Progress Energy

Serial: NPD-NRC-2010-068 10CFR52.79
August 18, 2010

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
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 086 RELATED TO FOUNDATIONS

Reference: 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"

Ladies and Gentlemen:

Progress Energy Florida, Inc. (PEF) hereby submits our response to the Nuclear Regulatory Commission's (NRC) request for additional information provided in the referenced letter.

A response to the NRC request is addressed 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.

Executed on August 18, 2010.

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

Progress Energy Florida, Inc.
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NRO

Levy Nuclear Plant Units 1 and 2
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-0728	Response enclosed – see following pages
03.08.05-5	L-0729	Response enclosed – see following pages
03.08.05-6	L-0730	Response enclosed – see following pages
03.08.05-7	L-0731	Response enclosed – see following pages

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-0728

PGN Response to NRC RAI:

1. The proposed RCC construction at the Levy plant will follow standard RCC construction practice, as described in the USACE Engineering Manual, with additional enhancements related to nuclear safety grade Quality Assurance.

It is important to note that the USACE correlations are being used for preliminary conceptual design. Laboratory testing, as described in Attachment 1, "Pre-COL RCC Test Plan", will verify that these relationships are appropriate for the specific RCC and Bedding Mixes that are proposed for use at Levy. 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. Quality control and inspection during production, as described in Attachment 2, "Post-COL RCC Test Plan", will ensure that the placement of production RCC is within project specifications.

The USACE 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 recommendations for lift surface preparation. These procedures are standard construction practice and will be followed at Levy. A "Commercial RCC Testing" document can be provided to the Staff to detail the design, testing, and construction methods used for large commercial RCC construction projects in the past. This document also describes how the experience gained on these projects is directly applicable to the Levy Nuclear Plant RCC Bridging Mats.

Because similar mixes are to be developed, standard construction practice is to be followed, and additional Quality Assurance measures are to be applied, it is appropriate to use USACE correlations for preliminary conceptual design.

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 quality RCC and Bedding Joints are placed. Attachment 2 describes the minimum testing that will occur after the issuance of the Combined Operating License, including quality control testing during production.

   As described in the response to Part 3 below, direct shear test results will not be used to predict design strength. Instead, the results of 108 direct shear tests will verify that the design shear strength is achievable.

3. Nominal capacities are established during the conceptual design phase using standard concrete codes, ACI 349 and ACI 318. The Finite Element Model of the RCC Bridging Mat has confirmed that these capacities are adequate for the anticipated loading conditions. The RCC Mix Design program will develop a suite of mixes that achieve the required strength properties. Laboratory testing of selected mixes at various ages and joint maturities will confirm that the nominal capacities are achievable under production construction conditions. As detailed in Attachment 1, for each mix and joint condition, nine block samples will be tested for direct shear at each testing age. Tests will be conducted at 90, 180, and 365 days. Samples will be tested at three different proposed normal stresses (σ_{n1} = 40 psi; σ_{n2} = 70 psi; σ_{n3} = 100 psi) to obtain a shear failure envelope, and three replicates will be tested for each normal stress. A total of 108 blocks will be saw-cut from the test panels for direct shear testing.

   ACI 349 and ACI 318 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% with the strict quality control measures that will be in place. Consistent with industry practice and ACI 349, the targeted RCC mix design strength accounts for forecasted variability.

   See Attachment 1 and Attachment 2 for a full written description of the RCC Test Program. These documents discuss the tests that will be performed during the conceptual design phase and during construction to evaluate variability of material properties and ensure that design strengths will be achieved.

In addition, ITAAC Table 3.8-3 for Roller Compacted Concrete will be revised to address consistency of the production LNP Bridging Mat placement and constituents with the design requirements resulting from the testing program.

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.

Associated LNP COL Application Revisions:

The following changes will be made to the LNP FSAR in a future revision:

1. COLA Part 2, FSAR, Section 2.5, revise the following text in Subsection 2.5.4.5.4.1 from:

A Roller Compacted Concrete (RCC) Test Pad will be constructed much in the same manner as is done for large dams, such as the Saluda Dam. Mix design, material control testing, strength testing, concrete placement, and field testing, including density testing and vebe testing, will be conducted to meet NQA-1 quality requirements.

A suite of mix designs will be established for this concrete, indicating the proportions of material constituents, as well as the target strength. Accelerated curing techniques and subsequent laboratory testing will indicate the preferred mix.

The RCC Test Pad will be constructed to specifications consistent with the design parameters set forth in FSAR Subsection 2.5.4.5.4. The Test Pad will be approximately 50 feet long and 40 feet wide, with two sides consisting of 3H:1V or flatter ramps for equipment access, and two sides consisting of vertically formed surfaces. The RCC Test Pad will consist of at least 6 one-foot vertical lifts.

The ramps associated with this RCC Test Pad will also be constructed to specifications consistent with the design parameters set forth in FSAR Subsection 2.5.4.5.4. The RCC in these ramps will be carefully placed, and will be used to train the constructors and equipment operators on the proper mixing and placement techniques for RCC.

As stockpiles of the materials are built, moisture tests and gradation analyses will be performed on an as-needed basis. The specific gravity of each material will also be verified. While the Test Pad is constructed, moisture testing will occur, and test specimens will be gathered for each lift of material. These specimens will be tested for compression, modulus of elasticity, and split tensile strength. Bedding materials used will also be tested for compressive strength. Holes will be drilled in the Pad to determine shear wave velocity properties of the material using crosshole logging techniques. These Testing Services will provide strength properties and in-place shear wave velocities, ensuring that target property requirements will be met.

The tests will also establish the placement techniques that will be directly applicable during AP1000 foundation construction. The RCC Test Program will provide pertinent information for the RCC Bridging Mat construction.

After the Test Section is constructed, long term (>30 days) compression tests will be performed and shear resistance will be measured at lift lines.

To read:

Prior to construction, it will be necessary to construct an RCC Test Pad to evaluate contractor methods and RCC behavior. The Test Pad will serve as training for both the Contractor and the RCC Inspectors, establish effective rolling patterns, and evaluate the effectiveness of cooling measures implemented to place RCC at the specified placement temperature.

The RCC Test Pad will be constructed by the constructor of the AP1000, and will use materials selected during the RCC mix design, with the material delivery systems and equipment intended for production. This Test Pad is intended to include the construction techniques, materials, and equipment anticipated for use in the construction of the LNP foundation.

This RCC Test Pad will be used to evaluate RCC lift surface preparation required at various maturities and curing conditions; placement procedures to eliminate segregation; and RCC mixing, placement and compaction including establishing effective rolling patterns and forming procedures.

Construction of the RCC Test Pad will include numerous stops/restarts (Hold Points and Decision Points) during material stockpiling, and Test Pad preparation and construction so that quality control testing and construction methodology evaluation can be performed, and perceived deficiencies can be addressed.

An RCC Testing Subcontractor will be responsible for field sampling and testing of materials and RCC.

The RCC 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 at least 6 subsequent RCC lifts with nominal thicknesses of 12 inches. It is anticipated that two "training" lifts will be placed at the bottom of the test pad, followed by six lifts to be used for testing. Approximately 700 to 800 total cubic yards of RCC will be placed in the Test Pad, including the Access Ramps and RCC Base Lift.

2. 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 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 placement will be performed. Deviations due to as-built conditions that fall outside the range considered in the design will be analyzed for 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.	i) A report exists which reconciles deviations from design in placing the RCC 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 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:

Attachment 1: Paul C. Rizzo Associates, “Pre-COL RCC Testing Plan,” Revision 0, August 2010

Attachment 2: Paul C. Rizzo Associates, “Post-COL RCC Testing Plan,” Revision 1, August 2010

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

NRC Letter Date: March 16, 2010

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 03.08.05-5

Text of NRC RAI:

In the applicant response to Question 3.8.5-02, Part 4, of RAI 2925 (NRC Letter No. 055) the applicant described the basis for the shear strength at lift joints, the expected seismic demand and the assumptions used in developing the design strength. However, the response indicates that the strength reduction factor from ACI is used to infer a factor of safety on allowable stress. Given that designs following the ACI concrete codes require load factors (e.g. increases in the dead, live, etc. loads) to achieve the desired performance, the staff is requesting that that the applicant clarify how the use of just the strength reduction factor to estimate a target factor of safety is adequate to assure the desired level of performance for the RCC mat to support the nuclear island structures.

PGN RAI ID #: L-0729

PGN Response to NRC RAI:

The desired level of performance of the RCC Bridging Mat is assured by the method of analysis described below.

The RCC Bridging Mat will be constructed using plain (unreinforced) concrete. Neither the AP1000 DCD nor ACI 349-01 address requirements for plain concrete. However, ACI 349-01 gives load factors and strength reduction factors for nuclear safety related concrete structures. ACI 318 (Chapter 22) provides design methodology for plain concrete. The approach used to conform to ACI requirements was thus to use load factors and strength reduction factors from ACI 349-01 in conjunction with the equations and methodology from ACI 318.

The RCC Bridging Mat is modeled using a finite element model (FEM) with solid elements under service loading conditions. The results of this FEM analysis are the stresses anticipated in the RCC under several design cases. These design cases modeled include 10-foot diameter voids and a 10-foot wide strip cavity beneath the RCC Bridging Mat. The maximum stress obtained by the FEM analysis is then compared to the allowable stress determined using ACI equations, load factors, and strength reduction factors.

A combined load factor is calculated based on best available loading information and the load factor combinations in Table 3.8.4-2 of the AP1000 Design Control Document (DCD), which are the same load factors and combinations listed in ACI 349-01. Dead loads and live loads are calculated as a percent of the total load, based on the best available loading conditions. These percentages are used in place of loads in the combinations in Table 3.8.4-2 of the AP1000 DCD. This results in a single combined load factor that is representative of the load distribution. For the RCC Bridging Mat, approximately 70% of the service loads are considered dead loads and 30% of the service loads are considered live loads. Therefore the combined load factor is calculated as $LF_c = 1.4\ (0.70) + 1.7\ (0.30) = 1.49$.

As RCC is unreinforced concrete, the determination of allowable tensile and compressive stresses in the RCC Bridging Mat follows the methodology of ACI 318, Chapter 22, for Structural Plain Concrete.

The equivalent allowable tensile stress can then be calculated using ACI 318-99 Equations 22-1 and 22-2. Equation 22-2 gives the nominal tensile capacity. The allowable tensile stress is obtained by dividing the tensile capacity by the combined load factor.

The equivalent allowable compressive stress is calculated in a similar manner, using ACI 318-08 Equations 22-1 and 22-3. Equation 22-3 gives the ultimate compressive capacity. The allowable compressive stress is obtained by dividing the compressive capacity by the combined load factor.

For the case of shear stresses across lift joints, the strength is represented by a Mohr envelope relationship, as described in ACI 207.5R-99 and the United States Army Corps of Engineers (USACE) EM 1110-2-2006. A factor of safety is then applied to ensure adequate performance. The discussion provided in our response to RAI 2925 (Letter No. 055, Part 4) was not intended to indicate that a strength reduction factor alone was used to imply a factor of safety. A factor of safety of 2 was used in the previous response to determine the allowable shear stresses. This is greater than 1.5, the factor of safety obtained by using a strength reduction factor alone. However, to be consistent with ACI Code, a factor of safety of 2.29 was used in a revised analysis of the shear stresses. This higher factor of safety incorporates both the combined load factor described above and the strength reduction factor for plain concrete (1.49 / 0.65 = 2.29). Even with the more conservative factor of safety, the calculated shear stresses across the lift joint do not exceed the allowable shear stress.

References:

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

2. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary," American Concrete Institute, Farmington Hills, MI, 2008.

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

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

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

Associated LNP COL Application Revisions:

The following changes will be made to the LNP FSAR in a future revision:

1. In FSAR Section 2.5.4.5.4, the last sentence of the third paragraph will be revised from:

The design of the RCC Bridging Mat has considered an allowable tensile stress of 230 psi.

to:

The design of the RCC Bridging Mat has considered a nominal tensile strength of 250 psi.

2. In FSAR Section 2.5.4.5.4, the seventh paragraph will be revised from:

The concrete tensile nominal capacity is 230 psi, using the ACI 318-05 equations for structural plain concrete tensile strength. ACI 349 does not include a Chapter for Plain Concrete. No strength factors were used since the nominal capacities are compared with service loads in order to calculate the factors of safety. Unlike reinforced concrete, in which tensile strength is neglected, an allowable tensile strength is permitted for structural plain (unreinforced) concrete, including RCC. A compressive strength of 2,300 psi was considered in this analysis, a conservative reduction from the 2,500 psi design strength. The tensile capacity will be verified with the RCC Test Pad.

to:

The concrete tensile nominal capacity is 250 psi, using the 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 structural 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.

Attachments/Enclosures:

None.

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

NRC Letter Date: March 16, 2010

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 03.08.05-6

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-0730

PGN Response to NRC RAI:

The capability of the bedding joints to transfer shear and tension will be addressed in two parts: laboratory testing and construction quality control. Direct shear and direct tension tests will be performed in the laboratory to verify that the selected RCC materials are capable of achieving the design strength required to transfer the shear and tensile forces anticipated in the RCC Bridging Mat. Construction quality control will ensure that the material placed at the site has the same engineering properties as the material tested as part of the COL Application.

Direct shear and direct tension tests will be performed during Pre-COL RCC Testing. A complete written description of this testing program is provided as an attachment to the response to RAI 03.08.05-4. The results of this testing will be supplied to the NRC when testing results become available. The anticipated schedule for the interim results of direct shear and tension testing is the Spring of 2011.

According to USACE EM 1110-2-2006, the following characteristics are required to obtain good bond strength at the lift joint: good-quality aggregate, good mixture workability and compaction effort, rapid covering of lift joints by subsequent lifts, and the use of bedding mortar. These items will be addressed during the Pre-COL RCC Testing Program and with strict Quality Control during Bridging Mat production as part of the Post-COL RCC Testing Program. Details about how each characteristic will be addressed are provided below.

Aggregate quality will be addressed during the RCC mix design. Multiple quarries will be evaluated, and once selected, RCC aggregate will undergo prequalification testing to ensure that it meets the standards set forth in the project documents. In addition, to limit the variability between aggregate sources, coarse aggregate that complies with ASTM C33 will be used in the mix design. The quality control testing during RCC Bridging Mat production is described in detail by the Post-COL Testing Plan, included as an attachment to the response to RAI 03.08.05-4. To ensure the quality and uniformity of the RCC during production, the aggregate will be tested daily for conformance to project 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.

Workability will be measured by Vebe testing for RCC and slump testing for bedding mix. During the Mix Design, the selected mixes will be required to have acceptable workability. During construction, Vebe time for RCC and slump of Bedding Mix will be recorded at least once per shift to monitor the workability of the mixes.

Laboratory testing will evaluate the effect of rapid covering of lift joints by subsequent lifts. Direct shear and tensile testing will be performed at two joint maturities. Joint maturity is defined as the integration of the temperature history, and it measures the exposure of the RCC. For example, an RCC placement at 75°F that is exposed for 24 hours will have a Joint Maturity Value (JMV) of 1800 Degree-hours. A lower value for joint maturity indicates less exposure, which generally results in an increased bond between successive RCC lifts. Conversely, a higher value for joint maturity indicates more exposure, which generally results in a decreased bond between successive RCC lifts. To evaluate the effect of joint maturity on lift joint shear and tensile strengths, testing will consist of samples with two JMVs: less than 2000 Degree Hours (a "warm" joint); and more than 3000 Degree Hours (a "cold" joint). These two maturities cover the range that is expected during Bridging Mat construction. Waiting 24 hours between placing successive lifts results in a JMV of approximately 2000 Degree Hours, and waiting 36 hours results in a JMV of approximately 3000 Degree Hours. Testing both a "warm" joint and a "cold" joint will help to evaluate the effect that joint maturity has on bond strength. During both Laboratory Testing and RCC production, thermocouples or thermistors will be used to monitor joint maturity.

While it is possible to construct RCC lift joints without bedding mortar, Bedding Mix will be used over each entire lift surface during RCC Bridging Mat production.

References:

Paul C. Rizzo Associates, "Post-COL RCC Testing Plan," Revision 1, August 2010.

Paul C. Rizzo Associates, "Pre-COL RCC Testing Plan," Revision 0, August 2010.

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

Associated LNP COL Application Revisions:

No COLA revisions have been identified associated with this response.

Attachments/Enclosures:

None.

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

NRC Letter Date: March 16, 2010

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 03.08.05-7

Text of NRC RAI:

In the applicant response to Question 3.8.5-03, Part 1, of RAI 2925 (Letter No. 055) the applicant described the approach used to compute seismic displacements at the foundation level for the Annex, Radwaste and the Turbine buildings. Evaluation of the response has lead to three additional questions.

1. It does not appear from the description provided in Part 1(d), that the effects of drilled shaft -to- drilled shaft interaction are considered. Interaction will reduce the stiffness of the foundation, thereby increasing the displacement to be expected. Discussions between the applicant and the NRC staff indicate that the design of these foundations are not complete, however, it has been assumed that the drilled shaft spacing will be sufficient to preclude interaction. Since the spacing and size of the deep foundations have not been developed, the potential effects of interaction cannot be dismissed out-of-hand. Please indicate the procedure(s) that will be used to assess the significance of the interaction effects between the drilled shafts in final design.
2. The description of application of loads to the pile group indicates that displacements were computed for the application of the inertial loading to the top of the piles. An additional source of relative displacement between the adjacent structures and the nuclear island, that appears to be neglected, is any additional displacement that may be developed from the soils along the sides of the RCC mat, including the engineered fill. This displacement will occur between the base of the RCC mat and the top of the soil corresponding to the elevation of the top of the pile foundation. See the attached sketch. Please provide the basis for neglecting this displacement including an estimate of its magnitude.
3. It appears that the ground motion used to assess liquefaction potential and global displacement of structures is the displacements associated with the GMRS and the related PBSRS. Since the performance goal is defined by the UHRS at the return period associated with the performance goal, please clearify why displacement and liquefaction are not evaluated to this higher desired performance level rather than the displacements associated with the GMRS.

PGN RAI ID #: L-0731

PGN Response to NRC RAI:

In response to the NRC RAI, Calculation LNG-0000-XCC-002 entitled "SSE Induced Displacements at the Foundations of Turbine / Radwaste and Annex Bldgs" was revised as follows:

1. The drilled shaft to drilled shaft interaction effects were included in the calculations for the relative displacement between the Nuclear Island (NI) and the adjacent building foundation mats.

2. The soil column displacement was included in the calculations for the relative displacement between the NI and the adjacent building foundation mats.
3. The maximum NI displacements at design grade elevation 15.2 m (51 ft.) NAVD88 from the AP1000 generic seismic analyses for the Certified Seismic Design Response Spectra (CSDRS) was conservatively used as the maximum NI displacement at the adjacent buildings' foundation mat elevation.
4. The probable maximum relative displacements between the NI and the adjacent Turbine, Annex, and Radwaste Buildings' foundation mat were calculated for the performance based surface response spectra (PBSRS). The relative displacement calculation included the drilled shaft to drilled shaft interaction effects, additional displacement due to soil column displacement, and the NI displacements.
5. The median relative displacements between the NI and the adjacent Turbine, Annex, and Radwaste Buildings' foundation mat were calculated for 10^{-5} Uniform Hazard Response Spectra (UHRS) from randomized soil profiles used for site response analysis to compute the 10^{-5} UHRS. The relative displacement calculation included the drilled shaft to drilled shaft interaction effects, additional displacement due to soil column displacement, and the NI displacements.

In response to the NRC RAI, a new Calculation LNG-0000-X7C-48 entitled "Liquefaction Analysis using UHRS Input" was prepared to evaluate median liquefaction potential for 10^{-5} UHRS.

Details for the relative displacement and liquefaction potential evaluations methodology and results are as follows:

1. Drilled Shaft to Drilled Shaft Interaction

   The drilled shaft to drilled shaft interaction factors were computed for the Turbine Building (N-S direction), Annex Building (E-W direction) and the Radwaste Building (N-S direction), using the S&L proprietary computer program SASSI2000 and the drilled shaft diameters and layout is shown in Figure RAI 03.08.05-07-1, as follows:

   a. The impedance function for a single 3 ft. and 4 ft. diameter drilled shaft for the Best Estimate (BE) soil profile presented in RAI 03.07.1-01 Table 2 was calculated using the SASSI2000 program. The drilled shaft head was considered free to rotate. The impedance functions were calculated in the 0.1 Hz. to 15Hz. frequency range.
   b. The drilled shaft group impedance functions for the Turbine Building (N-S direction), Annex Building (E-W direction), and the Radwaste Building (N-S direction) were computed at the drilled shaft group centroid of the respective buildings using the SASSI2000 program. The drilled shaft diameter and layout used in this analysis for the three buildings is shown in Figure RAI 03.08.05-07-1. The drilled shaft heads were considered free to rotate. Rigid beams were used to connect the drilled shaft heads to the respective building's drilled shaft group centroid to simulate the foundation mat and drilled shaft caps. The impedance functions were calculated in the 0.1 Hz. to 15Hz. frequency range.
   c. The drilled shaft group efficiency factors were calculated as the ratio of the horizontal stiffness of the drilled shaft groups and the horizontal stiffness of the single drilled shaft with a diameter of 4 ft. for the Turbine Building and for a drilled shaft of 3 ft. diameter for the Annex and the Radwaste Buildings in the 0.1

Hz. to 15 Hz. range. The computed drilled shaft group efficiency factors for the three building are as follows:

Turbine Building: 0.348 @ 6.0 Hz. to 0.59 @ 12 Hz.

Annex Building: 0.268 @ 6.0 Hz. to 0.40 @ 15 Hz.

Radwaste Building: 0.363 @ 6.0 Hz. to 0.50 @ 15 Hz.

d. The drilled shaft to drilled shaft interaction factor was calculated as the inverse of the efficiency factor. Conservatively, drilled shaft to drilled shaft interaction factors of 2.87, 3.73, and 2.75 (maximum over the frequency range) were used for relative displacement calculations for the Turbine, Annex, and Radwaste Buildings respectively.

2. Soil Colum Displacements

The soil column horizontal displacements were calculated for BE and Lower Bound (LB) soil profiles shown in RAI 03.07.1-01 Table 2 and RAI 03.07.1-01 Table 3 for PBSRS consistent Foundation Input Response Spectra (FIRS) applied at top of rock elevation -7.3 m (-24 ft.) NAVD88. The calculated soil column horizontal displacements for BE and LB soil column are 0.112 in. and 0.213 in. respectively. Soil column displacement were also calculated for the median shear wave soil profile derived from the randomized set of soil profiles used for 10^{-5} UHRS with 10^{-5} UHRS consistent FIRS applied at top of rock elevation -7.3 m (-24 ft.) NAVD88. The calculated soil column displacement for this median shear wave soil profile is 0.22 in. The median shear wave soil profile for 10^{-5} UHRS is shown in Table RAI 03.08.05-07-3.

3. Maximum NI Displacement at Design Grade Elevation

Maximum NI displacement at the design grade elevation 15.2 m (51 ft.) NAVD88 is 0.062 in, 0.053 in., and 0.113 in. towards the Turbine Building (TB), Radwaste Building (RB), and the Annex Building (AB) respectively. These maximum displacements are based on Westinghouse AP1000 seismic analysis for the six generic soil cases and CSDRS.

4. Probable Maximum Relative Displacements for PBSRS

The probable maximum relative displacements between the NI and the TB, AB, and RB foundation mats were calculated as follows:

a. The number and diameters of drilled shaft supporting the TB, AB, and RB foundation mats is noted on Figure RAI 03.08.05-07-1. The drilled shaft head is considered free to rotate, i.e., no moment constraint. The drilled shafts will be constructed with concrete having a compressive strength of at least 4,000 psi.

b. The BE and LB soil profiles presented in RAI 03.07.01-01 Table 2 and RAI 03.07.1-01 Table 3 respectively were considered. Because the drilled shaft displacements for the LB soil profile gives significantly larger drilled shaft displacements when compared to BE soil profile, the drilled shaft displacements for the Upper Bound (UB) soil profile were not computed because they would be smaller than the displacements for the BE and LB soil profiles due to the still higher stiffness of the drilled shaft-soil system.

c. The dynamic impedance functions for the drilled shaft was calculated using S&L proprietary computer program PILAY. The PILAY formulation is based on plane strain assumption for wave propagation. SASSI2000 program that uses finite elements and vertical transmission of waves in three-dimensional medium was used to benchmark the stiffness calculated from the PILAY program. The SASSI2000 computed stiffness results are higher than the PILAY results in frequency range of 1 Hz to 15 Hz by a factor approximately 1.25. Because the SASSI2000 uses a more accurate 3-dimensional formulation, the PILAY computed drilled shaft stiffnesses were increased by a factor of 1.25.

d. The fixed base natural frequencies for the Seismic Category II portions of the TB and the AB were provided by Westinghouse. The fixed base fundamental natural frequency of the non seismic portion of the TB and the non seismic RB were computed using IBC 2000 Equation 16-39. These frequencies together with the building mass, foundation mat mass, and the drilled shaft group stiffness was used to calculate the building- drilled shaft system frequencies for the TB, AB, and RB.

e. The base shear was then determined based on the combined building-drilled shaft system fundamental frequency for the PBSRS. A higher mode factor of 1.5 was considered. The maximum lateral displacement was calculated by dividing the computed base shear by the stiffness of the drilled shaft group for the TB, AB, and the RB respectively.

f. The probable maximum relative displacement between the NI and the TB, AB, and the RB foundation mats was computed by combining the soil column displacements for PBSRS consistent FIRS, the NI displacement at the design grade, and the TB, AB, and RB foundation mat displacements for PBSRS using the Square root of the sum of squares (SRSS) method. The computed probable maximum relative displacement between the NI and the TB, AB, and the RB foundation mats are:

Building	BE Soil Profile	LB Soil Profile
Turbine Building	0.28 in.	0.68 in.
Annex building	0.37 in.	0.96 in.
Radwaste Building	0.14 in.	0.34 in.

g. The computed probable maximum relative displacements between the NI and the adjacent Turbine, Annex, and Radwaste Buildings' foundation mat for PBSRS are less than the 50 mm (2.0 inch) gap between the NI and the adjacent buildings' foundation mats.

5. Median Relative Displacements for 10^{-5} UHRS

The median relative displacements between the NI and the TB, AB, and RB foundation mats were calculated using the same methodology as for the PBSRS except as follows:

a. The median drilled shaft lateral displacements were obtained from 21 randomly selected soil profiles form the set of several hundred randomized soil profiles used to develop the 10^{-5} UHRS. The median shear wave velocity profile for the 21 soil profile closely matches the median shear wave velocity profile for the entire set of randomized soil profiles used to develop the 10^{-5} UHRS as shown in Figure RAI 03.08.05-07-2.

b. The probable maximum relative displacement between the NI and the TB, AB, and the RB foundation mats was computed by combining the soil column displacements for 10^{-5} UHRS, the NI displacement at the design grade, and the TB, AB, and RB foundation mat displacements for 10^{-5} UHRS consistent FIRS using the Square root of the sum of squares (SRSS) method. The probable maximum relative displacement between the NI and the TB, AB, and the RB foundation mats are:

Building	Median Soil Profile
Turbine Building	0.52 in.
Annex building	0.67 in.
Radwaste Building	0.27 in.

c. The median relative displacements between the NI and the adjacent Turbine, Annex, and Radwaste Buildings' foundation mat for 10^{-5} UHRS are less than the 50 mm (2.0 inch) gap between the NI and the adjacent buildings' foundation mat.

6. Median Centered Liquefaction Potential for 10^{-5} UHRS

In response to the NRC RAI LNP median centered liquefaction potential (factor of safety <1.0) for 10^{-5} UHRS was evaluated. The methodology and design parameters used for 10^{-5} UHRS liquefaction analysis were the same as that used for design basis liquefaction analysis described in Subsection 2.5.4.8 except liquefaction was postulated when the computed factor of safety was <1.0 and the soil cyclic shear stress were computed for the 10^{-5} UHRS ground motions and the median shear wave velocity soil profile derived from the randomized soil profiles used to compute the 10^{-5} UHRS. In addition, the equivalent number of stress cycles was computed for the weighted average moment magnitude of 5.74 for the site. Table RAI 03.08.05-07-1 and Table RAI 03.08.05-07-2 present liquefaction analysis results for 10^{-5} UHRS for LNP 1 and 2 respectively. The results include the computed factors of safety against liquefaction and the depth below the Annex, Radwaste, or Turbine Building foundation mat where liquefaction is postulated. Figure RAI 03.08.05-07-3 and Figure RAI 03.08.05-07-4 show, in plan and elevation respectively, the location of the liquefaction zones identified in Table RAI 03.08.05-07-1 for LNP 1. Figure RAI 03.08.05-07-5 and Figure RAI 03.08.05-07-6 show, in plan and elevation view respectively, the liquefaction zones identified in Table RAI 03.08.05-07-2 for LNP 2. In these figures, the liquefaction zones with a factor of safety of less than or equal to 1.0 are shown by circles with yellow infill. For LNP 1, liquefiable zones were postulated in boreholes O-2, A-15, A-18/O-4, A-13, and B-28. Boreholes O-2, A-15 and A-18/O-4 are in the nuclear island excavation zone. Borehole A-13 (factor of safety = 1.0) is under the Radwaste Building, and B-28 is under the Annex Building. For LNP 2, liquefiable zones were postulated for boreholes B-01, B-07, B-07A, B-31, and B-33. Borehole B-01 is well away from the AP1000 footprint. Boreholes B-07, B-07A, B-31, and B-33 are under the Turbine Building. Based on these figures, it can be concluded that liquefiable zones under the LNP 1 and 2 footprints are confined to the northwest corner of the LNP 2 Turbine Building and in isolated random pockets under the remaining LNP 1 and 2 footprints. These conclusions for median centered liquefaction potential for 10^{-5} UHRS are the same as the conclusions for the design basis liquefaction analysis described in response to NRC Letter 055 RAI 03.08.05-3.

7. Remediation for Pockets of Potential Liquefaction

   For the area under the Annex, Turbine, and Radwaste building footprint, in-situ soil will be replaced or improved to a depth of approximately 2.1 m (7 ft.) below existing grade (elevation 12.8 m [42 ft.] NAVD88). The plant finished grade will be established at elevation 15.5 m (51 ft.) NAVD88 by placing engineered fill above the improved / replaced in-situ material. The earthwork design incorporates vertical and horizontal drains to prevent buildup of excess pore pressures that cause liquefaction as shown in Figures RAI 03.08.05-07-7 and 03.08.05-07-8 for LNP 1 and 2 respectively.

Associated LNP COL Application Revisions:

The following changes will be made to Subsections 2.5.4 and 3.7.2 of the FSAR in a future revision:

1) Text changes to Subsections 2.5.4.5, 2.5.4.8, and 3.7.2.8 as noted below;

2) New Figures for Subsections 2.5.4.8 and 3.7.2.8 are included in Attachment 03.08.05-07A;

3) New Tables for Subsection 2.5.4.8 and 3.7.2.8 are included in Attachment 03.08.05-07B.

<u>Text changes:</u>

A. *The last paragraph of Subsection 2.5.4.5.2 in the NRC Letter 085 RAI 03.07.02-1 response will be modified from:*

"Non safety-related structures will be supported on drilled shaft foundations. Considering the soil conditions at the site and the anticipated structural loads, shallow foundations will not provide adequate bearing capacity within permissible settlement and differential settlement requirements, and soil improvement techniques are not recommended due to the high water table and wetland conditions at the site. The specific design of these drilled shafts will be finalized prior to construction. Foundation design concepts under non safety-related structures are shown on Figures 2.5.4.5-201A, 2.5.4.5-201B, 2.5.4.5-202A, 2.5.4.5-202B, and RAI 03.07.02-01-1."

To read:

"Non safety-related structures will be supported on drilled shaft foundations. Considering the soil conditions at the site and the anticipated structural loads, shallow foundations will not provide adequate bearing capacity within permissible settlement and differential settlement requirements, and soil improvement techniques are not recommended due to the high water table and wetland conditions at the site. The layout and design of these drilled shafts will be finalized prior to construction. Foundation design concepts under non safety-related structures are shown on Figures 2.5.4.5-201A, 2.5.4.5-201B, 2.5.4.5-202A, 2.5.4.5-202B, RAI 03.07.02-01-1, and RAI 03.08.05-07-1."

B. *Subsection 2.5.4.8.5 text starting with the 3rd paragraph to the end in the revised response to NRC Letter 055 RAI 03.08.05-3 will be modified from:*

"For borings where the liquefaction analysis shows potential for liquefaction, the borehole identification, bottom depth of the SPT sample, soil type, and the field SPT N-Value used in the liquefaction analysis are summarized in revised Tables 2.5.4.8-202A and 2.5.4.8-202B. The revised Tables 2.5.4.8-202A and 2.5.4.8-202B also present the results of the liquefaction analysis including the factors of safety against liquefaction and the depth of the postulated liquefiable zone. Figures RAI 03.08.05-03-1 Rev.1 and RAI 03.08.05-03-2 Rev. 1 show, in plan and elevation respectively, the location of the liquefaction zones identified in revised Table 2.5.4.8-202A for LNP Unit 1. Figure RAI 03.08.05-03-3 Rev.1 and Figure RAI 03.08.05-03-4 Rev. 1 show, in plan and elevation view respectively, the liquefaction zones identified in revised Table 2.5.4.8-202B for LNP Unit 2. In these figures, the liquefaction zones with a factor of safety of less than or equal to 1.1 are shown by circles with yellow infill. For Unit 1, liquefiable zones were postulated in boreholes O-2, A-15, A-18/O-4, and B-28. Boreholes O-2, A-15 and A-18/O-4 are in the nuclear island excavation zone. Borehole B-28 is under the Annex Building. For Unit 2, liquefiable zones were postulated for boreholes B-01, B-07, B-07A, B-31, and B-33. Borehole B-01 with liquefiable zones is well away from the AP1000 footprint. Boreholes B-07, B-07A, B-31, and B-33 are under the Turbine Building. Based on these figures, it was concluded that liquefiable zones under the LNP Units 1 and 2 footprints are confined to the northwest corner of the Unit 2 Turbine Building and in isolated random pockets under the remaining LNP Units 1 and 2 footprints.

Soil beneath the nuclear island foundation will be removed and replaced with Roller Compacted Concrete (RCC). Thus, the bearing stability of the nuclear island foundation is not affected by the postulated liquefaction. The random isolated pockets of liquefiable soils also do not affect the nuclear island sliding and overturning stability based on Westinghouse analysis. The Westinghouse analysis concludes that the nuclear island is stable against sliding, and there is no quality requirement for backfill adjacent to the nuclear island to maintain stability against sliding. The Westinghouse analysis also concludes that there is no passive pressure required to maintain stability against overturning.

For the area under the Annex, Turbine, and Radwaste building footprint, in-situ soil will be replaced or improved to a depth of approximately 2.1 m (7 ft.) below existing grade (elevation 12.8 m [42 ft.]). The plant finished grade will be established at elevation 15.5 m (51 ft.) NAVD88 by placing engineered fill above the improved / replaced in-situ material. In addition, this earthwork design will incorporate measures that prevent the excess pore pressure from the deeper liquefiable pockets adversely affecting the shear modulus of the replaced / improved soil layer above. The resulting typical soil profile under the Turbine Building and the Annex and Radwaste Buildings is shown in Figure RAI 03.08.05-03-5 and Figure RAI 03.08.05-03-6 respectively. Calculations show that the lateral stiffness of the drilled shaft is primarily governed by soil properties in the top 10 ft. for drilled shafts up to 4 ft. in diameter and the top 16 ft. for 6 ft. diameter drilled shafts. No additional liquefaction evaluation or remediation for Annex and Radwaste Building foundation is necessary because their design uses 2.5 ft. diameter, 3 ft. diameter, or 4 ft. diameter drilled shafts and the top 10 ft. of soil under these buildings is engineered fill that is not susceptible to liquefaction. For the Turbine Building, the top of the 6 ft. diameter thick foundation mat is at two levels; at grade elevation 15.5 m (51 ft.) NAVD88 and at elevation 9.1 m (30 ft.) NAVD88. For the mat at grade, 4 ft. diameter drilled shafts will be used. Thus the top 10 ft. of these drilled shafts are laterally supported by engineered fill that is not susceptible to liquefaction. For the condenser pit area (elevation 9.1 m [30 ft.]) of the Turbine Building where 6 ft. diameter drilled shaft may be used, lateral support from 16 ft. of non-liquefiable in-situ soil is required. This condition is satisfied under the condenser pit of Unit 1 and 2 Turbine Buildings except in the northwest (plant coordinates) corner of the Unit 2 Turbine Building condenser pit. In this area, the earthwork design will incorporate provisions to prevent buildup of excess pore pressures that cause liquefaction within the 16 ft. depth required for lateral support. In addition, the earthwork design will incorporate measures that prevent the excess pore water pressures from the deeper liquefiable pockets from adversely affecting the shear modulus of soils within the 16 ft. depth during SSE.

The maximum foundation displacement of the Turbine, Annex, and Radwaste Building during the SSE is less than 1 inch which is less than the 2 inch gap at the foundation level between these buildings and the Nuclear Island."

To read:

"For borings where the liquefaction analysis shows potential for liquefaction, the borehole identification, bottom depth of the SPT sample, soil type, and the field SPT N-Value used in the liquefaction analysis are summarized in revised Tables 2.5.4.8-202A and 2.5.4.8-202B. The revised Tables 2.5.4.8-202A and 2.5.4.8-202B also present the results of the liquefaction analysis including the factors of safety against liquefaction and the depth of the postulated liquefiable zone. Figures RAI 03.08.05-03-1 Rev.1 and RAI 03.08.05-03-2 Rev. 1 show, in plan and elevation respectively, the location of the liquefaction zones identified in revised Table 2.5.4.8-202A for LNP 1. Figure RAI 03.08.05-03-3 Rev.1 and Figure RAI 03.08.05-03-4 Rev. 1 show, in plan and elevation view respectively, the liquefaction zones identified in revised Table 2.5.4.8-202B for LNP 2. In these figures, the liquefaction zones with a factor of safety of less than or equal to 1.1 are shown by circles with yellow infill. For LNP 1, liquefiable zones were postulated in boreholes O-2, A-15, A-18/O-4, and B-28. Boreholes O-2, A-15 and A-18/O-4 are in the nuclear island excavation zone. Borehole B-28 is under the Annex Building. For LNP 2, liquefiable zones were postulated for boreholes B-01, B-07, B-07A, B-31, and B-33. Borehole B-01 with liquefiable zones is well away from the AP1000 footprint. Boreholes B-07, B-07A, B-31, and B-33 are under the Turbine Building. Based on these figures, it was concluded that liquefiable zones under the LNP 1 and 2 footprints are confined to the northwest corner of the Unit 2 Turbine Building and in isolated random pockets under the remaining LNP 1 and 2 footprints.

Soil beneath the nuclear island foundation will be removed and replaced with Roller Compacted Concrete (RCC). Thus, the bearing stability of the nuclear island foundation is not affected by the postulated liquefaction. The random isolated pockets of liquefiable soils also do not affect the nuclear island sliding and overturning stability based on Westinghouse analysis. The Westinghouse analysis concludes that the nuclear island is stable against sliding, and there is no quality requirement for backfill adjacent to the nuclear island to maintain stability against sliding. The Westinghouse analysis also concludes that there is no passive pressure required to maintain stability against overturning.

For the area under the Annex, Turbine, and Radwaste building footprint, in-situ soil will be replaced or improved to a depth of approximately 2.1 m (7 ft.) below existing grade (elevation 12.8 m [42 ft.] NAVD88). The plant finished grade will be established at elevation 15.5 m (51 ft.) NAVD88 by placing engineered fill above the improved / replaced in-situ material. In addition, the earthwork design incorporates vertical and horizontal drains to prevent buildup of excess pore pressures that cause liquefaction as shown in Figures RAI 03.08.05-07-7 and RAI 03.08.05-07-8 for LNP 1 and 2 respectively. "

C. A new Subsection 2.5.4.8.6 will be added as follows:

2.5.4.8.6 Median Centered Liquefaction Evaluations for 10^{-5} UHRS

As a sensitivity analysis, the median centered liquefaction potential (factor of safety <1.0) for 10^{-5} UHRS was evaluated. The methodology and design parameters used for 10^{-5} UHRS liquefaction analysis were the same as that used for design basis liquefaction analysis described in Subsection 2.5.4.8 except liquefaction was postulated when the computed factor of safety was <1.0 and the soil cyclic shear stress were computed for the 10^{-5} UHRS ground motions and the median shear wave velocity soil profile derived from the randomized soil profiles used to compute the 10^{-5} UHRS. In addition, the equivalent number of stress cycles was computed for the weighted average moment magnitude of 5.74 for the site. Table RAI 03.08.05-07-1 and Table RAI 03.08.05-07-2 present liquefaction analysis results for 10^{-5} UHRS for LNP 1 and 2 respectively. The results include the computed factors of safety against liquefaction and the depth below the Annex, Radwaste, or Turbine Building foundation mat where liquefaction is postulated. Figure RAI 03.08.05-07-3 and Figure RAI 03.08.05-07-4 show, in plan and elevation respectively, the location of the liquefaction zones identified in Table RAI 03.08.05-07-1 for LNP 1. Figure RAI 03.08.05-07-5 and Figure RAI 03.08.05-07-6 show, in plan and elevation view respectively, the liquefaction zones identified in Table RAI 03.08.05-07-2 for LNP 2. In these figures, the liquefaction zones with a factor of safety of less than or equal to 1.0 are shown by circles with yellow infill. For Unit 1, liquefiable zones were postulated in boreholes O-2, A-15, A-18/O-4, A-13, and B-28. Boreholes O-2, A-15 and A-18/O-4 are in the nuclear island excavation zone. Borehole A-13 (factor of safety = 1.0) is under the Radwaste Building, and B-28 is under the Annex Building. For Unit 2, liquefiable zones were postulated for boreholes B-01, B-07, B-07A, B-31, and B-33. Borehole B-01 is well away from the AP1000 footprint. Boreholes B-07, B-07A, B-31, and B-33 are under the Turbine Building. Based on these figures, it can be concluded that liquefiable zones under the LNP 1 and 2 footprints are confined to the northwest corner of the LNP 2 Turbine Building and in isolated random pockets under the remaining LNP 1 and 2 footprints. These conclusions for median centered liquefaction potential for 10^{-5} UHRS are the same as the conclusions for the design basis liquefaction analysis described in Subsection 2.5.4.8.

D. *Subsection 3.7.2.8.1 text in the response to NRC Letter 085 RAI 03.7.02-1 will be revised from:*

"Add the following text to the end of DCD Subsection 3.7.2.8.1.

LNP SUP 3.7-5

In DCD Subsection 3.7.2.8.1, the maximum displacement of the roof of the Annex Building is reported as 1.6 inches for response spectra input at the base of the building that envelops the SSI spectra for the six soil profiles and also the CSDRS. The Annex Building foundation (top of mat) is at finished grade. RAI 03.07.01-01 Figure 1 shows a comparison of the LNP scaled performance based surface response spectra (PBSRS) at the plant finished grade and the CSDRS. The CSDRS envelops the LNP PBSRS by a wide margin. Thus, the LNP Annex Building roof displacement relative to its foundation is expected to be less than the 1.6 inches in the DCD for the CSDRS. The foundation displacement during SSE of the drilled shaft supported Annex Building is computed to be less than 1 inch. Thus, the LNP Annex building roof displacement during SSE is expected to be less than 2.6 inches. As stated in DCD Subsection 3.7.2.8.1, the minimum clearance between the structural elements of the Annex Building above grade and the nuclear island (NI) is 4 inches. Figure RAI 03.07.02-01-1 shows the conceptual design detail for the interface between the Nuclear Island (NI) and the drilled shaft supported foundation mat of the Annex Building. This design detail provides the 2 inch gap between the Annex Building foundation and the NI consistent with DCD Subsection 3.8.5.1. The top of the diaphragm wall and controlled low strength material fill between the diaphragm wall and the NI wall is at least 1.5 m (5 ft.) below the bottom of the Annex Building foundation mat as stated in Subsection 2.5.4.5.1. Engineered fill is used from the top of the controlled low strength material fill to the bottom of the Annex Building foundation as stated in Subsection 2.5.4.5.4. This interface is designed to avoid hard contact between the NI and the Annex Building foundation resulting from the relative displacements during the seismic event. Thus, no seismic interaction between the Annex Building and the NI is expected."

To read:

"Add the following text to the end of DCD Subsection 3.7.2.8.1.

LNP SUP 3.7-5

In DCD Subsection 3.7.2.8.1, the maximum displacement of the roof of the Annex Building is reported as 1.6 inches for response spectra input at the base of the building that envelops the SSI spectra for the six soil profiles and also the CSDRS. The Annex Building foundation (top of mat) is at finished grade. RAI 03.07.01-01 Figure 1 shows a comparison of the LNP scaled performance based surface response spectra (PBSRS) at the plant finished grade and the CSDRS. The CSDRS envelops the LNP PBSRS by a wide margin. Thus, the LNP Annex Building roof displacement relative to its foundation is expected to be less than the 1.6 inches in the DCD for the CSDRS. The computed probable maximum relative displacement during SSE between the NI and the Annex Building foundation mat is less than 2.5 cm (1 in.). The probable maximum relative displacement calculation included the drilled shaft supported foundation mat displacements including the drilled shaft to drilled shaft interaction effects, additional displacement due to soil column displacement, and the NI displacement at design grade. The Square root of the sum of squares (SRSS) method was used to compute the probable maximum relative displacement. Thus, the LNP Annex building roof displacement during SSE is expected to be less than 2.6 inches. As stated in DCD Subsection 3.7.2.8.1, the minimum clearance between the structural elements of the Annex Building above grade and the nuclear island (NI) is 4 inches. Figure RAI 03.07.02-01-1 shows the conceptual design detail for the interface between the Nuclear Island (NI) and the drilled shaft supported foundation mat of the Annex Building. This design detail provides a 5.0 cm. (2 in.) gap between the Annex Building foundation and the NI consistent with DCD Subsection 3.8.5.1. The top of the diaphragm wall and controlled low strength material fill between the diaphragm wall and the NI wall is at least 1.5 m (5 ft.) below the bottom of the Annex Building foundation mat as stated in Subsection 2.5.4.5.1. Engineered fill is used from the top of the controlled low strength material fill to the bottom of the Annex Building foundation as stated in Subsection 2.5.4.5.4. This interface is designed to avoid hard contact between the NI and the Annex Building foundation mat resulting from the relative displacement between the NI and the Annex Building foundation mat during the seismic event. Thus, no seismic interaction between the Annex Building and the NI is expected."

E. *Subsection 3.7.2.8.2 text in the response to NRC Letter 085 RAI 03.7.02-1 will be revised from:*

"Add the following text to the end of DCD Subsection 3.7.2.8.2.

LNP SUP 3.7-5

Peak foundation elevation displacement resulting from a Performance Based Surface Response Spectra (PBSRS) is conservatively computed to be less than 2.5 cm (1 in.). Figure RAI 03.07.02-01-1 shows the conceptual design detail for the interface between the Nuclear Island (NI) and the drilled shaft supported foundation mat of the Radwaste Building. This design detail provides the 2 inch gap between the Radwaste Building foundation and the NI consistent with DCD Subsection 3.8.5.1. The top of the diaphragm wall and controlled low strength material fill between the diaphragm wall and the NI wall is at least 1.5 m (5 ft.) below the bottom of the Radwaste Building foundation mat as stated in Subsection 2.5.4.5.1. Engineered fill is used from the top of the controlled low strength material fill to the bottom of the Radwaste Building foundation as stated in Subsection 2.5.4.5.4. This interface is designed to avoid hard contact between the NI and the Radwaste Building foundation resulting from the relative displacements during the seismic event. Thus, no seismic interaction between the Radwaste Building and the NI is expected."

To read:

"Add the following text to the end of DCD Subsection 3.7.2.8.2.

LNP SUP 3.7-5 The computed probable maximum relative displacement between the NI and the Radwaste Building foundation mat from a Performance Based Surface Response Spectra (PBSRS) is less than 2.5 cm (1 in.). The probable maximum relative displacement calculation included the drilled shaft supported foundation mat displacements including the drilled shaft to drilled shaft interaction effects, additional displacement due to soil column displacement, and the NI displacement at design grade. The Square root of the sum of squares (SRSS) method was used to compute the probable maximum relative displacement. Figure RAI 03.07.02-01-1 shows the conceptual design detail for the interface between the Nuclear Island (NI) and the drilled shaft supported foundation mat of the Radwaste Building. This design detail provides a 5.0 cm. (2 in.) gap between the Radwaste Building foundation and the NI consistent with DCD Subsection 3.8.5.1. The top of the diaphragm wall and controlled low strength material fill between the diaphragm wall and the NI wall is at least 1.5 m (5 ft.) below the bottom of the Radwaste Building foundation mat as stated in Subsection 2.5.4.5.1. Engineered fill is used from the top of the controlled low strength material fill to the bottom of the Radwaste Building foundation as stated in Subsection 2.5.4.5.4. This interface is designed to avoid hard contact between the NI and the Radwaste Building foundation mat resulting from the relative displacements during the seismic event. Thus, no seismic interaction between the Radwaste Building foundation mat and the NI is expected."

F. *Subsection 3.7.2.8.3 text in the response to NRC Letter 085 RAI 03.7.02-1 will be modified from:*

"Add the following text to the end of DCD Subsection 3.7.2.8.3.

LNP SUP 3.7-5 Peak foundation elevation displacement resulting from a Performance Based Surface Response Spectra (PBSRS) is conservatively computed to be less than 2.5 cm (1 in.). Figure RAI 03.07.02-01-1 shows the conceptual design detail for the interface between the Nuclear Island (NI) and the drilled shaft supported foundation mat of the Turbine Building. This design detail provides the 2 inch gap between the Turbine Building foundation and the NI consistent with DCD Subsection 3.8.5.1. The top of the diaphragm wall and controlled low strength material fill between the diaphragm wall and the NI wall is at least 1.5 m (5 ft.) below the bottom of the Turbine Building foundation mat as stated in Subsection 2.5.4.5.1. Engineered fill is used from the top of the controlled low strength material fill to the bottom of the Turbine Building foundation as stated in Subsection 2.5.4.5.4. This interface is designed to avoid hard contact between the NI and the Turbine Building foundation resulting from the relative displacements during the seismic event. Thus, no seismic interaction between the Turbine Building and the NI is expected. "

To read:

"Add the following text to the end of DCD Subsection 3.7.2.8.3.

LNP SUP 3.7-5 The computed probable maximum relative displacement between the NI and the Turbine Building foundation mat from a Performance Based Surface Response Spectra (PBSRS) is less than 2.5 cm (1 in.). The probable maximum relative displacement calculation included the drilled shaft supported foundation mat displacements including the drilled shaft to drilled shaft interaction effects, additional displacement due to soil column displacement, and the NI displacement at design grade. The Square root of the sum of squares (SRSS) method was used to compute the probable maximum relative displacement. Figure RAI 03.07.02-01-1 shows the conceptual design detail for the interface between the Nuclear Island (NI) and the drilled shaft supported foundation mat of the Turbine Building. This design detail provides the 5.0 cm. (2 in.) gap between the Turbine Building foundation and the NI consistent with DCD Subsection 3.8.5.1. The top of the diaphragm wall and controlled low strength material fill

LNP SUP 3.7-5

between the diaphragm wall and the NI wall is at least 1.5 m (5 ft.) below the bottom of the Turbine Building foundation mat as stated in Subsection 2.5.4.5.1. Engineered fill is used from the top of the controlled low strength material fill to the bottom of the Turbine Building foundation mat as stated in Subsection 2.5.4.5.4. This interface is designed to avoid hard contact between the NI and the Turbine Building foundation mat resulting from the relative displacements during the seismic event. Thus, no seismic interaction between the Turbine Building foundation mat and the NI is expected."

G. A new Subsection 3.7.2.8.4 will be added as follows:

3.7.2.8.4 Median Centered Adjacent Building Relative Displacements for 10^{-5} UHRS

As a sensitivity analysis, the median centered probable maximum relative displacements between the NI and the adjacent Turbine, Annex, and Radwaste Buildings' foundation mat were calculated for 10^{-5} UHRS. The drilled shaft supported foundation mat lateral displacements were obtained from 21 randomly selected soil profiles from the set of several hundred randomized soil profiles used to develop the 10^{-5} UHRS. The median shear wave velocity profile for the 21 soil profiles closely matches the median shear wave velocity profile for the entire set of randomized soil profiles used to develop the UHRS as shown in Figure RAI 03.08.05-07-2. The probable maximum relative displacement between the NI and the TB, AB, and the RB foundation mats was computed by combining the soil column displacements for UHRS, the NI displacement at the design grade, and the Turbine, Annex, and Radwaste Buildings' foundation mat displacements for 10^{-5} UHRS using the Square root of the sum of squares (SRSS) method. The computed probable maximum median relative displacements between the NI and the adjacent Turbine, Annex, and Radwaste Buildings' foundation mat for 10^{-5} UHRS are less than 2.5 cm. (1 in.). Figure RAI 03.07.02-01-1 shows the conceptual design detail for the interface between the Nuclear Island (NI) and the drilled shaft supported foundation mat of the Turbine Building. This design detail provides the 5.0 cm. (2 in.) gap between the Turbine, Annex, and Radwaste Buildings' foundation mat and the NI consistent with DCD Subsection 3.8.5.1. The top of the diaphragm wall and controlled low strength material fill between the diaphragm wall and the NI wall is at least 1.5 m (5 ft.) below the bottom of the Turbine Building foundation mat as stated in Subsection 2.5.4.5.1. Engineered fill is used from the top of the controlled low strength material fill to the bottom of the Turbine Building foundation as stated in Subsection 2.5.4.5.4. This interface is designed to avoid hard contact between the NI and the Turbine Building foundation resulting from the relative displacements during the seismic event. Thus, no seismic interaction between the Turbine, Annex, and the Radwaste Buildings' foundation mat and the NI is expected for 10^{-5} UHRS.

Attachments/Enclosures:

Attachment 03.08.05-07A: New Figures RAI 03.08.05-07-1 through RAI 03.08.05-07-8

Attachment 03.08.05-07B: New Tables RAI 03.08.05-07-1 through RAI 03.08.05-07-3

List of Attachments

1. NRC RAI NUMBER: 03.08.05-4 [L-0728]:

   Paul C. Rizzo Associates, "Pre-COL RCC Testing Plan," Revision 0, August 2010
   [63 pages]

2. NRC RAI NUMBER: 03.08.05-4 [L-0728]:

   Paul C. Rizzo Associates, "Post-COL RCC Testing Plan," Revision 1, August 2010
   [27 pages]

3. NRC RAI NUMBER: 03.08.05-7 [L-0731]:

   Attachment 03.08.05-07A: New Figures RAI 03.08.05-07-1 through RAI 03.08.05-07-8
   [9 pages total]

4. NRC RAI NUMBER: 03.08.05-7 [L-0731]:

   Attachment 03.08.05-07B: New Tables RAI 03.08.05-07-1 through RAI 03.08.05-07-3
   [6 pages total]

ENGINEERS & CONSULTANTS

PRE-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

PRE-COL ROLLER COMPACTED CONCRETE TESTING PLAN
LEVY NUCLEAR PLANT
REVISION 0

PROJECT NO. 07-3935
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APPROVALS

Project No.: 07-3935

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

Date: August 13, 2010

Revision No.: 0

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

Originator:	Brian A. Lucarelli, E.I.T. Engineering Associate	8/13/10 Date
Independent Technical Reviewer:	for Luis R. Gaekel RCC Principal Engineer	8/13/10 Date
Project Manager:	Michael J. Edwards, P.E. Project Manager	8/13/10 Date
Principal-In-Charge:	Paul C. Rizzo, Ph.D., P.E. Principal-In-Charge	8/13/2010 Date

CHANGE MANAGEMENT RECORD

Project No.: 07-3935

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

Revision No. 0

REVISION No.	DATE	DESCRIPTIONS OF CHANGES/ AFFECTED PAGES	PERSON AUTHORIZING CHANGE	APPROVAL[1]
0	8/13/10	Original submittal.	N/A	N/A

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

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REVISION 0

1.0 PROJECT BACKGROUND AND INTRODUCTION

A Roller Compacted Concrete (RCC) Bridging Mat will support the Levy Nuclear Plant (LNP) Nuclear Island Foundations. This document describes the RCC testing that will be performed prior to the issuance of the LNP Combined Operating License (COL). The purpose of this testing is to develop a suite of RCC and concrete bedding mixes and to evaluate the strength and thermal characteristics of the mixes and associated bedding joints that will be proposed for use in construction of the LNP RCC Bridging Mats.

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	Laboratory Testing (2 RCC mixes, 1 Bedding mix) to Verify RCC Thermal Properties and Joint Strength	Pre-COL
IV	On-Site Test Pad to Verify Production Equipment and Contractor Methodology	Post-COL
V	Quality Control Inspection Program during Bridging Mat construction	Post-COL

Phase I of the RCC Test Program is an evaluation of RIZZO's past experience with commercial RCC projects. This report highlights the methods used on past projects, provides results for specialty testing, and describes how this past experience applies to LNP RCC.

RCC Testing will begin with Phase II, a Laboratory Mix Design Program that will evaluate the strength and workability of various RCC and bedding mixtures. The mix designs for this Project will be developed by Paul C. Rizzo Associates, Inc. (RIZZO) and batched by Fall Line Testing, LLC (Fall Line). This Mix Design Program is described in ***Section 2.0***. The mix design program will conclude with the selection of two RCC mixes and one bedding mix for further evaluation in Phase III.

Phase III, a Laboratory Testing Program will follow the mix designs for further evaluation of the selected mixes. Phase III will evaluate strength properties of lift joints and thermal properties of RCC. Laboratory testing will be performed by Fall Line and expert RCC consultants Stephen Tatro and James Hinds. Shear wave velocity testing will be performed by Dr. Kenneth Stokoe, an expert consultant for measurement of dynamic material properties. This testing will conclude with a final report that includes design recommendations relative to shear and tensile strength of the RCC lift joints and the shear wave velocity of the RCC composite structure. Additionally, a detailed construction specification will be written at the conclusion of Phase III for use in Bridging Mat production. The Laboratory Testing Program is required to respond to Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) 03.08.05-4 and to verify the response to NRC RAI 03.08.05-6. The Laboratory Testing Program is described in ***Section 3.0***.

The RCC testing that will occur after the issuance of the COL (Phase IV and Phase V) is described by a separate document, "Post-COL RCC Test Plan."

2.0 PHASE II - MIX DESIGN

The objective of the Mix Design process is to determine the component proportions that will produce a workable RCC mix with mechanical and thermal properties satisfying project requirements. The Mix Design for RCC and bedding mixes will evaluate the effect that water-cementitious materials ratio, fly ash replacement, and admixtures have on mixture strength and workability. The Mix Design Process is described in the following subsections.

2.1 MATERIALS SELECTION

All constituents of the RCC and Bedding Mixes will be evaluated for commercial availability prior to procurement. In all cases, it is desirable to select a material whose properties will not change significantly between the mix design in Phase II and construction in Phase V. The properties that will be reviewed for each material are discussed in the following subsections.

2.1.1 Aggregate

To provide acceptable variability in the mix design moving forward to RCC production mat construction, the crystalline aggregates used will be obtained from two quarries. Additionally, the quarries will be selected such that the crystalline rock formation that they are extracting is also being quarried by several other suppliers.

While the aggregate used for construction must be of the same rock formation as that used during this mix design program, by selecting a rock formation that is being quarried by multiple suppliers, the aggregate supplier can be chosen through a competitive process at the time of construction without having to repeat the mix design program. The two aggregate suppliers used for this mix design program will be selected in part based on their aggregate gradations, allowing RIZZO to select two quarries that provide a range of percent fines, allowing the final mix design(s) to address the potential for variability in the aggregate selected by the EPC for project construction.

To limit the variability between aggregate sources, aggregate that complies with ASTM C33 will be used in the mix design. By using standard aggregate, it is more likely that the physical properties and gradations will remain constant in the time between mix design and RCC production.

2.1.2 Cement

Manufacturer certifications for several commercial cement suppliers in the Southeastern United States will be evaluated prior to procurement. Because the thermal properties of the Levy RCC are considered important, it is preferred that Type II cement be used. The selected cement should have the lowest heat of hydration while meeting all other criteria for Type II Cement in ASTM C 150, "Standard Specification for Portland Cement."

If Type II Cement cannot be procured or will not be available at the time of construction, the cement will be specified by performance using ASTM C 1157, "Standard Performance Specification for Hydraulic Cement."

2.1.3 Fly Ash

Fly ash will be commercial Class F ash complying with ASTM C 618. Class F ash is required because it does not contribute significantly to heat of hydration. The fly ash source will be a supplier in the Southeastern United States.

2.1.4 Water

Potable water will be used for both mix design and construction. Water for the mix design will be potable water from Fall Line's laboratory in Tucson, AZ.

2.1.5 Admixtures

Chemical admixtures will be used to evaluate their effect on RCC and Bedding Mixes. It is anticipated that a set retarder will be used in the RCC. For the Bedding Mix, it is anticipated that a mid-range water reducer and a set retarder will be used.

2.2 Materials Procurement and Certification

Prior to procurement, at least two quarries will be selected by RIZZO based on aggregate properties and availability. The criteria for the evaluation of these quarries are described in ***Section 2.1.1***.

The selected aggregate will be shipped from the quarries to Fall Line's laboratory in Tucson, Arizona. The cement and fly ash proposed for the RCC and bedding concrete mix designs will also be shipped to the laboratory in Tucson. A representative from RIZZO will be present for all packaging and loading procedures to ensure that proper chain-of-custody documentation is completed.

Upon arrival in Tucson, each material will be sampled and shipped to S&ME, an NQA-1 accredited materials certification laboratory for testing.

The following standards will be used as necessary to establish compliance with American Concrete Institute (ACI), United States Army Corps of Engineers (USACE) and ASTM requirements:

- ASTM C150 – Standard Specification for Portland Cement
- ASTM C 618 – Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
- ASTM C 494 – Standard Specification for Chemical Admixtures for Concrete
- ASTM C 1602 – Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
- ASTM C 33 – Standard Specification for Concrete Aggregates

The following tests will be performed on the aggregate to ensure compliance with ASTM C 33:

- ASTM C 136 – Gradation
- ASTM C 566 – Moisture Content
- ASTM C 117 – Material Finer than No. 200 Sieve
- ASTM C 29 – Unit Weight of Coarse Aggregate
- ASTM C 40 – Organic Impurities
- ASTM C 123 – Lightweight Pieces – Coal and Lignite

- ASTM C 142 – Clay Lumps and Friable Particles
- ASTM C 127 – Specific Gravity and Absorption of Coarse Aggregate
- ASTM C 128 – Specific Gravity and Absorption of Fine Aggregate
- ASTM C 88 – Soundness
- ASTM C 131 – Los Angeles Abrasion
- ASTM C 295 – Petrographic Examination
- ASTM D 4791 – Flat and Elongated Particles

The following additional tests will be performed on samples of water:

- ASTM C 151 – Soundness
- ASTM D 512 – Chlorides

2.3 RCC MIX DESIGN

A suite of 14 mixes will be developed with varying proportions of water and cementitious materials. An admixture may be used in conjunction with this program. The suite of 14 mixes is consistent with the industry practice for RCC mix design. They are needed to correlate test strength data to specific content of cement, fly ash, water, admixture, and aggregate percent fines in the RCC mix. As stated in ***Section 2.1.1***, to provide acceptable variability in the mix design moving forward to RCC production mat construction, the crystalline aggregates used will be obtained from two quarries. Approximately half the mixes will be made with aggregate from one quarry, with the other half of the mixes made with aggregate from the other quarry. No mixes will contain a blend of aggregate from both quarries.

As each mix is batched, testing will be performed as described in ***Section 2.2.1***, and cylinders will be cast for the testing discussed in ***Section 2.2.2***. RIZZO will develop the proposed mixes and Fall Line will batch and test the RCC.

As is standard practice for concrete mix designs, the RCC will be overdesigned to account for variability in strength properties. The specified compressive strength at one year is 2500 psi, and the specified tensile strength at one year is 250 psi. The required average compressive strength of RCC will meet the criteria set forth in ACI 349.

2.3.1 Tests on Fresh RCC

Each batch of RCC will be testing according to the following methods:

- ASTM C 231 – Air Content of Freshly Mixed Concrete by the Pressure Method (Adapted for RCC, See ***Appendix A***)
- ASTM C 1064 – Temperature of Freshly Mixed Hydraulic-Cement Concrete
- ASTM C 1170 – Consistency and Density of RCC Using a Vibrating Table (Vebe)

Once sampling and testing has been completed, cylinders will be cast in accordance with ASTM C 1435, "Molding RCC in Cylinder Molds Using a Vibrating Hammer." A set of 38 cylinders will be cast for each batch of RCC produced. Per the requirements of ASTM C 1435, cylinders will be 6 inches in diameter and 12 inches in height.

2.3.2 Tests on Hardened RCC

The strength of RCC cylinders will be tested according to the following standard methods:

- ASTM C 39 – Compressive Strength of Cylindrical Concrete Specimens
- ASTM C 469 – Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
- ASTM C 496 – Splitting Tensile Strength of Cylindrical Concrete Specimens

In addition to these standard methods, two cylinders of each mix will be subjected to an in-house accelerated curing and testing procedure, which can be found in ***Appendix A***. Accelerated curing gives compressive strength results that are representative of later testing ages in standard curing. The exact age represented depends on the mix proportions. Using 50% ash replacement, accelerated curing provides results that are approximately representative of 180-day strength.

Strength testing will be conducted on at least 30 cylinders per mix for the selected mixes. RCC cylinders will be tested according to the schedule in ***Table 2-1***. An additional 8 cylinders will be cast as hold cylinders to allow for additional testing.

TABLE 2-1
TESTING SCHEDULE FOR RCC CYLINDERS
FOR EACH MIX

TEST PERFORMED	NUMBER OF CYLINDERS TESTED								TOTAL
	3 DAYS	7 DAYS	14 DAYS	28 DAYS	56 DAYS[2]	90 DAYS[2]	180 DAYS[2]	365 DAYS[2]	
Compressive Strength	2	2	-	2	2	2	2	2	**14**
Modulus of Elasticity[1]	1	1	-	1	1	1	1	1	**7**
Split Tensile Strength	1	1	-	1	1	1	1	1	**7**
Accelerated Compressive Strength	-	-	2	-	-	-	-	-	**2**
Total	**4**	**4**	**2**	**4**	**4**	**4**	**4**	**4**	**30**

[1]Includes Compressive Strength, per ASTM C 469, Section 6.5
[2]Only the two selected mixes will be tested at these ages; see ***Section 2.5***

2.4 BEDDING MIX DESIGN

A suite of up to five mixes is to be developed with varying proportions of water and cementitious materials and/or admixtures. The specified compressive strength of the Bedding Mix is 4000 psi at 28 days. RIZZO will develop the mix designs and Fall Line will prepare the mixes, perform testing, and cast test cylinders for compressive strength testing.

As each mix is batched, testing will be performed as described in ***Section 2.4.1***, and cylinders will be cast for the testing discussed in ***Section 2.4.2***. RIZZO will develop the proposed mixes and Fall Line will batch the Bedding Mix.

2.4.1 Tests on Fresh Bedding Mix

Each batch of bedding mix will be tested according to the following methods:

- ASTM C 138 – Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- ASTM C 143 – Slump of Hydraulic-Cement Concrete
- ASTM C 231 – Air Content of Freshly Mixed Concrete by the Pressure Method
- ASTM C 1064 – Temperature of Freshly Mixed Hydraulic-Cement Concrete

Once sampling and testing has been completed, cylinders will be cast in accordance with ASTM C 192, "Making and Curing Compressive Strength Cylinders in the Laboratory." A set of ten cylinders, 6 inches in diameter and 12 inches in height, will be cast for each batch of bedding mix produced.

2.4.2 Tests on Hardened Bedding Mix

As each mix is batched, cylinders are to be cast for compressive strength, tensile strength, and modulus of elasticity testing at ages 3, 7, and 28 days.

TABLE 2-2
TESTING SCHEDULE FOR BEDDING MIX CYLINDERS FOR EACH MIX

TEST PERFORMED	NUMBER OF CYLINDERS TESTED			TOTAL
	3 DAYS	7 DAYS	28 DAYS	
Compressive Strength	1	1	1	**3**
Modulus of Elasticity[1]	1	1	1	**3**
Split Tensile Strength	1	1	1	**3**
Total	**3**	**3**	**3**	**9**

[1]Includes Compressive Strength, per ASTM C 469, Section 6.5

2.5 SELECTION OF MIXES FOR LABORATORY TESTING

Upon completion of 28-day strength testing, RIZZO will recommend two RCC mixes and one bedding mix for use in the next phase of testing. The selection of RCC mixes for further evaluation will be based on strength gain through the first 28 days, results of 14 day accelerated testing, mixture workability as determined by Vebe testing, and the anticipated thermal properties of the mix.

The selection of a bedding mix will be based on 28-day strength, workability as determined by slump testing, and anticipated shear properties of the bedding mix. A bedding mortar, without coarse aggregate, is more easily applied in the field. A bedding concrete, with a nominal maximum aggregate size of 3/4 of an inch, provides more shear and tensile strength at the lift joints. The selected bedding mix will balance workability and strength.

Once the two RCC mixes are selected, it may not be necessary to monitor the strength gain of the other twelve mixes. Testing as described in ***Section 2.2.2*** will be continued only for the selected mixes.

3.0 PHASE III - LABORATORY TESTING PROGRAM

The Laboratory Testing Program is a specialty testing program that will provide data regarding the strength properties of the lift joints and the thermal properties of the RCC. Two RCC mixes and one bedding mix will be evaluated as described in the following subsections.

3.1 EVALUATION OF JOINT MATURITY

Joint maturity is defined as the integration of the temperature history, and it measures the exposure of the RCC. For example, an RCC placement at 75°F that is exposed for 24 hours will have a Joint Maturity Value (JMV) of 1800 Degree-hours.

A lower value for joint maturity indicates less exposure, which generally results in an increased bond between successive RCC lifts. Conversely, a higher value for joint maturity indicates more exposure, which generally results in a decreased bond between successive RCC lifts.

To evaluate the effect of joint maturity on lift joint shear and tensile strengths, testing in Phase III will consist of samples with two JMVs: less than 2000 Degree Hours; and more than 3000 Degree Hours. These two maturities cover the range that is expected during Bridging Mat construction. Waiting 24 hours between placing successive lifts results in a JMV of approximately 2000 Degree Hours, and waiting 36 hours results in a JMV of approximately 3000 Degree Hours.

3.2 SAMPLE PREPARATION

Direct shear and tension tests require block samples composed of RCC with a joint formed at different joint maturities. For direct tension testing, two types of joints will be evaluated: a horizontal joint between RCC lifts and an inclined joint formed during a break in construction. Evaluating the tensile strength of construction joints will allow the contractor to stop RCC placement mid-lift if necessary without having to remove and replace the entire lift.

A vertical block sample assesses the strength of a lift joint between two layers of RCC. A typical vertical block sample is shown on ***Figure 3-1***. These samples will be used for all direct shear testing, all shear wave velocity testing, and half of the direct tension testing. A horizontal block sample assesses the strength of a construction joint formed at a 30° angle partway through a lift. A typical horizontal block sample is shown in ***Figure 3-2***. These samples will only be tested in direct tension.

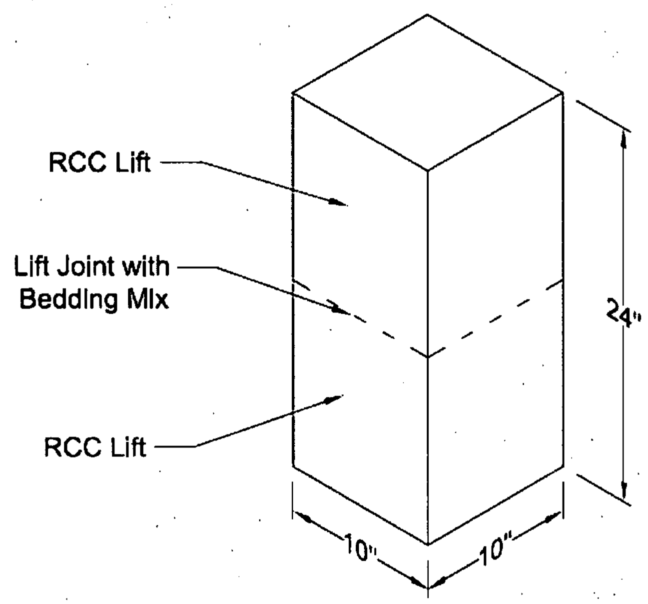

FIGURE 3-1
VERTICAL BLOCK SAMPLE

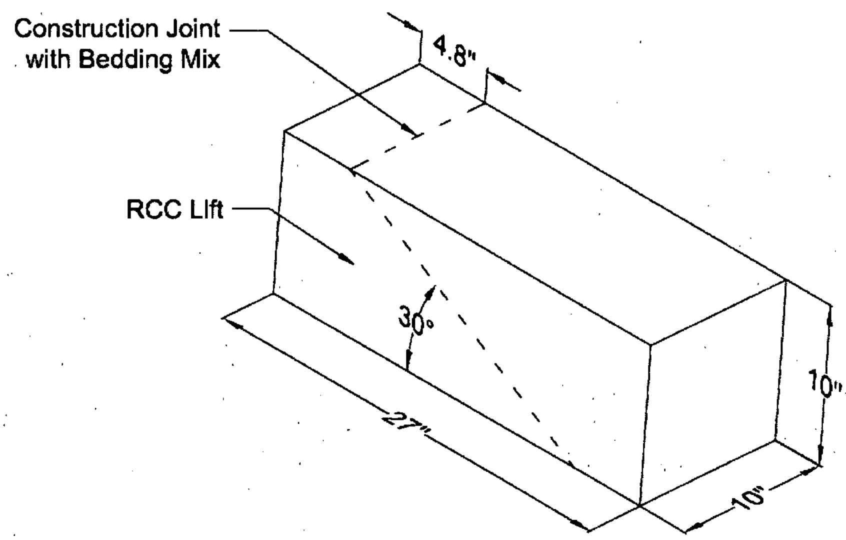

FIGURE 3-2
HORIZONTAL BLOCK SAMPLE

To obtain these samples, test panels will be cast in the laboratory. The dimensions for each panel will be at least 6'2" x 7'7" x 2'. Approximately 12 inches from the outside edge of each panel will be cut and discarded to avoid potential edge effects. A plan view of a typical test panel is shown on ***Figure 3-3***, with a section view shown in ***Figure 3-4***. Two test panels will be cast for each of the four cases, resulting in a total of eight test panels. Thermocouples will be placed in four test panels (one for each mix/JMV) to monitor RCC temperature and joint maturity. A set of 30 cylinders will be cast for compressive strength testing with each batch of RCC produced. Fresh mix RCC properties of each batch of RCC will also be recorded, as described in ***Section 2.3.1***.

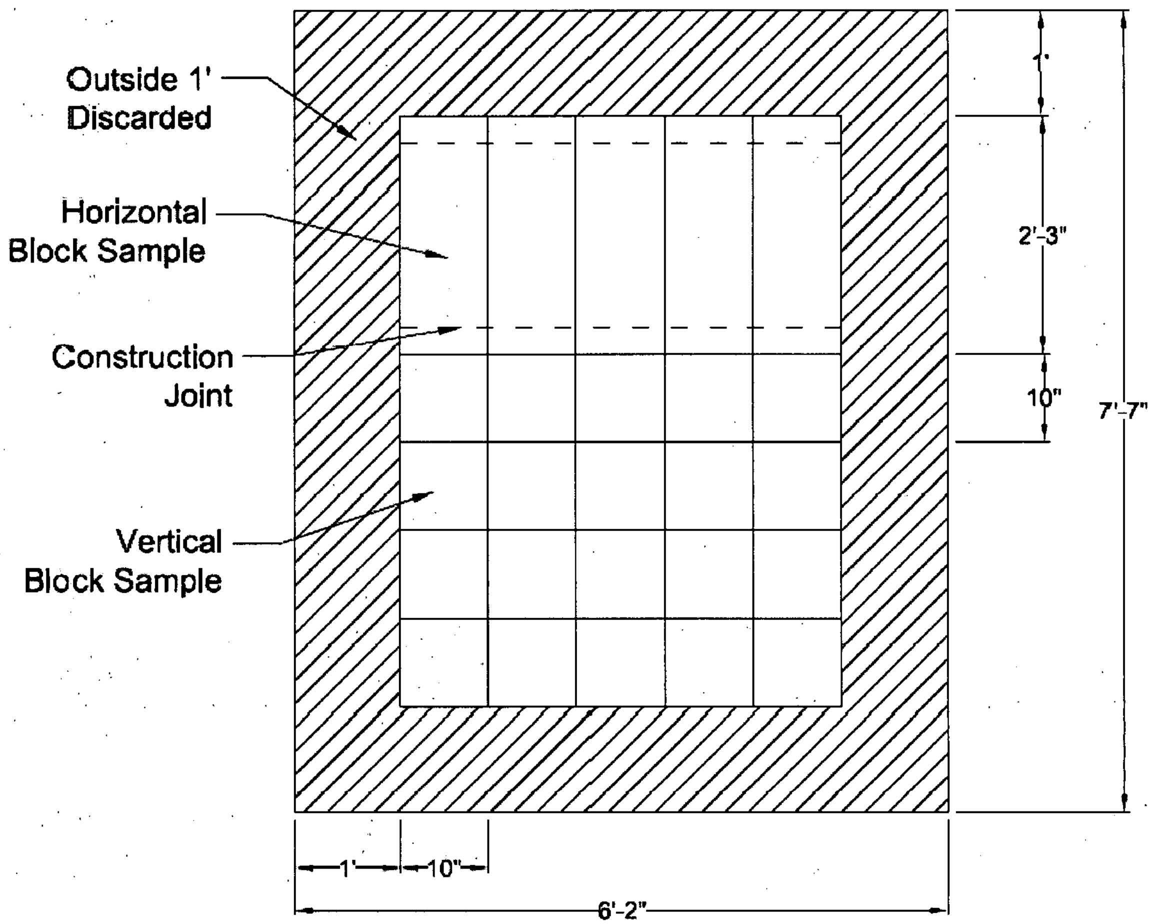

FIGURE 3-3
PLAN VIEW OF TYPICAL RCC TEST PANEL

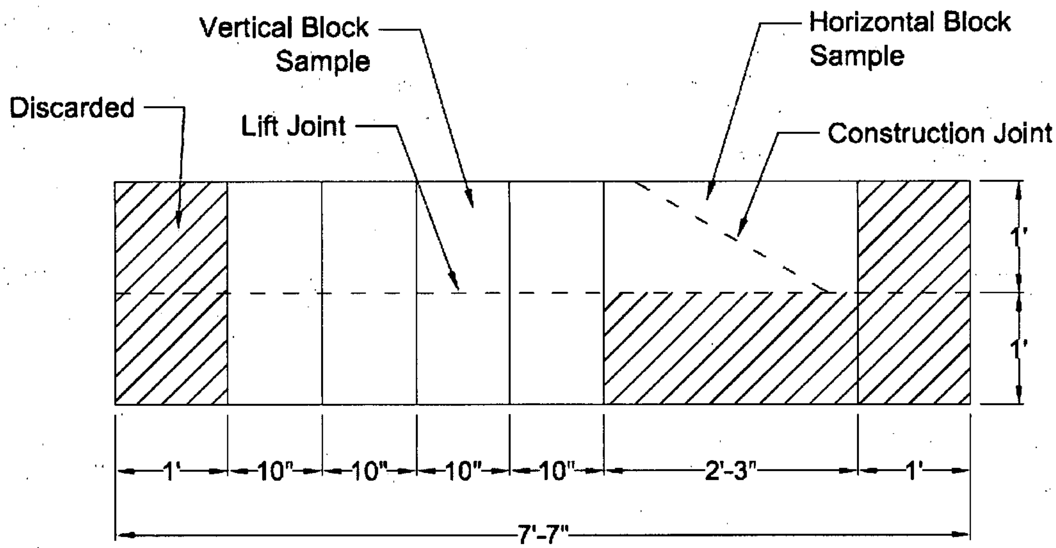

FIGURE 3-4
SECTION VIEW OF TYPICAL RCC TEST PANEL

The block samples will be saw-cut from the test panels for shear and tensile testing. Saw cutting will occur after the RCC has sufficient time to cure, approximately 60 days after the panels are formed. Horizontal block samples will be extracted from the test pad with dimensions of 10 inches x 12 inches x 27 inches. The top and bottom inch of the lift will be trimmed and discarded, as shown in ***Figure 3-5***, to avoid potential edge effects and to provide more uniform specimen dimensions. All block samples will be cut at the same time and stored in the cure room until testing. Due to the size and weight of the block samples, a forklift will be used for transport and to help align the sample in the testing apparatus.

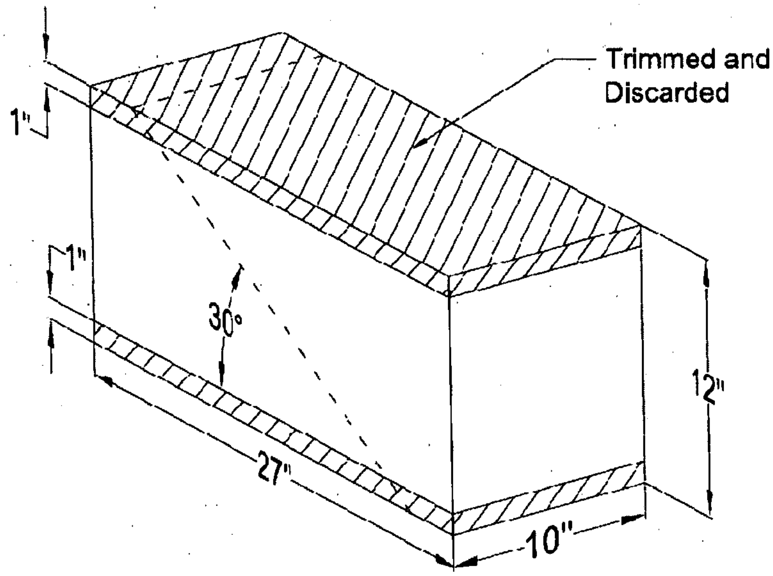

FIGURE 3-5
TRIMMING OF HORIZONTAL BLOCK SAMPLES

It is assumed that two test panels with the same mix/joint condition have the same strength properties. No testing is planned to evaluate the potential difference in strength between samples obtained from different test panels that have the same mix/joint conditions.

3.3 TESTING APPARATUS

The testing apparatus that will be used for direct shear and direct tensile testing has been constructed by RCC Consultants Stephen Tatro and James Hinds. This apparatus improves upon the shear testing methods used by the Corps of Engineers for more than 25 years. A picture of the apparatus is provided in ***Figure 3-6***. The main improvements are in more sophisticated sample instrumentation and improved grip of the sample. The improved instrumentation includes linear variable differential transformers (LVDTs) that measure sample movement and rotation. An image of the collars used to grip the sample is provided in ***Figure 3-7***.

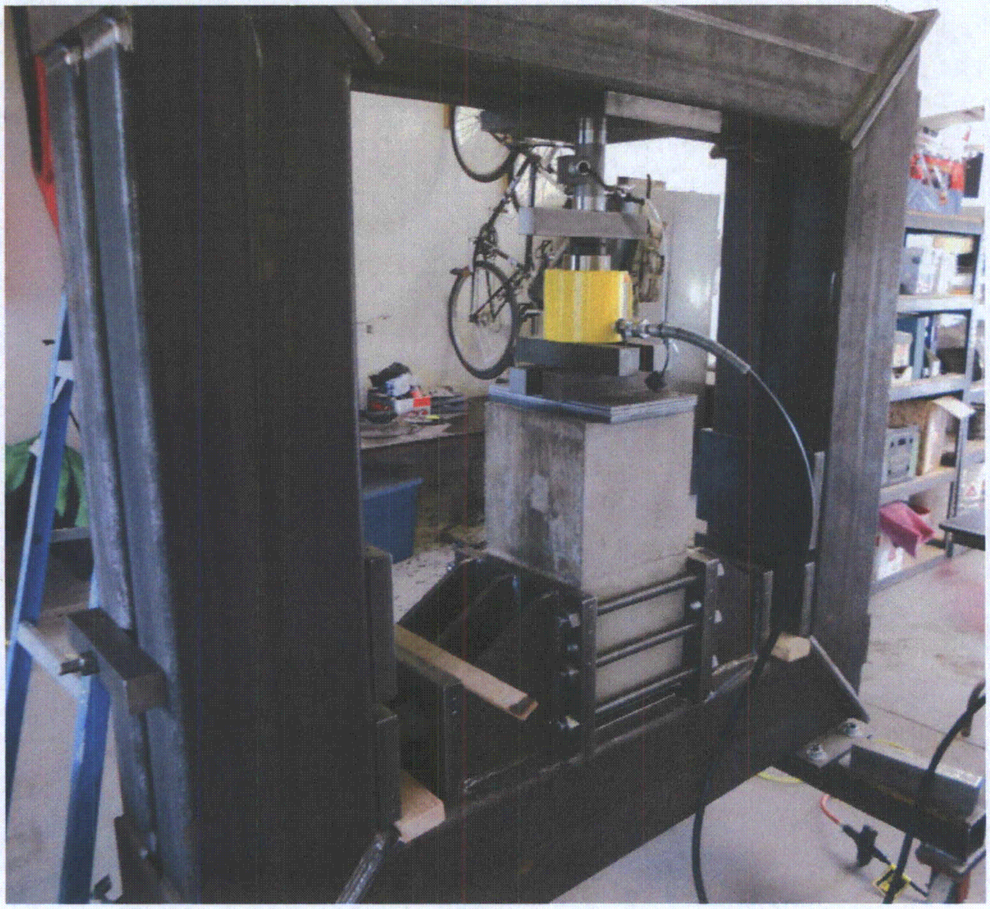

FIGURE 3-6
DIRECT TESTING APPARATUS

Direct shear testing is performed by applying a shear load with a hydraulic ram and a rigid load bar. Hydraulic rams and load bars are located on both the left and the right side of the frame, allowing the peak cohesion and friction angle to be measured by testing in one direction (e.g. from left to right) and the residual cohesion and friction angle to be measured by testing in the opposite direction (e.g. from right to left) without readjusting the sample. More information regarding direct shear testing is provided in ***Section 3.4***.

Direct tension testing is performed by applying a tensile load from above the sample. More information regarding direct tensile testing is provided in ***Section 3.5***.

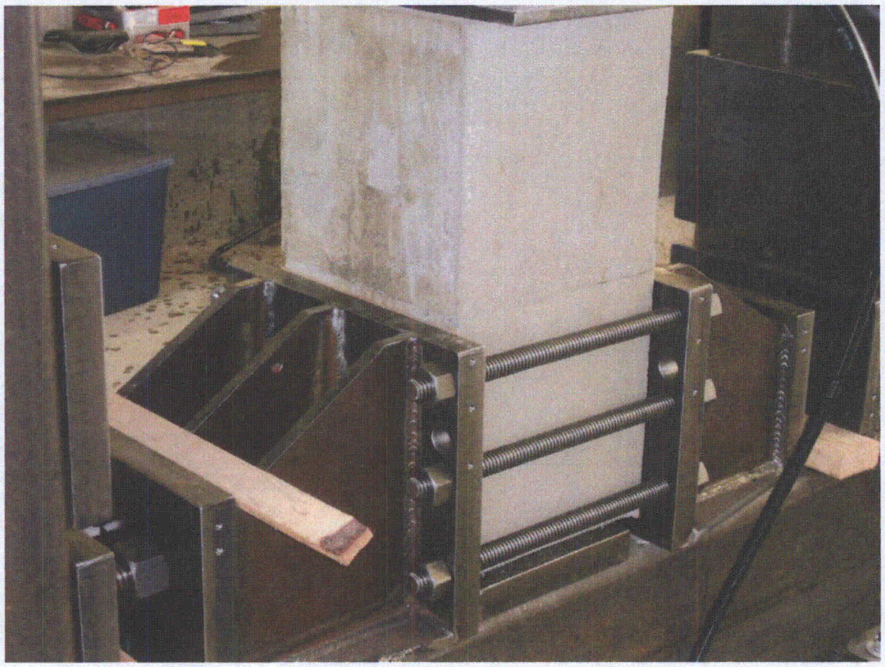

FIGURE 3-7
COLLARS USED TO GRIP SAMPLE

3.4 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 block has been displaced 0.5 inches. The values for residual cohesion and friction angle are determined by pushing the specimen in the opposite direction. Block Samples will be tested according to a method developed by USACE, based on CRD-C90 "Method of Test for Transverse Shear Strength Confined, Single or Double Plane."

Direct Shear testing will be performed by RCC Consultants Stephen Tatro and Jim Hinds with the assistance of personnel from Fall Line's Tucson laboratory.

For each mix and joint condition, nine block samples will be tested for direct shear at each testing age. Tests will be conducted at 90, 180, and 365 Days. Samples will be tested at three different proposed normal stresses (σ_{n1} = 40 psi; σ_{n2} = 70 psi; σ_{n3} = 100 psi) to obtain a shear failure envelope, and three replicates will be tested for each normal stress. A total of 108 blocks will be saw-cut from the test panels for direct shear testing, as summarized in ***Table 3-1***.

TABLE 3-1
DIRECT SHEAR TESTING SCHEDULE

MIX/JOINT CONDITION	NO. TESTS 90 DAYS			NO. TESTS 180 DAYS			NO. TESTS 365 DAYS			TOTAL
	σ_{n1}	σ_{n2}	σ_{n3}	σ_{n1}	σ_{n2}	σ_{n3}	σ_{n1}	σ_{n2}	σ_{n3}	
Mix I / <2000 Deg hr	3	3	3	3	3	3	3	3	3	**27**
Mix I / >3000 Deg hr	3	3	3	3	3	3	3	3	3	**27**
Mix II / < 2000 Deg hr	3	3	3	3	3	3	3	3	3	**27**
Mix II / >3000 Deg hr	3	3	3	3	3	3	3	3	3	**27**
Total	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**108**

3.5 DIRECT TENSILE TESTING

The method of gripping the direct tensile specimen is critical to successful testing. It is our opinion that optimum results are achieved using specially designed steel end plates bonded to the RCC specimen using an epoxy bonding adhesive. A sketch of the direct tension end plate attachment appears in ***Figure 3-8***. The direct tensile load is applied vertically using a configuration of clevis hooks, chain and rod attached to the steel end plates to allow load to transfer to the test specimen in a manner that minimizes load eccentricity and bending. Performing the test in a vertical direction will eliminate the potential of inducing bending stress and greatly improves the ability to align the specimen in the reaction test frame using mechanical equipment such as a forklift, as the direct tension test blocks can be very heavy and easily damaged.

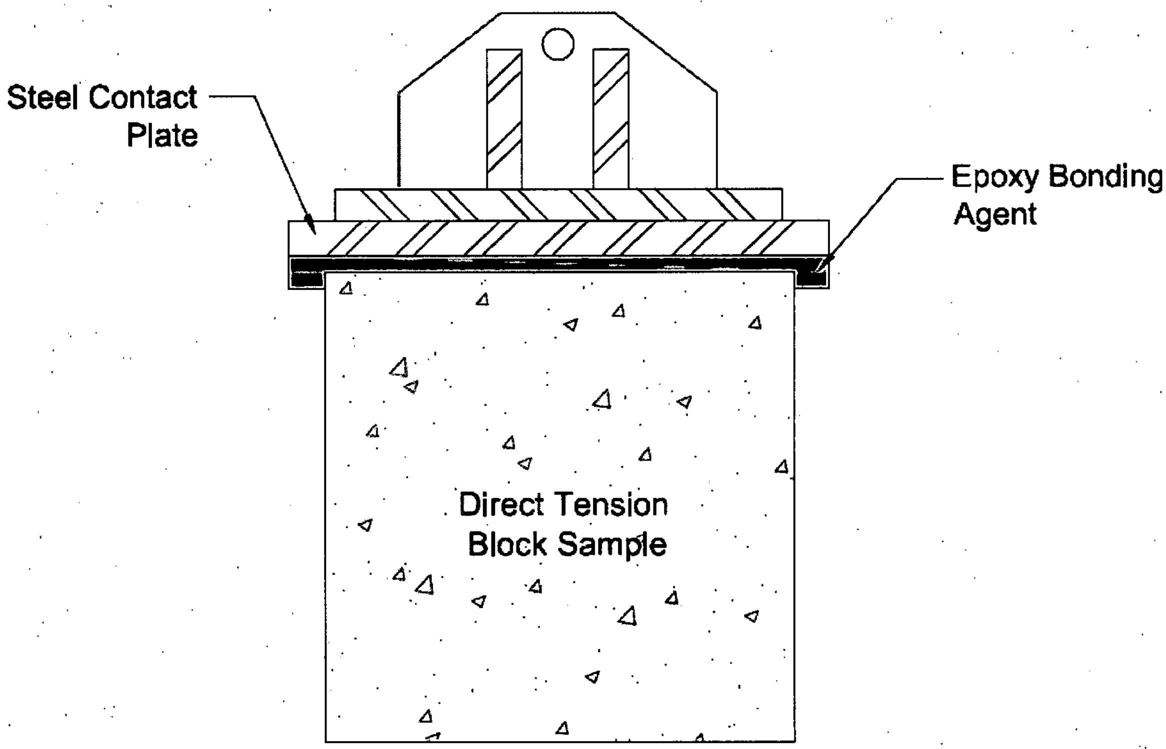

FIGURE 3-8
SKETCH OF DIRECT TENSION END PLATE ATTACHMENT

Tensile testing will evaluate both the tensile strength across the lift joint and the tensile strength across a construction joint. Vertical block samples and horizontal block samples will be used, as described in ***Section 3.1***. For Direct Tensile Testing, two replicates will be tested for each testing age. A total of 24 vertical blocks and 24 horizontal blocks will be saw-cut from the test panels for direct tensile testing, as shown in ***Table 3-2***.

TABLE 3-2
DIRECT TENSILE TESTING SCHEDULE

MIX / JOINT CONDITION	NO. TESTS 90 DAYS		NO. TESTS 180 DAYS		NO. TESTS 365 DAYS		TOTAL
	VERT.	HORIZ.	VERT.	HORIZ.	VERT.	HORIZ.	
Mix I / < 2000 Deg hr	2	2	2	2	2	2	**12**
Mix I / >3000 Deg hr	2	2	2	2	2	2	**12**
Mix II / < 2000 Deg hr	2	2	2	2	2	2	**12**
Mix II / >3000 Deg hr	2	2	2	2	2	2	**12**
Total	**8**	**8**	**8**	**8**	**8**	**8**	**48**

3.6 SHEAR WAVE VELOCITY TESTING

FSAR Table 2.5.4.5-201 lists a minimum shear wave velocity of 3500 fps for the as-placed RCC Bridging Mat. To determine the shear wave velocity of each RCC mix, a "free-free" resonant test will be performed on test blocks by Dr. Ken Stokoe. Shear wave velocity testing will both determine the shear wave velocity of the composite RCC-Bedding Mix and determine the effect that bedding mix has on shear wave velocity of the composite structure.

The test will be performed three times on a block sample taken from the test panel. The sample will then be sawn in half along the bedding plane, and both the upper half and the lower half will be tested in the same manner. The shear wave velocity testing schedule is summarized in ***Table 3-3***. Note that although 108 tests are being performed, only 12 blocks are required for testing (one block for each of 4 mix/joint conditions at 3 testing ages).

TABLE 3-3
SHEAR WAVE VELOCITY TESTING SCHEDULE

MIX / JOINT CONDITION	NO. TESTS 90 DAYS			NO. TESTS 180 DAYS			NO. TESTS 365 DAYS			TOTAL
	FULL BLOCK	UPPER HALF	LOWER HALF	FULL BLOCK	UPPER HALF	LOWER HALF	FULL BLOCK	UPPER HALF	LOWER HALF	
Mix I / < 2000 Deg hr	3	3	3	3	3	3	3	3	3	**27**
Mix I / > 3000 Deg hr	3	3	3	3	3	3	3	3	3	**27**
Mix II / < 2000 Deg hr	3	3	3	3	3	3	3	3	3	**27**
Mix II / >3000 Deg hr	3	3	3	3	3	3	3	3	3	**27**
Total	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**108**

3.7 RCC THERMAL TESTING

Measurement of RCC thermal properties is important for determining what procedures are necessary during production RCC placement to prevent mass gradient thermal cracking. To determine the thermal properties of the RCC proposed for use in construction of the Bridging Mat, testing will be performed in accordance with the test methods described in the following subsections.

These methods are the industry standard for the evaluation of concrete thermal properties, and they are published by the United States Army Corps of Engineers in the Handbook for Cement and Concrete. The texts of these procedures can be found in ***Appendix A***.

3.7.1 Adiabatic Temperature Rise

The adiabatic temperature rise will be monitored by following the procedure described in CRD-C 38. RIZZO will continue to record the temperature rise through 90 days, rather than the 28 days specified by CRD-C 38. This extended monitoring time is required to assess the effect of pozzolan at later ages. One sample of each of the selected RCC mixes will be tested.

3.7.2 Coefficient of Thermal Expansion

The coefficient of linear thermal expansion will be determined according to CRD-C 39. For each of the two selected mixes, the coefficient of thermal expansion will be tested at 28 days. Two samples from each mix should be cast for testing.

3.7.3 Specific Heat

The specific heat of RCC will be determined according to CRD-C 124. For each of the two selected RCC mixes, a sample will be tested at the age of 28 days. The sample should be two pounds of RCC, crushed so that no particles are larger than one inch. Per the requirements of CRD-C 124, the reported value of specific heat will be the average of at least seven determinations.

3.7.4 Thermal Diffusivity

Thermal diffusivity will be determined according to CRD-C 36. For each of the two selected RCC mixes, a sample will be tested at the age of 28 days. The sample will be a 6x12 molded cylinder with a thermocouple placed at the center of the mass.

3.7.5 Thermal Conductivity

Thermal conductivity will be calculated according to CRD-C 44. This calculation is based on the unit weight of RCC and the test results for thermal diffusivity and specific heat. As such, no additional sample preparation or testing is required for this determination.

3.8 REPORT PREPARATION

RIZZO will provide a report on laboratory testing after 90-day tests have been completed. After 180-day tests have been completed, RIZZO will provide a summary of the data.

The RCC Testing Final Report will be completed at the conclusion of 365-day laboratory testing. This report will summarize the results of all strength and thermal testing.

The Materials Certification Laboratory will report the results of the certification testing associated with the mix design. This Materials Certification Report will be included as an appendix to the Final Report.

A detailed RCC Construction Specification will be prepared as a result of the Phase II and Phase III testing. This specification will allow the contractor to recreate an RCC mix with similar properties during construction without needing to repeat the mix design process.

4.0 QUALITY ASSURANCE

This work will be completed in accordance with the requirements of the RIZZO QA Manual and applicable Procedures, and is supplemented by additional controls in the areas of inspection, handling, storage, shipping, inspections, tests, and operating status. The RIZZO QA Manual and QA Procedures were developed to satisfy the requirements of 10 Code of Federal Regulations (CFR) 50, Appendix B and NQA-1-1994.

All work performed by Fall Line and the expert RCC Consultants will be performed under the RIZZO QA Program. S&ME will perform all materials certification testing under their approved QA Program. RIZZO will perform a Commercial Grade Dedication of the shear wave velocity testing performed by Dr. Ken Stokoe.

REFERENCES

REFERENCES

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

ACI Committee 214, "Evaluation of Strength Test Results of Concrete," (ACI 214R-02), American Concrete Institute, Farmington Hills, Michigan, 2002.

ACI Committee 207, "Guide to Mass Concrete," (ACI 207.1R-05), American Concrete Institute, Farmington Hills, Michigan, 2005.

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

The following ASTM International Standards are referenced in the text by basic designation only. The latest version at the date of Work shall apply.

ASTM C 29/C 29 M – 09	Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
ASTM C 33/C 33 M – 08	Standard Specification for Concrete Aggregates
ASTM C 39/C 39 M – 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 88 – 05	Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM C 117 – 04	Standard Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C 123 – 04	Standard Test Method for Lightweight Particles in Aggregate
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/C 138 M – 09	Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
ASTM C 142 – 97(2004)	Standard Test Method for Clay Lumps and Friable Particles in Aggregates
ASTM C 143/C 143 M – 10	Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C 150/C 150 M – 09	Standard Specification for Portland Cement
ASTM C 151/C 151 M – 09	Standard Test Method for Autoclave Expansion of Hydraulic Cement
ASTM C 231/C 231 M – 09b	Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C 295 – 08	Standard Test Method for Petrographic Examination of Aggregates for Concrete
ASTM C 469 – 02e1	Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
ASTM C 494/C 494 M – 10	Standard Specification for Chemical Admixtures for Concrete
ASTM C 496/C 496M – 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 1064/C 1604M – 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 1170 M – 08	Standard Test Method for Determining Consistency and Density of Roller Compacted Concrete Using a Vibrating Table

ASTM C 1602/C 1602 M – 06	Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
ASTM D 512 – 04	Standard Test Methods for Chloride Ion in Water
ASTM D 4791 – 05e1	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

The following standards from the USACE Handbook for Cement and Concrete are referenced in the text by basic designation only. The latest version at the date of work shall apply.

CRD-C36 – 73	Method of Test for Thermal Diffusivity of Concrete
CRD-C38 – 73	Method of Test for Temperature Rise in Concrete
CRD-C39 – 81	Test Method for Coefficient of Linear Thermal Expansion of Concrete
CRD-C44 – 63	Method for Calculating Thermal Conductivity of Concrete
CRD-C124 – 73	Method of Test for Specific Heat of Aggregates, Concrete, and Other Materials (Method of Mixtures)

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

APPENDIX A

TESTING PROCEDURES

ACCELERATED CURING

FALL LINE IN-HOUSE PROCEDURE

Making, Accelerated Curing, and Testing RCC Compressive Test Specimens

In House Procedure Accel #1

1. Scope

1.1 This test method covers procedures for making, curing and testing RCC test cylinders stored under conditions intended to accelerate the development of strength. Procedure #1 in a high temperature water bath for an extended time frame.

2. Reference Documents

ASTM C 1435 – Molding Roller Compacted Concrete in Cylinder Molds Using a Vibrating Hammer.
ASTM C 617 – Practice for Capping Cylindrical Concrete Specimens.
ASTM C 39 – Test Method for Compressive Strength of Cylindrical Concrete Specimens.

3. Summary of Test Method

3.1 Concrete specimens are exposed to accelerated curing conditions that permit the specimens to develop a significant portion of their ultimate strength within a time period of 14 days.

4. Significance and Use

4.1 The accelerated curing procedure provides, at an early practical time, an indication of the potential strength of a specific concrete mixture. This procedure also provides information on the variability of the production process for use in quality control.
4.2 Correlation between accelerated strength and strength achieved at some later date by using conventional curing methods depends upon the materials comprising the RCC, the mix proportions, and the specific accelerated test method.

5. Apparatus

5.1 Molds Cylinder molds for test specimens shall conform to Specification C 470.
5.2 Standard Curing Conditions will be per ASTM C 31 10.1.3.1
5.3 Accelerated Curing Apparatus shall be a water bath that maintains a constant temperature of 160 F plus or minus 5 degrees F. maintaining a water level that completely covers the tops of the test cylinders.
5.4 If capping of the test specimen is required use the apparatus specified in Practice C 617 or Practice C1231.

6. Materials

7. Procedure
7.1 Prepare the RCC test specimen as pre Practice ASTM C 1435 – Molding Roller Compacted Concrete in Cylinder Molds Using a Vibrating Hammer.
7.2 After the initial curing period, remove the test specimen from the mold and cure the RCC test cylinder per Standard Curing Conditions as per ASTM C 31 10.1.3.1.
7.3 Remove the test specimen from standard curing condition a seven days of age and place in the accelerated curing tank for an additional 7 days at 160 F plus or minus 5 F.
7.4 Remove the test specimen, cap and test the specimen in accordance with ASTM standards.

8. Report
8.1 Report the following for each test specimen.
8.1.1 Identification Number,
8.1.2 Diameter in inches,
8.1.3 Cross-sectional area in square inches,
8.1.4 Maximum load in pounds force,
8.1.5 Compressive strength to the nearest 10 PSI,
8.1.6 Type of fracture, if other than the usual cone,
8.1.7 Defects in either the specimen or the caps,
8.1.8 Age of the specimen,

06/17/2008

Scott Nichols
President
Fall Line Testing & Inspection, LLC

AIR CONTENT OF RCC

FALL LINE IN-HOUSE PROCEDURE

[ADAPTED FROM ASTM C 231]

Standard test Method for Determining Unit Weight and air content of Roller-Compacted Concrete Utilizing a Pressure Style Air Meter and a Vibrating Hammer

1. Scope*

1.1 This test method covers determination of the air content and determination of unit weight of freshly mixed roller-compacted concrete.

1.2 This test method, intended for use in testing roller compacted concrete, may be applicable to testing other types of concrete such as cement-treated aggregate and mixtures similar to soil-cement.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information purposes only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)

2. Referenced Documents

2.1 *ASTM Standards:*

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 1170 Test Method for Determining Consistency and Density of Roller-Compacted Concrete Using a Vibrating Table

3. Significance and Use

3.1 This practice, intended for use in testing roller-compacted concrete, may be applicable to testing other types of cementitious material such as coarse-grained soil-cement. This practice provides standardized requirements for molding stiff to very dry consistency concrete mixtures commonly used in roller compacted concrete construction. This practice is used instead of rodding or internal vibration, which cannot properly consolidate concrete of this consistency (Note 1).

NOTE 1—Further description of roller compacted concrete consistency is given in ACI 207.5R and 211.3. The consistency of concrete using a vibrating table may be determined in accordance with Test Method C 1170.

3.2 This test method covers the determination of the air content of freshly mixed roller-compacted concrete. The test determines the air content of freshly mixed roller-compacted concrete exclusive of any air that may exist inside voids within aggregate particles. For this reason, it is applicable to roller-compacted concrete made with relatively dense aggregate particles.

4. Apparatus

4.1 *Air Meter*— Shall conform to the requirements for the Type B pressure meter as described in C231

4.2 *Vibrating Hammer*—A vibrating compaction hammer having a mass (without tamping plate and shaft) in the range of 8.5 to 13.5 kg [18 to 30 lbs]. It also shall have a minimum power input of 900 W and be capable of providing 2000 ± 200 impacts/min.

4.3 *Tamping Plate*—A circular steel plate attached to a steel shaft, which is inserted into the vibrating hammer chuck. The plate diameter shall be 194 ± 5 mm [7 5/8 ± 1⁄4 in.] and the mass of the plate and shaft assembly shall be in the range of 8.5 to 12.5 kg [19 to 28 lbs].

4.4 *Mallet*—A mallet (with a rubber or rawhide head) weighing approximately 1.25 ± 0.50 lb (0.57 ± 0.23 kg) for use with measures of 0.5 ft^3 (14 L) or smaller, and a mallet weighing approximately 2.25 ± 0.50 lb (1.02 ± 0.23 kg) for use with measures larger than 0.5 ft^3 (14 L).

4.5 *Strike-Off Plate*—A flat square metal plate at least 1⁄4 in. (6 mm) thick or an acrylic plate at least 1⁄2 in. (12 mm) thick with a length and width at least 2 in. (50 mm) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 1⁄16 in. (1.5 mm).

4.6 *Sieves*, 1 1⁄2-in. (37.5-mm) with not less than 2 ft^2 (0.19 m^2) of sieving area.

4.7 *Scoop*—of a size large enough so each amount of roller-compacted concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the measuring bowl.

4.8 *Balance*—A balance or scale accurate to 0.1 lb [45 g] or to within 0.3 % of the test load, whichever is greater, at any point within the range of use. The range of use shall be considered to extend from the mass of the measure empty to the mass of the measure plus its contents at 160 lb/ft^3 [2600 kg/m^3].

5. Calibration of Apparatus

5.1 Calibrate apparatus in accordance with C231

6. Sampling

6.1 Samples of freshly-mixed concrete shall be obtained in accordance with Practice C 172.

6.2 Concrete samples shall have a maximum size aggregate of 50 mm [2 in.] or less. If the concrete has aggregate larger than 50 mm [2 in.] samples shall be obtained by wet sieving over a 50-mm [2-in.] sieve in accordance with Practice C 172.

6.3 Concrete test specimens shall be molded within 45 min after the completion of mixing unless otherwise specified.

6.4 *Technical Precautions*:

6.4.1 When obtaining samples, ensure that the samples are representative of the bulk production.

6.4.2 Concrete with stiff to very dry consistency is highly susceptible to segregation during handling. To minimize segregation, use care in obtaining samples and during transporting, remixing, and preparation of the specimens.

7. Procedure for Determining Air Content and Unit Weight of Roller-Compacted Concrete

7.1 *Placement and Consolidation of Sample*:

7.1.1 Prepare the roller-compacted concrete as described in Section 6. Dampen the interior of the measuring bowl and place it on a flat, level, firm surface. Using the scoop described in 4.7, place the roller-compacted concrete in the measuring bowl in three layers of approximately equal volume. While placing the roller-compacted concrete in the bowl, move the scoop around the perimeter of the bowl opening to ensure an even distribution of the roller-compacted concrete with minimal segregation. Consolidate each layer with the vibrating hammer and tamping plate described in 4.2 and 4.3. Strike-off the final consolidated layer (7.1.2).

7.1.2 *Strike Off*—After consolidation of the roller-compacted concrete, strike off the top surface by sliding the strike-off plate across the top flange or rim of the measuring bowl with a sawing motion while the vibrating hammer and the tamping plate are in contact with the strike-off plate, until the bowl is just level full. On completion of consolidation, the measuring bowl must not contain an excess or deficiency of roller-compacted concrete. Removal of 1⁄8 in. (3 mm) during strike off is optimum.

7.1.3 *Cleaning and Weighing*—After strike-off, clean all excess concrete from the exterior of the measure and determine the mass of the concrete and measure to an accuracy consistent with the requirements of 4.8.

NOTE 6—A small quantity of representative roller-compacted concrete may be added to correct a deficiency. If it is necessary to add additional roller-compacted concrete repeat 7.1.2.

NOTE 7—The use of the strike-off plate on cast aluminum or other relatively soft metal air meter bases may cause rapid wear of the rim and require frequent maintenance, calibration, and ultimately, replacement.

7.2 *Procedure—Air Content*:
7.2.1 *Preparation for Test*—Thoroughly clean the flanges or rims of the measuring bowl and the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus. Close the main air valve between the air chamber and the measuring bowl and open both petcocks on the holes through the cover. Using a rubber syringe, inject water through one petcock until water emerges from the opposite petcock. Jar the meter gently until all air is expelled from this same petcock.
7.2.2 *Test Procedure*—Close the air bleeder valve on the air chamber and pump air into the air chamber until the gauge hand is on the initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gauge hand at the initial pressure line by pumping or bleeding off air as necessary, tapping the gauge lightly by hand. Close both petcocks on the holes through the cover. Open the main air valve between the air chamber and the measuring bowl. Tap the sides of the measuring bowl smartly with the mallet to relieve local restraints. Lightly tap the pressure gauge by hand to stabilize the gauge hand. Read the percentage of air on the dial of the pressure gauge. Release the main air valve. Failure to close the main air valve before releasing the pressure from either the container or the air chamber will result in water being drawn into the air chamber, thus introducing error in subsequent measurements. In the event water enters the air chamber, it must be bled from the air chamber through the air bleeder valve followed by several strokes of the pump to blow out the last traces of water. Release the pressure by opening both petcocks before removing the cover.

8. Calculation
8.1 *Density (Unit Weight)*—Calculate the net mass of the concrete in pounds or kilograms by subtracting the mass of the measure, *Mm*, from the mass of the measure filled with concrete, *Mc*. Calculate the density, *D*, ft^3 or yd^3,by dividing the net mass of concrete by the volume of the measure, *Vm* as follows:
$D = (Mc - Mm)/Vm$

9. Report
9.1 Report the following information:
9.1.1 Identification of concrete represented by the sample.
9.1.2 Date of test.
9.1.3 Volume of density measure to the nearest 0.001 ft3 [0.01 L].

9.1.4 Density (Unit Weight) to the nearest 0.1 lbs/ft3 [1.0 kg/m3].
9.1.5 The air content of the roller-compacted concrete sample to the nearest 0.1 %, unless the gauge reading of the meter exceeds 8 %, in which case the reading shall be reported to the nearest 1/2 scale division on the dial.

10. Precision and Bias
10.1 *Precision*:
10.1.1 *Single-Operator Precision*—The single-operator standard deviation cannot be established because the sampling requirements for this test, as established in Practice C 172, do not allow a single operator time to conduct more than one test on a sample.
10.1.2 *Multilaboratory Precision*—The multilaboratory standard deviation has not been established.
10.2 *Bias*—This test method has no bias because the air content of freshly mixed roller-compacted concrete can only be defined in terms of the test methods.

12. Keywords
11.1 air content; calibration; roller-compacted concrete; measuring bowl; meter; pressure; pump; unit weight; vibrating hammer; tamping plate

THERMAL DIFFUSIVITY

USACE HANDBOOK FOR CEMENT AND CONCRETE

CRD-C 36-73

CRD-C 36-73

METHOD OF TEST FOR THERMAL DIFFUSIVITY OF CONCRETE

1. Scope

1.1 This method of test outlines a procedure for determining the thermal diffusivity of concrete. The thermal diffusivity is equal to the thermal conductivity divided by the heat capacity per unit volume and may be used as an index of the facility with which the material will undergo temperature change.

Note. - A method for determining the thermal diffusivity of 8-cu-ft (0.0227-m^3) cube specimens of mass concrete is given in CRD-C 37.

2. Apparatus

2.1 The apparatus shall consist of:

2.1.1 Bath. - A heating bath in which concrete cylinders can be raised to uniform high temperature (212 F, 100 C).

2.1.2 Diffusion Chamber.- A diffusion chamber containing running cold water.

2.1.3 Temperature Indicating or Recording Instrument.- Consisting of iron-constantan thermocouples, Type K Potentiometer, ice bath, standard cell, galvanometer, switch, and storage battery; or thermocouples and suitable recording potentiometer.

2.1.4 Timer. - Timer capable of indicating minutes and seconds.

3. Procedure

3.1 Preparation of Specimen. - The test specimen shall be a 6- by 12-in. (152- by 305-mm) cylinder (for other shapes and sizes, see Sec. 5). If molded, shall be made in accordance with the applicable provisions of CRD-C's 10 and 49 and shall contain a thermocouple placed at the center of mass. If prepared from a hardened concrete core, shall contain a similarly placed thermocouple inserted in an axially drilled hole 3/8 in. (9.5 mm) in diameter which has been subsequently grouted. Molded specimens shall be moist-cured for 28 days prior to testing.

3.2 Heating. - Each specimen shall be heated to the same temperature by continuous immersion in boiling water until the temperature of the center is 212 F (100 C). The specimen shall then be transferred to a bath of running cold water, and suspended in the bath so that the entire surface of the specimen is in contact with the water. The temperature of the cold water shall be determined by means of another thermocouple.

3.3 Cooling.- The cooling history of the specimen shall be obtained from readings of the temperature of the interior of the specimen at 1-min intervals from the time the temperature difference between the center and the water is 120 F (67 C) until the temperature difference between the center and water is 8 F (4 C). The data shall be recorded. Two such cooling histories shall be obtained for each test specimen, and the calculated diffusivities shall check within ± 0.002 ft^2/h ($0.0052 \times 10^{-5} m^2/s$).

4. Calculations

4.1 The temperature difference in degrees F shall be plotted against the time in minutes on a semilogarithmic scale. The best possible straight line shall then be drawn through the points so obtained. A typical graph is shown in Fig. 1. The time elapsed between the temperature difference of 80 F (44 C) and 20 F (11 C) shall be read from the graph, and this value inserted in equation (1) below, from which the thermal diffusivity shall be calculated:

$$\alpha = 0.812278/(t_1 - t_2)$$

where:

α = thermal diffusivity, ft^2/hr (Note),

$(t_1 - t_2)$ = elapsed time between temperature differences 80 F (44 C) and 20 F (11 C), minutes, and

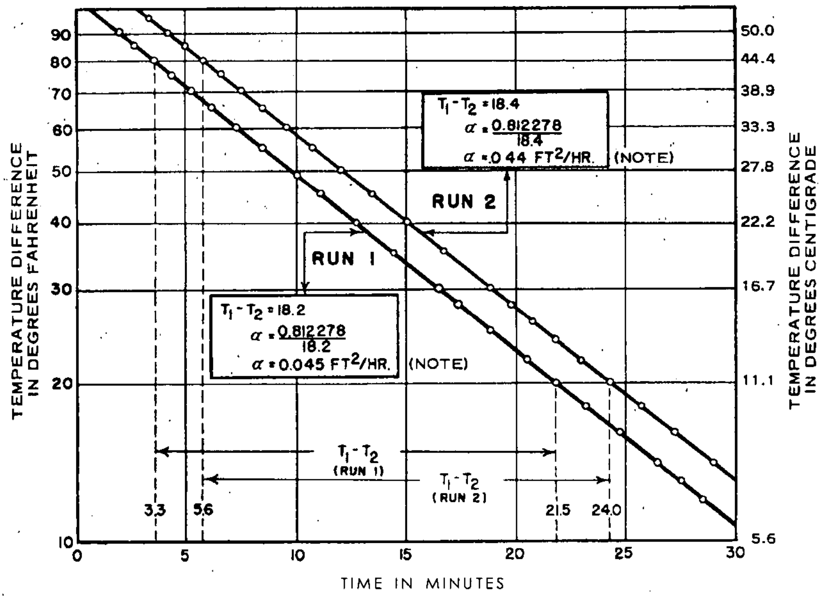

Fig. 1. Calculation of thermal diffusivity of a concrete cylinder

0.812278 = numerical factor applicable to 6- by 12-in. (152-by 305-mm) cylinder.

Note. - The SI equivalent of ft^2/h is m^2/s; $ft^2/h \times 2.580640\ E\text{-}05 = m^2/s$.

5. Specimens of Other Sizes and Shapes

5.1 The method given above is directly applicable to a 6- by 12-in. (152- by 305-mm) cylinder. Specimens of other sizes and shapes may be treated in the manner described below.

5.2 The thermal diffusivity of a specimen of regular shape is, to a first approximation:

$$\alpha = M/(t_2 - t_1)$$

where:

α = thermal diffusivity, ft^2/hr (Note),

M = a factor depending on the size and shape of the specimen, and

t_1, t_2 = times at which the center of the specimen reaches any specified temperature differences, min.

5.3 For a prism,

$$M = \frac{60 \ln(T_1/T_2)}{\pi^2\left(\frac{1}{a^2} + \frac{1}{b^2} + \frac{1}{c^2}\right)}$$

where:

$\ln(T_1/T_2)$ = natural logarithm of the temperature difference ratio,

T_1, T_2 = temperature differences at times t_1 and t_2, deg F, and

a, b, c = dimensions of prism, ft.

5.4 For a cylinder,

$$M = \frac{60 \ln(T_1/T_2)}{\left(\frac{5.783}{r^2} + \frac{\pi^2}{l^2}\right)}$$

where:

$\ln(T_1/T_2)$ = natural logarithm, as above,

r = radius of cylinder, ft, and

l = length of cylinder, ft.

5.5 For specimens whose minimum dimension is more than 3 in. (76 mm), this approximate calculation will yield the required accuracy. For smaller specimens or when more precise determinations are desired, reference may be made to Heat Conduction, by L. R. and A. C. Ingersoll, and O. J. Zobel, McGraw-Hill Book Company, Inc., 1948, pp. 183-185 and appended tables. Charts which may be used are also found in Williamson and Adams, Phys. Rev. XIV, p. 99 (1919) and Heat Transmission, W. H. McAdams, McGraw-Hill Book Company, Inc., 1942, pp. 27-44.

ADIABATIC TEMPERATURE RISE

USACE HANDBOOK FOR CEMENT AND CONCRETE

CRD-C 38-73

CRD-C 38-73

METHOD OF TEST FOR TEMPERATURE RISE IN CONCRETE

1. Scope

1.1 This method covers a procedure for determining the temperature rise in concrete under adiabatic conditions primarily due to heat liberated on hydration of cement.

2. Apparatus

2.1 The apparatus used shall consist of:

2.1.1 Cabinet.- An insulated cabinet with heating elements and fans.

2.1.2 Room.- A controlled temperature room capable of maintaining any selected temperature within the range of 35 to 135 F (2 to 58 C), and also of automatic variation to maintain a constant difference of 0 to 10 F (0 to 6 C) between the room temperature and the temperature in the insulated cabinet, which is situated within the room.

2.1.3 Control Apparatus.- The temperature control apparatus (Fig. 1) shall consist of the following:

2.1.3.1 An electronic indicating potentiometer accurate to ±0.3 F (0.2 C) to control the temperature of the room, and

2.1.3.2 a d-c amplifier, a magnetic amplifier, and an electronic recording potentiometer with an 11-in. (279-mm) scale having a range of -0.4 to +0.4 F (-0.2 to +0.2 C), with least division of 0.004 F (0.002 C). These three instruments act in combination and are actuated by unbalance in a resistance bridge, one leg of which represents concrete specimen temperature and another of which represents cabinet temperature. They shall be capable of maintaining cabinet air temperature the same as specimen temperature or slightly higher or lower than specimen temperature as may be necessary for the adjustments described in Paragraph 3.10. Accuracy of control shall be ±0.004 F (±0.002 C).

2.1.4 Recording Apparatus.- The temperature measuring and recording apparatus (Fig. 1) shall consist of the following:

2.1.4.1 An electronic recording potentiometer accurate to ±0.3 F (±0.2 C),

2.1.4.2 a precision resistance bridge, the least dial division of which is 0.0001 ohm,

2.1.4.3 an electronic null indicator,

2.1.4.4 ten precision resistance thermometers, and

2.1.4.5 five iron-constantan thermocouples.

2.1.5 Jacket.- A sheet metal jacket (Fig. 2) to hold insulation material around the specimen container. The jacket shall be 34 in. (864 mm) in diameter and 36 in. (914 mm) high; its bottom shall be covered on the inside with polystyrene insulation 2 in. (51 mm) thick.

2.1.6 Specimen Container.- A sheet metal specimen container, 30 in. (762 mm) in diameter and 30 in. (762 mm) high, with a 1/2-in. (13-mm)-flange at the top. A strap (1/8 by 1 in.) (3.2 by 25 mm) shall extend diametrically across the inside of the container at the top. The strap shall have five 1/2-in.- (13-mm-) diameter holes, one at the midpoint and two on either side at 2 and 12 in. (50 and 305 mm) from the midpoint.

2.1.7 Specimen Container Cover.- A specimen container cover of sheet metal with holes corresponding to the holes in the strap (subpara 2.1.6). Airtight packing glands shall be brazed or soldered in place on the container cover over the five holes. The packing glands shall be of a size suitable for tightening on the shafts of the resistance thermometers which will pass through the holes (para 3).

3. Test Procedure

3.1 Calibration.- The ten resistance thermometers, which shall be permanently wired to a terminal strip within the cabinet, shall be calibrated, by clipping the leads, to read to ±0.005 F (±0.003 C) at three constant temperatures covering the expected range of the adiabatic temperature-rise test. For this purpose the

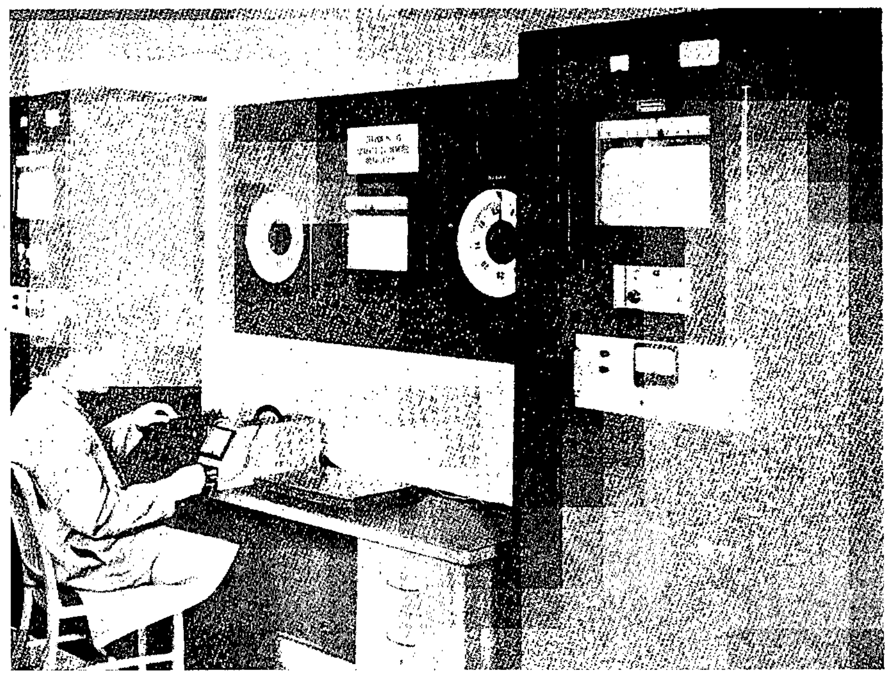

Fig. 1. Temperature control and measuring equipment for two adiabatic calorimeters

Fig. 2. Preparing mass concrete specimen for temperature-rise test; jacket and positioning of thermometers in specimen are shown

thermometers shall be taped together and tested in a vacuum flask located within the cabinet. During the calibration, air currents shall be excluded from the vacuum flask by use of packing material at the top. When the calibration of all thermometers is within ±0.005 F (±0.003 C) of the average, each thermometer's remaining deviation from the average shall be used as a correction for that thermometer.

3.2 Positioning of Thermometers.- The resistance thermometers shall be positioned as follows: one suspended in the air of the cabinet, two on opposite sides inside the jacket, two on opposite sides outside the specimen container, and five (Fig. 2) inside the specimen container. The five thermometers placed in the specimen container shall be threaded through the holes in the cover, passed through the holes in the strap across the top of the container, and held in place during placement of concrete by wooden straps near the top. Except for the air thermometer, all the thermometers shall be positioned in a straight line passing diametrically through the midplane of the specimen container.

3.3 Insulation.- The jacket shall be placed on a warehouse dolly in such a position that it will be in the approximate center of the cabinet when the dolly is rolled into the cabinet. The specimen container shall be placed inside the jacket, the annular space filled with expanded vermiculite insulation (ASTM Designation: C 516, Type 2), and the whole assembly allowed to remain overnight in the calorimeter room, which shall be maintained at approximately the expected casting temperature.

3.4 Room Temperature Adjustment.- The next day the approximate casting temperature shall be determined as soon as possible, and the room temperature shall be adjusted to agree closely with the casting temperature. Room temperature will later be adjusted and controlled as prescribed in Subparagraph 3.8 below. The door of the cabinet shall remain open during casting of the specimen.

3.5 Specimen.- The specimen shall be made from a single 11.9 ft^3 (0.3 m^3) batch of concrete, made in accordance with the applicable provisions of CRD-C's 10 and 49, shall be placed and vibrated in three layers in the specimen container to form a cylindrical specimen 30 in. (762 mm) in diameter and approximately 29 in. (737 mm) in height.

3.6 Temperature Balancing.- When the precision thermometers are covered with concrete during the placement of the specimen, the difference between concrete temperature and room temperature shall be noted and reduced promptly by manual control of room temperature so that the difference shall be no more than ±0.4 F (±0.2 C), the total range of the control potentiometer, which operates in an indicating, rather than a control, capacity during this step of the procedure. This type of control is possible, and necessary, only during the time the door of the cabinet is open.

3.7 Sealing Specimen.- Immediately after the concrete has been placed (subpara 3.5 above) and vibrated, the cover shall be soldered in place and the packing glands tightened; it is essential that the specimen container, cover, and packing glands be vapor-tight. One thermocouple shall be taped against the metal cover near the center, two suspended in air within the cabinet, and two suspended in air in the controlled temperature room; of these, one at each location shall be connected to the electronic recording potentiometer and one at each air location shall be connected to the electronic indicating potentiometer used to control room air temperature.

3.8 Final Insulation.- Expanded vermiculite insulation shall be placed on top of the specimen container to a depth of about 3 in. (76 mm). The total amount of vermiculite used on the sides (Sec. 3.3) and top shall be 120 ± 20 lb (54 ± 9 kg). The test assembly shall be rolled into the cabinet, and the door closed. The temperature of the room shall then be lowered to and thereafter controlled at a temperature about 10 F (6 C) below cabinet temperature.

3.9 Temperature Recording.- The temperatures indicated by the ten precision thermometers, as measured by means of the precision bridge, shall be recorded as soon as the thermometers are covered, again after 1 hr and after 2 hr, and thence daily (during workdays) for 28 days. The air thermometer and the central concrete thermometer are normally connected to the automatic cabinet air temperature control, forming two legs of the resistance bridge network, Paragraph 2.1.3.2. They may, however, be be switched to the precision bridge for their temperatures to be read.

3.10 Temperature Control Adjustment.- The temperature of the concrete for the record and for control adjustment purposes shall be the average of four temperatures, two of which are the temperatures of the thermometers that are 2 in. (51 mm) distant from the center of the specimen and two of which are the temperatures of the thermometers that are 12 in. (305 mm) distant from the center. The controls shall be adjusted to initiate compensation for any difference between the concrete temperature so obtained and the temperature of the air as represented by the average temperature of the two thermometers that are located inside the metal jacket. The adjustment is accomplished either by moving the pointer of the recording potentiometer, Paragraph 2.1.3.2, or by varying resistors that are placed for this purpose in series with the air and concrete resistance thermometers. The difference noted on the casting day may be ignored; but beginning the first day after casting, adjustments shall be made as necessary on each workday, and a cumulative record of the difference kept. The accumulated difference at the end of the test should not be more than ±0.02 F (±0.01 C).

3.11 Correction for Heat Loss.- The temperature rise at any time shall be increased by 4.0 percent to account for the heat loss to the insulation (Note).

Note.- This correction is based on approximate calculations involving heat capacities and the ratio of inside area to total area of the container.

4. Report

4.1 The report shall contain relevant data on aggregates and mixture proportions, and a table and plot of the corrected temperature-rise data.

COEFFICIENT OF THERMAL EXPANSION

USACE HANDBOOK FOR CEMENT AND CONCRETE

CRD-C 39-81

CRD-C 39-81

TEST METHOD FOR COEFFICIENT OF LINEAR THERMAL EXPANSION OF CONCRETE

1. Scope

1.1 This method covers the determination of the coefficient of linear thermal expansion of concrete test specimens by determinations of length change due to temperature changes. Because the thermal coefficient of concrete varies with moisture condition, being a minimum when saturated or oven dry and a maximum at about 70 percent saturated, it is important to select the relevant moisture condition for the tests to be made.

2. Apparatus

2.1. The apparatus shall consist of:

2.1.1 *Heating Bath* - A water bath in which concrete specimens can be maintained at a temperature of 140 ± 2 F (60 ± 1.1 C) (Note 1)

2.1.2 *Cooling Bath* - A water bath in which concrete specimens can be maintained at a temperature of 40 ± 2 F (5 ± 1.1 C). (Note 1)

2.1.3 *Length Comparator (Horizontal), Reference Bars, and Inserts* - As described in CRD-C 25. (Note 2)

NOTE 1-In the event that the longer storage time required to achieve temperature equilibrium is tolerable and the use of water baths is not desired, heating and cooling rooms or cabinets may be used.

NOTE 2-When laboratory molded specimens are used, strain meters that can be embedded may be used. Such meters are described in CRD-C 54.

3. Procedure

3.1 *General* - Tests for coefficient of linear thermal expansion require careful control (± 2 F, ± 1.1 C) of the temperature of the specimen which is being tested for length change. Length determinations shall be conducted only when the specimens are in thermal equilibrium. Tests shall be made to determine the minimum heating and cooling periods for attainment of equilibrium by specimens of any particular size and shape. The period which shall be used will be 25 percent greater than the minimum time to insure equilibrium regardless of aggregate type. Further tests will be necessary to determine the maximum permissible time interval between removal of the specimen from the bath and completion of length determination when measurements are made in air. This maximum time interval shall be established so that no discernible change in length will occur during the course of the determination.

3.2 *Test Conditions* - When tests on different specimens are to be compared, the specimens must be in a comparable moisture condition and must be tested over the same temperature range. Unless other conditions are specified,[1] it is recommended that specimens be tested in a saturated condition (immersed in water at least 48 hr before the starting of the test) and over the temperature range of 40 to 140 F (5 to 60 C). In cases where the data are to be used to evaluate dry rather than saturated concrete or where thermal coefficient over a different temperature range is required, the procedures used should be modified so that the results obtained will be most directly applicable to the pertinent conditions. Where sealed specimens are appropriately employed, the sort described in CRD-C 54 are recommended.

4. Calculation and Report

4.1 The coefficient of linear thermal expansion shall be calculated from the measurements by the use of the following formula:

$$C = \frac{(R_h - R_c)}{G\Delta T}$$

where:

C = coefficient of linear thermal expansion of the concrete 10^{-6}/deg F (deg C),

R_h = length reading at higher temperature, in. or mm,

R_c = length reading at lower temperature, in. or mm,

[1]Tests using immersed specimens are reported in "Comparison of Methods of Test for Coefficient of Linear Thermal Expansion of Concrete," WES MP 6-108, November 1954.

G = gage length between inserts, in. or mm, and

ΔT = difference in temperature of specimen between the two length readings, deg F or deg C.

4.2 In cases where the length change has been determined between only two temperatures, a single value will be reported. Where readings of length change have been made at various temperatures, the report should include a curve from which any significant variation in coefficient may be determined. In such cases, the coefficients for the several ranges in temperature shall be stated.

4.3 The report should include the test results calculated as indicated above, adequate information to identify the specimens tested, and information on the moisture conditions, temperatures, and procedures used in the test

5. Interpretation

5.1 Powers and Brownyard[2] discussed the effect of moisture content on volume change of concrete during heating and cooling and stated that "from the above, it follows that the thermal coefficient of a given sample of concrete is not a constant, unless the sample is completely dry or saturated." Meyers[3] showed that the thermal coefficients of concrete vary over a wide range under different storage conditions as well as with the kind of concrete.

[2] Powers, T. C. and Brownyard, T. L., "Studies of the Physical Properties of Hardened Portland Cement Paste," *Jour. Amer. Conc. Inst. Proc.*, Vol 43, 1947, p 988

[3] Meyers, S. L., "Thermal Coefficient of Expansion of Portland Cement," *Ind. and Engineering Chemistry*, Vol 32, August 1940, pp 1107-1112.

THERMAL CONDUCTIVITY

USACE HANDBOOK FOR CEMENT AND CONCRETE

CRD-C 44-63

CRD-C 44-63

METHOD FOR CALCULATION OF THERMAL CONDUCTIVITY OF CONCRETE

Scope

1. This method is suitable for calculating the thermal conductivity of concrete from results of tests for diffusivity and specific heat.

Calculation

2. (a) The thermal conductivity of concrete shall be calculated from the following equation:

$$k = \alpha s W$$

where:
k = thermal conductivity, Btu/ft-hr-deg F,
α = thermal diffusivity, ft^2/hr,
s = specific heat, Btu/lb-deg F,
W = actual unit weight, lb/ft^3.

The thermal diffusivity of concrete shall be determined using either Method CRD-C 36 or CRD-C 37. The specific heat of the concrete shall be determined according to the procedure of Method CRD-C 124. The unit weight of concrete shall be determined using the procedures of Method CRD-C 7.

(b) The thermal conductivity of lightweight concrete and similar materials at various moisture contents shall be calculated from the following equation:[1]

$$k = \alpha C$$

where:
k = thermal conductivity, Btu/ft-hr-deg F,
α = thermal diffusivity, ft^2/hr,
C = volumetric heat capacity, Btu/ft^3-deg F.

The thermal diffusivity shall be determined using method of test for thermal diffusivity of lightweight concrete and similar materials. A curve shall be made of diffusivity versus moisture content for the range used. The volumetric heat capacity shall be calculated from the following equation:

$$C = \gamma(c_1 \div \frac{w}{100})$$

where:
C = volumetric heat capacity, Btu/ft^3-deg F,
γ = dry unit weight, lb/ft^3,
c_1 = specific heat of dry sample,
w = moisture content, percent dry weight.

The specific heat of material removed from diffusivity specimen shall be determined according to the procedure of Method CRD-C 242.

Report

3. The calculated value for thermal conductivity shall be reported to two decimal places, e.g., k = 1.35 Btu/ft-hr-deg F.

[1] Procedure based on paper: "Tests for Thermal Diffusivity of Granular Materials" by William L. Shannon and Winthrop A. Wells, published in *Proceedings* of the American Society for Testing Materials, Vol 47, 1947.

Specific Heat

USACE Handbook for Cement and Concrete

CRD-C 124-73

CRD-C 124-73

METHOD OF TEST FOR SPECIFIC HEAT OF AGGREGATES, CONCRETE, AND OTHER MATERIALS (Method of Mixtures)

1. Scope

1.1 This method of test covers a procedure for determining the mean specific heat (c, heat capacity) of aggregates, concrete, and other materials by the method of mixtures using particles smaller than 1 in. (or 25 mm) in size (Notes 1 and 2).

Note 1.- When more precise values are desired and the specimen may be pulverized or ground to pass a No. 20 sieve the method given in CRD-C 242 should be used.

Note 2.- The term "specific heat" has been used to refer to the dimensionless ratio of the amount of heat required to raise a unit weight of a material 1 deg to the amount of heat required to raise the same unit weight of water 1 deg. However, the quantity referred to as "specific heat" in this method is that also known as heat capacity (c), which is the amount of heat required to raise the temperature of a unit mass of the material 1 deg. When the units of heat used are those for which the heat capacity of water is 1.0, as Btu (International Table)/lb mass-deg F or cal/g-deg C then the numerical values for heat capacity and specific heat are equal. In the metric (SI) system the unit for heat capacity is the joule/kilogram-kelvin (J/kg K) which is numerically equal to the J/kg C. The conversion factor from either Btu/lb mass-deg F or from cal/g-deg C to J/kg C is 4.1868E + 03.

2. Apparatus

2.1 The apparatus used in this test shall consist of:

2.2 Calorimeter.- A calorimeter of the vacuum-flask type with external insulation, large enough to accommodate samples of approximately 2 lb (or 1 kg) in weight placed in a wire basket, and provided with an insulated cover in which are openings for thermometer and stirrer.

2.3 Thermometer.- A thermometer graduated to 0.1 F (0.06 C), in the range 32-150 F (0-65.6 C).

2.4 Constant-Temperature Bath, Hot.- An electrically heated constant temperature bath with thermostat set at 125 ± 1 F (51.7 ± 0.56 C).

2.5 Constant-Temperature Bath, Cold.- A refrigerated bath, with refrigeration thermostatically controlled at 35 ± 1 F (1.67 ± 0.56 C).

2.6 Basket.- A wire-mesh basket, of material of known specific heat, approximately 4 in. (or 100 mm) in diameter by 4 in. (or 100 mm) high.

2.7 Balance.- A balance capable of weighing 5 lb (2.27 kg) with an accuracy of ±0.005 lb (2.3 g).

2.8 Standard Specimen.- A specimen of material of known specific heat, approximately 0.20 Btu/lb-deg F (837.4 J/kg-deg C).

2.9 Timer.- A timer reading in minutes and seconds.

3. Specimen

3.1 For determinations of mean specific heat of aggregates, concrete, and other materials according to the method outlined herein the specimen to be used shall consist of approximately 2 lb (or 1 kg) of the material to be tested. The specimen shall contain no particles larger than 1 in. (or 25 mm) in size. When the material to be tested includes larger particles they shall be crushed before testing.

Note.- If a larger calorimeter is used the weight of the specimen may be increased proportionally.

4. Procedure

4.1 Determination of the Water-Equivalent of the Calorimeter.- Approximately 2 lb (or 1 kg) of water, weighed to the nearest 0.01 lb (4.6 g), shall be placed in the calorimeter. The calorimeter shall be placed in the constant temperature room until temperature equilibrium is attained. A weighed standard specimen of known specific heat shall be placed in the wire basket, the basket shall then be suspended by a fine wire in either the hot or the cold constant-temperature bath until equilibrium is reached (about 15 min). The specimen shall have been weighed previously both dry, and in a dripping condition after immersion. The water carry-over shall be treated as described in Paragraph 5 below. The temperature of the constant-temperature bath and of the water in the calorimeter shall be recorded to 0.05 F (0.03 C), and the standard sample shall be placed inside the calorimeter. The water in the calorimeter shall be stirred by manually raising and lowering the wire attached to the specimen. This supporting wire shall pass through a minute hole in the cover. Temperatures shall be recorded each minute during the temperature change, and for several minutes after the maximum change has occurred. The time-temperature curve shall then be plotted as indicated by the example given in Fig. 1 and the curve shall be extrapolated as described below to correct for the heat lost during the time the measurements were being taken. The line EGF shall be so drawn that the area BFG is equal to the area EGC. The approximate position of line EGF shall be determined by inspection. The line between points E and F gives the maximum temperature change which the specimen would have attained had there been no heat loss from the calorimeter. This temperature change shall be used in the calculations described in Paragraph 5 below.

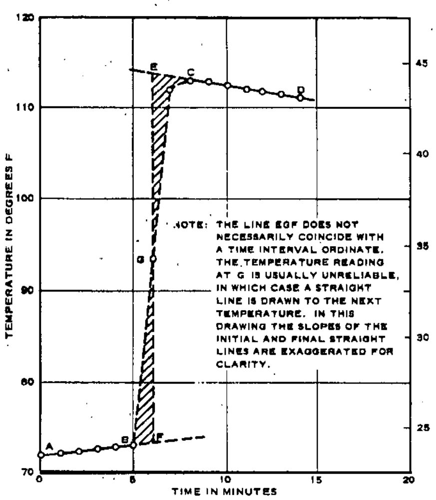

Fig. 1. Time-temperature history, specific heat determination

4.2 Determination of the Mean Specific Heat of Aggregates, Concrete, and Other Materials.- The mean specific heat of an aggregate shall be determined by placing a weighed sample, approximately 2 lb (or 1 kg), in either the hot or the cold water bath, and proceeding as in subparagraph 4.1. The sample shall have been weighed previously both dry, and in a dripping condition immediately after removal from the bath, and the water carry-over shall be treated in accordance with the calculations described in Paragraph 5 below. At least seven determinations shall be made. Hot and cold specimens shall be tested alternately in order to prevent the temperature of the water in the calorimeter from becoming greatly different from the room temperature, so that heat losses will be small or negligible.

5. Calculations

5.1 The water equivalent of the calorimeter and the mean specific heat of the sample of aggregate shall be calculated from the following formulas:

5.2 Water Equivalent.-

$$M_e = \left[\frac{(c_s M_s T + c_1 M_o T + c_b m_b T)}{c_1 T_1} \right] - M_1$$

where

M_e = water equivalent of calorimeter, lb (kg),

c_s = mean specific heat of standard, B/lb-deg F (J/kg-deg C),

M_1 = weight of water placed in calorimeter, lb (kg),

c_1 = mean specific heat of water, B/lb-deg F (J/kg-deg C),

Note.- The specific heat of water may be assumed to be 1.000 Btu/lb-deg F (4186.8 J/kg-deg C) without significant error.

T_1 = temperature change of water, corrected for heat loss, deg F (C),

M_s = weight of samples, lb (kg),

M_o = weight of water carry-over, lb (kg),

T = temperature change of sample, corrected for heat loss, deg F (C),

c_b = specific heat of basket, B/lb-deg F (J/kg-deg C),

M_b = weight of basket, lb (kg).

5.3 Mean Specific Heat.-

$$c_s = \frac{(M_l + M_c)\,c_l T_1 - (M_o c_l + M_b c_b)\,T}{M_s T}$$

where:

c_s = mean specific heat of specimen, B/lb-deg F (J/kg-deg C), and the remaining symbols have the same meaning as above.

ENGINEERS & CONSULTANTS

POST-COL ROLLER COMPACTED CONCRETE TESTING PLAN

LEVY NUCLEAR PLANT

Engineering & Construction Management
Hydro-Nuclear-Fossil

Geotechnical Engineering

Seismic and Structural Engineering

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Tunnel Engineering

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PROJECT NO. 07-3935

POST-COL ROLLER COMPACTED CONCRETE TESTING PLAN
LEVY NUCLEAR PLANT
REVISION 1

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: August 13, 2010

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.

Originator:	Brian A. Lucarelli, E.I.T. Engineering Associate	8/13/10 Date
Independent Technical Reviewer:	for Luis R. Gaekel RCC Principal Engineer	8/13/10 Date
Project Manager:	Michael J. Edwards, P.E. Project Manager	8/13/10 Date
Principal-In-Charge:	Paul C. Rizzo, Ph.D., P.E. Principal-In-Charge	8/13/2010 Date

CHANGE MANAGEMENT RECORD

Project No.: 07-3935

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

Revision No. 1

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

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 1

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 2 RCC mixes, 1 Bedding Mix) to Verify RCC Thermal Properties and Joint Strength	Pre-COL
IV	On-Site Test Pad to Verify Production Equipment and Contractor Methodology	Post-COL
V	Quality Control Inspection Program during Bridging Mat construction	Post-COL

Rev 1

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 RCC Test Pad include verifying materials and RCC mixes and conducting Production Uniformity Testing of the RCC batching and delivery system.

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 Phase III testing. RCC verification testing will be performed after the batch facilities are prepared and prior to Production Uniformity Testing.

Verification testing of RCC materials will include the tests listed in ***Table 2-1***. If Phase III Testing identifies "primary" and "backup" sources of materials, this testing will be conducted for both sources. 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 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. Fresh mix testing will occur for both the "preferred" mix and the "backup" mix. Testing of fresh RCC will include the tests listed in ***Table 2-2***.

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. Casting of cylinders for compressive strength testing will occur for both the "preferred" mix and the "backup" mix. 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.

2.2 PRODUCTION UNIFORMITY TESTING

Prior to commencing Test Pad construction, several trial runs of the batching and delivery system will be performed to confirm proper, smooth operation and that the system is capable of timely delivery of the specified material to the Test Pad Area. The Batch Plant for RCC production will be subjected to uniformity testing prior to placing the RCC Bridging Mat. Uniformity testing will evaluate the suitability of the concrete mixing plant for use on the Project, the individual properties of the fresh RCC mixture for comparison with the design mixture, and the uniformity of the mixed RCC.

A batch plant will be used for RCC production to obtain better control over RCC gradation. RCC batch plant 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 plant 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 batch plant 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 RIZZO's 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 the acceptance range shown in ***Table 2-3***; otherwise, RCC batch plant 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 1

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 RCC TEST PAD

Prior to construction, it will be necessary to construct an RCC Test Pad to evaluate contractor methods and RCC behavior. The Test Pad will serve as training for both the Contractor and the RCC Inspectors, establish effective rolling patterns, and evaluate the effectiveness of cooling measures implemented to place RCC at the specified placement temperature.

The RCC Test Pad will be constructed by the constructor of the AP1000, and will use materials selected during the RCC mix design, with the material delivery systems and equipment intended for production. This Test Pad is intended to include the construction techniques, materials, and equipment anticipated for use in the construction of the LNP foundation.

This RCC Test Pad will be used to evaluate RCC lift surface preparation required at various maturities and curing conditions; placement procedures to eliminate segregation; and RCC mixing, placement and compaction including establishing effective rolling patterns and forming procedures.

Construction of the RCC Test Pad will include numerous stops/restarts (Hold Points and Decision Points) during material stockpiling, and Test Pad preparation and construction so that quality control testing and construction methodology evaluation can be performed, and perceived deficiencies can be addressed.

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 RCC 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 at least 6 subsequent RCC lifts with nominal thicknesses of 12 inches. Approximately 700 to 800 total cubic yards of RCC will be placed in the Test Pad, including the Access Ramps and RCC Base Lift.

3.2 RCC PLACEMENT AND COMPACTION

The RCC Test Pad will be constructed by placing at least eight lifts of RCC, each approximately 12 inches in height (after compaction). It is anticipated that two "training" lifts will be placed at the bottom of the test pad, followed by six lifts to be used for testing. The RCC will be conveyed into dump trucks and transported to the Test Pad area where the RCC will be emptied into a re-mixer and conveyed to the Test Pad. Dump trucks will travel a route that simulates transport conditions anticipated during plant construction. RCC will be placed by a Creter Crane (a mobile, telescopic conveyor with 360 degrees of swing), or similar equipment that is capable of conveying RCC to the lift location. Dozers will be used to spread the RCC. Vibratory rollers will be used to compact the RCC. The primary roller is anticipated to be a 10-ton smooth double drum roller. Smaller sized rollers and walk-behind plate compactors will also be used in areas adjacent to the forms.

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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 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, and compaction before the next lift of RCC will be placed.

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 maturities of less than 2,000 Degree-Hours and at a minimum of 3000 Degree-Hours. The temperature will be recorded and stored within 1-Hour, 180-Day, Unalterable, Uninterruptable Temperature Recording Thermistors. Each Thermistor will be tagged with a permanent waterproof tag, and stamped with the identification of the Thermistor. The tag will be attached to the readout terminal end of the wire. A minimum of two Thermistors will be used per lift of RCC. The temperature will be recorded and stored within the Thermistors. 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.

To bound all expected construction conditions, the Contractor will practice lift surface treatment for both "warm" joints (less than 2,000 degree hours) and "cold" joints (minimum 3,000 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. After water/air jetting, the entire surface will be cleaned of any remaining loose debris and excess moisture by compressed air and/or vacuum.

3.4 LABORATORY EVALUATION OF TEST PAD

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

3.4.1 Materials Quality Control Testing

During RCC 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***.

TABLE 3-1
RCC TEST PAD MATERIALS TESTING SCHEDULE

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	Batch Plant
	ASTM C 566	Total Moisture	1 test per day	Batch Plant
Cement	ASTM C 150	Standard Specification	Monthly Certifications	Factory
Fly Ash	ASTM C 618	Standard Specification	Monthly Certification	Fly Ash Source

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***.

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

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.

TABLE 3-3
STRENGTH TESTING OF RCC TEST PAD

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

3.5 FIELD EVALUATION OF TEST PAD

Wire saw cuts may be used to qualitatively assess the homogeneity of the RCC mixes, the effectiveness of the bedding mix layers, and the nature of the lift joints. Once the RCC has had time to cure as determined by RIZZO, the wire saw will provide a more detailed analysis of the Test Pad. Saw cutting the Test Pad allows visual observation of the homogeneity of the mix and the quality of the bond formed at lift joints. Note that this method of evaluation will not be performed on the production Bridging Mat.

3.5.1 Field Observation Procedures

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

- 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 batch plant 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 plant control system to verify batch weights of each ingredient loaded into the mix.

- 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 RCC Test Pad construction contractor will be responsible for ensuring that RCC consistency, workability, and placing procedures are adequate for compaction requirements. Visual observation of the RCC operation is a critical tool for segregation control and in monitoring for a quality product. The RCC Testing Subcontractor will be responsible for the testing of RCC to include Vebe tests at the plant and on the placement area, nuclear density tests, aggregate moisture tests, and gradation tests.

- 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 will be determined as an outcome of the Pre-COL Testing Program. The following subsections describe the industry-standard Quality Control Inspection Program (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.

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 breach of quality 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.

- ***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 mixing plant and 1 every four hours at placement.	For information only, adjust as necessary.
	Temperature	ASTM C 1064	At least 2 per shift at mix plant 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

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.

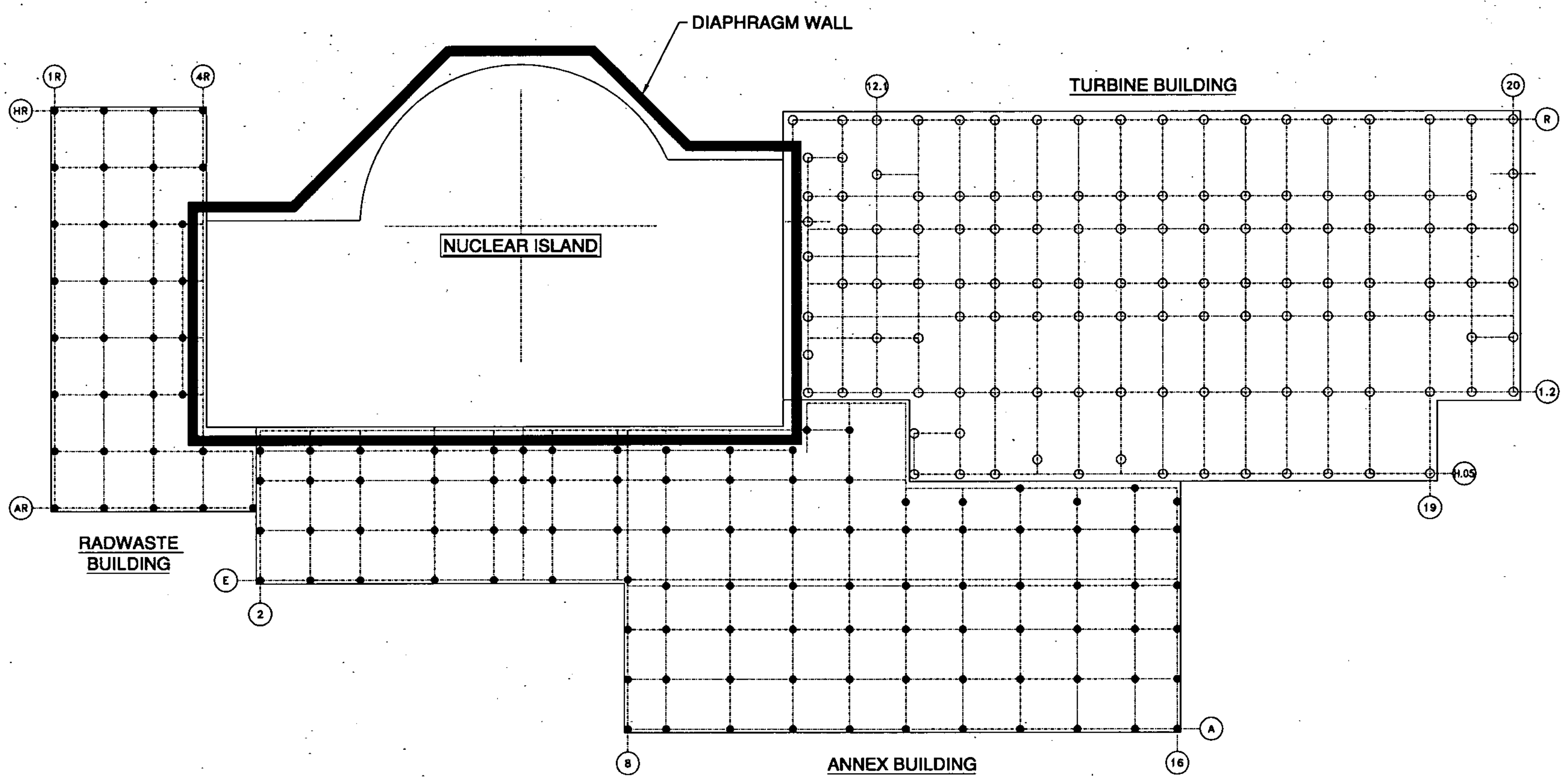
ACI Committee 349, "Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-01)," American Concrete Institute, Farmington Hills, MI, 2001.

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

Attachment 03.08.05-07A

New Figures RAI 03.08.05-07-1 through RAI 03.08.05-07-8

[8 pages following this cover page]



LEGEND:

● 3-FOOT DIAMETER DRILLED SHAFT

○ 4-FOOT DIAMETER DRILLED SHAFT

DRILLED SHAFT QUANTITIES		
BUILDING	NUMBER	
	3'ø	4'ø
TURBINE	0	125
RADWASTE	33	0
ANNEX	99	0

NOTE:
LAYOUT SHOWN IN THIS FIGURE IS CONCEPTUAL AND IS BASED ON A BUILDING LAYOUT AND DESIGN LOADS THAT HAVE YET TO BE FINALIZED.

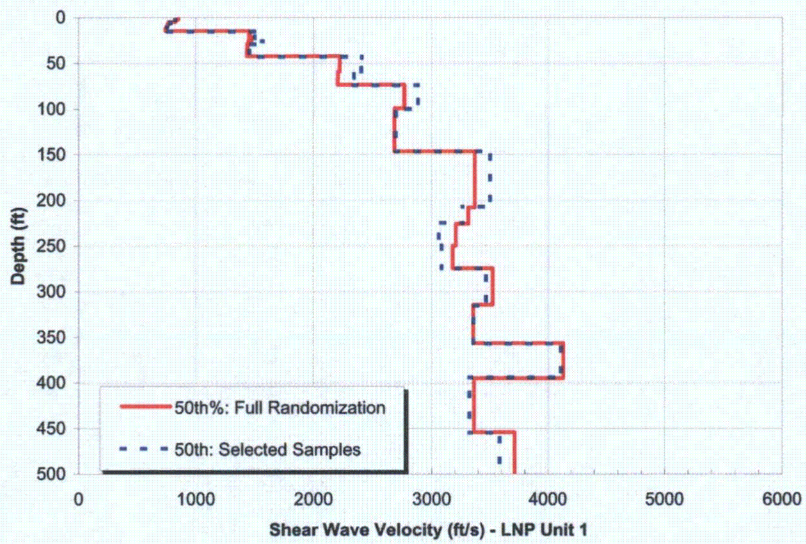
Progress Energy Florida

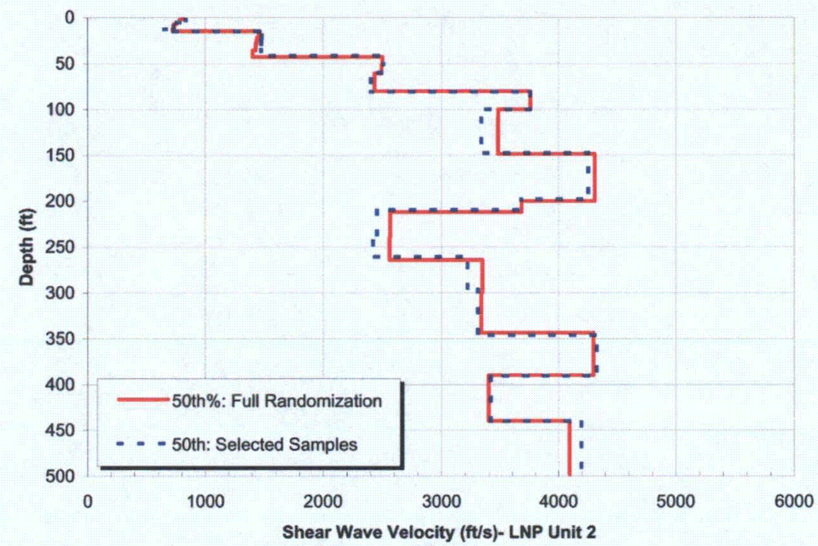
Levy Nuclear Plant
Units 1 and 2
Part 2, Final Safety Analysis Report

Drilled Shaft Layout For Turbine, Annex, and Radwaste Buildings

FIGURE RAI 03.08.05-07-1

Rev. 0





NOTE:
SHEAR WAVE VELOCITY PROFILES SHOWN IN THE THIS FIGURE ARE BASED ON THE 850fps MEDIAN SHEAR WAVE VELOCITY FOR FILL.

Progress Energy Florida

Levy Nuclear Plant
Units 1 and 2
Part 2, Final Safety Analysis Report

Comparison of Shear Wave Velocity Profile from Full Randomized Set and Selected 21 Samples

FIGURE RAI 03.08.05-07-2

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State Plane North

Plant North (N45E)

LEGEND

- A Series
- B Series
- D Series
- E Series
- I Series
- AD Series
- GSC Series
- Control Point
- LNP 1 and 2

BOREHOLES

- Offset Borehole

LIQUEFACTION POCKETS

- Postulated Liquefaction Pocket (Low FS<1.0)

Sources

Hydrography and Base Data: Florida Geographic Data Library
LNP Site: Sargent & Lundy, 2007
Borehole Locations: CH2M HILL, 2008
Offset Borehole Locations: PCR, 2010

0 10 20
Meters

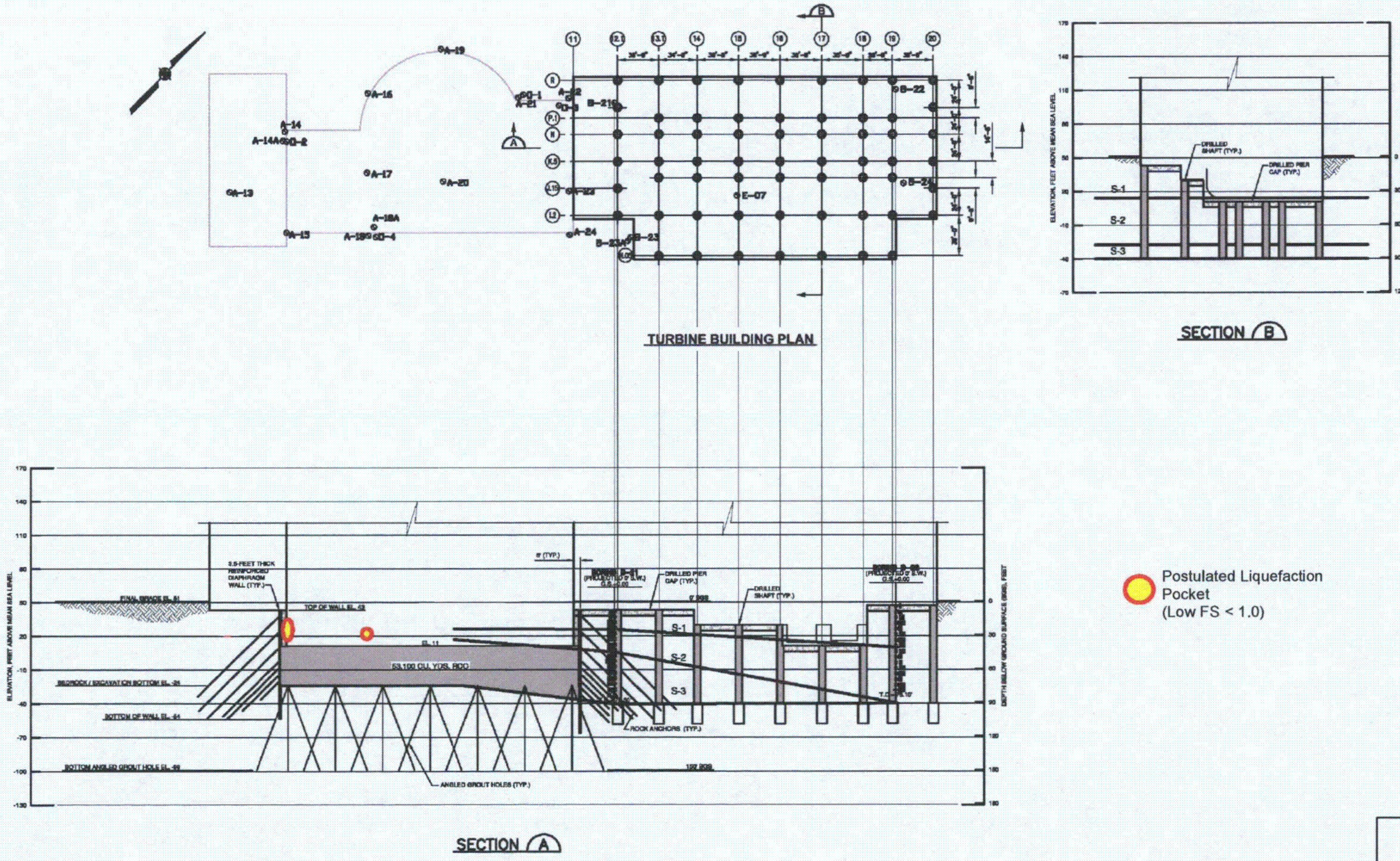
0 50 100
Feet

Progress Energy Florida

Levy Nuclear Plant
Units 1 and 2
Part 2, Final Safety Analysis Report

LNP 1 Postulated Liquefaction Pockets (plan)
For 10^{-5} UHRS

Figure RAI 03.08.05-07-3 Rev 0



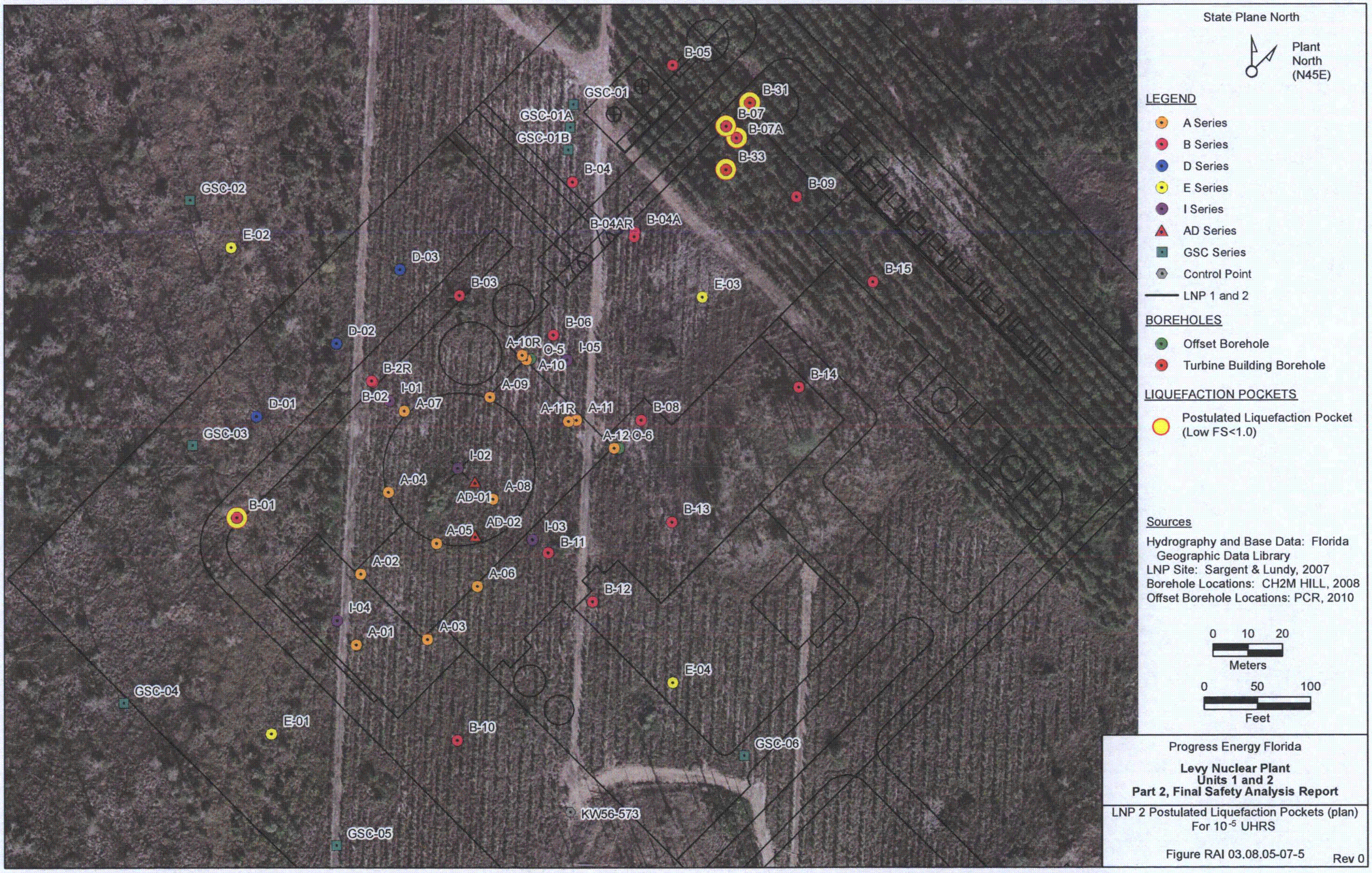
Progress Energy Florida

Levy Nuclear Plant
Units 1 and 2
Part 2, Final Safety Analysis Report

LNP 1 Postulated Liquefaction Pockets (Section)
For 10^{-5} UHRS

Figure RAI 03.08.05-07-4

Rev 0



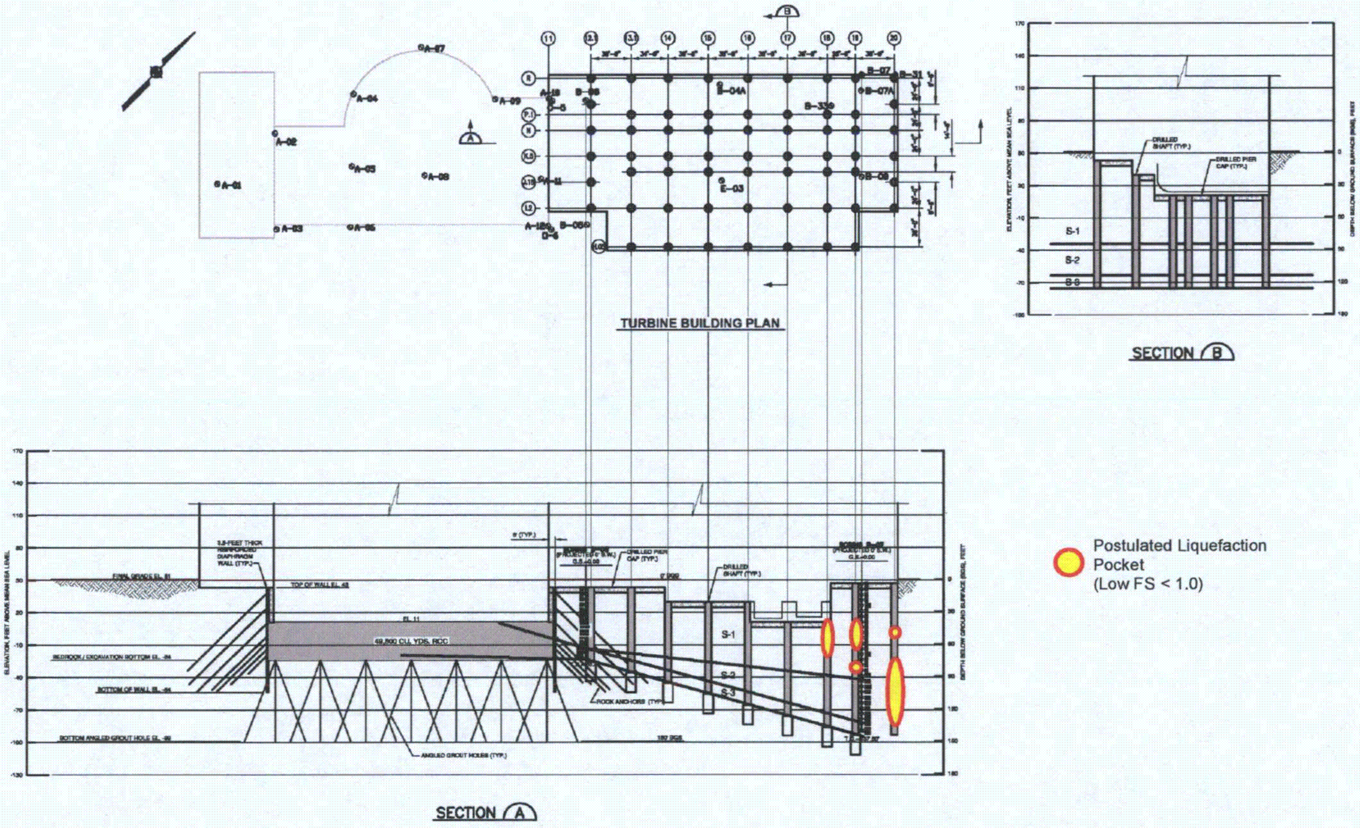
Progress Energy Florida

Levy Nuclear Plant
Units 1 and 2
Part 2, Final Safety Analysis Report

LNP 2 Postulated Liquefaction Pockets (plan)
For 10^{-5} UHRS

Figure RAI 03.08.05-07-5

Rev 0



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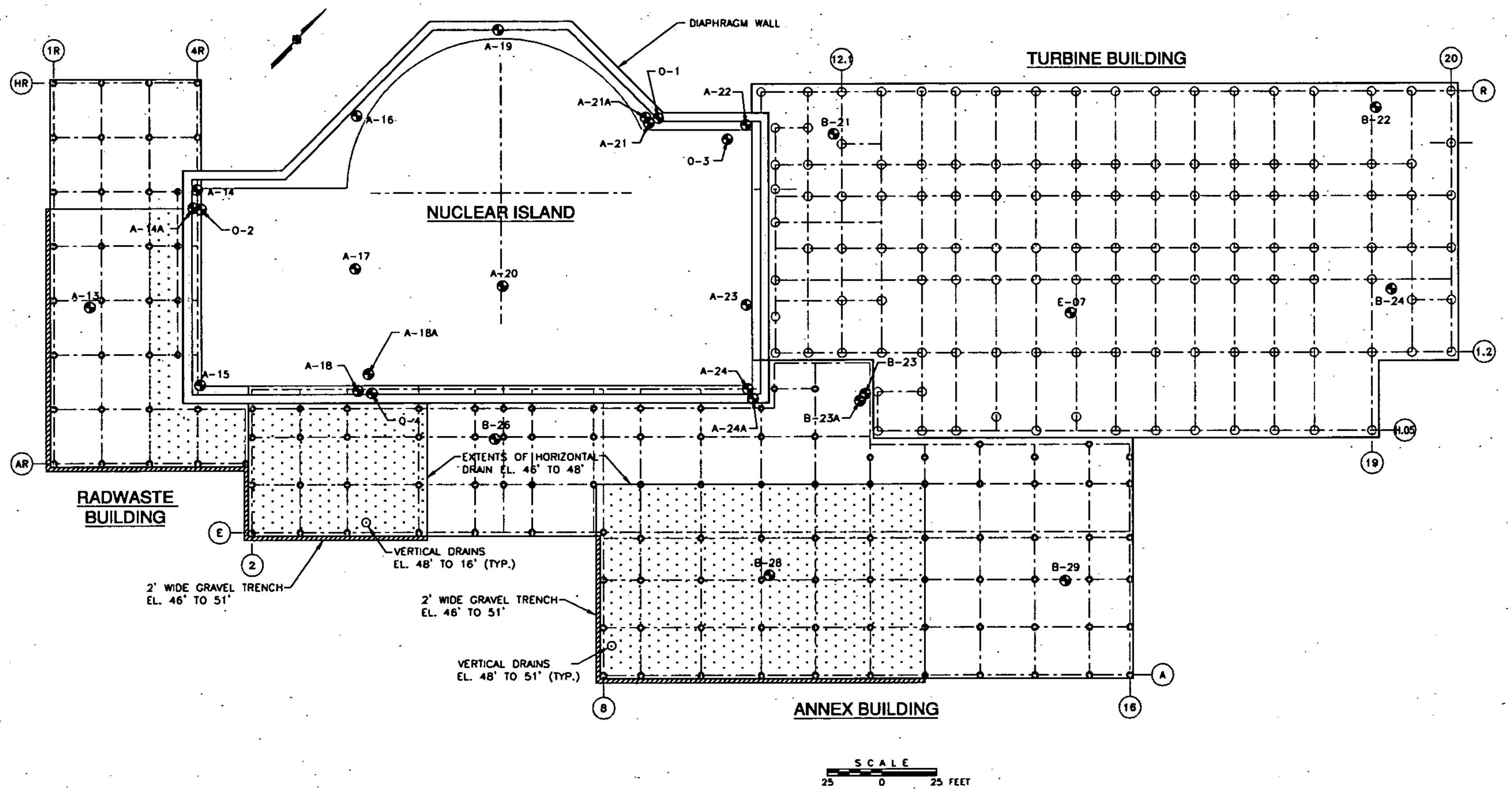
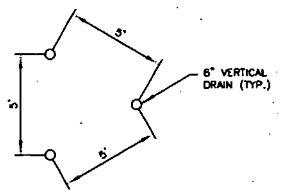
LNP 2 Postulated Liquefaction Pockets (Section) For 10^{-5} UHRS

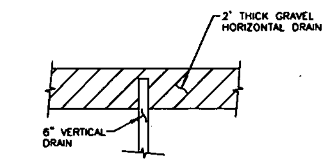
Figure RAI 03.08.05-07-6 Rev 0





TYPICAL SPACING OF VERTICAL DRAINS

SCALE
3 0 3 FEET



HORIZONTAL & VERTICAL DRAINS TYPICAL DRAINS

SCALE
3 0 3 FEET

NOTE:

VERTICAL DRAINS WILL BE COMPOSED OF A POLYPROPYLENE CORE WRAPPED WITH A GEOTEXTILE FILTER FABRIC.

LEGEND:

- 3-FOOT DIAMETER DRILLED SHAFT
- 4-FOOT DIAMETER DRILLED SHAFT
- VERTICAL DRAIN – SEE TYP SPACING
- BORE HOLE

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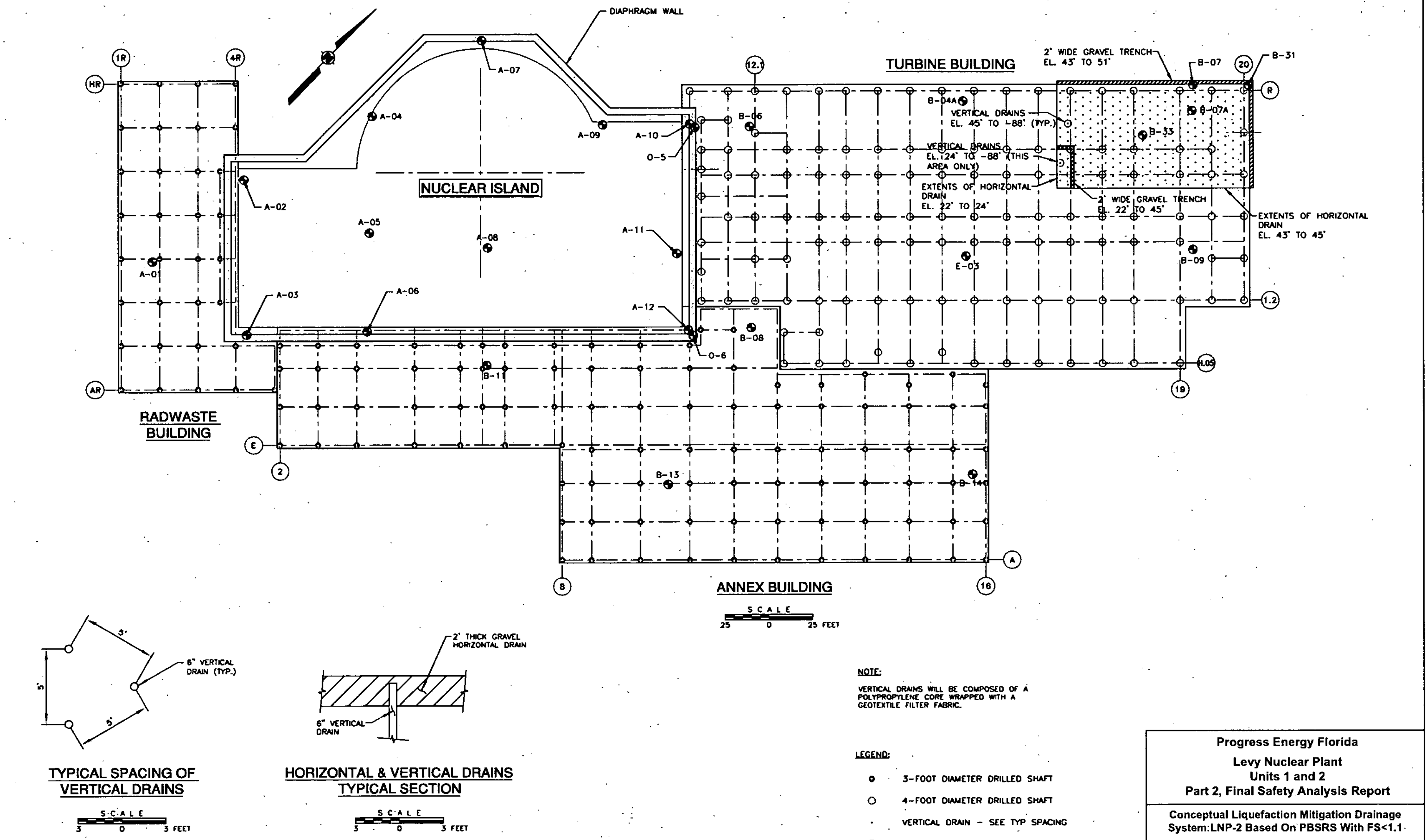
Conceptual Liquefaction Mitigation Drainage System:LNP-1 Based On PBSRS With FS<1.1

Figure RAI 03.08.05-07-7 Rev 0



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Units 1 and 2
Part 2, Final Safety Analysis Report

Conceptual Liquefaction Mitigation Drainage System:LNP-2 Based On PBSRS With FS<1.1

Figure RAI 03.08.05-07-8 Rev 0

Attachment 03.08.05-07B

New Tables RAI 03.08.05-07-1 through RAI 03.08.05-07-3

[5 pages following this cover page]

LNP COL 2.5-9

Table RAI 03.08.05-07-1 (Sheet 1 of 1)
Summary of Soil Layers Susceptible to Liquefaction in LNP 1 Site For 10^{-5} UHRS

Borehole	Bottom Depth of SPT Sample (ft.) [(a)]	Soil Type [(c), (d), (e), (f), (g)]	Field SPT N-Value (BPF) [(b)]	Factor of Safety (FS)
A-15	16.0	SP	5	0.8
A-15	21.0	SP	1	0.7
A-15	26.0	SC	2	1.0
A-18	20.0	NR	0	0.5
B-28	36.5	ML	0	0.8
O-2	9.0	SP-SC	2	0.8
O-2	10.5	SP-SC	2	0.8
O-2	12.0	SP-SC	1	0.6
O-4	24.0	ML	0	0.8
A-13	16.5	SM	3	1.0

Notes:

a) Depth of SPT sample is relative to original site grade at approximately El 41-43 ft. NAVD88

b) BPF = Blows per Foot

c) SC = Clayey Sand

d) SM = Silty Sand

e) SP = Poorly Graded Sand

f) NR = Not Recorded

g) ML = Silt with Sand

LNP COL 2.5-9

Table RAI 03.08.05-07-2 (Sheet 1 of 3)
Summary of Soil Layers Susceptible to Liquefaction in LNP 2 Site
For 10^{-5} UHRS

Borehole	Bottom Depth of SPT Sample (ft.) [a]	Soil Type, [c], [d], [e], [f], [g]	Field SPT N-Value (BPF) [b]	Factor of Safety (FS)
B-01	26.5	SM	2	0.7
B-01	31.5	SM	2	0.7
B-07	31.5	SP-SM	3	0.9
B-07	36.5	SP-SM	2	0.7
B-07	51.5	SP-SM	2	0.7
B-07	56.5	SP-SM	2	0.7
B-07	61.5	SP-SM	3	0.8
B-07	76.5	SP-SM	3	0.9
B-07A	26.5	SP-SM	5	0.9
B-07A	31.5	SM	4	1.0
B-07A	36.5	SP-SM	3	0.7
B-07A	41.5	SM	3	0.7
B-07A	51.5	SM	2	1.0
B-07A	76.5	SP-SM	6	0.8
B-31	40.5	SP	4	0.9
B-31	69.0	SP	5	0.9
B-31	70.5	SP	6	1.0
B-31	73.5	SP	5	0.9
B-31	76.5	SP	2	0.7
B-31	78.0	SP	6	1.0
B-31	79.5	SP	4	0.8
B-31	81.0	SP	2	0.7
B-31	82.5	SP	3	0.7
B-31	84.0	SP	3	0.7

LNP COL 2.5-9

Table RAI 03.08.05-07-2 (Sheet 2 of 3)
Summary of Soil Layers Susceptible to Liquefaction in LNP 2 Site For 10^{-5} UHRS

Borehole	Bottom Depth of SPT Sample (ft.) [a]	Soil Type, [c], [d], [e], [f], [g]	Field SPT N-Value (BPF) [b]	Factor of Safety (FS)
B-31	85.5	SP	3	0.7
B-31	87.0	SP	2	0.7
B-31	88.5	SP	1	0.6
B-31	90.0	SP	0	0.6
B-31	91.5	SP	4	0.8
B-31	93.0	SP	3	0.7
B-31	94.5	SP	7	1.0
B-31	96.0	SP	0	0.6
B-31	97.5	SP	0	0.6
B-31	99.0	SP	1	0.6
B-31	103.5	SP-SM	7	1.0
B-31	109.5	SP-SC	5	0.8
B-31	118.5	SP-SM	0	0.6
B-31	120.0	SP-SM	0	0.6
B-31	121.5	SP-SM	0	0.6
B-31	123.0	SP-SM	0	0.6
B-31	124.5	SP-SM	0	0.6
B-31	126.0	SP-SM	0	0.6
B-31	127.5	SP-SM, ML	0	0.9
B-31	129.0	SP-SM	0	0.6
B-31	130.5	SP-SM	0	0.6
B-33	28.5	SP	4	0.9
B-33	30.0	SP	5	1.0
B-33	31.5	SP	3	0.8
B-33	33.0	SP	2	0.7

LNP COL 2.5-9

Table RAI 03.08.05-07-2 (Sheet 3 of 3) Summary of Soil Layers Susceptible to Liquefaction in LNP 2 Site For 10^{-5} UHRS

Borehole	Bottom Depth of SPT Sample (ft.) [a]	Soil Type, [c], [d], [e] [f], [g]	Field SPT N-Value (BPF) [b]	Factor of Safety (FS)
B-33	34.5	SP	2	0.7
B-33	36.0	SP	1	0.6
B-33	37.5	SP	2	0.7
B-33	39.0	SP	2	0.7
B-33	40.5	SP	2	0.7
B-33	42.0	SP	1	0.6
B-33	43.5	SP	0	0.6
B-33	45.0	SP	0	0.6
B-33	46.5	SP	0	0.6
B-33	58.5	SP	5	1.0
B-33	66.0	SP	7	1.0

Notes:

a) Depth of SPT sample is relative to original site grade at approximately El 41-43 ft. NAVD88

b) BPF = Blows per Foot

c) SC = Clayey Sand

d) SM = Silty Sand

e) SP = Poorly Graded Sand

f) NR = Not Recorded

g) ML = Silt with Sand

Table RAI 03.08.05-07-3: Median Soil Profile to 10^{-5} UHRS Relative Displacements Calculations

Layer	Thickness (ft)	Total Depth (ft)	Unit Weight (pcf)	Shear Wave Velocity (ft/sec)	Damping Ratio (%)	Compression Wave Velocity (ft/sec)	Elevation of Layer Base (ft)
1	2.5	2.5	110	828.7	1.5	1590.2	48.5
2	2.5	5	110	804.6	2.2	1590.2	46.0
3	2.5	7.5	110	761.9	2.9	1590.2	43.5
4	3.5	11	110	744.2	3.5	1590.2	40.0
5	2	13	110	742.7	3.9	5000.0	38.0
6	2	15	110	730.5	4.2	5000.0	36.0
7	3.5	18.5	120	1461.6	3.1	5600.0	32.5
8	2.5	21	120	1454.1	3.3	5600.0	30.0
9	1	22	120	1454.1	3.3	5600.0	29.0
10	3.5	25.5	120	1457.0	2.1	5600.0	25.5
11	3.5	29	120	1442.3	2.2	5600.0	22.0
12	6.9	35.9	120	1434.1	2.1	5600.0	15.1
13	4.1	40	120	1419.4	2.4	5600.0	11.0
14	2.8	42.8	120	1419.4	2.4	5600.0	8.2
15	8.4	51.2	130	2221.9	1.7	7550.0	-0.2
16	8.4	59.6	130	2221.2	1.8	7550.0	-8.6
17	7.1	66.7	130	2206.2	2.0	7550.0	-15.7
18	7.1	73.8	130	2202.1	2.0	7550.0	-22.8
19	1.2	75	138	2768.2	1.4	8700.0	-24.0
20	24.6	99.6	138	2768.2	1.4	8700.0	-48.6
21	47.4	147	138	2685.3	1.4	8550.0	-96.0
22	61.3	208.3	138	3369.3	1.4	10600.0	-157.3
23	17.9	226.2	138	3313.8	1.4	9450.0	-175.2
24	24.1	250.3	120	3204.8	1.8	7250.0	-199.3
25	24.6	274.9	120	3177.0	1.8	7250.0	-223.9
26	40	314.9	120	3522.5	1.3	7900.0	-263.9
27	42	356.9	120	3356.5	1.3	7900.0	-305.9
28	38.4	395.3	140	4130.9	0.9	8900.0	-344.3
29	59.4	454.7	140	3361.0	0.9	8100.0	-403.7
30	59.4	514.1	140	3712.0	0.9	9000.0	-463.1
31	242.7	756.8	140	4537.1	0.9	11000.0	-705.8
32	355.8	1112.6	140	5928.9	0.9	14400.0	-1061.6
33	249.4	1362	150	7276.9	0.7	17850.0	-1311.0
34	252.9	1614.9	150	5087.2	0.7	12350.0	-1563.9
35	148.3	1763.2	150	7277.1	0.7	17400.0	-1712.2
36	106.1	1869.3	150	6240.9	0.7	14900.0	-1818.3
37	199	2068.3	150	7165.6	0.7	17500.0	-2017.3
38	601.2	2669.5	150	5424.6	0.8	13000.0	-2618.5
39	149.2	2818.7	150	5949.2	0.8	14200.0	-2767.7
40	192.7	3011.4	150	6195.7	0.8	14950.0	-2960.4
41	652.3	3663.7	150	5155.8	0.8	12600.0	-3612.7
42	603.7	4267.4	150	5553.3	0.8	13450.0	-4216.4
43	96.6	4364	150	4797.8	0.8	11500.0	-4313.0
44	Halfspace	4364	169	9382.7	0.1	16100.0	-4313.0