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低合金高强度结构钢

High strength low alloy structural steels

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Contents

High strength low alloy structural steels

1. Scope

This Standard specifies the designation, dimension, shape, weight, tolerance, technical requirements, testing methods, inspection regulations, packing, marks and quality certificate of the high strength low alloy structural steels

This Standard is applicable to common structural high strength low alloy steel sheets, steel straps and shapes and steel sticks.

2. Normative References

The articles contained in the following documents have become this standard when they are quoted herein. For the dated documents so quoted, all the modifications (excluding corrections) or revisions made thereafter shall not be applicable to this Standard. For the undated documents so quoted, the latest editions shall be applicable to this Standard.

GB 222　Method of sampling steel for determination of chemical component and permissible variations for product analysis.

GB/T 223.5 Methods for chemical analysis of iron, steel and alloy The reduced molybdosilicate spectrophotometric method for the determination of acid-soluble silicon content

GB/T 223.10　Methods for chemical analysis of iron, steel and alloy－The cupferron separation-chrome azurol S photometric method for the determination of aluminium content

GB/T 223.12　Methods for chemical analysis of iron, steel and alloy－The sodium carbonate separation-diphenyl carbazide photometric method for the determination of chromium content

GB/T 223.14 Methods for chemical analysis of iron, steel and alloy － The N-benzoy-N-phenylhydroxylamine extraction photometric method for the determination of vanadium content

GB/T 223.16　Methods for chemical analysis of iron, steel and alloy－The chromotropic acid photometric method for the determination of titanium content

GB/T 223.19　Methods for chemical analysis of iron, steel and alloy－The neocuproine-chloroform extraction photometric method for the determination of copper content

GB/T 223.24 Methods for chemical analysis of iron, steel and alloy－ The extraction seperation-The dimethylglyoxime spectrophotometric method for the determination of nickel content

GB/T 223.27　Methods for chemical analysis of iron, steel and alloy－The thiocyanate-butyl acetate extraction spectrophotometric method for the determination of molybdenum content

GB/T 223.37　Methods for chemical analysis of iron, steel and alloy－The indophenal blue photometric methods for the determination of nitrogen content after distillation separation

GB/T 223.39　Methods for chemical analysis of iron, steel and alloy－The sulphochlorophenol S photometric method for the determination of niobium content

GB/T 223.62　Methods for chemical analysis of iron, steel and alloy－The butyl acetate extraction photometric method for the determination of phosphorus content

GB/T 223.63 Methods for chemical analysis of iron, steel and alloy－ The sodium(potassium)periodate photometric method for the determination of manganese content

GB/T 223.67 Methods for chemical analysis of iron, steel and alloy － The reducing distillation-methylene blue photometric method for the determination of sulfur content
GB/T 223.69 Methods for chemical analysis of iron, steel and alloy－The gas- volumetric method after combustion in the pipe furnace for the determination of carbon content
GB/T 223.78 Methods for chemical analysis of iron, steel and alloy－Curcumin spectrophotometric method for the determination of boron content
GB/T 228 Metallic materials--Tensile testing at ambient temperature (GB/T 228-2002，eqv ISO 6892:1998)
GB/T 229 Metallic materials – Charpy pendulum bob impact test（GB/T 229-2007，ISO 148-1:2006，MOD）
GB/T 232 Metallic materials – bend test（GB/T 232-1999，eqv ISO 7438:1985）
GB/T 247 General rule of acceptance, package, mark and quality certification for steel plates (sheets) and strips
GB/T 2101 General requirements of acceptance, packaging, marking and certification for shape steel
GB/T 2975 Steel and steel products Sampling regulations for mechanical performance test（GB/T 2975-1998，eqv ISO 377:1997）
GB/T 4336 Carbon steel and middle &low alloy steel Spark source atom launch spectrum analysis method (common method)
GB/T 5313 Through-thickness characteristics steel
GB/T 17505 Steel and iron Sampling and sample making method for chemical contents test（GB/T 17505-1998，eqv ISO 404:1992）
GB/T 20066 Steel and iron Sampling and preparation of samples for the determination of chemical composition（GB/T 20066-2006，eqv ISO 40414284：1996:）
YB/T 081 Judging rule of numerical value rounding for technical standard of metallurgy and testing data

3. Terms and Definition

3.1 Thermomechanical rolling
The ultimate deformation is a rolling procedure, which is carried out within a certain temperature range. This procedure makes the material obtain the special performance which is not obtained only through heat treatment.
Note 1: If the temperature is increased to 580℃ after the rolling, the material strength value may be reduced. If it is necessary to increase the temperature to 580℃, it shall be supplied by the seller.
Note 2: Thermomechanical rolling delivery state may contain accelerated cooling or accelerated cooling plus tempering (contain self tempering), but excludes direct quenching or quenching plus tempering.
3.2 Normalizing rolling
The ultimate formation is a rolling procedure, which is carried out within a certain temperature range. This procedure makes the material obtain the performance which is equivalent to that after the normalizing.

4. Designation Expressions

The designation of steel consists of 3 parts in order: the first letter of China phonetic symbol for yield point, yield strength value, and symbol of quality class

For example: Q345D

Within it:

Q—the first letter of China phonetic symbol for yield point;

345—yield strength, unit MPa;

D—D is quality class of the steel.

If the buyer need the steel to have performance of thickness direction, the above required designation should be added with perforce grade of thickness direction (direction Z), such as : Q345DZ15.

5. Dimension, shape, weight, and tolerance

The dimension, shape, weight and tolerance should conform to stipulations in relative standards.

6. Technical requirements

6.1 Designation and chemical composition

6.1.1 The steel designation and chemical composition (fusion) analysis of steel shall conform to the regulation in Table 1.

6.1.2 If refined grain cement is needed to be added, the steel shall at least contain one of Al, Nb, V, Ti. The content of added refined grain cement should be stated in the quality certificate.

6.1.3 If it is expressed with all aluminum (Alt) content, Alt shall not less than 0.020%.

6.1.4 The nitrogen cement in steel shall conform to table 1. If the supplier can make sure about it, the analysis of nitrogen cement is not necessary. If add alloy cement such as Al, Nb, V, Ti, the nitrogen cement content is not restricted, and the content of nitrogen fixation cement should be stated in the quality certificate.

6.1.5 If Cr, Ni, Cu are residual cements, their content shall not more than 0.30%. If the supplier can make sure about it, the analysis is not necessary. If they are needed to be added, the content shall conform to table 1 or required by supplier and buyer.

6.1.6 To improve the performance of steel. RE cement could be added. The adding content is counted as 0.02%~0.20% of the weight of liquid steel.

6.1.7 To make the mechanical performance of steel conform to this standard, C, Si, Mn of grade A steel of all the designations could not be taken as the delivery condition.

Table 1

Designation	Grade of quality	Chemical Components [a, b](weight fraction)，%														
		C	Si	Mn	P	S	Nb	V	Ti	Cr	Ni	Cu	N	Mo	B	Als
					Not more than											Not less than
Q345	A	≤0.20	≤0.50	≤1.70	0.035	0.035	0.07	0.15	0.20	0.30	0.50	0.30	0.012	0.10	—	-
	B				0.035	0.035										
	C				0.030	0.030										0.015
	D	≤0.18			0.030	0.025										
	E				0.025	0.020										
Q390	A	≤0.20	≤0.50	≤1.70	0.035	0.035	0.07	0.20	0.20	0.30	0.50	0.30	0.015	0.10	—	—
	B				0.035	0.035										
	C				0.030	0.030										0.015
	D				0.030	0.025										
	E				0.025	0.020										
Q420	A	≤0.20	≤0.50	≤1.70	0.035	0.035	0.70	0.20	0.20	0.30	0.80	0.30	0.015	0.20	—	—
	B				0.035	0.035										
	C				0.030	0.030										0.015
	D				0.030	0.025										
	E				0.025	0.020										
Q460	C	≤0.20	≤0.60	≤1.80	0.030	0.030	0.11	0.20	0.20	0.30	0.80	0.55	0.015	0.20	0.004	0.015
	D				0.030	0.025										
	E				0.025	0.020										
Q500	C	≤0.18	≤0.60	≤1.80	0.030	0.030	0.11	0.12	0.20	0.60	0.80	0.55	0.015	0.20	0.004	0.015
	D				0.030	0.025										
	E				0.025	0.020										

Table 1 (Continued)

Designation	Grade of quality	Chemical Components [a, b](weight fraction)，%														
		C	Si	Mn	P	S	Nb	V	Ti	Cr	Ni	Cu	N	Mo	B	Als
					Not more than											Not less than
Q550	C	≤0.18	≤0.60	≤2.00	0.030	0.030	0.11	0.12	0.20	0.80	0.80	0.80	0.015	0.30	0.004	0.015
	D				0.030	0.025										
	E				0.025	0.020										
Q620	C	≤0.18	≤0.60	≤2.00	0.030	0.030	0.11	0.12	0.20	1.00	0.80	0.80	0.015	0.30	0.004	0.015
	D				0.030	0.025										
	E				0.025	0.020										
Q690	C	≤0.18	≤0.60	≤2.00	0.030	0.030	0.11	0.12	0.20	1.00	0.80	0.80	0.015	0.30	0.004	0.015
	D				0.030	0.025										
	E				0.025	0.020										

[a] The content of P.S in sections and sticks could be in creased by 0.005%. The upper limit of that of grade A steel could be 0.045%.

[b] If add refined grain cement, 20(Nb + V + Ti)≤0.22，20(Mo + Cr)≤0.30%。

6.1.8 Except grade A steel, the maximum CEV of the steels of all the designations shall conform to table 2 if they are delivered in the condition of rolling or controlled rolling; while the maximum CEV of them shall conform to table 3 if they are delivered in the condition of normalizing, normalizing rolling or normalizing plus tempering; the maximum CEV of them shall conform to table 4 if they are delivered in the condition of hot mechanical rolling (TMCP) or hot mechanical rolling plus tempering. CEV should be analyzed by melting analysis and counted with formula (1).

$$CEV=C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15 \quad (1)$$

Table 2 – CEV of hot rolling and TMCP state steel

Designation	CEV，%		
	Nominal thickness or diameter ≤63mm	Nominal thickness or diameter>63mm～250mm	Nominal thickness >250mm
Q345	≤0.44	≤0.47	≤0.47
Q390	≤0.45	≤0.48	≤0.48
Q420	≤0.45	≤0.48	≤0.48
Q460	≤0.46	≤0.49	—

Table 3 – CEV of normalizing, normalizing rolling, normalizing + tempering state steel

Designation	CEV，%		
	Thickness≤63mm	Thickness＞63mm～120mm	Thickness＞120mm～250mm
Q345	≤0.45	≤0.48	≤0.48
Q390	≤0.46	≤0.48	≤0.49
Q420	≤0.48	≤0.50	≤0.52
Q460	≤0.53	≤0.54	≤0.55

Table 4 – CEV of TMCP or TMCP + Tempering state steel

Designation	CEV，%		
	Thickness≤63mm	Thickness＞63mm～120mm	Thickness＞120mm～150mm
Q345	≤0.44	≤0.45	≤0.45
Q390	≤0.46	≤0.47	≤0.47
Q420	≤0.46	≤0.47	≤0.47
Q460	≤0.47	≤0.48	≤0.48
Q500	≤0.47	≤0.48	≤0.48
Q550	≤0.47	≤0.48	≤0.48
Q620	≤0.48	≤0.49	≤0.49
Q690	≤0.49	≤0.49	≤0.49

6.1.9 If CEV of the steel delivered in the condition of hot mechanical rolling (TMCP) or hot mechanical rolling plus tempering is not more than 0.12%, sensitivity index of welded cracks (Pcm) could be used to replace CEV to evaluate the weldability of steel. Pcm should be analyzed by melting analysis and counted by formula (2). Its value shall conform to table 5.

Pcm=C+Si/30+Mn/20+Cu/20+Ni/60+Cr/20+Mo/15+V/10+5B (2)

Through agreement of supplier and buyer, CEV or sensitivity index of welded cracks could be fixed as index to evaluate the weldability. If they are not fixed, supplier can choose any of them.

Table 5 – Pcm value of TMCP or TMCP + Tempering state steel

Designation	Pcm，%
Q345	≤0.20
Q390	≤0.20
Q420	≤0.20
Q460	≤0.20
Q500	≤0.25
Q550	≤0.25
Q620	≤0.25
Q690	≤0.25

6.1.10 The allowed deviation of the chemical composition of steel, steel billet shall conform to GB/T 222.

6.1.11 if the buyer requires make sure the steel plate with through-thickness characteristics, the chemical

component shall conform to GB/T 5313.

6.2 The method of smelting

The steel is smelted by the converter or electric furnace. If necessary it should be added with refined smelting.

6.3 The delivery condition

Steel delivery condition is hot rolled, controlling rolled, normalized or normalized plus tempered, hot mechanical rolled (TMCP) or hot mechanical rolled plus tempered.

6.4 The property of mechanics and process

6.4.1 Tensile test

Tensile test of steel shall conform to table 6.

6.4.2 Charpy (V) impact test

6.4.2.1 Temperature and absorbed energy of impact of Charpy (V) impact test shall conform to table 7.

6.4.2.2 If adopt steel with thickness not less than 6mm or diameter not less than 12mm for impact test, the samples small be standard sample of 10mm×10mm×55mm. If the steel is not big enough to make standard sample, smaller samples of 10mm×7.5mm×55mm or 10mm×5mm×55mm should be adopted. Absorbed energy of impact shall respectively not less than 75% or 50% of the required value in table 7. the bigger sample shall be used as a priority.

6.4.2.3 Result of impact test should be counted from the average value of 3 samples in one group. One of the tested values is allowed to be lower than the required value but not lower than 70%. Otherwise, 3 samples should be taken from the same products, and the average of test result of all the 6 test pieces shall not be lower than the required. Result of 2 test samples is allowed to be lower than the required value, but among them only 1 test piece is allowed to has the value of 70% lower than the required value.

6.4.3 Reduction of area on through-thickness Z-direction shall conform to GB/T 5313.

Table 6 – Tensile properties of steel

Designation	Quality grade	Tensile test [a, b, c]																				
		Yield strength for the following normal thickness (diameter, side length) R_{eL}, MPa (mm)									Tensile strength for the following normal thickness (diameter, side length) R_m, MPa (mm)							Percentage elongation after fracture A / % Normal thickness (diameter, side length) (mm)					
		≤16	>16～40	>40～63	>63～80	>80～100	>100～150	>150～200	>200～250	>250～400	≤40	>40～63	>63～80	>80～100	>100～150	>150～250	>250～400	≤40	>40～63	>63～100	>100～150	>150～250	>250～400
Q345	A	≥345	≥335	≥325	≥315	≥305	≥285	≥275	≥265	—	470-630	470 – 630	470 - 630	470 - 630	450 - 600	450 - 600	—	≥20	≥19	≥19	≥18	≥17	—
	B																						
	C																	≥21	≥20	≥20	≥19	≥18	
	D									≥265							450 - 600						≥17
	E																						
Q390	A	≥390	≥370	≥350	≥330	≥330	≥310	—	—	—	490–650	490 – 650	490 – 650	490 – 650	470 – 620	—	—	≥20	≥19	≥19	≥18	—	—
	B																						
	C																						
	D																						
	E																						
Q420	A	≥420	≥400	≥380	≥360	≥360	≥340	—	—	—	520–680	520–680	520–680	520–680	500–650	—	—	≥19	≥18	≥18	≥18	—	—
	B																						
	C																						
	D																						
	E																						
Q460	C	≥460	≥440	≥420	≥400	≥400	≥380	—	—	—	550–720	550–720	550–720	550–720	530–700	—	—	≥17	≥16	≥16	≥16	—	—
	D																						
	E																						

Table 6 (Continued)

Designation	Quality grade	Tensile test [a, b, c]																				
		Yield strength for the following normal thickness (diameter, side length) R_{eL}, MPa (mm)									Tensile strength for the following normal thickness (diameter, side length) R_m, MPa (mm)							Percentage elongation after fracture A / % Normal thickness (diameter, side length) (mm)					
		≤16	>16～40	>40～63	>63～80	>80～100	>100～150	>150～200	>200～250	>250～400	≤40	>40～63	>63～80	>80～100	>100～150	>150～250	>250～400	≤40	>40～63	>63～100	>100～150	>150～250	>250～400
Q500	C D E	≥500	≥480	≥470	≥450	≥440	—	—	—	—	610–770	600–760	590–750	540–730	—	—	—	≥17	≥17	≥17	—	—	—
Q550	C D E	≥550	≥530	≥520	≥500	≥490	—	—	—	—	670–830	620–810	600–790	590–780	—	—	—	≥16	≥16	≥16	—	—	—
Q620	C D E	≥620	≥600	≥590	≥570	—	—	—	—	—	710–880	690–880	670–860	—	—	—	—	≥15	≥15	≥15	—	—	—
Q690	C D E	≥690	≥670	≥660	≥640	—	—	—	—	—	770–940	750–920	730–900	—	—	—	—	≥14	≥14	≥14	—	—	—

[a] If the yield is not obvious, Rp0.2 could be measured to replace the yield strength

[b] For flat products with width of not smaller than 600mm, horizontal test pieces should be taken for tensile test. For flat products, section and sticks with width smaller than 600mm, it shall use longitudinal test pieces.

[c] The value of thickness>250mm – 400mm applies to flat products

Table 7 – Test temperature and impact absorb energy of Charpy (V)Test

Designation	Quality grade	Test Temperature，℃	Impact absorb energy under following nominal thickness KV_2 [a]，J		
			Nominal thickness (Diameter and side length)		
			12mm – 150mm	>150mm – 250mm	>250mm – 400mm
Q345	B	20	≥34	≥27	—
	C	0			
	D	-20			27
	E	-40			
Q390	B	20	≥34	—	—
	C	0			
	D	-20			
	E	-40			
Q420	B	20	≥34	—	—
	C	0			
	D	-20			
	E	-40			
Q460	C	0	≥34	—	—
	D	-20		—	—
	E	-40		—	—
Q500、Q550、Q620、Q690	C	0	≥55	—	—
	D	-20	≥47	—	—
	E	-40	≥31	—	—

[a] Take longitudinal test piece for impact test

6.4.4. If buyer requires making bend test, it shall conform to table 8. While if the supplier can make the bending is qualified, bend test is not necessary.

Table 8 – Bending test

Designation	Direction of test piece	180° Bend test d=Diameter of curve center，a=Test piece thickness (diameter)	
		Steel thickness（diameter）	
		≤16 mm	＞16mm～100mm
Q345 Q390 Q420 Q460	For flat products with width of not smaller than 600mm, horizontal test pieces should be taken for tensile test. For flat products, sections and sticks with width smaller than 600mm, it shall use longitudinal test pieces.	2a	3a

6.5 Surface quality

Steel surface quality should conform to standards for relative product

6.6 Special requirements

6.6.1 According to agreement between supplier and buyer, steel could be tested by NDT. The test standard and grade should be specified in the agreement.

6.6.2 According to agreement between supplier and buyer, the steel with requirement of though-thickness characteristics could be purchased as per this standard.

6.6.3 According to agreement between supplier and buyer, steel also could be tested for other items.

7. Testing method

The testing item, samples quantity, method of sampling, and testing method shall conform to the stipulations in Table 9.

Table 9

Item No.	Testing item	samples quantity	sampling method	Testing method
1	chemical composition (heat analysis)	1/heat	GB 20066	GB/T 223, GB/T4336, GB/T 20215
2	Tensile test	1/ lot	GB 2975	GB/T 228
3	Bending test	1/lot	GB 2975	GB/T 232
4	Impact test	3/lot	GB 2975	GB/T 229
5	Percentage of shrinkage of the section in Through-thickness Z direction	3/lot	GB 5313	GB/T 5313
6	NDT test	Every piece	As per NDT standard	By agreement
7	Surface quality	Every piece	---	Visual test
8	Dimension, shape	Every piece	---	Proper measurement devices

8. Testing regulations

8.1 Test and acceptance

The technical supervising department of the supplying party should be responsible for the check and acceptance of steel.

8.2 The steel should be checked and accepted by lots, each lot of steel is composed of steel with the same designation, same quality grade, same heat furnace number, same type, and same rolling or heat treatment system. Weight of each lot shall not more than 60t. weight of the whole lot of steel shall conform to relative product standard.

For A grade steel and B grade steel with different designations, it is permitted to mix them into the same lot that have same designation, same quality grade, same smelting and casting method, different furnace number. But each lot shall not contain steels of more than 6 furnace numbers, and the difference of C content among furnaces should not exceeds 0.02%, Mn content difference shall not exceeds 0.15%. Making lots of Z direction steel shall conform to GB/T 5313.

8.3 Recheck and judging rule

8.3.1 Recheck and judging of mechanical property

If the result of impact test is not accepted by 6.4.2.3, the sample steel is rejected. It shall random take another two sample products from the same pack of steel and take a new group of 3 test samples on each sample product. Test result of these two group of test samples shall be qualified, otherwise this lot of steel will be rejected. Recheck and judging of tensile test shall conform to GB/T 17505.

8.3.2 Recheck and judging of other test items

The recheck and judging of other test items shall conform to GB/T 17505.

8.4 Revision and making agreement of mechanical property and chemical components

Unless there is other requirements in the agreement or order, when it is needed to judge whether the test result is conform to the required value, the test result of mechanical property and chemical components should be revised and agreed until to have identical digit with that of required value. The revision and agreement method shall conform to YB/T 081. CEV shall be revised and agreed after counting as per formula.

9. Packing, marking and quality certification

All the packing, marking and quality certification of steel shall fully meet the stipulations of GB/T 247 and GB/T 2101.