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Case Study: Tack Welded Reinforcing Bar

By

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Subject

Evaluation of tack welded reinforcing bar used in masonry piers to determine the effect of the tack welding on the strength of the reinforcing bar. The reinforcing bar material was supposed to have been ASTM A706 Grade 60. Normally, reinforcing bars are wire-tied together, not tack welded, to prevent brittleness associated with the weld heat affected zone. Tack welded reinforcing bars were examined at the construction site and no broken welds were observed. The 5/8 inch diameter vertical reinforcing bars are the ones that there was concern about. Two exemplar tack welded reinforcing bars were prepared by the masonry crew for destructive testing. The exemplar reinforcing bars were examined by visual examination, break testing, hardness testing, and metallographic examination.

Reinforcing Bar Inspection

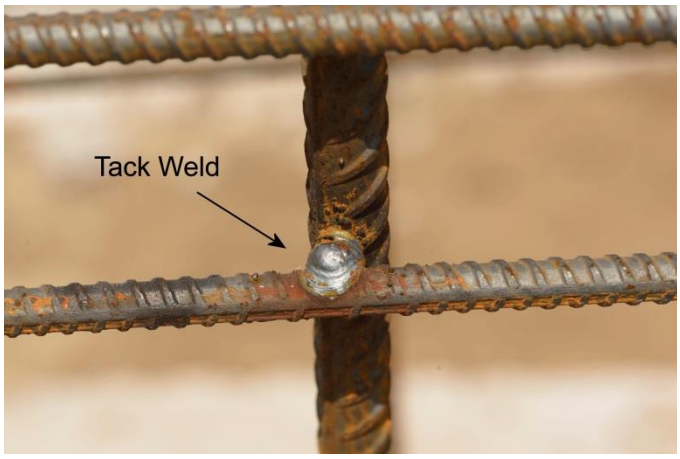

Figure 1 – Tack Welded Reinforcing Bar

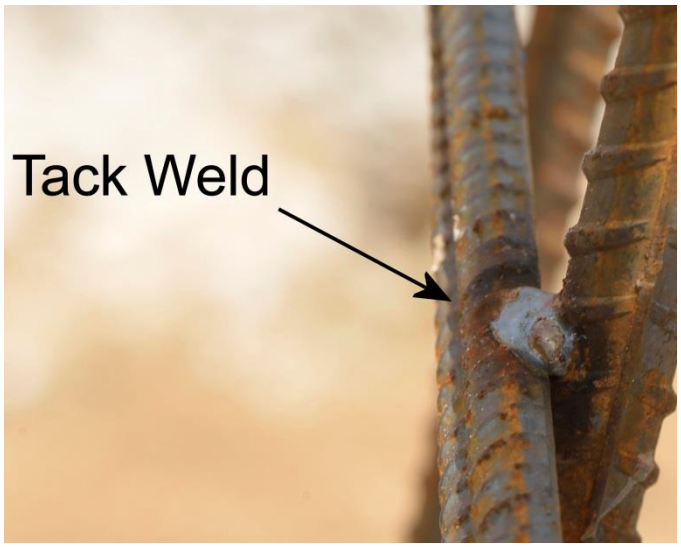

Figure 2 – Tack Welded Reinforcing Bar

Figures 1 and 2 show two examples of the tack welded reinforcing bar at the construction site. The two examples shown were typical of all of the tack welds that were examined.

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Visual Examination of the Exemplar Reinforcing Bars

Figure 3 – Identification on 5/8 Inch Reinforcing Bar, Exemplar 1

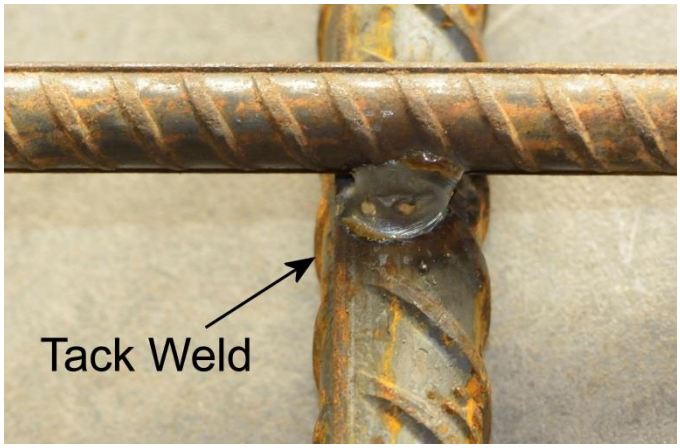

Figure 4 – Tack Weld, Exemplar 1

Figure 3 shows markings on a 5/8 inch reinforcing bar used for Exemplar 1. The markings indicate that the bar is Grade 60. Exemplar 1 was used for hardness testing and metallographic examination. Figure 4 shows the tack weld on Exemplar 1. The metallographic cross section that was used for hardness testing and metallographic examination was made by cutting through the tack weld.

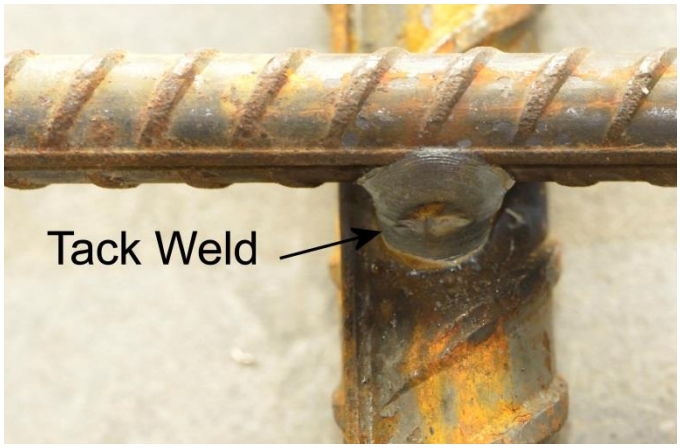

Figure 5 – Tack Weld, Exemplar 2

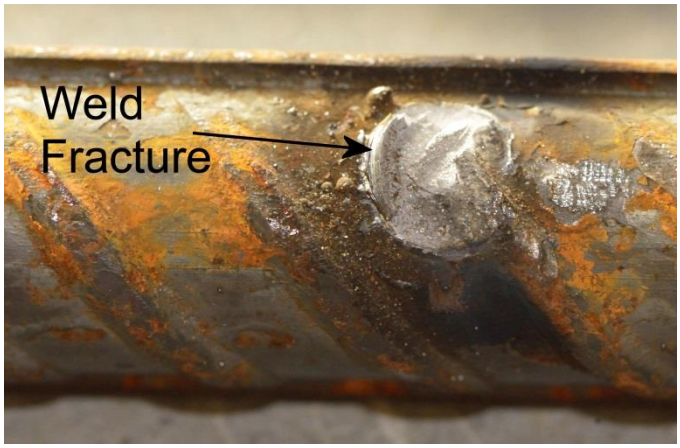

Figure 6 – Fractured Tack Weld, Exemplar 2

Exemplar 2 was used for break testing to determine the quality of the tack weld, Figure 5. Figure 6 shows the fractured weld metal after the break test. The weld meets the requirements of an AWS D1.1 tack weld. It was free of porosity and lack of fusion. It was found that the fracture mode was brittle fracture instead of the preferred ductile rupture. Brittle fracture means that the tack weld would not resist impact or high strain rate loading. It is not likely that the welds at the construction site would be subjected to impact loading inside the concrete pier.

Hardness Test

The hardness testing was done according to ASTM E384, using a Vickers indenter and a 500 gram load. The results were converted to Brinell Hardness Number. The hardness was based on an average of 10 readings. The hardness data is given in the table that follows. Brinell Hardness Number can be used to estimate the tensile strength of the steel tested, by multiplying it by 500.

Hardness Test Data
(Brinell Hardness Number)

Sample	Vickers	STD DEV	MAX VALUE	MIN VALUE	HARDNESS
Core	211.00	6.69	216.00	200.00	201.40 BHN
HAZ 1	610.00	4.72	615.00	604.00	574.60 BHN
HAZ 2	398.00	17.06	423.00	381.00	376.80 BHN
Weld	346.00	19.58	364.00	318.00	328.00 BHN

Based on the core hardness of the 5/8 inch reinforcing bar, the tensile strength of the reinforcing bar was 100 ksi. The yield strength of the 5/8 inch reinforcing bar is likely around 80 ksi.

Heat affected zone one (HAZ 1) is much too hard at 574.60 BHN, or 287 ksi tensile strength. The extremely high hardness is the reason for the brittle fracture associated with the tack weld seen in Exemplar 2.

Metallographic Examination

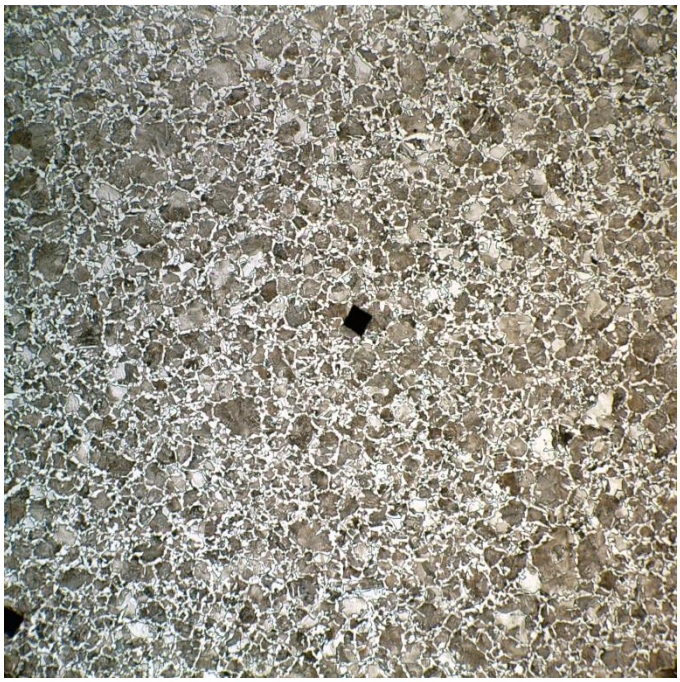

Figure 7 – 100X Core Microstructure, Exemplar 1

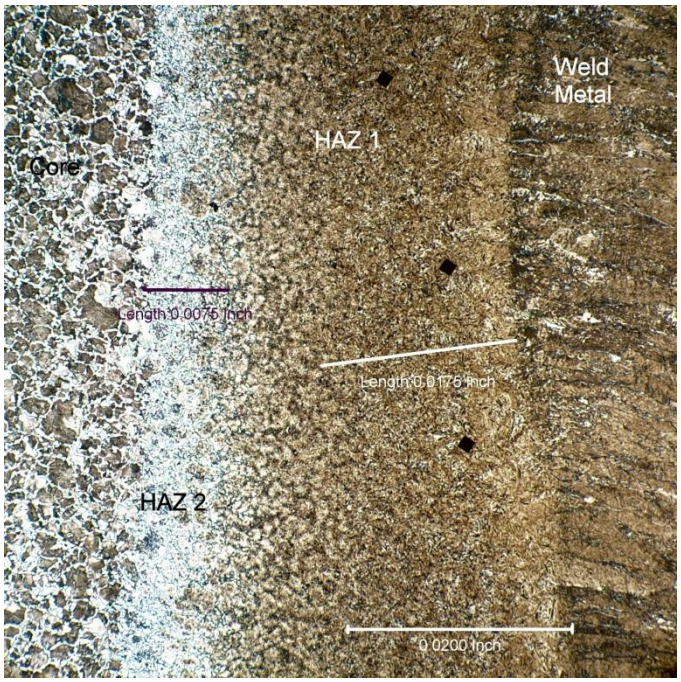

Figure 8 – 100X Weld HAZ, Exemplar 1

Figure 7 shows the core microstructure of the 5/8 inch reinforcing bar Exemplar 1. The microstructure consists of pearlite and ferrite, and is typical of hot rolled carbon steel having a carbon content between 0.30 and 0.40 percent.

Figure 8 shows the Exemplar 1 heat affected zone. HAZ 1 is primarily lightly tempered martensite, which is very brittle. HAZ 2 is low carbon martensite, which has a much lower hardness and is not likely to be as brittle. The martensitic heat affected zone is the result of not preheating and post-heating the 5/8 inch reinforcing bar prior to and after doing the tack welding. The microstructures and hardness of the heat affected zone indicates that manganese in the bar steel could be as high as one percent or higher. This in turn indicates that the reinforcing bar is ASTM A706 Grade 60. The martensitic microstructure of the weld heat affected zone is very brittle, and has very poor fracture toughness. The presence of the martensitic heat affected zone has the effect of reducing the cross section area of the 5/8 diameter reinforcing bar. The heat affected zone reduced the sectional area of the reinforcing bar by about 6%. Since the yield strength of the bar is likely 80 ksi instead of 60 ksi, the tack welding will have little or no effect on the strength of the piers.

Opinion

It is my professional opinion to a responsible degree of scientific certainty based on the information available and discussed in this report that the tack welding done on the 5/8 inch Grade 60 reinforcing bar will have an insignificant effect on the static load bearing characteristics of the masonry piers. Reinforcing bars should not be welded without using the proper preheating and/or post-heating to prevent brittleness of the heat affected zones.

Standard practice in connecting reinforcing bar is to use wire ties. Tack welding may appear to be more efficient, but the welding operator and weld procedure need to be qualified to AWS D1.1 for each and every job. The need for preheating and/or post-heating of Grade 60 and higher reinforcing bar, and the need for weld procedure and operator qualification, makes the cost of welding much more expensive and time consuming than using wire ties.