भारतीय मानक

Indian Standard

IS 16651 : 2017

कंक्रीट प्रबलन के लिए उच्च शक्ति विरुपित स्टेनलेस स्टील के सरिए एवं तारें — विशिष्टि

High Strength Deformed Stainless Steel Bars and Wires for Concrete Reinforcement — Specification

ICS 77.140.15; 91.080.040

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Concrete Reinforcement Sectional Committee, CED 54

FOREWORD

This Indian Standard 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 performance of a reinforced cement concrete (RCC) structure decreases substantially in a corrosive environment. India has a large coastline where chances of chloride induced corrosion in the reinforcing steel used in RCC structure made in the marine type environment of this area, are high. A need was therefore felt to provide options to users, to consider use, in appropriate cases, such material, which in addition to satisfying mechanical properties required for reinforcing steel for use in RCC structure, also provide better corrosion resistance properties than carbon steel. Stainless steel reinforcement bars are one such material which offer these properties. This standard has therefore been formulated to fulfil the need of prescribing quality requirements of stainless steel deformed bars/wires for use in reinforced concrete constructions as steel reinforcement.

This standard covers three categories of stainless steel alloy, namely, austenitic, austenitic-ferritic (duplex) and ferritic. Guidance on selection and use of stainless steel reinforcement bars, as also their use with carbon steel reinforcement on selective use basis, is given at Annex A for information only.

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 India. Considerable assistance has been derived from the following standards:

ASTM A 955/A955M	Standard specification for deformed and plain stainless-steel bars for concrete reinforcement
BS 6744 : 2016	Stainless steel bars — Reinforcement of concrete — Requirements and test methods
JIS G 4322 : 2008	Stainless steel bars for concrete reinforcement

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

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.

Indian Standard

HIGH STRENGTH DEFORMED STAINLESS STEEL BARS AND WIRES FOR CONCRETE REINFORCEMENT — SPECIFICATION

1 SCOPE

1.1 This standard covers requirements and describes methods of test for high strength deformed stainless steel bars/wires of the following strength grades, for use as concrete reinforcement:

a) SS 500,
b) SS 550,
c) SS 600, and
d) SS 650.

NOTE — The values following the symbol SS indicate the specified minimum 0.2 percent proof stress or yield stress in N/mm^2.

1.2 This standard applies to solid stainless steel bars/wires in which the deformations/ribs have been formed by cold working or hot rolling processes.

1.3 This standard applies to hot rolled steel without subsequent heat treatment, or to hot rolled steel subsequently annealed and cold worked. The production process is at the discretion of the manufacturer.

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

1.5 Deformed stainless steel reinforcing bars/wires produced by rerolling finished products such as plates, or from material whose metallurgical history is not known and fully documented is not acceptable in this standard.

2 REFERENCES

The standards listed below contain provisions which, through reference in this text, constitute provision 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
1599 : 2012/ ISO 7438 : 2005	Metallic materials — Bend test (*third revision*)
1608 : 2005/ ISO 6892 : 1998	Metallic materials — Tensile testing at ambient temperature (*third revision*)
1757 (Part 1) : 2014 ISO 148-1 : 2009	Metallic materials Charpy pendulum impact test: Part 1 Test method (*third revision*)
1786 : 2008	High strength deformed steel bars and wires for concrete reinforcement — Specification (*fourth revision*)
2062 : 2011	Hot rolled medium and high tensile structural steel — Specification (*seventh revision*)
2770 (Part 1) : 1967	Methods of testing bond in reinforced concrete: Part 1 Pull out test
3711 : 2012/ ISO 377 : 1997	Steel and steel products location and preparation of samples an test pieces from mechanical testing (*second revision*)
8910 : 2010/ ISO 404 : 1992	General technical delivery requirements for steel and steel products (*first revision*)
10461 (Part 2) : 1994	Resistance to intergranular corrosion of austenitic stainless steel method of determination: Part 2 Corrosion test in a sulphuric acid/ copper sulphate medium in the presence of copper turnings (Monypenny Strauss test) (*first revision*)

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 strength grade and processed from an identical heat or cast, whether in coils or bundles presented for examination and test at one time.

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

3.3 Elongation — Elongation is 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 bars/wires (before cold working, if any).

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

3.6 Nominal Mass — The mass of the bar/wire of nominal diameter and of density 0.007 9 kg/mm^2/m, for austenitic, 0.007 8 kg/mm^2/m for austenitic-ferritic (duplex) and 0.007 74 kg/mm^2/m for ferritic grade alloys.

3.7 Nominal Perimeter of a Deformed Bar/Wire — 3.14 times of 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 (*see* Fig. 1).

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 stainless steel with no such definite yield point, proof stress shall be applicable.

4 DESIGNATION, MANUFACTURE, CHEMICAL COMPOSITION AND SURFACE QUALITY

4.1 Designation

The stainless steel deformed bars/wires shall be designated in the following sequence:

a) Nominal diameter of the bar/wire (*see* **6**);
b) Steel designation number as per this standard (*see* Table 1); and
c) Strength grade (*see* Table 5).

Example — A bar with a nominal diameter of 16 mm, steel designation number 'A' and strength grade 500 N/mm^2 shall be designated as 16-A-SS500.

4.2 Manufacture

The stainless steel used, for manufacturing of high strength deformed stainless steel reinforcement bars/wires, shall be manufactured either by electric arc furnace (EAF) or induction furnace and argon oxygen decarburization (AOD) process or ladle refining furnace (LRF). In case any other process is employed by the manufacturer, prior approval of the purchaser should be obtained.

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

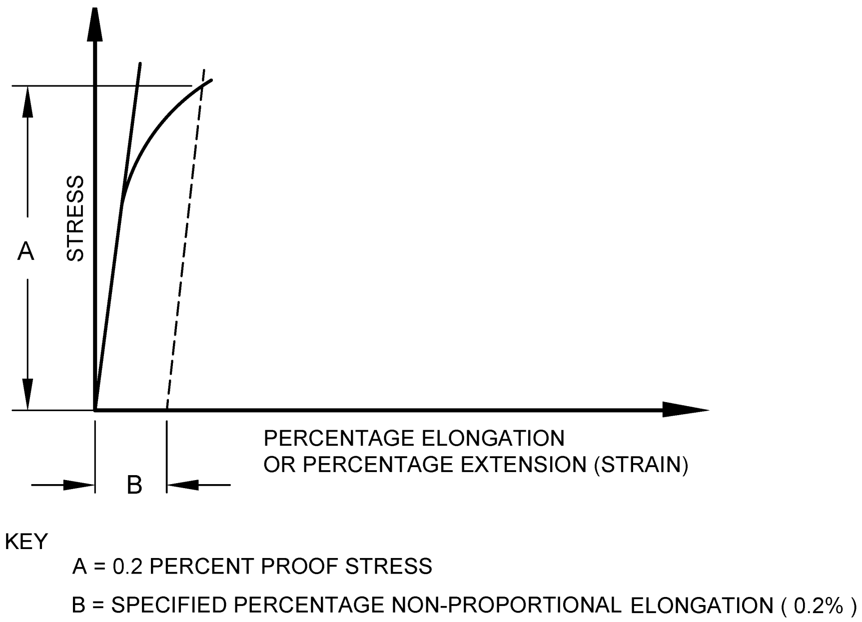


FIG. 1 0.2 PERCENT PROOF STRESS

4.2.2 The stainless 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.

4.3 CHEMICAL COMPOSITION

4.3.1 *Ladle Analysis*

The chemical composition of the steel as determined on the ladle sample for each cast as per the method in relevant parts of IS 228 or any other established instrumentation/chemical method shall conform to the requirements of Table 1. In case of dispute, the procedure given in IS 228 and its relevant parts shall be referee method.

4.3.2 *Product Analysis*

The maximum permissible deviations in the product analysis from the values specified for cast analysis in Table 1 shall be as given in Table 2.

In case of deviations beyond the maximum permissible deviations specified in Table 2, 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.

4.4 Surface Quality

All stainless steel reinforcing bars/wires shall be supplied in pickled/fully passivated condition. They shall be substantially free from mill scale, oxides, mud, oil or other contaminants that can adversely affect their performance or increase the risk of contamination/ galvanic corrosion or affect their bond strength, when immersed in concrete or affect the corrosion properties of the steel specified in this standard.

5 REQUIREMENTS FOR BOND

5.1 High strength deformed stainless steel 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 stainless bars/wires, the mean area of ribs (in mm^2) 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 ϕ for $\phi \le 10$ mm,

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

c) 0.17 ϕ for $\phi > 16$ mm.

Where ϕ is the nominal diameter of the bars/wires, in mm.

Table 1 Chemical Composition (Cast Analysis), Percent by Mass
(*Clause* 4.3.1)

Sl No.	Steel Designation Number		International Standard Designation	C *Max*	Si *Max*	Mn *Max*	S *Max*	Cr *Min/Max*	Ni *Min/Max*	Mo *Min/Max*	P *Max*	Cu *Min/Max*	N *Min/Max*
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	A	Austenitic	1.4301	0.07	1.0	2.0	0.030	17.00 / 19.50	8.00 / 10.50	—	0.045	—	0.0 / 0.11
ii)	B	Austenitic	1.4311	0.03	1.0	2.0	0.030	17.50 / 19.50	8.50/ 11.50	—	0.045	—	0.12 / 0.22
iii)	C	Austenitic	1.4436	0.05	1.0	2.0	0.030	16.50 / 18.50	10.50 / 13.00	2.50 / 3.00	0.045	—	0.0 / 0.11
iv)	D	Austenitic-Ferritic	1.4162	0.04	1.0	4.0 to 6.0	0.015	21.00 / 22.00	1.35 / 1.70	0.10 / 0.80	0.040	0.10 / 0.80	0.20 / 0.25
v)	E	Austenitic-Ferritic	1.4362	0.03	1.0	2.0	0.015	22.00 / 24.50	3.50 / 5.50	0.10 / 0.60	0.035	0.10 / 0.60	0.05 / 0.20
vi)	F	Austenitic-Ferritic	1.4462	0.03	1.0	2.0	0.015	21.00 / 23.00	4.50 / 6.50	2.50 / 3.50	0.035	—	0.10 / 0.22
vii)	G	Ferritic	410L	0.03	1.0	1.0	0.030	11.00/ 13.50	0.0/ 0.60	—	0.040	—	—

Table 2 Maximum Deviations Allowed in the Product Analysis
(*Clause* 4.4)

Sl No.	Element	Specified Limits, Cast Analysis Percent by Mass	Permissible Tolerance (*see* Note) Percent by Mass
(1)	(2)	(3)	(4)
i)	Carbon	≤ 0.030	+ 0.005
		> 0.030 to ≤ 0.20	± 0.01
		> 0.20 to ≤ 0.50	± 0.02
		> 0.50 to ≤ 0.60	± 0.03
ii)	Silicon	≤ 1.00	+ 0.05
		> 1.00 to ≤ 4.5	± 0.10
iii)	Manganese	≤ 1.00	+ 0.03
		> 1.00 to ≤ 2.00	± 0.04
		> 2.00 to ≤ 10.5	± 0.10
iv)	Phosphorus	≤ 0.045	+0.005
v)	Sulphur	> 0.015	+0.003
		> 0.015 to ≤ 0.030	±0.005
		≥ 0.15 to ≤ 0.35	± 0.02
vi)	Nitrogen	≤ 0.11	± 0.01
		≥ 0.11 to ≤ 0.50	± 0.02
vii)	Chromium	≥ 10.5 ≤ 15.0	± 0.15
		> 15.0 to ≤ 20.0	± 0.20
		> 20.0 to ≤ 30.0	± 0.25
viii)	Copper	≤ 1.00	± 0.07
		> 1.00 to ≤ 5.0	± 0.10
ix)	Molybdenum	≤ 0.60	± 0.03
		> 0.60 to ≤ 1.75	± 0.05
		> 1.75 ≤ 8.0	± 0.10
x)	Nickel	≤ 1.00	± 0.03
		> 1.00 to ≤ 5.0	± 0.07
		> 5.0 to ≤ 10.0	± 0.10
		> 10.0 to ≤ 20.0	± 0.15
		> 20.0 to ≤ 32.0	± 0.20

NOTE — If several product analysis are carried out on one cast, and the contents of an individual element determined lies outside the permissible range of the chemical composition specified for the cast analysis, then it is only allowed to exceed the permissible maximum value or to fall short of the permissible minimum value, but not both at the same time.

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 bars/wires, and are spaced along the bars/wires at substantially uniform distance, except in the area of marking.

5.4 The mean projected rib area per unit length, A_r (in mm^2/mm) may be calculated from the following formula:

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

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. 2) or area of transverse rib of uniform height on its own axis, in mm^2 ;

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. 2, 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:

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

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.

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 bars/wires equal to at least 10 ϕ by the number of spaces between ribs in the measured length, ϕ being the nominal diameter of the bars/wires. The measured length of the bars/wires 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.

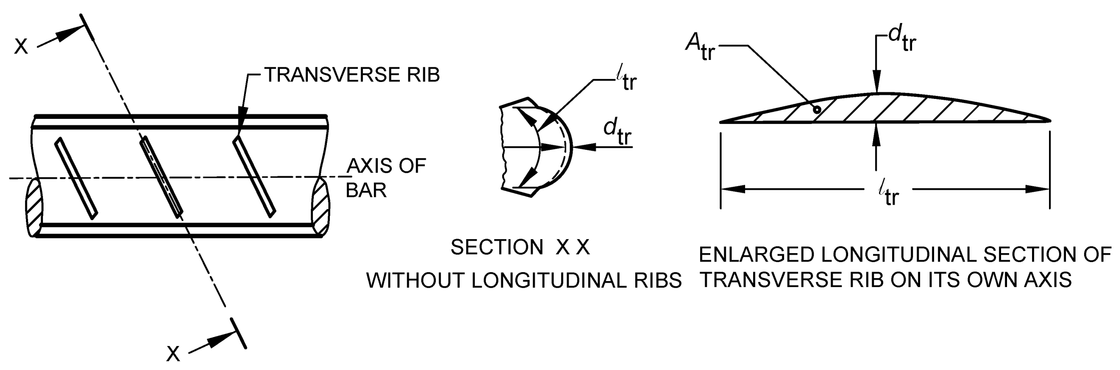
6 NOMINAL SIZES

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

6 mm, 8 mm, 10 mm, 12 mm, 16 mm, 20 mm, 25 mm, 28 mm and 32 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 3 subject to the tolerance on nominal mass as given in Table 4.



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

FIG. 2 DETERMINATION OF LONGITUDINAL SECTION AREA A_{tr} OF A TRANSVERSE RIB

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:

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

where

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

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

ρ = density for various steel designation (*see* Table 1) to be taken as given below:

Sl No.	*Steel Designation Number*	*Density* kg/mm²/m
(1)	(2)	(3)
i)	A and B	0.007 850
ii)	C	0.007 9
iii)	D, E and F	0.007 8
iv)	G	0.007 74

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 mm² shall be taken as:

$$\text{Gross cross-sectional area, in mm}^2 = \frac{1.03\,w'}{\rho \times L}$$

where

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

L = length, in m; and

ρ = density for various steel designation number as given in **6.3.1**.

For routine test purposes, a nominal ratio of effective to gross cross-sectional area of bars/wires covered by **6.3.2** (b) 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 bars/wires shall be cut within the deviations of $^{+75}_{-25}$ mm on the specified length, but if minimum lengths are specified, the deviation shall be $^{+50}_{-0}$ mm.

7.2 Nominal Mass

7.2.1 For the purpose of checking the nominal mass, the density of stainless steel shall be taken as per the informal table given in **6.3.1**.

7.2.2 Unless otherwise agreed to between the manufacturer and the purchaser, the tolerances on nominal mass shall be as given in Table 4. For bars/wires whose effective cross-sectional area is determined

Table 3 Nominal Cross-Sectional Area and Nominal Mass per metre Run

(*Clause* 6.2)

Sl No.	Nominal Size mm	Nominal Cross-Sectional Area mm²	Nominal Mass per meter Run Stainless Steel Designation: A and B (1.4301 and 1.4311) kg	C (1.4366) kg	D, E and F (1.4162/1.4362 / 1.4462) kg	G (410L) kg
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	6	28.3	0.224	0.226	0.221	0.219
ii)	8	50.3	0.397	0.402	0.392	0.389
iii)	10	78.5	0.620	0.628	0.612	0.608
iv)	12	113.1	0.893	0.905	0.882	0.875
v)	16	201.1	1.589	1.609	1.569	1.555
vi)	20	314.2	2.482	2.514	2.451	2.430
vii)	25	490.9	3.878	3.927	3.829	3.797
viii)	32	804.2	6.353	6.434	6.266	6.222

as in **6.3.2** (b), the nominal mass per meter shall correspond to the gross mass and the deviations in Table 4 shall apply to the nominal mass.

Table 4 Tolerances on Nominal Mass
(*Clauses* 6.2 *and* 7.2.2)

Sl No.	Nominal Size Mm	Nominal Cross-Sectional Area mm^2	Tolerance on Mass per metre Run Percent
(1)	(2)	(3)	(4)
i)	6	28.3	±9.0
ii)	8	50.3	±6.0
iii)	10	78.5	±6.0
iv)	12	113.1	±6.0
v)	16	201.1	±4.5
vi)	20	314.2	±4.5
vii)	25	490.9	±4.5
viii)	32	804.2	±4.5

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

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 **9** 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 **9** 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 1 m length taken from each end of the coil and dividing the same by the actual total length of the samples.

8 MECHANICAL, PHYSICAL AND CORROSION RESISTANCE PROPERTIES

8.1 The mechanical, physical and corrosion resistance properties of stainless steel deformed bars/wires shall be as per the requirements given in **8.2** to **8.6**.

8.2 Tensile Properties

The 0.2 percent proof strength ($R_{p0.2}$), percentage elongation after fracture (A_5), tensile strength (R_m) and percentage total elongation at maximum force (A_{gt}) of the steel obtained from test samples selected, prepared and tested in accordance with **9.2**, and determined on effective cross-sectional area (*see* **6.3**), shall be as specified in Table 5.

8.3 Bend and Rebend Properties

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

8.4 Bond Strength

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

Table 5 Mechanical Properties of High Strength Deformed Stainless Steel Bars and Wires
(*Clause* 8.2)

Sl No.	Properties	SS 500	SS 550	SS 600	SS 650
(1)	(2)	(3)	(4)	(5)	(6)
i)	0.2 percent proof stress ($R_{p0.2}$), *Min*, N/mm^2	500	550	600	650
ii)	Percentage elongation after fracture (A_5), *Min*, on gauge length $5.65\sqrt{A}$, where A is the cross-sectional area of the test piece	16	14.5	10.0	10.0
iii)	Tensile strength (R_m), *Min*, N/mm^2	10 percent more than the actual 0.2 percent proof stress but not less than 565 MPa	10 percent more than the actual 0.2 percent proof stress but not less than 600 MPa	10 percent more than the actual 0.2 percent proof stress but not less than 660 MPa	10 percent more than the actual 0.2 percent proof stress but not less than 715 MPa
iv)	Percentage total elongation at maximum force (A_{gt}), *Min*, on gauge length $5.65\sqrt{A}$, where A is the cross-sectional area of the test piece	5	5	5	5

8.5 Fatigue Test

The fatigue characteristics of stainless steel deformed bars shall be verified every five years or after 1 000 tonne are produced for each diameter, steel designation and strength grade manufactured, whichever occurs sooner. Test samples shall be selected and prepared in accordance with IS 1608 and subjected to type testing in accordance with Annex B, to determine the characteristics of a particular geometric shape, designation and grade. When subjected to 5×10^6 cycles of stress at a stress ratio, $\sigma_{min} / \sigma_{max}$ of 0.2 and a frequency not exceeding 120 Hz, the test samples shall show no visible sign of fracture.

8.6 Charpy Impact Test

The Charpy impact test shall be carried out on bars of Grade D, E or F [austenitic-ferritic (duplex) grades] and diameter 16 mm or above in accordance with IS 1757 (Part 1) for checking for potential brittle phase of such bars. The impact properties for each defined bar at room temperature for Grades D, E, F in solution annealed condition shall have a minimum value defined in Table 6. Requirements of solution annealing are given in Table 7. The solution annealing may be omitted, if the conditions for hot working and subsequent cooling are such that the requirements of Table 6 are met.

Table 6 Minimum Impact Energy for Charpy Impact Test
(*Clause* 8.6)

Sl No.	Steel Designation Number	International Designation Number	Impact Energy *Min* J
(1)	(2)	(3)	(4)
i)	D	1.4162	60
ii)	E	1.4362	100
iii)	F	1.4462	100

Table 7 Requirements of Solution Annealing for Charpy Impact Test
(*Clause* 8.6)

Sl No.	Steel Designation Number	International Designation Number	Solution Annealing °C	Type of Cooling
(1)	(2)	(3)	(4)	(5)
i)	D	1.4162	1 020-1 080	Water, air
ii)	E	1.4362	950-1 050	Water, air
iii)	F	1.4462	1 020-1 100	Water, air

8.7 Inter-Granular Corrosion Test

The resistance to inter-granular corrosion shall be tested in accordance with IS 10461 (Part 2) and shall conform to the requirements given in IS 10461 (Part 2).

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; or
b) if, he so desires, from any bar 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 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 various 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 specified in case of Charpy impact test (*see* **8.6**) and inter-granular corrosion test [*see* IS 10164 (Part 2)]. Any straightening which a test piece may require shall be carried out when samples are at cold stage.

9.1.2.1 For the purpose of carrying out tests for tensile strength, 0.2 percent proof stress, percentage elongation after fracture and percentage total elongation at maximum force for bars 28 mm in diameter and above, deformation of the bars only may be machined. For such bars, the physical and tensile properties shall be calculated using the actual area obtained after machining.

9.1.3 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

9.2.1 The tensile strength, percentage elongation after fracture, 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.

9.2.2 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 8. 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.

The test shall be carried out on test samples having a temperature between 10°C and 40°C and in such a way as to produce a continuous and uniform bending deformation (curvature) at every section of the bend. The method of bending shall be one of the following:

a) On a power bending machine in which the test sample is adequately supported by plain smooth surfaces or rolls which do not offer resistance to longitudinal movement of a test piece; and
b) On a three-point hydraulic bending machine.

The chosen machine shall be serviceable and capable of imparting constant loading to the sample and be without impact effect.

The rate of application of the load shall not exceed 3 rev/min or equivalent.

Table 8 Bend Test Mandrels
(*Clause* 9.3)

Sl No.	Nominal Size of the Bar	Maximum Diameter of Mandrel
(1)	(2)	(3)
i)	Up to and including 16 mm	Three times the nominal size of the bar
ii)	Over 16 mm	Six times the nominal size of the bar

9.4 Rebend Test

The test piece shall be bent to an included angle of 135° using a mandrel of appropriate diameter. The bent piece shall be then be allowed to cool at atmospheric temperature. The piece shall then be bent back to have an included angle of 157.5°. 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 rebend portion. The diameter of the mandrel shall be as given in Table 9.

9.5 Retests

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 compiled with this standard. Retests for fatigue test shall however be as per Annex B.

9.6 Sampling

9.6.1 For checking nominal mass, deformations and surface characteristics (*see* **5.2**), tensile properties, bend test and rebend test, test specimen of sufficient length shall be cut from each size of the finished bars/wires at random at a frequency not less than that specified in Table 10.

9.6.2 *Charpy Impact Test*

Charpy impact test shall be performed at a frequency of three impact tests for each batch. The average obtained from three test pieces shall be considered to be the test result.

9.6.3 *Intergranular Corrosion Test*

Inter-granular corrosion test shall be carried out at a frequency of one test per batch.

9.6.4 *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.

9.6.5 *Fatigue Test*

The fatigue characteristics of stainless steel deformed bars shall be verified every five years or after

Table 9 Mandrel Diameter for Rebend Test
(*Clause* 9.4)

Sl No.	Nominal Size of Specimen	Diameter of Mandrel for 500	Diameter of Mandrel for 550	Diameter of Mandrel for 600	Diameter of Mandrel for 650
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to and including 10mm	4 ϕ	6 ϕ	7 ϕ	8 ϕ
ii)	Over 10mm	6 ϕ	7 ϕ	8 ϕ	9 ϕ

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

Table 10 Selection of Test Samples
(*Clause* 9.6.1)

Nominal Size	Quantity	
	For Casts/Heats below 100 t	For Casts/Heats of 100 t or more
(1)	(2)	(3)
For all sizes	2 per cast/heat	3 per cast/heat

1 000 tonne are produced for each diameter, steel designation and strength grade manufactured, whichever occurs sooner. Sampling shall be done in accordance with Annex B.

10 ROUTINE INSPECTION AND TESTING

All material shall be subjected to routine inspection and testing by the manufacturer or the 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 for 5 years. 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 DELIVERY, INSPECTION AND TESTING FACILITIES

11.1 Unless otherwise specified, general requirements relating to the supply of material, inspection and testing shall conform to IS 8910.

11.2 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* **12.4**).

11.3 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.

11.4 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 test applicable to the material purchased and the chemical composition. Each test certificate shall indicate the number of the cast/heat 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) Name and place of the manufacturer of the reinforcing steel;
b) Designation of the steel as per Table 1;
c) Strength grade of the reinforcing steel;
d) Nominal size of the reinforcement bar/wire;
e) Rolled-in marking on the steel;
f) Cast/Heat number;
g) Batch reference;
h) Date of testing;
j) Mass of the tested lot; and
k) Individual test results for all the properties.

12 IDENTIFICATION AND MARKING

12.1 Product Marking

The manufacturer or supplier shall have ingots, billets and bars or bundles of bars/coils 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/coils to the cast from which they were made.

12.2. Deformed stainless steel bars shall be identified by rolled-on legible marks on the surface at intervals not greater than 1.5 m to identify the manufacturer. Such identification marks like brand name, trade-mark, etc, shall be designed and located in such a manner that the performance in use of the bar is not affected.

12.3 For each bundle/coil of bars/wires a tag shall be attached indicating name of the manufacturer, cast/heat number, batch reference, steel designation number, strength grade and size.

12.4 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.

12.4.1 The use of 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*)

GUIDANCE ON SELECTION AND USE OF STAINLESS STEEL REINFORCEMENT BARS

A-1 GUIDANCE ON RAW MATERIAL SELECTION TO PREVENT CORROSION

It is assumed that corrosion resistance is of primary concern when stainless steel reinforcement is specified. The permutations in exposure conditions, service life, rebar depth, concrete type, construction methods, etc, mean that each situation will require a unique corrosion resistance and therefore there is little validity to existing guidance on raw material selection.

Increasingly, concrete designers on major projects are using predictive modeling to assess where they need to selectively replace carbon steel reinforcement bar with stainless steel reinforcement bar for a given chloride exposure condition, concrete mix, rebar depth, and service life.

The *p*H of the concrete at design life, surface finish of the reinforcement bar and the temperature decides the critical chloride threshold level (CCTL) of the reinforcement, which leads to decide where to use stainless steel reinforcement bars in the structure. Expert advice should be sought when deciding on stainless steel selection.

A-1.1 Guidance on Use of Stainless Steel Reinforcement Bars in Combination with Carbon Steel on Selective Use Basis

Corrosion happens from the outer periphery of the concrete structure. Thus, it is advisable to use stainless steel reinforcement bars only in the critical areas, where corrosion is at stake. The CCTL and the predictability model helps to decide the critical corrosion prone areas in a structure, and if stainless steel reinforcement bars are used only in those areas, the purpose will be served. Selective use of stainless steel reinforcement bars is used mainly to resist corrosion.

A-1.1.1 *Galvanic Corrosion*

As the corrosion potentials are identical in carbon steel and stainless steel placed well within the concrete, with a minimum concrete cover of 30 mm, there is no fear of galvanic corrosion when both carbon steel and stainless are used in combination within a structure (*see* Fig. 3).

If the carbon steel rebar is in the active state (that is, it is de-passivated, due to the influence of chlorides and/ or carbonation), galvanic corrosion is possible. However, in most cases, this effect is much less significant than that of the inevitable element formation between active and passive carbon steel rebar (galvanic corrosion through an active/passive element), since the cathodic efficiency of stainless steel is much lower than of carbon steel.

A-2 HANDLING ON SITE

When handling stainless steel bars, it is advisable to avoid direct contact with carbon steel. Stainless steel reinforcement should be stored clear of the ground and

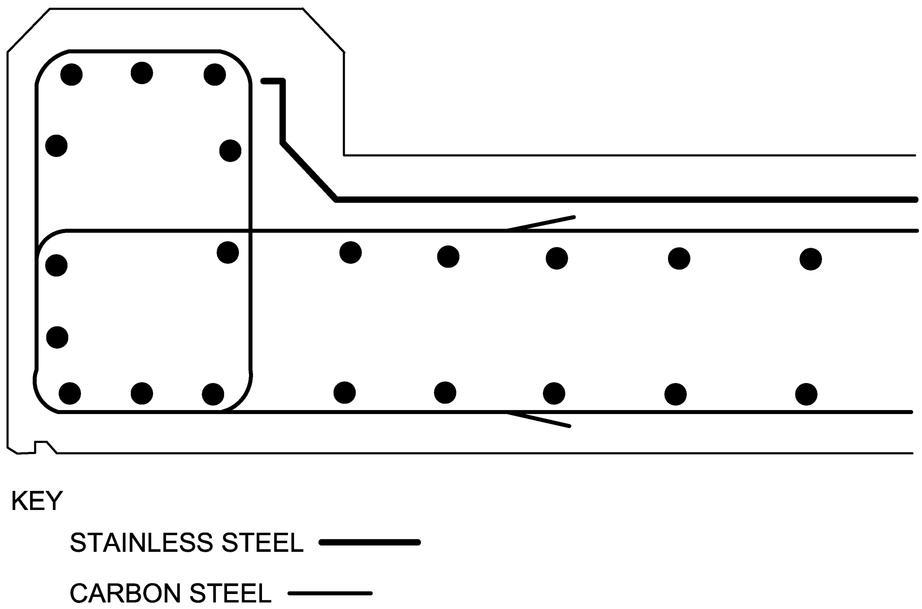


FIG. 3 SELECTIVE USE OF STAINLESS STEEL IN COMBINATION OF CARBON STEEL

stored separately from carbon steel reinforcement because of the risk of rust staining.

To restore the corrosion resistance after welding or by contamination after contact with carbon steel, the stainless steel should be cleaned before use. The aim is to remove welding slag, spatter, weld tint (weld oxides) and contamination from carbon steel. Recommended methods are brushing with a stainless brush, blasting, hot water pressure cleaning and/or chemical pickling. When considering chemical pickling, local safety regulations shall be followed.

Stainless steel bars should be always fixed or tied to each other firmly using stainless steel wires. Any tie bars, spacers or chairs to be used for placing stainless steel bars or to support them should have a corrosion resistance comparable or greater than that of the stainless steel bars themselves. They shall be made from stainless steel, plastic, concrete or cement mortar.

A-3 MAGNETIC PROPERTIES

Austenitic stainless steels (Grades A, B and C) are generally considered to be non-magnetic. However, after cold working some magnetic permeability may be evident in such steels. Conversely, duplex stainless steels and ferritic stainless steels (Grades D to G of Table 2) are considered to be magnetic.

Relative magnetic permeability, μ_r, is defined as the ratio of the magnetic flux density produced in the material relative to that produced in free space by the same magnetizing force. Therefore, the lowest achievable relative magnetic permeability is 1.

However, as noted above, the magnetic permeability is directly affected by the manufacturing route. Therefore, where low magnetic permeability is of importance (μ_r = 1.005), the purchaser should agree the specific supply condition and chemical composition with the manufacturer at the time of order.

A-4 COEFFICIENTS OF THERMAL EXPANSION

Closer the thermal coefficient of expansion of the metal and concrete, better would be their performance together. Table 11 provides comparative thermal coefficient of expansion data for different grades of stainless steel reinforcement bars.

Table 11 Comparative Thermal Coefficient of Expansion Data
(*Clause* A-4)

Sl No.	Steel Designation Number		Co-efficient of Thermal Expansion × 10^{-6} (20 to 100°C)
	Designation	International Designation	
(1)	(2)	(3)	(4)
i)	A	1.4301	16.0
ii)	B	1.4311	16.0
iii)	C	1.4436	16.0
iv)	D	1.4162	13.0
v)	E	1.4362	13.0
vi)	F	1.4462	13.0
vii)	G	410L	11.25

A-5 GUIDANCE ON WELDING, CUTTING, BENDING, LAPPING AND BINDING OF STAINLESS STEEL REINFORCEMENT BARS ON SITE

A-5.1 Welding Procedures

Site welding of stainless steel reinforcement shall not be attempted, unless the correct welding conditions can be maintained. As a general rule, welded or gas-pressure welded splices shall not be used with stainless steel bar. If there is no alternative to processing on site, the method of welding as given in **A-5.1.1** shall be adopted.

A-5.1.1 The Grades A, B and C (austenitic grades) can be welded with all methods normally used for welding stainless reinforcing steels. If the welding is carried out with filler material, austenitic reinforcing steel with a corresponding designed matching composition should be used.

The Grades D, E and F [austenitic-ferritic (duplex) grades] can be welded with all methods normally used for welding stainless steels. If the welding is carried out with filler material, fillers with a composition specifically designed for these stainless reinforcing steels should be used.

The Grade G (ferritic grades) can be welded like austenitic grades and the recommended welding electrodes are 309LSi/309L type.

In case of welding stainless steels to carbon steels, fillers with a composition over-alloyed as compared to stainless steel shall be used.

NOTE — For the composition of the above recommended electrodes, specialist literature shall be followed.

A-5.2 Cutting and Bending of Stainless Steel Rebar on Site

It is acknowledged that the relative price of stainless steel compared to carbon steel is higher and therefore any pre-forming of the bars into shapes should ideally be performed prior to delivery on site, hence reducing the potential for waste when compared to processing of shapes from straight bars delivered to site.

If there is no alternative to processing on site, then the recommendations given in **A-5.2.1** and **A-5.2.2** for cutting and bending should be followed.

A- 5.2.1 *Cutting*

Cutting should ideally be undertaken using a mechanically assisted device. Stainless steel work hardens when processed and may prove difficult to cut by current manual methods. Oxy-acetylene torch shall not be used for cutting.

A-5.2.2 *Bending*

Stainless steel bars may be bent similarly to carbon steel bars, however bent stainless steel bars should not be straightened. It is recommended to use equipment designated solely for cutting and bending stainless steel bars. Fabrication of stainless steel reinforcement should be such that the bars surfaces are not contaminated with deposits of iron and non-stainless steel.

A-5.3 Lapping

Where lapping of reinforcement is not recommended, instead of welding reinforcement steel at site, mechanical splicing of stainless steel bars shall be done. As a general rule, a method of splicing that has been experimentally verified shall be used as mechanical splice of stainless steel bars. Reinforcement couplers like stainless steel threaded couplers or mortar grouted sleeve joint using a stainless steel sleeve may be used. It should be ensured that the quality of stainless steel coupler or stainless steel sleeve is comparable or better than that of the bar material.

Binding wire used to tie stainless steel bar and carbon steel bar together, should be 1.2 mm diameter stainless steel wire preferably of Grade 304.

ANNEX B

(*Clause* 8.6)

FATIGUE TEST

B-1 Testing shall be carried out on bars in the straight condition using the test stress ranges in Table 12.

Table 12 Fatigue Test Stress Ranges
(*Clause* B-1)

Sl No.	Bar Size mm	Stress Range MPa
(1)	(2)	(3)
i)	Up to and including 16	200
ii)	Over 16 up to and including 20	185
iii)	Over 20 up to and including 25	170
iv)	Over 25 up to and including 32	160

B-2 SAMPLING

Samples shall be taken from a batch at random. The bars shall not exhibit isolated defects that are not characteristic of the product. Samples shall have a minimum length of 30ϕ and a minimum free length of 10ϕ, where ϕ is the nominal diameter of the sample. Each test unit shall comprise five test samples.

B-3 TEST PROCEDURE

Samples shall be tested in air under axial tensile loading, using tapered grips and a suitable gripping medium. The stress ratio shall be 0.2 and the frequency shall not exceed 120 Hz. A sine wave form shall be used. Testing shall be carried out under load control and stresses shall be calculated on the nominal area.

The test shall be considered invalid, if a sample fails the test due to a defect unique to the sample, or if failure occurs in an area adjacent to the testing machine grips. In these cases, a further sample shall be tested.

B-4 RETEST

If two or more samples fail to endure 5×10^6 cycles, and the test is valid, the batch shall be deemed not to conform to this standard.

If one sample fails the test, a further five test samples shall be selected from the same batch. If one or more of these samples fail, the batch shall be deemed not to conform to this standard.

ANNEX C

(Foreword)

COMMITTEE COMPOSITION

Concrete Reinforcement Sectional Committee, CED 54

Organization	*Representative(s)*
In Personal Capacity, (*17, Nalanda Apartment, D Block, Vikaspuri, New Delhi 110018*)	Shri G. Sharan (***Chairman***)
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Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards : Monthly Additions'.

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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