 400	42 200	43 800	50 600	67 400 ¹⁾	75 900	87 700	103 000
14	2	115	38 000	46 000	48 300	57 500	59 800	69 000	92 000 ¹⁾	104 000	120 000	140 000
16	2	157	51 800	62 800	65 900	78 500	81 600	94 000	125 000 ¹⁾	141 000	163 000	192 000
18	2,5	192	63 400	76 800	80 600	96 000	99 800	115 000	159 000	—	200 000	234 000
20	2,5	245	80 800	98 000	103 000	122 000	127 000	147 000	203 000	—	255 000	299 000
22	2,5	303	100 000	121 000	127 000	152 000	158 000	182 000	252 000	—	315 000	370 000
24	3	353	116 000	141 000	148 000	176 000	184 000	212 000	293 000	—	367 000	431 000
27	3	459	152 000	184 000	193 000	230 000	239 000	275 000	381 000	—	477 000	560 000
30	3,5	561	185 000	224 000	236 000	280 000	292 000	337 000	466 000	—	583 000	684 000
33	3,5	694	229 000	278 000	292 000	347 000	361 000	416 000	576 000	—	722 000	847 000
36	4	817	270 000	327 000	343 000	408 000	425 000	490 000	678 000	—	850 000	997 000
39	4	976	322 000	390 000	410 000	488 000	508 000	586 000	810 000	—	1 020 000	1 200 000

TABLE 7 — Proof loads — ISO metric coarse thread

Nominal thread diameter mm	Pitch of the thread mm	Nominal stress area mm ²	Property class									
			3.6	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9
			Proof load (A _s × S _p), N									
3	0,5	5,03	910	1 130	1 560	1 410	1 910	2 210	2 920	3 270	4 180	4 880
3,5	0,6	6,78	1 220	1 530	2 100	1 900	2 580	2 980	3 940	4 410	5 630	6 580
4	0,7	8,78	1 580	1 980	2 720	2 460	3 340	3 860	5 100	5 710	7 290	8 520
5	0,8	14,2	2 560	3 200	4 400	3 980	5 400	6 250	8 230	9 230	11 800	13 800
6	1	20,1	3 620	4 520	6 230	5 630	7 640	8 840	11 600	13 100	16 700	19 500
7	1	28,9	5 200	6 500	8 960	8 090	11 000	12 700	16 800	18 800	24 000	28 000
8	1,25	36,6	6 590	8 240	11 400	10 200	13 900	16 100	21 200	23 800	30 400	35 500
10	1,5	58,0	10 400	13 000	18 000	16 200	22 000	25 500	33 700	37 700	48 100	56 300
12	1,75	84,3	15 200	19 000	26 100	23 600	32 000	37 100	48 900 ²⁾	54 800	70 000	81 800
14	2	115	20 700	25 900	35 600	32 200	43 700	50 600	66 700 ²⁾	74 800	95 500	112 000
16	2	157	28 300	35 300	48 700	44 000	59 700	69 100	91 000 ²⁾	102 000	130 000	152 000
18	2,5	192	34 600	43 200	59 500	53 800	73 000	84 500	115 000	—	159 000	186 000
20	2,5	245	44 100	55 100	76 000	68 600	93 100	108 000	147 000	—	203 000	238 000
22	2,5	303	54 500	68 200	93 900	84 800	115 000	133 000	182 000	—	252 000	294 000
24	3	353	63 500	79 400	109 000	98 800	134 000	155 000	212 000	—	293 000	342 000
27	3	459	82 600	103 000	142 000	128 000	174 000	202 000	275 000	—	381 000	445 000
30	3,5	561	101 000	126 000	174 000	157 000	213 000	247 000	337 000	—	466 000	544 000
33	3,5	694	125 000	156 000	215 000	194 000	264 000	305 000	416 000	—	570 000	673 000
36	4	817	147 000	184 000	253 000	229 000	310 000	359 000	490 000	—	678 000	792 000
39	4	976	176 000	220 000	303 000	273 000	371 000	429 000	586 000	—	810 000	947 000

1) For structural bolting 70 000, 95 500 and 130 000 N respectively.

2) For structural bolting 50 700, 68 800 and 94 500 N, respectively.

TABLE 8 — Minimum ultimate tensile loads — ISO metric fine thread

Nominal thread diameter mm	Pitch of the thread mm	Nominal stress area mm ²	Property class									
			3.6	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9
			Minimum ultimate tensile load ($A_s \times R_m$), N									
8	1	39,2	12 900	15 700	16 500	19 600	20 400	23 500	31 360	35 300	40 800	47 800
10	1,25	61,2	20 200	24 500	25 700	30 600	31 800	36 700	49 000	55 100	63 600	74 700
12	1,25	92,1	30 400	36 800	38 700	46 000	47 900	55 300	73 700	82 900	95 800	112 000
14	1,5	125	41 200	50 000	52 500	62 500	65 000	75 000	100 000	112 000	130 000	152 000
16	1,5	167	55 100	66 800	70 100	83 500	86 800	100 000	134 000	150 000	174 000	204 000
18	1,5	216	71 300	86 400	90 700	108 000	112 000	130 000	179 000	—	225 000	264 000
20	1,5	272	89 800	109 000	114 000	136 000	141 000	163 000	226 000	—	283 000	332 000
22	1,5	333	110 000	133 000	140 000	166 000	173 000	200 000	276 000	—	346 000	406 000
24	2	384	127 000	154 000	161 000	192 000	200 000	230 000	319 000	—	399 000	469 000
27	2	496	164 000	194 000	208 000	248 000	258 000	298 000	412 000	—	516 000	605 000
30	2	621	205 000	248 000	261 000	310 000	323 000	373 000	515 000	—	646 000	758 000
33	2	761	251 000	304 000	320 000	380 000	396 000	457 000	632 000	—	791 000	928 000
36	3	865	285 000	346 000	363 000	432 000	450 000	519 000	718 000	—	900 000	1 050 000
39	3	1 030	340 000	412 000	433 000	515 000	536 000	618 000	855 000	—	1 070 000	1 260 000

TABLE 9 — Proof loads — ISO metric fine thread

Nominal thread diameter mm	Pitch of the thread mm	Nominal stress area mm ²	Property class									
			3.6	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9
			Proof load ($A_s \times S_p$), N									
8	1	39,2	7 060	8 820	12 200	11 000	14 900	17 200	22 700	25 500	32 500	38 000
10	1,25	61,2	11 000	13 800	19 000	17 100	23 300	26 900	35 500	39 800	50 800	59 400
12	1,25	92,1	16 600	20 700	28 600	25 800	35 000	40 500	53 400	59 900	76 400	89 300
14	1,5	125	22 500	28 100	38 800	35 000	47 500	55 000	72 500	81 200	104 000	121 000
16	1,5	167	30 100	37 600	51 800	46 800	63 500	73 500	96 900	109 000	139 000	162 000
18	1,5	216	38 900	48 600	67 000	60 500	82 100	95 000	130 000	—	179 000	210 000
20	1,5	272	49 000	61 200	84 300	76 200	103 000	120 000	163 000	—	226 000	264 000
22	1,5	333	59 900	74 900	103 000	93 200	126 000	146 000	200 000	—	276 000	323 000
24	2	384	69 100	86 400	119 000	108 000	146 000	169 000	230 000	—	319 000	372 000
27	2	496	89 300	112 000	154 000	139 000	188 000	218 000	298 000	—	412 000	481 000
30	2	621	112 000	140 000	192 000	174 000	236 000	273 000	373 000	—	515 000	602 000
33	2	761	137 000	171 000	236 000	213 000	289 000	335 000	457 000	—	632 000	738 000
36	3	865	156 000	195 000	268 000	242 000	329 000	381 000	519 000	—	718 000	838 000
39	3	1 030	185 000	232 000	319 000	288 000	391 000	453 000	618 000	—	855 000	999 000

8 TEST METHODS

8.1 Tensile test for machined test pieces

The following properties shall be checked on machined test pieces by tensile tests in accordance with ISO 82 :

- tensile strength, R_m
- yield stress, R_{eL} or stress at permanent set limit 0,2 %, $R_{p0,2}$
- percentage elongation after fracture :

$$A_5 = \frac{L_u - L_o}{L_o} \times 100$$

The test piece shown in figure 1 shall be used for the tensile test.

When machining the test piece, the reduction of the shank diameter of the heat-treated bolts and screws over 16 mm thread diameter shall not exceed 25 % of the original diameter (about 44 % of the cross-sectional area) of the test piece.

8.2 Tensile test for full size bolts, screws and studs

The tensile test shall be carried out on full size bolts in conformity with the tensile test on machined test pieces

(see 8.1). It is carried out for the purpose of determining the tensile strength. The calculation of the tensile strength is based on the stress area

$$A_s = \frac{\pi}{4} \left(\frac{d_2 + d_3}{2} \right)^2$$

where

d_2 is the pitch diameter of the thread;

d_3 is the minor diameter of the thread.

When carrying out the test, a free threaded length of 6 pitches of thread (6P) shall be subjected to the tensile load. To meet the requirements of this test, the fracture shall occur in the shank or the thread of the bolt and not at the junction of the head and the shank. The test nut must be designed accordingly.

The speed of testing, as determined with a free-running cross head, shall not exceed 25 mm/min. The grips of the testing machine should be self-aligning to avoid side thrust on the specimen.

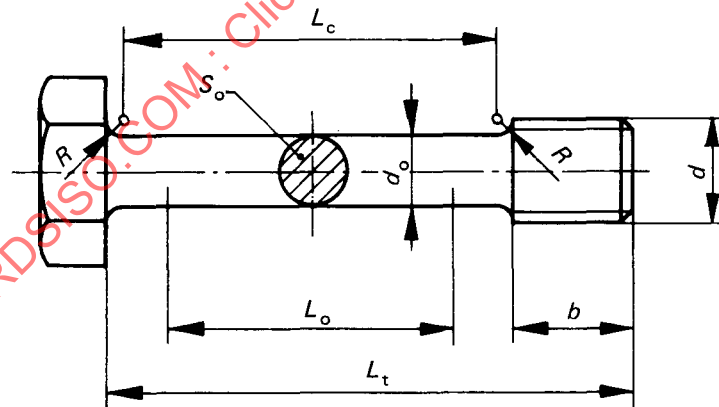


FIGURE 1 – Test piece for tensile test

d = nominal thread diameter

d_o = diameter of test piece ($d_o < \text{minor diameter of thread}$)

b = length of thread ($b \geq d$)

L_o = 5 d_o or (5,65 $\sqrt{S_o}$)

L_c = length of straight portion ($L_o + d_o$)

L_t = total length of test piece ($L_c + 2R + b$)

L_u = length after fracture

S_o = cross-sectional area

R = fillet radius ($R \geq 4$ mm)

8.3 Hardness tests

For routine inspection, hardness of bolts, screws and studs may be determined on the head, end or shank after removal of any plating or other coating and after suitable preparation of the specimen.

If the maximum hardness is exceeded, a retest shall be conducted at the mid-radius position, one diameter back from the end, at which position the maximum hardness specified shall not be exceeded. In case of doubt the Vickers hardness test is decisive for acceptance.

Hardness readings for the surface hardness shall be taken on the ends or hexagon flats, which shall be prepared by lightly grinding or polishing to ensure reproducible readings. Vickers 300 g shall be the referee test for surface hardness testing.

8.3.1 Vickers hardness test

The Vickers hardness test shall be carried out in accordance with the provisions of ISO/R 81.

8.3.2 Brinell hardness test

The Brinell hardness test shall be carried out in accordance with the provisions of ISO/R 79.

8.3.3 Rockwell hardness test

The Rockwell hardness test shall be carried out in accordance with the provisions of ISO/R 80.

8.4 Proof load test for full size bolts

The proof load test consists of two main operations, as follows :

- a) application of a specified tensile proof load (see figure 2), and
- b) measurement of permanent extension, if any, caused by the proof load.

The proof load shall be applied axially to the bolt in a normal tensile testing machine. The full proof load shall be held for 15 s. The length of free thread above the nut shall be 6 pitches of thread (6 P).

For measurement of permanent extension, the bolt shall be axially centre drilled (60° cone) at each end. Before and after the application of the proof load, the bolt shall be placed in a bench-mounted measuring instrument fitted with spherical anvils. Gloves or tongs shall be used to ensure that the total of the measuring inaccuracies is less than ± 5 µm.

The allowed permanent extension is 12,5 µm.

The speed of testing, as determined with a free-running cross head, shall not exceed 3 mm/min. The grips of the testing machine should be self-aligning to avoid side thrust on the specimen.

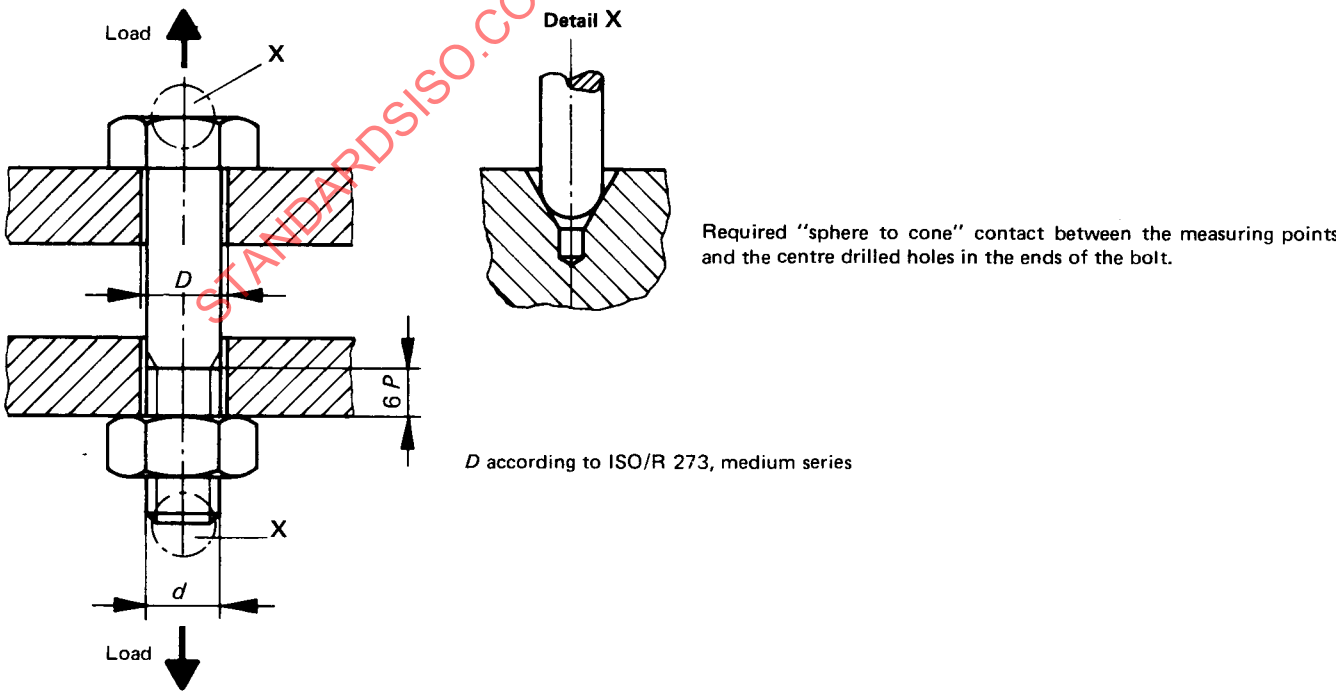


FIGURE 2 — Application of proof load to full size bolt

Variables, such as straightness and thread alignment (plus measurement error), may result in apparent elongation of the fasteners when the proof load is initially applied. In such cases, the fasteners may be retested using a 3 % greater load, and may be considered satisfactory if the length after this loading is the same as before this loading (within the 12,5 µm tolerance for measurement error).

8.5 Test for strength under wedge loading of full size bolts and screws (not studs)

The test for strength under wedge loading shall be carried out as illustrated in figure 3.

The distance from the thread run-out of the bolt to the contact surface of the nut or fastening device shall be *d*. A hardened wedge in accordance with table 10 shall be placed under the head of the bolt. A tensile test shall be continued until fracture occurs.

To meet the requirements of this test, the fracture shall occur in the shank or the thread of the bolt and not between the head and the shank. The bolt shall meet the requirements for minimum tensile strength, either during wedge tensile testing or in a supplementary tensile test without a wedge, according to the values given for the relevant properties class before fracture occurs.

Screws threaded to the head shall pass the requirement of this test if a fracture which causes failure originates in the free length of thread, even if it has extended or propagated into the fillet area or the head before separation.

For product grade C, a radius *R* should be used according to

$R = r \text{ max.} + 0,2$

where $r \text{ max.} = \frac{d_a \text{ max.} - d_s \text{ min.}}{2}$

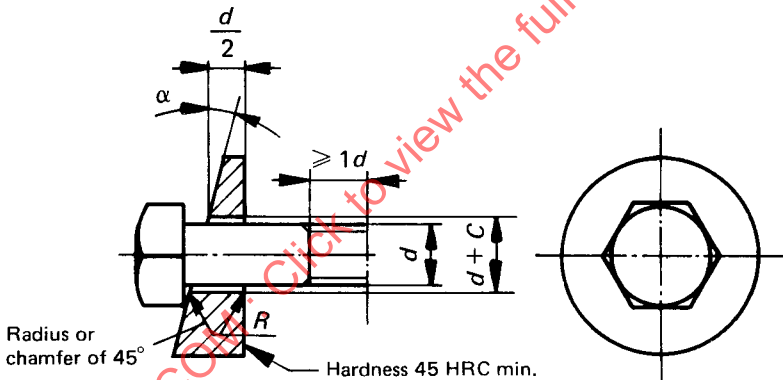


FIGURE 3 — Wedge loading of full size bolts

TABLE 10 — Wedge dimensions

Nominal diameter of bolt and screw mm	C mm	R mm	Angle $\alpha \pm 30'$			
			For bolts and screws with plain shank length $\geq 2 d$		For bolts and screws threaded to the head or with plain shank length $< 2 d$	
			Property class		Property class	
			3.6, 4.6, 4.8, 5.6 5.8, 8.8, 9.8, 10.9	6.8, 12.9	3.6, 4.6, 4.8, 5.6 5.8, 8.8, 9.8, 10.9	6.8, 12.9
≤ 6	0,5	0,7				
$> 6 \leq 12$	0,8	0,8	10°	6°	6°	4°
$> 12 \leq 20$	1,6	1,3				
$> 20 \leq 39$	3,2	1,6	6°	4°	4°	4°

8.6 Impact test for machined test pieces

The impact test shall be carried out in accordance with ISO/R 83. The test piece shall be taken lengthwise, located as close to the surface of the bolt or screw as possible. The non-notched side of the test piece shall be located near the surface of the bolt. Only bolts of thread diameters ≥ 16 mm can be tested.

8.7 Head soundness test for full size bolts $\leq$ M16 and with lengths too short to permit wedge load testing

The head soundness test shall be carried out as illustrated in figure 4.

When struck several blows with a hammer, the head of the bolt or screw shall bend to an angle of $90^\circ - \beta$ without showing any sign of cracking at the fillet between shank and head.

Where screws are threaded up to the head, the test will be regarded as satisfied even if a crack should appear in the first thread, provided that the head does not snap off.

This test can also be carried out for longer bolts, but for referee purposes the wedge load test is obligatory.

8.8 Decarburization test

Using the appropriate measuring method (8.8.2.1 or 8.8.2.2 as applicable), the longitudinal section of the thread shall be

examined to determine that the height of the zone of base metal (E) and the depth of the zone with complete decarburization (G) are within specified limits (see figure 5).

The minimum value for E and the maximum value for G are specified in table 3.

8.8.1 Definitions

8.8.1.1 **base metal hardness** : The hardness closest to the surface (when traversing from core to outside diameter) just before an increase or decrease occurs denoting carburization or decarburization.

8.8.1.2 **decarburization** : Generally, the loss of carbon at the surface of commercial ferrous materials (steels).

8.8.1.3 **partial decarburization** : Decarburization with loss of carbon sufficient to cause a lighter shade of tempered martensite and significantly lower hardness than that of the adjacent base metal.

8.8.1.4 **complete decarburization** : Decarburization with sufficient carbon loss to show only clearly defined ferrite grains under metallographic examination.

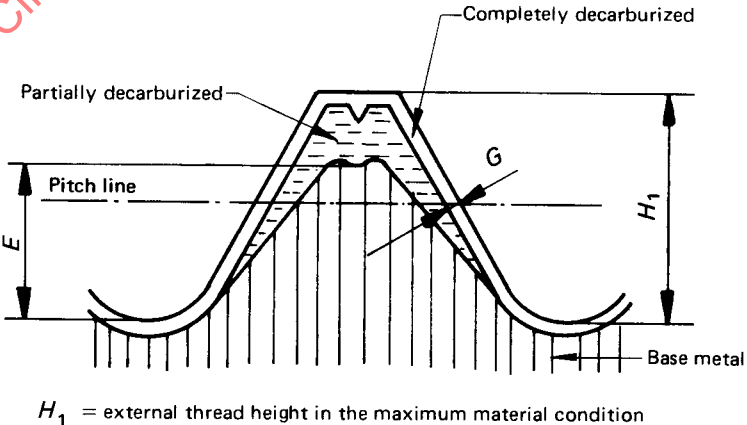
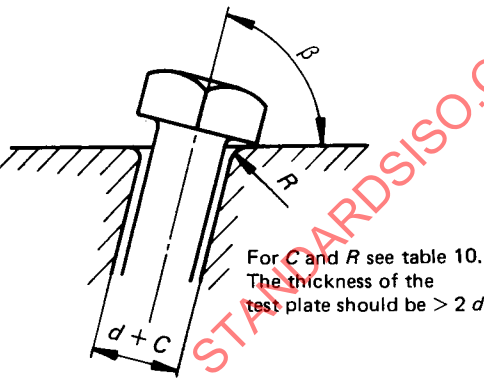


FIGURE 4 -- Head soundness test

FIGURE 5 -- Zones of decarburization

TABLE 11 -- Values of angle β

Property class	3.6	4.6	5.6	4.8	5.8	6.8	8.8	9.8	10.9	12.9
Angle β	60°			80°						