

# **Steel Reinforcing Bars for the Reinforcement of Concrete**

**香港特別行政區政府**

The Government of the Hong Kong Special Administrative Region

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## **FOREWORD**

### **Introduction**

This Construction Standard has been prepared by the Working Group on Review of CS2 under the Standing Committee on Concrete Technology (SCCT), Development Bureau, the Government of the Hong Kong Special Administrative Region. This Construction Standard supersedes CS2:1995.

During the course of the review and preparation of this Construction Standard, consultations with SCCT Consultative Committee and key stakeholders of the industry, including the Association of Construction Materials Laboratories, Hong Kong Construction Association Limited, Hong Kong Institution of Engineers, MTR Corporation Limited, steel reinforcing bar stockists and manufacturers, have been made.

### **This Construction Standard**

Review of the CS2 comprises two stages. Stage 1 of the review is to update the technical specification and quality assurance system for steel reinforcing bars to align with the quality and performance levels as stipulated in the latest international standards, with due consideration of the conditions and practices of the local industry. Stage 2 of the review will include the requirements for product certified steel reinforcing bars.

This Construction Standard relates to Stage 1 of the review with regard to non-product certified steel reinforcing bars.

CS2:1995 was prepared by making reference to BS 4449:1988, which has been superseded by subsequent versions in 1997 and 2005. This Construction Standard makes reference to the latest version of BS 4449, viz. BS 4449:2005+A2:2009 for ribbed steel reinforcing bars, and BS 4482:2005 for plain steel reinforcing bars up to 12 mm diameter. It does not cover steels delivered in the form of coils and decoiled products, and plain steel reinforcing bars of grade 250 with diameter larger than 12 mm, for which other standards should be referred to.

This Construction Standard provides full material specifications for grade 250 (for steel reinforcing bars up to 12 mm diameter), grade 500B and grade 500C steel reinforcing bars, including requirements on mass per metre, chemical composition, mechanical properties and bond property. The local requirements for certification of Quality Assured (QA) Stockists and the purchasers testing have been updated in Sections 4 and 5 of this Construction Standard.

Requirements for product certified steel reinforcing bars will be included in Stage 2 of the review. Product certification schemes for both the manufacturing and stockholding processes of steel reinforcing bars to suit the local Hong Kong conditions will be prepared.

### **Quality Assurance**

Under a system of quality assurance, the responsibilities for testing of the steel reinforcing bars and ensuring its compliance with this Construction Standard lie with the manufacturer. A third party certification of the manufacturer's quality management system by an accredited certification body to the requirements of ISO 9001 is required to ensure that the manufacturer's system of quality assurance is being implemented successfully.

The current three-tier system of quality assurance comprising QA Manufacturers, QA Stockists and purchaser's tests, is maintained. In consideration of the current situation that all QA Manufacturers and most stockists are quality assured, Class 3 steel reinforcing bars in CS2:1995 are deleted. Such deletion

will raise the quality standard of all steel reinforcing bars used in Hong Kong by ensuring that the supplies are provided by QA Manufacturers and QA Stockists. Besides, the meaning of “traceability” for Class 1 steel reinforcing bars is also defined in this Construction Standard.

### **QA Stockists**

The requirement for QA Stockists to be certified to the BSI QA System for Registered Stockists is no longer applicable as the BSI System has been withdrawn. QA Stockists are now required to be certified to the requirements of ISO 9001 by a certification body accredited by Hong Kong Accreditation Service with a scope related to good practices on storage, handling and supply of steel reinforcing bars in accordance with the specific requirements stipulated in this Construction Standard.

In addition, QA Stockists are also required to implement specific control on non-conforming products as stated in Cl. 4.2 of this Construction Standard.

### **Purchasers Testing**

In this Construction Standard, bend test is no longer required. Determination of mass per metre is explicitly required as one of the purchaser’s tests since control on mass within permissible deviations is crucial. Any reduction in mass will mean a lowering in capacity of the steel reinforcing bar.

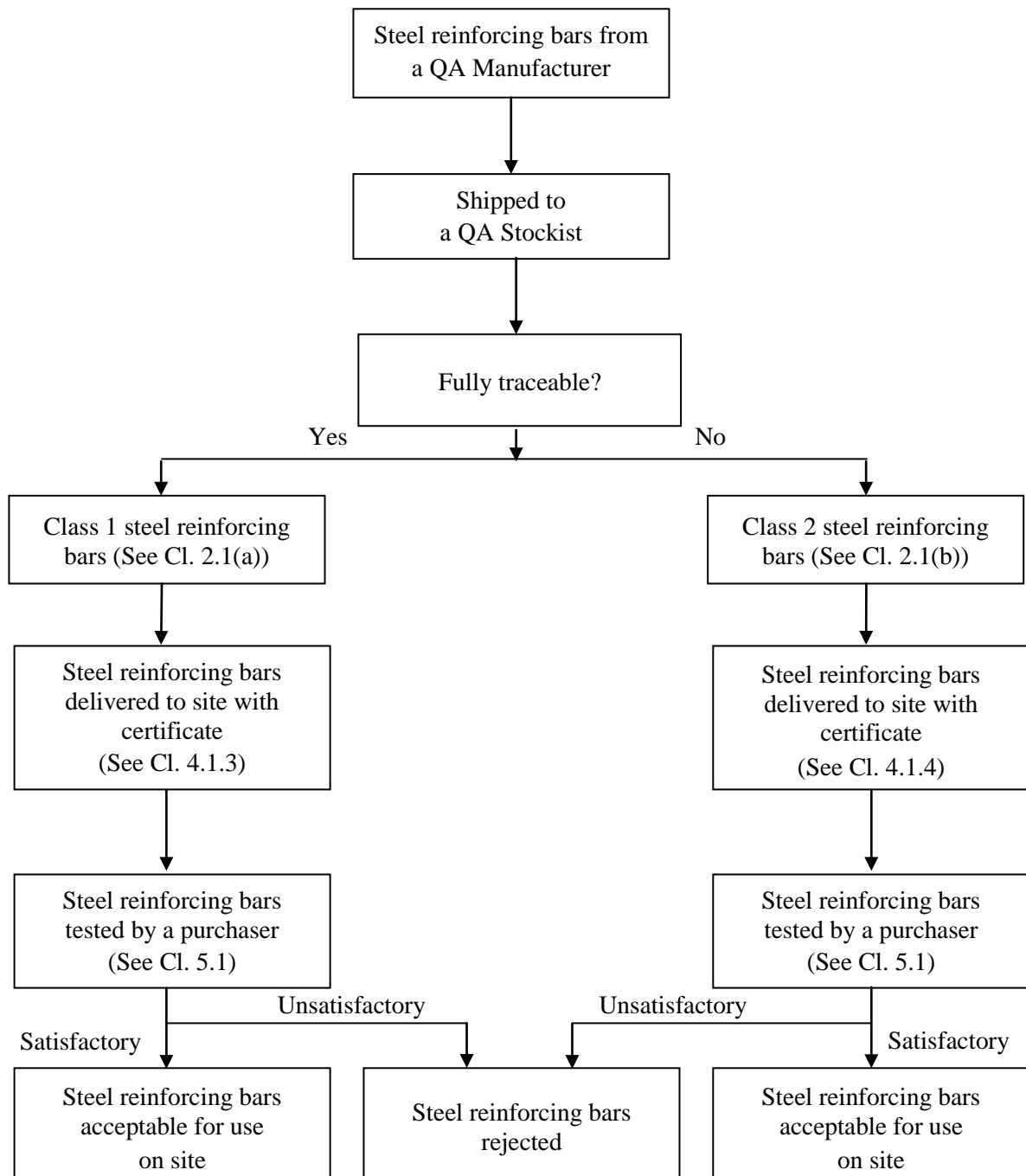
For Class 1 and Class 2 steel reinforcing bars, purchasers testing includes determination of mass per metre, tensile test and rebend test. In addition, chemical analysis and determination of bond property are also required to be carried out by the purchasers.

The meanings of “batch” of steel reinforcing bars for manufacturers testing and for purchasers testing are also defined in order to ensure that sampling of test specimens is conducted in a consistent manner.

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## FLOW CHART FOR INSPECTION, TESTING AND CERTIFICATION OF STEEL REINFORCING BARS



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# SECTION 1

## SPECIFICATION

### 1.1 SCOPE

This Construction Standard (Standard) specifies requirements for weldable steel reinforcing bars used for the reinforcement of concrete structures. This Standard covers steel delivered in the form of bars and contains provisions for plain steel reinforcing bars in grade 250 up to 12 mm in diameter and ribbed steel reinforcing bars in grades 500B and 500C.

The durability and weldability requirements for all grades of steel reinforcing bars are specified in terms of the chemical composition, and in particular the carbon equivalent value.

**NOTE 1:** *All steel reinforcing bars complying with this Standard are of weldable quality. Welding procedures and consumables appropriate to the particular grade and quality should be used.*

**NOTE 2:** *This Standard does not cover cold worked steel reinforcing bars.*

### 1.2 TERMS AND DEFINITIONS

For the purposes of this Standard, the following definitions apply:

#### 1.2.1 Batch

For manufacturers testing, a batch is the quantity of steel reinforcing bars of one nominal diameter and one heat/cast produced by one manufacturer and presented for examination at any one time.

For purchasers testing, a batch is the quantity of steel reinforcing bars delivered to site within a week under one delivery order, of one nominal diameter, and one steel grade and produced by the same manufacturer. A batch shall not exceed 200 tonnes for steel reinforcing bars of diameter 20 mm and above and shall not exceed 100 tonnes for steel reinforcing bars of diameter less than 20 mm.

#### 1.2.2 Characteristic value

A value of a material or product property having a prescribed probability of not being attained in a hypothetical unlimited test series.

**NOTE:** *This value generally corresponds to a specific fractile of the assumed statistical distribution of the particular property of the material or product.*

#### 1.2.3 Heat/cast number

An identifying number assigned to the product of one melting in a steel production furnace.

#### 1.2.4 Length

A length of nominally straight bar cut to a specified length.

**1.2.5 Longitudinal rib**

A uniform and continuous protrusion parallel to the axis of the steel reinforcing bar.

**1.2.6 Manufacturer**

A manufacturer is an organisation that produces steel reinforcing bars including steelmakers and re-rollers from billets. All manufacturers shall be Quality Assured (QA) Manufacturers.

A QA Manufacturer is a manufacturer with a third party certification by a certification body. The certification body shall be accredited by Hong Kong Accreditation Service (HKAS) or its 'Multilateral Recognition Agreements/Arrangements' (MLA) partner(s) to the requirements of ISO 9001 for its quality management system with a scope related to good practices of steel reinforcing bar production to meet requirements of this Standard.

**1.2.7 Maximum value**

The value which no test result shall exceed.

**1.2.8 Minimum value**

The value below which no test result shall fall.

**1.2.9 Nominal cross-sectional area,  $A_n$** 

A cross-sectional area equivalent to the area of a circular plain bar of the same nominal diameter,  $d$  (i.e.  $\frac{\pi d^2}{4}$ ).

**1.2.10 Plain steel reinforcing bar**

A steel reinforcing bar with a smooth surface.

**1.2.11 Purchaser**

A party who incorporates steel reinforcing bars into works.

**1.2.12 Relative rib area,  $f_R$** 

An area of the projection of all ribs on a plane perpendicular to the longitudinal axis of the steel reinforcing bar divided by the rib spacing and the nominal circumference.

**1.2.13 Rib height,  $h$** 

A distance from the highest point of the rib (transverse or longitudinal) to the surface of the core, to be measured normal to the axis of the steel reinforcing bar.

**1.2.14 Rib spacing,  $c$** 

A distance between the centres of two consecutive transverse ribs measured parallel to the axis of the steel reinforcing bar.

**1.2.15 Ribbed steel reinforcing bar**

A steel reinforcing bar with at least two rows of transverse ribs, which are uniformly distributed over the entire length.

**1.2.16 Special property**

A property which is not determined as part of the routine inspection and test requirements. (e.g. fatigue properties).

**1.2.17 Standard property**

A property which is determined as part of the routine inspection and test requirements.

**1.2.18 Steel reinforcing bar**

A steel product with a circular or practically circular cross-section which is suitable for the reinforcement of concrete.

**1.2.19 Stockist**

A stockist is an organisation that receives steel reinforcing bars from a manufacturer or another stockist, and performs the requirements in accordance with this Standard. All stockists shall be Quality Assured (QA) Stockists.

A QA Stockist is a stockist certified to the requirements of ISO 9001 by a certification body accredited by HKAS for its quality management system with a scope related to good practices of storage, handling and supply of steel reinforcing bars to a purchaser in accordance with this Standard.

**1.2.20 Traceability**

Each delivered batch shall be identifiable and traceable to the manufacturer and to its production data. Such production data shall include country of origin, name of the QA Manufacturer, standard of compliance (namely CS2:2012), steel grade, nominal length, nominal diameter and heat/cast number of the steel reinforcing bars. The manufacturer's product traceability tag affixed on a steel reinforcing bar bundle / package is one of the acceptable measures to prove its traceability.

**1.2.21 Transverse rib**

A rib on the surface of the steel reinforcing bar other than a longitudinal rib.

**1.2.22 Transverse rib flank inclination angle,  $\alpha$** 

An angle of the rib flank measured perpendicular to the longitudinal axis of the rib.

**NOTE:** See Figure 1.

**1.2.23 Transverse rib inclination angle,  $\beta$** 

An angle between the axis of the transverse rib and the longitudinal axis of the steel reinforcing bar.

### 1.3 SYMBOLS

A list of symbols used in this Standard is given in Table 1.

**Table 1 – List of symbols**

Symbol	Description	Unit
$A_n$	Nominal cross-sectional area	$\text{mm}^2$
$A_{gt}$	Percentage total elongation at maximum force	%
$c$	Transverse rib spacing	mm
$C_v$	Specified characteristic value	<sup>a</sup>
$d$	Nominal diameter of the steel reinforcing bar	mm
$f_R$	Relative rib area	-
$h$	Rib height	mm
$\bar{x}$	Average value of test results	<sup>a</sup>
$R_e$	Yield strength	MPa <sup>b</sup>
$R_{eH}$	Upper yield strength	MPa <sup>b</sup>
$R_m$	Tensile strength	MPa <sup>b</sup>
$R_m/R_e$	Tensile /yield strength ratio	-
$R_{p0.2}$	0.2% proof strength, plastic extension	MPa <sup>b</sup>
$s$	Estimated standard deviation of the population	<sup>a</sup>
$\alpha$	Transverse rib flank inclination angle	degrees
$\beta$	Transverse rib inclination angle	degrees
$2\sigma_a$	Stress range in the axial load fatigue test	MPa <sup>b</sup>
$\sigma_{max}$	Specified maximum stress in the fatigue test	MPa <sup>b</sup>
$\sigma_{min}$	Specified minimum stress in the fatigue test	MPa <sup>b</sup>
$a_1$	Increment for calculation of batch release criteria	<sup>a</sup>
$\tau_{bu}$	Bond stress at maximum force (beam test)	MPa <sup>b</sup>
$\tau_{0.01}, \tau_{0.1}, \tau_1$	Bond stress at 0.01mm, 0.1mm and 1 mm slip (beam test)	MPa <sup>b</sup>
<sup>a</sup> The unit depends on the property.		
<sup>b</sup> 1 MPa = 1 N/mm <sup>2</sup> .		

### 1.4 DIMENSIONS, MASS PER METRE AND PERMISSIBLE DEVIATION

#### 1.4.1 Preferred diameters, nominal cross-sectional area and nominal mass per metre

The range of nominal diameters of steel reinforcing bars shall be 6 mm to 50 mm.

**NOTE 1:** The preferred nominal diameters in millimetre are 8, 10, 12, 16, 20, 25, 32 and 40.

**NOTE 2:** If a steel reinforcing bar smaller than 8 mm is required, the recommended diameter is 6 mm.

**NOTE 3:** If a steel reinforcing bar larger than 40 mm is required, the recommended diameter is 50 mm.

The values for the nominal cross-sectional area and nominal mass per metre of preferred diameters shall be as given in Table 2.

**NOTE 4:** The values for the nominal mass per metre are evaluated from the values of the nominal cross-sectional area on the basis that steels have a mass of 0.00785 kg/mm<sup>2</sup> per metre run.

**NOTE 5:** Plain steel reinforcing bars of grade 250 with diameter greater than 12 mm are not covered in this Standard.

**Table 2 – Nominal cross-sectional area and nominal mass per metre**

Nominal diameter, $d$ (mm)	Nominal cross-sectional area, $A_n$ (mm <sup>2</sup> )	Nominal mass per metre (kg)
6 <sup>a</sup>	28.3	0.222
8	50.3	0.395
10	78.5	0.617
12	113.1	0.888
16	201.1	1.579
20	314.2	2.466
25	490.9	3.854
32	804.3	6.313
40	1256.6	9.864
50 <sup>a</sup>	1963.5	15.413
<sup>a</sup> These are non-preferred sizes.		

#### 1.4.2 Permissible Deviation

Nominal mass per metre shall be determined by the test as described in Cl. 6.1 and 6.2. The permissible deviation from nominal mass per metre shall be as given in Table 3.

**Table 3 – Permissible deviation from nominal mass**

Grade	Nominal diameter, $d$ (mm)	Permissible deviation from nominal mass per metre run (%)
250	$d > 8$	$\pm 4.5$
500B 500C	$d \leq 8$	$\pm 6.0$

#### 1.4.3 Length

The nominal length of steel reinforcing bars shall be agreed at the time of order. The permissible deviation from the nominal length shall be +100/–0 mm.

### 1.5 CHEMICAL COMPOSITION

1.5.1 The values of individual elements and the carbon equivalent shall not exceed the limits given in Table 4. The carbon equivalent value  $C_{eq}$  shall be computed using the following formula:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

where

$C$  is the percentage carbon content;

$Mn$  is the percentage manganese content;

$Cr$  is the percentage chromium content;

$Mo$  is the percentage molybdenum content;

$V$  is the percentage vanadium content;  
 $Ni$  is the percentage nickel content; and  
 $Cu$  is the percentage copper content.

**Table 4 – Chemical composition (maximum % by mass)**

	Grade	Carbon	Sulphur	Phosphorus	Nitrogen <sup>b</sup>	Copper	Carbon Equivalent
Cast analysis	250	0.22	0.05	0.05	0.012	0.80	0.42
	500B & 500C	0.22	0.05	0.05	0.012	0.80	0.50
Product analysis	250	0.24	0.055	0.055	0.014	0.85	0.44
	500B & 500C	0.24 <sup>a</sup>	0.055	0.055	0.014	0.85	0.52
<sup>a</sup> It is permitted to exceed the maximum values of carbon by 0.03% by mass, provided that the carbon equivalent value is decreased by 0.02% by mass. <sup>b</sup> A higher nitrogen content is permissible if it can be demonstrated that there are sufficient quantities of nitrogen binding elements to combine with the nitrogen such that the free nitrogen does not exceed that specified in this Standard.							

- 1.5.2 Chemical composition (product analysis) shall be determined by chemical analysis as described in Cl. 6.1 and 6.3.

## 1.6 MECHANICAL PROPERTIES

Steel reinforcing bars should be free from features such as seams, porosity, segregation and non-metallic inclusions, etc., which would cause the product to fail to meet the specified mechanical properties.

### 1.6.1 General

The characteristic values as given in Table 5 are (unless otherwise indicated) the lower or upper limit of the statistical tolerance interval at which there is a 90% probability ( $1-\alpha = 0.90$ ) that 95% ( $p = 0.95$ ) or 90% ( $p = 0.90$ ) 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.

### 1.6.2 Tensile properties

The tensile properties of the steel reinforcing bars as determined in accordance with Cl. 6.1 and 6.4 shall comply with the specified characteristic values for the tensile properties as given in Table 5.

**Table 5 – Characteristic tensile properties**

<b>Grade</b>	<b>Yield strength, <math>R_e</math> (MPa)</b>	<b>Tensile/yield strength ratio, <math>R_m/R_e</math></b>	<b>Total elongation at maximum force, <math>A_{gt}</math> (%)</b>
250	250	1.15	5.0
500B	500	1.08	5.0
500C	500	$\geq 1.15$ and $< 1.35$	7.5
<b>NOTES:</b> 1. Values of $R_e$ specified are characteristic with $p = 0.95$ . 2. Values of $R_m/R_e$ specified are characteristic with $p = 0.90$ . For grade 500C steel reinforcing bar, the upper limit of $R_m/R_e$ is 1.35. 3. Values of $A_{gt}$ specified are characteristic with $p = 0.90$ . 4. Values of $R_m$ and $R_e$ are calculated using the nominal cross-sectional area.			

The absolute maximum permissible value of yield strength of grade 500 steel reinforcing bar is 650 MPa.

For yield strength ( $R_e$ ) of grade 500 steel reinforcing bar, the upper yield strength ( $R_{eH}$ ), which is the maximum value of stress prior to the first decrease in force, shall apply.  $R_e$  shall be determined from the 0.2% proof strength ( $R_{p0.2}$ ) in accordance with Appendix A if a yield phenomenon is not present. For Grade 250 steel reinforcing bars,  $R_e$  shall be determined from  $R_{p0.2}$ .

### 1.6.3 **Bend performance**

Bend performance shall be demonstrated by means of the rebend test as described in Cl. 6.1 and Cl. 6.5. After the test, the specimen shall show no sign of fracture or visible cracks.

### 1.6.4 **Fatigue properties (Optional)**

Determination of fatigue properties of ribbed steel reinforcing bars is an optional requirement of the purchaser. The purchaser should decide, on the basis of the type of structure in which the steel reinforcing bars are to be cast, whether fatigue properties are to be determined.

Where fatigue properties are to be determined, the steel reinforcing bars shall be Class 1 as described in Cl. 2.1 and shall be subjected to testing as described in Cl. 6.6. Test reports from the manufacturer may be used to verify compliance of this fatigue properties requirement.

The fatigue testing is to determine the fatigue characteristics of steel reinforcing bars with a particular geometrical shape and process route in a production place. The fatigue properties for each steel grade and process route shall be established 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 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.

Each test unit shall comprise ten test specimens of steel reinforcing bars. For each diameter, five test specimens shall be selected for test from each test unit. The test specimens shall not exhibit isolated defects that are not characteristic of the steel reinforcing bars from which they are selected.

The steel reinforcing bars shall be deemed to comply with this Standard if all five test specimens can endure  $5 \times 10^6$  cycles of stress in the fatigue test as described in Cl. 6.6.

If one of the five test specimens fails in the test, a further five test specimens from the test unit shall be tested. If one of these further test specimens fails the test, the batch shall be deemed not to comply with this Standard. If all five further test specimens endure  $5 \times 10^6$  cycles of stress, then the batch 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 region within  $2d$  of the testing machine grips (where  $d$  is the nominal steel reinforcing bar diameter); in this case a further single test shall be carried out.

## 1.7 BOND PROPERTY

### 1.7.1 General

Ribbed steel reinforcing bars are characterised by their surface geometry, by means of which bond with the concrete is achieved.

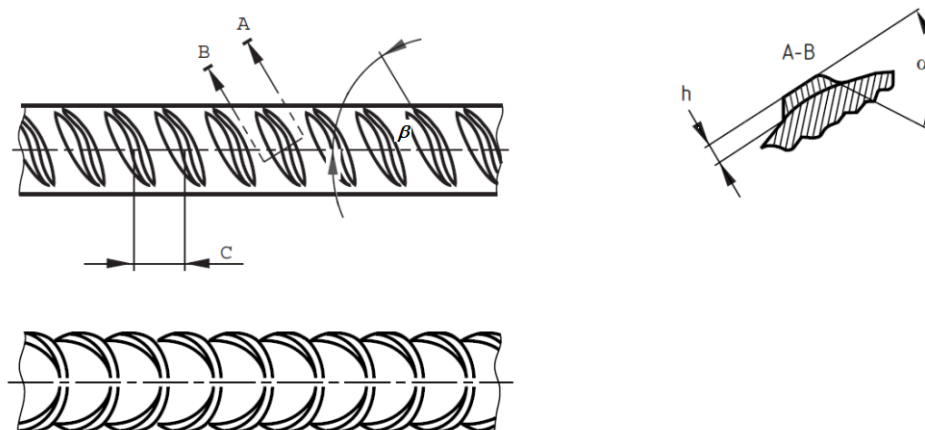
Bond property requirements of ribbed steel reinforcing bars shall be based on surface geometry as determined in Cl. 6.1 and 6.7.2 or bond stresses as determined by beam test in Cl. 6.1 and 6.7.3. Bond property requirements based on surface geometry are preferred. The assessment criteria for the beam tests shall be as given in the appropriate design documents. A suitable means of factory production control based on the control of surface geometry shall be derived from the beam test results.

### 1.7.2 Surface geometry

#### 1.7.2.1 General

Ribbed steel reinforcing bars are characterised by the dimensions, number and configuration of transverse and longitudinal ribs. They shall have two or more rows of transverse ribs uniformly distributed around the perimeter. Within each row the ribs shall be uniformly spaced. Longitudinal ribs can be present or not.

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



**Figure 1 – Example of rib geometry with two rows of transverse ribs**



The values for the spacing, height and rib inclination angle of transverse ribs shall be within the ranges given in Table 6.

**Table 6 – Ranges for the rib parameters**

Rib height, $h$	Rib spacing, $c$	Transverse rib inclination angle, $\beta$
$0.03d$ to $0.15d$	$0.4d$ to $1.2d$	$35^\circ$ to $75^\circ$

The characteristic relative rib area shall meet the requirements of Table 7. The characteristic values as shown in Table 7 are for  $p = 0.95$ .

**Table 7 – Characteristic relative rib area**

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

#### 1.7.2.2 Transverse ribs

The projection of the transverse ribs shall extend over at least 75% of the circumference of the steel reinforcing bar, which shall be calculated from the nominal diameter.

The transverse rib flank inclination angle  $\alpha$  shall be greater than or equal to  $45^\circ$ , and the transition from the rib to the core shall be radiused.

#### 1.7.2.3 Longitudinal ribs

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

#### 1.7.3 Beam test

The bond stresses, as measured in the beam test in Cl. 6.7.3, shall satisfy the following expressions:

$$\tau_m \geq 0.098 \times (80 - 1.2d)$$

$$\tau_r \geq 0.098 \times (130 - 1.9d)$$

where

$d$  is the nominal bar size (mm);

$\tau_m$  is the mean value of the bond stresses (MPa)  $\tau_{0.01}$ ,  $\tau_{0.1}$ ,  $\tau_1$  corresponding to 0.01, 0.1 and 1 mm slip; and

$\tau_r$  is the bond stress at failure by slipping (MPa) (the value of  $\tau_{bu}$  as determined from the beam test in Cl. 6.7.3 may be taken as the value for  $\tau_r$ )

### 1.8 IDENTIFICATION

### 1.8.1 General

Each ribbed steel reinforcing bar shall have identification marks to identify the manufacturer, according to the requirements of Cl. 1.8.2.

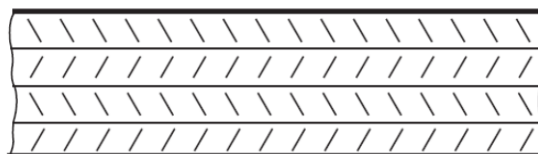
### 1.8.2 Identification requirements

Each steel reinforcing bar shall be identified by legible rolled-on identification marks on the surface at an interval of not greater than 1.5 m to indicate the origin of manufacture.

### 1.8.3 Identification of steel grade

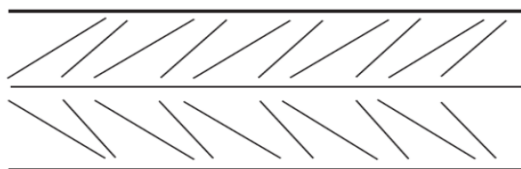
The steel grade shall be identified by the steel reinforcing bar's surface features such as rolled-on identification marks or arrangement of the transverse ribs. For transverse ribs, the arrangement shall be as follows:

Grade 500B: the ribbed steel reinforcing bars shall have two or more series of parallel transverse ribs. For ribbed steel reinforcing bars with two or three rib series, one of the series shall be at a contrary angle to the others; and for ribbed steel reinforcing bars with four rib series, two of the series shall be at a contrary angle to the others. An example of rib pattern of grade 500B with four transverse rib series is given in Figure 2.



**Figure 2 – Example of rib pattern for grade 500B**

Grade 500C: the ribbed steel reinforcing bars shall have the same arrangement of rib series as for grade 500B. However, in each rib series, the ribs shall alternate between a higher and lower angle with respect to the bar axis. The difference between the angles of the different ribs and the bar axis shall be at least  $10^\circ$ . An example of rib pattern of grade 500C with two transverse rib series is given in Figure 3.



**Figure 3 – Example of rib pattern for grade 500C**

## SECTION 2

### CLASSIFICATION

#### 2.1 CLASSIFICATION OF STEEL REINFORCING BARS

All steel reinforcing bars shall be manufactured by QA Manufacturers, and handled by QA Stockists throughout the supply chain, and shall be classified as follows:

(a) **Class 1 steel reinforcing bars**

Steel reinforcing bars that are fully traceable to their manufacturer and production data.

(b) **Class 2 steel reinforcing bars**

Steel reinforcing bars that are traceable to their manufacturers and production data except their heat /cast numbers.

## SECTION 3

### MANUFACTURERS INSPECTION AND TESTING

#### 3.1 ROUTINE INSPECTION AND TESTING

##### 3.1.1 General

Steel reinforcing bars shall be produced under a permanent system of routine inspection and testing, which shall include evaluation of specified properties, as described in Cl. 3.1.2 and 3.1.3.

##### 3.1.2 Sampling and testing

The test unit shall be the heat/cast or part quantity of the heat/cast.

The rate of testing shall be as follows:

- (a) For chemical composition, one analysis per test unit. The chemical composition (cast analysis) of the steel reinforcing bar shall have been determined by the QA Manufacturer.
- (b) For rebend tests and nominal mass per metre, one test specimen per test unit and nominal diameter.
- (c) For surface geometry, one test specimen per test unit and nominal diameter. Alternatively, beam test with the same rate of testing may be used.
- (d) For tensile tests, one test specimen per 30 tonnes with at least three test specimens per test unit and nominal diameter.

Test results shall be evaluated in accordance with Cl. 3.1.3.

##### 3.1.3 Evaluation of test results

###### 3.1.3.1 Mass per metre

All test specimens shall comply with the requirements of Cl. 1.4.2.

###### 3.1.3.2 Chemical composition (cast analysis)

The chemical composition (cast analysis) shall comply with the requirements of Cl. 1.5.1.

###### 3.1.3.3 Tensile properties

###### 3.1.3.3.1 Where the characteristic value $C_v$ is specified as a lower limit as given in Table 5, the results shall be deemed to comply with this Standard if either:

- (a) all individual values of the test results are greater than or equal to the specified characteristic value  $C_v$ ; or
- (b)  $\bar{x} \geq C_v + a_1$  and all individual values of the test results are greater than or equal to the minimum values given in Table 8

where

$\bar{x}$  is the average value of the test results; and

$a_1$  is the increment for calculation of batch release criteria.

( $a_1$  is 10 MPa for  $R_e$ , zero for  $R_m/R_e$  and 0% for  $A_{gt}$ )

**Table 8 – Absolute minimum and maximum values of tensile properties**

Performance characteristic	Minimum value			Maximum value		
	250	500B	500C	250	500B	500C
$R_e$ , MPa	243	485	485	N/A	650	650
$R_m/R_e$	1.13	1.06	1.13	N/A	N/A	1.38
$A_{gt}$ , %	4.0	4.0	6.0	N/A	N/A	N/A

3.1.3.3.2 Where the characteristic value  $C_v$  is specified as an upper limit as given in Table 5 (i.e. for  $R_m/R_e$  of grade 500C), the results shall be deemed to comply with this Standard if either:

- (a) all individual values of  $R_m/R_e$  are equal to or lower than the specified upper value of characteristic value of 1.35; or
- (b)  $\bar{x} \leq 1.35$  for  $R_m/R_e$  and all individual values for  $R_m/R_e$  are equal to or lower than the maximum value of 1.38 as given in Table 8.

3.1.3.3.3 All individual values of  $R_e$  for grade 500 steel reinforcing bar shall be equal to or lower than the maximum value of 650 MPa as given in Table 8.

#### 3.1.3.4 **Bend performance and bond property**

For rebend test, all test specimens shall comply with the requirements of Cl. 1.6.3.

For surface geometry measurement or beam test, all test specimens shall comply with the requirements of Cl. 1.7.2 or Cl. 1.7.3 respectively.

#### 3.1.3.5 **Retests**

If any test specimen fails to meet the tensile properties, rebend, or bond property requirements, two additional test specimens shall be taken from different bars of the same batch to undergo the required tests. If both additional test specimens pass the retests, the batch shall be deemed to comply with this Standard. If any additional test specimen fails in the retests, the batch shall be deemed not to comply with this Standard.

#### 3.1.4 **Chemical composition (product analysis)**

If product analysis is carried out and a single sample falls outside the maximum product analysis values given in Table 4 for any element, further samples shall be selected from the remainder of the batch as follows:

- (a) at least two samples from the same heat/cast for a batch with mass up to 5 tonnes;
- (b) at least five samples from the same heat/cast for a batch with mass up to 20 tonnes; and
- (c) at least eight samples for a batch with mass over 20 tonnes.

If any of the further samples analysed falls outside the maximum product analysis values given in Table 4 for any element, the batch shall be deemed not to comply with this Standard.

### 3.1.5 **Manufacturer record and delivery documentation**

The manufacturer shall establish and maintain the records required and shall identify the steel reinforcing bars and their delivery documentation accordingly.

For each delivery, the manufacturer shall supply the following information:

- (a) manufacturer's name and place for production;
- (b) nominal diameter and grade;
- (c) the heat/cast number and cast analysis, including all specified elements and elements used for the calculation of the carbon equivalent value;
- (d) the carbon equivalent value;
- (e) the results of the tensile test and rebend test;
- (f) the mass per metre;
- (g) the result of surface geometry measurement or beam test;
- (h) the manufacturing process route;
- (i) for ribbed steel reinforcing bar, the rolled-on identification mark; and
- (j) the result of fatigue test (if required by the purchaser).

## 3.2 ASSESSMENT OF THE LONG-TERM QUALITY LEVEL

### 3.2.1 General

The results of tests on all test units of continuous production shall be collated and statistically evaluated for  $R_e$ ,  $A_{gt}$  and  $R_m/R_e$ , taking either the number of results corresponding to the preceding six months' operation or the last 200 test results, whichever is the greater.

### 3.2.2 Determination of the long-term quality level

The evaluation shall be carried out per nominal diameter.

The following requirement shall be satisfied for  $R_e$ ,  $A_{gt}$  and  $R_m/R_e$ :

$$\bar{x} - k_1 \times s \geq C_v \text{ for } R_e \text{ or}$$

$$\bar{x} - k_2 \times s \geq C_v \text{ for } A_{gt} \text{ and } R_m/R_e$$

where

$\bar{x}$  is the average value of the test results;

$s$  is the estimated standard deviation of the population;

$k_1$  is the coefficient listed in Table 9 for  $R_e$  and  $k_2$  is the coefficient listed in Table 9 for  $A_{gt}$  and  $R_m/R_e$ ; and

$C_v$  is the specified characteristic value.

The foregoing is based on the assumption that the distribution of a larger number of test results is normal but this is not a requirement of this Standard. However, the following alternative methods may be used to establish conformity of the production with the requirements of this Standard:

- (a) graphical methods including control charts; and
- (b) non-parametric statistical techniques.

**Table 9 – Coefficients  $k_1$  and  $k_2$  as a function of the number  $n$  of test results**

$n$	$k_1^a$	$k_2^b$	$n$	$k_1$	$k_2$
5	3.40	2.74	30	2.08	1.66
6	3.09	2.49	40	2.01	1.60
7	2.89	2.33	50	1.97	1.56
8	2.75	2.22	60	1.93	1.53
9	2.65	2.13	70	1.90	1.51
10	2.57	2.07	80	1.89	1.49
11	2.50	2.01	90	1.87	1.48
12	2.45	1.97	100	1.86	1.47
13	2.40	1.93	150	1.82	1.43
14	2.36	1.90	200	1.79	1.41
15	2.33	1.87	250	1.78	1.40
16	2.30	1.84	300	1.77	1.39
17	2.27	1.82	400	1.75	1.37
18	2.25	1.80	500	1.74	1.36
19	2.23	1.78	1000	1.71	1.34
20	2.21	1.77	$\infty$	1.64	1.28

<sup>a</sup>  $k_1$  is a coefficient for a reliable failure rate of 5% [ $p = 0.95$ ] at a probability of 90%.

<sup>b</sup>  $k_2$  is a coefficient for a reliable failure rate of 10% [ $p = 0.90$ ] at a probability of 90%.



## SECTION 4

### STOCKIST'S CERTIFICATION

#### 4.1 QA STOCKIST'S CERTIFICATION OF STEEL REINFORCING BARS

##### 4.1.1 Application

This section applies to QA Stockists certified to the requirements of ISO 9001 by a HKAS accredited certification body. In addition, the QA Stockists shall comply with the specific requirements stated in Section 4.2 of this Standard and incorporate such requirements into their quality management system.

##### 4.1.2 Classification

The QA Stockist shall classify the steel reinforcing bars from a QA Manufacturer arriving in his yard as either Class 1 or Class 2.

##### 4.1.3 Certificates for Class 1 steel reinforcing bars

##### 4.1.3.1 Stockist certificate

If the steel reinforcing bar is classified as Class 1 steel reinforcing bar, a certificate shall be issued by the QA Stockist. This shall state the following information:

- (a) the QA Stockist's name, address, certificate serial number, stockist's lot number and date;
- (b) the date of dispatch;
- (c) the purchaser's order number or other reference;
- (d) product description and quantity supplied;
- (e) the QA Stockist's and manufacturer's certification numbers of the ISO 9001 certificates issued by accredited certification bodies;
- (f) the reference number of the manufacturer's certificate/document in respect of the manufacturer's supplied information as indicated in Cl. 3.1.5 of this Standard; and
- (g) the following statement, authorised by a designated means to indicate that the requirements of this Standard are satisfied:

*“Certified that the steel reinforcing bars supplied hereon are covered by the manufacturer's Certificate of Conformity or Test Certificate referenced hereon and have been subjected to the traceable part of our certification to ISO 9001 and the requirements stated in Sections 4.2 of CS2:2012.”*

#### 4.1.3.2 **Manufacturer's certificate/document**

A copy of the manufacturer's certificate/document in respect of the manufacturer's supplied information stated in Cl. 3.1.5 of this Standard for each batch of steel reinforcing bars delivered shall be provided by the QA Stockist.

The QA Stockist shall make available for inspection, such original manufacturer's certificate/document as well as a copy of the manufacturer's ISO 9001 certificate from a certification body accredited by HKAS or one of its MLA partners.

#### 4.1.4 **Certificate for Class 2 steel reinforcing bars**

##### 4.1.4.1 **Stockist certificate**

If the steel reinforcing bar is classified as Class 2 steel reinforcing bar, a certificate shall be issued by the QA Stockist. This shall state the following information:

- (a) the QA Stockist's name, address, certificate serial number, stockist's lot number and dates;
- (b) the date of dispatch;
- (c) the purchaser's order number or other reference;
- (d) product description and quantity supplied;
- (e) the QA Stockist's and manufacturer's certification numbers of the ISO 9001 certificates issued by accredited certification bodies;
- (f) the reference number of the manufacturer's certificate/document in respect of the manufacturer's supplied information as indicated in Cl. 3.1.5 of this Standard; and
- (g) classification of steel reinforcing bar i.e. Class 2 in accordance with this Standard.

##### 4.1.4.2 **Manufacturer's certificate/document**

A copy of the manufacturer's certificate/document in respect of the manufacturer's supplied information stated in Cl. 3.1.5 of this Standard for each batch of steel reinforcing bars delivered shall be provided by the QA Stockist.

The QA Stockist should make available for inspection, such original manufacturer's certificate/document as well as a copy of the steel reinforcing bar manufacturer's ISO 9001 certificate from a certification body accredited by HKAS or one of its MLA partners.

#### 4.2 **SPECIFIC REQUIREMENTS FOR QA STOCKISTS**

Specific requirements for QA Stockists shall include procedures on handling of non-conforming products for all classes of steel reinforcing bars and maintenance of product traceability from the QA Manufacturer to the delivery site for Class 1 steel reinforcing bars. The requirements are as follows:

- (a) The customer who has purchased the non-conforming steel reinforcing bars is notified of the corrective action to be taken including details of disposition on the non-conforming steel reinforcing bars.
- (b) The non-conforming steel reinforcing bars arising from (a) above shall not be sold, supplied and/or used as conforming steel reinforcing bars of the original grade.
- (c) Records of the above (a) and (b) are to be kept as Quality Records.
- (d) For Class 1 steel reinforcing bars, acceptable measures such as proper fixing of the manufacturer's product traceability tags to steel reinforcing bars shall be taken throughout the handling, storage and delivery processes to prove product traceability.

#### 4.3 **DIRECT SUPPLY OF STEEL REINFORCING BARS TO SITE BY QA MANUFACTURER**

Direct supply of steel reinforcing bars to site by a QA Manufacturer is permitted if the manufacturer is also a QA Stockist, takes the role of QA Stockist as required in this Standard and all the relevant stockist's certificates are fulfilled.

## **SECTION 5**

### **PURCHASERS TESTING**

#### **5.1 PURCHASER'S TESTS OF STEEL REINFORCING BARS**

##### **5.1.1 General**

Steel reinforcing bars arriving on site shall be tested by the purchaser. All tests shall be performed by a laboratory accredited by HKAS under the HOKLAS. All test results shall be presented in HOKLAS endorsed test reports.

For each batch of steel reinforcing bars delivered to site, test specimens shall be taken from different bars in the batch to undergo the purchasers testing and the rate of testing shall be in accordance with Table 10. The determination of mass per metre, chemical composition (product analysis), tensile properties, bend performance and bond property shall be carried out in accordance with Cl. 6.2, 6.3, 6.4, 6.5 and 6.7 respectively.

**Table 10 – Rate of purchaser’s tests**

Description	No. of test specimens per batch											
	Class 1						Class 2					
	Size of batch	Tensile	Rebend	Mass per metre	Chemical composition (product analysis)	Bond property	Size of batch	Tensile	Rebend	Mass per metre	Chemical composition (product analysis)	Bond property
Steel reinforcing bar nominal size 6 mm - 16 mm	0 - 60 tonnes	3	1	3	1	1	0 - 35 tonnes	3	1	3	1	1
	each additional 60 tonnes or part of 60 tonnes	1	Nil	1	Nil	Nil	each additional 35 tonnes or part of 35 tonnes	3	Nil	3	Nil	Nil
Steel reinforcing bar nominal size 20 mm - 32 mm	0 - 80 tonnes	3	1	3	1	1	0 - 45 tonnes	3	1	3	1	1
	each additional 80 tonnes or part of 80 tonnes	1	Nil	1	Nil	Nil	each additional 45 tonnes or part of 45 tonnes	3	Nil	3	Nil	Nil
Steel reinforcing bar nominal size exceeding 32 mm	0 - 100 tonnes	3	1	3	1	1	0 - 55 tonnes	3	1	3	1	1
	each additional 100 tonnes or part of 100 tonnes	1	Nil	1	Nil	Nil	each additional 55 tonnes or part of 55 tonnes	3	Nil	3	Nil	Nil

## 5.1.2 Evaluation of test results

### 5.1.2.1 Mass per metre

All test specimens shall comply with the requirements of Cl. 1.4.2.

### 5.1.2.2 Chemical composition (product analysis)

The chemical composition (product analysis) shall comply with the requirements of Cl. 1.5.1.

### 5.1.2.3 Tensile properties

5.1.2.3.1 Where the characteristic value of  $C_v$  is specified as a lower limit as given in Table 5, the results shall be deemed to comply with this Standard if either:

- (a) all individual values of the test results are greater than or equal to the specified characteristic value  $C_v$ ; or
- (b)  $\bar{x} \geq C_v + a_1$  and all individual values of the test results are greater than or equal to the minimum values in Table 8,

where

$\bar{x}$  is the average value of the test results; and

$a_1$  is the increment for calculation of batch release criteria.

( $a_1$  is 10 MPa for  $R_e$ , zero for  $R_m/R_e$  and 0% for  $A_{gt}$ )

5.1.2.3.2 Where the characteristic value of  $C_v$  is specified as an upper limit as given in Table 5 (for  $R_m/R_e$  of grade 500C), the results shall be deemed to comply with this Standard if either:

- (a) all individual values of  $R_m/R_e$  are equal to or lower than the specified upper value of characteristic value of 1.35; or
- (b)  $\bar{x} \leq 1.35$  for  $R_m/R_e$  and all individual values for  $R_m/R_e$  are equal to or lower than the maximum value of 1.38 as given in Table 8.

5.1.2.3.3 All individual values of  $R_e$  for grade 500 steel reinforcing bar shall be equal to or lower than the maximum value of 650 MPa as given in Table 8.

### 5.1.2.4 Bend performance

For rebend test, all test specimens shall comply with the requirements of Cl. 1.6.3.

### 5.1.2.5 Bond property

The bond property of test specimens shall comply with the requirements of Cl. 1.7. Where measurement of surface geometry is used to determine the bond property, the characteristic value  $C_v$  of relative rib area shall be assessed by the formula  $\bar{x} \geq C_v + a_1$  where  $a_1$  is 0.

### 5.1.3 **Compliance**

If the results of the tests performed on the test specimens meet the requirements of Cl. 5.1.2, the batch shall be deemed to comply with this Standard.

### 5.1.4 **Retests**

For each test specimen, taken in accordance with Table 10, and failing to meet the requirements for the mass per metre, chemical composition (product analysis), tensile properties, bend performance or bond property, two additional test specimens may be taken from different steel reinforcing bars of the same batch and be subjected to the test or tests which the original specimen failed.

If all of the additional test specimens pass the retests, the batch from which they have been taken shall be deemed to comply with this Standard. For properties other than chemical composition (product analysis), the batch shall be deemed not to comply with this Standard if any of them fails. For chemical composition (product analysis), the batch shall be deemed not to comply with this Standard if any of them fails unless demonstrated by alternative method as accepted in Cl. 6.3.

# SECTION 6

## METHODS OF TESTING

### 6.1 CONDITIONS OF TEST SPECIMENS

The determination of mass per metre, chemical analysis, tensile test, rebend test, fatigue test and the determination of bond property shall be carried out on weldable steel reinforcing bars used for the reinforcement of concrete structures in the delivery condition. The test specimens shall be tested at a room temperature between 5°C and 35°C unless otherwise specified.

The length of the test specimen for rebend test shall be adjusted to suit the type of test machine in use and must be sufficient for the test specimen to be bent to such extents that comply with the requirements of Cl. 6.5.

The length of the test specimen for the tensile test shall be 1 metre long.

### 6.2 DETERMINATION OF MASS PER METRE

The determination of the deviation from nominal mass per metre shall be carried out on a test specimen which shall have square cut ends. The length and mass of the test specimen shall be measured to an accuracy of at least  $\pm 0.5\%$ . The percentage deviation from nominal mass per metre of the test specimen shall be determined from the difference between the actual mass per metre of the test specimen deduced from its mass and length and nominal mass per metre as given in Table 2.

### 6.3 CHEMICAL ANALYSIS

The chemical composition (product analysis) shall be determined by spectrometric methods or an appropriate method specified in the International Standards listed in the bibliography of BS EN ISO 15630-1:2010.

### 6.4 TENSILE TEST

#### 6.4.1 Test equipment

The force-measuring system of the testing machine shall be calibrated to at least Class 1 in accordance with ISO 7500-1:2004. The extensometer shall be calibrated to at least Class 1 in accordance with ISO 9513:1999 for the determination of  $R_{p0.2}$ ; for the determination of  $A_{gt}$ , a Class 2 extensometer (see ISO 9513:1999) can be used.

#### 6.4.2 Test procedure

The tensile test shall be carried out in accordance with Cl. 10 of BS EN ISO 6892-1:2009.

For yield strength of grade 500 steel reinforcing bars, the upper yield strength ( $R_{eH}$ ), which is the maximum value of stress prior to the first decrease in force, shall apply.

If a yield phenomenon is not present, the yield strength from 0.2% proof strength ( $R_{p0.2}$ )



shall be determined in accordance with Appendix A. For grade 250 steel reinforcing bars, the yield strength shall be determined from the 0.2% proof strength ( $R_{p0.2}$ ).

For determination of percentage total elongation at maximum force ( $A_{gt}$ ), test shall be carried out in accordance with Appendix B.

The mechanical properties of the test specimen including upper yield strength ( $R_{eH}$ ) or 0.2% proof strength ( $R_{p0.2}$ ), tensile strength ( $R_m$ ) and the percentage total elongation at maximum force ( $A_{gt}$ ) shall be determined in tensile test. The nominal cross-sectional area ( $A_n$ ) of the test specimen shall be used for calculating the tensile properties ( $R_{eH}$  or  $R_{p0.2}$ ,  $R_m$ ) unless otherwise specified in the relevant product standards.

## 6.5 REBEND TEST

The rebend test shall be carried out in such a way as to produce a continuous and uniform bending deformation (curvature) at every section of the bend. The test shall be conducted either:

- (a) on a power bending machine in which the test specimen is adequately supported by plain smooth surfaces or rolls which do not offer resistance to longitudinal movement of the test specimen; or
- (b) on a 3-point hydraulic bending machine.

The test machine shall be serviceable and capable of imparting constant loading to the test specimen and shall be without impact effect. It is recommended that the bending and rebending rate shall be approximately three revolutions per minute.

The test specimen shall be tested according to the following sequence of operations:

- (a) the test specimen shall be bent through an angle of 90° round a mandrel with diameter not exceeding those specified in Table 11;
- (b) ageing shall be performed artificially by placing the test specimen at a temperature of 100°C, maintaining at this temperature  $\pm 10^\circ\text{C}$  for a period of 1 hours  $^{+15}_0$  min. and then cooling in still air to room temperature; and
- (c) the test specimen shall be bent back towards its original shape (partially re-straightened) by a steadily applied force through at least 20° on the same bending machine as used above.

**Table 11 – Rebend test mandrel**

Grade	Nominal diameter, $d$ (mm)	Maximum mandrel diameter
250	All sizes	$2d$
500B & 500C	$\leq 16$	$4d$
	$> 16$	$7d$

## 6.6 DETERMINATION OF FATIGUE PROPERTIES OF RIBBED STEEL REINFORCING BARS

### 6.6.1 Fatigue Test

Testing shall be carried out on ribbed steel reinforcing bars in the nominally straight condition. The stress range for the relevant bar size is given in Table 12.

### 6.6.2 Test specimen

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

The straightness of the test specimen is critical for the fatigue test. To achieve satisfactory straightness, a production straightening machine may be used. The means of straightening the test specimen (manual, laboratory machine, production machine) shall be recorded in the test report.

### 6.6.3 Test equipment

The fatigue testing machine shall be calibrated according to ISO 7500-1:2004. The relative error of accuracy shall be at least  $\pm 1\%$ . The testing machine shall be capable of maintaining the upper force,  $F_{up}$ , within  $\pm 2\%$  of the specified value, and the force range,  $F_r$ , within  $\pm 4\%$  of the specified value where the  $F_{up}$  and  $F_r$  can be determined as follows:

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

$$F_r = 2\sigma_a \times A_n$$

where

$\sigma_{max}$  is the maximum stress in the axial load;

$2\sigma_a$  is the stress range in the axial load; and

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

### 6.6.4 Test procedure

The test specimen shall be gripped in the test equipment in such a way that the force is transmitted axially and free of any bending moment along the test specimen. The test shall be carried out under condition of stress ratio ( $\sigma_{min}/\sigma_{max}$ ) of 0.2 and stress range as given in Table 12 and frequency of load cycles between 1 Hz and 200 Hz. The test frequency of load cycles shall be stable during the test and also during test series. The sine wave form shall be used. Testing shall be carried out under load control and stresses shall be calculated on the nominal cross-sectional area. There shall be no interruptions in the cyclic loading throughout the test. However, it is permissible to continue a test if it is accidentally interrupted. Any interruption shall be reported. The number of load cycles shall be counted inclusively from the first full load range cycle. The test shall be terminated upon failure of the test specimen before reaching the specified number of cycles, or on completion of the specified number of cycles without failure.

**Table 12 – Fatigue test stress ranges for nominal bar sizes**

Bar size, $d$ (mm)	Stress range, $2\sigma_a$ (MPa)
$d \leq 16$	200
$16 < d \leq 20$	185
$20 < d \leq 25$	170
$25 < d \leq 32$	160
$d > 32$	150

## 6.7 DETERMINATION OF BOND PROPERTY

### 6.7.1 General

Where the bond property of a ribbed steel reinforcing bar is to be determined, the test specimens shall comply with the requirements of Cl. 1.7.

### 6.7.2 Surface geometry

#### 6.7.2.1 Test specimen

The length of the test specimen shall be sufficient to allow measurements of the geometrical characteristics for calculating the relative rib area in accordance with Appendix C.

#### 6.7.2.2 Measuring equipment

The geometrical characteristics shall be measured with an instrument of a resolution of at least the following:

- (a) 0.01 mm for the height of transverse or longitudinal ribs for the measurements less than or equal to 1 mm;
- (b) 0.02 mm for the height of transverse or longitudinal ribs for the measurements greater than 1 mm;
- (c) 0.5 mm for the distance between transverse ribs when determining the transverse rib spacing;
- (d) 0.05 mm for the gap between the transverse ribs of two adjacent transverse ribs; and
- (e) one degree for the transverse rib inclination angle and the transverse rib flank inclination angle.

#### 6.7.2.3 Measurements

All the following geometrical characteristics shall be measured and recorded:

- (a) The maximum height of transverse ribs ( $a_{\max}$ ) shall be determined as the mean of at least three measurements per row of the maximum height of individual transverse ribs.
- (b) The height of transverse ribs at a given position, e.g. at the quarter-point or at the mid-point or at the three-quarters point, respectively designated  $a_{1/4}$ ,  $a_m$  and  $a_{3/4}$ , shall be determined as the mean of at least three measurements in this position per row on different transverse ribs.

- (c) The height of longitudinal ribs ( $a'$ ) shall be determined as the mean of at least three measurements of the height of each longitudinal rib at three different positions.
- (d) The spacing of the transverse ribs ( $c$ ) shall be determined from the measured length divided by the number of the rib gaps included in it. The measured length is deemed to be the interval between the centre of a rib and the centre of another rib on the same row of the steel reinforcing bar determined in a straight line and parallel to the longitudinal axis of the bar. The measured length shall be at least 10 rib gaps.
- (e) The average gap ( $e$ ) shall be determined from at least three measurements, and the part of the circumference without ribs ( $\sum e_i$ ) shall be determined as the sum of the average gap ( $e$ ) between each pair of two adjacent ribs.
- (f) The transverse rib inclination angle ( $\beta$ ) to the steel reinforcing bar axis shall be determined as the mean of the individual angles measured for each row of ribs with the same nominal angle.
- (g) Each transverse rib flank inclination angle ( $\alpha$ ) shall be determined as the mean of the individual inclinations on the same side of the ribs, measured as indicated in Figure 12 on at least two different transverse ribs per row.

#### 6.7.2.4 **Determination of the relative rib area**

The relative rib area ( $f_R$ ) shall be calculated in accordance with Appendix C by using the results of measurements of the geometrical characteristics made in Cl. 6.7.2.3.

### 6.7.3 **Beam test**

#### 6.7.3.1 **General**

The beam test is intended to determine the bond of steel reinforcing bar and to serve as a basis for the comparison of steel reinforcing bars of approximately the same diameter but with different surface configurations. The test method is applicable for steel reinforcing bar with diameters  $\leq 32$  mm.

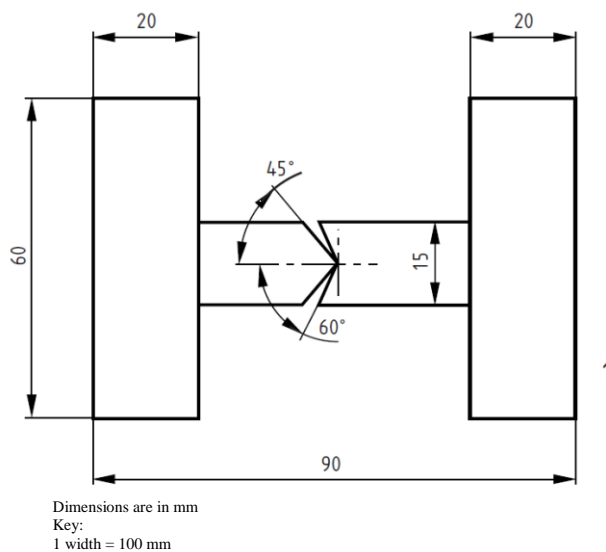
#### 6.7.3.2 **Principle of the test**

A test beam shall be loaded by simple flexure until complete bond failure of the steel reinforcing bar occurs in both half-beams or until the failure of the steel reinforcing bar itself. During loading, the slip of the two ends of the steel reinforcing bar shall be measured and recorded.

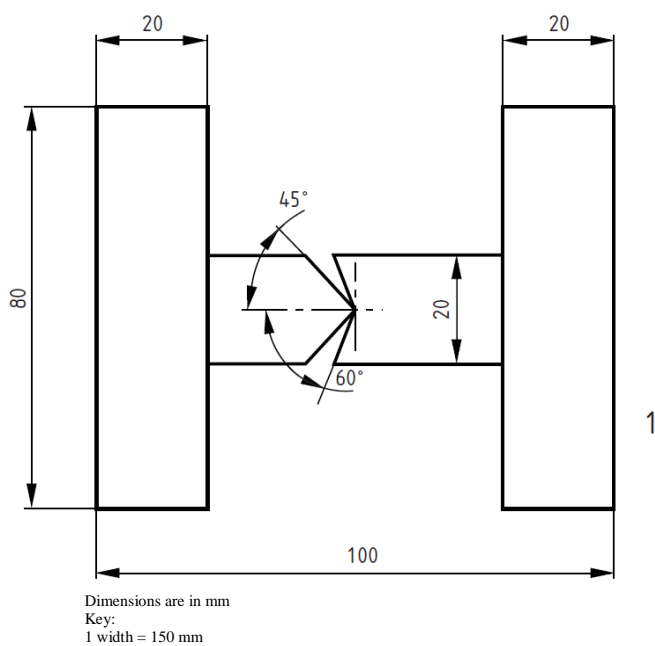
The beam used for the test shall consist of two parallelepipedal reinforced concrete blocks interconnected at the bottom by the steel reinforcing bar of which the bond is to be tested, and at the top by a steel hinge. The dimensions of the two blocks and the hinges are determined by the diameter of the steel reinforcing bar to be tested. The test is illustrated in Figure 4, Figure 5, Figure 6 and Figure 7.

The dimensions of the test beams depend on the nominal diameter of the steel reinforcing bar for which the bond is to be tested. For nominal diameter less than 16 mm, a beam specimen of type A is used and for nominal diameter equal to or larger than 16 mm, a beam specimen of type B is used (see Figure 6 and Figure 7).

**NOTE:** Due to limited experience in testing bars with diameters larger than 32 mm, a type testing program should be performed to evaluate the applicability of the test method for bars with larger diameter.



**Figure 4 – Dimensions of the hinge for beam test for specimen type A ( $d < 16$  mm)**



**Figure 5 – Dimensions of the hinge for beam test for specimen type B ( $d \geq 16$  mm)**



### 6.7.3.3 Test specimens

To test steel reinforcing bars with various sizes but of the same surface configuration, it would be more desirable to test them in groups. All diameters within a group shall have the same rib configuration. Typical groups of steel reinforcing bar diameters are shown in Table 13.

**NOTE:** *The same surface configuration means the same relationship between rib height, rib spacing and bar diameter as well as the rib inclination.*

**Table 13 – Groups of steel reinforcing bar diameters for beam test**

Denomination of the group	Range of nominal diameters, $d$ (mm)	Representative nominal diameter of the group (mm)
Small diameters	$d \leq 10$	8
Medium diameters	$10 < d \leq 20$	16
Large diameters	$20 < d \leq 32$	32
Very large diameters	$32 < d \leq 50$	Each size to be tested

Twenty-five beam tests shall be carried out for each group and type of surface geometry with the representative nominal diameter of the group. Test specimens shall be selected to minimise the variation in surface configuration within a group. If all the test specimens are not taken from the same steel reinforcing bar, then they should be taken from as few bars as possible.

If the representative nominal diameter of a group is not manufactured, then the largest nominal diameter produced in the group shall be tested.

If steel reinforcing bars with the same surface geometry but with different specified yield strength are to be characterised, then the tests shall be carried out with the product having the highest specified yield strength.

### 6.7.3.4 Preparation of test specimens

The steel reinforcing bar to be tested shall be in the “as manufactured” condition without loose mill scale, preferably entirely free from rust and, if necessary, carefully degreased with carbon tetrachloride ( $\text{CCl}_4$ ) or ethylene tri-chloride ( $\text{C}_2\text{HCl}_3$ ). The test specimen shall be without any machining. If the test specimen is corroded, the conditions of the test specimen shall be described in the test report and supported by photographs of the surface. The test specimen shall not be cleaned in any way that might change its roughness.

Auxiliary steel reinforcing bars shall have the same strength and surface characteristics as the steel reinforcing bar to be tested. Figure 8 and Figure 9 detail the components for the auxiliary steel reinforcing bars.

Sleeves used to avoid the adherence of the concrete to the steel reinforcing bar to be tested shall be of plastic. These sleeves shall be rigid so as not to become deformed during the test.

The concrete for the beam specimen as well as the cylindrical test specimens shall be produced, placed and stored according to BS EN 1766:2000 (except that the curing temperature under water shall be maintained at  $27 \pm 3^\circ\text{C}$ ) with the strength class of concrete

to be either of Type C (0,70) of BS EN 1766:2000 with a compression strength target value of  $(25 \pm 5)$  MPa, or of Type C (0,45) of BS EN 1766:2000 with a compressive strength target value of  $(40 \pm 5)$  MPa, measured on 150 mm  $\times$  300 mm cylindrical specimens and tested according to BS EN 12390-3:2009. Unless otherwise agreed, the tests shall be performed with concrete Type C (0,70) of BS EN 1766:2000. The age of the concrete shall not be more than 35 days and not less than 21 days.

**NOTE:** *It is recommended that the test specimens for 25 tests are prepared in 5 lots or mixes, making 5 specimens from each lot.*

#### 6.7.3.5 Test equipment

Moulds for the test beams shall be made of steel, cast iron or any other non-absorbent material which does not react with the components of the concrete. Water tightness and dimensions should be maintained after use.

Steel hinges shall be formed from two specimens of steel in a T shape, as shown in Figure 4 and Figure 5, which interconnect the transversal interior faces of the two blocks. The width of the hinge shall be the same as the width,  $b$ , of the beam.

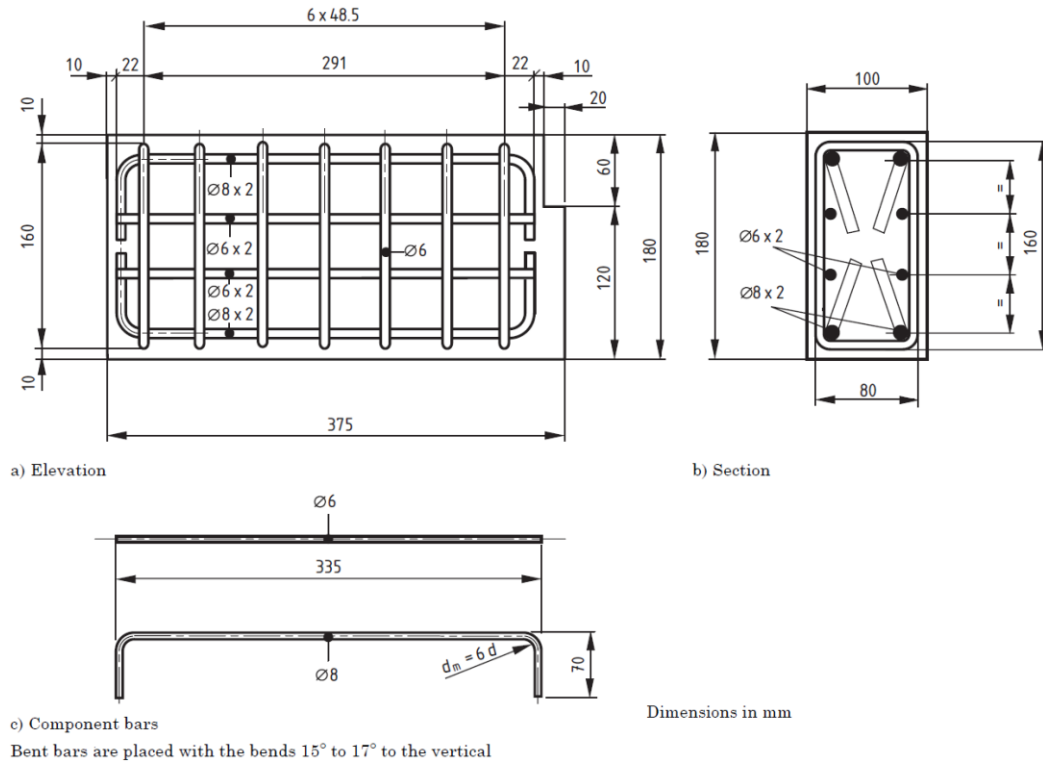
A system for regulating forces shall be fitted to the mechanism for applying forces, which shall enable them to be increased continuously, within the limits described in Cl. 6.7.3.6.

A force application system shall be used to apply forces perpendicular to the face of the beam specimen. The mechanism for applying forces shall be composed of steel rotating knife-edges or roller bearings; two to support the beam specimen and another two for loading.

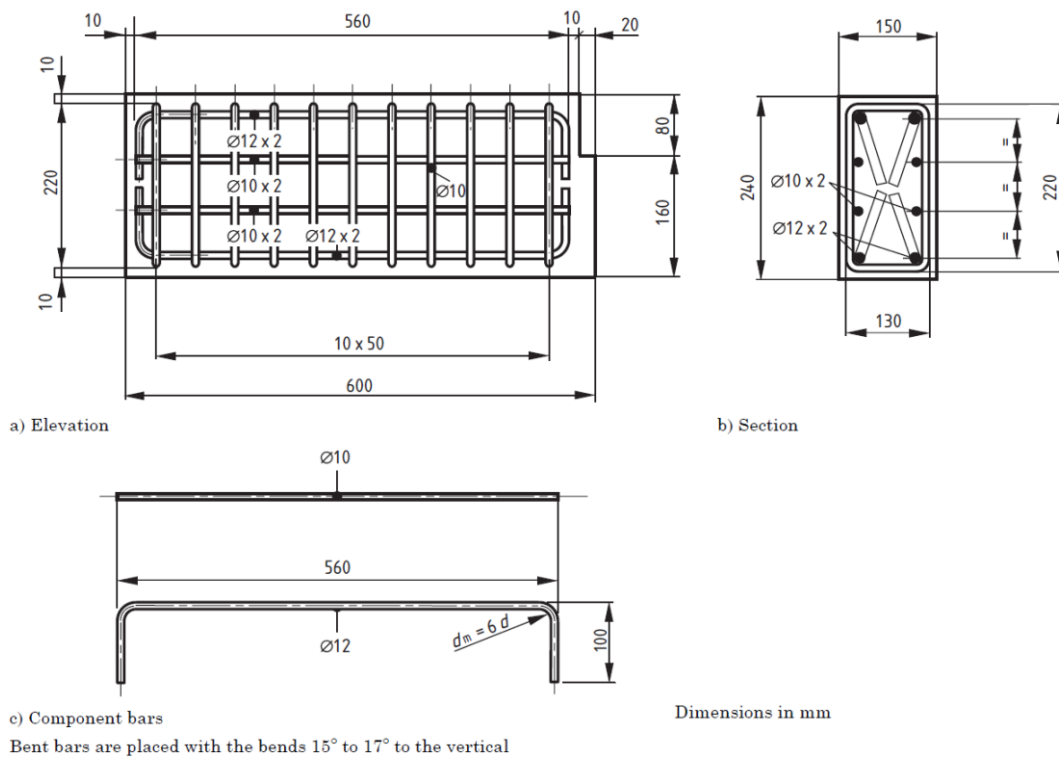
Instruments for measuring forces shall be accurate to at least 1% of the test result and the reading device shall give an indication of the maximum force reached during the test.

Instruments for measuring slip shall be accurate to  $\pm 0.01$  mm.





**Figure 8 – Auxilliary steel reinforcing bars for beam specimen type A ( $d < 16$  mm)**



**Figure 9 – Auxilliary steel reinforcing bars for beam specimen type B ( $d \geq 16$  mm)**

### 6.7.3.6 Procedure

The test beam shall be placed on two rotating knife-edges or rolling bearings, and loaded with two forces of equal magnitude, disposed symmetrically with regard to mid-span and likewise applied through movable knife-edges or rollers.

The total force,  $F_a$ , applied to the test specimen is given by one of the followings:

$$F_a = \frac{A_n \sigma_s}{1.25}, \text{ for } d < 16 \text{ mm}$$

$$F_a = \frac{A_n \sigma_s}{1.50}, \text{ for } d \geq 16 \text{ mm}$$

where

$A_n$  is the nominal cross-sectional area of the steel reinforcing bar.

The load shall be applied in one of the following three ways:

- (a) in consecutive increments corresponding to stresses,  $\sigma_s$  in the steel reinforcing bar of 0 MPa, 80 MPa, 160 MPa, 240 MPa, etc.;
- (b) in smaller increments; or
- (c) continuously, by logging with electronic devices.

For (a) or (b), the force shall be increased, at each stage, gradually and continuously. Each increment shall be reached in half a minute and the load shall be maintained long enough to stabilise the slip, or, at the most, for two minutes. For (c), a loading speed not exceeding a corresponding stressing rate of 1 MPa/s in the steel reinforcing bar shall be used.

The slip shall be measured at the beginning and at the end of each increment in loading. The test shall be continued until complete bond failure of the steel reinforcing bar occurs in both half-beams or until failure of the steel reinforcing bar itself. Bond failure generally does not take place simultaneously in the two half-beams. For this reason, when the half of the steel reinforcing bar whose bond has failed attains a slip of 3 mm, this half-bar shall be held in a gripping device which will bear against the concrete and prevent any further slip.

Force-slip curves may be either recorded automatically, or plotted point by point from dial gauge readings.

### 6.7.3.7 Test results

#### 6.7.3.7.1 Calculation of the bond stress

If the total force applied to the beam test is  $F_a$ , for a given slip, the bond stress,  $\tau_b$ , is given by:

$$\tau_b = \frac{\sigma_s}{40}$$

where

$\sigma_s$  is the stress of the bar, given by one of the following formulae:

$$\sigma_s = \frac{1.25F_a}{A_n}, \text{ for } d < 16 \text{ mm}$$

$$\sigma_s = \frac{1.50F_a}{A_n}, \text{ for } d \geq 16 \text{ mm.}$$

#### 6.7.3.7.2 Values of bond stresses

The bond stresses for the following measured slip values or at maximum force shall be calculated:

- (a)  $\tau_{0.01}$  = Bond stress at 0.01 mm slip;
- (b)  $\tau_{0.1}$  = Bond stress at 0.1 mm slip;
- (c)  $\tau_1$  = Bond stress at 1 mm slip; and
- (d)  $\tau_{bu}$  = Bond stress at maximum force

Other values may be agreed between the parties. The force-slip curves shall be recorded and made available on request.

#### 6.7.3.8 TEST REPORTS

The report for each test shall affirm that the test was carried out in accordance with this Standard and shall include the following:

- (a) identification number of the test specimen;
- (b) date of receipt of the test specimen at the laboratory;
- (c) condition of the test specimen when received;
- (d) steel grade and nominal diameter of the test specimens and the group they represent;
- (e) surface geometry of the test specimens, i.e. rib heights, rib spacing, transverse rib inclination angle, transverse rib flank inclination angle and relative rib area;
- (f) manufacturer's heat/cast number and batch number;
- (g) strength class of the concrete, i.e. Type C (0,70) or Type C (0,45) according to BS EN 1766:2000;
- (h) compression strength of the concrete at the date of testing;
- (i) dates of the tests;
- (j) all single test results;
- (k) force slip curves;
- (l) description of the failure mode;
- (m) other remarks, if any; and
- (n) name and signature of the person responsible for the test.

**NOTE 1:** *The person responsible for a particular test is not necessarily the same as the person actually carrying out the test. For HOKLAS accredited laboratories, the person responsible should be an approved signatory.*

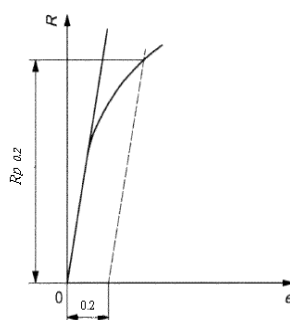
**NOTE 2:** *The person responsible for the test must ensure that all the information listed for the inclusion in a test report is fully and accurately stated. However, some of the information listed for inclusion in a test report may not be known to the person responsible for the test. In such a case, the words "not known" should be entered in the test report.*

**NOTE 3:** *If any test is performed on a test specimen which does not fully comply with this Standard or if the test itself does not fully comply with the requirements of this Standard, the relevant details must be stated in the test report.*

## Appendix A - METHOD FOR THE DETERMINATION OF 0.2% PROOF STRENGTH, $R_{p0.2}$

### A.1 General

The proof strength (plastic extension) shall be determined from the force-extension curve by drawing a line parallel to the linear portion of the curve and at a distance from it equivalent to the plastic percentage extension of 0.2. The point at which this line intersects the curve gives the force corresponding to the desired proof strength (plastic extension). The latter shall be obtained by dividing this force by the nominal cross-sectional area of the test specimen (see Figure 10).



Key

$e$  percentage extension

$R$  stress

$R_{p0.2}$  0.2% proof strength

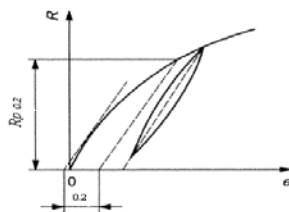
**Figure 10 – Proof strength, plastic extension**

If the straight portion of the force-extension curve is limited or not clearly defined, thereby preventing drawing the parallel line with sufficient precision, one of the following two methods (i.e. Method A and Method B) shall be applied. In case of dispute, Method B shall be applied.

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 shall be considered as invalid.

### A.2 Method A

When the presumed proof strength has been exceeded, the force shall be reduced to a value equal to about 10% of the force obtained. The force shall then be increased again until it exceeds the value obtained originally. To determine the desired proof strength, a line shall be drawn through the hysteresis loop. A line shall then be drawn parallel to this line, at a distance from the corrected origin of the curve, measured along the abscissa, equal to the plastic percentage extension of 0.2. The intersection of this parallel line and the force-extension curve shall give the force corresponding to the proof strength. The latter shall be obtained by dividing this force by the nominal cross-sectional area of the test specimen (see Figure 11).



### Key

- $e$  percentage extension  
 $R$  stress  
 $R_{p0.2}$  0.2% proof strength

**Figure 11 – Proof strength, plastic extension, Method A**

- NOTE 1:** Various methods can be used to define the corrected origin of the force-extension curve. One of these is to draw a line parallel to that determined by the hysteresis loop so that it is tangential to the force-extension curve. The point where this line intersects the abscissa is the corrected origin of the force-extension curve.
- NOTE 2:** The plastic strain at the starting point of force reduction is only slightly higher than the specified plastic extension of  $R_{p0.2}$ . Starting points at much higher strain values shall reduce the slope of the line through the hysteresis loop.
- NOTE 3:** If not specified in product standards or agreed by the customer, it is not appropriate to determine proof strength during and after discontinuous yielding.
- NOTE 4:** The test should be considered invalid when the slope of this line differs by more than 10% from the theoretical value of the modulus of elasticity

## A.3

### Method B

The straight portion of the force-extension curve shall be considered as the line joining the points corresponding to  $0.2F_m$  and  $0.5F_m$ , where  $F_m$  shall be the maximum force in the tensile test.

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

## Appendix B - METHOD FOR THE DETERMINATION OF PERCENTAGE TOTAL ELONGATION AT MAXIMUM FORCE, $A_{gt}$

### B.1 By extensometer

The extensometer used shall have a gauge length of at least 100 mm. The gauge length shall be indicated in the test report.

This method consists of determining the extension at maximum force on the force-extension curve obtained with an extensometer.

The percentage total elongation at maximum force,  $A_{gt}$ , shall be calculated by using the formula:

$$A_{gt} = \frac{\Delta L_m}{L_e} \times 100$$

where

$L_e$  is the extensometer gauge length; and  
 $\Delta L_m$  is the extension at maximum force.

**NOTE:** For materials which show a plateau at maximum force, the percentage total elongation at maximum force is the extension at the mid-point of the plateau (see Figure 12).

If the tensile test is carried out on a computer controlled testing machine having a data acquisition system, the elongation shall be directly determined at the maximum force.

### B.2 By manual method

The method consists of measuring the plastic elongation at maximum force, from which the percentage total elongation shall be calculated.

Before the test, equidistant marks shall be made on the free length of the test specimens. The distance between the marks shall be 20 mm, 10 mm or 5 mm, depending on the test specimen diameter. The initial gauge length shall be 100 mm and the marking of the initial gauge length shall be accurate to within  $\pm 0.5$  mm.

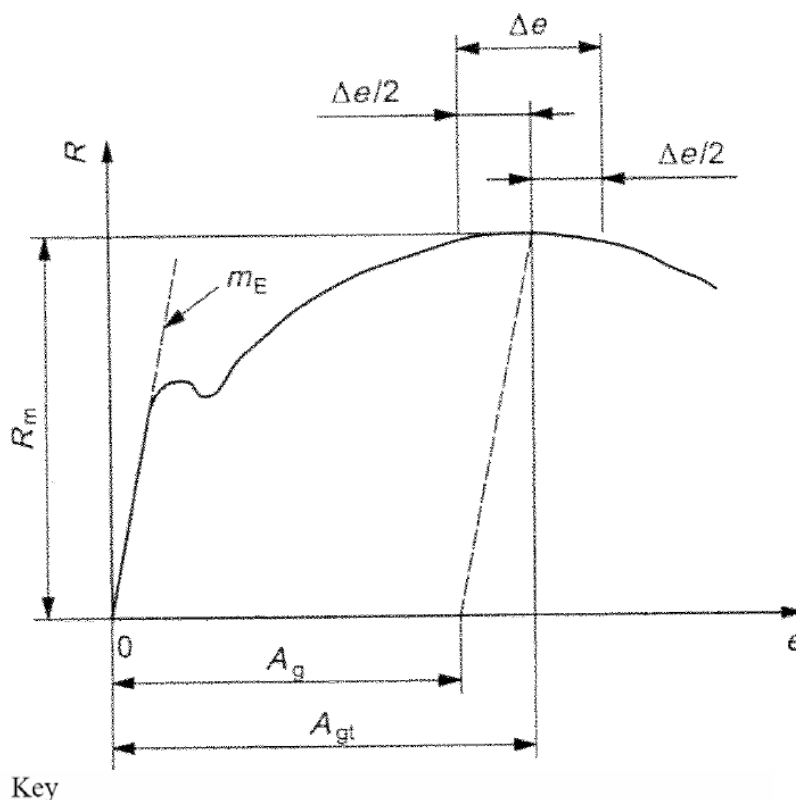
The measurement of the final gauge length after fracture shall be made on the longest broken part of the test specimens and shall be accurate to within  $\pm 0.5$  mm.

The percentage total elongation at maximum force,  $A_{gt}$  can be calculated by using the formula (see Figure 12):

$$A_{gt} = A_g + \frac{R_m}{2000}$$

where

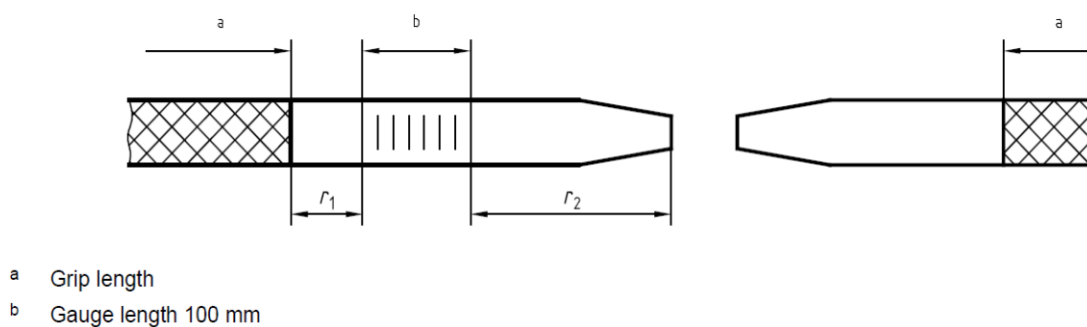
$R_m$  is the tensile strength of the test specimen; and  
 $A_g$  is the percentage plastic elongation at maximum force.



$A_g$	percentage plastic elongation at maximum force
$A_{gt}$	percentage total elongation at maximum force
$e$	percentage elongation
$m_E$	slope of the elastic part of the stress-percentage elongation curve
$R$	stress
$R_m$	tensile strength
$\Delta e$	plateau extent (for determination of $A_g$ and $A_{gt}$ , see Appendix B)

**Figure 12 – Definitions of elongation**

The measurement of  $A_g$  shall be made on a gauge length of 100 mm, as close as possible to the fracture but at a distance,  $r_2$ , of at least 50 mm or  $2d$  (whichever is the greater) away from the fracture. This measurement shall 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 greater). (See Figure 13)



**Figure 13 – Measurement of  $A_{gt}$  by the manual method**

**B.3 Choice of different methods**

The extensometer method may be replaced by the manual method. In case of dispute, the manual method shall be applied.



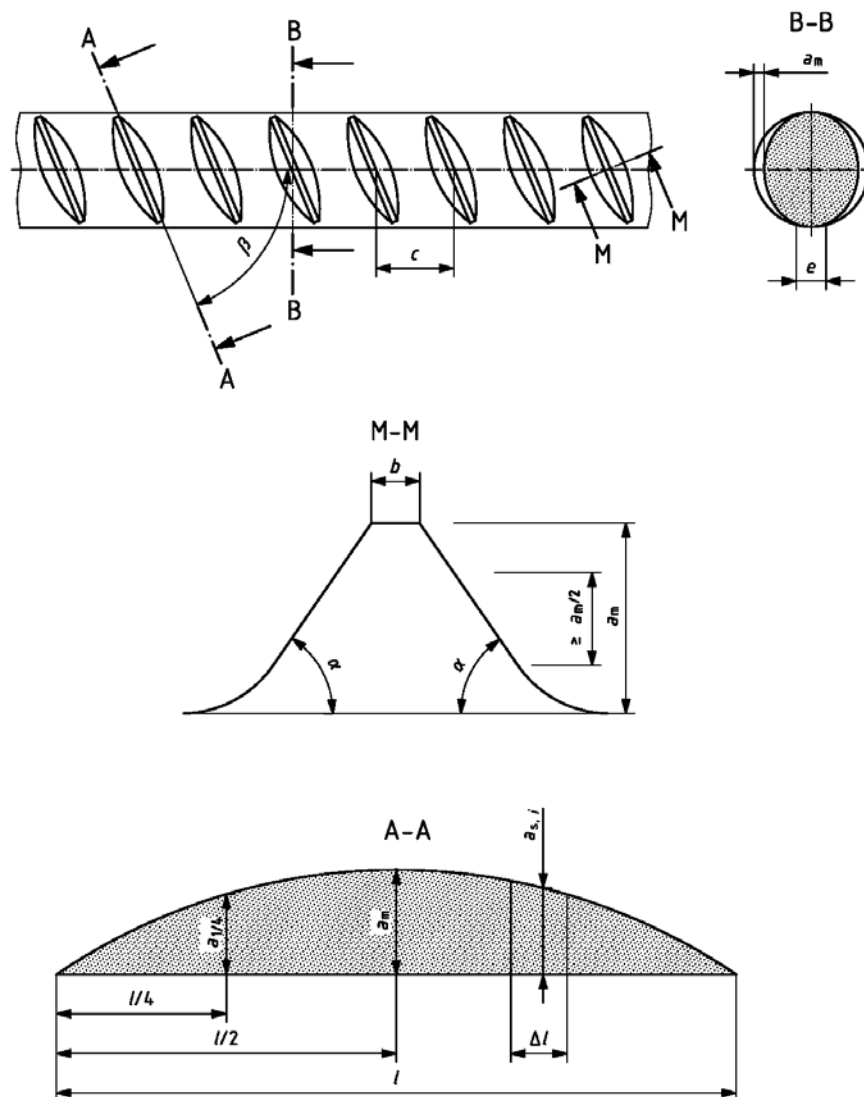
## Appendix C - RECOMMENDED FORMULA FOR CALCULATING OF RELATIVE RIB AREA

The relative rib area,  $f_R$ , for ribbed steel reinforcing bars shall be calculated by using the Simpson's rule formula (see Figure 14):

$$f_R = (2a_{1/4} + a_m + 2a_{3/4}) \times (\pi d - \sum e_i) \times \frac{1}{6\pi dc}$$

where

- $a_m$  is the height of transverse ribs at the mid-point determined as the mean of at least three measurements in this position per row on different transverse ribs;
- $a_{1/4}$  is the height of transverse ribs at the quarter-point determined as the mean of at least three measurements in this position per row on different transverse ribs;
- $a_{3/4}$  is the height of transverse ribs at the three-quarters point determined as the mean of at least three measurements in this position per row on different transverse ribs;
- $d$  is the nominal diameter of the bar;
- $\sum e_i$  is the part of the circumference without ribs determined as the sum of the average gap ( $e$ ) between each pair of two adjacent ribs.  $e$  shall be determined from at least three measurements; and
- $c$  is the spacing of the transverse ribs determined from the measured length divided by the number of the rib gaps included in it. The measured length is deemed to be the interval between the centre of a rib and the centre of another rib on the same row of the product determined in a straight line and parallel to the longitudinal axis of the product. The measured length shall be at least 10 rib gaps.



NOTE Section A-A is a flattened representation of a transverse rib.

**Figure 14 – Calculation of relative rib area**