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"जानने का अधिकार, जीने का अधिकार"
Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

"पुराने को छोड़ नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"
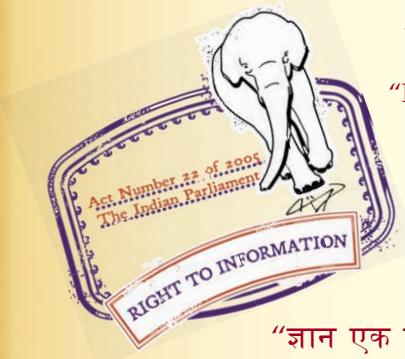
IS 1786 (2008): High strength deformed steel bars and wires for concrete reinforcement- [CED 54: Concrete Reinforcement]

"ज्ञान से एक नये भारत का निर्माण"
Satyanarayan Gangaram Pitroda
"Invent a New India Using Knowledge"

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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भारतीय मानक

कंक्रीट प्रबलन के लिए उच्च शक्ति विरूपित इस्पात सरिए एवं तार — विशिष्टि

(चौथा पुनरीक्षण)

Indian Standard

HIGH STRENGTH DEFORMED STEEL BARS AND WIRES FOR CONCRETE REINFORCEMENT — SPECIFICATION
(Fourth Revision)

ICS 77.140.15; 91.080.40

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Price Group 6

FOREWORD

This Indian Standard (Fourth Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Concrete Reinforcement Sectional Committee had been approved by the Civil Engineering Division Council.

The standard was first published in 1961 and subsequently revised in 1966, 1979 and 1985. In its second revision of 1979, the title of the standard was modified to 'Specification for cold-worked steel high strength deformed bars for concrete reinforcement'.

In the third revision, IS 1139 : 1966 'Specification for hot rolled mild steel, medium tensile steel and high yield strength steel deformed bars for concrete reinforcement' was merged in the standard and the title was modified to 'Specification for high strength deformed steel bars and wires for concrete reinforcement'. The restriction to cold working was removed in this revision and the manufacturers were allowed to resort to other routes to attain high strength.

High strength deformed bars and wires for concrete reinforcement are being produced in the country for many years by cold twisting and by controlled cooling and micro-alloying. A brief note on controlled cooling process is given in Annex A for information only. In the past few years there has been increasing demand for higher strength grades with higher elongation for various applications. This revision has been taken up to incorporate various changes found necessary as a result of experience gained and technological advances made in the field of steel bars and wires manufacturing. This revision incorporates the properties of high strength deformed steel bars and wires, and it is left to the manufacturer to adopt any process to satisfy the performance requirements.

Following are some of the important modifications incorporated in this revision:

a) A new strength grade Fe 600 has been introduced.

b) Two categories based on elongation for each grade except Fe 600 have been introduced.

c) A new parameter 'percentage total elongation at maximum force' has been introduced.

d) Nominal sizes have been rationalized and nominal sizes 7 mm, 18 mm, 22 mm, 45 mm and 50 mm have been removed.

In the formulation of this standard, due weightage has been given to international coordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

The following test methods given in this standard correspond to those given in ISO Standards:

Sl No.	Title	IS No.	ISO No.
i)	Mechanical testing of metals — Tensile testing	1608	6892
ii)	Methods for bend test	1599	7438 and 15630-1
iii)	Method for re-bend test for metallic wires and bars	1786	15630-1

The composition of the Committee responsible for the formulation of this standard is given in Annex B.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (revised)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

AMENDMENT NO. 1 NOVEMBER 2012
TO
IS 1786 : 2008 HIGH STRENGTH DEFORMED BARS AND WIRES FOR CONCRETE REINFORCEMENT — SPECIFICATION

(Fourth Revision)

(*Second cover page, Foreword*) — Insert the following after sixth para as a separate para:

'Provisions in this standard are at variance with similar provisions in ISO 6935-2 : 2007 'Steel for the reinforcement of concrete — Part 2: Ribbed bars', in view of the following:

a) Geographical factors which determine the earthquake zoning and consequently the structural design considerations, structural design method/principles adopted, the design parameters and the required material properties;

b) Technological factors associated with the process of manufacture of the product (such as through secondary processes/induction furnace), which influence the product characteristics (like chemical composition and mechanical properties like yield strength, tensile strength, elongation, ductility, etc); and

c) Construction techniques and practices adopted in this country, the equipments used and the skill level of construction workers which also influence the product characteristics (such as bend and bond strength).

The major deviations are:

a) The steel grades covered are at variance. This standard covers requirements for high strength bars only whereas ISO 6935-2 also covers bars of lower tensile strengths.

b) Chemical compositions vary from that in ISO 6935-2.

c) Mechanical properties specified in this standard are individual values, whereas the tensile properties in ISO 6935-2 are primarily the specified characteristic values.

d) Bend and re-bend test requirements vary from those in ISO 6935-2.

e) Bond requirements in this standard are specified on basis of mean area of ribs whereas the requirements in ISO 6935-2 are for rib geometry. This standard additionally specifies pull out test as a requirement for approval of new or amended rib geometry.'

(*Page* 1, *clause* **1.1**) — Substitute the following for the existing clause:

'**1.1** This standard covers the requirements of deformed steel bars and wires for use as reinforcement in concrete, in the following strength grades:

a) Fe 415, Fe 415D, Fe 415S;

b) Fe 500, Fe 500D, Fe 500S;

c) Fe 550, Fe 550D; and

d) Fe 600.

NOTES
1 The figures following the symbol Fe indicate the specified minimum 0.2 percent proof stress or yield stress, in N/mm^2.
2 The letters D and S following the strength grade indicates the categories with same specified minimum 0.2 percent proof stress/yield stress but with enhanced and additional requirements.'

(*Page* 2, *clause* **4.2**) — Substitute the following for the existing clause:

'**4.2** The ladle analysis of steel for various grades, when carried out by the method specified in the relevant parts of IS 228 or any other established instrumental/chemical method, shall have maximum permissible percentage of constituents as follows. In case of dispute, the procedure given in IS 228 and its relevant parts

Price Group 2

shall be the referee method and where test methods are not specified shall be as agreed to between the purchaser and the manufacturer/supplier.

Constituent	Percent, Maximum								
	Fe 415	Fe 415D	Fe 415S	Fe 500	Fe 500D	Fe 500S	Fe 550	Fe 550D	Fe 600
Carbon	0.30	0.25	0.25	0.30	0.25	0.25	0.30	0.25	0.30
Sulphur	0.060	0.045	0.045	0.055	0.040	0.040	0.055	0.040	0.040
Phosphorus	0.060	0.045	0.045	0.055	0.040	0.040	0.050	0.040	0.040
Sulphur and phosphorus	0.110	0.085	0.085	0.105	0.075	0.075	0.100	0.075	0.075

NOTES

1 For guaranteed weldability, the Carbon Equivalent, CE using the formula:

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}$$

shall not be more than 0.53 percent, when micro-alloy/low alloys are used. When micro-alloys/low alloys are not used, carbon equivalent using the formula:

$$CE = C + \frac{Mn}{6}$$

shall not be more than 0.42 percent. Reinforcement bars/wires with carbon equivalent above 0.42 percent should, however be welded with precaution. Use of low hydrogen basic coated electrodes with matching strength bars/wires is recommended.

2 Addition of micro-alloying elements is not mandatory for any of the above grades. When strengthening elements like Nb, V, B and Ti are used individually or in combination, the total contents shall not exceed 0.30 percent; in such case manufacturer shall supply the purchaser or his authorized representative a certificate stating that the total contents of the strengthening elements in the steel do not exceed the specified limit.

3 Low alloy steel may also be produced by adding alloying elements like Cr, Cu, Ni, Mo and P, either individually or in combination, to improve allied product properties. However, the total content of these elements shall not be less than 0.40 percent. In such case, the manufacturers shall supply the purchaser or his authorized representative a test certificate stating the individual contents of all the alloying elements. In such low alloy steels when phosphorus is used, it shall not exceed 0.12 percent and when used beyond the limit prescribed in **4.2**, the carbon shall be restricted to a maximum of 0.15 percent, and in such case the restriction to maximum content of sulphur and phosphorus as given in **4.2** and the condition of minimum alloy content 0.40 percent shall not apply.

User may note that there is a danger of pitting and crevice corrosion when weathering steels (that is those with chemical composition conforming to IS 11587) are embedded in chloride contaminated concrete."

4 Nitrogen content of the steel should not exceed 0.012 percent (120 ppm), which shall be ensured by the manufacturer by occasional check analysis. Higher nitrogen contents up to 0.025 percent (250 ppm) may be permissible provided sufficient quantities of nitrogen binding elements, like Nb, V, Ti, Al, etc, are present. In order to ascertain whether sufficient quantities of nitrogen binding elements are present, following formula may be used, where all elements are in ppm.

$$(N - 120) < \frac{Al_{free}}{10} + \frac{(Ti + V)}{7} + \frac{Nb}{14}$$

(*Page* 4, *clause* **6.1**) ▬ Substitute the following for the existing clause:

'**6.1** The nominal sizes of bars/wires shall be as follows:

Nominal size, 4 mm, 5 mm, 6 mm, 8 mm, 10 mm, 12 mm, 16 mm, 20 mm, 25 mm, 28 mm, 32 mm, 36 mm, 40 mm, 45 mm, 50 mm.

NOTE — Other sizes may be supplied by mutual agreement.'

(*Page* 4, *Table* 1) ▬ Insert the following at the end of the Table 1:

Sl No.	Nominal Size mm	Cross Sectional Area mm^2	Mass per Metre kg
(1)	(2)	(3)	(4)
xiv)	45	1591.1	12.49
xv)	50	1964.4	15.42

(*Page* 6, *Table* 3) ▬ Substitute the following for the existing Table 3:

**Table 3   Mechanical Properties of High Strength
Deformed Bars and Wires**
(*Clause* 8.1)

Sl No.	Property	Fe 415	Fe 415D	Fe 415S	Fe 500	Fe 500D	Fe 500S	Fe 550	Fe 550D	Fe 600
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	0.2 percent proof stress/ yield stress, *Min,* N/mm^2	415.0	415.0	415.0	500.0	500.0	500.0	550.0	550.0	600.0
ii)	0.2 percent proof stress/ yield stress, *Max,* N/mm^2	—	—	540.0	—	—	625.0	—	—	—
iii)	TS/YS ratio[1], N/mm^2	≥ 1.10, but TS not less than 485.0 N/mm^2	≥ 1.12, but TS not less than 500.0 N/mm^2	1.25	≥ 1.08, but TS not less than 545.0 N/mm^2	≥ 1.10, but TS not less than 565.0 N/mm^2	1.25	≥ 1.06, but TS not less than 585 N/mm^2	≥ 1.08, but TS not less than 600.0 N/mm^2	≥ 1.06, but TS not less than 660 N/mm^2
iv)	Elongation, percent, min. on gauge length $5.65\sqrt{A}$, where *A* is the cross-sectional area of the test piece	14.5	18.0	20.0	12.0	16.0	18.0	10.0	14.5	10.0
v)	Total elongation at maximum force, percent, *Min,* on gauge length $5.65\sqrt{A}$, where *A* is the cross-sectional area of the test piece (*see* **3.9**)[2]	—	5	10	—	5	8	—	5	—

[1] TS/YS ratio refers to ratio of tensile strength to the 0.2 percent proof stress or yield stress of the test piece
[2] Test, wherever specified by the purchaser.

(*Page* 6, *clause* **9.1.2.1**) ▬ Insert the following note at the end of clause:

'NOTE– In case of any dispute, the results obtained from full bar test pieces (without machining to remove deformations) shall be treated as final and binding.'

(*Page* 7, *clause* **9.2.1**, *line* 7) ▬ Substitute 'Fe 415, Fe 415D and Fe 415S bars/wires' *for* 'Fe 415 and Fe 415D bars/wires'.

Amend No. 1 to IS 1786 : 2008

(*Page* 7, *clause* **9.2.1**, *line* 8) ― Substitute 'Fe 500, Fe 500D and Fe 500S bars/wires' *for* 'Fe 500 and Fe 500D bars/wires'.

(*Page* 7, *clause* **9.3**, *line* 2) ― Insert 'maximum' before 'mandrel'.

(*Page* 7, *clause* **9.3**, Table 4) ― Substitute the following for the existing Table 4:

Table 4 Maximum Mandrel Diameter for Bend Test
(*Clause* 9.3)

Sl No.	Nominal Size mm	Maximum Mandrel Diameter for Different Grades								
		Fe 415	Fe 415D	Fe 415S	Fe 500	Fe 500D	Fe 500S	Fe 550	Fe 550D	Fe 600
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	Up to and including 20	3 φ	2 φ	2 φ	4 φ	3 φ	3 φ	5 φ	4 φ	5 φ
ii)	Over 20	4 φ	3 φ	3 φ	5 φ	4 φ	4 φ	6 φ	5 φ	6 φ

NOTE — φ is the nominal size of the test piece, in mm.

(*Page* 7, *clause* **9.4.1**) ― Substitute the following for the existing clause:

9.4.1 The maximum diameter of the mandrel shall be as given below:

Sl No.	Nominal Size of Specimen	Maximum Dia of Mandrel for Fe 415 and Fe 500	Maximum Dia of Mandrel for Fe 415D, Fe 415S, Fe 500D and Fe 500S	Maximum Dia of Mandrel for Fe 550 and Fe 600	Maximum Dia of Mandrel for Fe 550D
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to and including 10 mm	5 φ	4 φ	7 φ	6 φ
ii)	Over 10 mm	7 φ	6 φ	8 φ	7 φ

NOTE — φ is the nominal size of the test piece, in mm.

Indian Standard

HIGH STRENGTH DEFORMED STEEL BARS AND WIRES FOR CONCRETE REINFORCEMENT — SPECIFICATION
(Fourth Revision)

1 SCOPE

1.1 This standard covers the requirements of deformed steel bars and wires for use as reinforcement in concrete, in the following strength grades:

    a) Fe 415, Fe 415D;

    b) Fe 500, Fe 500D;

    c) Fe 550, Fe 550D; and

    d) Fe 600.

NOTES

1 The figures following the symbol Fe indicate the specified minimum 0.2 percent proof stress or yield stress in N/mm².

2 The letter D following the strength grade indicates the category with same specified minimum 0.2 percent proof stress/yield stress but with enhanced specified minimum percentage elongation.

1.2 This standard allows the chemical composition and carbon equivalent to be limited so that the material can be readily welded by conventional welding procedures. Material not conforming to these limits is generally difficult to weld for which special care and precautions will have to be exercised.

1.3 This standard applies to hot-rolled steel without subsequent treatment, or to hot-rolled steel with controlled cooling and tempering and to cold-worked steel. The production process is at the discretion of the manufacturer.

1.4 This standard also applies to reinforcing bars and wires supplied in coil form but the requirements of this Indian Standard apply to the straightened product.

1.5 This standard also applies to reinforcing bars and wires which may be subsequently coated.

1.6 Deformed bars produced by re-rolling finished products such as plates and rails (virgin or used or scrap), or by rolling material for which the metallurgical history is not fully documented or not known, are not acceptable as per this Indian Standard.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	Title
228 (Parts 1 to 24)	Methods for chemical analysis of steels
1387 : 1993	General requirements for the supply of metallurgical materials *(second revision)*
1599 : 1985	Method for bend test *(second revision)*
1608 : 2005	Metallic materials—Tensile testing at ambient temperature *(third revision)*
2062 : 2006	Hot rolled low, medium and high tensile structural steel *(sixth revision)*
2770 (Part 1) : 1967	Methods of testing bond in reinforced concrete: Part 1 Pull-out test.
9417 : 1989	Recommendations for welding cold-worked steel bars for reinforced concrete construction *(first revision)*
11587 : 1986	Structural weather resistant steels

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Batch — Any quantity of bars/wires of same size and grade whether in coils or bundles presented for examination and test at one time.

1

3.2 Bundle — Two or more coils or a number of lengths properly bound together.

3.3 Elongation — The increase in length of a tensile test piece under stress. The elongation at fracture is conventionally expressed as a percentage of the original gauge length of a standard test piece.

3.4 Longitudinal Rib — A uniform continuous protrusion, parallel to the axis of the bar/wire (before cold-working, if any).

3.5 Nominal Diameter or Size — The diameter of a plain round bar/wire having the same mass per metre length as the deformed bar/wire.

3.6 Nominal Mass — The mass of the bar/wire of nominal diameter and of density $0.007\,85$ kg/mm² per meter.

3.7 Nominal Perimeter of a Deformed Bar/Wire — 3.14 times the nominal diameter.

3.8 0.2 Percent Proof Stress — The stress at which a non-proportional elongation equal to 0.2 percent of the original gauge length takes place.

3.9 Percentage Total Elongation at Maximum Force — The elongation corresponding to the maximum load reached in a tensile test (also termed as uniform elongation).

3.10 Tensile Strength — The maximum load reached in a tensile test divided by the effective cross-sectional area of the gauge length portion of the test piece (also termed as ultimate tensile stress).

3.11 Transverse Rib — Any rib on the surface of a bar/wire other than a longitudinal rib.

3.12 Yield Stress — Stress (that is, load per unit cross-sectional area) at which elongation first occurs in the test piece without increasing the load during the tensile test. In the case of steels with no such definite yield point, proof stress shall be applicable.

4 MANUFACTURE AND CHEMICAL COMPOSITION

4.1 Steel shall be manufactured by the open-hearth, electric, duplex, basic-oxygen process or a combination of these processes. In case any other process is employed by the manufacturer, prior approval of the purchaser should be obtained.

4.1.1 Steel shall be supplied, semi-killed or killed.

4.1.2 The bars/wires shall be manufactured from properly identified heats of mould cast, continuously cast steel or rolled semis.

4.1.3 The steel bars/wires for concrete reinforcement shall be manufactured by the process of hot rolling. It may be followed by a suitable method of cold working and/or in-line controlled cooling.

4.2 Chemical Composition

The ladle analysis of steel for various grades, when made as per relevant parts of IS 228 shall have maximum permissible percentage of constituents as follows:

Constituent	Percent, Maximum						
	Fe 415	Fe 415D	Fe 500	Fe 500D	Fe 550	Fe 550D	Fe 600
Carbon	0.30	0.25	0.30	0.25	0.30	0.25	0.30
Sulphur	0.060	0.045	0.055	0.040	0.055	0.040	0.040
Phosphorus	0.060	0.045	0.055	0.040	0.050	0.040	0.040
Sulphur and phosphorus	0.110	0.085	0.105	0.075	0.100	0.075	0.075

NOTES

1 For guaranteed weldability, the Carbon Equivalent, CE using the formula

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}$$

shall not be more than 0.53 percent, when microalloys/low alloys are used. When microalloys/low alloys are not used, carbon equivalent using the formula:

$$CE = C + \frac{Mn}{6}$$

shall not be more than 0.42 percent. Reinforcement bars/wires with carbon equivalent above 0.42 percent should, however be welded with precaution. Use of low hydrogen basic coated electrodes with matching strength bars/wires is recommended.

2 Addition of microalloying elements is not mandatory for any of the above grades. When strengthening elements like Nb, V, B and Ti are used individually or in combination, the total contents shall not exceed 0.30 percent; in such case manufacturer shall supply the purchaser or his authorized representative a certificate stating that the total contents of the strengthening elements in the steel do not exceed the specified limit.

3 Low-alloy steel may also be produced by adding alloying elements like Cr, Cu, Ni, Mo and P, either individually or in combination, to improve allied product properties. However, the total content of these elements shall not be less than 0.40 percent. In such case, manufacturers shall supply the purchaser or his authorized representative a test certificate stating the individual contents of all the alloying elements. In such low alloy steels when phosphorus is used, it shall not exceed 0.12 percent and when used beyond the limit prescribed in **4.2**, the carbon shall be restricted to a maximum of 0.15 percent, and in such case the restriction to maximum content of sulphur and phosphorus as given in **4.2** and the condition of minimum alloy content 0.40 percent shall not apply.

User may note that there is a danger of pitting and crevice corrosion when weathering steels (that is those with chemical composition conforming to IS 11587) are embedded in chloride contaminated concrete.

4 Nitrogen content of the steel should not exceed 0.012 percent, which shall be ensured by the manufacturer by occasional check analysis.

4.2.1 In case of product analysis, the permissible variation from the limits specified under **4.2** shall be as follows:

Constituent	Variation, Over Specified Maximum Limit, Percent, Max
Carbon	0.02
Sulphur	0.005
Phosphorus	0.005
Sulphur and phosphorus	0.010

4.2.2 For welding of deformed bars, the recommendations of IS 9417 shall be followed.

4.2.3 In case of deviations from the specified maximum, two additional test samples shall be taken from the same batch and subjected to the test or tests in which the original sample failed. Should both additional test samples pass the test, the batch from which they were taken shall be deemed to comply with this standard. Should either of them fail, the batch shall be deemed not to comply with this standard.

4.3 Rolling and Cold-Working of Bars/Wires

4.3.1 All bars/wires shall be well and cleanly rolled and shall be sound and free from surface defects and pipe, or other defects detrimental to its subsequent processing and to its end use. Rust, seams, surface irregularities or mill scale shall not be the cause for rejection provided a hard wire brushed test specimen fulfils all the requirements of this specification.

4.3.2 Stretching may or may not be combined with cold-working. The unworked length at each end of the bar/wire shall not exceed 100 mm or 4 times the nominal diameter, whichever is greater.

5 REQUIREMENTS FOR BOND

5.1 High strength deformed bars/wires shall satisfy the requirements given in either **5.2** or **5.7** for routine testing. Pull-out test in accordance with **5.7** shall be done in addition to **5.2** for approval of new or amended geometry for first time.

5.2 Deformations and Surface Characteristics

For high strength deformed bars/wires, the mean area of ribs (in mm²) per unit length (in mm) above the core of the bar/wire, projected on a plane normal to the axis of the bar/wire calculated in accordance with **5.4** shall not be less than the following values:

a) $0.12 \, \phi$ for $\phi \leq 10$ mm,

b) $0.15 \, \phi$ for 10 mm $< \phi \leq 16$ mm, and

c) $0.17 \, \phi$ for $\phi > 16$ mm.

where ϕ is the nominal diameter of bar/wire, in mm.

The mean projected area of transverse ribs alone shall be not less than one-third of the values given above.

5.3 The ribs contributing the projected area considered in **5.2** shall consist of:

a) Two longitudinal ribs in the form of continuous helix in case of twisted bars/wires, and optional longitudinal ribs in case of untwisted bars/wires which may be continuous or discontinuous; and

b) Transverse ribs which after hot-rolling or cold-working are uniform in size and shape in each row along the length of the bar/wire, and are spaced along the bar/wire at substantially uniform distance, except in the area of marking.

5.4 The mean projected rib area per unit length, A_r (in mm²/mm) may be calculated from the following formula :

$$A_r = \sum_{i=1}^{n_{tr}} \left[\frac{A_{tr} \sin \theta}{S_{tr}} \right]_i + \frac{n_{lr} \, d_{lr} \, \pi \phi}{S_p}$$

where

n_{tr} = number of rows of transverse ribs;

A_{tr} = area of longitudinal section of a transverse rib on its own axis (see Fig. 1) or area of transverse rib of uniform height on its own axis, in mm² ;

θ = inclination of the transverse rib to the bar axis (after twisting for cold-worked twisted bars) in degrees. Average value of two ribs from each row of transverse ribs shall be taken;

S_{tr} = spacing of transverse ribs, in mm;

n_{lr} = number of longitudinal ribs;

d_{lr} = height of longitudinal ribs, in mm;

ϕ = nominal diameter of the bar/wire, in mm;

S_p = pitch of the twist, in mm; and

i = variable.

NOTES

1 In the case of hot rolled bars/wires which are not subjected to cold twisting, the value of s_p in the second term of the expression for A_r shall be taken as infinity rendering the value of the second term to zero.

2 A_{tr} may be calculated as $2/3\ l_{tr}d_{tr}$ where l_{tr} and d_{tr} are shown in Fig.1 or, A_{tr} may be calculated as $l_{tr}d_{tr}$ where transverse ribs are of uniform height on its own axis.

3 In the case of cold-worked bars/wires with some discontinuous longitudinal ribs, the number of longitudinal ribs, n_{lr} shall be calculated as an equivalent number using the following formula and accounted for in the expression for A_r:

$$n_{lr} = \frac{n'_{lr}\ l'_{lr}\ d'_{lr}}{s'_{lr}\ d_{lr}} + \text{Number of continuous longitudinal ribs}$$

where

$n'_{lr} =$ number of discontinuous longitudinal ribs,
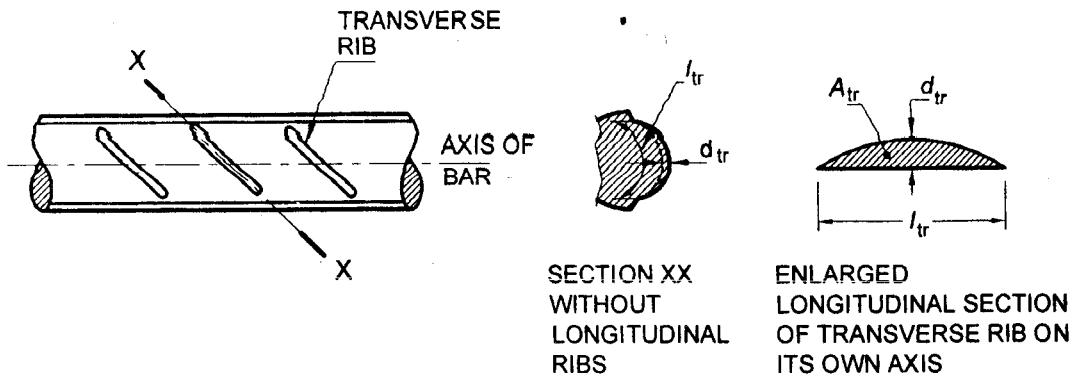
$l' =$ average length of discontinuous longitudinal ribs,

$d'_{lr} =$ height of discontinuous longitudinal ribs,

$s'_{lr} =$ average spacing of discontinuous longitudinal ribs, and

$d_{lr} =$ height of continuous longitudinal ribs.

4 The average length of discontinuous longitudinal ribs shall be determined by dividing a measured length of the bar equal to at least 10 φ by the number of discontinuous longitudinal ribs in the measured length, φ being the nominal diameter of the bar. The measured length of the bar shall be the distance from the centre of one rib to the centre of another rib.

NOTE—A_{tr}, d_{tr} and l_{tr} represent longitudinal sectional area, height and length respectively of transverse rib

FIG. 1 DETERMINATION OF LONGITUDINAL SECTIONAL AREA A_{tr} OF A TRANSVERSE RIB

5.5 The heights of longitudinal and transverse ribs shall be obtained in the following manner:

a) The average height of longitudinal ribs shall be obtained from measurements made at not less than 4 points, equally spaced, over a length of 10 φ or pitch of rib, whichever is greater.

b) The height of transverse ribs shall be measured at the centre of 10 successive transverse ribs.

5.6 The average spacing of transverse ribs shall be determined by dividing a measured length of the bar/wire equal to at least 10 φ by the number of spaces between ribs in the measured length, φ being the nominal diameter of the bar/wire. The measured length of the bar/wire shall be the distance from the centre of one rib to the centre of another rib.

5.7 When subjected to pull-out testing in accordance with IS 2770 (Part 1), the bond strength calculated from the load at a measured slip of 0.025 mm and 0.25 mm for deformed bars/wires shall exceed that of a plain round bar of the same nominal size by 40 percent and 80 percent respectively.

6 NOMINAL SIZES

6.1 The nominal sizes of bars/wires shall be as follows:

Nominal size, 4 mm, 5 mm, 6 mm, 8 mm, 10 mm, 12 mm, 16 mm, 20 mm, 25 mm, 28 mm, 32 mm, 36 mm, 40 mm.

NOTE — Other sizes may be supplied by mutual agreement.

6.2 The values for the nominal cross-sectional area and nominal mass of individual bars/wires shall be as given in Table 1 subject to the tolerance on nominal mass given in Table 2.

4

6.3 Effective Cross-Sectional Area and Mass of Deformed Bars and Wires

6.3.1 For bars/wires whose pattern of deformation is such that by visual inspection, the cross-sectional area is substantially uniform along the length of the bar/wire, the effective cross-sectional area shall be the gross sectional area determined as follows, using a bar/wire not less than 0.5 m in length:

$$\text{Gross cross-sectional area, in mm}^2 = \frac{w}{0.007\,85\,L}$$

where

w = mass weighed to a precision of ±0.5 percent, in kg; and

L = length measured to a precision of ±0.5 percent, in m.

Table 1 Nominal Cross-Sectional Area and Mass
(*Clause* 6.2)

Sl No.	Nominal Size mm	Cross-Sectional Area mm^2	Mass per Metre kg
(1)	(2)	(3)	(4)
i)	4	12.6	0.099
ii)	5	19.6	0.154
iii)	6	28.3	0.222
iv)	8	50.3	0.395
v)	10	78.6	0.617
vi)	12	113.1	0.888
vii)	16	201.2	1.58
viii)	20	314.3	2.47
ix)	25	491.1	3.85
x)	28	615.8	4.83
xi)	32	804.6	6.31
xii)	36	1 018.3	7.99
xiii)	40	1 257.2	9.86

6.3.2 For a bar/wire whose cross-sectional area varies along its length, a sample not less than 0.5 m long shall be weighed (w) and measured to a precision of ±0.5 percent in the as rolled and/or cold-worked condition, and after the transverse ribs have been removed, it shall be reweighed (w'). The effective cross-sectional area shall then be found as follows:

a) Where the difference between the two masses ($w - w'$) is less than 3 percent of w', the effective cross-sectional area shall be obtained as in **6.3.1**.

b) Where the difference is equal to or greater than 3 percent, the effective cross-sectional area in mm^2 shall be taken as:

$$\frac{1.03\,w'}{0.007\,85\,L}$$

where

w' = mass of the bar with transverse ribs removed, in kg; and

L = length, in m.

For routine test purposes, a nominal ratio of effective to gross cross-sectional area of bars/wires covered by **6.3.2**(b) above shall be declared and used by the manufacturer.

7 TOLERANCES ON DIMENSIONS AND NOMINAL MASS

7.1 Specified Lengths

If bars/wires are specified to be cut to certain lengths, each bar/wire shall be cut within deviations of $^{+75}_{-25}$ mm on the specified length, but if minimum lengths are specified, the deviations shall be $^{+50}_{-0}$ mm.

7.2 Nominal Mass

7.2.1 For the purpose of checking the nominal mass, the density of steel shall be taken as 0.007 85 kg/mm^2 of the cross-sectional area per metre.

7.2.2 Unless otherwise agreed to between the manufacturer and the purchaser, the tolerances on nominal mass shall be as in Table 2. For bars/wires whose effective cross-sectional area is determined as in **6.3.2**(b), the nominal mass per metre shall correspond to the gross mass and the deviations in Table 2 shall apply to the nominal mass.

7.2.3 The nominal mass per metre of individual sample, batch and coil shall be determined as given in **7.2.3.1** to **7.2.3.3**.

Table 2 Tolerances on Nominal Mass
(*Clauses* 6.2 *and* 7.2.2)

Sl No.	Nominal Size mm	Tolerance on the Nominal Mass, Percent		
		Batch	Individual Sample[1]	Individual Sample for Coils Only[2]
(1)	(2)	(3)	(4)	(5)
i)	Up to and including 10	±7	−8	±8
ii)	Over 10 up to and including 16	±5	−6	±6
iii)	Over 16	±3	−4	±4

[1] For individual sample plus tolerance is not specified. A single sample taken from a batch as defined in **3.1** shall not be considered as individual sample.

[2] For coils batch tolerance is not specified.

7.2.3.1 *Individual sample*

The nominal mass of an individual sample shall be calculated by determining the mass of any individual sample taken at random as specified in **11.1** and dividing the same by the actual length of the sample. The sample shall be of length not less than 0.5 m.

7.2.3.2 *Batch*

The nominal mass of a batch shall be calculated from the mass of the test specimens taken as specified in **11.1** and dividing the same by the actual total length of the specimens. Each specimen shall be of length not less than 0.5 m.

7.2.3.3 *Coils*

The nominal mass of a coil shall be calculated by determining the mass of two samples of minimum one metre length taken from each end of the coil and dividing the same by the actual total length of the samples.

8 PHYSICAL PROPERTIES

8.1 Mechanical properties for all sizes of deformed bars/wires determined on effective cross-sectional area (*see* **5.3**) and in accordance with **9.2** shall be as specified in Table 3.

8.2 The bars/wires shall withstand the bend test specified in **9.3** and the rebend test specified in **9.4**.

8.3 Bond

Bars/wires satisfying the requirements given in **5** shall be deemed to have satisfied the bond requirements of a deformed bar/wire.

9 TESTS

9.1 Selection and Preparation of Test Sample

Unless otherwise specified in this standard, the requirements of IS 2062 shall apply.

9.1.1 All test pieces shall be selected by the purchaser or his authorized representative, either:

a) from the cuttings of bars/wires; or

b) if, he so desires, from any bar/wire after it has been cut to the required or specified size and the test piece taken from any part of it.

In neither case, the test piece shall be detached from the bar/wire except in the presence of the purchaser or his authorized representative.

9.1.2 The test pieces obtained in accordance with **9.1.1** shall be full sections of the bars/wires and shall be subjected to physical tests without any further modifications. No reduction in size by machining or otherwise shall be permissible, except in case of bars of size 28 mm and above (*see* **9.1.2.1**). No test piece shall be annealed or otherwise subjected to heat treatment except as provided in **9.1.3**. Any straightening which a test piece may require shall be done cold.

9.1.2.1 For the purpose of carrying out tests for tensile strength, proof stress, percentage elongation and percentage elongation at maximum force for bars 28 mm in diameter and above, deformations of the bars only may be machined. For such bars, the physical properties shall be calculated using the actual area obtained after machining.

Table 3 Mechanical Properties of High Strength Deformed Bars and Wires

(*Clause* 8.1)

Sl No.	Property	Fe 415	Fe 415D	Fe 500	Fe 500D	Fe 550	Fe 550D	Fe 600
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	0.2 percent proof stress/ yield stress, *Min*, N/mm^2	415.0	415.0	500.0	500.0	550.0	550.0	600.0
ii)	Elongation, percent, *Min*. on gauge length $5.65\sqrt{A}$, where A is the cross-sectional area of the test piece	14.5	18.0	12.0	16.0	10.0	14.5	10.0
iii)	Tensile strength, *Min*	10 percent more than the actual 0.2 percent proof stress/ yield stress but not less than 485.0 N/mm^2	12 percent more than the actual 0.2 percent proof stress/ yield stress but not less than 500.0 N/mm^2	8 percent more than the actual 0.2 percent proof stress/ yield stress but not less than 545.0 N/mm^2	10 percent more than the actual 0.2 percent proof stress/ yield stress but not less than 565.0 N/mm^2	6 percent more than the actual 0.2 percent proof stress/ yield stress but not less than 585.0 N/mm^2	8 percent more than the actual 0.2 percent proof stress/ yield stress but not less than 600.0 N/mm^2	6 percent more than the actual 0.2 percent proof stress/ yield stress but not less than 660.0 N/mm^2
iv)	[1]Total elongation at maximum force, percent, *Min* on gauge length $5.65\sqrt{A}$, where A is the cross-sectional area of the test piece (*see* **3.9**)	—	5	—	5	—	5	—

[1]Test wherever specified by the purchaser.

9.1.3 Notwithstanding the provisions in **9.1.2**, test pieces may be subjected to artificial ageing at a temperature not exceeding 100°C and for a period not exceeding 2 h.

9.1.4 Before the test pieces are selected, the manufacturer or supplier shall furnish the purchaser or his authorized representative with copies of the mill records giving the mass of bars/wires in each bundle/ cast with sizes as well as the identification marks, whereby the bars/wires from that cast can be identified.

9.2 Tensile Test

The tensile strength, percentage elongation, percentage total elongation at maximum force and 0.2 percent proof stress of bars/wires shall be determined in accordance with requirements of IS 1608 read in conjunction with IS 2062.

9.2.1 Alternatively and by agreement between the purchaser and the supplier, for routine testing, the proof stress may be determined in conjunction with the tensile strength test and may be taken as the stress measured on the specimen whilst under load corresponding to an increase measured by an extensometer of 0.4 percent for Fe 415 and Fe 415D bars/wires, 0.45 percent for grade Fe 500 and Fe 500D bars/wires and 0.47 percent for grade Fe 550, Fe 550D and Fe 600 bars/wires the total strain on any convenient gauge length. When this alternative is availed, the total strain shall be measured only by extensometer and not by any other means. In case of dispute the proof stress determined in accordance with IS 1608 shall be the deciding criteria.

9.2.2 The stresses shall be calculated using the effective cross-sectional area of the bar/wire.

9.3 Bend Test

The bend test shall be performed in accordance with the requirements of IS 1599 and the mandrel diameter for different grades shall be as specified in Table 4. The test piece, when cold, shall be doubled over the mandrel by continuous pressure until the sides are parallel. The specimen shall be considered to have passed the test if there is no rupture or cracks visible to a person of normal or corrected vision on the bent portion.

9.4 Rebend Test

The test piece shall be bent to an included angle of 135° (*see* Fig. 2) using a mandrel of appropriate diameter (*see* **9.4.1**). The bent piece shall be aged by keeping in boiling water (100°C) for 30 min and then allowed to cool. The piece shall then be bent back to have an included angle of 157½°. The specimen shall be considered to have passed the test if there is no rupture or cracks visible to a person of normal or corrected vision on the rebent portion.

Table 4 Mandrel Diameter for Bend Test

(*Clause* 9.3)
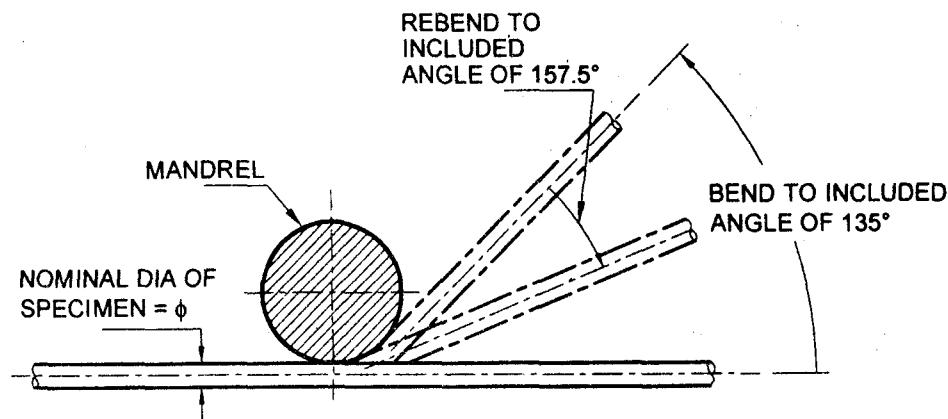
Sl No.	Nominal Size mm	Mandrel Diameter for Different Grades						
		Fe 415	Fe415D	Fe500	Fe500D	Fe550	Fe550D	Fe600
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Up to and including 20	3 φ	2 φ	4 φ	3 φ	5 φ	4 φ	5 φ
ii)	Over 20	4 φ	3 φ	5 φ	4 φ	6 φ	5 φ	6 φ

where φ is the nominal size of the test piece, in mm.

9.4.1 The diameter of the mandrel shall be as given below:

Sl No.	Nominal Size of Specimen	Dia of Mandrel for Fe 415 and Fe 500	Dia of Mandrel for Fe 415D and Fe 500D	Dia of Mandrel for Fe550 and Fe 600	Dia of Mandrel for Fe 550D
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to and including 10 mm	5 φ	4 φ	7 φ	6 φ
ii)	Over 10 mm	7 φ	6 φ	8 φ	7 φ

where φ is the nominal size of the test piece, in mm.

NOTE—φ Represents the nominal size in mm of the test piece.

FIG. 2 REBEND TEST

9.5 Retest

Should any one of the test pieces first selected fail to pass any of the tests specified in this standard, two further samples shall be selected for testing in respect of each failure. Should the test pieces from both these additional samples pass, the material represented by the test samples shall be deemed to comply with the requirements of that particular test. Should the test piece from either of these additional samples fail, the material presented by the samples shall be considered as not having complied with this standard.

10 ROUTINE INSPECTION AND TESTING

All material shall be subjected to routine inspection and testing by the manufacturer or supplier in accordance with this standard and a record of the test results of material conforming to this standard shall be kept by the manufacturer or the supplier. The records shall be available for inspection by the purchaser or his representative.

In the case of material delivered to a supplier, the manufacturer shall supply a certificate containing the results of all the required tests on samples taken from the delivered material.

11 SELECTION OF TEST SPECIMENS

11.1 For checking nominal mass, mechanical properties, bend test and rebend test, test specimen of sufficient length shall be cut from each size of the finished bar/wire at random at a frequency not less than that specified below:

Nominal Size	Quantity	
	For Casts/ Heats Below 100 tonnes	For Casts/ Heats of 100 tonnes or More
For all sizes	2 per cast	3 per cast

11.2 Bond Test

The frequency of bond test as required in 5.7 shall be as agreed to between the manufacturer and the purchaser/testing authority.

12 DELIVERY, INSPECTION AND TESTING FACILITIES

12.1 Unless otherwise specified, general requirements relating to the supply of material, inspection and testing shall conform to IS 1387.

12.2 No material shall be dispatched from the manufacturer's or supplier's premises prior to its being certified by the purchaser or his authorized representative as having fulfilled the tests and requirements laid down in this standard except where the bundle containing the bars/wires is marked with the Standard Mark (see 13.4).

12.3 The purchaser or his authorized representative shall be at liberty to inspect and verify the steel maker's certificate of cast analysis at the premises of the manufacturer or the supplier. When the purchaser requires an actual analysis of finished material, this shall be made at a place agreed to between the purchaser and the manufacturer or the supplier.

12.4 Manufacturer's Certificate

In the case of bars/wires which have not been inspected at the manufacturer's works, the manufacturer or supplier, as the case may be, shall supply the purchaser or his authorized representative with the certificate stating the process of manufacture and also the test sheet signed by the manufacturer giving the result of each mechanical test applicable to the material purchased, and the chemical composition, if required. Each test certificate shall indicate the number of the cast to which it applies, corresponding to the number or identification mark to be found on the material. The test certificate shall contain the following information:

a) Place of manufacture of the reinforcing steel,

b) Nominal diameter of the steel,

c) Grade of the steel,

d) Rolled-in marking on the steel,

e) Cast/heat number,

f) Date of testing,

g) Mass of the tested lot, and

h) Individual test results for all the properties.

13 IDENTIFICATION AND MARKING

13.1 The manufacturer or supplier shall have ingots, billets and bars or bundles of bars/wires marked in such a way that all finished bars/wires can be traced to the cast from which they were made. Every facility shall be given to the purchaser or his authorized representative for tracing the bars/wires to the cast from which they were made.

13.2 For each bundle/coil of bars/wires a tag shall be attached indicating cast/lot number, grade and size.

13.3 All bars/wires should be identifiable by marks/brands introduced during rolling which indicate the name of the manufacturer or their brand name.

13.3.1 Identification marks like brand name, trade-mark, etc, that are introduced during rolling shall be designed and located in such a manner that the performance in use of the bar is not affected.

13.4 BIS Certification Marking

Each bundle containing the bars/wires may also be suitably marked with the Standard Mark in which case the concerned test certificate shall also bear the Standard Mark.

13.4.1 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which a license for the use of Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

ANNEX A

(*Foreword*)

INFORMATION ON CONTROLLED COOLING PROCESS

A-1 The processing of reinforcing steel is usually through one or combination of processes which may include hot rolling after microalloying, hot rolling followed by controlled cooling (TMT process) and hot rolling followed by cold work.

Heat treatment is a thermal process undergone by the steel in the solid state. The most common practice is finishing online heat treatment while rolling, commonly known as thermomechanical treatment (TMT) process. After leaving the last stand of the rolling mill, the bars are quenched (rapidly cooled) in water from a final rolling temperature of about 950°C. The quenching is partial, only until a surface layer has been transformed from austenite (a steel phase stable only at very high temperatures) to martensite (stable at temperatures below 350°C). This controlled quenching is achieved in one or more online water cooling devices through which the steel passes at a very high speed before reaching the cooling bed.

Because the quenching is only partial, a part of the original heat remains in the core of the steel and, on the cooling bed, this heat migrates towards the surface. This results in an automatic self-tempering process where the surface layer of martensite is tempered; this 'tempering temperature' (or equalization temperature) refers to the maximum temperature attained by the bar surface after quenching. Tempering enables a partial diffusion of carbon out of the extremely brittle but strong martensite, thus relieving the inherent stresses locked in during the sudden quenching of the red-hot steel in cold water. The resulting tempered-martensite shows improved deformability compared to the as-quenched martensite.

The core of the heat treated reinforcing bars/wires consist of ferrite and perlite – more ductile but less strong than the martensite. Computerized process control is used to dynamically adjust the many rapidly changing parameters depending on the chemical composition of the steel, the desired grade and size of the reinforcing bar/wire etc. For the larger diameters, small addition of microalloys is usual.

Sometimes it becomes necessary to determine if a particular reinforcing bar/wire, or lot, has undergone proper heat treatment or is only a mild steel deformed bar. Because the two cannot be distinguished visually, the following field test may be used for purposes of identification. A small piece (about 12 mm long) can be cut and the transverse face lightly ground flat on progressively finer emery papers up to '0' size. The sample can be macroetched with nital (5 percent nitric acid in alcohol) at ambient temperature for a few seconds which should then reveal a darker annular region corresponding to martensite/bainite microstructure and a lighter core region. However, this test is not to be regarded as a criterion for rejection. The material conforming to the requirements of this standard for chemical and physical properties shall be considered acceptable.

ANNEX B

(*Foreword*)

COMMITTEE COMPOSITION

Concrete Reinforcement Sectional Committee, CED 54

Organization	*Representative(s)*
Ministry of Shipping, Road Transport and Highways, New Delhi	SHRI G. SHARAN (***Chairman***) ADG (ROAD TRANSPORT)
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Central Public Works Department, New Delhi	SUPERINTENDING ENGINEER (CDO) EXECUTIVE ENGINEER (CDO) (*Alternate*)
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