



# Welding of Reinforcing Steels

## 1.0 Introduction

In the UK Designers, Engineers and Contractors are increasingly seeing the benefits of specifying factory made pre-assembled welded fabrications to improve on-site productivity. Many reinforcement fabricators now offer this service, and the use of pre-assembled welded fabrications is increasing significantly. Under controlled conditions away from the construction site, **(Figure 1)** welding can provide:

- Efficient joining of reinforcement robust enough to survive transportation, lifting and installation.
- When required, load bearing joints can be produced to specified strength levels.

Pre-assembled welded fabrications can be manufactured into a range of shapes and sizes to suit applications such as:

- **Pile reinforcement** - factory-assembled pile cages with the appropriate number of bars, helicals, rings, cage stiffeners and lifting bands **(see Figure 2)**.
- **Beam and column cages** - factory-assembled with the required number of bars and links.
- **Shear head reinforcement** - for flat slabs, including a variety of pre-assembled arrangements of stud rails, shear stirrups, shear ladders, shear hoops, etc.
- **Diaphragm walls** - factory-assembled with the appropriate number of bars and links.
- **'Carpet' reinforcement (e.g. Bamtec and Rollmat)** - reinforcement rolls of the required size and spacing are factory welded and placed on site.

These and other products give the designer a broad range of options for specifying pre-assembled welded fabrications.

## Factory welding of steel reinforcement



Figure 1 Courtesy of ROM

## 2.0 Welding processes

The welding processes used for pre-assembled welded reinforcement fabrications are:

- Gas shielded metal arc welding - Metal inert gas (MIG) and metal active gas (MAG)
- Manual metal arc welding (MMA), also known as 'stick' welding
- Electrical resistance spot welding

### 2.1 Metal inert gas welding (MIG) / Metal active gas welding (MAG)

With MIG and MAG welding an arc is maintained between a continuous solid wire electrode and the work piece. The arc and weld pool are shielded by a stream of inert or active gas. The process is suitable for most materials and filler wires are available for a wide range of metals.

The main items of equipment are the power source, a wire electrode that is a continuous wire, fed from a spool, to the welding torch head automatically and a separate external cylinder containing the shielding gas.

The arc is struck by short circuit of the wire on contact with the work piece, as it is driven by the drive rolls through the liner, and then out through the contact tip. **(Figure 3)** The type of metal transfer that occurs is entirely dependent on gas type being used and amperage/wire feed speed and voltages set. As the electric arc length is controlled by the power source the process is classified as a semi automatic welding process, which may be used manually, fully automated by robotics, or can be simply mechanised by using a tracking and/or weaving system.



### ■ 2.1.1 Key variables:

In this process wire feed speed, voltage, shielding gas and inductance are vitally important. When MIG/MAG welding it is necessary to ensure the welding equipment, the electrode wire and the drive rolls and liner are in good condition and regularly inspected. Also the contact tip, all connections, type of gas and gas flow rate are important. All of the essential variables must be included in the approval of the welding procedure.

The significant majority of the pre-assembled welded fabrications produced away from the construction site are produced using MAG welding processes.

## 2.2 Manual Metal Arc Welding (MMA) or 'stick' welding

Manual metal arc (MMA) or 'stick' welding is a process that was first developed in the late 19th century using bare wire electrodes. In MMA welding an electric arc is maintained between the end of a coated metal electrode and the work piece. (Figure 4) As molten metal droplets from the electrode are transferred across the arc and into the molten weld pool, they are shielded from the atmosphere by the gases produced from the decomposition of the flux coating. The molten slag floats to the top of the weld pool where it protects the weld metal from the atmosphere during solidification. The slag must be removed after depositing each weld run. Hundreds of different varieties of electrodes are produced, often containing alloys to add durability, strength and ductility to the weld.

As well as for reinforcing steel this process is also used for ferrous alloys in the structural steelwork, shipbuilding and general fabrication industries. Despite the relative slowness of the process, because of electrode changes and slag removal, it remains one of the most flexible techniques and has advantages in areas of restricted access.

### ■ 2.2.1 Key variables:

In this process the key variables are voltage, current, polarity, angle of electrode, arc gap distance and speed of travel. When MMA welding, it is necessary to ensure that the welding equipment, especially the welding electrodes (sticks), are properly maintained in accordance with the manufacturer's recommendations and in

## Pile reinforcement



Figure 2 Courtesy of ROMTECH

good condition. Checks should be made to ensure that the correct specification of electrode is being used and it is of the correct diameter, the flux coating is in good condition and that any basic coated electrode being used has been pre-baked as specified in the welding procedure. Vacuum pack pre-baked electrodes do not need to undergo this pre-baking treatment.

MMA is a relatively simple process in terms of equipment and consumables, using short flux covered electrodes but the process demands a high level of skill from the welder to obtain consistent high quality welds. Therefore the welding procedure and welder approval are of paramount importance; an unqualified welder should not be used.

## 2.3 Electrical resistance spot welding

Electrical resistance spot welding is used primarily in a factory environment where there is a considerable amount of process automation. The required heat in electrical resistance spot welding for

joining is generated at the welding interface by the electrical resistance of the joint. Welds are made in a relatively short time, tenths of a second, using a low-voltage, high-current power source with force applied to the joint through two electrodes, one on each side. In electrical resistance spot welding, the parts are locally heated until a molten pool forms. The parts are then allowed to cool, and the pool freezes to form a weld nugget. On a typical machine, the operator has control over the current setting, electrode force and weld time. To create heat, copper electrodes pass an electric current through the work pieces. The heat generated depends on the electrical resistance and thermal conductivity of the metal, and the time that the current is applied. Steel has a higher electrical resistivity and lower thermal conductivity than the copper electrodes, making welding relatively easy.

Two copper electrodes are held in the jaws of the spot welding machine, and the material to be welded is clamped between them. Pressure is applied to hold the electrodes tightly together, and

electrical current flows through the electrodes and the material. The resistance of the steel being welded is so much higher than that of the copper electrodes that enough heat is generated to melt the metal. The pressure on the electrodes forces the molten spots in the two pieces of metal to unite, and this pressure is held after the current stops flowing long enough for the metal to solidify. The amount of current, pressure, and dwell time are all carefully controlled and matched to the steel thickness to produce the correct spot welds. (Figure 5)

Reinforcing fabric and some carpet reinforcement, e.g. Bamtec, are manufactured using this process.

### 3.0 Control of welding processes and typical welding imperfections

Control of welding processes is vital, since the combination of heat input and rapid cooling rates has the potential to produce hard, brittle structures, susceptible to fracture.

The susceptibility to cracking is further increased if significant hydrogen absorption occurs in the welding process, which may cause hydrogen cracking in the heat affected zone (HAZ). Hydrogen may be absorbed into the arc from moisture in the atmosphere (if the arc is not suitably shielded), from organic contaminants (oil, paints etc), or from the use of incorrect electrodes.

Improperly made welds introduce defects into the reinforcement, such as cracks, pores and other stress raisers which also impair mechanical properties, and can act as initiation sites for failure.

All of the above effects can lead to degradation of material properties, whether the welds are locational (tack) welds, or structural welds. For this reason, all welding of reinforcing steels requires strict adherence to proven welding procedures and an acceptable level of welder competence.

Reinforcing steels used in the UK today are produced by a range of processes and with varying chemical analyses (CARES Guide Part 2). It is vital that proper control of the welding process is maintained if the negative effects of welding on the performance of the reinforcing steel are to be avoided. Welds must be fit for their intended purpose, whether they are load-bearing

## MIG/MAG welding

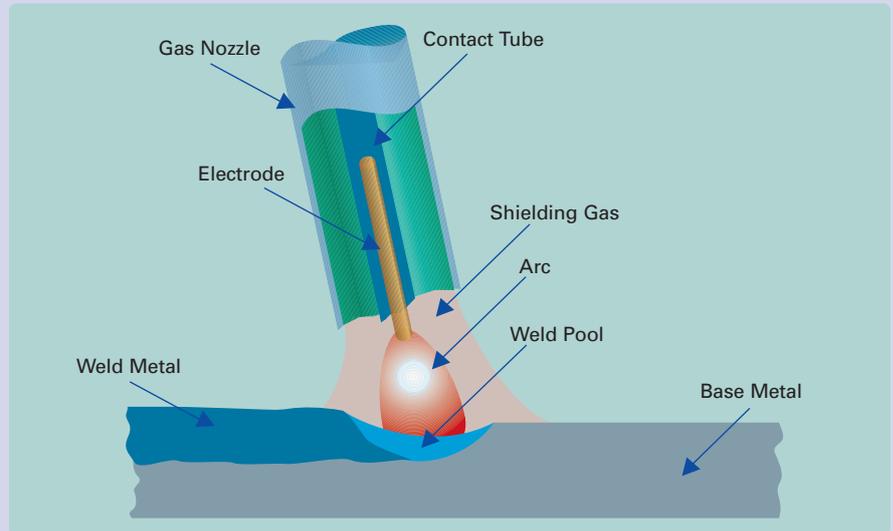


Figure 3

## MMA (stick) welding

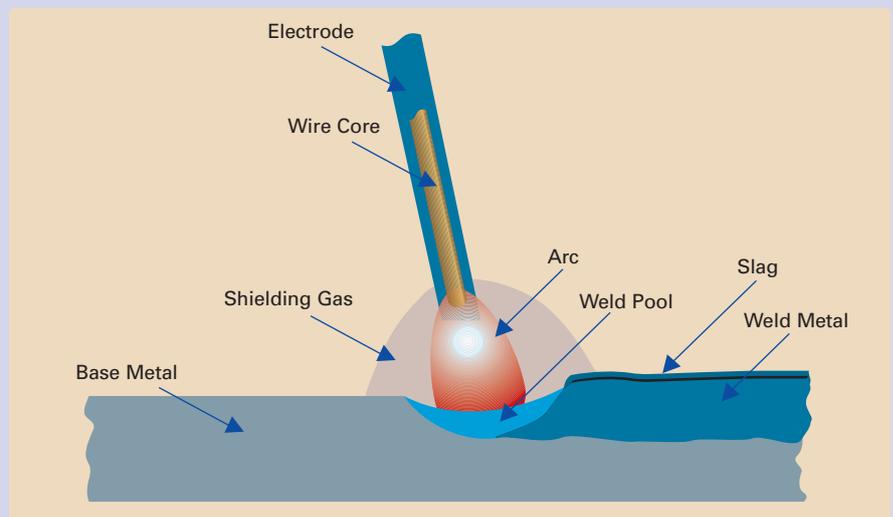


Figure 4

structural welds or non-load-bearing tack welds. Reinforcement fabricators need to demonstrate that welded assemblies meet the requirements of the reinforcing steel specifications, and are safe to transport, handle, lift and install.

Improper welding can have severe effects on both the structural performance of the steel, and on the safety of welded assemblies.

In the UK, BS 7123 1989, specification for metal arc welding of steel for the reinforcement of concrete, has been the dominant standard accepted by industry for specifying the requirements for

materials, approval of weld procedures and welders, workmanship and inspection and testing of electric arc welding of reinforcing steels. This Standard is still the basis for the CARES scheme for welded reinforcement which also includes reference to other relevant European Standards.

Although welding can be conducted on the construction site, the CARES scheme described here applies only to welding away from the construction site, where close control over the welding processes and its many variables can be better maintained. These requirements do not apply to the welding of stainless steel.

## Electrical resistance spot welding

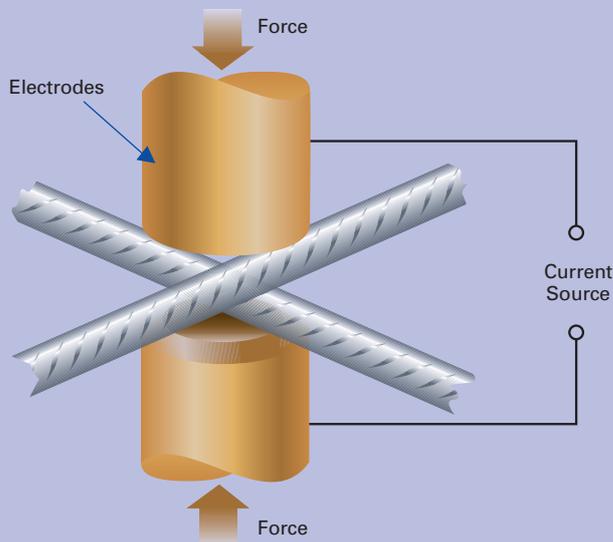


Figure 5

### 4.0 The CARES Scheme for welded reinforcement

The CARES Scheme for welding of steel reinforcement is designed to provide independent assurance that the required level of quality of the welding activities is consistently achieved.

A contractor receiving prefabricated steel reinforcement from a supplier approved by CARES for welding should be able to use the material without the need for any further product testing, with the full confidence that the pre-assembled welded fabrication complies with their specified requirements.

### 4.1 Welding Standards

With the increased use of pre-assembled welded fabrications it is apparent that the requirements of BS 7123 and also, its successor BS EN ISO 17660, Welding of reinforcing steel, do not address all of the needs of the industry. In particular there are significant health and safety issues relating to the efficacy of non-load bearing welds, 'tack' welds, where BS 7123 does not cover joints designed to support loads during transport and placement at the construction site to ensure safe handling, lifting, transport and placement in the permanent works. Whilst BS EN ISO 17660 is to be reviewed, the CARES scheme has been designed to overcome these inadequacies.

### 4.2 The scope of the Scheme

The CARES steel for the reinforcement of concrete scheme enables reinforcement fabricators to demonstrate objectively that they are complying with the relevant CARES assessment schedule, BS 7123 and/or customer requirements, whilst providing specifiers with confidence that welded assemblies from CARES approved fabricators will meet all of the requirements of the reinforcing steel standard, and the requirements of the welding standard. It recognises that, to be effective in practice, it must cover all welded joint types that it defines as follows:

- **Tack welds** - Welds used to hold together assemblies of reinforcing bars for locational purposes only. A tack weld should not be relied upon for safe handling, lifting and transport.
- **Semi-structural joints** - A joint designed to support loads during transport and placement at the construction site to ensure safe handling, lifting, transport and use of the fabricated structure. This is a temporary works engineering requirement. In the permanent works sense, these connections can be regarded as redundant once the surrounding concrete has cured.

- **Structural joints** - A joint designed to support loads during service. In addition to the requirements for semi-structural joints, these welds require the demonstration of adequate transmission of the specified shear load across the joint. This is a permanent works requirement for the assembly.

Two CARES Quality and Operations Assessment Schedules have therefore been produced and are used by approved firms and by CARES auditors in their assessment.

- **Appendix 6** - Quality and operations assessment schedule for the tack welding of reinforcing steel.
- **Appendix 10** - Quality and operations assessment schedule for the manufacture of pre-assembled welded fabrications using welded semi-structural and/or structural joints.

These are an integral part of the CARES Steel for the Reinforcement of Concrete Scheme.

### 4.3 The operational and quality requirements of the Scheme

All reinforcement manufacturers approved by CARES must have a quality management system in place which meets the requirements of ISO 9001:2008. In addition, the CARES scheme for welded reinforcement requires the fabricator to effectively implement the following:

#### Contract review.

The manufacturer should have a documented procedure for the review, agreement and documentation of contract details. The review should clearly identify if there is a design requirement and who is responsible for design. Where design activities are undertaken by the manufacturer, the design process should be documented. A critical element of the contract review process should be the determination of the different types of welds in the pre-assembled welded fabrication.

**Design process.** Where applicable, records should be kept of the design process used to ensure the integrity of the welded joints, in handling, transportation, lifting, installation, and (where appropriate) in service.

**Manufacturing processes.**

There should be a documented procedure for the manufacture of welded fabrications, which should include the weld type, size, length, location, selection of materials, use of appropriate jigs and fixtures, and precise parameters for the welding methods employed.

**Approval of welding procedures.**

There should be a documented procedure for the approval of welding procedures, whether manual or automatic, in accordance with the requirements of clause 12 of BS 7123. The procedure should state requirements for the essential variables of the welding process used and specify the maximum acceptable carbon equivalent value as well as acceptable manufacturing process routes for the parent reinforcing steel. The hardness profile of the welded joints should satisfy the requirements of BS EN ISO 15614-1, Table 2. A typical hardness profile is shown in **Figure 6**.

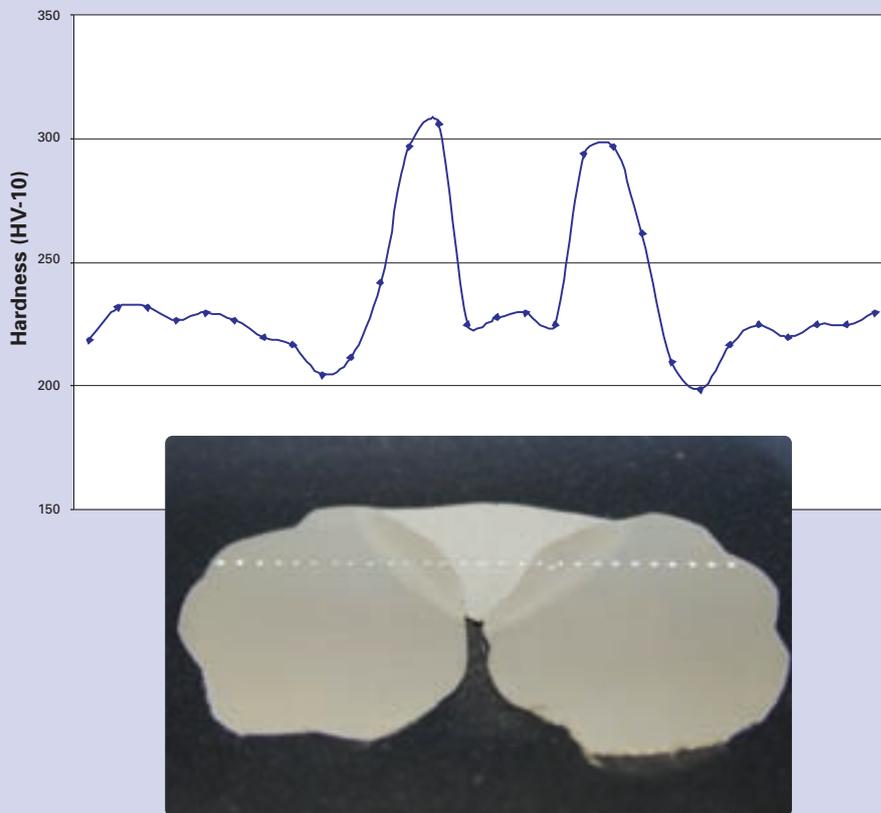
**Approval of welders.** There should be a documented procedure for the approval of welders, in accordance with the requirements of clause 13 of BS 7123. The procedure should ensure that welders are re-approved, when significant variables described in BS 7123 are altered. Extension of the welder's approval should be in accordance with the requirements of EN 287-1 clause 9.3.

**Manufacturing infrastructure.**

The manufacturing infrastructure, a factory, used for the welding of reinforcing steel is stated on the certificate of approval. Welding records should demonstrate that immediately before welding the surface of the reinforcement was not at a temperature below 0°C. Welding should not be carried out when the welding surfaces are damp.

**Traceability.** Traceability should extend through the manufacturing process to the final product. Each pre-assembled welded fabrication should be uniquely identified and traceable to original material cast information. A key element of the

## Typical hardness profile of a welded joint



**Figure 6** Courtesy of R-Tech Services

CARES Product Certification Scheme is the requirement for full product traceability from steel production through to the products delivered to site. As a result requests for copies of test certificates by contractors or engineers are of limited value and unnecessary for material supplied by a CARES approved firm.

**Inspection and despatch.** There should be a documented procedure for testing, inspection and despatch, including a delivery plan, which should ensure that welds and pre-assembled welded fabrications comply with the design requirements and the requirements of the appropriate standard or customer specification.

### 4.4 The certification process

■ **Assessment**

Initial approval of a fabricator is based upon an assessment of the quality system as outlined above, plus independent testing of weld procedures and welders against the requirements of BS 7123 and other relevant Standards using recognised quantitative and

qualitative tests. These tests are performed by independent UKAS accredited laboratories with the necessary competence.

■ **Maintenance of certification**

Once approved CARES undertakes regular surveillance audits of the fabricator. The CARES assessors audit the quality system in place, to ensure ongoing compliance with the requirements of BS 7123 and the CARES scheme. They also conduct dimensional checks, and witness the preparation of weld samples for independent testing.

### 5.0 Receipt, storage and use by the Contractor

In order to maintain the benefits of the strict controls adopted by the CARES approved pre-assembled welded fabrication manufacturers, it is vitally important to recognise that these products must be treated properly by the contractor from the time they are received on site and throughout the construction process.

Upon receipt of the pre-assembled welded fabrications at the construction site it is the responsibility of the contractor to implement effective procedures to ensure the pre-assembled welded fabrications are appropriately handled, stored and correctly fixed to avoid any defects in the permanent works.

In particular, when placing pile cages into position the contractor should ensure the correct lifting points are used to avoid intense point loading on the relatively flexible transverse links or rings. Once in place and after initial concrete casting, the contractor should ensure that proper care is taken when 'breaking-down' reinforced concrete pile heads to avoid mechanical damage or fracture of the reinforcing bars.

Guidance on the appropriate temporary works methods of lifting, handling and working with pre-assembled welded fabrications should be obtained from the reinforcement fabricator.

When it is necessary to weld reinforcement at the construction site it is important that the contractor ensures that the technical requirements described above are satisfied in order to produce acceptable welds.

## 6.0 Specification of CARES approved manufacturers of pre-assembled welded fabrications

When a CARES approved manufacturer is not specified, there is an additional onus on the purchaser to verify compliance, which may require inspection and testing involving both significant cost, and potential delays on site.

The suggested wording for inclusion in a specification is as follows:

### ■ Semi-structural / structural welding activities:

"Only firms that have achieved certification to CARES **Appendix 10** - Quality and operations assessment schedule for the manufacture of pre-assembled welded fabrications using welded semi-structural and/or structural joints, shall be permitted to bid for or undertake contracts to supply pre-assembled welded fabrications."

### ■ Tack welding activities:

"Only firms that have achieved certification to CARES **Appendix 6** - Quality and operations assessment schedule for the tack welding of reinforcing steel, shall be permitted to bid for or undertake contracts to supply pre-assembled tack welded fabrications."

**Note: Evidence of compliance with the above should be requested for submission with contract bids.**

## 7.0 CARES list of approved manufacturers

CARES regularly updates the list of approved firms, [www.ukcares.com](http://www.ukcares.com), that describes the firm's scope of approval and useful contact information. Occasionally pre-assembled welded fabrication manufacturers have falsely claimed to hold CARES approval because they only use steel from CARES approved sources, and/or have an approval for cutting and bending to BS 8666 / BS 4466. In these cases the pre-assembled welded fabrications supplied by these firms is not covered by the CARES approval. If there are any doubts concerning the scope of approval of a firm then the CARES List of Approved Firms should be consulted, [www.ukcares.com](http://www.ukcares.com), or alternatively the CARES office can be contacted for verification, contact details are given below.

## 8.0 References

1. **CARES Guide Part 2**, Manufacturing process routes for reinforcing steels April 2004.
2. **BRITISH STANDARDS INSTITUTION. BS 7123: 1989** Specification for metal arc welding of steel for concrete reinforcement.
3. **UK CARES** "Steel for the Reinforcement of Concrete Scheme". June 2010.
4. **BRITISH STANDARDS INSTITUTION. BS EN ISO 17660:2006.** Welding of reinforcing steel.
5. **BRITISH STANDARDS INSTITUTION. BS EN ISO 9001:2008.** "Quality Management Systems-Requirements".
6. **BRITISH STANDARDS INSTITUTION. BS 8666:2005** "Specification for scheduling, dimensioning, bending and cutting of steel for the reinforcement of concrete".
7. **BRITISH STANDARDS INSTITUTION. BS 4466:1989.** "Specification for scheduling, dimensioning, bending and cutting of steel for the reinforcement of concrete".
8. **"Steel for the Reinforcement of Concrete Scheme"** Appendices 6 and 10, "Quality and operations assessment schedule for the tack welding of reinforcing steel and Quality and operations assessment schedule for the manufacture of pre-assembled welded fabrications using welded semi-structural and/or structural joints. June 2010.
9. **BRITISH STANDARDS INSTITUTION. BS EN ISO 15614-1:2004,** Specification and qualification of welding procedures for metallic materials. Welding procedure tests; arc and gas welding of steels and arc welding of nickel and nickel alloys.
10. **BRITISH STANDARDS INSTITUTION. BS EN 287-1:2004.** Approval testing of welders for fusion welding. Steels.



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