Welded Wire Reinforcement: A Primer for the Bridge Designer, Part 1

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Welded wire reinforcement (WWR) is mild steel reinforcement for structural concrete with a long-standing acceptance in reference design standards such as the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1] and the American Railway Engineering and Maintenance-of-Way Association's (AREMA's) *Manual for Railway Engineering.*[2] The material is manufactured in accordance with the requirements of ASTM A1064, *Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete.*[3]

WWR manufacture starts with the cold-working of hot-rolled steel rods through dies or rollers to produce structural wires of specified diameters. These wires are then run through programmable, highly automated machines on which the wires are arranged and then securely connected at intersections by an electric resistance welding process. This welding method combines pressure and the passage of electrical current through the interface of the orthogonally intersecting wires to create fused joints.

Attributes

The following attributes of WWR mats are noteworthy.

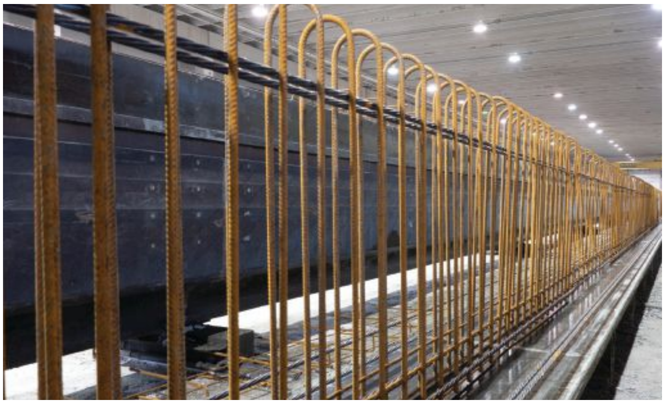
Wire surface: Wires of a WWR mat can be either deformed or plain. Deformed wires are characterized by surface protrusions or indentations that, similar to deformed reinforcing bars, develop bond at the interface with hardened concrete primarily through a bearing mechanism. Plain wires are characterized by a smooth wire surface.

Dimensional flexibility: Wire diameters range from approximately 0.100 to 0.628 in., the latter being roughly equivalent to a no. 5 reinforcing bar. Wire spacing is also variable, with increments ranging from as small as 2 in. up to a maximum spacing of approximately 8 ft, an interval driven more by transport and handling limitations than by the manufacturing equipment or ASTM A1064 requirements. With this in mind, it is common for WWR mats to have variable wire sizes and spacings in both the longitudinal and transverse directions. Furthermore, it is possible for both deformed and plain wires to be part of a single WWR mat.

Size and fabrication: WWR mats can be manufactured in widths up to roughly 12 ft and lengths exceeding 40 ft. It is possible to produce mats with variable wire lengths in a common direction, which is another example of the versatility of modern WWR manufacturing equipment. Flat mats can then be taken from the welding equipment directly to a bending station, where the mats are fabricated into shapes to suit the profile of the structural element into which they will be placed at the precast concrete plant or on the jobsite.

Structural design: Calculation of flexural, torsional, axial, and shear sectional strengths using design procedures established in the AASHTO LRFD specifications and the AREMA *Manual for Railway Engineering* is straightforward for WWR: The design equations are identical to those for individual deformed bars or wires. Only the development length, lap splice length, and limitations for seismic applications are different.

Strength: WWR with a yield strength up to 80 ksi is commonly produced at no premium, with 70 ksi being standard



Welded wire reinforcement installed as the stem reinforcement for an inverted-tee section. Note the 180-degree bends at the top and the longitudinal anchor wires at the bottom of the mats. All Photos: Wire Reinforcement Institute.

Following the installation of the stem welded wire reinforcement (WWR) in an inverted-tee section, the bottom-flange reinforcement is installed in the form of bent WWR mats.

The bundle of mats shown here—characterized by varying lengths of individual reinforcement pieces all automatically assembled and welded—is an example of the versatility of modern welded wire reinforcement manufacture.

for welded deformed wire reinforcement and 65 ksi being standard for welded plain wire reinforcement. The AASHTO LRFD specifications currently allow reinforcement with a yield strength of 75 ksi, increased to 100 ksi for certain applications, whereas the AREMA manual requires designs to be based on a 60-ksi maximum yield strength.

Tension development and lap splice lengths: For welded deformed wire reinforcement, the designer can calculate development length and lap splice length based either on a combination of contributions by welded intersection anchorage and deformed wire surface or on the deformed wire surface alone. In the case of the former calculation, the combined contribution of welds and deformed surface can result in reduced development and lap splice lengths. The latter calculation essentially defaults to equations used for loose individual pieces of deformed bar or wire. For welded plain wire reinforcement, because the smooth wire surfaces are incapable of bond with the surrounding hardened concrete, development length and lap splice length calculations are based entirely on anchorage provided by the welded intersections.

Prebent welded wire reinforcement mats are used here as girder bottom-flange confinement steel.

Use in Bridge Elements

There is perhaps no better example of the utility and economy of WWR than the bridge girder. Although the scale of these elements is typically such that flexural capacity is primarily achieved through the use of prestressing steel, practically all other mild steel reinforcement applications within a girder are well suited to a WWR solution.

Vertical stem or transverse reinforcement to suit varying magnitudes of shear demand along the member's length is easily managed in the form of modules of WWR mats fabricated with variable wire sizes and spacings to suit the design. The vertical wires of these mats can terminate in standard hooked anchorages at their ends, or they can derive anchorage from welded structural anchorage wires. Both options are commonly manufactured, with the latter's popularity born out of a desire to minimize interference between hooked terminations and other embedded features without compromising the anchorage of the shear reinforcement legs.

Girder top-flange reinforcement in both the transverse and longitudinal directions is a natural fit for flat WWR mats, with the solution composed of mat modules that are installed such that longitudinal wires can lap end-for-end along the girder's length. Likewise, girder bottom-flange confinement reinforcement is often fabricated in the form of prebent WWR modules. Bent WWR mats are also used in the prestressing anchorage zones at girder ends, where control of bursting forces is critical.

WWR has been successfully deployed in I-beams, bulb-tee girders, segmental box girders, and slab beams. Additionally, WWR continues to be a popular mild steel reinforcement solution for cast-in-place bridge decks, slip-formed barrier rails, precast concrete arch bridges, and box culverts.

The Benefits

For the design professional, there is ease in having design interchangeability between WWR and individual reinforcing bars in the provisions of the AASHTO LRFD specifications and AREMA manual. This opens the door to the most tangible benefits of WWR: the contractor's ability to greatly reduce installation time and streamline the allocation of labor for reinforcement placing activities, all while installing a structural reinforcement with unparalleled control of fabrication and placement tolerances. These on-site advantages over loose reinforcement have never been more valuable given today's climate of increasing labor shortages and accelerated construction timelines.

A future article will discuss best practices for implementing WWR in contract drawings and the critical role played by the manufacturer's WWR detailing staff in preparing shop drawing and placement submittals for engineer and contractor reviews.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*. 9th ed. Washington, DC: AASHTO.
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3. ASTM International. 2018. *Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete*. ASTM A1064/ASTM1064M-18a. West Conshohocken, PA: ASTM International. https://astm.org/a1064_a1064m-18a.html.

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Welded wire reinforcement (WWR) mats in place before the concrete pour for a bridge girder. WWR is used in the girder stem and both flanges.