WIRE REINFORCEMENT INSTITUTE®

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Technical Blog

Bending Welded Wire Reinforcement

The use of bent mats of welded wire reinforcement (WWR) is common practice in the structural precast concrete and cast-in-place concrete markets. Some examples are as follows:

- U-stirrups for concrete beams
- Closed ties for columns
- Roadway and bridge barrier rail
- Dowel mats at the interface between CIP footings and walls
- Hooked terminations on mats used as flexural reinforcement in slabs
- Circumferential reinforcement for box culverts
- Hooked web reinforcement in precast prestressed concrete bridge girders
- Stair-step WWR mats for use in precast stadium risers

Shaping of WWR mats is done on hydraulic bending machines that are fitted with interchangeable mandrels to suit the specific wire size and spacing. The machines vary in length from approximately 8 feet to 40 feet, and while this equipment is most commonly operated by the WWR manufacturers themselves, capable precasters and contractors are also able to run their own bending operation if it is determined to be appropriate for a project's logistics and scheduling.

A WWR mat to be used in a roadway barrier is bent on a hydraulic bending machine.

Steel mandrels of various sizes are interchangeable and can be positioned on the bending machine at intervals that suit the spacing of the wires to be bent.

On the manufacturing / fabrication side, the bent WWR material must conform to the requirements of ASTM A1064.

Section 8.2 of the ASTM A1064 specification states that the wire shall withstand a bend test, and that the bend test is to be performed on a wire specimen taken from between weld locations.

The requirements of the bend test itself are laid out in Section 7.1.5 for plain wire and Section 7.2.6 for deformed wire.

Section 7.1.5 - plain wire

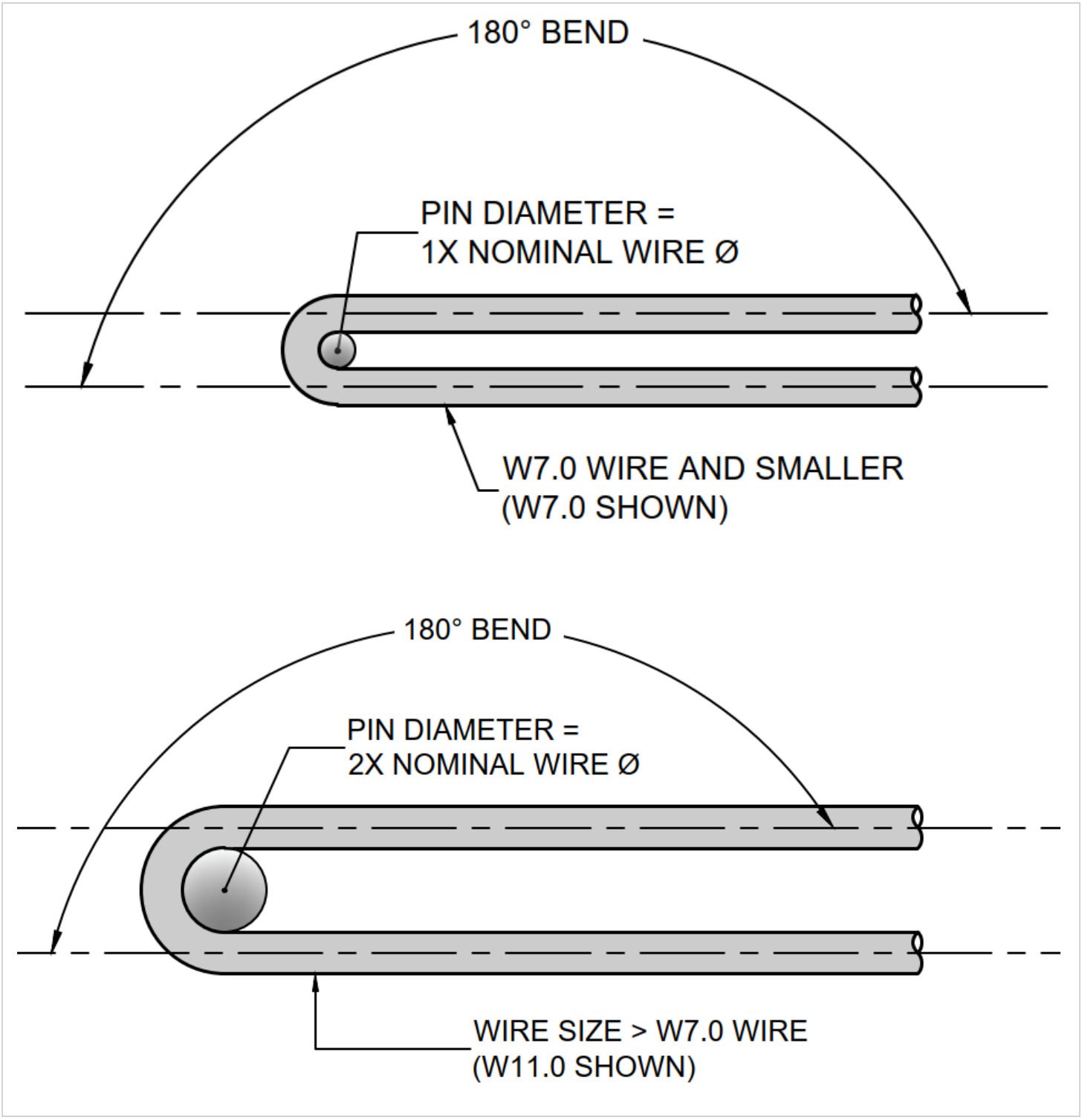
The bend test specimen shall be bent at room temperature through 180-degrees without cracking on the outside of the bent portion visible to a person with normal or corrected vision.

The pin (mandrel) diameter for the test shall be equal to 2X the nominal wire diameter for wires larger than W7.0, and equal to 1X the nominal wire diameter for wires W7.0 and smaller.

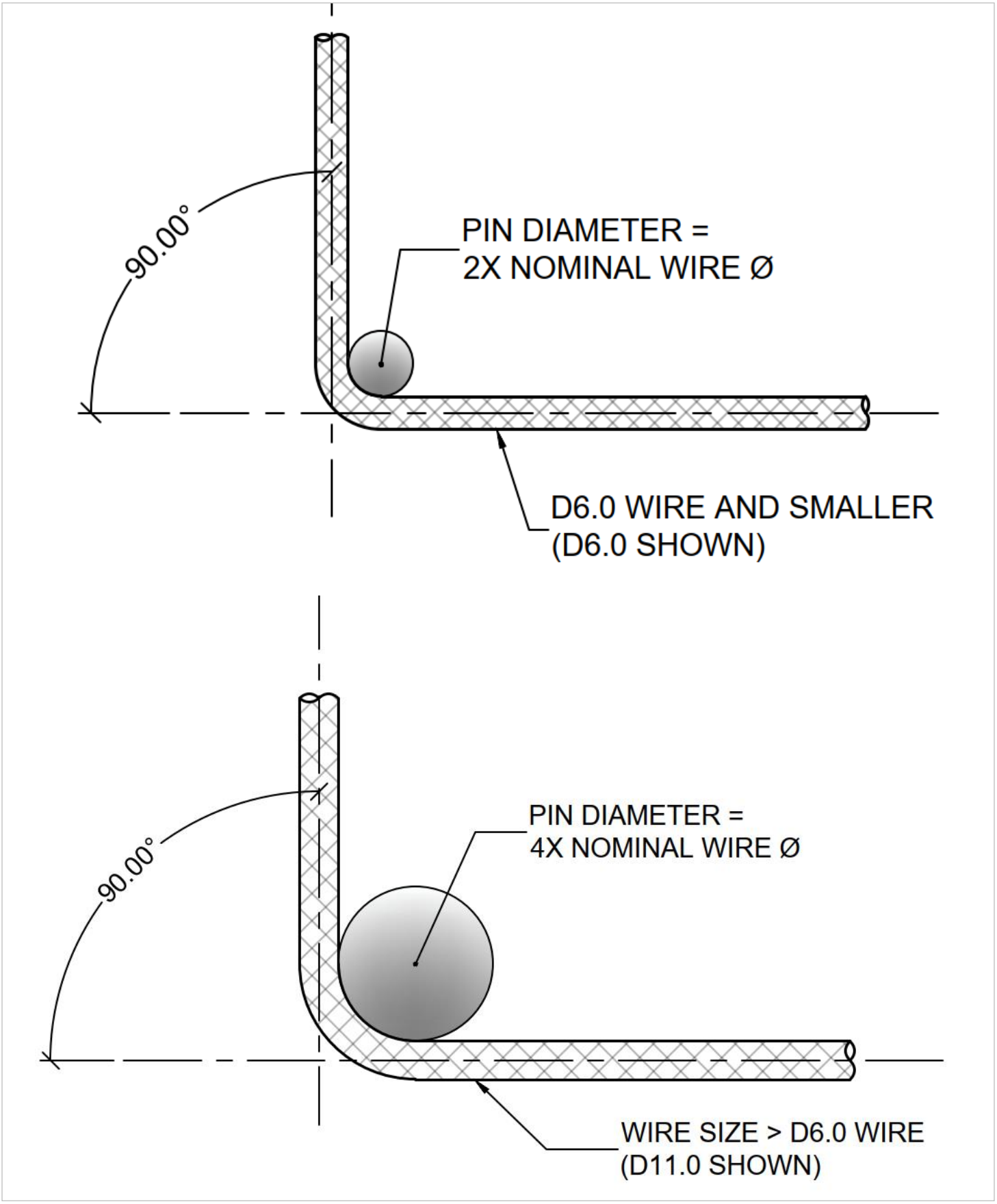
Section 7.2.6 - deformed wire

The bend test specimen shall be bent at room temperature through 90-degrees without cracking on the outside of the bent portion visible to a person with normal or corrected vision.

The pin (mandrel) diameter for the test shall be equal to 4X the nominal wire diameter for wires larger than D6.0, and equal to 2X the nominal wire diameter for wires D6.0 and smaller.



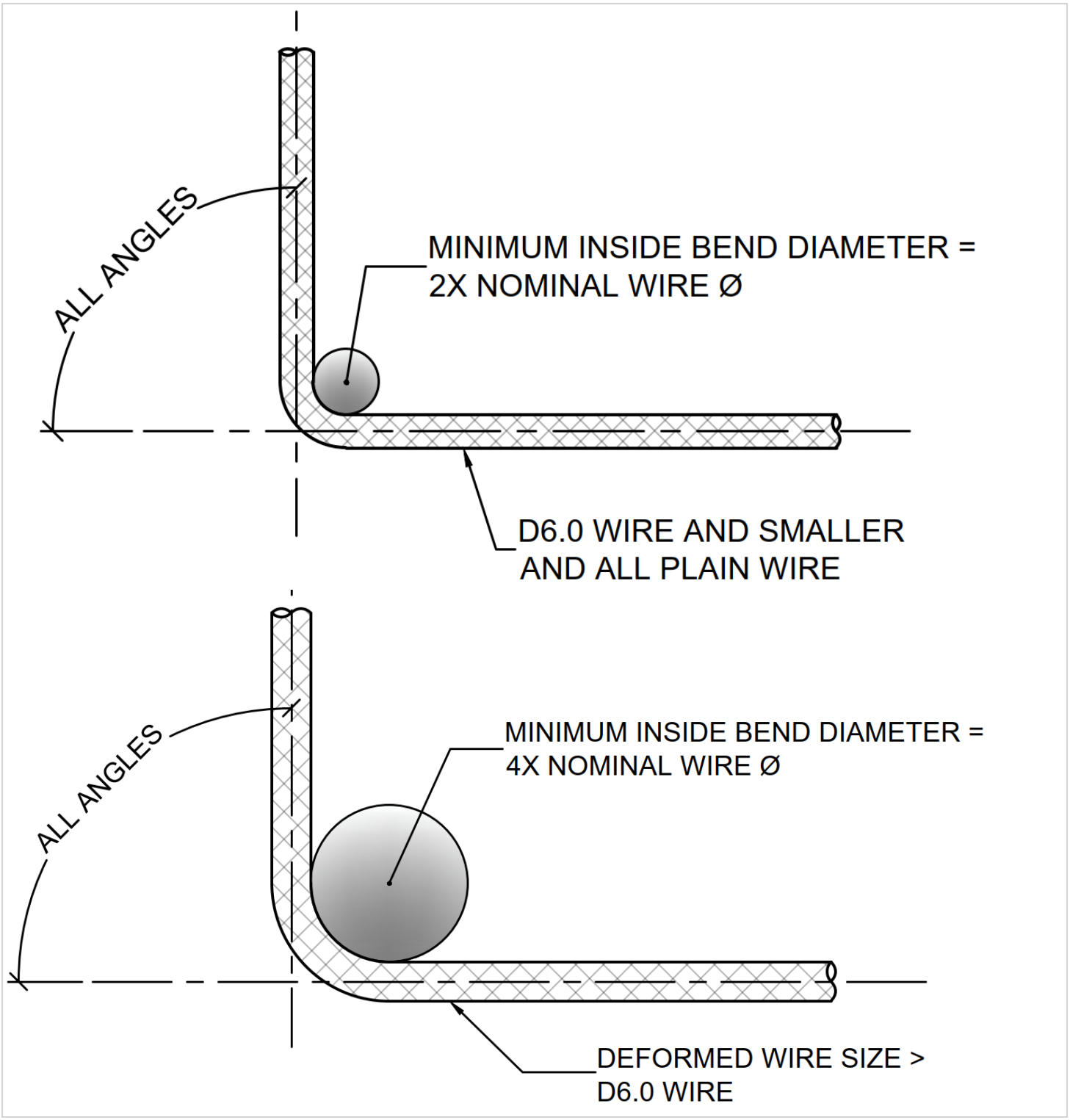
ASTM A1064 Section 7.1.5 requirements for plain wire



ASTM A1064 Section 7.2.6 requirements for deformed wire

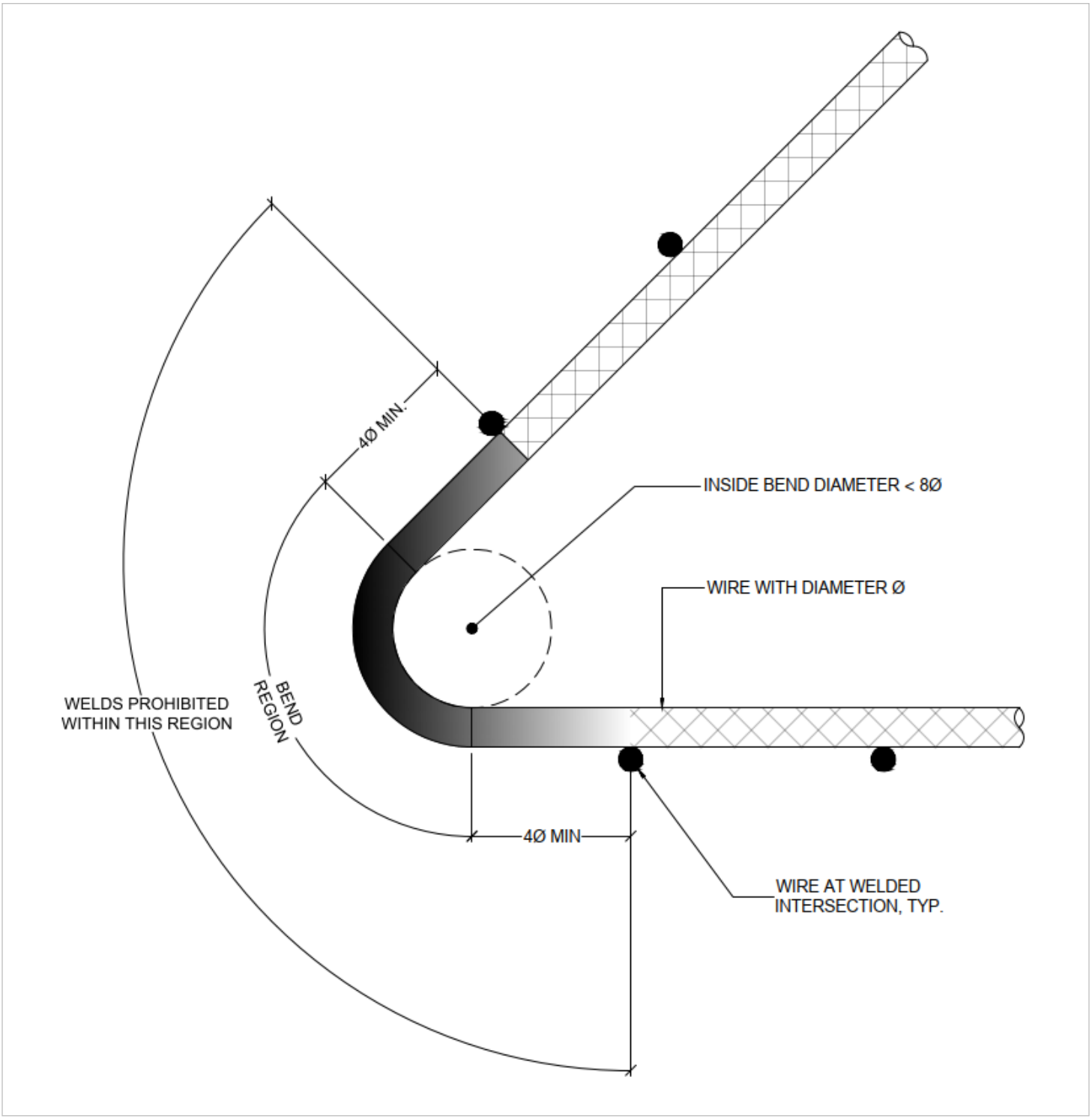
On the design side, both ACI and AASHTO establish the following requirements for bent WWR.

Per ACI 318-19 Section 25.3.3 and AASHTO LRFD Bridge Design Specifications Article 5.10.2.3, the minimum inside bend diameter for welded wire reinforcement used as stirrups and ties shall not be less than 4X the nominal wire diameter for deformed wire larger than D6 and 2x the nominal wire diameter for all other wires.



ACI and AASHTO requirements for bent WWR used as stirrups and ties

It is also noteworthy that these same ACI and AASHTO design standards require that the positioning of a bend with inside diameter less than 8X the nominal wire diameter shall not be less than 4X the nominal wire diameter from the nearest welded intersection. This requirement is intended to ensure that the effects of welding temperature have sufficiently dissipated so as not to affect the ductility and bendability of the wire in the region to be bent.



ACI and AASHTO requirement for the proximity of welded intersection to a bend region

A manufacturer may not possess precise bending pin/mandrel sizes for every wire size that is capable of being produced. After all, there are nearly 300 unique wire size increments between W1.4 and W/D31. As such, the manufacturer would typically use a "best fit" approach both in the ASTM mandated bend testing phase as well as in the production phase.

As part of testing for conformance with ASTM A1064, the specification indicates the pin diameter as a direct function of the wire size. Downstream, as mandated by ACI and/or AASHTO for design, minimum inside diameters are specified. The following is a sampling of how a manufacturer of bent WWR could go about satisfying both:

WIRE SIZE	WIRE DIAMETER	ASTM-DEFINED TEST PIN DIAMETER	TEST PIN DIAMETER USED	MINIMUM BEND DIAMETER FOR DESIGN	PRODUCTION PIN/MANDREL DIAMETER USED
W4.5	0.239"	0.239"	3/16"	0.478"	1/2"
D5.5	0.265"	0.530"	1/2"	0.530"	9/16"
W6.7	0.292"	0.292"	1/4"	0.584"	5/8"
W17.5	0.472"	0.944"	7/8"	0.944"	1"
D23.3	0.545"	2.180"	2 1/8"	2.180"	2 1/4"
W25.0	0.564"	1.128"	1 1/8"	1.128"	1 1/4"
D31.0	0.628"	2.512"	2 1/2"	2.512"	2 9/16"

As shown, the general rule of thumb for bend testing is to use a pin diameter equal to or smaller than the ASTM-defined test pin size. The general rule of thumb for production is to use a pin size equal to or greater than the pin size corresponding to the ACI / AASHTO-defined minimum bend diameter.

Finally, manufacturers, contractors, and designers alike should understand that the minimum bend diameter used in applications other than stirrups and ties is defined by ACI (Table 25.3.1) and AASHTO (Table 5.10.2.3-1) to be 6X the nominal diameter of the bar, with this requirement applicable to reinforcing bars up to and including a #8 rebar. It is common for the WWR manufacturer to default to this same 6X provision unless superseded by a different project requirement. For example, a superseding requirement in the production of WWR for precast concrete box culverts (per ASTM C1577) is a minimum bend diameter equal to 8X the wire diameter for wires sizes equal to and larger than W6.0 / D6.0.

For more information visit www.wirereinforcementinstitute.org.

References:

1. "LRFD Bridge Design Specifications, 9th Edition", American Association of State Highway Transportation Officials, Washington, DC, 2020.

2. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)," American Concrete Institute, Farmington Hills, MI, 2019 (Reapproved 2022).

3. "Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete (ASTM A1064/A1064M-22)", ASTM International, West Conshohocken, PA, 2022.

4. "Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers Designed According to AASHTO LRFD (ASTM C1577-20e1)", ASTM International, West Conshohocken, PA, 2022.