Standards, Codes and Regulations

1.0 Introduction

The production of a European standard for reinforcing steels began in 1988. The key stumbling block to bringing what may be regarded as a 'normal' European standard to fruition remains the inability to agree a common set of steel grades and associated bar marking. This problem still exists, and the current European standard EN 10080, is an 'open' standard, i.e. with no steel grades. The process was further interrupted by the requirement for the standards committee to account for the requirements placed upon it by the Construction Products Regulation, which required the standard to be structured in such a way as to enable the application of the CE Marking, including the associated certification. This is termed 'harmonisation'.

Running in parallel to this process was the creation of a European Concrete design code, BS EN 1992-1-1, Eurocode 2, Design of Concrete Structures, which provides the base design specification for the European product standards. This has now been issued, superceding the UK's National design code, BS8110, Structural use of concrete – code of practice for design and construction.

One key aim was to ensure that a package of European codes and standards was issued at approximately the same time, thereby enabling a smooth transition to emerging codes and standards, bearing in mind their interdependence. Despite the delay in issuing a 'harmonised' European Standard for reinforcing steels, BS4449, BS4483 and BS8666 were re-issued in 2005, correlating with the draft of BS EN10080 at that time. Whilst this suite of documents is being used successfully, it must be stressed that the operation of sound management systems throughout the concrete supply chain will ensure that 'old' and 'new' standards and codes will be able to be run successfully in parallel for a period of time.

This part of the CARES Guide describes the key differences between the 'old' and 'new' systems, showing how they can be used during any continuing co-existence period. It also describes the key area of CE marking and the strategy to be employed by CARES and its approved firms to ensure that construction clients and designers receive the appropriate reinforcing steel for their particular projects.

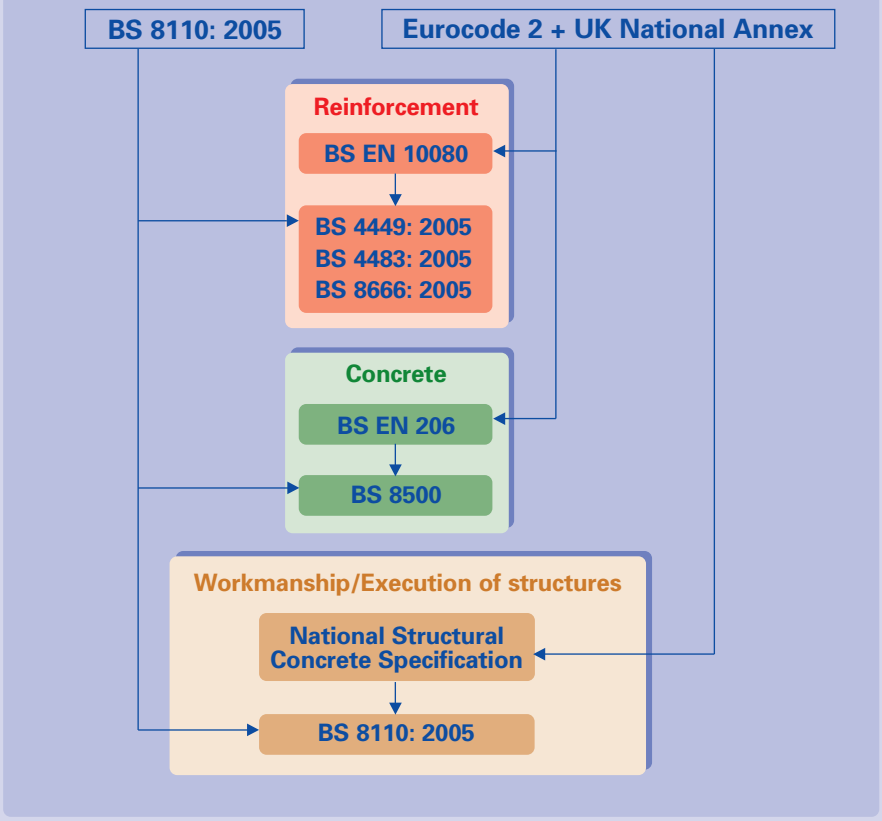


Figure 1

2.0 Design

2.1 General

Eurocode 2 was introduced into the UK in 2010 and its use, as considered appropriate, will dramatically affect the way concrete structures are designed. This will include the use of steel reinforcement. BS8110 was withdrawn by BSI in 2010 meaning that, whilst it may be used for a period of time, it will not be supported by the relevant BSI committee as a standard. The same applies to BS5400 and BS8007 and any associated standards that were withdrawn. The workmanship requirements of BS8110 are now included in another standard, BS EN 13670, Execution of Concrete Structures. In the UK, concrete is covered by BS8500:Concrete – complimentary British Standard to BS EN 206-1.

The various Eurocodes, as well as the product and execution standards, have been produced by CEN (Comité Européen de Normalisation), which publishes these as full European Standards. Under CE rules, all National codes that conflict with the Eurocodes must be withdrawn.

During the period within which BS 8110 and EC2 co-exist, it is important to create a similar path for the use of each, with their respective supporting standards.

Amendments to the reinforcing steel standards, BS 4449, BS4483 and BS8666, has ensured that current practice, albeit with the use of reinforcing steel with different properties, can continue. Successful use of EC2 will therefore be possible, as the British standards for both reinforcing steel and concrete will now support the use of EC2 in the UK. **Figure 1**. shows how this is achieved.

2.2 Eurocode 2

Eurocode 2 has the following parts :

BS EN 1992: Eurocode 2:
Design of concrete structures

BS EN 1992-1-1: Part 1-1:
General rules and rules for buildings (EC2 Part 1-1)

BS EN 1992-1-2: Part 1-2:
General rules - Structural fire design (EC2 Part 1-2)

BS EN 1992-2: Part 2:
Reinforced and prestressed concrete bridges (EC2 Part 2)

BS EN 1992-3: Part 3:
Liquid retaining and containing structures (EC2 Part 3)

2.2.1 Structure of EC2

All Eurocodes follow a common editorial style. The codes contain **Principles** and **Application Rules**. Principles are identified by the letter P following the paragraph number, and are general statements and definitions for which there is no alternative, as well as requirements and analytical models for which no alternative is permitted unless specifically stated. Application rules are generally recognised rules which comply with the Principles and satisfy their requirements. **Alternative Rules** may be used provided that compliance with the Principles can be demonstrated, however the resulting design cannot be claimed to be wholly in accordance with the Eurocode, although it will remain in accordance with the Principles.

Each Eurocode gives values, with notes indicating where national choice may have to be made. These national choices are recorded in the National Annex for each Member State, and are referred to as Nationally Determined Parameters (NDPs). Each Eurocode may have a number of Annexes which can be Normative or Informative. The Normative Annexes must be considered to be part of the code for which there is no alternative. Because the European product standard, EN 10080, does not provide any mechanical properties for the reinforcement, EC2 Part 1-1 contains a Normative Annex C, *Properties of reinforcement suitable for use with this Eurocode* (see **Table 1**).

Properties of reinforcement

Product form	Bars and de-coiled rods			Wire Fabrics		
Class	A	B	C	A	B	C
Characteristic yield strength f_{yk} or $f_{0,2k}$ (MPa)	400 to 600					
Minimum value of $k = (f_t/f_y)_k$	≥1,05	≥1,08	≥1,15 <1,35	≥1,05	≥1,08	≥1,15 <1,35
Characteristic strain at maximum force, ε_{uk} (%)	≥2,5	≥5,0	≥7,5	≥2,5	≥5,0	≥7,5

Table 1

2.2.2 Key changes

The principle changes that Eurocode 2 brings to the UK designer are:

- It permits a range of yield strengths from 400 to 600 MPa, although this range is not utilised in the UK. The UK now uses reinforcing steel with a yield strength of 500 MPa, which is reflected in the changes in 2005 to BS 4449. The partial safety factor for reinforcement in EC2 is set at present in the UK National Annex to 1.15, although this is currently under review.
- A further class of steel, Class C, has been included in BS4449. This has a higher level of ductility (characteristic strain at maximum force, ε_{uk}), as compared to the A and B grades of steel, although the same yield strength of 500 MPa applies.
- The design values for steel strengths will be similar to those used with the bi-linear relationship of BS 8110. However, EC2 allows for an increase in the design strength as shown in the upper branch in **Figure 2**. And this is sometimes used in specialist design.
- A distinction is made between hot rolled and cold worked steel as shown in **Figure 3**. The Tabulated data method of EC2, Part 1-2, "General rules – Structural Fire Design", requires the hogging tension reinforcement over intermediated supports in continuous solid slabs to be $\geq 0.005 A_c$ for cold worked steel. (In practice, the distinction can rarely be guaranteed on site and it is therefore usual to assume a worse case.)
- If Class A reinforcement is used then restrictions are placed on the redistribution of moments permitted for continuous beams and slabs. The use of Class A reinforcement is not recommended for plastic analysis.
- The maximum actual yield stress, $f_{y,max}$, should not exceed 1.3 f_{yk}. This equates to 650MPa for a Grade 500 reinforcing steel, and this limit is now included as a requirement in BS4449.
- The use of plain mild steel is not included.

2.2.3 Guidance for use of EC2

A number of handbooks and worked examples have been published to assist with the introduction of EC2. These include:

- Manual for the design of reinforced concrete building structures to Eurocode 2 – IStructE and ICE.
- Standard method of detailing structural concrete - A manual for best practice – IStructE and the Concrete Society.
- Precast Design Manual – British Precast.
- Concise Eurocode 2 – The Concrete Centre.
- Worked Examples – The Concrete Centre.
- How to Design leaflets/compendium – The Concrete Centre.
- Designers Handbook to Eurocode 2 by R S Narayanan and A W Beeby – Thomas Telford.

Idealised and design stress-strain diagrams for reinforcing steel (for tension and compression)

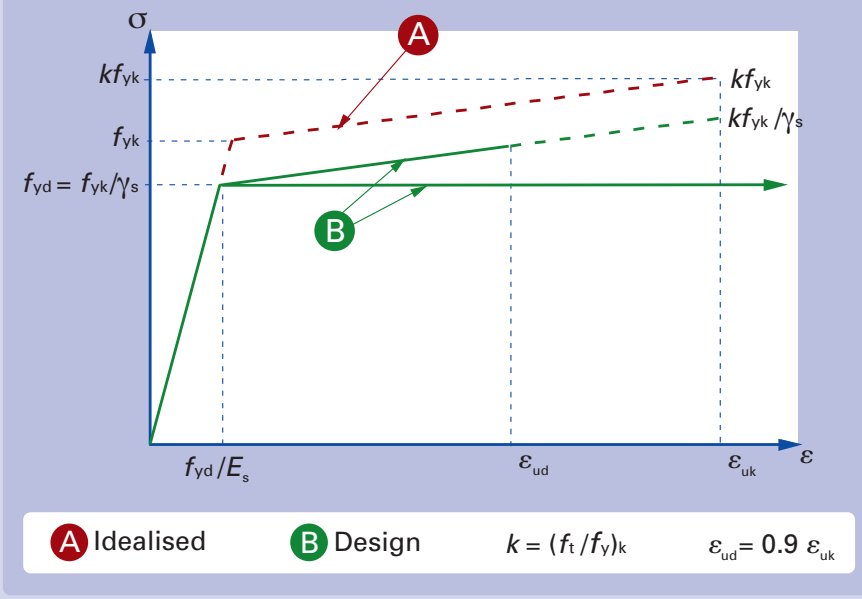
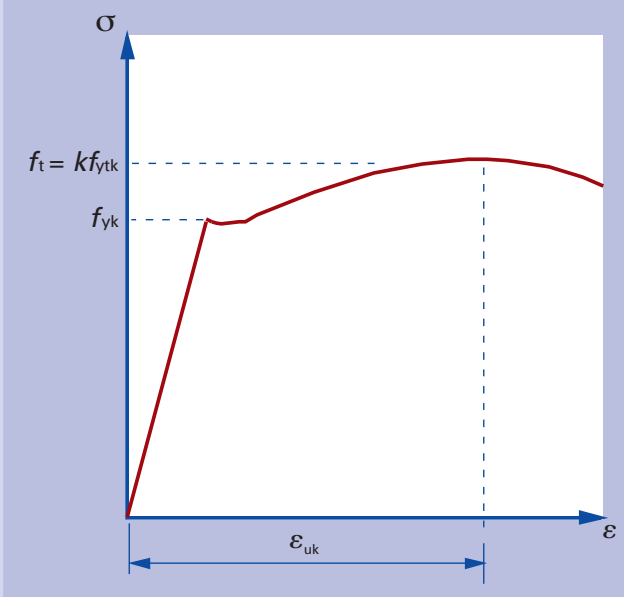
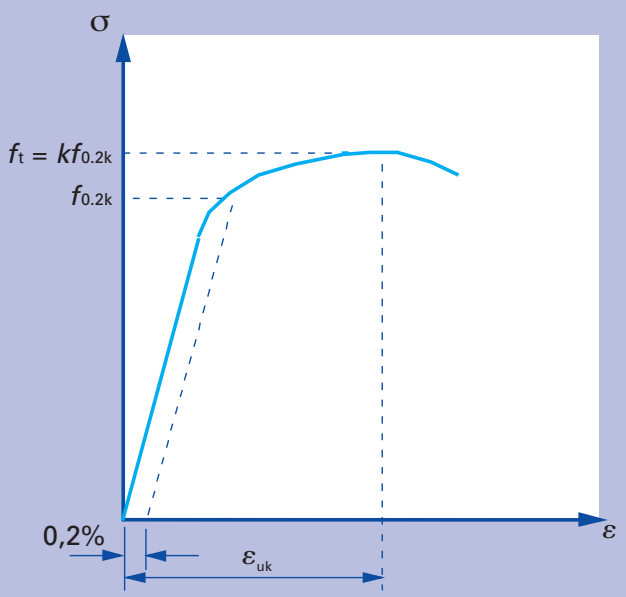


Figure 2

Stress-strain diagrams of typical reinforcing steel (absolute values are shown for tensile stress and strain)



a) Hot rolled steel



b) Cold worked steel

Figure 3

3.0 Product Standards

3.1 EN 10080

BS EN 10080, "Steel for the reinforcement of concrete- Weldable reinforcing steel- General", was published in 2005. Under the rules of CEN, the British Standards for reinforcing steel were to be either withdrawn or amended. As BS EN 10080 did not include any steel grades or a method of readily differentiating between grades, BS4449 was retained. This was amended not to conflict with BS EN 10080, and followed its structure, albeit that it included strength and ductility levels as well as a rib pattern for each ductility grade.

In following the structure of BS EN10080, BS4449 and its related standard for reinforcing steel fabric, BS4483, have been designed to link with the requirements of Eurocode 2 (EC2), as described in its Annex C.

Whilst not describing levels of performance, BS EN 10080 is useful in providing the following:

- A common set of performance characteristics which must be assessed by the manufacturer of the reinforcing steel bars/coils.
- A common set of test methods for these product characteristics.
- A system of manufacturer's evaluation for these characteristics.
- A system of attesting conformity, which in the case of reinforcing steels involves the intervention of an independent certification body.

Apart from chemical composition, rib dimensions, dimensional tolerances, and weld shear (welded fabrics), BS EN 10080 does not define the values associated with those product characteristics normally used by designers:

Yield strength
Elongation
Bendability
Stress ratio (Tensile strength to yield strength ratio)
Fatigue

In BS EN10080, and therefore in BS4449, weldability is determined by chemical composition, as is durability. Bond strength is determined by either rib geometry, or if the rib dimensions are not met, by means of a bond test.

As stated above, BS EN10080 does not have all of the detail required to fully define a specification and cannot therefore be used as a stand-alone document. It must be used in conjunction with another technical specification such as a National Standard or manufacturer's specification, which will link to EN10080, and will specify the values of the performance characteristics, which will define a grade of steel. The complementary technical specification may specify any performance level for these characteristics, as appropriate.

3.2 British Standards

The British standards for reinforcing steel are:

- BS4449 – Bar/Coil.
- BS4482 – Wire.
- BS4483 – Fabric.
- BS8666 – Scheduling.

The key changes made in the 2005 issue of BS4449 were as follows;

3.2.1 BS 4449:2005 "Carbon steel bars for the reinforcement of concrete"

- Strength. The yield strength (Re) specified in BS 4449:2005 is 500 MPa. As before, this is a characteristic value, based on the long-term statistical distribution of results. The standard also specifies absolute minimum values for individual test results, as well as a maximum value for yield strength of 650 MPa.
- The mechanical properties, including yield strength, are now measured using the nominal rather than the actual cross sectional area.
- Ductility (elongation) is now defined by the elongation at maximum load, A_{gt}, (uniform elongation), and not by elongation to fracture. A_{gt} was specified in the 1997 revision, but was for information only, and was not a cause for non-compliance.
- A new high ductility class "Grade C" has been introduced. This has both maxima and minima applied to yield strength and also higher levels of uniform elongation and stress ratio than the requirements in BS4449:1997, Grade 460B.
- Rebend test. The bending former diameter for sizes equal to or below 16mm has been reduced from 5d to 4d (where d is the bar diameter).

Tolerance on mass per metre (%)

Size (mm)	BS 4449:1997	BS 4449:2005
6	± 9 %	± 6.0 %
8	± 6.5 %	± 6.0 %
10	± 6.5 %	± 4.5 %
≥ 12	± 4.5 %	± 4.5 %

Table 2

The angles of bending have also changed, so that the test in BS4449:2005 is slightly more severe than in the 1997 revision.

- Sizes and tolerances. The preferred sizes remain unchanged. The size tolerances on small sizes are slightly amended as in **Table 2**.

- Rib area is now defined as relative rib area, as opposed to projected rib area in the 1997 revision. (Projected rib area is converted to relative rib area by dividing by πd, where d is bar diameter.) The result of this change is that on sizes up to 12mm, the rib area requirements are reduced, whereas on sizes above 12mm, the requirements are more severe. The proposed relative rib area requirements are given in **Table 3**, and can be compared with an equivalent value of 0.048 across the entire size range in the 1997 revision.

- Plain round Grade 250 steel has been removed. Plain round steel is not recognised by EC2. For those who require to use it, PD6687-1:2010 gives guidance. Alternatively, there are steel specifications available for plain round mild steel, which are given in BS4449:2005.

- Decoiled material has been introduced into the standard. This is recognised as a discrete product in BS EN 10080. It relates to reinforcing steel bar produced in coil form. As steel in coil form cannot be directly used, it must be 'de-coiled'. It may then be sold on in straight lengths as complying with BS EN 10080 (BS4449:2005). If so, it is then covered by the standard.

- A new bond test based on the RILEM beam test has been introduced as an option. This replaces the pull-out test which was present in the 1997 revision of the standard.

- The transverse rib pattern will continue to define the ductility level of the steel. For Grade A and B, this will not change. For Grade C, i.e. the higher ductility grade, another rib pattern is used (see **Fig 4**). The manufacturer's identification is contained in the code of marks placed between ribs, as currently employed in the CARES scheme, the format of which is essentially unchanged.

Relative rib area requirements of BS 4449:2005

Size (mm)	BS 4449:2005
≤ 6	0.035
>6 ≤ 12	0.040
> 12	0.056

Table 3

Rib pattern of Grades B500A, B500B and B500C

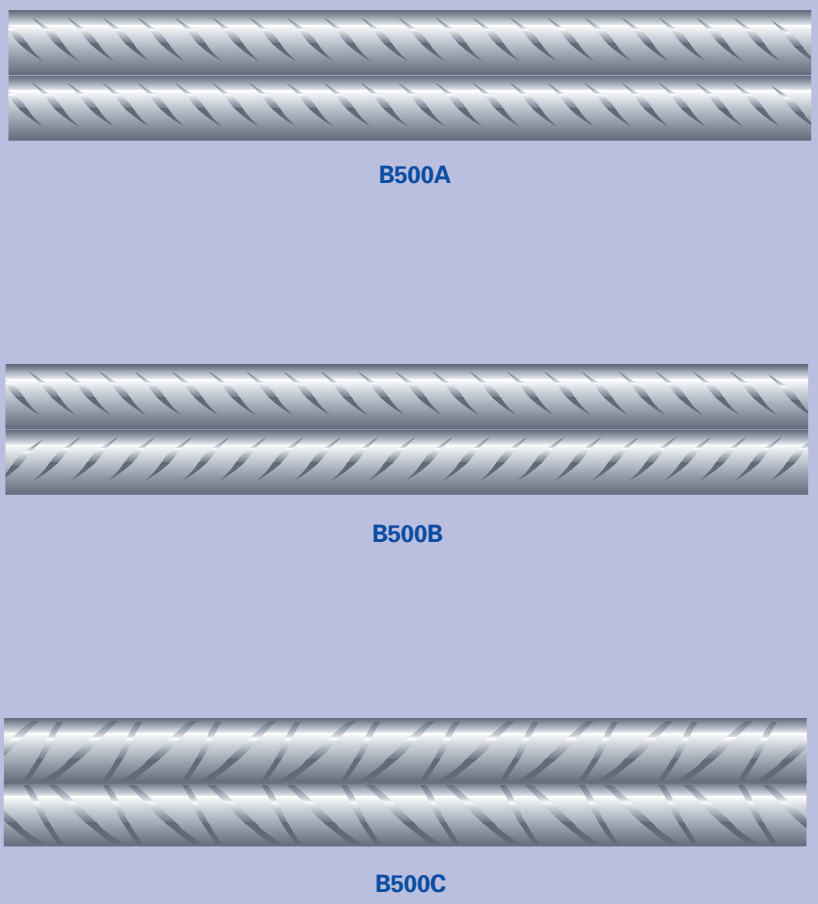


Figure 4

Table 5

Comparison of properties

Standard	Grade	R_e (MP_a)	$R_m{}^c/R_e$	A_5 (%)	A_{gt} (%)
BS 4449:1997	460A	460	1.05	12	2.5
BS 4449:1997	460B	460	1.08	14	5.0
BS 4449:2005	B500A	500	1.05[a]	N/a	2.5[b]
BS 4449:2005	B500B	500	1.08	N/a	5.0
BS 4449:2005	B500C	500	>1.15 ≤1.30	N/a	7.5

[a] 1.02 for sizes < 8mm [b] 1.0% for sizes < 8mm [c] Rm = Ultimate Tensile Strength

The mechanical properties of the three new grades are compared with the current grades in **Table 5**.

BS 4449:2005 does not contain any reference to the means of CE marking, but makes reference to BS EN 10080 for this. It is recognised that British Standards will continue to be used in many other parts of the world and, in recognition of their voluntary nature, there is to be no reference made to a requirement for third part certification, as this relates only to CE marking, i.e. a regulatory mark related to the Construction Products Regulation.

3.2.2 BS 4483:2005 - Welded Fabric

- Welded fabric to this standard, with wire sizes of 6mm and above, may only be manufactured from reinforcing steels which comply with BS 4449. Previously, i.e. in the 1998 revision, steels to either BS4449 or BS 4482 were allowed. The use of BS 4449 reinforcing steel ensures that all welded fabric to BS 4483:2005 in wire sizes above 6mm may be considered as "structural", and suitable for use in designs to EC2. This also means that plain and indented wires are excluded from these welded fabrics.
- The current welded mesh designations are retained, but wrapping meshes D98 and D49 may continue to be made from plain round sectioned reinforcing steel to BS4482, and are considered non-structural.

3.2.3 BS 4482:1985 - Cold reduced wire for the reinforcement of concrete

- Many of the changes are similar to those described for BS4449.
- This material is not intended for use in welded fabric to BS4483, or structural applications according to EC2, but may be used for non-structural fabric, and other concrete products.
- BS 4482:2005 has been written to link with BS EN10080. Reinforcing steels manufactured to this standard do not comply with the requirements of EC2.
- Properties are aligned to grade B500A of BS4449:2005, with the exception of fatigue testing, which is not required.
- Plain, indented and ribbed alternatives are available.
- Requirements for the geometry of indentations are introduced to align with BS EN 10080.

3.2.4 BS 8666 "Scheduling of Reinforcing Steels"

In addition to the material standards mentioned above, the British Standard for scheduling of reinforcing steels (cutting and bending - BS 8666) was also revised in 2005, with a further subsequent amendment detailed below. This standard does not link directly to BS EN 10080, but does link to BS 4449 and BS 4483. The notation that BS8666 uses for calling up different grades of reinforcing steel on fabrication schedules is shown in **Table 6**.

The general form of schedules for cut and bent bar, and for fabric, remain unchanged.

Notation of reinforcement

Type of steel reinforcement	Notation
For diameters ≤ 12mm, Grade B500A, B500B or B500C conforming to BS 4449:2005 For diameters ≥ 12mm, Grade B500B or Grade B500C conforming to BS4449:2005	H
Grade B500A according to BS 4449:2005	A
Grade B500B or grade B500C according to BS 4449:2005	B
Grade B500C according to BS 4449:2005	C
A specified grade and type of ribbed stainless steel conforming to BS 6744:2001	S
Reinforcement of a type not included in the above list having material properties that are defined in the design or contract specification	X

Table 6 **Note 1** In the Grade description B500A, etc., "B" indicates reinforcing steel.
Note 2 Within the ranges given, the grade(s) supplied for notations H and B are at the supplier's discretion.

The opportunity was taken to rationalise some of the bending shapes in the standard, although these changes will not be described here. The 2005 revision also introduced testing of de-coiled product.

4.0 Product Certification

In a market increasingly moving towards globalisation in terms of steel supply, where the production source is further removed from the place of use and where suppliers of unknown ability are being used, there is a growing need to provide certification to ensure that steel arriving on site complies in all respects with the specification.

The British reinforcing steel standards deal with this by providing two streams for compliance:

- Batch testing with a prescribed sampling and testing regime.
- Statistical control of production by the manufacturer, supported by Product Certification.

These are "balanced" in their requirements in order to provide an equivalence of confidence, taking account of the relevant consumer and producers risks in the process.
The CARES Scheme accounts for this in its structure, although the high risks and testing costs associated with batch testing mean that it is seldom if ever used in practice. The British reinforcing steel standards are used widely throughout the world, as is CARES certification, and it is likely that this situation will increase, as major construction clients seek to reduce the risk of purchasing material of unknown quality and origin.

4.1 CE Marking

In Europe, a particular consequence of the Construction Products Regulation (CPR) to producers of construction products and materials has been the availability of CE marking to manufacturers and the requirement to use it in Member States. Unfortunately, there has been much confusion over the purpose and meaning of the CE marking and who it was designed to satisfy.

CE marking has a regulatory basis and is not a voluntary mark of quality. The declared values given with CE marking, either by reference to a specification or by reference to measured properties, provide a basis for demonstrating that a product meets regulatory requirements. The responsibility for affixing the CE Mark on the product rests with the manufacturer or his agent. The CE Mark may only be affixed when a product is covered by a 'harmonised' standard (or a European Technical Assessment – relating to products which may not be covered by a harmonised standard). Unfortunately, as yet, there is no such 'harmonised' standard for reinforcing steel. BS EN 10080 is not a 'harmonised' standard. When it eventually becomes 'harmonised', such a CE Mark applied to reinforcing bars and coils, produced to the requirements of BS EN10080 and a supporting specification, will indicate to the appropriate regulatory authorities that the steel to which it has been affixed meets the regulatory legal requirements for placing it onto the single European Market, providing a presumption of conformity with the CPR.

4.2 Voluntary marks of quality

It is however recognised that construction clients, designers and manufacturers may have needs over and above those covered by CE marking and therefore quality marks, such as those provided by CARES, have a place. The CPR allows CE marking and Voluntary marks to co-exist. The CARES Scheme is entered into voluntarily by a manufacturer, as a way of improving his products and systems, as well as providing a strong indicator to his customers and the market that a certain level of confidence can be attributed to the products and services to which the CARES marks are attached.

4.3 Benefits of the CARES Scheme

Whilst giving recognition to the meaning of both marks as described above, and recognising that CARES will support both, it is necessary to set out the principal benefits that are provided by the CARES voluntary scheme:

- A system of "cascade" certification, which not only applies to the bars and coils, but to their supply and subsequent processing downstream to the installation on the construction site.
- A combination of product, process and system audits by highly experienced auditors, managed by a certification team immersed in the industry, including the standards writing process.
- A detailed examination of the manufacturer's process control, from the production of hot metal through all stages of production, up to and including the final product. This includes all feedstock materials purchased for use in the manufacture of these products.
- Full traceability of reinforcing steel and associated test data from hot metal to finished bars and coils.
- The publication of a register of marks and associated company details, which provides an invaluable purchasing tool.
- A test programme, which includes a statistical evaluation of witness and independent test results.
This provides a "calibration" mechanism between producer and independent testing.
- The use of selected testing laboratories experienced in the testing of reinforcing steels and associated products. These have conducted "round-robin" testing programmes, results being used by CARES.
- The ability to adopt a flexibility of product testing and audit frequency, in order to account for the relative experience of the manufacturers in the production of the particular grade and type of steel under assessment.
- Direct control of the use of the certification marks and any actions, such as withdrawals or suspensions, which may be felt necessary due to contraventions of scheme regulations.
- A system of complaint investigation on behalf of any purchaser or construction client who feels that the certification scheme is not being applied satisfactorily by approved firms.

4.4 Certificates of conformity

One of the significant changes that will occur as a result of the introduction of a 'harmonised' BS EN10080 will be the provision by CARES to the steel producer of one or both of two types of certificate:

- A CARES certificate which will continue to demonstrate that the producer meets all of the requirements of its Product Certification Scheme for Steel for the Reinforcement of Concrete.
- An EC Certificate of Conformity which will:
  - Confirm the legal status of the product
  - Support the manufacturer's "Declaration of Conformity" based on a form of product conformity certification.
  - Permit the manufacturer to affix the CE Mark.

Copies of these certificates will be available from the manufacturer.

5.0 CARES implementation of certification to the new standards

CARES endeavours to assess any of its approved firms that currently manufacture according to the British Standards for reinforcing steels, in all its forms, according to any applicable requirements. By testing according to these requirements, and by using those testing standards required in BS EN10080 (BS4449/BS4483/BS4482), CARES is able to issue appropriate product conformity certificates to its approved firms. In this way, it is intended that reinforcement supply is not disrupted during any phase of product standard or design code development.

6.0 References:

1. **BRITISH STANDARDS INSTITUTION. BS 4449:1997** "Carbon steel bars for the reinforcement of concrete".
2. **BRITISH STANDARDS INSTITUTION. BS 4482:1985** "Cold reduced steel wire for the reinforcement of concrete".
3. **BRITISH STANDARDS INSTITUTION. BS 4483:1998** "Steel fabric for the reinforcement of concrete".
4. **BRITISH STANDARDS INSTITUTION. BS 8110:Part 1:1997** "Structural use of concrete. Code of practice for design and construction".
5. **BRITISH STANDARDS INSTITUTION. BS 5400:Part 4:1990** "Steel, concrete and composite bridges. Code of practice for design of concrete bridges".
6. **CEN prEN1992-1-1** "Eurocode 2: Design of concrete structures-Part 1: General rules and rules for buildings (currently final draft).
7. **BSEN10080** "Steel for the reinforcment of concrete-weldable reinforcing steel-General".
8. **BRITISH STANDARDS INSTITUTION. BS 8666:2000** "Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete".
9. **BRITISH STANDARDS INSTITUTION. BS 6744:2001** "Stainless steel bars for the reinforcement of and use in concrete-Requirements and test methods".
10. **BRITISH STANDARDS INSTITUTION. BS8007: 1987** Code of practice for design of concrete structures for retaining aqueous liquids.
11. **BRITISH STANDARDS INSTITUTION. BS8500-1: 2002** Concrete. Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier.
12. **BRITISH STANDARDS INSTITUTION. EN206-1: 2000** Concrete. Specification, performance, production and conformity.
13. **BRITISH STANDARDS INSTITUTION.** Published Document PD6687 – 1:2010 Background paper to the National Annexes to BS EN 1992-1 and BS EN 1992-3.
14. **BRITISH STANDARDS INSTITUTION. BS EN13670** Execution of concrete structures.

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