

Characterization of Concrete Exposed to the H-Canyon Exhaust

M.G. Serrato C.A. Langton A.J. Duncan J.N. Corley L.N. Ward January 2018 SRNL-TR-2017-00356, Revision 0

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EXECUTIVE SUMMARY

This report provides a summary of concrete characterization results for the concrete cores collected from the north and south walls of the 221-H Section 3 Personnel Tunnel during 2016 and 2017. The goal was to (1) support the H-Area Canyon Exhaust (CAEX) Soil and Concrete Core Sampling and Analysis effort and (2) characterize the effects and depth of affected concrete exposed to the canyon exhaust environment (3) collect additional physical property data on 1950's concrete. The results of this characterization will be used to refine input parameters to the 2014 H-Area CAEX Tunnel Seismic Qualification Calculations.¹ The details of the testing and the results are reported herein.

The driver for the work is the observation that about 50 mm (2 inches) of wall thickness has been lost (exposed rebar) in the H-Canyon Cross-over Tunnel and the H-Canyon Exhaust Tunnel (CAEX) over more than 60 years of service. Figure ES-1 shows a view into the Cross-over Tunnel as viewed from a core hole in the wall separating the Personnel Tunnel from the Cross-over Tunnel, i.e., north wall. Approximately 2 inches of concrete wall loss has occurred exposing the first layer of the reinforcement bar structure. Thus, it was assumed there is a potential that the remaining concrete wall material may be altered as a function of depth from the surfaces exposed to the nitric acid vapor in the exhaust air stream.



Figure ES-1 – Cross-over tunnel viewed from core position N-3 looking west (May 2017 photograph).

The harvesting of the concrete cores and the core materials characterization was performed at the request of H-Canyon Engineering. This work provides supplemental information that can be applied to the CAEX structural qualification calculations and analysis of its structural capacity to meet design basis service demands. The specific application of the information in this report to the structural qualification analysis is outside the scope of this report.

Compressive Strength Properties of the 221-H Personnel Tunnel Walls (Bulk Concrete)

Mechanical and physical property testing of Section 3 of the 221-H Personnel Tunnel nonradioactive concrete core sections to provide concrete compressive strength, density, and porosity using standard ASTM methods was performed at the SRS Construction Materials Testing Laboratory (CMTL), and the results are reported herein. The complete set of test records are reproduced in Appendices E and G to this report.

The design thickness of both the north and south walls was 0.9 m (36 inches). Concrete coring operations were conducted in two phases. Phase 1, the full thickness of the south wall and about 2/3 of the thickness of north wall were cored from November to December 2016. Field measurements of the south wall thickness through the core holes showed the wall thickness of approximately 1.1 m (44 inches). A sheet pile panel abuts the exterior surface of the south wall. The increase in wall thickness from design thickness is an artifact from the corrugations in the sheet pile used in the 1950's facility construction.

Phase 2 coring operations were conducted from April to May 2017 to obtain core sections from the remaining wall thickness (about one third of the wall thickness). These cores were considered radioactive core sections because they had a surface exposed to the H-Canyon exhaust.

The north wall design thickness was 0.9 m (36 inches). The north wall thickness measured through the core holes was 0.86 m (33 ³/₄ inches) at the west end and 0.87 m (34 ¹/₄ inches) east end of the corridor. The decrease in the wall thickness is presumed to be the result of more than 60 years of continuous exposure to nitric acid vapor in the exhaust air stream.

Statistical analysis of the compressive strength measurements made on the nonradioactive, "clean", core sections collected in 2017 from Section 3 of the 221-H Personnel Tunnel north and south walls are summarized below:

- Compressive strength measurements indicate that the north and south wall concretes are two separate materials populations;
- The mean compressive strength of the south wall concrete was calculated to be 26.4 MPa (3835 psi) based on 20 measurements corrected for coring damage and dimension (design strength for this concrete is 2500 psi); and
- The mean compressive strength of the north wall concrete is calculated to be 16.1 MPa (2336 psi) based on 29 measurements corrected for coring damage and dimension (design strength for this concrete is 2500 psi).

The Section 3 of the 221-H Personnel Tunnel north and south wall compressive strength data will be added to a larger database of concrete strength measurements for concrete placed at SRS during the early 1950s.

Petrographic analyses of two nonradioactive north and two nonradioactive south wall concrete cores were performed by the U.S. Army Core of Engineers in a separate task. The results were reviewed by the SRNL staff. Observations and interpretations of the petrographic evaluation of the nonradioactive, herein referred to as "clean" core sections are summarized below:

- The clean concrete in Section 3 of the 221-H Personnel Tunnel north and south walls is not expected to lose strength in the future due to normal aging.
- The clean concrete cores examined showed no indication of physical or chemical degradation.
- No evidence was found for alkali silica reaction (ASR) or any other degradation mechanism expressed as cracking from expansive reactions in the concrete.
- "Rims" on some of the coarse schist aggregates in the north wall cores were identified as clay which was present on the aggregate when the concrete was batched.
- Relatively high capillary porosity and microcracking were attributed to initial shrinkage. These microstructural features are consistent with a high water to cement (w:c) ratio of greater than 0.5 in the initial mixes.

• Clay coated aggregates and high capillary porosity in Section 3 of the 221-H Personnel Tunnel north wall concrete are most likely responsible for poor bonding between the paste and aggregates and the lower compressive strength of this wall compared to the south wall of the Tunnel.

Characterization of North Wall Core Sections Exposed to Canyon Exhaust

Five (5) radioactive concrete core sections, approximately 8" to 9" in length, were cut from the 221-H Personnel Tunnel north wall. A sixth core section was damaged during coring operations and was not fully characterized. These core sections included the surface of the Cross-over Tunnel wall exposed to the canyon exhaust, nitric acid vapor/air stream.

The suite of tests and measurements made on these radioactive core sections focused on identifying and understanding depth-dependent changes that occurred in the concrete and paste/matrix as a function of distance from the surface exposed to the canyon exhaust environment. The tests and measurements to provide depth-dependent material characterization are listed below:

Concrete

- Visual examination of the external surface features of the as-received cores: cracking, defects, color, macroscopic texture, uniform aggregate distribution, general integrity
- X-ray computed tomography of two cores (full length): internal porosity, macrotexture, uniformity, and identify differences or gradients in these properties as a function of distance from the exposed surface
- Alkalinity: colorimetric pH determination to evaluate carbonation sufficient alkalinity for rebar passivation
- Ultrasonic pulse velocity (UPV) measurements: nondestructive measurement of 54KHz ultrasonic wave travel time through concrete to identify differences in materials with the expectation of correlating measurements to physical and/or chemical differences.
- Petrographic examination using scanning electron microscopy coupled with energy dispersive spectroscopy (SEM/EDS) microstructure characterization and phase identification

Matrix/paste

- X-ray diffraction (XRD): mineralogy of the matrix phases
- Microhardness characterization: depth dependency of matrix hardness as an indicator of changes in competency
- Chemistry of matrix pore solution and soluble constituents in the concrete as an indication of the extent of nitric acid penetration into the wall: Pore solution chemistry was inferred from leaching of crushed matrix material and analysis of leachates for anions and cations.

The test records for the materials characterizations are contained in Appendices A through F to this report.

Observation of Physical Condition Changes

Loss of wall material exposed in the H-Canyon Cross-over Tunnel has occurred as indicated by the exposed aggregate and rebar documented in inspection photographs of the tunnel and protruding aggregates on the exposed surfaces of the cores. The exposed aggregates in the cores received by SRNL were securely attached to the matrix material as indicated through handling of the cores. There was no indication that the coring process dislodged exposed aggregates. The gravel aggregates and the quartz sand grains were securely anchored in the matrix and dislodging them required a hammer and chisel. The matrix was not friable, powdery, or obviously fractured.

The surfaces of all five concrete cores exposed to the canyon exhaust had a glossy appearance. The concrete cores (matrix not aggregate) were a darker color from the exposed surface to a depth. In four cores, the discolored region extended about 38 to 64 mm ($1\frac{1}{2}$ to 2 $\frac{1}{2}$ inches) into the concrete. The discolored portion of Core N1-D extended about 89 mm ($3\frac{1}{2}$ inches) into the sample. The color transition was irregular because it followed aggregates but was distinct.

Observation of Chemical Alteration

Chemical alteration of the concrete with depth was observed. The changes were ascribed to nitric acid vapor and carbon dioxide/bicarbonate ion ingress into the concrete.

<u>Nitric acid ingress</u>: Chemical reactions between nitic acid and the alkaline phases in hydrated portland cement are expected to result in formation of soluble nitrate salts. Two cores, N4-D and N5-C, were evaluated for depth dependent soluble anions and cations concentrations. Leachates from pulverized matrix samples collected as a function of distance from the surface exposed to the canyon exhaust were collected and analyzed. High concentrations of nitrate ion (1000 to 3000 μ g/mL) were contained in the leachates of material collected to a depth of about 50 mm (2 inches) from the surface. The charge balancing cation in these leachates was primarily Ca²⁺.

<u>Carbon dioxide/Carbonic acid ingress</u>: Calcite, CaCO₃, was observed (XRD results) in the matrix. Calcite is the reaction product between atmospheric CO₂ in calcium phases in hydrated portland cement, Ca(OH)₂, C-S-H gel, and other calcium aluminate hydrate phases. For concrete exposed to moist air, this reaction typically occurs through intermediate acid compounds, such as bicarbonate ion, HCO_3^- .

The absence of portlandite, Ca(OH)₂, is also evidence of acid attack (nitric acid and/or carbonic acid). Portlandite was absent from the matrix phase assemblages of cores N3-D, N4-D, and N5-C between the surface, 76 mm (3 inches) for core N3-D, and 127 mm (5 inches) for cores N4-D and N5-C. Samples from cores N4-D and N5-C were not collected at 102 mm (4 inches). Calcite was detected in all five of these cores, N1 to N5, over the entire 7 to 9 inches of core evaluated.

The colorimetric phenolphthalein test for alkalinity confirmed XRD results that showed incomplete carbonation of all alkaline phases in the full length of the radioactive core sections. This test supports the conclusion that the alkalinity of the bulk concrete and the section exposed to the canyon exhaust provides rebar passivation (pH > 10.2). Completely carbonated matrix material was assumed to be removed from the surface by erosion due to the velocity (30 mph) of the canyon exhaust air stream.

<u>Non-Destructive Evaluation of Compressive Strength:</u> Direct measurements of compressive strength of the exposed surface region were not made using conventional testing (ASTM C39) because the strength was expected to be depth-dependent over distances much smaller than the minimum test specimen length required by 1½ inch aggregate. Therefore, a non-destructive technique, ultrasonic pulse velocity (UPV), was used to assess relative differences in material response as a function of distance from the exposed surface. UPV measurements were made at one-inch intervals.

A relationship was developed between the UPV and compressive strength results for the clean concrete core sections from the north and south walls. When the resulting equation was applied to the depth-dependent UPV results from the north wall radioactive core sections it did not result in a defensible correlation between these two properties. The compressive strength of the two inches of concrete nearest the exposed surfaces was predicted to be higher than the strength of the material between 2 and 8 inches from the exposed surface. However, this UPV-Compressive strength relationship for the radiologically contaminated core sections was judged to be invalid because the material near the surface was shown to be

chemically and mineralogically altered compared to the bulk material. Evidence of the impact of chemical alteration on the UPV results was shown with a chart superimposing the UPV and chemical and mineralogical results. The nitrate-rich layers of these cores correspond to the regions with higher UPV velocities and roughly correspond to the 38 to 64 mm (1.5 to 2.5 inch) thick darker colored regions.

Microhardness measurements were made on the matrix in the core sections exposed to the canyon exhaust with the intent of evaluating relative differences in the matrix portion of the concrete as a function of distance from the exposed surface. Statistical analysis of the data showed that the average microhardness value of the depth-discrete matrix measurements was unchanged as a function of distance from the exposed surface.

<u>Concluding Statement on Mechanical Properties of the Concrete Exposed to and Affected by the</u> <u>Canyon Exhaust</u>

The composite conclusion from the radiologically contaminated core characterization is that two concurrent chemical alteration mechanisms of the hydrated portland cement matrix, selective nitric acid dissolution and secondary carbonate precipitation, coupled with wind erosion and scouring of damaged material are responsible for the physical features observed in the concrete exposed to the canyon exhaust. The exhaust air flow erosion conditions have not been investigated in detail.

The testing performed on the affected portions of the north wall cores do not conclusively demonstrate a change relative to the 2017 compressive strength of the north wall unaffected wall strength. That is, several depth-dependent material changes were observed, however there is no firm case to conclude that these material changes were manifested in an increase or a decrease from the bulk concrete compressive strength.

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ACI	American Concrete Institute
AD	Analytical Development
ASTM	American Society for Testing and Materials
CAEX	H-Canyon Exhaust Tunnel
CMTL	SRS Construction Materials Testing Laboratory
CSEM	Contained Scanning Electron Microscope
C-S-H	Calcium Silicate Hydrate
СТ	Computed Tomography
DI	Deionized
DOT	Department of Transportation
EDS	Energy Dispersive Spectroscopy
ERDC	Engineering Research and Development Center
FE-SEM	Field Emission Scanning Electron Microscope
GS	General Services
HEU	High Enriched Uranium
LEU	Low Enriched Uranium
mph	Miles per hour
N	North (north wall)
РТ	Personnel Tunnel
QA	Quality Assurance
S	South (south wall)
SDD	Silicon Drift Detector
SEM	Scanning Electron Microscopy
SRNS	Savannah River Nuclear Solutions, LLC
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
UPV	Ultrasonic Pulse Velocity
USACE- ERDC	US Army Corps of Engineers-Engineering Research and Development Center, (Concrete and Materials Branch of the Geotechnical and Structures Laboratory, Vicksburg, MS)
VP	Variable Pressure
WDS	Wavelength Dispersive X-Ray Spectrometer
ХСТ	X-ray Computed Tomography
XRD	X-ray Diffraction

LIST OF ABBREVIATIONS

1.0 Introduction

This report provides a summary of concrete characterization results for the concrete cores collected from the north and south walls of the 221-H Personnel Tunnel during 2016 and 2017. The goal was to support H-Area Canyon Exhaust (CAEX) Soil and Concrete Core Sampling and Analysis and characterize the effects and depth of affected concrete exposed to the CAEX environment to refine and update input parameters to the 2014 H-Area CAEX Tunnel Seismic Qualification Calculations.¹ This task was requested by SRNS H-Canyon Engineering through a Technical Task Request.² The full scope of this concrete core characterization effort is provided in the H-Canyon Cross-Over Tunnel (HCAEX) Concrete Cores/Samples Characterization Task Technical and Quality Assurance Plan³ and the SRNL H-Area Exhaust Tunnel (CAEX) Concrete Cores/Sample Characterization Plan.⁴

SRNL characterization activities were completed in two phases: Phase 1, non-radiological, "clean", cores from the north and south walls of the Personnel Tunnel⁵ and Phase 2, radiologically contaminated core sections recovered from the north wall of the Personnel Tunnel with surfaces exposed to the H-Canyon Cross-over Tunnel environment.

1.1 Objective

The objective of this task was to characterize up to eighteen (18) cores either 102 or 152 mm (4 or 6 inch) diameter collected from the 221-H Section 3 Personnel Tunnel, as outlined in the CAEX Tunnel Concrete Core Sampling Plan¹ and to provide updated concrete characterization data for the H-Canyon CAEX qualification calculations.⁶ The concrete core characterization effort was designed to identify the depth of alteration caused by exposure to the exhaust tunnel environment.

The characterization activities included:

- Measure physical and mineralogical properties of the clean core sections to provide baseline information for the 60+ year old CAEX concrete which was not exposed to the canyon exhaust environment. These results support the preliminary assessment of residual strength of the altered concrete exposed to the canyon exhaust environment.
- Conducting testing to identify chemical, mineralogical and radiological profile as a function of distance from the exposed surface, and analyze results to provide a interpretation of the mechanisms responsible for the loss of wall thickness and alteration profiles.

Results from this characterization approach were not intended to address the projected serviceability of the CAEX tunnel.

1.2 Background

The primary mission of H-Canyon (221-H) is to dissolve, purify and blend-down surplus highly enriched uranium (HEU) and aluminum-clad foreign and domestic research reactor fuel to produce a low enriched uranium (LEU) solution suitable for conversion to commercial reactor fuel. H-Canyon was constructed in the early 1950s and began operations in 1955. The building is called a canyon because the footprint is long, high, and deep and includes two continuous rectangular subsurface structures that contains the process vessels. All work is remotely controlled, and employees are further protected from radiation by thick concrete walls.⁷

After more than 60 years of service with exposure to the high velocity (48 km/h, 30 mph) exhaust air containing nitric acid vapor and damp conditions, the concrete tunnel has experienced loss of wall thickness. The concrete condition has been monitored during inspections of the H-Canyon Exhaust Tunnel and Cross-over Tunnel conducted in 2003, 2009, 2011, 2014, and 2015, and 2017).⁸ These inspections document that

the loss of wall thickness has progressed to the point of exposing aggregate and steel reinforcement, i.e., about 50 to 65 mm (about 2 to 2.5 inches).⁸ See Figure 1-1.



Figure 1.1. Pole Camera photographs at the Pitot Tube location in Section 4 of the H-Canyon Exhaust Tunnel.

Access to the CAEX is limited with respect to concrete core collection. Consequently, the north and south walls of the 221-H Section 3 Personnel Tunnel were selected for concrete core collection because of ease of access, lower worker safety risks, and minimal impact to the CAEX tunnel.¹ The south wall concrete was not in contact with canyon exhaust. Cores from the south wall were collected and characterized to provide information on 60+ year old SRS concrete. The north wall separates the Personnel Tunnel from the H-Canyon Cross-over Tunnel and is where the exhaust air streams from the warm and hot canyons are combined prior to entering the Exhaust Tunnel. The concrete in the Cross-over Tunnel and Exhaust Tunnel have experienced comparable thickness losses as is shown in Figure 1-2. Therefore, characterization of the Cross-over Tunnel served as a reasonable surrogate for evaluating the Exhaust Tunnel.



Figure 1.2. H Canyon Exhaust Tunnel Section 4 downstream of the current Recycle Vessel Vent and former Process Vessel Vent input streams (left) compared to the Cross-over Tunnel looking west through the N2 core hole (right)

The north and south walls of the 221-H Personnel Tunnel were constructed of reinforced concrete and are located below the 221-H base-mat. The north wall of the Personnel Tunnel separates the Personnel Tunnel and the Cross-over Tunnel which combines the process exhaust air from the warm and hot canyons and HB-Line into a single tunnel before exiting the H-Canyon structure to continue underground to the Sand Filter System. Schematic representations of the H-Canyon exhaust ventilation system and the locations of the cores that penetrated into the Cross-over Tunnel are shown in Figure 1.3 and Figure 1.4, respectively.



Figure 1.3. 221-H Canyon Exhaust Ventilation Diagram.



Figure 1.4. 221-H Section 3 Personnel Tunnel north wall illustrating the relative locations of the warm and hot canyon exhaust entry points into the Cross-over Tunnel relative to the radioactive core locations (Best Available Figure).

The south wall separates the Personnel Tunnel from the exterior soil environment. The north wall separates the CAEX from the Personnel Tunnel. The design thickness of both walls is 0.9 m (36 in.). The south wall was cored the entire thickness during December 2016 and January 2017. During the December 2016 and January 2017 coring activities, the north wall was initially cored to a depth of approximately 0.6 m (2 ft.). All concrete cores recovered from north and south walls during the December 2016 and January 2017 were designated clean samples based on radiological scans. During April and May 2017, the north wall core holes were extended the full thickness of the wall, i.e. into the radioactively contaminated Cross-over Tunnel. Photos of the 221-H Section 3 Personnel Tunnel before coring and with the core drill in place on the north wall are shown in Figure 1.5.

A sketch of the approximate core locations for 12 cores obtained through the north and south walls of the 221-H Personnel Tunnel is provided in Figure 1.6. Three additional cores up to approximately two feet long (non-radioactive) were taken at location N2 and three more were collected at location N6 (Figure 1.7). A six-inch core barrel was used to retrieve cores N2 and N5. All others were collected with a four-inch core barrel.



(a) Looking east: prior to coring



(b) Looking west: core drill set up for south wall nonradiologically contaminated sections.

Figure 1.5. 221-H Section 3 Personnel Tunnel.



Figure 1.6. Concrete core locations in the north and south walls of the 221-H Section 3 Personnel Tunnel (Best Available Figure).



Figure 1.7. Additional core locations at positions N2 and N6 in the north wall of the 221-H Section 3 Personnel Tunnel. N2 and N6 cores were located between 2B and 2C and 6B and 6C, respectively.

1.3 Quality Assurance

The results presented in this technical report supersedes preliminary results presented in SRNL-L3100-2017-00010 and SRNL-L3200-2017-00087.

Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.

2.0 Core Handling and Characterization Methods

2.1 Core Identification and Handling

The clean concrete cores (non-radiologically contaminated) extracted from the south and north walls were sent to the Construction Materials Testing Laboratory (CMTL) in wooden boxes for physical and mechanical property measurements. They were cut into sections approximately 0.2 m (10 in.) long. Core sections were labeled using the scheme shown in Figure 2.1. Short pieces of core were used for porosity measurements and were labeled, BB (between B and C) and CC between C and D. Core identification numbers were assigned by H-Canyon Engineering. Cores from the north wall of the 221-H Personnel Tunnel were designated as 221H-PT-N#-C or D. The south wall cores were designated as 221H-PT-S#-D. For the purposes of this report the identification has been shortened to N#-C or D and S#-D.

Four clean cores sections, S2-D, S6-D, N1-B, and N2-B, and a piece of over core were sent to the USACE ERDC for additional evaluation.¹⁴ The radiologically contaminated core sections from the 221-H Personnel Tunnel north wall were sent to SRNL for characterization.



Figure 2.1. Core section labeling where red outlines indicate radiological sections.

2.2 Radiological Core Section Handling and Work Flow

The radiologically contaminated core sections were received at SRNL in DOT 7A containers. Cores N1-D, N2-C, N3-D, N4-D and N5-C were received intact. Due to problems encountered during coring (no cooling water), core N6-D was broken into many pieces. Consequently, SRNL characterization of N6-D was limited to radiological screening.

After unpackaging each core, a visual examination was performed to identify macroscopic features (cracks, color, irregularities) and non-destructive ultrasonic pulse velocity (UPV) measurements on the as received core sections. To assign appropriate radiological work control measures for additional characterization, two 20 g samples of matrix material were chipped out of each core and sent for radiological screening. One sample was collected near the exposed surface and the just below the transition in color which was about 2 inches (51 mm) from the surface. As the result of this initial sampling, Cores N1-D, N3-D and N4-D were broken (through core fracture) near the color discontinuity. Each core was repackaged for later characterization.

After radiological work control measures were identified and implemented, slabs were cut for microhardness and scanning electron microscopy (SEM) analysis. The mineralogical characterization required ground matrix material extracted from slabs as a function of distance from the surface. Figure 2-2 provides the scheme used to identify sub-sample locations from the radiologically contaminated core sections.



Figure 2.2. Labeling Scheme for Identifying Sub-sample Locations from Radiologically Contaminated Cores Sections.

2.3 Alkalinity Dye Test

The alkalinity test was performed in H-Area soon after each core was extracted (Figure 2.3). Alkalinity of the concrete was measured on core samples using an acid-base indicator solution. The solution of 1% phenolphthalein in isopropyl alcohol was applied to newly exposed cross-sectioned surfaces of each cores. If the area to which the dye was applied turned fuchsia, the pH of the concrete was greater than 10. The brighter the color, the higher the pH. If the dyed area was not stained fuchsia, the concrete pH was less than 8.2. Carbonation of concrete is commonly observed and results from reaction of hydrated Portland cement phases with atmospheric CO_2 . The phenolphthalein dye test is therefore often referred to as the carbonation test.



Figure 2.3. Illustration of alkalinity as a function of distance from a surface of core S-5-D (left) and core S-2-A (right).

2.4 Visual examination

Visual examination consisted of describing the as-received condition of the radiologically contaminated core sections with respect to core integrity, uniformity, unusual flaws, features on the surface exposed to the canyon exhaust, fine and coarse aggregate, cracking, and color. Each core was marked at 13 mm ($\frac{1}{2}$ inch) intervals along the long axis to identify the circumferential 0, 90, 180, 270° positions for UPV measurements. The exposed matrix surface was set as the zero point. Figure 2.4 is an example of a core section marked with distance from the exposed radioactive surface. Aggregates are shown protruding from the exposed surface. Note that the surface appeared "varnished" and the first few inches were a darker color than the rest of the core section.



Figure 2.4. Radiologically contaminated core section from the north wall of the 221-H Personnel Tunnel.

2.5 <u>Ultrasonic Pulse Velocity</u>

Ultrasonic pulse velocity (UPV) is a non-destructive method used to assess the concrete by measuring the velocity of a pulsed ultrasonic wave through concrete. A Pundit PL-200 unit with two 54 KHz bandwidth probes was used to measure transmission time and establish ultrasonic pulse velocity. Because ultrasound does not travel well in air, a gel couplant medium was applied to the probes to improve signal transmission time to verify or correct transducer bandwidth reception from the unit processor and general system cohesion.

ASTM C597, Standard Method for Pulse Velocity Through Concrete⁹ methodology was modified to evaluate each of the cores using one inch diameter probes (Figure 2.5). Given the size of the aggregate, 38 mm (1.5 inch), and the diameters of the cores, 10 and 15 cm (4 and 6 inches), the cores could not be trimmed to provide a flat surface. Hence the modification consisted of using the 1-inch diameter probes on the cylindrical surfaces. This modification (flat probe on a curved surface) was determined to not affect the results based measurements made on two clean north wall core sections (flat probes on flat surfaces, Appendix B Core N3-A Sections 1 and 2) and measurements made on south wall cores (flat probes on curved surfaces, Appendix F).



Figure 2.5. Ultrasonic Pulse Velocity (UPV) Sensor Layout.

UPV measurements were made on as-received cores clean and radioactive core sections with the probes oriented perpendicular to the core axis (Figure 2.5). UPV data were recorded a function of depth from the exposed surface. Measurements were taken in two transmission point configurations, with probes oriented around the circumference of the core at 0-180 degrees and 90-270 degrees. The transmission distance (core diameter) was measured at every measurement location along the core with calipers to 0.01 inches. Travel times were measured to 1×10^{-07} seconds.

Velocity is a measurement of distance / time. For a given distance a higher velocity results in a faster (lower) transmission time. All other factors being equal, a faster transmission time is indicative of a denser material. However, variables such as higher proportion of non-porous aggregate and moisture content can accelerate sound and give the appearance of higher density.

UPV measurements were made at a minimum of three locations on clean core sections at the Construction Materials Testing Laboratory (CMTL). Measurements on the radioactively contaminated cores from the north wall were made on 13 mm ($\frac{1}{2}$ inch) intervals for the first four inches and then 25 mm (1 inch) intervals for the remaining length of the as-received core. UPV measurements on the radioactively contaminated cores were conducted at SRNL in a radiological hood.

2.6 Compressive Strength, Porosity and Density

Standard concrete test methods were used for evaluating mechanical and physical properties of the nonradiologically contaminated north and south wall concrete cores.¹⁰⁻¹² ASTM C39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens,¹⁰ identifies correction factors for sample length to diameters ratios other than the standard ratio of 2/1. The CMTL concrete technicians applied these corrections where needed. The American Concrete Institute Manual of Standard Practice, ACI 214-4R Chapter 8¹² identifies additional correction factors for core samples. These additional factors were applied where applicable by SRNL personnel (Equation 1).

$f_c = F_{I/d} F_{dia} F_{mc} F_{df_{core}}$ Equation 1

where: f_c = equivalent in-place strength

 f_{core} = measured compressive strength

 $F_{l/d}$ = correction factor for core length to diameter ratio

 F_{dia} = correction factor for core diameter

 F_{mc} = correction factor for moisture content other than that of the as received sample

 F_d = correction factor for damage due to coring

A correction factor, f_d , of 1.06 was applied to all core samples. A correction factor F_{dia} of 0.98 applied to the 6 inch cores (Core N-2-C and N-5-C). The moisture content of all cores was as-received so no correction factor was applied for moisture.

Concrete density was determined by measuring the length, diameter, and mass of selected compressive strength samples prior to capping per ASTM C39/C39M¹⁰. Triplicate measurements of each parameter were measured and the average was calculated and reported by CMTL technicians.

ASTM C642, Standard Test Method for Density, Absorption, and Voids in Hardened Concrete, was used by the CMTL to determine the porosity of the non-radioactive core samples.¹¹ Porosity was reported as volume of permeable pore space.

2.7 Matrix Microhardness

Microhardness measurements were performed to ASTM C1327-15, Standard Test Method for Vickers Indentation Hardness of Advanced Ceramics.¹³ The indenter used was a Vickers type indenter with an applied load which varied from 50 to 100 grams-force and a loading duration of 15 seconds. The indentations were measured in micrometers using a 40X objective (i.e., 400X magnification) microscope. The data are reported in Vickers hardness numbers (HV) which are calculated using Equation 2.

$$HV = 1854.4 \frac{Force}{d^2}$$
 Equation 2

where: *Force* = grams-force (gf)

d = mean diagonal length of the indentation (µm)

In some cases, the following exceptions in the ASTM C1327-15 method were noted: (1) specimens were ground and (2) specimens were polished to 1 μ m instead of 0.1 μ m.

Measurements were discarded and the data was not collected for the following conditions: (1) localized regions of the cement matrix to deviate from the standard orientation to the indenter axis (i.e., $< 2^{\circ}$ from perpendicular) due to differential polishing which resulted in the two diagonal lengths measuring more than 5% of the mean value; and (2) porosity, cracking and the presence of aggregate beneath the surface resulted in unacceptable indentations as defined in the standard.

2.8 Mineralogy by X-Ray Diffraction

Mineralogical evaluation is used to identify solid phases that make up the matrix and changes in these phases as a function of aging and environmental exposure. Both the USACE ERDC staff and the SRNL Analytical Development Section (ADS) researchers analyzed matrix samples extracted from the concrete cores. The USACE ERDC analyzed matrix from the clean, non-radioactive core section. Their sampling approach and x-ray diffraction (XRD) instrument are described their report.¹⁴ SRNL collected and analyzed matrix sub-samples from the radioactive core sections (C or D) as a function of distance from the surface exposed in the Cross-over Tunnel to determine whether the matrix had been effected by the canyon exhaust.

At SRNL, small pieces of matrix material were chipped from locations identified along the axis of each radioactive concrete core section. The same measurement scheme was used for these samples as was used for the UPV and microhardness measurements, i.e., intact matrix on the exposed surface was set at zero and the cores were marked in half inch intervals the length of the rad cores. Sample/data gaps represent locations occupied by coarse aggregate in the slabs sampled. Portions of the small pieces were ground to approximately -200 mesh in the x-ray laboratory and mounted on substrates for XRD analyses.

XRD data were collected on a Bruker D8 X-ray Diffractometer by step scanning over the 2 θ ranges of 5-70° with a step size of 0.02° and a dwell time of 1 second. Instrument parameters are listed in Table 2-1.

Input Parameter	Instrument Setting
Radiation Source	CuKa X-ray
Source Power	45 kV, 40 mA
Wavelength	1.5405982 Å
Goniometer	Bruker D8
Divergence Slit (auto)	NA
Divergence Soller Slit	None
Divergence Antiscatter (fixed)	2mm
Specimen Rotation	No
Diffracted Beam Antiscatter(auto)	NA
Diffracted Beam Anitscatter(fixed)	Open
Diffracted Beam Soller Slit	2°
Receiving Slit	0.6mm
Secondary Monochromator	Curved pyrolytic graphite
Detector Scatter Slit	2mm
Detector	NaI Scintillation
20 Range	5° - 70°
Step Interval	0.02° (20)
Fixed Counting Time	1 s/step

 Table 2-1. Instrument 1A Parameters for Bruker D8 X-Ray Diffractometer.

Search-match identification of all the phases was performed with Jade 2010 software from Materials Data Inc. and the PDF4 database from the International Centre of Diffraction Data. Additional pattern analysis was performed using portland cement data base and other information from the literature.²¹ Some phases identified by the JADE software were ruled out because their presence is highly unlikely in portland cement systems and in typical schist aggregate or quartz sand.

2.9 <u>Scanning Electron Microscopy (SEM)</u>

At SRNL, slabs were cut from the north wall core sections using Buehler Delta Orbital sectioning saw, equipped with a diamond abrasive blade and cooling water. The slabs were mounted in epoxy to facilitate grinding and polishing (starting with 600 grit silicon carbide grinding paper and finishing with 1 μ m diamond paste). The radioactively contaminated cores were cut into sub-samples about 51 x 89 mm (2 x 3.5 inches) so the sub-samples would fit into the SEM chamber (Figure 2.6). Aluminum foil boats were used as containers for the epoxy mounting and impregnation.



Figure 2.6. Epoxied and Polished Concrete Core Samples.

Two different scanning electron microscopes were used by SRNL ADS personnel to analyze the radioactive core sections. Carl Zeiss Microscopy LLC Sigma VP field emission scanning electron microscope (FESEM) with secondary electron, backscattered electron, and in lens secondary electron detectors was used to evaluate the microstructure of the radioactive sections of cores N-3-D, N-4-D, and N-5-C collected from the north wall of the H-Canyon Personnel Tunnel. The FESEM has an imaging capability up to 500,000X. This instrument has the variable pressure (VP) option which allows a variable pressure up to 133 Pascals of nitrogen gas to reduce or eliminate charging for uncoated samples. Energy dispersive spectroscopy (EDS) is performed using an Oxford Instruments X-Max 20 silicon drift detector to detect elements greater than atomic number 3 (Z > 3). EDS data and maps were analyzed using Oxford Instruments INCA 4.15 data analysis software. A conductive coating was not necessary because the variable pressure SEM setting was used and surface charging in the chamber atmosphere was minimal. Backscatter images and EDS data, including maps, were collected using an accelerating voltage of 30 kV for the electron beam.

The LEO S440 contained scanning electron microscope (CSEM), with an accelerating voltage up to 30 kV and capability of secondary electron imaging, backscatter electron imaging, and x-ray microanalysis was used to examine the radioactive sections of cores N1-D and N2-C. This instrument is contained in a radiological glovebox train. The CSEM includes an Oxford Instruments energy dispersive spectrometer (EDS) for detection of elements greater than atomic number 3 (Z > 3) and an Oxford Instruments wavelength dispersive x-ray spectrometer (WDS) for lower detection limits, resolution of EDS overlaps, and higher resolution x-ray collection. The Oxford Instruments INCA 4.15 software package allows for standardless semi-quantitative analysis, elemental mapping, and simultaneous EDS/WDS measurements. Samples were carbon coated to reduce charging. Secondary electron and backscatter images and EDS data, including maps, were taken using an accelerating voltage of 30 kV for the electron beam.

2.10 Soluble Ion Analysis

The reaction of nitric acid with the portland cement matrix phases was assumed to result in dissolution of calcium phases and formation of soluble nitrate salts/salt solution. Extraction of nitrate form sub-samples collected as a function of distance from the concrete surfaces exposed to the H-Canyon exhaust was performed on Cores N4-D and N5-C. Crushed matrix samples were leached in DI water. The sample to water ratio was 20x by weight. These slurries were tumbled continuously for approximately five days. At the end of the five days, the solids were separated from liquids through a 0.45 μ m filter. The filtered aqueous samples were submitted to SRNL Analytical Development Section (ADS) for ion chromatography (anion) and inductively coupled plasma emission spectroscopy (cation) analyses.

2.11 Core X-ray Imaging

X-ray computed tomography (XCT) is a nondestructive technique for visualizing interior features within solid objects. Digital XCT was performed on half of core N3-D (N3D12, N3D22) and 1/4 of a core N4-D (N4D11, N4D21). The samples are shown in Figure 2.7. The SRNL XCT 420 System operated with a tungsten anode at 300 kV. Each core was contained in a Nalgene jar during the scanning as shown in Figure 2.8. Computed tomography images were compiled from the x-ray data.



Figure 2.7. Core samples N4-D (top) and N3-D (bottom) submitted for digital radiography and x-ray computed tomography.



Figure 2.8. Digital radiography equipment set up and core N4-D.

3.0 Results of Contaminated North Wall Core Sections

3.1 <u>Radiological Screening of Contaminated North Wall Core Sections</u>

The radiological screening results are provided in Table 3-1. These results were used to identify radiological work control measures needed to perform the required analyses.

Table 3-1. Radiological screening results for cores sections exposed to the H-Canyon Exhaust.

Core ID	Preliminary Radiological Results								
N1-D	H-3 - 5.13E-04 μ Ci/g (exposed end) α - 507 dpm/g (internal) & 1860 dpm/g (exposed end) β - 3240 dpm/g (internal) & 8130 dpm/g (exposed end) γ - 944.04 dpm/g (internal) & 3233.85 dpm/g (exposed end) Gamma contributors include K-40, Cs-134, Cs-137, Eu-154, Pa-233, Np-237,								
	Am-241								
N2-C	H-3 - non-detect α - 135 dpm/g (internal) & 2220 dpm/g (exposed end) β - 1870 dpm/g (internal) & 5420 dpm/g (exposed end) γ - 382.64 dpm/g (internal) & 4495.47 dpm/g (exposed end) Gamma contributors include K-40, Cs-134, Cs-137, Eu-154, Bi-212, Bi-214,								
	Pa-233, Np-237, Am-241								
N3-D	H-3 - non-detect α - 124 dpm/g (internal) & 146 dpm/g (exposed end) β - 2210 dpm/g (internal) & 1630 dpm/g (exposed end) γ - 179.87 dpm/g (internal) & 1867.11 dpm/g (exposed end)								
	Gamma contributors include K-40, Cs-134, Cs-137, Pb-212, Am-241								
N4-D	H-3 - non-detect α - 148 dpm/g (internal) & 174 dpm/g (exposed end) β - 1280 dpm/g (internal) & 2260 dpm/g (exposed end) γ - 110.73 dpm/g (internal) & 1134.6 dpm/g (exposed end)								
	Gamma contributors include K-40, Cs-137, Pb-212, Am-241								
N5-C	H-3 - non- detect α - non-detect (internal) & 628 dpm/g (exposed end) β - 503 dpm/g (internal) & 1180 dpm/g (exposed end) γ - 186 dpm/g (internal) & 2548 dpm/g (exposed end)								
	Gamma contributors include K-40, Cs-134, Cs-137, Eu-154, Pa-233, Np-237, Am-241								
N6-D	H-3 – non-detect α - 430 dpm/g β - 11500 dpm/g γ - 408 dpm/g Gamma contributors include Cs-137								

3.2 Visual Examination

Samples were initially measured, photographed, examined for color and other macroscopic features (Table 3-2 and Table 3-3). During the initial examination, three of the cores were broken at or near the color discontinuity visible on the outer surface of the cores as the result of sub-sample collection using a hammer and chisel.

Sample	Date Received at	Initial	Core Diameter		Approximate Length	
ID	SRNL	Observations	(inches)	(<i>cm</i>)	(inches)	(<i>cm</i>)
N1-D	April 12, 2017 Retrieved from wall	Intact core with discoloration at	4	10	9	23
	4/10/17	exposed end				
	April 12, 2017	Intact core with		15	0	
N2-C	Retrieved from wall 4/10/17	discoloration at exposed end	6	15	9	23
	May 24, 2017	Intact core with	4	10	9	23
N3-D	Retrieved from wall 5/10/17	discoloration at exposed end				
N4-D	May 24, 2017	Intact core with	4	10	9	23
	Retrieved from wall 5/10/17	discoloration at exposed end				
	May 3, 2017	Intact core with	6	15	9	23
N5-C	Retrieved from wall 5/1/17	discoloration at exposed end				
N6-D	May 3, 2017	Many pieces Core was				
	Retrieved from wall 5/1/17	damaged during coring operations	4	10	unknown	

Table 3-2.	H-Canyon co	re sample receip	ot, initial o	observations,	and	planned	characterization.

Table 3-3. Summary of visual characterization of 221-H-PT3 north wall	l core sections C	or D.
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Sample ID	Description from Visual Examination*
N1-D	 Condition: 100 mm (4 inch) diameter core arrived intact Aggregate: Schist coarse aggregate (multicolor (brown, gray and pink 10R 7/4), quartz sand fine aggregate. Matrix: Variable color with sharp transition. Darker brown-gray color (10YR 6/2) extending from the exposed surface to about 63 to 89 mm (2¹/₂ to 3¹/₂ inches) into the wall. Beyond 89 mm (3¹/₂ inches) the matrix was lighter gray (2.5Y 7/1). The color transition line was irregular because it followed coarse aggregates. Other: When collecting samples for radiological analyses, core broke at the color transition. The concrete surface exposed in the Cross-over Tunnel appeared shiny or varnished (not friable or powdery). Coarse aggregates protruded from exposed surface about 19 to 25 mm (³/₄ to 1 inch) but were securely anchored in matrix.
	Honeywell Honeyw
	 Condition: 152 mm (6-inch) diameter core arrived intact. Irregular surfaces on the core and at the end of the core about 178 mm (7 inches) from the exposed surface were the result of coring technique. Aggregate: Schist coarse aggregate (multicolor, brown, gray and pink 10R 7/4), quartz sand fine aggregate. Matrix: Three color zones were observed as a function of distance from the exposed surface: darkest gray approximately 25 mm (1 inch) depth, lighter gray between 25 to 50 mm (1 to 2 inches). Other: Exposed surface appeared shiny or varnished (not friable or powdery). Coarse aggregate protruded from the exposed surface about 10 to 20 mm (½ to ¾ inches) but were securely anchored in matrix.
N2-C	Contraction of the second seco

* Colors were selected based on the Munsell Soil Color Charts.¹⁵
Table 3-3 (continued). Summary of visual characterization of 221-H-PT3 north wall core sections C or D.

Sample ID	Description from Visual Examination*										
	 Condition: 100 mm (4-inch) diameter core arrived intact. Aggregate: Schist coarse aggregate (multicolor (brown, gray and pink 10R 7/4), quartz sand fine aggregate. Matrix: Color change approximately 38 to 50 mm (1½ to 2 inches) from the exposed surface. Darker gray-yellow-brown color (10 YR 6/2) from exposed surface to a depth of approximately 38 to 50 mm into the wall. Remainder of the core was lighter gray and mottled (10YR 8/1 to 2.5Y 8/1 to 7/1). Other: Exposed surface appeared shiny/varnished (not friable or powdery). Coarse aggregates protruded from the exposed surface 20 to 25 mm (¾ to 1 inch) but were securely anchored in matrix. 										
N3-D	Rai-H-PT3-N Rai-H-PT3-N Rai-D Right House										
	 Condition: 100 mm (4-inch) diameter core arrived intact. Aggregate: Schist coarse aggregate (multicolor (brown, gray and pink 10R 7/4), quartz sand fine aggregate. Matrix: Color change approximately 38 to 50 mm (1½ to 2 inches) from exposed surface. Darker gray (10Y 7/1 or 10YR 6/1) transitioning to lighter gray (2.5Y 8/2 or 7/2). Transition is irregular. Other: Exposed surface appears shiny/varnished (not friable or powdery). Coarse aggregates protruded from exposed surface up to about 19 to 25 mm (¾ to 1 inch) but were securely anchored in matrix. 										
N4-D	William Alexandre Alexandr										

* Colors were selected based on the Munsell Soil Color Charts.¹⁵

Table 3-3 (continued). Summary of visual characterization of 221-H-PT3 north wall core sections C or D.

Sample ID	Description from Visual Examination*
	 Condition: 150 mm (6-inch) diameter core arrived intact. Aggregate: Schist coarse aggregate (multicolor (brown, gray and pink 10R 7/4), quartz sand fine aggregate. Matrix: Color change about 50 mm (2 inches) from exhaust tunnel surface. Darker gray (10YR 6/2 or 7/2) transitioning to lighter gray (2.5Y 8/2 or 7/2). Transition is irregular. Other: Uneven coring produced a pronounced lip on the surface of the core at approximately 178 mm (7 inches) from exposed surface. Exposed surface appears shiny/varnished (not friable or powdery). Coarse aggregates protruded from exposed surface up to about 19 to 25 mm (¾ to 1 inch) but were securely anchored in matrix.
N5-C	2'21#- PT3-
	 Condition: 100 mm (4-inch) diameter core arrived in pieces. One piece of core was approximately 25 mm (1 inch) thick, but the location with respect to the exposed surface could not be determined. Aggregate: Schist coarse aggregate (multicolor (brown, gray and pink 10R 7/4), quartz sand fine aggregate Matrix: Color 10 YR 8/1 Other: Limited characterization was performed due to the condition of core upon arrival.
N6-D	

* Colors were selected based on the Munsell Soil Color Charts.¹⁵

3.3 Non-Destructive Matrix Characterization

SRNL performed the alkalinity dye test (phenolphthalein color indicator tests) at a field location in H-Area on cores N3-D and N4-D shortly after each core was removed from the wall. Discrete carbonated surface layers were not detected on core surfaces exposed to the CAEX environment nor the 221-H Section 3 Personnel Tunnel environment. Given the high porosity of the north and south wall concretes, the presence of partially carbonated regions was expected rather than a discrete carbonated surface layer that is more typical of higher strength, lower porosity concrete. Consequently, the chemical environment in the concrete is providing adequate alkalinity to maintain rebar passivation. Images of the alkalinity dye tests are provided in Appendix A.

The UPV results for the radiologically contaminated north wall cores exposed to the tunnel exhaust air are presented in Table 3-4. Measurements were made at 12.7 mm (1/2 inch) intervals along the long axes of the cores for the first 102 mm (4 inches) and then at 25 mm (1 inch) intervals for the remainder of the core section. The velocities ranged between 3337 m/s and 4724 m/s (10948 ft./s and 15500 ft./s). The data are presented in Appendix B. The highest velocities were measured within 76 mm (3 inches) of the core surfaces exposed to the canyon exhaust. The velocities decreased slightly as a function of increasing distance from the exposed surface. Statistical analysis of the UPV data is discussed in Section 6.2.

	Distance from Exposed Surface (inches)												
(Inches)	0.5	1	1.5	2	2.5	3	3.5	4	5	6	7	8	
(mm)	1.3	6.4	12.7	19.1	25.4	31.8	38.1	44.5	50.8	76.2	101.6	127.0	
Core Location						UPV	(feet/s)						
N1-D 0-180°	14787	15317	13029	12757	13565	13029	13462	13593	14273	13684	13640	N/A	
N1-D 90-270°	15171	15000	13013	12757	12851	13234	13463	13946	13405	12540	12188	N/A	
N2-C 0-180°	14351	14264	12708	13915	13874	13673	14368	14368	14545	12317	12009	N/A	
N2-C 90-270°	14178	14208	14051	13724	11427	13764	14093	13112	11454	10948	N/A	N/A	
N3-D 0-180°	N/A	15423	15122	14286	12302	12016	11654	11742	12450	12109	12109	N/A	
N3-D 90-270°	14486	14976	14692	13091	13537	12863	13305	12863	12971	N/A	N/A	N/A	
N4-D 0-180°	14286	14352	13839	14091	15271	15500	13478	12157	12653	12863	N/A	N/A	
N4-D 90-270°	15196	15347	14486	13478	12757	12500	12253	12500	12450	12450	N/A	N/A	
N5-C 0-180°	14937	14937	14390	13111	13563	13761	13524	13333	13447	11859	11792	12412	
N5-C 90-270°	14658	14347	14132	13296	12986	13111	13184	13148	12421	12896	12487	12487	
Number of Samples	9	10	10	10	10	10	10	10	10	9	6	2	
Mean	14817	14672	13946	13451	13345	13278	13213	13076	13007	12450	12407	12371	
Standard Deviation	377	481	798	541	1024	942	797	801	932	760	662	53	
Mean Absolute Difference to Mean	312	419	639	448	749	664	549	609	728	533	462	38	
Mean Absolute Difference to Median	310	396	618	448	749	641	507	601	721	528	401	38	

 Table 3-4. UPV measurements as a function of circumference and distance from exposed surface.

3.4 Matrix Microhardness

Core sections from radiologically contaminated cores N1-D through N5-C were sectioned and polished for microhardness measurements. Microhardness indentations were performed on select samples of the concrete core sections as a function of distance from the exposed surface. Samples were prepared by sectioning as discussed in Section 2.2. A grid was transcribed to the sample surface to enable the determination of the distance of each indent from the exposed surface (Figure 3.1). Core N1-D could not be measured due to the low surface quality of the polished specimens and large amounts matrix paste "pullout" which caused an uneven surface of the polished sections. Indentations of the cores N2-D through N5-C were measured periodically as a function of depth and the results are shown in Table 3-5 and plotted in Figure 3.2 through Figure 3.5. From these data, no trends in matrix hardness as a function of distance from the exposed surface were apparent. Some observations are listed below:

- Large scatter in measured hardness values.
- Slight increase in hardness was observed in cores N3-D and N5-C from 0 to 32 mm (1.25 inches) from the exposed surface.
- No increase in hardness was noted in cores N2-C and N4-D over the same region.
- The overall average of microhardness is 27.6 for the north wall cores, slightly higher than the sample from the south wall of the Personnel Tunnel (HV = 22.6).



Figure 3.1. A grid transcribed to the sample surface of Core N5-C to enable the ability to track the distance from the exposed surface.

	Distance from Exposed Surface												
(inches)	0.05	0.25	0.5	0.75	1	1.25	1.5	1.75	2	3	4	5	6
<i>(mm)</i>	1.3	6.4	12.7	19.1	25.4	31.8	38.1	44.5	50.8	76.2	101.6	127.0	152.4
Core						Ha	ardness	5 (HV)					
		24.1	23.3	21.4	16.5	22.2	31.6		37.7	21.1	18.4		
		15.4	29.3	19.6	18.8	20.4	27.1		24.0	23.8	21.8		
		31.1	54.4	24.7	29.0	16.3	17.9		25.4	22.4	25.6		
		23.6	15.8	18.4	19.0	16.5	32.4		36.1	25.1	15.6		
N2-C		26.5	20.1	14.1	17.3	23.9	26.4		34.3	39.6	19.9		
		23.6	21.7	27.5	12.6	15.4	17.9		25.0	28.9	15.5		
			18.1	18.1	16.1	15.2	14.5		24.1	32.5	11.9		
							16.9		26.5				
									24.5				
		27.0	45.9	25.2	20.9	32.0	23.3	42.6	25.4	16.4	24.3	22.8	
		35.7	34.8	32.2	43.2	54.1	30.3	15.1	31.9	20.2	28.3	16.3	
		49.2	48.5	22.0	49.3	42.7	47.6	19.6	15.7	16.1	19.3	13.6	
N/2 D		25.0	34.9	25.6	21.0	38.6		36.2	13.0	14.3	25.2	14.0	
No-D		28.1	42.5	36.8	49.6	58.5		15.9	18.6	15.2	16.9	17.4	
		22.3	17.4	19.8	44.5	25.1		17.2	22.0		30.6	14.8	
		27.0	17.5	17.3	27.3	30.6		21.7	28.7				
				27.0	47.9			23.8					
								35.0					
			45.0	29.3	71.1	47.9	22.5	44.2	29.9	20.7	30.3	16.1	42.2
			19.6	36.9	27.3	25.5	20.3	40.0	31.8	29.1	28.8	18.8	26.2
			21.2	30.4	39.3	21.9	34.3	45.1		46.7	42.0	29.6	18.8
N4-D			16.8	27.2	30.5	24.9	28.6	32.3		27.6	30.2	21.7	32.6
			44.1	26.1	30.6	26.4		29.2		21.1	26.4	19.3	30.6
			32.9	22.4	33.6	34.5				20.4	30.5	29.6	18.4
			38.6	23.8	17.8	23.3				15.9	45.8		21.5
	21.9	23.3	36.6	26.3	49.6	40.6	44.7		27.9	28.6	23.8		
	17.6	48.8	36.3	37.8	41.5	60.7	30.7		22.7	20.4	31.8		
	21.9	18.5	33.1	26.0	34.4	28.0	29.9		17.6	39.5	25.2		
	18.4	11.3	27.2	18.2	23.8	48.1	20.5		20.4	34.7	18.7		
	16.4	16.2	25.7	24.9	33.4	44.9	40.4		21.4	23.7	24.5		
N5-C	24.4	25.1	14.4	29.6	40.6	57.7	23.2		29.8	26.2	15.6		
	26.7	22.3	25.5	36.6	53.2	31.9	27.5		28.1	32.0	15.7		
	22.4	23.1	25.4		47.3								
	16.9	17.0			50.0								
	22.1	28.4			31.7								
	18.5	18.6											
		23.1											

Table 3-5. Microhardness measurements for the north wall core sections exposed to exhaust tunnel environment.

-- Indicates no data collected. Core N1-C was not evaluated.

		Distance from Exposed Surface											
(inches)	0.05	0.25	0.5	0.75	1	1.25	1.5	1.75	2	3	4	5	6
(<i>mm</i>)	1.3	6.4	12.7	19.1	25.4	31.8	38.1	44.5	50.8	76.2	101.6	127.0	152.4
	Hardness (HV)												
Number of Samples	11	25	29	29	32	28	22	14	25	26	27	12	7
Mean	20.7	25.4	29.9	25.7	34.0	33.1	27.7	29.9	25.7	25.5	24.5	19.5	27.2
Standard Deviation	3.3	8.8	11.2	6.3	14.0	14.0	8.8	11.0	6.2	8.3	8.0	5.5	8.6
Standard Error Mean	2.95	1.96	1.82	1.82	1.73	1.85	2.08	2.61	1.96	1.92	1.88	1.92	3.69
Lower 95 % Mean	14.9	21.5	26.3	22.1	30.6	29.5	23.6	24.7	21.9	21.7	20.8	13.9	19.9
Upper 95 % Mean	26.5	29.2	33.5	29.3	37.4	36.8	31.8	35.0	29.6	29.2	28.2	25.1	34.5

 Table 3-5 (continued). Microhardness measurements for the north wall core sections exposed to exhaust tunnel environment.



Figure 3.2. Microhardness of cement paste for core N2-C as a function of distance from surface exposed to canyon exhaust.



Figure 3.3. Microhardness of cement paste for core N3-D as a function of distance from surface exposed to canyon exhaust.



Figure 3.4. Microhardness of cement paste for core N-4-D as a function of distance from surface exposed to canyon exhaust. Note: Data point at 1 inch is not shown due to out of range.



Figure 3.5. Microhardness of cement paste for core N5-C as a function of distance from surface exposed to canyon exhaust.

3.5 Matrix Mineralogy

Matrix samples were collected as a function of distance from the surface exposed to the canyon exhaust. Results for hydrated phases which bind the sand and gravel aggregates together are presented in Table 3-6. XRD powder patterns are provided in Appendix C.

Poorly ordered calcium silicate hydrate, commonly referred to as C-S-H gel, and crystalline phases typical of hydrated portland cement: hydrogarnet, ettringite, and a phase identified by the JADE software as hydrocalumite (which is a hydrated calcium aluminoferrite monosulfate hydrate) were identified in samples collected at the exposed surfaces and throughout the entire radioactive core sections.

Portlandite, Ca(OH)₂, was absent in patterns for sub-samples collected at the exposed surface and to a depth of approximately 76 mm (3 inches) from the exposed surface. Portlandite was detected in core N1-D at 152 mm (6 inches) (no samples between 76 and 152 mm), in core N2-C at 178 mm (7 inches) (no samples between 50 and 178 mm), in core N3-D between 76 and 102 mm (3 and 4 inches), in core N4-D at 152 mm, and in core N5-C at 127 mm (5 inches) (no samples between 76 and 127 mm).

Calcite, assumed to be an alteration product, was detected in most of the sub-samples from the surface to a depth of 229 mm (9 inches), i.e., the length of the radiologically contaminated core sections. The ubiquitous presence of calcite is suspicious but not unreasonable given the high porosity of the north wall concrete. However, another possible explanation may be that calcite and the calcium carbonate polymorphs aragonite and vaterite are impurities associated with the aggregates.

Phases other than hydrated matrix phases were detected in the x-ray powder patterns. These phases were grouped according to their origin and include:

Unreacted cement clinker phases which is commonly found in aged hydrated portland cement concrete.

- Larnite
- Brownmillerite

Anhydrous phases:

- Carbonated phases that were assumed to be formed by reaction of CO₂ and water^a and the hydrated matrix phases.^b
 - Three polymorphs of CaCO₃ were identified in the patterns (calcite, aragonite, and vaterite) in addition to a carbonated calcium aluminate hydrate.
- Quartz (sand fine aggregate).
- Quartz and albite (schist coarse aggregate).

Unexpected phases assumed to be from poorly washed aggregates.

- Illite and kaolilnite clay: assumed to be weathered schist phases, impurities, or fines associated with the aggregate.
- Other phases which were identified in numerous patterns were cancrinite, hydroxycancrinite, and chantalite. These phases do not form in hydrated portland cement. A review of the literature indicated that they are associated with weathered granite, schist, and other igneous and metamorphic rocks and are reported to be constituents of "red mud".¹⁶
- Phases that could not be rationalized. These XRD peaks were reassigned or assumed to be misidentified.
 - Peaks identified as ye'elimite matched those for a calcium aluminate carbonate hydrate phase, Ca₂Al(OH)₆[0.5CO₃·2.5H₂O]
 - Hilbrandite forms in hydrothermally cured portland cements
 - Dmitryivanovite has only been detected in meteorites.

^a $CO_2 + H_2O = H_2CO_3$ (carbonic acid) = HCO_3 (bicarbonate ion) + $H^+ = CO_3^{2-}$ (carbonate ion) + 2 H_2O

^b Calcite is reported in "red mud" and therefore weathered schist or dirty aggregate cannot be ruled out as a source of some of the calcite. Aragonite was observed near the exposed core surface and vaterite is a metastable polymorph that had limited presence in the samples.

Table 3-6. Summary of concrete matrix phases identified by x-ray diffraction in the radioactive core sections from the north wall of the H-Canyon Personnel Tunnel (surface to 2.5 to 3 inches).

	Surface	0.25 to 0.5 inches	0.5 to 0.75 inches	0.75 to 1 inch	1 to 1.5 inches	1.5 to 1.75 inches	2 inches	2.5 to 3 inches
N1-D	C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)	No sample	C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)		C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)	C-S-H* Hydrogarnet (Grossular) Ettringite)	No sample
N2-C	Calcite C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)	C-S-H * Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm) Caleite	Calcite C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)		 C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)	Calcite C-S-H* Hydrogarnet (Grossular) Ettringite		No sample
N3-D	Calcite Surface to 0.25 inches C-S-H* Hydrogarnet (Grossular) Hydrocalumite (AFm) Calcite AFM phase	No sample	C-S-H* Hydrogarnet (Grossular) Hydrocalumite (AFm) Calcite	No sample	C-S-H* Hydrogarnet (Grossular) Hydrocalumite (AFm) Calcite Vaterite	1.5 to 2 inches C-S-H * Hydrogarnet (Grossular) Hydrocalumite (AFm) Calcite	2 to 2.5 inches C-S-H * Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm) Portlandite Calcite Vaterite	C-S-H * Hydrogarnet (Grossular) Ettringite
N4-D	Ca2Al(OH) ₆ [0.5CO ₃ · 2.5H ₂ O] C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm) Calcite	C-S-H* Hydrogarnet (Grossular) Hydrocalumite (AFm) Calcite	No sample	C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm) Calcite	C-S-H* Hydrogarnet (Grossular) Ettringite AFm (Calcium aluminate monosulfate) Calcite	No sample	C-S-H* Hydrogarnet (Grossular) Hydrocalumite (AFm) Calcite	Vaterite C-S-H * Monosulfoaluminate Ettringite Calcite Vaterite
N5-C	C-S-H* Hydrogarnet (Grossular) Hydrocalumite (AFm)	C-S-H* Hydrogarnet (Grossular) Hydrocalumite (AFm)	C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)	C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)	C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)	C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)	C-S-H* Hydrogarnet (Grossular) Ettringite Hydrocalumite (AFm)	C-S-H * Hydrogarnet (Grossular)
	Calcite	Calcite	Calcite	Calcite	Calcite			$(Ca_2AI(OH)_6[0.5CO_3 \cdot 2.5H_2O])$

 Calcite
 Calcite
 Calcite
 Calcite
 Calcite
 -- (Ca2AI(OH)6[0.5CO3·2.5H2O])

 *C-S-H, calcitum silicate hydrate, is the primary binding phase in the matrix and has a disordered crystal structure (short range order) and is indicated on x-ray diffraction patterns between approximately 20° and 40° 2-Theta as a very broad peak (rise in background). Red text indicates alteration and --- indicates alteration product not detected
 -- (Ca2AI(OH)6[0.5CO3·2.5H2O])

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	4 inches	5 inches	6 inches	7 inches	8 inch	9 inches
N1-D	No sample	No sample	C-S-H* Hydrogarnet (Grossular) Ettringite Portlandite Calcite	No sample	No sample	No sample
N2-C	No sample	No sample	No sample	C-S-H* Hydrogarnet (Grossular) Ettringite Portlandite Calcite	No sample	No sample
N3-D	3 to 4 inches C-S-H * Hydrogarnet (Grossular) Ettringite AFm (Calcium aluminate monosulfate) Portlandite Gypsum Calcite Vaterite	C-S-H* Hydrogarnet (Grossular) Portlandite Calcite Vaterite	C-S-H* Hydrogarnet (Grossular) Portlandite Calcite Vaterite	C-S-H* Hydrogarnet (Grossular) AFm phase (Ca2Al(OH)6[0.5CO3·2.5H2O]) Calcite Vaterite	No sample	No sample
N4-D	No sample	C-S-H* Hydrogarnet (Grossular) Calcite	C-S-H* Hydrogarnet (Grossular) Portlandinte Calcite	C-S-H* Hydrogarnet (Grossular) Portlandinte Calcite Vaterite	No sample	No sample
N5-C	No sample	C-S-H* Hydrogarnet (Grossular) Ettringite AFm (Calcium aluminate monosulfate) Portlandite	C-S-H* Hydrogarnet (Grossular) Ettringite AFm (Calcium aluminate monosulfate) Portlandite	C-S-H* Hydrogarnet (Grossular) Ettringite AFm (Calcium aluminate monosulfate) Portlandite	C-S-H* Hydrogarnet (Grossular) Ettringite AFm (Calcium aluminate monosulfate) Portlandite	C-S-H* Hydrogarnet (Grossular) Ettringite AFm (Calcium aluminate monosulfate) Portlandite
		Calcite	Calcite	Calcite	Calcite	Calcite

Table 3-6 (continued). Summary of concrete matrix phases identified by x-ray diffraction in the radioactive core sections from the north wall of the H-Canyon Personnel Tunnel (4 inches to 9 inches).

 Calcite
 Calcite
 Calcite
 Calcite
 Calcite

 *C-S-H, calcium silicate hydrate, is the primary binding phase in the matrix and has a disordered crystal structure (short range order) and is indicated on x-ray diffraction patterns between approximately 20° and 40° 2-Theta as a very broad peak (rise in background). Red text indicates alteration and --- indicates alteration tot detected

$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	JCPDF Pattern Number	Phase Name	Composition	Cement Notation		
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Hydrated Portland Cement Phases	·				
	Broad peak between about 20° and 40° 2-Theta	Poorly crystalline calcium silicate hydrate	Calcium silicate hydrate	C-S-H		
	00-004-0733	Portlandite	Ca(OH) ₂	СН		
	00-045-1447	Grossular (hydrogarnet)	Ca ₃ Al ₂ (SiO ₄)1.25· (OH) ₇	C ₃ AH ₆		
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	00-041-1451	Ettringite	Ca ₆ Al ₂ (SO ₄) ₃ (OH) ₁₂ ·26H ₂ O	C ₆ A S H ₃₂ (AFt Phase)		
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	00-045-0158	Calcium aluminate monosulfate hydrate	$Ca_4Al_2SO_{10} \cdot 12H_2O$	C_4ASH_{12}		
tetracalcium aluminate monosulfate hydrate tetracalcium aluminate monosulfate hydrate Residual Unhydrated Portland Cement Phases Casch Ca	00-042-0558 Highway Research Boar SP 12700-045-0158	Hydrocalumite identified with x-ray diffraction phase analysis software. More likely solid solution between tetracalcium aluminate hydrate and	$Ca_2AIOH)_6CI \cdot 2H_2O$ $Ca_2AI(OH)_6[OH \cdot 2.5 \text{ to } 3 \text{ and } H_2O]$ $Ca_2AI(OH)_6[0.5(SO_4) \cdot 3H_2O]$	C_4AH_{13} and C_4ASH_{12} (AFm phases)		
Residual Unhydrated Portland Cement Phases 04-008-1786 Larnite Ca ₂ SiO ₄ C ₂ S 00-030-0226 Brownmillerite Ca ₂ (Al,Fe ⁻³) ₂ O ₅ C ₂ (A,F) Alteration Phases (all carbonated) 00-050-0586 Calcite CaCO ₃ CC 00-005-0586 Calcite CaCO ₃ CC 00-005-0583 Vaterite CaCO ₃ CC 00-005-0483 Vaterite CaCO ₃ CC 00-005-0453 Aragonite CaCO ₃ CC Highway Research Boar SP 127 AFm phase (carbonated) Ca2Al(OH) ₆ [0.5CO ₃ · 2.5H ₂ O] C ₄ ACH ₁₁ Aggregate Phases and Clays 00-046-1045 Quartz SiO2 00-044-1480 Albite (Na,Ca)Al(Si,Al) ₅ O ₈ 00-026-091 00-026-091 Illite (Na,Ca)Al(Si,Al) ₅ O ₈ 00-025-091 00-025-0911 Illite (Na,Ca)Al(Si,Al) ₅ O ₈ 00-045-10{(OH) ₂ (H ₂ O)] 00-025-0911 Illite (Na,Ca)Al(Si,Al) ₅ O ₈ 00-045-10{(OH) ₂ (H ₂ O)] 00-025-0911 Illite (Na,Ca)Al(Si ₃ O ₂ O ₃ (OH) ₂ : 2H ₂ O) 00-045-1457 Hydroxycancrinite Na ₈ Al ₃ Si ₈ (O ₃ O ₃ O ₂) ₂ : 2H ₂ O 00-048-145		tetracalcium aluminate monosulfate hydrate				
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Residual Unhydrated Portland Cement Phases	<u> </u> §	1	1		
00-030-0226Brownmillerite $Ca_2(A1,Fe^{+3})_2O_5$ $C_2(A,F)$ Alteration Phases (all carbonated) $Calcite$ $CaCO_3$ CC 00-005-0586CalciteCaCO_3CC00-005-0586Vaterite $CaCO_3$ CC00-005-0483Vaterite $CaCO_3$ CC00-005-0433Aragonite $CaCO_3$ CC11 ghway Research Boar SP 127AFm phase (carbonated) $Ca_2Al(OH)_6[0.5CO_3 \cdot 2.5H_2O]$ C_4ACH_{11} Aggregate Phases and Clays00-046-1045QuartzSiO2 OC_4ACH_{11} 00-046-1045QuartzSiO2 OC_4ACH_{11} OD-046-1045QuartzSiO2 OC_4ACH_{11} OD-046-1045QuartzSiO2 OC_4ACH_{11} OD-045-1480Albite $(Na,Ca)Al(Si,Al)_3O_8$ OC_4ACH_{11} OD-045-1480Albite $(Na,Ca)Al(Si,Al)_3O_8$ OC_4ACH_{11} OD-045-1480Albite $(Na,Ca)Al(Si,Ca)_2O_4(OH)_2(H_2O)]$ OD-045-1457Hydroxycancrinite $Na_8Al_6Si_6O_2A(OH)_4$ OD-045-1457Hydroxycancrinite $Na_8Al_6Si_6O_2A(OH)_2(2H_2O)$ OD-045-1457OL-045-1457OD-045-1457OD-045-1457OL-045-1457OD-045-1457OL-045-1457OD-045-1457OL-045-140OD-029-1410Chanalite<	04-008-1786	Larnite	Ca ₂ SiO ₄	C ₂ S		
Alteration Phases (all carbonated)00-005-0586CalciteCaCO3CC00-005-0586VateriteCaCO3CC00-005-0483VateriteCaCO3CC00-005-0453AragoniteCaCO3CCHighway Research Boar SP 127AFm phase (carbonated)Ca2Al(OH) ₆ [0.5CO3·2.5H ₂ O]C ₄ ACH ₁₁ Aggregate Phases and Clays00-046-1045QuartzSiO200-004-104500-041-1480Albite(Na,Ca)Al(Si,Al) ₂ O800-041-004500-045-0911Illite(K,HO ₃)Al ₂ Si ₃ AlO·10[(OH) ₂ (H ₂ O)]00-045-004100-045-1470KaoliniteAl ₂ Si ₂ O ₆ (OH) ₄ 100-048-1862CancriniteNases reported to be found in "red mud" ¹⁶ O0-048-1862CancriniteNa ₈ Al ₆ Si ₆ (O(A) ₂) ₂ ·2H ₂ OO0-048-1862CancriniteNa ₈ cathSi ₆ O ₂₄ (OH) ₂ ·2H ₂ OO0-045-1457HydroxycancriniteNa ₈ Al ₆ Si ₆ O ₂₄ (OH) ₂ ·2H ₂ OO0-048-1862CancriniteNa ₆ CaAl ₆ Si ₆ (CO3)O ₂₄ ·2H ₂ OO0-045-1457HydroxycancriniteNa ₆ CaAl ₆ Si ₆ (CO3)O ₂₄ ·2H ₂ OO0-048-1862CancriniteO0-042-04ODOD-042-04ODODOD <th <="" colspan="2" td=""><td>00-030-0226</td><td>Brownmillerite</td><td>$Ca_2(Al,Fe^{+3})_2O_5$</td><td>$C_2(A,F)$</td></th>	<td>00-030-0226</td> <td>Brownmillerite</td> <td>$Ca_2(Al,Fe^{+3})_2O_5$</td> <td>$C_2(A,F)$</td>		00-030-0226	Brownmillerite	$Ca_2(Al,Fe^{+3})_2O_5$	$C_2(A,F)$
00-005-0586CalciteCaCO3CC00-005-0483VateriteCaCO3CC00-005-0453AragoniteCaCO3CC11 ghway Research Boar SP 127AFm phase (carbonated)Ca2Al(OH)_6[0.5CO3·2.5H_2O]C_4ACH_1Aggregate Phases and Clays00-046-1045QuartzSiO2CaCO300-046-1045QuartzSiO200-046-1045QuartzSiO200-046-1045QuartzSiO200-046-1045QuartzSiO200-046-1045QuartzSiO200-046-1045QuartzSiO200-046-1045QuartzSiO2Odu (n., Ca)Al(Si,Al)_3O8On-046-1045QuartzSiO2Odu (n., Ca)Al(Si,Al)_3O8On-046-1045QuartzSiO2Odu (n., Ca)Al(Si,Al)_3O8On-046-1045Phases reported to be found in "red mud" ¹⁶ Odu (n., Ca)Al(Si,Al)_3O8On-045-1457HydroxycancriniteNagAcaAleSia(CO3)O24·2H2OOn-048-1462CancriniteNagCaAleSia(CO3)O24·2H2OOn-0412-141Phases with questionable identification	Alteration Phases (all carbonated)					
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	00-005-0586	Calcite	CaCO ₃	CC		
00-005-0453AragoniteCaCO3CCHighway Research Boar SP 127AFm phase (carbonated) $Ca_2AI(OH)_6[0.5CO_3 \cdot 2.5H_2O]$ C_4ACH_{11} Aggregate Phases and Clays 00-046-1045QuartzSiO200-041-1480Albite $(Na,Ca)AI(Si,AI)_3O_8$ 100-026-0911Illite $(K,HO_3)AI_2Si_3AIO \cdot 10[(OH)_2(H_2O)]$ 100-058-2001Kaolinite $AI_2Si_2O_6(OH)_4$ 1 Phases reported to be found in "red mud" 00-045-1457U HydroxycancriniteNagkaIs/Si_6O_2(OH)_2 · 2H_2O00-048-1862CancriniteNagkaCaAIs/Si_6(CO_3)O_24 · 2H_2OO-048-1862CancriniteNagkaSwith questionable identification00-061-0248Dmitryivanovite found in meteoriteCaAI(OH)/0 SCO2 · 2 SH-QIFound in hydrated y, high aluminate cemer	00-060-0483	Vaterite	CaCO ₃	CC		
Highway Research Boar SP 127 AFm phase (carbonated) Ca ₂ Al(OH) ₆ [0.5CO ₃ ·2.5H ₂ O] C ₄ ACH ₁₁ Aggregate Phases and Clays O	00-005-0453	Aragonite	CaCO ₃	CC		
Aggregate Phases and Clays $00-046-1045$ QuartzSiO2 $00-041-1480$ Albite $(Na_{a}Ca)Al(Si,Al)_{3}O_{8}$ $00-026-0911$ Illite $(K,HO_{3})Al_{2}Si_{3}AlO-10[(OH)_{2}(H_{2}O)]$ $00-058-2001$ Kaolinite $Al_{2}Si_{2}O_{6}(OH)_{4}$ Phases reported to be found in "red mud" ¹⁶ 00-045-1457HydroxycancriniteNa ₈ Al ₆ Si ₆ O ₂₄ (OH) ₂ · 2H ₂ O00-048-1862CancriniteNa ₆ CaAl ₆ Si ₆ (CO ₃)O ₂₄ · 2H ₂ OOu-048-1862CancriniteNa ₆ CaAl ₆ Si ₆ (CO ₃)O ₂₄ · 2H ₂ OOu-048-1862CancriniteNa ₆ CaAl ₆ Si ₆ (CO ₃)O ₂₄ · 2H ₂ OOu-048-1862CancriniteNa ₆ CaAl ₂ Si ₆ (OH) ₄ Phases with questionable identificationOU-045-1457Mitryivanovite found in meteoriteCaAl ₂ O ₄ (OH) ₄ CaAl ₂ Si ₀ 4(OH) ₄	Highway Research Boar SP 127	AFm phase (carbonated)	$Ca_2Al(OH)_6[0.5CO_3 \cdot 2.5H_2O]$	C_4ACH_{11}		
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Aggregate Phases and Clays					
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	00-046-1045	Quartz	SiO2			
00-026-0911 Illite (K,HO ₃)Al ₂ Si ₃ AlO·10[(OH) ₂ (H ₂ O)] 00-058-2001 Kaolinite Al ₂ Si ₂ O ₆ (OH) ₄ Phases reported to be found in "red mud" ¹⁶ 00-045-1457 Hydroxycancrinite Na ₈ Al ₆ Si ₆ O ₂₄ (OH) ₂ ·2H ₂ O 00-048-1862 Cancrinite Na ₆ CaAl ₆ Si ₆ (CO ₃)O ₂₄ ·2H ₂ O 00-029-1410 Chantalite CaAl2SiO4(OH)4 Phases with questionable identification 00-061-0248 Dmitryivanovite found in meteorite CaAl ₂ O ₄ 00-033-0256 Ye'elimite Ca ₂ Al(OH) ₆ [0 5CO ₂ ·2 5H ₂ O] Found in hydrated v. high aluminate cemer	00-041-1480	Albite	(Na,Ca)Al(Si,Al) ₃ O ₈			
00-058-2001 Kaolinite Al ₂ Si ₂ O ₆ (OH) ₄ Phases reported to be found in "red mud" ¹⁶ 00-045-1457 Hydroxycancrinite Na ₈ Al ₆ Si ₆ O ₂₄ (OH) ₂ · 2H ₂ O 00-048-1862 Cancrinite Na ₆ CaAl ₆ Si ₆ (CO ₃)O ₂₄ · 2H ₂ O 00-029-1410 Chantalite CaAl2SiO4(OH)4 Phases with questionable identification 00-061-0248 Dmitryivanovite found in meteorite CaAl ₂ O ₄ 00-033-0256 Ye'elimite Ca>l(OH) ₆ [0 5CO ₃ · 2 5H ₂ O] Found in hydrated y high aluminate cemer	00-026-0911	Illite	$(K,HO_3)Al_2Si_3AlO\cdot 10[(OH)_2(H_2O)]$			
Phases reported to be found in "red mud" ¹⁶ $00-045-1457$ HydroxycancriniteNa ₈ Al ₆ Si ₆ O ₂₄ (OH) ₂ · 2H ₂ O $00-048-1862$ CancriniteNa ₆ CaAl ₆ Si ₆ (CO ₃)O ₂₄ · 2H ₂ O $00-029-1410$ ChantaliteCaAl2SiO4(OH)4Phases with questionable identification $00-061-0248$ Dmitryivanovite found in meteoriteCaAl ₂ O ₄ $00-033-0256$ Ye'elimiteCa2Al(OH) ₆ [0 5CO ₃ ·2 5H ₂ O]Found in hydrated y high aluminate center	00-058-2001	Kaolinite	$Al_2Si_2O_6(OH)_4$			
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		Phases reported to be for	und in "red mud" ¹⁶			
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	00-045-1457	Hydroxycancrinite	$Na_8Al_6Si_6O_{24}(OH)_2 \cdot 2H_2O$			
00-029-1410 Chantalite CaAl2SiO4(OH)4 Phases with questionable identification One-optimize CaAl2O4 00-061-0248 Dmitryivanovite found in meteorite CaAl2O4 00-033-0256 Ye'elimite CaAl2O10H)c[0 5CO3: 2 5H2O] Found in hydrated y, high aluminate center	00-048-1862	Cancrinite	Na ₆ CaAl ₆ Si ₆ (CO ₃)O ₂₄ ·2H ₂ O			
Phases with questionable identification 00-061-0248 Dmitryivanovite found in meteorite CaAl ₂ O ₄ 00-033-0256 Ye'elimite Ca ₂ Al(OH) ₆ [0 5CO ₃ ·2 5H ₂ O] Found in hydrated y high aluminate center	00-029-1410	Chantalite	CaAl2SiO4(OH)4			
00-061-0248Dmitryivanovite found in meteoriteCaAl2O400-033-0256Ye'elimiteCa2Al(OH)cl0 5CO32 5H2O1Found in hydrated y high aluminate ceme	Phases with questionable identification					
00-033-0256 Ye'elimite Ca2Al(OH)el0 5CO3: 2 5H2Ol Found in hydrated y high aluminate cent	00-061-0248	Dmitryivanovite found in meteorite	CaAl ₂ O ₄			
	00-033-0256	Ye'elimite	Ca ₂ Al(OH) ₆ [0.5CO ₃ ·2.5H ₂ O]	Found in hydrated v. high aluminate cement		

Table 3-7. Mineral names and chemical formulas for all phases identified in diffraction patterns of radioactive core sections from the north wall of the H-Canyon Personnel Tunnel.

3.6 Matrix Leachate Analyses

Matrix samples of two radioactive cores, N4-D and N5-C, were collected as a function of distance from the surface exposed to the canyon exhaust. These samples were crushed and leached in DI water as described in Section 2.10. The matrix to leachate mass was 1:20 for all samples. The leachates were analyzed for anions, specifically nitrate, NO_3^- , and selected elements, specifically Ca, K, and Na. Nitrate salts are the reaction products between nitric acid and alkaline phases, such as those present in the portland cement matrix. The results are tabulated in Table 3-8 and plotted in Figure 3.6. Nitrate concentrations in the leachate were above the uncertainty value of 10 μ g/mL to a depth of 5 inches in core N4-D and a depth of 9 inches in core N5-C. For both cores, the amount of nitrate extracted from the matrix decreased considerably between about 51 and 102 mm, respectively (2 and 4 inches) from the surface.

N4-D Distance from	(inches)	0.125	0.375	0.875	1.25	1.625	2.25	5	6	7
exposed surface	(mm)	3.2	9.5	22.2	31.7	41.3	57.2	127	152	178
Nitrate in Leachate	(µg/mL)	2550	2510	1820	1860	280	400	22.5	10	10
N5-C Distance from	(inches)	0.125	0.375	0.625	0.875	1.25	1.625	2	4	9
exposed surface	(mm)	3.2	9.5	15.9	22.2	31.7	41.3	50.8	101.6	228.6
Nitrate in Leachate	(µg/mL)	1800	2380	3660	3080	3800	2190	980	149	22.7

 Table 3-8. Nitrate concentration in matrix leachates as a function of distance from the exposed surface.*

* uncertainty in nitrate values is 10 µg/mL



Figure 3.6. Nitrate concentration in matrix leachates as a function of distance from surface exposed to the H-Canyon exhaust.

Ca, K, and Na concentrations in the leachates are tabulated in Table 3-9. The objective of analyzing and reporting these constituents was to evaluate the potential for alkali silica reaction by measuring the soluble alkalis involved in formation of ASR expansive gel, K and Na. Ca in the pore solution and leachate is available to form non-expansive C-S-H gel in the presence of reactive silica.

N4-D Distance	(inches)	0.125	0.375	0.875	1.25	1.625	2.25	5	6	7
from surface	(mm)	3.2	9.5	22.2	31.7	41.3	57.2	127	152	178
K in Leachate	(mg/L)	< 131	< 131	< 131	< 131	< 131	< 131	< 131	< 131	< 131
Na in Leachate	(mg/L)	< 24.3	< 24.3	< 24.3	< 24.3	< 24.3	< 24.3	< 24.3	< 24.3	< 24.3
Ca in Leachate	(mg/L)	906	924	593	723	231	299	79.2	185	100
N5-C Distance	(inches)	0.125	0.375	0.625	0.875	1.25	1.625	2	4	9
from surface	(mm)	3.2	9.5	15.9	22.2	31.7	41.3	50.8	101.6	228.6
K in Leachate	(mg/L)	< 131	< 131	< 131	< 131	< 131	< 131	< 131	< 131	< 131
Na in Leachate	(mg/L)	< 24.3	< 24.3	< 24.3	< 24.3	< 24.3	< 24.3	< 24.3	< 24.3	< 24.3
Ca in Leachate	(mg/L)	631	826	1290	960	1190	776	362	88.5	191

 Table 3-9. Selected cation concentrations in matrix leachates as a function of distance from the exposed surface.

3.7 Core Imaging (X-ray Computed Tomography)

X-ray computed tomography (XCT) of core sections N3-D and N4-D indicated uniform profiles throughout the entire length of these samples. No macroscopic or internal degradation features (cracking or porosity or density gradations) were observed in any of the XCT images. The matrix-aggregate interfaces appear intact throughout the entire core sections. No delamination, cracking, low-density regions in the matrix were discernable as a function of distance from the Cross-over Tunnel wall surface exposed to the canyon exhaust environment.

XCT images of two orthogonal planes in Core N3-D and Core N4-D are provided in Figure 3.7 and Figure 3.8, respectively. The N3-D images were taken on half of the cylindrical core retrieved from the wall. The N4-D images were taken from one-quarter of the cylindrical core retrieved from the wall. Both cores were in two pieces which were reassembled for the CT scans. They had been previously broken about 50 to 76 mm (2 to 3 inches) from the exposed surface as the result of sub-sampling techniques used to collected matrix material for radiological screening.

Black spots in Figure 3.7 and Figure 3.8 are voids present in the initial concrete placement. Schist (coarse aggregate) and quartz sand (fine aggregate) are angular features which are lighter in color than the hydrated cement matrix. Vertical and horizontal "rastering" features in these images are artifacts of the data collection and processing.



Figure 3.7. XCT scan of core N3-D in both the XZ and YZ planes.



Figure 3.8. XCT scan of core N4-D in both the XZ and YZ planes.

3.8 Concrete Microstructure

Cores N3-D, N4-D, and N5-C were examined by SEM and EDS as described in Section 2.9. General observations include: (1) the concrete in these core sections has a high porosity and microcracks interpreted as resulting from shrinkage (2) macrocracks in these core sections were the result of coring and SRNL sample handling (subsampling, cutting, grinding, and polishing), and (3) the matrix is a multiphase material that includes hydrated portland cement phases and unreacted particles of portland cement clinker.

Qualitative Ca/Si ratios of the bulk of the matrix are within the typical ranges for calcium silicate hydrates as determined by qualitative EDS. Area elemental analyses of the surfaces exposed to the canyon exhaust (between 0 mm and approximately 2.2 mm) indicated a mixture of typical cement phases (Ca, Si, Al, S, Fe, and Mg) and the presence of carbon. Carbon dioxide in the exhaust was assumed to be the carbon source and the EDS results were interpreted as carbonation of the matrix. However, additional investigation is necessary to confirm a single or multiple source of carbon. See Figure 3.9 to Figure 3.11.

Images as a function of distance from the exposed surface are provided for cores N3-D, N4-D and N5-C in Figures 3-12 to 14, Figures 3-15 to 17 and Figure 3-18 to 21, respectively.

The exposed surfaces of each of the three cores examined had distinct features, however the matrices in cores N3-D and N4-D were similar about 500 μ m below the surface (Figure 3-12 and 3-15, respectively). Surface layering was not evident on Core N3-D. Between 0 and 250 μ m from the surface EDS area scan spectra indicate the presence of Ca, Si, Al, S and C. Matrix phases at the surface include: calcium aluminate sulfate hydrates and carbonated calcium aluminate sulfates and C-S-H phases.

Discrete layers were observed on the surface of core N4-D (Figure 3.15 to Figure 3.17). The outermost layer is discrete and made up of several phases based on high magnification particle morphologies and most likely contains a calcium aluminosulfate hydrate phases which appears to be partially carbonated in addition to C-S-H (Figure 3.16). The second layer or lens is higher in carbon/carbonate compared to the outer layer. The third layer (approximately 150 µm from the exposed surface) contains Ca and Si in ratios typical of hydrated portland cement but also contains some carbon suggesting carbonation (Figure 3.17).

Disruption of the matrix due to expansive reactions, e.g., alkali silica reaction, was not observed in any of the samples examined. Localized cracks and irregular shaped voids were attributed to initial porosity and shrinkage that was inferred to indicate a relatively high water to cement ratio in the initial concrete mix (Figure 3.9 to Figure 3.11). However, Core N5-D contained small features that were indicative of drying not associated with initial shrinkage. Although these features resembled desiccated alkali-silica gel EDS spectra did not support an ASR interpretation (Figure 3-20 upper left image). Based on the SEM petrographic evaluation coupled with EDS spectra, ASR was not observed in the core sections examined. However, the potential exists that soluble alkali in the original portland cement clinker could react with decalcified C-S-H gel resulting from exposure to nitric acid. No ASR was associated with the schist or quartz aggregates. Consequently, ASR was not observed in theses cores

Core N5-C images contained unidentified features which were too thin walled to obtain reliable EDS spectra. These features were observed in localized regions of the matrix between the surface and 35 mm (about 1.5 inches) from the surface. See Figure 3-21.



Spectrum	In	С	Ν	0	Mg	Al	Si	S	Cl	Κ	Ca	Fe	Total
	stats.				Ū								
Spectrum 1	Yes	37.38	0.00	39.87	0.29	0.87	4.50	0.63	0.14	0.04	15.86	0.42	100.00
Spectrum 2	Yes	42.66	0.00	36.12	0.46	1.39	4.47	0.36	0.19	0.06	13.36	0.92	100.00
Spectrum 3	Yes	61.44	0.00	23.22	0.20	0.73	3.19	0.25	0.12	0.12	10.17	0.56	100.00
Spectrum 4	Yes	35.93	0.00	39.35	0.40	1.46	5.46	0.51	0.15	0.04	15.63	1.07	100.00
Spectrum 5	Yes	48.40	0.00	34.36	0.34	1.06	5.94	0.23	0.15	0.04	8.95	0.54	100.00
Spectrum 6	Yes	25.48	0.00	45.85	0.61	1.48	7.91	0.36	0.13	0.10	17.31	0.76	100.00
Spectrum 7	Yes	29.52	0.00	43.75	0.47	1.50	8.62	0.24	0.09	0.12	15.20	0.49	100.00
Spectrum 8	Yes	26.05	0.00	45.97	0.42	1.45	7.84	0.34	0.09	0.08	16.56	1.20	100.00
Spectrum 9	Yes	34.68	0.00	40.80	0.48	1.13	6.76	0.26	0.12	0.14	15.06	0.58	100.00
Spectrum 10	Yes	27.13	0.00	45.94	0.33	1.40	7.46	0.32	0.08	0.08	16.24	1.02	100.00
Spectrum 11	Yes	25.89	0.00	44.76	0.49	1.29	7.32	0.61	0.15	0.07	18.64	0.78	100.00
Spectrum 12	Yes	24.77	0.00	45.60	0.49	1.57	7.49	0.66	0.12	0.10	18.21	1.00	100.00
Spectrum 13	Yes	23.50	0.00	46.56	0.42	1.45	8.34	0.36	0.11	0.20	18.18	0.88	100.00
Spectrum 14	Yes	24.28	0.00	46.33	0.77	1.96	8.48	0.29	0.11	0.11	16.40	1.26	100.00
Spectrum 15	Yes	28.89	0.00	43.74	0.51	1.88	7.47	0.33	0.15	0.09	15.99	0.95	100.00
Spectrum 16	Yes	41.92	0.00	36.78	0.38	1.03	6.12	0.33	0.16	0.06	12.65	0.57	100.00
Spectrum 17	Yes	30.97	0.00	41.55	0.35	1.56	6.71	0.45	0.12	0.10	17.13	1.05	100.00
Spectrum 18	Yes	43.12	0.00	36.94	0.17	0.96	7.70	0.40	0.12	0.05	9.89	0.63	100.00
Spectrum 19	Yes	39.93	0.00	36.91	0.31	0.93	5.58	0.56	0.14	0.08	15.00	0.55	100.00
Mean		34.31	0.00	40.76	0.42	1.32	6.70	0.39	0.13	0.09	15.07	0.80	100.00
Std.		10.07	0.00	5.87	0.14	0.33	1.51	0.14	0.03	0.04	2.85	0.26	
deviation													
Max.		61.44	0.00	46.56	0.77	1.96	8.62	0.66	0.19	0.20	18.64	1.26	
Min.		23.50	0.00	23.22	0.17	0.73	3.19	0.23	0.08	0.04	8.95	0.42	

Figure 3.9 Image of core N3-D (top) and elemental analysis of selected areas between 0 mm and approximately 2.2 mm from surface exposed to the canyon exhaust (bottom).





Figure 3.10. Core N4-D image (top) and elemental analysis of selected areas between 0 mm and approximately 2.2 mm from surface exposed to the canyon exhaust (bottom).



Figure 3.11. Core N5-C image (top) and elemental analysis of selected areas between 0 mm and approximately 2.2 mm from surface exposed to the canyon exhaust (bottom).



N3-D 6 mm from exposed surface

N3-D 8 mm from exposed surface

N3-D 10 mm from exposed surface









N3-D 100 mm (4 in.) from exposed surface

N3-D 180 mm (7 in.) from exposed surface

N3-D 200 mm (7.9 in.) from exposed surface

Figure 3.14. SEM micrographs of core N-3-D illustrating porous matrix. Black areas are pores, initial voids, and cracks introduced during coring and sample preparation.



N4-D 20 mm (0.75 in.) from exposed surface

N4-D 130 mm (5.1 in) from exposed surface Crack filling (linear features lower left) and secondary mineralization around particles or pores (bright curved lines)

N4-D 190 mm (7.5 in) from exposed surface secondary alteration around particles or pores (bright curved lines)

Figure 3.15. SEM micrographs of core N-4-D as a function of distance from the exposed surface.



Figure 3.16. Elemental map of core N4-D surface layer (0 to .3 mm from exposed surface) indicating presence of Ca, S, Si, Al C surface layer (top) Si, Al, and a near surface lens of carbonated matrix phases Ca, Si C, Mg, carbon (bottom).



Figure 3.17. Elemental map of core N4-D near surface partially carbonated cement matrix phases (Ca, Si, C S, Al, Mg) in contact with a quartz sand grain.



Figure 3.18. SEM micrographs of core N-5-C as a function of distance from the exposed surface.



N5-C 80 mm (3.1 inches) from exposed surface

N5-C 100 mm (3.9 inches) from exposed surface

N5-C 100 mm (3.9 inches) from exposed surface





Figure 3.20. Example of unexplained features in core N5-C such as hollow Si-O and Ca-C-O features and tube-like structures.



Figure 3.21. Images of tube-like structures on the surface of core N5-C at a distance of 35 mm from the exposed surface. Structure of tube interior suggests an organic origin and possible impurities in the concrete sand.

4.0 Results of Clean North Wall Core Sections

4.1 Mechanical and Physical Properties

Compressive strength, porosity, density, and UPV results for the clean sections of the 221-H Personnel Tunnel north wall cores are tabulated in Table 4-1. The 29 compressive strength measurements and values corrected for coring effects were obtained from core sections that were collected from 12 locations in the north wall.

The mean value for the as measured/reported data set was 15.2 MPa (2208 psi) and the standard deviation was 1.8 MPa (263.2 psi). The upper 95% mean value was 15.9MPa (2308 psi) and the lower 95% mean value was 14.5 MPa (2108 psi). The mean value for the 29 measurements corrected for geometry and coring damage was 16.1 MPa (2336 psi) and the standard deviation was 1.9 MPa (278.7 psi). The upper 95% mean value for the corrected compressive strength data was 17.3 MPa (2515 psi) and the lower 95% mean value was 14.9 MPa (2156 psi).

Density (unit weight) was measured on 31 core sections. The mean density was 2269.9 kg/m³ (141.7 lbs/ft³). The standard deviation was 23.5 kg/m³ (1.46 lbs/ft³). The upper and lower 95 % mean values were 2277.8 kg/m³ (142.2 lbs/ft³) and 2261.8 kg/m³ (141.2 lbs/ft³). The data tested positive for a normal distribution.

Porosity that transmits moisture as the result of wetting and drying was measured on 12 north wall core sections. The data tested positive for a normal distribution. The mean transmissive porosity for this data set was 18.6 volume percent. The standard deviation was 1 volume percent and the upper and lower 95% mean values were 19.2 and 17.9 volume percent, respectively.

UPV measurements were made on 15 clean core sections from north wall. Multiple measurements were made on each core section, and the average value for each core section is tabulated in Table 4-1. The mean value was 36,141 m/s (11,856 ft/s) with a standard deviation of 287 m/s (942.3 ft/s).

UPV data sheets are included in Appendix D. Compressive strength, density and porosity data sheets are included in Appendix E.

				Compressive	Strength (psi)	
Core Location	Compressive Strength Sample ID 221-H-PT3-	Density as reported (lbs/cft)	Porosity (vol. %)	As Measured	Corrected for drilling damage*	UPV Average** (ft/s)
	N1-A	144		2480	2629	
	N1-B (US ERDC)	143				13,350
N1	N1-C	141		2280	2417	
	N1-CC		17.8			
	N1-D					
	N2-A	140		2080	2161	
N2	N2-B (US ERDC)	141				11,964
112	N2-CC		18.0			
	N2-C		17.8			
	N3-A	142		2080	2205	11,418
N3	N3-B	142		2040	2162	9,759
113	N3-C					
	N3-D					
	N4-A	140		1930	2046	
	N4-B	140		2190	2321	
N4	N4-CC		19.0			
	N4-C	141		2150	2279	
	N4-0C		20.1			
	N4-D					
	N5-A	140		2420	2514	
	N5-B	141		2200	2285	
N5	N5-BB		18.7			
	N5-0C		19.4			
	N5-C					
	N6-A	142	18.6	2110	2237	
N6	No-B	142	18.3	2140	2268	
	N6-C	141	16.8	2230	2364	
	NOU-C		20.2			
N/2 A	N2A-A N2A B	142		2080	2014	11200
INZA	N2A-B	142		2080	2203	11599
	N2A-C	143		2190	2321	12508
N2B	N2B-R	141		1890	2333	12308
1120	N2B-C	139		1960	2003	11639
	N2D-C	141		1770	1876	12564
N2C	N2C-B	141		2060	2184	12095
	N6A-A	145		2690	2851	13008
N6A	N6A-B	145		2610	2767	12639
	N6A-C	143		2940	3116	12247
	N6B-A	143		2500	2650	
N6B	N6B-B	143		2550	2703	
	N6B-C		18.0			
	N6C-A	140		2030	2152	
N6C	N6C-B	142		2180	2311	
	N6C-C	142		2130	2258	
Nu	umber of Samples	31	12	29	29	15
	Mean	141.7	18.6	2208	2336	11,856
Standard Deviation		1.5	1.0	263.2	278.7	942.3
Star	ndard Error Mean	0.26	0.29	48.9	51.7	
Lo	ower 95 % Mean	141.2	17.9	2108	2156	
U	pper 95 % Mean	142.2	19.2	2308	2515	

Table 4-1. Mechanical and physical properties of concrete core sections from the north wall of the 221-H Personnel Tunnel.

*A Correction factor (f_d) of 1.06 was applied to all core compressive strength measurements due to presumed damage due to coring. Inaddition a correction factor (F_{dia}) of 0.98 was applied to the 6 inch cores (core N2 and N5). Correction factors for l/d ratio ($F_{l/d}$) and moisture content (F_{mc}) were both 1.0 for all core section. $f_c = F_{l/d}F_{dia}F_{mc}F_df_{core}$ per ACI 214-4R- Chapter 8.¹²

**Average of measurements taken at several locations along these core sections.

-- Indicates no data were collected.

4.2 Petrographic Evaluation

Two concrete core sections and a piece of overcore from the 221-H Personnel Tunnel north wall were characterized by the USACE ERDC to: (1) determine the ingredients in the concrete, (2) estimate the mix proportions, and (3) identify potential chemical degradation mechanisms by petrographic analysis.¹⁴

The concrete contained portland cement, schist coarse aggregate, quartz fine aggregate and a high capillary porosity which was interpreted as being due to a relatively high water to cement ratio, i.e., at least 0.5. The proportions of these ingredients were determined by two methods and are listed in Table 4-2. The concrete did not contain supplementary cementitious material such as fly ash. Small microcracks (~10 μ m long) were ubiquitous throughout the samples examined and were attributed to shrinkage during curing. Some appeared to be infilled with secondary phases. Clay coated schist aggregates were observed in the north wall concrete cores.

Ingredient	Petrographic thin section estimate (vol. %)	ASTM C457 SEM point count estimate (vol. % range)
Coarse Aggregate	40	32 - 49
Fine Aggregate	40	20 - 30
Cement Paste	20	25 - 37
Air Voids	Not measured	1 - 7

Table 4-2. Estimates of north wall concrete mix proportions.¹⁴

No indications of chemical degradation were observed in the two clean north wall cores analyzed. Petrographic results are summarized below:

- Chemical Degradation
 - Portlandite, Ca(OH)₂ was detected in both core sections. Consequently, the pH of the concrete pore solution is alkaline (pH = 12.4), i.e., in equilibrium with Ca(OH)₂.
 - Rebar is passivated and corrosion is not expected to be a degradation mechanism.
 - Calcite was not detected in XRD patterns of the matrix from these core sections.
 - Carbonation is a form of acid attack which is ubiquitous for concrete exposed to air.
 - No evidence for alkali silica reaction was observed.
 - Sulfate attack was not observed.
 - No other phases or features associated with or resulting from chemical degradation were observed.

SRNL personnel evaluated the concrete alkalinity using a phenolphthalein dye test to estimate pH of the concrete sections. The alkalinity of all of the non-radioactive north wall core sections was greater than pH 10.2 except on the surface in the Personnel Tunnel. This result supports rebar passivation.

5.0 Results of Clean South Wall Core Sections

5.1 Mechanical and Physical Properties

Compressive strength, porosity, density, and UPV results for the clean sections of the 221-H Personnel Tunnel south wall cores are tabulated in Table 5-1. The 20 compressive strength measurements and were obtained from core sections that were collected from 6 locations in the south wall.

The mean value for the as measured/as reported data set is 24.9 MPa (3618 psi) and the standard deviation was 4.4 MPa (638 psi). The upper 95% mean value was 30 MPa (3916 psi) and the lower 95% mean value was 22.9 MPa (3319 psi). The mean value for the 20 measurements corrected for geometry and coring damage was 26.4 MPa (3835 psi) and the standard deviation was 4.7 MPa (676 psi). The upper 95% mean value for the corrected compressive strength data was 28.6 MPa (4151 psi) and the lower 95% mean value was 24.3 MPa (3518 psi). The data set tested positive for a normal distribution.

Density (unit weight) was measured on 18 core sections from the south wall. The mean density was 2275 kg/m³ (142 lbs/ft³). The standard deviation was 35.2 kg/m³ (2.2 lbs/ft³). The data set tested positive for a normal distribution.

Porosity that transmits moisture as the result of wetting and drying was measured on 8 core sections from the south wall. The mean transmissive porosity volume was 17.4 volume percent. The standard deviation was 1.48 volume percent and the upper and lower 95% mean values were 18.6 and 16.2 volume percent, respectively. The data tested positive for a normal distribution.

Ultrasonic pulse velocity measurements were made on 7 core sections from the south wall. Multiple measurements were made on each core section and the average value for each core section is provided in Table 5-1. The mean value for these cores sections was 4644 m/s (15,237ft/s). The standard deviation was 180.7 m/s (593 ft/s) and the upper and lower 95% mean values were 4811and 4476 m/s (15,785 and 14,688 ft/s), respectively.

Microhardness measurements were also made on a section of core adjacent to compressive strength sample S2-BB. Microhardness results are provided in Table 5-2. The corrected compressive strength of core section S2-BB was 4039 psi. The mean value for these cores sections was 22.6 HV. The standard deviation was 4.5 HV and the upper and lower 95% mean values were 24.5 and 20.5 HV, respectively.

UPV data sheets are included in Appendix F. Compressive strength, density and porosity data sheets are included in Appendix G.

Table 5-1.	Mechanical and physical properties non-radioactive concrete core sections from the
	221-H Personnel Tunnel H-Canyon Exhaust Tunnel south wall.

		As		Compressive Strength (psi)		
	Core Section /	Reported		As	Corrected	UPV
Core	Sample ID	Density	Porosity	Measured /	for drilling	Average
Location	221Н-РТЗ-	(lbs/cft)	(vol. %)	Reported	damage**	(ft/s)
	S1-A	143	15	2150	2279	
S1	S1-B	145	16.5	3380	3583	
51	S1-C	145		3800	4028	
	S1-D (S1-Spare)	143		3640	3858	15297
S2	S2-A		18.6			
	S2-B			2610*	2767	
	S2-BB	142		3810	4039	
	S2-C	142	17.7	3420	3625	
	S2-D ERDC					15546
	S3-A	141		3310	3509	
	S3-B	144		3900	4134	
S 3	S3-C	144		4540	4812	
	S3-CC		16.1			
	\$3-D					15611
S4	S4-A	141		2960	3138	
	S4-B	140		3710	3933	
	S4-C	141		3960	4198	
	S4-CC		19.2			14159
	S4-D					14724
	S5-A	138		3100	3286	
	S5-B	140		3560	3774	
S5	S5-C	140		3650	3869	
	S5-CC		18.9			
	S5-D					15448
	S6-A	138		3310	3509	
	S6-B	144		4360	4622	
S6	S6-C	144		4540	4812	
	S6-CC		17.2	4640*	4918	
	S-6D USERDC					15872
Numl	per of Samples	18	8	20	20	7
Mean		142	17.4	3618	3835	15237
Standard Deviation		2.2	1.48	638	676	593
Standard Error Mean		0.52	0.52	142.7	151.2	224.2
Upper 95 % Mean		143.0	18.6	3916	4151	15785
Lower 95 % Mean		140.8	16.2	3319	3518	14688

*Values were corrected by CMLT for l/d correction factors. S-2A measured value, 2720 psi, was corrected as follows: 2720 psi x 0.96 = 2767 psi (reported). S6-D measured value, 4640 psi was corrected as follows: 4640 psi x 0.98 = 4918 psi (reported).

** A Correction factor (f_{core}) of 1.06 was applied to all core compressive strength measurements (f). All cores were made with 4-inch core barrels.

-- Indicates no data was collected
Core Section ID	Hardness (HV)
	24.3
	21.6
	18.7
	20.2
	23.2
	25.5
	18.9
	25.5
	16.7
	29.9
S-2-ВВ	30.4
	14.6
	24.7
	21.9
	14.7
	20
	26.1
	24.2
	29.6
	21.2
	22.6
Number of Samples	21
Mean	22.6
Standard Deviation	4.5
Standard Error Mean	0.97
Upper 95 % Mean	24.5
Lower 95 % Mean	20.5

Table 5-2. Microhardness measurements for the south wall core sections approximately 305 mm(12 inches) from Personnel Tunnel.

5.2 Petrographic Evaluation

Two concrete core sections from the 221-H Personnel Tunnel south wall were characterized by the USACE ERDC to: (1) determine the ingredients in the concrete, (2) estimate the mix proportions, and (3) identify potential chemical degradation mechanisms by petrographic analysis.¹⁴

The concrete contained portland cement, schist coarse aggregate, quartz fine aggregate, and a high capillary porosity which was interpreted as being due to a relatively high water to cement ratio, i.e., at least 0.5. The proportions and ingredients were determined by two methods and are listed in Table 5-3. The concrete did not contain supplementary cementitious material such as fly ash. Small microcracks (~10 μ m long) were ubiquitous throughout the concrete and were most likely due to early age shrinkage. Some cracks appeared to be infilled with secondary phases.

Ingredient	Petrographic thin section estimate (vol. %)	ASTM C457 SEM point count estimate (vol. % range)
Coarse Aggregate	40	36 - 50
Fine Aggregate	40	21 - 26
Cement Paste	20	25 - 35
Air Voids	Not measured	3.2 - 3.4

Table 5-3. Estimates of south wall concrete mix proportions.¹⁴

No indications of chemical degradation were observed in the two clean south wall cores analyzed. Petrographic results are summarized below:

- Chemical Degradation
 - Portlandite, Ca(OH)₂ was detected in both core sections. Consequently, the pH of the concrete pore solution is alkaline (pH = 12.4), i.e., in equilibrium with Ca(OH)₂.
 - Rebar is passivated and corrosion is not expected to be a degradation mechanism.
 - Calcite was not detected in XRD patterns of the matrix from these core sections.
 - Carbonation is a form of acid attack which is ubiquitous for concrete exposed to air.
 - No evidence for alkali silica reaction was observed.
 - Sulfate attack was not observed.
 - No other phases or features associated with or resulting from chemical degradation were observed.

6.0 Discussion

The characterization approach was focused to evaluate material properties for both clean and radiologically contaminated concrete cores recovered from the 221-H Section 3 Personnel Tunnel. The south wall and north wall cores were examined to: (1) provide current concrete physical and mechanical properties (clean samples) and (2) effects of 60+ years of aging in a passive environment (clean samples) as compared to exposure to the corrosive canyon exhaust environment (radioactive samples). The characterization plan was constructed with the assumption that chemical, mineralogical, and mechanical gradients were present in the concrete exposed to the canyon exhaust. This gradient concept is expressed as an affected zone with the most altered material directly in contact with the canyon exhaust. See Figure 6-1. Mechanical properties (such as compressive strength) were not directly measured (ASTM C39) on the concrete core sections exposed to the canyon exhaust because they were assumed to vary as a function of distance from the exposed surface. The depth of the affected zone and the nature and degree of alteration were unknown at the time this study was initiated and could not be derived based on tunnel inspections and surveillance activities.



Concrete Surface Exposed to Tunnel H- Canyon Exhaust

Figure 6.1. Conceptual Concrete Core Suspected Affected Zone Location to Tunnel Surface. (not to scale)

6.1 North and South Wall Mechanical and Physical Properties: Direct Measurements

A statistical analysis of the clean north and south wall compressive strength measurements indicated that (1) results for each wall pass the test for a normal distribution and (2) the results from each wall represent different populations. This is illustrated in Figures 6-2 to 6-4 by various statistical representations of the means, variances and scatter in the data.

The mean compressive strength corrected for coring damage and dimensional variations for 29 core sections from the north wall was 16.1 MPa (2336 psi). This is slightly below the design strength of 17.2 MPa (2500 psi). The mean corrected compressive strength for 20 core sections collected from the south wall was 26.4 MPa (3835 psi) which is well above the design strength of 17.2 MPa (2500 psi). ERDC concluded that both walls were constructed of concrete with fairly similar mix proportions except that the north wall concrete had a higher in air content and possibly a higher water to cement ratio than the south wall concrete.

ERDC did detect extensive capillary porosity, especially in the north wall clean samples which they interpreted as indicating that the water to cement ratio in the north wall concrete was probably higher than that in the south wall concrete. This conclusion was corroborated by the higher non-evaporable water loss of the cement paste fraction for the south wall concrete compared to that for the north wall concrete, i.e., 18.5 mass percent compared to 21.4 mass percent, respectively.¹⁴

ERDC personnel observed small amounts of illite and kaolinite clay in petrographic samples coating some of the coarse aggregates in the north wall clean samples. ERDC postulated that the clay coatings resulted in poor adhesion between the aggregate and paste and concluded that this condition along with the high capillary porosity and high air content were the likely "culprits" responsible for the lower north wall compressive strengths.¹⁴

The densities (as received unit weights) and transmissive porosities for the north and south wall concrete samples were similar. The unit weights were typical, about 2275 kg/m³ (142 lbs/ft³), of concrete containing schist and quartz aggregates. The average transmissive porosities for both walls were high, 17 (south wall) and 19 (north wall) volume percent. These high concrete porosities support the ERDC conclusion, high water to cement ratios of at least 0.5 and a higher water to cement ratio for the north wall concrete mix.



Figure 6.2. Normal distributions 221-H personnel corridor north (left) and south wall (right) concrete samples compressive strength (corrected for coring damage and dimensional variability).



Figure 6.3. North and south wall compressive strength results relative to the average of the mean of the north plus south wall values. Green line = average of all measurements.

ERDC and SRNL did not observe any physical or chemical degradation by direct observation or the petrographic evaluation of the non-radioactive cores collected from Section 3 of the 221-H Personnel Tunnel. No indication of alkali silica reaction or cracking due to any other expansive reaction was observed. ERDC attributed microcracks in the clean cores to initial shrinkage during early age curing and attributed this cracking to a high water to cement ratio in the fresh concrete.



Figure 6.4. Variability chart for compressive strength measurements

Colors denote the wall of origin of the core (red=north, blue=south); Symbols refer to subsets of data from individual cores (\bullet = Cores N-1, N-6 and S-6, \blacktriangle = Cores N-1 and N-6A, \blacktriangledown = Cores N-2 and N-6B, \blacksquare = Cores N-2A and N-6C, \blacklozenge = Cores N-2B and S-1, \blacktriangleleft = Cores N-2C and S-2, \blacktriangleright = Cores N-3 and S-3, \blacksquare = Cores N-4 and S-4, \blacksquare = Cores N-5 and S-5). Green lines indicate average values.

6.2 North and South Wall Mechanical and Physical Properties: Indirect Measurements

6.2.1 Interpretation of UPV Results

UPV values are related to the elastic modulus of the concrete which is a function of material properties such as porosity (micro and macro), defects (cracks), density (bulk and phase), moisture saturation, and microstructure.¹⁷⁻²² UPV measurements were made on the north wall radiological samples as a function of distance from the surface exposed to the canyon exhaust using the same techniques as used on the clean cores (radial measurements across the core diameter). Compression tests were not performed on the radiological cores sections.

Statistical analyses of the UPV data collected from 5 different north wall radiological cores were compiled as a function of distance from the exposed surface and plotted in Figure 6.5. The depth-discrete data were compared to all of the measurements collected from clean core sections which were grouped and assigned a single depth from the exposed surface of 18 inches. The depth-discrete mean values suggest a decline in the velocities as a function of distance from the surface exposed to the canyon exhaust. One possible explanation is that this is a result of a decrease in density as a function of increasing distance from the surface. Secondary mineralization of the matrix – calcite replacement of portlandite in the affected region could be responsible for the higher density near the surface compared to the density of the unaffected concrete.



Figure 6.5. All north wall UPV measurements as a function of distance from the exposed surface $(14671 \text{ ft./s} > \text{UPV}_{avg} > 11673 \text{ ft./s}).$

6.2.2 Correlation of UPV and Compressive Strength Results

The possibility of using the UPV data to predict compressive strength of the radiological core sections affected by canyon exhaust was evaluated using the following approach. A subset of results was compiled from the clean core sections. This subset consisted of both UPV and compressive strength measurements made on thirteen clean cores from the north wall and 1 core from the south wall. See Table 6-1. The compressive strengths were plotted against the averaged UPV measurements for each core section and a trend line was fitted to the data using the polynomial equation shown in Figure 6-6.

Core ID	Compressive Strength (psi)	Average UPV (ft./s)	Compressive Strength (MPa)	Average UPV (m/s)
S1-D (S1-Spare)*	3858	15297	26.4	4662.5
N3-A**	2205	11,418	15.2	3480.2
N3-B	2162	9,759	14.9	2974.5
N2A-A	2014	10905	13.9	3323.8
N2A-B	2205	11399	15.2	3474.4
N2A-C	2321	11642	16.0	3548.4
N2B-A	2353	12508	16.2	3812.4
N2B-B	2003	10709	13.8	3264.1
N2B-C	2078	11639	14.3	3547.5
N2C-A	1876	12564	12.9	3829.5
N2C-B	2184	12095	15.1	3686.6
N6A-A	2851	13008	19.7	3964.8
N6A-B	2767	12639	19.1	3852.4
N6A-C	3116	12247	21.5	3732.9
Average Values	2428	11,988	16.7	3653.9

Table 6-1. Comparison of compressive strength and UPV measurements made on individual core sections.

*S wall core data from Table 5-1.

**All N core data from Table 6-1.



Figure 6-6. North and south wall UPV measurements for concrete cylinders plotted against the compressive strength of each cylinder (13 from the north wall and 1 from the south wall. (Data were taken from Tables 4-1 and 5-1, respectively.)

The trend line was used to predict compressive strengths and a function of the depth discrete UPV measurements made on the radiological core sections. The predicted strengths are listed in Table 6-2 and plotted in Figure 6-7. Two other properties of these core sections that exhibited depth-discrete trends, leachable nitrate and the presence $Ca(OH)_2$ in the matrix are summarized in Table 6-2 and Figure 6-7.

Because matrix chemistry and mineralogy were shown to vary as a function of distance from the exposed surface and are known to affect porosity, density and UPV values, the attempt to relate UPV measurements to compressive strength of the radiological core sections did not result in a defensible correlation between these two properties. The core sections exposed to the canyon exhaust clearly showed inherent differences in the concrete chemistry and mineralogy which may or may not influence mechanical properties of these cores. Consequently, the affected regions of the cores may have higher or lower or the same mechanical properties as the unaffected concrete in the north wall. Currently, characterization results are insufficient to determine a residual strength value for the portion of the north wall affected by exposure to the canyon exhaust.

Distance from		Predicted compressive		Presence of
surface exposed to	Average UPV	strength from trend	Nitrate Leachate	Portlandite
canyon exhaust	from Table 3-4	line in Figure 6-6	Concentration	and Calcite
(inches)	(ft./s)	(psi)	(mg/L)	in Matrix
0.125			2175	
0.375			2445	
0.5	14817	2963		
0625			3660	Calcite
0.875			2450	
1	14672	2887		No
1.25			2830	Portlandite
1.5	13946	2542		
1.625			1235	
2	13451	2344	980	
2.25			400	
2.5	13345	2305		Calcite
3	13278	2281		Portlandite in
3.5	13213	2258		Core N3-D
4	13076	2213	149	
5	13007	2190	22.5	
6	12450	2032	10	Portlandite in
7	12407	2021	10	all cores
8	12371	2012		samples
9			22.7	Calcite

Table 6-2. Depth-discrete compressive strength values for a composite north wall exposed core
section calculated using the UPV-compressive strength relationship in Figure 6-5.



Figure 6-7. Comparison of averaged depth-discrete UPV data and averaged leachable nitrate concentrations to predicted compressive strength values as a function of distance from the surface exposed to canyon exhaust.

6.2.3 Interpretation of Microhardness Results

The intent of the microhardness measurements was to evaluate the (1) sensitivity of microhardness measurements to other concrete properties (2) difference in matrix integrity as a function of distance from the exposed surfaces of the radiological core sections.

Based on published literature, microhardness results for cement paste and concrete have been shown to vary due to matrix mineralogy, porosity or microstructural evolution.¹⁸⁻²⁰ Variations within individual sample sets have also been attributed to environmental factors, sample preparation, carbonation, and/or proximity to aggregates.^{19, 20}

Microhardness measurements from the north and south wall concrete cores are shown in Figure 6-8. Differences between north and south wall microhardness measurements were not as apparent as the differences in the north and south wall UPV and compressive strength measurements. Some differences between north wall and south wall cores may be inferred. Specifically, the scatter from south wall data is less and the average value for south wall is slightly lower $(22.6 \pm 4.6 \text{ HV})$ than that of the north wall (27.6 \pm 10 HV). Three possible explanations for the lower scatter in the south wall results are (1) higher matrix integrity in the south wall corresponding to higher compressive strength and/or (2) fewer number of cores evaluated (3) differences in matrix mineralogy between the concrete exposed to canyon exhaust and concrete from the interior of the south wall. The north wall microhardness data from four cores exposed to the canyon exhaust were averaged as a function of distance from the exposed surface in Figure 6-9. Statistical analysis showed that average microhardness value of the matrix phase is unchanged as depth from the surface exposed to the canyon exhaust.

In the north wall radiological core sections, depth-discrete mineralogy analysis indicated that the original cement matrix phases have been chemically altered by the canyon exhaust. These reaction products have been shown to coexist with typical hydrated portland cement phases present in unaffected portions of the north wall concrete and did not result in detectable changes in matrix microhardness.



Figure 6.8. North and south wall microhardness comparison. Reported Mean for data sets are 27.6 (north wall) and 22.6 (south wall)

Colored symbols denote the core from which measurements were taken ($\bullet = N-2-C$, $\blacktriangle = N-3-D$, $\checkmark = N-4-D$; $\blacksquare = N-5-C$) Distance from surface denotes the approximate distance in inches from the surface exposed to tunnel environment.



Figure 6.9. All north wall microhardness measurements as a function of distance from the exposed surface (HV_{avg} of 27.6)

Colored symbols denote the core (• = N-2-C, • = N-3-D, \checkmark = N-4-D; • = N-5-C).

6.3 Degradation / Alteration of 221-H Personnel Tunnel the North and South Wall Concrete

ERDC did not observe any degradation of the clean portions of Section 3 of the 221-H Personnel Tunnel north and south walls. ERDC performed petrographic analyses on two clean cores and a piece of over core collected from the north wall and two clean core sections collected from the south wall. They determined that the concrete had not been subjected to deleterious chemical alteration or reactions, such as sulfate attack or ASR, and the clean concrete samples did not show carbonation.¹⁴ Therefore, ERDC concluded that the "clean" concrete in both walls is not expected to lose strength in the future.¹⁴ ERDC also recommended continued monitoring of the degraded north wall concrete exposed to the canyon exhaust (interior walls of the Cross-over Tunnel and Exhaust Tunnel).

Degradation of the north wall concrete exposed to the H-Canyon exhaust over 60+ years has been previously documented.⁸ Recent photographs of the surface were obtained as part of the 2016-2017 coring and inspection effort and show exposed rebar and angular aggregates protruding from the walls. Debris from the walls has accumulated on the floor of the tunnel and on a duct in the tunnel.

Two field measurements in 2017 through core borings through the wall that separates Section 3 of the 221-H Personnel Tunnel and Cross-over Tunnel indicated that the north wall thickness is 0.86 m (33.75 inches)and 0.87 m (34.25 inches) on the west and east ends, respectively. These measurements are less than the design thickness of 0.9 m (36 inches). The loss of thickness is presumed to be the result of erosional loss resulting from 60+ years of H-Canyon operation. Despite this, exposed aggregate on the tunnel surfaces does not appear loose nor does the wall surface appear to be powdery or crumbling. The protruding/exposed aggregates are firmly fixed in the concrete matrix.⁸

The primary factors responsible for the observed degradation were identified as nitric acid and wind erosion (48 to 64 km/h (30 to 40 mph air stream). Concurrent nitric acid dissolution of portlandite, $Ca(OH)_2$ and exposure to atmospheric CO₂, resulted in secondary matrix mineralization, i.e., formation of calcite in the

matrix of affected portions of the concrete to the canyon exhaust. This interpretation is supported by the petrographic and mineralogical results.

The absence of portlandite, $Ca(OH)_2$ and presence of calcite, $CaCO_3$, is evidence of reaction of atmospheric CO_2 with water to form bicarbonate HCO_3^- which reacted with portlandite to form calcite as a secondary matrix phase. Portlandite was absent from the matrix phase assemblages of cores N1-D, N2-C, N-4-D, and N-5-C between the surface and about 76 mm (3 inches). Portlandite was present in N3-D at the matrix collected between 51 and 64 mm (2 and 2.5 inches). The extent of CO_2 / bicarbonate ion penetration and carbonation in the north wall is unclear because calcite or a $CaCO_3$ polymorph appears throughout the entire 228 mm (9 inch) length of the radioactive north wall core sections. A discrete calcite surface was not observed on the expose surfaces of the radiological cores, and compete carbonation of the hydrated alkaline cement matrix phases was not observed in any of the five cores examined. This feature was attributed to the high porosity of the concrete which facilitated penetration of CO_2 into the bulk material rather than intense localized conversion on the surface.

Nitrate was detected in leachates from pulverized matrix material collected from two cores (N4-D and N5-C). The concentrations were reported as a function of distance from the surface exposed to the canyon exhaust (Figure 3.6). Relatively high concentrations of nitrate (1000 to 3800 μ g/mL) were extracted from N-4-D and N-5-C matrix sub-samples collected between 0 and about 51mm (2 inches). See Table 3-8. Lower concentrations of nitrate (1000 to150 μ g/mL) were extracted from subsamples about 2 to 4 inches from the exposed surface. Very low concentrations of nitrate (22.5 to 10 μ g/mL) were detected to depths beyond 102 mm (4 inches) in these cores (Table 3-8).

The most nitrate-rich portions of these cores correspond to the regions with higher UPV velocities (about 10 % higher) and roughly correspond to the darker colored regions observed on the as-received radioactive core sections. The darker surface regions were initially referred to as the "affected zones". See Figure 6-1.

SEM and XCT imaging and x-ray diffraction analyses of the radioactive north wall core sections did not indicate sulfate attack or cracking from any other expansive reaction. However, a few features in core N5-C physically resembled gel formed by ASR. These features were only present in the near surface region (0 to 500 μ m) and did not have chemical signatures indicative of ASR gel. Other unidentified features (Figure 3.21) were observed in N5-C and were attributed to artifacts of sample preparation.

The surface of each of the three cores examined by SEM-EDS was unique. The surface of N3-D was characterized by at least two layers with similar elemental signatures but different textures. Each layer was about 200 μ m thick (Figure 3-13). A discrete multiphase layer about 50 μ m thick was observed on portions of the surface of core N4-D. (Figure 3.17). No layering was observed on Core N5-C.

Based on the results presented in this report, mechanical properties, i.e., compressive strength or residual compressive strength values cannot be assigned to the "affected" region. However, XCT imaging indicated material continuity in the N3-D and N4-D core profiles over their entire length which included the exposed surface, affected region, and unaffected material (6-9 inches from the surface). No obvious changes/gradients in density or porosity and no internal macrocracking or delamination were observed. See Figure 3-7 and 3-8.

6.4 Effects of H-Canyon Exhaust on Cross-over Tunnel Concrete

The H-Canyon Cross-over Tunnel is constructed of reinforced concrete with a design strength of 17.2 MPa (2500 psi). The design thickness of the Cross-over Tunnel south wall was 0.91 m (36 inches). The mean strength of 29 core sections collected from the wall in 2017 was 2336 psi, and the standard

deviation was 1.9 MPa (279 psi). The tunnel was initially painted and remote inspections indicated that the concrete was protected until the early 1970s. The exposure environment has been somewhat variable because the exhaust composition has varied over the 60+ years of operation.

Measurements made during the 2017 coring activity indicated the current north wall thickness, measured through the core holes, was 0.86 m (33 ³/₄ inches) at the west end and 0.87 m (34 ¹/₄ inches) at the east end of the tunnel. A 9.1 m (30-foot) section of the Cross-over Tunnel south wall has exposed vertical rebars as well as some exposed horizontal rebar.²³ This indicates that about 57 mm (2.25 inches) of concrete cover has been lost over limited portions of the Cross-over tunnel. The decrease in the wall thickness is the result of a combination of exposure to nitric oxide (NO) vapors and erosion by the high velocity exhaust flow through the tunnel (30 to 40 mph) over 60+ years of operation. Concrete debris consisting of gravel, sand, and matrix particulates has accumulated on the tunnel floor and along the sides of the walls. Some surfaces show more material loss than other areas as would be expected in a dynamic environment. A sketch of the various features observed in the H-Canyon tunnel are shown in Figure 6-10.



Figure 6.10. Sketch of cross over tunnel cross section illustrating current features. (Dashed line indicates original painted concrete surface. Not to Scale.)

Characterization to date indicates that nitric oxide and carbon dioxide in the exhaust air stream concurrently reacted with moisture in the tunnel and in the concrete to form nitric acid and bicarbonate ion which in turn reacted with the matrix phases in the concrete.

 $4NO_2 + O_2 + 2H_2O = 4HNO_3$

 $CO_2 + H_2O = H_2CO_3 + OH = HCO_3$ (aqueous) + H₂O in alkaline concrete pore solution

Based on the current phase assemblages in the core sections exposed to the canyon exhaust air stream, these acids reacted with alkaline phases in the concrete matrix, i.e., the hydrated alkaline portland cement

phases. Both nitric acid and bicarbonate ion preferentially react with alkali hydroxides and calcium hydroxide, Ca(OH)₂, and to a lesser extent with other calcium minerals present in the cement matrix. Exposure of the unprotected concrete (paint lost by early 1970s presumably by the due to erosion and chemical exposure) resulted in the following chemical reactions:

Nitric acid attack: $2HNO_3 + Ca(OH)_2 = Ca^{2+}_{(aqueous)} + 2NO_3^{-}_{(aqueous)} + 2H_2O = Ca(NO_3)_{2(soluble)} + 2H_2O$

Carbonation:

 $Ca^{2+}_{(aqueous)} + 2(OH)^{-}_{(aqueous)} + CO_2 = CaCO_{3 (solid)} + H_2O$

and

 $Ca^{2+}(aqueous) + HCO_3^{-}(aqueous) = CaCO_3^{-}(solid)$

Nitric acid attack and carbonation also resulted in progressive decalcification of the C-S-H phases and carbonation of the calcium aluminum sulfate hydrates

Because the solubility of calcium nitrate in water is very high, about 1212 g/L (at 20 °C), calcium ions were available to react with bicarbonate ion to form calcite which has a solubility about 3 orders of magnitude lower than that of calcium hydroxide, about 1.73 g/L (at 20 °C). The presence of calcite in the matrix was documented as a secondary cementing phase. Calcite is intimately intermixed with portlandite, C-S-H, calcium aluminum monosulfate (AFm), ettringite (AFt) and hydrogarnet phases. Calcite and the solid phases in hydrated portland cement are also susceptible to dissolution by nitric acid but much less so than calcium hydroxide. Based on petrography and x-ray diffraction results, partial decalcification of the C-S-H poorly ordered matrix phase and carbonation of the calcium aluminum monosulfate phase have also occurred. The phase alteration profiles are gradational and irregular and are influenced by the large angular aggregates in the concrete.

Thin (few tenths of a mm) carbonated sulfate-rich material which had several forms ranging from discrete discontinuous layers to continuous porous layers were observed on the surfaces of the cores which were exposed to the canyon exhaust. Physical erosion of these thin layers by the canyon exhaust air stream was presumed to result in progressive matrix loss and wall thinning. These features are illustrated in Figure 6-11.

The concrete aggregates are composed of silica minerals which are much more resistant nitric acid or bicarbonate ion than the calcium rich alkaline hydrates in the cement matrix. The schist gravel and quartz sand, did not appear to be affected by the canyon exhaust air stream expect that the aggregates exposed on the surface appeared polished or varnished. This was attributed to the high velocity air flow but a chemical effect or coating cannot be eliminated because it was not specifically investigated.

Characteristics observed in the five exposed core sections were grouped into those that were depthdependent and those that were depth-independent summarized in Figure 6-11. Although compressive strength was not directly measured on the radiologically contaminated cores characterized in this study, properties relevant to residual strength were evaluated. Cracking, delamination, paste/aggregate debonding and rebar corrosion were not observed in the radiological core sections. Based on the field alkalinity test (pH >10.2) and presence of C-S-H and other alkaline phases in the matrix (pH >11), sufficient rebar passivation is provided such that its function is maintained and concrete cover is present.

Rad concrete cores (8-9 inches)

Concrete Surface Exposed to Tunnel H-Canyon

Exhaust

Cored April to May 2017

Non-rad concrete cores (~24 inches)

Cored December 2016 to January 2017

Carbonated sulfate-rich layers on exposed core surfaces ~ 0.1 to 0.2 mm thick

Rad Core Section

- Physical Observations
- Darker color (gray brown) between 0 and ~64 mm (2.5 in.)
- Core N1-D dark brown zone (0 to ~89 mm) was atypical
- UPV faster between 0 and ~ 64 mm (2.5 in.) from surface
- No macrocracking
- No delamination parallel to the exposed surface
- Paste-aggregate bonding intact
- Capillary porosity and drying shrinkage cracking were similar to rad cores

Matrix Mineralogy Gradients: Rad Cores

- Thin mineralized layer ~ 0.1 to 0.2 mm thick on exposed surface
- Portlandite completely converted to calcite between 0 and ~ 51 mm (2 in.) and partially converted between ~ 51 and 127 mm (2 and 5 in.) from the exposed surface
- Decreasing calcite and increasing portlandite gradients between ~ 51 and 229 mm (2 and 9 in.)
- High nitrate between 0 and ~ 51 mm (2 in.)
- Moderate nitrate between ~ 51 and 127 mm (2 and 5 in.)
- Decalcification of C-S- H decreased from 0 to about 127 mm (5 in.)
- Alkalinity at least 10.2 over entire exposed core length

Chemical Degradation Gradients:

- Nitric acid attack (nitrate gradient)
- Carbonation (calcite gradient)
- No expansive reactions
- No indication of ASR, sulfate attack, or rebar corrosion

Bulk Core Sections (non rad) Matrix Mineralogy Bulk Concrete:

- Portlandite, C-S-H, AFm, AFt, hydrogarnet
- pH > 10.2 to ~12.4 in equilibrium with Ca(OH)₂

Compressive strength:

• 2336 psi (average of 29 cores)

Chemical degradation / disruptive expansion

- No alkali silica reaction (ASR)
- No sulfate attack
- No rebar corrosion

Physical Observations:

- Capillary porosity and drying shrinkage cracking consistent with mix design
- No macrocracking
- No delamination
- Paste-aggregate bonding consistent with mix design and initial condition

Figure 6-11. Summary of features observed in the radiological concrete core sections that supports concurrent alteration reactions – nitric acid and carbonate matrix conversion to calcium nitrate and calcium carbonate.

7.0 Conclusions

This report provides a summary of characterization results for the concrete cores collected from the north and south walls of the 221-H Section 3 Personnel Tunnel during 2016 and 2017. The goal was to (1) support the H-Area Canyon Exhaust (CAEX) Soil and Concrete Core Sampling and Analysis effort; (2) characterize the effects and depth of affected concrete exposed to the canyon exhaust environment; and (3) collect additional physical property data on 1950's concrete. The results of this characterization will be used to refine input parameters to the 2014 H-Area CAEX Tunnel Seismic Qualification Calculations.¹

Eighteen (18) concrete cores, twelve from the north wall and six from the south wall, were harvested from the 221-H Section 3 of the Personnel Tunnel. Sections from these clean cores were tested by the SRS Construction Materials Testing Laboratory (CMTL) to obtain compressive strengths, porosity and density of the bulk concrete comprising the walls. The mineralogy and petrography of four (4) clean core sections and one over core sample were analyzed by the U.S. Army Corps of Engineers Engineering Research Development Center (ERDC). Six (6) radiologically contaminated core sections were characterized by SRNL to identify the effects of the canyon exhaust on the mineralogy and microstructure of the affected concrete.

Compressive strength, porosity, and density of the "clean" concrete sections from the north and south walls of the 221-H Personnel Tunnel were determined from measurements made by CMTL. Mechanical and physical property results of the clean cores sections are summarized below:

- ERDC concluded that a similar mix was used for the north and south wall concretes.
- The mean compressive strength of the south wall concrete is 26.4 MPa (3835 psi) based on 20 measurements corrected for coring damage and dimension. Design strength for this concrete was 17.2 MPa (2500 psi).
- The mean compressive strength of the north wall concrete is 16.1 MPa (2336 psi) based on 29 measurements corrected for coring damage and dimension. Design strength for this concrete was 17.2 MPa (2500 psi).

SRNL attributed the difference in the mean compressive strengths between the north and south wall concretes to be due to different aging conditions over the 60 + years of service (moist subsurface versus exposed to air or canyon exhaust). The large variance in strength measurements of the south wall cores was also attributed to the exterior wall being exposed to a moist subsurface environment, whereas the interior wall surface was exposed to air. The north wall surfaces were exposed to air on both sides and showed a lower variance.

- The mean as-received densities of the north wall and south wall concretes were typical of material containing schist and quartz aggregates; 2269.8 kg/m³ (141.7 lbs/ft³) and 2275 kg/m³ (142.0 lbs/ft³) for the north and south walls, respectively.
- The mean porosities transmitting moisture and air were relatively high, 18.6 and 17.4 volume % for the north and south wall, respectively.

Concrete in the south wall and portion of the north wall of the Personnel Tunnel which was unaffected / unaltered by exposure to the canyon exhaust showed no indication of deleterious chemical alteration or reactions such as ASR. ERDC concurred with this observation and concluded that the concrete in these walls is not expected to lose strength in the future due to normal aging.

ERDC observed rims/coatings on surfaces of some schist (silica-rich) aggregates. They identified the material comprising the rims as clay, either kaolinite or illite. Clay was also observed in the matrix mixed with the cement hydration phases. These features were interpreted as being contaminants brought into the mix on the aggregates. ERDC observed small microcracks, some of which appeared to be infilled with secondary mineralization and high capillary porosity which was attributed to early age shrinkage resulting from high water to cement ratios in the fresh concrete. No indication of cracking due to mechanical load or post curing expansion was observed. These conclusion are based on the ERDC petrographic analysis.¹⁴

The SRNL suite of tests and measurements made on the radioactive core sections focused on identifying and understanding depth-dependent changes that occurred in the concrete and paste/matrix as a function of distance from the surface exposed to the canyon exhaust environment. It was not possible to quantify the mechanical properties of the north wall concrete affected / altered by exposure to the canyon exhaust with the tests that were performed. There is no standard protocol for directly measuring mechanical strength gradients in the affected region of the concrete exposed to the canyon exhaust. Matrix microhardness and ultrasonic pulse velocity as a function of distance from the exposed surface were used to provide an indication of potential changes in relative density and hardness both of which may be indicators of relative strength. A summary of the test results is provided below:

- Visual examination indicated:
 - Cores were recovered and received at SRNL intact. Except for core N6-D which was damaged during coring operations. Angular schist aggregates up to 38 mm (1¹/₂ inch) in size protruded from all five intact core sections exposed to the exhaust. The aggregates and the quartz sand grains were securely anchored in the matrix. Dislodging the aggregates and surrounding matrix required a hammer and chisel. The matrix was not friable or powdery or obviously fractured.
 - The exposed surface (coarse aggregate, sand, and matrix) of these cores had a glossy (varnished) appearance which was inferred to be the result of chemical and/or physical polishing.
 - The cores sections were a darker color from the exposed surface to a depth of about 38 to 64 mm (1½ to 2½) inches. The darker portion of the core were referred to as the "affected zone" even though the cause of the color was initially unknown. The darker color portion of Core N1-D extended about 89 mm (3½ inches) from the surface but was not considered representative of the rest of the wall because it was located directly in front of the warm canyon exhaust entry point.
- Depth discrete analyses of the mineralogy, microstructure, and leachability of soluble ions in the matrix indicated:
 - Two concurrent chemical alteration mechanisms altered the matrix phases (1) nitric acid attack and (2) carbonation in the affected zone.
 - The schist and quartz aggregates were not affected by either of these chemical alteration mechanisms. They were physically affected by the wind erosion from the canyon exhaust.
 - Nitric acid dissolution of matrix minerals, primarily portlandite, Ca(OH)₂, and carbonation of soluble calcium, resulted in formation of secondary calcite, CaCO₃ in the matrix and were the only forms of chemical alteration observed.
 - Secondary calcite was intermixed with hydrated portland cement phases and was an integral part of the cementing material in the altered matrix.

- The presence of soluble calcium nitrate in the concrete pore solution was inferred from leaching data. Soluble nitrate and calcium ions were extracted from pulverized matrix samples.
- Neither alkali silica reaction, nor cracking that could be attributed to any other expansive reactions were observed in the radioactive core sections analyzed by SRNL. This observation was confirmed by the ERDC characterization of the non-radioactive core sections from the north and south wall of the 221-H Personnel Tunnel.
- The alkalinity of the radiological core sections indicated some variability but overall the pH was > 10.2 which is sufficient to maintain rebar passivation.
- X-ray computed tomography (XCT) imaging indicated that neither delamination along planes parallel to the exposed surface nor macrocracking nor density gradients in the matrix or in the concrete itself were present in the two full-length exposed core sections evaluated.
- Microhardness data showed that the average microhardness values of the depth-discrete matrix measurements were not statistically different as a function of distance from the exposed surface.
- UPV data were confounded because many material properties in these cores, e.g., density, porosity, moisture, mineralogy were depth dependent and consequently may have influenced the measured velocities in ways and to degrees that were not quantified in this evaluation. A correlation of UPV and compressive strength for the bulk north and south wall concrete was attempted but could not be applied to the portions of the cores affected by exposure to the canyon exhaust for the same reason.

In summary, loss of the concrete wall thickness, i.e. erosion, in the H-Canyon Cross-over Tunnel and Exhaust Tunnel has been documented in surveillance activities over many years.⁸ Exposed aggregates and rebar and concrete debris on the floor have been observed in these tunnels and have been attributed to a combination of physical and chemical attack by the canyon exhaust. Results from this study suggest a chemically-assisted erosion mechanism is responsible for the observed loss of wall thickness. This study focused on the chemical reactions involved and concluded that concurrent acid attack and carbonation are responsible for the chemical and mineralogical gradients observed in the affected concrete. The exhaust air flow erosion conditions have not been investigated in detail.

The composite results from the characterization study performed on the radiologically contaminated north wall core sections do not conclusively demonstrate a change in compressive strength relative to the mean compressive strength of the unaffected north wall measured in 2017. That is, several depth-dependent material changes were observed, however there is no firm case to conclude that these material changes were manifested in an increase or a decrease from the bulk concrete compressive strength.

8.0 References

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Appendix A. Radiologically Contaminated North Wall Concrete Cores - Field Alkalinity Test Photographs

SRNL performed the alkalinity dye test (phenolphthalein color indicator tests) at a field location in H-Area shortly after each core was removed from the wall. The images in this section show the results of the alkalinity dye test for the radiologically contaminated north wall cores. If the area to which the dye was applied remains pink to red, the pH of the concrete is greater than 10. The brighter and redder the color, the higher is the pH. If the dyed area is not stained pink, the concrete pH is less than 8.2.



Figure A-1. Field Alkalinity Test on Core N-3-D.



Figure A-2. Field Alkalinity Test on Core N-4-D

Appendix B. Radiologically Contaminated North Wall Concrete Cores - UPV Inspection Sheets.

•	H-Canyon / North Wall Concrete Cores				-	Examiner.	Ji	Jason N Corley			INDE JOD #.	H20170369			
Number of Samples:		1 Core	Sample		-	Date:	A	oril 26th, 20	17	NC	E Report #:	20)17-IR-11-0	382	
		C													
Direct Transmission Cro 221-H-PT3-N-1D	oss Sectional 0° - 180°	Scans	1"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"	7"	8"	Average	
Transmission Time	0 100	21.1	20.5	24.1	24.3	23	24.2	23.4	23.1	22	22.8	22.8	N/A	22.8	
Distance (ft)		0.312	0.314	0.314	0.310	0.312	0.314	0.315	0.314	0.314	0.312	0.311	N/A	0.313	
Pulse Velocity (ft/s)		14787	15317	13029	12757	13565	13029	13462	13593	14273	13684	13640	N/A	13740	
Physical Measurement	(in)	3.745	3.765	3.765	3.725	3.745	3.765	3.755	3.762	3.770	3.745	3.735	N/A	3.753	
		TU	NNEL SIDE D	ISCOLORATI	ON						FR	ACTURED E	ND		
Direct Transmission Cro	oss Sectional	Scans													
221-H-PT3-N-1D	90° - 270°	1/2"	1"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"	7"	8"	Average	
Transmission Time		20.5	20.8	23.9	24.3	24.2	23.5	23.1	22.3	23.2	24.8	25.6	N/A	23.3	
Distance (ft)		0.311	0.312	0.311	0.310	0.311	0.311	0.311	0.311	0.311	0.310	0.312	N/A	0.311	
Pulse Velocity (ft/s)		15171	15000	13013	12757	12851	13234	13463	13946	13405	12540	12188	N/A	13415	
Physical Measurement	: (in)	3.730	3.740	3.730	3.725	3.730	3.730	3.728	3.732	3.732	3.720	3.740	N/A	3.730	
		TU	NNEL SIDE D	ISCOLORATI	ON				r		FR	ACTURED E	ND	Overall Av	
		05	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0		
Position (in)		0.5	-	-											
Position (in) Average (ft/s)		14979	15159	13021	12757	13208	13132	13463	13770	13839	13112	12914		13577	
Position (in) Average (ft/s) 18000 16000 14000 14000 12000 12000 1000000 100000 10000 10000 10000 1000		0.3	15159	13021	12757	13208	13132	13463	13770	13839	13112	12914		13577	
Position (in) Average (ft/s) 18000 16000 14000 14000 12000 10000 10000 4000 2000 0 0 0		0.3 14979	15159	13021	12757	13208	<u>13132</u>	13463	2	13839	<u>13112</u>	12914		13577	
Position (in) Average (ft/s) 18000 16000 14000 14000 12000 12000 0 0 0 0 0 0 0		0.3 14979	15159 15159	13021	12757	13208		13463	13770	13839		12914		13577	
Position (in) Average (ft/s) 18000 16000 14000 12000 12000 10000 4000 2000 0 0 0 0 0 0 0 0 0		0.3 14979	15159 0.2	13021	12757	13208	13132	13463	13770	13839 	<u>13112</u>	12914		13577	

Area / System:	H-Canyo	I-Canyon / North Wall Concrete Cores				H-Canyon / North Wall Concrete Cores Exa						ason N Corl	ey	_	NDE Job #:		H20170369		
Number of Samples:		1 Core Sample			-	Date:			April 20th, 2017			20	2017-IR-11-038						
Direct Transmission	Cross Sectior	nal Scans																	
221-H-PT3-N-2C	0° - 180°	1/2"	1"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"	7"	8"	Average					
Transmission Time		32.8	33	37.2	33.9	34	34.5	32.9	32.9	32.5	38.3	39.2	N/A	34.7					
Distance (ft)		0.471	0.471	0.473	0.472	0.471	0.472	0.473	0.473	0.473	0.472	0.471	N/A	0.472					
Pulse Velocity (ft/s)		14351	14264	12708	13915	13874	13673	14368	14368	14545	12317	12009	N/A	13672					
Physical Measureme	nt (in)	5.650	5.655	5.673	5.660	5.655	5.660	5.668	5.670	5.679	5.668	5.665	N/A	5.670					
		TUI	NEL SIDE D	ISCOLORAT	TION						FRACTURED END								
Direct Transmission	Cross Section	nal Scans																	
221-H-PT3-N-2C	90° - 270°	1/2"	1"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"	7"	8"	Average					
Transmission Time		33.1	33.2	33.5	34.3	41.2	34.2	33.4	35.9	41.1	43	N/A	N/A	36.3					
Distance (ft)		0.471	0.472	0.471	0.471	0.471	0.471	0.471	0.471	0.471	0.471	N/A	N/A	0.471					
Pulse Velocity (ft/s)		14178	14208	14051	13724	11427	13764	14093	13112	11454	10948	N/A	N/A	13096					
Physical Measureme	nt (in)	5.652	5.658	5.655	5.654	5.655	5.652	5.650	5.654	5.658	5.657	N/A	N/A	5.655					
TUNNEL SIDE DISCOLOR					TION						FRACTURED END			Overall Avera					
Position (in)		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0						
Average (ft/s)		14265	14236	13380	13820	12651	13719	14231	13740	13000	11633	12009		13398					



Area / System:	H-Canyo	Canyon / North Wall Concrete Cores				Examiner:	Ja	Jason N Corley			NDE Job #:			H20170369		
Number of Samples:		1 Core	Sample		-	Date:	N	lay 30th, 20	17	ND	E Report #:	20	17-IR-11-C	382		
					-	-				-						
Direct Transmission C	ross Sectior	nal Scans	-		-			1	7	1	1					
21-H-PT3-N-3D	0° - 180°	1/2"	1"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"	7"	8"	Average		
ransmission Time		N/A	20.1	20.5	21.7	25.2	25.8	26.6	26.4	24.9	25.6	25.6	N/A	24.2		
istance (ft)		N/A	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.311	0.311	N/A	0.310		
ulse Velocity (ft/s)		N/A	15423	15122	14286	12302	1 201 6	11654	11742	12450	12109	12109	N/A	12921		
hysical Measuremen	it (in)	N/A	3.723	3.721	3.721	3.721	3.721	3.721	3.721	3.721	3.730	3.726	N/A	3.723		
TUNNEL SIDE DISCOLORA			ION						FR	ACTURED E	ND					
irect Transmission C	ross Sectior	nal Scans				-		-						-		
21-H-PT3-N-3D	90° - 270°	1/2"	1"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"	7"	8"	Average		
ansmission Time		21.4	20.7	21.1	22	22.9	24.1	23.3	24.1	23.9	N/A	N/A	N/A	22.6		
istance (ft)		0.311	0.311	0.310	0.310	0.310	0.310	0.310	0.310	0.310	N/A	N/A	N/A	0.310		
ulse Velocity (ft/s)		14486	14976	14692	13091	13537	12863	13305	12863	12971	N/A	N/A	N/A	13643		
hysical Measuremen	it (in)	3.728	3.728	3.721	3.721	3.721	3.721	3.724	3.725	3.734	3.742	N/A	N/A	3.727		
		TUN	INEL SIDE D	ISCOLORAT	ION						FRACTURED END			Overall Ave		
osition (in)		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0			
verage (ft/s)		14486	15200	14907	13689	12920	12440	12480	12303	12711	12109	12109		13263		
18000 - 16000 - 14000 - 12000 - 12000 - 10000 - 8000 - 4000 -	•••		•							•			-			
2000 -		1.0 -	C	- D.7	3.0 -	C	D.44	5.0 -		- 0.9	7.0 -		8.0			
					Positi	on relative to	o exposure	(inches)								
							-	-		 0° - 1	180°					
										→ 90° -	270°					

Area / System:	H-Cany	on / North \	Wall Concret	e Cores		Examiner:	J	ason N Corle	ו N Corley		NDE Job #:		H20170369		
Number of Samples:		1 Core Sample				Date: May 3		1ay 30th, 201	30th, 2017		NDE Report #:		2017-IR-11-038		
Direct Transmission Cro	oss Sectional	Scans				0.4/01	- "			- "		_"			
21-H-PT3-N-4D	0° - 180°	1/2"	1"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"	7"	8"	Average	
ransmission Time		21.7	21.6	22.4	22	20.3	20	23	25.5	24.5	24.1	N/A	N/A	22.5	
Distance (ft)		0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.311	N/A	N/A	0.310	
Pulse Velocity (ft/s)		14286	14352	13839	14091	15271	15500	13478	12157	12653	12863	N/A	N/A	13849	
hysical Measurement	(in)	3.720	3.720	3.721	3.721	3.725	3.725	3.725	3.725	3.725	3.730	N/A	N/A	3.726	
TUNNEL SIDE DISCOLORAT			ON						FR	ACTURED E	ND				
Direct Transmission Cro	oss Sectional	Scans													
21-H-PT3-N-4D	90° - 270°	1/2"	1"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"	7"	8"	Average	
ransmission Time		21.7	21.6	22.4	22	20.3	20	23	25.5	24.5	24.1	N/A	N/A	22.5	
Distance (ft)		0.313	0.313	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	N/A	N/A	0.311	
Pulse Velocity (ft/s)		15196	15347	14486	13478	12757	12500	12253	12500	12450	12450	N/A	N/A	13342	
Physical Measurement	(in)	3.755	3.755	3.721	3.721	3.721	3.721	3.721	3.721	3.721	3.721	N/A	N/A	3.721	
		TU	INNEL SIDE D	ISCOLORATI	ON						FR	ACTURED E	ND	Overall A	
Position (in)		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0		
Average (ft/s)		14741	14850	14163	13785	14014	14000	12866	12329	12552	12657			13595	
Velocity (ft/second)	18000 16000 14000 12000 10000 8000 6000 4000			•			•	-							
	2000	, ,	- D.	2.0 -	0. E Position	n relative to ex	o vposure (inc	- 0'5 hes)	6.0	-∎ -0° - 180 -→ 90° - 27	00° - م	8.0			

Area / System:	H-Cany	on / North \	Wall Concret	e Cores	_	Examiner:	J	Jason N Corley			NDE Job #:	H20170369			
Number of Samples:		2 Core	Samples		Date: May 18th, 2017					N	DE Report #:	2017-IR-11-0382			
Direct Transmission Cr	occ Soctional	Scane													
221-H-PT3-N-5C	0° - 180°	1/2"	1"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"	7"	8"	Average	
Transmission Time		31.6	31.6	32.8	36	34.8	34.3	34.9	35.4	35.1	39.8	38.5	36.9	35.1	
Distance (ft)		0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.454	0.458	0.469	
Pulse Velocity (ft/s)		14937	14937	14390	13111	13563	13761	13524	13333	13447	11859	11792	12412	13422	
Physical Measurement	: (in)	5.660	5.660	5.660	5.660	5.660	5.660	5.660	5.665	5.665	5.660	5.448	5.499	5.630	
		TU	NNEL SIDE D	ISCOLORAT	ION						FF	FRACTURED END			
Direct Transmission Cr	oss Sectional	Scans													
21-H-PT3-N-5C	90° - 270°	1/2"	1"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"	7"	8"	Average	
Transmission Time		32.2	32.9	33.4	35.5	36.6	36	35.8	35.9	38	36.6	37.8	37.8	35.7	
Distance (ft)		0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.472	0.456	0.456	0.457	0.468	
Pulse Velocity (ft/s)		14658	14347	14132	13296	12986	13111	13184	13148	12421	12896	12487	12487	13263	
Physical Measurement	: (in)	5.660	5.660	5.660	5.660	5.658	5.658	5.665	5.660	5.660	5.473	5.474	5.484	5.614	
		TU	NNEL SIDE D	ISCOLORAT	ION						Ff	RACTURED E	ND	Overall Av	
Position (in)		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0		
Average (ft/s)		14798	14642	14261	13204	13275	13436	13354	13241	12934	12378	12140	12450	13342	
18000 16000 14000 12000 10000 10000 4000 2000				***								one area t to ultrason transmissi revealed a of 23.5 an 13404.	hat was su nic pulse on. This a transimise d a pulse v	sceptible rea sion time elocity	
0.0	1.0 -	((- 0.7	3.0	4.0 -	5.0 -	- 0.9	0	0.	8.0					
			I	Position rela	tive to expo	sure (inches)	-	■—0° - 180° ◆—90° - 270	•						

Appendix C. X-Ray Diffraction Powder Patterns for Radiologically Contaminated North Wall Concrete Cores.



Figure C-1. XRD Pattern for Core N-1-D Surface.



Figure C-2. XRD Pattern for Core N-1-D 1 to 1.5 inches.



Figure C-3. XRD Pattern for Core N-1-D 1 to 1.5 inches.



Figure C-4. XRD Pattern for Core N-1-D 1.5 to 2 inches.



Figure C-5. XRD Pattern for Core N-1-D 6 inches.



Figure C-6. XRD Pattern for Core N-2-C Surface.



Figure C-7. XRD Pattern for Core N-2-C 0 to 0.5 inches.



Figure C-8. XRD Pattern for Core N-2-C 0.5 to 1 inch.



Figure C-9. XRD Pattern for Core N-2-C 1 to 1.5 inches.



Figure C-10. XRD Pattern for Core N-2-C 7 inches.


Figure C-11. XRD Pattern for Core N-3-D 0 to 0.025 inches.



Figure C-12. XRD Pattern for Core N-3-D 0.5 to 0.75 inches.



Figure C-13. XRD Pattern for Core N-3-D 1.5 to 2 in.



Figure C-14. XRD Pattern for Core N-3-D 1 to 1.5 in.



Figure C-15. XRD Pattern for Core N-3-D 2 to 2.5 in.



Figure C-16. XRD Pattern for Core N-3-D 2.5 to 3 in.



Figure C-17. XRD Pattern for Core N-3-D 3 to 4 in.



Figure C-18. XRD Pattern for Core N-3-D 5 inches.



Figure C-19. XRD Pattern for Core N-3-D 6 inches.



Figure C-20. XRD Pattern for Core N-3-D 7 inches.



Figure C-21. XRD Pattern for Core N-3-D 6 to 7 in.



Figure C-22. XRD Pattern for Core N-4-D Surface.



Figure C-23. XRD Pattern for Core N-4-D 0.5 inches.



Figure C-24. XRD Pattern for Core N-4-D 1 inch.



Figure C-25. XRD Pattern for Core N-4-D 1.5 inches.



Figure C-26. XRD Pattern for Core N-4-D 2 inches.



Figure C-27. XRD Pattern for Core N-4-D 2.5 inches.



Figure C-28. XRD Pattern for Core N-4-D 3 inches.



Figure C-29. XRD Pattern for Core N-4-D 5 inches.



Figure C-30. XRD Pattern for Core N-4-D 6 inches.



Figure C-31. XRD Pattern for Core N-4-D 7 inches.



Figure C-32. XRD Pattern for Core N-5-C Surface.



Figure C-33. XRD Pattern for Core N-5-C 0.25 to 0.5 inches.



Figure C-34. XRD Pattern for Core N-5-C 0.5 to 0.75 inches.



Figure C-35. XRD Pattern for Core N-5-C 0.75 to 1 inch.



Figure C-36. XRD Pattern for Core N-5-C 1 to 1.5 inches.



Figure C-37. XRD Pattern for Core N-5-C 1.5 to 1.75 inches.



Figure C-38. XRD Pattern for Core N-5-C 2 inches.



Figure C-39. XRD Pattern for Core N-5-C 4 inches.



Figure C-40. XRD Pattern for Core N-5-C 5 inches.



Figure C-41. XRD Pattern for Core N-5-C 6 inches.



Figure C-42. XRD Pattern for Core N-5-C 7 inches.



Figure C-43. XRD Pattern for Core N-5-C 8 inches.



Figure C-44. XRD Pattern for Core N-5-C 9 inches.

Appendix D. Non-Radiologically Contaminated North Wall Concrete Cores - UPV Data Sheets

1/13/17 Harea concrete Rebar embedded at position #3

Transmission Time 22.21s 2.1.4 2.2.1 Distance 0.3080 0.310 0.3103 Pluse Velocity Compressive Strength 13964 14496 14027 Pluse Velocity 12964 14027 Compressive Strength 3.717 3.720 3.724 3.74 5.6 7 Provision Measurement 3.717 3.720 3.74 0.474 0.4715 0.473 0.473 0.474 0.4715 0.473 0.474 0.4715 0.4743 0.4773 0.473	PT3-5-4-CC	1	2	3	4	5	6	7	
Distance 0.3068 0.310 0.303 Pulse Velocity 13967 14486 14627	Transmission Time	22,245	21.4	22.1]
Pulse Velocity 13964 14486 14527 Compressive Strength	Distance	0.3098	0-310	0.3103					
Compressive Strength Second Strength Seco	Pulse Velocity	13964-	14486	14027					
E-Modulus 3.717 3.720 3.724 1 Physical Measurement 3.717 3.720 3.724 1 2 3 4 5 6 7 Transmission Time 33.91 37.9 37.3 37.8 39.6 30.4 37.5 0.473	Compressive Strength								
Physical Measurement 3.717 3.720 3.724 Image: constraint of the strength of	E-Modulus								
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	Physical Measurement	3.717	3.720	3.724					1
Transmission Time $38,71$ $37,9$ $39,3$ $39,6$ $39,6$ $39,6$ $39,6$ $39,75$ $37,5$ $37,5$ $37,5$ $37,5$ $37,5$ $37,5$ $37,5$ $37,5$ $37,5$ $37,5$ $37,5$ $37,5$ $327,5$ $37,5$ <t< td=""><td>PT3-N-2-B</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td></td></t<>	PT3-N-2-B	1	2	3	4	5	6	7	
Distance 0.473 0.473 0.474 0.4745 0.473	Transmission Time	38,9	37.9	39.3	39.8	39.6	30.9	37.5	1
Pulse Velocity 12 159 12 420 12 420 14 935 14 944 11 795 12 613 Compressive Strength -	Distance	0.473	0.473	0.474	0.4745	0.473	D.473	0,473	
Compressive Strength -	Pulse Velocity	12159	12480	12092	11935	11944	11795	12613	1
E-Modulus S. 675 5.680 5.694 5.680 5.670 5.675 q a q b $(0 t)$ 4 5 6 7 Transmission Time 38.4 44.6^+ 43.5 $ -$ Distance 0.472 0.472 $ -$ Pulse Velocity 12350 11425 (0251) $ -$ Compressive Strength $ -$ Physical Measurement 5.630 5.672 $ -$ Physical Measurement 5.630 5.672 $ -$ Physical Measurement 5.630 5.672 22.5 22.5 22.9 23.8 $ -$ Distance 0.311 0.311 0.311 0.311 0.311 0.511 $ -$	Compressive Strength	2							
Physical Measurement 5,675 5,600 5,699 5,694 5,680 5,670 5,675 G, \$ 9 \$ (0 \$ 4 5 6 7 Transmission Time 33.4 41.6^4 43.5 - - - Puise Velocity 12,35,0 11,42.5 0,477. -	E-Modulus								
q q <td>Physical Measurement</td> <td>5.675</td> <td>5.680</td> <td>5,689</td> <td>5.694</td> <td>5.680</td> <td>5.670</td> <td>5.675</td> <td></td>	Physical Measurement	5.675	5.680	5,689	5.694	5.680	5.670	5.675	
Transmission Time 38.4 $4+6+$ 43.5 Image: constraint of the system of the sy		33	98	OF	4	5	6	7	
Distance 0.473 0.473 0.472 1 Puise Velocity 12350 11425 10951 <	Transmission Time	38.4	41.4	43.5					
Pulse Velocity 12350 11425 10951 F 11964 Compressive Strength	Distance	0.473	OA73	0,472					
Compressive Strength Image: Compressive Strength Imag	Pulse Velocity	12350	114-25	0851					r 11964
E-Modulus 5.680 5.678 5.672	Compressive Strength								
Physical Measurement 5.630 5.678 5.672 Image: Constraint of the second s	E-Modulus								
PT3-N-1-B 1 2 3 4 5 6 7 Transmission,Time 25.7 22.5 22.5 22.9 23.8 0.311 <	Physical Measurement	5.680	5.678	5.672					
Transmission Time 2.5.7 22.5 22.5 22.9 23.8 Distance 0.311	PT3-N-1-B	1	2	3	4	5	6	7	
Distance 0.311	Transmission Time	25.7	22.5	22.5	225	2209	23.8		
Pulse Velocity [2.10] 3822 13822 13822 13663 13067 1334* Compressive Strength	Distance	0.311	0.311	0.311	0.311	0.311	0.311		
Compressive StrengthImage: constraint of the strengthImage: constraint of the strengthE-Modulus3.72.63.73.03.73.03.73.03.73.2Physical Measurement3.72.63.73.03.73.03.73.21234567Transmission TimeImage: constraint of the strengthImage: constraint of the strengthImage: constraint of the strengthDistanceImage: constraint of the strengthImage: constraint of the strengthImage: constraint of the strengthE-ModulusImage: constraint of the strengthImage: constraint of the strengthImage: constraint of the strengthDistanceImage: constraint of the strengthImage: constraint of the strengthImage: constraint of the strengthDistanceImage: constraint of the strengthImage: constraint of the strengthImage: constraint of the strengthPulse VelocityImage: constraint of the strengthImage: constraint of the strengthImage: constraint of the strengthE-ModulusImage: constraint of the strengthImage: constraint of the strengthImage: constraint of the strengthE-ModulusImage: constraint of the strengthImage: constraint of the strengthImage: constraint of the strengthE-ModulusImage: constraint of the strengthImage: constraint of the strengthImage: constraint of the strength	Pulse Velocity	12101	3322	13822	13822	13463	13067		1334
E-Modulus 3.72.6 3.73.0 3.73.0 3.73.0 3.73.2 Physical Measurement 3.72.6 3.73.0 3.73.0 3.73.0 3.73.2 1 2 3 4 5 6 7 Transmission Time	Compressive Strength								
Physical Measurement 3.72.6 3.73.0 3.73.0 3.73.0 3.73.2 1 2 3 4 5 6 7 Transmission Time <td>E-Modulus</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	E-Modulus								
1 2 3 4 5 6 7 Transmission Time Distance	Physical Measurement	3.726	3.730	3.730	3,730	3.730	3.732		
Transmission Time Image: constraint of the system of t		1	2	3	4	5	6	7	
Distance Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength 1 2 3 4 5 6 7 Transmission Time Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength	Transmission Time								
Pulse Velocity Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Physical Measurement Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength	Distance								
Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength	Pulse Velocity								
E-Modulus Image: Constraint of the second secon	Compressive Strength								
Physical Measurement I I I I 1 2 3 4 5 6 7 Transmission Time I I I I I I Distance I I I I I I Pulse Velocity I I I I I Compressive Strength I I I I	E-Modulus								
1 2 3 4 5 6 7 Transmission Time	Physical Measurement								
Transmission Time		1	2	3	4	5	6	7	
Distance Pulse Velocity Compressive Strength E-Modulus	Transmission Time								
Pulse Velocity Compressive Strength E-Modulus	Distance								
Compressive Strength E-Modulus	Pulse Velocity								
E-Modulus	Compressive Strength						-		
	E-Modulus								
Physical Measurement	Physical Measurement								

D-2

1/13/17 Harea concrete Rebar embedded at position #3

Transmission Time 22.21s 2.1.4 2.2.1 Distance 0.3080 0.310 0.3103 Pluse Velocity Compressive Strength 13964 14496 14027 Pluse Velocity Pluse Velocity E-Modulus 0.717 3.720 3.720 3.724 5.6 7 Physical Measurement 3.717 3.720 3.747 0.474 0.4715 0.473 0.473 0.473 0.474 0.4715 0.473 0.474 0.4715 0.4743	PT3-5-4-CC	1	2	3	4	5	6	7	
Distance 0.3068 0.310 0.303 Pulse Velocity 13967 14486 14627	Transmission Time	22,245	21.4	22.1]
Pulse Velocity 13964 14486 14527 Compressive Strength	Distance	0.3098	0-310	0.3103					
Compressive Strength Second Strength Seco	Pulse Velocity	13964-	14486	14027					
E-Modulus 3.717 3.720 3.724 1 Physical Measurement 3.717 3.720 3.724 1 2 3 4 5 6 7 Transmission Time 33.91 37.9 37.3 37.8 39.6 30.4 37.5 0.473	Compressive Strength								
Physical Measurement 3.717 3.720 3.724 Image: constraint of the strength of	E-Modulus								
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	Physical Measurement	3.717	3.720	3.724					1
Transmission Time $38,71$ $37,9$ $39,3$ $39,6$ $39,6$ $39,6$ $39,6$ $39,75$ $37,5$ Distance 0.473 0.4772 0.473 0.4772 <	PT3-N-2-B	1	2	3	4	5	6	7	
Distance 0.473 0.473 0.474 0.4745 0.473	Transmission Time	38,9	37.9	39.3	39.8	39.6	30.9	37.5	1
Pulse Velocity 12 159 12 420 12 420 14 935 14 944 11 795 12 613 Compressive Strength -	Distance	0.473	0.473	0.474	0.4745	0.473	D.473	0,473	
Compressive Strength -	Pulse Velocity	12159	12480	12092	11935	11944	11795	12613	1
E-Modulus S. 675 5.680 5.694 5.680 5.670 5.675 q a q <	Compressive Strength	2							
Physical Measurement 5,675 5,600 5,699 5,694 5,680 5,670 5,675 G, \$ 9 \$ (0 \$ 4 5 6 7 Transmission Time 33.4 41.6^{+} 43.5 1 <t< td=""><td>E-Modulus</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	E-Modulus								
q q <td>Physical Measurement</td> <td>5.675</td> <td>5.680</td> <td>5,689</td> <td>5.694</td> <td>5.680</td> <td>5.670</td> <td>5.675</td> <td></td>	Physical Measurement	5.675	5.680	5,689	5.694	5.680	5.670	5.675	
Transmission Time 38.4 $4+6+$ 43.5 Image: constraint of the system of the sy		33	98	OF	4	5	6	7	
Distance 0.473 0.473 0.472 1 Puise Velocity 12350 11425 10951 <	Transmission Time	38.4	41.4	43.5					
Pulse Velocity 12350 11425 10951 F 11964 Compressive Strength	Distance	0.473	OA73	0,472					
Compressive Strength Image: Compressive Strength Imag	Pulse Velocity	12350	114-25	0851					r 11964
E-Modulus 5.680 5.678 5.672	Compressive Strength								
Physical Measurement 5.630 5.678 5.672 Image: Constraint of the second s	E-Modulus								
PT3-N-1-B 1 2 3 4 5 6 7 Transmission,Time 25.7 22.5 22.5 22.9 23.8 0.311 <	Physical Measurement	5.680	5.678	5.672					
Transmission_Time 2.5.7 22.5 22.5 22.9 23.8 Distance 0.311	PT3-N-1-B	1	2	3	4	5	6	7	
Distance 0.311	Transmission Time	25.7	22.5	22.5	225	2209	23.8		
Pulse Velocity [2.10] 3822 13822 13822 13663 13067 1334* Compressive Strength	Distance	0.311	0.311	0.311	0.311	0.311	0.311		
Compressive StrengthImage: compressive StrengthImage: compressive StrengthE-Modulus3.72.63.73.03.73.03.73.03.73.2Physical Measurement3.72.63.73.03.73.03.73.23.73.2Transmission Time1234567DistanceImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthE-ModulusImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthDistanceImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthDistanceImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthPulse VelocityImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthE-ModulusImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthE-ModulusImage: compressive StrengthImage: compressive StrengthImage: compressive StrengthImage: compressive Strength	Pulse Velocity	12101	3322	13822	13822	13463	13067		1334
E-Modulus 3.72.6 3.73.0 3.73.0 3.73.0 3.73.2 Physical Measurement 3.72.6 3.73.0 3.73.0 3.73.0 3.73.2 1 2 3 4 5 6 7 Transmission Time	Compressive Strength								
Physical Measurement 3.72.6 3.73.0 3.73.0 3.73.0 3.73.2 1 2 3 4 5 6 7 Transmission Time <td>E-Modulus</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	E-Modulus								
1 2 3 4 5 6 7 Transmission Time Distance	Physical Measurement	3.726	3.730	3.730	3,730	3.730	3.732		
Transmission Time Image: constraint of the system of t		1	2	3	4	5	6	7	
Distance Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength 1 2 3 4 5 6 7 Transmission Time Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength	Transmission Time								
Pulse Velocity Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Physical Measurement Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength	Distance								
Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength	Pulse Velocity								
E-Modulus Image: Constraint of the second secon	Compressive Strength								
Physical Measurement I I I I 1 2 3 4 5 6 7 Transmission Time I I I I I I Distance I I I I I I Pulse Velocity I I I I I Compressive Strength I I I I	E-Modulus								
1 2 3 4 5 6 7 Transmission Time	Physical Measurement								
Transmission Time		1	2	3	4	5	6	7	
Distance Pulse Velocity Compressive Strength E-Modulus	Transmission Time								
Pulse Velocity Compressive Strength E-Modulus	Distance								
Compressive Strength E-Modulus	Pulse Velocity								
E-Modulus	Compressive Strength						-		
	E-Modulus								
Physical Measurement	Physical Measurement								

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Appendix E. Non-Radiologically Contaminated North Wall Concrete Cores - Compressive Strength, Porosity, and Density Data Sheets

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ASR 18-203 (04/13)

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Savannah River Site

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Repor	rt	X	Cover She	et		Page	<u>1</u> of <u>3</u>
Approvals (If required)		Work	Package No.		152	5456	
Senior Civil Technician (Level III):		QCIR	No.:		N/A		
Charles A. Bookhamer		Projec	t No.:		N/A		
Civil Testing & Inspection Superintendent:		Design	Category:	CAB 1-1	1-17 €	18 SC	
W. Pope, Jr.		Report	: No.: 20	016-CAEX-0	011	Date:	12-29-16
Lab. No.: 160104	Test M	ethod:		See atta	ched pag	ges	
Discipline: Civil	Des	cription	:	С	oncrete	•	
Location: 221H Personnel Tunnel 3 Nort	h Wall		Reported to	0:	J. Car	ter, 8-172	27
ASTM C642-13 covering the determination of de Line 7 on page 2 references Sample ID 221H-PT3 See page 3 for the results of "Compressive Stren are provided in the page 3 Remarks Section. All information in this report is from core segmen	ensity, pero 3-N-1CC for agth of Dril nts from se	cent absorber this r lled Cor ample lo	eport. es". Also no 22/ cation 22111	percent void	is in hard ities of th $-\lambda I - I$ 3 - 2 2 - 1	dened con he core se -17 W.	ncrete. gments P.
M&TE: See attached pages Cal. Due Date:	See a	ttached	pages	Procedure		C-OCP-	.002
NCR No.: N/A		2	,	Rev			
Fest Conforming Non	conformin	g	*X _{N/A}	PCN(s):		 N/A	
Remarks: * For engineering evaluation		4		Spec.:	Si	ESA ERS-11-0 - 1-12-	0044
13/73				D		0	
11/7				Rev.:			
				DCF(s):		N/A	
Fechnician (Print/Sign): Charles A. Bookhamer/	"harles .	1.Rn	Merur	DCF(s):	II Da	N/A ate:	1-11-17

ASR 18-250 (04/13)

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Savannah River Site

Summary Report of Testing Activities (Continuation Sheet)

Page $\frac{2}{100}$ of $\frac{3}{100}$

Report Title: 221H Personnel Tunnel 3 North Wall Report No.: 2016-CAEX-0011 Item # Summary 18.0 20.1 17.8 ള 19.2 18 19.0 8 2.34 2.32 2.33 2.34 2.32 2.34 2.36 BDAIB le/cm² VPP = Volume of permeable pore speac (voids) [%] AAIB = Absorption after immersion and boiling [g] BDAIB = Bulk density after immersion and boiling Density, Absorption, and Voids in Hardened Concrete 2.32 2.30 2.34 2.33 2.32 2.32 le/cm² BDAI AAI = Absorption after immersion [%] BDAI = Bulk density after immersion 8.7 80 9.5 83 8.2 9.1 AAIB 8 7.9 8.5 7.3 S. 8.2 7.8 g₂ = Apparent Density g₁ = Bułk density, dry ₹ 8 1.00 1.00 00 8 8 1.0 8 BDAIB = [C/(C-D)] X p BDAI = [B/(C-D)] X p % = (g₂ - g₁)/g₂ x 100 % = [(C-A)/A] X 100 % = [(B-A)/A] X 100 E/cm g₁ = [A/(C-D)] Χρ g₂ = [A/(A-D)] X p a 2.65 2.65 2.64 2.65 2.65 2.64 2.65 ຼີ ພ 2.14 2.15 2.15 2.12 2.16 2.18 , m g 712.6 698.5 783.5 D = apparent mass of sample in water after immersion and boiling [g] 1034.2 1324.2 597.5 C = mass of surface-dry sample in air after immersion and boiling [g] 1042.7 6 1051.06 1822.62 2314.88 1251.99 1811.47 3110.20 1213.60 B = mass of surface-dry sample in air after immersion [g] a 1807.66 2295.52 /olume of permeable pore space (voids) [%] 1243.83 1041.49 3082.55 1205.50 1797.27 Absorption after immersion and boiling [g] ā Bulk density after immersion and boiling $B_2 = aparent bulk density, Mg/m³, or g/cm³$ $\rho = \text{density of water} = 1 \text{ Mg/m}^3 = 1 \text{ g/cm}^3$ A = mass of oven-dried sample in air [g] $B_1 = bulk density, dry, Mg/m³, or g/cm³$ 1143.25 1660.96 1676.66 2127.10 1121.66 959.79 2871.57 Absorption after immersion [%] 6 4 Bulk density after immersion *221H-PT3-N- 50C 221H-PT3-N-60C *221H-PT3-N-40C 221H-PT3-N-4CC 221H-PT3-N-5BB 221H-PT3-N-2CC 221H-PT3-N-1CC Bulk density, dry Apparent Density * Over Core Sample ID ine. ŝ LC **Comments:**

Savannah River Site

Page 3 of 3

	ASTM C 39- (14) ASTM C 42-(13) ASTM C 617-(12)											
Report No.: 2016-CAEX-0011 Project No.: N/A Work Package No.: 152										D	esign Cat.:	SC
QCIR No.:	N/A	<u> </u>	Date & Time (Core Taken:	12-29-16 @]	N/A C	oncrete Suppli	ier: <u>N/</u> 4	Plac	ement D	ate:1	952
Placement L	ocation:	221H- Sec	tion 3, Personn	el Tunnel North	Wall Mix I	Design: _	<u>N/A</u>	Design	Strength:	2500	psi @N/A	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Leve}
160104	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-1-A	5	1-3-17	7.16	7.36	3.73	10.93	27085	1.97	1.00	2480	2480	LOS TIE
N-1-C	5	1-3-17	7.08	7.29	3.74	10.99	25094	1.95	1.00	2280	2280	Las TIL
A												
						N						
												1
Direction of A	Applicatio	on of the L	oad on the Sp	ecimen with R	espect to the I	Iorizonta	l Plane of the	Concrete Place	ed:		N/A	
Nominal Ma	iximum Si	ize of Aggı	egate:	<u> </u>	N/A			Method of T	est:	N/A		
M&TE:							Cal. Due Dat	e:				
		<u></u>	1) CA-002; 2) 7	M-5					1) 9-23-17; 2) 1-12-17	5445	
Test Results:		Conformin	g 🗌	Nonconformi	ng *X] N/A	NCR No.:		1	∛/A		
Remarks: *Fo	or Engineer	ing Evalua	tion. Dens	ity of Cores foll	ows:		Procedure:	C-QCP	-002	Rev.:	0 PCN(s)	1: N/A
221H-PT3	-N-1-A = 1	44 pcf; 221]	H-PT3-N-1-B =	143 pcf; 221H-	PT3-N-1-C <mark>= 14</mark>	l <mark>1 p</mark> cf;	Spec.: C	-ESR-H-00044	Rev.: 0	DCI	F(s):	N/A
Note, Sample	221H-PT3-	N-1-B was	given to SRNL	for testing.			Dwg(s):	N/A	Rev.: N/.	A DCI	?(s):	N/A
lechnician (Print/Sign	I): Glenn C	. Spencer/	Ale	-15	17			Lev	el: <u>I</u>	II Date	: 1-3-17
Reviewer (P	rint/Sign)	: Charles	A. Bookhamer/	Charles	a-6 100	then	n		Lev	el:	II Date	: <u>1-11-17</u>

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Savannah River Site

Summery Report of Acoung Meeting	Summary	Report	of Testing	Activities
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(Report	X Cover	Sheet	Page 1 of 3							
Approvals (If req	uired)	Work Package	No.:	1525456							
Senior Civil Technician (Level III):		QCIR No.:	N/A								
Charles A. Bookhamer		Project No.:	N	I/ A							
Civil Testing & Inspection Superintende	nt:	Design Categor	SY: CAB 1-11-17	68 SC							
W. Pope, Jr.		Report No.:	2016-CAEX-0010	Date: 12-27-16							
Lab. No.: 160103	Test Me	ethod:	See attached	pages							
Discipline: Civil	Des	cription:	Concre	ete							
Location: 221H Personnel Tun	nel 3 North Wall	Report	ed to: J.	Carter, 8-1727							
Summary. Inis report presents the data required by the H-Area CAEA funnel Concrete Core Sampling Plan, C-ESR-H-00044, Revision 0. Page 2 contains a spreadsheet for data and results provided by the calculations of ASTM C642-13 covering the determination of density, percent absorption, and percent voids in hardened concrete. Line 6 on page 2 references Sample ID 221H-PT3-N-2CC for this report. See page 3 for the results of "Compressive Strength of Drilled Cores". Also note, the densities of the core segments are provided in the page 3 Remarks Section. 221 H - PT 3 - N - 2. All information in this report is from core segments from sample location 221H-PT3-S-2: B-22-17 to P.											
M&TE: See attached pages Cal.	Due Date: See a	ttached pages	Procedure:	C-QCP-002							
NCK No.: 			Rev.:	0							
Results: Conforming	Nonconformin	g X N/	A PCN(s):	N/A							
Remarks: * For engineering evaluation			Spec.:	ESA C-ERS-H-00044							
N/	A	······		0							
	<u>, , , , , , , , , , , , , , , , , , , </u>		DCF(s):	N/A							
Technician (Print/Sign): Charles A. Bool	chamer Suche le	Brokhama	Level: III	Date: 1-11-17							
Reviewer (Print/Sign): Charles Z. Moo	re/ 0 2. CZM 1.	n	Level: II Km II 8	Date: 1.11-17 22-17							

ASR 18-250 (04/13)

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Savannah River Site

Summary Report of Testing Activities (Continuation Sheet)

Page 2 of 3

221H Personnel Tunnel 3 North Wall **Report Title:** 2016-CAEX-0010 Report No.: Item # Summary 18.0 17.8 19.0 20.1 ยู่ 2 120 \$.33 2.34 2.34 2.32 2.34 2.36 3 BDAIB [g/cm³ VPP = Volume of permeable pore speac (voids) [%] AAIB = Absorption after immersion and boiling [g] BDAIB = Bulk density after immersion and boiling Density, Absorption, and Voids in Hardened Concrete 2.32 2.32 2.30 2.34 2.31 2.32 2.31 E/cm³ **BDAI** AAI = Absorption after immersion [%] BDAI = Bulk density after immersion 80.00 9.5 9.1 8.7 8.3 8.2 AAIB 8 00 5.9 8.5 7.3 7.5 28 $g_1 = Bulk density, dry$ g₂ = Apparent Density ¥ 1.8 8 8 10 8 1.00 BDAIB = [C/(C-D)] X p8 BDAI = [B/(C-D)] X p% = (g₂ - g₁)/g₂ x 100 % = [(B-A)/A] X 100 % = [(C-A)/A] X 100 ່ຮ g1 = [A/(C-D)] X p g₂ = [A/(A-D)] X ρ c 2.65 2.64 2.65 2.65 2.65 59 2.64 E 60 2.14 2.15 2.15 2.12 2.16 2.18 5 υž D = apparent mass of sample in water after immersion and boiling [g] 1034.2 597.5 698.5 1324.2 712.6 C = mass of surface-dry sample in air after immersion and boiling [g]1042 1783. 1822.62 2314.88 3110.20 1251.99 1213.60 1051.06 1811.47 B = mass of surface-dry sample in air after immersion [g] Ξ 1807.66 2295.52 /olume of permeable pore space (voids) [%] 1243.83 1041.49 1205.50 3082.55 1797.27 Absorption after immersion and boiling [g] Bulk density after immersion and boiling œ B $g_2 = aparent bulk density, Mg/m³, or g/cm³$ p = density of water = 1 Mg/m³ = 1 g/cm³ A = mass of oven-dried sample in air [g] $g_1 = bulk density, dry, Mg/m^3$, or g/cm^3 1676.66 959.79 1143.25 1660.96 2127.10 2871.57 1121.66 Absorption after immersion [%] Bulk density after immersion b *221H-PT3-N- 50C 221H-PT3-N-60C *221H-PT3-N-40C 221H-PT3-N-5BB Bulk density, dry Apparent Density 221H-PT3-N-2CC 221H-PT3-N-1CC 221H-PT3-N-4CC * Over Core Sample ID line **Comments:** THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.

1-12-17

Savannah River Site

Page _3_of _3_

		ASTM	C 39- (14	Com	pressive S AST	Strength M C 42-(of Drille	ed Cores	STM C 617-((12)	<u>_</u>	
Report No.:	201	6-CAEX-00	10 Pro	ject No.:	N/A	V	Vork Packa	ge No.:	1525456	De	esign Cat.:	SC
QCIR No.:	N/2	<u> </u>	Date & Time	Core Taken:	12-27-16 @	N/A Co	ncrete Supp	lier:N/A	A Pla	acement Da	ite:1	952
Placement L	ocation:	221H- Sec	tion 3, Personn	el Tunnel Nort	h Wall Mix	Design:	N/A	Design	Strength:	2500	_ psi @N/A	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, Ibs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level
160103	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-2-A	5	1-3-17	10.94	11.30	5.68	25.34	52790	1.99	1.00	2080	2080	CSTI
							1-					
					N					-		
	u											
Direction of A	Applicatio	on of the La	oad on the Sp	ecimen with R	lespect to the l	Horizontal	Plane of the	e Concrete Place	ed:		N/A	
Nominal Ma	ximum S	ize of Aggr	egate:		N/A			Method of T	'est:	N/A		
A&TE:							Cal. Due Da	ite:		······	·····	
			1) CA-002; 2) 1	<u>M-5</u>					1) 9-23-17;	2) 1-12-17		
est Results:		Conformin	g	Nonconformi	ng 🔀	N/A	NCR No.:	COCR	002	N/A David		
Remarks: *Fo	r Enginee	ring Evaluat	tion. Dens	ity of Cores fol	lows:		Spec :	C-QCI-	-002 Bay -): N/A
	221H-	PT3-N-2-A	= 140 pcf; 221E	I-PT3-N-2-B=	141 pcf;				Nev			N/A
Fechnician	Print/Sign	1): Glenn (Spencer/	M .	ior testing.		ראאג(<u>s</u>):	N/A	Kev.: N	A DCF	(s):	N/A
Reviewer (P	rint/Sign)): Charles	A. Bookhamer	Cont.	10 1	A.c.	4		Le		u Date	1.11-17
				-and	a par	and null	1		Le		Date	2: 1-11-11
		THIS REP	ORT SHALL N	OT BE REPROD	UCED, EXCEPT	IN FULL, W	ITHOUT THI	E WRITTEN APPR	OVAL OF THI	E LABORAT	ORY.	

ASR 18-203 (03/17)

System|One Savannah River Site

Summary I	Report	of Tes	ting A	Activities
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		Report	t	X	Cover S	heet		Page	<u>1</u> of <u>2</u>
	Approvals	(If required)		Work	Package N	lo.:	152	5456	
Senior Civil Tech	nician (Level II)	[):		QCIR	No.:		N/A		
Glenn-Spencer Hm 4-6-17	KEVIN MILI	LER	·····	Projec	t No.:		N/A		
Civil Testing & In	nspection Superi	ntendent:		Design	Category	• •	G ∂+	16 -5C	
W. Pope, Jr.			.	Report	No.:	2017-CAEX	K-0003	Date:	3-28-17
Lab. No.:	17002	0	Test M	ethod:		See a	attached pa	ge	
Discipline:	Civ	vil	Des	cription	:		Concrete		
Location:	221H Personn	el Tunnel 3 North	Wall		Reported	l to:	J. Car	ter, 8-172	27
Summary: This C-ESR-H-00044 Also note, the d data required t PHI INFO FROM SA	4, Revision 0. Se ensities of the co by the H-Area C DR mAfion mpla Loca	the data required e pages 2, for the ore segments are p AEX Tunnel Conc ZN This 1 2400 221	by the H results of provided i crete Core REPORT H - PT	-Area C f "Com n the pa e Sampli - Z s - N	AEX Tuni pressive Sf ges 2 This ng Plan, - 3 32	report pres	e Core Sam prilled Core tents the SEG me W.P.	pling Play	
M&TE: See A	ttached Page	Cal. Due Date:	See 4	Attached	l Page	Procedu	ire:	C-QCP-	002
NCR No.:		N/A				Rev.:		0	
Results:	Conformin	g Nonc	onformin	g	*X N/A	PCN(s):		N/A	
Remarks:	* F	or enginnering eva	aluation			- Spec.:	C-	ESR-H-0	0044
	<u>-</u>	NIA	<u>r</u>			Rev.:		0	
	1-11-11-11-1-1-11-1-1-1-1-1-1-1-1-1-1-	<u>~//A</u>	<u>-</u>						
Cechnician (Print/	Sign): Clenn Sn	$\frac{N}{N}$	<u> </u>			Level:	III Da	N/A	43.17
Reviewer (Print/Si	gn): Kevin Mi	iller/ KEVIN	MILLI KM 8	GR -22-17		Level:	Da	ite: <u>4-6</u>	4-3-17 -17
THIS REPORT	SHALL NOT BE RE	EPRODUCED, EXCEP	PT IN FULI	L, WITHO	OUT THE W	RITTEN APP	ROVAL OF T	HE LABOR	ATORY. MA

					Savanr	1ah Rive	r Site				Page 2	of Z.
		4.027		Com	pressive S	trength	of Drille	d Cores				
		AST	MC 39-(14)	ASTI	M C 42-(13)	<u>A</u>	STM C 617-	(12)		
Report No.:	201	7-CAEX-00	<u>03</u> Pro	ject No.:	N/A		Work Packag	e No.:	1525456	D	esign Cat.:	-03-50
QCIR No.:	N/	A]	Date & Time	Core Taken:	3-28-17	ONACO	oncrete Suppl	ier:N/.	APla	icement D	ate: 1	.Z-17WF
Placement I	ocation:		221H-PT	3-N-3	Mix I	Design:	N/A	Design	1 Strength:_	2500	_ psi @N/A_	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Leve
170020	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3A	6	4-3-17	7.23	7.47	3.73	10.93	22734	2.00	1.00	2080	N/A	1 C TTT
3B	6	4-3-17	7.15	7.33	3.73	10.93	22279	1.97	1.00	2040	N/A	65 TT
							2					
							A					
Direction of A	Applicatio	on of the Lo	oad on the Sp	ecimen with R	espect to the H	Iorizontal	Plane of the	Concrete Plac	ed:		N/A	
Nominal Ma	ximum S	ize of Aggr	egate:		N/A		A	Method of T	'est:	N/A	Mining and a second	
A&TE:			1)CA-002, 2)T	M-5			Cal. Due Dat	e:	1\0.32.17	>>1 11 10		
fest		Conformin		N]	NCR No.:		1)9-23-17,	2)1-11-18 N/A		
lesults:	· لـــا	Contormin	<u> </u>	INOLCOLIOFINI		<u>I</u> N/A	Procedure:	C-QCP	-002	Rev.:	0 PCN(s)	: N/A
	*Fc 221H-1	PT3-N-3-A =	ng Evaluation.	Density of	Cores follows:		Spec.: C	-ESR-H-00044	Rev.:	0 DCI	F(s): I	N/A
				x 10-11-0-0 - 1	N/A		Dwg(s):	N/A.	Rev.: N	A DCI		
Technician (I	Print/Sign	1): Glenn S	pencer/ M	lun,					Le	vel: I	II Date:	4/3/17
Reviewer (P	rint/Sign)	: Kevin M	iller/ KEV	IN MILL	EK	Km	8-22-17		Le	vel:	II Date	4-6-17

System|One

ASR 18-202 (03/17)

SRNL-TR-2017-00356

Revision 0

ASR 18-203 (04/13)

URS Savannah River Site

Summary Report of Testing Activities

Report	X Cover Sheet Page 1 of	3
Approvals (If required)	Work Package No.: 1525456	
Senior Civil Technician (Level III):	QCIR No.: N/A	
Charles A. Bookhamer	Project No.: N/A	-
Civil Testing & Inspection Superintendent:	Design Category: CAB 1-11-17 -GS-SC	
W. Pope, Jr.	Report No.: 2016-CAEX-0009 Date: 12-22-	16
Lab. No.: 160102 T	est Method: See attached pages	
Discipline: Civil	Description: Concrete	
Location: 221H Personnel Tunnel 3 North Wa	all Reported to: J. Carter, 8-1727	
ASTM C642-13 covering the determination of density Line 4 on page 2 references Sample ID 221H-PT3-N-4 221H-PT3-N-4OC for this report. See page 3 for the results of "Compressive Strength of are provided in the page 3 Remarks Section. All information in this report is from core segments a	y, percent absorption, and percent voids in hardened concrete. 4CC and Line 5 on page 2 references Sample ID of Drilled Cores". Also note, the densities of the core segments 221H-PT 3-N-4. Ind over core from sample location 321H-PT3-84. B-22-17 W.P.	
NCR No.: N/A	See anacueu pages roccoure: C-QCP-002	
Test Results: Conforming Nonconf	forming *X N/A PCN(s): N/A	
Remarks: * For engineering evaluation	Spec.: G-ERS-H-00044	
N/A	Rev.: 0	
	DCF(s): N/A	
Technician (Print/Sign): Charles A. Bookhamer/	ark a lookkemer Level: III Date: 1-11-17	
Reviewer (Print/Sign): Charles Z. Moore/ CZM	- 2. M Level: II Date: 1-11.17	

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Savannah River Site

Page $\frac{2}{100}$ of $\frac{3}{100}$

Item	#								Su	mn	nary	^т у
			٩٩٧	[%]	20.2	19.4	18.7	19.0	20.1	18.0	17.8	
		s [8] 6 [%]	BDAIB	[g/cm ³]	2.32	2.33	2.34	2.34	2.32	2.34	2.36	
crete		[%] and boilin _e and boilir peac (void	BDAI	[g/cm ³]	2.31	2.31	2:32	2.32	2.30	2.32	2.34	
	Con	mersion mersion nmersior nmersior	AAIB	[%]	9.5	9.1	8.7	8.8	9.5	8.3	8.2	
	ned	ı after im after im y, dry y after ir y after ir bensity permeat	AI	8	8.8	8.2	7.8	7.9	8.5	7.3	7.5	
	larde	Absorption Absorption Bulk densit Bulk densit Bulk densit Apparent C Volume of	•	[g/cm ³]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4 X 100 4 X 100 1)] X ρ C-D]] X ρ (C-D]] X ρ /k ₂ x 100
	s in H	AAI = AAIB = BDA! = BDA! = BDA!B = \$2 = VPP =	5	[g/cm ³]	2.65	2.65	2.64	2.65	2.65	2.64	2.65	6= [(8-4)// 6= [(C-4)// 1 = [4/(C-D DAI = [5/(DAI = [C/ DAI = [C/ 5 = [5, - 8,]
	Void		61	[g/cm ³]	2.12	2.14	2.15	2.15	2.12	2.16	2.18	۲۵ میں ۵۵ ۵۵ ۲۵ ۲۵
	and	oiling [g] ooiling [g]	٥	6	712.6	1034.2	1042.7	1324.2	597.5	1783.5	698.5	
	otion,	sion [g] sion and b rsion and t	ີ ບ	<u></u>	1251.99	1811.47	1822.62	2314.88	1051.06	3110.20	1213.60	
psorp	(g) after immers after immers after immer , ³ , /cm ³	8	<u>.</u>	1243.83	1797.27	1807.66	2295.52	1041.49	3082.55	1205.50	ling [g] oling oids] [%]	
	ity, Al	nple in air (g mple in air a mple in air a ble in water a ¹ , or g/cm ³ hg/m ³ = 1 g/c g/m ³ = 1 g/c	A	1	1143.25	1660.96	1676.66	01.7212	959.79	2871.57	1121.66	sion [%] sion and bo rision rision and b
ſ	Dens	if oven-dried san f surface-dry sar if surface-dry sar int mass of samp int mass of samp int mass of samp int wares t bulk density, M i of water = 1 M(0	PT3-N-60C	PT3-N- 50C	T3-N-588	13-N-4CC	P13-N-40C	T3-N-2CC	13-N-1CC	Core tion after immer nsity, dry nsity after imme nsity after imme nsity of permeable p of permeable p
		: mass c = mass c = appare = appare = aparer = densit		Sample	-221H	ĦZ.	221H-F	-H122	HIZZ	221H-P	4-HIZZ	* Over Absorp Bulk de Bulk de Bulk de Appare Volume
		2 8 0 6 8 8 6 8 8 0 0 8 8 8 6		· jë	-1		m 1	4	<u>~[</u> ,			
Comments:	- Palandija - 14	a		10	1	<u> </u>			7	_	3	-
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Summary Report of Testing Activities (Continuation Sheet)

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Savannah	River	Site
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Page 3 of 3

Report No.: 2016-CAEX-0009 Project No.: N/A Work Package No.: 1525456 Design Cat.: SC QCIR No.: N/A Date & Time Core Taken: 12-22-16 @ N/A Concrete Supplier: N/A Placement Date: 1952 Placement Location: 221H- Section 3, Personnel Tunnel North Wall Mix Design: N/A Design Strength: 2500 psi @ N/A Days Lab. Number Aged Tested Before Length After Average Diameter, Sq.in. Area, Ibs, Total Ibameter, Ratio Correction Unit Load, psi Corrected Ratio Technician Init/Level 160102 N/A N/A N/A N/A N/A N/A N/A N/A 160102 N/A N/A N/A N/A N/A N/A N/A N/A N4-4 7 12-29-16 7.16 7.40 3.73 10.93 23068 1.98 1.00 1930 (25 777) N-4-C 7 12-29-16 7.24 7.44 3.73 10.93 23495 1.99 1.00 2150 </th
QCIR No.: N/A Date & Time Core Taken: 12-22-16 @ N/A Concrete Supplier: N/A Placement Date: 1952 Placement Location: 221H-Section 3, Personnel Tunnel North Wall Mix Design: N/A Design Strength: 2500 psi @ N/A Days Lab. Days Date Length Length Average Area, Total Length to Correction Unit Corrected Psi @ N/A Days 160102 N/A So TIT So TIT
Placement Location: 221H- Section 3, Personnel Tunnel North Wall Mix Design: N/A Design Strength: 2500 psi @ N/A Days Lab. Days Date Length Length Average Area, Total Length to Correction Unit Load, psi Technician Init/Level 160102 N/A A A A
Lab. Number Days Aged Date Tested Length Before Capping, in. Length After Capping, in. Average Diameter, in. Total sq.in. Length to Diameter, Bbs. Correction Factor Unit Load, psi Corrected psi Technician Init/Level 160102 N/A N
160102 N/A N-4-A 7 12-29-16 7.16 7.40 3.73 10.93 21068 1.98 1.00 1930 1930 C_S 7.77 N-4-B 7 12-29-16 7.24 7.44 3.73 10.93 23910 1.99 1.00 2190 2190 C_S 7.77 N-4-C 7 12-29-16 7.25 7.44 3.73 10.93 23910 1.99 1.00 2190 2150 C_S 7.77 N-4-C 7 12-29-16 7.25 7.44 3.73 10.93 23495 1.99 1.00 2150 2150 C_S 7.77 N-4-C 7 12-29-16 7.25 7.44 3.73 10.93 23495 1.99 1.00 2150 C_S 7.77 N-4 -
N-4-A 7 12-29-16 7.16 7.40 3.73 10.93 21068 1.98 1.00 1930 CoS 777 N-4-B 7 12-29-16 7.24 7.44 3.73 10.93 23910 1.99 1.00 2190 25 777 N-4-C 7 12-29-16 7.24 7.44 3.73 10.93 23910 1.99 1.00 2190 6.5 777 N-4-C 7 12-29-16 7.25 7.44 3.73 10.93 23495 1.99 1.00 2150 6.5 777 N-4-C 7 12-29-16 7.25 7.44 3.73 10.93 23495 1.99 1.00 2150 6.5 777 N-4-C -
N-4-B 7 12-29-16 7.24 7.44 3.73 10.93 23910 1.99 1.00 2190 25 TT N-4-C 7 12-29-16 7.25 7.44 3.73 10.93 23495 1.99 1.00 2190 2190 6.5 TT N-4-C 7 12-29-16 7.25 7.44 3.73 10.93 23495 1.99 1.00 2150 2150 6.5 TT Image: Comparison of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A N/A N/A Method of Test: N/A Method of Test: N/A N/A N/A
N-4-C 7 12-29-16 7.25 7.44 3.73 10.93 23495 1.99 1.00 2150 2150 65 7# Image: Construction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A N/A N/A Image: Construction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A N/A Image: Construction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A N/A Image: Construction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A Image: Construction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A Image: Construction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A Image: Construction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A Image: Construction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A Image: Construction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A
Image: Second
Image: Second state of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A Nominal Maximum Size of Aggregate: N/A Method of Test: N/A Method of Test: N/A
Direction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A Nominal Maximum Size of Aggregate: N/A Method of Test: N/A
Direction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A Nominal Maximum Size of Aggregate: N/A Method of Test: N/A 1) CA-002: 2) TM-5
Direction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A Nominal Maximum Size of Aggregate: N/A Method of Test: N/A A&TE: 1) CA-002: 2) TM-5
Direction of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A Nominal Maximum Size of Aggregate: N/A Method of Test: N/A A&TE: 1) CA-002: 2) TM-5
Nominal Maximum Size of Aggregate: N/A Method of Test: N/A A&TE: 1) CA-002: 2) TM-5 Cal. Due Date: 1) 9-23-17: 2) 1-12-17
A&TE: Cal. Due Date: 1) CA-002: 2) TM-5 1) 9-23-17: 2) 1-12-17
1% TE: Cal. Due Date: 1) CA-002: 2) TM-5 1) 9-23-17: 2) 1-12-17
tesults: Conforming X N/A Procedure: C-QCP-002 Rev.: 0 PCN(s): N/A
emarks: *For Engineering Evaluation. Density of Cores follows: 2014 PT3 N 4 A = 140 - 5 2014 PT3 N 4 B = 140 - 5 2014 PT3 N 4 C = 141 - 5 Spec.: C-ESR-H-00044 Rev.: 0 DCF(s): N/A
$\frac{221 \text{III-r 13-N-4-A} = 140 \text{ pcl}; 221 \text{III-r 13-N-4-B} = 140 \text{ pcl}; 221 \text{III-r 13-N-4-C} = 141 \text{ pcl};}{\text{N/A}}$ $\frac{140 \text{ pcl}; 221 \text{III-r 13-N-4-B} = 140 \text{ pcl}; 221 \text{III-r 13-N-4-B} = 140 \text{ pcl}; 221 \text{III-r 13-N-4-C} = 141 \text{ pcl};}{\text{N/A}}$
Fechnician (Print/Sign): Glenn C. Spencer/
Reviewer (Print/Sign): Charles A. Bookhamer/ Charles A. Bookhamer/ Level: III Date: 1-1/-1/7
THIS REPORT SHALL NOT BE REPRODUCED. EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY

5 ASR 18-203 (04/13)

URS Savannah River Site

Summary Report of Testing Activities

L Kepo	ort	X Cover Sh	eet	
Approvals (If required)		Work Package No	.: 1	525456
Senior Civil Technician (Level III):		QCIR No.:	N/A	
Charles A. Bookhamer	32	Project No.:	N/	A
Civil Testing & Inspection Superintendent:	10	Design Category:	CAB 1-11-17	es se
W. Pope, Jr.		Report No.: 2	016-CAEX-0008	Date: 12-21-16
Lab. No.: 160101	Test Me	thod:	See attached	pages
Discipline: Civil	Des	cription:	Concre	te
Location: 221H Personnel Tunnei 3 Nor	rth Wall	Reported	to: J. C	Carter, 8-1727
ASTM C642-13 covering the determination of d Line 2 on page 2 references Sample ID 221H-PT for this report. See page 3 for the results of "Compressive Stre	iensity, perc 13-N-5OC at angth of Dril	ent absorption, and nd Line 3 on page 2 led Cores''. Also n	l percent voids in h references Sample	ardened concrete. ID 221H-PT3-N-SBB
are provided in the page 3 Remarks Section. All information in this report is from over core a	and core seg	ments from sample	22(H- location-22111 PT	РТ.3- <i>Ы-5</i> , 255. 8-22-17 W.P.
are provided in the page 3 Remarks Section. All information in this report is from over core a	and core seg	ments from sample	22(H-)	PT.3-N-5, 255. 8-22-17 W.P.
are provided in the page 3 Remarks Section. All information in this report is from over core a light the second sector of the	and core seg	ments from sample	221H-	PT.311-5. 3-5-5- 8-22-17 W.P. C-QCP-002
are provided in the page 3 Remarks Section. All information in this report is from over core in the page of	and core seg	ments from sample	221H- location-221H PT Procedure: Rev.:	PT.3 <i>M</i> -5. 255. 8-22-17 <i>W.P.</i> C-QCP-002 0
are provided in the page 3 Remarks Section. All information in this report is from over core in the page of t	and core seg	ments from sample	221H- location-221H PT Procedure: Rev.: PCN(8):	PT.3M-5, 255. 8-22-17 W.P. C-QCP-002 0 N/A F51.
are provided in the page 3 Remarks Section. All information in this report is from over core is All information in this report is from over core is Identification I	and core seg	ments from sample	221H- location-221H PT Procedure: Rev.: PCN(8): Spec.:	PT.3-AI-5, 2-5-8-22-17 W.P. C-QCP-002 0 N/A =52 C-ER4-11-00044 2-7
are provided in the page 3 Remarks Section. All information in this report is from over core a All information in the information is from over core a All information is from over core a A	and core seg	ments from sample	221H- location-221H PT Procedure: Rev.: PCN(8): Spec.:) Rev.:	PT.3-AI-5, 2-5-8-22-17 W.P. C-QCP-002 0 N/A F52 C-ERS-H-00044 F-7-72 0
are provided in the page 3 Remarks Section. All information in this report is from over core in the page of t	and core seg	ments from sample	22(H- location-22111 PT Procedure: Rev.: PCN(s): Spec.: Rev.: DCF(s):	PT.3-AI-5. 255.8-22-17 W.P. C-QCP-002 0 N/A F52 C-ERS-H-00044 F52 C-ERS-H-00044 F52 C-ERS-H-00044 F52 C-ERS-H-00044 F52 C-RS-H-00044 C-RS-H-00044 F52 C-RS-H-0004 F52 C-RS-H-0004 F52 C-RS-H-000 C-RS-H-0004 C-RS-H-0004
are provided in the page 3 Remarks Section. All information in this report is from over core is 1&TE: See attached pages Cal. Due Date: 1&TE: See attached pages Cal. Due Date: 1&CR No.: N/A est esuits: Conforming Noi emarks: * For engineering evaluation N/A echnician (Print/Sign): Charles A. Bookhamer/2	and core seg	ments from sample	22(H- location-22111 PT Procedure: Rev.: PCN(s): Spec.:) Rev.: DCF(s): Level: III	PT.3 <i>M</i> 5. 2-5-8-22-17 <i>W</i> -P. C-QCP-002 0 N/A <i>F</i> 52 C-ERS-H-00044 <i>F</i> -52-72 0 N/A Date: 1-11-17

 $\frac{2}{1}$ of $\frac{3}{1}$

Page

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Savannah River Site

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ASR 18-250 (04/13)

Report Title: 221H Personnel Tunnel 3 North Wall **Report No.:** 2016-CAEX-0008 Item # Summary 18.7 20.1 2 19.4 19.0 18.0 17 **PP** 8 2.33 2.34 2.34 2.34 2.36 0.33 2.32 **BDAIB** cm, VPP = Volume of permeable pore speac (voids) [%] AAIB = Absorption after immersion and boiling [g] BDAIB = Bulk density after immersion and boiling Density, Absorption, and Voids in Hardened Concrete 2.32 2.32 2.30 2.32 2.34 2.31 2.31 BDAI E/cm AAI = Absorption after immersion [%] BDAi = Bulk density after immersion 00 9.5 2.0 33 AAIB 5 6 8 ac ac 8.2 7.9 50 2.5 g₂ = Apparent Density g1 = Bulk density, dry A 8 8 8 8 8 1.00 1.8 1.00 BDAIB = [C/(C-D)] X p $% = [(C-A)/A] \times 100$ $g_1 = [A/(C-D)] \times \rho$ BDAI = [B/(C-D)] X p $% = (g_2 - g_3)/g_2 \times 100$ ์ เ % = [(B-A)/A] X 100 ₂₂ = [A/(A-D)] X ρ 2.65 2.65 2.64 2.65 2.64 2.65 2.65 p/cm 15 2.18 2.14 H 2.12 2.16 e/cm² 597.5 1783.5 698.5 D = apparent mass of sample in water after immersion and boiling [g] 1324.2 1034.2 1042.7 C = mass of surface-dry sample in air after immersion and boiling [g] 712.(-1251.99 1822.62 2314.88 1051.06 1811.47 1213.60 B = mass of surface-dry sample in air after immersion [g] 3110.20 1041.49 1243.83 1807.66 2295.52 3082.55 1205.50 Volume of permeable pore space (voids) [%] 1797.27 Absorption after immersion and boiling [g] 3 Bulk density after immersion and boiling 00 $B_2 =$ aparent bulk density, Mg/m³, or g/cm³ $\rho = \text{density of water} = 1 \text{ Mg/m}^3 = 1 \text{ g/cm}^3$ A = mass of oven-dried sample in air [g] $B_1 = bulk density, dry, Mg/m^3$, or g/cm³ 1660.96 1676.66 959.79 1121.66 1143.25 2127.10 2871.57 Absorption after immersion [%] 6 4 Bulk density after immersion *221H-PT3-N- 50C *221H-PT3-N-60C *221H-PT3-N-40C Apparent Density 221H-PT3-N-5BB 221H-PT3-N-2CC 221H-PT3-N-1CC Bulk density, dry 221H-PT3-N-4CC * Over Core Sample ID ine **Comments:** THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY. 7

Summary Report of Testing Activities (Continuation Sheet)

1-12-17

Page 3 of 3

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Savannah	River	Site

port No.: 2016-CAEX-0008 Project No.: NA Work Package No.: 1525456 Design Cat.: SC CIR No.: NA Date & Time Core Taken: 12-21-16 @ N/A Concrete Supplier: N/A Placement Date: 1952 lacement Location: 221H-Section 3. Personand Tuneel North Wall Mix Design: N/A Design Strength: 2500 psi @ N/A Days Lab. Days Date Length Length Average Average Total Length Length Average Total Length Longth Int/Level 160101 N/A N/A N/A N/A N/A N/A N/A N/A N/A 160101 N/A N/A N/A N/A N/A N/A N/A N/A N/A N-5A 7 12-29-16 11.09 11.35 5.67 25.25 5520 2.00 1.00 2200 220 /S.777 N-5B 7 12-29-16 11.01 11.35 5.67 25.25 5520 2.00 1.00 2200 /S.777			ASTM (C 39- (14))	pressive S AST	strength M C 42-(of Drilled	Cores	STM C 617-(12)	<u> </u>	
CIR No.: NA Date & Time Core Taken: 12-21-16 @ N/A Concrete Supplier: N/A Placement Date: 1952 lacement Location: 221H- Section 3, Personnel Tunnel North Wall Mix Design: N/A Design Streagth: 2560 psi @ N/A Days Lab. Days Date Length Arena, Longth Diameter, Baineter, Init/Level Number Aged Tested Before Capping, in, Diameter, Init/Level Date Tested Tested Tested Tested Tested Tested Tested Tested Tested Arena, Data Length Data Tested T	Report No.:	201	6-CAEX-00	08 Pro	ject No.:	N/A	v	Vork Package	No.:	1525456	De	sign Cat.:	SC
lacement Location: 21H-Section 3, Personnel Tunnel North Wall Mix Design: N/A Design Strength: 2500 psi @ N/A Days Lash. Daye Tested Length Length Area, Total Length of Pactor Paster Pas	QCIR No.: _	N/4	<u> </u>	Date & Time	Core Taken:	12-21-16@	N/A Co	ncrete Supplie	r:N/#	Plac	ement Da	te:	.952
Lab. Number Days Aged Date Tested Length Before Capping, in. Capping, in.	Placement L	ocation:	221H- Sect	tion 3, Personn	el Tunnel Nort	h Wall Mix	Design:	N/A	Design	Strength:	2500	psi @ <u>N/A</u>	Days
160101 N/A N/A <t< td=""><td>Lab. Number</td><td>Days Aged</td><td>Date Tested</td><td>Length Before Capping, in.</td><td>Length After Capping, in.</td><td>Average Diameter, in.</td><td>Area, sq.in.</td><td>Total Load, lbs.</td><td>Length to Diameter Ratio</td><td>Correction Factor</td><td>Unit Load, psi</td><td>Corrected psi</td><td>Technician Init./Level</td></t<>	Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level
N-5-A 7 12-29-16 11.09 11.39 5.67 25.25 61113 2.01 1.00 2420 2420 26.5 7////////////////////////////////////	160101	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-5-B 7 12-29-16 11.01 11.35 5.67 25.25 55520 2.00 1.00 2200 2200 6.5 TT Image: Second Secon	N-5-A	7	12-29-16	11.09	11.39	5.67	25.25	61113	2.01	1.00	2420	2420	65TT
rection of Application of the Load on the Specimen with Respect to the Horizontal Plane of the Concrete Placed: N/A ominal Maximum Size of Aggregate: N/A Method of Test: N/A &TE: 1) CA-002; 2) TM-5 1) 9-23-17; 2) 1-12-17 K &TE: 1) CA-002; 2) TM-5 1) 9-23-17; 2) 1-12-17 N/A aults: Cal. Due Date: N/A marks: "For Engineering Evaluation. Density of Cores follows: Spec.: C-QCP-002 221H-PT3-N-5-A = 140 pcf; 221H-PT3-N-5-B = 141 pcf; Spec.: C-ESR-H-00044 Rev.: 0 More (Print/Sign): Glenn C. Spencer/ John John John John John John John John	N-5-B	7	12-29-16	11.01	11.35	5.67	25.25	55520	2.00	1.00	2200	2200	6S TH
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&TE: 1) CA-002; 2) TM-5 Cal. Due Date: 1) 9-23-17; 2) 1-12-17 St St Conforming Nonconforming *X N/A NCR No.: N/A Procedure: C-QCP-002 Rev.: 0 PCN(s): N/A Procedure: C-QCP-002 Rev.: 0 PCN(s): N/A Spec.: C-ESR-H-00044 Rev.: 0 DCF(s): N/A Conforming N/A Dwg(s): N/A Rev.: N/A DCF(s): N/A Conforming Charles A. Bookhamer/ Charles G. Boothamer Level: III Date: 12-29-16 PCN(s): III Date: 12-29-16 Conforming Charles A. Bookhamer/ Charles A. Bo	Nominal Ma	ximum S	ize of Aggr	egate:		N/A			Method of T	est:	N/A		
1) CA-002; 2) TM-5 1) 9-23-17; 2) 1-12-17 st Conforming Nonconforming *X N/A sults: Nonconforming *X N/A marks: *For Engineering Evaluation. Density of Cores follows: Procedure: C-QCP-002 Rev.: 0 PCN(s): N/A 221H-PT3-N-5-A = 140 pcf; 221H-PT3-N-5-B = 141 pcf; Spec.: C-ESR-H-00044 Rev.: 0 DCF(s): N/A N/A Dwg(s): N/A Rev.: N/A DCF(s): N/A echnician (Print/Sign): Glenn C. Spencer/ Jultary Level: III Date: 12-29-16 eviewer (Print/Sign): Charles A. Bookhamer/ Charles G. Bookhamer/ Level: III Date: 1-1/-17 THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY. Yi-12-17 Yi-12-17 Yi-12-17	A&TE:							Cal. Due Date:	· · · · · · · · · · · · · · · · · · ·				
st Conforming *X N/A NCR No.: N/A sults: Conforming *X N/A Procedure: C-QCP-002 Rev.: 0 PCN(s): N/A marks: *For Engineering Evaluation. Density of Cores follows: Spec.: C-ESR-H-00044 Rev.: 0 DCF(s): N/A 221H-PT3-N-5-A = 140 pcf; 221H-PT3-N-5-B = 141 pcf; Dwg(s): N/A Rev.: 0 DCF(s): N/A schnician (Print/Sign): Glenn C. Spencer/ Multiple Level: III Date: 12-29-16 eviewer (Print/Sign): Charles A. Bookhamer/ Charles Genders Genders Genders Level: III Date: 1-//- //7 THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY. Y-//- //7 Y-//- //7				1) CA-002; 2) 1	ſ M-5					1) 9-23-17; 2)) 1-12-17		
Procedure: C-QCP-002 Rev.: 0 PCN(s): N/A 221H-PT3-N-5-A = 140 pcf; 221H-PT3-N-5-B = 141 pcf; Spec.: C-ESR-H-00044 Rev.: 0 DCF(s): N/A N/A N/A Dwg(s): N/A Rev.: N/A DCF(s): N/A echnician (Print/Sign): Glenn C. Spencer/ June Level: III Date: 12-29-16 eviewer (Print/Sign): Charles A. Bookhamer/ Charles Genderee Level: III Date: 12-29-16 THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY. I-(2-17) I-(2-17)	lest Results:		Conformin	g	Nonconformi	ng ×x	N/A	NCR No.:		Ň	V/A		
221H-PT3-N-5-A = 140 pcf; 221H-PT3-N-5-B = 141 pcf; N/A N/A N/A Dwg(s): N/A Rev.: N/A Charles A. Bookhamer/ Charles G. Spencer/ Level: III Date: 12-29-16 Level: III Date: 1-1/-1/7	Remarks: *Fo	or Enginee	ring Evaluat	tion. Dens	ity of Cores fol	lows:		Procedure:	C-QCP	-002 1	Kev.:	0 PCN(s	:: N/A
N/A Dwg(s): N/A Rev.: N/A DCF(s): N/A echnician (Print/Sign): Glenn C. Spencer/ Jecule III Date: 12-29-16 eviewer (Print/Sign): Charles A. Bookhamer/ Charles G. Bookhamer/ Level: III Date: 1-//- //7 THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY. Image: 1-1/- //7 Image: 1-1/- //7		221H-	PT3-N-5-A =	= 140 pcf; 221E	I-PT3-N-5-B =	141 pcf;		Spec.: C-E	SR-H-00044	Rev.: 0	DCF	(s):	N/A
echnician (Print/Sign): Glenn C. Spencer/ June 1 Date: 12-29-16 eviewer (Print/Sign): Charles A. Bookhamer/ Charles G. Bookhamer/ Level: III Date: 1-1/- 17 THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY. I-(2-17)				N/A				Dwg(s):	N/A	Rev.: N/A	A DCF	(s):	N/A
A series A. Bookhamer/ Charles & collowing Level: III Date: /-//- /7 THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY. III Date: /-//- /7	Technician (Print/Sig	n): <u>Glenn C</u>	. Spencer/	Ble		10			Lev	el: <u>I</u>	Dat	: 12-29-16
THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.	Reviewer (P	rint/Sign)): Charles	A. Bookhamer	Chark	s le-is or	ofkom	er		Lev	el: I	II Date	» <u>1-11-17</u>
			THIS REP	ORT SHALL N	OT BE REPROD	UCED, EXCEPT	IN FULL, W	ITHOUT THE W	RITTEN APPR	OVAL OF THE	LABORAT	ORY. 7	-12-17 7

ASR 18-203 (04/13)

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Savannah River Site

Summary Acport of Testing Activities	Summary	Report	of Testing	Activities
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	Report	X Cov	er Sheet	Page 1 of 3
Approvals (If required	d)	Work Packag	ge No.:	1525456
Senior Civil Technician (Level III):		QCIR No.:	N	/A
Charles A. Bookhamer		Project No.:		N/A
Civil Testing & Inspection Superintendent:		Design Categ	ory: CAB	-11-12-SC
W. Pope, Jr.		Report No.:	2016-CAEX-000	7 Date: 12-20-16
Lab. No.: 160100	Test Me	thod:	See attach	ed pages
Discipline: Civil	Des	cription:	Cor	icrete
Location: 221H Personnel Tunnel 3	North Wall	Repo	rted to:	J. Carter, 8-1727
ASTM C642-13 covering the determination Line 1 on page 2 references Sample ID 221H See page 3 for the results of "Compressive are provided in the page 3 Remarks Section All information in this report is from over c	of density, perc H-PT3-N-6OC for Strength of Dril core and core seg	ent absorption or this report. led Cores''. A ments from sa	n, and percent voids Also note, the densition 22/1 Ample location 22111	in hardened concrete. es of the core segments H-PT3-N- し. PT3-S-6: 8-22-17 W.P.
M&TE: See attached pages Cal. Due I	Date: See a	ttached pages	Procedure:	C-QCP-002
NCR No.: N	i/ A		Rev.:	0
Results: Conforming	Nonconformin	g X	N/A PCN(s):	N/A
Remarks: <u>* For engineering evaluation</u> N/A		·····	Spec.:	ESA GERS-H-00044
			Rev.;	0
			DCF(s):	N/A
Technician (Print/Sign): Charles A. Bookham	eri Anles C	6. Jallan	Level: III	Date: 1-11-17
Reviewer (Print/Sign): Charles Z. Moore/	CZM CZM	1-12-17	Level: 11	Date: 1-11-17 8-22-17

 $CZM - 10 \cdot 17$ THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY. $V_{1-12-17}$ $V_{1-12-17}$ $V_{1-12-17}$
SRNL-TR-2017-00356 Revision 0

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Savannah River Site

Summary Report of Testing Activities (Continuation Sheet)

Page 2 of 3

Item #		Summary	
		PP 88 19.0 113.0 117.8 12.0 17.8 17.8 17.8 17.8 17.8 17.8 17.8 17.8	
		(IB V 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
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Cor	nmersior nmersior mmersic mmersic ble pore	AAIB [%] 9.5 9.5 9.1 8.3 8.3 8.3 8.3 8.3 8.3	
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rptic	nersion [nersion a mersion	C C C C C C C C C C C C C C C C C C C	
losd	g] after imn after imn after im cm³ cm³	B [g] 1797.27 1797.27 1797.26 1797.26 1797.25 2295.55 3082.55 1205.56	voids) [9]
ty, A	ple in air (ple in air	A [6] 1143.25 1660.96 959.79 959.79 959.79 1121.66	ion [%] ion and bc sion and h sion and h re space (
ensi	ried sam dry sam dry sam dry sam y, Mg/m h, Mg/m r = 1 Mg,		immers immers r immer r immer y eable po
Ω	f oven-d f surface f surface at mass nsity, dr t bulk de t bulk de of wate	ID PT3-N-61 T3-N-5B T3-N-40 T3-N-40 T3-N-20 T3-N-20	Core ion after ion after nsity, dry nsity afte nsity afte of perm
	mass o mass o mass o mass o appare bulk de aparen aparen	Sample 5ample *221H-P 221H-P 221H-P 221H-P 221H-P 221H-P	* Over Absorpt Bulk de Bulk de Bulk de Bulk de Apparet Volume
	4 8 U 5 8 8 4	Line 2 3 3 7 7 7 7	
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omments:			
		N/A	
		/ 11	

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Savannah River Site

Page 3 of 3

		ASTM C	C 39- (14) Com	pressive S	trength MC 42-(of D _r illed	Cores	STM C 617-(12)		
Report No.:	201	6-CAEX-000	07 Pro	ject No.:	N/A	W	ork Package	No.:	1525456	De	sign Cat.:	SC
QCIR No.:	N/2	<u> </u>	Date & Time	Core Taken:	12-20-16 @	N/A Con	acrete Supplie	r:N/A	APlac	cement Da	te:1	952
Placement I	Location:	221H- Sect	tion 3, Personn	el Tunnel Nort	h Wall Mix	Design:	N/A	Design	Strength:	2500	psi @N/A_	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, Ibs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level
160100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-6-A	7	12-29-16	7.10	7.35	3.73	10.93	23009	1.97	1.00	2110	2110	65 TIE
N-6-B	7	12-29-16	7.00	7.22	3.73	10.93	23437	1.94	1.00	2140	2140	65 TT
N-6-C	7	12-29-16	7.05	7.21	3.73	10.93	24358	1.93	1.00	2230	2230	65 TT
					N		r					
Direction of	Applicatio	on of the Lo	oad on the Sp	ecimen with R	lespect to the]	Horizontal	Plane of the C	oncrete Place	ed:		N/A	
Nominal Ma	aximum S	ize of Aggr	egate:		N/A			Method of T	'est:	N/A		
M&TE:							Cal. Due Date:		· · · · · · · · · · · · · · · · · · ·			1
			1) CA-002; 2) 7	ſ M-5					<u>1) 9-23-17; 2</u>) 1-12-17		
Fest Results:		Conformin	g 🗌	Nonconformi	ng *X	N/A	NCR No.:]	N/A		
Remarks: *Fe	or Enginee	ring Evaluat	tion. Dens	ity of Cores fol	lows:		Procedure:	C-QCP	-002	Rev.:	0 PCN(s)	: N/A
221H-PT3-N-	6-A = 142	ocf; 221H-P	F3-N-6-B = 142	2 pcf; 221H-PT3	8-N-6-C = 141 p	cf;	Spec.: C-E	CSR-H-00044	Rev.: 0	DCF	'(s):	N/A
			N/A	.1.0			Dwg(s):	N/A	Rev.: N/	A DCF	(s):	N/A
Technician (Print/Sigi	1): Glenn C	. Spencer/	yen	- 1-2-	11			Lev	/el:	Date	: 12-29-16
-			4 979 9 9	1 11 11 11	11 ST							

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Savannah River Site

Summary Re	port o	of Testi	ng Activ	ities			
Report	_	X	Cover Shee	t		Page	e <u>1</u> of <u>6</u>
Approvals (If required)		Work Pa	ackage No.:		152	25456	
Senior Civil Technician (Level III):		QCIR N	o.:		N/A		
Glenn Specner		Project	No.:		N/A		
Civil Testing & Inspection Superintendent:		Design (Category:		12.7	SC	
W. Pope, Jr.		Report I	No.: 201	7-CAEX	-0002	Date:	3-1-17
Lab. No.: 170011,170012,170013,170014	Test Mo	ethod:		See at	tached pa	ages	
Discipline: Civil	Des	scription:			Concrete	e	
Location: 221H Personnel Tunnel 3 North V	Wall	:	Reported to	:	J. Ca	rter, 8-17	27
C-ESR-H-00044, Revision 0. Page 6 contains a spread ASTM C642-13 covering the determination of dens Line 7 on page 6 references . See pages 2 ,3,4 and 5 Also note, the densities of the core segments are p All INFORMATION IN FROM SAMPLE 2211	eadshee sity, pero for the provided <i>Thi</i> . <i>LocA</i> <i>Y</i> -PT.	et for data cent absor results of in the pa S REP $HONS3-N-221H$	and results rption, and p "Compress ges 2,3,4 an pet Is 22/H 2A, 2. 1-PT3- N A	provided percent vo sive Stren ad 5 Rema FROM -PT3 21H-1 N-21	by the calculation by the calculation of Dr arks Section $-N-Correct - N-Correct - N-C$	Iculation rdened co illed Core on. <i>RE SEC</i> <i>V-2B</i> <i>22-1</i>	s of oncrete. es". gmEuts AND T.W.P.
M&TE: See attached pages Cal. Due Date: NCR No.: N/A	See	attached	pages	Procedu Rev.:	re:	C-QC	P-002
Test Results: Conforming Nonco	onformi	ng (*X N/A	PCN(s):		N/A	
Remarks: <u>* For engineering evaluation</u>			19	Spec.:	(C-ESR-H-	00044
N/A	1000			Rev.:		0	1.000000-00000000
				DCF(s):	900 - 900 - 940e	N/A	
Technician (Print/Sign): Glenn Spencer/	-1-	~	20.57	Level:	III 1	Date:	3/20/17
Reviewer (Print/Sign): Kevin Miller KEVエム	MILL	EVL 8-22-1	1	Level:		Date: <u>3</u>	127/17

THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORA 4 coli7 4-3-17

-	- 15)				_	UNS						
					Savann	ah River	·Site				Page	2_of <u>6</u>
				Com	pressive St	trength	of Drilled	Cores				
		ASTM	C 39- (14)	ASTN	1 C 42-(13)	Α	STM C 617-(12)		
eport No.:	201	7-CAEX-00	02 Pro	ject No.:	N/A	W	ork Package	No.:	1525456	De	esign Cat.:	-08-5C
CIR No.: _	N/A	A 1	Date & Time	Core Taken:	3-1-17 @ N/	A Con	ncrete Supplie	er: <u>N/</u>	A Plac	cement Da	nte:	1952
Placement Lo	ocation:	221H- Sect	ion 6A, Person	nel Tunnel Nort	h Wall Mix D	Design:	N/A	Design	Strength:	2500	_ psi @N/A	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, Ibs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level
170011	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6A-A	6	3-8-17	7.42	7.62	3.72	10.87	29280	2.05	1.00	2690	N/A	65 TT
6A-B	6	3-8-17	7.43	7.62	3.71	10.81	28209	2.05	1.00	2610	N/A	65 TH
6A-C	6	3-8-17	7.40	7.57	3.71	10.81	31745	2.04	1.00	2940	N/A	65 TH
irection of A	pplicatio	on of the L	oad on the Sp	ecimen with R	espect to the H	Iorizontal	Plane of the C	Concrete Place	ed:		N/A	
lominal Max	kimum S	ize of Agg	regate:		N/A			Method of T	'est:	N/A		
&TE:			1) CA-002; 2) T	T M-5		•	Cal. Due Date	:	1) 9-23-17; 2) 1-11-18		
esults:		Conformin	ng	Nonconformi	ng 🔀	N/A	NCR No.:	C 000	N	N/A		
emarks: *For	Enginee	ring Evalua	tion. Densi	ty of Cores follo	ws:				-UU2]	NEV.:	U PCN(S): N/A
	221H-P	ГЗ-N-6А-А	= 145 pcf; 221H	I-PT3-N-6A-B =	145 pcf;		Spec.: C-I	ESK-H-00044	Kev.: 0	DCF	(\$):	N/A
		221F	I-PT3-N-6A-C	= 143 pcf;			Dwg(s):	N/A	Rev.: N/2	A DCF	r(s):	N/A

RE-REVIEW

ASR 18-202 (4/13)

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SRNL-TR-2017-00356 Revision 0

Page	<u>3</u> 0	of	6
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Com	pressive	Strength	of Drilled	Cores
Com	DICOSIVC	Suchen	UI DI IIICU	COLCS

		ASTM	C 39- (14)	ASTN	M C 42-(13)	A	STM C 617-(12)		
Report No.:	201	7-CAEX-00	02 Pro	ject No.:	N/A	<u> </u>	Vork Packa	ge No.:	1525456	D	esign Cat.:	3:24-17 Jr. 66:5C
QCIR No.:	N/2	<u> </u>	Date & Time	Core Taken:	3-1-17 @ N	/A Co	oncrete Sup	plier: N/	A Pla	cement Da	ate:	1952
Placement L	ocation:	221H- Sect	ion 2A, Person	nel Tunnel Nort	h Wall Mix I	Design:	<u>N/A</u>	Desig	n Strength:	2500	_ psi @N/.	A Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Tota Load lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level
170012	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2A-A	6	3-8-17	7.38	7.55	3.73	10.93	2077	8 2.02	1.00	1900	N/A	Les III
2A-B	6	3-8-17	7.47	7.64	3.73	10.93	2272	3 2.05	1.00	2080	N/A	Les TI
2A-C	6	3-8-17	7.45	7.59	3.72	10.87	2384	4 2.04	1.00	2190	N/A	les TI
										-		
							2					
Direction of A	Applicatio	on of the Lo	 oad on the Sp	ecimen with R	espect to the H	Horizontal	Plane of th	e Concrete Plac	ced:		N/A	
Nominal Ma	iximum S	ize of Aggr	regate:		N/A			Method of 7	ſest:	N/A		
M&TE:			1) CA-002; 2)]	`M-5			Cal. Due D	ate:	1) 9-23-17; 2) 1-11-18		
Test Results:		Conformin	g	Nonconformi	ng X] N/A	NCR No.:	C 00		N/A Dout		
Remarks: *Fo	or Enginee	ring Evaluat	tion. Densi	ty of Cores follo	ows:		Spec.:	C-ESR-H-00044	Rev.: (DCF	<u> </u>	N/A N/A
-	221H-P	<u>13-N-2A-A =</u> 221H	= 142 pct; 221F -PT3-N-2A-C	-РТЗ-N-2А-В = = 143 pcf;	= 142 pc1;		Dwg(s):	N/A	Rev.: N/	A DCF		N/A
Technician (I	Print/Sig	1): Glenn S	pencer	lun 1.			6(-)-		Lev	vel: I	II Da	te: 3-8-17
Reviewer (P	rint/Sign)	: Kevin M	liller/ KGV	IN WILL	-R Re-Ri	esieve K	evin ni	LLCA 3-29-	(7 Lev	/el: _I	II Da	te: 3/27/17

					Savann	ah Rive	er Site				Page _4	of
		ACTM	C 20 (14	Com	pressive S	trengtl	h of Drilled	l Cores	STM C 617-(12)		
	-	ASIM	C 39- (14)	ASIN	MC 42-(13)	A	51WLC 017-(12)	31	17 km
Report No.:	201	7-CAEX-00	002 Pro	oject No.:	N/A		Work Package	No.:	1525456	D	esign Cat.:	1. 106-5C
QCIR No.:	N/.	A	Date & Time	Core Taken:	3-1-17 @ N	A C	oncrete Supplie	er: <u>N/</u> .	A Plac	ement Da	ate:	1952
Placement 1	Location:	221H- Sect	tion 2B, Person	nel Tunnel Nort	h Wall Mix I	Design: _	N/A	Design	n Strength:	2500	psi @N/A	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level
170013	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2B-A	6	3-8-17	7.31	7.47	3.73	10.93	24248	2.00	1.00	2220	N/A	105 THE
2B-B	6	3-8-17	7.47	7.62	3.73	10.93	20684	2.04	1.00	1890	N/A	LS TIL
2B-C	6	3-8-17	7.33	7.52	3.73	10.93	21430	2.04	1.00	1960	N/A	las III
						_	Å					
Direction of Nominal Ma	Applicatio	on of the L Size of Agg	oad on the Sp regate:	ecimen with R	espect to the H	Iorizonta	l Plane of the C	Concrete Plac Method of T	ed: 	N/A	N/A	<u> </u>
M&TE:			1) CA-002; 2) 1	ſM-5			Cal. Due Date	:	1) 9-23-17; 2) 1-11-18		
Fest Results:		Conformi	ng	Nonconformi	ng *X] N/A	NCR No.:		1	N/A		
Remarks: *F	or Enginee	ring Evalua	tion. Dens	ity of Cores follo)ws:		Procedure:	C-QCP	-002	Rev.:	0 PCN(s): N/A
1	221H-P	T3-N-2B-A	= 141 pcf; 221H	I-PT3-N-2B-B =	= 140 pcf;		Spec.: C-I	ESR-H-00044	Rev.: 0	DCI	F(s):	N/A
		2211	H-PT3-N-2B-C	= 139 pcf;			Dwg(s):	N/A	Rev.: N/	A DCI	F (s):	N/A
Technician (Print/Sig	n): Glenn S	Spencer	hand -					Lev	vel: I	II Date	e: <u>3-8-17</u>

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SRNL-TR-2017-00356 Revision 0

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				Com	Savann prossivo St	an Kive	r ole of Drillod	Cores			Page 5	_of <u>6</u>
		ASTM	C 39- (14)	ASTN	1 C 42-(13)	A	STM C 617-(12)		
Report No.:	201	7-CAEX-00	02 Pro	ject No.:	N/A		Work Package	No.:	1525456	De	esign Cat.: 🤊	24-17 D
QCIR No.: _	N /2	A 1	Date & Time (Core Taken:	3-1-17 @ N/	A Co	oncrete Supplie	er: <u>N/</u>	A Plac	ement Da	i te:	952
Placement L	ocation:	221H- Sect	ion 2C, Personi	nel Tunnel Nort	h Wall Mix D	esign:	N/A	Design	n Strength:	2500	_ psi @N/A	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Leve
170014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2C-A	6	3-8-17	7.40	7.59	3.73	10.93	19372	2.03	1.00	1770	N/A	LSTI
2C-B	6	3-8-17	7.51	7.63	3.73	10.93	22507	2.05	1.00	2060	N/A	65 TI
							N	-				
							A					
virection of A Nominal Ma	Application	on of the L ize of Agg	oad on the Sp regate:	ecimen with R	espect to the H N/A	lorizontal	Plane of the C	Concrete Plac Method of I	ed: `est:	N/A	N/A	
1&TE:			1) CA-002; 2) 7	M-5			Cal. Due Date	:	1) 9-23-17; 2) 1-11-18	-0-0	
est		Conformir		Nonconformi	ng [*v]	N/A	NCR No.:		ľ	, \/A		
esults:							Procedure:	C-QCP	-002	Rev.:	0 PCN(s)): N/A
emarks: *Fo	or Enginee	ring Evalua	tion. Densi	ty of Cores follo)WS:		Spec.: C-l	ESR-H-00044	Rev.: 0	DCF	(s):	N/A
	221 11- P	13-N-2U-A	- 141 pci; 221H	I-1 13-N-2C-B =	= 142 pci;		Dwg(s):	N/A	Rev.: N/.	A DCF	'(s):	N/A
Feebrician (Print/Sig	n): Glenn S	nencer	line	-				Lev	ol· I	II Det	. 3_8_17

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Savannah River Site

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Summary Report of Testing Activities (Continuation Sheet)

Ite	m #						Sum	mary				_	_
	Don	city A	hsor	ation	and	Voide	in U	ardor	hod (Con	croto		
	Den	SILY, A	nzoit	Juon,	anu	VOIUS		aruer	leu	COIN	ciete	:	
A = B =	mass of oven-dried s mass of surface-dry s	ample in air (g sample in air a	ː] fter immei	rsion [g]			AAI = A AAIB = A	Absorption Absorption	after im after im	mersion mersion	[%] and boilin	g (g)	
C = D =	mass of surface-dry s apparent mass of sar	sample in air a nple in water	fter immer after imme	rsion and bo ersion and bo	iling (g) piling (g)		g1 = BDAI =	Bulk densit Bulk densit	y, dry y after in	mersior	1		
g ₁ = g ₂ =	bulk density, dry, Mg aparent bulk density, density of water	/m³, or g/cm³ , Mg/m³, or g/ Mg/m³ = 1 = 1	cm ³				BDAB = 1 $g_2 = 1$	Bulk densit Apparent D	y after in Density	imersion	n and boili	ng Ic) (9∠1	
h =	density of water = 1	rvig/m ≈1g/0	an				vrr =	Forume of	Permeab	ie pore s	hear (AOIC	-37 [70]	
ine	Sample ID	A (g)	B	C [g]	D [g]	B ₁ [g/cm ³]	82 [g/cm ³]	ρ [g/cm ³]	AAI [%]	AAIB [%]	BDAi [g/cm ³]	BDAIB	VPP [%]
1 2	221H-PT3-N-6A 221H-PT3-N-2C	1079.20 986.60	1156.80 1060.20	1172.70 1067.60	671.2 613.6	2.15 2.17	2.65 2.65	1.00 1.00	7.2	8.7 8.2	2.31 2.34	2.34 2.35	18.6 17.8
s:	Absorption after imm Absorption after imm Bulk density, dry Bulk density after im Bulk density after im Apparent Density Volume of permeable	mersion and be mersion and be mersion and be e pore space (oiling (g) voids) (%)				% = [(C-A)// % = [(C-A)// B ₁ = [A/(C-L BDAI = [B/(BDAI B = [C/ 32 = [A/(A-C % = (g ₂ - g ₁)	A] X 100 A] X 100 J] X p C-D)] X p ((C-D)] X p J] X p J] X p /g ₂ x 100					
						~	1		-	-	-	-	
							_						

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Savannah River Site

Summary Re	port c	of Test	ing Activ	vities		
Report		X	Cover She	et	Page	1_of_4_
Approvals (If required)		Work F	ackage No.:	:	1525456	
Senior Civil Technician (Level III):		QCIR	No.:	N/A		
Glenn Specner		Project	No.:	Ν	V/A	
Civil Testing & Inspection Superintendent:		Design	Category:		SC	
W. Pope, Jr.		Report	No.: 20)17-CAEX-0001	Date:	2-28-17
Lab. No.: 170008-170009	Test Me	ethod:		See attached	l pages	
Discipline: Civil	Des	cription	:	Concr	ete	
Location: 221H Personnel Tunnel 3 North	Wall		Reported to	o: J.	Carter, 8-172	7
Summary: This report presents the data required by C-ESR-H-00044, Revision 0. Page 4 contains a spr ASTM C642-13 covering the determination of dense Line 7 on page 4 references . See page 2 and 3 for to Also note, the densities of the core segments are portion of	by the H readshee sity, pero he result provided ZN T H - P	Area C. t for data cent abso ts of "Co in the pa his R CALIC T_3-N	AEX Tunne a and results orption, and ompressive S age 2 and 3 E = poset A = N A = N	el Concrete Core : s provided by the percent voids in Strength of Drille Remarks Section <u>IS FROM</u> <u>1H-PT3-N</u> <u>8-22-17</u>	Sampling Plar e calculations of hardened con ed Cores".	a, of crete.
M&TE: See attached pages Cal. Due Date:	See	attached	pages	Procedure:	C-QCP-	002
NCR No.: N/A				– Rev.:	0	<i>z</i> – z
Results: Conforming Nonce	onformi	ng	*X N/A	PCN(s):	N/A	
Remarks: <u>*</u> For engineering evaluation				- Spec.:	C-ESR-H-0	0044
N/A				Rev.:	0	
				DCF(s):	N/A	
Technician (Print/Sign): Glenn Spencer/				Level: III	Date:	3/20/17
Reviewer (Print/Sign): Kevin Miller KEVIみ	MILL	KM	8-22-17	Level:III	Date: 3	127/17

THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY. Makel 4-3-17

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ASR 18-202 ((4/13)					URS					Revis	sion 0
					Savann	ah River	Site				Page 2	_of _4_
				Com	pressive St	rength	of Drilled	Cores				
		ASTM	C 39- (14)	ASTM	1 C 42-(13)	A	STM C 617-(12)		
Report No.:	201	7-CAEX-00	01 Pro	ject No.:	N/A	W	/ork Package N	lo.:	1525456	De	sign Cat.: 3-2	4-17 Jun 00 SC
QCIR No.: _	N/2	A]	Date & Time	Core Taken:	2-28-17 @ N	/A Cor	ncrete Supplier	:N/A	A Plac	ement Da	te: <u>1</u>	952
Placement L	location:	221H- Sect	tion 6c, Person	el Tunnel Nort	h Wall Mix D	esign:	<u>N/A</u>	Design	Strength:	2500	psi @N/A	_ Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level
170009	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6C-A	6	3-6-17	7.37	7.56	3.70	10.75	21794	2.04	1.00	2030	N/A	Les TH
6C-B	6	3-6-17	7.33	7.52	3.71	10.81	23583	2.03	1.00	2180	N/A	65 TI
6C-C	7	3-7-17	7.53	7.71	3.71	10.81	22997	2.08	1.00	2130	N/A	las TI
	-							_		_		
							#					
Direction of A	Applicatio	on of the L	oad on the Sp	ecimen with R	espect to the H	[orizontal]	Plane of the Co	oncrete Plac	ed:		N/A	
Nominal Ma	ıximum S	ize of Aggı	regate:		N/A]	Method of T	'est:	N/A	_	
M&TE:			1) CA-002; 2) 1	°M-5		(Cal. Due Date:		1) 9-23-17; 2)) 1-11-18		
Test Results:		Conformin	ng	Nonconformi	ng X	N/A	NCR No.:	6.007	N	I/A		DI/A
Remarks: *Fo	or Enginee	ring Evalua	tion. Densi	ty of Cores follo	WS:		rroceaure:	C-QCP	-002 1	xev.:	U PCN(s)	N/A
221H-P7	13-N-6C-A	= 140 pcf; 2	221H-PT3-N-60	C-B = 142 pcf; 2	21H-PT3-N-6C-	C =	Spec.: C-E	SK-H-00044	Rev.: 0	DCF	(s):	N/A
		221	H-PT3-N-6C-C	=142pcf;]	Dwg(s):	N/A	Rev.: N/2	A DCF	(s):	N/A
Technician ()	Print/Sig	n): Glenn S	pencer M	h.			-		Lev	el: II	I Date	: 3-4-17 J-24-17
Reviewer (P	rint/Sign)	: Kevin M	liller/ KE	VIN MI	LLER	Re-None	w kevin a	TLLEN :	3.29-17 Lev	el: _I	I Date	: 3/27/17

ASR 18-202	(4/13)					URS					Rev	1s10n ()
					Savann	nah River	r Site				Page	3_of_4_
				Com	pressive S	trength	of Drilled	l Cores				
7	_	ASTM	C 39- (14)	ASTN	M C 42-(13)	Α	STM C 617-(12)	_	
Report No.:	201	7-CAEX-00	001 Pro	ject No.:	N/A	V	Vork Package	No.:	1525456	D	esign Cat.:	3-24-17 »~ 485 C
QCIR No.:	N/2	A	Date & Time	Core Taken:	2-28-17 @ N	N/A Co	ncrete Suppli	er: <u>N//</u>	A Plac	ement Da	ate:	1952
Placement L	ocation:	221H- Sect	tion 6B, Person	nel Tunnel Nort	h Wall Mix I	Design:	N/A	Design	n Strength:	2500	_ psi @N/A	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level
170008	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6B-A	6	3-6-17	7.38	7.58	3.71	10.81	27031	2.04	1.00	2500	N/A	6STI
6B-B	6	3/6/17	7.35	7.52	3.68	10.64	27151	2.04	1.00	2550	N/A	Les TIE
		-										
							4					
		-					A					
					-		L.					
Direction of A	Applicatio	on of the L	oad on the Sp	ecimen with R	espect to the H	Horizontal	Plane of the (Concrete Plac	ed:		N/A	
Nominal Ma	ximum S	ize of Agg	regate:		N/A			Method of T	`est:	N/A		
A&TE:							Cal. Due Date	:				
	-		1) CA-002; 2)	TM-5					1) 9-23-17; 2) 1-11-18		
'est lesults:		Conformin	ng 🗌	Nonconformi	ng 🔀] N/A	NCR No.:	0.007	N	V/A		
emarks: *Fo	r Enginee	ring Evalua	tion. Dens	ty of Cores follo	ws:		Procedure:	C-QCP	-002	Rev.:	0 PCN(s): N/A
	221H-P	T3-N-6B-A	= 143 pcf; 221H	I-PT3-N-6B-B =	143 pcf;		Spec.: C-	ESR-H-00044	Rev.: 0	DCF	r(s):	N/A
							Dwg(s):	N/A	Rev.: N/2	A DCF	F(s):	N/A
Fechnician (Print/Sig	n): Glenn S	pencer #	Alm 1	-				Lev	el: I	II Dat	e: <u>3-6-17</u>
Reviewer (P	rint/Sign)): Kevin N	1iller/ KE	VIN M:	ELLER A	Re-Review	KEVEN "	TLLOA 3-	29-17 Lev	el: I	II Dat	e: 3/27/17

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Savannah River Site

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Summary Report of Testing Activities (Continuation Sheet)

Iter	n #	-				-	_				5	Summa	ry					
	A = B = C = B = B = B =	mass of c mass of s mass of s apparent bulk dens aoarent b	Der oven-dried urface-dry urface-dry mass of sa sity, dry, M	sample sample sample imple in g/m³, o y. Mg/m	in air (in air a in air a water rg/cm ¹ a ³ or rg/	bso fter imi after imi after imi	ner: mer: me)tion, sion [g] sion and b rsion and l	oiling (g)	d Void	ds	AAI = AAIB = BDAI = BDAIB = g_1 = BDAIB = g_2 =	Absorptior Absorptior Bulk densit Bulk densit Bulk densit Aogarent C	after im after im y, dry y after in y after in y after in ensity	Con Immersion Immersion Immersion	Crete [%] and boilin n n and boili	2 ng (g) ng	
	ρ=	density o	f water = 1	Mg/m ³	= 1 g/c	2m ³						VPP =	Volume of	permeal	ble pore	speac (void	ds) [%]	
F	Line	Samolo		T	A	B	T	C	D	B1	T	B2	p	AAt	AAIB	BDA1	BDAIB	VPP
ł	1	221H-PT3	3-N-6C	10	81.80	ig 1159.	70	1164.40	(g) 673	5 2.2	0	1g/cm ²] 2.65	[g/cm ³] 1.00	[%] 7.2	7.6	1g/cm ³ 2.36	[@/cm ²] 2.37	16.8
F	2	221H-РТ3 221H-РТ3	3-N-6B-C	9	40.10	1012.	80 20	1018.20	585	.5 2.1	17	2.65	1.00	7.7	8.3 8.4	2.34	2.35	18.0
		Absorptic Absorptic Bulk dens Bulk dens Bulk dens Apparent Volume o	on after im on after im ity, dry ity after in ity after in Density if permeab	mersior mersio nmersio nmersio	n (%) n and bo n and t space (oiling (g ooiling voids) ('	 %]				9 9 8 8 8 9	6 = ((B-A)/. 6 = ((C-A)/. 1 ₂ = [A/(C-C BDAI = [B/(BDAI = [C/ 1 ₂ = [A/(A-C 6 = (g ₂ - g ₁)	A] X 100 A] X 100)]] X p (C-D)] X p ((C-D)] X p)] X p //g ₂ X 100					
ıment	5:										~	1		_				

Appendix F. Non-Radiologically Contaminated South Wall Concrete Cores - UPV Data Sheets

1/13/17 Harea concrete Rebar embedded at position #3

Transmission Time 22.2.1s 2.1.4 22.1 1 Distance 0.3098 0.3108 0.3093 1 Pulse Velocity 13964 1.4466 14027 1 Compressive Strength 1 1.4466 14027 1 Pulse Velocity 13.717 3.720 3.724 1 1 Physical Messurement 3.717 37.3 23.8 34.5 6 7 Transmission Time 38.71 37.3 29.73 20.473 0.473 0.473 0.473 0.473 0.473 0.473 0.4743	PT3-5-4-CC	1	2	3	4	5	6	7 7	٦
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	Transmission Time	22.24	\$ 21.4	22.1	1			+	-
Pulse Velocity 13964* (4486 14627 Compressive Strength	Distance	0.3098	0-310	0.3/03	-	1		+	-
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Pulse Velocity	13964	14486	14023					4
E-Modulus 3.717 3.720 3.724 Physical Measurement 3.717 3.720 3.724 Physical Measurement 3.717 3.720 3.724 Physical Measurement 3.717 3.720 3.724 9.4 5 6 7 Transmission Time 329 37.9 39.3 31.8 31.6 40.9 37.5 0.473 0.474 0.475 0.474 0.4	Compressive Strength		1.1.0	1.001					-
Physical Measurement 3.717 3.720 3.724 7 PT3-N-2-D 1 2 3 4 5 6 7 Transmission Time 38.7 37.9 37.6 40.7 37.5 57.6 37.5 Puise Velocity 12.159 12.472 0.473 0.472 0.473 0.473 0.472 0.473	E-Modulus		1			-			-
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	Physical Measurement	3.717	3 720	3.72.4				-	-
Transmission Time 38.9 37.9 37.3 37.8 37.6 40.7 37.5 Distance 0.473 0.473 0.474 0.473	PT3-N-2-B	1	2	3	4	E	1 6		and the
Distance 0.473 0.473 0.474 0.474 0.4745 0.473	Transmission Time	38,9	37.9	39.3	39.8	29.6	ZAO	270	Photos
Pulse Velocity 12 159 12 420 12 012 11 13 12 15 12 15 12 15 Compressive Strength 1 12 012 11 03 11 03 11 04 11 75 12 613 E-Modulus 1 12 012 11 03 5 6 70 5 637	Distance	0.473	0473	0.474	0.474	1432	0412	472	-
Compressive Strength 1	Pulse Velocity	12159	12480	12092	1102	LUCAL	LIDAE	0417.5	-
E-Modulus $5,675$ $5,690$ $5,694$ $5,690$ $5,670$ 5675 Transmission Time $38,3$ $41e^4$ 43.5 67 7 Distance $0,473$ $0,472$ $0,472$ 7 7 Pulse Velocity 12350 11425 10951 11964 $41e^3$ Compressive Strength 11964 86.5 7 7 7 Pulse Velocity 12350 11425 10951 11964 $41e^3$ Compressive Strength 12350 11425 10951 11964 11964 Physical Measurement 5.680 5.678 5.672 22.5 22.5 22.7 23.8 32.80 3349 Pulse Velocity 12.01 3022 13463 13367 13349 13349 Physical Measurement 3.726 3.730 3.730 3.732 3.732 77 77 Transmission Time 1234 34567 577 77 77 77 77 77 77 <t< td=""><td>Compressive Strength</td><td></td><td>1-1-0</td><td>-</td><td>11122</td><td>LIGHT</td><td>11-15</td><td>172613</td><td>1</td></t<>	Compressive Strength		1-1-0	-	11122	LIGHT	11-15	172613	1
Physical Measurement 5,675 5,680 5,674 5,670 5,676 g, x 9 & (D & 4 5 6 7 Transmission Time 38,3 $A_1 + 1$ 43.5 7 7 Distance $0,473$ $0,472$ 7 7 7 Puise Velocity 123.5.6 14.2.5 7 7 7 Compressive Strength 7 7 7 7 7 7 7 Physical Measurement 5.6.620 5.6.72 7	E-Modulus								
A = A = C = <thc< td=""><td>Physical Measurement</td><td>5.675</td><td>5,680</td><td>5.699</td><td>5 194</td><td>E COD</td><td>E 170</td><td>5100</td><td></td></thc<>	Physical Measurement	5.675	5,680	5.699	5 194	E COD	E 170	5100	
Transmission Time 38.4 41.4 43.5 7 Distance 0.4773 0.4772 1 1		01	9 2	DE	13.01-	10.000	DIDID	2.645	
Distance 0.473 0.472 Image: Compressive Strength Image: Comp	Transmission Time	38.4	414	43.5			0		
Putse Velocity 12350 1425 10851 11964 Ave Compressive Strength	Distance	0.473	OAT3	0.477	-				
Compressive Strength IIII IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	Pulse Velocity	12350	11425	Inaci					11064 1.10
E-Modulus 5.680 5.678 5.672 1 2 3 4 5 6 7 Transmission Time 25.7 22.5 22.5 22.5 22.9 23.8 1 0.311 0	Compressive Strength		11	IL RALL					117 TAVES
Physical Measurement 5.680 5.678 5.672	E-Modulus								
PT3 - N - [-13] 1 2 3 4 5 6 7 Transmission Time 2.5.7 22.5 22.5 22.4 2.3.8 7 Distance 0.311 0.311 0.311 0.311 0.311 0.311 7 Puise Velocity 12101 3822 13822 13463 13067 13349 Compressive Strength	Physical Measurement	5.680	5.678	5.672					
Transmission Time 2.5.7 22.5 22.5 22.5 22.4 23.8 Distance 0.311	PT3-N-1-13	1	2	3	4	5	6	7	
Distance 0.311	Transmission Time	257	22.5	225	77 6	22.9	220		
Pulse Velocity 12.101 38.22 13.822 13.822 13.822 13.823 13.949 Compressive Strength	Distance	0311	0.311	0.311	0.31	0311	A 211		
Compressive Strength 13722 13722 13723 130051 13947 E-Modulus 3.726 3.730 3.730 3.732 1 2 3 4 5 6 7 Transmission Time	Pulse Velocity	12101	3322	13827	12022	121/2	120(7)		10010
E-Modulus Image: state strength 3.72.6 3.73.0 3.73.0 3.73.0 3.73.2 Image: strength	Compressive Strength			10-0-	1.50	LITES	LOOT		13947
Physical Measurement 3.72.6 3.73.0 3.73.0 3.73.0 3.73.2 1 2 3 4 5 6 7 Transmission Time 1 2 3 4 5 6 7 Distance 1 2 3 4 5 6 7 Pulse Velocity 1	E-Modulus								
1 2 3 4 5 6 7 Transmission Time 1 2 3 4 5 6 7 Qistance 1 2 3 4 5 6 7 Pulse Velocity 1 1 1 1 1 1 1 Compressive Strength 1 1 1 1 1 1 Physical Measurement 1 1 2 3 4 5 5 7 Transmission Time 1 2 3 4 5 5 7 Distance 1 2 3 4 5 5 7 Compressive Strength 1 1 1 1 1 1 1 Pulse Velocity 1 1 1 1 1 1 1 Compressive Strength 1 1 1 1 1 1 1 Physical Measurement 1 1 1 1 1 1 1 Physical Measurement 1 1 1 1 1 1 1	Physical Measurement	3.726	3730	3 720	3,220	2 732	2722		
Transmission Time Distance Pulse Velocity Compressive Strength E-Modulus Physical Measurement 1 2 3 4 5 6 7 Transmission Time Distance Quise Velocity 1 2 3 4 5 5 7 Compressive Strength 1 2 3 4 5 5 7 Compressive Strength 1 2 1 2 3 4 5 5 7		1	2	3	4	5,700	5.772		
Distance Image: strength Pulse Velocity Compressive Strength E-Modulus Physical Measurement 1 2 3 4 5 5 7 Transmission Time Distance Pulse Velocity Compressive Strength Image: stre	Transmission Time						0		
Pulse Velocity Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength 1 2 3 4 5 5 7 Transmission Time Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Pulse Velocity Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Physical Measurement Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength	Distance			1					
Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength 1 2 3 4 5 5 7 Transmission Time Image: Compressive Strength Image: Compressive Streng	Pulse Velocity								
E-Modulus Image: Constraint of the surement Image: Constraint of the surement 1 2 3 4 5 5 7 Transmission Time Image: Constraint of the surement Distance Image: Constraint of the surement Image: Constraint of the surement Image: Constraint of the surement Pulse Velocity Image: Constraint of the surement Image: Constraint of the surement Image: Constraint of the surement	Compressive Strength								
Physical Measurement 1 2 3 4 5 5 7 Transmission Time Distance Puise Velocity Compressive Strength F-Modulus	E-Modulus						-		
1 2 3 4 5 5 7 Transmission Time Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength E-Modulus Image: Compressive Strength Image: Compressive Strength Image: Compressive Strength	Physical Measurement					-			
Transmission Time		1	2	3	4	5			
Distance Pulse Velocity Compressive Strength E-Modulus Physical Measurement	Transmission Time			-			0		
Pulse Velocity Compressive Strength E-Modulus Physical Measurement	Distance								
Compressive Strength E-Modulus Physical Measurement	Pulse Velocity								
E-Modulus Physical Measurement	Compressive Strength								
Physical Measurement	E-Modulus								
	Physical Measurement								

E C. II.Y

24.7 23.7 13122

Ar- Personnel 221-H

Turren		Sound	WALL			LJOG	-1014	10/
PT3-5-7-D	1	2	3	4	5	6	7	1
Transmission Time	208	19.3	20.3	20.2	19.2	-	- /	
Distance	.310	,310	1312	310	310	1 /	- /	
Pulse Velocity	11901	11.0.2	15971	15547	1/10/	N/	11	150
Compressive Strength	1 mm	- North	1.76/1	11211	Theret	A	A	2.
E-Modulus						110	170	261
Physical Measurement	31/2 720	13.720	3.727	3,72 8	3.728.	1/	/	21
PT3-K/-D	1	2	3	4	S	6	7	23.2
Transmission Time	19.7	19.9	19.5	19.5	19.6			
Distance	.81	3.11	311	.311	1.310	1	/	
Pulse Velocity	15736	15579	1/114	16114	icall	N/	1/	150-
Compressive Strength	12 in	mina	agent	14111	12014	A	TA	407
E-Modulus						10	10	401
Physical Measurement	3.724	3.750	3.730	3.780	3.725	1	/	25
DT3-5-1-D	1	2	3	4	5	6	7	28.
Transmission Time	19.2	20.5	21	21	20.1	207	70.1	152.9
Distance	.311	.3/	.3/1	311	312	312	1317	824
Pulse Velocity	161995	15/71	1086	idals	15171	15396	15577	504
Compressive Strength	- WILLIE	- and	fice	HILDES	0// 1/	102 14	11166	21.
E-Modulus								23.9
Physical Measurement	3.734	3.732	3.7%	3.757	3 7/10	2.740	3740	
M3-5-5-D	1	2	3	4	5	6	7	
Transmission Time	21.7	18.7	18.9	20.4	211	7	1	1-1
Distance	34	.3/	310	.310	.310	N/	NT	1344
Pulse Velocity	14286	165795	16499	INIAL.	111.07	A A	A	543
Compressive Strength	- at	ising	and	131-14	134-160	170	10	22.
E-Modulus						/	/	23.
Physical Measurement	3.725	3.777	3.773	3 723	3.714	/		
PT3-15-4-D	1	2	3	4	5	6	7	
Transmission Time	71.2	22	21.1	20.7	19.9	1		
Distance	131	1310	.30	.310	.3.10	/	/	
Pulse Velocity	14/23	IVOOI	14352	1497/	16579	NI	NT	1472
Compressive Strength	- un	the li	11.005	17 114	132.0	A	A	354
-Modulus						1	10	24
Physical Measurement	3.715	3.71/5	3.7197	3.718	3.770	/	/	64
PTZ-5-036	1	2	3	4	5	6	7	26
Transmission Time	19.5	20.1	20.2	10.2	19.9			156
Distance	.31	.3	310	30	.211			291
Pulse Velocity	15897	15022	15123	ISLCT	16(57			511
ompressive Strength	L'ATT	12462	13.167		12/2/			25
Modulus								27
hysical Measurement	3.77.0	3.720	3.797	8 772	3 729			
injacan measurement	1.100	31/20	1.100	2.162	3.14			

In Distance

A-0 Ave 23.06 %

Ar - Personnel 22 - H 23.7 [C-Core Tunnel #3 22 - H 13122 [JOE-Forelle)

DT3.6.2.D		1 2	1 2			1 4		1
Transmission Time	208	10.0	202	4	100	6	7	1
Dietance	40.0	14.2	20.5	20.6	14.2	- /	- /	
Distance Dulca Valacity	111901	1310	15421	1310	.310	/	- /	
Compressive Strength	19709	14046	152/1	15241	16144	N/A	N/	15546
E-Modulus						1/A	/A	3280
Dhuelcal Mansurament	1/2 720	10 790	2717	1 70 0	0.720	1/	/	21 %
DTZ / D	13.110	75.120	5.121.9	13.120.	3.722	1/	/	12.25
Transmission Time	107	10.0	105	4	5	6	7	23.00
Distance	19.1	19.9	19.7	14.5	19.6	- /	- /	
Pulse Velocity	121	12.11	1.5.11	17/11	1310	1/	-,/	1
Pulse velocity	12/34	152/8	1414	16119	15814	N/	N/	15871
Compressive Strength						/ A	/A	4070
E-Iviodulus	0.001	0.54	3710	1.74		Y	1	2590
Physical Measurement	3.72 4	3.730	3.130	3.730	3.725		/	28.4%
1-2-2-1-1)	107	205	3	4	5	6	7	
Transmission Time	19.4	2013	21	21	200	10.2	20.1	15297
Distance	13/1	20	13/1	.31/	312	1.312	.312	3243
Pulse Velocity	16190	15/11	19810	1480	15171	15396	15522	2629
Compressive Strength								72.57
E-Modulus								63.21
Physical Measurement	3.734	3.732	3.736	3.737	3.740	3.740	3740	
P13-5-5-D	1	2	3	4	5	6	7	
Transmission Time	21.7	18.7	18.8	20.9	2.1	. /	. /	15119
Distance	.30	.311	310	.310	.30	N/	NI	2187
Pulse Velocity	14286	16578	16489	15196	14692	A A	ZA	2421
Compressive Strength						1		22.27
E-Modulus						/	/	23,5 9
Physical Measurement	3.723	3.727	3.723	3.723	3.724	/		
P13-15-4-D	1	2	3	4	5	6	7	
Transmission Time	21.2	22	21.6	20.7	19.9	7	/	
Distance	131	1310	.310	.310	.3.10	. /	1	
Pulse Velocity	14/23	14001	14352	14976	15579	N/	NT	14724
Compressive Strength				11	une	/A	/A	3543
E-Modulus				1		1	10	240
Physical Measurement	3.715	3.71.5	3.71967	3,718	3,720	/	1	
PT 2-5-036	1	2	3	4	5	6	7	2690
Transmission Time	19.5	70.1	20.2	10.2	19.8	-		15611
Distance	.31	13	310	30	.211			29.7
Pulse Velocity	15897	15422	151/23	56.57	16157			5111
Compressive Strength	- aut	13102	11461	U/II	12421			2570
E-Modulus								27 %
Physical Measurement	3.72.2	3.720	3.797	2 772	3 770			
in a sear in the astar entitient	1100	1140	1100	2.167	2.16			

In Distance

A-0 Ave 23.06 %

F-3

1/13/17 Harea concrete Rebar embedded at position #3

ē:

PT3-5-4-CC	1	2	3	4	5	6	7	1
Transmission Time	22.245	21.4-	22.1					1
Distance	0.3098	0-310	0.3/03					1
Pulse Velocity	13964	14486	14027					1
Compressive Strength								1
E-Modulus								1
Physical Measurement	3.717	3.720	3.724					- Annah
PT3-N-2-B	1	2	3	4	5	6	7	21-1-
Transmission Time	38,9	37.9	39.3	39.8	39.6	30.9	37.5	
Distance	0,473	0.473	0.474	0.4745	0,473	DA73	0,473	
Pulse Velocity	12159	12480	12092	11935	11944	11795	12613	
Compressive Strength								
E-Modulus								
Physical Measurement	5,675	5,680	5,689	5.694	5.680	5.670	5.675	
	9×	94	IDE	4	5	6	7	
Transmission Time	38.1	41.7	43.5					
Distance	0.473	0,473	0,472					
Pulse Velocity	12350	114-25	10851					11964 Ave
Compressive Strength		-						
E-Modulus								
Physical Measurement	5.680	5.678	5.672					
PT3-N-1-13	1	2	3	4	5	6	7	
Transmission Time	25.7	22.5	225	225	2209	23.8		
Distance	0.311	0.311	0.311	0.311	0.311	0.311		
Pulse Velocity	12101	3322	13822	13822	13463	13067		13349
Compressive Strength				Second and				
E-Modulus	-	-						
Physical Measurement	3.726	3,730	3.730	3,730	3.730	3.732		
	1	2	3	4	5	6	7	
Transmission Time								
Distance								
Pulse Velocity						L		
Compressive Strength				A				
E-Modulus								
Physical Measurement								
	1	2	3	4	5	6	7	
Transmission Time								
Distance								
Pulse Velocity								
Compressive Strength						1		
E-Modulus			0.000					
Physical Measurement								

E C. II.Y

24.7 23.7 13122

Ar- Personnel 221-H

Turren		Sound	WALL			LJOG	-1014	10/
PT3-5-7-D	1	2	3	4	5	6	7	1
Transmission Time	208	19.3	20.3	20.2	19.2	-	- /	
Distance	.310	,310	1312	310	310	1 /	- /	
Pulse Velocity	11901	11.0.2	15971	15547	1/10/	N/	11	150
Compressive Strength	1 mm	- North	1.76/1	11211	Theret	A	A	2.
E-Modulus						110	170	261
Physical Measurement	31/2 720	13.720	3.727	3,72 8	3.728.	1/	/	21
PT3-K/-D	1	2	3	4	S	6	7	23.2
Transmission Time	19.7	19.9	19.5	19.5	19.6			
Distance	.81	3.11	311	.311	1.310	1	/	
Pulse Velocity	15736	15579	1/114	16114	icall	N/	1/	150-
Compressive Strength	12 in	mina	agent	14111	12014	A	TA	407
E-Modulus						10	10	401
Physical Measurement	3.724	3.750	3.730	3.780	3.725	1	/	25
DT3-5-1-D	1	2	3	4	5	6	7	28.
Transmission Time	19.2	20.5	21	21	20.1	207	70.1	152.9
Distance	311	.3/	.3/1	311	312	312	1317	824
Pulse Velocity	161995	15/71	1086	idals	15171	15396	15577	504
Compressive Strength	- WILLIAM	- and	fice	HILDES	0// 1/	102 14	11166	21.
E-Modulus								23.9
Physical Measurement	3.734	3.732	3.7%	3.757	3 7/10	2.740	3740	
M3-5-5-D	1	2	3	4	5	6	7	
Transmission Time	21.7	18.7	18.9	20.4	211	7	1	1-1
Distance	34	.3/	310	.310	.310	N/	NT	1344
Pulse Velocity	14286	165795	16499	INIAL.	111.07	A A	A	543
Compressive Strength	- at	ising	and	131-14	134-160	170	10	22.
E-Modulus						/	/	23.
Physical Measurement	3.725	3.777	3.773	3 723	3.714	/		
PT3-15-4-D	1	2	3	4	5	6	7	
Transmission Time	71.2	22	21.1	20.7	19.9	1		
Distance	131	1310	.30	.310	.3.10	/	/	
Pulse Velocity	14/23	IVOOI	14352	1497/	16579	NI	NT	1472
Compressive Strength	- un	the li	11.005	17 114	132.0	A	A	354
-Modulus						1	10	24
Physical Measurement	3.715	3.71/5	3.7197	3.718	3.770	/	/	64
PTZ-5-036	1	2	3	4	5	6	7	26
Transmission Time	19.5	20.1	20.2	10.2	19.9			156
Distance	.31	.3	310	30	.211			291
Pulse Velocity	15897	15022	15123	ISLCT	16(57			511
ompressive Strength	L'ATT	12462	13.167		12/2/			25
Modulus								27
hysical Measurement	3.77.0	3.720	3.797	8 772	3 729			
injacan measurement	1.100	31/20	1.100	2.162	3.14			

In Distance

A-0 Ave 23.06 %

Ar - Personnel 22 - H 23.7 [C-Core Tunnel #3 22 - H 13122 [JOE-Forelle)

DT3.6.2.D		1 2	1 2			1 4		1
Transmission Time	208	10.0	202	4	100	6	7	1
Dietance	40.0	14.2	20.5	20.6	14.2	- /	- /	
Distance Dulco Valacity	111901	1310	15421	1310	.310	/	- /	
Compressive Strength	19709	14046	152/1	15241	16144	N/A	N/	15546
E-Modulus						1/A	/A	3280
Dhuelcal Mansurament	1/2 720	10 790	2717	1 70 0	0.720	1/	/	21 %
Prysical Measurement	13.110	75.120	5.121.9	13.120.	3.722	1/	/	12.25
Transmission Time	107	10.0	105	4	5	6	7	23.00
Distance	19.1	19.9	19.7	14.5	19.6	- /	- /	
Pulse Velocity	121	12.11	1.5.11	17/11	1310	1/	-,/	1
Pulse velocity	12/34	152/8	1414	16119	15814	N/	N/	15871
Compressive Strength						/ A	/A	4070
E-Iviodulus	0.001	0.54	3710	1.74		Y	1	2590
Physical Measurement	3.72 4	3.730	3.130	3.730	3.725		/	28.4%
1-2-2-1-1)	107	205	3	4	5	6	7	
Transmission Time	19.4	2013	21	21	200	10.2	20.1	15297
Distance	13/1	20	13/1	.31/	312	1.312	.312	3243
Pulse Velocity	16190	15/11	19810	1480	15171	15396	15522	2629
Compressive Strength								72.57
E-Modulus								63.21
Physical Measurement	3.734	3.732	3.736	3.737	3.740	3.740	3740	
P13-5-5-D	1	2	3	4	5	6	7	
Transmission Time	21.7	18.7	18.8	20.9	2.1	. /	. /	15119
Distance	.30	.311	310	.310	.30	N/	NI	2187
Pulse Velocity	14286	16578	16489	15196	14692	A A	ZA	2421
Compressive Strength						1		22.27
E-Modulus						/	/	23,5 9
Physical Measurement	3.723	3.727	3.723	3.723	3.724	/		
P13-15-4-D	1	2	3	4	5	6	7	
Transmission Time	21.2	22	21.6	20.7	19.9	7	/	
Distance	131	1310	.310	.310	.3.10	. /	1	
Pulse Velocity	14/23	14001	14352	14976	15579	N/	NT	14724
Compressive Strength				11.00	une	/A	/A	3543
E-Modulus						1	10	240
Physical Measurement	3.715	3.71.5	3.71967	3,718	3,720	/	1	
PT 2-5-036	1	2	3	4	5	6	7	2690
Transmission Time	19.5	70.1	20.2	10.2	19.8	-		15611
Distance	.31	13	310	30	.211			2017
Pulse Velocity	15897	15422	151/23	56.57	16157			5111
Compressive Strength	- aut	13102	11461	U/II	12421			2570
E-Modulus								27 %
Physical Measurement	3.72.2	3.720	3.797	2 772	3 770			
in a sear in the astar entitient	1100	1140	1100	2.167	2.16			

In Distance

A-0 Ave 23.06 %

F-3

Appendix G. Non-Radiologically Contaminated South Wall Concrete Cores - Compressive Strength, Porosity, and Density Data Sheets Appendix G. Non-Radiologically Contaminated South Wall Concrete Cores - Compressive Strength, Porosity, and Density Data Sheets ASR 18-203 (04/13)

Reviewer (Print/Sign): Charles Z. Moore/

URS

Savannah River Site

Summary Report of Testing Activities

	Report	_	X	Cover Shee	et	Page	<u>1</u> of <u>3</u>
Approvals	(If required)		Work	Package No.:		1525456	
Senior Civil Technician (Level III)):		QCIR	No.:	N/A		
Charles A. Bookhamer			Project	t No.:		N/A	
Civil Testing & Inspection Superin	ntendent:		Design	Category:		GS	
W. Pope, Jr.			Report	No.: 20	16-CAEX-0001	Date:	11-15-16
Lab. No.: 160088	3	Test M	lethod:		See attache	d pages	
Discipline: Civ	il	De	scription	:	Conc	rete	
Location: 221H Personn	el Tunnel 3 South	Reported to	: J	. Carter, 8-172	27		
Summary: This report presents C-ESR-H-00044, Revision 0. Pa ASTM C642-13 covering the det Lines 1 and 2 on page 2 reference undersized and the data is provi See page 3 for the results of "Co are provided in the page 3 Rems All information in this report is	the data required age 2 contains a spi termination of den ce Sample IDs 2211 ded for Informatic ompressive Streng arks Section. from core segment	by the I readshe sity, per H-PT3-S on Only th of Dr ts from s	H-Area C et for dat rcent abso S-1A and illed Cor sample lo	AEX Tunnel a and results orption, and 221H-PT3-S es". Also no cation 221H-	Concrete Core provided by th percent voids in -1B for this rep ote, the densities PT3-S-1.	Sampling Pla e calculations n hardened co fort. These sam s of the core se	n, of ncrete. nples are syments
M&TE: See attached pages	Cal. Due Date:	See	attached	pages	Procedure:	C-QCP	-002
NCR No.:	N/A				Rev.:	0	
Test Results: Conforming	g 🗌 Nonc	onform	ing	*X N/A	PCN(s):	N/A	. ALT - A.
Remarks: * For engineering evalu	ation N/A				Spec.:	C-ERS-H-(0044
a al antaicticean	NIA		-		Rev.:	0	
	NIA				DCF(s):	N/A	
Technician (Print/Sign): Charles	A. Bookhamer/	and.	1.J.	Marin	Level: III	Date:	12-13-16

~

Level: II Date: 12-14-14

- 2 m-

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ASR 18-250 (04/13)

URS

Savannah River Site

Page 2 of 3

Item #	•						Su	mmar	ary
		7PP %1 15.0	16.5	18.6	111	19.2	18.9	17.2	
	(g) (%)	BDAIB V [e/cm ³] 2.40	2.37	233	236	2.32	2.32	2.34	
crete	%) Ind bailing and boilin peac (voids	BDAI [<u>e</u> /cm ³] 2.39	2.36	231	2.33	2.30	2.30	233	
Con	nersion [nersion a mersion mersion	AAIB [%] 6.6	7.5	8.6	7.3	0.6	8.9	6.7	
ned	after imn after imn after im rafter im ensity ermeab!	AAI [%] 6.0	7.0	7.8	69	8.1	8.1	7.4	
arde	bsorption bsorption ulk density ulk density ulk density oparent D	P [g/cm ³] 1.00	100	1.8	8 8	100	1.00	1.00]X 100]X 100]]Xp [[2, 100 [[2, 100 [[2, 100
s in H	AAI = A AAIB = A 81 = B 81 = B BDAI = B BDAIB = B 82 = A VPP = V	62 [e/cm ³] 2.65	2.64	2.64	2.64	2.63	2.63	2.62	6 = [(B-A)/A 6 = [(C-A)/A 1 = [A/(C-D 1 = [B/(C 10Ai = [B/(C 10Ai = [B/(C 10Ai = [C/(A-D 10Ai = (B_2 - g_1)) 6 = (B_2 - g_1)
Void		81 [e/cm ³] 2.26	2.20	2.15	2.20	2.12	2.13	2.17	* * * * *
and	boiling (g) I boiling (g)	D 274.4	275.1	747.0	460.5	823.6	825.2	752.2	
otion,	ersion (g) ersion and nersion anc	69.71	475.94	1307.48	802.03 1179 36	1449.57	1451.20	1312.65	
bsorp	[g] after imm after imm rafter imn g/cm ³ /cm ³	8 466.80	473.57	1296.86	796.10	1437.36	1440.20	1306.20	bailing [g] d boiling e (voids) [%
ity, A	smple in air ample in air ample in wate nple in wate (m ³ , or g/cr Mg/m ³ = 1 g	A [g] 440.51	442.75	1203.44	741.60	1329.62	1332.80	1216.33	rersion [%] nersion and mersion and mersion and
Dens	en-dried 5; rface-dry 5 rface-dry 5 rface-dry 5 rface-dry 5 rface-dry 5 nrace-dry 5 nated 5 th, dry, Mg ulk density, water = 1 f	3-51A	3-5-1B	S-2A	3-5-2C	5-400	5500	S-6CC	eed Sample n after imm n after imm ty, dry ity after imi ty after imi bensity i permeable
	mass of ov mass of su mass of su apparent i bulk densi density of	Sample ID	*221H-PT	221H-PT3	*221H-PT	221H-PT3	221H-PT3	221H-PT3	* Undersi Absorptio Absorptio Bulk dens Bulk dens Apparent Volume of
	P = = = = = = = = = = = = = = = = = = =	Line	~	m	4 4	2	-	∞	
			_		-		7		
ments:					1	/		-	aller aller and a second se
			-	1		A			

Summary Report of Testing Activities (Continuation Sheet)

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Savannah River Site

Page _3_of _3_

		AST	VI C 39-(14)	ASTN	1 C 42-(13)	A	STM C 617-(12)		
Report No.:	201	6-CAEX-00	01 Pro	ject No.:	N/A	V	Vork Package	No.:	1525456	De	sign Cat.:	GS
QCIR No.: _	N//	<u>A</u>]	Date & Time	Core Taken:	11-1 5 -16@N	MA Co	ncrete Supplie	er:N//	Plac	ement Da	ite:	1952
Placement L	ocation:	221H- Sec	tion 3, Personn	el Tunnel South	Wall Mix D	esign:	<u>N/A</u>	Design	Strength:	2500	_ psi @N/A	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technicia Init./Leve
160088	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
S-1-A	7	11-23-16	6.98	7.23	3.73	10.93	23524	1.94	1.00	2150	N/A	CAB/I
S-1-B	7	11-23-16	6.94	7.22	3.72	10.87	36709	1.94	1.00	3380	N/A	CABIT
S-1-C	7	11-23-16	7.56	7.80	3.71	10.81	41033	2.10	1.00	3800	N/A	CAB/D
S-1-Spare	7	11-23-16	7.51	7.73	3.72	10.87	39549	2.07	1.00	3640	N/A	CAB/I
							A					
						N						
irection of A	Application	on of the L	oad on the Sp	ecimen with R	espect to the H	Iorizontal	Plane of the C	Concrete Plac	ed:		N/A	
Nominal Ma	ximum S	ize of Aggi	egate:		N/A			Method of T	'est:	N/A	_	
1&TE:			1) CA-002; 2) 7	T M-5			Cal. Due Date	:	1) 9-23-17; 2	1-12-17		
'est		Conformin	"	Nonconformi	ng [+¥	N/A	NCR No.:		N	i/A		-
esults: emarks: *Fo	or Enginee	ring Evaluat	tion. Densi	ty of Cores follo			Procedure: Spec.: C-J	C-QCP ESR-H-00044	-002 I Rev.: 0	Rev.:	0 PCN(s): N/A
221H-PT	3-S-1-A =	143 pcf; 221	H-PT3-S-1-B =	145 pcf; 221H-	PT3-S-1-C = 14	5 pcf;	Dung(a)		Davis NV	DCE	(-)- M-)-	
Contraining (Duint/Si-	221H	-r 13-8-1-Spar	e = 145 pcr	12.	11	Dwg(s):	N/A	Kev.: N/	A DCR	(S):	N/A
ecnnician (.	rrinvsig	DJ: Charles	A. Bookhamer	- Charles	1 a. D at	stan	17		Lev	ei:	Dat	e: 11-23-10
keviewer (P	rint/Sign): Charles	Z. Moore/		$\sim m$	~			Lev	el:	Dat	e: 12-14-1

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ASR 18-203 (04/13)

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Savannah River Site

Report	:	X	Cover She	et		Page	<u> </u>	
Approvals (If required)		Work Pa	ackage No.		152	5456		
Senior Civil Technician (Level III):		QCIR N	0.:	N	/A			
Charles A. Bookhamer		Project 1	No.:		N/A			-
Civil Testing & Inspection Superintendent:		Design C	Category:		(GS		
W. Pope, Jr.		Report I	No.: 20	016-CAEX-000	2	Date:	11-16-	-16
Lab. No.: 160089	Test M	ethod:		See attach	ed pa	ges		
Discipline: Civil	De	scription:		Cor	ıcrete			
Location: 221H Personnel Tunnel 3 South	Wall	1	Reported t	D:	J. Cai	rter, 8-172	27	
ASTM C642-13 covering the determination of dem Lines 3 and 4 on page 2 reference Sample IDs 221 221H-PT3-S-2C is undersized and the data is prov See page 3 for the results of "Compressive Streng are provided in the page 3 Remarks Section. All information in this report is from core segmen	nsity, per H-PT3-S vided for th of Dr ts from s	Cent absor S-2A and 2 Informati illed Cores sample loca	rption, and 21H-PT3-S ion Only. s''. Also n ation 221H	percent voids S-2C for this re ote, the densiti -PT3-S-2.	in har port. es of t	dened con Note that he core se	acrete. t Sample gments	<u>e</u>
	V		A					-
M&TE: See attached pages Cal. Due Date:	See	attached	Dages	Procedure:		C-QCP	-002	
Test			_	Rev.:		0		
Results: Conforming None	conformi	ing	*X N/A	PCN(s):		N/A		
Remarks: * For engineering evaluation	- the second	# 1		Spec.:	С	-ERS-H-0	10044	
		10000		Rev.:		0		
NIA	1			DCF(s):		N/A		
Technician (Print/Sign): Charles A. Bookhamer/	Ink	1.300	lang	Level: III	D	ate:	12-13-16	5
Reviewer (Print/Sign): Charles Z. Moore/	~ 2.	m	-	Level: II	D	ate: 12	. 14 - 1	4

Summary Report of Testing Activities

THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.

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Savannah River Site

Summary Report of Testing Activities (Continuation Sheet)

Page _____ of _____

Report Title: 221H Personnel Tunnel 3 South Wall 2016-CAEX-0002 Report No.: Item # Summary 18.9 16.1 18.6 19.2 16.5 17 1 d d 8 2.36 2.33 2.35 2.32 2.32 2.40 2.37 M BDAIB [ه/مت] VPP = Volume of permeable pore speac (voids) [%] AAIB = Absorption after immersion and boiling [g] Density, Absorption, and Voids in Hardened Concrete **BDAIB** = Bulk density after immersion and boiling 2.36 2.30 2.36 2.31 2.33 2.30 2.33 e/cm³] BDAI AAI = Absorption after immersion [%] **BDA!** = Bulk density after immersion 8.6 7.3 8.9 6. 9.0 8.1 ANB 8 0 7.8 6.9 8.1 3 8.1 g₂ = Apparent Density $g_1 = Bulk density, dry$ ₹ 8 1.00 1.00 1.00 BDAIB = [C/(C-D)] X p 8 1.00 108 8 8 % = (g₂ - g₁)/g₂ x 100 BDAI = [B/(C-D)] X p % = [(C-A)/A] X 100 e/cm K = [(B-A)/A] X 100 B1 = [A/(C-D)] Χρ B2 = [A/(A-D)] X p a 2.64 2.62 2.63 2.64 2.63 2.62 2.65 2.64 2.15 2.20 2.12 2.13 2.26 2.20 11 2.1 le/cm D = apparent mass of sample in water after immersion and boiling [g] C = mass of surface-dry sample in air after immersion and boiling [g] 747.0 823.6 460.5 680.4 825.2 752.2 275.1 B = mass of surface-dry sample in air after immersion [g] 1179.36 1312.65 1307.48 475.94 802.03 1449.57 1451.20 469.71 /olume of permeable pore space (voids) [%] Absorption after immersion and boiling [g] 1175.48 1440.20 1306.20 466.80 796.10 473.57 1296.86 1437.36 Bulk density after immersion and boiling $B_2 = aparent bulk density, Mg/m³, or g/cm³$ p = density of water = 1 Mg/m³ = 1 g/cm³-6 A = mass of oven-dried sample in air [g] $B_1 = Bulk density, dry, Mg/m³, or g/cm³$ 741.60 Absorption after immersion [%] 442.75 1203.44 1329.62 1099.22 440.51 1332.80 1216.33 Bulk density after immersion • 9 **Undersized Sample** Apparent Density Bulk density, dry 221H-PT3-5-1B 221H-PT3-S-6CC AL-2-21H-PT3-S-1A *221H-PT3-5-2C 221H-PT3-S-3CC 221H-PT3-5-4CC 221H-PT3-5-5CC 221H-PT3-5-2A Sample ID B ع **Comments:** THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.

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SRNL-TR-2017-00356 Revision 0

ASR 18-202 (4/13)
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Page <u>3</u> of <u>3</u>

		AST	MC 39-(14)	ASTI	M C 42-(1 of Drilled	I Cores	STM C 617-(12)		
Report No.:	201	6-CAEX-00	02 Pro	ject No.:	N/A		Work Package	No.:	1525456	D	esign Cat.:	GS
QCIR No.:	N//	A I	Date & Time (Core Taken:	11-16-16 @	N/A Co	oncrete Supplie	er:N//	A Plac	ement Da	ite:	<u>N/A</u>
Placement I	Location:	221H- Sec	tion 3, Personn	el Tunnel South	Wall Mix	Design: _	N/A	Design	Strength:	2500	psi @N/A	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level
160089	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
S-2-B	7	11-23-16	5.59	5.83	3.73	10.93	29654	1.56	0.96	2720	2610	CAR/III
S-2-BB	7	11-23-16	7.12	7.29	3.72	10.87	41399	1.96	1.00	3810	N/A	CAB/IH
S-2-C	7	11-23-16	7.02	7.17	3.72	10.87	37201	1.93	1.00	3420	N/A	CAB FUE
						N	A					
Direction of A	Applicatio	on of the La	oad on the Sp regate:	ecimen with R	espect to the N/A	Horizonta	l Plane of the (Concrete Plac Method of T	ed: `est:	N/A	N/A	
A&TE:			<u>1) CA-002; 2) 1</u>	TM-5			Cal. Due Date	:	<u>1) 9-23-17; 2</u>) 1-12-17		
lest		Conformin	g 🗌	Nonconformi	ng [•x	N/A	NCR No.:			N/A		
emarks: *F	or Enginee 221H-	ring Evalua PT3-S-2-BB	tion. Dens 3 = 142 pcf; 221	ity of Cores foll H-PT3-S-2-C =	ows: 142 pcf		Procedure: Spec.: C-	C-QCP ESR-H-00044	-002 Rev.: (Rev.: DCH	0 PCN(s F(s):): N/A N/A
221H-PT3-S-	2-B was fo	r informatio	on only because	of L/D Ratio Co	orrection Facto	or applied.	Dwg(s):	N/A	Rev.: N/	A DCH	r(s):	N/A
Technician (Reviewer (F	Print/Sign	n): Charles): Charles	A. Bookhamer Z. Moore/	cherles	1.8000 Z. ~	chans	n		Lev Lev	/el:	II Dat II Dat	e: <u>11-23-16</u> e: <u>12 - 14 - 1</u>

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ASR 18-203 (04/13)

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Savannah River Site

Summary Report of Testing Activities

	Report		X Cover Sheet Page 1 of									
Approvals	(If required)		Work Package No.: 1525456									
Senior Civil Technician (Level III	Ŋ:		QCIR No.: N/A									
Charles A. Bookhamer			Project No.: N/A									
Civil Testing & Inspection Superi	ntendent:	-	Design Category: GS									
W. Pope, Jr.		-	Report No.: 2016-CAEX-0003 Date: 11-17-1									
Lab. No.: 16009	0	Test M	Method: See attached pages									
Discipline: Civ	vil	scription:		Con	crete							
ocation: 221H Person	nel Tunnel 3 South	1	Reported	to:	J. Car	ter, 8-172	27					
See page 3 for the results of "C are provided in the page 3 Rem All information in this report is	Compressive Streng arks Section. from core segment	th of Dri ts from s	ample loca	s". Also n	note, the densitie H-PT3-S-3.	s of th	ie core se	gments				
					<u> </u>	/	/	~				
L&TE: See attached pages	Cal. Due Date:	See	attached p	ages	Procedure:		C-QCP	-002	_			
est					- Rev.:		0		_			
esults: Conformin	ng 🗌 Nonc	onformi	ng L	*X N/A	PCN(s):		N/A					
	ation		and a second		- Spec.:	C-	ERS-H-0	0044				
emarks: * For engineering evalu					-							
emarks: * For engineering evalu	N/A				- Rev.:		0					
emarks: <u>* For engineering evalu</u>					Rev.:		0		_			

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Savannah River Site

Summary Report of Testing Activities (Continuation Sheet)

Page 2 of 3

Item #				_			_	S	un	nmar	у	
		ddy	15.0	16.5	18.6	17.7	16.1	19.2	18.9			
0	[8] 8 [%] (BDAIB	[e/cm ⁻¹] 2.40	2.37	2.33	2.35	2.36	2.32	7.32	2.34		
crete	%) nd boiling and boilin ₁ eac (voids	BDAI	[s/cm ²] 2.39	2.36	2.31	2.33	2.36	2.30	2.30	2.33		
Con	iersion a mersion a mersion mersion a	AAIB	9.9 9.9	7.5	8.6	7	<u>.</u>	0.6	2.2	7.9		
ned	ofter imm ofter imm dry after imi after imi ensity ermeable	W	6.0	7.0	7.8	7.3	6.9	20	2	7.4		
ardei	bsorption a bsorption a bsorption a ulk density ulk density pparent De olume of p	<u>م</u>	1.00	1.00	1.00	8	8	8	B	1.00		X 100 X 100 X p X p X p X p X p
s in H	AAI= A AAIB= A 81 = B 80A1 = B 80A1B = B 80A1B = B 82 = A VPP = V		[s/cm ²] 2.65	2.64	2.64	2.64	2.62	2.63	2.63	2.62		6 = [(8-A)/A] 6 = [(C-A)/A] 1 = [A/(C-D] 10 a = [B/(C 10 a B = [C/(10 a B = [C/(10 a - D] 6 = (82 - 81)/ 6 = (82 - 81)/
Void		13	[e/cm ²] 2.26	2.20	2.15	2.17	2.20	2.12	2.13	2.17		* * * * * *
, and	boiling [g] I boiling [g	-	[g] 274.4	275.1	747.0	460.5	680.4	823.6	825.2	752.2		
otion,	ersion [g] ersion and nersion an	U :	[g] 469.71	475.94	1307.48	802.03	1179.36	1449.57	1451.20	1312.65		9
bsor	.[g] r after imm er after imm m ³ g/cm ³	æ :	(g) 466.80	473.57	1296.86	796.10	1175.48	1437.36	1440.20	1306.20		boiling (g) d boiling e (voids) [9
ity, A	ample in ai sample in ai sample in ai mple in wat Mg/m ³ or g/c Mg/m ³ = 1.	<	[g] 440.51	442.75	1203.44	741.60	1099.22	1329.62	1332.80	1216.33	a	mersion [%] mersion and mersion an mersion an the pore space
Dens	wen-dried s urface-dry: urface-dry: mass of sai mass of sai ity, dry, Mą oulk density f water = 1		AL-S-ET	T3-5-18	3-5-2A	T3-S-2C	3-S-3CC	3-5-4CC	3-S-SCC	3-S-6CC	sized Sampl	on after imr on after imr sity, dry sity after irr sity after irr of permeab of permeab
	mass of o mass of s mass of s apparent buik dens aparent t density o		*221H-P	*221H-P	221H-PT	*221H-P	221H-PT	221H-PT	221H-PT	221H-PT	* Under	Absorpti Absorpti Bulk den Bulk den Bulk den Volume (Volume
	P C C B F		Line	1	m	4	S	9	2	80		
		_		<u></u>	1	-	-	_	/	_		
			-+	V	-	1	1	-	4	-		
				-	1	_	-	1	1			

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Savannah River Site

Page <u>3</u> of <u>3</u>

		AST	MC 39-(14	Com	pressive S ASTI	trengtl MC 42-(n of Drilled	Cores	STM C 617-(12)		
Report No.:	201	6-CAEX-00	03 Pro	ject No.:	N/A		Work Package	No.:	1525456	De	esign Cat.:	GS
QCIR No.:	N/2	A 1	Date & Time	Core Taken:	11-17-16 @ I	N/A Co	oncrete Supplie	er:N/#	A Plac	ement Da	nte:	<u>N/A</u>
Placement L	ocation:	221H- Sec	tion 3, Personn	el Tunnel South	Wall Mix I	Design: _	N/A	Design	Strength:	2500	psi @N/A	Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level
160090	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
S-3-A	6	11-23-16	7.18	7.35	3.73	10.93	36149	1.97	1.00	3310	N/A	CAB MIL
S-3-B	6	11-23-16	7.29	7.45	3.72	10.87	42346	2.00	1.00	3900	N/A	VAB/T
S-3-C	6	11-23-16	7.12	7.31	3.72	10.87	49344	1.97	1.00	4540	N/A	CABIO
							A					
						~~				-		
Direction of A	Applicatio	on of the La	ad on the Sp	ecimen with R	espect to the l	Horizonta	I Plane of the C	Concrete Place	ed:		N/A	
M&TE.		JZE UI Aggi	cgate		IN/A		Cal Due Date	Miethod of 1	est:	N/A		
100 1 19.			1) CA-002; 2)	FM-5			Can Due Date		<u>1)</u> 9-23-17; 2)) 1-12-17		
'est lesults:		Conformin	lg 🗌	Nonconformi	ng * X] N/A	NCR No.: Procedure:	C-OCP	<u>ا</u> 1	N/A Rev.:	0 PCN(s): N/A
emarks: *Fo 221H-PT	or Enginee 3-S-3-A =	ring Evaluat 141 pcf; 221	tion. Den: H-PT3-S-3-B =	ity of Cores foll 144 pcf; 221H-	ows: PT3-S-3-C = 14	4 pcf;	Spec.: C-J	ESR-H-00044	Rev.: 0	DCI	r(s):	N/A
			N/A				Dwg(s):	N/A	Rev.: N/	A DCH	?(s):	N/A
Гесhnician () Reviewer (Р	Print/Sign	n): Charles): Charles	A. Bookhamer Z. Moore/	- Chall	a.B.	She	piel		Lev Lev	el: I	II Date	e: 11-23-16

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ASR 18-203 (04/13)

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Savannah River Site

Summa	ry Report o	of Testin	g Activi	ties							
	Report	x	Cover Sheet		Pag	e 1 _ of 3					
Approvals (If required	d)	Work Package No.: 1525456									
Senior Civil Technician (Level III):		QCIR No.: N/A									
Charles A. Bookbamer		Project N	D.:		N/A						
Civil Testing & Inspection Superintendent:		Design Category: GS									
W. Pope, Jr.		Report No.: 2016-CAEX-0004 Date: 11-21-2									
Lab. No.: 160091	Test Me	Viethod: See attached pages									
Discipline: Civil	Desc	scription: Concrete									
ocation: 221H Personnel Tunnel 3	South Wall	R	eported to:	J	. Carter, 8-17	127					
ASTM C642-13 covering the determination Line 6 on page 2 references Sample ID 221 See page 3 for the results of "Compressive are provided in the page 3 Remarks Section All information in this report is from core s	a of density, perc H-PT3-S-4CC for Strength of Drill a. Segments from sa	ent absorp or this repo led Cores' ample locat	tion, and pe ort. Also note	ercent voids in e, the densitie T3-S-4.	n hardened co s of the core s	egments					
					-						
I&TE: See attached pages Cal. Due	Date: See a	ttached pa	iges	Procedure:	C-QC	P-002					
CR No.:	N/A			Rev.:	0						
est Conforming	Nonconformin	ig 🛃		PCN(s):	N/A						
emarks: * For engineering evaluation				Spec.:	C-ERS-H						
N/A											
NIA				Kev.:	0						
<u> </u>]	DCF(s):	N/A						
echnician (Print/Sign): Charles A. Bookhan	ner/ Marks	A.bon	lenn L	evel: III	Date:	12-13-16					
eviewer (rrint/Sign): Charles Z. Moore/	v c.	v	L	evel: 11	_ Date: 2	14-16					

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Summary Report of Testing Activities (Continuation Sheet)

Page 2 of 3

221H Personnel Tunnel 3 South Wall 2016-CAEX-0004 **Report Title:** Report No.: Item # Summary 16 16.1 19.2 17.2 1 8 5 8 Å 8 2.35 2.32 2.36 2.32 2.34 2.40 2.37 2.33 **BDAIB** [e/cm] VPP = Volume of permeable pore speac (voids) [%] AAIB = Absorption after immersion and boiling [g] Density, Absorption, and Voids in Hardened Concrete BDAIB = Bulk density after immersion and boiling 2.36 2.30 2.30 2.33 2.39 2.36 2.31 2.33 BDA [e/cm] AAI = Absorption after immersion [%] BDAI = Bulk density after immersion 9.0 8.9 7.9 2.2 8.6 8.1 7.3 6.6 AIB X 0 7.3 6.9 8.1 7.4 6.0 8. 8.1 ₹ g₂ = Apparent Density g₁ = Bulk density, dry 8 1.00 1.00 1.00 8 8 1.00 BDAIB = [C/(C-D)] X p 1.00 8 K = (g₂ - g₁)/g₂ x 100 BDAi = [B/[C-D)] X p % = [(C-A)/A] X 100 K = [(B-A)/A] X 100 o/cm³ g₂ = [A/(A-D)] X ρ g₁ = [A/(C-D)] X ρ 2.64 2.62 2.63 2.63 2.62 2.65 2.64 2.64 2.15 2.20 2.12 2.13 2.20 2.17 2.17 2.26 , m j D = apparent mass of sample in water after immersion and boiling [g]C = mass of surface-dry sample in air after immersion and boiling [g] 823.6 747.0 680.4 825.2 752.2 460.5 275.1 274. 0 6 B = mass of surface-dry sample in air after immersion [g] 1179.36 1451.20 1307.48 802.03 1449.57 469.71 475.94 1312.65 . (olume of permeable pore space (voids) [%] Absorption after immersion and boiling [g] 1296.86 1175.48 796.10 1437.36 1306.20 466.80 1440.20 473.57 Bulk density after immersion and boiling $3^2 = a parent bulk density, Mg/m³, or g/cm³$ p = density of water = 1 Mg/m³ = 1 g/cm³ A = mass of oven-dried sample in air [g] $\mathbf{3}_1 = \mathbf{bulk density, dry, Mg/m^3, or g/cm^3}$ Absorption after immersion [%] 442.75 1203.44 741.60 1329.62 22.0001 1216.33 1332.80 440.51 Bulk density after immersion g 4 **Undersized Sample** Apparent Density Bulk density, dry A1-2-5-14-H125* *221H-PT3-5-18 *221H-PT3-S-2C 221H-PT3-S-3CC 221H-PT3-S-4CC 221H-PT3-S-SCC 221H-PT3-5-6CC 221H-PT3-S-2A Sample ID Ë **Comments:** 12-1524 THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.

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Page <u>3</u> of <u>3</u>

		AST	MC 39-(14) Com	pressive S	Strength M C 42-(13)	Cores	STM C 617-(12)		
Report No.:	201	6-CAEX-00	04 Pro	ject No.:	N/A		Work Package	No.:	1525456	D	esign Cat.:	GS
QCIR No.:	N/.	<u> </u>	Date & Time	Core Taken:	11-21-16@	N/A Co	oncrete Supplie	er:N/#	A Plac	ement Da	nte:	952
Placement L	ocation:	221H- Sec	tion 3, Personn	el Tunnel South	Wall Mix	Design:	<u>N/A</u>	Design	Strength:	2500	_ psi @N/A	_ Days
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Leve
160091	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
S-4-A	6	11-29-16	7.15	7.32	3.73	10.93	32338	1.96	1.00	2960	N/A	CAB/I
S-4-B	6	11-29-16	7.20	7.76	3.72	10.87	40352	2.09	1.00	3710	N/A	CABLO
\$4-C	6	11-29-16	7.24	7.51	3.73	10.93	43256	2.01	1.00	3960	N/A	CAB/0
							A					
Direction of A	Application	on of the La	ad on the Sp	ecimen with R	espect to the	Horizonta	l Plane of the (Concrete Plac	ed:		N/A	
Nominal Ma	ximum S	ize of Aggr	egate:		N/A			Method of T	`est:	N/A		
l&TE:			1) CA-002; 2) 1	°M-5			Cal. Due Date	:	1) 9-23-17; 2) 1-12-17		
est esults:		Conformin	g 🗌	Nonconformi	ng •>	N/A	NCR No.:		1	V/A	a DONK	
emarks: *Fo 221H-PT	r Enginee	ring Evaluat 141 pcf; 221	tion. Dens H-PT3-S-4-B =	ity of Cores foll 140 pcf; 221H-J	ows: PT3-S-4-C = 14	41 pcf;	Spec.: C-	C-QCP ESR-H-00044	-002 Rev.: 0	Rev.: DCI	0 PCN(s ?(s):): N/A N/A
			N/A	4			Dwg(s):	N/A	Rev.: N/	A DCH	?(s):	N/A
l'echnician (l Reviewer (P	Print/Sig rint/Sign	n): Charles): Charles	A. Bookhamer Z. Moore/	and and	2. m	hlan	и		Lev Lev	el: I	II Data II Data	e: 11-29-16

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Savannah River Site

S	ummary	Re	port	of	Testi	ing	Acti	ivi	t	ies
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	Report		X Cover Sheet Page 1 of										
Аррго	vals (If required)		Work Pac	kage No.:		152	5456						
Senior Civil Technician (Leve	I III):		QCIR No.: N/A										
Charles A. Bookhamer			Project No.: N/A										
Civil Testing & Inspection Su	perintendent:		Design Category: GS										
W. Pope, Jr.	and the second		Report No	o.: 20	16-CAEX-000	5	Date:	11-22-1					
2ab. No.: 16	0092		See attach	ied pa	ges								
discipline:	ne: Civil Description:												
ocation: 221H Pers	sonnel Tunnel 3 South	Wall	R	eported to	:	J. Ca	rter, 8-172	27					
See page 3 for the results of are provided in the page 3 F All information in this repor	"Compressive Streng Remarks Section. It is from core segment	th of Dri	ample locat	ion 221H	PT3-S-5.	es of t	he core se	gments					
						~	/						
&TE: See attached page	s Cal. Due Date:	See	attached pa	ges	Procedure:		C-OCP	-002					
CR No.:	N/A				Rev.:		0						
est esults: Confor	ming Nonc	onformi	ng 🛃	K N/A	PCN(s):		N/A						
emarks: * For engineering e	valuation				Spec.:	C	ERS-H-0	0044					
Secure State and	N/A												
	<u>NIA</u>				Kev.:		0						
	NIA				DCF(s):		N/A	_					
echnician (Print/Sign): Char	les A. Bookhamer/	and	1. José	nomen	Level: III	D	ate:	12-13-16					
eviewer (Print/Sign):	les Z. Moore/ 0	- 2	. m		Level:II	_ D	ate: 12	.14-14					

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Summary Report of Testing Activities (Continuation Sheet)

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Item #	¥	_			_	_			5	Sur	nmar	у						_
		ddy	8	15.0	16.S	18.6	17.1	16.1	19.2	18.9	17.2							
	(E) (%)	BDAIB	ig/cm ³ 1	2.40	2.37	2.33	2.35	2.36	2.32	2.32	2.34							
Icrete	%) Ind boiling and boiling peac (voids)	BDAI	lg/cm ³ 1	2.39	2.36	2.31	2.33	2.36	2.30	2.30	2.33							
Con	nersion (nersion a imersion imersion	AAIB	8	6.6	7.5	8.6	20	2	6	8.9	7.9							
ned	after imr after imr /, dry / after im / after im ensity oermeabl	M	X	6.0	7.0	7.8	7.3	6.9	2	8.1	7.4							
larde	Absorption Absorption Bulk density Bulk density Apparent D Volume of f	-	[g/cm ³]	1.00	1.00	100	1.00	1.00	1.00	1.00	1.00		A) X 100	A) X 100	c-D)] X p	((C-D)) X p	/g ₂ x 100	
sin F	AAI= / AAIB= / BIDAI= 1 BIDAIB= 1 82= / VPP= /	3	[e/cm ³]	2.65	2.64	2.64	2.64	2.62	2.63	2.63	2.62		% = [(B-A)//	% = [(C-A)// 8, = [A/(C-D	BDAI = [B/(BDAIB = [C/ 2, = [A/(A-C	% = (8 ₂ - 8 ₁)	
Void	-	8	[s/cm ³]	2.26	2.20	21.5	2.17	2.20	2.12	2.13	71.2		•					
, and	boiling [g] d boiling [g	-	[8]	274.4	275.1	747.0	460.S	680.4	823.6	825.2	752.2							
otion,	ersion [g] iersion and nersion and	5	3	469.71	475.94	1307.48	802.03	1179.36	1449.S7	1451.20	1312.65						5	
bsor	(6) r after imm er after imm g/cm ³ g/cm ³	-	R.	466.80	473.57	1296.86	796.10	1175.48	1437.36	1440.20	1306.20			boiling (g)		d boiling	e (voids) [9	
ity, A	ample in air sample in ai sample in wat mple in wat wg/m ³ or g/c Mg/m ³ = 1 (A	[8]	440.51	442.75	1203.44	741.60	1099.22	1329.62	1332.80	1216.33	a	nersion [%]	nersion and	Imersion	imersion an	le pore spac	
Dens	ss of oven-dried s ss of surface-dry ss of surface-dry arent mass of sa k density, dry, M irent bulk density sity of water = 1		nple ID	21H-PT3-S-1A	21H-PT3-S-1B	LH-PT3-S-2A	21H-PT3-5-2C	LH-PT3-S-3CC	LH-PT3-S-4CC	LH-PT3-S-SCC	LH-PT3-S-6CC	Indersized Sampl	sorption a fter i mi	sorption after im	k density after in	k density after in	parent vensity lume of permeab	
	A = max B = max C = max C = max B = bui B = bui B = bui	F	Line Sar	1 12	2 2	3 221	4 42	5 221	6 221	7 221	8 22:	*	ą	AP I	3 3		8	
_		_	-	_														
Comments:			_	Â,	1		-	Z	1	~								
			-	V	_	Z	_	_	F		-					-		

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	ASTM C 39-(14)				AST	ASTM C 42-(13) ASTM C 617-(12)							
Report No.:	201	2016-CAEX-0005 Project No.:			N/A		Work Package No.: 152		1525456	25456 Design		GS	
QCIR No.:	N/A Date & Time Core Taken:				11-22-16 @ N/A Concrete Supplier: N/A Placement Date: 1952							1952	
Placement L	ocation:	221H- Sec	tion 3, Personn	el Tunnel South	Wall Mix	Design: _	<u>N/A</u>	Design	Strength:	2500	_ psi @N/A	Days	
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Leve	
160092	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
S-5-A	6	11-29-16	7.24	7.39	3.74	10.99	34100	1.98	1.00	3100	N/A	CAR /TH	
S-5-B	6	11-29-16	7.04	7.19	3.73	10.93	38912	1.93	1.00	3560	N/A	CAB/TE	
S-5-C	6	11-29-16	6.76	6.96	3.73	10.93	39872	1.87	1.00	3650	N/A	CAB/TU	
						~	A						
										-			
irection of A	Application	on of the La ize of Aggr	oad on the Sp cegate:	ecimen with R	espect to the N/A	Horizonta	l Plane of the C	Concrete Plac Method of T	ed: `est:	N/A	N/A		
M&TE: 1) CA-002; 2) TM-5							Cal. Due Date: 1) 9-23-17; 2) 1-12-17						
Test Conforming Nonconforming *X N/A							NCR No.: N/A						
Remarks: *For Engineering Evaluation. Density of Cores follows: 221H-PT3-S-5-A = 138 pcf; 221H-PT3-S-5-B = 140 pcf; 221H-PT3-S-5-C = 140 pcf;							Procedure: Spec.: C-	C-QCP ESR-H-00044	-002 Rev.: 0	Rev.: DCI	0 PCN(s F(s):): N/A N/A	
N/A							Dwg(s):	N/A	Rev.: N/	A DCI	F(s):	N/A	
l'echnician (l Reviewer (P	Print/Sign	n): Charles	A. Bookhamer Z. Moore/	- Clerke	e le Bert	kham -	n		Lev	el: <u>I</u>	II Dat	e: 11-29-16	

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Approvals (If required) Worl Senior Civil Technician (Level III): QCIE Charles A. Bookhamer Proje	Cover Sheet Fage 1 of 2					
Approvals (If required)WorlSenior Civil Technician (Level III):QCIICharles A. BookhamerProje	Package No.: 1525456					
Senior Civil Technician (Level III): QCII Charles A. Bookhamer Proje						
Charles A. Bookhamer Proje	QCIR No.: N/A Project No.: N/A					
Civil Testing & Inspection Superintendent: Desig	Design Category: GS					
W. Pope, Jr. Repo	t No.: 2016-CAEX-0006 Date: 11-23-16					
Lab. No.: 160093 Test Method:	See attached pages					
Discipline: Civil Description	a: Concrete					
ocation: 221H Personnel Tunnel 3 South Wall	Reported to: J. Carter, 8-1727					
ASTM C642-13 covering the determination of density, percent ab Line 8 on page 2 references Sample ID 221H-PT3-S-6CC for this See page 3 for the results of "Compressive Strength of Drilled Co are provided in the page 3 Remarks Section. All information in this report is from core segments from sample N A	orption, and percent voids in hardened concrete. eport. res". Also note, the densities of the core segments ocation 221H-PT3-S-6.					
L&TE: See attached pages Cal. Due Date: See attache	l pages Procedure: C-QCP-002					
CR No.: N/A	Rev.: 0					
esults: Conforming Nonconforming	*X N/A PCN(s): N/A					
emarks: * For engineering evaluation	Spec.: C-ERS-H-00044					
	Rev.: 0					
NIA	DCF(s): N/A					
echnician (Print/Sign): Charles A. Bookhamer/ Charle C.	Level: III Date: 12-13-16					

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Summary Report of Testing Activities (Continuation Sheet)

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Report Title: 221H Personnel Tunnel 3 South Wall 2016-CAEX-0006 Report No.: Item # Summary 19.2 17.2 16.1 89 **PP** 5 9 8 1 X 2.36 2.33 2.35 2.32 2.32 2.34 8.9 2.37 BDAIB [e/cm²] VPP = Volume of permeable pore speac (voids) [%] AAIB = Absorption after immersion and boiling [g] Density, Absorption, and Voids in Hardened Concrete BDA(B = Bulk density after immersion and boiling 2.36 2.30 2.33 2.36 2.31 2.33 2.30 2.39 e/cm²] BDA AAi = Absorption after immersion [%] **BDAI = Bulk density after immersion** 9.0 7.9 7.3 8.9 ANB 6.6 7.5 8.6 8.1 2 0 7.8 7.3 6.9 8.1 8.1 7.4 **g₂ = Apparent Density** ₹ $g_1 = Bulk density, dry$ 8 10 1.00 1.00 1.00 BDAIB = [C/(C-D)] X p 8.1 18 1.0 8. % = (g₂ - g₁)/g₂ x 100 BDAi = [B/(C-D)] X p 6 % = [(B-A)/A] X 100 % = [(C-A)/A] X 100 B2 = [A/(A-D)] X p g1 = [A(C-D)] Xρ 3 2.62 2.63 2.63 2.62 2.65 2.64 2.64 <u>ה</u> 2 2.13 2.20 2.20 2.15 2.12 2.26 2.17 2.17 e/cm D = apparent mass of sample in water after immersion and boiling [g] C = mass of surface-dry sample in air after immersion and boiling [g] 747.0 823.6 460.5 680.4 825.2 752.2 275.1 B = mass of surface-dry sample in air after immersion [g] 475.94 1307.48 1179.36 1449.57 1451.20 1312.65 469.71 802.03 Volume of permeable pore space (voids) [%] Absorption after immersion and boiling [g] 1296.86 1175.48 1440.20 796.10 1306.20 466.80 473.57 1437.36 Bulk density after immersion and boiling $_{2_2}$ $^{\pm}$ aparent bulk density, Mg/m 3 , or g/cm 3 p = density of water = 1 Mg/m³ = 1 g/cm³ 0 A = mass of oven-dried sample in air [g] 31 = bulk density, dry, Mg/m³, or g/cm³ Absorption after immersion [%] 1329.62 442.75 741.60 1216.33 1203.44 1099.22 1332.80 440.51 **Bulk density after immersion** 4 . * Undersized Sample **Apparent Density** Bulk density, dry 221H-PT3-S-1A 221HPT3-5-18 221H-PT3-S-2C 221H-PT3-S-6CC 221H-PT3-S-4CC 221H-PT3-S-SCC 221H-PT3-S-3CC 221H-PT3-S-2A Sample ID **Comments:** 12-15-16 THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.

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	_	AST	MC 39-(14)	pressive St ASTM	trengti 1 C 42-(13)	Cores	STM C 617-(12)		-	
Report No.:	.: 2016-CAEX-0006 Project No.:				N/A		Work Package	No.:	1525456 Design (Cat.: GS	
QCIR No.:	No.: N/A Date & Time Core Taken: 11-23-16@N/A Concrete Supplier: N/A								A Plac	_ Placement Date: 1952			
Placement I	ocation:	221H- Sec	tion 3, Personn	el Tunnel South	Wall Mix D	esign:	<u>N/A</u>	Design	Strength:	2500	psi @N/A	Days	
Lab. Number	Days Aged	Date Tested	Length Before Capping, in.	Length After Capping, in.	Average Diameter, in.	Area, sq.in.	Total Load, lbs.	Length to Diameter Ratio	Correction Factor	Unit Load, psi	Corrected psi	Technician Init./Level	
160093	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
S-6-A	7	11-30-16	7.18	7.35	3.74	10.99	36403	1.97	1.00	3310	N/A	CARTIN	
S-6-B	7	11-30-16	7.19	7.45	3.74	10.99	47966	1.99	1.00	4360	N/A	CAB/III	
S-6-C	7	11-30-16	7.28	7.45	3.73	10.93	49676	2.00	1.00	4540	N/A	MAB/T	
S-6-CC	7	11-30-16	6.18	6.42	3.73	10.93	51804	1.72	.98	4740	4640	CAB/IA	
							A					-	
						N							
Direction of	Applicatio	on of the L	ad on the Sn	ecimen with R	espect to the F	Iorizonta	I Plane of the (Concrete Plac	ed•		N/4	-	
Nominal Ma	ximum S	ize of Aggr	egate:		N/A			Method of T	'est:	N/A			
M&TE:			1) CA-002; 2) 1	M-5			Cal. Due Date	:	1) 9-23-17; 2) 1-12-17			
Test Conforming N/A Results:					NCR No.: N/A Procedure: C-OCP-002 Rev: 0 PCN(c): N/A								
Remarks: *For Engineering Evaluation. Density of Cores follows: 221H-PT3-S-6-A = 138 pcf; 221H-PT3-S-6-B = 144 pcf; 221H-PT3-S-6-C = 144 pcf;					Spec.: C-ESR-H-00044 Rev.: 0 DCF(s): N/A								
221H-PT3-S-6-CC was for information only because of L/D Ratio Correction Factor applied.					Dwg(s): N/A Rev.: N/A DCF(s): N/A								
Fechnician (Print/Sig	n): Charles	A. Bookbamer	1 Charles	A.B. all	men			Lev	el: I	II Dat	e: 11-30-16	
Reviewer (P	rint/Sign): Charles	Z. Moore/	2 2	m				Lev	el:	I Dat	e:)2-14-1	

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