WWR 400-R-03

WIRE REINFORCEMENT INSTITUTE®

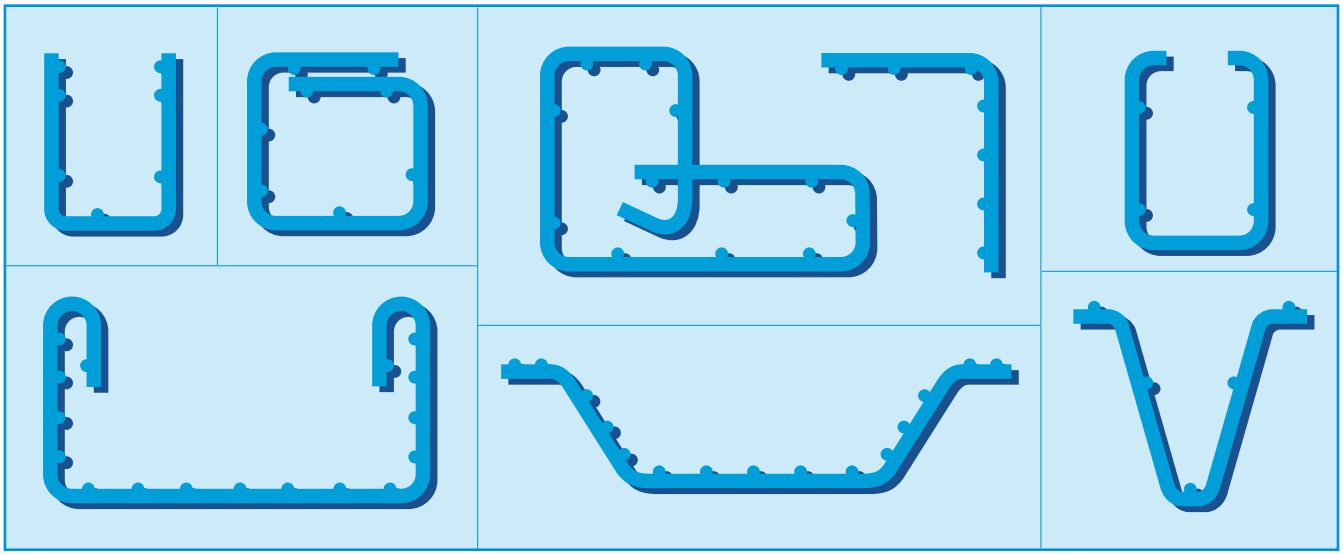
TECH FACTS

Excellence Set in Concrete®

942 Main Street • Suite 300 • Hartford, CT 06103 (800) 552-4WRI [4974]

# BENDING WELDED WIRE REINFORCEMENT

## FOR REINFORCED CONCRETE



WIRE REINFORCEMENT INSTITUTE®
942 Main Street • Suite 300 • Hartford, CT 06103 (800) 552-4WRI [4974]

# Bending Welded Wire Reinforcement

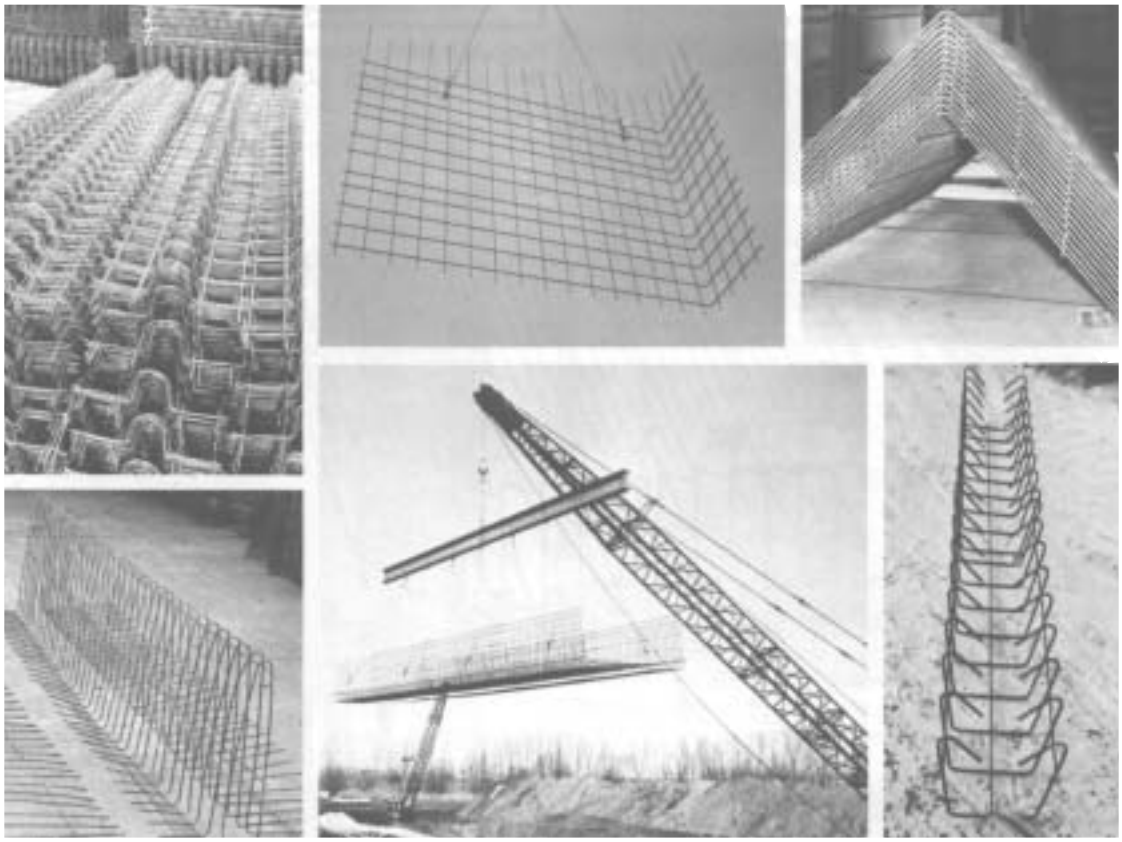
**FOR REINFORCED CONCRETE**

## Table of Contents




Manual WWR-400-R Printed in U.S.A.
10th Publishing, 2003

# I. INTRODUCTION



Where construction requires the repetitious bending and shaping of reinforcement, welded wire reinforcement has resulted in faster and more economical production. The development of new hydraulic equipment now simplifies the production of reinforcement cages made form sheets of welded wire. Research and construction experience using wire reinforcement with its design strength equivalent to or greater than grade 60 reinforcing bars, show excellent time savings and sound design performance. The fabrication and placement of large sections of reinforcement made from welded wire reinforcement provide optimum use of labor and simplify project supervision and inspection.

Formed into shapes for beam stirrups, column ties, corner reinforcement and other configurations, welded wire has increased savings in placement time in both pre-case and cast-in-place construction. During recent construction of a high rise office building the contractor converted from individual bar stirrups to welded wire reinforcement for stirrup cages and experienced a 75% savings in time and labor for the reinforcement placement. In forming cages for utility vaults, precasters have cut assembly time from three hours, using rebars, to only 40 minutes, using welded wire reinforcement. Contractors have found that reinforcement, used as shear reinforcement for prestressed double tees, may be easily and confidently positioned without fear of the reinforcement shifting during tensioning and concrete placement.

In planning your next project consider the advantages of bent welded wire reinforcement as outlined in the following pages.

## II. EQUIPMENT

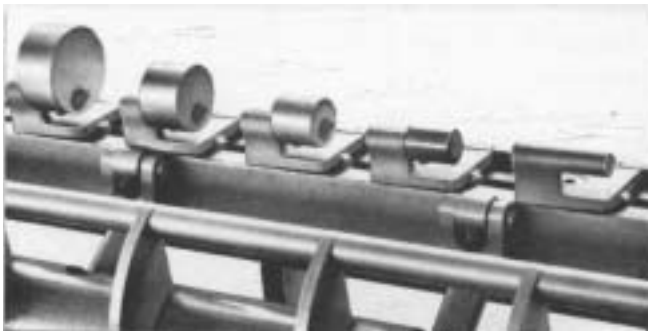
The fabrication of welded wire reinforcement into various structural shapes is readily accomplished with two basic pieces of portable equipment, a bending machine and a cutting device.

The bending machine provides the flexibility of adjusting to various wire spacings, angles of bend and bending radii. This equipment is manufactured in sizes ranging in length from 8 to 40 feet. Capacities range from the small wire sizes used primarily in precast operations to heavy W45 structural wires, 0.757 in. diameter. The sheets of welded wire are bent on the machine by an arm which rotates through an angle of 0° to 180°, shaping the wires around the mandrels. This arm can be preset to stop at any angle and the mandrels can be varied to meet the design requirement for bend radius and wire spacing.

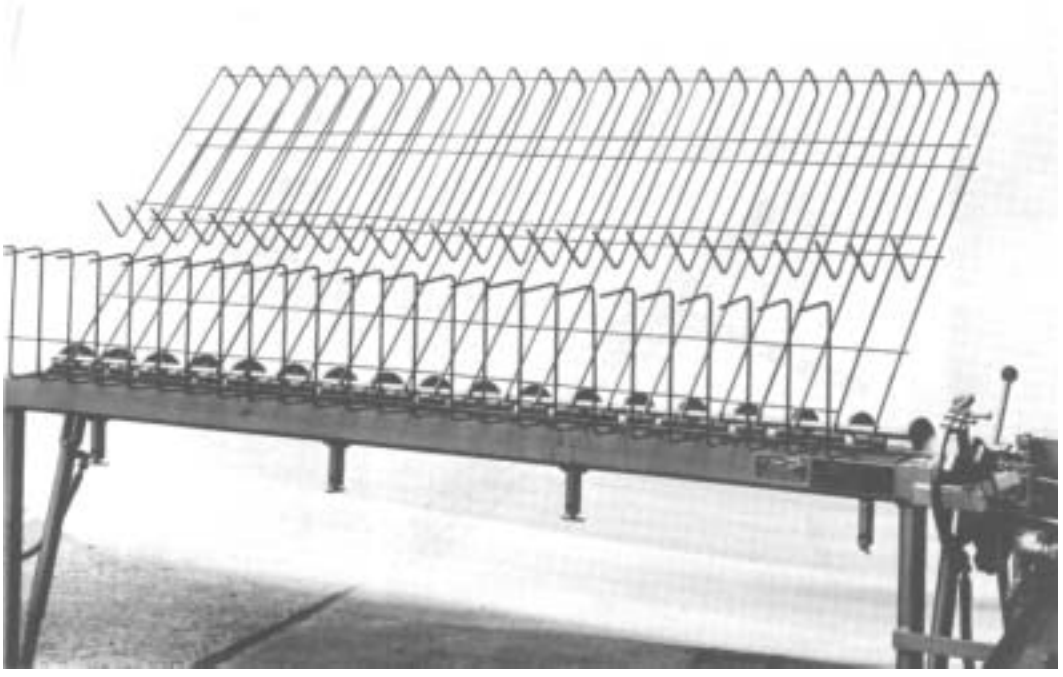
The cutting equipment can be a simple hand tool capable of cutting one wire at a time or larger powered equipment which cuts the full width of a sheet in one operation. This powered equipment allows the use of more economically manufactured sheets of wire reinforcement.

The bending and cutting equipment are comparatively low cost investments which require no special skills for efficient operation. Both machines, operating on electric power, can be conveniently moved from one project to another, lending themselves very readily to on-site construction, precast operations and use in fabricating shops.

Welded Wire Reinforcement manufactured for concrete pipe.



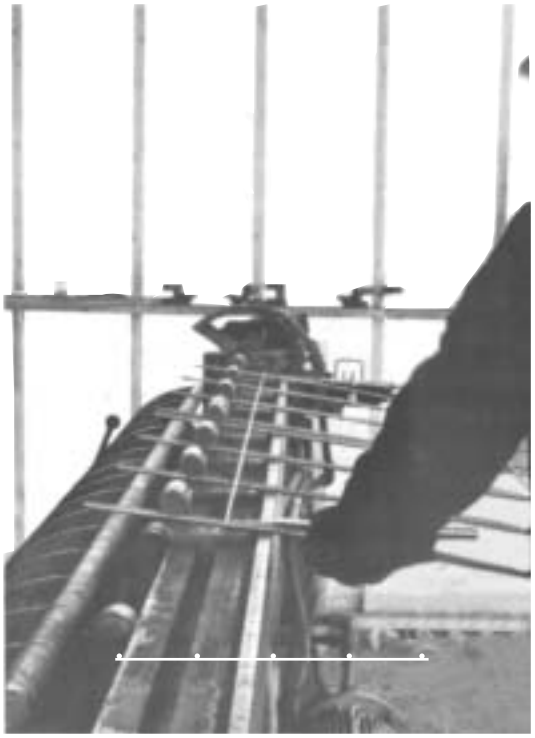
Various mandrel sleeve diameters can be used to obtain desired bending radii.



Bending machine provides flexibility of adjustment to meet design requirements.

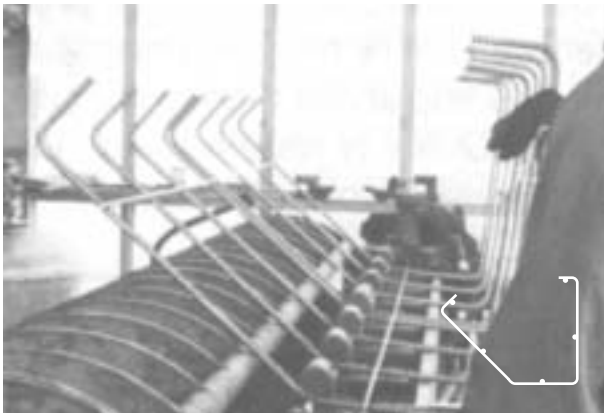
## TYPICAL BENDING SEQUENCE

### Making a Stirrup



**START:** Workers feed sheet of welded wire under mandrels.

**3RD BEND:** Sheet has been advanced into machine and now another 90° bend has been made.



**4TH BEND:** Bending arm is rotating and putting the final 90° bend into fabric shape.

**1ST & 2ND BENDS:** Bending arm (left) is rotating and putting 90° bend into end of sheet. Other end of sheet next will be shaped identically.

**COMPLETION:** Stirrup is completed and ready for removal from the machine.

## III. WELDED WIRE REINFORCEMENT: NOMENCLATURE & PRODUCTION

Welded wire is produced from a series of longitudinal and transverse high strength steel wires, resistance welded at all intersections. The wires are produced from controlled-quality hot-rolled rods which are cold-drawn through a series of dies reducing the rod to the specified wire diameter. This wire is then fed into a rigid grid of reinforcement. The manufacturing process can be varied to accommodate various style changes and dimensions. However, consideration should be given to the complexity of the change. The manufacturing variables are listed in the general order of time involved, starting with the most time consuming:

1. Longitudinal wire spacing
2. Longitudinal wire size
3. Width
4. Side and end overhangs
5. Transverse wire size
6. Transverse wire spacing
7. Length

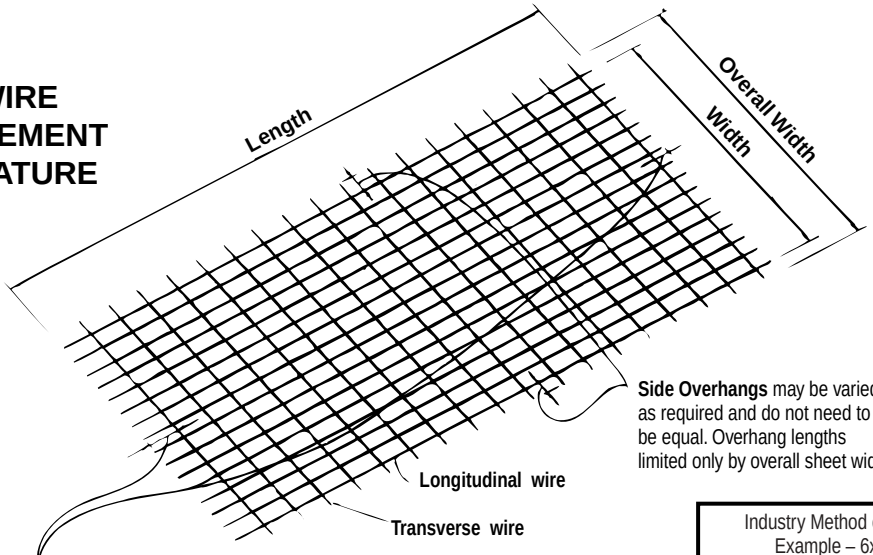
The more difficult machine changes require greater quantities per item, in order to offset the additional production time required. Generally, it is more economical to order a few basic sheet sizes and styles than to specify many variations in the sheet. Quantity requirements for each change usually vary between producers.

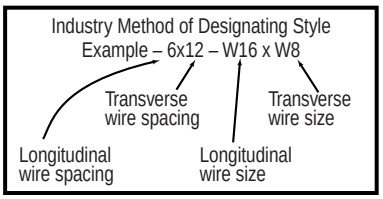
The cross-sectional steel area is the basic element used in specifying the required wire size. The nomenclature used to indicate wire size is a letter followed by a number. The letter "W" identifies a plain wire and the letter "D" a deformed wire. The number which follows is the cross-sectional area of the wire given in hundredths of a square inch. For example: W16 denotes a plain wire with cross-sectional area of 0.16 sq. in.; D7.5 indicates a deformed wire with a cross-sectional area of 0.075 sq. in.

The welded wire reinforcement style identifies the spacing and size of the transverse and longitudinal wires and takes the format: 6 x 12—W16 x W8, where the longitudinal wire spacing is 6 in. with wire size W16 and the transverse wire spacing is 12 in. with wire size W8.

The complete designation also includes the dimensions of the fabric sheet such as: 90", (+1" +3") x 20—0" where the width (given in inches) is equal to 90 in., with side overhangs of 1 in. on one side and 3 in. on the other for an overall width of 94 in., and the length is equal to 20 ft.—O in. The standard end overhang, equal to one half the transverse wire spacing, is assumed unless otherwise specified. It is important to note that the length is the tip-to-tip dimension of the longitudinal wire (20 ft.—0 in. in above example) and that the tip-to-tip dimension of the transverse wires is called the overall width, equal to the width plus both side overhangs (94 in. in above example).

**WELDED WIRE REINFORCEMENT NOMENCLATURE**



# IV. DESIGN CODES AND SPECIFICATIONS

The use of welded wire as a structural concrete reinforcing material is governed by codes such as the ACI 318 Building Code and by specifications such as ASTM A-82, A-185, A-496, and A-497. These references provide the necessary criteria for designing with the unique structural grid of reinforcement provided by welded wire. The following is a summary of ACI code specifications which pertain to the use of bent welded wire:

**SPECIFICATIONS**

- Welded wire reinforcement, both plain and deformed, is defined as deformed reinforcement (Ref. ACI 318, Section 2.1).
- Current ASTM Standards for welded wire allow up to 80,000 psi yield strength and refer to local building codes for stress/strain tests when structural welded wire reinforcement is specified. If 60,000 psi, fy or lower is specified, the ASTM Standards state that fy shall be the stress corresponding to a strain of 0.50%. The ACI building code states that when yield strength, fy exceeds 60,000 psi, fy shall be the stress corresponding to a strain of 0.35%. (Ref. ACI 318, Sections 3.5.3.4, 3.5.3.5 and 3.5.3.6)

**BENDS AND HOOKS:** (Ref. ACI 318, Section 7.2.3)
Inside diameter of bends in welded wire used for stirrups and ties shall not be less than four wire diameters for deformed wire larger than D6 and two wire diameters for all other wires, both plain and deformed. Bends with inside diameters of less than eight wire diameters shall not be less than four wire diameters from nearest welded intersection.

**LATERAL REINFORCEMENT**

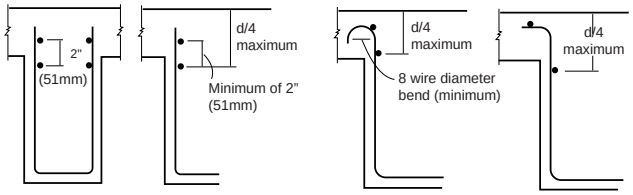
- Equivalent areas of welded wire may be used to furnish the lateral reinforcement requirements specified in ACI 318, Section 7.11.
- Design yield strength of shear reinforcement shall not exceed 60,000 psi, except that the design yield strength of welded deformed wire shall not exceed 80,000 psi. (Ref. ACI 318, Section 11.5.2).
- Design yield strength of nonprestressed torsion reinforcement shall not exceed 60,000 psi. (Ref. ACI 318, Section 11.6.3.4)
- Design yield strength of shear-friction reinforcement shall not exceed 60,000 psi. (Ref. ACI 318, Section 11.7.6)

• Anchorage of web reinforcement for each leg of a simple U-shaped stirrup formed from welded wire must meet one of the following: (Ref. ACI 318, Section 12.13.2.3).

(1) Welded wire may be used as shear reinforcement when the wires are located perpendicular to the axis of the member. (Ref. ACI 318, Section 11.5.1.1,b)

(2) One longitudinal wire located not more than d/4 from the compression face and a second wire closer to the compression face and spaced not less than 2 in. from the first wire. The second wire shall be permitted to be located on the stirrup leg beyond a bend, or on a bend with an inside diameter of bend not less than8 wire diameters.

**EPOXY-COATED WIRES AND WELDED WIRE**
When epoxy-coated wire or welded wire is specified, it shall comply with the "Specification for Epoxy-Coated Steel Wire and Welded Wire for Reinforcement" (ASTM A 884) (Ref. ACI 318, Section 3.5.3.8)




**ANCHORAGE OF WEB REINFORCEMENT USING WELDED WIRE (Non-Seismic Applications)**

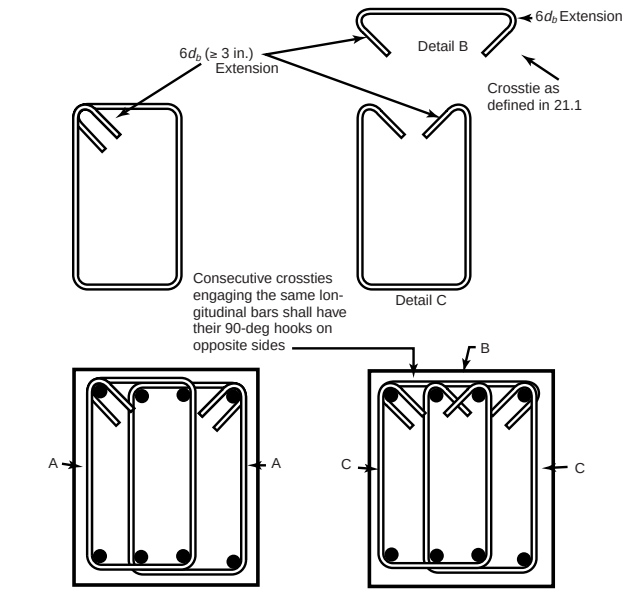



*Fig. R21.3.3 – Example of overlapping hoops*

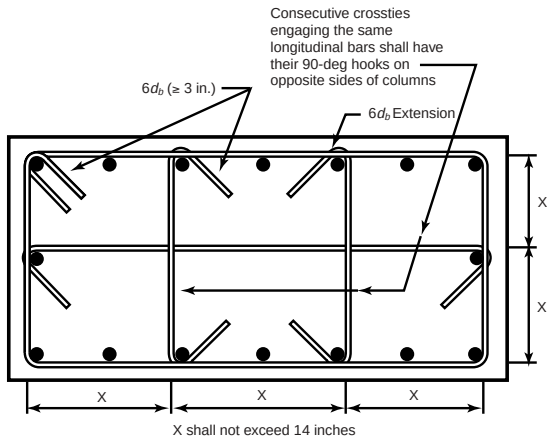



*Fig. R21.4.4 – Example of transverse reinforcement in columns*

**Transverse Reinforcement Detailing Required for Seismic Applications (Ref. ACI 318, Chapter21)**

## V. ADVANTAGES OF BENDING WELDED WIRE REINFORCEMENT

Bending welded wire fabric literally adds a third dimension to concrete reinforcement. It provides the structural engineer with new options in design. The welded wire can be bent to the desired shape and placed where it is needed. Equally important, the contractor can be reasonably sure that it will remain intact as placed. Here are some of its many advantages:

### EXCELLENT BONDING AND DEVELOPMENT CHARACTERISTICS

The welded cross wires of welded wire reinforcement provide unique anchorage for the reinforcement. ACI 318 code provides for the use of either hooked or straight "U" stirrups when designed from wire reinforcement. The straight "U - shaped stirrup can be designed from plain welded wire when at least two separate longitudinal wires are located in the anchorage zone. The use of the "U" shaped stirrups eliminates several bends allowing stirrup cages to be formed in less time. Effective designs using welded deformed wire for stirrups have been developed using both the development length of the deformed wire in addition to the weld shear strength, to meet anchorage requirements.

### OPTIMUM USE OF LABOR/SIMPLIFIED SUPERVISION

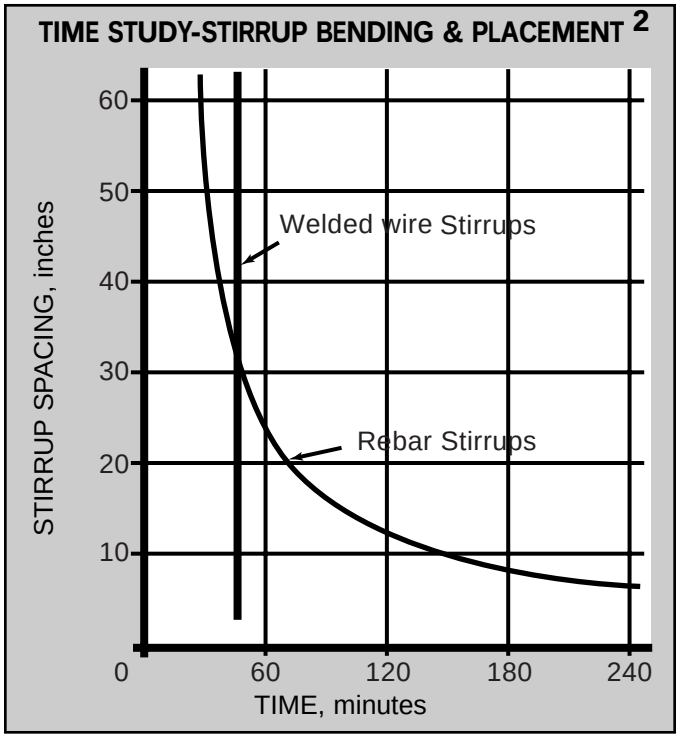
Equipment is basic and easily operated by construction crews who require no special training. Sections of bent welded wire reinforcement, with the steel spacing already fixed, are quickly set into place, therefore reducing supervision and simplifying inspection of the reinforcement.

### BETTER CRACK CONTROL

The high efficiency of small wire sizes and closely spaced reinforcement serves to distribute and equalize the stresses that may result in cracking. Research' has shown that closely spaced wires, 2 to 4in. apart, in welded wire represent the most favorable type of reinforcement for shear and torsion.

### MINIMIZES WELDING PROBLEMS

Because welded wire reinforcement is made form low carbon, cold-drawn steel it has greater weldability, therefore reducing special fabrication problems.




*2 "Welded Wire for Web Reinforcement—Beam Tests," report by Arthur Anderson, ABAM Engineers, Inc., Tacoma, Wash.*

### BENDING AND PLACEMENT TIME REDUCED

Fabrication and placement of individual rebars as stirrups takes up to five times longer than bent units of welded wire, depending on the stirrup spacing.2 Only when stirrup spaces were greater than 30 in. were the individual bars found more economical.

## ADVANTAGES OF BENT WIRE REINFORCEMENT . . .

### TIME SAVED IS MONEY

Bent welded wire reinforcement can save money two ways—particularly on large, complicated jobs. First, it reduces the time required to place the reinforcement. Second, in many instances, it can speed up construction cycles. For instance, the contractor on a major structure recently reduced his time per floor slab from 10 days to 6 days. This job was large and involved complicated reinforcement. It is an unusual case, but indicative of possible savings in time that can speed up the job.

### IMPORTANT IN MEETING COVER REQUIREMENTS

Concrete cover requirements are by necessity both stringent and critical. Here again the rigidity of bent welded wire helps contractors meet cover requirements.

### HELPS MEET LACING TOLERANCES

The intersecting wires of welded wire reinforcement are firmly welded together and thus do not slip out of place. Welding also gives the reinforcement a certain degree of rigidity which is helpful during concrete placement. Thus bent welded wire reinforcement is easy to place and helps assure that reinforcement is positioned exactly where it is supposed to be after placement of the concrete.

### PORTABLE AND FLEXIBLE EQUIPMENT

The bending and cutting equipment for welded wire reinforcement can be easily set up on location, providing close coordination and control of the production of the bent reinforcement. Angles and diameter of the bend can be easily adjusted to meet the design. Shaping the reinforcement on the job site or at the fabricating plant also allows the welded wire reinforcement to be shipped more economically as flat sheets.

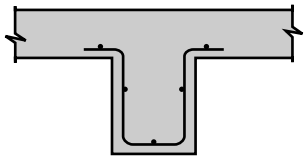
## VI. BENT REINFORCEMENT: MANY APPLICATIONS

### CAST-IN-PLACE CONSTRUCTION

Recent highrise construction projects have shown significant savings when using welded wire stirrup reinforcement:

• Midway through construction of a 32story of office building the stirrup reinforcement was converted from bars to welded wire. “once the stirrups were used, production shot up, steel placement costs dropped and the slab construction cycle was reduced from 9-10 days to 6 days . . . for a time/labor savings of 75%.”

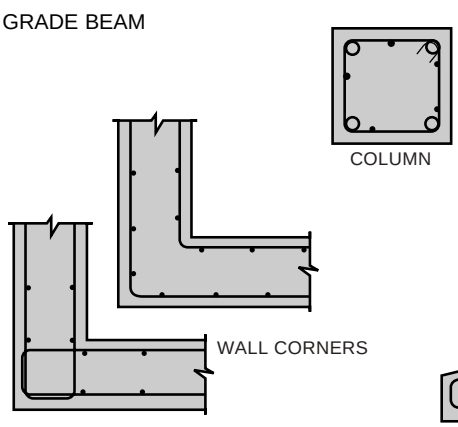
• Contractors on similar highrise construction projects have reported reduction in bending and placement of stirrups from 16 man-hours per ton for rebar stirrups to 8 man-hours per ton to place welded wire reinforcement stirrups.

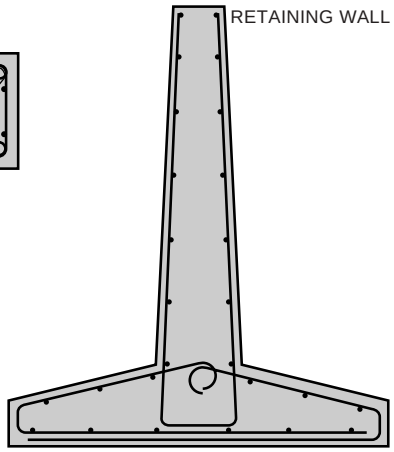


BEAM

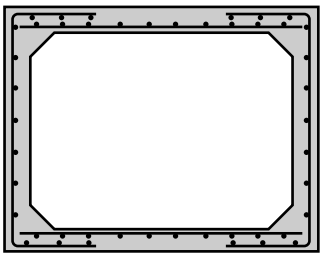
Placing Stirrup

## OTHER CAST-IN-PLACE APPLICATIONS



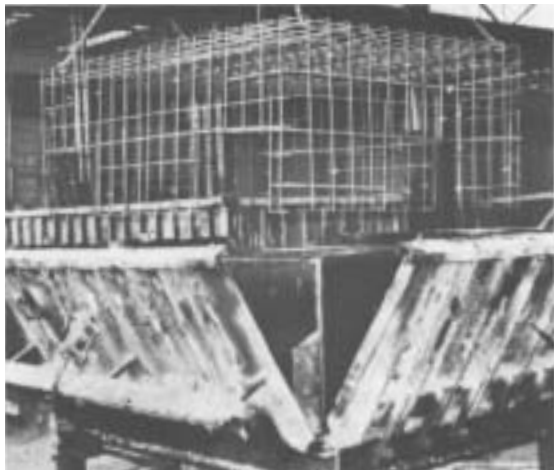

## PRECAST/PRESTRESSED CONSTRUCTION



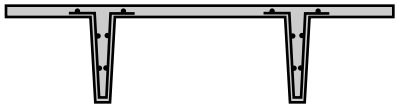
BOX SECTION

The preshaping and assembly of welded wire reinforcement is a natural time saver in the production of precast/ prestressed products:

• The precaster of utility vaults, box culverts and other underground precast products achieved a significant savings in reinforcing case assembly time by using welded wire reinforcement. The assembly of the reinforcement for a typical manhole structure 6'x12'x6' once required three hours to assemble from bars. With welded wire this same cage takes 40 minutes.



Placing WWR Welded wire cage in a box culvert form.

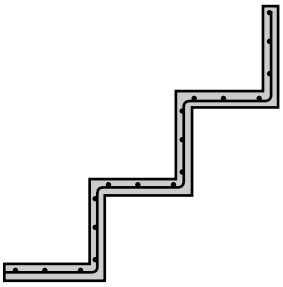


DOUBLE-TEE BEAM

• The use of shaped welded wire reinforcement results in similar savings of time and money in the production of prestressed box beams and single and double-tee beams.

Forms for Double-Tees

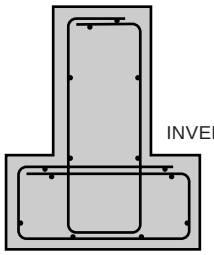
• Welded wire reinforcement, shaped to the contours of 3-tiered risers for a large stadium, helped the precaster of these prestressed components to achieve assembly line efficiency by reducing handling and placement time for the reinforcement. The wire reinforcing's rigidity assured correct position in the riser forms and correct concrete cover.

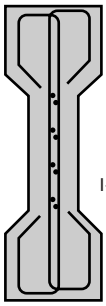


RISER SECTION

Form and completed riser

## OTHER PRECAST APPLICATIONS




# DESIGN TABLES

**Table 1:** Sectional Areas of Welded Wire Reinforcement

*(Area—sq. in. per ft. of width for various spacings)*

| Wire Size Smooth | Number Deformed | Nominal Diameter Inches | Nominal Weight Lbs/Lin/ Ft | Center to Center Spacing 2" | 3" | 4" | 6" | 8" | 10" | 12" |
|---|---|---|---|---|---|---|---|---|---|---|
| W45 | D45 | 0.757 | 1.530 | 2.70 | 1.80 | 1.35 | 0.90 | 0.675 | 0.540 | 0.45 |
| W31 | D31 | 0.628 | 1.054 | 1.86 | 1.24 | .93 | .62 | .465 | .372 | .31 |
| W30 | D30 | 0.618 | 1.020 | 1.80 | 1.20 | .90 | .60 | .45 | .36 | .30 |
| W28 | D28 | 0.597 | .952 | 1.68 | 1.12 | .84 | .56 | .42 | .336 | .28 |
| W26 | D26 | 0.575 | .884 | 1.56 | 1.04 | .78 | .52 | .39 | .312 | .26 |
| W24 | D24 | 0.553 | .816 | 1.44 | .96 | .72 | .48 | .36 | .288 | .24 |
| W22 | D22 | 0.529 | .748 | 1.32 | .88 | .66 | .44 | .33 | .264 | .22 |
| W20 | D20 | 0.505 | .680 | 1.20 | .80 | .60 | .40 | .30 | .24 | .20 |
| W18 | D18 | 0.479 | .612 | 1.08 | .72 | .54 | .36 | .27 | .216 | .18 |
| W16 | D16 | 0.451 | .544 | .96 | .64 | .48 | .32 | .24 | .192 | .16 |
| W15 | D14 | 0.422 | .476 | .84 | .56 | .42 | .28 | .21 | .168 | .14 |
| W12 | D12 | 0.391 | .408 | .72 | .48 | .36 | .24 | .18 | .144 | .12 |
| Wll | D11 | 0.374 | .374 | .66 | .44 | .33 | .22 | .165 | .132 | .11 |
| W10.5 | | 0.366 | .357 | .63 | .42 | .315 | .21 | .157 | .126 | .105 |
| W10 | D10 | 0.357 | .340 | .60 | .40 | .30 | .20 | .15 | .12 | .10 |
| W9.5 | | 0.348 | .323 | .57 | .38 | .285 | .19 | .142 | .114 | .095 |
| W9 | D9 | 0.338 | .306 | .54 | .36 | .27 | .18 | .135 | .108 | .09 |
| W8.5 | | 0.329 | .289 | .51 | .34 | .255 | .17 | .127 | .102 | .085 |
| w8 | D8 | 0.319 | .272 | .48 | .32 | .24 | .16 | .12 | .096 | .08 |
| W7.5 | | 0.309 | .255 | .45 | .30 | .225 | .15 | .112 | .09 | .075 |
| W7 | D7 | 0.299 | .238 | .42 | .28 | .21 | .14 | .105 | .084 | .07 |
| W6.5 | | 0.288 | .221 | .39 | .26 | .195 | .13 | .097 | .078 | .065 |
| W6 | D6 | 0.276 | .204 | .36 | .24 | .18 | .12 | .09 | .072 | .06 |
| W5.5 | | 0.265 | .187 | .33 | .22 | .165 | .11 | .082 | .066 | .055 |
| W5 | D5 | 0.252 | .170 | .30 | .20 | .15 | .10 | .075 | .06 | .05 |
| W4.5 | | 0.239 | .153 | .27 | .18 | .135 | .09 | .067 | .054 | .045 |
| W4 | D4 | 0.226 | .136 | .24 | .16 | .12 | .08 | .06 | .048 | .04 |
| W3.5 | | 0.211 | .119 | .21 | .14 | .105 | .07 | .052 | .042 | .035 |
| W3 | | 0.195 | .102 | .18 | .12 | .09 | .06 | .045 | .036 | .03 |
| W2.9 | | 0.192 | .099 | .174 | .116 | .087 | .058 | .043 | .035 | .029 |
| W2.5 | | 0.178 | .085 | .15 | .10 | .075 | .05 | .037 | .03 | .025 |
| W2 | | 0.160 | .068 | .12 | .08 | .06 | .04 | .03 | .024 | .02 |
| W1.4 | | 0.134 | .048 | .084 | .056 | .042 | .028 | .021 | .017 | .014 |

*Note: Wire sizes other than those listed above may be produced provided the quantity required is sufficient to justify manufacture.*

## **Table 2:** Wire size Comparison

| W & D Size Number Smooth | Deformed | Area (sq. in.) | Nominal Diameter (in.) |
|---|---|---|---|
| W45 | D45 | 0.450 | 0.757 |
| W31 | D31 | 0.310 | 0.628 |
| W30 | D30 | 300 | .618 |
| W28 | D28 | .280 | .597 |
| W26 | D26 | .260 | .575 |
| W24 | D24 | .240 | .553 |
| W22 | D22 | .220 | .529 |
| W20 | D20 | .200 | .505 |
| W18 | D18 | .180 | .479 |
| W16 | D16 | .160 | .451 |
| W14 | D14 | .140 | .422 |
| W12 | D12 | .120 | .391 |
| W11 | D11 | .110 | .374 |
| W10.5 | | .105 | .366 |
| W10 | D10 | .100 | .357 |
| W9.5 | | .095 | .348 |
| W9 | D9 | .090 | .338 |
| W8.5 | | .085 | .329 |
| W8 | D8 | .080 | .319 |
| W7.5 | | .075 | .309 |
| W7 | D7 | .070 | .299 |
| W6.5 | | .065 | .288 |
| W6 | D6 | .060 | .276 |
| W5.5 | | .055 | .265 |
| W5 | D5 | .050 | .252 |
| W4.5 | | .045 | .239 |
| W4 | D4 | .040 | .226 |
| W3.5 | | .035 | .211 |
| W3 | | .030 | .195 |
| W2.9 | | .029 | .192 |
| W2.5 | | .025 | .178 |
| W2 | | .020 | .160 |
| W1.4 | | .014 | .134 |