Reinforcement Bar

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.

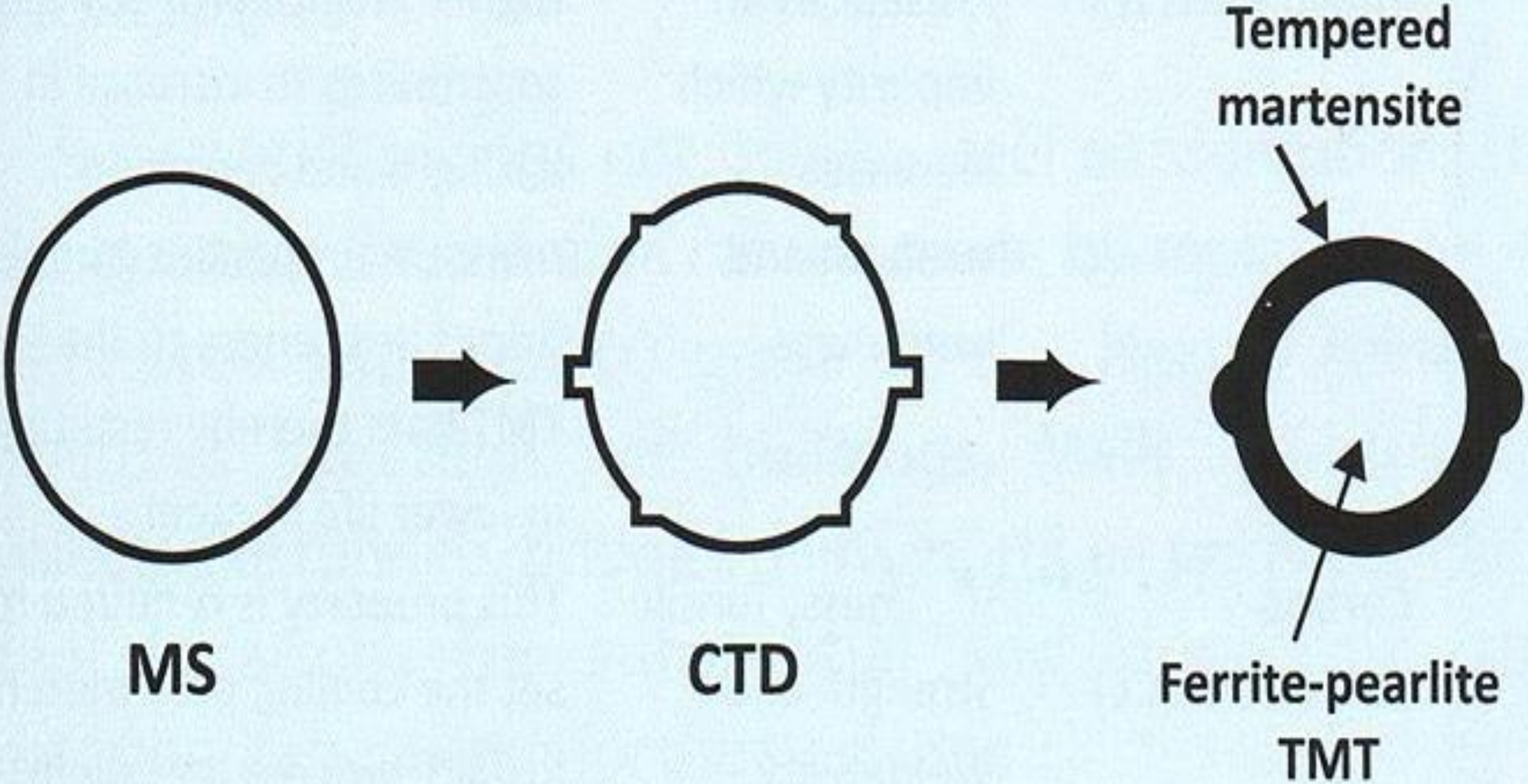
Sometimes it becomes necessary to determine if a particular reinforcing bar/wire, or lot, has undergone proper heat treatment or is only a mild steel deformed bar. Because the two cannot be distinguished visually, the following field test may be used for purposes of identification. A small piece (about 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.

INTRODUCTION

Thermomechanically Treated (TMT) or Quenched and Self-Tempered (QST) Bars

- Identification/Selection of TMT/QST bars
  - Select only of the hardened periphery and softer core are uniform and concentric in nature
  - Ideal if 20 to 30% of bar cross-sectional area is hardened periphery
  - Not ideal if >50% of bar cross-sectional area is hardened periphery (ductility reduces)

Transformation in Steel Industry



M.S. Round Bars | **CTD Bars** | **TMT Bars**

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

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/mm²	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/mm²	—	—	540.0	—	—	625.0	—	—	—
iii)	TS/YS ratio[1], N/mm²	≥ 1.10, but TS not less than 485.0 N/mm²	≥ 1.12, but TS not less than 500.0 N/mm²	1.25	≥ 1.08, but TS not less than 545.0 N/mm²	≥ 1.10, but TS not less than 565.0 N/mm²	1.25	≥ 1.06, but TS not less than 585 N/mm²	≥ 1.08, but TS not less than 600.0 N/mm²	≥ 1.06, but TS not less than 660 N/mm²
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.

THANK YOU