

Guidance Note 4.02

Weld procedure tests

Scope

This note is intended to give the reader an insight into the fundamental principles involved in the formulation, testing and qualification of weld procedures.

What used to be referred to as weld procedure trials (now called tests) are expensive and time consuming. Even on a small structure there can be a large number of combinations of variables. It was therefore usual to make reference to previously approved trials, and for those trials to have been conducted in such a way that a range of weld procedure specifications (WPS) for production could be derived from them.

Requirements

BS EN 1090-2 clause 7 specifies all welding requirements.

Clause 7.1 requires that welding shall be undertaken in accordance with the requirements of the relevant part of BS EN ISO 3834 (fusion welding) or BS EN ISO 14554 (resistance welding) as applicable. It further requires, among other things, that arc welding of ferritic steels shall follow the requirements and recommendations of the relevant parts of BS EN 1011.

Clause 7.4.1 covers the qualification of welding procedures.

Sub-clause 7.4.1.1 requires that welding shall be carried out with qualified procedures using a welding procedure specification (WPS) in accordance with the relevant parts of standards covering, among other things, arc and resistance welding by various welding processes.

Sub-clause 7.4.1.2 for processes 111, 114, 12, 13 and 14, covers most of the processes likely to be used for steel bridgework fabrication. Sub-clause 7.4.1.3 covers processes including 783 and 784 for resistance welding, which would include those for shear stud welding. These sub-clauses refer to Tables 12 and 13, respectively, which list the methods of qualification

and the applicable standards for different Execution Classes under BS EN 1090-2.

The three standards relevant to this Guidance Note are:

- BS EN ISO 15614-1 for Welding Procedure Test using a standardised test piece;
- BS EN ISO 15613 for Pre-production Welding Test using a non-standard test piece representative of the production conditions and
- BS EN ISO 14555 for stud welding.

These methods are applicable to EXC3 and EXC4, where they are called for.

Terminology

BS EN ISO 15607, *Specification and qualification of welding procedures for metallic materials – General rules* describes the sequence of testing and approval which is laid out in three informative Annexes A, B and C.

Having considered the technical and practical requirements of a proposed welded joint or range of welded joints, the welding engineer will formulate a preliminary Weld Procedure Specification (pWPS).

Based on the pWPS, weld procedure tests will then be carried out in accordance with BS EN ISO 15614 for a standardised test piece or BS EN ISO 15613 for a non-standard test piece. If the results are satisfactory, a Welding Procedure Qualification Record (WPQR) will be prepared recording details of the weld procedure and test results.

From each WPQR a number of Weld Procedure Specifications (WPS) can be prepared, since a single WPQR approves a range of variables (see BS EN ISO 15614). All production work should be carried out in strict accordance with an appropriate WPS.

BS EN 1011-2:2001 – Recommendations for welding of metallic materials – Part 2: Arc welding of ferritic steels.

This standard was developed from, and superseded, BS 5135 (This section of the Note is included to provide the historical background to the development of requirements for formal written weld procedures and the tests to qualify them.)

BS 5135 contained references to the standards covering the manufacture of various types of welding consumables together with the requirements for their satisfactory storage.

There were also general clauses setting basic workmanship requirements for the execution of welds. However, the main body of the text related to the development of weld procedures for the avoidance of cracking.

Three categories of cracking are cited:

- Hydrogen induced delayed cold cracking
- Solidification cracking
- Lamellar tearing

BS 5135 was first published in 1974, and in that version all of the above issues were covered in terms of guidance notes given in the appendices rather than expressed requirements.

The 1984 revision changed the situation, with the provisions for the control of hydrogen induced delayed cracking becoming expressed requirements of the standard.

The measures for the avoidance of solidification cracking and lamellar tearing remained only as recommendations in the appendices.

Regarding the mechanical properties of the welded joint, BS 5135 stated that these were to be as required by the application standard, but gave no guidance on how this might be achieved.

In formulating a pWPS for a particular joint or family of joints, the welding engineer had therefore to follow the expressed requirements of BS 5135 in respect of hydrogen induced delayed cold cracking, but then rely on professional judgement regarding the attainment of the necessary mechanical properties and the avoidance of solidification cracking and lamellar tearing.

In addition a competent welding engineer had to consider measures for distortion limitation.

The requirements of BS EN 1011-1 and –2

Specific to the welding of ferritic steels, BS EN 1011-1 and 2 aim to cover all the aspects of welding technology previously covered by BS 5135. Part 1 provides general guidance where more specific guidance is given in Part 2. It should be noted that both parts are titled "Recommendations", not "Specifications" or "Requirements". As such there is a much greater reliance on the competence, technical qualification and experience, and judgement of those using these standards than was the case when BS 5135 was invoked.

This Guidance Note is limited to the subject of standard and pre-production welding tests. There are many other cross-references in the latest BS EN and ISO standards, which should be consulted where necessary.

In the UK, for steel bridgework for highways and railways, the use of BS EN 1090-2 leads (through the standards invoked in 7.4.1.1) to the requirement for the provision and use of written weld procedures. BS EN 1011-1 requires that the preparation of a weld procedure specification (WPS) shall be in accordance with BS EN ISO 15609. For arc welding, BS EN ISO 15609-1 applies and the technical content requirements of the WPS are covered by clause 4 of this Standard. An (informative) example is given in Annex A of the Standard.

Welding tests

The welding tests are carried out on standardised test pieces as specified in BS EN ISO 15614, clause 6.

The test pieces are required to represent, rather than totally replicate the joints to be welded in production. Their configurations are standardised to ensure that the necessary test specimens can be obtained.

A competent welding engineer will carefully select the features of each weld procedure test so that, if possible, the resulting Weld Procedure Qualification Records (WPQRs) will approve the full range of joints to be encountered in the production work, with the minimum number of tests.

It is usual for the formal welding tests to be witnessed by an examiner from an independent examining body. The witness countersigns and stamps the WPQR certificate.

As well as destructive testing of samples taken from the test pieces, non-destructive testing of the test piece to an acceptance level of class B of BS EN ISO 5817 is required (although level C applies to visual imperfection types: excess weld metal, excess convexity, excess throat thickness and excessive penetration).

The extent of non-destructive and destructive testing is set out in clause 7 of BS EN ISO 15614. Figure 1 of this note shows examples of the test specimens typically required to qualify a butt weld.

Weld Procedure Qualification Record (WPQR)

The WPQR is the formal record of a satisfactory weld procedure test. It records all the parameters for the test and the test results. It is certified by the examiner/examining body that witnessed the tests. The welder successfully undertaking the test also gains the relevant qualification.

Since the parameters for any test are variables, the WPQR qualifies a range of essential variables for which the test is considered to be valid. (For details on these and the qualification ranges, see BS EN ISO 15614-1, clause 8.) This allows a number of Weld Procedure Specifications to be prepared from a single welding test.

Specialist bridge fabricators usually hold a large library of WPQRs. Provided that the records are properly witnessed by an examiner/examining body, they will form a satisfactory basis for the development of the specific WPSs necessary to carry out the production work, with only occasional need for a supplementary weld procedure test.

If there is any doubt regarding the authenticity of an existing WPQR, then fresh welding tests should be carried out.

Weld Procedure Specifications

The review of relevant WPQRs and the preparation of WPSs for production work is a complex matter and should always be carried out by a qualified welding engineer.

It must be remembered that a WPS is valid for production welding only when all the parameters are within the limits of validity of the various items of recorded data in the WPQR.

Any changes in welding process, consumable designation, and type of welding current, always require the establishment of a new pWPS and procedure qualification test.

Fabricator's equipment and operatives

It is prudent to ensure that the welding equipment used in production is properly calibrated and maintained and appropriate to the WPQR, and to check that welders' qualifications are relevant to the WPS and up to date.

The new BS EN standards require that, subject to specific conditions, the welder's approval certificate be signed at 6-monthly intervals by the employer's authorised signatory. Should the employer wish to prolong a welder's approval beyond its expiry date, records of volumetric inspection and tests must be maintained and attached to the welder's approval certificate for verification by the examiner/examining body. This can be a problem for a fabricator undertaking a wide range of bridgework - some procedures and equipment may not have been used for some time.

Application tests/trials

The contractual requirements are set out above. The Client cannot demand more unless it is clearly specified and/or allowed for in the Contract. Sometimes, however, while the WPQRs and the particular WPSs may seem to cover the essential features of all the joints in the work, some applications may be constrained in some way, e.g. lack of clear access or by one type of joint leading into another. In such circumstances, it may be prudent to specify (and pay for) extra welding tests, called Pre-production tests. These trials are covered by BS EN ISO 15613 which is used as a basis for qualifying any project specific pre-production tests necessary. It has been found worthwhile to call for them in particularly difficult circumstances, to ensure that the welds can be completed properly. The trials are carried out on purpose made, non standard test pieces that truly represent the application. The testing of such pieces can be limited to visual and dimensional inspection,

i.e. a demonstration that the welding of the joint can be performed physically. However, sectioning and the preparation of macro specimens and hardness testing of the weld and HAZ are also further confirmation of the quality of the weldment. Depending on the complexity of the test piece it may be possible to devise non-destructive examination techniques for checking production work. Finally, the test specimens are also useful as comparative visual reference pieces for the workshop inspectorate during the performance of the work.

References

- [1] BS EN 1090-2: 2018+A1:2024 – Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures.
- [2] BS EN 1011-1: 2009, Welding. Recommendations for welding of metallic materials. General guidance for arc welding.
- [3] BS EN 1011-2: 2001, Welding. Recommendations for welding of metallic materials. Arc welding of ferritic steels.
- [4] BS EN ISO 5817: 2023, Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections.
- [5] BS EN ISO 15607: 2019, Specification and qualification of welding procedures for metallic materials. General rules.
- [6] BS EN ISO 15609-1: 2019, Specification and qualification of welding procedures for metallic materials. Welding procedure specification. Arc welding
- [7] BS EN ISO 15613: 2004, Specification and qualification of welding procedures for metallic materials. Qualification based on pre-production welding test..
- [8] BS EN ISO 15614-1: 2017+A1:2019, Specification and qualification of welding procedures for metallic materials. Welding procedure test. Arc and gas welding of steels and arc welding of nickel and nickel alloys.



Tensile test piece



Butt weld macro



Bend test (note opening of root defect)



Fillet weld macro



Charpy impact test pieces

Figure 1 Examples of test specimens