Traditionally, the Concrete Reinforcing Steel Institute (CRSI) has strongly recommended that reinforcing bars be assembled with tie wire. At the same time, CRSI has discouraged welding of crossing bars as a means for assembling reinforcement for site-cast, reinforced concrete construction because such welding of crossing bars may adversely affect the strength and ductility of the reinforcement. To date, “tack welding” has been firmly established and embedded in building codes and in design and construction specifications to describe the connection of crossing bars by small arc welds. In this article, the author describes the benefits of fusion welding when shop welding reinforcement.

**CURRENT CODE REQUIREMENTS**

CRSI’s long-standing position on assembling reinforcement is consistent with provisions in current building codes. For example, Section 7.5.4 in the ACI Building Code (ACI 318-02) states:

“7.5.4 — Welding of crossing bars shall not be permitted for assembly of reinforcement unless authorized by the engineer.”

The companion Commentary Section, R7.5.4, of ACI 318-02 describes the potential detrimental effects of welding crossing bars and states how such welding can be performed safely:

“R7.5.4 — ‘Tack’ welding (welding crossing bars) can seriously weaken a bar at the point welded by creating a metallurgical notch effect. This operation [tack welding] can be performed safely only when the material welded and welding operations are under continuous competent control, as in the manufacture of welded wire fabric.” (Italics added by author.)

Chapter 21, Special Provisions for Seismic Design, in ACI 318-02 also includes provisions regarding the welding of crossing bars. Code Section 21.2.7.2 states:

“21.2.7.2 — Welding of stirrups, ties, inserts, or other similar elements to longitudinal reinforcement that is required by design shall not be permitted.”

The companion Commentary Section, R21.2.7.2, states:

“R21.2.7.2 — Welding of crossing reinforcing bars can lead to local embrittlement of the steel. If welding of crossing bars is used to facilitate fabrication or placement of reinforcement, it should be done only on bars added for such purposes. The prohibition of welding crossing reinforcing bars does not apply to bars that are welded with welding operations under continuous, competent control as in the manufacture of welded wire fabric.” (Italics added by author.)

**EMERGING PRACTICE**

In recent years, new welding machine technology came to the U.S. from Europe and now impacts...
our shop fabrication practices. In California, for example, many fabricators also act as subcontractors, placing (installing) reinforcing steel on site. These fabricator/placer firms often preassemble reinforcement in their shops. Several California fabricator/placer firms, as well as a few fabricators in other parts of the U.S., are currently using the state-of-the-art welding machines to produce fusion-welded assemblies of reinforcing bars.

**Description of fusion-welded assemblies**

The fusion-welded assemblies consist of low-alloy steel reinforcing bars conforming to ASTM A 706/A 706M, and longitudinal wires, which are called “holding wires,” conforming to ASTM A 82 or A 496. For building construction, typical assemblies fusion welded in the shop are beam and column cages. Figure 1 and 2 show examples of stirrup cages for beams. Depending on whether single stirrups or multiple stirrups make up the assembly, three or more “holding wires” are fusion welded to the stirrups. After the fusion welding is completed, the assembly can be shipped to the job site. At the job site, the assembly is placed in the form and longitudinal top and bottom bars are placed in the stirrup cage. Longitudinal bars are fastened to the stirrups with tie wire; so, job-site placing and fastening of the longitudinal bars reverts to the traditional practice of using tie wire to complete the beam cage. Practice to date among West Coast fabricators/placers is to assemble the “partial” shop-welded beam cages, placing the longitudinal bars in the “partial” cage at the job site.

Assembling column cages is similar. Holding wires would be fusion welded to the ties or transverse reinforcement. For column cages, the fabricator/placer may decide to do more preassembly. After the fusion welding is completed, the “partial cage” might be moved to another location of the fabricator’s facility. Ironworkers would then place and fasten the longitudinal column bars with tie wire to the ties or transverse reinforcement. Then, the “complete” assembly would be transported to the job site.

The advantages/benefits of shop-welded assemblies of reinforcing bars are:

- Eliminates the time-consuming field placing and handling of the small reinforcement elements, for example, stirrups and ties;
- Results in very accurate positioning of stirrups or ties in the cage; and
- Provides for better overall dimensional control of the resulting complete cage, which enhances constructibility.

**Welding process**

Electric resistance welds result from a fusion process that uses a combination of pressure and heat generated by electric impulses. In other words, the intersections of the low-alloy steel bars and the “holding wires” are fused together; no foreign matter is introduced during the welding process. The welding machines are computer-controlled so, other than operating and controlling the welding machines, shop personnel are never engaged in the actual welding process.

The welding process for preassembling reinforcing bars is the same process as that used for manufacturing welded-wire fabric. ASTM A 185 and A 497/A 497M prescribe: “... Longitudinal and transverse wires

---

*The term “welded wire reinforcement” has replaced “welded wire fabric” in ASTM Specifications A185 and A497/A497M.*
shall be securely connected at every intersection by a process of electrical-resistance welding which employs the principle of fusion combined with pressure."

**Mechanical properties of fusion-welded assemblies**

Independent testing laboratories have conducted a large number of tensile and bend tests on shop-welded specimens. These test results have confirmed that the controlled welding process does not adversely affect the mechanical properties of the bars. In the tensile tests, the test specimens developed yield strengths and tensile strengths in excess of the minimum values prescribed in ASTM A 706/A 706M. There were no significant differences in the strength properties of welded versus nonwelded bars. The test specimens also exhibited excellent ductility in the tensile tests; there were no significant reductions in percentage of elongation in the welded versus nonwelded bars. Bend tests of shop-welded specimens also met the requirements prescribed by ASTM A 706/A 706M.

**CRSI’S POSITION**

CRSI has modified its long-standing position on using welding as a means for assembling reinforcement. This new welding technology and extensive quality control testing have demonstrated the successful application of welding low-alloy steel bars.

First and foremost, field tack welding as a means for assembling reinforcement should be wholly differentiated from the controlled welding performed in the fabricating shop. Thus, CRSI still recommends that field tack welding should not be permitted unless authorized by the architect/engineer.

Alternatively, preassembly of reinforcing bar cages in the fabricating shop by fusion welding should be permitted. CRSI’s basis for endorsing the practice of preassembling reinforcing bar cages by shop welding are:

1. The welding process is the same as that used for manufacturing welded-wire fabric. It is a continuous, controlled process. Such a welding process for assembling reinforcement is implicitly permitted by ACI 318-02 via Commentary Sections R7.5.4 and R21.2.7.2; and
2. The results of tests on shop-welded specimens show conclusively that the controlled welding process does not cause any detrimental effect on the mechanical properties of the low-alloy steel reinforcing bars.

**SHOP WELDING PERMITTED**

Shop-welded assemblies of reinforcing bars should be permitted in reinforced concrete construction provided that:

- Reinforcing bars conform to ASTM A 706/A 706M;
- Holding wires conform to ASTM A 82 or A 496;
- Shop welding is performed by machines under a continuous, controlled process; and
- Quality control tests are performed on shop-welded specimens and the test results are available, upon request, to the architect/engineer.

**References**

1. ACI Committee 318, “Building Code Requirements for Structural Concrete (ACI 318-02) and Commentary (318R-02),” American Concrete Institute, Farmington Hills, MI, 443 pp.

Selected for reader interest by the editors.

—Concrete Reinforcing Steel Institute

Circle 61

David P. Gustafson, FACI, is Vice President of Engineering, Concrete Reinforcing Steel Institute, Schaumburg, IL. He is a member of ACI Committees 222, Corrosion of Metals in Concrete; 301, Specifications for Concrete; and 318, Structural Concrete Building Code. He is a past member of the Technical Activities Committee.