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U.S. ATOMIC ENERGY COMMISSION

REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.10

MECHANICAL (CADWELD) SPLICES IN REINFORCING BARS OF CATEGORY I CONCRETE STRUCTURES[1]

A. INTRODUCTION

General Design Criterion 1 of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," requires that structures, systems and components important to safety be designed, fabricated, erected and tested to quality standards commensurate with the importance of the safety functions to be performed. This guide describes an acceptable method of implementing this criterion with regard to the testing and sampling of mechanical splices in reinforcing bars used on Category I concrete structures.[2] The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

B. DISCUSSION

Reinforcing bars for concrete structures are joined together either by lapping, welding, or mechanical splicing. The most common type of mechanical splice is called a Cadweld splice. The minimum requirements for lapping and welding splices are established by existing codes; however, the strength and testing requirements for mechanical splices are not specifically defined in such codes.

The mechanical (Cadweld) splice is used most frequently for #14 and #18 reinforcing bars because (1) the welding of these bars can be performed reliably only if the bar chemistry is controlled and the bar chemistry is not normally controlled to an extent that would permit reliable welding, and (2) the lapping of these bars is prohibited by applicable codes (American Concrete Institute: Building Code Requirements for Reinforced Concrete, ACI 318-71).

Visual inspection of all the mechanical splices is the fundamental inspection technique, and it can reveal certain deficiencies. However, some splices that pass the visual inspections may not meet tensile test specifications. In order to provide a check on the visual inspections, and to detect symptomatic deficiencies, destructive testing of some splice samples is considered essential as a supplement to the visual inspections. A suitable destructive testing program would provide an adequate basis for assuring that mechanical splices made on in-place reinforcing bars achieve at least the load-carrying capability of the bars.

The testing program in this guide is generally based on present industry practice, and is directed at sampling typical, highly redundant bar-to-bar tensile mechanical splices.

C. REGULATORY POSITION

The following procedures should be used for the testing of reinforcing bar mechanical splices in Category I concrete structures:

1. **Crew Qualification**: Each member of the splicing crew (or each crew if the members work as a unit) should prepare two qualification splices for each of the splice positions (e.g., horizontal, vertical, diagonal) to be used. The qualification splices should meet the requirements specified by the designer of the structure and approved by the licensee, pass visual inspection as provided by paragraph 2 below, and meet the tensile tests as provided by paragraph 3 below.

[1] This guide is a revision of former Safety Guide 10. As such, it is applicable to water-cooled nuclear power plants.

[2] Structures, systems and components of a nuclear power plant are designated as Category I if they are designed to withstand the effects of the Safe Shutdown Earthquake (SSE) and remain functional. See Safety Guide 29, "Seismic Design Classification."

Each member of the splicing crew (or each crew of the members work as a unit) is subject to requalification if (1) the specific splice position (e.g., horizontal, vertical, diagonal) has not been used for a period of three months or more, or if (2) completed splices fail to pass the visual inspection test in paragraph 2 below, or fail to pass the tensile tests in paragraph 3 below, or if (3) there is another reason to question their ability. The requalification procedure should be identical to the original qualification procedure described above.

2. **Visual Inspection**: Each splice should be inspected prior to forming to assure that all preparations required by the designer and the splice manufacturer have been properly carried out (e.g., cleaning, drying, alignment). All completed mechanical splices should be inspected at both ends of the splice and at the tap hole in the center of the splice sleeve in accordance with the requirements specified by the designer of the structure and approved by the licensee. All visual inspections on completed splices should be performed only after the splices have cooled to ambient temperatures.

Among the items which should be included in the specifications are longitudinal centering of sleeve on the spliced ends, allowable voids in filler metal, extent of leaking of filler metal, permissible gap between rebar ends, cartidge size, gas blowout, amount of packing and slag at the tap hole. Splices that fail to pass visual inspection should be discarded and replaced, and should not be used as tensile test samples.

3. **Tensile Testing**: Splice samples may be production splices (i.e., those cut directly from in-place reinforcing) or sister splices (i.e., those removable splices made in-place next to production splices and under the same conditions).

Since curved reinforcing bars will not tensile test accurately, production splice samples should not be removed from curved reinforcing bars for tensile testing. Straight sister splice samples should be made as testing substitutes for each of the required curved reinforcing bar production splices. The sampling frequency specified in paragraph 4b. should then be followed.

Production splice samples should not be cut from the structure where the mechanical splicing sleeve is shop welded to an anchorage in a region of high stress concentration, and/or at a leak-tight barrier (e.g., embedded structural steel sections or liner plate). Representative sister splice samples should be used in such cases.

Splice samples should be subjected to tensile tests in accordance with the sampling frequency specified in paragraph 4a. or paragraph 4b. below, to determine conformance with the following acceptance standards:

a. The tensile strength of each sample tested should equal or exceed 125 percent of the minimum yield strength specified in the ASTM Standard appropriate for the grade of reinforcing bar using loading rates set forth in ASTM A 370-68, "Standard Methods and Definitions for Mechanical Testing of Steel Products."[3]

b. The average tensile strength of each group of 15 consecutive samples should equal or exceed the guaranteed ultimate tensile strength specified for the reinforcing bar.

If any sample tested fails to meet the provisions of paragraph 3a. above, the procedure of paragraph 5a. below should be followed. If the average tensile strength of the 15 samples tested fails to meet the provisions of paragraph 3b. above, the procedure of paragraph 5b. below should be followed.

The locations of all reinforcing bar splices, including replacements for production test samples of mechanical splices should be shown on the as-built drawings which are kept for the plant lifetime. For one year after the commencement of commercial operation, additional records should be kept of all splice samples tested, showing the splice location and identification number, as well as whether the tested splice was a production or sister splice.

4. **Tensile Test Frequency**: Separate test cycles should be established for mechanical splices in horizontal, vertical, and diagonal bars, for each bar size, and for each splicing crew as follows:

a. Test Frequency for Production Splice Test Samples. (Program to be used where no curved bars are Cadwelded). If only production splices are tested, the sample frequency should be:

1 of the first 10 splices
1 of the next 90 splices
2 of the next and subsequent units of 100 splices

b. Test Frequency for Combinations of Production and Sister Splices. If production and sister splices are tested, the sample frequency should be:

1 production splice of the first 10 production splices
1 production and 3 sister splices, for the next 90 production splices
3 splices, either production or sister splices, for the next and subsequent units of 100 splices. At least one-fourth of the total number of splices tested should be production splices.

5. **Procedure for Substandard Tensile Test Results**

a. If any production or sister splice tested fails to meet the tensile test specification of paragraph 3a.

[3] Copies may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103.

above, and the observed rate of splices that fail the tensile test at that time does not exceed 1 for each 15 consecutive test samples, the sampling procedure should be started anew.

If any production or sister splice used for testing fails to meet the tensile test specification in paragraph 3a. above, and the observed rate of splices that fail the tensile test exceeds 1 for each 15 consecutive test samples, mechanical splicing should be terminated. In addition, the adjacent production splices on each side of the last failed splice and four other splices distributed uniformly throughout the balance of the 100 production splices under investigation should be tested, and an independent laboratory analysis should be made to identify the cause of all failures. The results of these tests should be evaluated by the designer of the structure and the licensee to determine the required corrective action. The designer and the licensee should specify the extent of repairs necessary and the actions required to prevent further failures from the identified causes.

If two or more splices from any of these six additional splice samples fail to meet the tensile test specification of paragraph 3a. above, the balance of the 100 production splices under investigation should be rejected and replaced.

When mechanical splicing is resumed, the sampling procedure should be started anew.

b. If the average tensile strength of the 15 consecutive samples fails to meet the provisions of paragraph 3b. above, the designer of the structure and the licensee should evaluate and assess the acceptability of the reduced average tensile strength with respect to the required strength at the location from which the samples were taken.