Ancillary Products for Reinforced Concrete Construction

1.0 Introduction

Earlier parts of this Guide have 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 the 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.

Punching Shear System

Figure 1 Courtesy of RFA

2.0 CARES Technical Approval Procedure

The procedure begins with a detailed discussion between the applicant firm 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 experts selected from it's Board of Management and applied by it's assessors and nominated test houses. All product assessment schedules include quality system requirements and the quality management systems of producers are assessed and audited twice-yearly by CARES auditors' 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.

2.1 Key differences

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

- Creation of bespoke tests and testing programme to be included within the assessment schedule. Such testing may be defined in a product standard, or alternatively designed by CARES. CARES 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 any Assessment Schedule used. 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. **Punching Shear Systems**

3.1 Mechanical Splices

Basic principles

The basic principle of lapping, which is common in reinforced concrete construction, is to lay two bars parallel to one another, overlapping for a certain designed length (lap length), and connect them with tying wire. The load in the first bar is transmitted to the concrete by the bond between steel and concrete to the second bar. Since this load transference is indirect, the efficiency of this joint and therefore the lap length depends on many factors, including the properties of the concrete. This complexity requires design regulations for lapping and that design engineers and site engineers be familiar with these design requirements.

Design codes typically recommend that joints in rebar are to be placed away from points of high stress and that these joints are staggered. Some codes restrict overlapping to areas subject to lower stresses or restrict overlapping to smaller bar diameters, e.g. less that 32mm.

In some circumstances lapping of reinforcement is neither practicable nor cost effective and to solve this problem, the construction industry has developed mechanically coupled splices. This product is known as a coupler and is designed to join two reinforcing bars together and transmit the load in one bar to another. 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

Tapered thread

Figure 2 Courtesy of Erico

Parallel thread

Figure 3 Courtesy of G-Tech

Thread/swage combination

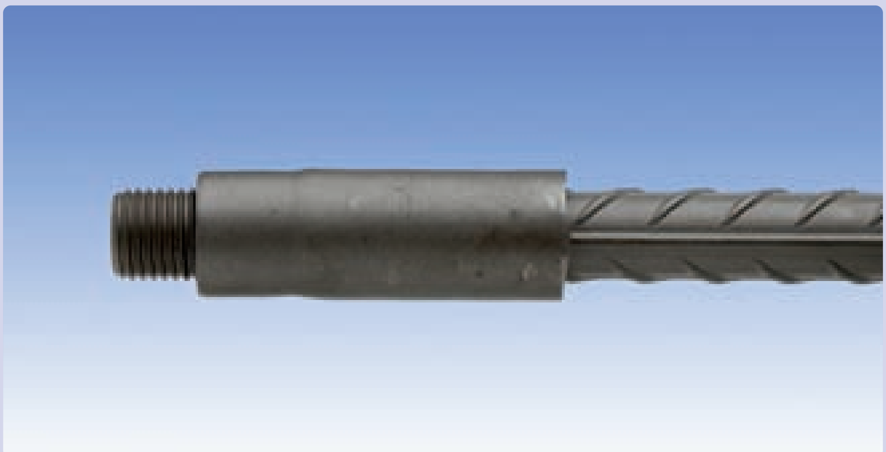

Figure 4 Courtesy of Dextra

created from one bar to another that is independent of the condition and quality of the concrete. Furthermore, the mechanical splice is relatively quick, easy and inexpensive to test.

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 approved 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. The coupler is a assembled using a torque wrench (**Figure 3**).

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 developed 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 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 full 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 reinforcement grades):

- **TA1-A, for use with Highway Structures**

  The tensile strength requirements are based on the Ratio (tensile strength/yield strength) and yield strength.

  The minimum UTS = R_e x (R_m/R_e) =

  540Mpa for grade B500B reinforcement and 575MPa for grade B500C.

  Permanent set ≤ 0.10mm @ 0.6 fy.

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

  There are two fatigue classes, D and R. 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 and EC2**

  The tensile strength requirements are based on the above and are 497MPa for grade 460B reinforcement, 540Mpa for grade B500B and 575MPa for grade B500C.

  Permanent set ≤ 0.10mm @ 0.65 f_y in tension and compression for EC2 and tension and optional compression for BS8110.

- **TA1-C for use in nuclear applications**

  Only B500C grade reinforcement is permitted for nuclear applications and the tensile strength requirement is based on the actual yield strength and is

  ≥ $R_{e,\ act}$ x 1.15 and ≤ $R_{e,\ act}$ x 1.35.

  UTS ≥ load required to produce 2% strain in reinforcing bar.

  The effective strain across the splice shall be ≤ strain in the control bar +40%.

  Permanent set ≤ 0.10mm @ 0.6f_y.

  Additionally some of the samples are subject to a cold soak (-7°C) or low cycle fatigue (100 cycles, between 5% and 90% f_y).

  For "Type A" couplers the mode of failure must be by bar break.

Finally, and whilst outside the direct remit of the Technical Approval assessment, CARES also assesses how reinforcement fabricators produce and apply mechanical splices.

Continuity strip

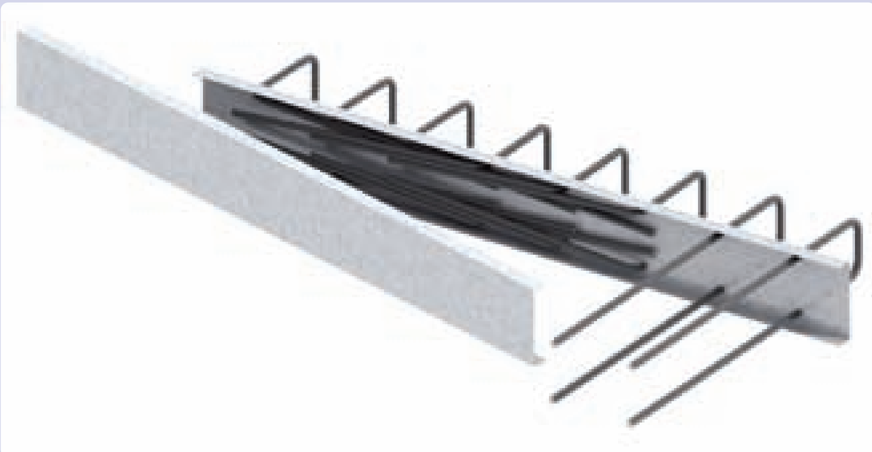

Figure 5 Courtesy of Ancon

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.

Continuity Strip in operation

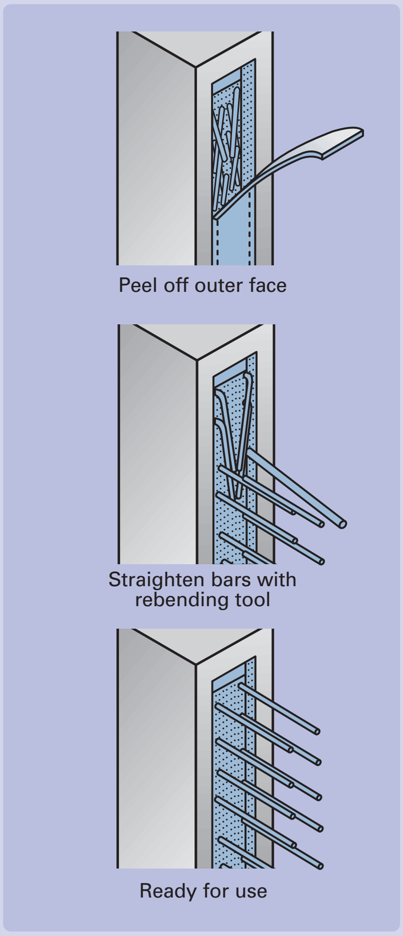

Figure 6 Courtesy of RFA

Bending tool

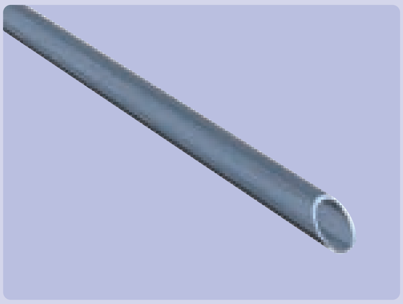

Figure 7 Courtesy of Ancon

3.2 Reinforcement continuity system (TA2)

Basic principles

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

The typical reinforcement continuity system consists of reinforcement, pre-bent and housed in a purpose-designed carrier casing (**Figure 5**). 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 (**Figure 6**). Using a specially designed tool (**Figure 7**), 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 subsequent pour of the adjoining member, eliminating the need for traditional preparation, such as scabbling at the joint.

CARES assessment

The CARES Technical Approval covers the use of these systems in accordance with EC2. 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. Ductlity is clearly the key property here and, whilst of course ensuring that all steel used meets the requirements of BS4449, 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. Also after bending and straightening twice, the reinforcement must not have any surface rupture. Regular independent testing is also performed as part of the CARES assessment.

Continuity Strip in situ

Figure 8 Courtesy of Ancon

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 comparable to equivalent, traditionally formed construction joints.

Punching Shear System in situ

Figure 9 Courtesy of RFA

3.3 Punching Shear Systems (TA7)

Basic principles

A concentrated load on a slab causes high punching shearing stresses on the section around the load. Traditionally shear link reinforcement is used to resist punching shear however shear studs connected to rails are a popular alternative, offering a prefabricated solution that is relatively easy to install (**figure 9**).

Shear studs are fabricated from ribbed reinforcing steel, usually with hot forged enlarged ends; the shaft of each stud provides the shear reinforcement and the stud heads and ribs on the shaft provide anchorage and bond with the concrete. EC2 enables the calculation of area punching shear reinforcement required and also gives guidance on its spacing.

CARES assessment

CARES assessment comprises:

a Mechanical testing of the studs to ensure that the stud's tensile properties comply with BS4449 and that the stud heads remain attached under full tensile load.

b Structural testing in concrete to verify that the producers stud system and design and detailing guidance provide adequate punching shear resistance.

Product Requirements

Product testing:

a Tensile strength: The studs are tested to determine their tensile strength in accordance with BS4449 and must comply with the tensile properties of BS4449 for the specified grade of reinforcement. The tensile load must be applied via the head and the mode of failure must be by ductile failure of the shaft and not by detachment of the head.

b Elongation at maximum force: The studs must be tested to determine their total elongation at maximum force in accordance with BS4449 and must comply with the requirements of BS4449 Table 10.

c Structural testing: reinforced concrete slab/column samples, designed in accordance with the manufactures guidance and subject to punching shear loads. The slabs/columns must achieve the necessary punching shear capacity and the mode of failure must be ductile and flexural in nature.

4.0 The CARES Scheme

Whilst being different in nature to the CARES Product Certification scheme, in that it does not deal with standardised products, the CARES Technical Approval Scheme uses many of the same principles as they are described in Part 1 of this Guide.

The Technical Approval 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 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 auditors 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 its declared purpose.
- An assessment of the quality management systems of producers both initially and periodically by CARES auditors' expert in the products and processes involved. This includes any sub-contracting production and testing used by the applicant manufacturer. This assessment is based on the requirements of ISO9001:2008.
- An evaluation of the technical data of the manufacturer, 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 if CARES approval is to be maintained.
- On completion of testing an assessment report and Technical Approval report are produced, both of which detail the product scope and scope of use that has been assessed and approved. It is important to note that the Technical approval report must be accompanied by a specific CARES Technical Approval certificate as proof that the approval is current and valid.

CARES Technical Approval Document

Figure 10 Technical Approval Report and Certificate

5.0 The Technical Approval Report

The Technical Approval Report is an important document for the end product user in that 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 10** shows a CARES Technical Approval Certificate alongside its associated Certificate of Approval.

All CARES Technical Approvals are published in PDF format on CARES' website: www.UKCARES.com

UK CARES
Pembroke House
21 Pembroke Road
Sevenoaks
Kent TN13 1XR

Tel: 01732 450000
Fax: 01732 455917
e-mail: general@ukcares.com
website: www.ukcares.com

6.0 References

1 **BRITISH STANDARDS INSTITUTION. BS 4449: 2005** Steel for the reinforcement of concrete – Weldable reinforcing steel - Bar, coil and decoiled product - Specification.

2. **BRITISH STANDARDS INSTITUTION. BS EN 1992-1-1: 2004** Eurocode 2 Design of concrete structures- Part 1-1: General rules for buildings.

3. **BRITISH STANDARDS INSTITUTION. BS 8110:Part 1:1997** "Structural use of concrete. Code of practice for design and construction".

4. **UK CARES** "Steel for the Reinforcement of Concrete Scheme" **Edition 3 September 1999, appendices 6 and 10.**

5. **BRITISH STANDARDS INSTITUTION. BS EN ISO 9001:2008** "Quality Management Systems- Requirements".

6. **CARES Guide to Reinforcing Steel Part 1**, The Product Certification Scheme for Steel for the Reinforcement of Concrete.

7. **CARES Guide to Reinforcing Steel Part 6**, The Welding of Reinforcing Steel.

UK CARES
Pembroke House, 21 Pembroke Road, Sevenoaks, Kent TN13 1XR
Phone: +44(0)1732 450000 Fax: +44(0)1732 455917
E-mail: general@ukcares.com
URL: www.ukcares.com

This guide is available in pdf format. If you wish to receive a pdf copy and receive future updates, please send an e-mail to the address above