Fabrication of Reinforcement

1.0 Introduction

The fabrication of reinforcing steels, into shapes suitable for fixing into the concrete formwork, is normally performed 'off-site' in the UK, by specialist reinforcement fabricators, although it is recognised that this differs globally. Very little reinforcement is cut and bent on-site in the UK today. Although the cutting and bending of reinforcement appears relatively straightforward, the specialist reinforcement fabricator is well equipped to do so in a consistently accurate manner and, by working within a defined set of quality management criteria, as provided by the CARES Scheme, provides an important link in the reinforcement supply chain. The accuracy of cutting and bending operations is vital to ensure proper fit on site, and to maintain required lap lengths, anchorage lengths and cover.

Part 4 of the CARES Guide describes the cutting and bending operations, providing an understanding of the processes involved, as well as the role that the CARES scheme for fabricators plays in providing assurance of the quality of fabricated reinforcement.

2.0 British Standards

Within the UK and abroad, BS 8666, Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete, specifies requirements for scheduling, dimensioning, bending and cutting of reinforcing steels. It is of vital importance that the standard being used, e.g. BS8666:2005, is clearly stated on the cutting and bending schedule. A helpful fact sheet entitled "Publication of British Standard BS8666:2000" is available from CARES, explaining the differences between BS8666 and its predecessor BS4466 which may still be in use by some practices. BS 8666 also includes requirements for the scheduling and fabrication of welded fabric. This is covered in Part 5 of this Guide.

Fixing on-site

Courtesy of COSTAIN Ltd

Notation for reinforcing steels (from BS 8666:2005 including amendment)

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 1 **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.

BS8666, and the now superseded BS4466, are the basis for the UK CARES scheme for reinforcement fabricators. Under CARES approval, all approved reinforcement fabricators are required to fully understand the requirements of their customers and to provide reinforcement to the specified standards and related bending schedule.

The scheduling standard defines the bar schedule used to transmit requirements for cut and bent shapes from the designer/detailer to the contractor and reinforcement fabricator. Bending schedules have specified notations for calling up the different reinforcing materials available on the market, including the different grades of conventional carbon steels (BS4449), stainless steels (BS6744) and any other special steels. The Notations are given in **Table 1**.

The scheduling standard BS8666 and the product standard BS4449 were both revised in 2005, and BS 8666 has been further amended to define a specific notation

BS 8666:2000 Shape Codes

Shape and total length of bar (L) measured along centre-line

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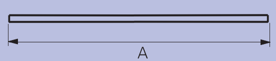
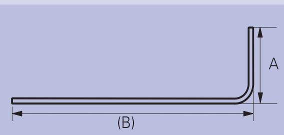


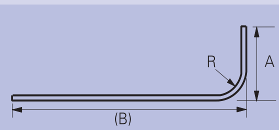
Total length (L) = A

11



Total length (L) = A + (B) - 1/2r - d

12



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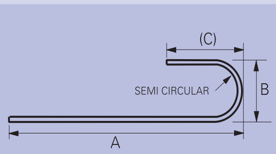
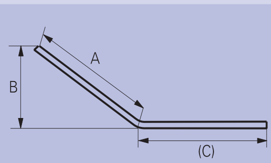
13



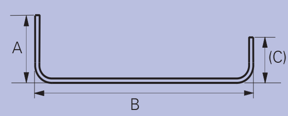
Total length (L) = A + 0.57B + (C) - 1.57d

15



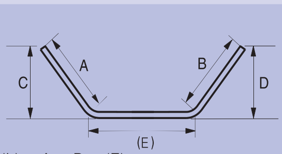
Total length (L) = A + (C)

21



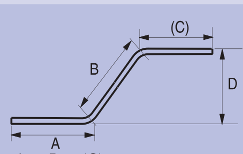
Total length (L) = A + B + (C) - r - 2d

25



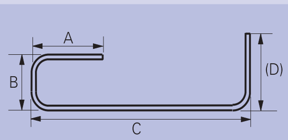
Total length (L) = A + B + (E)

26



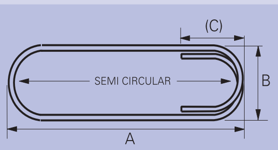
Total length (L) = A + B + (C)

31



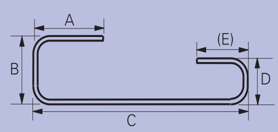
Total length (L) = A + B +C +(D) - 1 1/2r - 3d

33



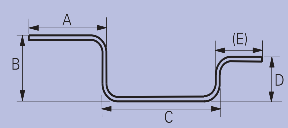
Total length (L) = 2A + 3B +17d

41



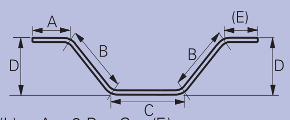
Total length (L) = A + B +C +D +(E) - 2r - 4d

44



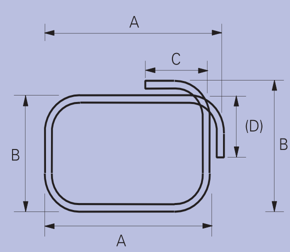
Total length (L) = A + B + C + D +(E) - 2r - 4d

46



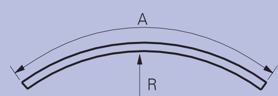
Total length (L) = A + 2 B + C + (E)

51



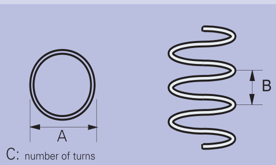
Total length (L) = 2 (A + B + C) - 2 1/2r - 5d

67



Total length (L) = A

77



C: number of turns

Total length (L) = C.π.(A - d)

99 All shapes where standard shapes cannot be used. A dimensioned sketch shall be drawn over the dimension columns A - E.
Total length (L) = To be calculated

Table 2 **Note:** For all practical purposes, this table must be used in conjunction with BS 8666, latest issue. Should you have any queries regarding the use of this standard, please contact your CARES approved fabricator, or CARES directly.

Minimum Radius for Scheduling in BS 8666

Bar Size (mm)	Grade Notation		
	R	T, B, S	F, D, W
≤ 16mm	2d	2d	2d
> 16mm	2d	3.5d	2d

Table 3

requirement for Grade A steel. It is important that the specific revisions of both standards be used.

Bent shapes are defined by means of standard shape codes (**Table 2**). When non-standard shapes are required, guidance is given as to how these should be referenced (as shape code 99's), and specified by an appropriate drawing. For each standard shape, the standard gives the overall length of bar used, as a function of the principle dimensions.

BS 8666 specifies various restrictions on the bending of shapes as follows:

- The minimum bend radius is specified for the different material grades (see **Table 3**).
- The minimum dimension from a bend to the end of the bar (bob length) is specified as a function of bar diameter and grade.
- The maximum limit for which a pre-formed radius is required.
- The restrictions on dimensions of particular shapes.

BS 8666 specifies the format for the schedule in which the requirements for cut and bent reinforcement are to be specified. Schedules are often supplied to fabricators in the form of faxed copies of rather poor quality, leading to errors in transcription of data. An alternative is for schedules to be e-mailed by means of commercially available software packages. This saves significant time for the fabricators, and improves the accuracy of information. In some cases, this electronic schedule information can be linked directly to the computer control system of the production equipment. There are also significant benefits for designers and contractors in terms of reduced errors, fewer queries, and easier change procedures. The subject of electronic handling of data throughout the supply chain for reinforcement is covered in Part 9 of this Guide.

3.0 Fabrication processes

The basic fabrication processes consist of cutting and bending the reinforcing steel. The actual processes employed in the bending and cutting of reinforcing steel depend principally on the form of material being processed, whether bar or coil.

Generally reinforcing bar is supplied to the fabricator from the mill in bundles of straight lengths. Stock lengths are normally 12m, 14m and 15m, and can be up to 18m. Non-standard lengths can also be supplied, usually subject to a minimum tonnage requirement. Bar is fabricated by cutting on shear lines, and subsequently by bending on power bending machines.

Reinforcing bar, in coil form, is also supplied from the mill in a continuous length. This may be in a 'spooled' form. Coil is normally available in sizes 8-16mm, although larger diameters are being developed.

Coil weights may typically be two to three tonnes, so that for the smaller diameters, the coil can be several kilometres in length. Coil can be unwound and cut to length in a single operation, called either "decoiling" or "straightening". Coil can also be straightened, bent and cut to most shapes, in continuously operating machines commonly referred to as Automatic Link Benders (or ALB's).

3.1 Cutting

Bars will normally be cut to the required length in machines called Shear Lines (**Figure 1**). These machines normally consist of an unscrambler, where bundles of steel are split and loaded into the shear line, a roller table which presents the bars to the cutting shears, a hydraulically activated set of shear blades, a run-out table to take the cut bars, and pockets into which the cut lengths of steel are deposited. In an automated line, the different cuts required from each mill length can be programmed into the machine, improving efficiency and accuracy, and decreasing wastage. The minimum length that can normally be processed by a shear line is around 600mm. The tolerance specified in BS 8666 for cutting is ± 25mm, which is easily achieved by these machines.

Shear line

Figure 1 Courtesy of Stema/Pedax

Power bender

Figure 2 Courtesy of Stema/Pedax

3.2 Bending

Bending of reinforcing bar is invariably carried out on power bending machines. These are normally driven by an electric motor, through a gearbox with a number of selectable speeds. Bending is achieved by placing the bar across a rotating turntable. The bending mandrel is placed at the centre of the turntable. A carrier pin, placed off-centre of the table deforms the bar continuously as the turntable is rotated, whilst the back end of the bar is restrained by a resistance roller or stop. (**Figure 2**). All deforming rollers are normally free rotating, so as not to offer resistance to the bar, which could cause stretching. Benders may be single-headed or double-headed, the latter used to speed up production of shapes having bends at both ends.

Although the concept of bending of reinforcing steel is simple, it does require some skill and experience. Ribbed reinforcing steel is not a consistent product to bend for the following reasons:

a) The hot rolling process employed in the steel mill may produce significant variation in dimensions along the length of bars/coils.

b) The ribs on the bar surface may result in a cross section which is not exactly round. This means that resistance to bending depends on bar orientation.

c) The hot rolling process may introduce a degree of twist along the length of the bar, thus exacerbating the problems of a) and b) above.

d) The degree of spring-back when the bending load is released is a function of bar profile, steel type, and cast characteristics. Suitable allowance must be made for this.

Bar shape requirements, e.g. in terms of twist or straightness, which can affect consistent bending performance, are not covered by BS 4449. It is the responsibility of steel mills, to supply product that is fit for purpose in this respect. This is covered in the CARES scheme, whereby the CARES assessments of such steel mills, which includes process control requirements, ensures that bar shape is being controlled.

It is not uncommon for designers to specify shapes which are outside the bending specifications of BS8666. In particular, bends tighter than allowed are often specified, particularly on small size links. This should be avoided wherever possible. If unavoidable however, designers will normally be asked to authorise the fabrication outside specified limits.

3.3 Decoiling

The processes of decoiling and/or straightening of coil have already been described in Part 2 of this Guide. From the perspective of the reinforcement fabricator, processing coil instead of bar has many benefits, including increased productivity, increased material yield and increased flexibility. The use of coil in sizes up to 16mm has increased markedly, particularly in the UK but also elsewhere, and many fabricators prefer to use coil exclusively on these sizes. The decoiling process must be properly controlled to ensure proper straightness of the product, and to minimise any damage to the ribs, or change of mechanical properties. The quality of the ingoing coil in terms of consistency of geometry and mechanical properties is important in enabling reinforcement fabricators to process steel efficiently.

3.4 Automatic Link Benders (ALB's)

ALB's process coil directly to bent shapes. These machines incorporate a roller straightening system, a shear and a bending table (**Figure 3**). ALB's increase efficiency of fabrication, compared to conventional cutting and bending. Because of the continuous nature of the operation, there are aspects of the bending, which cannot be as closely controlled as for a slower, manual operation however. In particular, problems may be created such as links bending out of plane. This is principally a function of the consistency of the ingoing coil.

Automatic Link Bender (ALB)

Figure 3 Courtesy of Stema/Pedax

3.5 Developments

Although the basic processes of cutting and bending have remained relatively un-changed, reinforcing fabricators are increasingly seeing the benefits of increased automation, computer control, and electronic data interchange (see Part 9 of this Guide).

Fabricators are increasingly using welded pre-fabrication to manufacture assembled reinforcement cages, ready for fast assembly on site (see Part 6 of this Guide).

A relatively recent innovation is the development of carpet reinforcement, consisting of a series of reinforcing bars welded to a thin steel strip. This product can be rolled up like a carpet, and then simply unrolled on site for very rapid fixing. It is claimed that these systems can give 80-90% reduction in fixing costs, and a 20-40% material saving. The systems are suitable for reinforcement of many types of slabs (see Part 8 of this Guide).

Other developments include Continuity Strips and bespoke Shear reinforcement.

4.0 The CARES Scheme for Fabricators

Appendix 2 of the CARES Scheme for Steel for the Reinforcement of Concrete covers "Quality and operations schedule for the processing and/or supply of steel products for the reinforcement of concrete.

The element of the scheme provides for:

- Independently verified compliance with the specified standard (BS 8666).
- Quality management system assessment using ISO 9001 as a basis.
- Verification that raw material is only purchased from CARES approved manufacturers, thus ensuring approval for the whole process route, from steel making, rolling, processing, fabricating to delivery to site.
- Full traceability throughout the supply chain. All batches of fabricated reinforcement can be traced back to the original mill test data.
- Verification of the long-term quality level as defined in BS 8666.
- Resolution of any complaints made to CARES approved suppliers.
- Removing the need for purchasers to have their own testing and inspection regime on site, saving considerable time and cost.

Carpet reinforcement being rolled out on site

Figure 4 Courtesy of Hy-Ten Reinforcements

CARES approval is gained by a fabricator only after demonstrating that its quality management system meets the requirements of ISO 9001and additional product-specific CARES requirements. This includes checking the fabricated shapes against the requirements of BS 8666.

Once approval has been granted, it is maintained by twice-yearly surveillance audits conducted by CARES specialist auditors. At these inspections, the quality system is audited, dimensional checks are made to ensure product is consistently complying with BS 8666 and customer requirements, and traceability systems are examined.

It should be emphasised that the fabricator plays a vitally important role in the reinforcing steel supply chain. Some fabricators have claimed that they do not need themselves to be CARES approved, because they only purchase steel from CARES approved sources. This is not the case, since only CARES approved fabricators have independent verification of their quality systems, bending capability and traceability systems.

4.1 The CARES Scheme-verified compliance

When using CARES approved fabricators, specifiers can be confident that all steel supplied will be from CARES approved manufacturers. The product can be used without the need for further product testing. Where CARES approved fabricators are not specified, the onus is on the purchaser to verify compliance, which may require inspection and testing involving both significant cost in both testing and the associated site delays.

4.2 CARES list of approved fabricators

CARES maintains, in an updated form, a list of approved firms. This is published on the CARES Website at www.ukcares.com in an easily searchable form and includes reinforcement fabricators. The list describes the firms' scope of approval and useful contact information. The scope of certification allocated to each CARES approved firm will include the product standards for which that fabricator is approved to cut, bend and distribute. If there are any doubts about the scope of approval of a reinforcement fabricator, the CARES list of approved firms should be consulted, or alternatively, the CARES office can be contacted for advice.

5.0 References

1. "Improving rebar information and supply" Best Practice Guide for In-Situ Concrete Frame Buildings. **British Cement Association 2000.**
2. **BRITISH STANDARDS INSTITUTION. BS 8666:2000** Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete.
3. **BRITISH STANDARDS INSTITUTION. BS 8666:2000** Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete.
4. **BRITISH STANDARDS INSTITUTION. BS 8666:2005** Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete - Specification.
5. "Publication of British Standard BS 8666:2000" **CARES Information Sheet.**
6. **CARES Reinforcement Guide No. 5** Welded Fabric.
7. "Steel for the reinforcement of concrete" Appendix 2 "Quality and operations assessment schedule for the processing and/or supply of steel products for the reinforcement of concrete. **UK CARES.**
8. **CARES Reinforcement Guide No. 2** CARES approved reinforcing steels; processes and properties.
9. **CARES Reinforcement Guide No. 6** Welded Pre-fabrication.

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