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TECH FACT

WWR For Structural Applications

A Discussion of Current Product Knowledge and Practices

INTRODUCTION

With its greater strength, generally higher ductility, and significantly lower placing and overall costs, Welded Wire Reinforcement (WWR) offers a highly practical and cost-efficient alternative to traditional rebar concrete reinforcement.

WWR may be used in virtually any structural application-buildings, bridges, highways, tunnels, pipelines, and precast component systems, for instance - that typically would rely on rebar to fortify concrete. In fact, both ACI and AASHTO have considered WWR comparable to rebar for many years, and testing requirements -i.e., tensile, yield strength at various strain rates, and bend testing — are similar for both products. WWR, moreover, adheres to additional required tests, such as reduction of area (ROA) and wrap and weld shear testing (with 50% of the samples having the weld in the center of the gage length).

Ironically, this present-day testing agrees with the more than 17-year-old data of Allen B. Dove, a prolific engineer and honorary member of WRI. Reporting in the September-October 1983 issue of ACI Journal (Title No. 80-41), Mr. Dove commented: "*...the wrap test is the best way to prove the full ductility of WWR. When you turn the reinforcement 360 degrees around a mandrel either the same size as the wire or twice the diameter of the wire, in accordance with the ASTM Standards, you extend the outer fibers of the wire more than 50%. That's a true test of wire ductility*".

WWR ductility — a measure of the steel wires flexibility and, therefore, one measure of its ability to withstand large strains and redistribute stress — compares very favorably with that of rebar. For example, McGill University (Montreal, Quebec, Canada) researcher Dr. Denis Mitchell, attested to WWR's ductility in a report in the March-April 1994 issue of ACI Structural Journal. "We can provide material which is over 75,000 psi yield strength and will test at 0.35% strain (as ACI has required for many years)", he wrote, "and it has ductility that matches or exceeds rebar ductility".

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With better techniques for assessing ductility, as well as to increase this property's presence in the finished product, the trend for WWR is toward higher ductility wire while maintaining desired minimum yield strengths and producing larger wire diameters (now up to 3/4"). In fact, recent production research has focused on using rod sizes that are closer to the finished wire sizes. This reduces the amount of cold-working needed to attain the desired wire size and that, in turn, raises the level of ductility.

There are a great many examples of WWR used in structural applications throughout the country, and WRI has a number of research reports and case studies available that demonstrate how and where high strength and higher ductility WWR has been used.

WWR's strength, flexibility and other advantages have long been relied upon by the precast industry, particularly for applications that may be subjected to high flexure and shear stresses. In recent years, with advances in assessment and manufacturing technologies, WWR's use in a broader base of structural applications is growing rapidly.

With respect to this greater interest in and growing use of WWR, the following discussion examines important aspects of this superior product, including manufacturing, specifications and applications, handling and unloading, placing, coated WWR and metric WWR.

MANUFACTURING

Frequently referred to as fabric or wire mesh, WWR is manufactured from hot rolled steel rods. The rods are cold drawn or cold rolled through a series of dies or carbide rolls to reduce the diameter and to increase the yield strength of the steel.

WWR for construction is usually manufactured in 5- to 8-foot-wide sheets and rolls. Sheets 12' wide and some larger are produced primarily for highway paving and precast components. Special widths can be furnished on request. Sheets can be provided up to 40 feet or more in length, but 12-foot 6-inch, 15-feet, 20-feet, and 25-feet are the more common lengths for ease in shipping and placing. Pipe and standard building fabric are produced in roll form. Most standard building fabric is available in sheet form.

Wire sizes are available from W1.4-W45 and D4-D45. Other wire sizes are available and vary with individual manufacturers. The "W" for plain or "D" for deformed wire numbers are usually whole numbers. For a style designation of 12x12-D10xD10, the first set of numbers is the spacing of wires in inches for both the longitudinal and transverse directions, respectively. The second set is the cross-sectional areas of the respective wires in square inches multiplied by 100 (.10 sq. in. x 100 = 10, etc.).

Spacings of longitudinal wires can vary from 3" to 18" (larger spacings are obtainable and vary with individual manufacturers). Transverse spacings are usually 3, 4, 6, 12, or 18". Wires can be cut flush or have overhangs on the sides of the welded wire. The ends will generally have overhangs of one-half the transverse spacing unless other multiples of the transverse spacing are requested, i.e., for 12-inch transverse spacing, 6" & 6" or 8" & 4" or 10" & 2", etc.

SPECIFICATIONS AND APPLICATIONS

WWR is manufactured in accordance with specifications by the American Society for Testing and Materials (ASTM). ASTM A82 and A496 specify the strength and manufacture of plain and deformed wire used in WWR. ASTM A185 and A497 specify the manufacture and testing of plain and deformed welded wire for concrete reinforcement.

WWR is manufactured with the wires in either square or rectangular patterns, referred to as styles, and is welded by electrical resistance at each intersection. The bond strength of WWR is provided by the welded intersections and deformations when specified.

Welded wire is commonly used to control temperature/shrinkage stresses and add reserve strength in slabs on grade. The more common or standard WWR styles are designated: 6x6-W1.4xW1.4, 6x6-W2.1xW2.1, 6x6-W2.9xW2.9 and 6x6-W4xW4. Heavier WWR styles utilizing wire diameters up to 1/2" (some manufacturers can exceed 1/2" diameter) can be used for structural applications.

The size and area of reinforcement required is specified by the engineer and depends on the slab thickness, the spacing of the construction and control joints, the type and density of the subbase, a friction factor for the sub-grade and the yield strength of the welded wire. There are a number of design methods used when the WWR is used for strength in the reinforced concrete slab or structure.

The ACI Building Code (ACI-318) assigns a minimum yield strength (f_y) value of 60,000 psi to most steel reinforcing but allows yield strengths up to 80,000 psi for many design applications.

Welded wire reinforcement can be used as ties and stirrups for column, beam, and joist cage (confinement) reinforcement. WWR cage reinforcement is also used for concrete encased columns. The WWR supplier uses a welded wire bending machine to shape the materials into required configurations. The placing drawings will identify the location and details of the cage assemblies.

When WWR is used for wall reinforcing, form support accessories are available to hold the sheets of WWR in place to provide the necessary cover.

HANDLING AND UNLOADING

WWR is shipped in two forms — rolls, usually specified for light commercial and residential building construction or concrete pipe, and sheets for general commercial/ industrial construction and precast components. If produced in roll form, a number of rolls are unitized in a bundle for ease of handling. Individual rolls are securely tied, so uncoiling will not occur when the bundles are cut.

Sheets are bundled in quantities depending on size and weight of sheets and in accordance with the customer's requirements. Generally, bundles of rolls or sheets will weigh between 2000 and 6000 pounds. Banding is used for shipping stability only. Bundles should never be lifted by the steel banding.

If the rolls or sheets must be lifted by crane at the job site, the customer may request the WWR manufacturer to install lifting eyes.

Sheet bundles without lifting eyes are placed on dunnage (as specified by the customer) for easier unloading with either a forklift or a crane using a sling chain hooked or threaded through the bundle. At all times during off-loading of materials, caution must be exercised, and all safety regulations and practices must be observed.

PLACING

WWR rolls are unrolled, cut to proper length, and turned over to prevent ends from curling. Flattening the material is best accomplished, mechanically, i.e., roller straightener, which will provide the necessary flatness to achieve proper positioning. All WWR should be placed on support accessories to maintain the required position and cover as specified by the engineer.

Splices or laps, either structural or temperature/ shrinkage types, should be specified by the engineer and in conformance with the ACI Building Code. Typically, structural laps for welded wire fabric are a minimum length of 6” + overhangs for plain wire and 8” including overhangs for deformed wires. The Code requires that one or two cross wires, depending on type of wire, occur in structural laps of WWR. Deformed wire structural laps, when no cross wires are included in the splice region, are a minimum of 12”. In areas of low stress, splice lengths can be reduced.

For slab on grade construction: With slab thicknesses less than 5”, a single layer of welded wire is placed in the middle of the slab. For slabs 6” and greater, the top cover is 1/3 the depth of the slab.

When two layers are specified (usually over 8” thick), the top cover will be 1” to 2” depending on saw cuts.

(WWR is placed below the saw cuts). The bottom cover will be 1-1/2” min. on earth or 1” on vapor barriers. Support manufacturers produce concrete blocks or steel (coated and uncoated) and plastic chairs, bolsters, and WWR support accessories made specifically for either single layer or double layer reinforcing applications.

Placing WWR on appropriately spaced concrete blocks, steel or plastic supports with base plates and typing the WWR at laps is adequate to maintain its position during concrete placement. WWR should not be placed on the sub grade and pulled up during concrete placement. Following is a suggested guide for spacing support accessories:

Heavy WWR styles	W9 or D9 and larger:	4’-6’*
Medium WWR styles	W5 or D5 to W8 or D8:	3’-4’
Light WWR styles	W4 or D4 or less	2’-3’ or less**

* Spacing of supports for WWR with wires larger than W or D9could possibly be increased over the spacings shown depending on the construction loads applied.

**Consider using additional rows of supports when large deflections or deformations occur — also spacing of supports may be increased provided supports are placed and properly positioned as concrete is needed.

CORROSION RESISTANT WWR

There are several coating specifications for welded wire reinforcement: one is a vinyl-coated wire and WWR, ASTM A933. There are two types of zinc-coated (galvanized) coatings for wire and WWR. They are ASTM A641 (hot-dip process for wire (A 82 and A 496) before welding (very popular in the precast panel industry) - then there is ASTM A123 (hot dip coating) of the manufactured welded wire sheets. Another coating is ASTM A884 - a fusion bonded epoxy-coating applied to the welded wire sheets. Now, there is an ASTM standard for stainless steel wire and WWR. It is ASTM A1022-02.Wide

METRIC WELDED WIRE REINFORCEMENT

Generally, when styles of WWR are converted from inch-pound to metric, both spacings and wire areas are soft metricated and rounded to whole numbers. Pipe fabric is an exception. There will be two lists for both spacings and wire sizes. One will be a call-out listing (rounded to whole numbers). The other is an actual spacing or wire size with numbers carried out to 0.1 decimal increments. Examples appear below.

In the future, when more styles are specified in metric, wire sizes can be in 5 or 10 square millimeter areas. Keep in mind, all manufacturers can produce wire sizes in 1 square millimeter increments (0.001 in2). (See Tables 1 & 2)

Examples of styles converted from inch-pound to metric:
Metric Standard style (in-#):
152x152-MW 19 x MW 19 (6x6-W 2.9 x W2.9)

Metric Structural style:
305x305-MD 71 x MD 71 (12x12-D11 x D11)

Metric Pipe style, Call-out:
51x203-MW 77 x MW 32)2 x 8-W12 x W5)

Metric Pipe style, Actual:
50.8x203.2-MW 77.4 x MW 32.3 (2 x 8[W12 x W5)

Note: Conversion factors used: 25.4 mm = 1 inch, 645 mm2 = 1 in2 — A reminder, the inch-pound wire areas in the examples are in2 multiplied by 100.

Note: Table 2 is included for use in selecting areas of steel with various wire spacings.

TABLE 1

METRIC WIRE AREA, DIAMETERS & MASS WITH EQUIVALENT INCH-POUND UNITS G

Metric Units				Inch-pound Units (conversions)				Gage Guide
Size ✦ (MW=Plain) (mm^2)	Area (mm^2)	Diameter (mm)	Mass (kg/m)	Size ✦ (W=Plain) (in^2x100)	Area (in^2)	Diameter (in)	Weight (lb./ft.)	
MW290	290	19.22	2.27	W45	.450	.757	1.53	
MW200	200	15.95	1.57	W31	.310	.628	1.054	
MW130	130	12.9	1.02	W20.2	.202	.507	.687	7/0
MW120	120	12.4	.941	W18.6	.186	.487	.632	6/0
MW100	100	11.3	.784	W15.5	.155	.444	.527	5/0
MW90	90	10.7	.706	W14.0	.140	.422	.476	
MW80	80	10.1	.627	W12.4	.124	.397	.422	4/0
MW70	70	9.4	.549	W10.9	.109	.373	.371	3/0
MW65	65	9.1	.510	W10.1	.101	.359	.343	
MW60	60	8.7	.470	W9.3	.093	.344	.316	2/0
MW55	55	8.4	.431	W8.5	.085	.329	.289	
MW50	50	8.0	.392	W7.8	.078	.314	.263	1/0
MW45	45	7.6	.353	W7.0	.070	.298	.238	1
MW40	40	7.1	.314	W6.2	.062	.283	.214	
MW35	35	6.7	.274	W5.4	.054	.262	.184	2
MW30	30	6.2	.235	W4.7	.047	.245	.160	3
MW26	26	5.7	.204	W4.0	.040	.226	.136	4
MW25	25	5.6	.196	W3.9	.039	.223	.133	
MW20	20	5.0	.157	W3.1	.031	.199	.105	
MW19	19	4.9	.149	W2.9	.029	.192	.098	6
MW15	15	4.4	.118	W2.3	.023	.171	.078	8
MW13	13	4.1	.102	W2.0	.020	.160	.068	
MW10	10	3.6	.078	W1.6	0.16	.143	.054	
MW9	9	3.4	.071	W1.4	.014	.135	.048	10

*Metric wire sizes can be specified in 1 mm^2 increments. **Inch-Pound sizes can be specified in .001 in^2 increments.
Note ✧ -For other available wire sizes, consult other WRI publications or discuss with WWR manufactures.

U.S. CUSTOMARY (INCH-POUND) WIRE SIZES AND AREAS
TABLE 2 - SECTIONAL AREAS OF WELDED WIRE REINFORCEMENT

Wire Size Number* (area of steel x 100)	Nominal Diameter Inches	Nominal Weight Lbs./Lin. Ft.	Area in Sq. In. Per Ft. Of Width For Various Spacing				
			Center-To-Center Spacing				
Plain			3"	4"	6"	12"	18"
W45	.757	1.530	1.80	1.35	.90	.45	.30
W34	.658	1.160	1.36	1.02	.68	.34	.23
W31	.628	1.054	1.24	.93	.62	.31	.21
W25	.564	.850	1.00	.75	.50	.25	.17
W23	.541	.782	.92	.69	.46	.23	.15
W20	.505	.680	.80	.60	.40	.20	.13
W18	.479	.612	.72	.54	.36	.18	.12
W16	.451	.544	.64	.48	.32	.16	.11
W15	.437	.510	.60	.45	.30	.15	.10
W14	.422	.476	.56	.420	.28	.14	.090
W12	.391	.408	.48	.360	.24	.12	.080
W11	.374	.374	.44	.330	.22	.11	.073
W10.5	.366	.357	.42	.315	.21	.105	.070
W10	.357	.340	.40	.300	.20	.10	.068
W9.5	.348	.323	.38	.285	.19	.095	.063
W9	.338	.306	.36	.270	.18	.090	.060
W8.5	.329	.329	.34	.255	.17	.085	.057
W8	.319	.272	.32	.240	.16	.080	.053
W7.5	.309	.309	.30	.225	.15	.075	.050
W7	.299	.238	.28	.210	.14	.070	.047
W6.5	.288	.221	.26	.195	.13	.065	.043
W6	.276	.204	.24	.180	.12	.060	.040
W5.5	.265	.187	.22	.165	.11	.055	.037
W5	.252	.170	.20	.150	.10	.050	.033
W4.5	.239	.153	.18	.135	.09	.045	
W4	.226	.136	.16	.12	.08	.040	
W3.5	.211	.119	.14	.105	.07	.035	
W3	.195	.102	.12	.09	.06	.030	
W2.9	.192	.098	.116	.087	.058	.029	
W2.5	.178	.085	.100	.075	.050	.025	
W2.1	.162	.070	.084	.063	.042	.021	
W2	.160	.068	.080	.060	.040	.020	
W1.5	.138	.051	.060	.045	.030	.015	
W1.4	.134	.049	.056	.042	.028	.014	

Examples Using Various Minimum Yield Strengths for Economy - Consider:

- Grade 60 wire by style 12X12 - W31/W31 (Standard)
- Grade 75 wire by style 12X12 - W25/W25 (20% savings by weight & steel area)
- Grade 80 wire by style 12X12 - W23/W23 (25% savings by weight & steel area)

Note: The above listing of plain wire sizes represents wires normally selected to manufacture welded wire reinforcement styles to specific areas of reinforcement. Wires may be deformed using prefix D, except where only W is required on building codes (usually less than W4). Wire sizes other than those listed above may be available if the quantity required is sufficient to justify manufacture.

*The number following the prefix W identifies the cross-sectional area of the wire in hundredths of a square inch.

The nominal diameter of a deformed wire is equivalent to the diameter of a plain wire having the same weight per foot as the deformed-wire.

Refer to ACI 318 for The ACI Building Code requirements for tension development lengths and tension lap splices of welded wire reinforcement. For additional information see Welded Wire Reinforcement Manual of Standard Practice and Structural Welded Wire Reinforcement Detailing Manual, published by the Wire Reinforcement Institute.