CDPNS 49:2001
As of 27 June 2001

Steel bars for concrete reinforcement - Specification

1 Scope and application

1.1 This standard specifies the requirements for hot-rolled deformed steel bars derived from billets or ingots used for concrete reinforcement as rolled or hot-rolled with subsequent treatment by quenching and self- tempering

1.2 Hot-rolled weldable deformed steel bars are intended for special applications where welding or bending, or both, are of importance.

NOTE - Welding technique is of fundamental importance and the welding procedure should be as prescribed in ANSI/AWS/D1.4 or PNS 1425.

2 References

The titles of the standard publications referred to in this standard are listed on the inside back cover.

3 Definitions

For the purpose of this standard the following definitions shall apply:

3.1 billet - A semi-finished steel product, hot-rolled or forged continuously cast.

3.2 deformed steel bar - A steel bar, the surface of which is provided, during hot-rolling, with lugs or protrusions called deformations.

3.3 elongation - A permanent extension in the gauge length of test specimen, measured after rupture, expressed as percentage of the original gauge length.

3.4 hot-rolled bar - A steel bar rolled to finish above the recrystallization temperature.

3.5 ingot - A mass of metal cast into some convenient shape for storage or transportation to be remelted later for casting or finished by rolling, forging, etc.

3.6 length - A piece of straight bar without joint or weld, cut to a specified size.

3.7 nominal diameter of a deformed bar - The diameter of a deformed bar equivalent to the diameter of a plain bar having the same mass per metre.

3.8 prime steel ingot/billet - A metal product of the highest commercial quality and free from visible defects to include trade seconds (steel ingot/billet of odd lengths).

3.9 reinforcement - Rods, bars or fabrics, usually of steel, embedded in concrete for the purpose of resisting particular stresses.

3.10 tensile strength - The value obtained by dividing the maximum load observed during the tensile straining until failure occurs, by the nominal specimen cross sectional area before straining, also called ultimate strength.

3.11 yield point - The load on nominal cross sectional area, when at constant loading speed, there begins a brief interval during which the test specimen elongates while the load remains constant or decreases and after which, the increase of load with increase of elongation resumes.

3.12 quenched and self-tempered process - the quenching and self-tempering process (QST) consist of in line heat treatment and cooling rate controls which result in mechanical properties in the finished condition that are equivalent to those attained using heat treating processes which entail reheating after rolling.

4 Classification and grading

4.1 Deformed steel bars shall be classified as

- hot-rolled non-weldable deformed steel bar; and
- hot-rolled weldable deformed steel bars

4.2 Each class of steel bar shall be graded according to its minimum yield strength as specified in table 2.

5 Chemical requirements

5.1 Ladle analysis - An analysis of each heat shall be made and the chemical composition, thus determined shall be reported to the purchaser or his representative. The percentages of carbon, manganese, phosphorous, sulfur and silicon shall conform to the specified values in table 1.

Table 1 - Chemical composition

Class	Grade	Chemical composition, percent, maximum					
		C	Mn	P	S	Si	C.E.**
Non-weldable steel bar	230	-	-	0.05*	0.05*	-	-
	275	-	-	0.05*	0.05*	-	-
	415	-	-	0.05*	0.05*	-	-
Weldable steel bar	230	0.30	0.90	0.05	0.05	-	0.55
	275	0.30	1.20	0.05	0.05	-	0.55
	415	0.30	1.50	0.05	0.05	0.50	0.55

* 0.06% maximum S and 0.06% maximum P are allowed provided that the carbon content is not more than 0.25% and the mechanical property requirements are met.

** Carbon equivalent test applies to ladle analysis only.

5.2 Alloying elements - The choice and use of alloying elements, combined with carbon, phosphorous, and sulfur, to give the mechanical properties of weldable steel bars as prescribed in table 2, shall be made by the manufacturer. Elements commonly used include manganese, silicon, copper, nickel, chromium, molybdenum, vanadium, columbium or niobium, titanium and zirconium.

5.3 Heat analysis - The heat analysis for weldable grades shall provide a carbon equivalent (C.E.) to be calculated by the following formula, and shall conform to the values specified in table 1.

$$C.E. = \% C + \frac{\%\_Mn}{6} + \frac{\%\_Cu}{40} + \frac{\%\_Ni}{20} + \frac{\%\_Cr}{10} - \frac{\%\_MO}{50} - \frac{\%\_V}{10}$$

5.4 Product (check) verification analysis - An analysis may be made by the purchaser from finished bars representing each heat. The contents determined shall not exceed those specified in table 1 by more than the following values:

Class	C%	S%	P%	Mn%	Si%
Non-weldable steel bar	-	+ 0.0125	+ 0.0125	-	-
Weldable steel bar	0.03	+ 0.008	+ 0.008	+ 0.06	+ 0.05

6 Mechanical and physical requirements

6.1 Mechanical properties - The mechanical properties of steel bars for concrete reinforcement shall conform to those specified in table 2.

Table 2 - Mechanical properties

Class	Grade	Yield Strength MPa, min.	Tensile strength MPa, min.**	Specimen	Elongation in 200 mm, Percent min	Bending angle, Degree	Diameter of Pin (d = nominal diameter of specimen)
Non-weldable steel bar	230	230	390	d< 25 mm d? 25mm	18 16	180	3d 4d
	275	275	480	d< 25 mm d? 25 mm	10 8	180	4d 5d
	415	415	620	d< 25 mm d? 25 mm	8 7	180	5d 6d
Weldable steel bar	230	230	390	d< 25 mm d? 25 mm	18 16	180	3d 4d
	275	275	480	d< 25 mm d? 25 mm	16 14	180	4d 5d
	415	415*	550	d< 25 mm d? 25 mm	14 12	180	5d 6d

***** Maximum yield strength of weldable steel bar is 540 MPa, however a value of 560 MPa shall be allowed for retest

****** Actual tensile strength for sizes up 16 mm shall not be less than 1.18 time the actual yield strength. Actual tensile strength for sizes 20 mm and above shall not be less than 1.25 times the actual yield strength.

6.2 Dimension, mass and tolerance

6.2.1 The dimensions and mass of steel bars shall conform to table 3.

Table 3 - Nominal dimensions and unit Mass

Nominal diameter, mm	Nominal perimeter,* mm	Nominal cross-sectional area, ** mm^2	Unit mass, + kg/m
10	31.4	78.54	0.617
12	37.7	113.10	0.888
16	50.3	201.06	1.578
20	62.8	314.16	2.466
25	78.6	490.88	3.853
28	88.6	615.75	4.834
32	100.5	804.25	6.313
36	113.1	1 017.88	7.990
40	125.68	1 256.64	9.865
50	157.08	1 963.5	15.413

* Nominal perimeter, mm = 3.1416 x nominal diameter in mm
**Nominal cross-sectional area, mm^2= 3.1416/4 x (nominal diameter)^2
+ Unit mass, kg/m = 0.00785 g/mm^3 x nominal cross-sectional in mm^2

6.2.2 The standard length of steel bars shall be 6.0, 7.5, 9.0, 10.5 and 12.0 metres.

6.2.3 The tolerance for length of steel bars shall conform to the values specified below:

Length	Tolerance
6 m	± 40 mm
For every additional 1 m or fraction thereof	add 5 mm to the above but not exceeding ± 60 mm

6.3.1 The tolerance on the mass of one piece of steel bar shall ± 6 percent.

6.2.5 The tolerance on the mass of one lot of steel bars shall be ± 4 percent.

6.3 Deformation requirements

6.3.1 Deformed bars shall be provided with surface protrusions, any one of which, in the direction parallel to the axis is called a "rib" and any other, a "lug". Lugs shall be spaced along the entire length of the deformed bar at substantially uniform distances, and shall be similar in shape and dimensions. When the figures or symbols are embossed, the lugs at these locations may be omitted.

6.3.2 The lugs shall be placed with respect to the axis of the bar so that the included angle is not less than 45 degrees. Where the line of deformation forms an included angle with the axis of the bar from 45 degrees to and including 70 degrees, the deformations shall be alternately reversed in direction from those on the opposite side. Where the line of deformation is over 70 degrees, a reversal in direction is not required.

6.3.3 The average spacing between lugs measured on the same side of deformed bars shall not exceed 70 percent of the nominal diameter of the bar.

6.3.4 The height of lugs on deformed bars, in relation to the nominal diameter, shall not be less than the values specified below:

Nominal diameter, mm	Minimum height of lugs*
10	4.0
12 and 16	4.5
20 and above	5.0
* Percent of nominal diameter	

6.3.5 The summation of gaps between the ends of the lugs on the opposite sides of the deformed bar shall not exceed 25 percent of the nominal perimeter of the bar.

6.3.6 The spacing, height, and gap of deformations shall conform to the requirements specified in table 4.

Table 4 - Deformation requirements

Nominal diameter, mm	Max. average spacing of lugs*, mm	Height tolerance of lugs, Mm		Max. value++ summation of gaps of lugs, mm
		min. value**	max. value+	
10	7.0	0.4	0.8	7.8
12	8.4	0.5	1.0	9.4
16	11.2	0.7	1.4	12.6
20	14.0	1.0	2.0	15.7
25	17.5	1.2	2.4	19.6
28	19.6	1.4	2.8	22.0
32	22.4	1.6	3.2	25.1
36	25.2	1.8	3.6	28.3
40	28.0	2.0	4.0	31.41
50	35.0	2.5	5.0	39.3

* Values calculated according to sub-clause 6.3.3
** Values calculated according to sub-clause 6.3.4
\+ Twice the minimum value
++ Values calculated according to sub-clause 6.3.5

6.4 Surface finish

6.4.1 The steel bars shall be free from injurious defects.

6.4.2 Rust, seams, surface irregularities, or mill scale shall not be a cause for rejection, provided the mass, dimensions, cross-sectional area, and tensile properties of a hand wire brushed test specimen are not less than the requirements of this specification.

7 Sampling

Sampling shall be in accordance with annex A.

8 Test methods

8.1 The deformation measurements shall be determined in accordance with the procedures given in annex B.

8.2 The steel bar shall be tested for its chemical composition and mechanical properties following the procedures given in annex C.

9 Marking

9.1 The manufacturer's identifying mark, bar size and grade shall be clearly embossed in each bar. The system of marking shall be as given below and as shown in fig. 1.

a) Manufacturer's identifying mark - a logo or symbol registered or to be registered with the Philippine Patent Office and published in the Official Gazette.

b) Bar size - Arabic number reflecting the nominal diameter.

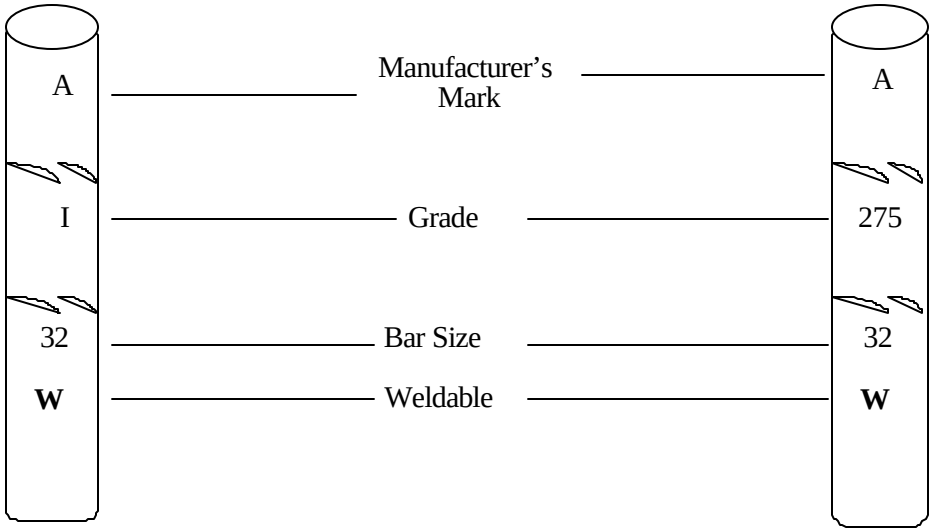

Fig. 1 - Marking for Grade 275, Size 32, Weldable Deformed Bar

c) Grade - Dash (parallel to the rib) or the grade number itself

No dash - grade 230
1 dash - grade 275
2 dashes - grade 415
No W - non-weldable
W - weldable

9.2 Color codes painted on the surface of the ends of each bar may also be used in lieu of sub-clause 9.1c and shall be as follows:

Grade 230 - white
Grade 275 - yellow
Grade 415 - green
Weldable Grade - red (additional color code)
Quenched & tempered - silver

9.3 Other marks will be made on a tag securely attached to each bundle of bars, each bundle composed of bars of the same size and grade.

Annex A

Sampling

A1 For all classes of bars

A1.1 Ladle chemical analysis of each heat of steel shall be made from test samples taken midway during the pouring of the heat and verification analysis may be made also from finished bars representing each heat of steel.

A1.2 Deformation measurements shall be made on representative bars taken at selected points of at least one bar from each size rolled from every lot of 20 tons or fraction thereof.

A2 For non-weldable steel bars

Unit mass, tension and bend tests shall be made on the largest sized rolled from each heat. If, however, material from one heat differs by three or more designation numbers, tests shall be made from both the highest and lowest designation numbers of the steel bars rolled.

A3 For weldable steel bars

Unit mass, tension, bend tests shall be made on each bar size rolled from a heat.

Annex B

Measurement of deformation

B1 Test specimen

The test specimen shall be the full section of the bar as rolled and shall not be less than 0.5 m in length.

B2 Method

B2.1 Average spacing

The average spacing of deformations shall be determined by dividing the length of a test specimen with at least eleven deformations by the number of spaces on any one side of the test specimen. The length of the test specimen shall be considered the distance from a point of any deformation to a corresponding point of another deformation on the same side of the bar at least ten spaces away.

B2.2 Height

The average height of deformations shall be determined from measurement made on not less than two typical deformations. Determinations shall be based on three measurements per deformation, one at the center of the over-all length, and the two at the quarter points of the over-all lengths.

B2.3 Gap

The distance between the extreme ends of the lugs shall be measured and considered as the gap where the extreme ends do not terminate in a rib, or where the deformed bar has no rib. Where the extreme ends terminate in a rib, the width of ribs shall be measured and considered as the gap.

Annex C

Methods for chemical analysis and mechanical tests

C1 Chemical analysis

C1.1 Test specimen

Test specimens shall be taken midway during the pouring of the heat for ladle chemical analysis and from finished bars representing each heat of steel for verification analysis.

C1.2 Procedure

C1.2.1 Chemical analysis of the following elements shall be performed in accordance with the procedures specified herein:

a) Test methods for determination of carbon, sulfur, nitrogen, and oxygen in steel and in iron, nickel, and cobalt alloys - ASTM E 1019
b) Chromium by the atomic absorption method - PNS 882/ASTM E 350
c) Copper by the sulfide precipitation - Electrodeposition gravimetric method - PNS 882/ASTM E 350
d) Manganese by the spectrophotometric method - PNS 557/ISO 629
e) Molybdenum by the photometric method - PNS 882/ASTM E 350
f) Nickel by the Ion exchange-atomic absorption method - PNS 882/ASTM E 350
g) Phosphorus by the alkalimetric method - PNS 882/ASTM E 350
h) Silicon by the gravimetric method - PNS 882/ASTM E 350
i) Sulfur by the combustion-iodate titration method - PNS 882/ASTM E 350
J) Vanadium by reduction with ferrous sulfate and titration with permanganate - PNS 815/ASTM E 30

C1.2.2 Chemical analysis for all the elements involved may be performed by Optical emission vacuum spectrometric method - PNS 823/ASTM E 415.

C2 Mechanical tests

C2.1 Tension

C2.1.1 Test specimen

The test specimen shall be the full section of the bar as rolled and shall not be less than 500 mm in length.

C2.1.2 Procedure

a) For tension test of steel bars, the cross-sectional area used for unit stress determinations shall be obtained from the nominal cross-sectional area given in table 3.

b) The tension test specimen is subjected to uniaxial tensile stresses resulting from load applied to the ends of the test specimen. The load is applied until a specified stress or strain has been reached and continued to rupture the specimen. Three important characteristics of a reinforcing bar are determined from the tension tests: yield strength, tensile strength and percent elongation.

c) The yield strength shall be determined by one of the following methods:

1) Drop of the beam or halt in the gauge of the testing machine.
2) Where the steel tested does not have a well-defined yield point, the yield strength shall be determined by one of the methods indicated in (i) and (ii).

i) Extension under load using dividers with a 200 mm gauge length - The extension under load shall be 1.00 mm, and shall be determined by scribing on the specimen a 200 mm gauge length, pivoted from a prick punch mark. The yield load shall be recorded when the total gauge length under load becomes 201 mm as measured by dividers.

ii) Extension under load using an autographic diagram method or an extensometer - The extension under load shall be determined by an automatic diagram method or an extensometer. However, the extension under load shall be 0.5% of the gauge length.

C2.2 Bend

C2.2.1 Test specimen

The test specimen shall be the full section of the bar as rolled and shall not be less than 500 mm in length for sizes up to 32 mm and not less than 700 mm for sizes 36 mm and above to insure free bending.

C2.2.2 Procedure

a) The test specimen shall withstand being bent at room temperature around a pin without cracking on the outside of the bent portion.

b) The apparatus for the bend test shall provide:

1) Continuous and uniform application of force throughout the duration of the bending operation;

2) Unrestricted movement of the test specimen at points of contact with the apparatus and bending around a pin free to rotate or bending about a central pin on a simple span with end supports free to rotate;

3) Close wrapping of the test specimen around the pin during the bending operation.

C3 Retest

C3.1 If any test specimen fails because of mechanical reasons such as failure of the testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

C3.2 Upon visual inspection, if the test specimen shows any flaws, it may be discarded and another specimen of the same size from the same lot be substituted.

C3.3 If any tensile property of any tension test specimen is less than that specified, and any part of the fracture is outside the middle third of the gauge length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

C3.4 If the results of an original tension test specimen fail to meet the specified minimum requirements and are within 14 MPa of the required tensile strength, within 7 MPa of the required yield strength, or within two percentage units of the required elongation, a retest shall be permitted on two random specimens for the lot. If all results of these retest specimens meet the specified requirements, the lot shall be accepted, if not, it shall be rejected.

C3.5 If a bend test fails, a retest shall be permitted on one random specimen from the heat or lot. If this test specimen meets the specified requirements, the lot shall be accepted, if not, it shall be rejected.

C4 Rejection

C4.1 Unless otherwise specified, any rejection based on test made in accordance with clause 6 shall be reported to the manufacturer within five working days from the receipt of the samples by the purchaser. Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

C4.2 Insufficient height, or insufficient circumferential coverage, or excessive spacing of deformation in three out of five samples of the same size taken from a lot may be made a basis for rejection of a lot.

C5 Rehearing

Samples tested in accordance with clause 6 that represent rejected material shall be preserved for two weeks from the date rejection is reported to the manufacturer. In case of disagreement with the results of the test, the manufacturer may request for a rehearing within two weeks after receipt of notice by the manufacturer of that particular test result.

References

The following standards contain provisions which, through reference in this text form part of this national standard. At the time of publication of this PNS, the editions indicated were valid.

PNS 557:1993/ISO 629-1982, Steel and cast iron - Determination of manganese content - spectrophotometric method

PNS 822:1996/ASTM E350-1995, Standard test methods for chemical analysis of carbon steel, low-alloy steel, silicon electrical steel, ingot iron, and wrought iron

PNS 815:1993/ASTM E 30-1989, Standard test methods for chemical analysis of steel, cast iron, open-heart iron and wrought iron

ANSI/AWS D1.4-1992, Structural welding code - Reinforcing steel

PNS 823:1996/ASTM E 415-1995, Standard test method for optical emission vacuum spectrometric analysis of carbon and low-alloy steel

AS 1554.3-1983, Welding of reinforcing steel

ASTM E 1019-94, Test methods for determination of carbon, sulfur, nitrogen, and oxygen in steel and in iron, nickel, and cobalt alloys

Abbreviations

PNS - Philippine National Standard
ISO - International Organization for Standardization
ANSI - American National Standards Institute
AS - Australian Standard
ASTM - American Society for Testing and Materials
AWS - American Welding Society