WIRE REINFORCEMENT INSTITUTE®

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Technical Blog

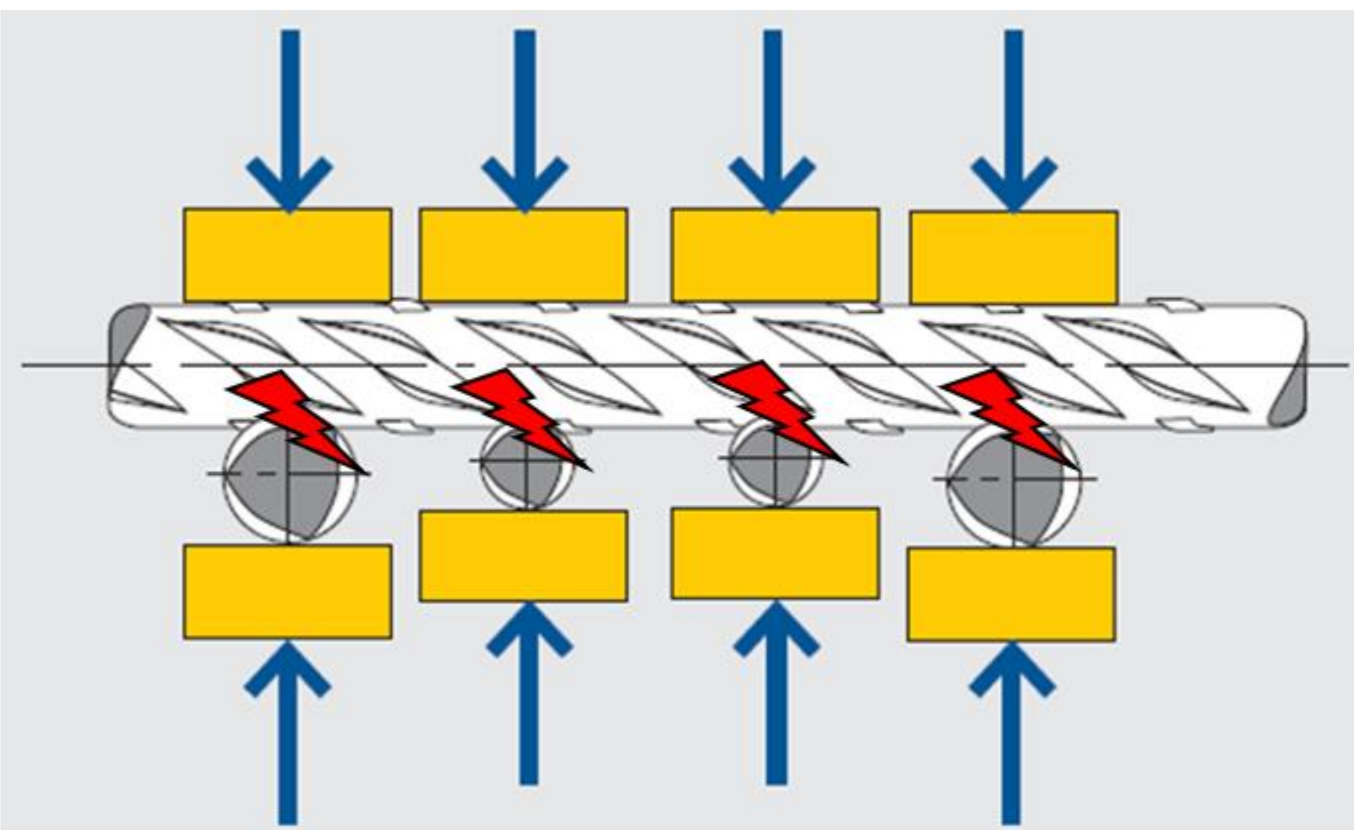
What the Specifier Needs to Know About Welding of Welded Wire Reinforcement (WWR)

This month's technical blog is intended to provide the design professional and specifier with a quick primer on welding of welded wire reinforcement (WWR). The WWR product is inherently a welded assembly of individual pieces of reinforcement, with the weld itself sometimes being a source of consternation when it comes time to specify the product in contract documents. This article seeks to provide guidance and clarification on common questions we've received related to the welding of WWR.

1. **Welds used in WWR are achieved through electric resistance welding, NOT a "manual" welding process.**

   The production of WWR conforming to ASTM A1064 is predicated on using an automated machine-based Electric Resistance Welding (ERW) process.

   In the case of WWR, ERW is simply the passing of electrical current from one copper electrode to another, through "stacked" planes of constituent wire oriented at a 90-degree angle relative to each other. The electrode elements (shown in yellow in the image below) apply pressure (blue arrows) to the wires (white and grey), resulting in snug and direct physical contact between the wires at their interface. In applying this pressure in the presence of electrical current, heat is generated at the interfacing surfaces of the stacked wires (shown as red "charges" in the image below) and the steel material is fused together, creating a welded cruciform-shaped joint. This is also known as "cross-wire" welding.



Source imagery courtesy of Schlatter Industries AG and WRI Associate Member Schlatter North Americ

It is noteworthy that during the fully automatic ERW process, there is no consumable electrode/filler metal being deposited at the weld site nor use of shielding gas as is characteristic of the following arc welding procedures:

A. **Shielded Metal Arc Welding (SMAW)** – also known as "stick" welding, is the most common form of arc welding and is a 100% manual process.
B. **Gas Metal Arc Welding (GMAW)** – machine-fed solid metal wire is used as the consumable filler metal fed through the operator's welding gun in the presence of an external shielding gas; Metal Inert Gas Welding (MIG) is a common form of GMAW.
C. **Flux Cored Arc Welding (FCAW)** – similar to GMAW, but with a hollow wire filled with flux powder that can be used as the shielding gas as it burns.
D. **Gas Tungsten Arc Welding (GTAW)** – a high-precision, low-deposition process using a non-consumable tungsten electrode to produce a weld from filler metal in the presence of inert shielding gas; also known as Tungsten Inert Gas Welding (TIG).

Neither the ERW process nor the resulting characteristic welded "cross-wire" joint of WWR are informed by the American Welding Society (AWS). As such, AWS D1.4 should not be referenced by the designer as a standard or guideline as it relates to the automatic welding process used in the manufacture of WWR. In fact, Section 6.2.3 of AWS D1.4 goes so far as to indicate that cross welding of bars shall not be permitted unless authorized by the Engineer. This statement could be interpreted as an indication of the difficulty of reliably executing a cross-welded joint using the SMAW, GMAW, GTAW, and FCAW processes referenced therein.

At the time of the preparation of this article, the author's only known reference for cross-welding of reinforcement other than that using the ERW process for WWR can be found in ACI 318 Sections 16.5.6.3 and 26.6.4.2(b), which are related to the cross-welding of bars in reinforced concrete brackets and corbels .Even with this reference, there is little direction related to the actual welding process itself and the method by which it is tested and certified.

2. **WWR weld requirements are governed by ASTM A1064.**

The source of testing and certification requirements for WWR welding is found in ASTM A1064.

Testing is required for weld shear strength using the weld test apparatus shown to the right. A cruciform specimen is seated into the apparatus with the horizontal wire segment in direct bearing against a back-sloped saddle. A downward tensile force is applied to the bottom end of the vertical wire, in turn imposing direct shear force across the welded intersection. A breaking strength is then recorded at failure of the weld.

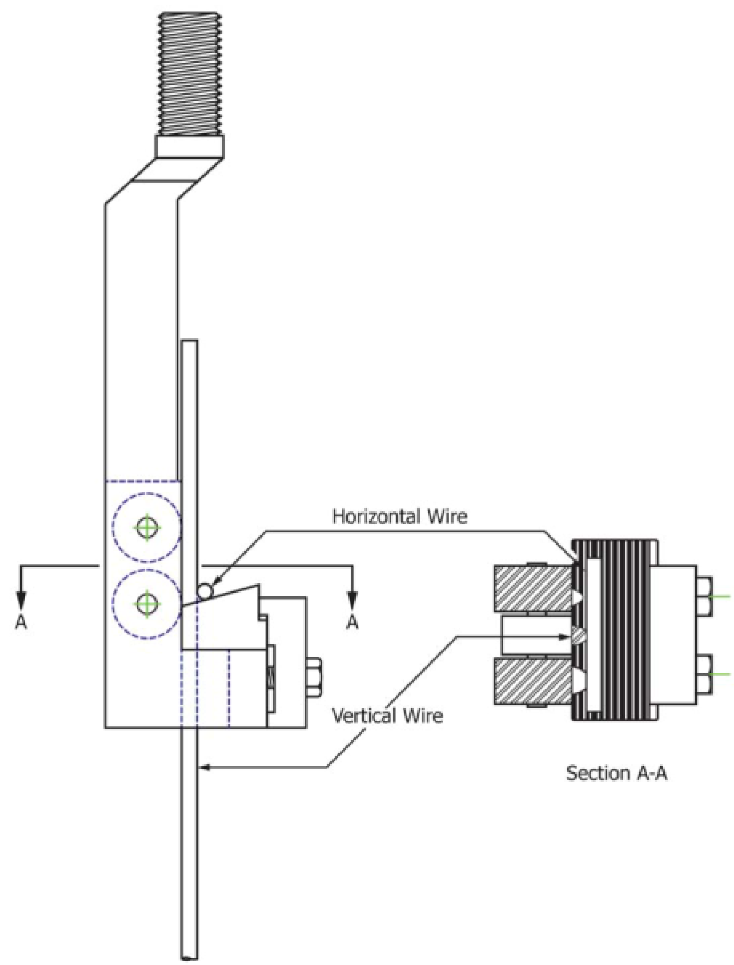


Image courtesy of ASTM International

For tensile tests of WWR, wherein the yield strength and tensile strength are recorded, at least 50% of the tests must be carried out “across weld”, which simply means that the tension test specimen contains a welded cross-wire segment within the gauge length being tested in tension. This test is entirely separate from the aforementioned weld shear test.

ASTM A1064 defined the frequency/interval of both weld shear testing and tension testing as follows (ASTM A1064 Sections indicated):

8.4.1 *At least one test for conformance to minimum tensile strength and bend test requirements shall be made for each 75,000 ft^2 of welded wire reinforcement or remaining fraction thereof.*

8.4.3 *At least one set of weld shear tests for conformance to weld shear strength requirements shall be made for each 300,000 ft^2 or remaining fraction thereof.*

A weld shear test is derived and comprised as follows:

11.2 *Test specimens for determining weld-shear properties shall be obtained by cutting from the finished welded wire reinforcement a full-width section of sufficient length to perform testing described in 8.3.4.*

8.3.4 *Four welds selected at random from the specimen described in 11.2 shall be tested for weld shear strength. The smaller diameter wire of each test specimen shall extend approximately 1 in. on each side of the larger diameter wire. The larger wire of each test specimen shall be of such length below the smaller wire so as to be adequately engaged by the grips of the testing machine. The larger wire shall be of such length above the smaller wire that its end shall be above the center line of the upper bearing of the weld tester. These four weld shear test results constitute a set.*

Conforming weld shear test results are defined and established as follows:

8.3.5 *The material shall be deemed to conform to the requirements for weld shear strength if the average of the test results of the four specimens complies with the value stipulated in 8.3. If the average fails to meet the prescribed value, all the welds across the specimen shall then be tested. The welded wire reinforcement shall be deemed acceptable if the average of all weld shear test values across the specimen meets the prescribed minimum value.*

Section 8.3 of ASTM A1064 defines the requirements for weld shear strength as indicated below:

- For plain welded wire reinforcement and deformed welded wire reinforcement, where the smaller wire has an area of 40% or more of the larger wire, the minimum average shear value (in pounds-force) shall be not less than 35,000 multiplied by the nominal area of the larger wires.
- Where deformed welded wire reinforcement is characterized by the smaller wire having an area of less than 40% of the larger wire, the minimum average shear value shall be not less than 800 pounds-force.
- Where plain welded wire reinforcement is characterized by the smaller wire having an area of less than 40% of the larger wire, the WWR is not subjected to a weld shear requirement. *(WRI Note: It is important to understand that this composition of plain WWR could not be relied upon as a structural reinforcement in concrete.)*

Generally speaking, a wire size relationship of 40% or more constitutes a "structural" welded intersection that can be relied upon for anchorage and development purposes in design standards such as ACI 318 and AASHTO LRFD Bridge Specifications. In contrast, a wire size relationship of less than 40% constitutes a "non-structural" weld that cannot be relied upon for anchorage and development purposes.

For more information on this topic, see the WRI's January 2023 Technical Blog titled *"Weld Shear Requirements in ASTM A1064"*.

3. **For deformed WWR, most welds are not structurally critical. For plain WWR, all welds are structurally critical.**

Deformed WWR is generally considered to be more versatile than plain WWR. Deformed WWR can be deployed as structural reinforcement in the following instances:

DWWR Scenario #1: WWR deformed wire surface in combination with the presence of structural welded intersections (≥40% wire size relationship) are utilized in design to determine development and anchorage characteristics in structural concrete. It is worth noting that in this instance, only those welds within the tension development region, tension lap splice region, and/or anchorage region are critical. The balance of the welded intersections (say, within the field of the mat at locations away from the mat's perimeter where development, laps, and anchorage occur) are not structural contributors.

DWWR Scenario #2: WWR deformed wire surface in combination with the presence of structural welded intersections (≥40% wire size relationship) are available, but the designer elects to ignore any structural contribution from the latter. As such, determination of tension development lengths and tension lap splices are calculated based on the deformed wire surface only, with calculated lengths using identical equations to those used for loose individual deformed wires or deformed reinforcing bars. In effect, then, even though the ≥40% wire size relationship exists, none of the welded intersections on the WWR mat are relied upon by the designer to be structural contributors.

DWWR Scenario #3: WWR deformed wire surface in combination with the presence of non-structural welded intersections (<40% wire size relationship) exists. As such, determination of tension development lengths and tension lap splices are calculated based on the deformed wire surface only, with calculated lengths using identical equations to those used for loose individual deformed wires or deformed reinforcing bars. None of the welded intersections on the WWR mat are capable of being relied upon to be structural contributors.

Plain WWR can be deployed as structural reinforcement in the following scenario:

PWWR Scenario #1: the WWR is characterized by structural welded intersections (≥40% wire size relationship). All welds on the WWR mat are considered critical and are utilized in design to determine development and anchorage characteristics in structural concrete.

As mentioned previously, plain WWR with a <40% wire size relationship is not to be used as structural reinforcement.

4. Broken welds are not cause for WWR rejection.

ASTM A1064 allows for the presence of a small amount of weld breakage without the WWR being subject to rejection:

> ***8.4.3*** *Welded intersections shall withstand normal shipping and handling without becoming broken, but the presence of broken welds, regardless of cause, shall not constitute cause for rejection unless the number of broken welds per sheet exceeds 1% of the total number of intersections in a sheet. For material furnished in rolls, not more than 1 % of the total number of intersections in 150* ft^2 *of welded wire reinforcement shall be broken. Not more than one-half the permissible maximum number of broken welds shall be located on any one wire.*

Note, however, that this threshold for acceptance is a condition of prescriptive <u>manufacturing quality control</u> only. If a designer wishes to define more stringent limitations on weld breakage, they can do so via Section 4.2 of the Specification, wherein additional / special requirements can be established and the manufacturer can in turn impose additional measures to further reduce the potential for weld breakage.

It is critical that requirements beyond those prescriptions published in ASTM A1064 be communicated clearly on the contract documents, and that this information is made readily accessible prior to a purchaser's request for quotation upon which an order placement would be based.

Ultimately, it is unlikely that the designer himself/herself will also be the purchaser. The purchaser is the entity placing the order, which is most likely the project contractor or subcontractor. As such, there is a shared responsibility in clearly defining special requirements. It obviously starts with the designer, but it needs to be passed along by the purchaser as a condition serving as the basis of quotation and subsequent ordering.

Note, too, that the product's procurement life cycle matters a great deal. There are several key milestones to be aware of, and a WWR manufacturer typically has little to no control over the condition of its produced material beyond the point at which it has been delivered to the purchaser. As such, the matter of ownership of potential damage done to the product is a real consideration for producer and purchaser alike.

5. ACI 318 permits the use of ASTM A1064 WWR in special seismic systems for lateral support of longitudinal reinforcement, concrete confinement, and shear - with one important caveat.

ACI 318-19(22) Table 20.2.2.4(a) allows the use of WWR as transverse reinforcement in special seismic systems without exception provided the curtailment is in the form of hooked terminations. In other words, U-stirrups that rely upon welded anchorage wires (Section 25.7.1.4 & 25.7.1.5) in lieu of hooked terminations are prescriptively prohibited. This is because ASTM A1064 only requires the welds to develop 35,000 psi at a welded intersection (i.e., weld shear strength discussed in Item #2 above).

With this in mind, however, it may be possible in select instances for anchorage wires to be used in lieu of hooked curtailment, provided the following minimum requirements would need to be satisfied (see also ACI 318 R20.2.2.4):

A. The welded product is approved as an "alternative construction material" in accordance with ACI 318 Section 1.10. This would ultimately require jurisdictional building official acceptance, likely on a project-specific basis, as well as independent testing confirmation.

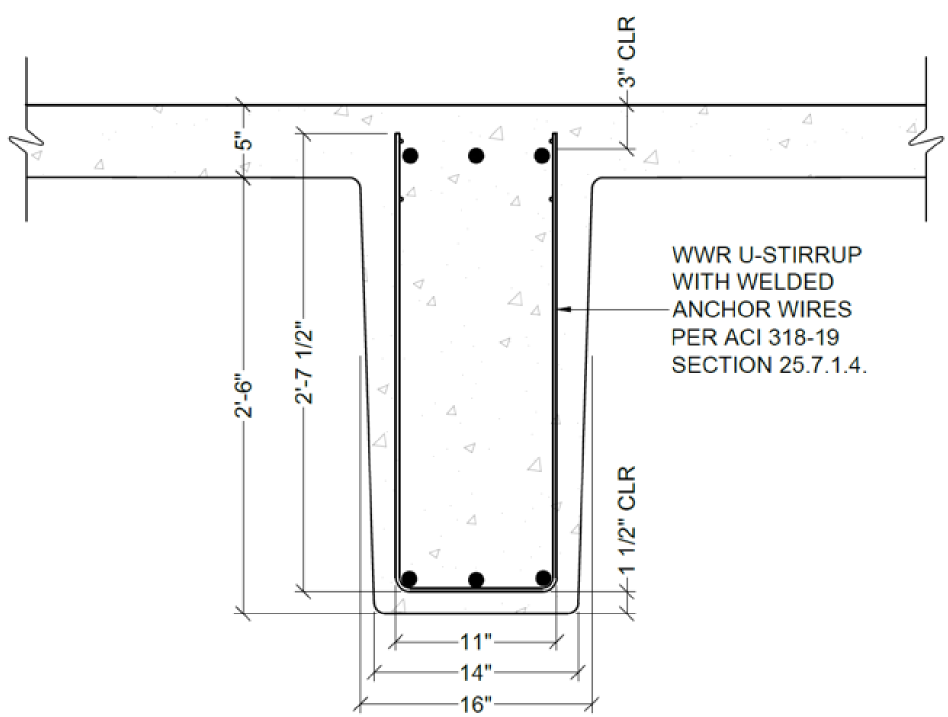
B. Applications in which two anchorage wires are used as the anchorage in lieu of a single hook would need to be shown to achieve a cumulative weld shear strength of 1.25 x yield strength of the wire being developed, but not less than the tensile strength of the wire.

As an example, assume in the image below that the 80-ksi U-stirrups are D12.0 wires and the anchorage wires (two each at the top of each U-stirrup leg) are D4.8. For these anchor wires to be used in lieu of hooks in a special seismic system member, each anchor wire's welded intersection would need to achieve a weld shear strength as follows:

A. 1.25 x 80 ksi = 100 ksi x 0.12 in^2 = 12 kips cumulative, provided by 2 wires = 6 kips per anchor wire.

B. 80 ksi wire has 90 ksi minimum tensile strength per ASTM A1064, therefore 90 ksi x 0.12 in^2 = 10.8 kips cumulative, provided by 2 wires = 5.4 kips

Therefore, the larger magnitude applies, resulting in minimum weld shear strength = 6.0 kips per anchor wire (compare this to the minimum ASTM A1064 requirement of 35 ksi x 0.12 in^2 = 4.2 kips).



For more information, visit www.wirereinforcementinstitute.org.

References:

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