CS2:1995

Construction Standard

# Carbon Steel Bars for the Reinforcement of Concrete

Hong Kong Government

# FOREWORD

## Introduction

In May 1992, the Works Branch Standing Committee on Concrete Technology set out to review the standard for steel bar reinforcement used in Hong Kong, and taking into account the situation of supply and usage, consider whether any amendments to the standard was necessary.

2. A sub-committee was formed consisting of representatives from Government Works Departments, Buildings Department, Housing Department, Hong Kong Institution of Engineers, Hong Kong Construction Association Ltd., Stockists, Manufacturers, Private Laboratories and Mass Transit Railway Corporation and started meeting in September 1992. Work was completed in April 1995.

## CS2

3. This Standard incorporates the full product standard for carbon steel bars for the reinforcement of concrete BS 4449:1988 including the certification requirements and testing regimes for manufacturers covered by a certification scheme and those not covered by a certification scheme. This Standard also incorporates the Hong Kong requirements for classification and certification by QA Stockists, and end purchaser testing of the reinforcement.

## Fatigue Properties

4. Inherent in adopting BS 4449:1988 is the requirement for fatigue testing to be carried out during the manufacturing process and not all manufacturers worldwide are equipped to comply with this requirement. However, this is not seen as an insurmountable problem. Although it is a Code requirement in the UK, the determination of fatigue will not be mandatory in Hong Kong. Instead, the users will be free to decide, on the basis of the type of structure into which the steel bar reinforcement is to be cast, whether fatigue properties need to be determined.

5. In cases where the determination of fatigue properties is necessary, reinforcement should be purchased from a manufacturer carrying out the full product size range of fatigue testing on a three yearly cycle. All the reinforcement should be supplied from a manufacturer holding a third party certification and be traceable through the supply chain to the original production records for that cast of reinforcement, Class 1 reinforcement. Then end purchaser fatigue testing would not be necessary in Hong Kong.

## QA Stockists

6. QA Stockist classification and certification is included in this Standard to aid the Hong Kong purchaser in ascertaining the source and quality of reinforcement being supplied.

7. QA Stockists are required to be certified to the BSI QA System for Registered Stockist. Under this Standard the QA Stockist is to receive the bulk shipments of reinforcements usually from overseas, check the manufacturers documentation against the reinforcement supplied, and eventually dispatch the reinforcement to site clearly classified Class 1, 2 or 3 as appropriate.

**Quality Assurance**

8. BS 4449:1988 has a provision for third party certification of product conformity based on testing and continuous product surveillance coupled with assessment of a supplier's quality system against ISO 9002. Advantage is taken of this provision of quality assurance. Under a system of quality assurance the primary responsibilities for testing of the reinforcement and ensuring its compliance with the British Standard lie with the manufacturer of the reinforcement. A system of third party certification of the manufacturer to the quality standards of ISO 9002 is designed to ensure that this is being carried out properly.

9. All reinforcement used in Hong Kong must be manufactured strictly in accordance with BS 4449:1988. However, once the reinforcement is shipped into Hong Kong it is envisaged that most will be handled through a QA Stockist where classification and certification will be carried out. Reinforcement produced by Quality Assured Manufacturers and handled by a QA Stockist will be classified either Class 1, fully lot traceable, or Class 2, not lot traceable, and reinforcement produced by non Quality Assured manufacturers or not handled by a QA Stockist will be classified Class 3. All reinforcement will then be delivered to site and depending on the reinforcement classification, Class 1, Class 2 or Class 3, a series of purchasers tests will be carried out.

10. All reinforcement shipped to Hong Kong or manufactured locally and not handled through a QA Stockist will be classified Class 3 irrespective of whether it is quality assured material or not. It will be subject to purchasers tests for Class 3 reinforcement carried out when the reinforcement is delivered to site.

11. A series of purchasers tests is required to be carried out on all reinforcement delivered to site before it is used in the construction work. The frequency of testing will depend on the classification of the reinforcement; less frequent testing for Class 1 reinforcement where much is known about the manufacture and testing history; an increasing frequency of testing for Class 2 and Class 3 reinforcement where less is known about the quality of the reinforcement.

**Long Term Objective**

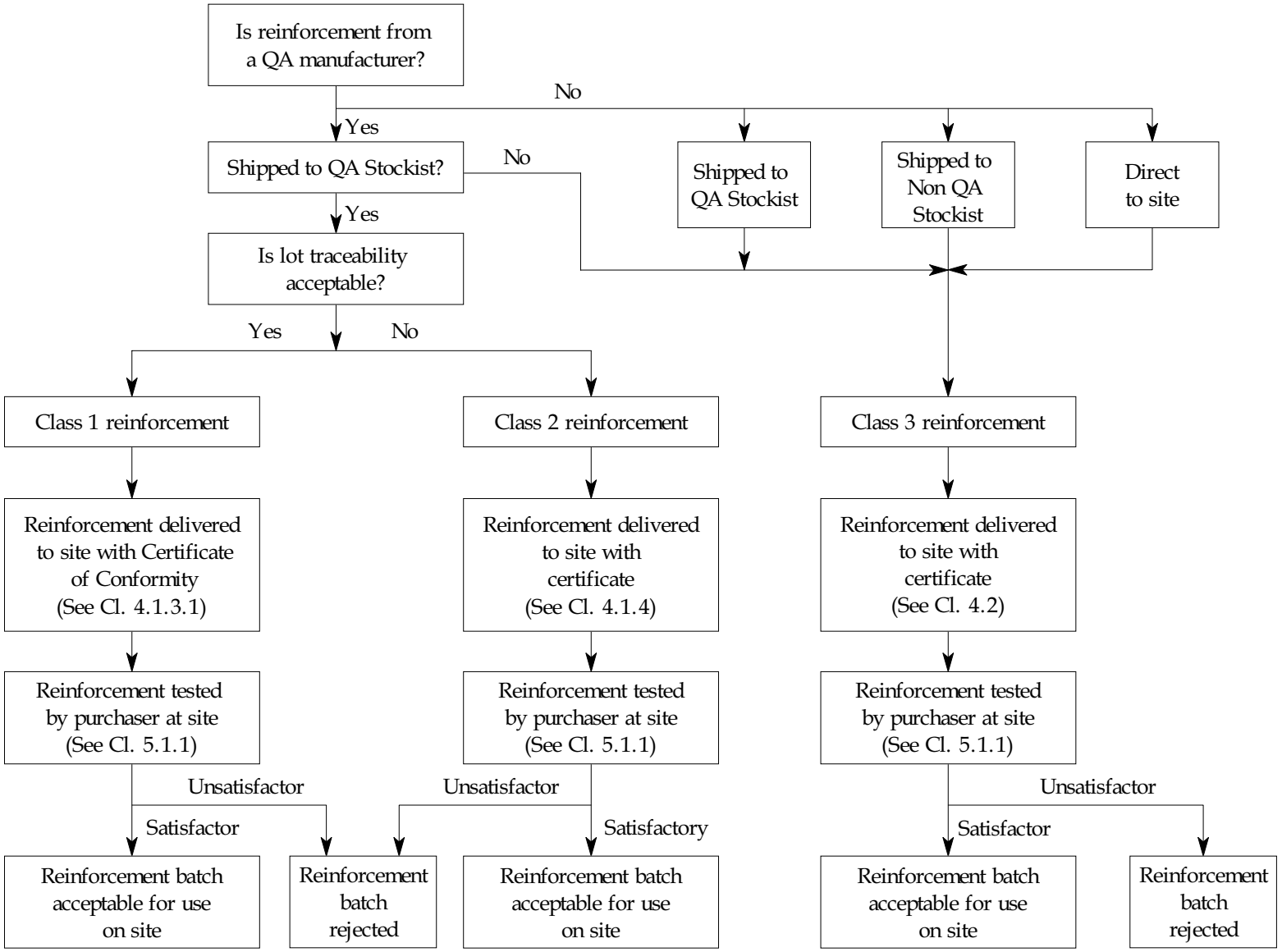
12. The long term objective is to rely on the third party certification of product conformity based on testing and continuous product surveillance and on the quality assurance of the stockists. The purchaser would know the quality of the reinforcement being received and would not need to carry out further testing for quality assured reinforcement.

13. However, in the initial stage of introducing this scheme, it is felt that end purchaser testing of quality assured reinforcement should continue. The Public Works Central Laboratory will monitor the results of these tests over a period of two years, after which a review of the purchaser testing requirements will be undertaken.

**Permission from the British Standards Institution**

14. Extracts from BS 4449:1988 are incorporated into this Standard with the permission from the British Standards Institution. Complete copies of the British Standard BS 4449:1988 can be obtained by post from BSI Sales, Linford Wood, Milton Keynes, MK14 6LE, UK.

## FLOWCHART FOR INSPECTION, TESTING AND CERTIFICATION OF REINFORCING STEEL BARS



# DRAFTING COMMITTEE

The preparation of this Standard was undertaken by a sub-committee of the Hong Kong Government, Works Branch, Standing Committee on Concrete Technology. The organizations represented on the Sub-Committee and the names of the persons who contributed to the drafting of the Standard are listed below :-

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# SECTION 1

## SPECIFICATION

### 1.1 SCOPE

This Construction Standard specifies requirements for weldable steel bars for the reinforcement of concrete. It covers plain round steel bars in grade 250 and deformed high yield steel bars in grade 460.

The weldability requirements for both grades of steel are specified in terms of the carbon equivalent value.

Note : 1. All steels complying with this Standard are of weldable quality. Welding procedures and consumables appropriate to the particular grade and quality should be used.

2. This Standard does not cover cold worked deformed bars.

### 1.2 DEFINITIONS

For the purposes of this Standard the following definitions apply.

#### 1.2.1 Bars

A steel product of plain round or deformed cross section.

#### 1.2.2 Hot rolled deformed bar

A bar which has been so shaped during hot rolling that it complies with the geometrical classification given in Cl. 1.8.

#### 1.2.3 Nominal size

The diameter of a circle with an area equal to the effective cross-sectional area of the bar.

#### 1.2.4 Yield stress

The stress measured during the tensile test when the total extension of the gauge length is that specified for the grade.

#### 1.2.5 Length

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

1.2.6 **Longitudinal rib**

A uniform continuous protrusion parallel to the axis of the bar.

1.2.7 **Transverse rib**

Any rib on the surface of the bar other than a longitudinal rib.

1.2.8 **Manufacturer**

An organization that produces reinforcing steel including steelmakers and re-rollers from billets or wire rod.

1.2.9 **Quality assured manufacturer**

A manufacturer with a third party certification of product conformity based on testing and continuous product surveillance.

1.2.10 **QA Stockist**

Any organization certified to the BSI QA System for Registered Stockists supplying reinforcing steel to a purchaser in accordance with this Standard.

1.2.11 **Purchaser**

The party that incorporates the reinforcing bar into the works and who will be responsible for carrying out the purchasers tests.

1.2.12 **Characteristic strength**

That value of the yield stress below which fall not more than 5% of the test results.

1.2.13 **Supplier**

QA Stockist or Non QA Stockist or manufacturer supplying reinforcement direct to site.

## 1.3 SIZES

### 1.3.1 Range

The preferred nominal sizes of bars are given in Table 1.

**Table 1 Preferred nominal sizes**

| Grade | Nominal size (mm) |
|---|---|
| 250 | 10, 12, 16 |
| 460 | 10, 12, 16, 20, 25, 32, 40 |

Note 1. If a bar smaller than 10 mm is required, the recommended size is 8 mm or 6 mm.

Note 2. If a bar larger than 40 mm is required, the recommended size is 50 mm.

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### 1.3.2 Tolerance

The deviation of any cross-sectional dimension, other than those of ribs, from its nominal size, shall not exceed 8%.

## 1.4 CROSS-SECTIONAL AREA AND MASS

The cross-sectional area and mass of the bars shall be calculated on the basis that these steels have a mass of 0.00785 kg/mm² per metre run.

The values for the nominal cross-sectional area shall be as given in Table 2. The mass of individual bars shall be as given in Table 2, subject to the tolerances given in Table 3. For bars where the effective cross-sectional area is determined as in Appendix A.2, the nominal mass per metre run shall equate to the gross mass per metre run.

The total cross-sectional area and total mass of two or more bars shall be calculated pro-rata on the basis of the values for an individual bar. All cross-sectional areas derived from the values in Table 2 shall be expressed to three significant figures.

| Table 2 Cross-sectional area and mass | | |
|---|---|---|
| Nominal size (mm) | Cross-sectional area ($mm^2$) | Mass per metre run (kg) |
| 6 * | 28.3 | 0.222 |
| 8 * | 50.3 | 0.395 |
| 10 | 78.5 | 0.616 |
| 12 | 113.1 | 0.888 |
| 16 | 201.1 | 1.579 |
| 20 | 314.2 | 2.466 |
| 25 | 490.9 | 3.854 |
| 32 | 804.2 | 6.313 |
| 40 | 1256.6 | 9.864 |
| 50 * | 1963.5 | 15.413 |
| * These are non-preferred sizes | | |

| Table 3 Tolerance on mass | |
|---|---|
| Nominal size (mm) | Tolerance on mass per metre run (%) |
| 6 | ± 9.0 |
| 8 and 10 | ± 6.5 |
| 12 and over | ± 4.5 |

## 1.5 LENGTH

Each bar shall be cut to ± 25 mm of the length specified by the purchaser.

Where a minimum length is requested it shall be subject to a tolerance of +50 mm/-0 mm.

Where a maximum length is requested it shall be subject to a tolerance of +0 mm/-50 mm.

## 1.6 STEELMAKING PROCESS

The steel shall be made by refining molten iron in a top-blown basic oxygen converter or by melting in a basic-lined electric arc furnace.

## 1.7 CHEMICAL COMPOSITION

### 1.7.1 Cast analysis

The chemical composition of the steel based on cast analysis shall be in accordance with Table 4. The analysis shall include the elements listed in Table 4 and those in the formula for the carbon equivalent value.

The two grades shall have a carbon equivalent value, based on cast analysis, not exceeding the maximum values given in Table 5.

The following formula shall be used to calculate the carbon equivalent value where the individual values are calculated as percentages.

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

In cases of dispute the appropriate methods of test given in BS 6200:Part 3 shall be used.

**Table 4 Chemical composition of steel grades : cast analysis**

| Element | Grade 250 (% max) | Grade 460 (% max) |
|---|---|---|
| Carbon | 0.25 | 0.25 |
| Sulphur | 0.060 | 0.050 |
| Phosphorus | 0.060 | 0.050 |
| Nitrogen | 0.012 | 0.012 |

Note 1. The maximum value for nitrogen does not apply if the chemical composition shows a minimum aluminium content of 0.020% or if sufficient other nitrogen binding elements are present.

Note 2 Nitrogen is not normally quoted on a release certificate.

**Table 5 Maximum carbon equivalent values : cast analysis**

| Grade | Maximum carbon equivalent value (%) |
|---|---|
| 250 | 0.42 |
| 460 | 0.51 |

1.7.2 **Product analysis and permitted deviations**

1.7.2.1 The product analysis may vary from the cast analysis due to heterogeneity arising during casting and solidification. The maximum deviations on product analysis from the values specified for cast analysis (see Tables 4 and 5) shall be as given in Table 6.

**Table 6 Maximum deviations in chemical composition on product analysis**

| Element | Deviation above the specified maximum given in tables 4 and 5 (%) |
|---|---|
| Carbon | 0.02 |
| Sulphur | 0.005 |
| Phosphorus | 0.005 |
| Total nitrogen | 0.001 |
| Carbon equivalent value | 0.03 |

1.7.2.2 Samples for product analysis shall be taken in accordance with the appropriate method of BS 6200:Part 3.

1.7.2.3 Any bar which on product analysis falls outside the limits of maximum deviation from the specified composition range for a specified element given in Table 6 shall be deemed not to comply with this Standard.

1.7.2.4 In the event of a single sample falling outside the maximum deviations on the product analysis given in Table 6, further samples shall be selected for check analysis 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 these further samples are proved to be outside the maximum deviation for any element given in Table 6 the batch shall be deemed not to comply with this Standard.

1.8 **DEFINITION OF DEFORMED BARS**

Deformed bars shall be determined by their surface shape.

The surface shape shall be that of a bar with transverse ribs with a substantially uniform spacing not greater than 0.8 $\Phi$, having a mean area of ribs (per unit length) above the core of the bar projected on a plane normal to the axis of the bar not less than 0.15 $\Phi$ mm²/mm, where $\Phi$ is the nominal bar size (in mm).

Note : Recommended formulae for the calculation of the projected rib area are given in Appendix C.

## 1.9 MECHANICAL PROPERTIES

All bars should be free from defects, e.g. seams, porosity, segregation, non-metallic inclusions etc., which can be shown to adversely affect the mechanical properties.

### 1.9.1 Tensile properties

1.9.1.1 The tensile properties of the steel obtained from test specimens selected, prepared and tested in accordance with Cl. 6.1 and 6.2, shall comply with Cl. 1.9.1.2 and 1.9.1.3.

1.9.1.2 The specified characteristic strength and elongation of the two strength grades of steel shall be as given in Table 7.

1.9.1.3 The tensile strength shall be either :

(a) at least 10% greater than the actual yield stress measured in the tensile test in accordance with Cl. 6.2; or

(b) between 5% and 10% greater than the actual yield stress measured in the tensile test in accordance with Cl. 6.2. In this case the actual yield stress shall be not less than the value determined from the following formula, in MPa :

$$A\,(2.1 - B)$$

where $A$ is either 250 or 460 according to the grade concerned;

$B$ is the ratio of measured tensile strength to actual yield stress.

**Table 7 Tensile properties**

| Grade | Specified characteristic strength ($cv$) (MPa) | Minimum elongation on gauge length $5d$* % |
|---|---|---|
| 250 | 250 | 22 |
| 460 | 460 | 12 |
| *$d$ is the nominal size of the test piece | | |

Note : The method of calculation of the effective cross-sectional area of deformed bars is given in Appendix A.

### 1.9.2 Bend test

The method of bend testing shall be in accordance with Cl. 6.3. The test specimens shall withstand being bent through 180° round a former of the diameter specified in Table 11. For the purpose of this test, the presence of any mill scale shall be ignored. The test specimens shall show no sign of fracture on visual examination.

1.9.3 **Rebend test**

When test specimens selected and prepared in accordance with Cl. 6.4 are subjected to the test described, the test specimens shall show no sign of fracture or irregular bending deformation.

## 1.10 FATIGUE PROPERTIES OF DEFORMED BAR

Fatigue properties testing of deformed bars is an optional requirement as required by the purchaser. The purchaser should decide, on the basis of the type of structure into which the steel bar reinforcement is to be cast, whether fatigue properties are to be determined. Where fatigue properties are to be determined, the reinforcement shall be Class 1 as described in Cl. 2.1 and the deformed bars shall be subjected to testing as described in Cl. 6.5.

## 1.11 MARKING

Deformed bars shall be identified by rolled-on legible marks on the surface at intervals not greater than 1.5 m to indicate the origin of manufacture.

# SECTION 2

## CLASSIFICATION

### 2.1 CLASSIFICATION OF STEEL BAR REINFORCEMENT

All steel bar reinforcement shall be classified as follows :-

(a) **Class 1 reinforcement**

Reinforcement from quality assured manufacturers, handled by a QA Stockist and retaining manufacturer's lot traceability.

(b) **Class 2 reinforcement**

Reinforcement from quality assured manufacturers, handled by a QA Stockist but without manufacturer's lot traceability.

(c) **Class 3 reinforcement**

Reinforcement other than Class 1 and Class 2 reinforcement.

# SECTION 3

## MANUFACTURER'S INSPECTION, TESTING AND CERTIFICATION

### 3.1 MANUFACTURER'S INSPECTION AND TESTING

#### 3.1.1 General

All units of continuous production shall be tested and certified in accordance with Cl. 3.1.2 to 3.1.10.

#### 3.1.2 Selection of test specimens

The unit of production from which test specimens are selected shall be the cast.

Test specimens shall be either at least 600 mm long or 20 times the nominal size, whichever is the greater. The rate of testing shall be :

(a) for casts of 100 t or less : 3 tensile tests, 1 bend test and 1 rebend test;

(b) for casts greater than 100 t : 3 tensile tests, 1 bend test and 1 rebend test and an additional tensile, bend and rebend test for each 30 t or part of 30 t.

#### 3.1.3 Conditions of test specimens

The condition of test specimens shall be in accordance with Cl. 6.1.

#### 3.1.4 Tensile test

The tensile test shall be carried out in accordance with Cl. 6.2.

#### 3.1.5 Evaluation of tensile test results

3.1.5.1 The following requirements on the individual values ($x$) and on the average value ($m$) of the cast shall be met in assessing the characteristic strength.

(a) $x \geq 0.93 \times cv$, where $cv$ is the characteristic strength specified in Table 7.

(b) $m \geq cv + a$, where $a = 10$ MPa.

Note : It is not necessary to assess the mean value m of the cast if all individual values of $x$ are equal to or greater than the characteristic strength $cv$.

3.1.5.2 Each individual value for the tensile strength shall comply with the requirements of Cl. 1.9.1.3 and each individual value of the elongation shall comply with that specified in Table 7.

3.1.6 **Bend test**

The test specimens shall withstand being bent through 180° as specified in Cl. 6.3. There shall be no transverse rupture of the surface of the metal. For the purpose of this test, the presence of any mill scale shall be ignored.

3.1.7 **Rebend test**

The test specimens shall withstand being bent and rebent as specified in Cl. 6.4. The test specimens shall show no sign of fracture or irregular bending deformation.

In the event of failure in relation to rib damage, if there is any damage to the ribs caused by carrying out the initial bending, the test shall be considered invalid, and the test shall be repeated on another specimen.

Note : Damage to the ribs may be avoided by the use of an aluminium sheet insert placed between the specimen and the former. The maximum thickness of the aluminium sheet insert is 6 mm.

3.1.8 **Cross-sectional area and mass**

All individual values determined in the tensile test shall comply with the requirements of Cl. 1.4.

3.1.9 **Chemistry**

The cast analysis shall comply with the chemical composition requirements of Cl. 1.7.1.

3.1.10 **Test records**

The manufacturer shall maintain a record of the test results for a period of 10 years from the date of testing. These shall be made available for inspection, on request, by the purchaser or his representative.

## 3.2 MATERIAL FROM QUALITY ASSURED MANUFACTURERS

3.2.1 For the purpose of determining the consistency of the manufacturer's production the long term quality level shall be assessed at regular intervals.

3.2.2 **Determination of the long term quality level**

3.2.2.1 The yield stress results obtained on all casts for each size shall be collated at intervals of 3 months or after at least 200 results have been obtained. These shall be used to determine the long term quality level.

3.2.2.2 The average value $m$, shall satisfy the following requirements :

$$m \geq cv + k\sigma$$

where

$\sigma$ is the standard deviation of the population;
$cv$ is the characteristic strength specified in Table 7.
$k$ is the acceptability index for which values are given in Table 8.

**Table 8 Acceptability index ($k$) as a function of the number ($n$) of the test results (for a reliable failure rate of 5% (pass = 0.95) at a probability of 90% (1 - $\alpha$ = 0.90))**

| $n$ | $k$ |
|---|---|
| 5 | 3.40 |
| 6 | 3.09 |
| 7 | 2.89 |
| 8 | 2.75 |
| 9 | 2.65 |
| 10 | 2.57 |
| 11 | 2.50 |
| 12 | 2.45 |
| 13 | 2.40 |
| 14 | 2.36 |
| 15 | 2.33 |
| 16 | 2.30 |
| 17 | 2.27 |
| 18 | 2.25 |
| 19 | 2.23 |
| 20 | 2.21 |
| 30 | 2.08 |
| 40 | 2.01 |
| 50 | 1.97 |
| 60 | 1.93 |
| 70 | 1.90 |
| 80 | 1.89 |
| 90 | 1.87 |
| 100 | 1.86 |
| 150 | 1.82 |

| **Table 8** | **Acceptability index (*k*) as a function of the number (*n*) of the test results (for a reliable failure rate of 5% (pass = 0.95) at a probability of 90% (1 - $\alpha$ = 0.90))** |
|---|---|
| *n* | *k* |
| 200 | 1.79 |
| 250 | 1.78 |
| 300 | 1.77 |
| 400 | 1.75 |
| 500 | 1.74 |
| 1000 | 1.71 |
| ∞ | 1.64 |

3.2.3 **Test Certificates**

3.2.3.1 **Certificate of Compliance**

A certificate of compliance shall be issued by a manufacturer when requested. This shall state :

(a) that the material supplied complies with and has been tested at the frequency specified in this Standard;

(b) the address at which the record of test results is available for inspection.

The certificate shall include the approval number issued by the Certifying Authority.

3.2.3.2 **Certificate of routine testing**

Upon delivery of steel bar reinforcement, the manufacturer shall issue a certificate of routine testing stating the following :-

(a) The cast number and cast analysis. The cast analysis shall include all specified elements and those used for the calculation of the carbon equivalent value.

(b) The carbon equivalent value.

(c) The individual results of the tensile, bend and rebend tests on specimens taken from the material. The tensile test results shall include the effective cross-sectional area.

(d) In the case of deformed bars, the rolled on mill mark.

The certificate shall include the approval number of the third party product certification scheme issued by the Certifying Authority, if applicable.

## 3.3 MATERIAL FROM NON QUALITY ASSURED MANUFACTURERS

3.3.1 Materials from Non Quality Assured manufacturers shall be assessed by acceptance tests on each batch. Sampling and testing shall be carried out by an organization independent of the manufacturer at the manufacturer's works.

3.3.2 **Extent of sampling and testing**

For the purpose of testing, the delivery is to be subdivided into test units with a maximum mass of 100 tonnes each. Each test unit shall consist of products of the same steel grade and the same nominal diameter from the same cast. The manufacturer shall confirm in the certification that all products in the test unit originate from one cast.

Test specimens shall be taken from each test unit as follows :

(a) 15 test specimens (if appropriate 60 test specimens) from different bars for testing in accordance with Cl. 3.3.3 (a) and 3.3.3 (b);

(b) 2 test specimens from different bars for testing the chemical composition in the product (see Cl. 3.3.3 (c)).

The preparation of test specimens shall be carried out as described in Cl. 6.1.

3.3.3 **Properties to be tested**

The following properties are to be determined in testing the test specimens which have been taken in accordance with Cl. 3.3.2.

(a) Inspection by variables

(1) Tensile strength ( $R_m$ )

(2) Yield point ( $R_e$ )

(3) Elongation after fracture ( $A_5$ )

(b) Inspection by attributes

(1) Behaviour in the bend test

(2) Behaviour in the rebend test

(3) Deviations from the nominal cross-section

(4) Bond test

(c) Chemical composition according to the product analysis

All elements listed in Cl. 1.7 and the carbon equivalent are to be determined.

The test procedures shall be as described in Cl. 6.

3.3.4 **Evaluation of the results**

3.3.4.1 Inspection by variables. Inspection by variables shall be carried out as follows.

(a) The following indices are to be determined when testing for the properties listed in Cl. 3.3.3 (a).

(1) all individual values $x$ of the 15 test specimens ($n$ = 15)

(2) the mean value $m_{15}$ (for $n$ = 15)

(3) the standard deviations $S_{15}$ (for $n$ = 15)

The test unit shall be deemed to comply with the requirements of this Standard if the condition $m_{15}$ - 2.33 x $S_{15} \geq cv$ is fulfilled by the characteristic strength.

where

$x$ is as defined in Cl. 3.1.5.1;
$m$ is as defined in Cl. 3.1.5.1;
$n$ is the number of test specimens as given in Table 8;
2.33 is the value for the acceptability index $k$;
$cv$ is the characteristic strength specified in Table 7.

(b) If the condition stated in Cl..3.3.4.1 (a) is not fulfilled, the secondary calculation of the acceptability index

$$k' = \frac{m_{15} - cv}{S_{15}}$$

is to be determined from the test results available. Where $k' \geq 2$, testing can be continued. In this case 45 further test specimens shall be taken and tested from different bars in the test unit, so that a total of 60 test results are available ($n$ = 60).

The test unit shall be deemed to comply with the requirements of this Standard if the condition

$$m_{60} - 1.9 \, x \, S_{60} \geq cv$$

is fulfilled for all properties (1.93 is the value for the acceptability index $k$ for $n$ = 60 in accordance with Table 8).

3.3.4.2 Inspection by attributes. Inspection by attributes shall be carried out as follows.

(a) When testing the properties listed in Cl.3.3.3 (b) either all results determined on the 15 test specimens shall comply with the requirements of this Standard; or

(b) If a maximum of 2 of the 15 results do not comply with the requirements of this Standard, 45 further test specimens shall be taken and tested from different bars in the test unit, so that a total of 60 test results are available. The test unit shall be deemed to comply with this Standard if no more than 2 of the 60 test results do not comply with the requirements of this Standard.

3.3.4.3 **Chemical composition**

Any bar which on product analysis falls outside the limits of maximum deviation from the specified composition range for a specified element given in Table 6 shall be deemed not to comply with this Standard.

3.3.5 **Test report**

Upon delivery of steel bar reinforcement the manufacturer shall issue a test report containing the following data :

(a) Works producing the steel bar reinforcement

(b) Nominal diameter

(c) Grade of steel bar reinforcement

(d) Marking on the reinforcement

(e) Cast number

(f) Date of testing

(g) Mass of the test unit

(h) The individual test results for all the properties specified in Cl. 3.3.3.

# SECTION 4

## STOCKIST'S OR SUPPLIER'S CLASSIFICATION AND CERTIFICATION

### 4.1 QA STOCKIST'S CLASSIFICATION AND CERTIFICATION OF STEEL BAR REINFORCEMENT

#### 4.1.1 Application

This section applies to Stockists certified by the Hong Kong Quality Assurance Agency, or equivalent body, to the BSI QA System for Registered Stockists ISO 9002.

#### 4.1.2 Classification

The QA Stockist shall classify the reinforcement arriving in his yard as follows :-

(a) Steel bar reinforcement from a quality assured manufacturer shall be classified either Class 1 or Class 2; or

(b) Steel bar reinforcement from a non quality assured manufacturer shall be classified Class 3.

#### 4.1.3 Certificates for Class 1 reinforcement

##### 4.1.3.1 Stockist certificate

If the reinforcement is classified as Class 1 reinforcement, a certificate shall be issued by the QA Stockist. This shall state :

(a) The QA Stockist's name and address.

(b) The date of dispatch.

(c) The customer's order number or other reference.

(d) Product description and quantity supplied.

(e) The QA Stockist's and manufacturer's ISO 9002 certification number and the approval number issued by the certifying authority.

(f) Cast number, batch number or lot number.

(g) Certificate serial number and date.

(h) Manufacturer's certificate reference number.

(i) The following statement, authorized by a designated means to indicate that the requirements of the Scheme are satisfied :

Certified that the steel reinforcement bars supplied hereon are covered by the manufacturer's Certificate of Conformity or Test Certificate referenced hereon and have been subjected to the lot traceable part of our Certification to BSI QA System for Registered Stockists ISO 9002.

4.1.3.2 **Manufacturer's certificate**

A copy of the manufacturer's certificate of routine testing for each cast of reinforcement delivered shall be provided by the QA Stockist.

The QA Stockist should make available for inspection, the original manufacturer's certificate of routine testing as well as a copy of the reinforcement manufacturer's third party certificate if required.

4.1.4 **Certificate for Class 2 reinforcement**

If the reinforcement is classified as Class 2 reinforcement, a certificate shall be issued by the QA Stockist. This shall state :

(a) The QA Stockist's name and address.

(b) The date of dispatch.

(c) The customer's order number or other reference.

(d) Product description and quantity supplied.

(e) The QA Stockist's and manufacturer's ISO 9002 certification number and the approval number issued by the certifying authority.

(f) Cast number, batch number or lot number.

(g) Certificate serial number and date.

(h) Manufacturer's certificate reference number.

(i) Classification of reinforcement i.e. Class 2 in accordance with this Standard.

## 4.2 SUPPLIER'S CLASSIFICATION OF CLASS 3 REINFORCEMENT

If the reinforcement is classified as Class 3 reinforcement, a certificate shall be issued by the Supplier. This shall state :

(a) The Supplier's name and address.

(b) The date of dispatch.

(c) The customer's order number or other reference.

(d) Product description and quantity supplied.

(e) Name of manufacturer.

(f) Cast number, batch number or lot number.

(g) Copy of manufacturer's certificate.

(h) Classification of reinforcement. i.e. Class 3 in accordance with this Standard.

# SECTION 5

## PURCHASERS TESTING

### 5.1 PURCHASER'S TESTS OF STEEL BAR REINFORCEMENT

#### 5.1.1 General

All steel bar reinforcement arriving on site shall be tested by the purchaser. All tests shall be performed by a laboratory accredited by HOKLAS to carry out the tests in accordance with this Standard and test certificates shall be HOKLAS endorsed. For the purpose of testing, the reinforcement is to be subdivided into batches. Each batch shall consist of reinforcement of the same steel grade and the same nominal diameter. Test specimens shall be taken from each batch and the rate of testing shall be in accordance with Table 9 :-

Tensile, bend and rebend tests shall be carried out in accordance with Cl. 6.

#### 5.1.2 Evaluation of test results

(a) Tensile test

The following requirements on the individual values, $x$, and on the average value, $m$, of the batch shall be met in assessing the characteristic strength.

(A) $x \geq 0.93 \times cv$ where $cv$ is the characteristic strength in Table 7.

(B) $m \geq cv + a$, where $a = 10$ MPa.

Note : It is not necessary to assess the mean value $m$ if all individual values of $x$ are equal to or greater than the characteristic strength $cv$.

In addition each individual value for the tensile strength shall be in accordance with Cl. 1.9.1.3 and each individual value of the elongation shall be in accordance with Cl. 1.9.1.2.

(b) Bend test

The method of bend testing shall be as given in Cl. 6.3. The test specimens shall withstand being bent through 180° round a former of the diameter specified in Table 11. For the purpose of this test, the presence of any mill scale shall be ignored. The test specimens shall show no sign of cracks on visual examination.

(c) Rebend test

When test specimens selected and prepared in accordance with Cl. 6.4 are subjected to the test described, the test specimens shall not break into two pieces.

**Table 9 Rate of purchaser's tests**

| Description | No. of test specimens per batch | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class 1 | | | | Class 2 | | | | Class 3 | | | |
| | Size of batch | Tensile | Bend | Rebend | Size of batch | Tensile | Bend | Rebend | Size of batch | Tensile | Bend | Rebend |
| Bar reinforcement nominal size 6 mm - 16 mm | 0 - 60 tonnes | 3 | 1 | 1 | 0 - 35 tonnes | 3 | 1 | 1 | 0 - 35 tonnes | 10 | 1 | 1 |
| | each additional 60t or part of 60t | 1 | Nil | Nil | each additional 35t or part of 35t | 3 | Nil | Nil | each additional 10t or part of 10t | 3 | Nil | Nil |
| Bar reinforcement nominal size 20 mm - 32 mm | 0 - 80 tonnes | 3 | 1 | 1 | 0 - 45 tonnes | 3 | 1 | 1 | 0 - 45 tonnes | 10 | 1 | 1 |
| | each additional 80t or part of 80t | 1 | Nil | Nil | each additional 45t or part of 45t | 3 | Nil | Nil | each additional 15t or part of 15t | 3 | Nil | Nil |
| Bar reinforcement nominal size exceeding 32 mm | 0 - 100 tonnes | 3 | 1 | 1 | 0 - 55 tonnes | 3 | 1 | 1 | 0 - 55 tonnes | 10 | 1 | 1 |
| | each additional 100t or part of 100t | 1 | Nil | Nil | each additional 55t or part of 55t | 3 | Nil | Nil | each additional 20t or part of 20t | 3 | 1 | 1 |

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 satisfy the requirements of this Standard.

5.1.4 **Retests**

If any test specimen fails to meet the tensile strength, elongation, bend or rebend test requirements, two additional test specimens may be taken from different bars of the same batch and be subjected to the test or tests which the original specimen failed. If both additional test specimens pass the retests the batch from which they were taken shall be deemed to comply with this Standard. If either of them fails, the batch shall be deemed not to comply with this Standard.

# SECTION 6

## METHOD OF TESTING

### 6.1 CONDITION OF TEST SPECIMENS

The tensile, bend and rebend tests shall be carried out on straight bars in the delivery condition. Bars with a nominal diameter of 40 mm or less shall not be machined. The test specimens shall be at a temperature between 5°C and 30°C unless specified otherwise.

Note : At the option of the manufacturer, QA Stockist or purchaser and in order to simulate natural ageing, test specimens may be subjected to a temperature of $100^0$C for a period of not more than 2 hours, provided that both the tensile and rebend test samples are so treated and the fact is recorded on the test certificates.

The length of the test pieces for bend and rebend tests shall be adjusted to suit the type of test machine in use and must be sufficient to be bent to comply with the requirements of Cl. 6.3 and 6.4.

In the case of 50 mm hot rolled grade 460 bars, where a tensile testing machine of adequate capacity is not available, the bars may be machined to 40 mm diameter for tensile testing providing that there are multiplying factors predetermined by testing similar specimens of such bars as-rolled and machined as described in Appendix B.

In the case that the 50 mm hot rolled grade 460 bars are machined to 40 mm diameter for tensile testing, the gripped ends shall be co-axial with and have the same dimension of the parallel length of the machined test piece.

### 6.2 TENSILE TEST

Determine the tensile strength, yield stress and elongation of the steel by the methods described in BS 18 except where otherwise stated below, but using an extensometer calibrated in accordance with grade D or better of BS 3846.

Use a strain rate corresponding to a rate of loading not exceeding 10 MPa per second approaching the yield stress. The yield stress shall be derived from the load on the specimen corresponding to an increase measured by the extensometer of percentage total strain specified in Table 10 on any convenient gauge length.

| Table 10 Percentage total strain | |
|---|---|
| Specified characteristic strength ($N/mm^2$) | Percentage total strain (%) |
| 250 | 0.33 |
| 460 | 0.43 |

Note : It is recommended that test pieces be lightly scribed at one diameter (d) or 10 mm centres, whichever is more convenient, throughout their length, and that a gauge length be selected that is as nearly symmetrical about the fracture as possible and is clear of the machine grips.

For elongation values, regard the test results as valid, irrespective of the position of the fracture, provided that the minimum elongation specified in Table 7 has been obtained.

Where the minimum elongation is not obtained the sample shall be deemed not to comply with this standard, except in the following cases, where the test results shall be considered invalid :

(a) if the distance between the fracture and the nearer gauge mark is less than one third of the gauge length, or;

(b) if the relevant end of the gauge length used for measuring elongation is 2d or less away from the face of the testing machine grips.

Calculate the stresses using the effective cross-sectional area of the bar determined by weighing as described in Appendix A.

## 6.3 BEND TEST

The 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 piece, or ;

(b) on a 3-point hydraulic bending machine.

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

The maximum bending rate shall be 3 revolutions per minute or equivalent.

The test specimens shall withstand being bent through 180° round a former of the diameter specified in Table 11.

**Table 11 Bend test formers**

| Grade | Diameter of former |
|---|---|
| 250 | Twice the nominal size of the bar |
| 460 | Three times the nominal size of the bar |

## 6.4 REBEND TEST

Subject the test specimens to the following sequence of operations :

(a) bend the test specimen through 45° using the method of bending described in Cl. 6.3 round a former of diameter as specified in Table 12;

(b) immerse the test specimen in boiling water and keep the water boiling for not less than 30 min;

(c) allow the test specimen to cool to a temperature between 5°C and 30°C and bend it back towards its original shape (partially restraightened) by a steadily applied force through at least 23° on the same bending machine as used in (a) above.

**Table 12 Rebend test formers**

| Grade | Diameter of former |
|---|---|
| 250 | Twice the nominal size of the bar |
| 460 | Five times the nominal size of the bar |

## 6.5 METHOD OF TEST FOR FATIGUE PROPERTIES OF DEFORMED BARS

### 6.5.1 Fatigue Testing

The fatigue properties for each defined bar shape and process route shall be established by a competent test laboratory initially by testing three sizes selected from the top, intermediate and bottom of the preferred size range. The full product size range shall be tested on a three yearly cycle.

Testing shall be carried out in batches on bars in the commercially straight condition. Bars shall be deemed defective or non-defective depending upon their ability to endure $5 \times 10^6$ cycles of stress at the stress range given for the relevant bar size in Table 13.

6.5.2 **Sampling**

For sampling purposes bars shall be formed into batches of 50 bars of a single type and size, manufactured at the same time. Test specimens shall not be taken from bars exhibiting isolated defects which are not characteristic of the product. Each test specimen shall be cut from a bar selected at random and shall have a minimum length of 30 *d* and a minimum free length of 10 *d* where *d* is the nominal diameter of the test specimen. The test unit shall comprise five test specimens.

6.5.3 **Test procedure**

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

The batch shall be deemed to comply with this Standard provided that the number of cycles of stress specified in clause 11 have been achieved. Where this has not been achieved, the tests shall be considered invalid if the failure initiated from a defect unique to the test specimen or in an area adjacent to the testing machine grips.

6.5.4 **Retests**

The batch shall be deemed to comply with this Standard if all five test specimens endure 5 x $10^6$ cycles of stress.

Where two or more test specimens of the five initially selected fail to endure 5 x $10^6$ cycles, the batch represented shall be deemed not to comply with this Standard.

If one valid test specimen fails, a further five test specimens shall be selected from the batch represented. If one or more of these test specimens fails, the batch shall be deemed not to comply with this Standard.

**Table 13 Test stress ranges for nominal bar sizes**

| Bar size mm | Stress range N/mm² |
|---|---|
| Up to and including 16 | 200 |
| Over 16 up to and including 20 | 185 |
| Over 20 up to and including 25 | 170 |
| Over 25 up to and including 32 | 160 |
| Over 32 up to and including 40 | 150 |

## Appendix A - DETERMINATION OF THE EFFECTIVE CROSS-SECTIONAL AREA OF DEFORMED BARS

### A.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 gross cross-sectional area, in millimetres squared, determined by weighing and measuring to a precision of ± 0.5% a length of not less than 0.5 m and calculated as follows :

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

where $M$ is the mass of the bar (in kg);

$L$ is the length of the bar (in m);

### A.2 Variable cross-sectional area

A.2.1 For a bar where the cross-sectional area varies along its length, a sample not less than 0.5 m shall be weighed ($M$) and measured to a precision of ± 0.5% in the as-manufactured condition, and after the transverse ribs have been removed it shall be reweighed ($M'$).

A.2.2 Where the difference between the two masses ($M$ - $M'$) is less than 3% of $M'$, the effective cross-sectional area shall be obtained as in Appendix A.1.

A.2.3 Where the difference between the two masses ($M$ - $M'$) is equal to or greater than 3% of $M'$, the effective cross-sectional area $A$, in millimetres squared, shall be calculated as follows :

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

where $M'$ is the mass of the bar with transverse ribs removed (in kg);

$L$ is the length of the bar (in m).

For routine test purposes a nominal ratio of effective to gross cross-sectional area of bars covered by Appendix A.2.3 shall be stated and used by the manufacturer.

## Appendix B - TENSILE TEST MULTIPLYING FACTORS

B.1 Hot rolled grade 460 bars of 50 mm diameter may be machined to 40 mm diameter for testing purposes. In this case for each type of bar and pattern of deformations multiplying factors are to be used to convert the test values measured on the machined test specimen to equivalence values for the as-rolled bar.

B.2 For each type of bar and pattern of deformation the multiplying factors are to be determined once and for all by comparative testing of 25 adjacent pairs of test specimens cut from at least 5 bars.

B.3 The tensile tests on the as-rolled test specimens of each pair are to be carried out using an extensometer to record the total extension on the gauge length of 0.5%. The tensile tests on the machined test specimens are to be carried out using the same testing machine and extensometer.

The multiplying factors shall be calculated as follows :

$$r_y = \frac{Y_a}{Y_m}$$

$$r_u = \frac{T_a}{T_m}$$

$$r_e = \frac{E_a}{E_m}$$

where $Y_a$ is the yield stress of the as-rolled test piece (in MPa);

$Y_m$ is the yield stress of the machined test piece (in MPa);

$T_a$ is the tensile strength of the as-rolled test piece (in MPa);

$T_m$ is the tensile strength of the machined test piece (in MPa);

$E_a$ is the elongation of the as-rolled test piece (in %);

$E_m$ is the elongation of the machined test piece (in %);

The converted test results shall be given on the test certificate.

## Appendix C - RECOMMENDED FORMULA FOR CALCULATING PROJECTED RIB AREA

The projected rib area $R$, in millimetres squared per millimetre, for as-rolled deformed bars should be calculated using the following equation :

$$R = n\frac{la\sin\beta}{c}$$

where $n$ is the number of rows of transverse ribs. When more than one pattern of transverse ribs exists, e.g. alternate ribs having different angles or different rib patterns in each row, the first term shall be the sum of the calculated values for each set of ribs.

$l$ is the length of the transverse rib measured at the rib to core interface determined as the average of three measurements on each row or set of transverse ribs (in mm).

$a$ is the height of the transverse rib measured perpendicular to the core of the bar determined as the average of three measurements on each row or set of transverse ribs (in mm) (using Simpsons's rule for approximation under a curve, with rib height measurements at the mid and quarter points, the rib height for each rib profile may be established as a proportion of its mid point height. For transverse ribs of parabolic profile the rib height shall be taken as 2/3 of the mid point height).

$\beta$ is the angle of the centre line of the transverse rib to the bar axis (in degrees).

$c$ is the centre to centre spacing of transverse ribs determined by dividing the distance, measured parallel to the axis of the bar, between the mid points of two ribs, of the order of ten ribs apart, by the number of rib spaces in between.