
International Standard



4951

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High yield strength steel bars and sections

Barres, profilés et poutrelles en acier à haute limite d'élasticité

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FOREWORD

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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 4951 was developed by Technical Committee ISO/TC 17, *Steel*, and was circulated to the member bodies in November 1976.

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

Austria	Germany, F. R.	Romania
Brazil	Hungary	South Africa, Rep. of
Bulgaria	India	Spain
Canada	Iran	Sweden
Chile	Italy	Switzerland
Czechoslovakia	Korea, Rep. of	Turkey
Denmark	Mexico	United Kingdom
Egypt, Arab Rep. of	New Zealand	USSR
Finland	Norway	Yugoslavia
France	Poland	

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Belgium
Japan
USA

High yield strength steel bars and sections

1 Scope

This International Standard specifies the chemical composition, the mechanical properties and the acceptance testing of hot-rolled bars, sections and hollow sections of thickness up to and including 70 mm, in high yield strength steels (R_e min. > 355 N/mm²) used in bolted, riveted or welded structures.¹⁾

2 Field of application

This International Standard applies to bars and sections of thickness, diameter or length of side up to and including 70 mm, to hollow sections of thickness up to and including 40 mm and to beams with flange thickness up to and including 40 mm, made of steel and having a specified minimum yield strength of 355 to 420 N/mm² for thicknesses up to and including 16 mm.

3 References

ISO 82, *Steel — Tensile testing.*

ISO/R 148, *Beam impact test (V-notch) for steel.*²⁾

ISO/R 377, *Selection and preparation of samples and test pieces for wrought steel.*²⁾

ISO/R 404, *General technical delivery requirements for steel.*²⁾

ISO 2566/1, *Steel — Conversion of elongation values — Part 1 : Carbon and low alloy steels.*

4 Manufacture

4.1 Steelmaking method

4.1.1 Unless otherwise agreed at the time of enquiry and order, the steelmaking method is left to the choice of the manufacturer within the limitation of 4.1.2.

1) Compared with mild steels, these steels may require special precautions for welding. (See in particular the guide for welding and weldability of C-Mn and C-Mn micro-alloy steels published by Sub-commission IX-G of the International Welding Institute — document IIS/IIW 382-71.)

2) In course of revision.

4.1.2 The steel shall be produced in an open hearth furnace, in an electric furnace, or by an oxygen process. Other methods may be used by agreement between the parties concerned. The steelmaking method shall be stated to the purchaser on request, at the time of delivery.

4.2 Deoxidation process

The steels shall be from casts with addition elements capable of producing a fine grain. In addition, steels of qualities CC and DD may be supplied as non-rimming steel.

4.3 Delivery condition

The products covered by this International Standard shall be delivered in the as-rolled condition or in the normalized condition — or, unless otherwise agreed and stated in the order, in an equivalent condition obtained by controlled rolling¹⁾ — or in the normalized and tempered condition.

4.4 Surface appearance — Defects

4.4.1 Surface appearance

The products shall have a smooth surface consistent with the rolling process used; they shall not show any defects which may prejudice processing or their appropriate application.

4.4.2 Removal of defects

4.4.2.1 Surface defects may be removed by the manufacturer, before despatch, by grinding, provided that the depression does not extend below the rolled surface by more than

- 0,8 mm for material of thickness less than 10 mm;
- 1,6 mm for material of thickness 10 to 50 mm, inclusive;
- 3 mm for material of thickness over 50 mm.

4.4.2.2 Unless otherwise specified on ordering, deeper surface defects which reduce the thickness by more than the minimum limits specified above may be removed by grinding, chipping or arc-air gouging, followed by deposition of weld metal, subject to the following conditions :

- a) The total area of the chipped or ground surface of any piece prior to welding shall not exceed 2 % of the total surface area of that piece.
- b) The reduction of thickness of the material resulting from the removal of defects prior to welding shall not exceed 20 % of the nominal thickness at the location of the defect.
- c) The toes of angles, beams, channels and zeds, and the stems and toes of tees, may be conditioned by grinding, chipping or arc-air gouging and welding. Prior to welding, the depth of the depression, measured from the toe inward, shall be limited to the thickness of the material at the base of the depression with a maximum depth limit of 13 mm.

d) All welding shall be performed by competent welders using low-hydrogen welding electrodes appropriate for the grade being repaired. The electrodes shall be protected from moisture during storage and use. The manufacturer shall establish and follow documented welding procedures which are appropriate to the material being welded.

e) The weld and adjacent heat-affected zone shall be sound and free of cracks, the deposited metal being thoroughly fused to all surfaces and edges without undercutting or overlap. Any visible cracks, porosity, lack of fusion or undercut in any layer shall be removed prior to deposition of the succeeding layer. Weld metal shall project by at least 2 mm above the rolled surface after welding, and the projecting metal shall be removed by chipping or grinding, or both, to make it flush with the rolled surface and to produce a workmanlike finish.

f) The manufacturer shall draw up an inspection programme for the work to verify that

- 1) defects have been completely removed;
- 2) the limitations specified above have not been exceeded;
- 3) established welding procedures have been followed;
- 4) any weld metal is of acceptable quality as defined above.
- g) If materials are intended to be supplied in the as-treated condition (including normalizing), it shall be specifically agreed with the purchaser whether welding is to be carried out prior to heat treatment.

4.4.2.3 If agreed at the time of the order, the sites of repair welds shall be carefully recorded and pointed out to the purchaser.

5 General requirements

5.1 Chemical composition

5.1.1 Ladle analysis

Table 1 gives the composition limits for the ladle analysis.

5.1.2 Product analysis

If requested at the time of enquiry and order, a product analysis shall be carried out.

Table 2 gives the permitted deviations for the product analysis relative to the values for ladle analysis given in table 1.

5.2 Mechanical properties

Table 3 specifies the mechanical properties in the delivery conditions given in 4.3, determined on test pieces prepared in accordance with the requirements of 6.2.

1) Products produced by controlled rolling may be subject to deterioration of their properties if subsequently hot formed.

Table 1 — Chemical composition (ladle analysis)¹⁾

Grade	Quality	Chemical composition, %												
		C max.	Mn	Si max.	P max.	S max.	Nb ²⁾	V ²⁾	Al total min. ²⁾	Ti ²⁾	Cr max.	Ni max.	Mo max.	Cu max.
E 355	CC	0,20	0,9–1,6	0,50	0,040	0,040	0,005–0,060	0,02–0,20	0,015	0,02–0,20	0,25	0,30	0,10	0,35
	DD	0,20	0,9–1,6	0,50	0,035	0,035	0,005–0,060	0,02–0,20	0,015	0,02–0,20	0,25	0,30	0,10	0,35
E 390	CC	0,20	1,0–1,6	0,50	0,040	0,040	0,005–0,060	0,02–0,20	0,015	0,02–0,20	0,30	0,70	0,30	0,50
	DD	0,20	1,0–1,6	0,50	0,035	0,035	0,005–0,060	0,02–0,20	0,015	0,02–0,20	0,30	0,70	0,30	0,50
E 420	CC	0,20	1,0–1,7	0,50	0,040	0,040	0,005–0,060	0,02–0,20	0,015	0,02–0,20	0,40	0,70	0,40	0,60
	DD	0,20	1,0–1,7	0,50	0,035	0,035	0,005–0,060	0,02–0,20	0,015	0,02–0,20	0,40	0,70	0,40	0,60

1) As the chemical composition influences the welding characteristics, the purchaser shall be informed, if he so requests at the time of enquiry and order, of the type of steel which will be supplied and the maximum values or the range of the alloying elements which will be used in that steel.

2) The steels shall contain in the percentages indicated in the table at least one of the grain-refining elements. If these elements are used in combination, the content for at least one of them shall be not less than the specified minimum value.

Table 2 — Permissible deviations for the product analysis relative to the specified ladle analysis

Element	Specified limits, %	Permissible deviation ¹⁾
C	≤ 0,20	+ 0,03
Mn	0,9–1,7	± 0,10
Si	≤ 0,50	+ 0,05
P and S	≤ 0,040	+ 0,005
Nb	0,005–0,060	+ 0,005 – 0,002
V	0,02–0,20	+ 0,02 – 0,01
Ti	0,02–0,20	+ 0,02 – 0,01
Cr	≤ 0,40	+ 0,05
Ni	≤ 0,70	+ 0,05
Mo	≤ 0,40	+ 0,05
Cu	≤ 0,60	+ 0,05

1) The deviations apply either above or below the specified limits of the range, but not simultaneously.

When maxima only are specified, the deviations are positive only.

Table 3 — Mechanical properties

Grade	Quality	Specified yield strength, min. N/mm ²				R_m N/mm ²	A1) min. on $L_0 = 5,65\sqrt{S_0}$ %	KV, min.2) J	
		$e \leq 16$	$16 < e \leq 35$	$35 < e \leq 50$	$50 < e \leq 70$			0 °C	- 20 °C
E 355	CC	355	355	345	325	470—630	22	40	
	DD	355	355	345	325	470—630	22		40
E 390	CC	390	380	370	350	490—650	20	40	
	DD	390	380	370	350	490—650	20		40
E 420	CC	420	410	400	380	520—680	19	40	
	DD	420	410	400	380	520—680	19		40

1) The elongation values given in the table are to be reduced by two points for products supplied in the as-rolled condition.

2) Average of three tests; no individual result shall be less than 70 % of the specified minimum average value.

NOTE — In the cases of angles and beams, the thickness of the product means the thickness of the flange measured on the cross-section where the test pieces are taken for the mechanical tests (see the figure in the annex).

6 Acceptance testing

The products covered by this International Standard may be the subject of acceptance tests in accordance with conditions specified in clause 5 of ISO/R 404 relating to the chemical composition and mechanical properties of the product. Verification of the chemical composition of the product is only carried out if this is agreed and stated in the order.

6.1 Acceptance test unit

Products shall be tested separately for each cast and heat treatment condition. The acceptance test unit shall be 40 t or part thereof.

6.1.1 For each acceptance test unit and thickness range as indicated in table 3, a series of tests shall be carried out comprising :

- one tensile test (or more, in accordance with 6.1.3.1, in the case of products of thickness up to and including 16 mm);
- one set of three impact tests at the specified temperature;

and, if specified in the order,

- one product analysis.

6.1.1.1 A certificate stating the cast analysis shall be supplied to the purchaser.

6.1.2 The purchaser or his representative may select, at the time of rolling, the items from which test samples shall be taken for verification of the properties (see ISO/R 404).

6.1.3 Unless otherwise agreed, the procedure shall be as follows :

6.1.3.1 Tensile test samples

For each specified thickness range, a test sample shall be taken from the thickest product, except that for the range $e \leq 16$ mm the maximum thickness of the products shall be not greater than twice the minimum thickness.

6.1.3.2 Impact test samples

For each thickness range, a test sample shall be taken from the thickest product.

6.2 Position and orientation of test samples (see ISO/R 377)

Test samples shall be taken so that the axes of the test pieces — tensile and impact — will be parallel to the direction of rolling.

6.2.1 Sections

Test samples shall be taken so that the axis of the test pieces is at 1/3 from the outer edge of the half-flange (for I sections) or of the flange (for other sections) or, in the case of small sections, as near as possible to this position (see the figure in the annex). If agreed at the time of enquiry and order, test samples may also be taken at the outer quarter position of the web.

6.2.2 Rounds, squares, flats, hexagons and other similar products

For small sizes, the test piece shall consist of a length of the

product; in other cases, test samples shall be taken so that the axis of the test piece, as far as possible, is located :

- for squares and flat bars : at 1/3 of the half-width or the half-diagonal;
- for rounds and hexagons : at 1/3 of the half-diagonal or radius (see the figure in the annex).

6.2.3 Hollow sections

For small sections, the test piece shall consist of a length of the product.

For round sections, the test piece shall be taken longitudinally at any point on the section.

For square or rectangular sections, the test piece shall be taken longitudinally midway between the corners.

For longitudinally welded hollow sections, the test piece shall be taken from outside the weld zone.

7 Test methods

7.1 Tensile test (see ISO 82)

7.1.1 The test piece shall normally be a proportional prismatic or cylindrical test piece having an original gauge length L_0 given by the formula

$$L_0 = 5,65 \sqrt{S_0}$$

where S_0 is the original cross-sectional area of the gauge length.

A prismatic test piece of rectangular cross-section shall have a maximum gauge width of 40 mm and its thickness shall be that of the product; if the product thickness exceeds 30 mm, however, it may be reduced to 30 mm by planing or milling on one face.

A cylindrical test piece shall have a diameter of 10 to 30 mm, the initial gauge length being determined by the above formula.

A non-proportional test piece with a fixed initial gauge length (for example 200 mm) may be used, with reference being made to a conversion table (see ISO 2566/1). However, in case of dispute, only the results obtained on a proportional test piece shall be used.

7.1.2 The yield strength specified in table 3 is either the upper yield stress, R_{eH} , or the proof stress (0,5 % total elongation) $R_{t0,5}$. The specification of the material is complied with in this respect if either value satisfies the specified value of yield strength. In special cases where measurement of 0,2 proof stress (non-proportional elongation) $R_{p0,2}$, lower yield stress R_{eL} , or proof stress (total elongation) R_{Tx} , is specifically required by the material specification, that specification is complied with in this respect, if the value obtained by such measurement satisfies the specified value of "yield strength".

7.2 Impact test

7.2.1 The impact test shall normally be carried out on products having a thickness greater than or equal to 12 mm or a diameter greater than or equal to 16 mm. The test piece shall be machined so that the face nearest to the rolled surface is not more than 2 mm from it; the notch shall be perpendicular to the rolled surface.

If agreed at the time of enquiry and order, impact tests may be carried out on products having a thickness less than 12 mm; the dimensions of the test pieces shall be in accordance with the requirements of ISO/R 148, namely 10 mm × 7,5 mm or 10 mm × 5 mm, and the specified energy values shall be fixed by agreement. However, by agreement at the time of enquiry and order, the test pieces may have a width equal to the thickness of the product, subject to a minimum thickness of 5 mm.

7.2.2 The test shall be carried out using a V-notch test piece supported at both ends (see ISO/R 148), the value to be taken into account being the average of the results obtained from three test pieces cut adjacent to each other from the same product, unless there are reasons for a retest (see 7.4).

7.3 Faulty tests

When a test does not give the required result because of an error in execution, the test shall be cancelled. Error in execution means : incorrect machining; incorrect mounting in the test machine; a malfunction of the test machine, or any other anomaly independent of the metal itself.

7.4 Retests

If, during inspection, a test does not give the required result, additional tests, unless otherwise agreed, may be carried out as follows :

7.4.1 If a defective test piece gives satisfactory results, the batch shall be accepted, but the corresponding item (from which the test sample was taken) may be subjected to an individual examination for soundness.

7.4.2 Tensile test

7.4.2.1 If a test piece does not give the required values, the corresponding item is deemed not to comply with the specification, unless two other test pieces from the same item are tested and give satisfactory results. In this case, the item and the batch are deemed to comply with the specification.

7.4.2.2 If one or both of the additional test pieces does not satisfy the requirements, the corresponding item is deemed not to comply with the specification.

7.4.2.3 The remainder of the lot may be accepted provided that two items representing the lot in question are subjected to tests in accordance with the specification and give satisfactory results.

In the contrary case, the requirements of clause 9 may be applied.

7.4.3 Impact test

7.4.3.1 If the average of the three impact values is less than the specified value, or if one individual value is less than 70 % of this specified value, three additional test pieces shall be taken from the same sample and tested. The average value of the six results shall be not less than the specified value. Not more than two individual values shall be less than the specified value, and not more than one individual value shall be less than 70 % of this value.

7.4.3.2 If an item presented for the first time is considered not to comply with the specification, the remainder of the material may be accepted provided that two representative items are tested in accordance with the specification and give satisfactory results.

In the contrary case, the requirements of clause 9 may be applied.

7.5 Chemical analysis

7.5.1 In case of dispute, the method used for the chemical analysis shall be in accordance with the requirements stated in the corresponding International Standards. If no International Standard exists, the method to be used shall be agreed between the parties concerned.

7.5.2 If a product analysis is specified on the order, the number of samples to be taken shall be agreed between the parties concerned.

The samples may be taken from the test pieces used to verify the mechanical properties or from the full thickness of the product at the same location as the test pieces. In case of dispute, only the analysis of material from the full thickness of the product shall apply.

For the selection and preparation of samples for chemical analysis, the requirements of sub-clauses 3.2 and 3.3 of ISO/R 377 shall be applied.

8 Documents

The requirements of sub-clauses 4.1 to 4.2.2 of ISO/R 404 shall be applied. The type of certificate required shall be specified in the order.

9 Resubmission (see sub-clause 6.5 of ISO/R 404)

9.1 The manufacturer may resubmit for inspection products that have been rejected during earlier inspection because of unsatisfactory properties, after he has subjected them to a suitable processing (sorting, heat treatment) details of which, on request, will be disclosed to the purchaser. In this case, tests shall be carried out as if they applied to a new acceptance unit.

9.2 The manufacturer has the right to present items rejected during a first examination for re-examination for another quality or grade.

10 Non-destructive tests

If the purchaser requires non-destructive tests to verify the soundness of the products by means of radiographic, ultrasonic, magnetic or penetrant methods, these tests shall be agreed at the time of enquiry and order. This agreement shall include details of the test methods and interpretation of results.

11 Marking

Unless otherwise agreed at the time of order, products shall bear the following marks :

- the identification symbols for the grade and quality of the steel;
- the brand of the manufacturer;

and, where necessary,

- a symbol, letters and numbers which relate the test certificates, test pieces and products to each other.

In the case of products of small unit mass and which are consigned in bundles, the information specified above may be marked on a tag securely attached to each bundle or may be marked on the topmost item in the bundle.

Annex

Position and orientation of test samples

 Position of test sample

