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REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.55

CONCRETE PLACEMENT IN CATEGORY I STRUCTURES

A. INTRODUCTION

General Design Criterion 1, "Quality Standards and Records," of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," requires that sturctures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. Appendix B to 10 CFR Part 50, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," requires that measures be established to assure design control, material control, special processes control, and inspection and test controls. Appendix B also requires that activities affecting quality be accomplished under suitably controlled conditions. This guide describes some acceptable bases for implementing the above requirements with regard to the placement of concrete in Category I structures.[1] The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

B. DISCUSSION

Many standards, manuals, codes, and articles exist which address the proper designing, handling, and placing of concrete. Nevertheless, concrete continues to be improperly placed in nuclear power plants, resulting in lengthly delays and much wasted effort. In particular, the presence of numerous concrete voids which have been detected at or near the surfaces of nuclear containment buildings raises concern about the density of portions of these and other concrete structures that cannot readily be inspected. For such unaccessible areas, the only method of assuring a quality concrete structure is through good planning and control of the placement of concrete and all items embedded in it.

Proper planning and control require that the designer and the constructor be familiar with each other's requirements. The designer should be conscious of the practicality of the design from the constructor's point of view, while the constructor should recognize the consequences of deviating from conditions specified by the designer. It is essential that the two parties meet at an early stage and discuss how these structures will be constructed. Methods that seem expedient or economical may later turn out to have serious adverse consequences.

To date the standards applied to quality control of concrete in nuclear power plants have been based on standards for conventional building structures. Mass concrete standards have generally been considered inapplicable for nuclear construction because the quality level needed for each cubic yard of concrete placed more nearly approximates the quality level required for relatively slender sections of conventional buildings.

At the same time, it is necessary to recognize that in placing deep foundation mats and thick-walled structures or components in nuclear power plants, there are placement problems (e.g., shrinkage and control of heat of hydration during curing) also found in mass concrete pours. Consequently, consideration must be given to the problems and practices of mass concrete pours that are applicable to nuclear power plant structures.

A list of standards, codes, papers, and other references which are generally directed toward the quality placement of concrete is given in Appendix A of this guide. These documents, appropriately selected by the user for the particular application under consideration, provide useful guidance for the planning

[1] 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 Regulatory Guide 1.29, "Seismic Design Classification").

and coordinating activities prerequisite to concrete placement. However, the listing of these references in an appendix to this guide does not constitute a blanket endorsement of their contents.

Individual material specifications (ASTM, etc.) are not included in Appendix A of this guide, since this guide addresses only the requirements for proper planning and coordination in placing concrete so as to avoid the recurring problems of voids, cracks, and bulges which have been experienced in nuclear power plant construction.

C. REGULATORY POSITION

The regulatory positions given below for the applicant, the designer, and the constructor together with the guidance from appropriate documents listed in Appendix A of this guide represent a minimum basis for assuring compliance with the Commission's regulations in Appendices A and B to Part 50 and should be supplemented as necessary in the appropriate quality assurance programs and project specifications. (As an example, in several areas ACI 301 lists stricter concrete sampling requirements than ACI 318. In such cases, the relevant provisions of ACI 301 should govern in the interest of obtaining the best concrete quality practical under existing industry practices.)

1. **Applicant.** The applicant's quality assurance program should ensure that early and regular communication is established between the designer and constructor. Rapid access to the designer should be possible for the constructor in the event that a field condition requires immediate consultation with the designer, such as relocation of a construction joint or an embedded item while placing of concrete is in progress. Conversely, the designer should have rapid access to the constructor in the event that late revisions must be made in the field because of changes in design. Under the provisions of Appendix B to Part 50, the applicant's quality assurance program should also ensure the implementation of sections C.2. and C.3. below.

2. **Designer**

a. The designer should check the design and shop drawings for practicality of:

(1) Placement of reinforcing bars—continuity, congestion, interference, non-planar geometric bending and placing requirements, splice locations and their effect on minimum bar spacing.

(2) Location of embedded items—feasibility of placing concrete completely around the item, considering congestion and interference from other embedded items and reinforcing as well as the type of concrete to be placed (slump, aggregate size, whether preplaced appregate is used, etc.).

(3) Locations of construction joints—locations of acceptable construction joints should be noted, as well as any "windows" in congested reinforcing patterns needed for placing the concrete. Followup coordination and revision with the constructor is essential. Factors for consideration include: type and quantity of concrete to be placed; shrinkage and creep; accessibility; cleanout capability before and after placing the concrete; and acceptability from a strength or functional point of view. Alternative joint locations should be available to the constructor in the event that concrete placement cannot be completed as planned and started.

b. In addition to checking the drawings as noted above, the designer should assist the constructor as necessary in preplanning placement of reinforcement, embedded items, and concrete as well as the sequence to be followed in placing concrete. The designer should also follow the construction while it is in progress, including, if necessary, occasional site visits, and be available for assistance in resolving unanticipated field placement problems that might affect the structural or functional integrity of the structure. Field generated revisions should be approved by the designer.

3. **Constructor.** In addition to the coordination noted above, preplanning by the constructor is necessary for:

a. Cleanness—assuring cleanness of formed area prior to and during concrete placement, including access provisions for inspection and cleanout operations.

b. Installations—installations of reinforcing bars, splices, embedded items, formwork, and construction joint barriers should be checked prior to placing concrete.

c. Placement layout—practicality of construction joint locations, venting of potential air pockets to prevent voids, access to congested or confined areas, sequence of placement.

d. Equipment—availability of proper equipment in good operating condition and in sizes and quantities needed (vibrators, chutes, etc.). Sufficient spares (parts or equipment) should be readily available so that loss or breakdown of equipment will not interrupt the placing of concrete and result in unplanned cold joints.

e. Personnel—sufficient training and experience in the proper use of all equipment (especially vibrators) involved in the placing of concrete. Also sufficient supervisory knowledge and experience to enable the concrete placement to be completed in accordance with specifications.

APPENDIX

BIBLIOGRAPHY OF USEFUL REFERENCES

1. ACI 318-71 Building Code Requirements for Reinforced Concrete (and Commentary)–Chapter 5, "Mixing and Placing Concrete".

2. ACI 301-72 Specifications for Structural Concrete for Buildings.

3. ACI 305 72 Recommended Practice for Hot Weather Concreting.

4. ACI 306-66 Recommended Practice for Cold Weather Concreting.

5. ACI 308-71 Recommended Practice for Curing Concrete.

6. ACI 347-68 Recommended Practice for Concrete Formwork.

7. ACI 614–(Proposed Revision) Recommended Practice for Measuring, Mixing, Transporting and Placing Concrete.

8. ACI Special Publication No. 4–Formwork for Concrete.

9. ACI Committee 207 "Mass Concrete for Dams and Other Structures" ACI Journal April 1970, pp. 273-309.

10. "Cracking Controlled in Massive, Reinforced Structural Concrete by Application of Mass Concrete Practices." L. H. Tuthill and R. H. Adams, ACI Journal August 1972, pp. 481-491.

11. ACI/ASME Proposed Standard–Code for Concrete Reactor Vessels and Containments (ASME Sect. III, Division 2) CB 4200, CC 4200 and CB 4340-4370, CC 4340-4370.

12. ANSI N45.2.5-1972 (proposed) Supplementary Q.A. Requirements for Installation, Inspection, and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plants.

13. Concrete Manual, U.S. Bureau of Reclamation, Denver; Seventh Edition, 1966.

14. Standard Practice for Concrete (EM 1110-2-2000); Dept. of the Army, Office of Chief of Engineers, Washington, D.C.; November 1971.