Progress Energy

Serial: NPD-NRC-2011-044 10CFR52.79
May 27, 2011

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-0001

LEVY NUCLEAR PLANT, UNITS 1 AND 2
DOCKET NOS. 52-029 AND 52-030
SUPPLEMENT 4 TO RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 086 RELATED TO FOUNDATIONS

References:

1. Letter from Terri Spicher (NRC) to Garry Miller (PEF), dated March 16, 2010, "Request for Additional Information Letter No. 086 Related to SRP Section 3.8.5 for the Levy County Nuclear Plant, Units 1 and 2 Combined License Application"
2. Letter from John Elnitsky (PEF) to U. S. Nuclear Regulatory Commission (NRC), dated August 18, 2010, "Response to Request for Additional Information Letter No. 086 Related to Foundations," Serial: NPD-NRC-2010-068
3. Letter from John Elnitsky (PEF) to U.S. NRC, dated November 2, 2010, "Supplement 1 to Response to Request for Additional Information Letter No. 086 Related to Foundations", Serial: NPD-NRC-2010-080
4. Letter from John Elnitsky (PEF) to U.S. NRC, dated January 25, 2011, "Supplement 2 to Response to Request for Additional Information Letter No. 086 Related to Foundations", Serial: NPD-NRC-2011-001
5. Letter from John Elnitsky (PEF) to U.S. NRC, dated May 12, 2011, "Supplement 3 to Response to Request for Additional Information Letter No. 086 Related to Foundations", Serial: NPD-NRC-2011-042

Ladies and Gentlemen:

Progress Energy Florida, Inc. (PEF) hereby submits a supplemental response to the Nuclear Regulatory Commission's (NRC) request for additional information provided in Reference 1. Revised responses to NRC questions 03.08.05-4 and 03.08.05-6 are provided in the enclosure. The enclosure also identifies changes that will be made in a future revision of the Levy Nuclear Plant Units 1 and 2 application.

If you have any further questions, or need additional information, please contact Bob Kitchen at (919) 546-6992, or me at (727) 820-4481.

I declare under penalty of perjury that the foregoing is true and correct.

D094
NRO

Progress Energy Florida, Inc.
P.O. Box 14042
St. Petersburg, FL 33733

Executed on May 27, 2011.

Sincerely,

John Elnitsky
Vice President
New Generation Programs & Projects

Enclosure/Attachments

cc : U.S. NRC Region II, Regional Administrator
Mr. Brian C. Anderson, U.S. NRC Project Manager
Ms. Terri Spicher, U.S. NRC Project Manager

Levy Nuclear Plant Units 1 and 2
Supplement 4 to Response to NRC Request for Additional Information Letter No. 086
Related to SRP Section 3.8.5 for the Combined License Application,
Dated March 16, 2010

NRC RAI #	Progress Energy RAI #	Progress Energy Response
03.08.05-4	L-0860, L-0861 & L-0862	NPD-NRC-2010-080; November 2, 2010 & NPD-NRC-2011-042; May 12, 2011 & Revised response enclosed – see following pages
03.08.05-5	L-0729	NPD-NRC-2010-068; August 18, 2010
03.08.05-6	L-0923	Revised response enclosed – see following pages
03.08.05-7	L-0864	NPD-NRC-2011-001; January 25, 2011

NRC Letter No.: LNP-RAI-LTR-086

NRC Letter Date: March 16, 2010

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 03.08.05-4

Text of NRC RAI:

In the applicant response to Question 3.8.5-02, Part 2, of RAI 2925 (NRC Letter No. 055) the applicant provided a description of two testing programs associated with the RCC bridging mat. One program is associated with production testing and a second testing program associated with an RCC Test Program conducted prior to construction. The applicant provided a description of the tests that will be performed to assess shear strength both for the base material and for the lift joints including identification of the testing methods to be used. However, the response does not clearly address the number of tests to be performed and how the variability of RCC properties will be assessed. Thus, the staff is requesting that the applicant provide the following:

1. A detailed description as to how the proposed RCC construction for the Levy plant is similar to the construction for which the shear strength to compressive strength correlations provided by the USACE is appropriate.
2. Furthermore, direct shear tests are described which are to be used for the test program. It is not clear whether sampling of the production mat will be sampled to provide direct shear tests on "as-placed" material. Additionally, once the three direct shear tests are performed, how will the results of those tests be used to predict "design" strength?
3. If the mat is to be designed following typical concrete codes used for structures, then the concrete codes are targeting about a 1% probability of failure of the material, given the design load. It is not clear from the discussion how nominal capacities will be established from just three samples. Furthermore, it is not clear from the discussion provided whether factored loads, consistent with ACI structural codes are to be used for the design assessment.
4. The applicant has indicated in discussions with the NRC staff that an expanded test program is under development. A written description of this expanded program is required in order for the NRC staff to complete an evaluation of the acceptability of the final test program. This expanded program should include discussion that identifies the expected variability of material properties, methods used to quantify the variability, how this variability is incorporated into developing an appropriate factor of safety for design, as well as how the tests that will be performed during production will assure that the design strengths will be achieved.

PGN RAI ID #: L-0862

PGN Response to NRC RAI:

This is a revised response that replaces the NRC Letter 086, RAI 03.08.05-04 response and Attachments (PGN RAI ID #: L-0728) submitted via Progress Energy Letter NPD-NRC-2010-068 dated August 18, 2010. Supplement 1 to NRC Letter 086, RAI 03.08.05-04 response (PGN RAI ID #: L-0860) submitted via Progress Energy Letter NPD-NRC-2010-080 dated

November 02, 2010 and Supplement 3 to NRC Letter 086, RAI 03.08.05-04 response (PGN RAI ID #: L-0861) submitted via Progress Energy Letter NPD-NRC-2011-042 dated May 12, 2011 complement this revised response. This revised response also provides the following information requested by the NRC during the April 27-28, 2011, NRC meeting to witness the RCC Specialty Tests in Tucson, AZ as follows:

I. Summary report of commercial RCC experience and test data.

II. Description of materials, processes, and equipment types/sizes from commercial projects and a commitment that those used for LNP will be similar.

III. Identify the specific RCC mix design for the LNP project, and confirm the acceptability of this mix to provide the characteristics required for the foundation design.

IV. Submit the 90-day specialty test report verifying RCC strength characteristics.

V. Submit post-COL RCC Strength Verification and Constructability Testing plan.

VI. Add a new FSAR Subsection 3.8.5.11 summarizing information on commercial test results, RCC mix design, pre-COL 90-day testing, and commitments for the post-COL testing and the use of equipment and process validated by the post-COL testing in production construction of the RCC Bridging mat.

VII. Add a new License Condition for post-COL testing stating that the licensee will complete 180-days prior to construction, the 90-day test report for the Strength Verification and Constructability Testing in accordance with the criteria outlined in FSAR Section 3.8.5.11.3.

VIII. Revise COLA Part 10 "Table 3.8.3: LNP COLA RCC ITAAC" as discussed at the meeting.

The revised response to NRC Letter 086, RAI 03.08.05-04 is as follows:

1. LNP RCC construction will follow industry standard methods that have been successfully implemented on large commercial RCC projects. This provides assurance that LNP RCC bridging mat can be successfully constructed and will have the desired strength. Attachment 1, "Previous Commercial RCC Experience," Revision 1, summarizes the RCC production and placement practices that were used for three large commercial RCC projects.

   United States Army Corp of Engineers Engineering Manual EM 1110-2-2006 (USACE EM 1110-2-2006) describes standard equipment and practices that are used during RCC construction. These practices include guidance for developing RCC mixes, procedures for RCC placement and compaction, and for lift surface preparation. The LNP RCC construction specifications will specify RCC mixing, placement, and compaction equipment, as well as procedures associated with each to be consistent with USACE EM 1110-2-2006 guidelines and incorporate practices used in the successful commercial projects. The LNP RCC construction specifications will also specify additional requirements for nuclear safety grade Quality Assurance.

   Attachment 1, "Previous Commercial RCC Experience," compares the RCC mixes, aggregates, cement, and fly ash from three large commercial RCC projects to those planned for use in the LNP RCC bridging mat. The report concludes that the properties of the aggregates, cement, and fly ash planned for LNP will meet or exceed the requirements used for these successful commercial projects.

Quality control and inspection during production construction, as described in FSAR Subsection 2.5.4.12 and Attachment 2, "Post-COL Roller Compacted Concrete Test Plan," Revision 3, will ensure that the mixing, placement, and compaction of production RCC complies with the LNP RCC construction specifications.

The report "Previous Commercial Testing Results," Revision 0, submitted in Supplement 1 to NRC Letter 086, RAI 03.08.05-04 response (NPD-NRC-2010-080 Dated November 02, 2010) described the RCC testing results from three large commercial RCC projects. The following can be concluded from these commercial testing results:

- The compressive strengths measured during production construction exceeded those that were measured during pre-construction mix design laboratory testing. Thus, laboratory testing during RCC mix design provides reasonable assurance that the desired RCC compressive strength will be achieved or exceeded during production construction.
- The measured modulus of elasticity from commercial testing correlates well with that computed using ACI 318-99 Section 8.5.1 method. Thus use of ACI 318-99 Section 8.5.1 for modulus of elasticity for RCC design is appropriate.
- The USACE EM 1110-2-2006 correlation that the direct tensile strength of RCC is approximately 75 percent of the split tensile strength trends close to the ACI 318-99 equation 22-2 for tensile strength. Thus the use of ACI 318-99 equation 22-2 for tensile strength in RCC design is appropriate.
- Shear tests performed on pre-cracked (at lift joints) block samples show that the friction angle when concrete bedding mix is used is greater than the 45 degrees design value provided in the USACE EM 1110-2-2006. Thus, the use of 45 degrees friction angle for shear capacity in RCC design across lift joints is appropriate.

2. The production RCC bridging mat will not be cut for testing. Testing of the production mat will be confirmatory, using non-destructive testing methods to ensure that the construction of the RCC and bedding joints is in accordance with the RCC construction specifications. The report "Post-COL Roller Compacted Concrete Test Plan," Revision 3, (Attachment 2), describes the testing that will occur during construction of the RCC bridging mat, including quality control testing. According to USACE EM 1110-2-2006, the characteristics required to obtain good RCC and bond strength at the lift joint include good-quality aggregate, good mixture workability and compaction effort, rapid covering of lift joints by subsequent lifts, and the use of bedding mix. These items will be addressed in the RCC construction specifications and construction Quality Control program for RCC bridging mat construction as follows:

   The quality of aggregate, cement, and fly ash from multiple sources was evaluated during the RCC mix design program. The RCC construction specifications will specify aggregate, cement, and fly ash sources and quality requirements comparable to those used for the LNP RCC mix design program (Supplement 3 to NRC Letter 086 RAI 03.08.05-04 response (NPD-NRC-2011-042 dated May 12, 2011). Coarse aggregate complying with ASTM C33 will be used. Type II cement complying with ASTM C 150 and ASTM C 186 and Class F fly ash complying with ASTM C 618 requirements will be used.

To ensure the quality and uniformity of the RCC during production, the aggregate will be tested daily for conformance to construction specifications for gradation and moisture content. Monthly tests of each aggregate during construction will verify that it continues to meet requirements for specific gravity, organic impurities, and LA Abrasion.

RCC mix workability will be measured by Vebe testing for RCC and slump testing for bedding mix. The selected RCC and bedding mix from the RCC Mix Design program had acceptable workability. During construction, Vebe time for RCC and slump of bedding mix will be measured at least once per shift to monitor the workability of the mixes. Other properties, such as the temperature of the RCC at the point of placement, and the air content of the RCC will also be monitored. During RCC construction, thermocouples or thermistors will be used to monitor Joint Maturity Value (JMV).

Post-COL RCC and bedding mix strength verification and constructability testing (RCC Test Program Phase IV) will be performed on a large test pad as described in Attachment 2, "Post-COL Roller Compacted Concrete Test Plan," Revision 3. This testing is being performed post-COL but prior to construction of the LNP bridging mat for the following reasons:

- Due to the limitation on mixing and compaction equipment sizes that can be used in a laboratory setting, the required compaction cannot be achieved in a laboratory setting. A larger scale test pad in an open field setting is required.
- Because RCC design strength is specified as the 365-day strength, it is not practical to perform destructive testing on the RCC bridging mat during construction on cored or block cut test specimens.

The post-COL RCC strength verification and constructability testing will be performed post-COL at the LNP site. The tests will verify that the specified RCC compressive strength, ACI 318 specified tensile strength, and USACE EM 1110-2-2006 specified shear strengths across lift joints can be achieved. A RCC test pad measuring approximately 42 ft.x40ft.x6 ft. will be constructed using the specified RCC and bedding mixes. The test pad construction will use mixing, placement, and compaction procedures and equipment comparable to those that will be used during LNP RCC bridging mat construction. The constitutive materials for the RCC mix will be comparable to that used in the RCC mix design program (Supplement 3 to NRC Letter 086, RAI 03.08.05-04 response). Six inch cores from the RCC test pad will be used to verify that the design compressive strength is achieved and the split cylinder strength meets ACI 318-99 requirements. Blocks cut from the RCC test pad similar in size to those used in the pre-COL specialty testing program will be used to verify that USACE EM 1110-2-2006 shear strength are achieved across lift joints. Shear test specimens with JMV of approximately 2500 Degree Hours ("warm" joint) and with JMV of approximately 4700 Degree Hours ("cold" joint) will be tested. Thermocouples or thermistors will be used to monitor JMV. "Cold" joints will be green cut prior to placement of the subsequent RCC lift.

The geometry and loading on the LNP RCC bridging mat is such that there is no tension across lift joints. Thus, no tensile strength tests across lift joints will be performed.

The post-COL strength verification and constructability test report with 90-day test results will be completed at least 180-days prior to start of LNP RCC bridging mat construction.

The RCC construction specifications, non-destructive testing and quality controls during construction together with implementing procedures and equipment comparable to those used on past successful RCC projects, pre-COL RCC mix design testing, the pre-COL

RCC testing, and planned post-COL RCC testing using a large test pad provides sufficient assurance that the LNP design compressive and tensile strengths, and shear strengths across lift joints will be achieved during the RCC bridging mat construction using the RCC and bedding mix, mixing and placement procedures and equipment, and the compaction equipment specified for construction.

3. For design, RCC nominal strength capacities were established using ACI 349 and ACI 318 equations and USACE EM 1110-2-2006 guidance. The Finite Element Model (FEM) of the RCC Bridging Mat has confirmed that these capacities are adequate for the anticipated loading conditions and postulated conservative karst sizes and configurations as described in FSAR Subsection 2.5.4.5.4.

   The RCC Mix Design program and 56-Day test results are described in Supplement 3 to NRC Letter 086, RAI 03.08.05-04 response submitted via Progress Energy Letter NPD-NRC-2011-042 dated May 12, 2011. In the LNP RCC Mix Design program, sixteen trial RCC mixes were tested and all yielded RCC compressive strengths greater than the 2500 psi used in the FEM analysis. Five trial bedding mixes were tested and all yielded a compressive strength of greater than 4000 psi. The RCC mix and bedding mix design program evaluated the effects of water-cementitious material ratio, fly ash replacement percentage, fly ash sources, and aggregate sources with respect to strength and workability. This mix design program demonstrated that design workability and strength requirements can be achieved with the trial mixes and constituent materials procured for the program. The program concluded with the selection of a single RCC mix and a bedding mix that is workable, and meets design compressive strength while minimizing the cement content for favorable thermal characteristics. The results of the mix design program will be used to develop the LNP RCC construction specification for RCC constituents mix proportions and properties of the constituent materials.

   For the selected LNP design RCC mix, laboratory testing was performed as described in Attachment 3, "90-day Report Phase III Specialty Testing Program," Revision 0. In this program RCC test cylinders and three RCC test panels measuring approximately 7 ft.x7 ft.x2 ft. were cast. The RCC panels were cast in two layers with bedding mix between the two layers. The RCC constitutive materials used for this phase were from the same sources as for the RCC Mix design program. Test panels with JMV of approximately 2500 Degree Hours ("warm" joint) and with JMV of approximately 4700 Degree Hours ("cold" joint) were constructed. In the panel with the "cold joint", layer 1 was green cut prior to placing the bedding mix and the second layer of RCC.

   The compressive and split tensile strength test results from laboratory cast cylinders in this program were consistent with past RCC experience and validated use of ACI 318-99 equations for tensile strength and modulus of elasticity. The tests also verified that the selected LNP RCC mix yields compressive strength greater than the specified 2500 psi and split cylinder tensile strength consistent with ACI 318-99 correlations. However, preliminary testing on cored cylinders from the test panels indicated that the concrete in the test panels did not attain the desired compressive or tensile strengths. This low strength is believed to be due to the constructability issues related to construction of the laboratory-scale test panels that required the use of small mixing and compaction equipment. As stated before, LNP production RCC construction will use mixing, placement, and compaction equipment consistent with USACE EM 1110-2-2006 guidance and comparable to that used in large successful commercial projects.

Three block shear samples cut from the test panels were tested. These bi-axial shear tests yielded shear strengths at least 1.67 times the maximum design demand shear across lift joints even though the test panels did not achieve the desired compressive strength at 90-days.

Due to the low RCC strength achieved in the specialty test panels and the limitation of mixing and compaction equipment that can be used in a laboratory setting, it was decided that "RCC Strength Verification and Constructability Testing" will be performed post-COL at the LNP site using LNP specified RCC and bedding mixes. The test pad will be constructed using RCC mixing and placement procedures and equipment, and compaction equipment comparable to those that will be used in production construction as described in Attachment 2. Conducting the "Roller Compacted Concrete Strength Verification and Constructability Testing" post-COL but prior to production construction is acceptable because of the following reasons:

- RCC Mix Design testing shows that the specified compressive and split tensile strength can be achieved with the trial RCC mixes.
- Laboratory cast cylinders from both the mix design program and the RCC specialty test program using the LNP selected RCC design mix exceed the compression and tensile strengths required for the project.
- Biaxial shear test results on block samples from the RCC specialty test panel yielded shear strengths at least 1.67 times the maximum design demand shear across lift joints, despite the fact that the test panels did not achieve the desired compressive strength.
- Post-COL RCC Strength Verification and Constructability Testing (RCC Test Program Phase IV) as described in Attachment 2 "Post-COL Roller Compacted Concrete Test Plan," Revision 3, will be conducted prior to RCC bridging mat construction to verify that the design specified compressive strength, ACI 318-99 specified tensile strength, and USACE EM 1110-2-2006 specified shear strengths across lift joints can be achieved. For this post-COL test program, the test report with 90-day test results will be completed at least 180-days prior to start of RCC bridging mat construction. For these tests, constructability issues experienced during pre-COL specialty testing in a laboratory setting will be avoided by the use of production construction scale mixing, placement, and compaction equipment. The test pad for the pre-construction tests will be constructed using mixing and placement procedures similar to those that will be used for the LNP RCC bridging mat construction.
- The proposed License Condition for post-COL RCC testing states: "The licensee will complete 180-days prior to construction, the 90-day test report for the Strength Verification and Constructability Testing in accordance with the criteria outlined in FSAR Subsection 3.8.5.11.3 and make it available to the NRC."
- Revised ITAAC for RCC (COLA Part 10 Table 3.8.3) addresses consistency of the production LNP RCC Bridging Mat placement and constituents with the design requirements resulting from the testing program.

ACI 318-99 strength reduction factors and load factors of DCD Table 3.8.4-2 are used in the design. See response to RAI 03.08.05-5 for a complete discussion of load factors and strength reduction factors. Thus, the RCC failure probability is consistent with industry codes.

4. The variability of RCC materials is accounted for in the mix design process. Based on previous commercial RCC experience, the expected coefficient of variation on the compressive strength of RCC is approximately 14 percent with the strict quality control measures that will be in place. The targeted RCC mix design strength accounts for forecasted variability.

   Specific response to information requested by the NRC during the April 27-28, 2011, NRC visit to witness the RCC Specialty Tests in Tucson, AZ is being provided as follows:

   I. Summary report of commercial RCC experience and test data.

      This information was provided in Supplement 1 to NRC Letter 086, RAI 03.08.05-04 response submitted via Progress Energy Letter NPD-NRC-2010-080 dated November 02, 2010. The test conclusions are discussed in Paragraph 1 above.

   II. Description of material, processes, and equipment types/size from commercial projects and a commitment that those used for LNP will be similar.

      This information is presented in Attachment 1, "Previous Commercial RCC Experience," Revision 1, and is discussed in Paragraph 1 above.

   III. Identify the specific RCC mix design, and confirm the acceptability of this mix to provide the characteristics required for the foundation design.

      This information was provided in Supplement 3 to NRC Letter 086, RAI 03.08.05-04 response submitted via Progress Energy Letter NPD-NRC-2011-042 dated May 12, 2011. RCC Mix design conclusions are discussed in Paragraph 3 above.

   IV. Submit the 90-day specialty test report verifying RCC strength characteristics.

      This information is presented in Attachment 3, "90-day Report Phase III Specialty Testing Program," Revision 0 and is discussed in Paragraph 3 above.

   V. Submit post-COL RCC Strength Verification and Constructability Testing plan.

      This information is presented in Attachment 2, "Post-COL Roller Compacted Concrete Test Plan," Revision 3, and is discussed in Paragraph 2 above.

   VI. Add a new FSAR Subsection 3.8.5.11 summarizing information on commercial test results, RCC mix design, pre-COL 90-day testing, and commitments for the post-COL testing and the use of equipment and process validated by the post-COL testing in production construction of the RCC Bridging mat

      New FSAR Subsection 3.8.5.11 "Roller Compacted Concrete Pre-COL and Post-COL Testing" is being added. FSAR Subsection 2.5.4.5.4.1 "Roller Compacted Concrete Test Pad" will be deleted. See "Associated LNP COL Application Revisions" section of the RAI response.

   VII. Add a new License Condition for post-COL testing stating that the licensee will complete 180-days prior to construction, the 90-day test report for the Strength Verification and Constructability Testing in accordance with the criteria outlined in FSAR Subsection 3.8.5.11.3.

      New FSAR License Condition was added in COLA Part 10 as discussed at the April 27-28, 2011, NRC meeting. See "Associated LNP COL Application Revisions" section of the RAI response.

VIII. Revise COLA Part 10 "Table 3.8.3: LNP COLA RCC ITAAC" as discussed at the meeting

COLA Part 10 RCC ITAAC was revised as discussed at the April 27-28, 2011, NRC meeting. See "Associated LNP COL Application Revisions" section of the RAI response.

References:

ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-99) and Commentary (ACI 318R-99)," American Concrete Institute, Farmington Hills, Michigan, 1999.

ACI Committee 349, "Code Requirements for Nuclear Safety Related Concrete Structures," (ACI 349-01) American Concrete Institute, Farmington Hills, Michigan, 2001.

USACE, "Roller-Compacted Concrete," (EM 1110-2-2006), Department of the Army, United States Army Corps of Engineers, Washington, DC, January 15, 2000.

Paul C. Rizzo Associates, "Previous Commercial RCC Testing Results Levy Nuclear Plant," Revision 0, October 2010.

Paul C. Rizzo Associates, "56-Day Report Phase II Mix Design Program Levy Nuclear Plant," Revision 1, April 2011.

Paul C. Rizzo Associates, "Previous Commercial RCC Experience Levy Nuclear Plant," Revision 1, May 2011.

Paul C. Rizzo Associates, "Post-COL Roller Compacted Concrete Test Plan Levy Nuclear Plant," Revision 3, May 2011.

Paul C. Rizzo Associates, "90-Day Report Phase III Specialty Testing Program Levy Nuclear Plant," Revision 0, May 2011.

Associated LNP COL Application Revisions:

The following changes will be made to FSAR Sections 2.5 and 3.8 in a future revision:

1) Text changes to FSAR Subsections 2.5.4.5.4, 2.5.4.5.4.1, and 2.5.4.12 as noted below;
2) Add References in new FSAR Subsection 3.8.5.12 as noted below;
3) Add new FSAR Subsection 3.8.5.11 as noted below;
4) COLA Part 10 add new License Condition as noted below;
5) COLA Part 10 text changes to ITAAC Table 3.8.3 as noted below.

<u>Text changes:</u>

1. COLA Part 2, FSAR Subsection 2.5.4.5.4, delete the following paragraphs and subparagraphs because the same information is contained in the revised COLA Part 2, FSAR Subsection 2.5.4.12:

   "The specified density of RCC is the range of 143 pcf to 153 pcf. Field measurement of

RCC density will be performed using a "single probe nuclear densometer" for each 1-ft. lift during placement of the RCC.

Verification laboratory tests to confirm that the compressive strength level of RCC is satisfactory will be performed. The tests will be conducted using six-inch cylindrical test specimens molded during construction in accordance with ASTM C 1435/C 1435M-05: "Standard Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer". Concrete to make the test specimens will be taken from six different locations for each 0.3 m (1 ft.) lift of the RCC. Three samples will be taken at each of the six locations. The compressive strength tests will be conducted within 1 year of placement of the RCC. Compressive strength testing will be performed in accordance with ASTM C 39 "Test Method for Compressive Strength of Cylindrical Concrete Specimens". The strength level of RCC, adjusted for aging, will be considered satisfactory if either Condition 1 and 2 or Conditions 1 and 3 are satisfied:

1. The average of compressive strength from three cylinders molded at a location equals or exceeds f'c.
2. No individual strength test (average of two cylinders) fall below f'c by more than 500 psi.
3. If individual strength tests (average of two cylinders), adjusted for aging, fall below f'c by more than 500 psi, a minimum of three cores drilled from the area in question shall be tested. The cores shall be drilled in accordance with ASTM C 42: "Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete". RCC in areas represented by core tests shall be considered adequate if the average of compressive strength from three cores is equal to at least 85 percent of f'c, and if no individual core compressive strength is less than 75 percent of f'c. If this acceptance criterion is not met, an evaluation of the acceptability of the RCC for its intended function shall be performed before acceptance."

2. COLA Part 2, FSAR Subsection 2.5.4.5.4, seventh paragraph (as revised in response to NRC letter 086, RAI 03.08.05-5) and paragraph eight will be revised from:

"The concrete nominal capacity is 250 psi, using ACI 318 equations for structural plain concrete tensile strength because ACI 349 does not include a chapter for Plain Concrete. Unlike reinforced concrete, in which tensile strength is neglected, an allowable tensile strength is permitted for plain (unreinforced) concrete, including RCC. Load factors and strength reduction factors from ACI 349 were used in the analysis. The tensile capacity will be verified with large scale laboratory testing.

The nuclear island vertical load considered in the analysis is 287,000 kips. The total vertical load of 287,000 kips corresponds to an average uniform load of 8.93 ksf, which exceeds the actual DCD Tier 1 requirements for bearing capacity."

To read:

"RCC bridging mat will be constructed using unreinforced RCC. Neither the AP1000 DCD nor ACI 349-01 addresses requirements for unreinforced (plain) concrete. ACI 349-01 specifies load factors and strength reduction factors for nuclear safety related concrete structures. ACI 318-99 (Chapter 22) provides design methodology for unreinforced (plain) concrete. Thus, for the RCC bridging mat design, load factors and strength reduction factors from ACI 349-01 and methodology from ACI 318-99 Chapter 22 is used for compressive and tensile capacity. For shear stress across lift joints, the strength is represented by a Mohr envelop relationship as described in USACE EM 1110-2-2006. A safety factor of 2.29 was then applied to ensure adequate performance. The 2.29 factor of safety incorporates both the load factor and the strength reduction factor for plain concrete.

The Pre-COL RCC testing performed and the Post-COL RCC Testing planned is described in FSAR Subsection 3.8.5.11. The RCC testing is to verify that the specified 2500 psi RCC compressive strength, ACI 318-99 (Chapter 22) specified tensile strength, and USACE EM 1110-2-2006 specified shear strengths across lift joints can be achieved.

The nuclear island vertical load considered in the analysis is 287,000 kips. The total vertical load of 287,000 kips corresponds to an average uniform load of 8.93 ksf, which exceeds the DCD Tier 1 requirements for bearing capacity. For the RCC bridging mat analysis 70 percent of the total vertical load was considered dead load, and 30 percent was considered live load."

3. Delete COLA Part 2, FSAR Subsection 2.5.4.5.4.1 because the new FSAR Subsection 3.8.5.11 provides the revised RCC strength verification and constructability program described in this Subsection.

4. COLA Part 2, FSAR Subsection 2.5.4.12 Paragraphs 6 and 7, revise the following text from:

   "The RCC will be mixed on-site and a Creter Crane (or similar machine) will place materials delivered from the mixing plant. The delivered RCC will be spread with dozers to a compacted lift thickness of 1 foot. At least four passes of smooth drum vibratory rollers will be used to compact the RCC. A mix design program and full-scale test section is planned, as described in FSAR Subsection 2.5.4.5.4.1.

   During the construction of the RCC Bridging Mat, field measurements of RCC density will be performed using a "single-probe nuclear densometer" for each 1-ft. lift during placement of the RCC."

   To read:

   "The RCC will be placed in lift thicknesses of approximately 1 foot. Bedding Mix will be used over each entire lift surface for the RCC bridging mat construction. The Pre-COL RCC testing performed and the Post-COL RCC Testing planned is described in FSAR Subsection 3.8.5.11.

   The specified density of RCC is in the range 143 to 153 pcf. During the construction of the RCC Bridging Mat, field measurements of RCC density will be performed using a "single-probe nuclear densometer" for each 1-ft. lift during placement of the RCC."

5. COLA Part 2, FSAR Subsection 2.5.4.12 last paragraph 2nd sentence, revise the following text from:

"Subgrade improvement methods and details of the verification program anticipated to be included in this program are summarized in FSAR Subsection 2.5.4.5.3."

To read:

"Subgrade improvement and verification methods summarized in FSAR Subsections 2.5.4.5.3 and 3.8.5.11 or equivalent, will be included in this program."

6. COLA Part 2, add new FSAR Subsection 3.8.5.12 containing the following reference list:

03.08.05-4-1: Paul C. Rizzo Associates, "Previous Commercial RCC Experience Levy Nuclear Plant," Revision 1, May 2011.

03.08.05-4-2: Paul C. Rizzo Associates, "Post-COL Roller Compacted Concrete Test Plan Levy Nuclear Plant," Revision 3, May 2011.

03.08.05-4-3: Paul C. Rizzo Associates, "Previous Commercial RCC Testing Results Levy Nuclear Plant," Revision 0, October 2010.

03.08.05-4-4: Paul C. Rizzo Associates, "56-Day Report Phase II Mix Design Program Levy Nuclear Plant," Revision 1, April 2011.

03.08.05-4-5: Paul C. Rizzo Associates, "90-Day Report Phase III Specialty Testing Program Levy Nuclear Plant," Revision 0, May 2011.

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7. COLA Part 2, FSAR Section 3.8, add new Subsection 3.8.5.11 as follows:

3.8.5.11 Roller Compacted Concrete Strength and Constructability Verification Program

LNP SUP 3.8-3 A Roller Compacted Concrete (RCC) bridging mat will support the LNP Nuclear Island (NI) foundation as described in Subsections 2.5.4.5.4 and 2.5.4.12. This subsection describes the RCC strength and constructability verification program for LNP that was completed and that is planned post-COL.

3.8.5.11.1 Experience from Large Scale Commercial RCC Projects

LNP RCC construction will follow industry standard methods that have been successfully been implemented on large commercial RCC projects. This provides assurance that LNP RCC bridging mat can be successfully constructed and will have the desired strength.

United States Army Corp of Engineers Engineering Manual EM 1110-2-2006 (USACE EM 1110-2-2006) describes standard equipment and practices that are used during RCC construction. These practices include guidance for developing RCC mixes, procedures for RCC placement and compaction, and for lift surface preparation. The LNP RCC construction specifications will specify RCC mixing, placement, and compaction equipment, as well as procedures associated with each to be consistent with USACE EM 1110-2-2006 guidelines and incorporate practices from the successful commercial projects. The LNP RCC construction specifications will also specify additional requirements for nuclear safety grade Quality Assurance.

Reference 03.08.05-4-1 compares the RCC mixes, aggregates, cement, and fly ash from three large commercial RCC projects to those planned to be used for LNP RCC bridging mat. The report concludes that the properties of the aggregates, cement, and fly ash planned for LNP will meet or exceed the requirements used for these successful commercial projects.

Quality control and inspection during production construction, as described in Subsection 2.5.4.12 and Reference 03.08.05-4-2, "Post-COL Roller Compacted Concrete Test Plan Levy Nuclear Plant," Revision 3, will ensure that the mixing, placement, and compaction of production RCC complies with the LNP RCC construction specifications.

The report "Previous Commercial Testing Results Levy Nuclear Plant," Revision 0, (Reference 03.08.05-4-3) describes the RCC testing results from three large commercial RCC projects. The following can be concluded from these commercial testing results:

- The compressive strengths measured during production construction exceeded those that were measured during pre-construction mix design laboratory testing. Thus, laboratory testing during RCC mix design provides reasonable assurance that the desired RCC compressive strength will be achieved or exceeded during production construction.
- The measured modulus of elasticity from commercial testing correlates well with that computed using ACI 318-99 section 8.5.1 method. Thus use of ACI 318-99 equation for modulus of elasticity in RCC design is appropriate.
- The USACE EM 1110-2-2006 correlation that the direct tensile strength of RCC is approximately 75 percent of the split tensile strength trends close to the ACI 318-99 equation 22-2 for tensile strength. Thus the use of ACI 318-99 equation 22-2 for tensile strength in RCC design is appropriate
- Shear tests performed on pre-cracked (at lift joints) block samples show that the friction angle when concrete bedding mix is used is greater than the 45 degrees design value provided in USACE EM 1110-2-206. Thus, the use of 45 degrees friction angle for shear capacity in RCC design across lift joints is appropriate.

3.8.5.11.2 LNP Pre-COL RCC Testing

For design, RCC nominal strength capacities were established using ACI 349 and ACI 318 equations and USACE EM 1110-2-206 guidance. The Finite Element Model (FEM) of the RCC Bridging Mat has confirmed that these capacities are adequate for the anticipated loading conditions and postulated conservative karst sizes and configurations as described in Subsection 2.5.4.5.4.

The LNP RCC Mix Design program is described in "56-Day Report Phase II Mix Design Program Levy Nuclear Plant," Revision 1 (Reference 03.08.05-4-4). The RCC mix design program, sixteen trial RCC mixes were tested and all yielded RCC compressive strengths greater than the 2500 psi used in the FEM analysis. Five trial bedding mixes were tested and all yielded a compressive strength of greater than 4000 psi. The RCC mix and bedding mix design program evaluated the effects of water-cementitious material ratio, fly ash replacement percentage, fly ash sources, and aggregate sources with respect to strength and workability. This mix design program demonstrated that design workability and strength requirements can be achieved with the trial mixes and constituent materials procured for the program. The program concluded with the selection of a single RCC mix and a bedding mix that is workable, and meets design compressive strength while minimizing the cement content for favorable thermal characteristics. The results of the mix design program will be used to develop the LNP

RCC construction specification for RCC constituents mix proportions and properties of the constituent materials.

For the selected LNP design RCC mix, laboratory testing was performed as described in "90-day Report Phase III Specialty Testing Program Levy Nuclear Plant," Revision 0, (Reference 03.08.05-4-5). In this program RCC test cylinders and three RCC test panels measuring approximately 7 ft.x7 ft.x2 ft. were cast. The RCC panels were cast in two layers, with bedding mix between the two layers. The RCC constitutive materials used for this phase were from the same sources as for the RCC Mix design program. Test panels with Joint Maturity Values (JMV) of approximately 2500 Degree Hours ("warm" joint) and with JMV of approximately 4700 Degree Hours ("cold" joint) were constructed. In the panel with the "cold joint", layer 1 was green cut prior to placing the bedding mix and the second layer of RCC.

The compressive and split tensile strength test results from laboratory cast cylinders in this program were consistent with past RCC experience and validated use of ACI 318-99 equations for tensile strength and modulus of elasticity. The tests also verified that the selected LNP RCC mix yields compressive strength greater than the specified 2500 psi and split cylinder tensile strength consistent with ACI 318-99 correlations. However, preliminary testing on cored cylinders from the test panels indicated that the concrete in the test panels did not attain the desired compressive or tensile strengths. This low strength is believed to be due to the constructability issues related to construction of the laboratory-scale test panels that required the use of small mixing and compaction equipment. As stated before, LNP production RCC construction will use mixing, placement, and compaction equipment consistent with USACE EM 1110-2-2006 guidance and comparable to that used in large successful commercial projects.

Three block shear samples cut from the test panels were tested. These bi-axial shear tests yielded shear strengths at least 1.67 times the maximum design demand shear across lift joints even though the test panels did not achieve the desired compressive strength at 90-days.

3.8.5.11.3 LNP Post-COL RCC Testing

Post-COL RCC and bedding mix strength verification and constructability testing will be performed on a large test pad as described in Phase IV testing of Reference 03.08.05-4-2, "Post-COL Roller Compacted Concrete Test Plan Levy Nuclear Plant," Revision 3. This testing is being performed post-COL but prior to construction of the LNP bridging mat for the following reasons:

- Due to the limitation on mixing and compaction equipment sizes that can be used in a laboratory setting, the required compaction cannot be achieved in a laboratory setting. A larger scale test pad in an open field setting is required.
- Because RCC design strength is specified as the 365-day strength, it is not practical to perform destructive testing on the RCC bridging mat during construction on cored or block cut test specimens.

RCC strength verification and constructability testing will be performed post-COL at the LNP site. The post-COL RCC strength and constructability testing will verify that the specified RCC compressive strength, ACI 318 specified tensile strength, and USACE EM 1110-2-2006 specified shear strengths across lift joints can be achieved. A RCC test pad measuring approximately 42 ft.x40 ft.x6 ft. will be constructed with the specified RCC and bedding mixes. The test pad construction will use mixing, placement, and compaction procedures and equipment comparable to those that will be used during

LNP RCC bridging mat construction. The constitutive materials for the RCC mix will be comparable to that used in the RCC mix design program (Reference 03.08.05-4-4). Six inch cores from the RCC test pad will be used to verify that the design compressive strength is achieved and the split cylinder strength meets ACI 318-99 requirements. Blocks cut from the RCC test pad similar in size to those used in the pre-COL specialty testing program will be used to verify that USACE EM 1110-2-2006 shear strength are achieved across lift joints. Shear test specimens with Joint Maturity Values (JMV) of approximately 2500 Degree Hours ("warm" joint) and with JMV of approximately 4700 Degree Hours ("cold" joint) will be tested. Thermocouples or thermistors will be used to monitor JMV. "Cold" joints will be green cut prior to placement of the subsequent lift.

The geometry and loading on the LNP RCC bridging mat is such that there is no tension across lift joints. Thus, no tensile strength tests across lift joints will be performed.

The post-COL strength verification and constructability test report with 90-day test results will be completed at least 180-days prior to start of LNP RCC bridging mat construction.

3.8.5.11.4 LNP RCC Testing During Production Construction

The production RCC bridging mat will not be cut for testing. Testing of the production mat will be confirmatory, using non destructive testing methods to ensure that the construction of the RCC and bedding joints is in accordance with the RCC construction specifications. The report "Post-COL Roller Compacted Concrete Test Plan Levy Nuclear Plant," Revision 3, (Reference 03.08.05-4-2) describes the testing that will occur during construction of the RCC bridging mat, including quality control testing. According to USACE EM 1110-2-2006, the characteristics required to obtain good RCC and bond strength at the lift joint include good-quality aggregate, good mixture workability and compaction effort, rapid covering of lift joints by subsequent lifts, and the use of bedding mix. These items will be addressed in the RCC construction specifications and construction Quality Control program for RCC bridging mat construction as follows:

The quality of the aggregate, cement, and fly ash from multiple sources was evaluated during the RCC mix design program. The RCC construction specifications will specify aggregate, cement, and fly ash sources and quality requirements comparable to those used for the LNP RCC mix design program (Reference 03.08.05-4-4). Coarse aggregate complying with ASTM C33 will be used. Type II cement complying with ASTM C 150 and ASTM C 186 and Class F fly ash complying with ASTM C 618 requirements will be used. To ensure the quality and uniformity of the RCC during production, the aggregate will be tested daily for conformance to construction specifications for gradation and moisture content. Monthly tests of each aggregate during construction will verify that it continues to meet requirements for specific gravity, organic impurities, and LA Abrasion.

RCC mix workability will be measured by Vebe testing for RCC and slump testing for bedding mix. The selected RCC and bedding mix from the RCC Mix Design program had acceptable workability. During construction, Vebe time for RCC and slump of bedding mix will be measured at least once per shift to monitor the workability of the mixes. Other properties, such as the temperature of the RCC at the point of placement, and the air content of the RCC will also be monitored. During RCC construction, thermocouples or thermistors will be used to monitor Joint Maturity Value (JMV).

The RCC construction specifications, non destructive testing and quality controls during construction together with implementing procedures and equipment comparable to those used on past successful RCC projects, pre-COL RCC mix design testing, the pre-COL RCC testing, and the planned post-COL RCC testing using a large test pad provides sufficient assurance that the LNP design compressive and tensile strengths, and shear strengths across lift joints will be achieved during the RCC bridging mat construction using the RCC and bedding mix, mixing and placement procedures and equipment, and the compaction equipment specified for construction.

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8. COLA Part 10, Proposed License Conditions, including ITAAC will be revised to add new proposed License Condition 4:

   "4. POST-COL TESTING
   COLA FSAR Subsection 3.8.5.11 specifies certain post COL testing that must be completed 180-days prior to construction.

   PROPOSED LICENSE CONDITION:
   The licensee will complete 180-days prior to construction, the 90-day test report for the Strength Verification and Constructability Testing in accordance with the criteria outlined in FSAR Subsection 3.8.5.11.3 and make it available to the NRC."

9. COLA Part 10, Appendix B, Table 3.8-3, revise from:

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
The 35 foot thick RCC Bridging mat is seismic Category I and is designed and constructed to bridge over the design basis karst feature when subjected to design basis loads as specified in the Design Description in FSAR 2.5.4.5.4 without loss of structural integrity and the safety related functions.	i) An inspection of the bridging mat will be performed. Deviations from the design due to as-built conditions will be analyzed for the design basis karst feature when subjected to design basis loads. ii) An inspection of the as-built RCC thickness will be performed.	i) A report exists which reconciles deviations during construction and concludes that the as-built RCC bridging mat conforms to the approved design and will bridge over a design basis karst feature when subjected to design basis loads specified in the Design Description without loss of structural integrity and the safety related functions ii) A document exists that verifies that the as-built thickness of the RCC bridging mat is at least 35 feet.

To read:

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
The RCC Bridging mat is seismic Category I and is designed and constructed to bridge over the design basis karst feature when subjected to design basis loads as specified	i) An inspection of the bridging mat placement will be performed. Deviations due to as-built conditions that fall outside the range considered in the design will be analyzed for	i) A report exists which reconciles deviations from design and placement process of the RCC during construction and concludes that the as-built RCC bridging

in the Design Description in FSAR 2.5.4.5.4 without loss of structural integrity and the safety related functions.	the design basis karst feature when subjected to design basis loads. ii) An inspection of the RCC mix and bedding mix constituents will be performed. Deviations from the design constituents will be evaluated against the range of properties established for these materials during the design phase. iii) An inspection of the as-built RCC thickness will be performed.	mat conforms to the approved design and will bridge over a design basis karst feature when subjected to design basis loads specified in the Design Description without loss of structural integrity and the safety related functions. ii) A report exists which reconciles deviations in mix constituents used in construction and concludes that the as-built RCC conforms to the design requirements for these properties. iii) A document exists that verifies that the as-built thickness of the RCC bridging mat is at least as thick as the design requirement.

Attachments/Enclosures:

1) Paul C. Rizzo Associates, "Previous Commercial RCC Experience Levy Nuclear Plant," Revision 1, May 2011.
2) Paul C. Rizzo Associates, "Post-COL Roller Compacted Concrete Test Plan Levy Nuclear Plant," Revision 3, May 2011.
3) Paul C. Rizzo Associates, "90-Day Report Phase III Specialty Testing Program Levy Nuclear Plant," Revision 0, May 2011.

NRC Letter No.: LNP-RAI-LTR-086

NRC Letter Date: March 16, 2010

NRC Review of Final Safety Analysis Report

NRC RAI #: 03.08.05-6

Text of NRC RAI:

In the applicant response to Question 3.8.5-02, Part 5, of RAI 2925 (NRC Letter No. 055) the applicant described a number of quality control measures that will provide information needed to assure that the RCC material is of good quality and to determine the compressive strength and density of the as-placed material. However, none of the quality control measures appear to address the capability of the as-placed material to transfer shear or tension across the as-constructed bedding joints. Thus, the staff is requesting that the applicant provide additional information which adequately addresses the transfer of shear or tension between the as-placed material and the bedding joints.

PGN RAI ID #: L-0923

PGN Response to NRC RAI:

This is a revised response to NRC Letter 086, RAI 03.08.05-06 (PGN RAI ID #: L-0730) submitted via Progress Energy Letter NPD-NRC-2010-068 dated August 18, 2010. The revised response incorporates pre-COL RCC testing results and the revised post-COL RCC test plans as discussed at the April 27-28, 2011, NRC meeting to witness the RCC Specialty Tests in Tucson, AZ.

The revised response to NRC Letter 086, RAI 03.08.05-06 is as follows:

The RCC shear capacity across lift (bedding) joints is addressed in the revised response to NRC Letter 086, RAI 03.08.05-04 (PGN RAI ID # L-0862) as follows:

1. The LNP RCC bridging mat design shear capacity is based on USACE EM 1110-2-2006. Direct shear tests across lift joints on pre-cracked block samples from past commercial projects show that a ≥ 45 degree friction angle is achieved across lift joints. The LNP construction will use constituent materials, RCC mixing, RCC placement including lift joints and construction Quality Control practices that are equivalent or better than those used in past large commercial RCC construction.
2. The LNP specific direct shear tests performed on block samples from the laboratory cast RCC panels show that the shear capacity across lift joints was greater than 1.67 times the shear demand across the lift joints for the LNP RCC Bridging mat even though the panel RCC failed to gain the desired compressive strength.
3. Direct block shear tests to verify that the LNP RCC has the shear capacity specified in USACE EM 1110-2-2006 will be performed prior to AP1000 construction. The report documenting the 90-day results from this testing will be available at least 180-days prior to construction.

The post-COL RCC strength verification and constructability testing will be performed post COL at the LNP site as described in NRC Letter 086, RAI 03.08.05-04 revised response (PGN RAI ID

L-0862). Blocks cut from the RCC test pad will be used to verify that USACE EM 1110-2-2006 shear strength is achieved across lift joints. Shear test specimens with Joint Maturity Values (JMV) of approximately 2500 Degree Hours ("warm" joint) and with JMV of approximately 4700 Degree Hours ("cold" joint) will be tested. Thermocouples or thermistors will be used to monitor JMV. "Cold" joints will be green cut prior to placement of the subsequent RCC lift.

To ensure good bond between RCC lift joints, bedding mix will be used over each entire lift surface during RCC bridging mat construction.

The geometry and loading on the LNP RCC bridging mat is such that there is no tension across lift joints. Thus, no tension capacity testing across lift joints is planned. Split tension tests on cylinders cast during RCC bridging mat construction will be performed to verify that the RCC meets ACI 318-99 equation 22-2 requirements for tensile strength. In addition, tests on the LNP RCC trial mixes (NRC Letter 086, RAI 03.08.05-04 supplemental response [PGN RAI ID # L-0861]) show that the LNP RCC trial mixes meet ACI 318-99 equation 22-2 requirements for tensile strength. Similarly, 90-day split cylinder tensile strengths obtained from the LNP selected RCC Mix show that the selected RCC mix meets ACI 318-99 equation 22-2 requirements for tensile strength (NRC Letter 086, RAI 03.08.05-04 revised response [PGN RAI ID # L-0862]). In the post-COL RCC testing (NRC Letter 086, RAI 03.08.05-04 revised response [PGN RAI ID # L-0862]), split cylinder testing will be performed on cores taken within individual lifts of the RCC test pad to verify that the RCC meets ACI 318-99 equation 22-2 requirements for tensile strength.

References:

NRC Letter 086, RAI 03.08.05-04 revised response contained in this letter (PGN RAI ID # L-0862).

NRC Letter 086, RAI 03.08.05-04 supplemental response (PGN RAI ID # L-0861, NPD-NRC-2011-042).

USACE, "Roller-Compacted Concrete," (EM 1110-2-2006), Department of the Army, United States Army Corps of Engineers, Washington, DC, January 15, 2000.

ACI 318-99, "Building Code Requirements for Structural Concrete (318-99) and Commentary (318R-99)", American Concrete Institute.

Associated LNP COL Application Revisions:

No COLA revisions have been identified associated with this response in addition to those identified in NRC Letter 086, RAI 03.08.05-04 revised response contained in this letter (PGN RAI ID # L-0862).

Attachments/Enclosures:

None

Attachment 1

Revision 1

Previous Commercial RCC Experience Levy Nuclear Plant

[17 pages attached]

ENGINEERS & CONSULTANTS

Engineering & Construction Management
Hydro-Nuclear-Fossil

Geotechnical Engineering

Seismic and Structural Engineering

Hydrological & Hydraulic Engineering

Tunnel Engineering

Environmental Engineering & Permitting

PREVIOUS COMMERCIAL RCC EXPERIENCE

LEVY NUCLEAR PLANT

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PROJECT NO. 07-3935

PREVIOUS COMMERCIAL RCC EXPERIENCE
LEVY NUCLEAR PLANT

PROJECT NO. 07-3935
MAY 25, 2011
REVISION 1

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APPROVALS

Project No.: 07-3935

Report Name: Previous Commercial RCC Experience, Levy Nuclear Plant

Date: May 25, 2011

Revision No.: 1

Approval by the responsible manager signifies that the document is complete, all required reviews are complete, and the document is released for use.

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CHANGE MANAGEMENT RECORD

Project No.: 07-3935

Report Name: Previous Commercial RCC Experience, Levy Nuclear Plant

REVISION NO.	DATE	DESCRIPTIONS OF CHANGES/ AFFECTED PAGES[1]	PERSON AUTHORIZING CHANGE	APPROVAL[2]
0	5/16/11	Original submittal.	N/A	N/A
1	5/25/11	Corrected typographical errors (Section 2.1, Table 2-5). Added information regarding the types of rollers used (Sections 3.1, 3.2, 3.3). Revised description of RCC conveyance and placement at Saluda (Section 3.1). Clarified connection between lessons learned and construction specifications (Section 3.4).	MJE	MJE

NOTE:
[1] Changes are marked with a revision mark in margin, beginning with Rev. 1.
[2] Person authorizing change shall sign here for latest revision.

DCR

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PREVIOUS COMMERCIAL RCC EXPERIENCE
LEVY NUCLEAR PLANT

1.0 INTRODUCTION

This Report presents a description of the construction of three roller compacted concrete (RCC) dam projects where Paul C. Rizzo Associates (RIZZO) was involved in the project design and construction, with comparisons to the expected conditions at the Levy Nuclear Plant. This Report considers the primary materials used in the RCC, a description of the RCC production and placement, and a summary of the most important RCC equipment used. The projects are the Saluda Backup Dam, Taum Sauk Upper Reservoir, and Bear Creek Dam. Descriptions of these projects are provided in the "Previous Commercial RCC Testing Results, Levy Nuclear Plant," Revision 0, October 2010.

The size of the projects in terms of volume of RCC placed is shown in ***Table 1-1***.

TABLE 1-1
RCC VOLUME COMPARISON

PROJECT	VOLUME OF RCC (CUBIC YARDS)
Saluda Backup Dam	1,300,000
Taum Sauk Upper Reservoir Rebuild	2,840,000
Bear Creek Dam	76,000

2.0 MATERIALS

The mix design process is used to determine the most economical proportions of cementitious materials (Portland cement and fly ash) and water required to produce the required RCC consistency, strength, and thermal properties using the selected aggregates. A baseline mix is established and properties are varied to evaluate the effect on strength and workability. A summary of the final mixes selected from this process for the Saluda, Taum Sauk, Bear Creek Dam, and Levy Nuclear Plant projects is provided in ***Table 2-1***.

TABLE 2-1
RCC MIXES

PROJECT	SPECIFIED F'_C (PSI)	CEMENT (LB/CY)	FLY ASH (LB/CY)	TARGET VEBE (S)
Saluda	2300	150	150	27
Taum Sauk	1500	100	100	n/a[1]
Bear Creek	2000	130	130	30
LNP	2500	200	250	25

[1]The RCC used at Taum Sauk was a low paste, low strength mix. Therefore Vebe time was not specified.

The following subsections provide more detail regarding the materials used for the selected mixes.

2.1 AGGREGATES

As shown in ***Table 2-2***, successful RCC mixes have been produced using aggregate with high specific gravity, low absorption, and low loss to LA Abrasion. The Stone Mountain Formation Granite used for LNP mix design has desirable properties that meet or exceed those successfully used at the other three projects. The table also shows that the projects have used two to three aggregate stockpiles of different gradations. Rev 1

TABLE 2-2
AGGREGATE COMPARISON

PROJECT	AGGREGATE SOURCE	ROCK TYPE	NUMBER OF STOCKPILES	SPECIFIC GRAVITY	ABSORPTION (%)	LA ABRASION (%)
Saluda	On-Site	Gneiss	3	2.65	0.6	23
Taum Sauk	On-Site	Rhyolite	2	2.62	0.7	< 20
Bear Creek	Commercial	Limestone	2	2.63	1.6	31
LNP	Commercial	Granite	3	2.67	0.6	25

The aggregates from the stock piles were blended to meet a specified combined gradation. The specified combined gradations for the four projects are shown in ***Table 2-3***. The Saluda and Taum Sauk dam projects produced aggregates on-site. The Bear Creek dam used commercially available limestone aggregates.

TABLE 2-3
AGGREGATE GRADATION SPECIFICATION

SIEVE SIZE	PERCENT PASSING BY WEIGHT			
	SALUDA	TAUM SAUK	BEAR CREEK	LNP
2"	99 – 100	100	100	100
1.5"	97 – 100	95 – 100	99 – 100	95-100
1"	80 – 90	75 – 87	91 – 93	75 – 87
¾"	67 – 78	68 – 80	-	68 – 80
½"	55 – 67	56 – 70	63 – 72	56 – 70
3/8"	48 – 60	49 – 63	-	49 – 63
No. 4	40 – 50	38 – 50	39 – 51	38 – 50
No. 8	30 – 40	28 – 38	31 – 38	28 – 38
No. 16	22 – 31	21 – 31	23 – 28	21 – 31
No. 30	17 – 25	15 – 24	-	15 – 24
No. 50	12 – 19	10 – 18	14 – 17	10 – 18
No. 100	7 – 12	7 – 13	-	7 – 13
No. 200	3 – 7	4 – 10	9 – 11	4 – 10

As shown above, the aggregate specification for the Levy Nuclear Plant is identical to that which was successfully implemented at the Taum Sauk project.

2.2 CEMENT

The cements used in the Saluda, Taum Sauk and Bear Creek dam projects were Type I/II or Type II as defined by ASTM C 150. These types of cement are preferred because they have a lower heat of hydration and, in combination with fly ash replacement, contribute less to heat generation. ***Table 2-4*** summarizes the cement types used for these projects.

TABLE 2-4
CEMENT SUMMARY

PROJECT	CEMENT TYPE	SUPPLIER
Saluda	I/II	Holcim – Holly Hill
Taum Sauk	I/II	Buzzi – Festus
Bear Creek	II	National Cement
LNP	II	[TBD]

For the Levy Nuclear Plant, the preferable Type II cement has been specified.

2.3 FLY ASH

Fly ash is commonly used in RCC to replace a fraction of the cement. This contributes to strength gain at later ages while reducing the heat of hydration generated by the mix. The fly ash replacement ratio by weight used in the four projects is shown in ***Table 2-5***. RIZZO has evaluated fly ash replacement ratios ranging from 0 – 80 percent in past mix designs.

TABLE 2-5
FLY ASH SUMMARY

PROJECT	SOURCE	FLY ASH CLASS	REPLACEMENT RATIO (% BY WEIGHT)
Saluda	McMeekin Station Pond Ash	n/a[1]	50
Taum Sauk	Meramec Pond Ash	F	50
Bear Creek	Colbert Plant Silo Ash	F	50
LNP	[TBD]	F	56

[1]This ash met project requirements for pozzolanic effects, but did not meet Class F requirements for gradation, loss on ignition, and moisture content.

Rev 1

RIZZO has considered in mix designs the use of both Class C fly ash and Class F fly ash, as defined by ASTM C 618. Both classes of fly ash have pozzolonic properties, but Class C ash also has cementitious properties, thereby contributing to the heat of hydration. Prior testing and experience has shown that Class F is preferable, which is specified for the Levy Nuclear Plant.

2.4 MATERIAL CONCLUSIONS

The construction of the Specialty Test Pad and Bridging Mat will use similar materials to those used in previous commercial RCC projects.

The aggregates will be provided by a commercial supplier, quarrying from the Stone Mountain Granite Formation. This formation provides aggregate with high specific gravity, low absorption, and low loss to LA Abrasion.

A Type II cement is anticipated for use in LNP Bridging Mat construction, as it contributes to less heat generation. The fly ash will be a commercial Class F ash, similar to what was used during the construction of Taum Sauk and Bear Creek Dam.

3.0 RCC PRODUCTION AND PLACEMENT

A description of the RCC production and placement for the construction of the Saluda, Taum Sauk, and Bear Creek Dams are presented in the following subsections.

3.1 RCC PLACEMENT AT SALUDA DAM

The RCC production plant at Saluda consisted of two Aran Modumix II continuous plants with a rated peak capacity of 500 CY per hour each for a combined capacity of 1,000 CY per hour. Each plant was equipped with one continuous mixer (Pugmill).

Both Aran plants were complemented by an aggregate feed and cooling system sized to match the mixing plant capacity. The coarse and fine aggregates were volumetrically metered and then combined onto a common conveying belt. The aggregates were then sent through a rinse screen to remove material finer than 1/8-inch. Next, the aggregates traveled along a 220-foot wet belt conveyor where they were flushed with chilled water. The coarse aggregates then went over a dewatering screen onto another conveyor and then into a hopper in the Aran plant.

The fine aggregate was conveyed into sand drum chillers, which used cold air to drop the sand temperature to the required level. Then sand was then discharged onto another conveyor into a hopper on the Aran plant.

The cooling system supplied the Aran plant and wet belts with 33-degree water and the sand chillers with chilled air. The chilling system was comprised of seven 210-ton chilling units. The chillers produced 30-degree glycol, which in turn was used to produce chilled water. The glycol also was circulated through two stages of coils to produce chilled air for the sand coolers. The chilled water running over the wet belts was collected in a 200,000-gallon pond, where it was filtered and then re-circulated through the cooling system. Rev 1

The original RCC work plan established conveying and placing by belt only; however, in actuality during construction a variety of placement schemes were used. Initially, one placement front with the all-belt system was used. This system consisted of a 36-inch conveyor belt extending from the Aran plant to the Crawler Placer, which operated on the RCC lift. This system was sized to cope with the RCC plant throughput rates. Rev 1

After construction began, a second placement front was opened. A Gob Hopper was installed that loaded CAT 740 and D400 40-ton articulated ejector dump trucks from one Aran plant. The trucks were dumped into an Augermax hopper adjacent to the placement. The Augermax emptied onto a conveyor belt that fed a Creter Crane with a 24-inch-wide, 200-foot-long belt. The Creter Crane deposited the RCC mix in windrows on the lift. Rev 1

The placement system was again changed partway through construction. The Gob Hopper was placed on the lift. The Creter Crane was placed on temporary fill adjacent to the placement so that it could deposit material in the Gob Hopper. Additional conveyors were installed between the Aran plant and Creter Crane. Using this setup, trucks drove on the RCC lift, were loaded at the Gob Hopper, and placed concurrently in multiple locations. As each lift neared completion, the Gob Hopper would be removed from the lift and the lift would be finished with the Creter Crane. Rev 1

A different conveying system was used during the latter part of dam construction. Essentially, the system consisted of trucks hauling RCC from the plant to the Augermax, which fed the Creter Crane using 36-inch conveyor belts. The Creter Crane fed the Crawler Placer discharging onto a hopper located at the end of an independent 36-inch conveyor belt attached to the Placer. The downstream end of this belt was connected to the top of the Placer, while the free end was equipped with a wheeled support so that the belt could travel together with the Crawler Placer. Rev 1

After being deposited on the placement area, the RCC was spread by a CAT D-5 or D-6 bulldozer, or both. The dozer operator was assisted by a laser guided system to keep the lift surface to grade.

In general, eight to ten single passes (including one static pass) of a CAT CS56-series vibratory roller (or similar) were required to achieve the specified density. For restricted spaces and areas close to formwork and pre-cast panels, a variety of small compaction equipment was used; including a double small roller compactor, walk-behind plate compactors and jumping compactors. Rev 1

3.2 RCC Placement at Taum Sauk Upper Reservoir

The primary RCC mixing plants originally consisted of three individual weigh-batch type concrete plants (Plant Nos. 1, 3, and 4) modified for high capacity RCC production. Each plant was equipped with twin horizontal shaft compulsory mixers. The combined capacity of these plants was approximately 1,200 CY per hour. With the addition of a fourth RCC Plant (Plant No. 5) in the spring of 2009, the total RCC production capacity increased to 1,500 CY per hour.

Aggregates were supplied to Plant No. 3 by twin ground-mounted 16-CY-aggregate feed hoppers, which were kept full by 8 CY front-end loaders. During the operation of the Plant, these hoppers supplied both coarse and fine aggregate to a 65-CY, two compartment aggregate storage bin by way of twin 36-in. aggregate feed conveyors. Both overhead bins gravity fed two individual parallel scales. Aggregates were weighed in parallel by dual 6-CY capacity scales. After weighing, the aggregates were discharged into the mixer by a 48-in. mixer charging conveyor.

Meramec pond ash was delivered to the Site by commercial dump trucks and stockpiled near the RCC Plant. The pond ash was fed to the Plant by a hopper and belt system similar to the one used for the aggregates.

Cement was delivered to the Site from the supplier by 25-ton capacity commercial trucks. Cement was stored at the Site in vertical silos, in horizontal bulk storage units called "pigs," and in overhead silos. When necessary, cement storage was augmented with pre-loaded commercial 25-ton trucks. Typical on-site storage capacity provided cement for three to four shifts of RCC placement.

The water for the RCC was supplied from a temporary pipeline that transported water from the Lower Reservoir to the Upper Reservoir. During the operation of the RCC Plants, water was weighed on a water scale fed by gravity from an upper holding tank and controlled by a pneumatic butterfly valve. After weighing, the water was discharged to the mixer by a gravity feed.

The RCC was mixed using twin horizontal shaft compulsory mixers with a 4.5 to 8 CY capacity. Aggregate, cementitious materials (i.e., cement and fly ash) and water were discharged to the mixer through a vertical split chute and typically mixed for 25 seconds. Plant Nos. 3 and No. 4 mixers discharged into a 48-in. discharge conveyor that moved the material to a 60-in. conveyor belt. The 60-in. belt was sized to accommodate the RCC produced by both plants and moved the RCC to telestackers that would convey the RCC to gob hoppers or haul trucks on the RCC lift. At Plant Nos. 1 and 5, which were located outside of the Reservoir, RCC was discharged from the mixer directly to articulated CAT D-740 trucks.

Trucks operating permanently on the lift were used as the primary RCC placement method for the bulk of the RCC placed for the Dam. The trucks were loaded by gob hoppers located on the placement area and fed with a conveyor belt from the RCC mixing plants.

RCC placements at the foundation or lower elevations were normally supported by Plant Nos. 1 and 5, located outside of the Reservoir. After loading at the plant, articulated CAT-740D trucks typically transported the RCC to the placement area and delivered the material to a Creter Crane which conveyed the RCC to the lift. The Creter Crane would fill trucks on the lift or place RCC directly, depending on the particular placement conditions. RCC delivery with trucks traveling on and off the lift was only allowed if lift contamination could be effectively prevented. Once the RCC was deposited on the lift, it was spread in 1-ft-thick compacted lifts by a CAT D-5 or CAT D-6 bull dozer. The dozer operator was assisted by a GPS system to keep the lift surface on grade. After spreading, the RCC was compacted by four to five passes of 10-ton double vibratory drum rollers to achieve the specified density. | Rev 1

3.3 RCC Placement at Bear Creek Dam

In the beginning stages of construction, when the dam crest was below site grade, articulated dump trucks traveling on and off the dam were used to transport RCC to the placement area. After site grade was reached, standard dump trucks operating permanently on the lift were used as the primary RCC delivery method. These dump trucks were loaded by gob hoppers located near the placement area and fed with a conveyor belt from the RCC mixing plants. RCC was spread in 1-foot-thick compacted lifts by a CAT D-5 bulldozer. The dozer operator was assisted by a laser-guided system to keep the lift surface on grade. After spreading, the RCC was compacted by three to four passes of 10-ton double vibratory drum rollers to achieve the specified density. | Rev 1

3.4 Comparison to Levy

The construction at Levy will use RCC placement methods similar to the commercial projects described above. RCC will be transported to the lift by a Creter crane or similar, as with the

Saluda Dam placement, and will be spread by bulldozers with the assistance of a laser-guided system. Primary compaction will be performed by double drum vibratory rollers, with small compaction equipment to be used in restricted areas or close to formwork. The lessons learned from these three commercial projects will be incorporated into the construction specifications developed for the Levy Nuclear Plant. Rev 1

4.0 SUMMARY

This Report presents information related to the construction of the Saluda Backup Dam, Taum Sauk Upper Reservoir, and Bear Creek Dam RCC projects. The aggregate, cement, and fly ash used for Levy Nuclear Plant has properties that meet or exceed the requirements used for these commercial projects. The mixing, placement, and compaction equipment, as well as the procedures associated with each, will be specified to be consistent with these successful commercial projects for the construction of the LNP Specialty Test Pad and Bridging Mat.

Attachment 2

Revision 3

Post-COL Roller Compacted Concrete Test Plan Levy Nuclear Plant

[27 pages attached]

ENGINEERS & CONSULTANTS

POST-COL ROLLER COMPACTED CONCRETE TESTING PLAN

LEVY NUCLEAR PLANT

Engineering & Construction Management
Hydro-Nuclear-Fossil
Geotechnical Engineering
Seismic and Structural Engineering
Hydrological & Hydraulic Engineering
Tunnel Engineering
Environmental Engineering & Permitting

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PROJECT NO. 07-3935

POST-COL ROLLER COMPACTED CONCRETE TESTING PLAN
LEVY NUCLEAR PLANT
REVISION 3

PROJECT NO. 07-3935
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APPROVALS

Project No.: 07-3935

Report Name: Post-COL Roller Compacted Concrete Testing Plan
Levy Nuclear Plant

Date: May 24, 2011

Revision No.: 3

Approval by the responsible manager signifies that the document is complete, all required reviews are complete, and the document is released for use.

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CHANGE MANAGEMENT RECORD

Project No.: 07-3935

Report Name: Post-COL Roller Compacted Concrete Testing Plan
Levy Nuclear Plant

Revision No. 3

REVISION NO.	DATE	DESCRIPTIONS OF CHANGES/ AFFECTED PAGES	PERSON AUTHORIZING CHANGE	APPROVAL[1]
0	8/3/10	Original submittal.	N/A	N/A
1	8/13/10	Clarified the number of mixes performed in Phase II (Table 1-1); Clarified heat of hydration discussion (Section 2.1); Described basis of maximum allowable differences during uniformity testing (Section 2.2); and Added description of Creter Crane (Section 3.2). All pages replaced.	MJE	MJE
2	5/16/11	Changed title of Phase IV to Specialty Test Pad throughout document. Revised language throughout to reflect that only one RCC mix has been selected. Revised language discussing the purpose of the Specialty Test Pad (Section 3.0). Revised the number of lifts of specialty test pad (Section 3.0). Revised language discussing RCC placement and compaction (Section 3.2). Revised target joint maturities, added discussion of "green cut" (Section 3.3). Clarified strength testing requirements (Table 3-3). Revised testing of Specialty Test Pad (Section 3.5). Clarified that production testing is Phase V and discussed construction specification to be developed during Phase IV testing (Section 4.0). All pages replaced.	MJE	MJE

CHANGE MANAGEMENT RECORD
(CONTINUED)

REVISION No.	DATE	DESCRIPTIONS OF CHANGES/ AFFECTED PAGES	PERSON AUTHORIZING CHANGE	APPROVAL[1]
3	5/24/11	Changed title of Phase IV to Strength and Constructability Verification Testing throughout document. Changed name of "Specialty Test Pad" to "Test Pad" throughout document. Replaced references to "batch plant" with "batching system" throughout document. Removed reference to RIZZO (Section 2.2). Clarified when work will occur (Section 3.0). Revised the number of lifts (Section 3.1, 3.2). Clarified that work will be performed in a similar manner as Bridging Mat construction (Section 3.2). Clarified the purpose of testing and added references to acceptance criteria (Section 3.5). Removed reference to visual observation (Section 3.5.1). Clarified purpose of NCR (Section 4.1). Added reference to ACI 318-99 (References).	MJE	MJE

NOTE: [1] Person authorizing change shall sign here for latest revision.

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POST-COL ROLLER COMPACTED CONCRETE TESTING PLAN
LEVY NUCLEAR PLANT
REVISION 3

1.0 PROJECT BACKGROUND AND INTRODUCTION

A Roller Compacted Concrete (RCC) Bridging Mat will support the Levy Nuclear Plant (LNP) Nuclear Island Basemat. This document describes the RCC Testing and Inspection that will occur prior to and during construction of the Bridging Mat, after the issuance of the Combined Operating License (COL). This Phase IV and V testing will conclude the RCC Test Program, as shown in ***Table 1-1***.

TABLE 1-1
RCC TEST PROGRAM OVERVIEW

PHASE	PROGRAM DESCRIPTION	TIME FRAME
I	Evaluation of Commercial RCC Projects	Pre-COL
II	Mix Design (14 RCC mixes, 5 Bedding mixes)	Pre-COL
III	Large Scale Laboratory Testing (Test Panels with 1 RCC mix, 1 Bedding Mix) to Verify RCC Thermal Properties and Joint Strength	Pre-COL
IV	Strength and Constructability Verification Testing	Post-COL
V	Quality Control Inspection Program during Bridging Mat construction	Post-COL

Rev 1

Rev 3

The RCC Test Program was developed in response to Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) numbers 03.08.05-4 and 03.08.05-6 for the LNP COL Application. The purpose of Post-COL Testing is to verify that the RCC placed at the LNP Site has the engineering properties that are within the limits of the parameters used in the design and analysis of the Bridging Mat.

2.0 PRODUCTION UNIFORMITY TESTING

The first activities associated with the Phase IV Strength and Constructability Verification Testing include verifying materials and RCC mixes and conducting Production Uniformity Testing of the RCC batching and delivery system. Rev 3

2.1 MATERIALS CERTIFICATION AND RCC VERIFICATION

This testing will include testing of the materials that comprise the RCC (cement, fly ash, and aggregates), testing of the fresh RCC, and the casting of RCC cylinders for compressive strength testing. Verification testing will ensure that the Contractor is able to produce an RCC mix that is within the Project Specifications. Testing is performed to ensure that the properties of the cement, fly ash, aggregates, and mixed RCC are in compliance with the RCC specifications and requirements determined during previous testing. RCC verification testing will be performed after the batch facilities are prepared and prior to Production Uniformity Testing. Rev 2

Verification testing of RCC materials will include the tests listed in ***Table 2-1***. The heat of hydration values for the fly ash and cement reported by the manufacturer will be confirmed by laboratory testing performed by a third party. Rev 2 Rev 1

TABLE 2-1
VERIFICATION TESTING OF RCC MATERIALS

MATERIAL	TEST REFERENCE	TEST DESCRIPTION
Aggregate	ASTM C 117	Percent Passing No. 200 Sieve
	ASTM C 136	Gradation of Each Aggregate Stockpile
	ASTM C 136	Combined Gradation
	ASTM C 127	Specific Gravity & Absorption of Coarse Aggregate
	ASTM C 128	Specific Gravity & Absorption of Fine Aggregate
	ASTM C 70	Surface Moisture of Fine Aggregate
	ASTM C 566	Total Moisture
Cement	ASTM C 150	Standard Specification
	ASTM C 186	Heat of Hydration
Fly Ash	ASTM C 618	Standard Specification
Combined 50% Cement and 50% Fly Ash	ASTM C 186	Heat of Hydration

RCC mix samples will be prepared during the verification testing process. Testing of fresh RCC will include the tests listed in ***Table 2-2***. Rev 2

TABLE 2-2
VERIFICATION TESTING OF FRESH RCC

TEST DESCRIPTION	TEST METHOD
Moisture Content	ASTM C 566
Coarse Aggregate Content (+ No. 4)	ASTM C 94
Unit Weight	ASTM C 138
Air Content	ASTM C 231
Density Using Vibrating Table	ASTM C 1170
Compressive Strength at 7 days	ASTM C 39
Vebe Testing	ASTM C 1170

In addition to fresh mix properties, the compressive strength of this material will be evaluated by casting cylinders for compressive strength testing. The results of these strength tests will be monitored and compared to the results obtained in Phase II and Phase III. Testing will be performed at the following Break Ages: 3, 7, 14, 28, 56, 90, 180, and 365 days. Rev 2

2.2 PRODUCTION UNIFORMITY TESTING

Prior to commencing Test Pad construction, several trial runs of the batching system will be performed to confirm uniform, smooth operation. Rev 3 Rev 2

A batching system will be used for RCC production to obtain better control over RCC gradation. RCC batching system uniformity testing will be performed after the batch facilities are prepared and before the first lift of RCC is placed for construction of the Test Pad. The RCC produced during system shakedown and production uniformity testing will be placed as a 12 inch base for the Test Pad. Three samples of RCC will be obtained from the base lift (at different times and plan locations) during the RCC batching system uniformity test process. It is anticipated that the uniformity and RCC base lift production will be approximately 200 cubic yards. This material will be tested in accordance with ***Table 2-3***. In addition to fresh mix properties, the compressive strength of this material will be evaluated after seven days. The variation of results of the three sampling events will be compared to the maximum allowable difference in ***Table 2-3***. These maximum allowable differences are based on extensive experience with RCC mix design, testing, and placement. Variation is defined as the maximum value minus the minimum value, divided by the average of the three samples. The variation of the three samples shall fall within Rev 3 Rev 2 Rev 3 Rev 1 Rev 3 Rev 1 the acceptance range shown in ***Table 2-3***; otherwise, RCC batching system uniformity testing will be repeated until acceptable results are obtained or the facility disqualified. If a problem is suspected with RCC uniformity, the uniformity testing process may be repeated until acceptable results are obtained. Rev 3

TABLE 2-3
UNIFORMITY TESTING SCHEDULE

TEST DESCRIPTION	TEST METHOD	FREQUENCY	MAXIMUM ALLOWED DIFFERENCE (%)
Moisture Content	ASTM C 566	One test with three samples at RCC calibration/startup; thereafter only if suspect problem	15
Coarse Aggregate Content (+ No. 4)	ASTM C 94	One test with three samples at RCC calibration/startup; thereafter only if suspect problem	15
Unit Weight	ASTM C 138	One test with three samples at RCC calibration/startup; thereafter only if suspect problem	2
Air Content	ASTM C 231	One test with three samples at RCC calibration/startup; thereafter only if suspect problem	100
Compacted Wet Unit Weight	ASTM C 1170	One test with three samples at RCC calibration/startup; thereafter only if suspect problem	2
Compressive Strength at 7 days	ASTM C 39	One test with three samples at RCC calibration/startup; thereafter only if suspect problem	25
Vebe Testing	ASTM C 1170	At least once per shift, and with changes in workability of the mix	For information only – average of three separate tests on same batch of RCC

3.0 TEST PAD

Rev 3

After issuance of the COL and prior to construction, Progress Energy will construct a Test Pad as part of Phase IV Strength and Constructability Verification Testing. Samples of the as-placed material taken from the Test Pad will be used to perform compression, split tension, and direct shear strength testing. Samples will also be taken from the Test Pad to perform free-free testing to determine the shear wave velocity of the material. The Test Pad will also be used to validate the methodology that will be used to construct the Bridging Mat and develop construction plans and specifications.

Rev 3

Rev 2

An RCC Testing Subcontractor will be responsible for field sampling and testing of materials and RCC. The responsibilities of this agency are described in more detail in the following subsections.

3.1 SITE PREPARATION AND GENERAL DIMENSIONS

The Test Pad will be constructed on an aggregate base. The dimensions of the Test Pad will be approximately 42 feet by 40 feet excluding the access ramps and approximately 42 feet by 76 feet including the ramps. The base of the Test Pad will be larger to accommodate a perimeter work area. The Test Pad will consist of a maximum 12-inch-thick compacted Aggregate Base, a 12-inch RCC Base Lift constructed during the uniformity testing, and multiple subsequent RCC lifts with nominal thicknesses of 12 inches. It is anticipated that approximately 700 to 800 total cubic yards of RCC will be placed in the Test Pad, including the Access Ramps and RCC Base Lift.

Rev 3

3.2 RCC PLACEMENT AND COMPACTION

The Test Pad will be constructed by placing multiple lifts of RCC, each approximately 12 inches in height (after compaction). RCC will be transported, placed, spread, and compacted in a similar manner as will be used during Bridging Mat construction. Vibratory rollers are expected to be used to compact the RCC, although other compaction methods may be used in areas adjacent to the forms.

Rev 3

Rev 2

Rev 1

The RCC will be compacted in place to a specified average density or 98 percent of the theoretical air-free density, whichever is greater. Density will be measured using single-probe

Rev 2

nuclear density gages in accordance with ASTM C 1040. The average density will be determined by taking a minimum of three readings at the bottom, middle, and three inches from the top at each test location. A minimum of four test locations will be measured for each lift of RCC. The average density will therefore be determined from a minimum of twelve test readings per lift.

The compacted lift of RCC will be evaluated for compliance with the batch quantities, Joint Maturities (JMVs), and compaction before the next lift of RCC will be placed. Rev 2

3.3 BEDDING MIX AND JOINT MATURITY

A 4,000 psi high-slump (7-to 9-inch) Bedding Mix will be placed between compacted lifts of RCC. This material will be batched using a maximum ¾-inch aggregate. The bedding layer will be placed in a minimum of ¾-inch layer immediately prior to placement and compaction of the next lift of RCC.

The RCC Lifts/Bedding Layer Joints will be created at JMVs of approximately 2,500 degree hours and at approximately 4,700 Degree-Hours. The temperature will be recorded and stored by temperature recording devices. A minimum of two temperature recording devices will be used per lift of RCC. The data will be downloaded to a monitoring device and evaluated. When the RCC reaches the required maturity, the lift surface will be prepared, the Bedding Layer will be applied, and the next lift of RCC can be initiated. Rev 2

To bound all expected construction conditions, the Contractor will practice lift surface treatment for both "warm" joints (approximately 2,500 degree hours) and "cold" joints (approximately 4,700 degree hours). The "Warm" joint will be prepared for the subsequent Bedding layer placement by removing laitance (if any), loose debris, and contaminants from the entire surface by compressed air and vacuum. The "Cold" joint will be prepared by water/air jetting to expose but not undercut the aggregate. The industry term for this type of joint preparation is a "green cut." After green cutting, the entire surface will be cleaned of any remaining loose debris and excess moisture by compressed air and/or vacuum. Rev 2 Rev 2

3.4 LABORATORY EVALUATION OF RCC Rev 2

The laboratory evaluation of the RCC covers three general areas: verification of materials used, sampling and testing of fresh mix properties, and cylinder casting for evaluation of strength properties. Rev 2

3.4.1 Materials Quality Control Testing

During Test Pad construction, daily tests will be performed on RCC aggregate by the RCC Testing Subcontractor to verify conformance with project specifications. Additionally, monthly certifications will be retained for the commercially-supplied cement and fly ash. The anticipated quality control testing frequency is shown in ***Table 3-1***. Rev 3

TABLE 3-1
TEST PAD MATERIALS TESTING SCHEDULE Rev 3

MATERIAL	TEST REFERENCE	TEST DESCRIPTION	TYPICAL TEST FREQUENCY	LOCATION OF SAMPLING
Aggregate	ASTM C 117	Percent Passing No. 200 Sieve	1 test per day	Batch Area
	ASTM C 136	Gradation of Each Aggregate Stockpile	1 test per day	Batch Area
	ASTM C 136	Combined Gradation	1 test per day	Bin Feeders
	ASTM C 127	Specific Gravity and Absorption of Coarse Aggregate	1 test per day	Batch Area
	ASTM C 128	Specific Gravity and Absorption of Fine Aggregate	1 test per day	Batch Area
	ASTM C 70	Surface Moisture of Fine Aggregate	1 test per day	Batching System
	ASTM C 566	Total Moisture	1 test per day	Batching System
Cement	ASTM C 150	Standard Specification	Monthly Certifications	Factory
Fly Ash	ASTM C 618	Standard Specification	Monthly Certification	Fly Ash Source

Rev 3

3.4.2 Tests on Freshly Batched RCC

RCC and bedding mix will be tested as it is placed to ensure consistent placement properties. Fresh mix testing and casting of cylinders for strength testing will occur for each lift. For the RCC, two locations will be sampled and tested: the delivery chute of the batch area and the Test Pad lift. Bedding mix will be tested at the Test Pad lift. The anticipated quality control testing for fresh RCC and bedding mix are summarized in ***Table 3-2***. Rev 3

TABLE 3-2
TEST PAD TESTING SCHEDULE
FOR FRESH RCC AND BEDDING MIX

MATERIAL	TEST REFERENCE	TEST DESCRIPTION	TYPICAL TEST FREQUENCY	LOCATION OF SAMPLING
RCC	ASTM C 1435	Molding RCC test cylinders using a vibrating hammer	1 set of 24 cylinders per lift	Test Pad and Batch Area Delivery Chute
	ASTM C 1064	Temperature	As directed in field, 4 tests per lift minimum	Test Pad Lift after Compaction
	ASTM C 566	Moisture Content	1 test per lift minimum	Test Pad and Batch Area Delivery Chute
	ASTM C 94	Coarse Aggregate Content (+ No.4)	1 test per lift minimum	Test Pad and Batch Area Delivery Chute
	ASTM C 1170	Compacted Wet Unit Weight	1 test per lift minimum	Test Pad and Batch Area Delivery Chute
	ASTM C 138	Unit weight of air-free mortar and coarse aggregate cements	1 test per lift minimum	Test Pad and Batch Area Delivery Chute
	ASTM C 1040	Density and moisture measurement of RCC-nuclear method	As directed in field, 4 tests per lift minimum	Test Pad Lift after Compaction
	ASTM C 231	Air content by pressure method	As directed in field, 4 tests per lift minimum	Test Pad Lift after Compaction
Bedding Mix	ASTM C 143	Slump of Portland Cement Concrete	As directed in field, 4 tests per lift minimum	Test Pad Lift after Compaction
	ASTM C 1064	Temperature	As directed in field, 4 tests per lift minimum	Test Pad Lift after Compaction

Rev 3

3.4.3 Strength Testing on Hardened RCC

Strength testing will be conducted on cylinders cast during placement of RCC. As mentioned in ***Section 3.4.2***, a set of cylinders will be cast at the delivery chute of the Batch area and another set will be cast at the Test Pad. The results of these strength tests will be monitored. Testing will be performed as described in ***Table 3-3***. Testing will be performed at the following Break Ages: 3, 7, 14, 28, 56, 90, 180, and 365 days. Rev 3

TABLE 3-3
STRENGTH TESTING OF TEST PAD

Rev 3

MATERIAL	TEST REFERENCE	TEST DESCRIPTION	TYPICAL TEST FREQUENCY	LOCATION OF SAMPLING
RCC	ASTM C 39	Compressive Strength	1 test per batch per break date	Test Pad and Batch Area Delivery Chute
	ASTM C 469	Static Modulus of Elasticity and Poisson's Ratio	1 test per batch per break date, excluding accelerated 14-day breaks	Test Pad and Batch Area Delivery Chute
	ASTM C 496	Splitting Tensile Strength	1 test per batch per break date, excluding accelerated 14-day breaks	Test Pad and Batch Area Delivery Chute

Rev 3

3.5 STRENGTH AND CONSTRUCTABILITY VERIFICATION TESTING OF TEST PAD

Rev 3

After a curing period, one foot by one foot block samples consisting of two adjacent lifts and the bedded joint will be cut from the Test Pad to perform direct shear testing. Direct shear testing will evaluate the shear strength along lift surfaces by measuring the cohesion and friction angle for the peak load and the residual cohesion and friction angle. The peak values are obtained by testing the specimen to failure and continuing to test until the specimen has been displaced 0.5 inches. The residual cohesion and friction angle are calculated at several points along the displacement. Data from these tests will be used to verify that USACE EM 1110-2-2006 specified shear strengths are achieved across lift joints.

Rev 2
Rev 3
Rev 2
Rev 3

In addition, nominal 6" diameter cylindrical cores will be extracted from the Test Pad and tested in split tension and compression to determine the strength properties of the as-placed parent material. Data from these tests will be used to verify that the design compressive strength of 2,500 psi is achieved and the split tensile strength meets ACI 318-99 requirements. Free-free testing will also be performed on nominal 6" diameter cores extracted from the Test Pad to verify the shear wave velocity of the RCC.

Rev 3

The overall intent of this testing is to determine a correlation between the compressive strength of the as-placed material and the tensile and direct shear strength to show that the as-placed RCC demonstrates the strength requirement utilized in the RCC foundation design calculations.

Rev 3

3.5.1 Field Observation Procedures

The field procedures utilized for the Test Pad construction include the following: Rev 3

- The RCC Testing Subcontractor will ensure that the necessary equipment for determination of the various physical properties of the concrete mixes and aggregates are on hand at the batching or RCC mixing area. These tests may include, but may not be limited to, aggregate moisture and gradation, concrete unit weight, air content, slump of Bedding Mix, temperature, and compressive strength. They will also monitor the batching control system to verify batch weights of each ingredient loaded into the mix. Rev 3 Rev 3

- The RCC Testing Subcontractor will document the compaction equipment employed, verify the lift thickness, document the compactive effort, perform the moisture and density field tests with the nuclear density gage, and record the test results.

- The Test Pad construction contractor will be responsible for ensuring that RCC consistency, workability, and placing procedures are adequate for compaction requirements. The RCC Testing Subcontractor will be responsible for the testing of RCC to include Vebe tests at the batching system and on the placement area, nuclear density tests, aggregate moisture tests, and gradation tests. Rev 3

- Formwork will be placed to the required shape and dimensions and be in accordance with the established alignment and grades. Forms will be of sufficient strength and rigidity to maintain their positions and shapes under the loading and operations incident to placing and vibrating concrete. Formwork will be designed and constructed to withstand the calculated lateral stresses exerted by the plastic RCC during placement and compaction, and to maintain specified tolerances.

4.0 PRODUCTION TESTING AND INSPECTION

Final recommendations for production testing (Phase V) will be determined as an outcome of Phase IV Testing. Construction specifications will be developed as a result of Phase IV testing, and conformance to these specifications will be verified with a Quality Control Inspection Program (QCIP) implemented during Bridging Mat Construction. For reference, the following subsections describe the industry-standard QCIP that has been implemented on past commercial projects. This testing will allow for placement of RCC that is within Project specification. Additional verification testing may be added to this Program once results from the Pre-COL Testing Program are available. However, only nondestructive testing methods will be used in the evaluation of the RCC Bridging Mat. Rev 2

4.1 OVERVIEW OF QUALITY CONTROL INSPECTION PROGRAM

The QCIP is developed to provide a planned and disciplined approach for the achievement of Project quality objectives. The QCIP emphasizes the use of specific verification activities that are performed by qualified personnel assigned to monitor, report, and prevent conditions adverse to quality.

The Program defines organizational entities and their responsibilities with respect to quality; assures the prompt detection and correction of deviations, which may be detrimental to quality; monitors trends to detect problem areas for early correction; and generates documentation necessary to provide evidence of achievement of quality objectives during construction.

The key elements of the QCIP will be as follows:

- ***In-Process Inspections:*** Continuous observation of all work in progress is essential to the success of the Project. These observations will be recorded on Daily Inspection Reports to document that all completed work is in compliance with relevant plans and specifications. Inspectors will immediately notify appropriate superintendents or foremen of out-of-conformance work, and observe whether immediate corrective action is taken. If it is, the Inspector will make a notation on the Daily Report. However, if corrective action is not immediately taken, the Inspector will note the deficiency on the Daily Report and process a Non-Conformance Report (NCR).

- ***Reporting:*** Inspectors must note all observations on the Daily Report. Other report information will include deficiencies noted and/or corrected, NCRs issued, testing in progress, test results, and any item related to work quality. In addition, Inspectors will be required to report on the Contractor(s)'s work forces, on the various elements of work, as well as the weather, equipment in use, and other Project specific information.

- ***Deficiency Tracking:*** Inspectors will note all observed deficiencies on the Daily Inspection Reports. When a Contractor(s) corrects a deficiency, the Inspector will re-inspect the work. Acceptable corrections will be noted on the Daily Report. All deficiencies and corrective measures will also be recorded in a Deficiency Report Log that contains the Inspector's name, inspection report shift and date, a brief description of the deficiency, and the time of correction. The log will be maintained in the office of the Resident Engineer as part of the permanent Project records and will be regularly audited by QC staff.

- ***Non-Conformance:*** When a deficiency is not corrected within the pre-established time frame or when it can be expected to affect the progress of work, the Field Inspector, QCIP Manager, or the Resident Engineer will issue an NCR. The NCR records a deficiency and, as such, is issued to the Contractor(s) with a request for response within a reasonable time (usually five days). The Contractor's response must also be appropriate and include the proposed disposition and recommended corrective action(s) to preclude recurrence. The Resident Engineer and QCIP Manager must approve the proposed corrective action before implementation. Once issued, only the Resident Engineer can close an NCR. Before closure, the Inspector will re-inspect the work and report whether or not it complies with the corrective action Plan. Rev 3

- ***Offsite Inspections:*** Inspection, testing, and QC evaluation at suppliers' facilities will be performed on an as-needed basis.

4.2 MATERIALS TESTING

The materials testing for the LNP RCC Bridging Mat will consist of four major elements: materials sampling, materials testing, calibration, and reports of testing.

4.2.1 Materials Sampling

Materials sampling will be performed at the frequency designated in the Contract Specifications. A continuous numbering system will be instituted for tracking all tests taken and each sample will be assigned a lab number generated by the Laboratory Manager.

4.2.2 Materials Testing

Materials testing will be performed to the appropriate standard designated by ASTM or another applicable governing testing procedure. The testing schedule for the various QC functions is provided in ***Table 4-1***. This schedule provides a summary of all material testing anticipated for the Project along with the associated minimum testing frequencies. The testing frequencies may be increased at the discretion of the Resident Engineer.

TABLE 4-1
RCC MATERIAL TESTING SCHEDULE

MATERIAL	TEST	TEST METHOD	FREQUENCY	ACCEPTANCE CRITERIA
Cement	Physical/chemical properties	ASTM C 150 ASTM C 1157	Manufacturer's Certification (monthly)	ASTM C 150 - Types I,II
Fly Ash	Physical/chemical properties	ASTM C 618	Manufacturer's Certification (monthly)	ASTM C 618 – Class F
Aggregate	Deleterious Substances	ASTM C 33	1 per month or as directed by the Resident Engineer.	As per ASTM C 33, Table 1 (Fine)[1] Table 3 (Coarse)
	Specific gravity and absorption of Coarse Aggregate	ASTM C 127	As many as needed to verify stockpiling methods and then 1 per month.	Specific Gravity and Absorption as Established by Pre-COL Mix Design
	Specific gravity and absorption of Fine Aggregate	ASTM C 128	As many as needed to verify stockpiling methods and then 1 per month	Specific Gravity and Absorption as Established by Pre-COL Mix Design
	Gradation	ASTM C 117 ASTM C 136	Test for each stockpile per shift. Additionally, combined gradation per shift.	Gradation Established by Pre-COL Mix Design
	Moisture content	ASTM C 566	Start of each shift.	For information only
	Flat and Elongated Particles	ASTM D 4791 CRD 119 & 120	1 per week during initial production then 1 per every 50 shifts.	Flat and elongated particles not to exceed 40% on any individual sieve nor 30% total for all sieve sizes.
	L.A. Abrasion of Coarse Aggregate	ASTM C 131	As needed for verification of coarse aggregate/then one per month.	≤ 40% at 500 revolutions
	Organic Impurities in Fine Aggregate	ASTM C 40 ASTM C 87	As needed for verification of fine aggregate/then one per month.	Standard Color No. 3 Relative strength of Mortar not less than 95% of control.

[1]The restriction of material finer than the No. 200 sieve in Table 1 of ASTM C 33 does not apply to fine aggregate used in RCC.

4.2.3 Calibration

Calibration of testing equipment will be in accordance with guidelines, procedures specified by applicable standards, or equipment manufacturer's recommendations. All equipment used in field and laboratory testing will be calibrated at least annually. More frequent calibrations may be required based on the critical nature of test results or sensitivity of equipment. Calibrated equipment is marked to identify the date of calibration, date next calibration is due, and name of person performing calibration. Equipment out of calibration is to be repaired or removed from service until repair or recalibration is completed.

4.2.4 Testing Reports

The results of field and laboratory testing conducted for RCC and conventional concrete will be compiled and reviewed by the Laboratory Manager and QCIP Manager and will be summarized on materials testing forms. The materials testing forms at a minimum will contain the following information:

- Project name and number
- Testing/sample collection date
- Identification of testing personnel
- Test location (station, elevation, field coordinates)
- Identification of calibrated equipment used
- Identification of testing procedure used
- Identification of description of sample tested

4.3 DETERMINATION OF AS-PLACED PROPERTIES

The RCC and Bedding Mix will be testing according to the test schedule in ***Table 4-2***. Further recommendations for nondestructive evaluation of the Bridging Mat may be added as results of the Pre-COL RCC Testing become available.

TABLE 4-2
TESTING SCHEDULE FOR BRIDGING MAT

MATERIAL	TEST	TEST METHOD	FREQUENCY	ACCEPTANCE CRITERIA
RCC	In-place density	ASTM C 1040	4 density tests by Nuclear Methods per 10,000 sq. ft. on each lift.	Average Wet Density 98% of theoretical air free density (TAFD). For areas with small compaction equipment 96% of TAFD.
	Moisture	ASTM C 566 ASTM C 1040	1 each four hours of placement at batching area and 1 every four hours at placement.	For information only, adjust as necessary.
	Temperature	ASTM C 1064	At least 2 per shift at batching area and once every hour at placement.	RCC temp. ≤ max temp. determined by thermal analysis. Ambient temp. ≥ 32 F°
	Air Content	ASTM C 231	1 per shift min, as required to control mix.	For information only
	Compressive strength	ASTM C 1435 ASTM C 39	As requested (min. 1/day).	2,500 psi @ 365 days ACI 349 acceptance criteria
	Vebe Time	ASTM C 1170	At least 1 per shift and changes in mix workability.	For information only
	Fly Ash Content: washout test and gradation based mass balance	ASTM C 117 ASTM C 311	1 test per shift during RCC placement.	Delivery Accuracy limit within 1% by weight.
Bedding Mix	Compressive strength	ASTM C 39	1 per shift.	≥ 4,000 psi at 28 days; ACI 349 acceptance criteria.
	Air Content	ASTM C 231	1 per shift	For information only
	Slump	ASTM C 143	1 per shift min, as required to control workability.	7-9 inches

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5.0 QUALITY ASSURANCE

This work will be completed in accordance with the requirements of a Quality Assurance Program and applicable Implementing Procedures, supplemented by additional controls in the areas of inspection, handling, storage, shipping, inspections, tests, and operating status, that have been developed to satisfy the requirements of 10 Code of Federal Regulations (CFR) 50, Appendix B and NQA-1-1994.

REFERENCES

REFERENCES

The following ASTM standards are referred to in the text by basic designation only. The latest version at the date of the Work shall apply.

ASTM C 33/C 33 M – 08	Standard Specification for Concrete Aggregates
ASTM C 39 / C 39M – 09a	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C 40 – 04	Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
ASTM C 70 – 06	Standard Test Method for Surface Moisture in Fine Aggregate
ASTM C 87 – 05	Standard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
ASTM C 94/C 94M – 09a	Standard Specification for Ready-Mix Concrete
ASTM C 117 – 04	Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C 127 – 07	Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
ASTM C 128 – 07a	Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
ASTM C 131 – 06	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C 136 – 06	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C 138 / C138M – 09	Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
ASTM C 143/143M – 10	Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C 150 / C150M – 09	Standard Specification for Portland Cement
ASTM C 186 – 05	Standard Test Method for Heat of Hydration for Hydraulic Cement
ASTM C 231 / C231M – 09b	Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C 311 – 07	Standard Test Method for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete

ASTM C 469 – 02e1	Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
ASTM C 496/C496M – 04e1	Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
ASTM C 566 – 97(2004)	Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
ASTM C 618 – 08a	Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C 1040/C1040M – 08	Standard Test Methods for In-Place Density of Unhardened and Hardened Concrete, Including Roller Compacted Concrete, by Nuclear Methods
ASTM C 1064/ C 1064M – 08	Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
ASTM C 1157 / C 1157M – 10	Standard Performance Specification for Hydraulic Cement
ASTM C 1170 / C 1170M – 08	Standard Test Method for Determining Consistency and Density of Roller-Compacted Concrete Using a Vibrating Table
ASTM C 1435 / C1435M – 08	Standard Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer
ASTM D 4791 – 05e1	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

ACI Committee 207, "Roller-Compacted Mass Concrete," (ACI 207.5R-99), American Concrete Institute, Farmington Hills, Michigan, 1999.

ACI Committee 318, "Building Code Requirements for Structural Concrete," (ACI 318-99), American Concrete Institute, Farmington Hills, MI, 1999. Rev 3

ACI Committee 349, "Code Requirements for Nuclear Safety Related Concrete Structures," (ACI 349-01), American Concrete Institute, Farmington Hills, MI, 2001.

USACE, "Roller-Compacted Concrete," (EM 1110-2-2006), Department of the Army, United States Army Corps of Engineers, Washington, DC, January 15, 2000.

Attachment 3

Revision 0

90-Day Report Phase III Specialty Testing Program Levy Nuclear Plant

[26 pages attached]

DCR

ENGINEERS/CONSULTANTS/CM

90-DAY REPORT

PHASE III SPECIALTY TESTING PROGRAM

LEVY NUCLEAR PLANT

Engineering & Construction Management
Hydro-Nuclear-Fossil

Geotechnical Engineering

Seismic and Structural Engineering

Hydrological & Hydraulic Engineering

Tunnel Engineering

Environmental Engineering & Permitting

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90-DAY REPORT
PHASE III SPECIALTY TESTING PROGRAM
LEVY NUCLEAR PLANT

PROJECT NO. 07-3935
MAY 16, 2011
REVISION 0

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APPROVALS

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Approval by the responsible manager signifies that the document is complete, all required reviews are complete, and the document is released for use.

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CHANGE MANAGEMENT RECORD

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[1] Changes are marked with a revision mark in margin, beginning with Rev. 1.
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90-DAY REPORT
PHASE III SPECIALTY TESTING PROGRAM
LEVY NUCLEAR PLANT

EXECUTIVE SUMMARY

A Roller Compacted Concrete (RCC) Bridging Mat will support the Levy Nuclear Plant (LNP) nuclear island foundations. A specialty testing program was performed to evaluate the strength and thermal characteristics of the RCC and associated lift joints that will be used for construction of the project. Phase III of the RCC Test Program involved the construction of three test panels using the RCC and bedding mix specified from Phase II. The materials used for this phase are from the same sources as were used in Phase II.

Results from laboratory cast cylinders are consistent with past RCC experience and validated published relationships between tensile strength, elastic modulus, and compressive strength. However, preliminary tests on core samples extracted from the test panels indicate that the RCC used to construct the test panels did not attain the desired strength. This low strength is interpreted to be due to the constructability of laboratory-scale test panels.

Due to the low strength of the samples extracted from test panels, specialty testing will be postponed until after the issuance of the Combined Operating License. The postponement of specialty testing from Pre-COL to Post-COL is considered acceptable for the following reasons:

1. Strength test values determined from laboratory cast cylinders of the mixes that were developed in Phase II and Phase III exceed the compression and tensile strengths required for the project.
2. Biaxial shear test results indicated that the shear strength of the RCC test panels are at least 1.67 times the maximum design demand shear, despite the fact that the samples from the test panels did not yield the desired compressive strength.
3. Specialty testing will be performed prior to construction of the Bridging Mat, and the Phase IV Specialty Test Pad will include testing for biaxial direct shear strength, split tensile strength and shear wave velocity.
4. The constructability issues experienced during Phase III will be avoided in future phases by using full-scale equipment and the same methods used in commercial RCC construction.

90-DAY REPORT
PHASE III SPECIALTY TESTING PROGRAM
LEVY NUCLEAR PLANT

1.0 INTRODUCTION

A Roller Compacted Concrete (RCC) Bridging Mat will support the Levy Nuclear Plant (LNP) Nuclear Island foundation. A specialty testing program was performed to evaluate the strength and thermal characteristics of the RCC that will be used for construction of the project. A five phase RCC test program has been implemented that includes:

- Phase I – Evaluation of previous commercial RCC projects' test results and mixes
- Phase II – RCC and Bedding Mix Design Program
- Phase III – Specialty Testing Program to evaluate RCC and lift joint strength and thermal properties
- Phase IV – Specialty test pad to verify tensile strength, shear strength, and shear wave velocity
- Phase V – Quality Control Inspection Program during Bridging Mat construction

Phases I, II, and III are completed and Phases IV and V are to be completed after issuance of the Combined Operating License (Post-COL).

2.0 OVERVIEW OF LABORATORY TESTING

Laboratory testing activities for the RCC and bedding mix were performed by Fall Line Testing and Inspection LLC (Fall Line) under a subcontract to Paul C. Rizzo Associates, Inc (RIZZO) at Fall Line's laboratory in Tucson, Arizona. The mix constituents and properties were specified during the Phase II Mix Design Program. Fall Line performed testing on the physical properties of the coarse and fine aggregates, cement, and fly ash prior to batching of the RCC and bedding mix. MACTEC and CTL performed physical and chemical testing on the coarse and fine aggregates, cement, and fly ash to provide data for evaluating their long-term performance, durability, and compliance with ASTM standards. Fall Line's work was performed under the RIZZO Quality Assurance Program. Work by MACTEC and CTL was performed under their respective 10CFR50, Appendix B, and ASME NQA-1 Quality Assurance Programs.

Fall Line sampled the coarse and fine aggregates from the stockpiles located inside the laboratory and performed aggregate gradations on these materials. Specific gravity and absorption of the coarse and fine aggregates were also determined. The moisture contents in each stockpile were determined each day during placement of the RCC test panels.

2.1 RCC CYLINDER TESTING

A set of 38 cylinders were cast for each batch of RCC produced during Phase III. For each batch, all cylinders were cured under standard conditions, except two cylinders that followed the accelerated curing procedure.

Three hardened cylinder samples were tested for compressive strength at 3, 7, 14, 28, 56, and 90 days. One of the three compressive strength samples was used to simultaneously test the compressive strength and elastic modulus. Splitting tensile strength testing was performed at ages of 3, 7, 28, 56, and 90 days.

2.2 BEDDING MIX CYLINDER TESTING

Prior to batching and mixing the bedding mix to be used on lift joints, physical properties of #67 and W-10 aggregates were obtained. Gradation testing as well as specific gravity and absorption were performed. Fall Line also tested the moisture content of the aggregates in order to adjust the aggregate batching quantities needed in the mix. Following the bedding mix batching and mixing, the fresh properties of the mix were evaluated. A slump cone test was performed to verify the workability of the mix and assure it met all project requirements. Air content and unit weight of the mix were tested once the mix was deemed appropriate for use. Fall Line also obtained a small bedding mix sample to evaluate the initial and final setting time under penetration resistance.

A set of nine (9) cylinders was prepared to assess the hardened properties of the bedding mix. Compressive strength was performed at ages of 3, 7, and 28 days. Tensile properties and modulus of elasticity were also assessed at the same ages.

3.0 MATERIALS AND BATCHING

The following subsections summarize the materials used, the batch quantities, and the fresh mix properties of the RCC and bedding mixes for Phase III Testing.

3.1 MATERIALS

The aggregate and admixtures used in Phase III Specialty Testing were the same materials used in the Phase II Mix Design Program.

Additional quantities of cement and fly ash were procured for Phase III, using the same sources as were used in Phase II. The cement and fly ash were independently certified by MACTEC as Type II and Class F material, respectively. Additional details about the materials are provided in the following subsections.

3.1.1 AGGREGATE

The aggregate source was Martin Marietta's Camak Quarry. This material is quarried from the Stone Mountain Granite Formation. Aggregate blends for the RCC were proportioned to achieve the gradation specification listed in ***Table 3-1***. The approximate material proportions shown in ***Table 3-2*** were used for batching the RCC needed to construct the three test panels.

TABLE 3-1
BLENDED COARSE AND FINE AGGREGATE SPECIFICATION

U.S. STANDARD SIEVE SIZE	SPECIFICATION PERCENT FINER BY WEIGHT (WASHED)
2 inch	100
1 ½ inch	95-100
1 inch	75-87
¾ inch	68-80
½ inch	56-70
⅜ inch	49-63
# 4	38-50
# 8	28-38
# 16	21-31
# 30	15-24
# 50	10-18
# 100	7-13
# 200	4-10

TABLE 3-2
APPROXIMATE RCC AGGREGATE PROPORTIONS

SIZE NUMBER	PERCENT (BY WEIGHT)
#4	27%
#67	34%
M-10*	39%

NOTE:
* Manufacturer's designation

3.1.2 CEMENT

Type II cement from Titan America's Pennsuco Cement Mill was used for Phase III Testing. The cement was procured in standard 94-pound (lb) sacks and transported to the Fall Line facilities in Tucson, Arizona, where it was stored under laboratory conditions.

3.1.3 Fly Ash

Fly ash was supplied by the SEFA Group from Wateree Station. The material complies with the standard requirements of ASTM C 618 for Class F fly ash.

The fly ash was procured in standard 2,000-lb "supersacks" and transported to the Fall Line facilities in Tucson, Arizona, where it was stored under laboratory conditions.

3.1.4 Admixtures

GRACE ADVA 140M, a high range water reducing admixture, was procured as part of the Phase II Mix Design Program. This admixture was added to the bedding mix according to the manufacturer's recommended dosage. No admixtures were used in the RCC.

3.1.5 Water

Mixes were batched using municipal potable water from Tucson, Arizona, as obtained at the Fall Line Laboratory. Under ASTM C 1602, potable water can be used in the production of hydraulic cement concrete without testing or qualification.

3.2 RCC Batching

Based on the results from the Phase II Mix Design, a mix was specified for use in Phase III. The specified mix is a combination of Mix 1 and Mix 3 from Phase II, and it consists of 200 pounds of Type II Portland cement with 250 pounds of Class F fly ash (per cubic yard) and a 6.2% to 6.6% moisture content range. Mix proportions were established in accordance with the procedure given by the United States Army Corps of Engineers (USACE) Engineer Manual (EM) 1110-2-2006 for Roller Compacted Concrete.

3.2.1 Batch Proportions

The RCC mixes were prepared separately for each lift using the same quantity of cement and fly ash with a target moisture content between 6.2% and 6.6%. ***Table 3-3*** shows the Saturated Surface Dry (SSD) batch quantities for each batch of RCC produced. The batch quantities for Panel-1 Lift-1 resulted in a drier mix that expected. The batch quantities were subsequently adjusted and remained constant for all remaining batches.

TABLE 3-3
RCC BATCH QUANTITIES

Mix Id	Cement (lb/cy)	Fly Ash (lb/cy)	Water (lb/cy)	W/(C+FA)	#4 (lb/cy) (SSD)	#67 (lb/cy) (SSD)	M-10 (lb/cy) (SSD)
Panel-1 Lift-1	200	250	232	0.52	913	1150	1304
Panel-1 Lift-2	200	250	240	0.53	907	1143	1296
Panel-2 Lift-1	200	250	240	0.53	907	1143	1296
Panel-2 Lift-2	200	250	240	0.53	907	1143	1296
Panel-3 Lift-1	200	250	240	0.53	907	1143	1296
Panel-3 Lift-2	200	250	240	0.53	907	1143	1296

3.2.2 Fresh Mix Properties

The data in ***Table 3-4*** show the RCC mix fresh properties obtained for the test panel batches. To minimize segregation in the RCC mix and to improve lift joint bond strength, the mix proportioning targeted a Vebe time of 25 ± 5 seconds. The Vebe time for all mixes was between 25 and 30 seconds, except for Panel 1 Lift 1 which had a Vebe time of 45 seconds. In general, the mixes showed acceptable workability. RCC temperatures at placement ranged from 60 to 72 degrees Fahrenheit.

The unit weight of the mixes averages 147.4 pcf, with a range of 145.4 to 148.6 pcf. Air content ranges from 1.4 to 2.6 percent, with an average value of 2.3 percent.

TABLE 3-4
FRESH MIX PROPERTIES OF RCC

Date	Mix ID	Cement (lbs/cy)	Fly Ash (lbs/cy)	FA (%)	W/ (C+FA)	Air Temp (°F)	Mix Temp (°F)	Vebe Time (sec.)	Unit Weight (pcf)	Air (%)	Moist (%)
1/13/11	Panel-1 Lift-1	200	250	55.6	0.51	72.3	71.8	45	147.6	1.4	6.3
1/15/11	Panel-1 Lift-2	200	250	55.6	0.53	48.7	60.3	27	145.4	2.5	6.6
1/16/11	Panel-2 Lift-1	200	250	55.6	0.52	71.1	70.6	28	147.3	2.6	6.5
1/18/11	Panel-2 Lift-2	200	250	55.6	0.50	55.9	63.3	28	147.4	2.6	6.2
1/14/11	Panel-3 Lift-1	200	250	55.6	0.51	62.9	65.5	30	148.2	2.2	6.4
1/17/11	Panel-3 Lift-2	200	250	55.6	0.52	66.8	66.5	29	148.6	2.4	6.5

4.0 HARDENED RCC TEST RESULTS

A set of 38 cylinders were cast for strength testing for each batch of RCC produced during Phase III. A total of seven sets of RCC cylinders were produced: one for each of the six lifts of the test panels and one associated with the RCC for thermal testing. The following subsections detail the results of strength testing on these cylinders.

4.1 COMPRESSION TESTING

Figure 4-1 shows the summary of the compressive strength test on cylinders from the six lifts as a function of time. Note that two cylinders from each set were subjected to a 14-day accelerated curing process that provides an estimate of compressive strength at later ages. These data are plotted at 180 days on ***Figure 4-1***.

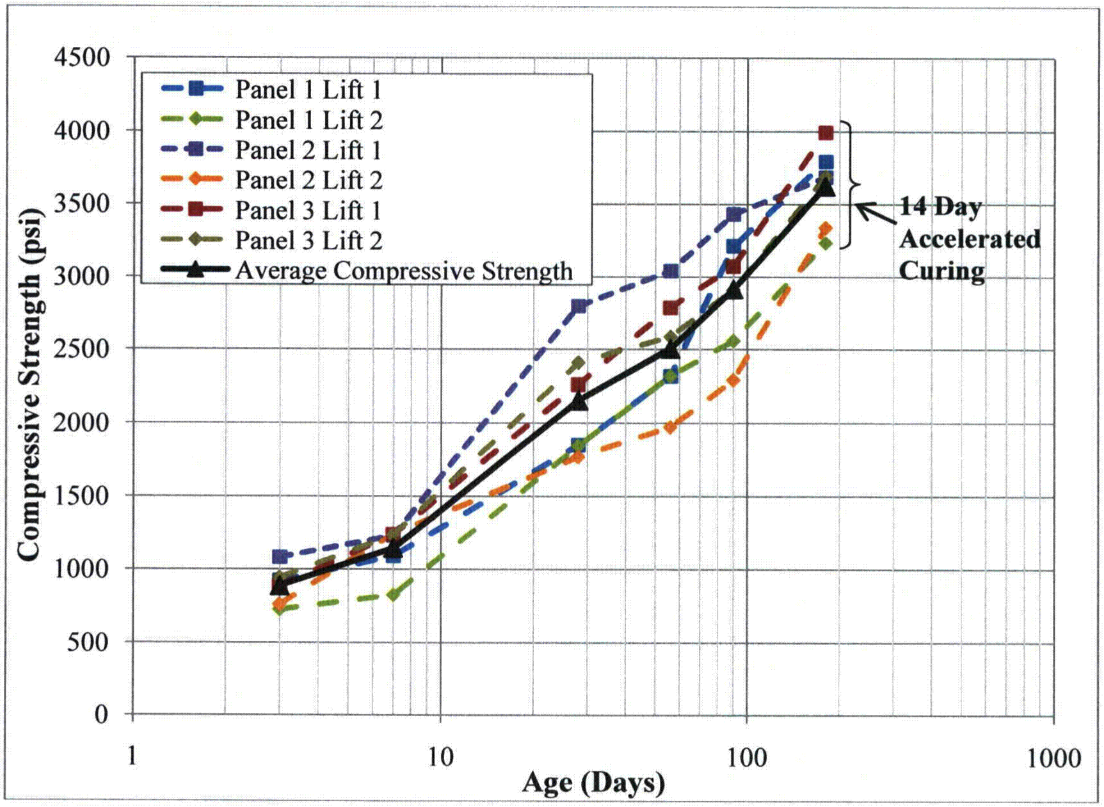

FIGURE 4-1
COMPRESSIVE STRENGTH GAIN FOR RCC MIXES

As shown on ***Figure 4-1*** above, the compressive strength gain already exceeds the 365-day required compressive strength of 2,500 psi. Additionally, the compressive strength gain over time is consistent with those observed in past commercial projects. ***Figure 4-2*** depicts the normalized strength (with respect to the 90-day strength) over time for both the Phase III test panel cylinders and for the construction control cylinders from three major RCC dam projects. From these data, it is concluded that the RCC mix used for the test panels will continue to gain strength through 365 days.

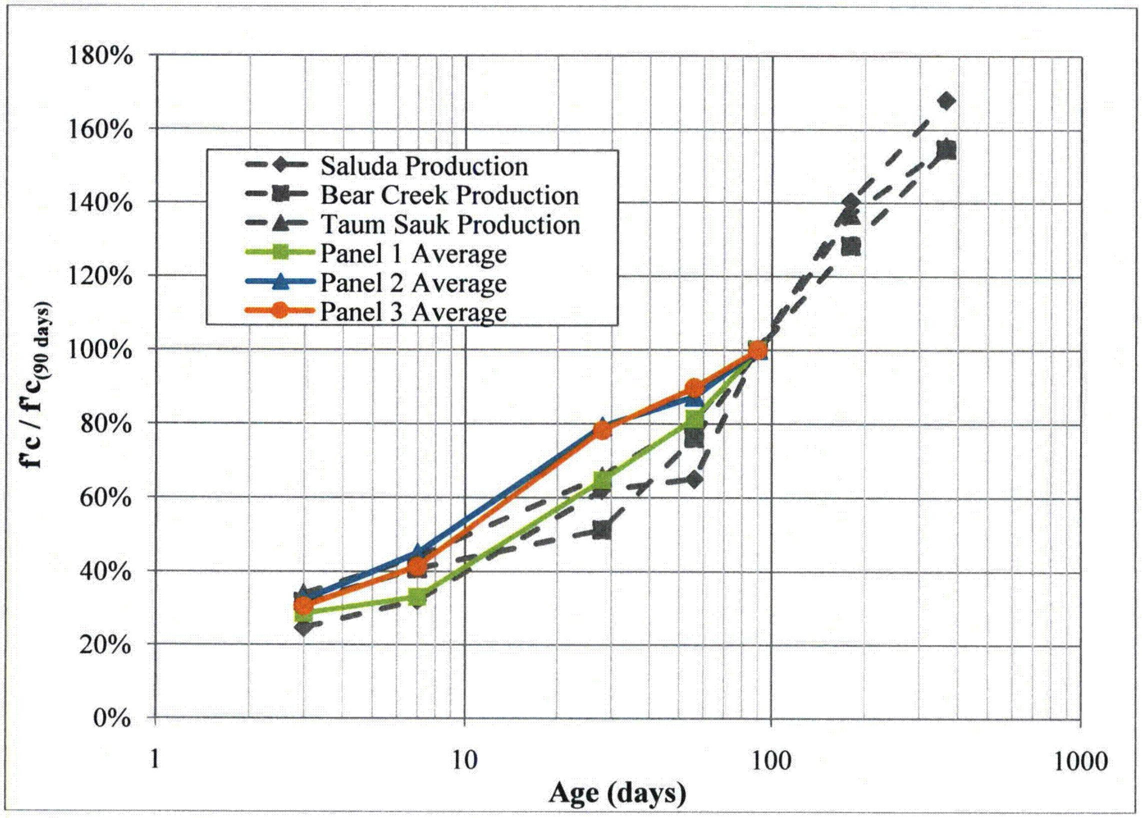

FIGURE 4-2
NORMALIZED STRENGTH GAIN AND COMPARISON TO PREVIOUS COMMERCIAL EXPERIENCE

4.2 TENSION TESTING

Split tensile strength testing was performed on cylinders in accordance with ASTM C 496. ***Figure 4-3*** depicts the tensile strength gain over time for the RCC mixes.

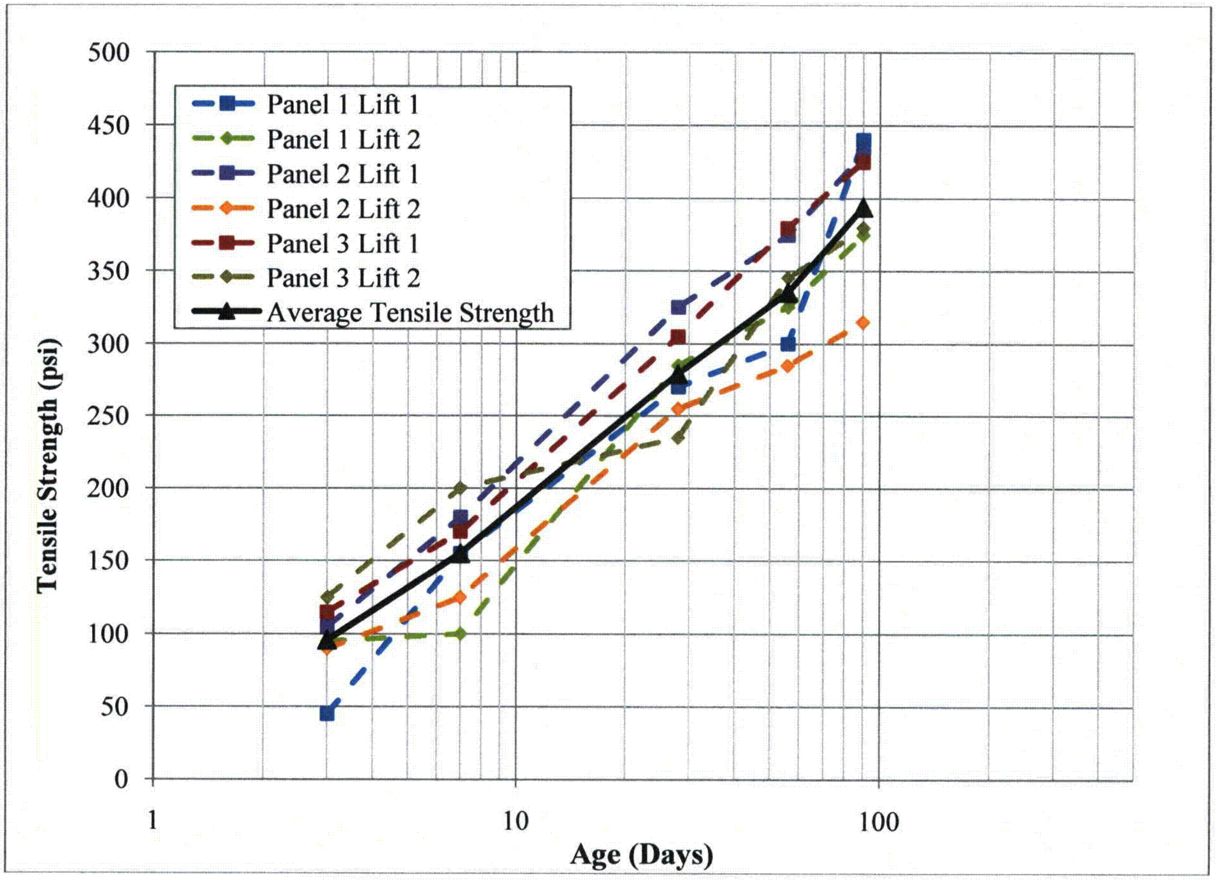

FIGURE 4-3
TENSILE STRENGTH GAIN FOR RCC

A plot of split tensile strength versus compressive strength is provided in ***Figure 4-4***. This figure indicates that the ACI equation for the prediction of tensile strength of concrete ($f'_t = 5 (f'_c)^{0.5}$) is appropriate. Break data from tests at 3 and 7 days were excluded from this figure because the ACI correlation is not applicable at such early maturity.

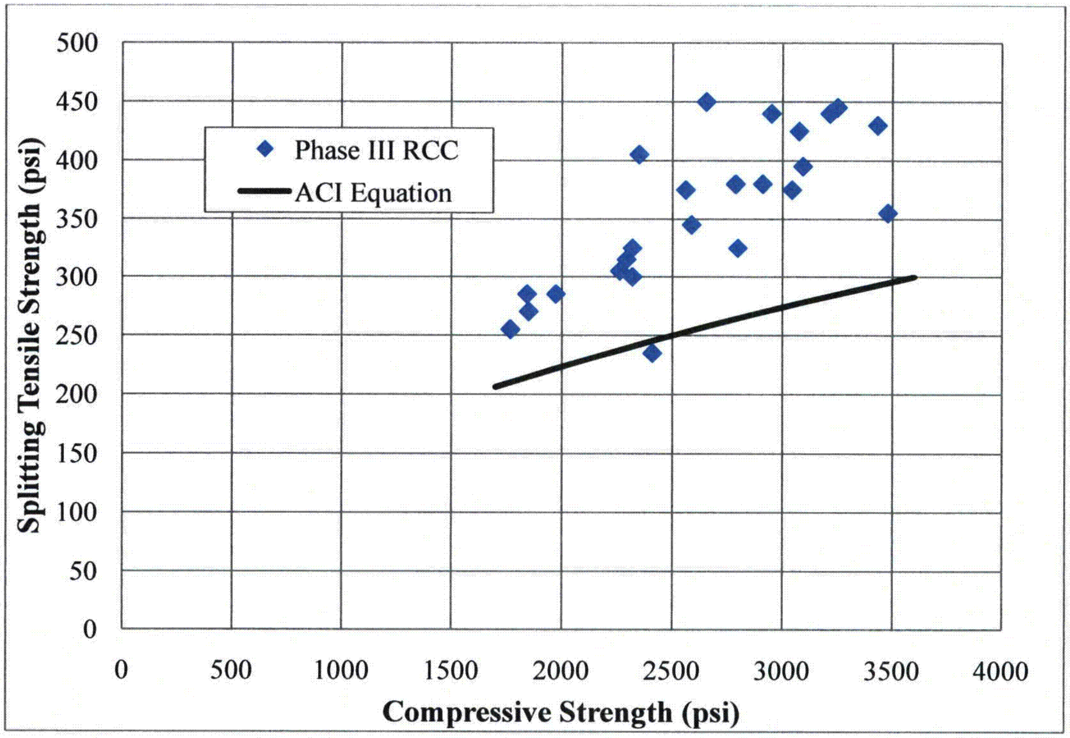

FIGURE 4-4
SPLITTING TENSILE STRENGTH VERSUS COMPRESSIVE STRENGTH OF RCC

4.3 ELASTIC MODULUS TESTING

Testing to determine the chord modulus of elasticity was performed in accordance with ASTM C 469. In the finite element stress and thermal analyses, using a higher value for elastic modulus is more conservative, as it results in higher stresses within the RCC. As shown in ***Figure 4-5***, the chord modulus of elasticity is generally lower than the value predicted by ACI ($E = 33*w_c^{1.50} (f'_c)^{0.5}$), where w_c is the unit weight of the RCC. Therefore, using the ACI equation for the elastic modulus as part of conceptual design is conservative, as a higher modulus value will predict thermal cracking at a given placement temperature and peak temperature before a lower modulus value.

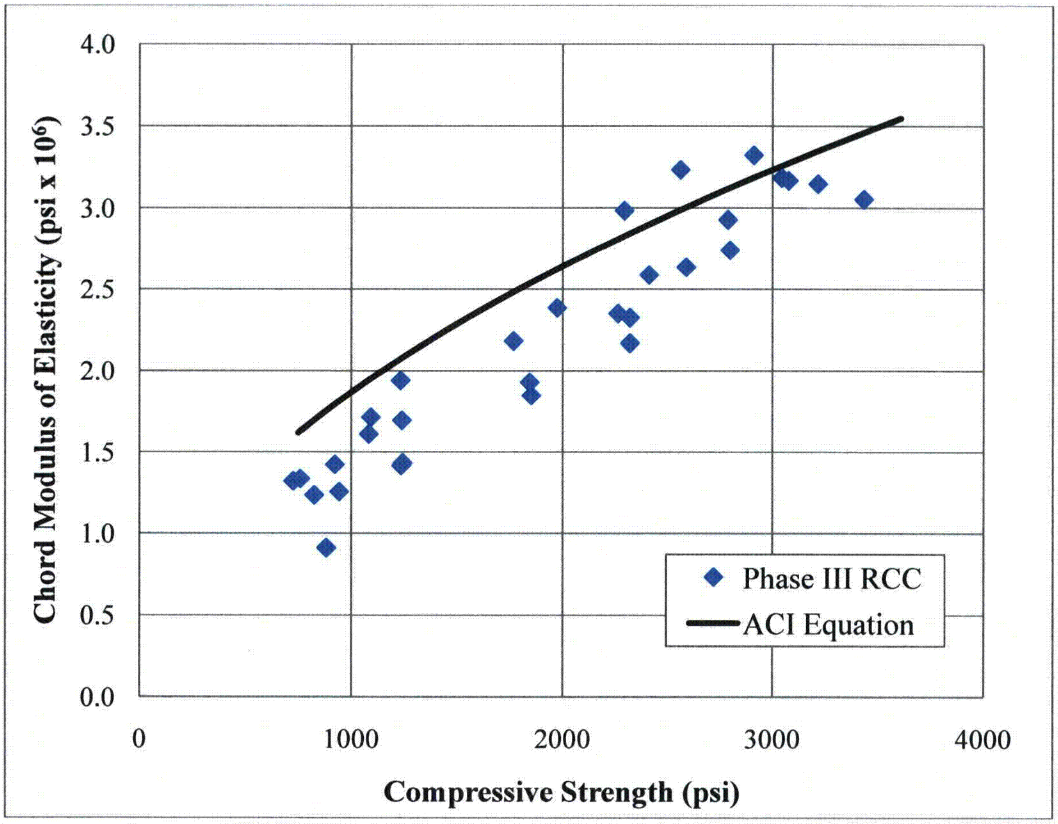

FIGURE 4-5
CHORD MODULUS VERSUS COMPRESSIVE STRENGTH OF RCC

5.0 SPECIALTY TESTING

5.1 PLANNED SCOPE OF PHASE III TESTING

In addition to the laboratory cylinder testing described in the previous sections, block samples were saw-cut from three RCC test panels constructed in the Fall Line laboratory in January 2011. The test panels were placed as two one-foot lifts of RCC separated by bedding mix at the lift joint. Testing on these block samples was to include 54 biaxial direct shear tests, 12 direct tension tests, and 18 determinations of shear wave velocity.

To measure the thermal properties of the RCC mix, adiabatic temperature rise testing was performed according to a RIZZO procedure based on CRD-C 38 and USBR 4911.

5.2 RCC TEST PANEL STRENGTH

Preliminary testing on the RCC test panels indicated that the strength of the as-placed test panels was significantly lower than the strengths of the companion laboratory cast cylinders. This was confirmed by coring 6-inch cylinders from the block samples and performing compression and split tension tests.

This is believed to be an issue with the constructability of test panels in the laboratory, possibly caused by one of the following factors:

1. A weakened cement matrix due to the fact that the fly ash did not activate in the panels. Thermocouple data in the panels indicate a minimal temperature rise. The fly ash may appears not to have acted as a cementitious material in the test panels. ***Figure 5-1*** shows the temperature rise in the test panels compared to the temperature rise of the same mix under adiabatic conditions.
2. Inadequate compaction due to using laboratory-scale compaction equipment. Due to the smaller size of the test panels, smaller compaction equipment than is typically used in the field was used during test panel RCC placement, possibly resulting in incomplete compaction.

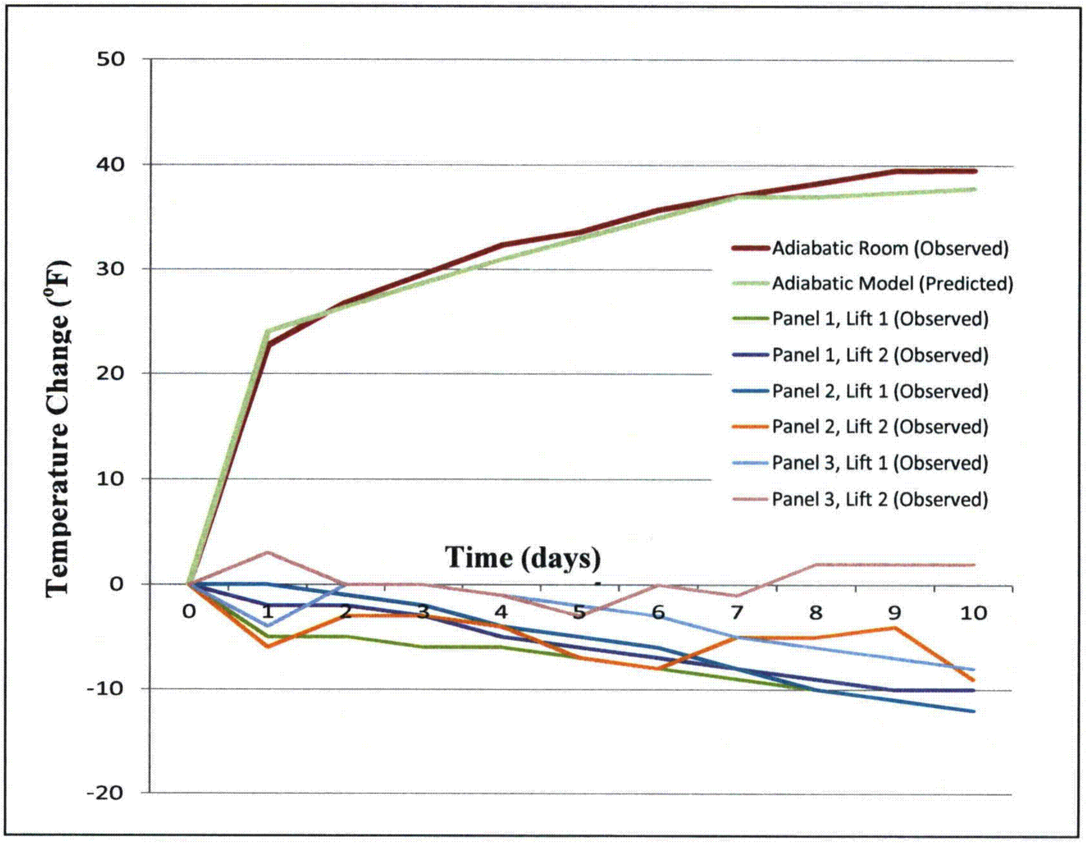

FIGURE 5-1
TEMPERATURE RISE IN PANELS

A root cause analysis is planned to further investigate the cause of the low strength in the RCC test panels. The results of the root cause analysis will be incorporated into the development of future project plans and specifications.

Due to the low strength of the RCC test panels and the fact that the block samples were not representative of the designed RCC, only a limited number of samples were tested as part of Phase III. Three direct shear tests and one direct tension test were performed. Free-free testing for shear wave velocity was not performed on the low-strength block samples.

Despite the low strength, the results of direct shear testing were at least 1.67 times higher than the maximum design demand at a testing age of approximately 100 days. The maximum design demand is based on recommendations of the United States Army Corps of Engineers for 2500 psi RCC. Results of direct shear testing are presented on ***Figure 5-2***.

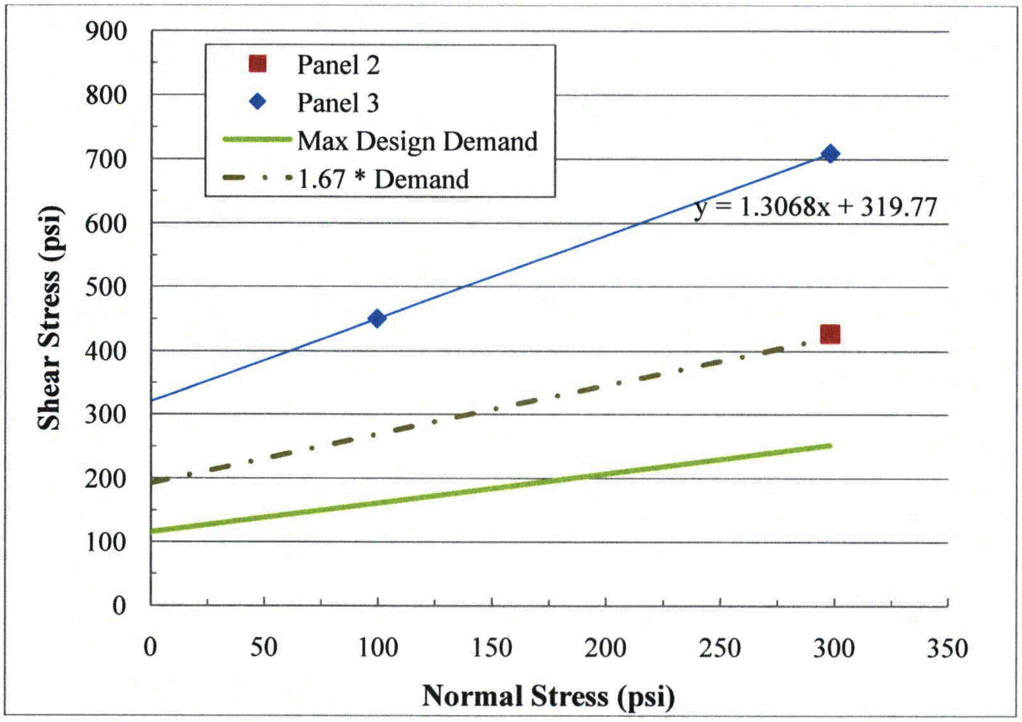

FIGURE 5-2
BIAXIAL DIRECT SHEAR RESULTS

5.3 POSTPONEMENT OF SPECIALTY TESTING

A full-scale test specialty test pad will be constructed Post-COL as Phase IV of the RCC Test Program, as described in the "Post-COL Roller Compacted Concrete Testing Plan, Levy Nuclear Plant," Revision 2, May 2011 (Post-COL Testing Plan). This Phase IV specialty test pad will be constructed using materials, procedures and equipment consistent with those proposed for the LNP Bridging Mat.

Samples will be saw-cut from Phase IV specialty test pad for biaxial direct shear testing, and cores will be taken for shear wave velocity and split tension testing. More details regarding the plan for testing in Phase IV can be found in the Post-COL Testing Plan.

The postponement of specialty testing from Pre-COL to Post-COL is considered to be acceptable for the following reasons:

1. Strength tests on laboratory cast cylinders of the mixes that were developed in Phase II and tested extensively in Phase III exceed the compression and tensile strengths required for the project.
2. Biaxial shear test results indicated that the shear strength of the RCC test panels was at least 1.67 times the maximum design demand shear, despite the fact that the test panels did not achieve the desired compressive strength.
3. Specialty testing will still be performed prior to construction of the Bridging Mat, as the Phase IV Specialty Test Pad will include testing for biaxial direct shear strength, split tensile strength and shear wave velocity.
4. The constructability issues experienced during Phase III will be avoided in future phases by using full-scale equipment and the same methods used in commercial RCC construction.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The constituent material testing confirmed that the constituents used for constructing the test panels meet industry standards. Coarse and fine aggregates from the Martin Marietta Camak Quarry in the Stone Mountain Granite Formation met ASTM C33, with the minor exceptions described in the Phase II Mix Design Report. The fly ash complied with ASTM C 618 for Class F Fly ash. The cement complied with ASTM C 150 for Type II cement.

The RCC and bedding mixes developed during the Phase II Mix Design continued to perform as expected. The strength gain displayed in the laboratory cylinders cast during Phase II and Phase III is consistent with past RCC experience. Furthermore, the relationships between compressive strength, tensile strength, and elastic modulus are consistent with the published relationships. It is concluded that the ACI equations used for conceptual design are appropriate.

Low strength of the RCC in the RCC test panels is believed to be due to the difficulty of simulating full-scale production of RCC on laboratory-scale test sections. A larger Test Pad will be constructed during Phase IV of the RCC Test Program (Post-COL), and samples will be sawn and cored from it for testing, as described in the Post-COL Testing Plan.