TVA JACOBS

KINGSTON ASH RECOVERY PROJECT
FIELD CHANGE NOTICE (FCN)

FCN Number:	FCN-034	**FCN Title:**	Cold Joints
Project Name:	Perimeter Wall Stabilization Segment 1 Sta. A161+50 to Sta. 179+50		

DOCUMENT(S) AFFECTED BY THIS FIELD CHANGE NOTICE

Document Number	Revision	Document Title
RDP-0113-E	R0 8/1/11	Technical Specification North Dredge Cell Segment 1 Section 02650

References/Work Package (if applicable):

Technical Specification Section 02650 -paragraph 4.3.8 "Cold Joints"

Reason for Change/Information Requested:

The current definition of 7 days does not allow enough physical separation of 1250 excavators during slurry wall construction which causes excessive pumping of water up from the local water table which contributes to instability of the working platform and potential safety problems for work in close proximity. Having a 14 or 21 day time would provide flexibility in spacing the work out to avoid local spots that are saturated from pumping of water to the surface, keep more reasonable physical separation of the excavators.

Existing Condition:

Currently the technical specification section 02650 paragraph 4.3.8 defines a cold joint as any butt joint or tee joints that are formed with an existing wall greater than 7 days.

Description of Change:

Stantec has initiated a field test program to help evaluate the requested extension of the time for the definition of a cold joint in paragraph 4.3.8. The defined cold joint should be the maximum time period that can be supported by Stantec to allow for project flexibility and safety.

Requested Date of FCN Disposition:

Requestor	Date	Field Engineer	Date
J.H. Miller	9/13/11	J.H. Miller	7/13/11

RESPONSE/DISPOSITION OF THE FIELD CHANGE NOTICE

FCN Approval:	☒ **Approved** (see remarks below, if any) ☐ **Disapproved** (see remarks below)
FCN Incorporation by DCN Required:	☐ Yes ☒ No

Response/Remarks :

The definition in Section 02650, Paragraph 4.3.8 is hereby modified. Construction joints formed when the existing wall is 14 days old or less will not be considered a cold joint. Please see the attached report for the data and discussion supporting this change.

Name	Signature	Date
Alan F. Rauch, PhD, PE **Lead Engineer / Engineer of Record**	Alan Rauch	14-Sept-2011
Bruce Haas **Project Management Coordinator**	[signature]	19-Sept-2011

Cc: ☐ EOR	☐ Mgr, NDE QC & Tech Spt	☐ Field Engineer
☐ Document Control	☐ Construction Manager	☐ QC Manager
☐ QA Officer	☐ Regulatory Interface Specialist	

FORM 023, Rev. 1

Cold Joint Criteria
Supporting Documentation for
Field Change Notice No. 034

Kingston Recovery Project
Perimeter Wall Containment
Kingston Fossil Plant
Harriman, Roane Co., Tennessee

Stantec
14 September 2011

The perimeter of the Kingston dredge cell is being stabilized with an intersecting grid of soil-cement walls founded in rock. The panels are being constructed by Geo-Con using slurry trench methods and self-hardening cement bentonite.

Cold Joint Definition

From the project specifications (Section 02650, Paragraph 4.3.8):

> *Construction Joints, including Butt Joints and Tee Joints, that are formed with an existing wall that is more than 7 days old shall be considered a Cold Joint. This definition of a Cold Joint may be altered in writing by the Perimeter Wall Stabilization QC Manager, on the basis of laboratory testing and/or observed field results that show other criteria will result in joint strengths consistent with the overall design.*

The 7-day limit has created operational challenges for the Perimeter Wall Stabilization Contractor (Geo-Con). At the planned production rates, two excavators must work in close proximity to avoid the need for frequent cold-joint mitigation. Hence, the design team has been asked to re-consider the defined time frame for cold joints.

Design Assumptions

The documented design analyses show that construction joints will have a detrimental impact on structural performance if the joint shear strength is less than about half the strength of walls (see Exhibit 20 in the calculation package for RDP-0113-E). The design assumes zero tensile capacity normal to the joint, so there is no requirement for a bond (adhesion) across the joint face.

There are two specific concerns related to joint performance:

(1) What is the shear strength at a joint between older and newer soil-cement panels?

(2) When the joint is formed, will the excavation process damage the existing, partially cured soil-cement panel?

The cold joint criteria in the specifications were established to provide a condition wherein the strength of the constructed joints would be commensurate with the design assumptions. The 7-day limit was conservatively selected during the project design, without the benefit of specific test data.

Laboratory Test Results

Geo-Con has provided laboratory test results with measured data on the shear strength across joints of different ages. Geo-Con's report (dated 11 August 2011) is included here as Appendix A.

Comparing the average direct shear strengths reported by Geo-Con for Tests 1, 2, 3, and 5, we find that the 7-day, 14-day, and 35-day joints respectively exhibited 76%, 64%, and 43% of the strength of the 7-day old material. Because the design assumes the joint shear strength is at least 50% of the strength of wall material, the laboratory test data suggest that the appropriate definition for a cold joint will be somewhere between 14 and 35 days.

Geo-Con's laboratory tests do not simulate the deep grooves that will be formed in a joint with the teeth of the excavator bucket (or the rock rippers on the back of Geo-Con's bucket). Interlocking within these grooves will substantially increase the shear strength across a joint, and the field joint strength is expected to be greater than measured in the laboratory tests. However, the potential for increased interlocking strength in the joint will be lost if the excavated face, particularly the ridges of material left between the grooves cut by excavator's bucket teeth, is fractured.

Cold Joint Test Trench

As enumerated above, there is some concern that excavation of a joint will damage the existing wall. In the early stages of curing, the weak, partially cured material may be subject to brittle fracturing as the excavator cuts the vertical face of the joint. To better understand this issue, a field test was conducted.

The cold joint test panel was constructed on August 19, 2011. The panel was 6 ft deep and approximately 75 feet long, and was built with a cement-bentonite having a 25% slag content. The test panel was located to the Northeast of Baseline "A" Station 174+00, adjacent to PZ-102, and is not part of the perimeter containment system currently under construction in Segment 1.

Periodically, the ends and sides of the test panel were excavated to simulate construction of butt joints and tee joints. The exposed faces were then observed by the QC Manager for indications of damage, cracking, or fracturing. These observations are documented here in Appendix B. The last excavation test was completed on September 13, simulating the construction of a 25-day old joint.

In general, there was an observable change in the excavated cement bentonite over the period of the excavation tests. The material was very soft and plastic in the earliest excavation tests. As the material hardened, the excavated face showed more fractures, particularly in the ridges of material between the cuts of the excavator teeth. Up to about 14 days, a few loose pieces could be pulled by hand from the ridges of material. At 21 and 25 days, the ridges were more heavily damaged and loose pieces more easily pulled away. However, there was no evidence that cracking penetrated significantly into the wall behind the joint face.

Conclusions

1. As documented in the design calculations, the shear strength across an excavated joint cannot be less than half the shear strength of the soil-cement wall. The design assumes zero tensile strength across a joint.
2. Based on the laboratory test data, the shearing resistance across a smooth interface will be adequate (greater than half the strength of the wall) if the older material is somewhere 14 days old at the time of the joint excavation.
3. The excavator bucket teeth and rippers will cut vertical grooves in the face of each joint. Additional shearing resistance develops via interlocking in the grooves, but only if the ridges of material left between the grooves are not broken up during the excavation.
4. The excavation tests provide subjective evidence of the condition of the excavated joint face. Up until about 14 days, the excavation process did not cause substantial damage to the ridges of material between the vertical grooves. Hence, for joints cut at 14 days or earlier, interlocking in the grooves should contribute to the joint strength.
5. The field tests demonstrated that the joints can be excavated without causing significant damage to the existing wall behind the joint face.

Accordingly, the definition of a cold joint can be modified to represent a time limit of 14 days. This corresponds to a period where the joint shear strength will be adequate with respect to the design assumptions, based on the evidence provided by the laboratory test data and field excavation tests. The project specifications (Section 02650, Paragraph 4.3.8) will be modified to read:

> *Construction Joints, including Butt Joints and Tee Joints, that are formed with an existing wall that is more than 14 days old shall be considered a Cold Joint.*

Appendix A

Laboratory Test Data
Provided by Geo-Con

Technical Memorandum
Construction Joint Strength Testing Program
RFP KAR 1 – Deep Mixing Perimeter Stabilization
Kingston Fossil Plant, Harriman, Tennessee

Geo-Con P10-063

August 11, 2011

INTRODUCTION

The stabilized perimeter wall system is being constructed with a series of interconnecting self-hardening cement-bentonite (CB) walls constructed by the slurry trenching method. The ends of each new (fresh slurry) wall are tied into the older (partially cured slurry) wall by scraping the previously constructed wall with the excavator bucket under slurry to provide a clean joint for the new wall to join. The action of the bucket teeth should create channels or keys into the older material and provide an interlock with the new material. Based on our previous experience with self-hardening slurry wall construction, we believe this method provides clean, strong construction joints. The self-hardening slurry used has a slower set and strength development than concrete or Portland cement based products. Joints made into walls several weeks old will gain considerable strength since the previously placed slurry is still green and is not considered a completely cold joint. Logically, the strength across a joint would be similar to the strength gain of the new slurry.

APPROACH

Geo-Con has developed a method to quantify the strength across a joint between two different aged CB slurries using standard soil testing techniques. The approach is based on conducting a series of direct shear tests (ASTM D-3080) at the interface of two slurries of varying cure time. The age differential between the two slurries tested represents the age of the old (existing wall) when the new wall is constructed and is referred to as the "age of the joint" or "joint age."

ASTM D-3080 is a method for measuring shear strength across an induced failure plane under varying normal loads. Direct shear tests are commonly performed in a series of three tests run at three different normal loads representing various confining pressure at related depths within the wall. This method provides a conservative strength since it measures the strength across a smooth joint and does not take into consideration the interlocking of the new wall by way of keys or channels likely cut into the older wall by the action of the excavator bucket.

The method consists of shearing prepared molds across the joint of two slurries of differing cure time. The molds consisting of two parts, upper and lower, are designed to fit a standard direct shear apparatus. The upper and lower portions of the molds are filled or poured with CB slurry at different times. The lower mold represents the older or existing wall and the upper portion represents the new wall. The lower portion will be molded from fresh slurry and allowed to cure for a selected duration. After curing, the surface of the initial slurry is prepared by removing a layer of cured slurry to model the scraping action of the excavator bucket in the field prior to adding fresh slurry to fill the remainder (upper portion) of the mold. The molds are sheared along the interface of the upper and lower molds following a predetermined cure time for the second slurry.

TESTING SUMMARY

The following five tests were performed:

Test 1: Solid Joint. This test consists of a single CB slurry pour to determine the baseline shear strength of the CB mix. The results are used to develop a ratio of joint shear strength to UCS strength of similar CB material.

Test 2: 7-day Joint Short-term. This test represents the early strength of a joint where the old (existing) wall has cured 7 days when the joint is constructed or new slurry placed. The shear test is conducted after the old material cures for 14 days and the new material cures for 7 days. This example represents the early strength of the majority of the joints constructed in the field where the existing wall is less than 7 days old.

Test 3: 14-day Joint Short-term. This test represents the early strength of a joint where the old wall has cured 14 days when the joint is constructed. The shear test is conducted after the old material cures for 21 days and the new material for 7 days. This example represents the early strength of a joint constructed in the field where the existing wall is 14 days old.

Test 4: 7-day Joint Long-term. This test represents the long-term strength of a joint where the old wall has cured 7 days when the joint is constructed. The shear test is conducted after the old material cures for 35 days and the new material cures for 28 days. This example represents the long-term strength of the majority of the joints constructed in the field where the existing wall is less than 7 days old.

Test 5: 35-day Joint Short-term. This test represents the short-term strength of a joint where the old wall has cured 35 days when the joint is constructed. The shear test is conducted after the old wall material cures for 42 days and the new material cures for 7 days. This example represents the short-term strength of colder joints where the existing wall is more than 28 to 35 days old when the joint is constructed.

All the CB samples were prepared by Geo-Con in Geotechnics' laboratory located in East Pittsburgh, Pennsylvania. Slurry samples were prepared following the same protocol as used for Geo-Con's Mix Design Program for this project. The shear testing was performed by Geotechnics laboratory which is accredited for direct shear testing at this location. Each series of shear tests were performed at three different normal loads ranging from 5 psi to 30 psi. A normal load of 30 psi represents the confining pressure at a depth of 60 feet considering a slurry density of approximately 72 pcf.

SAMPLE PREPARATION AND TESTING PROCEDURES

The following is a step by step description of the procedure for preparation and testing of the simulated CB joints. A photograph is attached to accompany each step:

1. Prepare bottom sample molds. Each mold is 2-inch inside diameter to fit the standard direct shear apparatus.

2. The bottom of each mold was sealed with tape.

3. The top molds are slightly higher than the bottom molds to fit the direct shear apparatus.

4. The bottom and top mold are temporarily sealed with tape.

5. The bottom slurry is prepared. Each component is measured with an electronic balance to 5/100ths of a gram.

6. Hydrated bentonite slurry is prepared in a blender.

7. The Portland cement and slag components are measured and blended with the hydrated bentonite slurry.

8. The prepared slurry is poured into the bottom portion of the mold. The slurry level is 1/4th inch above the joint.

9. Samples are stored in the curing box.

10. The bottom slurry is trimmed to the level of the joint simulating the scrapping action of the excavator.

11. The new slurry is poured to fill the top mold.

12. Sample molds are labeled with the mix design number and the date of pour for each slurry.

13. Samples are covered and allowed to cure in the curing box.

14. Following curing, the top and bottom of the sample is trimmed and the temporary tape is removed from the outside of the mold.

15. Molds are placed in the direct shear apparatus.

16. Shear testing is conducted.

17. Data from the shear test is recorded electronically.

18. Sheared sample is removed from the shear device. The markings along the shear failure plane indicate the sample is sheared across the interface of the two materials.

ANALYSIS

Results of the direct shear tests are reported in values of shear stress in psi. A shear stress versus normal stress plot is developed for each series of shear tests from which the angle of internal friction and cohesion value can be deduced. The cohesion value is the shear stress at a confining stress of zero. The ratio of shear strength to unconfined compressive strength (UCS) is typically 0.40 to 0.50 for most soils. In this application, Test 1 was used to determine the ratio of shear strength (S) to UCS (q). The direct shear value was compared to the UCS value for CB slurry cured for the same duration to determine a ratio of S/q equal to 0.33. This ratio was then used to reduce the UCS data for the remaining direct shear tests.

RESULTS

Results of the direct shear joint tests are summarized in 2 tables on the attached Summary of Joint Testing document. These results indicate the joint should develop considerable percentage of the UCS of the cured CB slurry. Short-term joint strengths range from 42.7% to 85.9% of the UCS of the CB slurry. Long-term joint strengths are estimated to range from 27.5% to 55.2% of the UCS of the cured CB slurry. Generally, cold joints 7 days or less old retain 55.2% of the UCS strength long-term whereas cold joints up to 35 days old retain 27.5% of the UCS strength long-term. Most important is that old joints up to 14 days old retain an estimated 47.3% of the UCS strength long term showing that there is little difference between a 7 day old cold joint and a 14 days old cold joint.

Summary of Joint Strength Testing
Direct Shear Tests
August 11, 2011

Geo-Con conducted a series of direct shear tests using cured CB slurry to simulate the strength across "cold" joints of various ages in the CB walls.

CB Mix Design for all testing: 16.0% Slag / 3.0% Bentonite / 0.5% Portland cement

TEST 1: Solid Joint –Short Term

Description: Determine baseline shear strength of the CB
Use to develop a ratio of joint shear strength to UCS strength of CB

Shear Strength, S: 26.69 psi

Age of Joint: 0 days

Top CB:	LH8e	poured 4/8/11	7 days	UCS = 81.33 psi
Bottom CB:	LH8e	poured 4/8/11	7 days	

Determine S/q ratio by comparing direct shear value to UCS value of same CB material

S/q = 26.69 psi / 81.33 psi = 0.33

TEST 2: 7-day Joint Short-term (7-day cure)

Description: Determine early strength of 7-day joint

Shear Strength, S: 20.32 psi

Age of Joint: 7 days

Top CB:	LH8c	poured 3/11/11	7 days	UCS = 71.67 psi
Bottom CB:	LH8b	poured 3/4/11	14 days	

Determine CB Material Strength
From Test 1, S = 0.33 q
S = 0.33 x 71.67 psi = 23.65 psi

Ratio of Joint Strength to CB Material Strength
20.32 psi / 23.65 psi = 85.9%

Joint Strength: 85.9% of the CB material shear strength

TEST 3: 14-day Joint Short-term (7-day cure)

Description: Determine early strength of 14-day joint

Shear Strength, S: 16.95 psi

Age of Joint: 14 days

Top CB:	LH8d	poured 3/18/11	7 days	UCS = 69.76 psi
Bottom CB:	LH8b	poured 3/4/11	14 days	

Determine CB Material Strength
From Test 1, S = 0.33 q
S = 0.33 x 71.67 psi = 23.02 psi

Ratio of Joint Strength to CB Material Strength
16.95 psi / 23.02 psi = 73.6%

Joint Strength: 73.6% of the CB material shear strength of CB material

TEST 4: 7-day Joint Long-term (28-day cure)

Description: Determine long-term strength of 7-day joint

Shear Strength, S: 26.59 psi

Age of Joint: 7 days

Top CB:	LH8c	poured 3/11/11	28 days	UCS = 146 psi (interpolated)
Bottom CB:	LH8b	poured 3/4/11	35 days	

Determine CB Material Strength
From Test 1, S = 0.33 q
S = 0.33 x 146 psi = 48.18 psi

Ratio of Joint Strength to CB Material Strength
26.59 psi / 48.18 psi = 55.2%

Joint Strength: 55.2% of the CB material shear strength

<u>TEST 5:</u> 35-day Joint Short-term (7-day cure)

Description: Determine short-term strength of 35-day joint

Shear Strength, S: 11.46 psi

Age of Joint: 35 days

Top CB: LH8e poured 4/8/11 7 days UCS = 81.33 psi
Bottom CB: LH8b poured 3/4/11 42 days

Determine CB Material Strength
From Test 1, S = 0.33 q
S = 0.33 x 81.33 psi = 26.84 psi

Ratio of Joint Strength to CB Material Strength
11.46 psi / 26.84 psi = 42.7%

Joint Strength: 42.7% of the CB material shear strength

Joint Strength Summary

Short-Term Joint Strength

Test	Joint Age	Joint Strength as Percent of CB Shear Strength
2	7 days	85.9%
3	14 days	73.6%
5	35 days	42.7%

Long-Term Joint Strength

Test	Joint Age	Joint Strength as Percent of CB shear Strength	Ratio of Long-Term to Short-Term
4	7 days	55.2% (3)	64.3% (1)
3	14 days	47.3% (2) (3)	
5	35 days	27.5% (2) (3)	

Notes:

(1) Ratio of Test (28 day cure) to Test 2 (7 day cure) results
(2) Based on 64.3% x Joint strength as a percent of CB strength
(3) Testing a solid joint for long-term conditions would likely result in increased values for Joint strength as a percent of CB shear strength

Appendix B

Observations from Field Excavation Tests

Cold Joint Test Trench Observations – 4 Days of Curing

On August 23, 2011, a Kobelco PC250LC excavator was utilized to excavate into the cold joint test panel. The test trench was excavated from both the end of the trench (simulating a butt joint), and from the side of the trench (simulating a t-joint). The in-place material in the trench following excavation exhibited a bluish-green color, visually similar as that observed in the demonstration walls and production walls. The material was observed to be stiff with low to moderate plasticity, based on the penetration of a stiff heavy-duty 1-¼" wide paint scraper and lack of cracking around the insertion of the stiff blade. The paint scraper was inserted into the in-place material to a depth of ¼" to ½". The surface of the material was visually observed to be free of visible cracks or signs of promulgating fractures into the panel. Photographs were taken to document the surface; two representative images are provided below.

Observation Performed by Brad Smiley – Stantec QC Manager

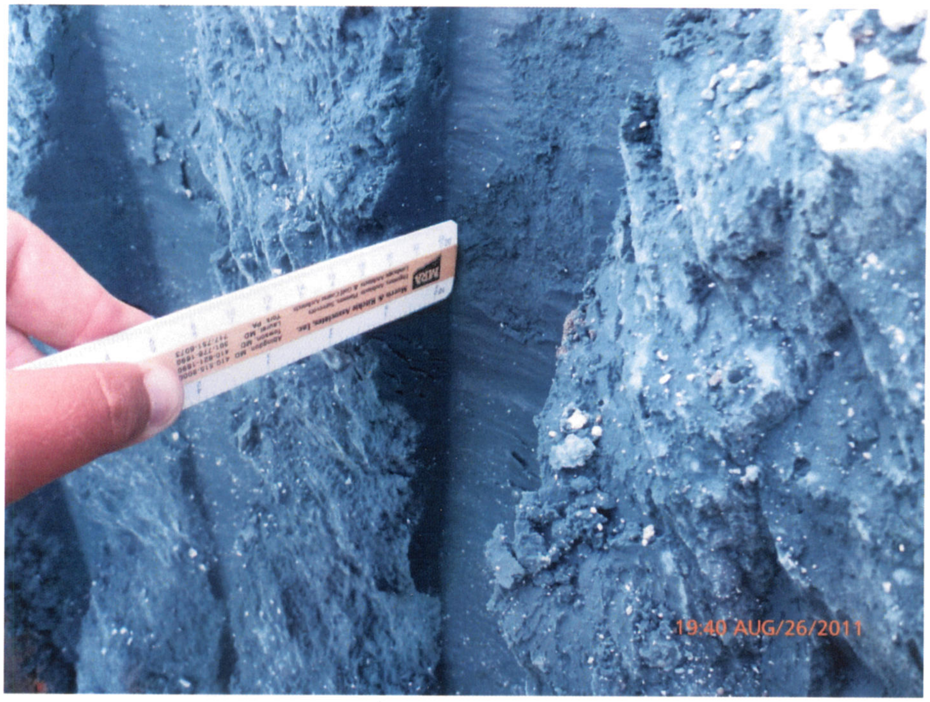
Excavation at 4 days (P100468.jpg)

Excavation at 4 days (P100471.jpg)

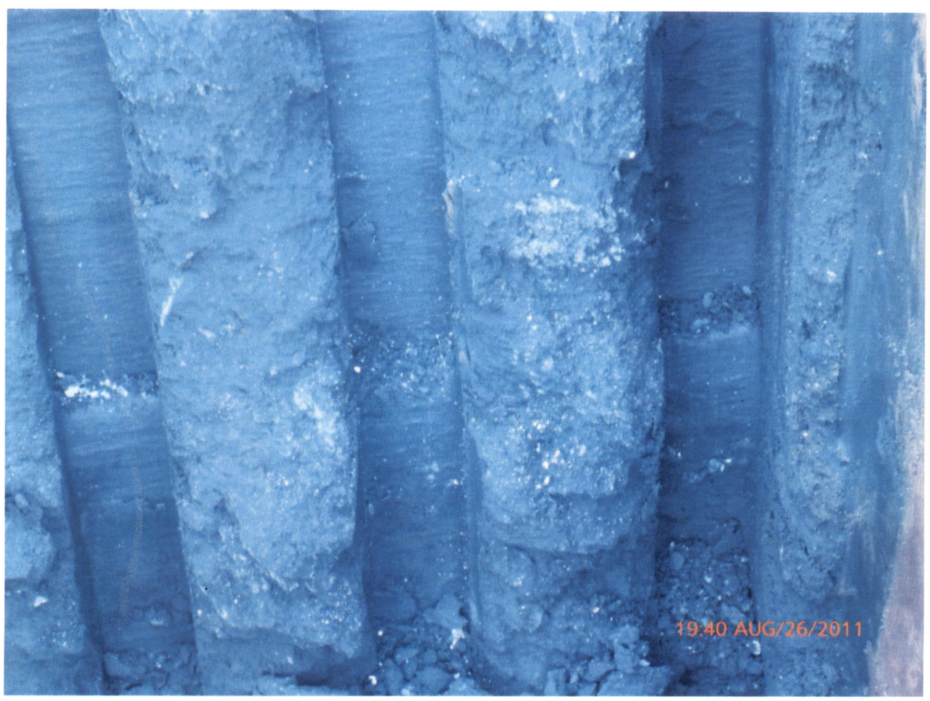
Cold Joint Test Trench Observations – 7 Days of Curing

On August 26, 2011, a Kobelco PC250LC excavator was utilized to excavate into the cold joint test panel. The test trench was excavated from both the end of the trench to simulate a butt joint (through the portion previously exposed for the 4-day observation), and from the side of the trench to simulate a t-joint (12" to 18" into the side of the panel). The teeth on the bucket of the Kobelco excavator were utilized to excavate into the material, essentially "teething" the material by creating teeth marks of various depths. Teeth marks ranged from approximate 1" to 4" in depth into the material. Sporadic loose material was observed between the teeth marks and was easily removed by hand, but did not visually exhibit additional fracturing. The in-place material in the trench following the excavation exhibited a bluish-green color, visually similar as that observed in the demonstration and production walls. The material was observed to be stiff with low to moderate plasticity, based on the penetration of a stiff heavy-duty 1-¼" wide paint scraper and lack of cracking around the insertion of the stiff blade. The paint scraper was inserted into the in-place material to a depth of ¼" to $^{3}/_{8}$". The surface of the material was visually observed to be free of visible cracks or signs of promulgating fractures into the panel. Photographs were taken to document the surface; two representative images are provided below.

Observation Performed by Brad Smiley – Stantec QC Manager



Excavation at 7 days (P100522.jpg)



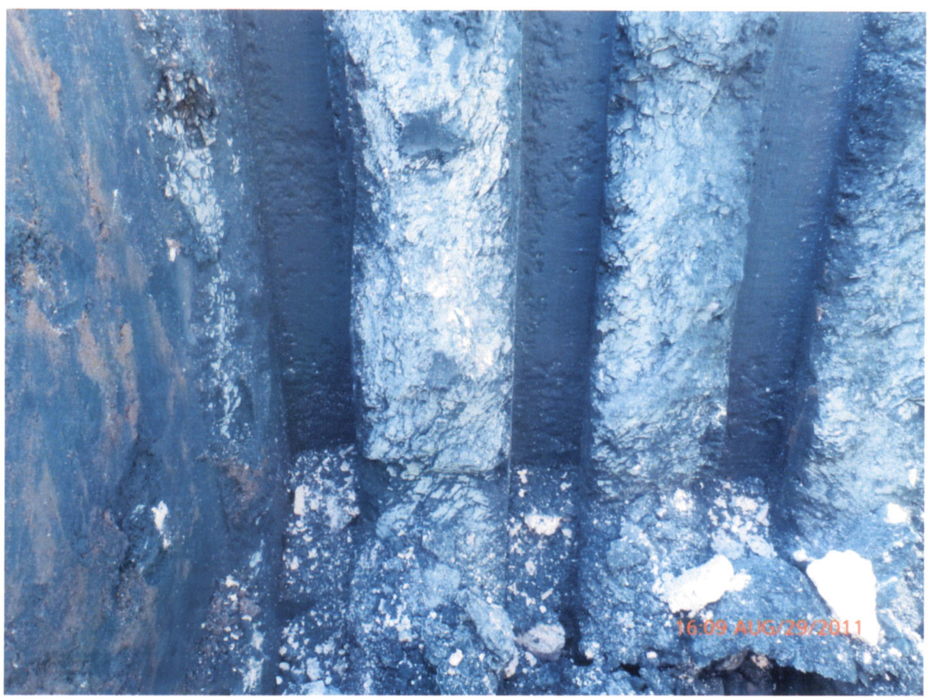
Excavation at 7 days (P100527.jpg)

Cold Joint Test Trench Observations – 10 Days of Curing

On August 29, 2011, a Kobelco PC250LC excavator was utilized to excavate into the cold joint test panel. The test trench was excavated from both the end of the trench to simulate a butt joint (through the portion previously exposed for the 7-day observation), and from the side of the trench to simulate a t-joint (12" to 18" into the side of the panel). The teeth on the bucket of the Kobelco excavator were utilized to excavate into the material, essentially "teething" the material by creating teeth marks of various depths. Teeth marks ranged from approximate 1" to 4" in depth into the material. Sporadic loose material was observed between the teeth marks and was easily removed by hand or by prying with the 1-¼" scraper, but did not visually exhibit additional fracturing. The in-place material in the trench following the excavation exhibited a bluish-green color, visually similar as that observed in the demonstration and production walls. The material was observed to be stiff with relatively low plasticity, based on the penetration of a stiff heavy-duty 1-¼" wide paint scraper and visual observation of the material where the teeth of the excavator bucket pressed against the in-place material. Areas where the teeth of the bucket pressed into the material during the downward stroke of the excavator was observed to be smooth with a consistent surface, without indication of cracking or brittleness. The paint scraper was inserted into the in-place material to a depth of approximately $^1/_8$", without visual indication of cracking around the penetration though a small amount of material did fall off with the removal of the scraper. The surface of the material was visually observed to be free of visible cracks or signs of promulgating fractures into the panel. The surface was also observed to be slightly moist to the touch, but without free moisture that would transfer to cloth (that could be detected by the unaided human eye or sense of touch). A water bottle was utilized to mist portions of the exposed surface in an effort to expose small cracks with no visual indication of small cracks in the surface material. A pocket penetrometer borrowed from Geo-Con, Inc. and operated by their representative, Mrs. Amy Robinson Grass, was observed to max out on the material. A large of area of loose material measuring approximately 6" wide by 18" long was observed between the teeth marks on the t-joint simulated excavation towards the bottom of the excavation. This area may have been impacted by the bucket during the removal of material. There was no further indication of cracking or damage to the in-place material after this area was removed by hand and cleaned with a stiff whisk broom. Photographs were taken to document the surface; two representative images are provided below.

Observation Performed by Brad Smiley – Stantec QC Manager

Excavation at 10 days (P100544.jpg)



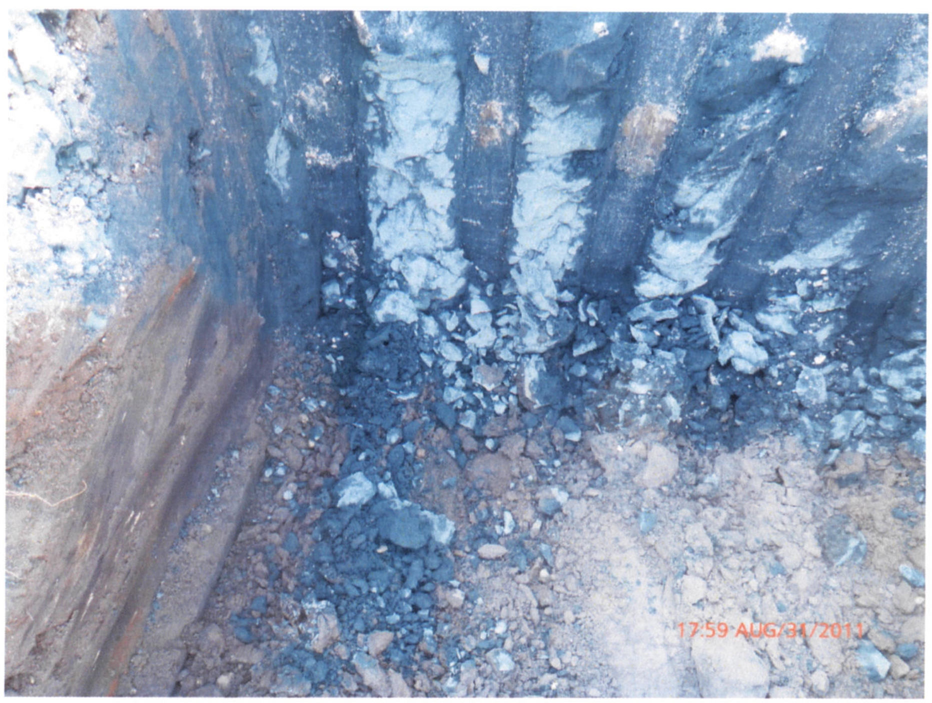
Excavation at 10 days (P100549.jpg)

Cold Joint Test Trench Observations – 12 Days of Curing

On August 31, 2011, a Kobelco PC250LC excavator was utilized to excavate into the cold joint test panel. The test trench was excavated from both the end of the trench to simulate a butt joint (through the portion previously exposed for the 10-day observation), and from the side of the trench to simulate a t-joint (12" to 18" into the side of the panel). The teeth on the bucket of the Kobelco excavator were utilized to excavate into the material, essentially "teething" the material by creating teeth marks of various depths. Teeth marks ranged from approximate 1" to 4" in depth into the material. Areas of small loose material were observed between the teeth marks and were easily removed by hand or by prying with the 1-¼" scraper, but did not visually exhibit additional fracturing promulgating into the wall. The in-place material in the trench following the excavation exhibited a bluish-green color, visually similar as that observed in the demonstration and production walls, but contained areas of a light grayish hue between the teeth marks. When pressed with a hard object, the light gray hue colored areas would turn light green, appearing as if the pressure of the object caused moisture to rise to the surface. The material was observed to be stiff with low plasticity, based on the penetration of a stiff heavy-duty 1-¼" wide paint scraper and visual observation of the material where the teeth of the excavator bucket pressed against the in-place material. Areas where the teeth of the bucket pressed into the material during the downward stroke of the excavator was observed to be relatively smooth, though less smooth than previous observations, and without indication of cracking or brittleness. The material contacted by the teeth exhibited slightly rough areas where material appeared to pull apart when the teeth raked across the surface. Some of these areas were scraped with the stiff paint scraper and material was easily removed in thin layers that remained mostly intact and not in chunks or irregular shaped pieces. The removed material was rolled between the observer's fingers and was slightly moist to the touch (without free moisture transfer to skin or cloth) and crumbled into small spherical pieces (1/16") after several passes. The paint scraper was inserted into the in-place material to a depth of approximately $^1/_8$" without visual indication of cracking around the penetration, though a small amount of material did fall off with the removal of the scraper (the material was typically attached to the scraper surface and did not fall freely). The surface of the material was visually observed to be free of visible cracks or signs of promulgating fractures into the panel. The surface was also observed to be slightly moist to the touch, but without free moisture that would transfer to cloth (that could be detected by the unaided human eye or sense of touch). A water bottle was utilized to mist portions of the exposed surface in an effort to expose small cracks with no visual indication of small cracks in the surface material. Photographs were taken to document the surface; two representative images are provided below.

Observation Performed by Brad Smiley – Stantec QC Manager

Excavation at 12 days (P100554.jpg)

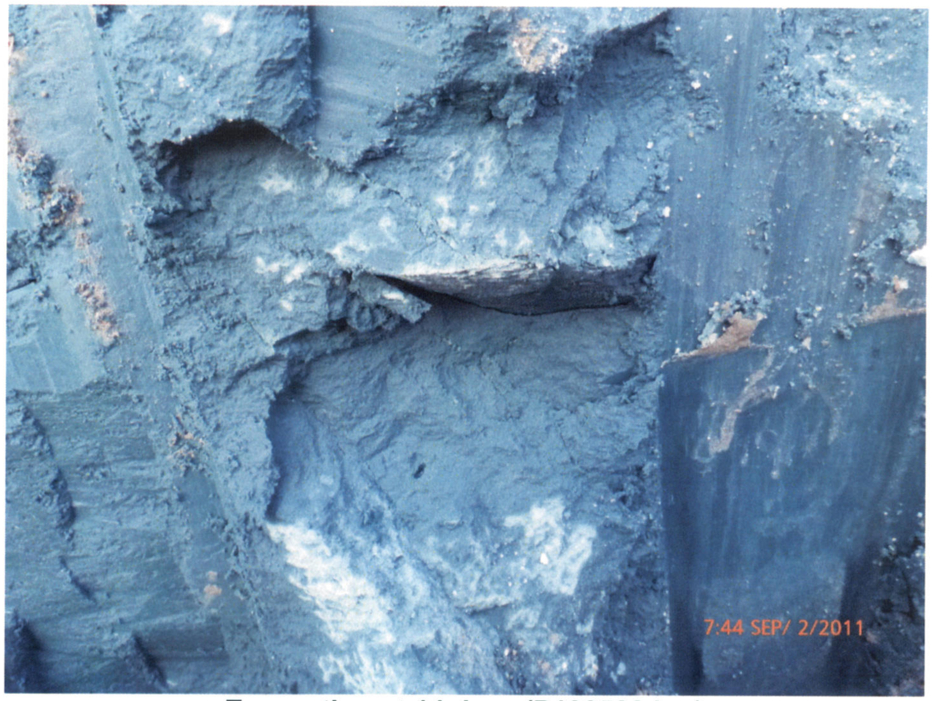


Excavation at 12 days (P100563.jpg)

Cold Joint Test Trench Observations – 14 Days of Curing

On September 2, 2011, a Kobelco PC250LC excavator was utilized to excavate into the cold joint test panel. The test trench was excavated from both the end of the trench to simulate a butt joint (through the portion previously exposed for the 12-day observation), and from the side of the trench to simulate a t-joint (12" to 18" into the side of the panel). The teeth on the bucket of the Kobelco excavator were utilized to excavate into the material, essentially "teething" the material by creating teeth marks of various depths. Teeth marks ranged from approximate 1" to 3" in depth into the material. Areas of loose material were observed between the teeth marks and were easily removed by hand or by prying with the 1-¼" scraper, but did not visually exhibit additional fracturing promulgating into the wall. The material between the teeth marks that was removed by hand or with prying broke off to be somewhat flush with the area impacted by the teeth and did not break off further into the wall. No additional material could be removed by force of hand in the immediate area(s). A piece of hardened wall was removed by hand that measured approximately 4" deep by 6" tall by 5" wide from the area between the teeth marks on the simulated butt joint. A second large piece of hardened wall was removed from between the teeth marks on the simulated t-joint, measuring 3" deep by 12" tall by 5" wide. The remaining faces behind these areas were nearly flush with the surrounding material, which was observed to be intact and could not be removed by prying. The in-place material in the trench following the excavation exhibited a bluish-green color, visually similar as that observed in the demonstration and production walls, but contained areas of a light grayish hue between the teeth marks. When pressed with a hard object, the light gray hue colored areas would turn light green, appearing as if the pressure of the object caused moisture to rise to the surface. The material was observed to be stiff with low plasticity, based on the penetration of a stiff heavy-duty 1-¼" wide paint scraper and visual observation of the material where the teeth of the excavator bucket pressed against the in-place material. Areas where the teeth of the bucket pressed into the material during the downward stroke of the excavator was observed to be relatively smooth, though less smooth than previous observations, and without indication of cracking or brittleness. The material contacted by the teeth exhibited slightly rough areas were material appeared to pull apart when the teeth raked across the surface. Some of these areas were scraped with the stiff paint scraper and material was easily removed in thin layers that did not remain intact and easily crumbled. The surface where the paint scraper was utilized to shave off material was however smooth when scraped and did not break off in chunks or irregular shaped pieces. The removed material was rolled between the observer's fingers and was slightly moist to the touch (without free moisture transfer to skin or cloth) and crumbled into small spherical pieces (1/16") after a few passes. The paint scraper was inserted into the in-place material to a depth of approximately $^{1}/_{8}$" without visual indication of cracking around the penetration, though a small amount of material did fall off with the removal of the scraper (the material was typically attached to the scraper surface and did not fall freely). The surface of the material was visually observed to be mostly free of visible cracks or signs of promulgating fractures into the panel. One potential promulgating crack was observed in the area between the teeth on the simulated butt joint. The actual depth of the crack could not be determined but appeared to be less than 2" based on the insertion of the stiff paint scraper. The area surrounding the crack was observed to be intact and could not be pried loose with a paint scraper or small pry bar. The surface was also observed to be slightly moist to the touch, but without free moisture that would transfer to cloth (that could be detected by the unaided human eye or sense of touch). A water bottle was utilized to mist portions of the exposed surface in an effort to expose small cracks with little visual indication of small cracks in the surface material, as only a few small cracks associated with small (<3") pieces of broken material along the surface. The simulated t-joint was excavated approximately 18" behind the simulated butt joint. The remaining area left in place between the two excavations, after the t-joint progressed into the wall, was observed to be intact without visual indication of cracking. Force was applied to this area by the observer's hands, attempting to push the remaining portion of wall, with no apparent indication of movement. Photographs were taken to document the surface; two representative images are provided below.

Observation Performed by Brad Smiley – Stantec QC Manager



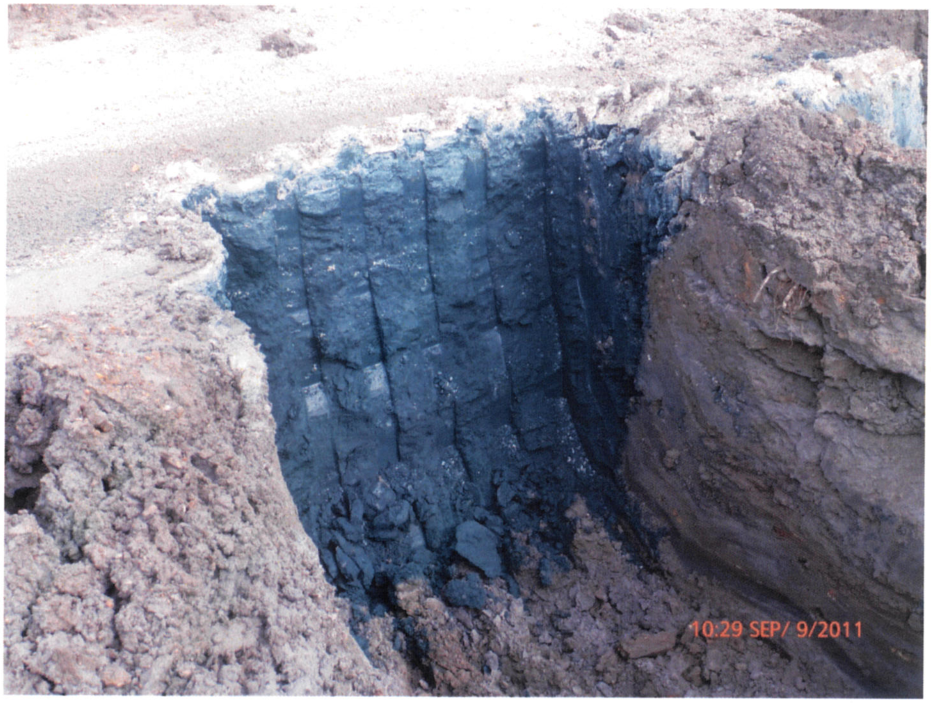
Excavation at 14 days (P100582.jpg)

Excavation at 14 days (P100589.jpg)

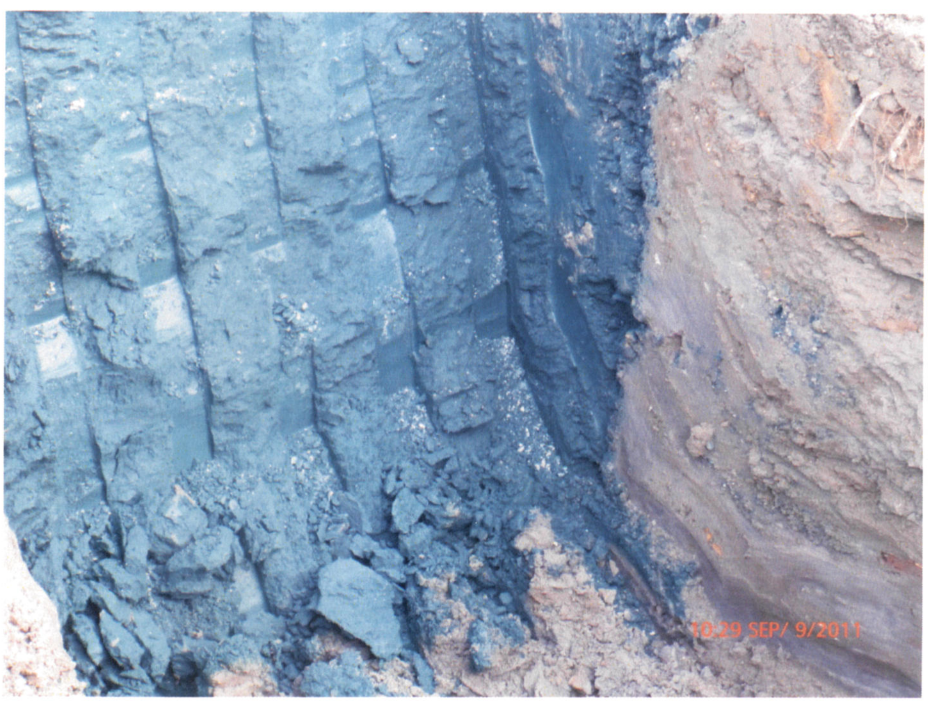
Cold Joint Test Trench Observations – 21 Days of Curing

On September 9, 2011, a Kobelco PC250LC excavator was utilized to excavate into the cold joint test panel. The test trench was excavated from both the end of the trench to simulate a butt joint (through the portion previously exposed for the 14-day observation), and from the side of the trench to simulate a t-joint (12" to 18" into the side of the panel). The teeth on the bucket of the Kobelco excavator were utilized to excavate into the material, essentially "teething" the material by creating teeth marks of various depths. Due to the highly saturated nature of the ash material surrounding the cold joint test trench and the visual indications of instability in the sides of the excavation, observations for the subject cure age were made from the top of the trench without personnel entering. During excavation of the butt joint, the excavator was observed to be unstable and the weight of the machine caused saturated material to be pushed into the excavation from beneath the tracks. Adjacent ash material (which had been excavated previously during the preceding cold joint observations) was observed to flow into the excavation under its own weight, even when sloped. Teeth marks ranged from approximate 0 to 2" in depth into the material, based on visual observation. Areas of loose material were observed between the teeth marks and were visually observed to fall freely from the surface of the exposed material. The material between the teeth marks that broke off following the excavation was observed to be somewhat flush with the area impacted by the teeth and did not appear to break off further into the wall. The in-place material in the trench following the excavation exhibited a bluish-green color, visually similar as that observed in the demonstration and production walls, and were observed to not contain the previously noted areas of a light grayish hue between the teeth marks. The lack of a grayish hue to the material may be attributed to the more than 7" of rain received since Sunday, September 4th. Portions of the material excavated from the trench were observed to be stiff with very low plasticity, based on the material crumbling with relative ease when rolled in the observer's hand. The excavated material, when rolled between the observer's fingers, was moist to the touch (without free moisture transfer to skin or cloth) and crumbled into small spherical pieces (1/16") after only a few passes. Areas where the teeth of the bucket pressed into the material during the downward stroke of the excavator was observed to be relatively smooth, though less smooth than previous observations, and with an indication of cracking and/or brittleness. The material contacted by the teeth exhibited slightly rough areas were material appeared to pull apart when the teeth raked across the surface. The surface of the material was visually observed to contain visible cracks, but did not clearly exhibit signs of promulgating fractures into the panel. The simulated t-joint was excavated approximately 18" behind the simulated butt joint. The remaining area left in place between the two excavations, after the t-joint progressed into the wall, was observed to be mostly intact without significant visual indication of cracking. The edges of the trench, where in contact with the existing ash material, were visually observed to indicate fracturing and brittleness. These areas were observed to contain angular pieces of slurry material, especially within the top 36" of the excavation (see photo P1000607.jpg). Photographs were taken to document the surface; two representative images are provided below.

Observation Performed by Brad Smiley – Stantec QC Manager



Excavation at 21 days (P1000607.jpg)



Excavation at 21 days (P1000610.jpg)

Cold Joint Test Trench Observations – 25 Days of Curing

On September 13, 2011, a Kobelco PC250LC excavator was utilized to excavate into the cold joint test panel. The test trench was excavated from the end of the trench to simulate a butt joint (through the portion previously exposed for the 21-day observation). The teeth on the bucket of the Kobelco excavator were utilized to excavate into the material, essentially "teething" the material by creating teeth marks of various depths. Teeth marks ranged from approximately 0 to 6" in depth into the material, based on visual observation. The material was observed to be a bluish green color with sporadic areas of discoloration that was indicated by a light grayish hue. Visible fracturing was observed in the material remaining between the teeth. Small pieces less than 5" in size were easily removed, with no visual indication of promulgating cracks into the wall material. An area in the bottom right corner of the material remaining between the teeth marks was broken off by the observer by striking the area several times with the sole of a work boot. The material broke free from the remainder of the wall material, and left an area that slightly protruded into the wall by approximately 1" or less. While this area was on the side of the trench material, there was no visual indication of additional fracturing into the wall. A second area in the bottom left of the trench, between the teeth marks, was forcibly removed by the observer by striking repeatedly with the toe of the same steel toe work boot. The piece of material removed was observed to be intact, and the remaining surface remained intact and did not exhibit visual indication of additional fracturing. The piece of material removed was approximately 3" thick, while the surface of the remaining material still protruded from the wall by approximately 3". The material left in place where the teeth impacted the wall was observed to be intact and relatively smooth. This material could be easily shaved in thin layers by light pressure from a 1 ¼" heavy duty putty knife. The shaved material was rolled between the observer's fingers and was noted to be dry to the touch with no indication of free moisture, and quickly broke into granular pieces of material approximately 1/16" of an inch in size after only a few passes. Based on the observations of the force required to remove material by striking with a boot, the nature of the material when rolled between the fingers, and the visual observations of the material, the material at the age of 25-days is noted as being low plastic and stiff with little indication of brittleness. A visual indication of brittleness was observed within the top 8 to 12" of the excavation and was noted as exhibiting an angular surface, and a grayish discoloration. Photographs were taken to document the surface; two representative images are provided below.

Observation Performed by Brad Smiley – Stantec QC Manager

Excavation at 25 days (P1000623.jpg)

Excavation at 25 days (P1000624.jpg)