WIRE REINFORCEMENT INSTITUTE®

TECH FACT

How to Specify, Order & Use Welded Wire Reinforcement in Light Construction

Welded Wire Reinforcement (WWR) Widely Used

Literally millions of square feet of residential slabs, driveways, sidewalks, patios and slabs for light construction are reinforced with welded wire reinforcement (WWR). This publication reviews the reasons for using welded wire reinforcement, its benefits and how to place it properly.

WWR Used to Control Cracking

Concrete by its very nature tends to crack. In residential and light construction, cracking is due primarily to drying shrinkage, temperature and moisture changes, weak subgrades and sometimes poor-quality concrete. Steps can be taken to reduce cracking while other procedures control cracking. **The primary purpose of welded wire reinforcement in slabs is to control cracking and crack widths in both directions.** Welded wire reinforcement keeps the cracked sections of a slab closely knit together so that the slab will act as a unit.

WWR Helps Aggregate Interlock

When a slab cracks, the faces within the crack are jagged. If the sections on each side of the crack are held closely together, the jagged faces of the concrete are interlocked which helps transfer loads across the crack. This factor is called aggregate interlock. As the crack becomes wider the interlock between the faces of the crack decreases and becomes less effective. In residential and light construction, aggregate interlock is usually ineffective when the crack width exceeds $^{1}/_{16}$ in. (0.06”). Welded wire reinforcement holds the cracks closely together so that aggregate interlock will function properly. Closely knit cracks are also less noticeable, and they minimize the movement of water through the slabs at cracks.

Proper Placement is Essential

Welded wire reinforcement must be properly placed if it is to perform effectively. For welded wire reinforcement with wire sizes smaller than W4.0 (D4.0), in addition to the design professional’s specified positioning within the concrete element, a project-specific placement tolerance must also be established and maintained.

Excellence Set in Concrete®

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Thicker Slabs vs. Reinforcement
This argument frequently arises but it overlooks three key points about cracking:

- Most cracks formed in residential and light construction are due to drying shrinkage and temperature changes.
- Both four and five inch slabs will contract the same amount due to drying shrinkage, and will contract equally as the temperature drops.
- Thickening the slab does not change shrinkage and temperature contraction.

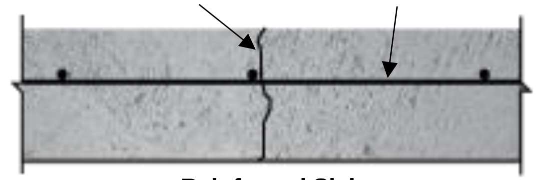
The material cost of reinforcement is almost always less than the material cost of extra concrete. Two widely used styles of reinforcement used in residential and light construction are 6x6 W1.4 x W1.4 (10 gauge) and 6x6 W2.9 x W2.9 (6 gauge). These sheets of WWR only weigh 0.21 lb. and 0.42 lb. per square foot respectively. We suggest that you compare total costs. A reinforced slab may cost the same or less than a slightly thicker unreinforced slab and there is a difference.

Some Additional Reasons to Use WWR
The main purpose of reinforcement is crack control. Crack control is important in a residence. A home is generally a family's largest investment and is a source of great pride. Concrete slabs with cracks or uneven surfaces are a matter of no little concern to homeowners. The proper placement of welded wire reinforcement in slabs will go a long way in reducing this concern.

Properly Positioned WWR Reinforcement will:

- Improve performance of concrete work which means higher owner satisfaction.
- Reduce or even eliminate callbacks for repairs by dissatisfied customers.
- Make compliance with NAHB's Home Owners Warranty (H.O.W.) provisions easier because of improved crack control. H.O.W. requires repairs when cracks exceed limits of H.O.W.'s Performance Standards (see Table 1).
- Allow for consideration of wider joint spacing. The only practical way to control cracking in plain concrete is to use joints at very close intervals – generally less than 15ft. apart. Joints are acceptable in sidewalks and driveways. Joints are not particularly desirable in floor slabs, porches, carports and garages. introduction of an appropriate amount of steel reinforcement can reduce the need for many joints in these slabs.

Proper Placement
Welded wire reinforcement with sizes less than W4.0 (D4.0) should be placed to suit the positioning indicated by the design professional, and held to tolerances that are established specifically for the project.

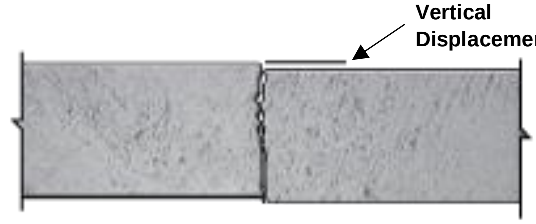


Reinforced Slab

WWR holds slab closely together across crack so that cracked sections remain interlocked and the slab acts as a unit. This action is known as "aggregate interlock"

Unreinforced Slab

As a crack widens, aggregate interlock becomes less effective. When cracks reach 1/16 inch or more in width, aggregate interlock is usually no longer effective. Wide cracks are also extremely noticeable.



Vertical displacement is the difference in elevation between two cracked sections of a slab. It is one of H.O.W.'s criteria on concrete slabs.

Table 1
Provisions Home Owners Warranty Program on Cracking of Concrete*

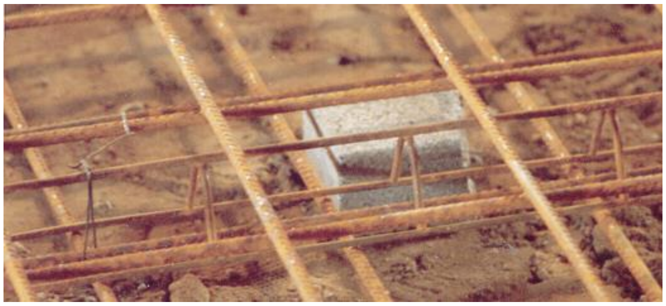
	Performance Standard	
	Maximum Permissible Crack Width	Maximum Permissible Crack Width
C.I.P. basement walls	1/8"	–
Basement floors	3/16"	*1/8"
Attached garage slabs	1/4"	1/4"
Stoops and steps	Hairline only (less 1/16")	–
Patios	1/4"	1/4"
Slab-on-grade	Any crack which significantly impairs appearance or performance of the finish flooring material is not acceptable.	

** Published by Home Owners Warranty Corporation, National Housing Center, Washington, D.C. 20005*

The most common methods of placing WWR are:

(1) chairing WWR
(1) placing concrete in two courses and placing WWR on the first course

When considering the cost of concrete, reinforcement, and vapor barriers, the cost to ensure proper placement is a small, but important, consideration. Variance in positioning of WWR outside of the design professional's established project-specific tolerances for sizes less than W4.0 (D4.0) can have a detrimental effect on overall slab performance. Laying WWR directly on the subgrade and "hooking up" the material during the concreting operation is not typically considered an acceptable placement method.



Place supports 2-3 feet apart for proper positioning of welded wire reinforcement during concrete placing. Concrete block, wire or plastic supports to hold reinforcement. These units are economical and effective.

Chairing WWR
The most widely used method of WWR support is the implementation of an arrangement of chairs, bolsters, or concrete blocks (dobies). A number of concrete accessory suppliers sell chairs and supports for this purpose. The supports are usually steel wires or plastic units and should have a solid base so they will not sink into the subgrade or subbase. Base plates are particularly important when a sand subbase is placed over the subgrade. The chair or support should not puncture the vapor barrier if one is used. Small concrete blocks with an embedded wire or grooved top surface are used for supports and require no base plates. These are often the most economical and effective way to bolster welded wire reinforcement for slabs on grade. A very simple chair or support is simply a piece of concrete 2 or 3 inches thick and about 4 x 4 inches square. Many other styles of supports are available and effective.

Support spacing will depend upon the wire size and the wire spacing. Common practice is to place supports 2 to 3 feet apart, though tighter intervals may be deemed appropriate by the project design and construction team to suit worker and/or equipment traffing during the concreting operation.

Placing WWR in Two-Course Work
Two-course placement of WWR is an effective positioning control method for small diameter reinforcement, though it does have an impact on the sequence and duration of the slab installation. The first course of concrete is generally placed to mid-depth or perhaps slightly more. The WWR is then placed and the second course should be placed before the lower course starts to harden to prevent formation of a "cold" joint between the courses. The two-course method must be confirmed to be compatible with and appropriate for the sequence and size of the slab construction, as well as the design professional's specified reinforcement positioning. This method may not be practical for large slab pours or for reinforcement positioning outside of the middle-third of the specified slab depth.

STYLE OF WWR TO USE
Slab thickness, joint spacing, subgrade composition, and external loading are primary considerations in selecting the appropriate style of WWR. As slabs become longer (and/or thicker) they generally require heavier WWR to suit a cumulative increase in internal tensile stresses.

The design professional should carry out project-specific analysis in conjunction with the recommendations noted in ACI 360 "*Guide to Design of Slabs-on-Ground*" for the determination of the necessary cross-sectional area of reinforcing steel.

Table 3 shows commonly available "stock" styles of WWR that are frequently specified and have a longstanding history of use in lightly-loaded slab-on-ground applications.

Table 2
Requirements for 4-Inch Thick Lightly Reinforced Slab-On-Ground

Maximum Dimension	Style Of WWR
Up to 35 ft.	6 x 6 W1.4 x W1.4
36 ft. to 45 ft.	6 x 6 W2.0 x W2.0
46 ft. to 60 ft.	6 x 6 W2.5 x W2.5
61 ft. to 75 ft.	6 x 6 W2.9 x W2.9 or 6 x 6 W3.0 x W3.0
76 ft. to 100 ft.	6 x 6 W4.0 x W4.0

Intermediate Control Joints
Intermediate control (or contraction) joints can be formed or sawcut in concrete reinforced with WWR for additional crack control. Sidewalks and driveways which are sometimes quite long should have control joints. An appropriate cross-sectional area of welded wire reinforcement continuous across and transverse to the control joint helps promote enhanced aggregate interlock and provides control of differential vertical displacement..

How to Specify and Order Welded Wire Reinforcement
WWR is a prefabricated reinforcing material, and thus the method of specifying and ordering can vary from that that which is used for other types of reinforcement. Some styles of WWR are commonly stocked by WWR producers, supply houses, distributors and fabricators. Table 3 lists many of the commonly stocked items.

WWR is sold in sheets and rolls. Both sheets and rolls are easy to haul and store and are available in stock-type styles, with sheets also being commonly produced in customizable, project-specific styles.

Stock-type sheet widths are typically manufactured in widths between 5 and 10 ft., with lengths normally between 10 and 20 ft. The biggest advantage of sheets is the ease with which they can be placed on site, as there is no need to unroll and straighten the WWR. As a result, sheets inherently give better placement control than rolls.

Stock-type roll width typically varies depending on its location of sale, but is generally 5 to 7 ft. in width and 150 to 200 ft. in length.

When specifying non-stock items, it is preferable for the item quantity to be sufficient for production to be carried out at an economical cost, as the WWR will often need to draw wires to diameters that are not regularly available as part of a stock style.

The production of WWR is similar to precast concrete production or to the use of forms in cast-in-place work: the greater the repetition, the lower the cost. As such, the smaller the number of styles used for a project will result in maximum economy, thus saving on the cost of WWR. Equally important is the fact that use of fewer styles helps to reduce on-site and in-plant inventory and handling costs, resulting in a simplified quality control effort.

Minimum quantity requirements vary with different producers. In the past, it was common for a prescriptive minimum quantity to be defined in order for production on a special order involving a major change to commence, an example fo which would be an adjustment to longitudinal wire size or spacing. Similarly, the minimum quantity on minor changes involving the same size longitudinal wire would have been considerably less, as would a change in size or spacing of transverse wires, length of side or end overhangs, or length changes. In recent years, however, advancements in welding equipment technology and process

Table 3
Common Styles of Welded Wire Reinforcement

Style Designation		Steel Area Sq. In. Per Ft.		
New Designation (by W-Number)	Old Designation (by Steel Wire Gauge)	Longit.	Tran.	Weight Approx. Lbs. Per 100 S.F.
6X6 - W1.4xW1.4	6 x 6 - 10 x 10	.028	.28	21
6X6 - W2 x W2	6 x 6 - 8 x 8	.040	.040	29
6X6 - W2.9xW2.9	6 x 6 - 8 x 8	.058	.058	42
6X6 - W4xW4	6 x 6 - 4 x 4	.080	.080	58
4X4 - W1.4xW1.4	4 x 4 - 10 x 10	.042	.042	31
4X4 - W2xW2	4 x 4 - 8 x 8	.060	.060	43

Table 4A
Specifications Covering WWR
Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed for Concrete

U.S. Specification	Title
ASTM A 1064	Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
Previous U.S. Specifications	
ASTM A 82	Cold-Drawn Steel Wire for Concrete Reinforcement
ASTM A 185	Welded Steel Wire Reinforcement for Concrete
ASTM A 496	Deformed Steel Wire for Concrete Reinforcement
ASTM A 497	Welded Deformed Steel Wire Reinforcement for Concrete

Table 4B
Specifications Covering WWR
Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed for Concrete

Canadian Standard	Title
CSA G 30.3	Cold-Drawn Steel Wire for Concrete Reinforcement
CSA G 30.5	Welded Steel Wire Reinforcement for Concrete
CSA G 30.14	Deformed Steel Wire for Concrete Reinforcement
CSA G 30.15	Welded Deformed Steel Wire Reinforcement for Concrete

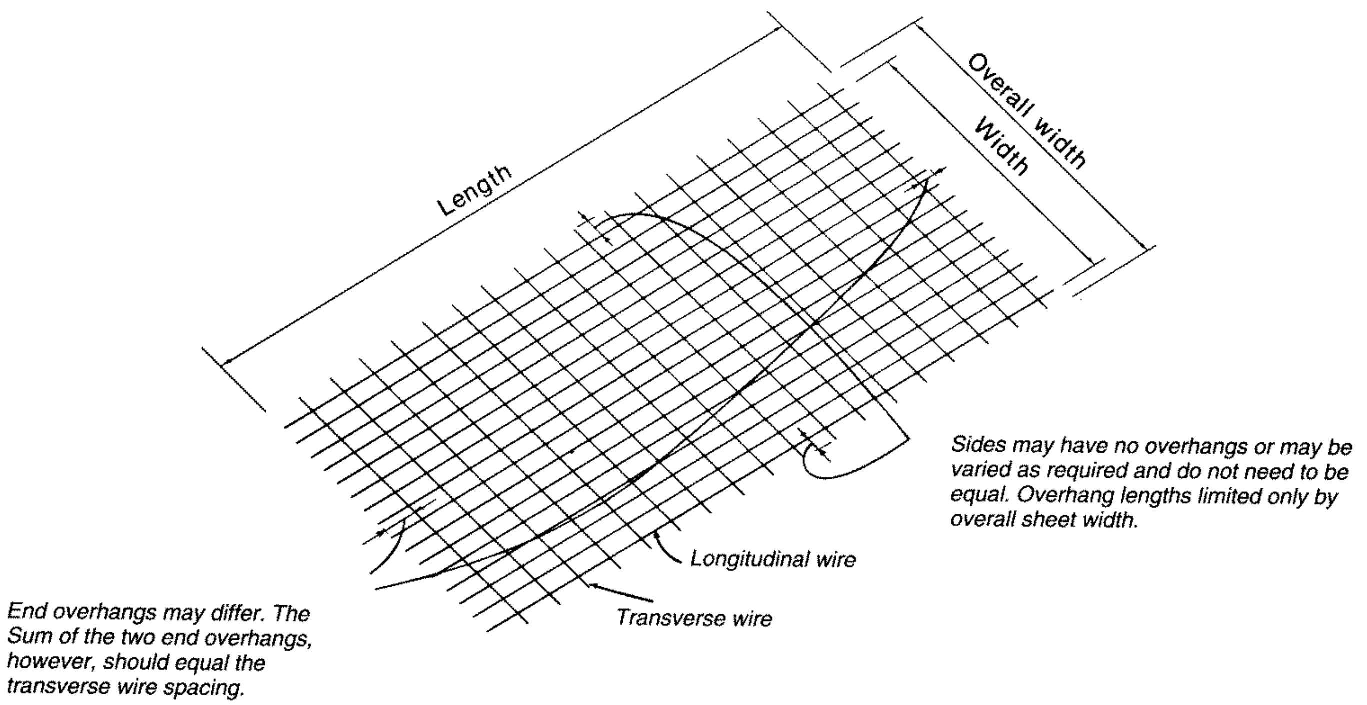
* The Titles of the ASTM Specifications and CSA Standards are identical

management have allowed manufacturers to refine the thresholds for what constitute minimum quantities and major changes, allowing for more efficient production of non-stock items.

Specifications

ASTM International publishes specifications for the wire used to manufacture WWR for both smooth and deformed welded wire reinforcement. The Canadian Standards Association publishes similar standards for use in Canada. The corresponding titles and numbers are given in Table 4B. These are considered to be the governing specifications for both wire and welded wire reinforcement.

Some governmental agencies have special specifications which will control if cited.



Concrete Shrinks with Age–A Cause of Cracking

Concrete has its greatest volume when it is first placed in the forms. As it sets, it starts to contract or shrink. The shrinkage process continues for several years. It is estimated, however, that 60% to 70% of the shrinkage will occur by the time the concrete is three to six months old.

Shrinkage varies with many factors, such as amount of mixing water and cement used, type of aggregate, humidity and slump. In plain concrete, the drying shrinkage varies from ½ to 1 inch per 100 ft. Assuming an average shrinkage of ¾ inch per 100 ft., a 30' x 60' slab would shrink or contract approximately one-quarter inch in the 30 ft. dimension, and roughly one-half inch in the long direction. If a plain (unreinforced) slab is not funished with intermediate joints or some other embedded means of resisting internal tensile stresses, it will most likely crack. If there are, for instance, only one or two randomly-located cracks, their width may become entirely too wide for satisfactory performance.

Subgrade Settlement and Loads – A Cause of Cracking

The subgrade (or subbase, if one is used) must provide uniform support for the slab. If uniform support is not provided, loads may cause the slab to crack and one section could drop considerably below the other – a condition referred to as vertical displacement. This problem is often observed in residential work. It is primarily the result of two factors – the crack opens too wide for aggregate interlock to be relied upon, and the support offered by the subgrade is not uniform. Loads such as cyclical presence of vehicles on a driveway exacerbate the problem.

The use of sound fill material, careful placement of fill materials ,and adequate compaction are critically important to the performance of a slab-on-ground. This is especially true of areaa over trenches excavated for utility lines. Many builders place a double layer of WWR over the trenched area. This provides additional structural strength. Subgrades inside foundation walls are difficult to fill and compact adequately. Excessive moisture under slabs also reduces support.

Traditional loading on residential and light slabs are usually not heavy enough to cause significant structural problems. Line loads and point load imposed by superimposed features such as bearing walls or fireplaces may sometimes necessitate special design. Driveways, garage and carport slabs, and sidewalks where they cross driveways are generally exposed to the most severe loads. However, a faulty subgrade or unusual load–or the combination of both - can cause severe cracking problems.

Temperature Changes Affect Concrete–A Cause of Cracking

As the temperature increases, a slab expands and as the temperature drops, it contracts. Since there is relatively little temperature change within a house, temperature may have little effect on interior slabs. Temperature does, however, have a profound effect on exterior concrete, such as sidewalks, driveways and porches, and carport and patio slabs. The effects of temperature changes must be considered in the construction of garage slabs, unheated buildings and outside flatwork. A drop of 100 degrees F, in temperature will cause a contraction of approximately ⅔ inch per 100 ft. A temperature drop of 50 degrees, F, say from 80 degrees to 30 degrees, will cause a contraction of ⅓ inch per 100 ft.

Drying shrinkage and temperature contraction are independent of each other. If a slab contracts ¾ inch per 100 ft. from drying shrinkage, it will contract or expand additionally for temperature changes. Thus, the total contraction on a cold day is considerable, often causing cracks to open up excessively in unreinforced concrete

Table 5
Approximate Slab Contraction Due to Drying Shrinkage and a Temperature Change of 75 Degrees, F

	30 ft.	40 ft.	50 ft.	60 ft.	75 ft.	100 ft.
Contraction due to drying shrinkage at rate of ¾″ per 100′	.23″	.30″	.38″	.45″	.56″	.75″
Contraction due to temperature drop of 75° F*	.15″	.20″	.25″	.30″	.37″	.50″
Total contraction	**.38″**	**.50″**	**.058**	**.63″**	**.93″**	**1.25″**

* For 100 ∞ F difference, increase contraction 1/3; for a 50 ∞ difference, subract 1/3 temperature contraction value.

Summary

The Benefits of properly positioned welded wire reinforcement in light construction:

- Promotes enhanced aggregate interlock, which is critical to minimizing the propagation of crack and joint width
- Improves durability of slabs subjected to traffic, freeze-thaw cycling, and temperature change, resulting in aesthetic and functional benefits
- Helps to distribute cracks throughout a slab’s surface, reducing the likelihood of smaller quantity of random cracks with large widths that have a detrimental effect on function and serviceability.
- With an appropriate cross-sectional area of reinforcing steel specified by the design professional, WWR facilitates the use of wider joint spacing
- Because the slab demand in light construction is such that a relatively small area of steel reinforcement is required computationally, readily available stock-styles of welded wire reinforcement are a natural fit.

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