Ancillary Products for Reinforced Concrete Construction

1.0 Introduction

This Guide to date has described how CARES has undertaken certification for products which have been the subject of product standards and, by specific reference to properties, processes and products, how its certification schemes provide confidence in the compliance of these products.

As the reinforced concrete market develops, certain products and systems have emerged which are designed to provide added value to the contractor and end product user through improved performance, however that is assessed. Very often, these new products are not covered by a product standard but are proprietary items designed for a specific construction situation, Nevertheless, users require confidence, often by external independent verification and, in order to deal with this, CARES has designed a system of certification to provide this.

Part 8 of this Guide describes the principles and practices of this system, which is called Technical Approval by CARES.

2.0 CARES Technical Approval Procedure

The procedure begins with a detailed discussion between the applicant and CARES, including any technical expert deemed necessary, to establish:

- The extent of the product family to be assessed.
- The scope of product use and its intended purpose.
- The general principles of testing and evaluation.

The procedure ensures that a comprehensive series of tests is performed on each product in relation to those characteristics considered important to meet its declared purpose. The product performance requirements are included in an assessment schedule which is produced by CARES and its agents, approved by selected experts and applied by its assessors and nominated test houses. All product assessment schedules include quality system requirements and the quality management systems of producers are assessed and periodically inspected by CARES assessors, expert in the products and processes involved. Furthermore there is an evaluation of the technical data of the producer, as applied to the product, which includes those procedures for installation and technical assistance. Any amendment to the product, production or design considered significant to its performance is assessed and further tests are initiated as required. On completion of testing the assessment report and the certificate, which includes the certificate of approval, are approved by a group selected from the CARES Board, before it is signed and issued.

Pile Cage Formers In-situ

Figure 1 Courtesy of ROMTECH

2.1 Key differences

The key differences between the CARES Technical Approval and its Product Certification are:

- Creation of a testing programme to be included within the assessment schedule. Very often such testing is bespoke. The CARES system does try to follow the basic ethos of standards writing in this respect, by the use of an expert and balanced panel in the approval of the assessment schedule. Testing may be full-scale and in-situ.
- Design considerations.
- Safety considerations.
- Detailed technical reporting as well as certification.

3.0 The procedure in operation

The following examples of product, types of which CARES has already assessed and certificated, are used to describe the operation of the scheme in practice:

1. **Mechanical Splices**
2. **Continuity Strips**
3. **Pile Cage Formers**

3.1 Mechanical Splices

Basic principles

The basic principle of splicing, which is common in reinforced concrete construction, is to lay two bars parallel to one another, over a certain length (lap length), and connect them with tying wire. The load present in the first bar is transmitted to the concrete by the bond between steel and concrete, which then transmits the load to the second bar. Since this load transference is indirect, the efficiency of this joint depends on many factors, including the properties of the concrete. This complexity leads in turn to complex regulations for lapping, and design engineers and site engineers must be familiar with these design requirements if the job is to be done properly.

To improve in this area, the construction industry has developed a mechanically coupled splice as an alternative. This uses a product known as a coupler, which is designed to join two bars together. There are many different types of coupler, but the most common are based on either a threaded bar and coupler, a sleeved coupler which is swaged onto the bar, or a combination of both. There is also a sleeved coupler which is bolted onto the bar. By creating an end-to-end bar connection, a continuous load path is created from one bar to another that is independent of the condition and quality of the concrete. Furthermore, the mechanical splice is easy to test relative to the overlapping method, which would require a test in concrete. Such testing is expensive and time consuming.

Design codes, including BS8110, allow both overlapped and coupled splices, with specific considerations for each. With respect to overlapped bars, BS8110 recommends that joints in rebar are to be placed away from points of high stress and that these joints be staggered. Some codes restrict overlapping to areas subject to lower stresses or restrict overlapping to smaller bar diameters, e.g. less that 32mm.

Tapered Thread

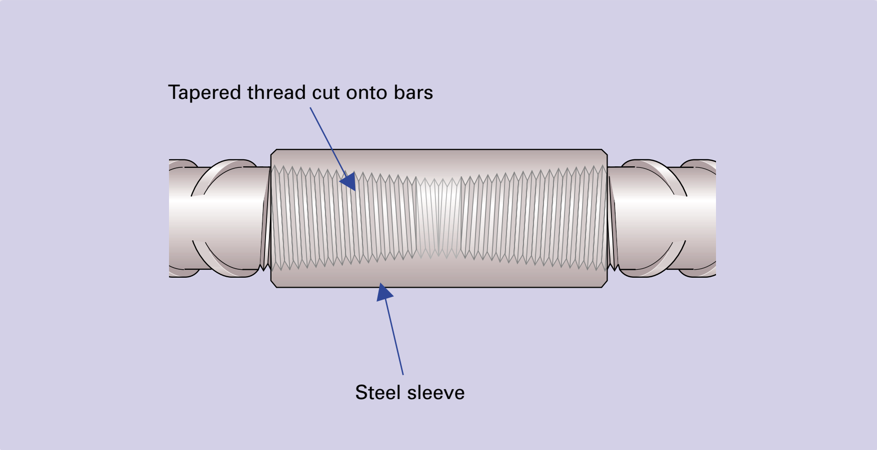

Figure 2 Courtesy of Ancon

Thread/swage combination

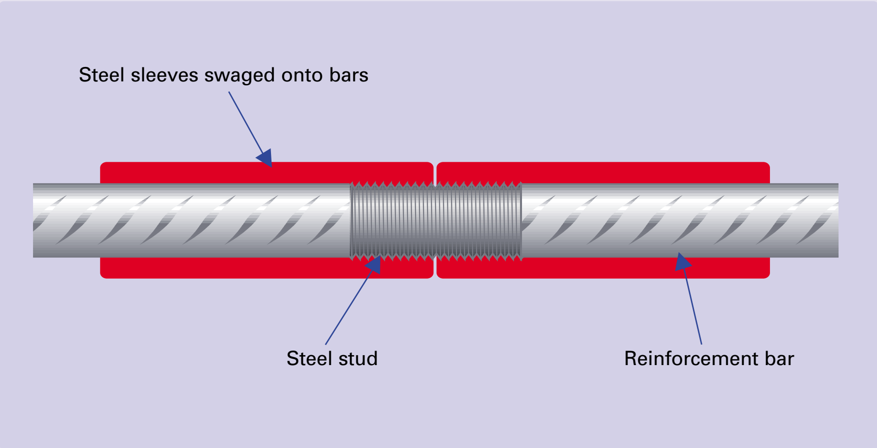

Figure 3 Courtesy of Dextra

Thread/swage combination

Figure 4 Courtesy of Halfen HBM

Types of mechanical coupler

There are a number of proprietary splicing systems that are sold, with various claims of performance and practical benefits. The most common of these, as assessed by CARES, are:

Tapered thread

The ends of the rebar are sawn square and a tapered thread is cut onto the bar, using a set of dies and a threading machine, to suite the taper thread of the coupler. The threading machine is usually provided by the coupler manufacturer. The coupler is assembled using a torque wrench, which should be calibrated for the purpose. A benefit of this system is that the bars are easily and correctly centred in the coupler, and the opportunity for cross-threading is reduced. This ensures ease of installation (**Figure 2**).

Parallel thread

After cutting square, the ends of the bar are enlarged, or "upset", by cold forging, such that the core diameter of the bar is increased to a predetermined diameter.
A parallel thread is then either cut or rolled onto the enlarged end. Using this technique, the effective diameter of the threaded bar is equal to the bar diameter thereby creating the conditions for failures within the bar and not the coupled joint. No torque wrench is required for assembly and it has the added benefit of "proof loading" the splice within the production process, thereby effectively testing each splice.

Swaged or thread/swage combination

Swaging of a coupler, in which a steel sleeve is attached to both bar ends by applying radial pressure to the bar/coupler assembly and resulting in a pressure sealed splice, is less common in today's market. This may be due to a very slow installation rate. To overcome this mechanical splices have been produced which employ a combination of swaging and parallel threading to ensure a full strength joint with flexibility of assembly. Sleeves, which are swaged onto the bar ends, are connected by means of a high performance threaded stud, thus ensuring a full strength joint (**Figure 3**). The Halfen HBM coupler employs the same principle, but in this product the male connector bar consists of a reinforcing bar which is mechanically upset and onto which a threaded end is machined (**Figure 4**).

CARES assessment

Claims of performance between the different types are wide and varied. As detailed above, the CARES approach to assessment is driven by design code/specification requirements. As a result, CARES has formulated three different assessment schedules for mechanical splices. In addition to a system of assessment of both management system, including mechanical splice and bar traceability and installer qualification, the following properties are assessed for all sizes under approval. (Based on use of BS4449 Grade 460B):

- **TA1-A, for use with BS5400**

  UTS• = 1.08 fy*

  Permanent Set ⩽ 0.1mm @ 0.6 fy.

  Fatigue = Fatigue testing in air and concrete using a range of endurance levels.

  There are two fatigue classes, D and R, which require the application of different stress ranges within the test, with R represnting the higher stress range. D class may be used in bridges but requires the designer to undertake a fatigue assessment. R class couplers may be used without the need for a fatigue assessment.

- **TA1-B, for use with BS8110**

  UTS = 1.08 fy.

  Permanent Set ⩽ 0.1mm @ 0.6 fy.

  This is tested in tension only, unless requested by the manufacturer.

- **TA1-C for use in nuclear applications (BNFL Specification)**

  UTS = 1.15 fy (including testing after cold soak)

  UTS ⩾ load to produce 2% strain in reinforcing bar.

  Permanent Set ⩽ 0.1mm @ 0.6 fy (including testing after cold soak)

  Low cycle fatigue (100 cycles, between 5% and 90% fy).

• fy = *Characteristic strength of bar*
* UTS = *Ultimate tensile strength of bar*

Finally, and whilst outside the direct remit of the Technical Approval assessment, CARES also assesses how reinforcement fabricators produce and apply mechanical splices. It covers the use of equipment particular to the type of coupler in question, as well as the approval of individuals who operate this equipment. This certification is defined in Appendix 8 of its Steel for the Reinforcement of Concrete Scheme.

3.2 Reinforcement continuity system

Basic principles

Traditional methods for forming construction joints on site can require the site bending and re-bending of reinforcing steel, which can adversely

Continuity Strip in operation

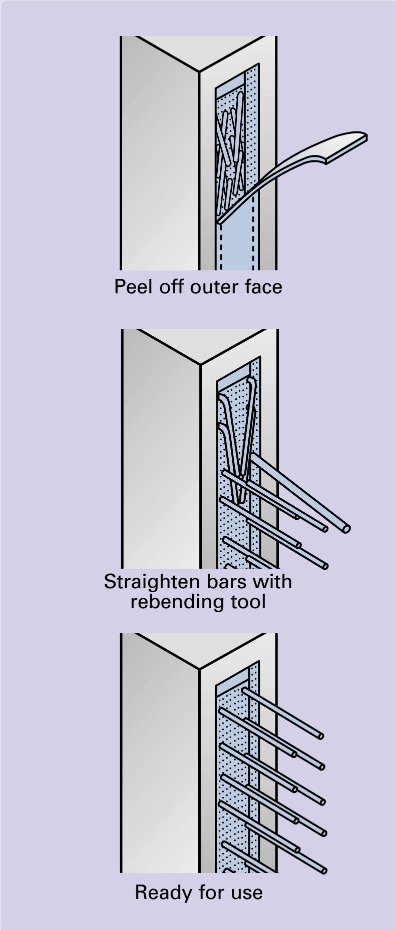

Figure 5 Courtesy of RFA

Continuity strip

Figure 6 Courtesy of Halfen HBM

affect the material properties. Reinforcement continuity systems are designed to maintain continuity across construction joints in concrete structures in a time saving and cost effective manner (**Figure 6**).

The typical reinforcement continuity system consists of reinforcement, pre-bent and housed in a purpose-designed carrier casing. On-site, the unit is fixed to the shutter and cast into the front face of the wall or floor. After the formwork is struck, the carrier case lid is removed to reveal the connection legs (starter bars) folded inside the casing. Using a specially designed tool, these legs are bent out by the contractor, ready for splicing the main reinforcement of the consequent pour. The casing remains embedded in the wall or floor, providing a rebate and key for the adjoining member, eliminating the need for traditional preparation, such as scabbling at the joint (**Figure 5**).

CARES assessment

The CARES Technical Approval covers the use of these systems in accordance with BS8110. Any site bending or re-bending of reinforcement protruding from concrete is a matter for the Engineer's approval. This is therefore a fundamental consideration in the assessment process, as successful re-bending of reinforcing steel is a matter of steel suitability, bend parameters and workmanship. Parts 2 and 3 of this Guide explain the varying properties of reinforcing process routes and properties relating to steel sold into the market today. Ductility is clearly the key property here and, whilst of course ensuring that all steel used meets the requirements of BS4449 Grade 460B, CARES undertake mechanical testing to ensure that steel of each process route, type, size and supplier is appropriately selected by the continuity strip producer prior to its use. After bending and straightening, steel must be shown to comply with the tensile property requirements of BS4449 Grade 460 B, exhibiting values for Total Elongation at Maximum Load (Agt) of greater than 5%. Regular independent testing is also performed.

Full scale in-situ structural testing is also performed to evaluate the performance of construction joints under combinations of high flexural and shear loading. These tests demonstrate that the flexural strength and shear strength of construction joints formed with these systems are no less than those of equivalent, traditionally formed construction joints and that full structural continuity is maintained.

3.3 Pile Cage Formers (with Lifting Clamps)

Basic principles

Pile cage formers are factory produced units which are designed to aid the on-site fabrication of pile reinforcement and lifting and placing of complete pile cages.

Welding requires critical control, which if not achieved, can adversely affect reinforcing steel and compromise the site safety aspects of pile cage lifting. The pile cage formers use mechanical clamps to fix to the main bars to avoid site welding under difficult or exposed conditions.

In the case of the cage former itself, welding of the product is carried out under controlled, certified factory conditions thereby reducing the contractors risk, and liability, in subsequent site cage assembly, lifting and installation as well as allowing the reinforcement fabricator to offer "factor of safety" lifting calculations for the cages, based on known, "as tested" clamp strengths.

Each cage former is constructed, utilising the specified amount of reinforcement in the form of two or

Pile Cage Former

Figure 7 Courtesy of ROMTECH

more rings or links. The rings are connected longitudinally by means of both "anti-racking" supports and internal cover spacers. The proposed cage lifting points are created by means of integral clamps which, like the anti rack supports and spacers, are securely jig welded to the cage former rings in the factory. The spacers and anti-racking supports also provide a method of circumferentially locating the main longitudinal cage reinforcement, as do the clamps. As a result, the cage former, when transported to site, becomes a highly accurate template for the rapid assembly of complete pile, column or beam cages. Typically, the loose main cage bars will be laid across support trestles and the rings or links, along with the cage formers, will be threaded over them. There are typically three cage formers per cage.

In the more traditional techniques such as the use of welded bands, the subsequent circumferential positioning of main bars around the cage is neither accurate nor rapid. However, this operation is assisted greatly by the cage former system, as bars are laid either against anti-racking supports or spacers and tied off or placed into clamps, each of which is then closed around its captive bar and torqued to a preset value, creating cage lifting points of a designated strength. On completion the reinforcement cage will then be ready for lifting and installation without any site welding having been performed on any of its joints.

CARES assessment

Product Requirements.

Quality:

a Reinforcing steel shall be CARES approved, BS4449 Grade 460B.

b All plastic spacer sleeves must be high density, rigid UPVC, extrusion grade complying with BS7413.

c Cage former fabrication shall comply with BS8666.

d Welded joints shall comply with CARES Appendix 6 or 10 of the scheme for steel for the reinforcement of concrete as appropriate.

Product testing:

e Spacers must comply with the performance requirements of BS7973: Part 1.

The spacers are load tested to ensure that their load/deflection characteristics are acceptable.

f The pile cage geometry must not deviate from the original alignment by more than 10mm and the diameter of the rings shall remain with +/- 5mm of the original ring diameter after lifting.

Full size pile cages are lifted on site, using specified lifting methods, the cages are placed back on the ground and the distortion is measured. The cage must remain intact and must not exceed the specified geometry limits.

g Concrete compaction and concrete flow shall not be adversely affected by the inclusion of the cage formers.

A section of pile cage is placed in circular shuttering and filled with a typical piling concrete mix. The sample is then cut into sections and examined for evidence of adverse concrete flow such as large voids.

h The clamps must achieve a tensile strength of at least 3 times the nominated safe working load.

Sections of pile cage former clamped to main reinforcement are tensile tested to ensure the strength of the clamped joint exceeds 3 times the nominated safe working load.

Part 6 of this Guide explained that CARES had produced assessment schedules for tack and structural welding of reinforcement. Cage Formers are factory welded under these quality requirements, utilising CARES Appendices 6 and 10.

4.0 The CARES Scheme

Whilst being different in nature, in that it does not deal with standardised products, the CARES Technical Approval Scheme uses many of the principles of its original product certification scheme as described in Part 1 of this Guide.

The procedure ensures the following:

- That the product, its specific application and the scope of certification are fully understood. This is subject to the scrutiny of CARES Members in order to ensure that it is within its area of defined expertise and that full support for assessment requirements are available.
- The formulation of an assessment schedule by CARES and its agents, approved by experts selected from it's Board of Management and applied by its assessors and nominated test houses. All product assessment schedules include quality system requirements and include consideration of the design requirements both for the product itself and for its application.
- The formulation of a comprehensive testing programme giving full consideration to each of those performance characteristics considered important to meet it's declared purpose.
- An assessment of the quality management systems of producers both initially and periodically by CARES assessors' expert in the products and processes involved. This includes any sub-contracting production and testing used by the manufacturer. This assessment is based on the requirements of ISO9001:2000.
- An evaluation of the technical data of the producer, as applied to the product, including those procedures for installation and technical assistance. Any amendment to the product production or design considered significant to its performance is assessed and further tests are initiated as required.
- On completion of testing the assessment report and the certificate, which includes the certificate of approval, are approved by a group selected from the CARES Board, before it is signed and issued.

CARES Technical Approval Document

Figure 8 Technical Approval Report and Certificate

5.0 The Technical Approval Report

The Technical Approval Report is an important document for the end product user. It defines the conditions of use of the product and therefore, in effect, its limitations. Important conditions in relation to the validity of the approval to be recognised include:

- The product design and specification remain unchanged from that assessed.
- The materials and method on manufacture remain unchanged.
- The product is installed and used as detailed in the report.

The Technical Approval Report must be read in conjunction with the relevant CARES Certificate of Approval. **Figure 8** shows a CARES Technical Approval Certificate alongside its associated Certificate of Approval.

All CARES Technical Approvals are published in a list, which is now located in an easily searchable form on the CARES website: www.UKCARES.com. Hard copies may be obtained from CARES at the following address;

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6.0 References

1. "Mechanical couplers for reinforcing bar splicing." **Jean-Jacques Braun, Technical Director, The Dextra Group**
2. **BRITISH STANDARDS INSTITUTION. BS 4449:1997** "Carbon steel bars for the reinforcement of concrete"
3. **BRITISH STANDARDS INSTITUTION. BS 8110:Part 1:1997** "Structural use of concrete. Code of practice for design and construction"
4. **BRITISH STANDARDS INSTITUTION. BS 5400:Part 4:1990** "Steel, concrete and composite bridges. Code of practice for design of concrete bridges"
5. **BNFL Specification, Mechanical Splices to Reinforcement for Concrete**
6. **UK CARES** "Steel for the Reinforcement of Concrete Scheme" **Edition 3 September 1999, appendices 6 and 10**
7. **BRITISH STANDARDS INSTITUTION. BS EN ISO 9001:2000** "Quality Management Systems-Requirements".
8. **CARES Guide to Reinforcing Steel Part 1**, The Product Certification Scheme for Steel for the Reinforcement of Concrete
9. **CARES Guide to Reinforcing Steel Part 6,** The Welding of Reinforcing Steel

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