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July 10, 1978

Director of Nuclear Reactor Regulation
Attention: Mr. Robert L. Baer, Chief
LWR Branch 2, DPM
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Subject: Docket Nos. 50-361 and 50-362
San Onofre Nuclear Generating Station, Units 2 and 3

SCE's letter of April 11, 1978 forwarded the report, "Offshore Circulating Water System/Ultimate Heat Sink, San Onofre Nuclear Generating Station, Units 2 and 3", for your review and use. The report indicated that SCE was evaluating the impact of the tack welding of ASTM A615 GR.40 reinforcing steel used in the construction of the intake conduit and would keep the NRC advised.

The evaluation has been completed and fifty copies of the report, "Evaluation of the Impact of Tack Welding, San Onofre Nuclear Generating Station, Units 2 and 3" are provided for your review and use.

If you have any questions or comments concerning the information provided, please contact me.

Sincerely,

K P Baskin

Enclosures
cc: R. H. Engelken (NRC, Director I&E - Region V)

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EVALUATION OF THE IMPACT OF TACK WELDING
ASTM A-615-GR.40 REINFORCING STEEL
SAN ONOFRE NUCLEAR GENERATING STATION UNITS 2&3

Introduction

The purpose of this report is to advise the NRC staff of the results of SCE's evaluation of the impact of tack welding ASTM A-615 Grade 40 reinforcing steel in the fabrication of the Offshore Circulating Water System Intake Conduits. The tack welding was discussed during the March 10, 1978 meeting with the NRC staff in Bethesda, Maryland.

Background

The Offshore Circulating Water System intake conduit is comprised of 18' inside diameter prestressed concrete pipe sections 24' in length. In the pipe sections that are completely prestressed, the reinforcing bars primarily carry the handling loads prior to the prestressing operation. The loads imposed on the pipe by transportation, installation and the in situ loads are carried by the prestressing. There are three pipe sections in the intake line containing access manholes. The manhole pipes have an 8' section around the opening that is conventionally reinforced concrete while the ends of the pipe are prestressed. In the nonprestressed section around the opening, the reinforcing bars carry all the loads to which the pipe is subjected. Thus, the tack welding evaluation primarily affects only the three pipe sections containing the access manholes.

The reinforcing steel cages in the pipe sections consist of #7 circumferential bars, and #5 and #7 longitudinal bars. The cages have been fabricated by tack welding the crossing bars. In addition, construction aids (3/8" chairs and 3/8" spacer plates) have been fastened to the bars by tack welds.

Tensile tests were performed on the combinations of members tack welded to the principal reinforcing bars. The test results show that the yield and tensile strength capabilities were not affected by the welding; i.e., all the bars tested were well in excess of the ASTM A-615 criteria for yield and tensile strength of Grade 40 steel. The ultimate elongation capability, however, was reduced to below the ASTM minimum requirements of 11% for #7 bars. The most severe reduction in ultimate elongation occurred in a #7 bar with a 3/8" chair attached; the elongation at rupture was 4.7%. Most of the bars tested had ultimate elongations in excess of 6%.

Basis of ASTM A-615 Criteria

The first step in evaluating the impact of the tack welding was to determine the basis for the ASTM A-615 elongation criteria. Discussions were held with the chairman of the ASTM committee on reinforcing steel regarding the basis for the elongation criteria. According to ASTM, the standards for elongation were established by vendors and users as acceptability criteria for the different grades of steel and various bar sizes. The elongation limits were based on past experience of the ductility required for bendability of bars, not on the behavior of bars in composite action with concrete. The elongation criteria in ASTM A-615 are intended as guidelines for commercial acceptability and thus are not important for our purpose. The conduit reinforcing steel was bent prior the tack welding, and there were no small radius bends. The design elongation requirements, discussed in the following section, are much lower.

Design Requirements

The conduits were designed to Seismic Category I criteria using the Strength Design Method specified in ACI 318-71. The assumptions of the Strength Design Method are: 1) The section can develop sufficient strength to carry the ultimate load (determined by application of the appropriate load factors) and 2) The percentage of steel reinforcing is such that the section fails in a ductile manner; i.e., the steel will yield but not rupture before the concrete crushes. The impact of the tack welding on the ability of the steel to meet these design assumptions was evaluated. The ability of the tack welded steel to withstand cyclic loading was also considered.

Tensile tests were performed by an independent materials testing company on tack welded reinforcing bars. The test results showed that the yield and tensile (ultimate) strength capabilities of the bars were not affected by the tack welding; i.e., all the bars tested exceeded the ASTM A-615 strength criteria. Similar tests by the Portland Cement Association (PCA) Structural Laboratory on tack welded reinforcing steel (reference 1) have also shown that yield and tensile strength are not affected by tack welding. The tests performed by the independent testing company, and the PCA tests show that the tack welded steel is capable of developing the design strength.

The Strength Design Method requires the percentage of steel to be such that ductile behavior of the section is ensured. The method of analysis outlined in reference 2 was used to calculate the percentage of steel required to ensure ductile failure, and to determine the steel strain capability required to ensure concrete crushing occurs prior to the steel rupturing. These calculations provide appropriate criteria for the ultimate elongation capability required for design purposes. The calculations showed the percentage of steel provided in the pipe is sufficient to ensure ductile failure; i.e., the amount of steel in the section is such that it will yield but will not rupture prior to the concrete crushing. As required by ACI 318-71, the percentage of steel is not sufficiently large such that the concrete crushes prior to steel yielding. The calculated steel strain at concrete crushing is 0.78% which is greater than yield but much less than the minimum test result of 4.7%. The calculations show that the tack welded reinforcing steel has sufficient ultimate elongation capability to meet the design requirements; i.e., the section will behave in a ductile manner.

The ability of the tack welded reinforcing steel to withstand cyclic loading was the subject of a study by the Portland Cement Association Structural Laboratory (reference 1). The study specifically considered the fatigue life of the tack welded reinforcing bars for various stress ranges. The main reinforcing bars tested were Grade 40 #8 bars with #3 stirrups tack welded to the #8. The tack welding was performed using poor welding techniques to simulate the worst conditions occurring in the field. The tests were performed by subjecting the concrete beams (strength 4500-5500 psi) to cyclic loads such that the steel was subjected to tensile stress ranges up to 40 KSI. The test steel strain rates are similar to strain rates for the conduit seismic loading. The tests provide an excellent model for the expected loading conditions to which the conduit steel will be subjected.

The study results show that for tack welded Grade 40 steel, the fatigue life of bars subjected to a stress range of approximately 40 KSI was in excess of 20,000 cycles. As the stress range is reduced, the fatigue life increases (e.g., for a stress range of 32 KSI the fatigue life is approximately 200,000 cycles.) The San Onofre Units 2 and 3 intake conduits are designed to withstand the maximum credible seismic event. The cyclic loading of the reinforcing steel during a DBE will occur at less than the 40 KSI stress range, and the number of cycles is much less than the minimum fatigue life at the 40 KSI stress range determined by the PCA tests.

<u>Conclusion</u>

The evaluation of the impact of tack welding of the reinforcing steel has shown the following:

1) The tack welding has not affected the steel yield and tensile strength capabilities.

2) Calculations show the tack welded steel has sufficient ultimate elongation capability to ensure ductile behavior.

3) The tack welded steel is capable of withstanding cyclic loadings resulting from all credible events.

Thus, the evaluation shows the design safety margins have not been reduced by the tack welding. Therefore, no further action is required.

Reference 1 - "Fatigue Tests of Reinforcing Bars - Tack Welding of Stirrups" ACI Journal, May 1967.

Reference 2 - "Effect of Steel Strength and Reinforcement Ratio on the Mode of Failure and Strain Energy Capacity of Reinforced Concrete Beams" ACI Journal, March 1969.