



WIRE REINFORCEMENT INSTITUTE®

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## A Consolidated Guide

# ACI 318 Provisions and ASTM References for Specifying WWR

For architects, engineers, contractors and others who intend to use or are considering the use of high-performance, lightweight, cost-efficient welded wire reinforcement (WWR), this publication contains key code provisions concerning wire and WWR for reinforced concrete design.

The reference can be used as a guide for design expressions, approved ASTM material references and commentary to assist in the design of WWR in concrete structures. The various chapters and sections that reference wire and WWR are taken from the current ACI 318 Building Code for Structural Concrete and Commentary\*. Refer to the ACI Code for complete documentation and commentary on specific sections. Permission to reprint these data has been granted by the American Concrete Institute.

### KEY CODE UPDATES OR CHANGES MADE IN RECENT YEARS:

1. Supported or suspended structural slabs with minimum steel reinforcement can be found in Chapter 7. An expression exists to substitute high strength WWR over 60 ksi yield strength - See Chapters 3 and 7. All ASTM Standard references noted throughout the Code, covering structural wire and WWR include a supplement allowing up to 80 ksi reinforcement. Note the ACI 318 code at present does not cover structural slabs on ground. Refer to other WRI references for the design procedures of structural slabs on ground.
2. The latest Code provisions for confinement and shear reinforcement can be found in Chapters 11. The Code now recognizes shear reinforcement up to 80,000 psi yield strength for deformed WWR. It has recognized up to 80,000 psi yield strength in flexure for many years and is stated in Chapter 9.
3. Wall reinforcement provisions and minimum requirements can be found in Chapters 14 and 21. Chapter 14 refers to steel ratio requirements for both rebar and

WWR. Both reinforcing materials can be specified. See Special Provisions for Seismic Design in Chapter 21. Higher ratios of reinforcement are required in Chapter 21. Paragraph 21.2.1.5 states that other structural materials or structural systems not previously recognized are approved if research data shows evidence of meeting strength and toughness equal to or exceeding Chapter 21 requirements.

4. Epoxy-coated welded wire reinforcement is now recognized by the Code in Chapters 3 and 12. Statements have been added to include the reference of ASTM A 884 for the coated reinforcement. Also testing is referenced in Chapter 12 which shows that no additional splice lengths are necessary over uncoated WWR. The welded intersections of WWR provide sufficient bond strength to resist shear stresses. Research work by the University of Texas on the subject is referenced in the Code. It can be found in the commentary of Chapter 12, R12.7 - Also see the footnote reference 12.11 in the back of the Code.

5. In future Codes the largest cold worked wire size will be increased to a W45 or D45 (3/4" diameter) wire sizes. The size wire is now available by some WRI producer plants.

6. Recent research work on high strength wire with high ductility is now noted in Chapter 11, R11.5.2. The research papers are listed near the back of the Code as 11.15, 11.16 and 11.17. As a reminder, these references can be considered for projects that fall in the category of special provisions as described in #3 above.

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*\*The provisions in this Tech Fact can be found in ACI 318-02. This Tech Fact may be inserted in the WRI Structural Detailing Manual section and will be updated as future Codes are published.*

*The last page has a listing of applicable ASTM Standards for wire and WWR.*

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## Section 1

### PROVISIONS OF ACI 318\* BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE WHICH APPLY TO WELDED WIRE REINFORCEMENT FABRIC

*Welded plain wire reinforcement fabric (WWR) and welded deformed wire reinforcement fabric are both defined in ACI 318, Section 2.1, as Deformed Reinforcement. Since welded wire reinforcement is supplied in sheets or mats instead of individual bars, additional descriptive provisions are necessary and are found in Section 2. See Appendix C, for wire diameters, wire areas and areas per unit of width. Other Wire Reinforcement Institute's publications are available for areas of reinforcement with various strengths, as well as development and splice lengths for different styles.*

*For the convenience of architects and engineers, some provisions related to WWR are reprinted from ACI 318 and will be referred to by code chapters and pertinent sections in this manual. Some metric data and formulas are presented in the Wire Reinforcement Institutes Manual of Standard Practice, Structural Welded Wire Reinforcement, copyright, 1999.*

### CHAPTERS OF ACI 318-95 FOR WELDED WIRE REINFORCEMENT:

#### CHAPTER 3 - MATERIALS

##### 3.5 - Metal reinforcement

##### 3.5.3 - Deformed reinforcement

**3.5.3.4** - Deformed wire for concrete reinforcement shall conform to "Specifications for Steel Wire, Deformed, for Concrete Reinforcement" (ASTM A 496), except that wire shall not be smaller than size D4 and for wire with a specified yield strength  $f_y$  exceeding 60,000 psi,  $f_y$  shall be the stress corresponding to a strain of 0.35 percent if the yield strength specified in the design exceeds 60,000 psi.

**3.5.3.5** - Welded plain wire reinforcement fabric for concrete shall conform to "Specification for Steel Welded Wire Reinforcement Fabric, Plain, for Concrete" (ASTM A 185), except that for wire with a specified yield strength  $f_y$  exceeding 60,000 psi,  $f_y$  shall be the stress corresponding to a strain of 0.35 percent if the yield strength specified in the design exceeds 60,000 psi. Welded intersections shall not be spaced farther apart than 12 in. in direction of calculated stress, except for wire fabric used as stirrups in accordance with 12.13.2.

**3.5.3.6** - Welded deformed wire reinforcement fabric for concrete shall conform to "Specification for Steel Welded Wire Fabric, Deformed, for Concrete Reinforcement"

(ASTM A 497), except that for wire with a specified yield strength  $f_y$  exceeding 60,000 psi,  $f_y$  shall be stress corresponding to a strain of 0.35 percent if the yield strength specified in the design exceeds 60,000 psi. Welded intersections shall not be spaced farther apart than 16 in. in direction of calculated stress, except for wire fabric used as stirrups in accordance with 12.13.2.

**3.5.3.8** - Epoxy - Coated wires and WWR shall comply with ASTM A 884.

**3.8** - Standards cited in this code

**3.8.1** - Standards of the American Society for Testing and Materials referred to in this code are listed below, and are declared part of this code:

- A 82 Standard Specification for Steel Wire, Plain, for Concrete Reinforcement
- A 185 Standard Specification for Steel Welded Wire Reinforcement \*Fabric, Plain, for Concrete
- A 496 Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement
- A 497 Standard Specification for Steel Welded Wire Reinforcement \*Fabric, Deformed, for Concrete
- A 884 Standard Specification for Epoxy - Coated Steel Wire and Welded Wire Fabric for Reinforcement

#### CHAPTER 7 - DETAILS OF REINFORCEMENT

##### 7.2 - Minimum bend diameters

**7.2.3** - Inside diameter of bends in welded wire fabric (plain or deformed) for stirrups and ties shall not be less than  $4d_b$  for deformed wire larger than D6 and  $2d_b$  for all other wires. Bends with inside diameter of less than  $8d_b$  shall not be less than  $4d_b$  from nearest welded intersection.

**7.5.3** - Welded wire fabric (with wire size not greater than W5 or D5) used in slabs not exceeding 10 ft. in span may be curved from a point near the top of slab over the support to a point near the bottom of slab at midspan, provided such reinforcement is either continuous over, or securely anchored at support.

##### 7.6 - Spacing limits for reinforcement

**7.6.5** - In walls and slabs other than concrete joist construction, primary flexural reinforcement shall not be spaced farther apart than 3 times the wall or slab thickness, nor 18 in.

##### 7.10.5 - Ties

Tie reinforcement for compression members shall conform to the following:

**7.10.5.1** - All nonprestressed bars shall be enclosed by lateral ties, at least #3 in size for longitudinal bars #10 or smaller, and at least #4 in size for #11, #14, #18, and

\* Expressions or factors being considered for change in future codes.

bundled longitudinal bars. Deformed wire or welded wire fabric of equivalent areas is allowed.

**7.10.5.2** - Vertical spacing of ties shall not exceed 16 longitudinal bar diameters, 48 tie bar or wire diameters, or least dimension of the compression member.

**7.11** - Lateral reinforcement for flexural members

**7.11.3** - Closed ties or stirrups shall be formed in one piece by overlapping standard stirrup or tie and hooks around a longitudinal bar, or formed in one or two pieces lap spliced with a Class B splice (lap of  $1.3l_d$ ), or anchored in accordance with 12.13.

**7.12** - Shrinkage and temperature reinforcement

**7.12.1** - Reinforcement for shrinkage and temperature stresses normal to flexural reinforcement shall be provided in structural slabs where the flexural reinforcement extends in one direction only.

**7.12.2.1** - Area of shrinkage and temperature reinforcement shall provide at least the following ratios of reinforcement area to gross concrete area, but not less than 0.0014:

- (a) Slabs where Grade 40 or 50 deformed bars are used . . . . . 0.0020
- (b) Slabs where Grade 60 deformed bars or welded wire fabric (plain or deformed) are used . . . 0.0018
- (c) Slabs where reinforcement with yield stress exceeding 60,000 psi measured at a yield strain of 0.35 percent is used . . . . .  $0.0018 \times \frac{60,000}{f_y}$

**7.12.2.2** - Shrinkage and temperature reinforcement shall not be spaced farther apart than 5 times the slab thickness, nor 18 in.

**7.12.2.3** - At all sections where required, reinforcement for shrinkage and temperature stresses shall develop the specified yield strength  $f_y$  in tension in accordance with Chapter 12.

*Note - For additional details of WWR refer to ACI 318-95, Chapter 7.*

**CHAPTER 9- STRENGTH AND SERVICEABILITY REQUIREMENTS**

**9.4** - Design strength for reinforcement

Designs shall not be based on a yield strength of reinforcement  $f_y$  in excess of 80,000 psi, except for prestressing tendons.

**CHAPTER 11 - SHEAR AND TORSION**

**11.5** - Shear strength provided by shear reinforcement

**11.5.1** - Types of shear reinforcement

**11.5.1.1** - Shear reinforcement may consist of:

- (a) Stirrups perpendicular to axis of member.
- (b) Welded wire fabric with wires located perpendicular to axis of member.

**11.5.1.2** - For nonprestressed members, shear reinforcement may also consist of:

- (a) Stirrups making an angle of 45 degrees or more with longitudinal tension reinforcement.
- (b) Longitudinal reinforcement with bent portion making an angle of 30 degrees or more with the longitudinal tension reinforcement.
- (c) Combinations of stirrups and bent longitudinal reinforcement.
- (d) Spirals.

**11.5.2** - Design yield strength of shear reinforcement shall not exceed 60,000 psi, except that the design yield strength of welded deformed wire fabric shall not exceed 80,000 psi.

**11.5.3** - Stirrups and other bars or wires used as shear reinforcement shall extend to a distance  $d$  from extreme compression fiber and shall be anchored at both ends according to 12.13 to develop the design yield strength of reinforcement.

**11.5.4** - Spacing limits for shear reinforcement

**11.5.4.1** - Spacing of shear reinforcement placed perpendicular to axis of member shall not exceed  $d/2$  in nonprestressed members and  $3/4h$  in prestressed members, nor 24 in.

**11.6** - Combined shear and torsion strength for non-prestressed members with rectangular or flanged sections

**11.6.7** - Torsion reinforcement requirements

**11.6.7.1** - Torsion reinforcement, where required, shall be provided in addition to reinforcement required to resist shear, flexure, and axial forces.

**11.6.7.2** - Reinforcement required for torsion shall be combined with that required for other forces, provided the area furnished is the sum of individually required areas and the most restrictive requirements for spacing and placement are met.

**11.6.7.3** - Torsion reinforcement shall consist of closed stirrups, closed ties, or spirals, combined with longitudinal bars.

**11.6.7.4** - Design yield strength of torsion reinforcement shall not exceed 60,000 psi.

**11.6.7.5** - Stirrups and other bars and wires used as torsion reinforcement shall extend to a distance  $d$  from extreme compression fiber and shall be anchored according to 12.13 to develop the design yield strength of reinforcement.

**11.6.7.6** - Torsion reinforcement shall be provided at least a distance  $(b_t + d)$  beyond the point theoretically required.

**11.6.8** - Spacing limits for torsion reinforcement

**11.6.8.1** - Spacing of closed stirrups shall not exceed the smaller of  $(x_1 + y_1)/4$ , or 12 in.

**11.6.8.2** - Spacing of longitudinal bars, not less than #3, distributed around the perimeter of the closed stirrups, shall not exceed 12 in. At least one longitudinal bar shall be placed in each corner of the closed stirrups.#3, distributed around the perimeter of the closed stirrups, shall not exceed 12 in. At least one longitudinal bar shall be placed in each corner of the closed stirrups.

**CHAPTER 12 - DEVELOPMENT AND SPLICES OF REINFORCEMENT**

**12.1 - Development of reinforcement - General**

**12.1.1** - Calculated tension or compression in reinforcement at each section of reinforced concrete members shall be developed on each side of that section by embedment length, hook or mechanical device or a combination thereof. Hooks may be used in developing bars in tension only.

**12.2 - Development of deformed bars and deformed wire in tension**

**12.2.1** - Development length  $l_d$ , in terms of diameter  $d_b$  for deformed bars and deformed wires in tension shall be determined from either 12.2.2 or 12.2.3, but  $l_d$  shall not be less than 12 in.

**12.2.2** - For deformed bars or deformed wire,  $l_d/d_b$  shall be as follows:

	No. 6 and smaller bars and deformed wires	No. 7 and larger bars
Clear spacing of bars being developed or spliced not less than $d_b$ , clear cover not less than $d_b$ , and stirrups or ties throughout $l_d$ not less than the code minimum or Clear spacing of bars being developed or spliced not less than $2d_b$ and clear cover not less than $d_b$	$\frac{l_d}{d_b} = \frac{f_y \alpha \beta \lambda}{25 \sqrt{f'_c}}$	$\frac{l_d}{d_b} = \frac{f_y \alpha \beta \lambda}{20 \sqrt{f'_c}}$
Other cases	$\frac{l_d}{d_b} = \frac{3f_y \alpha \beta \lambda}{50 \sqrt{f'_c}}$	$\frac{l_d}{d_b} = \frac{3f_y \alpha \beta \lambda}{40 \sqrt{f'_c}}$

**12.2.3** - For deformed bars or deformed wire,  $l_d/d_b$  shall be:

$$\frac{l_d}{d_b} = \frac{3}{40} \frac{f_y}{\sqrt{f'_c}} \frac{\alpha \beta \gamma \lambda}{\left(\frac{c + K_{tr}}{d_b}\right)}$$

in which the term  $(c + K_{tr})/d_b$  shall not be taken greater than 2.5.

**12.2.4** - The factors for use in the expressions for development of deformed bars and deformed wires in tension in Chapter 12 are as follows:

$\alpha$  = reinforcement location factor  
Horizontal reinforcement so placed that more than

12 in. of fresh concrete is cast in the member below the development length or splice . . . . .1.3

Other reinforcement . . . . .1.0

$\beta$  = coating factor

Epoxy-coated bars or wires with cover less than  $3d_b$ <sup>1</sup> or clear spacing less than  $6d_b$  . . . . .1.5

All other epoxy-coated bars or wires . . . . .1.2

Uncoated reinforcement . . . . .1.0

However, the product of need not be taken greater than 1.7.

$\gamma$  = reinforcement size factor

No. 6 and small bars and deformed wires . . .0.8

No. 7 and larger bars . . . . .1.0

$\lambda$  = lightweight aggregate concrete factor

When lightweight aggregate concrete is used 1.3

However, when  $f_{ct}$  is specified, shall be permitted to be taken as 6.7 but not less than . . . . .1.0

When normal weight concrete is used . . . . .1.0

$c$  = spacing or cover dimension, inc.

Use the smaller of either the distance from the center of the bar or wire to the nearest concrete surface or one-half the center-to-center spacing of the bars or wires being developed.

It shall be permitted to use  $K_{tr}=0$  as a design simplification even if transverse reinforcement is present.

**12.3 - Development of deformed bars in compression**

**12.3.1** - Development length  $l_d$ <sup>1</sup> in inches, for deformed bars in compression shall be computed as the product of the basic development length  $l_{db}$  of 12.3.2 and applicable modification factors of 12.3.3, but  $l_d$  shall be not less than 8 in.

**12.3.2 - Basic development length**

$l_{db}$  shall be . . . . . $.0.02d_b f_y / \sqrt{f'_c}$   
but not less than . . . . . $.0.0003d_b f_y$ \*\*

**12.3.3 - Basic development length  $l_{db}$  shall be permitted to be multiplied by applicable factors for:**

**12.3.3.1 - Excess reinforcement**

Reinforcement in excess of that required by analysis . . . . . $(A_s \text{ required})/A_s \text{ provided}$

**12.7 - Development of welded deformed wire fabric in tension**

**12.7.1** - Development length  $l_d$ , in inches, of welded deformed wire fabric measured from the point of critical section to the end of wire shall be

\* Expressions or factors being considered for change in future codes.  
\*\*The constant carries the unit of in.<sup>2</sup>/lb.

computed as the product of the development length  $l_d$ , from 12.2.2 or 12.2.3 times a wire fabric factor from 12.7.2 or 12.7.3. It shall be permitted to reduce the development length in accordance with 12.2.5 when applicable, but  $l_d$  shall not be less than 8 in. except in computation of lap splices by 12.18. When using the wire fabric factor from 12.7.2, it shall be permitted to use an epoxy-coated factor  $\beta$  of 1.0 for epoxy-coated welded wire fabric in 12.2.2 and 12.2.3.

**12.7.2** - For welded deformed wire fabric with at least one cross wire within the development length and not less than 2 in. from the point of the critical section, the wire fabric factor shall be the greater of:

$$\left( \frac{f_y - 35,000}{f_y} \right) \text{ or } \left( \frac{5d_b}{S_w} \right)$$

but need not be taken greater than 1.

**12.7.3** - For welded deformed wire fabric with no cross wires within the development length or with a single cross wire less than 2 in. from the point of the critical section, the wire fabric factor shall be taken as 1, and the development length shall be determined as for deformed wire.

**12.7.4** - When any plain wires are present in the deformed wire fabric in the direction of the development length, the fabric shall be developed in accordance with 12.8.

**12.8** - Development of welded plain wire fabric in tension. Yield strength of welded plain wire fabric shall be considered developed by embedment of two cross wires with the closer cross wire not less than 2 in. from the point of the critical section. However, the development length  $l_d$ , in inches, measured from the point of the critical section to the outermost cross wire shall not be less than:

$$0.27 \frac{A_w}{S_w} \left( \frac{f_y}{\sqrt{f'_c}} \right) \lambda$$

except that when reinforcement provided is in excess of that required, this length may be reduced in accordance with 12.2.5.  $l_d$  shall not be less than 6 in. except in computation of lap splices by 12.19.

**12.13** - Development of web reinforcement

**12.13.2** - Ends of single leg, simple U-, or multiple U-stirrups shall be anchored by one of the following means:

**12.13.2.1** - For #5 bar and D31 wire, and smaller, and for #6, #7, and #8 bars with  $f_y$  of 40,000 psi or less, a standard hook around longitudinal reinforcement.

**12.13.2.2** - For #6, #7, and #8 stirrups with  $f_y$  greater than 40,000 psi, a standard stirrup hook around a longitudinal bar plus an embedment between midheight of the member and the outside end of the hook equal to or greater than  $0.014d_b f_y / \sqrt{f'_c}$ .

**12.13.2.3** - For each leg of welded plain wire fabric forming simple U-stirrups, either:

- (a) Two longitudinal wires spaced at a 2 in. spacing along the member at the top of the U.
- (b) 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 may be located on the stirrup leg beyond a bend, or on a bend with an inside diameter of bend not less than  $8d_b$ .

**12.13.2.4** - For each end of a single leg stirrup of welded plain or deformed wire fabric, two longitudinal wires at a minimum spacing of 2 in. and with the inner wire at least the greater of  $d/4$  or 2 in. from middepth of member  $d/2$ . Outer longitudinal wire at tension face shall not be farther from the face than the portion of primary flexural reinforcement closest to the face.

**12.15** - Splices of deformed bars and deformed wire in tension

**12.15.1** - Minimum length of lap for tension lap splices shall be as required for Class A or B splice, but not less than 12 in., where:

- Class A splice . . . . . 1.0  $l_d$ .
- Class B splice . . . . . 1.3  $l_d$ .

where  $l_d$  is the tensile development length for the specified yield strength  $f_y$  in accordance with 12.2 without the modification factor of 12.2.5.

**12.15.2** - Lap splices of deformed bars and deformed wire in tension shall be Class B splices except that Class A splices are allowed when: (a) the area of reinforcement provided is at least twice that required by analysis over the entire length of the splice, and (b) one-half or less of the total reinforcement is spliced within the required lap length.

## 12.18 - Splices of welded deformed wire in tension

**12.18.1** - Minimum length of lap for lap splices of welded deformed wire fabric measured between the ends of each fabric sheet shall be not less than  $1.3\lambda_d$  nor 8 in., and the overlap measured between outermost cross wires of each fabric sheet shall not be less than 2 in.  $\lambda_d$  shall be the development length for the specified yield strength  $f_y$  in accordance with 12.7.

**12.18.2** - Lap splices of welded deformed wire fabric, with no cross wires within the lap splice length, shall be determined as for deformed wire.

## 12.19 - Splices of welded plain wire fabric in tension

Minimum length of lap for lap splices of welded plain wire fabric shall be in accordance with the following.

**12.19.1** - When area of reinforcement provided is less than twice that required by analysis at splice location, length of overlap measured between outermost cross wires of each fabric sheet shall be not less than one spacing of cross wires plus 2 in., nor less than  $1.5\lambda_d$ , nor 6 in.  $\lambda_d$  shall be the development length for the specified yield strength  $f_y$  in accordance with 12.8.

**12.19.2** - When area of reinforcement provided is at least twice that required by analysis at splice location, length of overlap measured between outermost cross wires of each fabric sheet shall be not less than  $1.5\lambda_d$ , nor 2 in.  $\lambda_d$  shall be the development length for the specified yield strength  $f_y$  in accordance with 12.8.

## CHAPTER 14 - WALLS

### 14.2 - General

**14.2.7** - Quantity of reinforcement and limits of thickness required by 14.3 and 14.5 are waived where structural analysis shows adequate strength and stability.

### 14.3 - Minimum reinforcement

**14.3.1** - Minimum vertical and horizontal reinforcement shall be in accordance with 14.3.2 and 14.3.3 unless a greater amount is required for shear by 11.10.8 and 11.10.9.

**14.3.2** - Minimum ratio of vertical reinforcement area to gross concrete area shall be:

- (a) 0.0012 for deformed bars not larger than #5 with a specified yield strength not less than 60,000 psi, or
- (b) 0.0015 for other deformed bars, or
- (c) 0.0012 for welded wire fabric (plain or deformed) not larger than W31 or D31.

**14.3.3** - Minimum ratio of horizontal reinforcement area to gross concrete area shall be:

- \*(a) 0.0020 for deformed bars not larger than #5 with a specified yield strength not less than 60,000 psi, or
- (b) 0.0025 for other deformed bars, or
- (c) 0.0020 for welded wire fabric (plain or deformed) not larger than W31 or D31.

**14.3.4** - Walls more than 10 in. thick, except basement walls, shall have reinforcement for each direction placed in two layers parallel with faces of wall in accordance with the following:

- (a) One layer consisting of not less than  $1/2$  and not more than  $2/3$  of total reinforcement required for each direction shall be placed not less than 2 in. nor more than  $1/3$  the thickness of wall from exterior surface.
- (b) The other layer, consisting of the balance of required reinforcement in that direction, shall be placed not less than  $3/4$  in. nor more than  $1/3$  the thickness of wall from interior surface.

**14.3.5** - Vertical and horizontal reinforcement shall not be spaced further apart than three times the wall thickness, nor 18 in.

**14.3.6** - Vertical reinforcement need not be enclosed by lateral ties if vertical reinforcement area is not greater than 0.01 times gross concrete area, or where vertical reinforcement is not required as compression reinforcement.

**14.3.7** - In addition to the minimum reinforcement required by 14.3.1, not less than two #5 bars shall be provided around all window and door openings. Such bars shall be extended to develop the bar beyond the corners of the openings but not less than 24 in.

## CHAPTER 21 - SPECIAL PROVISIONS FOR SEISMIC DESIGN

### 21.2 - General requirements

#### 21.2.1 - Scope

**21.2.1.1** - Chapter 21 contains special requirements for design and construction of reinforced concrete members of a structure for which the design forces, related to earthquake motions, have been determined on the basis of energy dissipation in the nonlinear range of response.

**21.2.1.2** - The provisions of Chapters 1 through 18 shall apply except as modified by the provisions of this chapter.

**21.2.1.3** - In regions of moderate seismic risk, reinforced concrete frames resisting forces induced by earthquake motions shall be proportioned to satisfy only 21.8 of Chapter 21 in addition to the requirements of Chapters 1 through 18.

**21.2.1.4** - In regions of high seismic risk, all structural reinforced concrete members shall satisfy 21.2 through 21.7 of Chapter 21 in addition to the requirements of Chapters 1 through 17.

**21.2.1.5** - A reinforced concrete structural system not satisfying the requirements of this chapter is allowed if it is demonstrated by experimental evidence and analysis that the proposed system will have strength and toughness equal to or exceeding those provided by a comparable monolithic reinforced concrete structure satisfying this chapter.

**21.2.6.2** - Welding of stirrups, ties, inserts, or other similar elements to longitudinal reinforcement required by design shall not be permitted.

**R21.2.6.2** - Welding or tack-welding or cross reinforcing bars can lead to local embrittlement of the steel. If such welding will facilitate fabrication or field installation, it must be done only on bars added expressly for construction.

*Provisions for tack-welding of crossing reinforcing bars do not apply to materials that are welded with welding operations under continuous competent control as in the manufacture of welded wire fabric.*

**21.3.3** - Transverse reinforcement

**21.3.3.1** - Hoops shall be provided in the following regions of frame members:

- (1) Over a length equal to twice the member depth measured from the face of the supporting member toward midspan, at both ends of the flexural member.
- (2) Over lengths equal to twice the member depth on both sides of a section where flexural yielding is likely to occur in connection with inelastic lateral displacements of the frame.

**21.3.3.2** - The first hoop shall be located not more than 2 in. from the face of a supporting member. Maximum spacing of the hoops shall not exceed (a)  $d/4$ , (b) eight times the diameter of the smallest longitudinal bars, (c) 24 times the diameter of the hoop bars, and (d) 12 in.

**21.3.3.3** - Where hoops are required, longitudinal bars on the perimeter shall have lateral support conforming to 7.10.5.3.

**21.3.3.4** - Where hoops are not required, stirrups shall be spaced at no more than  $d/2$  throughout the length of the member.

**21.3.3.5** - Stirrups or ties required to resist shear shall be hoops over lengths of members as specified in 21.3.3, 21.4.4, and 21.5.2.

**21.3.3.6** - Hoops in flexural members are allowed to be made up two pieces of reinforcement: a U-stirrup having hooks not less than 135 deg. with six-diameter (but not less than 3 in.) extension anchored in the confined core and a crosstie to make a closed hoop. Consecutive crossties engaging the same longitudinal bar shall have their 90-deg. hooks at opposite sides of the flexural member. If the longitudinal reinforcing bars secured by the crossties are confined by a slab only on one side of the flexural frame member, the 90-deg. hooks of the crossties shall all be placed on that side.

**21.6** - Structural walls, diaphragms, and trusses

**21.6.1** - Scope

**21.6.2** - Reinforcement

**21.6.2.1** - The reinforcement ratio,  $r_v$ , for structural walls shall not be less than 0.0025 along the longitudinal and transverse axes. If the design shear force does not exceed  $A_{cv}\sqrt{f'_c}$ , the minimum reinforcement for structural walls shall be in conformance with 14.3. The minimum reinforcement ratio for structural diaphragms shall be in conformance with 7.12. Reinforcement spacing each way in structural walls and diaphragms shall not exceed 18 in. Reinforcement provided for shear strength shall be continuous and shall be distributed across the shear plane.

**21.6.2.2** - At least two curtains of reinforcement shall be used in a wall if the in-plane factored shear force assigned to the wall exceeds  $2A_{cv}\sqrt{f'_c}$ .

\* Expressions or factors being considered for change in future codes.

\*\*The constant carries the unit of in.<sup>2</sup>/lb.

## **A Listing of ASTM Standards Applicable to Wire and WWR**

A 82 Specification for Steel Wire, Plain, for Concrete Reinforcement

A 123 Specification for Zinc (Hot-Dip) Coatings on Iron and Steel Products

A 185 Specification for Steel Welded Wire, Plain, for Concrete Reinforcement

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 496 Specification for Steel Wire, Deformed, for Concrete Reinforcement

A 497 Specification for Steel Welded Wire, Deformed, for Concrete Reinforcement

A 641 Specification for Zinc-Coated (Galvanized) Carbon Steel Wire

A 700 Practices for Packaging, Marking and Loading Methods for Steel Products

A 884 Specification for Epoxy-Coated Steel Wire and Welded Wire for Reinforcement

A 933 Specification for Vinyl (PVC) Coated Steel Wire and Welded Wire for Reinforcement

A 1022 Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement



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