Welded Wire Fabric for Shear Reinforcement

developed by

PCI Technical Activities Committee's Joint PCI/WRI Ad Hoc Committee on Welded Wire Fabric for Shear Reinforcement

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Presents minimum shear reinforcement requirements for welded wire fabric, commonly used in stems of double tees. Current limitations in the ACI Building Code are discussed and a rationale for acceptance of straight sheets of wire fabric is given.

Because the effect of the prestressing force is to reduce diagonal tension, the significance of shear is generally less in prestressed than in non-prestressed concrete. However, it is necessary to calculate the magnitude of the shear and, if it exceeds a value prescribed by the governing design code, to provide shear reinforcement. In wider members such as beams, this reinforcement, if required, is generally in the form of multiple leg U-stirrups or closed ties. However, in narrow members such as the stems of standard precast prestressed double tees, there is generally room for only a single layer of web reinforcement.

In accordance with Chapter 11 of the ACI Code,[1] when the "factored shear force" is greater than one-half of the "shear strength provided by the concrete," at least a specified minimum area of shear steel must be provided, unless tests indicate it is not required.* Generally, the required area will be small for thin-stemmed members. This fact, together with the labor savings of wire fabric placement compared to placing many single-plane stirrups as a unit, has made welded wire fabric a natural choice for shear reinforcement.

The committee was formed for two purposes: (1) to examine any code restrictions on the use of welded wire fabric for shear reinforcement, and (2) to explore the possibility of developing standard sizes of such reinforcement.

*See AC1 318-77, Section 11.5.5.2. For many typical applications, tests show that the minimum shear reinforcement requirements may be waived for prestressed concrete double tees.

Current Practice

The use of welded wire fabric for shear reinforcement in double-tee stems has become commonplace in the precast, prestressed concrete industry. Compared with reinforcing bars, the use of fabric for this purpose can result in significant savings in materials and labor, at no apparent reduction in quality. It can even be argued that quality is improved, since the fabric can often be more accurately placed and since there is less interference with concrete placement, and with strand and connection hardware.

Many double-tee manufacturers use standard sizes of welded wire fabric, cutting it to the required small size. At least one manufacturer will supply fabric in narrow widths especially for shear reinforcement. These special fabrics are available with either smooth or deformed wires. The use of standard fabric has the advantage of fewer materials to maintain in stock, but sacrifices the material and labor savings available through using specially manufactured styles.

Code Provisions

The use of welded wire fabric shear reinforcement is recognized in several sections of ACI 318-77. For example:

Section 2.1 — Includes in the definition of stirrup: "... bars, wires, or welded wire fabric (smooth or deformed) ..."

Section 11.5.1.1 — "Shear reinforcement may consist of: ... (b) Welded wire fabric with wires located perpendicular to axis of member."

However, in Section 12.14, "Development of web reinforcement," methods of anchorage of smooth welded wire fabric are specified only for the case of simple U-stirrups, and there is no provision for anchoring deformed wire fabric.

Also, while Section 12.14.2 specifically mentions single leg stirrups, there are no provisions for anchorage in the tension zone of the member other than a standard hook plus embedment. Thus, the designer has had to choose whether to apply the straight leg compression zone requirements to the tensile side, or to use the an-

chorage requirements for tension stated elsewhere in the chapter.

The lack of clarity in the application of these provisions suggests that changes in the ACI Building Code are desirable. In addition to the provisions mentioned above, Sections 3.5.3.6 and 3.5.3.7 of ACI 318-77, which specify welded wire fabric materials, are not clear regarding their use as shear reinforcement. Specifically, the maximum spacing requirements of 12 in. (305 mm) for smooth wire fabric and 16 in. (406 mm) for deformed wire fabric are unnecessary when used for shear reinforcement, as the only purpose of the cross wires is for anchorage of the main (vertical) wires. Also, the words "primary flexural reinforcement" obviously do not apply to fabric used as shear reinforcement.

ASTM A497, which ACI 318-77 specifies as the standard for deformed welded wire fabric makes no provision for the weld shear strength of wires smaller than D4 (5.72 mm). This, apparently, is because in the major use of deformed wire fabric, namely, tensile reinforcement for slabs, smaller wires are seldom used. Manufacturers of fabric using smaller deformed wires report no difficulties in providing equivalent weld shear strengths.

This committee believes that the intent of ACI 318-77 can be met by straight sheets of welded wire fabric anchored in both the tension and compression sides in the following manner:

1. For welded smooth wire fabric, two longitudinal wires with a minimum spacing of 2 in. (51 mm), with the inner wire not less than the greater of $d/4$ or 2 in. from the middepth of the member.

2. For welded deformed wire fabric, one longitudinal wire not more than $d/4$ from the extreme faces plus a development length above and below middepth in accordance with Section 12.8.2 of ACI 318-77.

In either case, on the tension side of the member, the longitudinal wire closest to the face should not be farther from the face than the lowest main reinforcement. These provisions are illustrated in Fig. 1.

Standardization

In most practical applications of thin-stemmed double-tee members, the amount of shear reinforcement will be determined by the minimum requirements. Hence, there was unanimous agreement among the members of this committee who represented the manufacturers of precast, prestressed concrete products that "standards" should be based on these minimums. When more shear reinforcement is required, it can be supplied by using multiple layers of the standard, or stock, sizes of welded wire fabric.

For prestressed members, either of two equations in ACI 318-77 may be used to calculate minimum shear reinforcement:

$$A_v = 50\frac{A_w s}{f_y} \qquad (11\text{-}14)$$

$$A_v = \frac{A_{ps} f_{pu} s}{80 f_y d}\sqrt{\frac{d}{b_w}} \qquad (11\text{-}15)$$

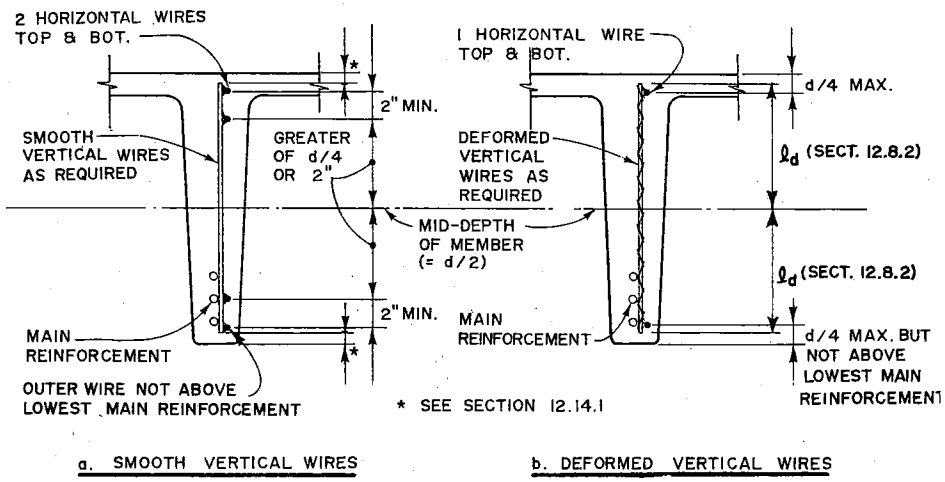

Fig. 1. Anchorage of single leg welded wire fabric shear reinforcement.

where

A_{ps} = area of prestressed reinforcement, sq in.
A_v = area of shear reinforcement within a distance, s, sq in.
b_w = web width, in. (for tapered stems, use average width)
d = distance from extreme compression fiber to centroid of prestressing tendons, but need not be less than $0.80h$, in.
f_{pu} = specified tensile strength of prestressing tendons, psi
f_y = specified yield strength of shear reinforcement, psi [limited to 60,000 psi (414MPa)].
s = spacing of shear reinforcement, in.

Note that Eq. (11-14) is applicable to all reinforced concrete members whereas Eq. (11-15) can only be used when the effective prestress force is at least 40 percent of the tensile strength of the main reinforcement.

Since either equation may be used, the required amount of minimum shear reinforcement may be based on Eq. (11-14). It should be noted, however, that less reinforcement may be permitted by Eq. (11-15)—typically for members with fewer strands. The yield strength of all wire commonly used in welded wire fabric meets or exceeds the upper limit of 60,000 psi (414 MPa), so Eq. (11-14) can be rewritten as:

$$A_v \text{ (per ft)} = 0.010\, b_w$$

For the most commonly manufactured double tees up to 24 in. (610 mm) deep, the average stem width will vary between 4 and 5 in. (102 and 127 mm). For the standard sections shown in the *PCI Design Handbook*,[2] the average stem width is 4.75 in. (121

Table 1. Area of shear reinforcement provided by various sizes and spacing of vertical wires (sq in./ft).

Vertical Wire Size	Spacing of Vertical Wires (in.)					
	5.5	6	6.5	7	7.5	8
W2.9, D2.9 (6 ga)	0.063	0.058*	0.054	0.050	0.046*	0.044
W2.5, D2.5 (7 ga)	0.055	0.050†	0.046	0.043	0.040	0.038

*Most common in current practice.
†Size recommended for flange reinforcement in double tees.[3]

NOTE: 1 in. = 25.4 mm; 1 sq in./ft = 2117 mm²/m

mm). Thus, from the above equation, the minimum shear reinforcement requirements can be met with an area of from 0.040 to 0.050 sq in./ft (85 to 106 mm²/m). With this small range, standardization of fabric size is possible.

In current practice, the most common vertical wire size used is W2.9 or D2.9 (6 ga. or 4.88 mm), followed by W2.5 or D2.5 (7 ga. or 4.52 mm). Table 1 shows the area of reinforcement provided by these two sizes.

Note that the sizes marked (*) and (†) in Table 1 are those most commonly used in current practice. It can be seen that even the least of these [W2.9 or D2.9 (4.88 mm) at 7.5 in. (191 mm)] will be within 3 percent of meeting the minimum requirements for the *PCI Design Handbook* standard and smaller sections.

ASTM specifications require that the smaller wire be at least 35 percent of the area of the larger wire in the case of welded deformed wire fabric, and 40 percent for welded smooth wire fabric. For the sizes of vertical wires listed in Table 1, these requirements are met if the cross wires are at least W1.4 (10 ga. or 3.43 mm).

References

1. ACI Committee 318, "Building Code Requirements for Reinforced Concrete (ACI 318-77)," American Concrete Institute, Detroit, Michigan.
2. *PCI Design Handbook* (Second Edition), Prestressed Concrete Institute, Chicago, Illinois, 1978.
3. "Standardization of Welded Wire Fabric," PCI JOURNAL, V. 21, No. 4, July-August 1976, pp. 30-37.

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Discussion of this report is invited.
Please forward your comments to
PCI Headquarters by March 1, 1981.

Bidding Practices and Construction Techniques for Long Span Bridges

The growing resurgence in bridge building across North America prompted a two-day conference on long span concrete bridges last March in Hartford, Connecticut (for program details, see Jan.-Feb. PCI JOURNAL, pp. 164-165).

The purpose of the conference was to present the latest information on design, construction, bidding practices and economics of long span concrete bridges.

In this issue of the PCI JOURNAL five of the papers presented at the Hartford Conference are being published. The first four articles cover bidding practices and construction options from the federal and state departments of transportation, consulting engineer, and contractor viewpoints. The fifth article discusses current segment casting methods and erection techniques in concrete segmental bridge construction.

The conference was sponsored by the Federal Highway Administration, Portland Cement Association, Prestressed Concrete Institute, Post-Tensioning Institute, and Concrete Reinforcing Steel Institute.