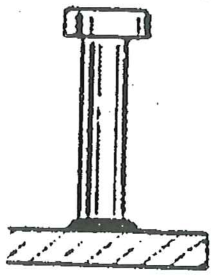
WMSCI Rochester BRF 0162(18)
welding Procedure for shear studs on BR19 Girders

STUD WELDING PROCEDURE SPECIFICATION (WPS) Yes ☐ OR PROCEDURE QUALIFICATION RECORD (PQR) Yes ☑ OR WELDER QUALIFICATION RECORD (WQR) Yes ☑

Company name ______
Supporting PQR no.(s) 3/4 7/8 1
Operator name ______
Stud material MILD STeel
Material specifications S3L
Weld base diameter 3/4" 7/8" 1"

Stud Base Sketch/Application Detail



Machine data

Power supply
Make Nelson Model Nelweld 6000
Stud gun model NS 20 HD
Weld time Secs. .8 - 1.4 ~~Cycles~~ ______
Current 1500 - 1900 ±5% OCV ______
Polarity STRAIGHT Lift .125
Plunge (protrusion) .250
Weld cable size 4/0 Length 500'
Number of grounds (workpiece leads) 1

Test no. ______
Revision no. ______ Date ______
By ______
Authorized by ______ Date ______

Base material

Specification A36
Alloy and temper ______
Group no. ______ Surface condition HR ☐ CR ☐
Coating ______
Cleaning method GRINDER
Decking gage ______

Shape

Flat ☒ Round ☐ Tube ☐ Angle ☐
Thickness ______

Ferrule

Part no. 100-101-140
Ferrule description FLAT

Position

Overhead ______ Downhand ✓ Sidehand ______
Angular ______ degrees from normal
Angle iron ______ Inside radius ______ Heel of angle ______

Shielding gas

Shielding gas(es) N/A
Composition ______
Flow rate ______

WELD TEST RESULTS

Stud No.	Visual Acceptance	Option #1 Bend Test	Option #2 Tension Test	Option #3 Torque Test*
1	Excellent	30°		
2	{	{		
3				
4				
5				
6				
7				
8				
9				
10	}	}		

*Note: Torque test optional for threaded fasteners only.

Mechanical tests conducted by Nelson STUD WeLDING Date ______
(Company)

We, the undersigned, certify that the statements in this record are correct and the test welds were prepared, welded, and tested in accordance with the requirements of AWS B2.1/B2.1M, (______), *Specification for Welding Procedure and Performance Qualification.*
(year)

Signed by Patricia Holmes Title ______ Date ______
(Contractor/Applicator)

Source: Adapted from AWS D1.1/D1.1M:2008, *Structural Welding Code—Steel*, Annex N Form N-9, American Welding Society.

Figure F.4—Example of a Welding Procedure Specification and Procedure Qualification Record for Stud Welding

MG/4/2/15

power source has fully recovered from making one weld before another weld is started.

7.5.3 While in operation, the welding gun shall be held in position without movement until the weld metal has solidified.

7.5.4 Welding shall not be done when the base metal temperature is below –20°C [0°F] or when the surface is wet or exposed to falling rain or snow.

7.5.4.1 When the temperature of the base metal is below 0°C [32°F], one additional stud in each 100 studs welded shall be tested by methods described in 7.7.1.3 and 7.7.1.4, except that the angle of testing shall be approximately 15°. This is in addition to the first two studs tested for each start of a new production period or change in setup.

7.5.4.2 Setup includes stud gun, power source, stud diameter, gun lift and plunge, total welding lead length, or changes greater than ±5% in current (amperage) and time.

7.5.5 At the option of the Contractor, studs may be fillet welded by the SMAW, provided the following requirements shall be met:

7.5.5.1 The minimum fillet size to be used shall be the larger of those required in Table 2.1 or 7.2.

7.5.5.2 Welding shall be done with low-hydrogen electrodes 4.0 mm [5/32 in] or 4.8 mm [3/16 in] in diameter except that a smaller diameter electrode may be used on studs 10 mm [3/8 in] or less in diameter or for out-of-position welds.

7.5.5.3 The stud base shall be prepared so that the base of the stud fits against the base metal.

7.5.5.4 All rust and mill scale at the location of the stud shall be removed from the base metal by grinding. The end of the stud shall also be clean.

7.5.5.5 The base metal to which studs are welded shall be preheated in conformance with the requirements of Table 4.4.

7.5.5.6 Fillet welded stud bases shall be visually inspected per 6.5.

7.6 Stud Application Qualification Requirements

7.6.1 Prequalification. Studs which are shop or field applied in the flat (down-hand) position to a planar and horizontal surface shall be deemed prequalified by virtue of the manufacturer's stud-base qualification tests (Annex E), and no further application testing is required. The limit of flat position is defined as 0°–15° slope on the surface to which the stud is applied.

The following are some nonprequalified stud applications that require tests of this section:

(1) Studs which are applied on nonplanar surfaces or to a planar surface in the vertical or overhead positions.

(2) Studs which are welded through decking. The tests should be with material representative of the condition to be used in construction.

(3) Studs welded to steels other than those described in 1.2.2.

7.6.2 Responsibilities for Tests. The Contractor or stud applicator shall be responsible for the performance of these tests. Tests may be performed by the Contractor or stud applicator, the stud manufacturer, or by another testing agency satisfactory to all parties involved.

7.6.3 Preparation of Specimens

7.6.3.1 Test specimens shall be prepared by welding the studs being qualified to specimen plates of M270M [M270] Grade 250 [36] (A 709M [A 709] Grade 250 [36]) steel or any base metal described in 1.2.2.

7.6.3.2 Weld position, nature of base metal and stud surfaces, current, and time shall be recorded.

7.6.4 Number of Specimens. Ten (10) specimens shall be welded consecutively using recommended WPSs and settings for each diameter, position, and surface geometry.

7.6.5 Tests Required. The ten (10) specimens shall be tested using one or more of the following test methods: bending, torquing, or tensioning.

7.6.6 Test Methods

7.6.6.1 Bend Test. Studs shall be bend tested by being bent 90° from their original axis. A stud application shall be considered qualified if all the test specimens are bent 90° and fracture occurs in the plate or shape material or in the shank of the stud and not in the weld.

7.6.6.2 Torque Test. Studs shall be torque tested using a torque-test arrangement that is substantially in conformance with Figure 7.3. A stud application shall be considered qualified if all test specimens are torqued to destruction without failure in the weld.

7.6.6.3 Tension Test. Studs shall be tension tested to destruction using any machine capable of supplying the required force. A stud application shall be considered qualified if none of the test specimens fail in the weld.

7.6.7 Application Qualification Test Data shall include the following:

(1) Drawings that show shapes and dimensions of studs and arc shields

(2) A complete description of stud and base materials and a description (part number) of the arc shield

(3) Welding position and settings (current, time)

(4) A record which shall be made for each qualification and that record shall be available for each contract

7.7 Production Control

7.7.1 Preproduction Testing

7.7.1.1 Before production welding with a particular setup (see 7.5.4.2) and with a given size and type of stud, and at the beginning of each day's or shift's production, testing shall be performed on the first two studs that are welded. The stud technique may be developed on a piece of material similar to the production member in thickness and properties. If actual production thickness is not available, the thickness may vary plus or minus 25%. All test studs shall be welded in the same general position as required on the production member (flat, vertical, or overhead).

7.7.1.2 Instead of being welded to separate material, the test studs may be welded on the production member, except when separate plates are required by 7.7.1.5.

7.7.1.3 The test studs shall be visually examined. They shall exhibit full 360° flash.

7.7.1.4 In addition to visual examination, the test shall consist of bending the studs after they are allowed to cool, to an angle of approximately 30° from their original axes by either striking the studs on the head with a hammer or placing a pipe or other suitable hollow device over the stud and manually or mechanically bending the stud. At temperatures below 10°C [50°F], bending shall preferably be done by continuous slow application of load. For threaded studs, the torque test of Figure 7.3 shall be substituted for the bend test.

7.7.1.5 If on visual examination the test studs do not exhibit 360° flash, or if on testing, failure occurs in the weld zone of either stud, the WPS shall be corrected, and two more studs shall be welded to separate material or on the production member and tested in conformance with the provisions of 7.7.1.3 and 7.7.1.4. If either of the second two studs fails, additional welding shall be continued on separate plates until two consecutive studs are tested and found to be satisfactory before any more production studs are welded to the member.

7.7.2 Production Welding. Once production welding has begun, any changes made to the welding setup (see 7.5.4.2) as determined in 7.7.1 shall require that the testing in 7.7.1.3 and 7.7.1.4 be performed prior to resuming production welding.

7.7.3 In production, studs on which a full 360° flash is not obtained may, at the option of the Contractor, be repaired by adding the minimum fillet weld as required by 7.5.5 in place of the missing flash. The repair weld shall extend at least 10 mm [3/8 in] beyond each end of the discontinuity being repaired.

7.7.4 Operator Qualification

7.7.4.1 The preproduction test required by 7.7.1, if successful, shall also serve to qualify the stud welding operator.

7.7.4.2 Before any production studs are welded by an operator not involved in the preproduction setup of 7.7.1, the first two studs welded by the operator shall be tested in conformance with 7.7.1.3 and 7.7.1.4. When two consecutively welded studs have been tested and found satisfactory, the operator may then weld production studs.

7.7.5 If an unacceptable stud has been removed from a component subjected to tensile stresses, the area from which the stud was removed shall be made smooth and flush.

7.7.5.1 Where in such areas the base metal has been pulled out in the course of stud removal, SMAW with low-hydrogen electrodes in conformance with the requirements of this code shall be used to fill the pockets, and the weld surface shall be ground flush.

7.7.5.2 In compression areas of members, if stud failures are confined to shanks or fusion zones of studs, a new stud may be welded adjacent to each unacceptable area in lieu of repair and replacement on the existing weld area (see 7.4.3). If base metal is pulled out during stud removal, the repair provisions shall be the same as for tension areas, except that when the depth of discontinuity is the lesser of 3 mm [1/8 in] or 7% of the base-metal thickness, the discontinuity may be faired by grinding in lieu of filling with weld metal.

7.7.5.3 Where a replacement stud is to be provided, the base-metal repair shall be made prior to welding the replacement stud.

7.7.5.4 Replacement studs (other than threaded type which should be torque tested) shall be tested by bending to an angle of approximately 15° from their original axis.

7.7.5.5 The areas of components exposed to view in completed structures shall be made smooth and flush where a stud has been removed.

7.8 Inspection Requirements

7.8.1 If visual inspection reveals any stud that does not show a full 360° flash or any stud that has been repaired by welding, such stud shall be bent to an angle of approximately 15° from its original axis.

7.8.2 The method of bending shall be in conformance with 7.7.1.4. The direction of bending for studs with less than a 360° flash shall be opposite to the missing portion of the flash.

7.8.3 Threaded studs shall be torque tested. Torque testing shall be in conformance with Figure 7.3.

7.8.4 The inspector, where conditions warrant, may select a reasonable number of additional studs to be subjected to the tests described in 7.8.1.

7.8.5 The bent stud shear connectors (Type B) and other studs to be embedded in concrete (Type A) that show no sign of failure shall be acceptable for use and left in the bent position. All bending and straightening when required shall be done without heating, before completion of the production stud welding operation, except as otherwise provided in the contract.

7.8.6 If, in the judgment of the Engineer, studs welded during the progress of the work are not in conformance with code provisions, as indicated by inspection and testing, corrective action shall be required of the Contractor at the Contractor's expense. The Contractor shall make the setup changes necessary to insure that studs subsequently welded will meet code requirements.

7.8.7 At the option and the expense of the Owner, the Contractor may be required, at any time, to submit studs of the types used under the contract for a qualification check in conformance with the procedures of Annex E.

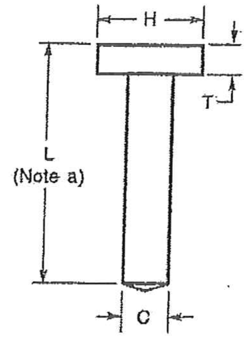
Table 7.1
Mechanical Property Requirements for Studs (see 7.3.1.2)

	Type A[a]	Type B[b]
Tensile strength	380 MPa [55 ksi] min.	415 MPa [60 ksi] min.
Yield strength (0.2% offset)	—	345 MPa [50 ksi] min.
Elongation (% in 50 mm [2 in])	17% min.	20% min.
Reduction of area	50% min.	50% min.

[a] Type A studs shall be general purpose of any type and size used for purposes other than shear transfer in composite beam design and construction.
[b] Type B studs shall be studs that are headed, bent, or of other configuration in 12 mm [1/2 in] through 23 mm [7/8 in] diameter that are used as an essential component in composite beam design and construction.

Table 7.2
Minimum Fillet Weld Size for Small Diameter Studs (see 7.5.5.1)

Stud Diameter, ϕ, mm [in]	Minimum Fillet Weld Size, mm [in]
$\phi \leq 10$ [3/8]	6 [1/4]
10 [3/8] $< \phi \leq 25$ [1]	8 [5/16]
$\phi > 25$ [1]	10 [3/8]



[a] L = manufactured length—length specified by Engineer plus upset distance.

Standard Dimensions, mm [in]			
Shank Diameter (C)	Length Tolerance (L)	Head Diameter (H)	Minimum Head Height (T)
12.7 [1/2] +0.00 −0.25 [−0.010]	±1.6 [±1/16]	25.4 ± 0.4 [1 ± 1/64]	7.1 [9/32]
15.9 [5/8] +0.00 −0.25 [−0.010]	±1.6 [±1/16]	31.7 ± 0.4 [1-1/4 ± 1/64]	7.1 [9/32]
19.0 [3/4] +0.00 −0.38 [−0.015]	±1.6 [±1/16]	31.7 ± 0.4 [1-1/4 ± 1/64]	9.5 [3/8]
22.1 [7/8] +0.00 −0.38 [−0.015]	±1.6 [±1/16]	34.9 ± 0.4 [1-3/8 ± 1/64]	9.5 [3/8]
25.4 [1] +0.00 −0.38 [−0.015]	±1.6 [±1/16]	41.3 ± 0.4 [1-5/8 ± 1/64]	12.7 [1/2]

Figure 7.1—Dimension and Tolerances of Standard-Type Shear Connectors (see 7.2.1)

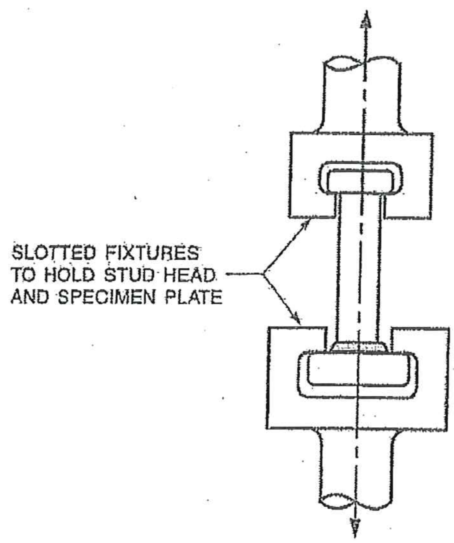


Figure 7.2—Typical Tension Test Fixture (see 7.3.2)

Table 3. Stud welding setups for mild and stainless steel studs welded to mild and stainless steel base materials.[14]

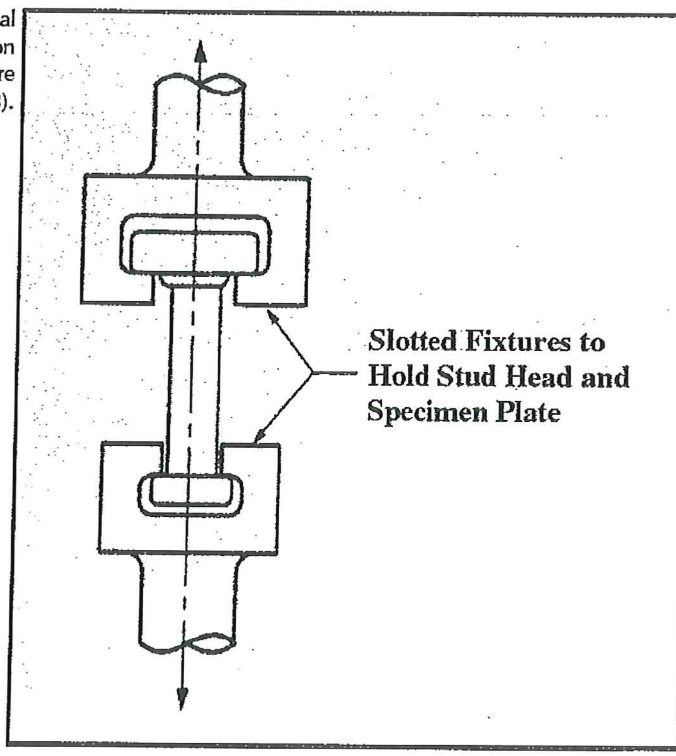
Diameter		Area	Downhand welding					Overhead welding					Vertical welding				
				Time					Time					Time			
in.	mm	sq in.	Amp	Sec	Cycles	Lift	Plunge	Amp	Sec	Cycles	Lift	Plunge	Amp	Sec	Cycles	Lift	Plunge
0.187	4.9	0.0276	300	0.15	8-9	0.062	0.125	300	0.15	8-9	0.062	0.125	300	0.15	8-9	0.062	0.125
0.250	6.4	0.0491	450	0.17	10-12	0.062	0.125	450	0.17	10-12	0.062	0.125	450	0.17	10-12	0.062	0.125
0.213	7.9	0.0767	500	0.25	15	0.062	0.125	500	0.25	15	0.062	0.125	500	0.25	15	0.062	0.125
0.375	9.5	0.1105	550	0.33	20	0.062	0.125	550	0.33	20	0.062	0.125	600	0.33	20	0.062	0.125
0.437	11.1	0.1503	675	0.42	25	0.062	0.125	675	0.42	25	0.062	0.125	750	0.33	20	0.062	0.125
0.500	12.7	0.1964	800	0.55	33	0.062	0.125	800	0.55	33	0.062	0.125	875	0.47	28	0.062	0.125
0.625	15.9	0.3068	1200	0.67	40	0.093	0.187	1200	0.67	40	0.093	0.187	1275	0.60	36	0.062	0.187
0.750	19.1	0.4418	1500	0.84	50-55	0.093	0.187	1500	0.84	50-55	0.093	0.187	1700	0.73	50	0.093	0.187
0.875	22.2	0.6013	1700	1.00	60-65	0.125	0.250	1700	1.00	65	0.125	0.250	Not Recommended				
1.000	25.4	0.7854	1900	1.40	85	0.125	0.250	2050	1.40	85	0.125	0.250	Not Recommended				

Note 1: These welding parameters should be considered as an initial setup guide for the stud diameter and position being welded. They should produce satisfactory results, but should not be considered so restrictive that they prevent modification based on physical and visual test evaluations of the finished welds as outlined in AWS D1.1 Structural Welding Code — Steel, AWS D1.6 Structural Welding Code — Stainless Steel and/or AWS C5.4 Recommended Practices for Stud Welding, which would assist in finalizing the weld setup based on the conditions and equipment at the production welding site.
Note 2: 1 in. = 25.4 mm; 1 sq in. = 645 mm^2.

verification measurement of both weld time and current.

Current controls can adjust for weld cable resistance, compensate for incoming power fluctuations, and provide system shutdown in the event of variations from the set weld parameters. As another example, welding guns with potentially erratic pneumatic weld plunge dampeners have been upgraded to very reliable, self-contained, sealed hydraulic dampener controls.

Fig. 6. Typical tension test fixture (Reference 8).



STUD WELDING SETUP

An understanding of the settings and adjustments and their relationship with weld quality is needed to ensure consistent stud welding results. The following definitions of specialized stud welding terms will make the narrative easier to understand.

- **Plunge** is the length of stud that protrudes beyond the ferrule. This portion of the stud is available to be "burned off," or melted, to develop the weld fillet. A short plunge may cause excessive splatter and high or uneven fillet formation. Plunge is a physical measurement set and measured with the stud and ceramic ferrule in place on the stud gun (see Fig. 2).

- **Lift** is the distance the gun pulls the stud away from the base material. Before the weld is started, the stud and base metal are in contact. Lift creates an air gap that the electric current must bridge. The current flow across the resistance of this gap creates the arc heat to melt the stud and base material.

If no gap exists, the current will not create sufficient heat to fuse the metal. A short lift may allow the molten metal to bridge the arc gap, resulting in a cold weld. An excessively long lift increases the chance of having arc blow and welds that are bonded on only one side of the fillet. Lift is physically set on the stud gun and is measured when the stud weld is initiated. Lift should be set and measured by placing the stud and ferrule on a nonconductive surface and initiating the weld cycle so that an actual molten weld is not made.

- **Time** is the duration of the weld. On thin base material, a shorter time and higher amperage can be used to achieve sufficient heat and prevent melting through the base material. On some base materials, a longer time and lower amperage improve the ductility of the weld zone. Weld time is set on the time setting indicator of the control system.

- **Amperage** is a measure of the current from the power source that flows across the air gap created by the lift.