Assembling Reinforcing Bars by Fusion Welding in the Fabrication Shop

Introduction

Traditionally, 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. Such welding of crossing bars may adversely affect the strength and ductility of the reinforcing bars.

The term “tack welding” has become firmly established and embedded in building codes and in design and construction specifications to describe the connection of crossing bars by small arc welds.

Current Code Requirements

CRSI’s long-standing position on assembling reinforcement is consistent with provisions in current building codes. For example, Section 26.6.4.1(b) in ACI 318-14 states:

“Welding of crossing bars shall not be used for assembly of reinforcement unless permitted by the licensed design professional.”

The companion Commentary Section R.26.6.4.1(b) of ACI 318-14 describes the potential detrimental effects of welding crossing bars and states how such welding can be performed safely:

“Tack” welding (welding crossing bars) can seriously weaken a bar at the point welded by creating a metallurgical notch effect. This operation can be performed safely only when the material welded and welding operations are under continuous competent control, as in the manufacture of welded wire reinforcement.”

Note the second sentence, i.e.: “...can be performed safely only when the material welded and welding operations are under continuous competent control, as in the manufacture of welded wire reinforcement.”

Chapter 18 – Earthquake-Resistant Structures in ACI 318-14 also includes provisions regarding the welding of crossing bars. Code Section 18.2.8.2 states:

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

The companion Commentary Section R18.2.8.2 states:

“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 reinforcement.”

Note the last sentence, i.e.: “…does not apply to bars that are welded with welding operations under continuous, competent control as in the manufacture of welded wire reinforcement.”

The California Building Code 2016, Section 1903.8A permits fusion welding of holding wires to cage assembly:

“Shop fusion welded stirrup/tie cage (or spiral assemblies) consisting of low-alloy steel reinforcing stirrups/ties conforming to ASTM A706 and longitudinal holding wires, conforming to ASTM A1064 shall be permitted. The fusion welds shall be made by machines using electric resistance welds. Tack welding of primary reinforcing bars together or to stirrups/ties is not permitted. Fusion welding of holding wires is not permitted on any portion of a reinforcing bar that is or will be bent in accordance with ACI 318 Section 25.3.”

The International Building Code 2015, Section 1705.3 also includes a provision in
welding of reinforcing bars, if permitted by the licensed design professional:

“Welding of Reinforcing Bars – Special inspections of welding and qualifications of special inspectors for reinforcing bars shall be in accordance with the requirements of AWS D1.4 for special inspection and of AWS D1.4 for special inspector qualification.”

“Weldability of reinforcing bars other than ASTM A706 is subject to verification.”

**Emerging Practice**

In recent years, high-technology welding machines have become available. The welding machine technology comes from Europe and has now impacted shop fabrication practices in the United States. In California, for example, many fabricators also place (install) reinforcing steel. These fabricator/placer firms often pre-assemble reinforcement in their shops.

Several California fabricator/placer firms, as well as a few fabricators in other parts of the country, are currently using 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 Specification A706/A706M*, and longitudinal wires, which are called “holding wires,” conforming to ASTM Specification A1064/A1064M.

For building construction, the typical fusion-welded assemblies are beam and column cages. Figure 1 shows examples of stirrup cages for beams. Also see Figure 2 on page 3. Depending upon 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 forms. Then the longitudinal bottom bars and longitudinal top bars are placed in the stirrup cage. The longitudinal bars would be fastened to the stirrups with tie wire. In other words, the 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 the West Coast fabricators/placers is to assemble the “partial” shop-welded beam cages and then place the longitudinal bars in the “partial” cage at the job-site.

Assembling column cages would be similar. Holding wires would be fusion-welded to the ties or transverse reinforcement. For column cages, the fabricator/placer may decide to do more pre-assembly. After the fusion welding is completed, the “partial cage” might be moved to another location of the fabricator’s facility. Ironworkers would 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 or benefits of shop-welded assemblies of reinforcing bars like the ones described are:

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

**Welding Process.** The welds made by the welding machines are electric resistance welds. This type of weld results 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 in the welding process.

The welding machines are computer-controlled. Except for operating and controlling the welding machines, shop personnel are never engaged in the actual welding process.

*For more information on low-alloy steel reinforcing bars, see “Questions and Answers on ASTM A706 Reinforcing Bars” by D. P. Gustafson and A. L. Felder, Concrete International, V. 13, No. 7, July 1991, pp. 54-57.*
The welding process for pre-assembling reinforcing bars is the same process as that used for manufacturing welded wire reinforcement. ASTM Specifications A1064/1064M prescribes: “…Longitudinal and transverse wires 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.** A number of tensile tests on shop-welded specimens have been conducted by independent testing laboratories. The results of the tests 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 Specification A706/A706M. There were no significant differences in the strength properties of welded vs. non-welded bars. The test specimens also exhibited excellent ductility in the tensile tests; there were no significant reductions in percentage of elongation in the welded vs. non-welded bars.

**CRSI’s Position on Shop Welding**

CRSI has modified its long-standing position on using welding as a means for assembling reinforcement. The 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.

On the other hand, pre-assembly of reinforcing bar cages in the Fabricating Shop by fusion welding should be permitted. CRSI’s basis or rationale for endorsing the practice of pre-assembling reinforcing bar cages by shop welding are:

1. The welding process is the same as that used for manufacturing welded wire reinforcement. It is a continuous, controlled process. Such a welding process for assembling reinforcement is implicitly permitted by the ACI 318 Building Code via Commentary Sections R18.2.8.2 and R26.6.4.1.

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.

**Summary**

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

- The reinforcing bars conform to ASTM Specification A706/A706M.
- The holding wires conform to ASTM Specification A1064/1064M.
- The shop welding is performed by machines under a continuous, controlled process.
- Quality control tests are performed on shop-welded specimens and the test results are available, upon request, to the Architect/Engineer.

![Figure 2 – Single stirrups and holding wires.](image-url)
References

Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14), American Concrete Institute, Farmington Hills, Michigan.


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Keywords: Beam cages, column cages, fusion-welded, shop-welded, tack welding, welding


Historical: Engineering Data Report 53.

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