INSPECTION PROCEDURE 46053

STRUCTURAL CONCRETE WORK OBSERVATION

PROGRAM APPLICABILITY: 2512

46053-01 INSPECTION OBJECTIVES

01.01 To determine by direct observation and independent evaluation whether work and inspection performance relative to structural concrete are being accomplished in accordance with specifications and procedures.

01.02 To determine whether inadequacies in work activities associated with structural concrete indicate a management control problem or generic weaknesses.

Inspection Schedule

May Be Started	Must Be Started	Must Be Completed
As safety-related structural concrete placement is started	Before the containment basemat placement is made	After the last significant Category I placement

46053-02 INSPECTION REQUIREMENTS

02.01 Review the results of the inspection performed under Inspection Procedure (IP) 46051.

02.02 Review the specifications, drawings, and QA/QC and construction procedures applicable to those concrete placements selected to be reviewed under 02.03, below.

02.03 Every three months during the first year of placement of Category I concrete, select at least two placements. Thereafter, select at least two placements per year. Ascertain whether the following activities are being controlled, inspected, and accomplished in accordance with the requirements of the documents reviewed in 02.02, above:

a. Reinforcing Steel and Embedment Placement. Verify the following items have been implemented:

   1. Reinforcing steel, embedments, and formwork are controlled and in accordance with specifications, codes, drawings, and procedures. Reinforcing steel and embedments are located properly in the

structure and in the forms, are secured and free of concrete or excessive rust, and have proper clearances. The areas where embedded plates with anchors are to be set in concrete should have sufficient concrete to provide bond and should not be excessively congested with reinforcing steel. Reinforcing steel bending is properly performed and controlled. Piping or conduit embedments in or through concrete should be capped or plugged prior to concrete placement. Forms are secure, leak tight, and free from water or snow.

2. For containments using post-tensioned tendons inspect the installation of trumpets, bearing plates, and tendon sheathing.

   Inspect the following before concrete is placed:

   (a) Trumpets, bearing plates, and sheathing are installed within specified tolerances and are clean and free of damage.

   (b) Tendon sheathing joints are mortar tight.

   (c) Sheathing vents and drains are installed as specified.

b. Reinforcing Steel Splices. Verify the following:

1. Process and crews are qualified.

2. Each splice is defined by materials used, location, crew, type of splice, and heat number (if applicable).

3. Sampling and testing are performed at proper frequency and acceptance criteria are defined.

4. Inspections are performed during and after splicing by qualified inspection personnel.

c. Liner Plate Erection and Fabrication. Verify the following:

1. Plate and other materials are controlled in accordance with specifications, codes, drawings, and procedures.

2. Forming, fitting, and aligning are properly controlled as required.

3. Welding is in accordance with approved procedures by qualified welders.

4. Examination and testing are in accordance with the specification, codes, drawings, and procedures.

d. Concrete Batching and Delivery. Verify the following items have been implemented in the concrete production and delivery process:

1. Batch plant is properly qualified and producing concrete of the proper mix design. Scales and meters are calibrated. Equipment performs properly - rotation speed, timing, and blade wear are not excessive. No contamination of materials or concrete mix. Batch records are generated, controlled, and indicate placement location, mix, volume, date, time, and special instructions. This item need only be done every 18 months.

2. Materials are properly qualified and traceable to approved sources. Storage and handling are not detrimental; i.e., cement is protected from moisture and

aggregate is not subject to excessive segregation of sizes, contamination, or mixing.

3. Batch water quality requirements are met and water is adjusted to account for moisture content of aggregates. Aggregate moisture content tests are representative of actual stockpile conditions.

4. Transporting equipment is suitable and in an acceptable condition.

5. Time limit between mixing and delivery has not been exceeded.

6. Temperature limits have been met.

7. Slump test results are being utilized at the batch plant to maximize placeability in more uniform batching. Water additions require remixing in the truck and conformance to ASTM C94 on uniformity of mix. There should be precautions on the amount of retempering water additions allowed in consideration of the water-cement ratio.

e. Placement. Verify that the following items have been incorporated in the concrete placement process:

1. Pre-placement planning and training has been completed as required to assure good quality construction and to protect against unplanned construction joints.

2. The pre-placement inspection performed by QC has been completed before any concrete is placed.

3. The equipment to deliver concrete to the actual placement location is suitable and in an acceptable condition - conveyors, lines, pumps, buckets, etc.

4. The placement has been cleaned and joint preparation is as specified in the construction specification.

5. Batch ticket is reviewed for verification of proper mix, placement location, and amount of temper water being added at the truck delivery point.

6. Placement drop distances do not exceed specification requirements and do not result in segregation.

7. Vibrators are approved, tested for frequency, and are used properly by trained individuals.

8. Special attention is given to areas of high reinforcing or embedment steel congestion to preclude areas of voids or honeycombing.

9. Records are produced, reviewed, and indicate mix, location, time placed, water additions, and temperature of the concrete mix and ambient conditions.

10. Inspection during placement is performed as required.

f. In-Process Testing. The following items should be verified in the review of the testing program conducted during the placements:

1. Concrete temperature, slump, air content, and unit weight are being determined at the proper location and frequency.

2. Taking of the sample and testing techniques conform to the procedures specified in the ASTM standards.

3. Test specimens for concrete strength determination are sampled at the required location and frequency and are molded and cured in accordance with specified requirements.

4. Personnel performing sampling and testing are trained and qualified.

g. Curing. Verify that curing is in accordance with specifications and procedures with regard to the method, materials, duration, temperature (concrete and ambient), inspections (during curing and after form removal), and records.

h. Interviews. Informal interviews with field craft and inspection personnel should be randomly conducted to determine their knowledge of the work activity being performed. Also, a sense for the degree of the adversary or intimidating relationship with the construction forces can be determined. Perceived management support should be identified. Any adverse trend should be identified to regional management.

i. Acceptance. Verify that the final inspection results after form removal, test results and other information related to the placement (including deficiencies, defects, etc.) have been subjected to an integrated review before acceptance of the placement and that the as-built documentation is complete.

02.04 Semiannually during the placement of Category I concrete, the on-site laboratory should be inspected to verify that the materials and concrete testing activities are being controlled as required.

a. Personnel Qualifications. The education, experience, and training of testing and inspection personnel have been verified by the employing organization. Verification must be supported by documentation. Certification of inspectors must show which ASTM tests the inspector is qualified to perform.

b. Evaluation of Test Results. The evaluations are being performed at an appropriate level and includes trending analysis. The records must be retrievable. There should be a mechanism for feedback to production control.

c. Observed Testing. Testing conforms to the procedures specified in the ASTM standards. The procedures must be available at the work location.

d. Calibration. Testing apparatus is being calibrated at the required frequency.

02.05 Special Considerations - The following items should be incorporated in the inspection of concrete placements when appropriate (refer to ACI standards for additional guidance):

a. Hot and Cold Weather. Provisions for maintaining concrete temperature within specification must be provided. Hot and cold weather conditions must be defined to avoid confusion.

b. Pumping Concrete. Slump and air content losses must be monitored in order to assure placeability and adequate consolidation.

c. Large Placements. Planning sessions must assure consideration of all contingencies.

02.06 Additional inspections, as determined by Regional management, may be conducted in the inspection areas covered above when licensee performance is classified as Category 3 by the SALP program, or if Regional management concludes that recent findings will likely result in a SALP Category 3 rating. In these cases, particular consideration should be given to an expanded sample of items to be inspected under Section 02.03a, 02.03d, 02.03e, 02.03f above.

46053-03 INSPECTION GUIDANCE

General Guidance. Before observing the activities in 02, above, review the pertinent construction and QC procedures as well as applicable codes, standards and Regulatory Guides. The American Concrete Institute "Manual of Concrete Inspection" should be utilized during the conduct of this inspection; however, the licensee's specific documents control the construction and inspection procedures.

Due to the difficulty in performing remedial work and post-placement inspections on placed concrete, the first use of safety-related concrete should receive special emphasis. In most cases these first safety-related activities will be associated with large basemat placements. At this point in time, consideration should be given to performing this inspection as a group effort with the lead inspector being someone with a civil engineering background. Subsequent to the inspection of the large basemat placements, periodic observation of concrete placements, as required in 02, above, will provide assurance that conformance to applicable requirements is being accomplished.

Selection of placements to be observed should provide for diversification of placement type and of safety-related structures. Placement types to be selected should therefore include:

- basemats (containment/reactor building and auxiliary building)
- containment/shield building wall (early and late placements, under large openings, and near the polar crane brackets)
- containment dome (early placements)
- columns, shear walls, beams, and slabs in the reactor building, auxiliary building, and fuel handling building
- primary or secondary shield walls/biological shield wall or other internal structural concrete
- other areas such as the intake structure or fuel handling building.

Findings from this inspection activity should address each element as being satisfactory, being unresolved and requiring resolution, or being in violation and requiring correction. When significant inadequacies are identified in specifications or procedures indicating weakness within the preparing technical organization, the inspector should inform cognizant regional supervision. The issue should be addressed at the appropriate level of licensee management. Some inspection requirements and guidance in this procedure may not apply to all facilities.

03.01 Specific Guidance

Note: The numbering of the guidance below refers to specific subsections of 02, above.

02.03a2(a) Exceeding specified tolerances may affect the tensioning force required due to frictional losses. Surveying instruments may be used for location measurements.

02.03b For splices, review the mechanical splicing instructions issued by the vendor. This document usually specifies the proper performance of all mechanical splicing operations. Ascertain whether it is being used.

When Cadwelding operations are being performed, observe that specified materials (sleeves, powder, packing) are properly stored, and that Cadwelding fixtures are in good condition. The reinforcing steel to be Cadwelded should be cleaned shortly before Cadwelding to remove all nonadherent rust. The reinforcing steel ends should be aligned and butted within the tolerances specified.

Observe the placement of sleeves and the use of a marking system to ensure centering. When the firing is complete and packing removed, examine the sleeve and reinforcing steel to ensure that metal is showing at the vent, no slag at the tap hole, and each end of the sleeve shows proper fill (allowable void area not exceeded).

Ascertain whether each Cadweld sleeve is identified. By interviews with two Cadwelding inspectors, ascertain whether they are familiar with the details of Cadwelding requirements; also determine whether inspections of Cadwelding conform to the specified frequency, whether inspection (QC) records are being maintained, and whether records are traceable to the location and identification of the sleeve (Reference RG 1.10 and ACI 318).

02.03d1 Concrete batch plants providing concrete for use at nuclear facilities are normally expected to have been certified under the NRMCA (National Ready Mixed Concrete Association) program. This certification provides evidence that a registered professional engineer has reviewed the facility and has seen evidence that certain necessary capabilities exist to produce quality concrete. Any other batch plant certification should include the inspection attributes listed in the NRMCA checklist which is used to inspect the facility prior to any recommendation for certification. This portion of the inspection need only be done every 18 months.

02.03d3 The moisture content determination of aggregates becomes very important if the aggregate stockpiles are exposed to the elements.

02.03d7 The practice of withholding water at the batch plant and then tempering at the point of placement should take into account the results of air content and slump measurements taken at the point of placement. Efficient radio communications between the batch plant and field QC testing personnel will minimize the need for water tempering at the point of placement and thus result in more uniform batching.

02.03e2 Quality control pre-placement inspections must not be unnecessarily rushed by advancing concrete work, especially during large slab or basemat placements. When possible, verify the actual as-built condition of reinforcing steel with respect to the engineering drawings. If deviations exist, verify that proper engineering evaluations have been performed.

02.03e3 Consider the potential for segregation of aggregates due to mishandling.

02.03e5 Check time of concrete receipt for truck transported, centrally mixed concrete. Also verify the amount of water added, if permitted, and mixing time. Be sure that the placement is in accordance with specifications using required equipment to prevent the occurrence of excessive air voids.

02.03e6 Concrete should not strike forms or bounce against reinforcing bars causing segregation of aggregates.

02.03e7 There should be a sufficient number of vibrator operators and, preferably, some spare vibrators, which should be checked for proper operation before starting to place concrete. Vibrators less than 3" diameter are generally designed to operate at about 7000-8000 vibrations per minute when immersed in concrete. Large vibrators, used in heavy section concrete placement, operate at about 6000 vibrations per minute. Vibrators less than 3" in diameter can be operated by one man; 4" or larger vibrators are 2-man tools. Proper vibrator operation involves duration of vibration, distance between vibrator insertions, and depth of insertions. The vibrators should be handled and operated vertically and never "cast" away from the operator horizontally and then retrieved. Concrete should be placed horizontally, in about 12" layers, and never allowed to pile much higher in one area of the form than another. The vibrator should penetrate through the new concrete well into the previously placed layer to avoid any "layer cake" effect. Occasional contact of a vibrator with the forms is permissible, and with the reinforcement is desirable. Form vibration is generally not desirable, and care should be taken that reinforcement is not displaced by vibrators, or by people walking on the steel. Vibrators should not be used to move concrete laterally.

02.03i This portion of the inspection may require subsequent followup to determine that final inspection, evaluation, and acceptance are being controlled and accomplished in accordance with QA/QC requirements. Final inspection procedures should include verifying embed locations and defining any defects and required repairs.

02.04a Particular attention should be directed toward the qualification of personnel and their work performance. There has been a tendency for commercial labs to hire untrained personnel near the site who had no prior work in materials testing, train them, and certify them. In some instances the lack of experience and depth of knowledge in this type of personnel has been found to be detrimental to a quality assurance and quality control program. Changing of personnel between different jobs and turnover of personnel can also result in problems.

There has been some confusion concerning whether or not the on-site testing laboratory must be inspected by a qualified national authority. In ACI 301, Specifications for Structural Concrete, Section 16.2 requires the testing laboratory meet ASTM E 329, which requires inspection by a qualified national authority. However, in the "Instructions to the Architect/Engineer" of ACI 301, Section 16.2 is listed as a supplemental requirement to be designated if applicable. Therefore, unless the construction specifications specify such inspection, there is no NRC requirement to do so.

In some instances the A/E, the constructor or the owner may have placed a requirement that defines a need for laboratory inspection or review. This may be by reference to ASTM E 329 which could be satisfied by the efforts of Cement and Concrete Reference Laboratory/Materials Reference Laboratories (CCRL/MRL) of the National Bureau of Standards. If such a review has been performed, the results can aid in NRC inspection efforts. These results should be obtained and reviewed prior to any NRC inspection efforts related to the materials and concrete test laboratory.

02.05a During periods when concrete is to be placed or cold weather is expected during the curing time, provisions must be made to keep the concrete above 40°F, preferably in the range of 50 to 60°F. If concrete is being mixed or transported in weather below 40°F, the ingredients may be prewarmed so that the temperature of the concrete after placement is elevated to account for losses. Heating the water is the most effective and most easily controlled technique, but the aggregate must not be frozen. The water should not be so hot as to cause "flash set" of the cement during mixing; that is, the temperature of the mortar should not exceed 100°F. If hotter water is required to warm the aggregate, the water and aggregate may be mixed prior to addition of cement. If the aggregate is heated, close control must be exercised, and the aggregate must be

frequently checked for variations in moisture content caused by local variations in heating. Direct fired heaters may produce carbon dioxide in the exhaust fumes forming calcium carbonate on the surface of fresh concrete.

Where the ambient temperature during concreting rises much above 70°F, consideration must be given to the effect of high temperatures on the concrete. Although concrete cured at temperatures up to 100°F gives higher early strength, with little degradation of long-term strength, high temperatures during mixing, transportation, and placement can be seriously detrimental. The most obvious effect is that the concrete requires more water for workability or the use of additives. A less obvious effect is the need for special attention to curing, because the higher temperature increases water evaporation from the concrete.

Exposure to strong summer sun can raise the temperature of ingredients, equipment, forms, etc. far above the air temperature. If this occurs, provisions should be made for appropriate shades or screens and the equipment, forms, metallic embedments, etc. should be wetted just prior to concrete placement. If the ambient temperature is high enough so that the bulk temperature of freshly mixed concrete exceeds 80°F or 90°F, consideration should be given to some method of cooling the ingredients, such as chilling the water or using ice. If ice is used, it must be crushed or flaked so that all the ice is melted by the time mixing is completed.

03.02 Prevalent Errors and Recent Concerns

a. This section is included to provide background for inspectors on past structural concrete problems that have been identified and to certain areas that should be more closely scrutinized so as to give the NRC early information on potential problems.

These items are aimed at assuring that the NRC is aware of how the project is actually being run with respect to design-construction interfaces, construction discipline interfaces, and the control exercised by the licensee, as well as the licensee's knowledge of how the project is progressing. The list is not intended to be all-inclusive but to provide some highlights on this subject.

1. Check design documents (specifications, drawings, etc.) for evidence of coordination with other disciplines and designers, suppliers, and contractors which address items such as embedded piping, electrical, mechanical and major equipment supports.

2. Examine how well the design office is permanently represented at the site and if the representatives spend time out in the work areas. Determine how well the licensee's engineering is represented at the site and the function of the group.

3. Determine how often design engineers come on site and actually follow-up at the work-site as part of their design is being constructed, and the methods of interchange between designer, constructors, inspectors, and managers. Determine how well the licensee's engineering function is represented by other than permanent personnel.

4. Determine whether field engineering and construction personnel are reviewing drawings, specifications, etc. released for construction for constructability, errors or omissions, and inconsistencies with other documents or instructions. Determine the licensee's real role in this process.

5. Check field construction progress and release of engineering design drawings including the revisions or changes to determine if the design and

the construction efforts are synchronized; that is, after design drawings are released for construction, design engineering should not make last minute changes and revisions just before concrete placements are made without close coordination with construction.

6. Determine how training is viewed by construction workers and QA/QC personnel and how well training is completed and used at the site.

7. Look at consistency (is there high turnover?) of the work force, the attitudes in work crews, and relations between construction personnel and QA/QC personnel.

8. Look for changes in the organization of the field construction forces, or QA and QC personnel organization.

9. Look at the controls and coordination exercised when a new work activity begins.

10. Look for changes in sources of materials from those originally being used. If major changes occur, reinspection of mix designs may be in order.

11. Check the controls used to ensure that all embedded items including reinforcing are in fact in place prior to concrete placement.

12. Determine whether the construction labor forces also perform their own checks of work as it is completed or if they rely solely on QA/QC.

13. Look at how the QA/QC inspectors perform their inspection and check-offs. Is it done sequentially as work is being done? For example, during reinforcing steel placement, do they wait until two weeks of reinforcing steel placement have been made and then on the day prior to concrete placement, identify bars placed on day number 4 in the sequence as being out of tolerance.

14. Look at the level (experience, training, and number) of supervision during concrete placement activities.

b. The following concrete-related violations, listed in order of frequency of occurrence, represent the potential findings that NRC inspectors should remain aware of: (Note - These are not listed in order of their perceived importance to safety.)

1. Inadequate QA/QC records of Category I work.

2. Improper use of vibrators.

3. Exceeding allowable time to place concrete.

4. Improper sampling of aggregates.

5. Improper curing of concrete test cylinders.

6. Exceeding allowable concrete temperatures.

7. Materials improperly certified.

8. Cylinder break test records exceed allowable coefficient of variation.

9. Improper splicing practices (reinforcement cleaning, alignment, gage marks, thread damage, inadequate swagging force, etc.).

10. Inadequate concrete curing.

11. Samples of concrete not taken where and when required.

12. Excessive doses of concrete admixtures.

13. Inadequate cleanliness of placement.

14. Spacing of reinforcing steel in error.

15. QC inspections not done conscientiously.

16. Excessive drop of concrete.

17. Batch plants improperly qualified.

46053-04 REFERENCES

SAR, Chapters 1, 3 and 17, including pertinent codes and standards referenced in these chapters.

Regulatory Guide 1.10, Mechanical (Cadweld) Splices in Reinforcing Bars of Category I Concrete Structures.[1]

Regulatory Guide 1.15, Testing of Reinforcing Bars of Category I Concrete Structures.[1]

Regulatory Guide 1.18, Structural Acceptance Test for Concrete Primary Reactor Containments.[1]

Regulatory Guide 1.19, Nondestructive Examination of Primary Containment Liner Welds.[1]

Regulatory Guide 1.38, Quality Assurance Requirements for Packaging, Shipping, Receiving, Storage and Handling of Items for Water-Cooled Nuclear Power Plants.

Regulatory Guide 1.55, Concrete Placement in Category I Structures.[1]

Regulatory Guide 1.58, Qualification of Nuclear Power Plant Inspection, Examination and Testing Personnel.

Regulatory Guide 1.94, Quality Assurance Requirements for Installation Inspection, and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plants.

Regulatory Guide 1.103, Post-Tensioned Prestressing Systems for Concrete Reactor Vessels and Containments.[1]

Regulatory Guide 1.107, Qualifications for Cement Grouting for Prestressing Tendons in Containment Structures.

Regulatory Guide 1.136, Materials, Construction, and Testing of Concrete Containments.

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[1] These Regulatory Guides were withdrawn by Regulatory Guide 1.136, Revision 2, June 1981. Implementation of Regulatory Guide 1.136, Revision 2 is for applications docketed after May 1981.

Regulatory Guide 1.142, Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containment).

END