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SPECIFICATION FOR

RIBBED STEEL BARS FOR THE REINFORCEMENT OF CONCRETE

(Fourth Revision)

SRI LANKA STANDARDS INSTITUTION

Sri Lanka Standard
SPECIFICATION FOR RIBBED STEEL BARS FOR THE REINFORCEMENT OF CONCRETE
(Fourth Revision)

SLS 375 : 2009

(AMD 422 Attached)

Gr. 12

SRI LANKA STANDARDS INSTITTION
No. 17, Victoria Place
Elvitgiala Mawatha
Colombo 08
SRI LANKA.

Sri Lanka Standards are subject to periodical revision in order to accommodate the progress made by industry. Suggestions for improvement will be recorded and brought to the notice of the Committees to which the revisions are entrusted.

This standard does not purport to include all the necessary provisions of a contract.

Sri Lanka Standard
SPECIFICATION FOR RIBBED STEEL BARS FOR THE REINFORCEMENT OF CONCRETE
(*Fourth Revision*)

FOREWORD

This standard was approved by the Sectoral Committee on Materials, Mechanical Systems and Manufacturing Engineering and authorized for adoption and publication as a Sri Lanka Standard by the council of the Sri Lanka Standards Institution on 2009-09-29.

This is the fourth revision of SLS 375 and in this revision grade of steel 500 MPa characteristic yield strength has been introduced in addition to 460 MPa.

Guidelines for the determination of compliance of a lot with the requirements of this standard based on statistical sampling and inspection are given in Appendix **A.**

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 an analysis shall be rounded off in accordance with **SLS 102**. The number of the significant figures to be retained in the rounded off value shall be the same as that of the specified value in this standard.

The Sri Lanka Standards Institution gratefully acknowledges the use of the following publications of the British Standards Institution and International Organization for Standardization.

BS 4449 : 2005 Steel for the reinforcement of concrete - Weldable reinforcing steel – Bar, coil and decoiled product – Specification

ISO 6935 : 2007 Steel for the reinforcement of concrete – Part 2 Ribbed bars

1 SCOPE

This standard specifies requirements for ribbed weldable reinforcing steel used for the reinforcement of concrete structures. The standard covers steel delivered in the form of bars, coils and decoiled products. This standard contains provisions for steel grades of 460 MPa and 500 MPa characteristic yield strength.

The weldability requirements of steel are specified in terms of the chemical composition, and in particular the carbon equivalent value.

Steel bars produced by re-rolling finished products or by rolling material of which the metallurgical history is not fully documented or not known are not covered by the Sri Lanka Standard.

2. REFERENCES

ISO 3951	Sampling procedures and charts for inspection by variables for percent nonconforming.
ISO 4965	Axial load fatigue testing machines – Dynamic force calibration - Strain gauge technique
ISO 7438	Metallic Materials – Bend test
ISO 7500 -1	Metallic materials – Verification of static uniaxial testing machines – Part 1: Tension/Compression testing machines – Verification and calibration of the force measuring system
ISO 9513	Metallic materials – Calibration of extensometers used in uniaxial testing
ISO 15630-1	Steel for the reinforcement and prestressing of concrete -Test Methods – Part 1 Reinforcing Bars, wire rod and wire
BS 6200	Sampling and analysis of iron, steel and other ferrous metals.
SLS 102	Presentation of numerical values
SLS 428	Random sampling methods
SLS 978	Tensile testing of metallic materials

3 DEFINITIONS

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

3.1 cast analysis : Chemical analysis of a sample of the molten steel during casting.

3.2 product analysis : Chemical analysis of a sample of finished ribbed steel bar.

3.3 characteristic strength : The value of yield strength having a prescribed probability of not being attained in a hypothetical unlimited test series. The characteristic value is the lower limit of the one sided statistical tolerance interval at which there is a 90 per cent probability (i.e $1-\alpha = 0.90$) that 95 per cent ($p = 0.95$) of the values are at or above this lower limit. This definition refers to the long-term quality level of production.

3.4 core : Part of the cross section of the bar containing neither ribs nor indentations.

3.5 nominal cross-sectional area : Cross-sectional area equivalent to the area of a circular plain bar of the nominal diameter.

3.6 relative rib area (f_R) : Area of the projections of all transverse ribs within a defined length on a plane perpendicular to the longitudinal axis of the bar divided by this length and the nominal circumference.

3.7 nominal diameter (nominal size) : The diameter of a circle with an area equal to the effective cross sectional area of the bar.

NOTE : *See Appendix **B** for effective cross sectional area*

3.8 length : A piece of nominally straight bar cut to a specified length.

3.9 longitudinal rib : A uniform continuous rib parallel to the axis of the bar. In the case of cold-twisted bars, before twisting (see Figure **1**).

3.10 transverse rib : Any rib on the surface of the bar other than a longitudinal rib (see Figure **1**).

3.11 pitch (for twisted bars only) : The distance between two consecutive corresponding points of a longitudinal rib on the same generatrix (see Figure **1**).

3.12 rib height (*h*) : The distance from the highest point on the rib (transverse or longitudinal) to the surface of the core, to be measured normal to the axis of the bar (see Figure **1**).

3.13 rib spacing (c) : The distance between the centres of two consecutive transverse ribs measured parallel to the axis of the bar (see Figure **1**).

NOTE : *In the case of twisted bars the measurement shall be prior to twisting.*

3.14 ribless perimeter $\sum fi$: Sum of the distances along the surface of the core between the end of the transverse ribs of adjacent rows measured on the projection on a plane perpendicular to the axis of the bar.

3.15 transverse rib flank inclination (α) : The angle between the transverse rib and the core surface of a bar measured perpendicular to the longitudinal axis of the transverse ribs.

3.16 transverse rib inclination (*β*) : The angle between the transverse rib and the longitudinal axis of the bar (see Figure **1**).

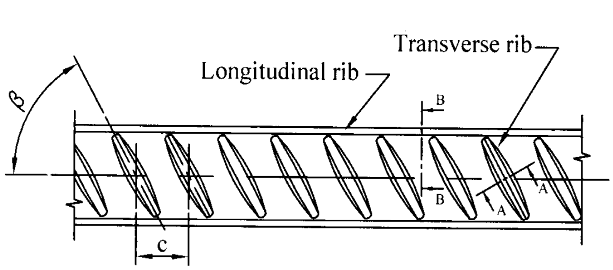
3.17 batch : Any quantity of bars of one size and grade, whether in coils or bundles, produced by one manufacturer or supplier, presented for examination at any one time.

3.18 bundle : Two or more coils or number of straight lengths properly bound together.

3.19 manufacturer : An organization that produces reinforcing steel. This includes steel makers, re-rollers and cold workers.

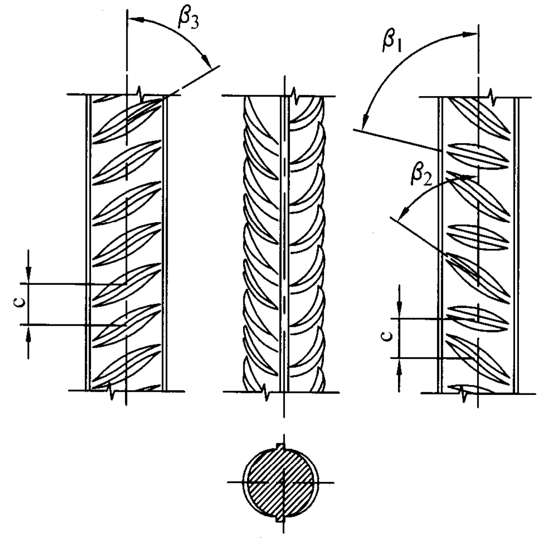
3.20 supplier : Any organization supplying reinforcing steel to an end user.

NOTE : *Reinforcing steel may be supplied in lengths or coils.*

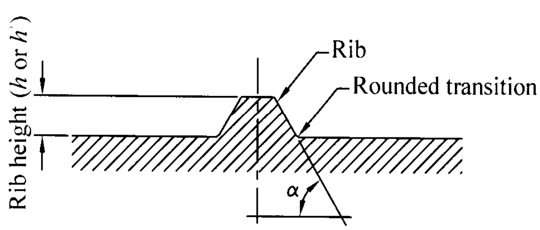


a) - Ribbed bar-definitions of geometry

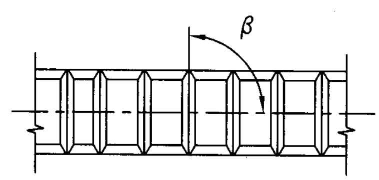
NOTE:
Rib spacing (c) shall be taken as the mean value measured along one pitch



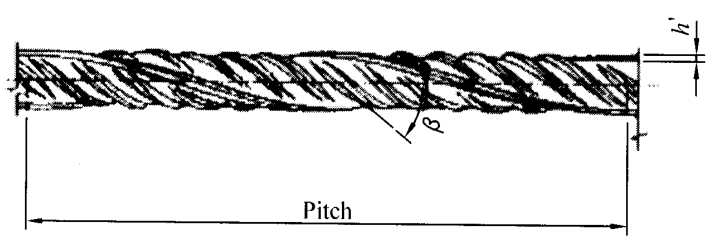
c) - Example of non-twisted bar with varying rib inclinations (β) to the longitudinal axis



b) - Rib flank inclination, (α) , and rib height (h) or (h')
Section A-A and section B-B from a)



d) - Example of non-twisted bar with transverse ribs of uniform height (β=90°)



e) - Twisted bar with oblique ribs

FIGURE 1 - Typical rib patterns and dimensions

4 SYMBOLS

TABLE 1 – Symbols, meanings assigned and relevant units

Symbol	Description	Unit
A_n	Nominal cross-sectional area	mm^2
A_t	Percentage total elongation at fracture	%
A_{gt}	Percentage total elongation at maximum force	%
c	Transverse rib spacing	mm
d	Nominal diameter of the reinforcing steel	mm
e	Gap between rib rows	mm
F_m	Maximum force in the tensile test	N
f_R	Relative rib area	-
h, h'	Rib height	mm
k	Coefficient as a function of the number of test results	-
$\bar{x}$	Mean of the test results	[a]
R_e	Yield strength	MPa[b]
R_{eH}	Upper yield strength	MPa[b]
R_m	Tensile strength	MPa[b]
R_m / R_e	Ratio tensile strength/ yield strength	-
$R_{p0.2}$	0.2 % proof strength, non proportional extension	MPa[b]
s	Standard deviation of the test results	[a]
α	Transverse rib flank inclination	degrees
β	Angle of transverse rib inclination	degrees
$2\sigma_a$	Stress range in the axial load fatigue test	MPa[b]
σ_{max}	Specified maximum stress in the fatigue test	MPa[b]
σ_{min}	Specified minimum stress in the fatigue test	MPa[b]
$R_{e,act}$	Actual value of Yield strength	MPa[b]
$R_{e,nom}$	Specified value of yield strength	MPa[b]
$R_{e,act} / R_{e,nom}$	Ratio actual value of yield strength/ Specified value of yield strength	-
[a] The unit depends on the property [b] 1 MPa = 1 N/mm^2		

5 DESIGNATION AND GRADE

Ribbed steel bars shall be designated as follows:

- nominal bar diameter in millimeters
- letters "RB" which stands for "Ribbed Bars"
- steel grade which indicate the characteristic strength in N/mm^2 (MPa)

Example : 16 RB 460

6 REQUIREMENTS

6.1 Material

6.1.1 *Chemical composition*

6.1.1.1 Cast analysis

The chemical composition of the steel, based on cast analysis, shall be in accordance with Table **2**.

Bars shall have Carbon Equivalent Value, based on cast analysis, not exceeding the value given in Table **2**.

The following formula shall be used to calculate the Carbon Equivalent Value, where the chemical symbols represent the percentages of each element :

$$\text{Carbon Equivalent Value} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

TABLE 2 – Chemical composition (maximum % by mass)

(1)	Carbon[1] (2)	Sulphur (3)	Phosphorus (4)	Nitrogen[2] (5)	Copper (6)	Carbon Equivalent (7)
Cast analysis	0.22	0.05	0.05	0.012	0.80	0.50
Product analysis	0.24	0.055	0.055	0.014	0.85	0.52

NOTES :

1. *It is permitted to exceed the maximum values of carbon by 0.03 per cent by mass, provided that the carbon equivalent value is decreased by 0.02 per cent by mass.*

2. *Higher nitrogen contents are permissible if sufficient quantities of nitrogen binding elements are present.*

6.1.1.2 Product analysis

The chemical composition of the steel, based on product analysis, shall be in accordance with Table **2**.

NOTE : *The product analysis may vary from the cast analysis due to chemical heterogeneity arising during the casting and solidification processes.*

In case of dispute, where product analysis falls outside the maximum limits specified in Table **2**, the procedure defined below shall be applied to determine whether the material conforms to the standard.

If during product analysis, a single sample falls outside the maximum deviation limits for the composition range of specified element, given in Table **2,** further samples shall be selected from the remainder of the batch as follows:

a) At least two samples from the same cast for delivered masses up to 5 t;
b) At least five samples from the same cast for delivered masses up to 20 t;
c) At least eight samples for delivered masses over 20 t.

If any of the further samples analyzed fall outside the maximum product analysis levels given in Table **2**, for any element, the batch shall be deemed not to conform to this standard.

6.2 Dimensions, mass per meter and tolerances

6.2.1 *Nominal cross sectional area and mass per meter*

The range of nominal diameters of bars shall be as given in Table **3**.

The range of nominal diameters of coil and de-coiled product shall be 6 mm to 16 mm.

The values for the nominal cross-sectional areas and mass per metre of nominal diameters shall be as given in Table **3**.

TABLE 3 - Nominal cross-sectional area and mass per metre

Nominal diameter mm (1)	Cross sectional area mm^2 (2)	Mass per metre kg (3)
6*	28.3	0.222
8	50.3	0.395
10	78.5	0.616
12	113	0.888
16	201	1.58
20	314	2.47
25	491	3.85
32	804	6.31
40	1257	9.86
50*	1963	15.4
* - non-preferred sizes		

NOTE : *Under special circumstances, by agreement between manufacturer and end user, ribbed bars whose nominal diameters are other than those shown in Table **3** may be used.*

6.2.2 *Tolerances*

The permissible deviation from nominal mass per metre shall be not more than ± 4.5 per cent on nominal diameters greater than 8 mm, and ± 6.0 per cent on nominal diameters less than or equal to 8 mm.

6.2.3 *Coil mass*

The nominal coil mass shall be agreed at the time of enquiry and order.

6.2.4 *Cross sectional area and mass*

The cross sectional area and mass of the bars shall be calculated on the basis that steels have a mass of 0.00785 kg per square millimeter per metre run. The mass of individual bars shall be given in Table **3**., subject to the tolerances given in **6.2.2**.

For bars where the effective cross sectional area is determined as in Appendix **B**, the nominal mass per metre run shall be the gross mass per metre run.

All cross sectional areas and mass derived from the values in Table **3** shall be expressed to three significant figures.

6.3 Length

Delivery lengths of straight bars shall be 6 m or 12 m, each bar shall be cut to $_{-0}^{+50}$ mm of the lengths specified.

NOTE : *Any other delivery length shall be agreed between the manufacturer and the end user.*

Where a minimum length is requested it shall be subjected to a tolerance of $_{0}^{+50}$ *mm.*

Where a maximum length is requested it shall be subjected to a tolerance of $_{-50}^{0}$ *mm.*

6.4 Surface geometry

6.4.1 *General*

Ribbed steels are characterized by the dimensions, number and configuration of transverse and longitudinal ribs. Bars, coils and decoiled products shall have two or more rows of transverse ribs uniformly distributed around the perimeter. Within each row the ribs shall be uniformly spaced.

An example of a ribbed steel is given in Figure **1**.

The values for the rib spacing, height and rib inclination of transverse ribs shall be within the ranges given in Table **4**.

TABLE 4 – Requirements for rib geometry

Geometrical Feature (1)	Nominal diameter d mm (2)	Non – twisted bar		Twisted bar Crescent-shaped Ribs (5)
		Ribs of uniform height (3)	Crescent-shaped ribs (4)	
Height of transverse ribs, (h) Minimum	$6 \leq d < 16$ $d \geq 16$	0.05d 0.05d	0.065d 0.065d	0.042d 0.052d
Height of longitudinal ribs, (h') Minimum	All	--	--	0.07d
Rib spacing, (c) Range	$6 \leq d < 10$ $d \geq 10$	$0.5d \leq c \leq 0.7d$ $0.5d \leq c \leq 0.7d$	$0.5d \leq c \leq 1.0d$ $0.5d \leq c \leq 0.8d$	$0.5d \leq c \leq 1.2d$ $0.5d \leq c \leq 1.2d$
Transverse rib inclination, (β)	All	$35^{o} \leq \beta \leq 90^{o}$	$35^{o} \leq \beta \leq 75^{o}$	$35^{o} \leq \beta \leq 75^{o}$
Nominal pitch, (p)	All	--	--	10d ± 2d
Ribless perimeter, ($\sum fi$) Maximum	All		0.25dπ	0.35dπ

NOTE : *The values specified in this table when applied for testing purposes should be taken, rounded off to first decimal place.*

6.4.2 *Transverse ribs*

Transverse ribs shall approximate to a crescent shape, and merge smoothly into the core of the product.

The transverse rib flank inclination(α) shall be greater than or equal to 45 ^{o}, and the transition from the rib to the core shall be reduced.

6.4.3 *Characteristic relative rib area*

The characteristic relative rib area shall meet the requirements of Table **5**.

TABLE 5 – Characteristic relative rib area

Nominal bar size, d mm (1)	Relative rib area (2)
$d \leq 6$	0.035
$6 < d \leq 12$	0.040
$d > 12$	0.056

NOTE : *Calculation of relative rib area is in accordance with **ISO 15630-1: 2002***

6.4.4 *Longitudinal ribs*

Where longitudinal ribs are present, their height shall not exceed 0.10 d, where d is the nominal diameter of the product.

6.5 Mechanical properties

6.5.1 *General*

The characteristics value is (unless otherwise indicated) the lower or upper limit of the statistical tolerance interval at which there is a 90 per cent probability ($1-\alpha = 0.90$) that 95 per cent ($p=0.95$) or 90 per cent ($p=0.90$) of the values are at or above the lower limit or at or below the upper limit respectively. This quality level refers to the long-term quality level of production.

NOTE : *Bars, coils and de-coiled products should be free from features such as seams, porosity, segregation and non-metallic inclusions, etc., where they would cause the product to fail to meet the specified mechanical properties.*

6.5.2 *Conditions of testing*

The conditions of testing shall conform to Table **6.**

TABLE 6 – Conditions of testing the mechanical properties

Manufacturing and delivery condition (1)	Condition of testing (2)
Produced in straight lengths by hot rolling	As delivered [a] or aged[b]
Produced in straight lengths by cold working	As delivered [a] or aged[b]
Produced as coil and delivered decoiled	Aged[b]
Produced and delivered as coil	Aged[b]

[a] Aged in the case of dispute

[b] Ageing method : heat the test piece to 100 °C, maintain at this temperature (±10 °C) for a period of 60^{+15}_{-0} min., and then cool in still air to room temperature. The method of heating is left to the discretion of the manufacturer.

6.5.3 *Tensile properties*

The specified characteristic values for the tensile properties are given in Table **7**.

TABLE 7 – Characteristic tensile properties

Grade (1)	Yield strength, R_e (min.) MPa (2)	Tensile/yield strength ratio, R_m/R_e(min.) (3)	Total elongation at maximum force, A_{gt} (min.) % (4)	Total elongation at fracture, A_t (min.) % (5)
RB 460	460	1.05[a]	2.5[b]	14
RB 500	500	1.05[a]	2.5[b]	14
[a] R_m/R_e characteristic is 1.02 for sizes below 8 mm [b] A_{gt} characteristic is 1.0 % for sizes below 8 mm Values of R_e specified are characteristic with p = 0.95 Values of R_m/R_e, A_{gt} and A_t specified are characteristic with p =0.90				
Calculate the value of R_m and R_e using the effective cross sectional area of the bar determined as described in Appendix **B**.				

The absolute maximum permissible value of yield strength is 650 MPa for RB 500. For yield strength (R_e), the upper yield strength (R_{eH}) shall apply. Determine the yield strength (R_e) from the 0.2 per cent proof strength ($R_{pO.2}$) if a yield phenomenon is not present.

Tensile test shall be carried out in accordance with Appendix **C**.

6.5.4 *Fatigue strength (Optional test)*

6.5.4.1 General

Reinforcing bars, coiled and decoiled, products shall be subjected to fatigue testing. When subjected to axial force controlled fatigue testing , using a stress ratio ($\sigma_{min.}/\sigma_{max.}$) of 0.2, and stress range given in Table **8**, test samples shall survive five million stress cycles.

TABLE 8 – Fatigue test conditions

Bar size mm (1)	Stress range MPa (2)
≤16	200
>16, ≤20	185
>20, ≤25	170
>25, ≤32	160
>32	150

6.5.4.2 Bars and coils

Reinforcing bars form each production site shall be subjected to fatigue testing, to determine the fatigue characteristics of a particular geometrical shape and process route. The fatigue properties for the each steel grade and process route shall be established at an applicable testing laboratory, initially by testing samples selected from the upper, middle and bottom of the product, diameter range. At least once a year, samples shall be tested from different bars or coils of one diameter from each process route. Test samples shall be selected so that all diameters for each process route shall be tested over a five-year period.

6.5.4.3 Decoiled product

Decoiled products, from each production site, shall be subjected to fatigue testing. Initially, samples shall be taken from each production site from one decoiling machine type from the largest diameter produced. At a frequency of at least once per year, samples of one diameter shall be selected for test from each production site, from one decoiling machine. Sampling shall be carried out in each such a way that the combination of material manufacturing route, type of decoiler and individual machines are covered over a five-year period.

Fatigue test shall be carried out in accordance with Appendix **C**.

6.5.4.4 Sampling

Sampling shall be carried out as given in Appendix **A**.

6.5.4.5 Retests

The products shall be deemed to conform to this standard if all five test pieces endure five million stress cycles.

If one of the five test pieces produces a valid failure, a further five samples from the test unit shall be tested. If one of these further samples fails the test, then the material shall be deemed not to conform to this standard, and an investigation shall be carried out and appropriate actions shall be taken. If all five further test pieces endure five million stress cycles then the material shall be deemed to comply with this standard.

In the case of any failure, the test shall be considered invalid if it is initiated from a defect unique to the test piece or in the area within 2d of the testing machine grips (where d is the nominal bar diameter) in this case a further single test shall be carried out (see **ISO 15630-1 : 2002**).

6.5.5 *Bending properties*

6.5.5.1 Bend test

The bend test shall be carried out in accordance with Appendix **C**. The test specimen shall show no sign of fracture or cracks on visual examination.

6.5.5.2 Rebend test (Optional test)

The rebend test shall be carried out in accordance with Appendix **C** if required by the purchaser. The test specimens shall show no sign of fracture or irregular bending deformations.

7 MARKING

7.1 The bars shall be securely bundled and a durable tag stamped with the following details attached to the bundle:

a) Manufacturer's name and/or trade mark;
b) Batch number;
c) Nominal diameter and length; and
d) Weight of bundle.

7.2 Individual bars shall be indelibly marked preferably by embossing, with the nominal diameter, strength grade and manufacturer's name and/or trade mark.

APPENDIX A

SAMPLING AND CRITERIA FOR CONFORMITY

A.1 LOT INSPECTION

The sampling scheme given in this appendix shall be applied where compliance for a lot to the requirements of this standard is to be assessed based on statistical sampling and inspection.

A.1.1 *Lot*

Any quantity of ribbed steel bars of same designation, length and belonging to one batch of manufacturer shall constitute a lot.

A.2 SCALE OF SAMPLING

A.2.1 The number of bars to be selected from a lot for testing for dimensions, mass, length, rib geometry and mechanical properties shall be in accordance with Table **9** . Only one bar shall be selected per bundle.

If the number of bundles is less than the number of bars to be selected, approximately equal number of bars shall be selected from each bundle.

TABLE 9 – Scale of sampling

Number of bars in the lot (1)	Number of bars to be selected (2)	Value of k (3)
Up to 500	5	1.53
501 – 1200	7	1.62
1201 – 3200	10	1.72
3201 and above	15	1.78

A.2.2 The bars to be tested shall be selected at random. To ensure randomness, the bars shall be drawn from bundles in accordance with **SLS 428**.

A.3 NUMBER OF TESTS

A.3.1 Each bundle of a lot shall be inspected for marking requirements (**7.1**)

A.3.2 Each bar selected in accordance with Table **8** shall be inspected for mass (**6.2.4**), length (**6.3**) surface geometry (**6.4**) and marking (**7.2**).

A.3.3 Each bar selected in accordance with Table **8** shall be tested for mechanical properties specified in **6.5.3** , **6.5.4**(optional) and **6.5.5**.

A.4 CRITERIA FOR CONFORMITY

A lot shall be declared as conforming to the requirements of this standard, if the following conditions are satisfied.

A.4.1 Each bundle inspected as in **A.3.1** satisfy the marking requirements.

A.4.2 Each bar inspected as in **A.3.2** satisfy the specified requirements for mass, length , surface geometry and marking.

A. 4.3 *Mechanical Properties*

A.4.3.1 Tensile Properties

Each bar tested shall satisfy the stress ratio requirements in Table **7.**

In respect of other tensile properties in Table **7** the value of the expressions ($\bar{x}$ - ks) calculated using test results of yield strength and elongation are not less than the specified property requirements in Table **7**.

$\bar{x}$ – Mean of the test results

The value for 'k' shall be taken from column 3 of Table **9**.

s – standard deviation of the test results

A.4.3.2 Bending properties

In respect of bending properties, each bar tested shall satisfy the requirements in **6.5.5**.

A.4.3.3 Fatigue properties

In respect of fatigue properties, each bar tested shall satisfy the requirements in **6.5.4**.

NOTE : *In process inspections*

Where compliance with this standard is to be assured at the manufacturing stage based on manufacturer's control systems and testing procedures, appropriate schemes of sampling and inspections should be adopted.

APPENDIX B

DETERMINATION OF THE EFFECTIVE CROSS SECTIONAL AREA OF RIBBED STEEL BARS

B.1 UNIFORM CROSS SECTIONAL AREA

For bars where the configuration is such that, by visual inspection, the cross sectional area is substantially uniform along the length of the bar, the effective cross sectional area *A* shall be the area in millimeter squared determined by weighing and measuring, to a precision of ± 0.5 per cent, a length of not less than 0.5 m, and calculating as follows :

$$A = \frac{M}{0.00785\,L}$$

where

M is the mass of the bar (kg);
L is the length of the bar (m)

B.2 VARIABLE CROSS SECTIONAL AREA

B.2.1 For a bar of which the cross sectional area varies along its length, a sample of not less than 0.5 m shall be weighed and measured, to precision of ± 0.5 percent, first in the as manufactured condition, and then again after removing the transverse ribs.

B.2.2 Where the difference between the mass of the as manufactured bar (*M*) and the mass of the bar with the ribs removed (*M'*) is less than 3 per cent of M' the effective cross sectional area shall be determined as in **B.1**.

B.2.3 Where the difference between the two masses (*M-M'*) is 3 percent of M' or above, the effective cross sectional area A, in millimeter squared shall be calculated as follows :

$$A = \frac{1.03\,M'}{0.00785\,L}$$

where

M' is the mass of the bar with the transverse ribs removed (kg);
L is the length of the bar (m)

APPENDIX C

GENERAL PROVISIONS CONCERNING TEST PIECES

Unless otherwise agreed, the test piece shall be taken from the bar, in the as-delivered condition.

In the case of a test piece taken from coil the test pieces shall be straightened prior to any tests by a simple bend operation with a minimum amount of plastic deformation.

For the determination of the mechanical properties in the tensile test and the fatigue test, the test piece may be artificially aged (after straightening if applicable) depending on the requirements of **6.5.2**.

NOTE : *For ageing treatment, the following conditions may be applied - Heat the test piece to 100 ^{o}C, maintaining at this temperature ± 10 ^{o}C, for a period of 60 $^{+15}_{-0}$ min. and then free cooling in still air to ambient temperature.*

When an ageing treatment is applied to the test piece, the conditions of the ageing treatment shall be stated in the test report.

C.1 TENSILE TEST

C.1.1 *Test piece*

In addition to the general provisions given above, the free length of the test piece shall be sufficient for the determination for the percentage elongations in accordance with **C.1.3**.

When percentage elongation after fracture (A_t) is determined, the test piece shall be marked according to clause **8** of **SLS 978 : 2004**.

When percentage total elongation at maximum force (A_{gt}) is determined by the manual method, equidistant marks shall be made on the free length of the test piece (see Appendix **H** of **SLS 978 : 2004**). The distance between the marks shall be 20 mm, 10 mm or 5 mm, depending on bar diameter.

C.1.2 *Test equipment*

The testing machine shall be verified and calibrated in accordance with **ISO 7500-1** and shall be at least of class 1.

When an extensometer is used, it shall be of class 1 (see **ISO 9513**) for the determination of R_{eH} or $R_{pO.2}$; for the determination of A_{gt}, a class 2 extensometer (see **ISO 9513**) can be used.

The extensometer which may be used to determine the percentage total elongation at maximum force (A_{gt}) shall have a gauge length of at least 100 mm. The gauge length shall be indicated in the test report.

C.1.3 *Test procedure*

The tensile test shall be carried out in accordance with **SLS 978** . For the determination of $R_{pO.2,}$ if the straight portion of the force-extension diagram is limited or not clearly defined, one of the following methods shall be applied.

- the procedure recommended in **13.1** of **SLS 978 : 2004**.
- The straight portion of the force-extension diagram shall be considered as the line joining the points corresponding to 0.1 F_m and 0.3 F_m.

In case of dispute the second procedure shall be applied.

NOTE : *The test should be considered invalid when the slope of this line differs by more than 10 percent from the theoretical value of the modulus of elasticity.*

For the calculation of tensile properties (R_{eH} or $R_{p0.2,}R_m$), the effective cross-sectional area of the bar determined as described in Appendix **B** shall be used.

Where fracture occurs in the grips or at a distance from the grips less than 20 mm or d (whichever is the greater), the test may be considered as invalid.

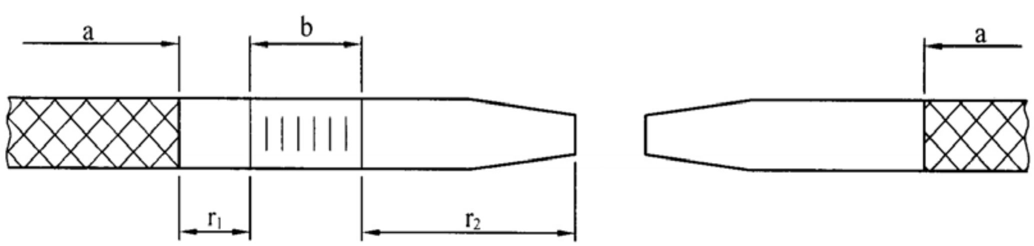
For the determination of the percentage total elongation at maximum force (A_{gt}), **SLS 978 : 2004** shall be applied with the following modifications or complements:

- If A_{gt} is measured by using an extensometer, A_{gt} shall be recorded before the force has dropped more than 0.5 per cent from its maximum value;
- If A_{gt} is determined by the manual method after fracture, A_{gt} shall be calculated from the following formula:

$$A_{gt} = A_g + R_m / 2000$$

Where A_g is the percentage non-proportional elongation at maximum force. The measurement of A_g made on a gauge length of 100 mm a distance, r_2, of at least 50 mm or 2d (whichever is the greater) away from the fracture. This measurement may be considered as invalid if the distance, r_1, between the grips and the gauge length is less than 20 mm or d (whichever is the grater) See Figure **2**.

- in case of dispute, the manual method shall apply.



a Grip length
b Gauge length 100mm

FIGURE 2 - Measurement of A_{gt} by the manual method

C.2 BEND TEST

C.2.1 *Test piece*

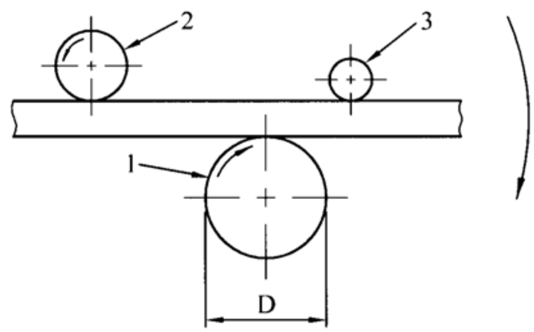
The general provisions given shall be applied.

C.2.2 *Test equipment*

C.2.2.1 A bending device, the principle of which is shown in Figure **3**, shall be used.

NOTE : *Figure **3** shows a configuration where the mandrel and support rotate and the carrier is locked. It is possible that the carrier rotates and the support or mandrel is locked.*

C.2.2.2 The bend test may also be carried out by using a device with supports and a mandrel (see **4.1** of **ISO 7438 : 1985**).



Key
1 Mandrel
2 Support
3 Carrier

FIGURE 3 - Principle of a bending device

C.2.3 *Test procedure*

The bend test shall be carried out at a temperature between 10 ^{o}C and 35 ^{o}C . The test piece shall be bent over a mandrel.

NOTE : *The maximum bending rate shall be 3 radians per minute.*

The angle of bend (γ) shall be 180 ^{o} and the diameter of the mandrel (*D*) shall be 3d.

C.2.4 *Interpretation of test results*

The interpretation of the bend test shall be carried out according to the requirements of **6.5.5**.

C.3 REBEND TEST

C.3.1 *Test piece*

The general provisions given shall be applied.

C.3.2 *Test equipment*

C.3.2.1 Bending device

A bending device as specified in **C.2.2** shall be used.

C.3.2.2 Rebending device

Rebending can be performed on a bending device as shown in Figure **4**. An example of an alternative rebending device is shown in Figure **5**.

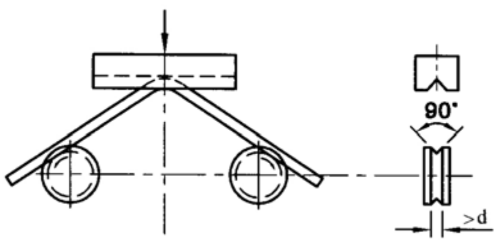


FIGURE 4 - Example of a rebending device

C.3.3 *Test procedure*

C.3.3.1 General

The test procedure consists of three steps

a) bending;
b) artificial ageing
c) rebending

The test procedure is illustrated by Figure **5.**

Key
1 Mandrel
2 Test piece
a Initial position
b Position after operation described in C.3.3.2
c Position after operation described in C.3.3.4

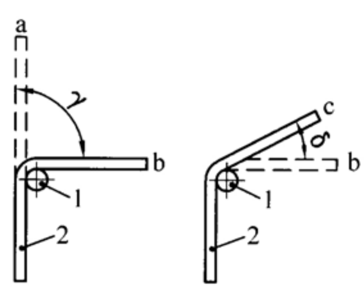


FIGURE 5 - Illustration of the test procedure for rebend tests

C.3.3.2 Bending

Bending shall be performed at a temperature between 10 ^{o}C and 35 ^{o}C. The test piece shall be bent over a mandrel.

NOTE : *The maximum bending rate shall be 3 radians per minute.*

The angle of bend (γ) shall be 90 ^{o} and diameter of mandrel (*D*) shall be in accordance with Table **10**.

The test piece shall be carefully inspected for cracks and fissures visible to a person with a normal or corrected vision.

C.3.3.3 Artificial ageing.

For ageing treatment, the following conditions may be applied: Heat the test piece to 100 ^{o}C, maintaining at this temperature ± 10 ^{o}C, for a period of $60\,^{+15}_{\;0}$ min. and then free cooling in still air to the ambient temperature..

C.3.3.4 Rebending

After free cooling in still air to a temperature between 10 ^{o}C and 35 ^{o}C, the test piece shall be bent back by a specified angle(δ).

NOTE: *The rebending should be performed at a rate of about 3 rad/min.*

Bend the test pieces through an angle of 90 ^{o}, around a mandrel with a diameter not exceeding those specified in Table **10**, age the test piece and then bend back by at lest 20^{o}.

Table 10 – Mandrel diameters for rebend test

Nominal diameter d mm (1)	**Maximum mandrel diameter D (2)**
≤16	4d
>16	7d

C.3.4 ***Interpretation of test results***

The interpretation of the rebend test shall be carried out according to the requirements of **6.5.5**.

C.4 AXIAL LOAD FATIGUE TEST

C.4.1 *Principle of test*

The axial load fatigue test consists of submitting the test piece to an axial tensile force, which varies cyclically according to a sinusoidal wave-form of constant frequency (see Figure **6**) in the elastic range The test is carried out until failure of the test piece, or until reaching the number of load cycles specified in **6.5.4.1**, without failure.

C.4.2 *Test piece*

The general provisions given shall be applied.

NOTE : *The straightness of the test piece is critical for the fatigue test. To achieve satisfactory straightness, a product straightening machine may be used.*

The means of straightening the test piece (manual, laboratory machine, product machine) shall be indicated in the test report.

The surface of the free length between the grips shall not be subjected to any surface treatment of any kind and shall not contain identification marks. The free length shall be at least 140 mm or 14 *d*, whichever is the greater.

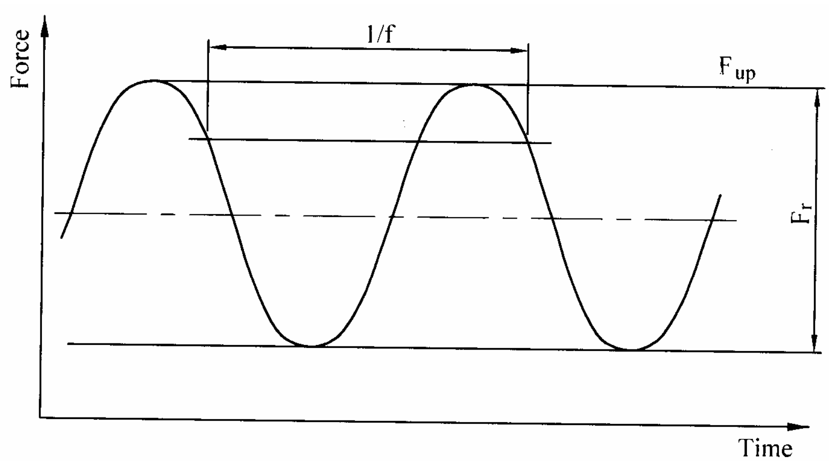


FIGURE 6 - Load cycle diagram

C.4.3 *Test equipment*

The fatigue testing machine shall be calibrated in accordance with **ISO 4965**. The accuracy shall be at least ± 1 percent. The testing machine shall be capable of maintaining the upper force, F_{up}, within ±2 percent of the specified value and the force range, F_r within ± 4 per cent of the specified value.

C.4.4 *Test procedure*

C.4.4.1 Provisions concerning the test piece

The test piece shall be gripped in the test equipment in such away that force is transmitted axially and free of any bending moment along the test piece.

C.4.4.2 Upper force (F_{up}) and force range (F_r)

F_{up} and F_r can be deduced from the maximum stress $(\sigma_{\max})$ and the stress range $(2\sigma_a)$ given in **6.5.4.1** as follows:

$F_{up} = \sigma_{\max} \times A_n$

$F_r = 2\sigma_a \times A_n$

where A_n is the nominal cross-sectional area of the bar.

C.4.4.3 Stability of force and frequency

The test shall be carried out under conditions of stable upper force (F_{up}), force range (F_r) and frequency (f). There shall be no interruptions in the cyclic loading throughout the test. However, it is permissible to continue a test which is accidentally interrupted. Any interruption shall be reported.

C.4.4.4 Counting of load cycles

The number of load cycles shall be counted inclusively from the first full load range cycle.

C.4.4.5 Frequency

The frequency of load cycles shall be stable during the test and also during test series. It shall be between 1 Hz and 200 Hz.

C.4.4.6 Temperature

The temperature of the test piece shall not exceed 40 °C throughout the test. The temperature of the testing laboratory shall be between 10 °C and 35 °C, unless otherwise specified. For tests carried out under controlled conditions the temperature of the testing laboratory shall be (23 ± 5) °C.

C.4.4.7 Termination of the test

The test shall be terminated upon failure of the test piece before reaching the specified number of cycles, or on completion of the specified number of cycles without failure.

C.4.4.8 Validity of the test

If failure occurs in the grips or within a distance of 2*d* of the grips or initiates at an exceptional feature of the test piece, the test may be considered as invalid.

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Amendment No. 01 Approved on 2011-10-27 to SLS 375:2009

SRI LANKA STANDARD SPECIFICATION FOR RIBBED STEEL BARS FOR THE REINFORCEMENT OF CONCRETE (*Fourth Revision*)

Wherever the symbol "A_t" appears in the text of the standard, it shall be read as symbol "A".

Clause 4 Symbols, Table 1

Third row shall be replaced by the following.

A	Percentage elongation after fracture	%

Clause 6.5.3 Table 7, Column (5)

Title shall be changed as "**Elongation after fracture *A* (min.)%**" .

Clause 6.5.3 Table 7

Add the following as the last row.

"By agreement between the manufacturer and purchaser, the type of elongation shall be selected between A and A_{gt}. If the type of elongation is not specified by agreement, A_{gt} shall be used"

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