WIRE REINFORCEMENT INSTITUTE®

TECH FACTS Excellence Set in Concrete®

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Historical Data on Wire, Triangular Wire Fabric/ Mesh and Welded Wire Concrete Reinforcement

Introduction

To: Architects, Structural Engineers, Contractors and Building Owners

We receive many technical inquiries on old wire spacings, wire sizes and descriptions. Also, many ask what the physical /mechanical properties are for wire (See p.1). The reprint of old ASTM Standards and the three tables that follow provide answers to a number of questions often posed. For example, what is the tensile strength and yield strength of the old wire and WWR? The answer can be found on Page 1. On Page 2 can be found the table of gauge numbers and the diameters, areas and weights of wires from 16 gauge to 1/2 inch wires. Page 3 is addressed to triangular mesh (before welded wire came on the scene) – the table gives style numbers with single wire or bundled wires that yield the areas of the longitudinal wires (the main or structural wires). Weights per 100 square feet are also included on Page 3. Triangular wire mesh was only made with longitudinal wires. Diagonal wires were used at 2, 4 or 8 inches to hold the longitudinal wires in place. If one desired to have the same wires in the transverse direction (for two-way reinforced slabs) – another sheet was made and placed on top of the other sheet at 90 degrees. Page 4 contains typical tables of wire properties similar to the way WWR is described today – however, in those tables gauges were used and not areas of wire. Those styles were used from 1915 through the 1960's.

These four pages should answer most questions about old wire and the various styles of WWR or mesh used in the past. It is always a good idea to take a sample of the wire reinforced concrete to check or confirm what wire sizes and spacings were used and where it was placed in the concrete. Many times field changes were made and material that was specified or shown on the plans may have been changed in the field.

Pages 5-7 tell the story of the history of WWR, followed by a conclusion page, titled "This Modern Era" - describing where the industry is today.

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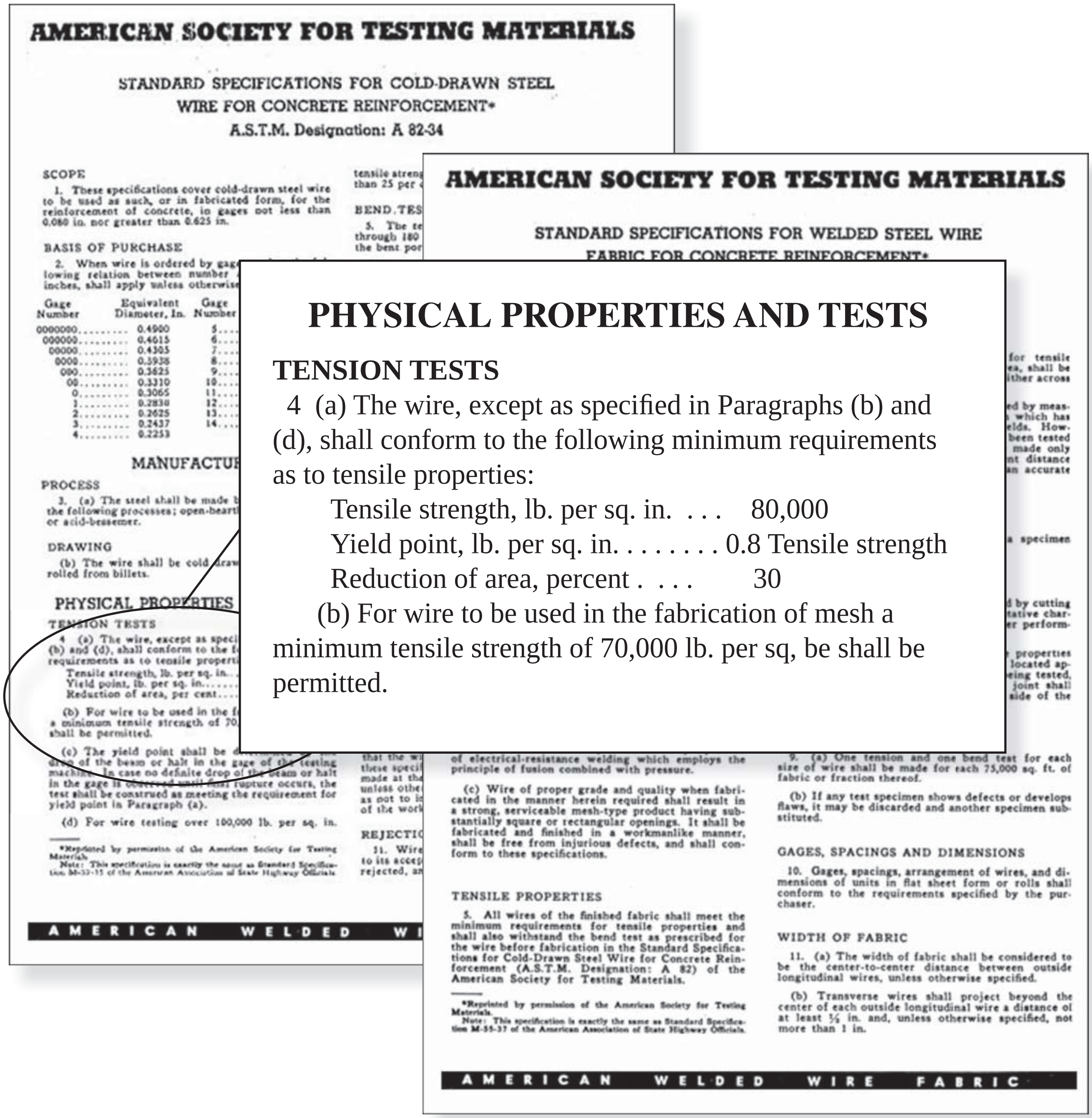
Physical Properties and Tests



AMERICAN SOCIETY FOR TESTING MATERIALS

STANDARD SPECIFICATIONS FOR COLD-DRAWN STEEL WIRE FOR CONCRETE REINFORCEMENT*
A.S.T.M. Designation: A 82-34

AMERICAN SOCIETY FOR TESTING MATERIALS

STANDARD SPECIFICATIONS FOR WELDED STEEL WIRE FABRIC FOR CONCRETE REINFORCEMENT*

PHYSICAL PROPERTIES AND TESTS

TENSION TESTS

4 (a) The wire, except as specified in Paragraphs (b) and (d), shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in. . . . 80,000
Yield point, lb. per sq. in. . . . . 0.8 Tensile strength
Reduction of area, percent 30

(b) For wire to be used in the fabrication of mesh a minimum tensile strength of 70,000 lb. per sq, be shall be permitted.

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Old Gauge Numbers with Diameters, Areas of Steel and Weights

Steel Wire Gauge Numbers	Wire		Weight Pounds Per Foot
	Diameter Inches	Area Square Inches	
1/2"	.5000	.19635	.6668
0000000	.4900	.18857	.6404
000000	.4615	.16728	.5681
00000	.4305	.14556	.4948
0000	.3938	.12180	.4136
000	.3625	.10321	.3505
00	.3310	.086049	.2922
0	.3065	.073782	.2506
1	.2830	.062902	.2136
2	.2625	.054119	.1838
1/4"	.2500	.049087	.1667
3	.2437	.046645	.1584
4	.2253	.039867	.1354
5	.2070	.033654	.1143
6	.1920	.028953	.09832
7	.1770	.024606	.08356
8	.1620	.020612	.07000
9	.1483	.017273	.05866
10	.1350	.014314	.04861
11	.1250	.011404	.03873
12	.1055	.0087417	.02969
13	.0915	.0065755	.02233
14	.0800	.0050266	.01707
15	.0720	.0040715	.01383
16	.0625	.0030680	.01042

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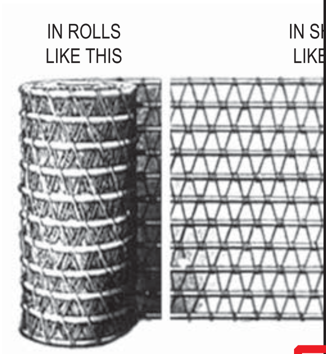
Triangular Wire Mesh Reinforcement 1901-1910's

The red circle on the example call-out is defined: Style 245 (the area of steel per foot of concrete cross section). The 2 wires were bundled together (2- No. 4 gauge @ 4" spacings = 0.245 square inches per foot of concrete cross section). Then the weight as we show it today (# per 100 square feet of wire sheet or roll). Note the column that is headed Sectional Area means that the cross section is allowed in ASTM Standard A 82 to be a minimum area as noted in that column titled Sectional Areas.

Description of Triangle Mesh Reinforcement

TRIANGLE MESH WOVEN W
is made from cold drawn mild steel
strength, the longitudinal or tension
inches, the diagonal cross wires eith
For the light styles of fabric the
one wire, for the medium styles two
styles three wires stranded. The size
obtain the desired cross sectional are
The reason for using stranded longit
is to reduce the stiffness of the finish
ing the tensile strength.
TRIANGLE MESH REINFORC
in standard rolls but can be furnishe
lengths when required providing the
amount. As a general rule roll mater
handled and installed in the work an
the user.



Style Number	Number and Gauge of Wires each Longitudinal American Steel & Wire Company's Steel Wire Gauge	Sectional Area Longitudinals square inches per foot width	Total Effective Longitudinal Sectional Area square inches per foot width	Approximate Weight lbs. per 100 square feet
032	1 - No. 12 gauge	.026	.032	22
040	1 - “ 11 “	.034	.040	25
049	1 - “ 10 “	.043	.049	28
058	1 - “ 9 “	.052	.058	32
068	1 - “ 8 “	.062	.068	35
080	1 - “ 7 “	.074	.080	40
093	1 - “ 6 “	.087	.093	45
107	1 - “ 5 “	.101	.107	50
126	1 - “ 4 “	.120	.126	57
146	1 - “ 3 “	.140	.146	65
153	1 - $\frac{1}{4}$ inch	.147	.153	68
168	1 - No. 2 gauge	.162	.168	74
180	2 - “ 6 “	.174	.180	78
208	2 - “ 5 “	.202	.208	89
245	2 - “ 4 “	.239	.245	103
267	3 - “ 6 “	.261	.267	111
287	3 - “ $5\frac{1}{2}$ “	.281	.287	119
309	3 - “ 5 “	.303	.309	128
336	3 - “ $4\frac{1}{2}$ “	.330	.336	138
365	3 - “ 4 “	.359	.365	149
395	3 - “ $3\frac{1}{2}$ “	.395	.395	160

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WWR from 1915-1960's

Description of American Electrically Welded Fabric

American Electrically Welded Fabric is a square or rectangular mesh made from cold drawn steel wire electrically welded at the intersections of the transverse and longitudinal wires. Various combinations of spacings of wires can be furnished but the standard spacings for the longitudinals are 2, 3, 4 or 6 inches and transverse wires 8, 12, 16 inches. For economical reasons it is advisable to select from the styles on the following pages.

The cross or transverse wires extend out one inch beyond the outside or selvage longitudinal wires.

The weights given in the following tables are based on a width of fabric measured to the center of the outside longitudinals. Square footage is also based on a width exclusive of the overhang of the cross wires outside of the longitudinals.

It is regularly made in rolls for fabric having number 3 gauge or smaller longitudinal wires. If the longitudinals are larger than number 3 gauge, flat sheets only will be furnished. Any of the styles can be furnished straightened and cut to lengths at an advance in price over that for rolls.

All widths are based on the distance center to center of the outside or selvage longitudinal wires. The maximum width of fabric depends on the spacing of the longitudinal wires, as follows; 96 inch maximum for 4 or 6 inch spacing, 84 inch maximum for 3 inch spacing and 60 inch maximum for 2 inch spacing.

American Electrically Welded Fabric combines the same high quality of material and service that has given Triangle Mesh Reinforcement its enviable reputation. When imbedded in concrete this fabric yields the maximum of its steel strength.

Spec
each cas

Note in the red circle an example call-out is defined : Style 66-77 which is similar to the designation we use today – the first two numbers are the spacing of longitudinal wires then the transverse wires (66 is 6" x 6" spacings) The next set of numbers is the wire gauges (77 is 7ga. x 7ga.). See p.2 – table of gauges with properties. Note 7 gauge wire has an area of 0.0246 square inches – therefore 2 wires per foot = 0,049 square inches per foot of concrete cross-section. This is very similar to how we call out wire styles today with the exception that the gauge numbers are now area numbers- which are multiplied by 100- Ex: a 7 gauge wire has an area of 0.0246 – Today we would put a W (for plain wire) or D (deformed wire) in front of the area multiplied by 100. The call out today would be 6x6-W or D2.5 x W or D2.5.

STANDARD PAVEMENT STYLES OF AMERICAN WELDED WIRE FABRIC

Showing Styles, Weights, Spacing and Gauges of Wires and Sectional Areas.

Style	Weight of Fabric Based on Net Width of 60 Inches		Spacings of Wires in inches		A.S. & W. Steel Wire Gauge Number		Sectional Area in Square Inches per Foot of Width of Fabric	
	Lbs. per 100 Sq. Ft.	Lbs. per Sq. Yd.	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
66-88	30	2.70	6	6	8	8	.041	.041
66-77	36	3.24	6	6	7	7	.049	.049
66-66	42	3.78	6	6	6	6	.058	.058
66-55	49	4.41	6	6	5	5	.067	.067
66-44	58	5.22	6	6	4	4	.080	.080
66-33	68	6.12	6	6	3	3	.093	.093
66-22	78	7.02	6	6	2	2	.108	.108

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A Story on the History of Wire and Welded Wire for Concrete Reinforcement

Over a hundred years ago in 1901, patent papers were filed by Massachusetts inventor John Perry for a machine that was able to weld together wires in sheet form. While his initial idea was to use welded wire sheets as fences, by 1906 catalogues were advertising these sheets as reinforcement for concrete.

In 1908, we saw the first major application of wire reinforcement in the construction of the Long Island Parkway. While it was only a lightweight mesh reinforcement weighing only 0.2 lbs. per sq/ft, it represented a step forward. From 1908 until the start of World War I, many eastern states specified wire reinforcement in pavement, eventually increasing to weights of about 0.65 lbs/sq ft.

It is not clear when welded wire was first used with Portland Cement for concrete pavement. Between 1910 and 1915, stretches of pavement in DeKalb, Illinois, California and Forest Park, Maryland were poured using WWR. However, the DuPont Road in Delaware, also shares honors. The road was the forerunner of all superhighways and was built with a variety of reinforcing materials, including welded wire reinforcement. While it was built using specs that we know today are not conducive to long life, it was another major development in the viability of WWR.

The biggest “proof” of the viability of welded wire took place in 1922 in Bates, Illinois, where a test took place studying 78 different types of road pavement. The best performing type of pavement would be used to construct several thousands of miles of highway in Illinois, so the stakes were high. The welded wire producers were able to persuade the project’s chief engineer to apply welded wire to one of the sections. At the end of the test, one engineer observed that the section with the welded wire was “...the only one of the sections which was in sufficiently suitable condition after the final heavy traffic test.” The results convinced a number of states to specify welded wire reinforcement in their roads.

While welded wire had proven itself for road usage, there were still some who still questioned its viability for construction of buildings. However, WWR was catching on in New York City because it offered the perfect proving ground for welded wire. Major fires plagued the city before the turn of the century so city authorities looked for ways to fireproof buildings. The answer came in the form of WWR in flooring slabs that were made using waste product from the city’s many coal burning generating plants. This ‘cinder-arch concrete floor system’ was key in the development of a number of the skyscrapers that grace the Manhattan’s skyline including the groundbreaking Empire State Building. To this day, many of the buildings have been stripped to slab and frame and renovated, but the early wire reinforced floors are still in use.

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Because WWR worked so well in New York City, other cities began to view WWR as a viable form of concrete reinforcement. In fact, welded wire reinforcement was so successful for building reinforcement that you can draw up a virtual “who’s who” of major buildings in America over the past 100 years that have used welded wire reinforcement:

- Grand Central Terminal, New York
- Empire State Building, New York
- Merchandise Mart, Chicago
- Chicago Tribune Towers, Chicago
- World Trade Center, New York
- Sears Tower, Chicago
- Hancock Tower, Chicago
- Rio Vegas Hotel, Las Vegas
- Pacific Park Plaza, San Francisco Area
- Marriott Hotel-Rivercenter, Covington, KY
- Hyatt Regency, San Francisco
- Columbia Center, Seattle
- Continental Plaza Building, Seattle
- One Peachtree Office Tower, Atlanta
- Harbor Place Tower, Long Beach, California

An interesting note about the Pacific Park Plaza Building is that structural WWR played a significant role in its weathering the Loma Prieta earthquake. In a report published by the Concrete Reinforcing Steel Institute in 1990, well-respected engineer Dr. S. K. Ghosh said “The Pacific Park Plaza was undamaged after experiencing significantly strong ground shaking” and WWR was used in all the beam and column joints as shear reinforcement in that building.

By the close of World War II, WWR showed its strength overseas. Because it requires less labor and time, it was seen as the perfect reinforcing material to help Europe rebuild after the war, when time and labor were short. Because of the success of the post-war rebuilding effort, European builders, architects and engineers started to realize WWR’s potential. In fact, WWR remains extremely popular in Europe - accounting for over 50% of all reinforced concrete projects. Because labor is still very expensive in Europe builders are keen on keeping costs low and getting projects completed quicker. These are two things that WWR affords.

In America, the post war years were very good for WWR. In 1956, President Eisenhower signed the National Highway Act and the states started building the current system of superhighways. Just prior to World War II, Pennsylvania started work on its turnpike between Irwin and Carlisle. Other states followed Pennsylvania’s lead and soon wire reinforcement was being used in the Ohio Turnpike, the New York Thruway, the Indiana Turnpike, the Oklahoma Turnpike and others. It is estimated that WWR producers in the US shipped enough product to those working on the interstate highway system in the late 1950s and 60s to pave over 69,000 two-lane miles. To put that in scale, picture a two-lane highway that can wrap 3 times around the Earth!

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WWR has also enjoyed great usage in other projects like airport runways (i.e. O'Hare Airport, George W. Bush Airport, Detroit Metro Airport) and a number of architecturally groundbreaking buildings (i.e. PanAm World Airways Terminal at JFK Airport, the Eli Lilly Plant in Indianapolis and Habitat '67 in Montreal). Much post-modern design requires thin and odd-shaped building sections and WWR allows for ultra-thin concrete sections with enormous strength. Because the wire can be pre-bent for customer order, prefabricators can cast geometric designs offsite and then the finished pieces can be assembled at the jobsite. A prime example is bent reinforcement for precast seating tiers in sports stadiums. Places like the Baltimore Ravens stadium, Camden Yards, and the Seattle Seahawks stadium, the Cleveland Browns stadium and others have used this technology. This quality has also lead to WWR being used for tilt-up wall panels as well as other architectural accents on buildings.

Almost any place that contractors have been using rebar, WWR will do the job. Because of the ability to shape and bend the wire and the potential for thin slabs, WWR has also been a large part of the concrete pipe and box culvert industries. In fact, welded wire accounts for nearly 80% of all concrete pipe reinforcement and is gaining momentum in the box culvert industry.

For bridge structures, WWR structural shear reinforcement is seeing its way into more precast/prestressed girders, beams, boxes and bulb-tees. When it comes to bridge construction, some bridges being built in the past 10 years that have precast/prestressed concrete spans of over 150 feet and most of the bridge components have WWR shear reinforcement the complete length of the spans. The NU 2000, 150-foot "I" girder, with a depth of 7 feet and a top flange width of four feet was developed at the University of Nebraska by Dr. Maher Tadros and his graduate students.

Dr. Tadros' girder has over two tons of shear reinforcement in the web and flanges. Similar 'I' girders are being designed by the State of Nebraska and other states with spans to 200 feet. The typical cast in place bridge decks or precast/prestressed replacement deck panels can also utilize mats of WWR. With WWR manufacturing capability or WWR up to 3/4" diameter, typical bridge reinforcing can be compared with WWR.

One of the greatest things to happen to WWR technology in the past few years has been the ever-increasing wire diameter and materials that manufacturers have been able to weld together. Not only are some manufacturers selling welded wire that is 3/4" in diameter, but there are also zinc-coated and epoxy-coated products available to resist corrosion. In addition, stainless steel welded wire reinforcement may soon come to the market. These advancements have allowed WWR to move from just road and slab reinforcement to structural components in bridges and buildings. There are current ASTM Standards for the above corrosion resistant wire and WWR products.

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This Modern Era

WWR is what the industry today refers to for all styles of Welded Wire Reinforcement. Every change involves a period of transition. For instance, in much of WRI's literature, WWR is often referred to as fabric or mesh or WWF, which imply light reinforcing materials. However, this industry is continuing to grow into what we call the structural WWR market. Future ASTM standards, e.g., Volume 01.04--Steel Reinforcement--will reflect this change of wording, from fabric and mesh to reinforcement.

With further changes to heavier wire and the structural WWR market tonnage increasing each year, structural reinforcement describes the product much more accurately. To be more specific, anytime an engineer uses a moment capacity similar to the one published as M_n in ACI 318, Chapters 9, 14, 15 and Appendix C (even for structural slabs on ground), it flags the fact that the reinforcement is structural or primary reinforcement. One can even apply the area of steel of a WWR style, e.g., 6x6-W1.4xW1.4 in the ACI equation, which yields an ultimate moment capacity of 16% of the cracking moment (Mcr) of a 4" slab.

Some will continue to call out the old but still common wire sizes today as 6 gage (W2.9), or 8 gage (W2.1) or 10 gage (W1.4). Those wire sizes in a 6x6 style are less than 42 #/100sf and some will refer to them as fabric or mesh. [Incidentally, the call-outs in parentheses are the areas of the wire multiplied by 100.] However, as mentioned above, all steel reinforcement areas can be classified as structural or primary reinforcement. Therefore, with the 3 wire sizes noted above, as well as the many sizes over a W4, i.e., W4 wires, each direction on 6 x 6 spacings yields a weight of 58#/100sf--and other wire spacings can be specified as structural WWR. By the way much of our industry produces wire sizes up to W or D 20 (1/2" diameter) and some have the capability to produce W or D 31 (5/8" diameter) and even W or D 45 (3/4" diameter).

The WWR industry can furnish a greater variety of wire spacings than what many are aware of, and areas of steel can match the design professional's requirements more accurately. The typical range of spacings--2, 3, 4, 6, 12, 16 & 18 inches (these occur in tables in the current WRI Manual of Standard Practice) -- can be greatly expanded. Sheets of WWR reinforcement have been furnished with 24-, 36-, 48- and even 60-inch spacings. It depends on the application and the size of wires specified. Call WRI member producers for their ability to meet your specific reinforcement needs.

Today the industry can produce over 80,000 psi yield strength reinforcement.