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 this to fruition was the inability to agree a common set of 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 Directive, which included the requirements for the application of the CE Marking and the associated certification.

In parallel to this process was the one of creating a European Concrete design code, Eurocode 2, which provides the design specification for the emerging European product standards. This will replace National design codes, which in the case of the UK is BS8110.

The aim of all parties has been to ensure that a package of European codes and standards be issued at the same time, thereby ensuring a smooth transition from current to emerging codes and standards, bearing in mind their interdependence. It is intended that these new codes and standards will be available in 2005, although it must be stressed that the operation of sound management systems throughout the concrete supply chain will ensure that old and new standards will be able to be run in parallel for a period of time.

This Guide describes the key differences between the old and new systems showing how they can be used during the co-existing 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.

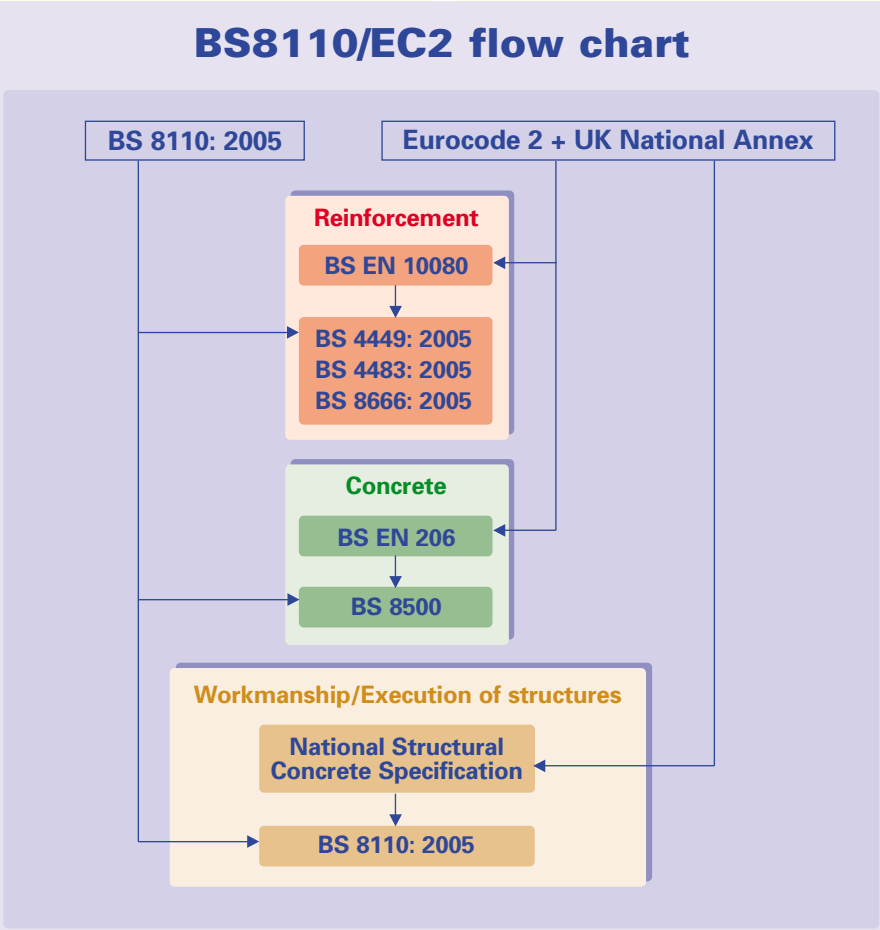


Figure 1

2.0 Design

2.1 General

Eurocode 2, the design code for structural concrete, is being introduced into the UK in 2005 and it will have a dramatic effect on the existing national codes and standards, including reinforcement. This change will be accompanied by amendments to BS 8110 (BS 5400, Part 4 and BS 8007) and associated standards. The amendments to BS 8110 and associated standards are considered necessary to allow their use with the new standards for both concrete and for reinforcement. This will make it possible for BS8110 to continue to be used during the overlap period.

The Eurocodes have been produced by CEN (Comité Européen de Normalisation), which is publishing these as full European Standards. Under CE rules, all National codes that conflict with the Eurocodes must be withdrawn by 2010. It is likely that BS 8110 will be withdrawn before then.

During the co-existance period of BS 8110 and EC2, it is important to create a similar path for the use of each, with their respective supporting standards. The amendments to BS 8110 and the associated British Standards BS8500, for concrete, and BS 4449, BS4483, BS8666, for steel, will ensure that current practice, albeit with the use of different material properties, can continue. The introduction of EC2 with the corresponding European material standards, EN 10080 and EN 206, will be possible assuming that the British Standards act as complimentary information to support their use in the UK. **Figure 1** shows how this will be 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 are recorded in the National Annex for each Member State 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 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:

- EC2 permits a range of yield strengths from 400 to 600 MPa, although this range is not utilised in the UK. The UK is to use a yield strength of 500 MPa, which is reflected in the changes to BS 8110. The partial safety factor for reinforcement in EC2 is set at present, in the UK National Annex, to 1.15. An amendment to BS8110 will reflect this, with a change from 1.05 to 1.15. The intention is to review the value of the partial safety factor, at some time in the future, with the possibility of returning to 1.05, when there is sufficient data available to support such a change.
- A further class of steel, Class C, will be made available. This will have greater specified ductility (characteristic strain at maximum force, ε_{uk}) and tensile strength, f_t, than currently provided for in BS4449:1997.
- The design values for steel strengths will be similar to those used with the bi-linear relationship of BS 8110 before amendment. However EC2 will allow an increase in the design strength as shown in **Figure 2**.
- 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 ≥ $0.005A_c$ for cold worked steel.
- 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.
- The use of plain mild steel is not included

2.2.3 Guidance during transition

In order to provide suitable guidance to designers in preparation for and throughout the changeover period, a number of handbooks and worked examples will be published in 2005 to assist designers. These will 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 Concrete Society.
- Precast Design Manual – British Precast.
- Concise Eurocode 2 – Concrete Centre
- Worked Examples – Concrete Centre
- How to Design leaflets – 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)

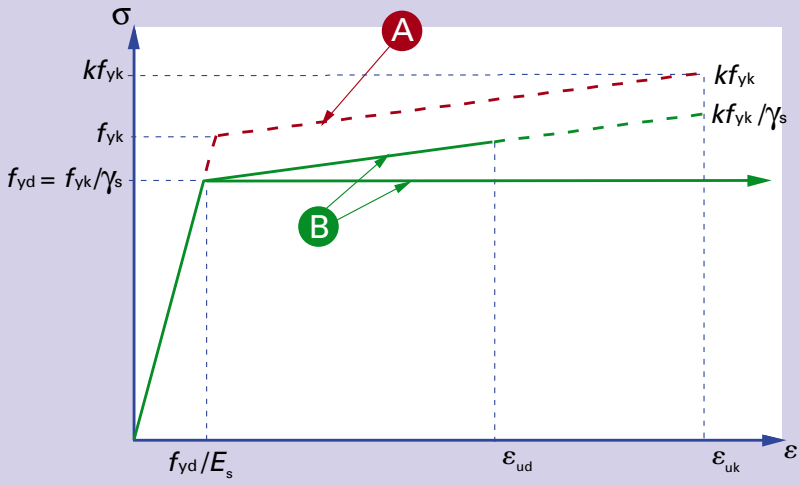
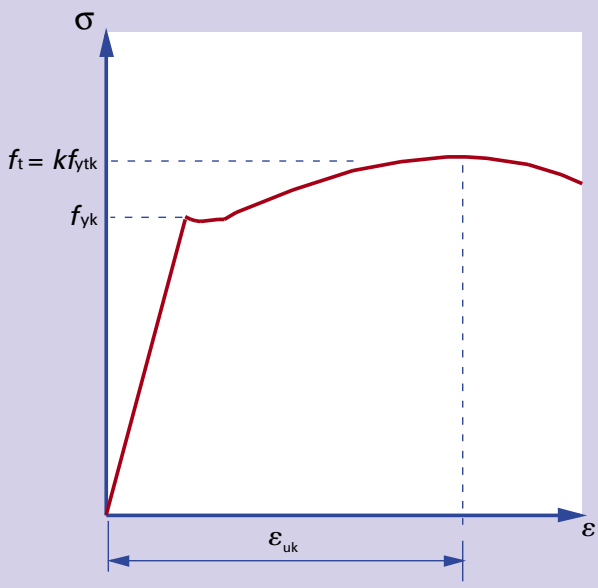
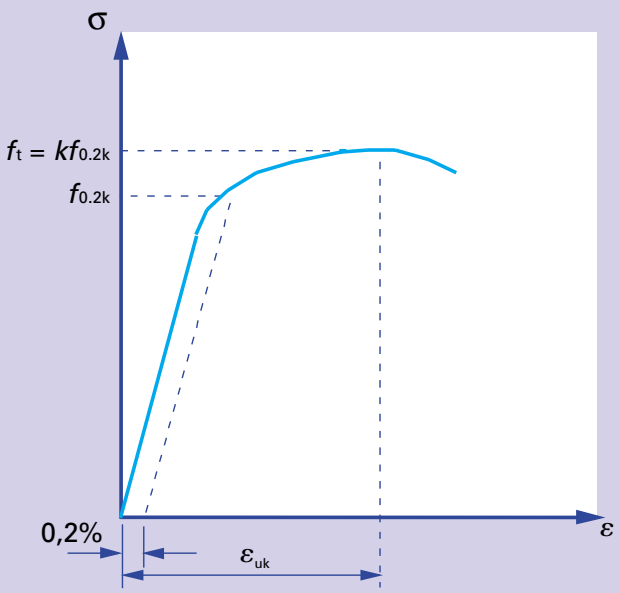


Figure 2

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

It is expected that EN 10080, "Steel for the reinforcement of concrete- Weldable reinforcing steel- General" will be published in mid-2005. This standard provides a mechanism for manufacturers to attach the CE marking to their reinforcing steel products, in line with the requirements of the EU's Construction Products Directive. It has also been designed to link with the requirements of Eurocode 2 (EC2), as described in BS EN1992-1-1 Annex C.

Because of the wide range of reinforcing steels produced and used across Europe, it was not possible to standardise on a small number of European standard grades. Instead, the standard provides a common means for the specification of grades of reinforcing steels.

EN 10080 provides the following:

- A common set of performance characteristics which must be assessed by the producer.
- A common set of test methods for these product characteristics.
- A system of producers 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 (in welded fabrics), 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 ratio)
Fatigue

In EN10080, weldability is determined by chemical composition, as is durability. Bond strength is determined by either rib geometry, or by means of a bond test.

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.

At the time of writing this part of the CARES Guide, these are currently being revised so that they can be used in conjunction with EN 10080 and conform with EC2, Annex C, when they are published. The changes in the standards will therefore enable them to be used with either design to EC2 or BS 8110 during the changeover period. The changes referred to below are those that are anticipated to be accepted. Please note that this part of the CARES Guide will be amended should any other significant changes occur as a result of the revision process.

The major proposed changes in the product standards compared to the previous revisions are 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 to be 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 to be 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" is to be introduced. This has both maxima and minima applied to yield strength and also higher levels of uniform elongation and stress ratio than the current grade 460B.

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

- Rebend test. The bending former diameter for sizes below 16mm is reduced from 5d to 4d (where d is the bar diameter). The angles of bending have also changed, so that the test 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 the **Table 2**.

- Rib area is 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 it, there are alternative steel specifications available for plain round mild steel.

- Decoiled material has been introduced into the standard. This is recognised as a discrete product in EN 10080. It relates to product produced as coil, which is subsequently decoiled and sold as straight lengths for further processing.

- 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, ie the higher ductility grade, another rib pattern is used (see **Figure 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

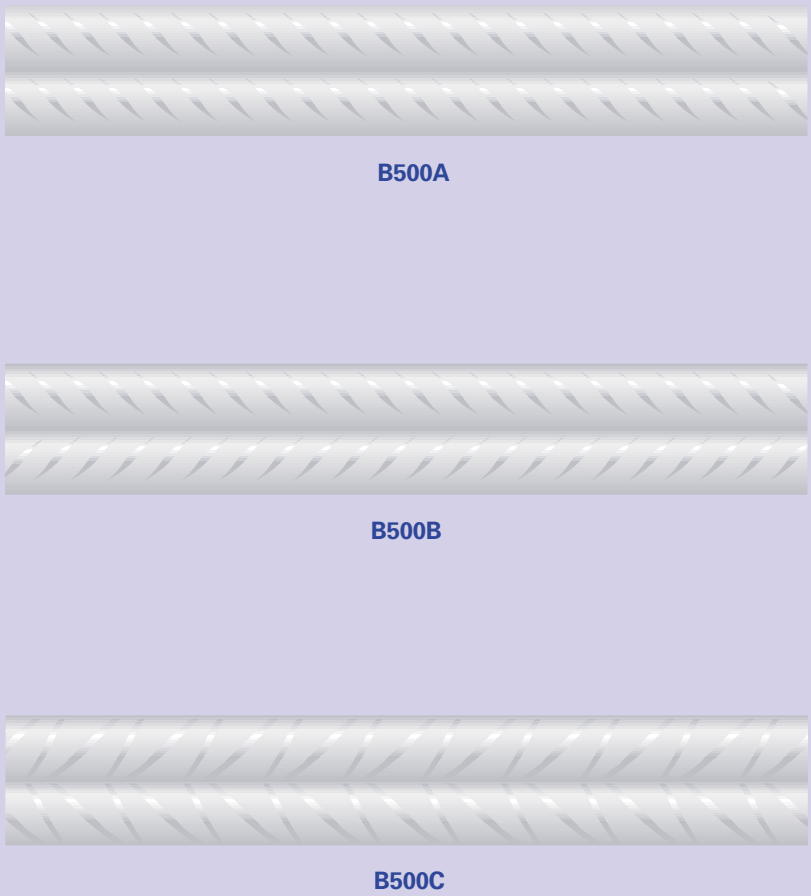


Figure 4

Table 5

Comparison of properties

Standard	Grade	R_e (MPa)	R_{mc}/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 does not contain any reference to the means of CE marking, but makes reference to 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 function under the CPD.

3.2.2 BS 4483: 1998 "Welded Fabric"

- Welded fabric to this standard, with wire sizes of 6mm and above, may only be manufactured from materials complying with BS 4449. Previously materials to either BS4449 or BS 4482 were allowed. The use of BS 4449 material ensures that all welded fabric to BS 4483 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 be made from material to BS4482, and are considered non-structural.

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

- Many of the proposed changes are similar to those described for BS4449.
- BS 4482 has been written to link with EN10080, and therefore enable CE Marking, although materials to this standard may not comply with EC2 requirements.
- Properties are aligned to grade B500A of BS4449, with the exception of fatigue testing, which is not required.
- Plain, indented and ribbed alternatives are available.
- 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.
- Requirements for the geometry of indentations are introduced to align with EN 10080.

3.2.4 BS 8666 "Scheduling of Reinforcing Steels"

In addition to the material standards mentioned above, the British Standard for cutting and bending (BS 8666) is also being revised. This standard does not link directly to EN 10080, but links to BS 4449 and BS 4483. The notation 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. The opportunity has been taken to rationalise some of the

Notation of reinforcement

Type of steel reinforcement	Notation
Grade B500A, B500B or B500C according to BS 4449:2005	H
Grade B500A according to BS 4449:2005	HA
Grade B500B or grade B500C according to BS 4449:2005	HB
Grade B500C according to BS 4449:2005	HC
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

bending shapes in the standard, although these changes will not be described here.

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 have in the past dealt 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 were "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 Directive (CPD), to producers of construction products and materials, has been the availability of CE marking to manufacturers and the requirement to use it in most 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, provides a basis for demonstrating that a product meets regulatory requirements. Such a marking applied to reinforcing bars and coils, produced to the requirements of EN10080 and a supporting specification, would indicate to the appropriate regulatory authorities that the steel to which it was affixed met the regulatory legal requirements for placing it onto the single European Market, providing a presumption of conformity with the CPD.

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 and may 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 manufacturers 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 material 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.
- 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 it is felt necessary due to scheme contraventions.
- 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 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 producer's "Declaration of Conformity" based on a form of product conformity certification.
  - Permit the producer to use the CE marking.

Copies of these certificates will be available from the manufacturer.

5.0 CARES implementation of certification to the new standards

During 2005, CARES will endeavour to assess any of its approved firms that currently manufacture according to the British Standards for reinforcing steels, in all its forms, according to the new requirements. By testing according to these new requirements, and using those testing standards required in EN10080, CARES will be able to issue appropriate product conformity certificates to its approved firms as and when the new standards are issued. In this way, it is intended that the UK supply is not disrupted during the changeover to what are, in essence and as described earlier, a set of different materials.

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. **PrEN10080** "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. **EN206-1: 2000** Concrete. Specification, performance, production and conformity

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