ACI COMMITTEE 439 on REINFORCING STEEL
MEETING NOTICE AND AGENDA

To: **Members of ACI Committee 439**
From: **Mark D. Marvin, Chair** e-mail: mdm.tmg@comcast.net
William C. Gallenz, Secretary e-mail: wgallenz@fast.net
Date **22 March 2008**

Address Chairman at:
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ACI COMMITTEE 439 MEETINGS SUMMARY
Spring 2008 — Century City, CA, Hyatt Regency Century Plaza

COMMITTEE NUMBER	COMMITTEE NAME	DAY	TIME	ROOM
439	Steel Reinforcement	Mon, Mar 31	8:30a-10p	Encino
439-A	Steel Reinf-Wire	Sun, Mar 30	3:30p-5p	Penthouse 1923

AGENDA -- COMMITTEE 439 ON STEEL REINFORCEMENT
(Main committee meeting on Monday, 31 March 2008)

1. Call to order
2. Membership overview
3. Approval of minutes from Fall 2007 meeting in Fajardo, PR
4. Subcommittee reports
   4.1. 439 A on Welded Wire Reinforcement – Ted Mize, Chair; Ryan Pelter, Secretary
5. Task Group Reports
   5.1. Field straightening reinforcement: testing status update – Mario Rodriquez, Chair
   5.2. “Steel Reinforcement - Physical Properties & U. S. Availability” (ACI 439.4R-89)
   Review and resolve TAC Comments (attached)
   5.3. New high strength steel – Salem Faza, Chair
   5.4. Staggering splices – Lou Colarusso, Chair – Update
   5.5. Initial review of Subcommittee document “Comprehensive Guide…” (attached)
6. Review of Mission Statement and Goals
7. Other Old Business
8. New Business
9. Adjournment

cc: D. Johnston, TAC Contact
Dan Falconer, ACI Engineering manager, Attn: Pat Levicki

DRAFT MINUTES FOR ACI COMMITTEE 439

November 4, 2007

Address writer at:
Reinforcement Solutions, Inc.
1117 N. 23rd Street
Allentown, PA 18104

To: Members of ACI 439
From: William C. Gallenz, Secretary
E-mail: wgallenz@rsinc.bz

Subject: **439 Main Committee minutes for the meeting held:**
Monday, October 15, 2007
Fajardo, PR, El Conquistador Resort, ICACO A

1. Call to order: 10:00 A.M.

2. Attendance:

2.1. Voting Members Present: L. Colarusso, J. Bohinsky, T. Mize, K. Williamson, C. Sabo, D. DeValve, S. Faza, L. Lutz, A. Carroll, R. Reiterman, R. Richardson, D. Starnes, R. Pelter, M. Marvin, W. Gallenz, T. Hawkinson

2.2. Voting Members Absent: D. Carreira, A. Felder, P. Fredrickson, S. Holdsworth, A. Hulshizer, H. Lancelot, K, Luttrell, P. Meza, C. Paulson, R. Ramsey, M. Rodriquez, P. Ross, R. Smith, W. Zert,

2.3. Other Members Present: S. Graham

2.4. Visitors Present: B. Risser, L. Caldwell, M. Chehab, R. O'Kane, D. Johnston

2.5. Summary: 16 Voting Members present, 14 Voting Members absent, 1 Other Members present, 5 Visitors present.

2.5.1. As of the date of the meeting, committee membership stood at 30 Voting, 3 Associate and 6 Consulting members.

3. Minutes Approval:

3.1. The minutes as presented from the April, 2007 Atlanta, GA meeting were unanimously approved. (Motion: T. Mize; Second: R. Reiterman)

4. Subcommittee Reports:

4.1 439-A on Wire Reinforcement (T. Mize, Chair, R. Pelter, Secretary) – Subcommittee A met on Sunday October 8, 2007.

4.1.1 Attendance: There were 13 in attendance of 16 total members.

4.1.2 D45 wire issue presented as active regarding development limitation.

4.1.3 Goals of the committee will be educational items and a new "Constructability Guide"

5 Task Group Reports:

5.1 Field straightening reinforcement: testing status update – Mario Rodriquez, Chair

5.1.1 M. Rodriguez was not in attendance. Report not provided at this time.

5.2 Report "Steel Reinforcement – Physical Properties & U.S. Availability" (ACI 439.4R-89) (L. Lutz, Chair) resolved negative comments:

5.2.1 A. Felder: general comments were accepted. The specific comments 1 through 5 were accepted. Comment 6 was altered to remove "new".

5.2.2 S. Holdsworth comments P4, P12, P17, P22, P26, P27, and P28 were reviewed and accepted by the committee.

5.2.3 C. Paulson: Vote on placement of chart. 13 voted yes, 0 voted no, motion carried.

5.2.4 L. Lutz to revise chart completely. Pin dia. comment, columns, title for bar sizes.

5.2.5 L. Lutz discussed new sentences added. L. Lutz motioned, T. Mize carried, 11 positive, 0 negative, motion carried.

5.2.6 Chairman Marvin to provide L. Lutz with updated member list prior to final draft

5.3 New High Strength Steel (S. Faza, Chair)

5.3.1 ITG 6 committee formed to give guidelines for ASTM 1035. 100 ksi yield strength to be utilized for confinement is a component. Currently there are 6 members at 30% stage of writing report. One goal is to see how people can utilize ASTM 1035 at different design levels. The purpose of ITG is to push the agenda. David Johnston, TAC Representative, offered a brief overview of ITG 6 and its current state. After document completion, Committee 439 will receive a copy for review.

5.4 Staggering Splices Update (L. Colarusso, Chair)

5.4.1 Document passed through sub-committed vote and soon to be issued to 439 main.

5.4.2 M. Marvin to email C. Paulson to keep this document moving through the system.

5.4.3 R. Richardson suggested that the sub-committee include documentation regarding the use of high strength wire to 100 KSI yield.

6 Review of Mission Statement and Goals (ACI Requirement):

6.1 The Mission Statement is to remain as “Develop and report information on steel reinforcement of concrete.

6.2 The newly adopted goals are as follows: 1) Ballot revisions to “Steel Reinforcement – Physical Properties and U.S. Availability” (ACI 439.4R); 2) Ballot “Guide to Welded Wire Reinforcement; 3) Develop “High Strength Steel Bar Requirement.” 4) L. Lutz suggests securing a slot for an upcoming session. All agree that it will be “High Strength” and “Constructability”.

7 Other Old Business:

7.1 No additional old business discussed.

8 New Business:

8.1 No new business discussed.

9 Adjournment:

9.1 S. Faza motioned, D. DeValve second.

cc: D. Johnston, TAC Contact
Ron Burg, TAC Chair
Dan Falconer, ACI Engineering manager, Attn: Pat Levicki

ACI SUBCOMMITTEE 439-A AGENDA

March 21, 2008

To: Members of ACI Subcommittee 439-A

From: Theodore A. Mize, Chairman
Ivy Steel & Wire
815 Bethany Lane
Concord, CA 94518

Phone and Fax: 925-685-9141 Email: tamize@sbcglobal.net

Date: Sunday, March 30, 2008
Place: Century City, CA – Hyatt Regency Century Plaza – Penthouse 1923
Time: 3:30 – 5:00pm

1 – Call to order.

2 – Introduction and welcome guests and new members.

3 – Approval of minutes from the Puerto Rico meeting (attached).

4 – Subcommittee membership update.

5 – Changes to ACI 318.
  a. Material and use related changes in 318-08.
  b. Proposed changes for 318-11.

6 – Discussion/report on proposed ACI Guide document.

7 – Subcommittee review of implementation goals.
  a. Discuss educational plan.
  b. Discuss new ideas for subcommittee goals.

8 – Report on new or revised ASTM Standards.

10 – New business.

11 – New meeting date & time.

12 – Adjournment.

ACI SUBCOMMITTEE 439-A MINUTES

Date: Sunday, October 14, 2007
Place: Puerto Rico – El Conquistador Resort – ICACO A
Time: 1:30 – 3:00pm

1 – Chairman Mize called the meeting to order at 1:30 pm.

2 – There were 13 members in attendance.

3 – Approval of minutes from the Atlanta meeting (attached). Marvin made motion, second by DeValve.

4 – Subcommittee membership update. No new members since last meeting. Subcommittee membership stands at 16.

5 – Report on changes to ACI 318-08.

- c. Material related changes. Lutz clarified that "welded plain wire reinforcement" being defined as "deformed reinforcement" is with respect to bond.
- d. Use related changes. Mize and Lutz believe that the code change related to splice length was considered editorial and did not receive comments. The code changes related to maximum wire spacing may not appear in the next edition. Mize agreed to follow up on the status of both with 318B.
- e. Mize recommended that we send a proposal to 439 about reducing the minimum wire size from D4 to D1. Marvin suggested we solicit input on the D4 minimum size from Ramsey and others.

6 – Discussion/report on proposed ACI Guide document. Marvin stated that he is rewriting the document with style changes and plans to put it on the website before the spring 2008 meeting so that it can be discussed at the 439 meeting in spring 2008.

7 – Subcommittee review of implementation goals.

- c. Discuss educational plan. Mize suggested that we target local ACI chapters and that we do presentations in conjunction with the publication of the Guide document. We may consider looking for university contacts in the ACI directory that would be more apt to be interested in ACI. Reiterman volunteered to be involved in the search for university contacts.
- d. Discuss new ideas for subcommittee goals. Marvin stated that with the reorganization of 439, we need to work on a new set of subcommittee goals. Mize suggested reviewing the mission statement for 439-A. DeValve suggested a constructability document for WWR with details of applications for using WWR that could be incorporated into a presentation. Marvin agreed that a use handbook for WWR would be beneficial. Consider a session through E702. Mize asked for volunteers

to define a format for a constructability document with “chapters” to be included. Mize volunteered to work on a proposed format and Marvin, DeValve, and Carroll agreed to help with the task.

8 – Report on new or revised ASTM Standards. The galvanized WWR standard needs to be reballoted to incorporate the latest changes from the last ballot. Mize reported that he’s still working on the combination of the four wire and WWR standards. The proposed standard for the welded reinforcement grids is nearly complete and will be presented at the next ASTM meeting in November. All of the wire and WWR standards are up-to-date.

9 – New business. No new business to discuss.

10 – New meeting date & time. Mize plans to request the same meeting date and time for the next meeting.

11 – Adjournment. Hawkinson made motion to adjourn, second by Richardson. Meeting adjourned at 2:55 pm.

Document: “Report on Steel Reinforcement – Material Properties and U.S. Availability” (ACI 439.4R-XX)	**Review Date:** Spring 2008

No.	Pg #	Line #	G/E/P/S	TAC Comment	Committee Response
1.	0	0	P	Numerous citations are made to specific sections of ACI 318-05. (For example page 6, line 12). ACI 318-08 is now available. Committee should review for consistency with ACI 318-08, revise where needed, and update citations. According to the *ACI Style Manual*, when referencing technical documents of a standards producing organization, such as ACI or ASTM, in the text of a nonmandatory-language document, titles are omitted, and only serial designations appear (without a year designation). An exception to this rule is if a reference is made to a specific section, such as Section 3.5.1 of ACI 318-05 (For example page 5, line 2). Another exception is if a reference to a specific edition of a standard or report is made for historical or other purposes that are essential to the discussion being presented; these references may be cited with their year designations in “Cited references.”	
2.	2	2	S	Consider adding Welded Reinforcement Grids to this list.	
3.	5	6	P	The definition of reinforcement in 318 does not include prestressed steel. Therefore, delete sentence starting “According to this definition,…”	
4.	5	10	E	Consider: … steel reinforcement in terms of availability and material properties, expressed in …	
5.	5	17	E	“f_y” “A_w” “d_b” appear in several instances	
6.	5	19	E	through line 21. -- Definition submitted: **project drawings**—The drawings that, along with project specifications, complete the descriptive information for constructing the work required or referred to in the contract documents (ACI 301). CCT definition: Term does not appear in CCT. Discussion: Revise definition to match that from the ACI Specifications Manual shown below. **project drawings**—graphic presentation of project requirements. Recommendation: Delete the definition as it does not add material understanding of the document.	
7.	5	22	P	Add ”See ACI CCT, ‘Cement and Concrete Terminology’, for definitions at the ACI website.”	
8.	6	15	P	It is suggested to add a subsection called “Deformation dimensions” or “Deformation patterns and dimensions,” where the ASTM requirements for the deformation dimensions would be presented and actual available	

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No.	Pg #	Line #	G/E/P/S	TAC Comment	Committee Response
				deformation patterns would be listed. The deformation dimensions, along with mechanical properties and chemical composition, are the most important properties of the reinforcing bars, which determine their composite behavior with concrete. The ASTM requirements for mechanical properties and chemical composition are presented in the report, while the requirements for deformation dimensions are not.	
9.	6	16	E	Suggest revision to "The mechanical property ... reinforcing bars are summarized in Tables 3.1 through 3.3."	
10.	6	18	P	There is a sentence saying, "Reinforcing bars are a hot-rolled product." It is proposed to mention quenched and self-tempered (QST) reinforcing bars, which are sometimes referred to as the thermex-processed bars (see Gamble, W.L., 2003, "Thermex-Processed Reinforcing Bars," *Concrete International*, July 2003, pp. 85-88. Such reinforcing bars are produced by at least one steel mill in the USA (in Knoxville, Tennessee).	
11.	7	4	E	Change "measurement of yield strengths" to "determination of yield strengths"	
12.	7	9	P	Isn't the purpose of code-required minimum yield strength that the ultimate strength design approach can be reliably applied rather than strain compatibility be achieved?	
13.	7	12	S	Ductility is one of the material properties. That is why, it is suggested either to remove this subsection title or to add a subsection 3.2.1—Strength (or Yield Strength) before line 3 on this page and change "3.3—Ductility" to "3.2.2—Ductility."	
14.	7	13	E	Change "Tensile test-ductility requirements" to "Tensile-test ductility requirements"	
15.	7	16	E	What about for structures subjected to "blast loads"? Should these not be included? Modify to read: "…, even in the case of structures subjected to seismic, blast, or wind forces."	
16.	7	21	E	Flexural members include columns with significant bending. Should "flexural members" be changed to slabs and beams?	
17.	7	23	E	Similar to page 7, line 16; modify to read: "An example would be a structure subjected to seismic, blast, or wind forces where…"	
18.	8	4	E	through line 6. -- Similar to page 7, line 16; modify to read: "…, that may be subjected to seismic, blast, or wind forces."	
19.	8	12	P	Insert ASTM designation to read: "…devised; Charpy tests (ASTM5942, withdrawn 1998) on machined specimens do not reflect…"	
20.	8	13	E	through line 16 -- It is proposed to move the last two sentences under	

No.	Pg #	Line #	G/E/P/S	TAC Comment	Committee Response
				subsection 3.4 to the Material properties subsection, because they are referring to strengths and ductility, which were described in subsection 3.2.	
21.	8	15	P	A search of Corps technical publications database did not locate cited reference. Verify that reference still exists after 50 yr. Are there not more current references available?	
22.	8	22	E	The SI units are for information only and should be "hard" conversions. 60, 40, 30, and 20 ft should be 18, 12, 9, and 6 m as examples. Search throughout the document and adjust conversions.	
23.	9	1	E	Modify to read: "…making special arrangements with a supplier having this capability."	
24.	9	10	E	The bars are not soft. Rephrase as "….production of bars conforming to soft metric (sizes)." The word "sizes" is implied in other parts of this and other paragraphs. The phrase should be consistent.	
25.	9	20	E	The paragraph starts out with metrication and then shifts back to producing bars – does production information fit better two paragraphs up?	
26.	9	20	E	Is it necessary to repeat this information from p 8, lines 22 and 23?	
27.	10	1	E	The "Mg" units look unusual. It would be better to write "1,400 kg" instead of "1.4 Mg".	
28.	10	3	E	There is a sentence that says "Coils of reinforcing bars in smaller sizes (No. 3 through No. 5…," while the previously mentioned reinforcing bars were No. 3 and No. 4 (see line 23 on page 9). It is proposed to change "Coils of reinforcing bars in smaller sizes (No. 3 through No. 5…" to "Coils of reinforcing bars in sizes No. 3 through No. 5…"	
29.	11	11	E	This section should also include the State of South Carolina's adoption of A706 for all DOT work, approximately 1999 or 2000.	
30.	12	15	P	After 'recommended' add 'because the welds can cause notch failures and may embrittle the steel', or some words that explain why not tack weld.	
31.	13	3	E	Replace "under" with "in accordance with"	
32.	14	4	E	The need to perform "MORE THAN ONE" tensile test as required by ASTM A615 or A706 will require that the producing mill be made cognitive of the requirement.	
33.	14	5	E	and line 8. -- The "Mg" units look unusual. It would be better to write "45 t" and "230 t" instead of "45 Mg" and "230 Mg", respectively.	
34.	15	4	E	Committee should consider placing this and similar definitions in Chap 2	
35.	16	13	P	Something is wrong here – Proper use of ASTM A767 … requires the	

Document: “Report on Steel Reinforcement – Material Properties and U.S. Availability” (ACI 439.4R-XX)	**Review Date:** Spring 2008

No.	Pg #	Line #	G/E/P/S	TAC Comment	Committee Response
				inclusion… How about stating the ASTM standards provide nonmandatory information regarding field handling? Field requirements are provided by ACI 301 or a project specification.	
36.	16	20	E	This sentence starting out “It is unclear …” is awkward. Perhaps “Zinc-coated bars are available in limited areas” would be better.	
37.	17	3	P	Delete sentence questioning stainless yield point + ‘As a result,…..’ or cite references substantiating the statement.	
38.	17	18	E	“…sewer pipes…” instead of “…sewer pipe…”	
39.	17	18	E	Limited to “sewer” pipe, or is it used other types of pipe?	
40.	18	15	S	Replace “weight” with “mass”	
41.	19	1	E	through line 4. -- There is same paragraph in lines 6-10 on page 22. Perhaps, one of them needs to be deleted.	
42.	19	19	E	Replace “usually” with “typically”	
43.	20	1	E	3 weasel words in one sentence; “commonly” “normally” and “some” Try to be more specific	
44.	21	17	E	Here the metric equivalent of 16 inches is given as 400 mm, whereas on page 25, line 18, it is given as 410 mm. It should be consistent. Use 400 mm for 16 inches.	
45.	21	17	S	I think this line sets up the expectation of a comment on the limits for shear reinforcing as well; i.e. what are the limits?	
46.	24	2	S	through line 6. -- The text under the “Minimum quantity requirements” subsection does not present the minimum requirements. Considering that the minimum quantity requirements are presented under the “5.8—Nonstock styles” subsection, should not “5.7—Stock styles” and “5.8—Nonstock styles” read “5.6.1—Stock styles” and “5.6.2—Nonstock styles,” respectively?	
47.	24	6	E	“fact sheet” on “product information” is redundant. Delete “information”	
48.	25	2	E	and lines 4 & 6. -- The “Mg” units look unusual. It would be better to write “9 to 18 t,” “2 to 5 t,” and “18 t” instead of “9.1 to 18.1 Mg,” “1.8 to 4.54 Mg,” and “18.1 Mg,” respectively.	
49.	25	12	E	Delete “in”	
50.	28	9	E	“is” should be “are”	
51.	28	14	S	External tendons should also be mentioned since a grouted external tendon is considered unbonded, not bonded; as written it implies that all grouted tendons are bonded (the strand is bonded to the grout, but not considered fully bonded along the length of the member)	
52.	28	22	P	Suggest that materials discussed in this section be defined in Chap 2	

No.	**Pg #**	**Line #**	**G/E/P/S**	**TAC Comment**	**Committee Response**
53.	31	1	E	and line 11. -- The committee should verify the references to the 423 documents carefully: the referenced 423.6 is now the new 423.7; the reference to 423.3 may be more appropriate as 423.7 based on the text following that reference (pg. 31, line 1)	
54.	33	13	E	through line 16. -- The committee may wish to use a published reference instead – there is an ACI Structural Journal paper on this topic from 1996 (Gregor P. Wollmann, David L. Yates, JOHN E. Breen, and Michael E. Kreger). I believe the findings were the same as referenced, but this should be verified.	
55.	33	13	E	The statement "as documented in unpublished tests" seems like an amusing contradiction. Reword.	
56.	33	16	P	Is there a reference for wedge anchors that result in a seven wire failure?	
57.	34	1	P	Are there some general material properties of stainless steel PT cable? Is it generally available?	
58.	34	23	E	Please identify the ASTM spec or reference section 7.3.	
59.	35	16	E	Verify that this specification has been adopted by ASTM prior to publication of this document otherwise revise to indicate that the specification is still being developed	
60.	36	3	E	Metric equivalent should appear in parentheses immediately following in-lb values. Revise to "… 100,000 psi (690 MPa) designated Grade 100 [690]."	
61.	36	4	E	Revise to "…120,000 psi (830 MPa) designated Grade 120 [830] were ..."	
62.	36	6	P	Delete this sentence questioning yield point or cite references substantiating the statement.	
63.	36	7	E	Revise to "…100,000 and 120,000 psi (690 and 830 MPa) designated Grade 100 [690] and Grade 120 [830], respectively, be determined ..."	
64.	36	10	E	"Grade 100 [690]"	
65.	36	11	E	"Grade 100 [830]"	
66.	36	13	P	Provide a reference or more information about development length, as well as serviceability issues.	
67.	37	12	E	Either update to reflect an adopted ASTM specification or delete.	
68.	43	6	S	Presenting information on actual mechanical properties, chemical composition and deformation dimensions of the reinforcement used in the US could improve the document. If that is not possible due to the space limitation, the references to the papers presenting the actual properties need to be provided. In the reviewer's opinion, at least the following references should be included in the report:	

Document: “Report on Steel Reinforcement – Material Properties and U.S. Availability” (ACI 439.4R-XX)	**Review Date:** Spring 2008

No.	Pg #	Line #	G/E/P/S	TAC Comment	Committee Response
				1. Mirza, S.A., MacGregor, G., “Variability of Mechanical Properties of Reinforcing Bars,” *Proceedings ASCE*, *Journal of the Structural Division*, Vol. 105, No. ST5, May 1979, pp. 921-937. 2. Helgason, T., Hanson, J.M., “Investigation of Design Factors Affecting Fatigue Strength of Reinforcing Bars—Statistical Analysis,” *Abels Symposium on Fatigue of Concrete*, ACI Publication SP-41, American Concrete Institute, Detroit, 1974, pp. 107-137. 3. Kudder, R.J., Gustafson, D.P., “Bend Tests of Grade 60 Reinforcing Bars,” *ACI Journal Proceedings*, Vol. 80, No. 3, May 1983, pp. 202-209. 4. Malvar, L.J., “Review of Static and Dynamic Properties of Steel Reinforcing Bars,” *ACI Materials Journal*, Vol. 95, No.5, September 1998, pp. 609-616.	

ACI 439.ZR-XX

Comprehensive Guide for the Specification, Manufacture and Construction Use of Welded Wire Reinforcement

Reported by ACI Committee 439

Mark D. Marvin, Chair William C. Gallenz, Secretary

Joseph A. Bohinsky Jean-Jacques Braun James L. Caldwell
Domingo J. Carreira Louis J. Colarusso Christian L. Dahl
David H. DeValve Alvin C. Ericson Salem S. Faza
Anthony L. Felder Paul S. Fredrickson Todd R. Hawkinson
Steven E. Holdsworth Allen J. Hulshizer James M. LaFave
Harry B. Lancelot, III Kenneth A. Luttrell LeRoy A. Lutz
Adolfo B. Matamoros Peter Meza Theodore A. Mize
Conrad Paulson Ryan Pelter Richard A. Ramsey
Roy H. Reiterman Robert C. Richardson Mario E. Rodriguez
Philip E. Ross Clifford A. Sabo Robert G. Smith
Dyke W. Starnes Cloyd E. Warnes Ken W. Williamson
William H. Zehrt, Jr.

Welded Wire Reinforcement (WWR) is a prefabricated reinforcement consisting of parallel series of high-strength, cold drawn or cold rolled steel wires welded together in square or rectangular grids. Each wire intersection is electrically resistance welded by a continuous automatic welder. Pressure and heat fuse the intersecting wires into a homogeneous section and fix all wires in their proper position. Plain wires, deformed wires or a combination of both may be used in WWR.

Welded plain wire reinforcement bonds to concrete by the positive mechanical anchorage at each welded wire intersection. Welded deformed wire reinforcement utilizes deformations plus welded intersections for bond and anchorage.

Concrete structures have been successfully and economically reinforced with high strength, uniformly distributed steel wires in WWR. The smaller diameter, closely spaced wires of WWR provide more uniform stress distribution and more effective crack control in footings, slabs, walls and roofs as well as providing for shear and confinement in columns, beams and girders. The wide range of wire sizes and spacing available makes it possible to furnish the exact cross-sectional steel area required. The welded cross wires hold the reinforcement in the proper position, uniformly spaced. The ease and speed with which WWR can be handled and installed considerably reduces placing time, resulting in reduced overall cost. Reduced construction time is of particular benefit to the owner by affording earlier occupancy and reducing total project cost. Material savings can be realized by specifying WWR with higher yield strengths as recognized by ACI 318 and ASTM.

Welded Wire Reinforcement is one of the recognized and established forms of concrete reinforcement. United States Patents covering its production were issued in 1901. The newly found industry moved rapidly forward. The Wire Reinforcement Institute has an archived hard-covered book on WWR that

was published in 1908 by the American Steel and Wire Company. Considering the date and the state of the art of reinforced concrete, the American Steel and Wire Company Manual was a sophisticated and advanced text on reinforced concrete.

Some of the most prestigious early buildings built in North America have made extensive use of WWR. Examples include the Empire State Building, New York City; the Marina City Towers, Chicago; the World Trade Center Towers, New York City and the Standard Oil Building in Chicago to name a few.

This manual will provide WWR product information, material specification, design and detailing requirements as well as an outline for manufacturing, shipping and construction use in various applications of concrete construction.

Keywords:

CONTENTS

Chapter 1 - WWR NOMENCLATURE

1.1 “W” and “D” Designations

Individual wire (plain and deformed) size designations are based on the cross-sectional area of a given wire. Gage numbers were used exclusively for many years but were eliminated in the 1970’s to reduce the confusion caused from the misunderstanding of how to read and understand the specified gage size. The prefixes “W” and “D” are used in combination with a number. The letter “W” designates a plain wire and the letter “D” denotes a deformed wire. The number following the letter gives the cross-sectional area in hundredths of a square inch. For instance, wire designation W4 would indicate a plain wire with a cross-sectional area of 0.04 in^2; a D10 wire would indicate a deformed wire with a cross-sectional area of 0.10 in^2. The size of wires in WWR is designated in the same manner. This system provides many advantages. Since the engineer knows the cross-sectional area of a wire and the spacing, the total cross-sectional area per foot of width can easily be determined. For instance, a D6 wire on 4” centers would provide 3 wires per foot with a total cross-sectional area of 0.18 in^2/ft of width.

When describing metric wire the prefix “M” is added. “MW” describes metric plain wire and “MD” metric deformed wire. The wire spacing in metric WWR is given in millimeters (mm) and the cross-sectional area of the wire is in square millimeters (mm^2).

Many companies developed common wire sizes in order to reduce peak season lead times and aid in overall plant efficiency while not compromising customer satisfaction. The common wire sizes were developed after an in-depth study of the most common conversion or design sizes. The wire sizes to be used along with the nominal diameter, area and weight/foot are shown in Table **1a** (plain wire) and 1b (deformed wire).

Size Number	**Nominal Diameter in. (mm)**	**Nominal Area in.2(mm2)**
W 0.5	**0.080 (2.03)**	**0.005 (3.23)**
W 1.2	**0.124 (3.14)**	**0.012 (7.74)**
W 1.4	**0.134 (3.39)**	**0.014 (9.03)**
W 2	**0.160 (4.05)**	**0.020 (12.9)**
W 2.5	**0.178 (4.53)**	**0.025 (16.1)**
W 2.9	**0.192 (4.88)**	**0.029 (18.7)**
W 3.5	**0.211 (5.36)**	**0.035 (22.6)**
W 4	**0.226 (5.73)**	**0.040 (25.8)**
W 4.5	**0.239 (6.08)**	**0.045 (29.0)**
W 5	**0.252 (6.41)**	**0.050 (32.3)**
W 5.5	**0.265 (6.72)**	**0.055 (35.5)**
W 6	**0.276 (7.02)**	**0.060 (38.7)**
W 8	**0.319 (8.11)**	**0.080 (51.6)**
W 10	**0.357 (9.06)**	**0.100 (64.5)**
W 11	**0.374 (9.50)**	**0.110 (71.0)**
W 12	**0.391 (9.93)**	**0.120 (77.4)**
W 14	**0.422 (10.7)**	**0.140 (90.3)**
W 16	**0.451 (11.5)**	**0.160 (103)**
W 18	**0.479 (12.2)**	**0.180 (116)**
W 20	**0.505 (12.8)**	**0.200 (129)**
W 22	**0.529 (13.4)**	**0.220 (142)**
W 24	**0.533 (14.0)**	**0.240 (155)**
W 26	**0.575 (14.6)**	**0.260 (168)**
W 28	**0.597 (15.2)**	**0.280 (181)**
W 30	**0.618 (15.7)**	**0.300 (194)**
W 31	**0.628 (16.0)**	**0.310 (200.0)**
W 45	**0.757 (19.2)**	**0.450 (290)**

Table 1a (Plain Wire)

This table represents the most readily available sizes in the Welded Wire Reinforcement industry in sizes using inch-pound units. Areas of wire should be checked with the most efficient and readily available material from producers. Other wire sizes are available and many manufacturers can produce them in 0.0015-in.^{2} increments.

Nominal Dimensions				Deformation Requirements			
Wire Size (a)	Unit Weight Lb/ft(kg/m)	Diameter in.(mm) (b)	Cross-sectional Area, in^2(mm2) (c)	Perimeter in.(mm)	Max. in.(mm)	Min. in.(mm)	Min. Avg. Height of Deformations, in.(mm) (e), (f)
D-1	0.034 (0.051)	0.113 (2.87)	0.010 (6.45)	0.354 (9.00)	0.285 (7.24)	0.182 (4.62)	0.0045 (0.114)
D-2	0.068 (0.101)	0.160 (4.05)	0.020 (12.9)	0.501 (12.7)	0.285 (7.24)	0.182 (4.62)	0.0063 (0.160)
D-3	0.102 (0.152)	0.195 (4.96)	0.030 (19.4)	0.614 (15.6)	0.285 (7.24)	0.182 (4.62)	0.0078 (0.198)
D-4	0.136 (0.202)	0.226 (5.73)	0.040 (25.8)	0.709 (18.0)	0.285 (7.24)	0.182 (4.62)	0.0101 (0.257)
D-5	0.170 (0.253)	0.252 (6.41)	0.050 (32.3)	0.793 (20.1)	0.285 (7.24)	0.182 (4.62)	0.0113 (0.287)
D-6	0.204 (0.304)	0.276 (7.02)	0.060 (38.7)	0.868 (22.1)	0.285 (7.24)	0.182 (4.62)	0.0124 (0.315)
D-7	0.238 (0.354)	0.299 (7.58)	0.070 (45.2)	0.938 (23.8)	0.285 (7.24)	0.182 (4.62)	0.0134 (0.304)
D-8	0.272 (0.405)	0.319 (8.11)	0.080 (51.6)	1.00 (25.5)	0.285 (7.24)	0.182 (4.62)	0.0143 (0.363)
D-9	0.306 (0.455)	0.339 (8.60)	0.090 (58.1)	1.06 (27.0)	0.285 (7.24)	0.182 (4.62)	0.0152 (0.386)
D-10	0.340 (0.506)	0.357 (9.06)	0.100 (64.5)	1.12 (28.5)	0.285 (7.24)	0.182 (4.62)	0.0160 (0.406)
D-11	0.374 (0.557)	0.374 (9.51)	0.110 (71.0)	1.18 (29.9)	0.285 (7.24)	0.182 (4.62)	0.0187 (0.475)
D-12	0.408 (0.607)	0.391 (9.93)	0.120 (77.4)	1.23 (31.2)	0.285 (7.24)	0.182 (4.62)	0.0195 (0.495)
D-13	0.442 (0.658)	0.407 (10.3)	0.130 (83.9)	1.28 (32.5)	0.285 (7.24)	0.182 (4.62)	0.0203 (0.516)
D-14	0.476 (0.708)	0.422 (10.7)	0.140 (90.3)	1.33 (33.7)	0.285 (7.24)	0.182 (4.62)	0.0211 (0.536)
D-15	0.510 (0.759)	0.437 (11.1)	0.150 (96.8)	1.37 (34.9)	0.285 (7.24)	0.182 (4.62)	0.0218 (0.554)
D-16	0.544 (0.810)	0.451 (11.5)	0.160 (103)	1.42 (36.0)	0.285 (7.24)	0.182 (4.62)	0.0225(0.572)
D-17	0.578 (0.860)	0.465 (11.8)	0.170 (110)	1.46 (37.1)	0.285 (7.24)	0.182 (4.62)	0.0232 (0.589)
D-18	0.612 (0.911)	0.479 (12.2)	0.180 (116)	1.50 (38.2)	0.285 (7.24)	0.182 (4.62)	0.0239 (0.607)
D-19	0.646 (0.961)	0.492 (12.5)	0.190 (122)	1.55 (39.2)	0.285 (7.24)	0.182 (4.62)	0.0245 (0.622)
D-20	0.680 (1.01)	0.505 (12.8)	0.200 (129)	1.59 (40.3)	0.285 (7.24)	0.182 (4.62)	0.0252 (0.604)
D-21	0.714 (1.06)	0.517 (13.1)	0.210 (135)	1.62 (41.3)	0.285 (7.24)	0.182 (4.62)	0.0259 (0.658)
D-22	0.748 (1.11)	0.529 (13.4)	0.220 (141)	1.66 (42.2)	0.285 (7.24)	0.182 (4.62)	0.0265 (0.673)
D-23	0.782 (1.16)	0.541 (13.7)	0.230 (148)	1.70 (43.2)	0.285 (7.24)	0.182 (4.62)	0.0271 (0.688)
D-24	0.816 (1.21)	0.553 (14.0)	0.240 (154)	1.74 (44.1)	0.285 (7.24)	0.182 (4.62)	0.0277 (0.704)
D-25	0.850 (1.26)	0.564 (14.3)	0.250 (161)	1.77 (45.0)	0.285 (7.24)	0.182 (4.62)	0.0282 (0.716)
D-26	0.884 (1.32)	0.575 (14.6)	0.260 (167)	1.81 (45.9)	0.285 (7.24)	0.182 (4.62)	0.0288 (0.732)
D-27	0.918 (1.37)	0.586 (14.9)	0.270 (174)	1.84 (46.8)	0.285 (7.24)	0.182 (4.62)	0.0293 (0.744)
D-28	0.952 (1.42)	0.597 (15.2)	0.280 (180)	1.88 (47.6)	0.285 (7.24)	0.182 (4.62)	0.0299 (0.759)
D-29	0.986 (1.47)	0.608 (15.4)	0.290 (187)	1.91 (48.5)	0.285 (7.24)	0.182 (4.62)	0.0304 (0.772)
D-30	1.02 (1.52)	0.618 (15.7)	0.300 (193)	1.94 (49.3)	0.285 (7.24)	0.182 (4.62)	0.0309 (0.785)
D-31	1.05 (1.57)	0.628 (16.0)	0.310 (200)	1.97 (50.1)	0.285 (7.24)	0.182 (4.62)	0.0314 (0.798)
D-45	1.53 (2.28)	0.757 (19.2)	0.450 (290)	2.38 (60.4)	0.285 (7.24)	0.182 (4.62)	0.0379 (0.961)

Table 1b (Deformed Wire)

a. For sizes other than those shown above, the Size Number shall be the number of one hundredths of a square inch in the nominal area of the deformed wire cross-section, prefixed by the letter D

b. 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

c. The cross-sectional area is based on the nominal diameter. The area in square inches may be calculated by dividing the unit weight in pounds by 0.2833 (weight of 1 in.3 of steel), or by dividing the unit weight per lineal foot of specimen in pounds by 3.4 (weight of steel 1 in. square and 1 foot long)

d. The minimum average height of the deformations shall be determined from measurements made on not less than two typical deformations from each line of deformations on the wire. Measurements shall be made at the center of indentation as described in 6.2.

e. These sizes represent the most readily available sizes in the Welded Wire Reinforcement industry. Other wire sizes are available and many manufacturers can produce them in 0.0015 in2 (1 mm2) increments.

1.2 Product Description

Spacing and size of wire in WWR are identified by “style”. The following subsections explain the orientation and definition of each part in the make-up of a WWR sheet. When the WWR sheet is designated for quotation or order entry it should be described as follows:

6 x 12 - D20.0 x D15.0 (Grade 80)
78”(+12, +6) x 20’-0”(24, 12)
263.53 Lbs./Sheet
150 Sheets Required

Where: 6 = spacing of longitudinal wires.
12 = spacing of transverse wires.
D20.0 = size and type (deformed or plain) of longitudinal wires.
D15.0 = size and type (deformed or plain) of transverse wires.
(Grade 80) = yield strength of specified wire sizes (ksi).
78”(+12, +6) x 20’-0”(24,12) = see sections 1.2.1 through 1.2.3.
263.53 Lbs./Sheet = see section 1.2.4.
150 Sheets Required = see section 1.2.5.

For sheets with variable wire spacing or variable length, the sheet should be described as follows:

Var. x Var. - D20.0 x D15.0 (Grade 80)
78”(+12, +6) x Var. Length (24, 12)
L.S. = 12” OH, 1 @ 8”, 7 @ 10”, 6” OH
T.S. = 24” OH, 2 @ 6”, 15 @ 12”, 2@ 6”, 12” OH
Var. Length = Alternate every other wire 20’-0”, 15’-0”, 20’-0” etc.
190.17 Lbs./Sheet
215 Sheets Required

Where: Var. = variable spacing of longitudinal wires.
Var. = variable spacing of transverse wires.
D20.0 = size and type (deformed or plain) of longitudinal wires.
D15.0 = size and type (deformed or plain) of transverse wires.
(Grade 80) = yield strength of specified wire sizes (ksi).
78”(+12, +6) x Var. Length (24, 12) = see sections 1.2.1 through 1.2.3.
L.S. = description of variable longitudinal spacing.
T.S. = description of variable transverse spacing.
Var. Length = description of variable length. See section 1.2.2.
190.17 Lbs./Sheet = see section 1.2.4.
215 Sheets Required = see section 1.2.5.

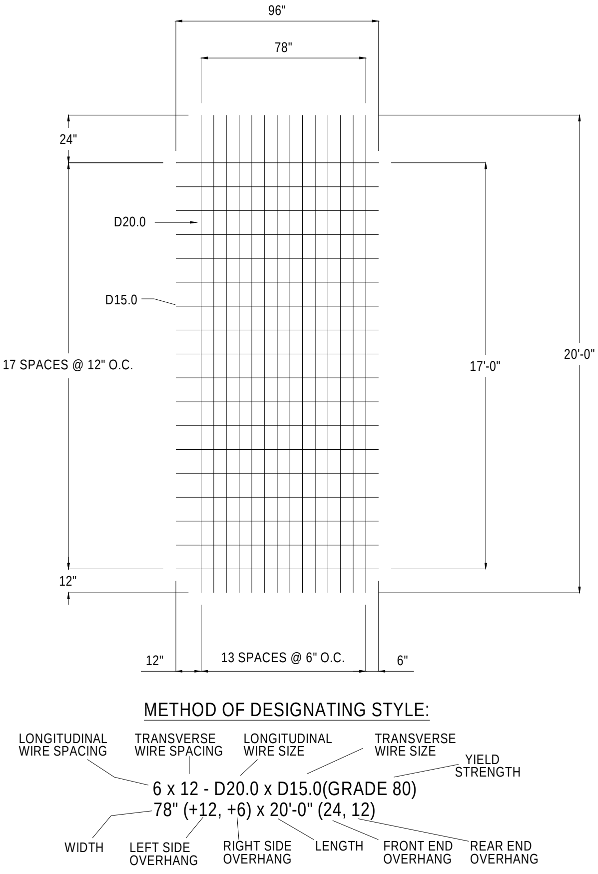

FIGURE 1: NOMENCLATURE

1.2.1 Width

Width is defined as the center-to-center distance between outside longitudinal wires. This dimension does not include overhangs as demonstrated in section 1.2.3. Overall width is the width plus the side overhangs or the tip-to-tip dimension of the transverse wires. The width should always be specified in inches as the first number on the second line of the sheet style designation. Figure 2 demonstrates graphically the definition of width and overall width.

1.2.2 Length

Length is defined as the tip-to-tip dimension of the longitudinal wires. The length dimension is inclusive of the end overhangs when being defined in the sheet style designation. The length should always be specified as the fourth entry on the second line of the sheet style designation. Figure 2 demonstrates graphically the definition of length.

1.2.3 Overhangs

There are two types of overhangs in defining a sheet style. The side overhang, which is added to the width to create the overall sheet width and the end overhang, which is included in the defined sheet length. The side overhang is defined as the extension of transverse wires beyond centerline of outside longitudinal wires. Side overhangs should be specified and defined in inches as the second and third entry on the second line of the sheet style designation. The second entry on the second line refers to the left side overhang as the sheet is oriented in the welding machine. The third entry on the second line refers to the right side overhang as the sheet is oriented in the welding machine.

The end overhang is defined as the extension of longitudinal wires beyond centerline of outside transverse wires. The end overhang is always included in the overall length shown as the fourth entry on the second line of the sheet style designation. The end overhangs are shown in inches as the fifth and sixth entries on the second line of the sheet style designation. The fifth entry refers to the front of the sheet as it will go into the machine for welding. The sixth entry refers to the rear of the sheet as it will go into the machine for welding. Figure 2 demonstrates graphically the definition of side and end overhang.

1.2.4 Weight

Weight is calculated by computing the weights of longitudinal and transverse wires separately and adding the two results for a total. The weight should always be entered after the width and length listing on line three of the sheet style designation. If variable spacing or length is used, the weight should be listed on the next line after the spacing and/or length reference. The calculation that was used to determine weight need not be shown on the sheet style designation. The written version of calculating weight is as follows:

Calculated actual weight = longitudinal weight + transverse weight
Longitudinal weight = $Wt_l \times N_l \times L$ (round to two decimal places)
Transverse weight = $Wt_t \times N_t \times OW$ (round to two decimal places)

Where: Wt_l = unit weight of one longitudinal wire (lbs./ft)
Wt_t = unit weight transverse wire (lbs./ft)
N_l = number of longitudinal wires
N_t = number of transverse wires
L = length of sheet (ft.)
OW = overall width (ft.)

1.2.5 Sheet Quantities

Sheet quantity is calculated by determining the total units required on a project and calculating the number of sheets per unit. For precast elements, sheet quantity per unit is multiplied by the total number of units for total sheet quantity. This quantity should always be listed on the line after the weight listing in the sheet style designation. For cast-in-place concrete, the total mass quantity (i.e.: square feet, linear feet) is divided by the total working dimension of the designed sheet. The working dimension of the WWR sheet is the total sheet square footage minus the end lap and the side lap in the same measurable units. This quantity would determine what is known as “lap waste”. This quantity should always be listed on the line after the weight listing in the sheet style designation.

Chapter 2 - CODES AND STANDARDS

Introduction - There are four main code and/or specification bodies that govern the manufacture, testing and design of concrete applications as they pertain to reinforcement. The four main bodies that govern design and manufacturing are outlined below including the appropriate specification numbers and a description for interpretation purposes.

2.1 AASHTO

AASHTO (American Association of State Highway and Transportation Officials) specifications are the governing body for all transportation-related design and construction. This means that any public road project such as bridge decks, bridge beams, roadway or airport paving or state funded box culvert work would fall under the appropriate AASHTO specification. As is usually the case, many AASHTO sections refer to or mirror the ASTM specifications for manufacture and testing. The specifications governing Welded Wire Reinforcement and the description of their meaning are as follows:

M31 - Deformed and plain Billet-Steel Bars for Concrete Reinforcement
M32 - Cold-Drawn Steel Wire for Concrete Reinforcement
M55 - Welded Steel Wire Fabric for Concrete Reinforcement
M42 - Deformed and Plain Rail – Steel Bars for Concrete Reinforcement
M221 - Welded Deformed Steel Wire Fabric For Concrete Reinforcement
M225 - Deformed Steel Wire for Concrete Reinforcement

2.2 ACI

The ACI (American Concrete Institute) Building Code Requirements for Structural Concrete is the governing code, specification and design guide for all structural concrete design in the United States of America. This code provides guidelines for testing and design as well as construction and placement. Although an engineer should be well versed in every aspect of the 318 code, the following sections are the most critical as they apply to concrete design using Welded Wire Reinforcement.

PROVISION	**ACI SECTION**
A. Definitions	
1. Deformed reinforcement — Deformed reinforcing bars, bar mats, deformed wire, and welded wire reinforcement conforming to 3.5.3.	**2.2**
B. Standards for Tests and Materials	
1. Bar mats for concrete reinforcement shall conform to "Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement" (ASTM A 184). Reinforcing bars used in bar mats shall conform to ASTM A 615 or A 706.	**3.5.3.3**
2. Deformed wire for concrete reinforcement shall conform to "Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement" (ASTM A 496), except that wire shall not be smaller than size D4 and for wire with f_y exceeding 60,000 psi, the yield strength shall be taken as the stress corresponding to a strain of 0.35 percent.	**3.5.3.4**
3. Welded plain wire reinforcement shall conform to "Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete" (ASTM A 185), except that for wire with f_y exceeding 60,000 psi, the yield strength shall be taken as the stress corresponding to a strain of 0.35 percent. Welded intersections shall not be spaced farther apart than 12 in. in direction of calculated stress, except for welded wire reinforcement used as stirrups in accordance with 12.13.2.	**3.5.3.5**
4. Welded deformed wire reinforcement shall conform to "Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete" (ASTM A 497), except that for wire with f_y exceeding 60,000 psi, the yield strength shall be taken as the stress corresponding to a strain of 0.35 percent. Welded intersections shall not be spaced farther apart than 16 in. in direction of calculated stress, except for welded deformed wire reinforcement used as stirrups in accordance with 12.13.2.	**3.5.3.6**
5. Epoxy-coated wires and welded wire reinforcement shall comply with "Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement" (ASTM A 884). Wires to be epoxy coated shall conform to 3.5.3.4 and welded wire reinforcement to be epoxy-coated shall conform to 3.5.3.5 or 3.5.3.6.	**3.5.3.8**

PROVISION	ACI SECTION
C. Details of Reinforcement	
1. The term standard hook as used in this code shall mean one of the following:	**7.1**
2. 180-deg bend plus $4d_b$ extension, but not less than 2-1/2 in. at free end of bar.	**7.1.1**
3. 90-deg bend plus $12d_b$ extension at free end of bar.	**7.1.2**
4. Inside diameter of bend in welded wire reinforcement 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.	**7.2.3**
5. All reinforcement shall be bent cold, unless otherwise permitted by the engineer.	**7.3.1**
6. Reinforcement partially embedded in concrete shall not be field bent, except as shown on the design drawings or permitted by the engineer.	**7.3.2**
7. Welded wire reinforcement (with wire size not greater than W5 or D5) used in slabs not exceeding 10 ft in span shall be permitted to 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.	**7.5.3**
8. Welding of crossing bars shall not be permitted for assembly of reinforcement unless authorized by the engineer.	**7.5.4 plus commentary**
9. It shall be permitted to waive the lateral reinforcement requirements of 7.10, 10.16, and 18.11 where tests and structural analysis show adequate strength and feasibility of construction.	**7.10.3 plus commentary**
10. Spiral reinforcement for compression members shall conform to 10.9.3 and to the following:	**7.10.4 plus commentary**
11. Spirals shall consist of evenly spaced continuous bar or wire of such size and so assembled to permit handling and placing without distortion from designed dimensions.	**7.10.4.1**

PROVISION	ACI SECTION
C. Details of Reinforcement (cont.)	
1. Spiral reinforcement shall be spliced, if needed, by any one of the following methods: (a) Lap splices not less than the larger of 12 in. and the length indicated in one of (1) through (5) below: (1) deformed uncoated bar or wire.......... **48d_b** (2) plain uncoated bar or wire .... **72d_b** (3) epoxy-coated deformed bar or wire ... **72d_b** (4) plain uncoated bar or wire with a standard stirrup or tie hook in accordance with 7.1.3 at ends of lapped spiral reinforcement. The hooks shall be embedded within the core confined by the spiral reinforcement .... **48d_b** (5)epoxy-coated deformed bar or wire with a standard stirrup or tie hook in accordance wit h 7.1.3 at ends of lapped spiral reinforcement. The hooks shall be embedded within the core confined by the spiral reinforcement.................................... **48d_b**	**7.10.4.5**
2. Compression reinforcement in beams shall be enclosed by ties or stirrups satisfying the size and spacing limitations in 7.10.5 or by welded wire reinforcement of equivalent area. Such ties or stirrups shall be provided throughout the distance where compression reinforcement is required.	**7.11.1**
3. 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.	**7.12.1**
4. Shrinkage and temperature reinforcement shall be provided in accordance with either 7.12.2 or 7.12.3.	**7.12.1.1**
5. Where shrinkage and temperature movements are significantly restrained, the requirements of 8.2.4 and 9.2.3 shall be considered.	**7.12.1.2**
6. Deformed reinforcement conforming to 3.5.3 used for shrinkage and temperature reinforcement shall be provided in accordance with the following:	**7.12.2**

C. Details of Reinforcement (cont.)	
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 reinforcement 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 x 60,000/ f_y	**7.12.2.1**
2. Shrinkage and temperature reinforcement shall be spaced not farther apart than five times the slab thickness, nor farther apart than 18 in.	**7.12.2.2**
3. At all sections where required, reinforcement to resist shrinkage and temperature stresses shall develop f_y in tension in accordance with Chapter 12.	**7.12.2.3**
D. Strength and Serviceability Requirements	
1. The values of f_y and f_{yt} used in design calculations shall not exceed 80,000 psi, except for prestressing steel and for spiral transverse reinforcement in 10.9.3.	**9.4 plus commentary**
E. Flexure and Axial Loads	
1. Design assumptions……………………………………………	**10.2 plus commentary**
2. General principles and requirements……………………….	**10.3 plus commentary**
3. Minimum reinforcement of flexural members……………..	**10.5 plus commentary**
4. Distribution of flexural reinforcement in beams and one-way slabs……………………………………………………………	**10.6 plus commentary**
F. Shear and Torsion	
1. The values of f_y and f_{yt} used in design of shear reinforcement shall not exceed 60,000 psi, except the value shall not exceed 80,000 psi for welded deformed wire reinforcement.	**11.5.2 plus commentary**

PROVISION	ACI SECTION
~~F.~~G. **Development and Splices of Reinforcement**	
1. Development length for deformed bars and deformed wire in tension, l_d shall be determined from either 12.2.2 or 12.2.3, but shall not be less than 12 in.	**12.2.1 plus commentary**
2. For deformed bars or deformed wire, l_d shall be: see table	**12.2.2**
3. For deformed bars or deformed wire, l_d shall be: $l_d = (3/40 \times f_y/\sqrt{f'_c} \times \psi_t \psi_e \psi_s \lambda / c_b + K_{tr}/d_b)\ d_b$ (12-1) in which the term $(c_b + K_{tr})/d_b$ shall not be taken greater than 2.5, and $K_{tr} = A_{tr} f_{yt}/1500 s n$ (12-2) where n is the number of bars or wires being spliced or developed along the plane of splitting. It shall be permitted to use $K_{tr} = 0$ as a design simplification even if transverse reinforcement is present.	**12.2.3 plus commentary**
4. The factors used in the expressions for development of deformed bars and deformed wires in tension in 12.2 are as follows: (a) Where horizontal reinforcement is placed such that more than 12 in. of fresh concrete is cast below the development length or splice, $\psi_t = 1.3$. For other situations, $\psi_t = 1.0$. (b) For epoxy-coated bars or wires with cover less than $3d_b$, or clear spacing less than $6d_b$, $\psi_e = 1.5$. For all other epoxy-coated bars or wires, $\psi_e = 1.2$. For uncoated reinforcement, $\psi_e = 1.0$. However, the product $\psi_t \psi_e$ need not be greater than 1.7. (c) For No. 6 and smaller bars and deformed wires, $\psi_s = 0.8$. For No. 7 and larger bars, $\psi_s = 1.0$. (d) Where lightweight concrete is used, $\lambda = 1.3$. However, when f_{ct} is specified, λ shall be permitted to be taken as $6.7/\sqrt{f'_c}\ /f_{ct}$ but not less than 1.0. Where normal weight concrete is used, $\lambda = 1.0$	**12.2.4 plus commentary**

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PROVISION	ACI SECTION
G. Development and Splices of Reinforcement (cont.)	
1. Development length in tension for welded deformed wire reinforcement, l_d, measured from the point of critical section to the end of wire shall be computed as the product of l_d, from 12.2.2 or 12.2.3, times a welded wire reinforcement factor from 12.7.2 or 12.7.3. It shall be permitted to reduce l_d 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 welded wire reinforcement factor from 12.7.2, it shall be permitted to use an epoxy coating factor ψ_e of 1.0 for epoxy-coated welded wire reinforcement in 12.2.2 and 12.2.3.	**12.7.1 plus commentary**
2. For welded deformed wire reinforcement with at least one cross wire within l_d and not less than 2 in. from the point of the critical section, the welded wire reinforcement factor shall be the greater of: $f_y - 35{,}000/f_y$ and $5d_b/s$ but not greater than 1.0, where s is the spacing between the wires to be developed.	**12.7.2 plus commentary**
3. For welded deformed wire reinforcement with no cross wires within l_d or with a single cross wire less than 2 in. from the point of the critical section, the welded wire reinforcement factor shall be taken as 1.0, and l_d shall be determined as for deformed wire.	**12.7.3 plus commentary**
4. When any plain wires are present in the welded deformed wire reinforcement in the direction of the development length, the reinforcement shall be developed in accordance with 12.8.	**12.7.4 plus commentary**
5. Yield strength of welded plain wire reinforcement 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, l_d shall not be less than $l_d = 0.27 \times A_b/s(f_y/\sqrt{f_c'})\,\lambda$ (12-3) where l_d is measured from the point of the critical section to the outermost crosswire, and s is the spacing between the wires to be developed. Where reinforcement provided is in excess of that required, l_d may be reduced in accordance with 12.2.5. Length, l_d, shall not be less than 6 in. except in computation of lap splices by 12.19.	**12.8 plus commentary**

G. Development and Splices of Reinforcement (cont.)	
1. Web reinforcement shall be as close to the compression and tension surfaces of the member as cover requirements and proximity of other reinforcement permits.	**12.13.1 plus commentary**
2. Ends of single leg, simple U-, or multiple U-stirrups shall be anchored as required by 12.13.2.1 through 12.13.2.5.	**12.13.2 plus commentary**
3. For No. 5 bar and D31 wire, and smaller, and for No. 6, No. 7, and No. 8 bars with f_{yt} of 40,000 psi or less, a standard hook around longitudinal reinforcement.	**12.13.2.1 plus commentary**
4. For No. 6, No. 7, and No. 8 stirrups with f_{yt} 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 $0.014 d_b f_{yt} / \sqrt{fc}$.	**12.13.2.2 plus commentary**
5. For each leg of welded plain wire reinforcement forming simple U-stirrups, either: (a) Two longitudinal wires spaced at a 2 in. spacing along the member at the top of the U; or (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 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 than $8d_b$.	**12.13.2.3 plus commentary**
6. For each end of a single leg stirrup of welded wire reinforcement, 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 $d/2$. Outer longitudinal wire at tension face shall not be farther from the face than the portion of primary flexural reinforcement closest to the face.	**12.13.2.4 plus commentary**
7. 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 calculated in accordance with 12.2 to develop f_y without the modification factor of 12.2.5.	**12.15.1 plus commentary**

G. Development and Splices of Reinforcement (cont.)	
1. 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.	**12.15.2 plus commentary**
2. Minimum lap splice length of welded deformed wire reinforcement measured between the ends of each reinforcement sheet shall be not less than the larger of **1.3** l_d and 8 in., and the overlap measured between outermost cross wires of each reinforcement sheet shall be not less than 2 in., where l_d is calculated in accordance with 12.7 to develop f_y.	**12.18.1 plus commentary**
3. Lap splices of welded deformed wire reinforcement, with no cross wires within the lap splice length, shall be determined as for deformed wire.	**12.18.2 plus commentary**
4. When any plain wires are present in the welded deformed wire reinforcement in the direction of the lap splice or when welded deformed wire reinforcement is lap spliced to welded plain wire reinforcement, the reinforcement shall be lap spliced in accordance with 12.19.	**12.18.3 plus commentary**
5. Minimum length of lap for lap splices of welded plain wire reinforcement shall be in accordance with 12.19.1 and 12.19.2.	**12.19 plus commentary**
6. Where A_s provided is less than twice that required by analysis at splice location, length of overlap measured between outermost cross wires of each reinforcement sheet shall be not less than the largest of one spacing of cross wires plus 2 in., **1.5** l_d, and 6 in., where l_d is calculated in accordance with 12.8 to develop f_y.	**12.19.1 plus commentary**
7. Where A_s provided is at least twice that required by analysis at splice location, length of overlap measured between outermost cross wires of each reinforcement sheet shall not be less than the larger of **1.5**l_d, and 2 in., where l_d is calculated in accordance with 12.8 to develop f_y.	**12.19.2 plus commentary**
H. Two-Way Slab Systems	**13.3.1 plus commentary**
1. Area of reinforcement in each direction for two-way slab systems shall be determined from moments at critical sections, but shall not be less than required by 7.12.	

PROVISION	ACI SECTION
H. Two-Way Slab Systems (cont.)	
1. Spacing of reinforcement at critical sections shall not exceed two times the slab thickness, except for portions of slab area of cellular or ribbed construction. In the slab over cellular spaces, reinforcement shall be provided as required by 7.12	**13.3.2 plus commentary**
I. Walls	
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.	**14.3.1 plus commentary**
2. Minimum ratio of vertical reinforcement area to gross concrete area, ρ_l, shall be: (a) 0.0012 for deformed bars not larger than No. 5 with f_y not less than 60,000 psi; or (b) 0.0015 for other deformed bars; or (c) 0.0012 for welded wire reinforcement not larger than W31 or D31.	**14.3.2**
3. Minimum ratio of horizontal reinforcement area to gross concrete area, ρ_t, shall be: (a) 0.0020 for deformed bars not larger than No. 5 with f_y not less than 60,000 psi; or (b) 0.0025 for other deformed bars; or (c) 0.0020 for welded wire reinforcement not larger than W31 or D31.	**14.3.3**
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 one-half and not more than two-thirds of total reinforcement required for each direction shall be placed not less than 2 in. nor more than one-third the thickness of wall from the 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 one-third the thickness of wall from the interior surface.	**14.3.4**
5. Vertical and horizontal reinforcement shall not be spaced farther apart than three times the wall thickness, nor farther apart than 18 in.	**14.3.5**
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.	**14.3.6**

2.3 ASTM

The ASTM (American Society for Testing and Materials) provides guideline procedures for all testing and/or types of tests to be performed as they pertain to Welded Wire Reinforcement. The following specifications govern the testing of Welded Wire Reinforcement as well as minimum and/or maximum values pertaining to said testing. We have also included the requirements for the application and testing of corrosion inhibiting materials. The specifications governing Welded Wire Reinforcement and the description of their meaning are as follows:

A82 – Standard Specification for Steel Wire, Plain, for Concrete Reinforcement
A123 – Standard Specification for Zinc (Hot-Dip Galvanized) coatings on Iron and Steel Products
A184 – Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement
A185 – Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete Reinforcement
A496 – Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement
A497 – Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete Reinforcement
A641 – Standard Specification for Zinc Coated (Galvanized) Carbon Steel Wire
A884 – Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement for Reinforcement
A1022 – Stainless Steel Wire and Welded Wire for Concrete Reinforcement

Chapter 3 - THE MANUFACTURING PROCESS

3.1 Cold-Working

The properties of wire, as they apply to the design of reinforced concrete, are probably not as well known as those of deformed bars and should be discussed with design engineers in order to separate the two products and eliminate confusion.

The basic material in the manufacture of wire is the rod. This is a hot-rolled steel product, approximately circular in cross-section that is made and shipped in coils. If a rod is subjected to a tensile test, a plot of the results will be a stress-strain curve similar to the lowest line in Figure 2. It will be noticed that there is a definite yield point, that is, a location at which the strain increases without a corresponding increase in stress, and a considerable extension between that point and rupture. Units are not shown for either stress or strain as their values and the relationships between them depend on the chemical composition of the steel. Since the rod is hot-rolled these properties are independent of the size of the rod.

To transform the rod into wire, it is processed through a series of reducing rollers or dies. In addition to decreasing the diameter and increasing the length, this operation has some very important effects on physical properties, as is shown by the stress-strain curve for Wire A in Fig. 2. Here there is no definite yield point in the conventional sense. Instead, once the steel has reached its proportional limit, the line is a continuous curve to ultimate strength or rupture. The ultimate tensile strength is increased above that of rod but the elongation at rupture is smaller. Since the wire is produced by cold working (there is no heat in the process except that caused by the friction of the rod against the rollers or dies) these changes are characteristic of any steel on which cold working is done and the amount of change depends on the amount of cold reduction. The latter is usually measured by the reduction in area. Large reductions in area result in higher tensile properties and smaller ultimate elongations. This is shown by the stress-strain curve for Wire B, also in Fig. 2, which is for a wire rolled from the same rod but with a smaller finished diameter. Wire C has a still larger amount of cold work and so the effect is even greater.

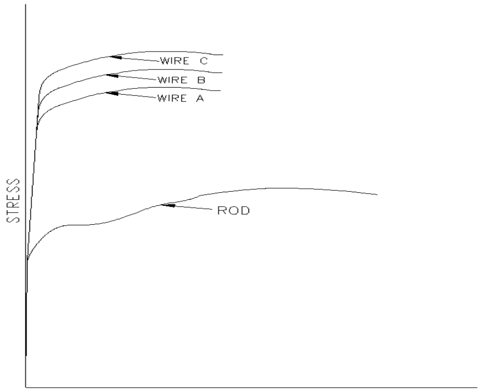


FIG. 2 IDEALIZED STRESS—STRAIN CURVES FOR HOT—ROLLED ROD AND COLD—ROLLED WIRE

2

From observations of this it may be stated that the physical characteristics of a wire are functions of two things: the chemistry of the rod and the amount of cold work done in rolling the wire. Wires are made in many sizes but rods are available in a limited number of diameters. Therefore, several different wire sizes are manufactured from one rod size

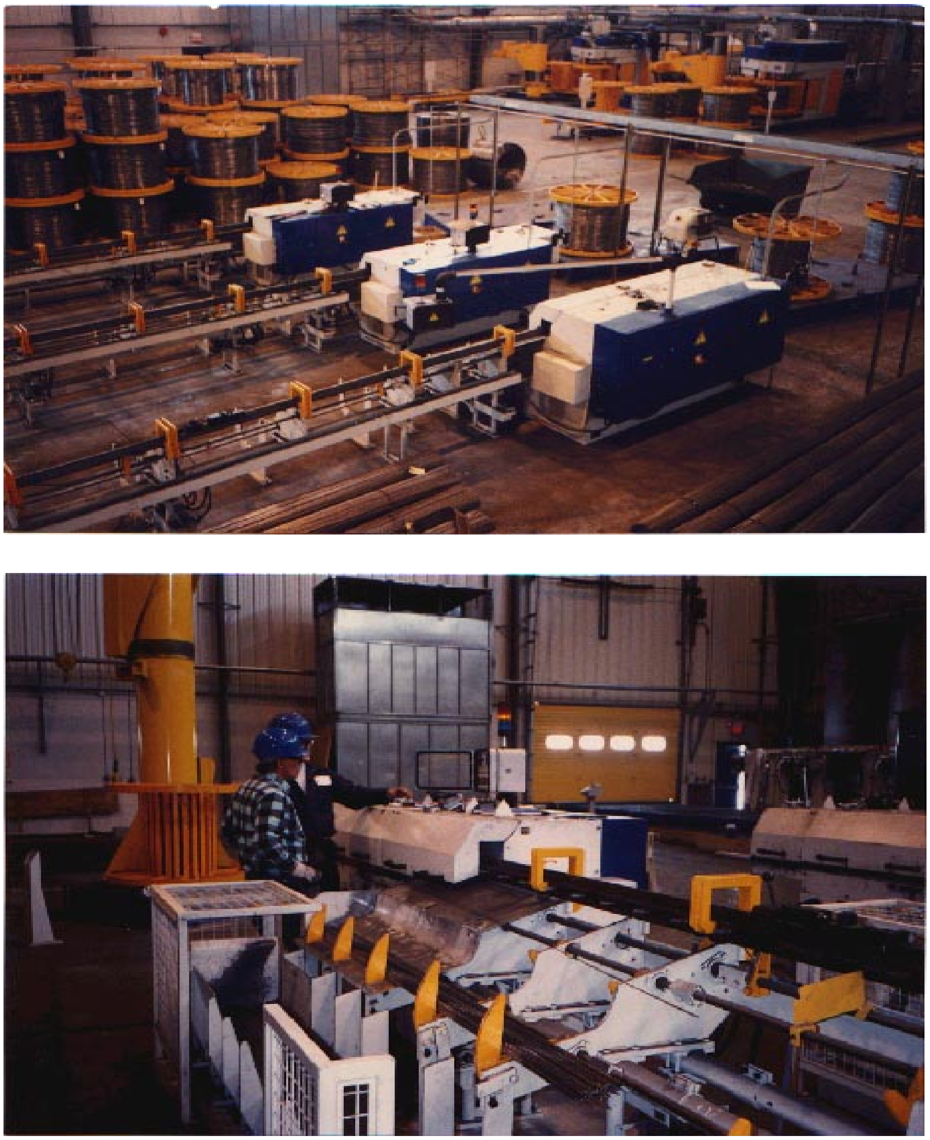
Although there is no true yield point for cold-worked wire, the yield point concept is so critical in structural analysis that an equivalent or substitute value is employed. This is generally stated as the stress at some specified elongation. According to the ASTM specifications governing the manufacture of reinforcing wire, the yield strength is arbitrarily fixed as the stress at which the total strain is .5% (0.005) for wire tested to 70,000 psi or below. For specified yield strengths exceeding 60,000 psi, the stress to strain correlation is set by ACI at .35% (.0035).

The American Concrete Institute (ACI) “Building Code Requirements for Reinforced Concrete” (ACI 318) specifically states that if a yield strength in excess of 60,000 psi is used for design of concrete structures it must not exceed the stress at which the total strain is .35% (.0035). This comes from the fact that the ultimate strain of concrete has been found to be between .3% and .4%. If steel and concrete are bonded together the strain in the former must be allowed to exceed the strain of the latter if the two are to function as a composite material. This is known as strain compatibility. This said, it is vital that when specifying WWR for concrete structures a definitive yield strength must be specified to the factory to assure proper design requirements and testing procedures are followed.

Cold Rolling Line

3.2 Straightening and Cutting

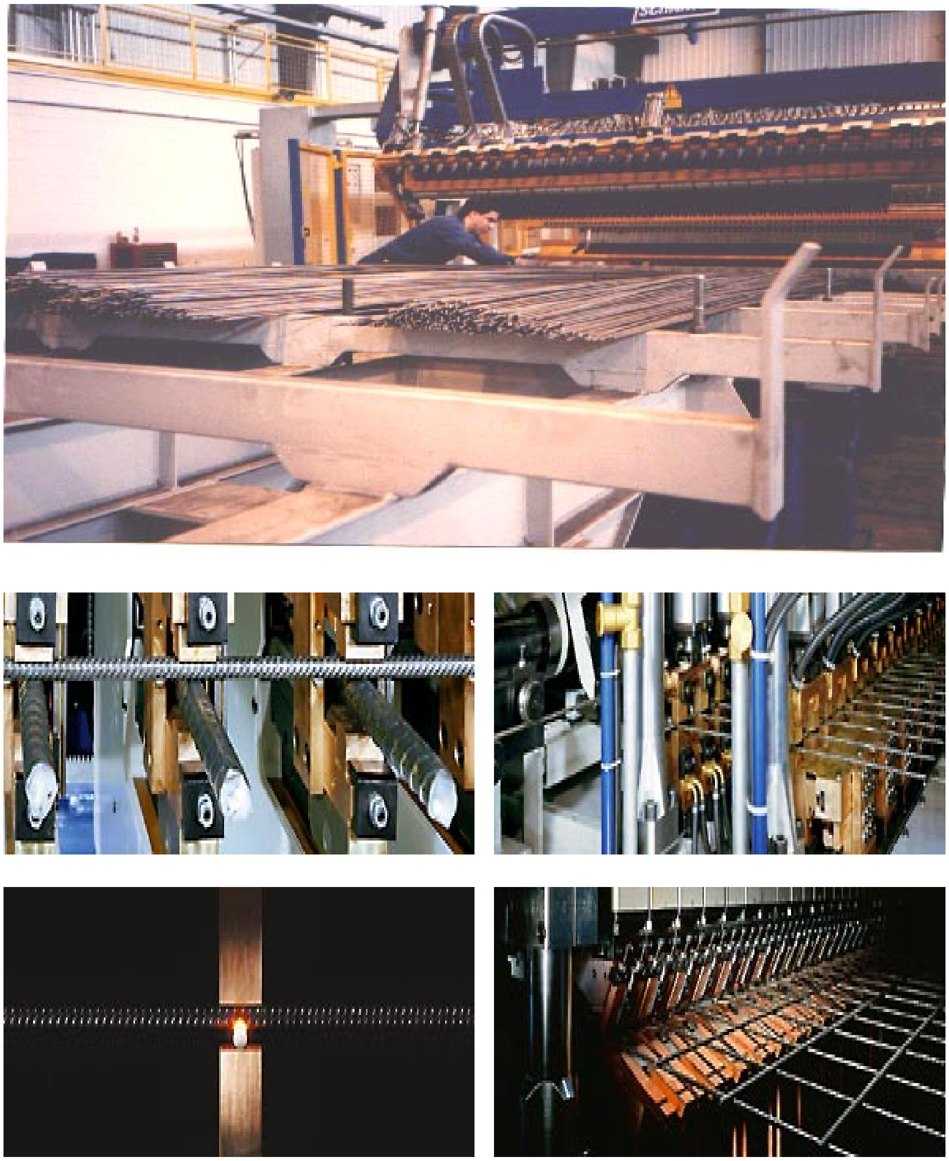
The straightening and cut operation is the second step in the manufacturing process of engineered Welded Wire Reinforcement. This is where the rolled wire is fed from spools into a straightening machine and then cut to exact lengths per the factory order. This step is introduced into the process to enable both batch processing and flatness of the finished sheets when working with large diameter wire.



Straightening and Cutting Lines

3.3 Welding

The welding process is the third step in the manufacturing process and as described in the introduction of this manual, consists of a parallel series of high strength, cold rolled wires welded together in square or rectangular grids. This process utilizes a resistance weld when the longitudinal wire is fed through the machine and the cross wire is either dropped onto the longitudinal wire by an overhead hopper or fed from a spool and the existence of a negative and positive current creates the welded intersection at every intersecting point.

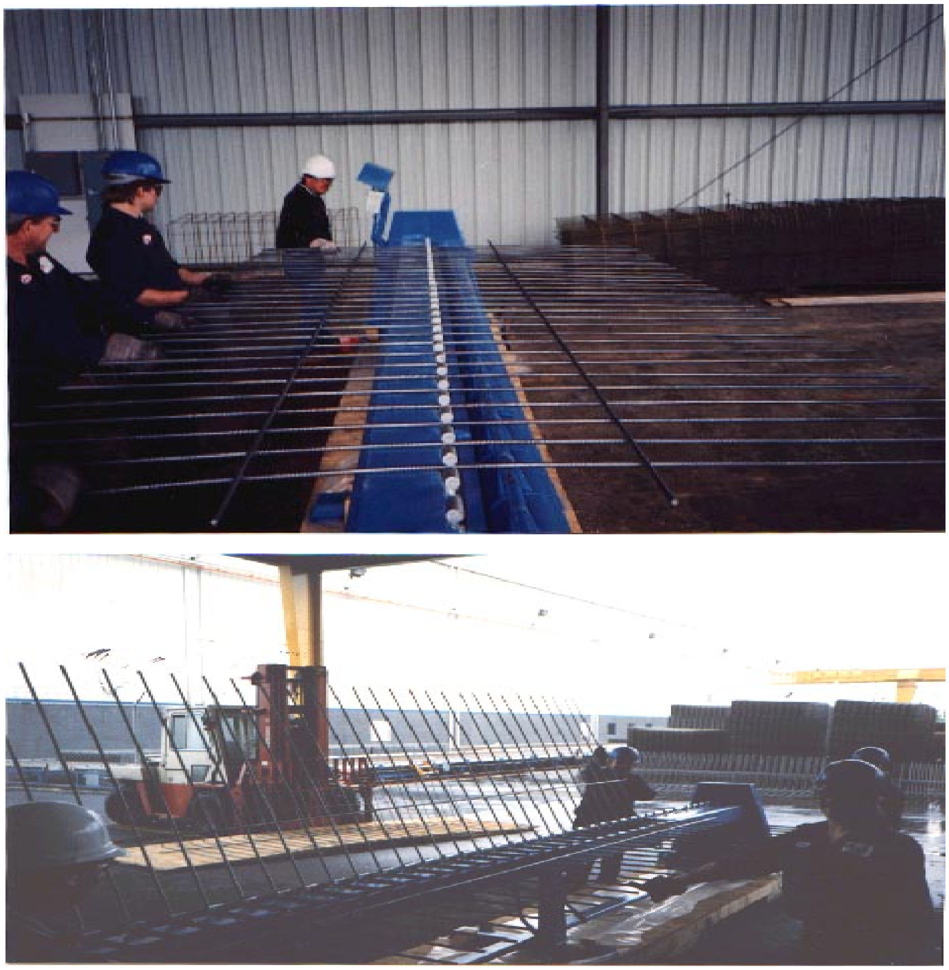


Resistance Welding Machines & Resistance Welding Heads

3.4 Fabrication

3.4.1 Bending

A potential post-welding process can be that of bending. The Welded Wire Reinforcement material can be bent either at the manufacturing facility or, if feasible, at the project site or precast yard. This process utilizes a single arm bending apparatus that places the wire under anvils for resistance. The moveable arm is then lifted through a hydraulically controlled foot or hand pedal to gain the appropriate bend angle and dimension. Virtually any angle or bend scenario can be performed for projects ranging from column cages to simple 90 degree bends for footing dowels.



Bending Machines

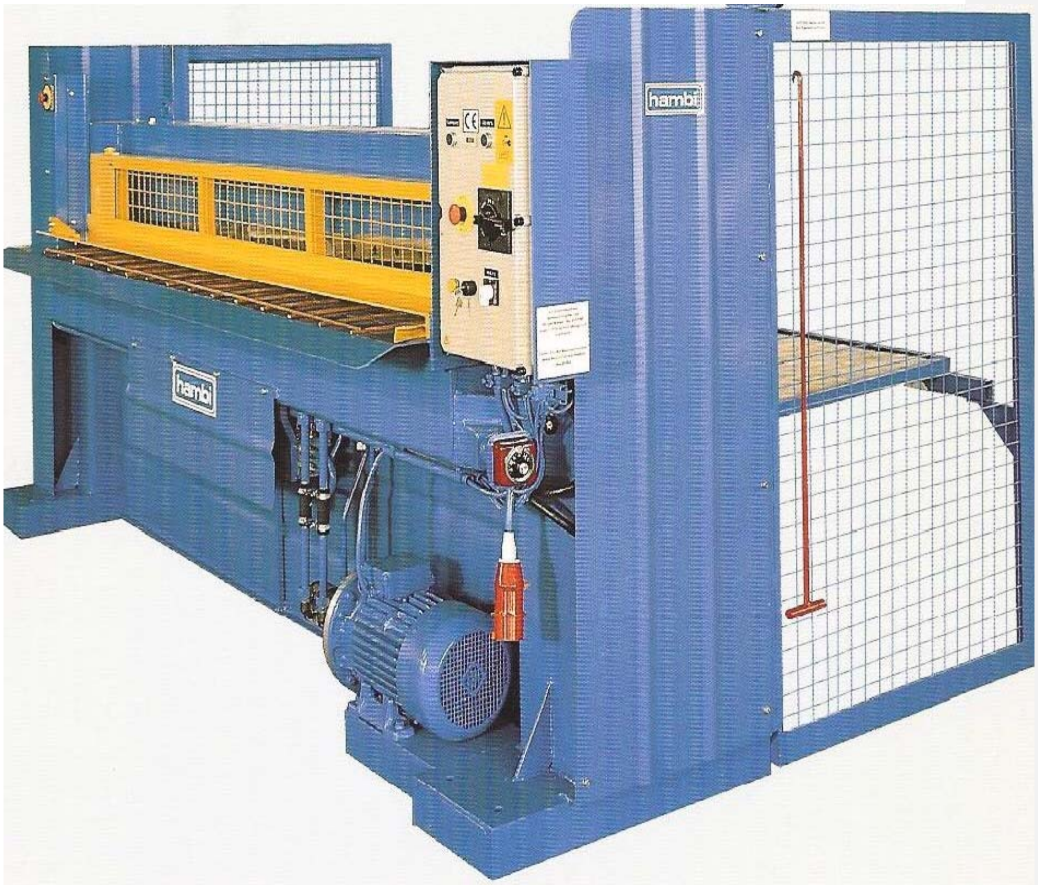
3.4.2 Rolling

Another post-welding process is that of rolling. The finished welded sheet is passed through a conventional 3-roll roller to form a curved shape for products such as tunnel linings or circular tanks. The roller can be set to accommodate virtually any wire size combination as well as any desired radius.

Mercer Street Tunnel Rolled WWR Sheets

3.4.3 Shearing

One additional post-welding process is cutting and/or shearing of sheets. This process can be either manual or by automatic hydraulic guillotine type method. Hand cutting is typically used to cut out various types of openings such as doors and windows, whereby automatic cutting is used to cut various size sheets from a single production run**.**



Shearing Machine

3.5 Shipping and Handling

The final component of the manufacturing process is shipping. This step becomes extremely important when various sizes and scenarios require multiple shipments and sheet style mark numbers.

3.5.1 Packaging and Tagging

Bundling instructions must be in accordance with the customer's job-site requirements and manufacturing needs. This step should be pre-planned and adhered to by the shipping department in order to assure proper project continuity. The following information outlines the basic bundling requirements of a typical factory.

Bundling Instructions

I. Bundling Parameters:
  $\leq$ 5,000#
  $\leq$ 21 inches

II. Nesting Parameters:
  - Maximum Length: 26'3"
  - Maximum Width: 106.25"
  - Maximum Cross Wire Overhang: 7.75"
  - Maximum Sheet Weight: 397 pounds
  - Minimum Longitudinal Wire Spacing: 4"

II. Examples:

1. 12X12-D11/D11 72"(+12,+12)X20'(12,12)

   cannot be flipped - overhangs too long

   two wire diameters per sheet (.374 inches nom.diam.X 2wire diam. per sheet = .748

   inches per sheet

   13' maximum legal capacity - 5' of trailer height = 8' or 96 inches of working space

   96 inches / .748 inches per sheet = 128 sheets per 20' stack

   two stacks per truckload equals 40' or <u>256 total sheets per truckload</u>

2. 12X12-D11/D11 96"X20'

   can be flipped

   1.5 wire diameters per sheet = .561 inches per sheet

   13' maximum legal capacity - 5' of trailer height = 8' or 96 inches of working space

   96 inches / .561 inches per sheet = 171 sheets per 20' stack

   two stacks per truckload equals 40' or <u>342 total sheets per truckload (possible)</u>

Chapter 4 - CONSTRUCTION APPLICATIONS

4.1 Cast-in-Place Concrete

Cast-in-place concrete is defined as concrete that is cast on site in its final state. Welded Wire Reinforcement has been used successfully in many applications pertaining to cast-in-place concrete.

4.1.1 Footings

Footings are designed as spread footings and continuous footings. Although neither type of footing is usually designed with Welded Wire Reinforcement, many contractors have realized the savings by placing this material in lieu of reinforcing bars. Spread footings offer great potential because they are generally square or rectangular in shape and usually require simple reinforcement in a single or double layer. As one can imagine, placing one mat or two mats of WWR greatly diminishes the labor cost involved with conventional steel placement.

WWR in Spread Footing for Ice Mountain Project

4.1.2 Columns and Beams

Column ties and beam stirrups can be designed using Welded Wire Reinforcement in a variety of ways. Depending upon code provisions and product application, the column cage can be designed and bent as a single closed cage unit or a multi-piece unit with a lap at the sides with the exception of seismic applications per ACI 318, Chapter 21. It may also be possible to incorporate the vertical (or longitudinal) main reinforcement as part of the column cage.

Rolled WWR Column Retrofit for Rykers Island Pier

4.1.3 Slab

The most frequent use of Welded Wire Reinforcement is for slabs that are cast directly on earth (slab-on-ground). Elevated slabs due to different design loads and types are not as frequently reinforced with WWR. The steel design for elevated slabs is necessary to carry tensile stresses caused by bending from applied loads, whereas slabs-on-grade are principally reinforced to control cracking caused by shrinkage, temperature changes and unequal sub-grade support. Due to the aforementioned lack of proper information regarding WWR, few designers are aware that the heavier reinforcement required in elevated slabs can be converted to WWR. With the versatility of new and existing equipment, more efficient configurations offer the contractor and designer attractive alternatives that at one time were unachievable. The so-called “finger splice” governed by the ACI code provides WWR lap conditions similar to reinforcing bars which do not compromise design parameters. Further, this machinery allows the conversion engineer to offer various sizes of mats within one project depending on the joint spacing rather than relying on the contractor to waste valuable time cutting sheets to fit an area.

WWR Sheets for Kansas City Airport Runway

4.1.4 Walls

For this document we will include slip-formed barrier walls as well as traditional cast-in-place walls. Wall design can be classified in four primary sections: non-bearing walls, bearing walls, retaining walls and shear walls. It is difficult to divide the functions of these walls precisely, but in general a bearing wall is designed primarily to support vertical loads, a retaining wall to carry horizontal forces perpendicular to the face of the wall and a shear wall to sustain horizontal forces parallel to the wall. However, many walls must serve more than one of these functions.

Steel reinforcement is used in concrete walls for two reasons: to assist the concrete in carrying tensile and compressive forces resulting from horizontal and vertical loading on the wall and to prevent or minimize and control cracking due to shrinkage, temperature changes and other unpredictable condition.

When purely vertical loading occurs the concrete is generally capable of carrying it without any reinforcing. However, when there is bending – whether it be from external forces or from eccentric application of the vertical load – or in cases where there is shear to be considered, reinforcing is required. WWR can be used advantageously in most walls, as the economy of placing large units is generally quite significant.

The best applications of WWR are those where there are many repetitive wall dimensions. Tilt-up construction with only a few open areas provides an excellent example of long run similar wall units. Also, multistory buildings with exterior and interior walls of the same height offer a great opportunity for cost-saving construction.

Normally the design documents will specify the type of reinforcement required to carry the loading conditions. It is important for the engineer to understand the nature of the forces involved prior to converting to Welded Wire Reinforcement. The engineer must know the type of wall being constructed and the type of forming system that will be used to assure an adequate WWR design that will work in tandem with the construction parameters. The engineer must also know what section of the ACI building code is governing the original design. This information will dictate the re-design into WWR.

A minimum area of steel is required in both the vertical and horizontal directions (see section 3.2). The specified horizontal steel is larger than the vertical steel in most applications. Caution must be exercised in the analysis of a Tilt-up panel in that the stresses occur in a vertical manner thus providing heavier steel in that direction. Further, the typical ACI code section 14 does not always govern the design of this form of wall due to deflection limitations. In any case it is the responsibility of the engineer to find out the design and construction parameters to assure an appropriate conversion design to WWR.

WWR Sheets for Tilt-up Wall Panels

4.2 Precast Concrete

Welded Wire Reinforcement is the most widely used form of reinforcement in many types of precast concrete. Steel reinforcing is provided to serve one or more of the following functions:

1. To carry tensile stresses caused by horizontal forces.
2. To carry tensile stresses due to the weight of the member itself and any vertical loads applied directly to it (such as windows, snow on sills, etc.).
3. To provide compressive reinforcement in load-carrying precast members.
4. To provide reinforcement against cracking because of shrinkage and temperature changes.
5. To reinforce the panel against handling and lifting stresses.

Welded Wire Reinforcement can be used in almost all precast concrete work. Usually the determination of the amount of reinforcing is the function of a design engineer and methodology.

Precast concrete is deposited in forms and cured at a location other than that at which it is to be finally used. With the exception of a few small items that may be cast at the job-site it is usually made at a location remote from the point of use, generally in an established precasting plant.

4.2.1 Building, Housing, Landscape and Specialty Products

These products are used to construct commercial and residential buildings and improve the appearance or usefulness of the physical site around a building or residential site.

Foundation systems such as precast steps, walls and slabs are an example of some products that fall under this category. Each one of these products utilizes Welded Wire Reinforcement, typically in a pre-fabricated and customized manner providing for the exact dimensions and layout of the home or office being built.

Also, architectural panels, which provide a certain finish of a specialty nature, ranging from exposed aggregate design to certain colored or patterned designs cast into the product during fabrication. Welded Wire Reinforcement is widely used in this product as it presents better crack-control on a surface that requires such. Further it provides ease of installation in a typically repetitive product.

Finally, Landscape type products such as retaining wall systems and modular paving products provide for easy use of Welded Wire Reinforcement. Because most of these designs do not require typically heavy reinforcement, the multitude of wire sizes makes it easier for the designer and precaster to meet the areas of steel with very little concern of “over-steeling” and thus additional money.

4.2.2 Sanitary and Stormwater Products

These products are typically used to convey or direct storm water or sanitary water from the initial source to a final destination.

Such products include, but are not limited to manholes, catch basins, curb inlets, precast pipe and pipe chambers. The primary reinforcement for the aforementioned products is Welded Wire Reinforcement. The use of WWR, usually in commonly stocked rolls, provides the best and most efficient layout for reinforcing these products.

4.2.3Water and Wastewater Products

These products are used to hold or contain water, oil or other liquids for the purpose of further processing into non-contaminating liquids and soil products.

The typical products that fall into this category are septic tanks, wet wells and distribution boxes. Many federal, state and local agencies have already referenced the use of Welded Wire Reinforcement for these products. The wire size is typically small and is bent and formed into the required shape for the product being cast.

4.2.4 Transportation Products

These products are used in the construction, safety and site protection of our road, airport and transportation systems.

Most of the products exclusively use Welded Wire Reinforcement as their primary method of reinforcement.

Traffic and median barriers commonly referred to as “Jersey Barriers” from where the idea originated, utilize many different style and shapes of WWR depending upon the barrier size and shape. When the barrier requires a sheet to be bent or shaped, it is usually performed at the manufacturing plant and shipped to the precast plant as a pre-bent product. Also, many barrier types simply require a flat sheet of WWR running vertically in the center of the barrier. Finally, WWR has been used extensively for the so-called “end-slot” detail at the connection point of the barrier.

Sound barrier wall panels have been used for many years to reduce the traffic noise from an adjacent highway into a nearby residential neighborhood. Because these panels are typically rectangular in shape and very repetitive in quantity, Welded Wire Reinforcement is primarily used as the reinforcement of choice. It is shipped to the precast plant in a sheet that is custom designed and fabricated to the dimensions required by the various heights and widths of the precast sound wall panel.

Another use for this type of reinforcement and increasing in popularity is the product known as a precast tunnel segment. This product is precast into forms with a pre-determined radius. Because of this radius, it is necessary to provide a sheet of reinforcement that is pre-rolled and will fit into the form with no apparent adjustments (see section 3.4.2). These segments utilize many different types of reinforcement configurations and all can be handled through the use of Welded Wire Reinforcement design and manufacturing.

One of the more popular uses of Welded Wire Reinforcement is for the box culvert precast member. The box culvert is similar in concept to the pipe culvert but typically provides for better hydraulic flow of the liquid passing through its opening. Box culverts have also been used as steam tunnels and walkways in steam rooms and under stadiums to name a few. The typical Welded Wire Reinforcement provides for superior crack control in both the circumferential and longitudinal areas of the box culvert. Also, these sheets are typically custom-designed to match the span and rise of the box culvert being cast.

4.2.5 Communication, Utility and Industrial Products

The last category of precast items provides for products that are incorporated into electrical, gas, telephone and other utility segments of construction.

Very similar to the distribution boxes mentioned above these products range from junction boxes to the similarly called distribution boxes and are typically specified for the use of Welded Wire Reinforcement.

4.3 Prestressed and Post-tensioned Concrete

Welded Wire Reinforcement is typically used in prestressed and post-tensioned products as temperature and shear reinforcement. The prestressing strand provides for the induction of main reinforcement and control of dead load and live load conditions induced upon the member being cast and placed into a final usable state. The additional reinforcement provided by the Welded Wire Reinforcement provides for the control of cracking that occurs as splitting stresses at the ends of beams during the induction of the prestressing load or to handle the camber conditions that arise after the prestressing strand is released.

Before a post-tensioned product is placed into use, it typically has been reinforced with mild steel reinforcement and/or prestressing strand. The Welded Wire Reinforcement will aid in the area of stripping and handling stresses that occur during transportation and erection as well as to control live load and dead loads induced upon the designed member.

4.3.1 Commercial Products

This type of product is typically used in the area of public buildings, mixed use/retail as well as office buildings and schools. This can be provided as a hollow-core slab for walls and ceilings or a solid panel for the same use. In any event, Welded Wire Reinforcement is used typically in the transverse direction across the beam to handle temperature cracking.

4.3.2 Industrial Products

These products span the manufacturing and food processing plants and the large warehouse and distribution centers. For many years, the typical wall construction for these building was the “double-tee”. This type of construction utilized a member that looks very much like its namesake. It is comprised of a single monolithic top slab cast into two vertical “legs” or “stems”. Welded Wire Reinforcement has been almost exclusively used for the product. Two different type of Welded Wire Reinforcement are used, one for the stem of the product and one for the top slab or flange of the product.

Two additional products that are typically cast with the double-tee system are prestressed (sometimes precast) columns and beams. These columns and beams typically use prestressing strand running longitudinal through the member with a reinforcement stirrup confining the main longitudinal steel. Many times, Welded Wire Reinforcement is provided as a pre-bent unit for the confinement stirrups around the prestressing strand.

4.3.3 Transportation Products

These products are primarily used for the construction of bridges and marine projects as well as used for the construction of sound wall panels.

One of the most popular methods for bridge building is the use of prestress girder members. These range from the “bulb-tee” to the AASHTO I-beam as well as the trapezoidal member developed in the State of Texas and the Box Beam widely used in many areas of the Country.

In the I-beam type of girder, Welded Wire reinforcement is used in the top and bottom flange for confinement and to control top flange cracking after the induction of the stressed load into the beam. Welded Wire Reinforcement is also used as vertical reinforcement in the web of the beam and is provided in flat and/or bent sheets to accommodate the height and length of the I-beam being cast.

4.3.4 Housing Products

An increasingly popular manner for constructing housing projects is through the use of prestressed modular units. These include, but are not limited to dormitories, hotels, healthcare facilities, single and multi-family houses and retirement facilities.

The above units are cast at the precast/prestress yard as a modular unit typically containing the floor, walls and roof or ceiling. The Welded Wire Reinforcement is provided as multiple styles for the floor, walls and roofs. The window openings are typically cut out at the plant in order to assure proper location of the opening.

4.3.5 Specialized Products

These products have a wide range of possibility and provide perfect applications for the use of Welded Wire Reinforcement and the versatility that it allows. They typically range from correctional facilities to stadiums of all types and parking structures to potentially any integrated precast/prestressed structure.

The above products use some of the prestressed members discussed above such as the column and beams and the double-tee system. They will also employ the modular type construction described in section 4.3.4.

One additional use under this type of specialized product would be for stadium risers. These members have the typical look of a stair unit and are precast and prestressed members with mild reinforcement to control extraneous loads and temperature cracking. Welded Wire Reinforcement is commonly used in this product and is either pre-bent at the manufacturer's location or shipped in flat sheets and bent by the prestress producer. In either event, the bent sheet is placed in the form after the initial tensioning of the strand and then concrete is cast into the form. Quality control inspection is kept to a minimum, as the sheets are pre-bent to industry standards.

Chapter 5 - CONSTRUCTIBILITY

5.1 Field Welding

It should be noted that ACI 318, Ch. 3, Commentary R3.5.2 states that " Machine and resistance welding as used in the manufacture of Welded Wire Reinforcement is covered by ASTM A185 and A497 respectively and is not a part of this concern". Therefore plant Welded Wire Reinforcement should be accepted as reinforcement in concrete structures.

Special procedures are followed in plant production of WWR and it is difficult to obtain the same welding techniques in the field. There are portable hand held electric resistance welders – but they are not used on job sites – only used in WWR plants where proper electrical power is provided and the correct safety procedures are followed.

Engineers have approved field welding of Welded Wire Reinforcement – but will not allow welds in the regions of high stress (in the middle of spans or close to columns).

Tack welding is not allowed – the engineer of record should specify requirements or performance criteria for field welding if it is desired over other methods of splicing – i.e., lapping sheets of WWR together. ANSI/AWS D1.4 should be used as a reference for specifying field welding.

5.2 Field Bending

Bending WWR in the field is done all the time. Benders can be placed on the truck with bundles of WWR sheets and trucked to the job site. Many general concrete contractors use this method to obtain the correct bend measurements to fit the project. Fabricators have benders in their yard or plant. Sometimes sheets are partially bent at the plant site then final bending is completed on the site to suit exact dimensions. Partially bent sheets can be nested to provide space and maximum weight for shipment. Bending machines can be made to suit any length or width of WWR sheet – 15', 20', 30' lengths or longer. Various size mandrels are used to provide the correct bend in accordance with building codes and ASTM standards. A reference for further reading is available from WRI – Chapter 5 of the WRI Structural Detailing Manual (SDM).

5.3 Cutting

Sheets of WWR can be cut to suit project layout requirements. It is more desirable and economical to provide quantities of the same size sheets than quantities of various size sheets. Sheets can be cut with overhangs, i.e. ½", 1", 2" or up to one half the wire spacing. The latter is most common with WWR manufacturers. Some manufacturers can provide flush cuts on the side or longitudinal length of the sheet. End overhangs of sheets are almost always one half the wire spacing, unless finger splices are required. See splicing for more detail.

Field cutting is simple with the use of common ordinary bolt cutters. Sheets can be supplied to the site without openings. Sheets can be cut on the site to obtain the exact desired location for openings.

5.4 Spirals

Column spirals are provided by fabricators that have special spiral coiling machines to shape the spirals to the exact round column dimensions.

5.5 Splicing

Splicing welded wire sheets can be accomplished by several preplanned designs. One is splices that are overlapped on the ends for one-way designs and on both the ends and the sides for two –way designs. Minimum splices dimensions are provide by building codes. Also close edge wires (providing half size end and or side wires at 3", 4", or 6" spacing). This splice option saves on material costs. Finally, finger splices (no cross wires in the splice zone) this provides just two wire depths at splices and avoids layers of wires at corner of splices thus reducing the cover at those locations. Building codes require longer splice lengths for this splice option. A minimum splice length is 16" and can be more with larger wires. A ready reference is available from WRI- titled WWR – 500 – WRI's Manual of Standard Practice. Tables are available that reflect building code requirements for minimum splice lengths.

5.6 Placing Tolerances

Tolerances of WWR sheets are made exact because the quality control by WWR manufacturers is vital. This is important when placing sheets within screed rails to maintain required cover around the forms.

A key to controlling cracking and to keep crack widths to a minimum to achieve aggregate interlock is to adequately support sheets of WWR. The sheets must be placed on sturdy supports to maintain uniform cover in accordance with building codes. A good reference is WRI's SDM, Chapter 3 or WRI's Tech Fact 702, titled Supporting WWR.

5.7 Detailing

Many WWR manufacturers have the capability of computer –aided detailing of WWR sheets into projects they are awarded. Many offer this service when WWR is specified and purchased by reinforcing fabricators.

A ready reference is WRI's SDM, Chapter 4 'Detailing one-way slabs"; Chapter 6, "Detailing column & beams"; Chapter 8, "Detailing reinforced concrete slabs". 5.2 FIELD BENDING

Chapter 6 - REFERENCES

References, Introduction

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1.1 ASTM International, ASTM A 82 *Standard Specification for Steel Wire, Plain, for Concrete Reinforcement*, Table 5&6.

1.2 ASTM International, ASTM A 496 *Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement*, Table 1&2.

References, Chapter 3

3.1 ASTM International, ASTM A 496 *Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement*, Supplementary Requirements S1 and ACI 318 3.5.3.4 to 3.5.3.6 and 3.8.1

References, Chapter 4

4.1 American Concrete Institute, *ACI 318 Building Code Requirements for Structural Concrete and Commentary*, Chapter 12

4.2 National Precast Concrete Associations, *Specifiers*, *Precast Products*, National Precast Concrete Associations, http://www.precast.org/specifiers/precast_products.htm (accessed June 16, 2006).

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References, Chapter 5

5.1 American National Standards Institute/American Welding Society, *ANSI/AWS D1.4/D1.4M Structural Welding Code-Reinforced Steel*, 6th Edition.

5.2 Wire Reinforcement Institute, WWR-500: *Manual of Standard Practice-Structural Welded Wire Reinforcement*. Chapters 5 and 6. http://www.wirereinforcementinstitute.org/HTDocs/Pages/WWR500.

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