Final Report of Inspection

Project Management Deficiencies in Constructing the Paul S. Sarbanes Silver Spring Transit Center

Report # OIG-14-007

April 15, 2014

Except as to the *Subsequent Event* information on pages 10 and 54, and the Chief Administrative Officer's Statement on page 163, which are as of May 8, 2014

Montgomery County Maryland

Office of the Inspector General

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Stakeholders in the SSTC Covered in this Report

Within this report, numerous stakeholders are mentioned. The following is a short overview of those interested parties that are mentioned throughout this report.

Owners:

Montgomery County Maryland, represented by Department of General Services (DGS)

Washington Metropolitan Area Transit Authority (WMATA)

Governmental Project Funding:

Federal Transit Administration (FTA)

Maryland Transit Administration (MTA)

Design Team:

Parsons Brinckerhoff, Inc. (PB) *(known as Parsons Brinkerhoff Quade and Douglas, Inc. and PB Americas, Inc. at commencement of the SSTC)*

Sub-Contractors to Parsons Brinckerhoff:

Zimmer Gunsul Frasca Architects LLP (ZGF) - architect

Construction Team:

Foulger-Pratt Contracting, LLC (FP)

Sub-Contractors to Foulger-Pratt:

Facchina Construction Company, Inc. (Facchina) - concrete project work

Sub-Contractors & suppliers to Facchina:

VStructural LLC (VSL) - post-tensioning

Gerdau Ameristeel - mild steel reinforcing design and installation supervision

R&R Reinforcing, Inc. - post-tensioning and mild steel reinforcing installation

Lafarge Concrete, and Rockville Fuel and Feed Co., Inc. (RFF) - concrete suppliers

Inspection Team:

Montgomery County Maryland under the Special Inspections Program administered by the Department of Permitting Services (DPS)

The Robert B. Balter Company (Balter)

Report in Brief

Project Management Deficiencies in Constructing the Paul S. Sarbanes Silver Spring Transit Center

April 15, 2014

Background

The Paul S. Sarbanes Silver Spring Transit Center (SSTC) is a ground transportation facility located in downtown Silver Spring, Maryland at the intersection of Colesville Road and Wayne Avenue.[1] It was designed to accommodate bus and taxi movements while loading and unloading passengers. Bus loops are located on the ground (Level 305) and second (Level 330) floors, while private vehicles and taxis use the third, smaller floor (Level 350). The Levels 330 and 350, which are the focus of this report, are made of concrete reinforced with mild steel reinforcing bars and post-tensioned tendons (a post-tensioned tendon consists of 7 high strength wires braided together to form one tendon) embedded in the floors to provide strength.

Under a formal Memorandum of Understanding (MOU) dated November 17, 2004 (amended and restated September 25, 2008) between the two owners of the land being used for this project - Montgomery County Maryland and Washington Metropolitan Area Transit Authority (WMATA) - Montgomery County, represented by its Department of General Services (DGS), is authorized to manage the development and construction of the SSTC. Upon completion of the project and WMATA's acceptance and approval, WMATA will control, operate, and maintain the facility.

Construction of the structure began in 2009 but project progress was severely delayed due to unforeseen contaminated soil and utility relocations. By June 2010, the project was already several months behind schedule. By November 2010, visible evidence of structural issues and concerns about durability had emerged, including:

- Cracks discovered in the concrete slabs, beams and girders;

[1] For additional background information about the SSTC, reference the *Silver Spring Transit Center Structural Evaluation of Superstructure* report dated March 15, 2013, prepared by KCE Structural Engineers, PC., pp. 3-4, and the *Evaluation of Silver Spring Transit Center, Silver Spring, Maryland* report dated May 2, 2013, prepared by Whitlock Dalrymple Poston & Associates, Inc., page 1.

- Concrete that broke away from the finished drive surface (spalling), revealing post-tensioned tendons and evidencing that an insufficient concrete cover had been placed over the tendons;
- Issues related to post-tensioned tendon elongations and tensioning; and
- Reinforcing bars that were incorrectly installed or partially omitted in a slab pour.

Although concerns about concrete thickness, inadequate concrete cover, and related structural deficiency and durability were continually raised in monthly project oversight meetings, potential repairs and remediation had not been resolved by the end of the major construction activities in 2012.

Project oversight was provided based on a formal Project Management Plan (PMP) by a Project Management Team (PMT) consisting of representatives of all major project stakeholders, including the property owners, Montgomery County and WMATA, and the state and federal government agencies that provided significant funding for the project (the Maryland Transit Administration [MTA] and the Federal Transit Administration [FTA]). The team held formal monthly meetings for which meeting minutes were kept. In April 2012 DGS reported to the PMT that the construction contractor would prepare a presentation regarding a remediation plan. Recommended actions, including a 2 inch Latex Modified Concrete (LMC) overlay, recommended by Parsons Brinckerhoff, Inc. (PB) and MTA in mid-2012, were proposed during the following months, but meeting minutes indicate "WMATA has not accepted this proposed fix and continues to question the root cause of the cracks."

In June 2012, Montgomery County contracted with KCE Structural Engineers, P.C. (KCE) to conduct a document review and structural evaluation of in-situ conditions at the SSTC. In July 2012, the firm of Whitlock Dalrymple Poston & Associates, P.C. (WDP) was retained by WMATA to evaluate the SSTC. Both evaluations had similar purposes - to determine the condition of the SSTC and to understand whether the structure as constructed satisfied the strength and durability requirements necessary to meet its intended use and service life. Both KCE and WDP based their findings on independent document reviews, field investigation observations, and engineering analyses.

On March 15, 2013 KCE issued its report that identified a number of serious deficiencies in the structure, and determined that the SSTC required strengthening and repairs to meet Building Code and WMATA requirements. On May 2, 2013, WDP released its report which documented construction deficiencies consistent with those identified in the KCE report.

As of March 2013, when the KCE report was issued, information we were provided by FTA indicated that total project cost stood at $104,618,000. However, approximately $7,000,000 in change orders were pending. FTA had provided $53,957,000. The balance had been provided by the MTA and Montgomery County. The initial estimate in 2004 was $35 million.

Why We Did This Inspection

The objective of our Inspection was to identify and document any project management deficiencies during the construction of the Silver Spring Transit Center. In achieving our objectives, we attempted to determine which project management controls failed, how these controls should have functioned, why they failed, and what measures should be taken to ensure controls will be effective in future projects undertaken by Montgomery County.

A report on the Silver Spring Transit Center entitled "Analysis of Project Controls" was prepared at our request by the Alpha Corporation. That report, which includes both recommendations and lessons learned, is included in its entirety as Exhibit I. The **objectives**, **scope, and methodology** of our report are provided in Exhibit II.

What We Found

The significant structural strength and structural durability concerns identified in both the KCE and WDP Reports resulted from deficiencies in construction, design issues cited in the KCE report, and failure to effectively address these issues when they were first identified. Each of these issues contributed to widespread cracking in the slabs, beams, and girders that is now evident in the Silver Spring Transit Center.

Project Controls ***(see page 11)***

Fourteen of the 22 relevant construction project controls analyzed for adequacy of design, implementation, and effectiveness were either weak or ineffective.

Structural Strength ***(see page 13)***

Concrete compressive strength ***(page 13)*** as measured by KCE is weaker in some areas than required by the contract documents. Although inspectors asserted that no undocumented water was added to the concrete, forensic testing in the SSTC suggests a presence of 36% more water than was documented by the concrete provider and the inspector.

Specifically, testing for the workability of concrete via slump measurements provided an indicator of additional water. Concrete with greater workability was documented for 19% of the second slump tests taken on the deck – a result that is inconsistent with the passage of time and the asserted absence of undocumented additional water. These results raise questions about the accuracy and validity of the recorded data, as the results are inconsistent with the other data. Greater amounts of water in a concrete mix would contribute to lesser compressive strength.

We found evidence that concrete did not cure properly in some areas, further impacting the compressive strength of the concrete placed in the structure (in-situ concrete). The condition of the in-situ concrete may have been affected by the failure to observe cold weather curing procedures, potentially contributing to the early shrinkage cracking observed in the structure. The placement of thermal protection was delayed and prematurely discontinued during some cold-weather pours, and temperatures were not monitored as indicated in the specifications.

The effects of extra water and improper curing should have been detected during testing, but concrete specimen samples upon which test results relied were not representative of the in-situ concrete.

Most specimen cylinders were collected at the construction site inspection station. For three trucks during each pour, however, comparative specimens were also collected on the deck where the concrete slabs were poured. Compressive strength tests relied upon for decision-making were primarily those from specimen cylinders collected and cured at the inspection station.

We found that for 49 of the 56 comparative specimen sets, cylinders collected from the deck slab pours demonstrated lower compressive strength than that of the cylinders taken at the inspection station. However, records do not indicate that the test results from cylinders collected at the two locations were ever compared by the contractors. As a result, the differences were not identified or investigated, and the same batch performance differences relative to specifications were not detected.

Concrete placement *(page 34)* resulted in insufficient concrete cover over reinforcing steel and post-tensioned tendons, which allowed the concrete covering tendon ducts in several locations to crack away when grout was placed in the ducts. Concrete drive paths as poured do not provide the minimum concrete cover (thickness) required by the design specifications. In other areas, the concrete cover was thicker than design specification requirements.

By late 2010, design, construction, and inspection personnel were aware that proper concrete thickness was not always being achieved, yet effective corrective measures were not taken, and the problem persisted throughout the period of the major construction project activities.

The three pour strips[2] *(page 37)* on the 330 and 350 levels were each constructed in a different manner and neither of the pour strips on the 330 level was constructed in a manner that conformed to the design requirements identified in the structural drawings. The Contractor's Quality Control plan provided for resolution of construction questions through a written process, but the contractor did not use this process to seek answers to questions it may have had about design requirements. The east pour strip on the 330 level was poured without post-tensioning tendons but with mild

[2] Pour strips are areas of a slab in the deck that are left out during construction and then placed after adjacent concrete has been poured and has been allowed an opportunity to shrink. See Finding 6.

steel reinforcement, while the west pour strip on the 330 level was poured without post-tensioning tendons and without sufficient steel reinforcement in one direction.

Pour strip deficiencies resulted from the failure to prepare necessary and/or accurate shop drawings and professional errors in detecting the omission and inaccuracy of the drawings.

Durability of the Structure ***(see page 42)***

Water penetrating the structure through the cracks could reach and corrode the embedded reinforcing steel, thus potentially shortening its life span significantly from the intended 50-year life. Significantly greater maintenance of the structure would be required, thus greatly increasing the cost of maintaining the structure through its projected life.

The primary causes of the reduced durability include widespread cracking of various sizes throughout the structure, which are attributable to the design of the structure that according to KCE and WDP was not prepared in accordance with applicable building codes, WMATA design criteria, or industry standards. A major issue was the lack of construction and design details to accommodate normal movement.

Although evaluation of The Robert B. Balter Company (Balter) (the project inspector) compressive strength testing of the sample cylinders led PB to determine that concrete had attained the 4,000 psi minimum strength necessary to commence post-tensioning stressing, the findings of this report conclude that in-situ concrete was likely less mature and of questionable strength at the time stressing commenced. Cracking observed during the first month following concrete placement appears consistent with drying and shrinkage resultant from improper curing, and the horizontal cracking in the beams and girders documented by KCE during its testing is likely resultant from excessive stressing force applied to immature concrete.

However, after this initial setting and curing period whose passage is approximated by the 28-day compressive strength tests, existing cracks worsened, and new cracking appeared. We have found no evidence that the cracking that persisted after the 28 day period could have resulted from any cause other than design issues.

Problems with structural design and construction were identified by late 2010, and repeatedly discussed in subsequent Project Management Team meetings, but were not effectively addressed.

In a reactive response to problems that were identified during construction, DGS contracted with an independent firm, KCE, but did not do so until 2012, when the structure was almost complete.

In hindsight, the County would have benefitted from retaining an objective third party firm to perform a "peer review" function during the design of the structure. [3] That firm could have been retained to work with the design professionals to either substantiate or modify the design.

[3] See discussion of Peer Review in Finding 7.

The County also would have benefitted from retaining an objective third party firm to perform the Construction Management function during the construction.

Structural Remediation ***(see page 53)***

As a follow-up to a meeting held on April 25, 2013, a Cooperative Remediation Working Group (CRWG)[4] was formed to develop a plan to remediate the defects at the SSTC with a resultant structure that meets the design and operational objectives and standards outlined in the project documents.

The CRWG quickly agreed upon, designed, and implemented corrective actions to strengthen both of the Level 330 pour strips. Those actions were completed by the end of 2013. The CRWG also adopted a plan to fill slab cracks and resolve the slab thickness deficiencies by topping the Level 330 and 350 slabs with a Latex Modified Concrete (LMC) overlay that will be applied once the weather and temperatures permit, and decisions about other remedial actions necessary to address durability issues have been made. As of the mid-April 2014, the CRWG had not agreed upon a remediation plan to address the latter issues.

What We Recommend

Recommendation 1: DGS should improve its controls for future projects in a manner that is consistent with the lessons learned and additional recommendations contained in Exhibit I, the report "Analysis of Project Controls," in addition to other recommendations made in this report.

Recommendation 2: DGS should ensure construction documents clearly establish responsibility for and performance of systematic analysis of data collected and recorded during construction in order to identify possible inconsistencies with specifications, project control weaknesses, and construction deficiencies that should be investigated and resolved.

Recommendation 3: In future projects, DGS should ensure that all specification requirements are reviewed and implemented unless a variance is mutually discussed and agreed upon. Temperature limits during curing should be monitored and maintained, and specification for duration of curing should be strictly observed. Confusion about where to take samples and about cold weather limits should be avoided by clearer language in

4 The CRWG is comprised of key participants in the SSTC project, representing Montgomery County, the Federal Transit Administration, the Maryland Transit Administration, the Washington Metropolitan Area Transit Authority, Parsons Brinkerhoff, Foulger Pratt, and KCE, as well as their respective consultants and subcontractors.

specifications. Any conflicts between specifications and standards should be resolved in favor of the more conservative of those required by stakeholders (in the case of the SSTC, the stakeholders are DGS, and WMATA).

Recommendation 4: DGS should modify its contract specifications for future construction projects to ensure that concrete test specimens are made as near as possible to the actual point where concrete is placed. Where referenced standards require testing at the point of delivery, DGS should clarify in the specification that such testing is in addition to typical testing.

Recommendation 5: In future projects, DGS should ensure its construction contractors utilize a construction method that allows direct measurement of floor thickness so that inspectors can help the Contractor by identifying problems before the concrete is placed. Alternatively, a second, independent survey should be performed. Survey equipment could be utilized by inspectors to continuously monitor concrete thickness during placement, and submit a report of survey results for Owner and Structural Engineer of Record (SEOR) approval.

DGS should hold construction contractors accountable for any remediation and increased maintenance costs that will likely result from the contractor's failure to ensure specified concrete slab thickness was attained during placement.

Recommendation 6: Those professionals whose lack of diligence resulted in the pour strip construction deficiencies should be held accountable.

DGS should consider implementation of changes to guard against occurrence of such errors in future projects, for example:

- All shop drawings could be required to be submitted before the pre-installation conference occurs, or
- A pre-installation conference could occur with each new area covered by a recently approved shop drawing, or
- A Submittal Registry should project the number and identity of proposed shop drawings anticipated for all phases. (For example, if only one pre-installation conference occurs at the beginning of the Definable Feature of Work, part of the conference should identify the number of submittals that will be generated for Designer review for the phased construction. Then as construction proceeds discussion should occur whether each of those proposed submittals have been approved during the progress meetings.)

Recommendation 7: DGS should develop procedures to identify circumstances under which an independent peer reviewer should be employed to review and improve the design of unique and challenging construction projects. The trigger for a peer review could be the nature and complexity of the project design.

Recommendation 8: DGS should develop procedures to identify circumstances under which an independent third party should be employed to serve as Construction Manager on an atypical construction project. The trigger could be a dollar value or uniqueness of the project.

DGS should develop protocols to ensure that controversial issues encountered/problems experienced by or with the construction contractors are promptly and effectively addressed. As an example, DGS could develop and incorporate into its contracts a systematic process that identifies deficiencies and withholds payments pending resolution. Once an item is identified as deficient, it would be added to a "rolling punch list" which is tied to payments. Therefore, the Contractor is motivated to correct issues in a timely manner. Foulger-Pratt Contracting (FP) generated their own internal contract compliance list, which was included and discussed at progress meetings, but evidently was not tied to payments.

Subsequent Event

On May 8, 2014, the County Chief Administrative Officer advised members of the County Council that the County Executive had directed County contractors to move ahead on remediation work at the Silver Spring Transit Center. That work would address the shear and torsion recommendations contained in the April 21, 2014 report commissioned by the County Executive entitled Report of the Independent Advisory Committee Regarding the Status of the Silver Spring Transit Center.

Summary of Chief Administrative Officer's Response

The response of the Chief Administrative Officer (CAO) to the final draft report is included in its entirety on page 55 of this report. The CAO addressed each recommendation individually in his response. The responses did not cause us to alter our findings or recommendations.

Analysis

Analysis of Project Controls

Project Controls

Finding 1: Fourteen of the 22 relevant construction project controls analyzed for adequacy of design, implementation, and effectiveness were either weak or ineffective.

We engaged the Alpha Corporation to evaluate those project controls used during the construction of the SSTC that should have directly controlled the construction activities related to the deficiencies identified by KCE and WDP in their reports. We asked that in their analysis, they first determine whether a control, if properly implemented, should have been effective as designed, and second, whether the control was in fact implemented as designed.

If a control was not properly designed but correctly implemented, the expected outcome would be that the control was ineffective and a negative result, such as an error or construction deficiency, could have gone undetected and uncorrected. Alternatively, if a control was properly designed but not correctly implemented that control would also be ineffective and a negative result, such as an error or construction deficiency, could also be have gone undetected and uncorrected. If all construction project controls were appropriately designed and implemented, the deficiencies identified by KCE and WDP at the SSTC should not have existed, with the possible exception of deficiencies that could have resulted from flawed design elements.

In their report to the OIG, "Analysis of Project Controls", the Alpha Corporation found that the design of nine construction project controls was either weak or inconsistent with contract requirements. They also found that implementation of ten controls was either weak or deficient. Overall, eleven controls were determined to be either weak or ineffective, and the effectiveness of four other controls could not be determined from the data available.[5] Their detailed analysis of these controls is presented in Exhibit I, page 10, and summarized in Chart 1.

Although each project control may have operated in isolation, many of these controls operated collectively during the construction period as systems intended to control time, cost, scope, and quality. This OIG staff analysis of the body of narrative and statistical information available to us, combined with the Alpha Corporation's analysis of individual project controls, identified specific areas of concern that are presented in findings 2 through 8 and the related recommendations that follow. The recommendations are consistent with those presented in "Analysis of Project Controls" even though only some of the recommendations are drawn directly from that report.

Chart 1: Deficient Project Controls

Control	Deficiency Observed in Control			Effectiveness	No
	Design	Implementation	Effectiveness	Unknown	Deficiency
Pour Strips					
RFIs & Meetings			✓		
Submittal Review		✓	✓		
Pre-Installation Conference	✓		✓		
Daily Reports			✓		
Concrete Composition					
Pumped Concrete Samples	✓		✓		
Batch Plant Inspections	✓	✓	✓		
Concrete Mix Design					✓
Water Added at Site			✓		
Slump Measurements	✓				
Cold Weather Curing	✓	✓	✓		
Surface Curing	✓	✓			
Entrapped Air					✓
Entrained Air		✓		✓	
Concrete Placement					
PT Tendon Placement			✓		
Steel Rebar Placement		✓		✓	
Floor Thickness	✓	✓	✓		
Post Tensioning					
Stressing Records					✓
Concrete Stresses	✓	✓	✓		
Grout Strength		✓		✓	
Time to Grouting		✓		✓	
Strength at Stressing	✓				
Age at Stressing					✓

Source: Alpha Corporation

The "Analysis of Project Controls" contains "lessons learned" and additional recommendations in the Considerations and Conclusions sections of the Alpha Corporation report.

Recommendation 1

DGS should improve its controls for future projects in a manner that is consistent with the lessons learned and additional recommendations contained in Exhibit I, the report "Analysis of Project Controls," in addition to other recommendations made in this report.

[5] Some controls deficiencies met more than one criteria of finding.

Deficiencies in structural strength resulted from work that did not meet contract requirements and was undetected by inspectors

Concrete compressive strength in some areas as measured by KCE is less than that required by the contract documents. All data we reviewed indicates that water was added to concrete after testing specimens were collected. In addition, concrete did not cure properly in many areas. Samples taken at the inspection station produced compressive strength test results that were not representative of the strength of the in-situ concrete. As a result, areas were identified in which concrete strength is weaker than required by the design. These results were based on an analysis that primarily focused on the concrete slabs on Levels 330 and 350 of the structure.

Structural Strength

Finding 2: Analysis of data collected during construction indicates that addition of water to concrete after collection of primary testing specimens but before placement of the **concrete in the structure accounts for the lesser strength of the in-situ concrete.**

Compressive strength was to be tested by collecting specimen cylinders of fresh concrete and measuring the force needed to break the concrete cylinders at prescribed intervals as they hardened.[6] Design and construction quality control specifications required that a set of test cylinders be made for each 50 cubic yards (yd^3) of concrete poured in order to confirm whether concrete in post-tensioned members had reached required design strengths. Controls were designed and observed to capture the adequate number of compressive strength test cylinders.

In order to achieve sufficient strength for designed loading requirements, SSTC Construction Documents[7] required that the concrete achieve a minimum compressive strength[8] of 4,000

[6] For an explanation of this test, reference the Portland Cement Association, Washington, DC 20001, “What are the most common tests for fresh concrete?” Web. 20 January 2014. <http://www.cement.org/cement-concrete-basics/faqs>.

[7] Construction Contract between Montgomery County and Foulger-Pratt Contracting dated September 3, 2008, Attachment A – Schedule of Documents, List of Specifications, § 03300-Cast-In-Place Concrete, Part 2.16(E)

pounds per square inch (psi) before commencing tendon stressing[9] and 8,000 psi 28 days after the concrete was poured.

During this project, the concrete was primarily collected for testing at the end of the *concrete truck chute* at the inspection station. For most testing sets made during a pour, twelve[10] specimen cylinders were collected from tested trucks at the inspection station and before discharge into the hopper of the pump used to deliver concrete to the point of placement on the deck. For three additional testing sets, The Robert B. Balter Company (Balter) was directed to cast another six comparison cylinders on the deck at the end of the *concrete pump hose*. This casting of comparison sets (which was directed by DGS) was fortuitous as it provided the evidence of differences between inspection station and in-situ concrete.

The majority of Balter-reported laboratory test results indicated that compressive strength of the collected specimens exceeded minimum required values. Much later, KCE Structural Engineers, P.C. (KCE) excised sample cores from slabs to test for the compressive strength of the in-situ concrete, and determined the samples "exhibited significantly lower compressive strengths when compared to [the Balter-reported compressive strengths]." Based on this structural analysis, KCE concluded that the concrete strength for all deck pours was 6,970 psi.[11]

KCE's report states "Our analysis of the as-built post-tensioned slabs indicates slab areas with thicknesses below approximately 9 inches and with compressive strengths at or below 6,970 psi do not have adequate shear capacity in certain locations to support the design loads (the areas less than 9 inches thickness are limited in extent and therefore do not limit overall load-carrying capacity)." (See our discussion of concrete thickness in Finding 5 of this report.)

Chart 2 displays a comparison of a sample of KCE test results (conducted on core samples excised from the deck of the SSTC) to results of testing conducted by Balter that had been taken from the same location in the SSTC (we identified nine sets of KCE and Balter test results that had been taken from concrete for the same location in the SSTC).[12] (A comparison of all results may be found in Exhibit IV of this report.) With the exception of comparison samples that were taken at the point of placement, Balter's primary test results were based on samples taken at the inspection station. As indicated in Chart 2, the compressive strength determined from KCE-tested, in-situ specimens ranged from 5,330 psi to 11,040 psi, while the Balter-tested, lab-cured

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8 The measured resistance of a concrete or mortar specimen to axial loading; expressed as pounds per square inch (psi) of cross-sectional area. Source: http://www.allmetalssupply.com/concrete_terms.htm @ 17:50 on 1 August 2013

9 The Construction Contract between Montgomery County and Foulger-Pratt Contracting dated September 3, 2008, Attachment A – Schedule of Documents, List of Specifications, § 03381-Bonded Post-Tensioned Concrete, Part 3.7(C) required that stressing operations not begin until concrete strength had reached 4,000 psi as indicated by compression tests of field-cured cylinders, and that stressing be limited to 50 percent of the total tendons until the concrete had achieved 6,000 psi strength. Part 3.7(D) required that stressing of 50 percent of the total tendons be completed within 96 hours of concrete placement.

10 During the course of the project, 14 primary cylinders were collected for later pours.

11 KCE strength values have been converted to "equivalent specified strengths", and are based on formulas recommended by ACI 214.4R-10 in an attempt to approximate equivalency with Balter values reported under the AASHTO T22. The reader should be aware of the professional judgments that are required when interpreting core sample strengths. Comparisons between test results obtained through application of different standards should be accompanied with an understanding that there is some uncertainty in the comparison. See Exhibit III: Standards

12 The location of the Balter sample was determined from the "Location of Sample" documented by the Balter inspector on the "Compressive Strength Test Specimen Data" report. The location of the KCE sample was determined by reference to the KCE exhibit that mapped the location of each extracted core.

specimens at 56 days after the pour dates ranged from 12,480 psi to 14,400 psi.[13] KCE's highest result was less than Balter's lowest result. For the four pours in this sample, the average compressive strength of the KCE samples was only 62% of the compressive strength of the Balter samples (with a minimum of 37% and a maximum of 86%).

Chart 2: Comparison of KCE In-Situ Compressive Strength & Petrographic Test Pairings to Balter Construction Inspection Tests

Pour Information		Testing Information		Strength		
Date	#	Core #	KCE TestType	(psi)	w/c	unhydrated
20-Dec-10	1D	72	Compressive Strength	7,100		
		71	Petrographic		.35 - .40	
KCE-Reported average compressive strength - Pour 1D				6,780		
56-day RBB Test Cylinder Batch91832: Test Report # 522*				14,400	.26	
30-Dec-10	1F	105	Petrographic		.35 - .40	
		106	Compressive Strength	9,350		
		107	Compressive Strength	9,000		
		108	Petrographic		.35 - .45	8% - 13%
KCE-Reported average compressive strength - Pour 1F				6,990		
56-day RBB Test Cylinder Batch 92297: Test Report # 551				13,495	.26	
7-Dec-10	2B	121	Compressive Strength	**11,040**		
		122	Petrographic		.35 - .40	
		123	Petrographic		.35 - .45	7% - 11%
		124	Compressive Strength	10,060		
KCE-Reported average compressive strength - Pour 2B				8,810		
56-day RBB Test Cylinder Batch 91111: Test Report # 486				13,575	.26	
56-day RBB Test Cylinder Batch 91160: Test Report # 495				13,740	.24	
14-Jan-11	2C	127	Petrographic		< .38	
		128	Compressive Strength	10,710		
		131	Petrographic		.35 - .45	7% - 12%
		132	Compressive Strength	5,330		
KCE-Reported average compressive strength - Pour 2C				6,870		
56-day RBB Test Cylinder Batch 93009: Test Report # 590				12,480	.26	
56-day RBB Test Cylinder Batch 93019: Test Report # 591				14,390	.26	

The factor that most influences concrete strength is the ratio of water to the cement that binds the aggregates together. The higher the ratio of water to cement, the weaker the concrete will be and vice versa. The Portland Cement Association opines that every desirable physical property that can be measured will be adversely affected by adding water.[14] Alternatively, by reducing water, the resulting higher-strength concrete can carry loads more efficiently than normal-strength concrete, possibly reducing the total amount of material placed, and lowering the overall cost of the structure.[15]

To achieve a high degree of durability and strength, the American Concrete Institute (ACI) recommends the use of a concrete mixture with a low *w/c*, but notes an insufficient amount of water can inhibit the complete hydration of the concrete mixture.[16] Too much water and the concrete does not achieve the pore density it needs for optimum strength. Water not absorbed during hydration remains as free water, which can bleed to the surface or evaporate. Excessive loss of water due to evaporation can promote the development of the plastic shrinkage cracking that was observed in late 2010 (see Finding 7).[17] Too much water produces a weaker, less

[13] All testing facilities reported observation of the same industry testing standards.

[14] Portland Cement Association, Washington, DC 20001, "What are the most common tests for fresh concrete?" Web. 20 January 2014. <http://www.cement.org/cement-concrete-basics/faqs>.

[15] Portland Cement Association, Washington, DC 20001, "High-Strength Concrete." Web. 20 January 2014. <http://www.cement.org/cement-concrete-basics/concrete-products/high-strength-concrete>.

[16] *American Concrete Institute (ACI)*, Farmington Hills, MI 48333-9094, Guide to Curing Concrete (ACI 308R-01), Chapter 1.3.1

[17] *Bonini, Julius PE, M and P Labs,* Schenectady, NY, and *Smith, Andrew, PhD, CERAM Research, Stoke-on-Trent, UK. "Forensic Investigation of Hardened Concrete: Water/Cement Ratio." Presentation at the Celebration of Capital District's National Engineers Week I7 February 2011. Albany, NY. Web. 20 January 2014.* <http://www.mandplabs.com/interface/uploads/files/pdfs/Forensic_Investigation_Hardened_ Concrete.pdf>

durable concrete that will contribute to early spalling of the surface. Too little water, and the cement does not complete the chemical reaction required to achieve optimum strength.[18]

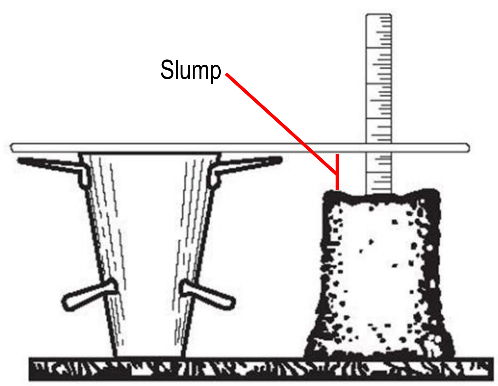
KCE's petrographic testing results presented in Chart 2 indicate each of those pours contained a water to cement ratio (*w/c*) ranging from 0.35 to 0.45. Balter reported *w/c* ranged from 0.24 to 0.26.

Slump Test Results were routinely inconsistent with other support data recorded by Inspectors

As previously stated, concrete matures and hardens as it cures via hydration. Concrete that has a low *w/c* ratio may be more difficult to work with due to its higher viscosity.[19] To overcome this problem, special additives (admixtures) may be added to the concrete in place of small amounts of water. Those admixtures improve the workability of the concrete.

The *w/c* ratio of fresh concrete cannot be directly tested, so the quantity of water added is controlled via records from both the batch plant and the project site. The Statement of Special Inspections[20] required that Balter provide project-site verification of the design mix in use.

Image 1: Illustration of Slump Test Measurement



Source: Gates Concrete Forming Systems

Absent a field test for *w/c*, an indicator of the amount of water in a mix may be its workability, and workability can be field measured by means of a slump test.[21] There is no established direct relationship between *w/c* and slump, but slump should be less (less workable) after a period of time than it was when it arrived on site unless water has been added. As an example, concrete with slump of 7" would be expected to contain less water than would concrete with a slump of 8" but an otherwise equal amount of admixture, cementitious material, and age.

As represented in Image 1, a standardized conical shape is filled with fresh concrete. When the mold is removed, the fresh concrete subsides and is measured against the original conical shape. Fresh concrete that is more viscous would contain a greater amount of water or admixture, and would have a greater tendency to collapse in height. Conversely, concrete would tend to stay close to its conical shape if lesser water and admixture are present or if the concrete has had an opportunity to age and commence the curing process.

For the high strength concrete mix to be used on levels 330 and 350, Parsons Brinckerhoff (PB) had approved a slump of "*4" or 8" for concrete with a verified slump [a test made at the*

[18] Portland Cement Association, Washington, DC 20001, "What are the most common tests for fresh concrete?" Web. 20 January 2014. <http://www.cement.org/cement-concrete-basics/faqs>.

[19] Viscosity is a measure of the friction between neighboring particles in a fluid. For liquids, it corresponds to the informal notion of "thickness". For example, honey has a higher viscosity than water. Source: Wikipedia, accessed 8 April 2014

[20] See the discussion of the Montgomery County Special Inspections Program in Exhibit I, page 57.

[21] A conical form is filled with concrete, inverted, and the form removed. The amount of height in inches the cone loses during a set period of time measures slump. Refer to "Slump Measurement" Alpha Corporations SME report.

batching plant and verified by an inspector that the concrete had a slump] of 2"-4" before a high-range water reducing admixture is added." WMATA provided only for a 2 to 4 inch slump. Slump tests conducted by Balter routinely measured at 7-8 inches. With the passage of time and absent the addition of water or admixtures to extend the workable life, concrete can be expected to begin setting up, which, in turn, would result in a smaller slump measure.

Data collected as a part of the normal construction process was analyzed by the OIG. Chart 3 includes data from a sample of four Rockville Fuel and Feed Co (RFF) batch tickets and Balter Reports of Concrete Cylinder Tests. This data compares Balter compressive strength test results of cylinders that their inspectors collected at the inspection station to the results for cylinders they collected at the point of placement, and catalogs for each test the slump measurement, the air content, the amount of water added on site, if any, the number of times the truck's mixing drum revolved, the water to cement ratio identified by RFF on its batch ticket, and the time that elapsed in minutes between batching the concrete at the plant and the collection of the specimen cylinder at the project site.

Chart 3: Comparison of Same Batch, Inspection Station to Surface Deck Field Cured Strength Results

Concrete Batch			Sample	RBB Strength Test		Slump	Air Content	Added H_2O (gal)	Revs	W/C ratio	Time Lapse	3-Day Strength		28-Day Strength	
Pour	Truck #	Ticket #		#	Location							Sample 1	Sample 2	Sample 1	Sample 2
1 D	67	91818	Set 1	518	Inspection Station	6.5	5.1%	20.0	71	0.25	53	10,480	10,220	13,100	13,440
				519	Deck	6.5	5.3%	20.0	71	0.25	74	5,140	5,020	10,620	10,890
	77	91837	Set 2	523	Inspection Station	7.0	6.2%	0.0	112	0.26	45	9,190	9,580	12,100	11,820
				524	Deck	8.0	5.7%	0.0	112	0.26	65	3,820	3,930	7,550	7,410
	79	91883	Set 3	530	Inspection Station	7.0	5.7%	0.0	250	0.26	53	9,910	10,190	11,470	11,460
				531	Deck	7.5	7.5%	0.0	250	0.26	73	4,460	4,130	9,120	9,510
1 F	77	92269	Set 1	543	Inspection Station	7.5	5.0%	0.0	116	0.26	19	6,560	6,730	12,220	11,700
				544	Deck	7.0	4.7%	0.0	150	0.26	44	6,910	6,960	8,780	9,340
	62	92282	Set 2	547	Inspection Station	8.0	6.3%	0.0	120	0.26	45	7,930	7,810	12,690	12,660
				548	Deck	7.5	5.8%	0.0	153	0.26	75	6,120	6,670	9,160	9,250
	32	92316	Set 3	554	Inspection Station	8.0	6.1%	0.0	128	0.25	52	5,700	5,310	12,040	11,910
				555	Deck	7.5	5.9%	15.0	160	0.27	101	7,190	7,550	8,680	8,730
2 B	67	91088	Set 1	481	Inspection Station	8.0	6.3%	0.0	195	0.25	41	4,080	4,150	11,150	10,670
				482	Deck	8.0	5.1%	0.0	195	0.25	62	4,270	4,590	9,280	8,840
	69	91152	Set 2	493	Inspection Station	7.5	5.1%	0.0	119	0.26	77	6,840	6,910	12,680	12,790
				494	Deck	8.0	4.6%	0.0	119	0.26	101	5,990	6,060	11,180	11,310
	37	91251	Set 3	507	Inspection Station	7.0	4.7%	0.0	88	DNA	78	4,300	3,960	11,240	10,130
				508	Deck	7.0	4.2%	0.0	88	DNA	94	5,750	5,740	10,100	10,260
2 C	67	92950	Set 1	578	Inspection Station	7.0	4.5%	0.0	176	0.26	57	7,060	6,490	11,400	11,600
				579	Deck	8.0	4.3%	20.0	195	0.28	67	7,080	7,170	11,200	11,140
	81	92978	Set 2	585	Inspection Station	8.0	5.6%	0.0	110	0.26	60	5,380	5,300	12,890	13,120
				586	Deck	8.0	5.4%	0.0	110	0.26	75	8,030	8,060	12,830	12,700
	61	93053	Set 3	594	Inspection Station	7.0	4.8%	0.0	250	0.26	95	6,380	6,590	13,170	12,650
				595	Deck	8.0	5.1%	0.0	250	0.26	109	5,390	5,160	9,620	9,110

DNA = Data Not Available. Source: Robert B. Balter Company Report of Concrete Cylinder Test and Rockville Fuel and Feed Company, Inc. job batching and delivery tickets. 3-Day Strength results for Pour 1 F were actually tested on Day 4.

Data for pour 1F in Chart 3 is typical for expected results. Over time and in the absence of additional water, the slump demonstrates less workable concrete resulting in smaller measures. Even though water is added in set three, it does not compensate for the additional setting time.

By referencing slump test results in Chart 3 for comparison specimen Set 2 of Pour 2B, the conical slump made at the inspection station dropped 7½" from the height of the shape during the test. Twenty-four minutes later, when the test was repeated on the deck, the shaped concrete "slumped" 8" - another ½" - demonstrating a lesser viscosity and more workability despite the passage of time and the absence of recorded additional water or admixture. Slump, as a measure of consistency and workability of wet concrete, is a standardized test that should yield consistent results when comparing as-mixed to as-placed slump values. An increase in the slump measurement could be an indicator of added water.[22]

In five of the twelve comparison sets, the slump measures presented in Chart 3 do not appear to be supported by the other data in the chart. The second slump test taken on the deck for Pour 1D comparison Sets 2 and 3, and Pour 2B comparison Set 2 demonstrated a slump with more workable concrete even though Balter did not record the addition of any water and there was a passage of 15 minutes or more since the first test at the inspection station. More workable concrete was also observed at Pour 2B comparison Sets 1 and 3and Pour 2C Set 2, although those results indicate no change in the slump measurement. Exhibit V (from which the sample in Chart 3 was extracted) illustrates that of all 37 comparison sets, there were seven occurrences when the second specimen collected at the deck presented a slump measure of concrete that was equal to or more workable than the slump tested at the inspection station despite no recorded addition of water or passage of 15 minutes or more between tests. It is possible that undocumented water could have been added in other instances without manifesting itself in the slump test. A slump test indicating a more workable concrete despite the passage of time with no addition of water raises questions about the accuracy and validity of the recorded data, as the results appear to be inconsistent with the other data.

Relationship between compressive strength and addition of water

Compressive strength test results indicated in Chart 3 show that concrete samples taken at the inspection station demonstrated different 28-day strength than the comparison tests of specimens collected at the deck.

Chart 3 uses Balter and RFF data to provide a comparison of field cured compressive strength test results on specimen cylinders made from the same batch of concrete, with one set collected at the inspection station and the other set on the deck. Of the 56 total field-cured specimens compared in Exhibit V, 49 deck specimens[23] demonstrated a lower compressive strength that was, on average, just 83% of the strength of its inspection station counterpart (with a minimum of 48%, and a maximum of 99%). For example, Set 2 of Pour 1D shows three-day compressive strength of 3,820 and 3,930 psi[24] for the specimens collected at the deck, while the specimens collected at the inspection station indicated strength of 9,190 and 9,580 psi. At 28 days, the strength disparity continued with deck specimens with 7,550 and 7,410 psi compared to inspection station specimens

[22] *Bonini, Julius PE, M and P Labs,* Schenectady, NY, and *Smith, Andrew, PhD, CERAM Research, Stoke-on-Trent, UK. "Forensic Investigation of Hardened Concrete: Water/Cement Ratio." Presentation at the Celebration of Capital District's National Engineers Week I7 February 2011. Albany, NY. Web. 20 January 2014.* <http://www.mandplabs.com/interface/uploads/files/pdfs/Forensic_Investigation_Hardened_Concrete.pdf>

[23] After three days of curing, 52% of the inspection station samples exhibited greater compressive strength than the deck samples.

[24] Note well that both of these compressive strength test results were below the 4,000 psi acceptance limit for 3-day test results.

with 12,100 and 11,820 psi. For most testing sets made during a pour, 12 specimen cylinders were collected at the inspection station. Foulger-Pratt Contracting (FP) primarily relied upon test results of the inspection station specimens. Three additional testing sets were made during the pour, from which 6 additional specimen cylinders were collected on the deck surface after the concrete had been pumped to the point of placement. Although data for all 18 specimens was available for these three comparison testing sets, records do not indicate a comparison was made by FP, nor do records indicate that Balter highlighted the matter as a possible concern in communications with DGS. These documented inconsistences in the compressive strength of cylinders could have been compared and the differences investigated.

The data in Chart 3 further indicate, for example, in Pour 1D Set 1, a difference in 28-day strength of specimens where records do indicate water was added to some concrete compared to those specimens collected at the inspection station before the addition of water. This added water could have acted to diminish the strength of the structure.

Estimation of additional water

Prior to commencement of construction activities, the Structural Engineer of Record (SEOR) approved the proportions of the ingredients to be used for concrete in the structure. Proportions of ingredients in the concrete varied depending upon on the strength of the concrete required for use. For the 8,000 psi concrete mix used for the slabs, beams, and girders, the SEOR approved mixture called for 32 gallons of water per cubic yard of concrete to obtain a 0.29 *w/c* ratio. Approval was granted for the use of optional admixtures, with a requirement to decrease water in an amount necessary to offset the moisture content represented by the admixture in order to maintain the 0.29 *w/c*. The admixtures used required that water be reduced by approximately one gallon for each gallon of admixture used in the mix. For each 10 cubic yard batch, the batch tickets noted that the total water content, including the admixtures, was not to exceed 310 gallons.

Balter asserts it noted on specimen cylinder data sheets the number of gallons of water its inspectors observed being added to the concrete, and further asserts that its sampling and testing was performed after any water was added to the concrete load at the project site. In every case in which added water is documented, the amounts of additional water that Balter reported were not in excess of RFF indicated amount of water allowed at the jobsite.

Of the 37 comparison sets analyzed in Exhibit V, Balter inspectors documented twelve sets (32%) where water was added to the concrete. In seven sets (19%) where the addition of water was documented, that addition occurred between the inspection station and point of placement, and after superplasticizer[25] and other admixtures had been added.

[25] A chemical added to concrete in lieu of water to improve the viscosity and flow of concrete.

In Chart 3, Pour 2B documents record no evidence of added water. However, KCE's petrographic results (presented in Chart 2 on page 15) indicate this pour presented *w/c* ranging from 0.35 to 0.45. The minimum *w/c* ratio in KCE's petrographic-tested cores was 0.35. The maximum *w/c* (before the addition of any on-site water) reported by RFF and documented by Balter was 0.26 for any location proximate to the KCE-excised core.

In Chart 4, the weight of the cementitious material is reported under the heading "C+P lbs", and the weight of the water content (water plus moisture content of admixtures) is reported under the heading "Water lbs". The *w/c* was then calculated by dividing the total "Water lbs" by the "C+P lbs". During the production of concrete, the sand and stone components would have contained some amount of moisture, an offset for which should have been quantified by RFF and held out of the water added to the mix. Based on OIG calculations in Chart 4, the KCE-excised core would have contained water content of 38 gallons per yd^3 of concrete. This core contained 36% more water ($\frac{(38\text{-}28)}{28}$) than the Balter specimen cylinder with 28 gallons of water per yd^3 and a 0.26 *w/c*. In Exhibit IV (data from which is represented in Chart 2), the average Balter reported *w/c* was 0.26 while the minimum *w/c* KCE reported was 0.35.

Chart 4: Difference in KCE-Excised Core and Balter Specimen Cylinder *w/c*

	KCE Core Minimum *w/c*		C+P *lbs*	Water Content lbs	Water Content gal	RFF Cylinder Maximum *w/c*		C+P *lbs*	Water Content lbs	Water Content gal
Sand	1,000	lbs			0.0	1,000	lbs			0.0
Stone	1,850	lbs			0.0	1,850	lbs			0.0
Cement	550		550			550		550		
Slag	360	lbs	360			360	lbs	360		
AEA	7.8	oz		0.5	0.1	7.8	oz		0.5	0.1
WRDA	41.0	oz				41.0	oz			
Super	54.6	oz		3.4	0.4	54.6	oz		3.4	0.4
DCI	256.0	oz		16.0	1.9	256.0	oz		16.0	1.9
Water	36	gal		298.6	35.8	26	gal		216.7	26.0
Water Added										
			910	318.5	38.2			910	236.6	28.4
w/c ratio			***319* / *910*** =	***0.35***				***237* / *910*** =	***0.26***	

weight of water in lbs/gallon ***8.32967***

Source: OIG original work paper.

Inspection inconsistencies

As indicated below, Balter did not fulfill all of the requirements set out for it under the Construction Documents, the Statement of Special Inspection, and its contract with the County.

The Statement of Special Inspections required Balter to periodically inspect RFF's plant operation to verify materials identified for the approved concrete mix were being provided.[26] Balter asserted that it had "requested [to inspect RFF's] plant several times, but authorization was never granted,"[27] even though PB advised Balter that the "concrete plant inspection can

26 Statement of Special Inspections, Concrete Element, part 4 – Verifying use of required design mix.

27 RBB Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, page 8. "[RBB] requested inspection of Rockville Fuel and Feed's plant several times, but authorization was never granted."

occur anytime, [DGS] and [Balter] to coordinate a time."[28] Based on available documentation, the requisite Balter inspections were not performed at any time during the period of major construction activities.

Concrete was transported from the plant to the site in trucks that carried a load of 10 yd^3 of concrete. The primary batch plant was located 11 miles from the SSTC.[29] Data from delivery documents revealed some concrete placed in the structure had reached or exceeded 90 minutes from the time it was batched. Construction Documents and industry standards[30] require that concrete be completely discharged within 90 minutes of mixing, or before 300 revolutions of the truck's mixing drum, to prevent concrete from setting up before placement. Seven of the test specimen sets evaluated in Chart 3 and Exhibit V reached or exceeded 90 minutes in age prior to discharge (and 4 of these more than 100 minutes in age).[31] We noted only one Balter daily report that documented a load of concrete had been rejected due to excessive age.

Conclusions

During concrete placement, three sets of specimen cylinders were collected on the deck for comparison to other specimen cylinders collected from the same batch at the inspection station. Inspection data records that between the two tests water was added to the concrete in seven of the 37 total comparison specimens (19%). These same records indicate that the water added did not exceed the hold back amount designated by RFF.

However, 888 concrete trucks loads would have delivered all the concrete used to construct levels 330 and 350. Only 233 (26%) of these were tested. Testing of concrete specimens collected from the deck occurred for only 37 (4%) of all truck loads.

KCE petrographic testing of extracted specimens suggests in-situ concrete contained 36% more water than RFF calculated and Balter reports document. Slump testing also suggests an addition of water. Nineteen percent (7 of 37) of the comparison sets record slump tests demonstrating an equal or more workable concrete (indicating thinner concrete) was placed on the deck despite the passage of 15 or more minutes and no documented addition of water.

If water was added, it could have been done so before placement the deck after arrival at the construction site or at the concrete plant when the concrete was batched.[32] While there may have been economic gain by substituting water in lieu of admixtures (admixtures are relatively

[28] PB Construction Progress Meeting #43, July 15, 2010 minutes. Item 3.1 of FP Preinstallation Conference minutes dated April 28, 2010 is similar and reads, "Mike Bailey indicated there is a requirement for [RBB] to inspect the concrete plant. John Hershey indicated any of us could call and come by anytime."

[29] Internet mapping systems approximate as a 16 minute journey.

[30] *ASTM International* (formerly American Society for Testing and Materials), West Conshohocken, Pennsylvania, Standard Specifications for Ready Mixed Concrete (ASTM C94/C94M), Section 12.7

[31] ASTM C94/C94M, Section 12.7– allows a waiver by the purchaser to the time and revolution limitation if the slump was reached without addition of water. Water was added to the concrete in all documented instances where more than 100 minutes elapsed. RBB asserted that Montgomery County and WMATA allowed a deviation of 10 to 15 min (not in hot weather) provided the concrete did not appear to change consistency

[32] Although it was possible a driver could have stopped in route to add water, that scenario is not probable and is inconsistent with documented transit times.

expensive), and the resultant *w/c* and petrographic analysis would have been consistent with KCE's test result, the 8,000 psi high strength mix would not be achievable without the admixtures.

From the data we examined, we found no single reason for the lower compressive strengths found by KCE. Evidence does exist that Balter samples were not representative of the concrete at the pump end, providing opportunity for undocumented water to be added at the construction site. The remaining difference between the Balter and KCE reported *w/*c may be found in the petrographic results themselves. The results are labeled as estimates, and the methodology in assigning a *w/c* value is not exact. However, it is likely that extra water was added at the construction site.

For the three comparison testing sets collected during the pour, twelve of 18 concrete specimen cylinders from each truck were collected before discharge into the hopper for the pump used to deliver concrete to the point of placement on the deck. If, as in-situ testing results suggest, and as Balter comparison specimen data indicate, water was added to the concrete mixture, controls as designed were inadequate for ensuring that water additions adhered to specifications and variances. In light of the recurring instances of shrinkage cracking documented throughout this construction project, analysis of the data collected, tested, and available to FP, Balter, PB, and DGS and their subcontractors could have identified inconsistences whose cause could have been investigated and remedied.

Recommendation 2

DGS should ensure construction documents clearly establish responsibility for and performance of systematic analysis of data collected and recorded during construction in order to identify possible inconsistencies with specifications, project control weaknesses, and construction deficiencies that should be investigated and resolved.

Structural Strength

Finding 3: Records collected during construction demonstrated that 1.) construction specifications for cold weather curing were not implemented correctly, and 2.) surface temperatures were not maintained or monitored as required by specifications.

Concrete is a composite material in which Portland cement, water, aggregates, and admixtures are bound together through a chemical and physical reaction of cement with water (hydration).[33] Concrete construction requires proper curing to increase concrete strength and durability. Concrete curing is defined as "the process by which concrete matures and develops hardened properties over time as a result of the continued hydration[34] of the cement in the presence of sufficient water and heat."[35] Diminishment of these hardened properties leaves the concrete susceptible to abnormal cracking which in turn can lessen the long-term durability of a concrete structure.

Controls relating to cold weather curing were not correctly implemented.

In normal conditions, cement absorbs 0.21 - 0.28 of its weight in water during complete hydration.[36] At an approved concrete mix *w/c* target of 0.29 and a Rockville Fuel and Feed concrete batch ticket documented *w/c* of 0.26, concrete would have been expected to achieve hydration. Yet, on average, the KCE Structural Engineers, P.C. (KCE) tests observed unhydrated cementitious material from 7% to 13%.[37] A possible reason for that level of unhydrated cementitious material would be inadequate or improperly observed curing procedures that would have allowed the concrete surface to dry before hydration had completed.[38] In KCE-tested locations, the presence of unhydrated cementitious material evidences that in-situ concrete was not properly cured, further slowing, or possibly arresting development of compressive strength of the concrete in the structure.

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[33] *American Concrete Institute (ACI)*, Farmington Hills, MI 48333-9094, Guide to Curing Concrete (ACI 308R-01), Chapter 1.3.1

[34] Hydration refers to the chemical and physical changes that take place when Portland cement reacts with water or participates in a pozzolanic reaction. *American Concrete Institute,* Guide to Curing Concrete (ACI 308R-01), *Chapter 1.2 – Definition of Curing.* See Exhibit III: Standards.

[35] *American Concrete Institute (ACI)*, Farmington Hills, MI 48333-9094, Guide to Curing Concrete (ACI 308R-01), *Chapter 1.2 – Definition of Curing.* See Exhibit III: Standards.

[36] *American Concrete Institute (ACI)*, Farmington Hills, MI 48333-9094, Guide to Curing Concrete (ACI 308R-01), Chapter 1.3.1 (cross-citing Powers and Brownyard 1947; Copeland, Kantro, and Verbeck 1960; Mills 1966). The *KCE report contradicts this value, stating that 0.28 as the theoretical minimum water/cement ratio that would be required for 100% cementitious material hydration.*

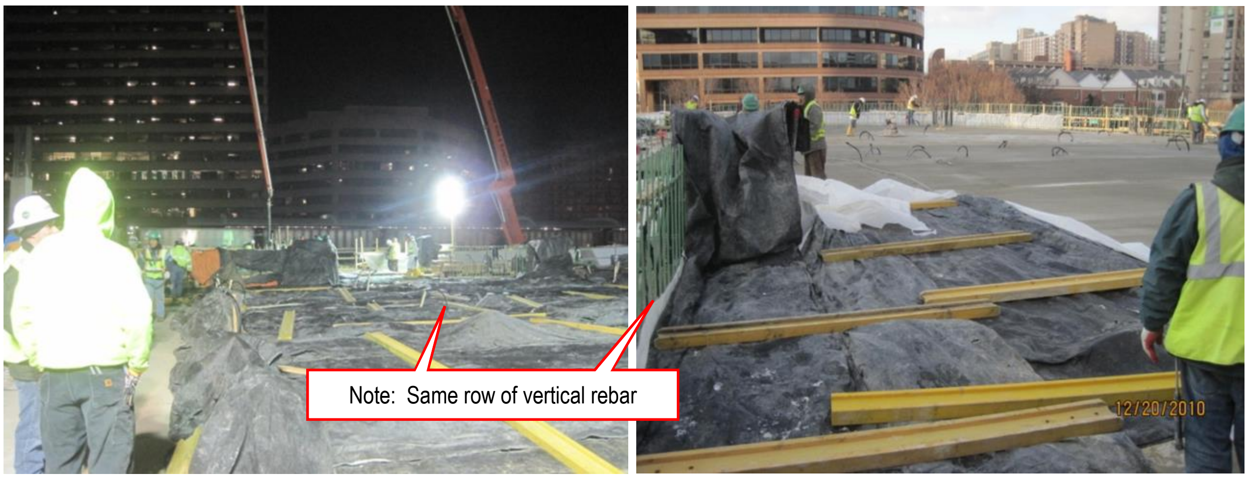
[37] See Chart 2, page 15

[38] A potential source of unhydrated cementitious material is a type of drying called self-desiccation. Self-desiccation can arise with mixtures having w/c ratios around 0.40 or less, when the water initially incorporated into the concrete is insufficient to completely hydrate all the cementitious materials. Self-desiccation can be prevented by using saturated, porous aggregate to provide internal curing.

Thermal protection was not maintained.

The unhydrated cementitious material was attributed by KCE to delayed placement and/or early removal of thermal protection during cold weather.[39] We reviewed photographic evidence from pour 1D on December 20, 2010, when temperatures required cold weather curing measures, that supports this conclusion. In the photographs in Image 2, below, 11 hours elapse[40] from the beginning to the end of the pour when requisite protective covers were placed. NOAA records reflect a mean temperature of 31^{o} F for the day of this pour, and temperatures ranging between 26^{o} and 41^{o} F over the ensuing 7 days. The mid-afternoon photograph from the end of the pour

Image 2: Photos taken near beginning & end of Pour 1D on December 20, 2010



4:35 am on 20 Dec 2010 **(img_3357.jpg)** **3:22 pm on 20 Dec 2010** **(img _3395.jpg)**

The first photograph shows commencement of Pour 1D at 4:35 am (orange pump arm to rear right, discharge pipe in rear center). Almost 11 hours later, the second photograph shows the construction crew beginning to cover the area of work in the first photograph, with the majority of the slab remaining uncovered (at picture rear). Balter inspection logs for the day record a temperature range of 25^{o} – 32^{o} F. NOAA weather archives report the day's low temperature at 22^{o}, the high at 35^{o}, and a mean of 28.5^{o}. Both temperature ranges would evoke cold weather curing per contract specifications.

Photographs source and courtesy of the Montgomery County Maryland Department of General Services.

depicts workers who were beginning to place the moisture-retaining plastic sheeting and blankets on the area where the pour had initiated in the early morning image. Industry standards indicate that covering "should follow closely the finishing of concrete."[41]

Construction specifications required Foulger-Pratt Contracting (FP) to "protect freshly placed concrete from premature drying and excessive cold or hot temperatures"[42] with "Moisture-Retaining-Cover Curing: [a process that covers] concrete surfaces with moisture-retaining cover for curing concrete, placed in widest practicable width, with sides and ends lapped at least 12

[39] KCE Structural Engineers, PC, Walter P Moore, and Wiss, Janney, Elstner Associates, Inc., Silver *Spring Transit Center Structural Evaluation of Superstructure*, March 15, 2013.

[40] The date, time, and other metadata were digitally recorded on the photographs provided by the Department of General Services.

[41] *American Concrete Institute (ACI)*, Farmington Hills, Michigan, Cold Weather Concreting (ACI 306R), Section 7.6 *Covering after placement.*

[42] Construction Contract between Montgomery County and Foulger-Pratt Contracting dated September 3, 2008, Attachment A – Schedule of Documents, List of Specifications, § 03300-Cast-In-Place Concrete, Part 3.13(A)

inches, and sealed by waterproof tape or adhesive" for "not less than seven days."[43] WMATA Specifications also required that curing protection should last 7 days.[44]

Standard ACI 306.1 Section 3.4.4[45] required a three-day minimal period of thermal protection during cold weather. Construction Meeting minutes document that there was confusion among participants about how long curing protection should last: "Facchina believed the cold weather protection requirement to be 3 days. Subsequent research of ACI leads the group to believe that 3 days cold weather cure time is proper."[46] As a result of this interpretation, controls for cold weather concrete as designed and implemented were less restrictive than contract documents and WMATA Specifications. Balter inspection reports only contain information about cold weather curing, when applicable, for the first three days following the pour. One report indicated that on the third day "Heat turned off under deck, stopped monitoring temps,"[47] suggesting that some of the cold weather curing activities ceased after 3 days whether or not blankets were removed.

Surface temperatures were not maintained or monitored as required by specifications.

The Statement of Special Inspection required the monitoring of fresh concrete temperature with one test hourly when air temperature is 40° F and below or when 80° F and above, and one test for each composite sample.[48] ACI standards call for concrete and the outdoor air temperatures to be recorded at regular time intervals but not less than twice per 24-hr period.[49] Balter inspection records reflect that inspectors used a high/low thermometer read twice a day.

The Standard Specification for Cold Weather Concreting ACI 306.1 establishes 55° F as the minimum, and 75° F as the maximum surface temperature for concrete immediately following a pour.[50] ACI 306.1 also sets 55° F as the minimum surface temperature for concrete during the period of curing protection, and sets 50° F as the maximum decrease in surface temperature over a 24-hour period. Contract specifications[51] referenced this standard which also required curing protection to be maintained until the concrete surface temperature was within 20° F of the ambient or surrounding temperature.[52] WMATA Specifications provide for a minimum surface temperature of 55° F, with no upper limit. The Contractor's Quality Control program required procedures for correcting any temperatures that were outside of these limits.

43 Construction Contract between Montgomery County and Foulger-Pratt Contracting dated September 3, 2008, Attachment A – Schedule of Documents, List of Specifications, § 03300-Cast-In-Place Concrete, Part 3.13(E)(2)
44 WMATA specification 03300 section 3.06 B.1.c.
45 *American Concrete Institute (ACI)*, Farmington Hills, MI 48333-9094, Standard Specification for Cold Weather Concreting (ACI 306.1), Section 3.4.4 *Protection against freezing*.
46 Item 4.1 of FP preparatory meeting 03300 Cold Weather Concrete minutes dated 11/4/2010.
47 Balter's 12/14/10 Daily Report, Concrete Slab Temperature Report monitoring the 12/10 Pour 1Eb.
48 Statement of Special Inspections, Concrete, 5 – Sampling Fresh Concrete
49 *American Concrete Institute (ACI)*, Farmington Hills, Michigan, Cold Weather Concreting (ACI 306R), Section 2.4.2 *Temperature Records.*
50 *American Concrete Institute (ACI)*, Farmington Hills, Michigan, Standard Specification for Cold Weather Concreting (ACI 306.1), Section 3.2.1 *Placement temperature.*
51 Construction Contract between Montgomery County and Foulger-Pratt Contracting dated September 3, 2008, Attachment A – Schedule of Documents, List of Specifications, § 03300-Cast-In-Place Concrete, Part 3.9(E)
52 ACI 306.1, §3.2.3.

Balter inspection reports document that concrete surface high and low temperatures were monitored at several locations, for pours meeting the ACI cold weather definition. Balter inspection reports were found to provide daily temperature monitoring reports for the three days following a pour.[53] Temperature monitoring reports were not prepared for some weekend days and holidays that fell within the three days post-pour. For one Friday pour (2C), only the third day report from the following Monday was available.

Chart 5a: How to Read the Comparison of Cold Weather Curing Temperatures (Degrees Fahrenheit)

Pour Location Pour Date	Average Ambient Temp	Mix Temp Day of Pour	Test Period			Concrete Inspection Temperatures								
						On Slab Surface		@ Inspection Station		@ Deck Cure Box		In Cure Shed		Under Deck
			Day	Time	Temp	Min	Max	Min	Max	Min	Max	Min	Max	
Pour 1 D 20 Dec 2010	31	59	Day 1	AM	28	75	96			45	60	68	108	**83**
			12/21/10	PM	36	82	108			60	64	76	80	84
			Day 2	AM	30	102	108			54	58	62	80	90
			12/22/10	PM	36	98	102			52	60	68	80	90
			Day 3	AM	25	84	94			48	50	62	82	80
			12/23/10	PM	30	76	86			43	44	68	75	88

Concrete for levels 330 and 350 of the SSTC was placed in 19 separate pours. These were designated by a number and letter: 1 for level 330 or 2 for level 350, with the letter further designating the location on the level. Mapping of the pours can be found on pages 74 and 75 of KCE Exhibit I. "Pour 1D", above, was the fourth section of level 330. Concrete for that pour was placed on December 20, 2010. The air temperature that day was 31 degrees, but the temperature of the concrete being poured was 59. Balter monitored temperatures at various locations for three days after the pour, typically taking a reading early in the morning, and another late in the afternoon, noting the air temperature at the time they took the readings. Inspectors used a thermometer that recorded the lowest and highest temperature since the last time the thermometer was reset - typically the last reading. One reading was taken from a thermometer laid on the concrete slab surface under the curing blankets. On occasion, a reading was taken for the field cured specimen cylinders stored at the inspection station. Another reading was taken for the comparison set of specimen cylinders that was cast on and cured in a curing box on the deck, and another set taken inside the curing shed where specimen cylinders to be laboratory cured were stored until transit to the lab. The last reading was taken under the deck where workers screened off the area and used space heaters to warm the area.

Chart 5b presents cold weather curing temperatures recorded by Balter inspectors. Chart 5a, which does not cite any specific deficiencies, serves as a "How to Read" orientation to Chart 5b. As indicated in Chart 5b, for three of the six cold weather pour dates examined in detail by the OIG, Balter inspectors recorded surface temperatures below the 55° F minimum specified by the ACI standard.[54] On three occasions, concrete temperatures below the ACI minimum were recorded on the last day the inspectors documented cold weather curing. Balter did not raise the occurrence of a temperature below the ACI 306.1 standard, nor did Balter Daily Reports or FP Daily Contractor Quality Control Reports document the quality control failure to observe the referenced standard. The reports also failed to note if any effort was made to alert the Contractor to the need to implement temperature correcting procedures.

[53] The OIG evaluated records for five of the seven ACI-defined cold weather concrete pours: , Pour 1D on December 20, 2010, Pour 1Eb on December 10, 2010, Pour 1G on February 8, 2011, Pour 2B on December 7, and Pour 2D on January 31, 2011.

[54] *American Concrete Institute (ACI)*, Farmington Hills, Michigan, Standard Specification for Cold Weather Concreting (ACI 306.1), Section 3.2.2 - *Protection temperature*

In five of these six cold weather curing periods, the last recorded low surface temperature was more than 20° above the ambient temperature recorded by either the Balter inspector or NOAA for that date. Balter Daily Reports did not document whether there was a gradual decrease in surface temperature since Balter did not monitor concrete temperatures [55] after area heat was discontinued, which typically occurred after 3 days. Inspection reports also failed to document when protective plastic and insulating blankets were removed by the contractor.

Chart 5b: Comparison of Cold Weather Curing Temperatures (Degrees Fahrenheit)

Pour Location / Pour Date	NOAA Average Ambient Temp	Mix Temp Day of Pour	Test Period			Concrete Inspection Temperatures								
						On Slab Surface		@ Inspection Station		@ Deck Cure Box		In Cure Shed		Under Deck
			Day	Time	Temp	Min	Max	Min	Max	Min	Max	Min	Max	
Pour 1 D 20 Dec 2010	31	59	Day 1 12/21/10	AM	28	75	96			45	60	68	108	**83**
				PM	36	82	108			60	64	76	80	84
			Day 2 12/22/10	AM	30	102	108			54	58	62	80	90
				PM	36	98	102			52	60	68	80	90
			Day 3 12/23/10	AM	25	84	94	> 20°		48	50	62	82	80
				PM	30	76	86			43	44	68	75	88

Observations for Pour 1D: Except for the maximum temperature recorded in the curing shed, each measure, minimum or maximum, for each location increased in temperature by day 2 and then started to cool. Inspectors did not record temperatures for the specimen cylinders that were field-curing at the inspection station. On the last day (Day 3) that inspectors recorded temperatures, the minimum temperature on concrete on the slab surface - 76 degrees - was not within 20 degrees of the ambient air temperature, 30 degrees, thus cold weather curing, including monitoring, should have continued.

Pour Location / Pour Date	NOAA Average Ambient Temp	Mix Temp Day of Pour	Day	Time	Temp	Slab Min	Slab Max	Insp. Min	Insp. Max	Cure Box Min	Cure Box Max	Cure Shed Min	Cure Shed Max	Under Deck
Pour 1 E(b) 10 Dec 2010	26	60	Day 3 12/13/10	AM		66	78					80	84	
				PM		56	70	> 20°				62	82	
			Day 4 12/14/10	AM	22	54	71					72	74	64
				PM	29			< 55°				70	84	

Observations for Pour 1E(b): This pour occurred on a Friday, so the first recorded data is for Monday, December 13 - 3 days following the pour. Inspectors were very inconsistent at recording data. In the morning of day four, the difference between the minimum slab temperature, 54, and the ambient air temperature is more than twenty degrees, thus cold weather curing should have continued, and at 54 degrees, the temperature was one degree below the minimum slab temperature allowed during cold weather curing.

Pour Location / Pour Date	NOAA Average Ambient Temp	Mix Temp Day of Pour	Day	Time	Temp	Slab Min	Slab Max	Insp. Min	Insp. Max	Cure Box Min	Cure Box Max	Cure Shed Min	Cure Shed Max	Under Deck
Pour 1 G 8 Feb 2011	27	64	Day 1 2/9/11	AM	20	77	106					70	84	71
				PM	33	78	108					73	78	73
			Day 2 2/10/11	AM	20	72	106					70	77	83
				PM	33	70	104					69		81
			Day 3 2/11/11	AM	23	96	109	> 20°				70	80	78
				PM	33	77	92					65	75	49

Observations for Pour 1G: In the afternoon of the last day that data was recorded, the difference between the minimum slab temperature and the ambient temperature was 44 degrees, yet it appears the heater under the slab was stopped, as the under deck temperature fell to 49 after hovering in the 70's and 80's during the preceding two days. Inspectors were inconsistent at recording data.

- - continues next page - -

[55] Balter's 12/14/10 Daily Report, Concrete Slab Temperature Report monitoring the 12/10 Pour 1Eb notes "Heat turned off under deck, stopped monitoring temps." The low surface temperature was 54° F (below ACI minimum), and the ambient temperature was 28° F (a difference between ambient and surface temperatures that was greater than the ACI 20° difference required to cease sold weather protection)

Chart 5b: Comparison of Cold Weather Curing Temperatures (Degrees Fahrenheit) - *continued*

Pour Location / Pour Date	NOAA Average Ambient Temp	Mix Temp Day of Pour	Test Period			Concrete Inspection Temperatures								
						On Slab Surface		@ Inspection Station		@ Deck Cure Box		In Cure Shed		Under Deck
			Day	Time	Temp	Min	Max	Min	Max	Min	Max	Min	Max	
Pour 2 B 7 Dec 2010	29	62	Day 1 12/8/10	AM	25	89		44	64					
				Noon	32	114		42	64					77
				PM	33	116		42	64					76
			Day 2 12/9/10	AM	24	106		40	64			70	88	74
				PM	34	Thermometer Broken		50	80	52		74	94	77
			Day 3 12/10/10	AM	19	76	94	46	78	42	56	82	88	76
				PM	35	72	90			43	55	72	75	75
			Day 6 12/13/10	AM		62	96			42	54	80	84	70
				PM		60	76	> 20°		38	52	82	62	46
			Day 7 12/14/10	AM	22	61	74	58	78	24	40	72	74	38
				PM	29			67				70	84	

Observations for Pour 2B: This was the longest recorded data set of any cold weather pour. The heater under the slab appears to have been turned off during the morning of Day 6 - temperatures dropped from the 70's to 46 and then 38. Yet, there was a 39 degree difference between ambient and slab temperatures, so cold weather curing should have continued. Although inspectors recorded full data on the mornings of Day 3 and Day 7, inspectors were still inconsistent at recording data.

Pour Location / Pour Date	NOAA Average Ambient Temp	Mix Temp Day of Pour	Day	Time	Temp	Slab Min	Slab Max	Insp. Min	Insp. Max	Deck Min	Deck Max	Shed Min	Shed Max	Under Deck
Pour 2 C 14 Jan 2011	34	58	Day 3 1/17/11	AM	25	44	104							
				PM				< 55°						

Observations for Pour 2C: January 14 was a Friday pour - the only data recorded was on the following Monday. Between the time of the pour and the recording of data, a minimum temperature of 44 degrees was recorded - 11 degrees colder than allowed by standards and specifications.

Pour Location / Pour Date	NOAA Average Ambient Temp	Mix Temp Day of Pour	Day	Time	Temp	Slab Min	Slab Max	Insp. Min	Insp. Max	Deck Min	Deck Max	Shed Min	Shed Max	Under Deck
Pour 2 D 31 Jan 2011	28	57	Day 1 2/1/11	AM	30	46	104	< 55°				70	77	91
				PM	32	90	90							62
			Day 2 2/2/11	AM	35	78	87					70	72	92
				PM	40	80	84					65	75	88
			Day 3 2/3/11	AM	30	72	79	> 20°				68	74	88
				PM	30	82	89					69	79	57

Observations for Pour 2D: On the last entry of recorded data, there was a 52 degree difference between ambient and slab temperatures, yet some cold weather curing was stopped as evidenced by the drop in “under deck” temperature from 88 to 57 consistent with turning off the heater under the slab .

Sources: The Robert B. Balter Company Concrete Slab Temperature Reports and 56-Day Reports of Concrete Cylinder Tests; KCE Report Table 12 C Alternative ACI 214R-10 PSI. Two cold weather pours - Pour 2 C and the Level 330 East Pour Strips - are not included in the evaluation due to a lack of statistically significant data.

Controls were in place during concrete curing to record temperatures at least during the first three days following a concrete pour. There was no evidence that the Balter Inspector alerted the Contractor and the Quality Control System Manager when measured temperatures exceeded project limits. Inspection records documented the difference between concrete surface and ambient temperatures great enough to have required a continuation of cold weather protection, yet daily reports evidence that supplemental cold weather curing heat was stopped after three days.

KCE reported that “[p]etrographic examinations of the concrete cores from the slabs indicate that unacceptable percentages of the Portland cement and slag were unhydrated. This observation is consistent with concrete experiencing a temperature [recorded in Balter Daily Reports that were]

Image 3a: Inspection Station Orientation
9:33 am on 20 Dec 2010 – Pour 1D (img_3387.jpg)

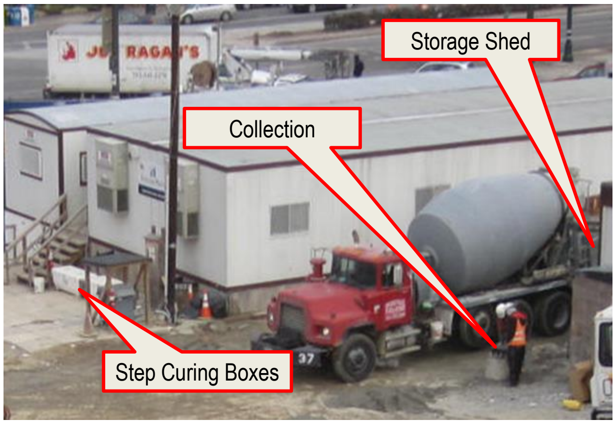


Image 3b: Field Cured Inspection Station Collection & Curing
4:29 am on 18 Feb 2011 – Pour 1H (img_4292.jpg)

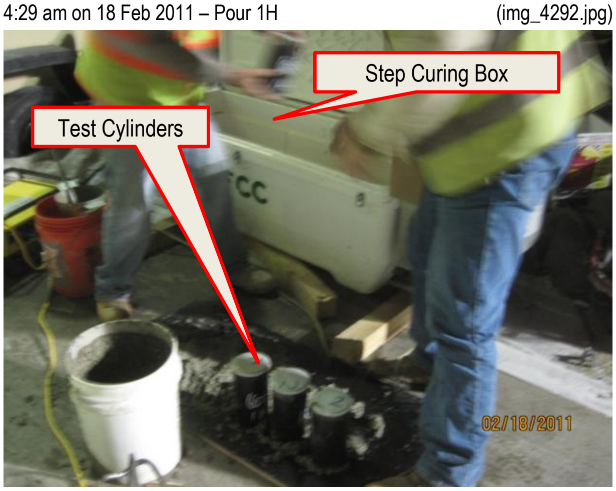
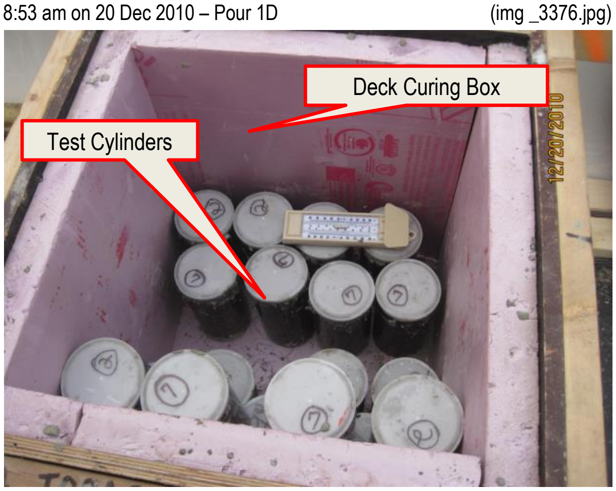


Image 3c: Field Cured Deck Collection & Curing
8:53 am on 20 Dec 2010 – Pour 1D (img _3376.jpg)



Photographs source and courtesy of the Montgomery County Maryland Department of General Services.

low enough to slow hydration to the point that the available water dried out before the cement could hydrate."[56]

By removing protection early, hydration of the concrete would have been slowed or stopped, which would explain the presence of unhydrated cement and slag. Controls for this project should have clearly conveyed temperature limits during cold weather curing, and the duration of these limits should have been coordinated with those set by WMATA.

Concrete testing specimens were cured in an environment not representative of in-situ concrete.

In Chart 5 (pages 26-27), inspection documents evaluated by the OIG confirm that the temperatures of the Balter compressive strength test cylinders stored in the curing box near the inspection station (field cured - see images 3a and 3b) and the cure box on the deck were not representative of the temperature of the concrete in the poured slabs. Six of the 18 cylinders were cast and cured on the slab deck (see image 3c). For three sample sets collect during each pour, six of the primary test cylinders were cast and cured at the inspection station, and six[57] cylinders were transported to a laboratory for the balance of the curing period (lab cured).

ASTM C31/C31M requires protection of the field-cured cylinders from the elements in as near as possible the same way as the formed work, and that cylinders should be provided with the same temperature and

56 KCE Report, page 76.
57 In later stage of the project, 14 primary cylinders were cast, with 7 remaining on site, and 7 transported to the lab.

moisture environment as the structural work. This standard was not observed for the field cured concrete compressive strength cylinders.

Cylinders were to be made and stored in or on the structure as near as possible to the point of deposit of the concrete represented by the sample (discharge end of the pump hose and stored under the poly and insulated blanket protective cover). The cylinders were to be cured either under ideal conditions in a laboratory or in the field experiencing the same condition as the concrete in the structure.

Documents prepared by Balter inspectors recorded that temperatures in the on field curing box on the deck and in the field curing boxes at the storage station were different from the temperatures on the deck slab under the curing blankets. Our analysis of these records indicates that while the temperatures differed, the effect cannot be determined from the limited data recorded.

Conclusions

Records collected by Balter and FP indicate that the details of curing concrete were not addressed in accordance with specification. Analysis of the records collected should have identified inconsistences between specification requirements and procedures implemented that could have been investigated and remedied.

Thermal protection was not placed early following the placement of the concrete in accordance with established specifications. Thermal protection was not continued in accordance with cold weather curing specifications. Surface temperature monitoring was not observed in accordance with specifications. As a result, the condition of the in-situ concrete may have been impacted by the failure to observe cold weather curing procedures, and potential contributing to plastic shrinkage cracking observed in the structure.

Recommendation 3

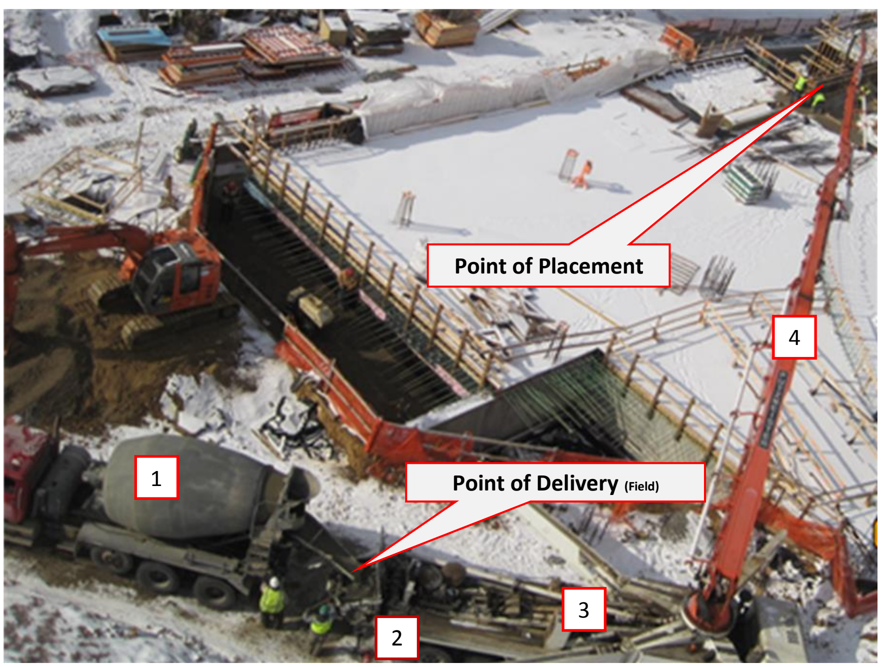
In future projects, DGS should ensure that all specification requirements are reviewed and implemented unless a variance is mutually discussed and agreed upon. Temperature limits during curing should be monitored and maintained, and specifications for duration of curing should be strictly observed. Confusion about where to take samples and about cold weather limits should be avoided by clearer language in specifications. Any conflicts between specifications and standards should be resolved in favor of the more conservative of those required by stakeholders (in the case of the SSTC, DGS, and WMATA).

Structural Strength

Finding 4: Construction documents referenced specifications and standards that differed as to where concrete testing samples should be taken. Reliance upon samples taken at the inspection station produced compressive strength test results that were not representative of the strength of the in-situ concrete.

Ambiguity existed over where to collect the concrete samples to be used to test for compressive strength. Construction Documents referenced specifications and applicable standards that differed as to where the specimen cylinders should be taken. The Statement of Special Inspections[58] that establishes the inspection criteria for the SSTC, and the Balter contract references ASTM International's (ASTM) standard C31/C31M, which indicates that cylinders should be *made and stored* in or on the structure *__as near as possible to the point of deposit__* (placement) of the concrete represented by the sample[59], which because of pumping operations during this project, was at the discharge end of *the pump hose*. This standard was not strictly observed.

Image 4: Level 330 East Pour Strip Concrete Placement – January 12, 2011



Legend: 1 – Concrete Truck; 2 – Pump Hopper; 3 – Concrete Pump Truck; 4 – Pump Discharge Pipe, Hose, and Crane assembly

Source: Montgomery County Maryland Department of General Services

[58] Statement of Special Inspections, Concrete, 5 – Sampling fresh concrete and performing slump, air content and determining the temperature of fresh concrete at the time of making specimens for strength tests: Compression Test Specimens

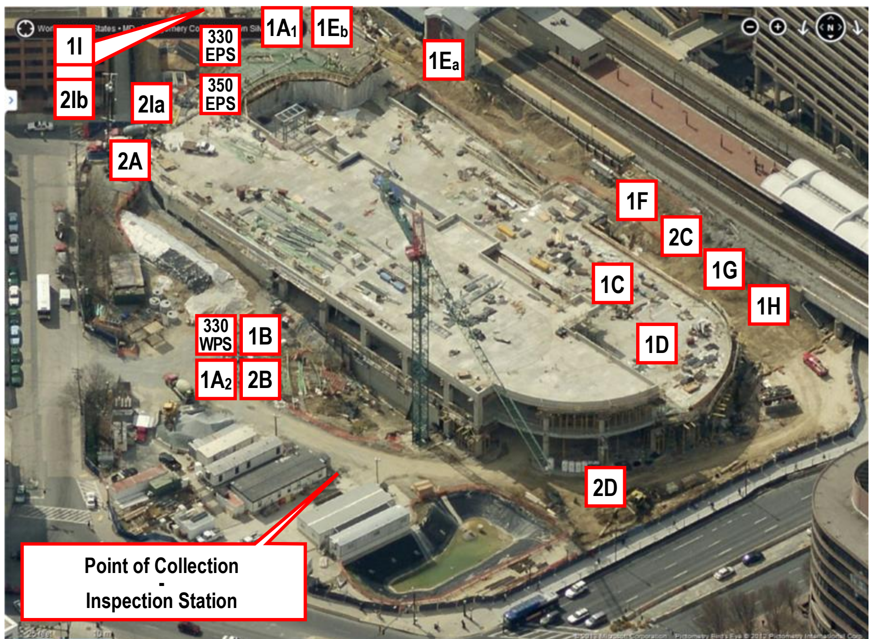
[59] *ASTM International* (formerly American Society for Testing and Materials), West Conshohocken, Pennsylvania, Standard Practice for Making and Curing Concrete Test Specimens in the Field (ASTM C31/C31M), Section 9.1 Place of Molding and 10.2.1 Field Curing - Cylinders

The construction contract's specifications section 03300.1.5.B references ASTM C 94[60], requiring concrete compressive strength testing to be in conformance with this international standard. The international standard states samples should be made and stored *as near as possible to the Point of Delivery* (see Image 4).

During this project, the concrete was primarily collected for testing at end of the *concrete truck chute* at the inspection station.

One truck out of every five was directed to the site's inspection station where concrete was drawn from the truck's load for use in on-site testing, and for casting the cylinders to be used for compressive strength testing. After the testing concrete was drawn, the truck was directed to a pumping location (Point of Delivery (Field)) located at numerous work areas throughout the site (see Image 5). The next 4 trucks delivering the remaining 40 cubic yards (yd^3) were sent directly to the pumping locations.[61]

Image 5: Transit Center Site Plan with Locations of Inspection Station & Concrete Points of Delivery



Key: 1A Location of Pump Trucks and Concrete Points of Delivery (Field) – in this example, the location for Pour 1A See Footnote 63. Source: Pictometry International Corp. © 2012

Entrained air content[63] and other properties can change during pumping. Additionally, low viscosity and high cohesion are needed for concrete to move easily through the pump - adding water can improve these properties when needed.

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[60] *ASTM International* (formerly American Society for Testing and Materials), West Conshohocken, Pennsylvania, Standard Specification for Ready-Mixed Concrete (ASTM C94/C94M), Section 17.2 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimen

[61] For concrete pours on levels 330 and 350, concrete pump trucks were used for most of the pours. Although this report focuses on pumping operations, some concrete was discharged directly from the truck chute, and other concrete was discharged from a bucket that was hoisted to the Point of Placement via tower crane.

[62] Location of pumping trucks approximated from site photographs taken on the days of pour: 1A1 – 2010-09-13 Pour 1A Pump 1 Location.jpg; 1A2 – 2010-09-13 Pour 1A Pump 2 Location.jpg; 1B – xx; 1C – 2010-18 Pour 1C Pump Location.jpg; 1D – IMG_3386.jpg; 1Ea – 2010-11-12 Pour 1Ea Pump Location.jpg; 1Eb – 2010-12-10 Pour 1Eb Pump Location.jpg; 1F – 2010-12-30 Pour 1F Pump Location (2 of 2).jpg; 1G – IMG_1539.jpg; 1H – IMG_4294.jpg; 1I – 2011-05-03 Pour 1I SOG Pump Location.jpg; East Pour Strip Level 330 – 2011-01-12 Pour Strip Level 330 East Pump Location (2 of 2).jpg; West Pour Strip Level 330 – IMG_1658.jpg (placed by bucket); 2A – 2010-11-02 Pour 2A Pump Location (2 of 3).jpg; 2B – 2010-12-07 Pour 2B Pump Location.jpg; 2C – 2011-01-14 Pour 2C Pump Location.jpg; 2D – 2011-01-31 Pour 2D Pump Location.jpg; 2Ia – 2011-03-29 Pour 2Ia pump Location (2 of 4).jpg; 2Ib – 2011-03-29 Pour 2Ia pump Location (2 of 4).jpg; East Pour Strip Level 350 – 2011-06-01 Pour Strip 350 Level Discharge Location (2 of 2).jpg; Inspection Station – 2010-10-02 Pour 1B Pump Location & Truck at Insp Stn by Trailers.jpg. Locations that appear to be on a transit center deck were pours completed before the pour of the indicated deck. Photographs source, and courtesy of Montgomery County Maryland Department of General Services.

[63] Entrained air is microscopic cells of air distributed throughout the concrete paste that are beneficial because they improve concrete's resistance to damage caused by freezing.

The ambiguity over where samples should be collected was discussed during the July 2010 pre-installation meeting. Minutes indicate that whether collection of samples should occur at the end of the truck chute at the inspection station or at the end of the pump was “left open for later resolution.”[64] In a meeting one month later, minutes record that RFF’s representative indicated that concrete samples should be collected from the truck and not at the end of the pump hose. WMATA’s representative disagreed.[65] Eventually, Balter was directed to cast a limited number of comparison cylinders at the end of the concrete pump hose while conducting the primary testing at the truck chute, although meeting minutes do not specify who directed the change. Balter Daily Inspection reports, however, note “(6) extra cyl[inder]s made [at] end of concrete pump on deck as per Montg[omery] Co[unty] Tim H[erbold].”[66] This DGS directed casting of comparison sets provided the opportunity to identify differences between inspection station and in-situ concrete. However there is no indication those comparisons were made during the period of major construction activity.

In its report, KCE Structural Engineers, P.C. (KCE) observed that in-situ sample cylinders of concrete it extracted from “pours 1A, 1B, 1E, 1H, and 2C [had] unacceptable concrete strength based on the ACI 318-02 [compressive strength] requirements.”[67] Based on records maintained by DGS, the average size for each the KCE-identified pours with unacceptable concrete strength[68] was 729 yd^3 of concrete which would have been delivered to the site in 73 concrete trucks[69], fifteen of these trucks would have been tested at the inspection station, with the remaining 58 trucks being sent directly to the remote pumping station.[70] While Balter asserts that an inspector observed each of the other 58 truckloads, no records were found that document the Point of Delivery (Field) inspections other than a general notation on the Balter inspector’s daily report.

Taking most of the samples at the inspection station as opposed to at the end of the pump hose increased the risk that the concrete samples would not be representative of the in-situ concrete, and thus that tests conducted on such samples might present compressive strength results that were not representative of the in-situ concrete. Appendix C demonstrates that samples from the end of the pump were, in fact, significantly weaker than those taken at the inspection station.

Recommendation 4

DGS should modify its contract specifications for future construction projects to ensure that concrete test specimens are made as near as possible to the actual point where concrete is placed. Where referenced standards require testing at the point of delivery, clarify in the specification that such testing is in addition to typical testing.

64 Minutes of the 7/13/10 SSTC Preparatory Meeting and Preinstallation Conference conducted by Foulger Pratt.
65 0300 Concrete Placement Methods, Logistics and Testing Meeting Agenda and notes, dated August 25, 2010.
66 Balter Compressive Strength Test Specimen Date ticket number 2 dated September 13, 2010 for concrete batch ticket 85320, et.al.
67 KCE Structural Engineers, PC, Walter P Moore, and Wiss, Janney, Elstner Associates, Inc., *Silver Spring Transit Center Structural Evaluation of Superstructure*, March 15, 2013.
68 KCE Structural Engineers, PC, Walter P Moore, and Wiss, Janney, Elstner Associates, Inc., *Silver Spring Transit Center Structural Evaluation of Superstructure*, March 15, 2013.
69 Each truck was loaded with 10 yd^3 of concrete.
70 OIG Work Paper - Establishing Average Size in yd^3 of Unacceptable Concrete Pours and Calculations Based Thereupon

Concrete placement resulted in insufficient concrete cover over reinforcing steel and post-tensioned tendons, which allowed the concrete covering tendon ducts in several locations to crack away when grout was placed to the ducts. In some areas concrete drive paths as poured do not provide the minimum concrete cover (thickness) required by the design specifications. In some areas, the concrete cover was thicker than design specification requirements.

Structural Strength

Finding 5: Design, construction, and inspection contractors had early knowledge that proper concrete thickness was not being achieved, but they took no effective steps to fix the problem.

By November 2010, visible evidence of structural and durability issues had raised concerns including:

- Cracks discovered in the concrete slabs, beams and girders;
- Concrete that broke away from the finished drive surface (spalling), revealing post-tensioned tendons and evidencing that an insufficient concrete cover had been placed over the tendons;

Although concerns about concrete thickness, inadequate concrete cover, spalled concrete above post-tensioned tendons, and related concerns regarding structural deficiency and durability were raised by WMATA soon after the commencement of Level 330 pours and in subsequent monthly meeting, potential repairs and remediation plans were not resolved.

In its WMATA-commissioned report, Whitlock Dalrymple Poston & Associates (WDP) opined that the "long-term durability of a structure is a function of initial construction quality, the extent of routine maintenance performed on [the] structure, and the extent of durability enhancement measures that should be installed on the structure to achieve its design service life."[71]

Durability is the ability of concrete to remain unchanged while in service, including its resistance to weathering action, chemical attack, and abrasion.[72] KCE Structural Engineers, P.C. (KCE) determined that "the durability of the in-situ concrete decks of [the] SSTC [will] not meet the 50-year useful life criteria as per WMATA requirements", and that the excessive cracking "would leave the structure vulnerable to water and chloride-ion intrusion, which reduces the time to initiation of corrosion" to occur well before design specifications. WMATA's consultant, WDP,

[71] Whitlock Dalrymple Poston & Associates, *Evaluation of Silver Spring Transit Center*, May 2, 2013. Page 69.
[72] Source: http://www.allmetalssupply.com/concrete_terms.htm @ 17:50 on 1 August 2013

concurred that the SSTC evaluations identified "initial construction quality issues that may compromise the long-term durability of the structure."

The depth of concrete cover over reinforcing steel and tensioning tendons affects concrete durability. Lesser amounts of concrete cover result in smaller distances through which water and chlorides must penetrate to reach the depth of the reinforcing steel to initiate corrosion. During the construction of the SSTC, concrete broke away from the finished drive surface, revealing post-tensioning tendons, and evidencing that an insufficient concrete cover had been placed over the tendons. Ground Penetrating Radar testing conducted for KCE indicated that "numerous tendons and reinforcing bars did not have the minimum specified concrete cover."[73]

In order for concrete slabs to have met ACI standards and Construction Document specifications[74], slab thickness should have ranged between 9 ¾" and 10 ⅜". Testing indicated that in-situ concrete slab thickness ranged between 7" and 12 ¼", with only 44 % of the level 330 and 38% of the level 350 concrete slabs in compliance with ACI and Construction Document requirements.[75]

Deficiencies with the concrete cover of completed work were identified as early as October 2010,[76] during a construction progress meeting, with an evaluation of the issue discussed during the next meeting.[77] In his October 30, 2010 site inspection report, the Structural Engineer of Record (SEOR) "observed three locations in the Pour 1A area where small portions of concrete directly over the high points of slab tendon ducts popped off during tendon grouting. It is clear that the cover over the duct in these locations was as little as 1/4 [inch]"

Thickness issues continued in concrete that was placed following this discovery,[78] with a WMATA-commissioned report indicating the "preliminary reports show that the deck thickness may be as much as 2 inches thinner than designed in certain areas," with "spalled concrete [present] above the tendons [at] 9 locations around the deck."[79] The result of WMATA's survey was confirmed by both DGS and Facchina in later meetings.[80]

Checklists used before each pour demonstrate that Balter checked to assure reinforcing steel and post tension tendons were properly situated within the formwork to allow for correct elevations with sufficient cover.[81] Efforts to control alignment did prevent some cover deficiencies.

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[73] KCE Report, page 92.

[74] In Table 6 on page 41 of its report, KCE illustrates that ACI 318-02 required top and bottom covers of 2" as a Minimum Concrete Cover For # 6 bars or greater Mild Steel Reinforcement while the Construction documents require a minimum 2" top and 1"bottom cover, while Table 7 indicates an ACI 318-02 Minimum Concrete Cover over Post-Tensioning Conduit as 1", top and bottom, for slabs, while the SSTC design call for a 2" top and. Bottom 2" – 2-1/2" bottom cover.

[75] KCE Report, page 42.

[76] SSTC Construction Progress Meeting, October 28, 2010 "popped concrete cover in three locations at slab tendons when grouting. Possibly did not have the proper coverage over the tendon."

[77] PB Construction Progress Meeting #51, November 16, 2010, minutes. "Area around popped tendons was surveyed for slab thickness. Slab came in thin in some areas."

[78] Greenhorne Thickness Survey. .

[79] In minutes from the SSTC Project Management Team Meeting # 12 held on 8/11/11, "WMATA indicated they received the results of the survey effort to check slab thickness."

[80] In minutes from the SSTC Project Management Team Meeting # 14 held on 10/18/11, it was reported that "WMATA's survey was confirmed by both MC's surveyor and Facchina's surveyor. The main issues discussed were: 1) is there a structural deficiency; 2) what is the effect on durability if the steel is less than 2 inches from the surface."

[81] Balter Daily Report by Tony Lord, 12/03/11.

However, insufficient cover of reinforcing steel and tendons was more likely attributable to insufficient concrete thickness.

Records document that the Contractor established floor thickness by establishing top surface with the desired shape using survey equipment operated while concrete was being placed.[82] The inspector did not (according to the response from Balter to the KCE report, the inspector could not) independently check thickness except at the perimeter.[83] In Exhibit I, the OIG's subject matter expert noted that wet depth checks using a simple rod inserted vertically into fresh concrete would have been a practical thickness check.

The Contractor and Inspector assert that thickness of concrete floors was not directly measured during concrete pours. Despite reminders from the SEOR to "all parties" during construction to maintain thickness,[84] no independent method to check thickness was developed.

The required discussions regarding reinforcement and tendon placement occurred during the pre-installation conference and several subsequent discussions occurred during progress meetings after the discovery that adequate cover was not being maintained. Nonetheless, the deficiencies persisted. If Foulger-Pratt Contracting (FP) was unable to provide the required cover due to congestion of many elements within the slab, a Request for Information (RFI) should have been generated. The lack of cover should have been flagged as a construction deficiency by Balter and corrected prior to continuation of subsequent pours.

Recommendation 5

In future projects, DGS should ensure its construction contractors utilize a construction method that allows direct measurement of floor thickness so that inspectors can help the Contractor by identifying problems as the concrete is placed.

DGS should hold construction contractors accountable for any remediation and increased maintenance costs that will likely result from the contractor's failure to ensure specified concrete slab thickness was attained during placement.

[82] Entry 1.13 of FP minutes from meeting held 8/25/2010 regarding 03300 Concrete Placement Methods, Logistics, and Testing: "How will grades and elevations be established on finished concrete surface? Facchina's surveyor/ layout man will shoot all elevations of top of concrete as placed during the pour for use by W concrete to rake out and screed to established top of concrete elevations."

[83] "Thickness of the slab at points away from the perimeter could not be measured without survey equipment." Balter Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, page 5.

[84] PB Field Observation Comments, 10/15/10, 10/30/10, 11/11/10. "Elevations of formwork, system for maintaining required design elevations at the top of the concrete, and system for maintaining typical concrete thickness at 10 inches should be verified by all parties."

The three pour strips on the 330 and 350 levels were each constructed in a different manner and neither of the pour strips on the 330 level was constructed in manner that conformed to the design requirements identified in the structural drawings. The Level 350 pour strip was constructed in conformance with design requirements. The east pour strip on the 330 level was poured without post-tensioning tendons but with mild steel reinforcement, while the west pour strip on the 330 level was poured without post-tensioning tendons and without sufficient steel reinforcement in one direction.

Structural Strength

Finding 6: Despite reasonably designed controls, identified pour strip deficiencies resulted from weaknesses in the submittal process and professional error.

Image 6: West Level 330 Pour Strip Concrete Pour – April 19, 2011

7:54 am on 19 Apr 2011 (img_1658.jpg)

Source and courtesy of the Montgomery County Maryland Department of General Services.

Pour strips are areas of a slab in the deck that are left out during construction and then placed after adjacent concrete has been poured and has been allowed an opportunity to shrink. Specifications required two pour strips on the 330 level, one each at the east and the west end. One pour strip was required on the smaller 350 level at the east end. Each pour strip was purposely installed at least 60 days later than the rest of the adjoining floor. The east 330 level strip was poured in January 2011while the west strip was poured in April. The level 350 strip was poured in June 2011. The SSTC Pour Strips are substantially wider than the normal industry practice of 3-4 feet. Both pour strips at the 330 level are 760 square foot

Image 7: Cracking Evident on Underside of Level 330 East Pour Strip – April 9, 2013

Source and courtesy of the Montgomery County Maryland Department of General Services.

rectangles approximately 10' wide and up to 76' in length while the 350 level pour strip is slightly larger at 800 square feet, 20' wide, and 40' Long

Drawings in the Construction Documents appear to require mild steel and post-tensioning tendons within the three pour strips on the 330 and 350 levels. A photograph taken by the County (see Image 6) captures workers pouring the concrete at the West 330 level pour strip without the presence of post-tensioning tendons and without most of the mild steel reinforcing in the North-South direction (although there is some at 51 inches on center).[85]

Ground Penetrating Radar (GPR) scans conducted by KCE Structural Engineers, P.C. (KCE) confirmed that neither the east nor the west pour strip on Level 330 was constructed with post-tensioning tendons, and that the west pour strip on Level 330 was missing the required mild steel reinforcing in the North-South direction. The pour strip constructed on the east end of Level 350, the last of the three to be placed, was constructed with both the mild steel reinforcing and post-tensioning tendons. KCE found that one of the Level 330 pour strips was constructed with mild steel reinforcing spaced at 51 inches on center, while the Contract Documents require mild steel reinforcing at 12 inches on center.

Further, the pour strips contain the severe cracks (see Image 7) and unacceptable concrete that are present in many other slabs. The KCE report states: "Results of an analytical 4.8-foot wide strip indicate that the slabs at these locations, as built, do not have sufficient shear or flexural capacity to support the design loads." The project control deficiencies associated with the concrete, as discussed in separate sections of this report, also apply to the concrete used in the pour strips.

[85] Post tensioning ducts would appear as wide, white, ribbed tubes draped under the green reinforcing steel bars that are present in the picture.

Shop Drawings

The failure to install post-tensioned tendons and some of the reinforcement steel in level 330 pour strips resulted from failures to ensure that shop drawings for the pour strips were received and conformed to the design requirements identified in the structural drawings.

According to the General Terms and Conditions of the construction contract, “Shop Drawings generally consist of those drawings, diagrams, schedules and other data specially prepared for the Work by the Contractor or a Subcontractor, Sub-subcontractor, manufacturer, Supplier or distributor detailing the fabrication or assembly of some portion of the Work, copies of which are submitted by the Contractor to the [Architect/Engineer] for approval to indicate the details of execution of that portion of the Work.”

As the Construction Contractor, Foulger-Pratt Contracting (FP) was required to interpret the Construction Documents and prepare (or cause to be prepared) trade-specific shop drawings that communicate FP’s understanding of the proposed construction. The designer of record, Parsons Brinckerhoff (PB), was to review and approve the shop drawings and submittals to ensure FP’s intended construction was in conformance with the design intent.

Shop drawings from VStructural LLC (VSL) were submitted in phases, and each drawing included a “key plan” to indicate the scope of the shop drawing. PB’s shop drawing reviewer would have reasonably expected that shop drawings for all phases of work would be submitted, and that pour strip drawings would have followed submission of other shop drawings since the pour strips would have been poured last. None of the key plans in shop drawings submitted by VSL included the two Level 330 pour strips.

The process for submission and review of shop drawings (part of the project control system) should have, but did not, detect the omission of the post-tensioned tendons shop drawings for the pour strips. The phased submission of drawings increased the vulnerability that PB would not have identified omission of a required shop drawing. The absence of these shop drawings should have been detected if the Design team had ensured that all required shop drawings were identified and contained in the submittal control system, and their preparation scheduled and tracked.

Request for Information and Meetings

In a response to the KCE report, Facchina stated that VSL shop drawings were intentionally prepared without post-tensioning tendons, and asserted that the level 330 drawings did not require such tendons.[86] VSL shop drawings were not submitted for the design and layout of the

[86] Facchina letter dated August 30, 2012, item 4, page 2.

post-tensioning tendons in Level 330 pour strips.[87] A VSL shop drawing, approved by PB, correctly indicating post-tensioning cables, does exist for the pour strip on the 350 level.

The required post-tensioning is indicated in the Construction Documents using "callout notations." VSL and FP claimed the variability in callout locations created ambiguity (for detailed explanation see Exhibit I, page 27-29).

The Contractor Quality Control Plan provided for the resolution of questions regarding interpretation or ambiguity of the Construction Documents through discussion at meetings or written answer via the RFI process.[88] FP and their subcontractors had multiple opportunities to ask for clarification of any ambiguity regarding callout notation for locations of post-tensioning tendons in/near pour strips. Adequate channels of communication, including regularly scheduled meetings, were available to the Contractor. The RFI process, available to address and clarify any such issues, was heavily used in the SSTC project. However, FP and VSL did not use these channels in this case, relying instead upon their judgment.

Due to phased shop drawing submittal, the pre-installation conference occurred before all shop drawings were reviewed. While this approach was not prohibited in the Specifications, it allowed for ambiguity regarding anticipated and outstanding submittals. Since shop drawings were prepared as construction progressed, it was critical that a strong document control system be in place to ensure that all submittals that needed to be prepared by the construction contractor and reviewed by Architect/Engineer were known and tracked. The failure of reviewers to detect the absence of specified post-tensioning shop drawings for two of the pour strips suggests not only a weakness of the submittal control system, but also a lack of diligence with regard to this work.

Professional Error

The mild steel reinforcement was omitted from shop drawings for the level 330 west pour strip, despite performance of the required review and approval process. That control provided for a review that should have been effective had all parties adequately exercised their professional responsibilities with respect to that shop drawing. Independent review by the Quality Control manager failed to highlight differences from the contract drawings that should have been identified as variances.

In the case of the mild steel reinforcement for the west Level 330 pour strip, diligent review by the Architect/Engineer of all shop drawings was not performed, thus the A/E did not ensure that submittals depicted Contractor interpretations and methodologies of the proposed work that were in accordance with design intent.

[87] "Based on a review of our shop drawing files, no post-tensioning shop drawing submittals were provided for the Level 330 delayed pour strip areas." PB letter dated August 24, 2012, page 3.

[88] Item 1.8.A of Specification 01310 reads, "Immediately on discovery of the need for interpretation of the Contract Documents, and if not possible to request interpretation at Project meeting, prepare and submit an RFI in the form specified."

Recommendation 6

Those professionals whose lack of diligence resulted in the pour strip construction deficiencies should be held accountable.

DGS should consider implementation of changes to guard against occurrence of such errors in future projects, for example:

- All shop drawings could be required to be submitted before the pre-installation conference occurs, or
- A pre-installation conference could occur with each new area covered by a recently approved shop drawing, or
- A Submittal Registry could project the number and identity of proposed shop drawings anticipated for all phases. (For example, if only one pre-installation conference occurs at the beginning of the Definable Feature of Work, part of the conference should cover how many submittals will be generated for Designer review for the phased construction. Then as construction proceeds discussion should occur whether each of those proposed submittals have been approved during the progress meetings.)

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Concerns regarding the durability of the structure are attributed to suspected design deficiencies

Water penetrating the structure through the cracks could reach and corrode reinforcing metal, thus potentially shortening its life span significantly from the intended 50-year life. Significantly greater maintenance of the structure would likely be required, greatly increasing the cost of maintaining the structure through its projected life. Some cracking is attributable, in part, to over tensioning of tendons in concrete that was inadequately cured. The primary causes of the reduced durability include widespread cracking of various sizes throughout the structure, which are attributable to the design of the structure that according to KCE and WDP was not prepared in accordance with applicable building codes, WMATA design criteria, or industry standards. A major issue was the lack of details in the structure to accommodate normal movement.

Structural Durability

Finding 7: Stakeholder concerns related to thermal and flexural design issues were raised in early 2010 to the Structural Engineer of Record for resolution, but cracking persisted throughout later stages of construction.

In an email sent on April 7, 2010, approximately five months before the level 330 (the first elevated level) slabs were poured, DGS asked Parsons Brinckerhoff (PB) to contact the Montgomery County Department of Permitting Services (DPS) in order to resolve "a structural issue" - potential cracks of the concrete slabs as a result of stressing the post-tensioned tendon cables. Notes from a May 11, 2010 discussion among representatives from PB, Foulger-Pratt Contracting (FP), Facchina, DGS and the DPS inspector that PB had been asked to contact indicate the DPS inspector's concerns that post tensioning of the slabs and girders with the built in wall would create a zone of cracking in the slabs along certain points. The notes further state: 1.) that the inspector identified the design as an "unusual application" and expressed his opinion that the slab would crack at stressing locations since it is the weakest point; 2.) that the DPS inspector expressed his understanding that his comments were only observations and that PB was the "Engineer of Record" who did (and would therefore be responsible for) the analysis; and 3.)

PB's responses that defended the design, indicating it was consistent with 2003 revision of the building code. It was agreed, however, that Facchina and VStructural LLC (VSL) (the post-tensioned tendons subcontractor) "should" evaluate and discuss the conditions and concerns with PB to respond to the DPS concerns.

The Department of Permitting Services inspector entered a note regarding the meeting in DPS' inspections system stating that: "The DPS position is that the joints shall be designed, detailed, and constructed to permit limited movement of the slab relative to its support in order to prevent cracking of the structure during stressing operations." (DPS does not require design calculation data, as part of the permit submission requirements. DPS asserted that if, during plan review, the DPS reviewer needed more information, the reviewer could ask for whatever information is needed.)

In a June 3, 2010 letter to Facchina regarding the potential cracking at the junction of the slab and wall, VSL opined that PB was taking the right approach to understanding the issue, but that VSL ***did not have access to the design data and assumptions used by PB to substantiate the design, and they could offer no further comments without having performed a full independent review of the design of those areas***

The appearance of cracking had been documented early in the process of constructing the 330 and 350 levels. The first three level 330 slabs (1A, 1B, and 1C) were poured between September 13, and October 18, 2010. Problems related to concrete cracks became evident within 24 hours after placement (see image 8). Three ducts became exposed to view through the surface of Pour 1A shortly after being grouted.[89] Significant cracks were observed in pours 1B and 1C prior to the post-tensioned tendon stressing operations. In a September 20, 2010 meeting to review Pour 1A - the first pour of these levels – shrinkage cracks were discussed, noting that the Structural Engineer of Record (SEOR) would visit the site to inspect.

Image 8: Slab Cracking Evident 2 Days Following Placement of Pour 1B

12:32 pm on 4 Oct 2010 **(img_2236.jpg)**

12:41 pm on 4 Oct 2010 **(img_2239.jpg)**

Source and courtesy of the Montgomery County Maryland Department of General Services.

[89] RBB Daily Report by Tony Lord, 10/28/10.

The issue of cracking in the concrete was again raised by WMATA in an email to the DGS Project Team Leader that had been relayed to him by the SEOR (with copies to the other DGS team members and Contract Administrator) on October 28 2010. Cracks had occurred in some concrete slab pours within 24 hours of placement, and WMATA asserted that field observations indicated the cracking was not consistent with shrinkage. WMATA requested that an evaluation of the cracking be made to determine the cause and proper corrective measures, and that "preliminary findings should be presented prior to further concrete deck placements." WMATA added that while the cracks may not have presented a structural concern, they would require additional long term maintenance and could result in structural issues.

The DGS Project Manager returned a copy of the WMATA e-mail to the SEOR, in which he requested the SEOR to look at the cracks and provide the DGS team with his assessment. The DGS Project Manager noted that one of the DGS team had seen some hairline cracks that did not appear out of the ordinary and that Balter had not raised that issue either. A more senior DGS manager sent a follow-up email to the SEOR stating: "The County will be looking to you as the SER to provide us the guidance in this issue. We all are sensitive to keeping with schedule, but that should not keep us from doing what is right for the long term of the facility."

An email response from the SEOR to the DGS team noted that "While much of the area is used for storage of materials, I was able to find two cracks to review." His message then quotes from a documented account of the subsequent on-site observations and discussions held by the SEOR on October 30, 2010 with FP and Facchina.

In his October 30, 2010 Site Observations report, the SEOR indicated he had "reviewed Pour 1B and 1C slab top surface to find and observe cracks noted in recent WMATA correspondence" which the SEOR indicated may have been caused by "the superstructure system [experiencing] some loading or movement at an early age" although he stated it was his opinion that the cracks in the concrete were "from surface drying and minor shrinkage of that near-surface concrete."

The "Field Observation Comments" report noted three locations in the pour 1A area where concrete popped off over the slab tendon ducts and that it was clear that cover over tendon ducts was as little as ¼ inch. The SEOR reiterated that the construction contractors were to verify the slab thickness. The document also noted surface cracks in slab pours 1B and 1C, (identified as having been the subject of WMATA correspondence), and offered an opinion that the very narrow cracks observed would have been from surface drying and shrinkage of near surface concrete. The document further states: "Typical for the project, continued and increased effort to eliminate potential causes for cracks should be made including verification that formwork/shoring is undisturbed and making every effort to keep slab surface "wet" and curing measures placed as early as possible."

A "Post Tensioning Summit" meeting was held at the construction trailer on November 30, 2010 to discuss issues stemming from post tensioning operations at the SSTC. The meeting resulted in a list of more than 15 "action items" (procedures) apparently intended to confirm that human error was not causing the problems that had been observed. VSL brought an additional level of supervision on the site and MTA later observed that the new procedures had been followed.

During 2012, KCE Structural Engineers, P.C. (KCE), and Whitlock Dalrymple Poston & Associates, P.C. (WDP) each separately conducted extensive testing and modeling of the structure's design to evaluate whether it had adequate strength to bear intended loads, and whether the structure had sufficient flexibility to withstand torsion and shearing forces. They both determined that restraint was present within the post-tensioned slab system due to omission of measures to deal with stresses and forces in the design of the slabs – slabs that had been poured without a bond breaker at the intersection of the slab and the concrete wall, and by integration of those walls with the columns that supported the stiff girders. Both KCE and WDP concluded that cracking was due to these design elements.

Although evaluation of the Balter comprehensive strength testing of the sample cylinders led PB to determine that concrete had attained the 4,000 psi minimum strength necessary to commence post-tensioning stressing, findings discussed earlier in this report conclude that in-situ concrete was likely less mature and of questionable strength at the time stressing commenced. Unlike the cracking observed during the first month following concrete placement, which does appear consistent with drying and shrinkage resultant from improper curing, the horizontal cracking in the beams and girders documented by KCE during its testing is likely resultant from excessive stressing force applied to immature concrete. After the initial setting and curing period, whose passage is approximated by the 28-day compressive strength tests, existing cracks worsened, and new cracking appeared. We have found no evidence that the cracking that persisted after the 28 days could have resulted from any cause other than the design issues identified in the KCE and WDP reports.

Conclusions

Despite the Department of Permitting Services' concerns about the design of the SSTC structure in early 2010, DPS lacked the authority under the County's Special Inspections Program to override the SEOR's professional judgment.[90] DGS relied upon the SEOR's assurance that the design would prove not to result in any of the problems DPS suspected. Construction contractors and certain subcontractors were consulted by the SEOR; however, they lacked the detailed design information necessary to perform a sufficient review of the design issues. Even though it was unclear whether the deficiencies identified during PMT meetings were related to the SSTC's "unique geometr[ic]"[91] design or to construction methods employed, DGS relied on its design

[90] Issues raised by DPS were about durability, not safety. Since the Engineer for PB was responsible for the durability issues, DPS didn't have the authority to make the decision or overrule the PB engineer. DPS would have had the authority to make the decision had the issues been about safety. The pouring strip issues, for example, are safety issues.

[91] VSL June 3, 2010 letter to Facchina Construction re: Silver Spring Transit Center Potential Wall/Slab Interface Cracking. KCE Report, Attachments Vol. II, pdf page 77.

and construction contractors to reach agreement among them regarding how to correct the deficiencies observed.

Ultimately, DGS also contracted with an independent firm, KCE, to provide objective advice on the design and construction of the SSTC structure; however, it did not do so until 2012, when the structure was almost complete. This was a reactive response to problems that arose during construction. Among the difficulties this situation presents is the requirement that DGS make decisions based on information provided by professional firms that disagree on significant aspects of the design.

DGS would have benefitted from retaining KCE or another objective third party firm at the beginning of the design process to perform a "peer review" function during the design of this unusual and challenging structure.[92] That firm could have been retained to work with PB to either substantiate or modify the design. A peer review would not only be performed in occurrence of a problem - it could also be a preventive control. However, it could also be utilized if during a project there is doubt with the Designer of Record's performance.[93]

Recommendation 7

DGS should develop procedures to identify circumstances under which an independent peer reviewer should be employed to review and improve the design of unique construction projects. The trigger for a peer review could be the nature and complexity of the project design.

[92] In 2009, after project modification was necessitated by large scale underground utility relocation and other unforeseen conditions that resulted in significant delay, DGS tasked PB with providing Construction Project Management Services. Within this contract's scope of services, PB was to provide a full-time, on-site project engineer to work under the direction of the DGS Project Manager. The scope of services in the Construction Project Management Services Contract included coordination of project design activities and issues with various outside agencies, production of required progress reports to outside agencies, coordination of document reviews, and documentation and assistance to the County staff in negotiating Construction Contract changes. The project engineer had no decision making authority.
The Construction Project Management Services provided by PB were handled separately from the company's other roles in this project as Designer of Record and SEOR. A different PB engineer sealed the Construction Documents, reviewed shop drawings, and provided site observations as the designer's representative.

[93] The OLO reports, and our SME's experience indicates, that the use of peer reviews on the County level is not widespread. The SME reports they regularly perform peer and constructability reviews for federal agencies (Veteran's Administration) and state level agencies (Maryland DGS, UMD, and VDOT).

Structural Durability

Finding 8: Problems with structural design and construction were identified during 2010, and repeatedly discussed in subsequent Project Management Team meetings, but were not effectively addressed.

In the Contractor's Quality Control Plan, the County is referred to as the Construction Manager (CM). Although the term implies broad responsibilities and authority over the construction project, in practice the role of a Construction Manager can vary between construction projects. DGS personnel had primary responsibility for continuous review of all operations and audit of all test reports, evaluation of payment requests, change order management, and interaction with contractors and outside stakeholders including MTA, FTA and WMATA as well as document control activities related to those entities.

However, as Chart 6 illustrates, the roles and responsibilities of the Construction Manager were shared among many entities, prompting WMATA to opine that it seems unclear who is responsible, allowing lapses and mistakes that potentially arise due to this troubling lack of clarity.[94]

Chart 6: SSTC "Construction Management" Responsibilities as Performed

Construction Management Element	Foulger Pratt	Parsons Brinckerhoff	Balter	MontCo DGS
Conduct & Document Periodic Progress Meetings		✓		✓
Document Control	✓			
Cost Tracking & Management				✓
Evaluation of Payment Requests,				✓
Change Order Management,	✓			✓
Quality Management	✓			
Review Daily Quality Control (QC) reports				✓
Complete Daily CM Log	✓			
Schedule Control	✓			
Review and verify contractor's project record drawings are updated		✓		
Monitoring Contractor Safety	✓			
Conduct inspections			✓	
Issue inspection deficiency letter to the contractor		✓		

Source: OIG Staff Analysis

As previously stated, oversight of the project was provided by a Project Management Team (PMT), consisting of representatives of DGS, WMATA, MTA and FTA. The Project Management Team meetings were a requirement of the Project Management Plan (PMP). The team held formal monthly meetings on a continuing basis. Meeting minutes were kept by an employee of Parsons Brinckerhoff (PB).

[94] Foulger Pratt 4/17/09 Quality Control Plan, Revised Submission dated 9/1/2009.

The DGS Contract Administrator reports to the Director of DGS. The Contract Administrator assigned six permanent staff members to work full-time overseeing the project on behalf of the County, and to serve as the County's principal representatives for the SSTC project. The specific duties of each staff member, as described by DGS, are identified in Exhibit I, Appendix B. The duties include reviews of schedules and Notices of Delay proposed by the contractor, reviews of Balter daily and monthly inspection reports, reviews of RFIs, Architect's Supplemental Instructions[95], and other change instruments on the project, attending subcontractor meetings and safety meetings, attending weekly SSTC project meetings, and attending weekly meetings with the design team (PB/ZGF). Biweekly and quarterly meetings were held with MTA.

Each month, Foulger-Pratt Contracting (FP) provided DGS with a Monthly Report in the form of a detailed notebook containing hundreds of pages of documents, including construction photographs from the month, a Critical Path method schedule update, various tracking and control logs and summary reports. The DGS project management staff summarized information provided by the contractor and provided its own monthly reports to MTA and FTA. The DGS Project Team Leader was, on a daily basis, responsible for keeping DGS Division management personnel informed of all issues that would affect the success of the project.

In 2009, after redesign was necessitated by large scale underground utility relocation and other unforeseen conditions that resulted in significant delay, DGS tasked PB with providing Construction Project Management Services. Within the Scope of Services, PB was to provide a full-time on-site project engineer to work under the direction of the DGS Contract Administrator. The scope of services in the Construction Management Services Contract also included coordination of project design activities and issues with various outside agencies, production of required progress reports to outside agencies, coordination of document reviews, and assistance to the County staff in negotiating Construction Contract changes. The responsibilities of the project engineer, who in some documents is referred to as Construction Manager, do not correlate to the role of a typical industry Construction Manager.[96] The project engineer was under the direct supervision of the County project manager and had no decision making authority.[97]

The Construction Project Management Services provided by PB were handled separately from the company's other roles in this project as Designer of Record (DOR) and Structural Engineer of Record (SEOR). A different PB engineer sealed the Construction Documents, reviewed shop drawings and provided site observations as designer's representative.

The construction contract between the county and FP uses the term "Project Manager" to refer to the person designated by FP as having authority to act on behalf of the contractor with respect to all aspects of the project and to whom the Superintendent reports. As defined by the general terms and conditions of the construction contract with FP, construction activities are performed

[95] Architect's Supplemental Instructions (ASI) are used when the Architect/Engineers proposes a modification to the Construction Documents.
[96] An Owner's Guide to Project Delivery Methods by the Construction Management Association of America, August 2012, page 15
[97] Memorandum dated June 16, 2009 attached to Construction Manager Contract

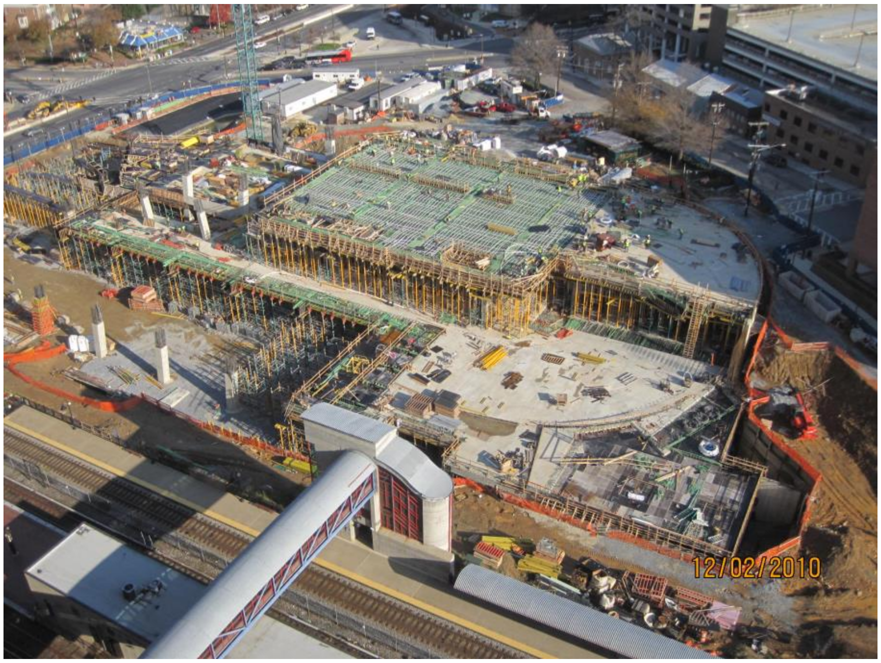
under the direction of the FP Project Manager. Responsibilities such as document control, quality management, and schedule control were performed by FP.

Quality control responsibilities, including inspecting, testing and checking the products of construction activity, were the responsibility of FP. However, responsibilities for inspections and testing were performed by Balter. In an April 17, 2009 letter transmitting a revised Quality Control plan to the County, FP states: "the independent testing agency provided by the Owner [Balter] is a major component in the QC for the project and the reviewers will note the inclusion of the testing agency and its forms in the QC Plan." [98]

PMT minutes from mid-November 2010reflect discussion of the concrete problems in the SSTC structure that were later discussed in the 2013 KCE Structural Engineers, P.C. (KCE) and Whitlock Dalrymple Poston & Associates, P.C. (WDP) reports. During that meeting, WMATA reportedly raised the issue of having the contractor perform a complete survey of deck thickness to identify thin slab locations. Other issues were to be addressed by the SEOR.

At the point in time of the November PMT meeting, less than half the slab concrete had been placed, and the structure was less than 50 percent complete (see Image 9).[99] The meeting minutes indicate that the issues were not unusual or unexpected in a complex structure like the SSTC and that the SEOR was working to address each one. Although the construction schedule and completion date were discussed during the meeting, there was no suggestion that these issues might further delay the completion of the SSTC.

Image 9: Silver Spring Transit Center Construction Progress – December 2, 2010



9:56 am on 2 Dec 2010 **(img_3024.jpg)**

Source and courtesy of the Montgomery County Maryland Department of General Services.

The meeting minutes suggested that participants might have, at that time, expected that remedial actions would be identified and applied to correct the problems, both in the constructed and unconstructed sections of the structure. These concrete issues were discussed in subsequent

[98] Foulger Pratt Quality Control Plan Revised Submission April 17, 2009 cover letter
[99] SSTC Report #49, MTA-Monthly Report for December 2010.

meeting but remained unresolved as work on the SSTC continued. Almost a full year later, October 18, 2011 meeting minutes indicated the PMT was still unable to determine the effect of and a resolution for the concrete cover and thickness and spalling issues on the potential project completion and acceptance delays. PMT meeting minutes reflect that structural strength and durability were recurring concerns in the context of actions to be pursued by WMATA and MTA.

The proposed actions included a complete building survey and Ground Penetrating Radar (GPR) survey to determine the extent of the thickness issues, petrographic testing, and spall repair. Slab laser scanning and GPR by MTA began in November 2011. Preliminary results provided to DGS indicated some remediation may be needed. WMATA's call in February 2012 for a comprehensive review that would include looking at cracking, post-tensioned tendon elongations, and thin slabs was reportedly taken under advisement by DGS. In the March 2012 PMT meeting, WMATA asserted that any remediation plan must be based on an analysis of the entire SSTC building structure to determine deficiencies. During the same meeting, FTA reportedly asked for a review of the PMP, indicating there appeared to be a requirement for a higher level meeting than the management team meeting. DGS representatives stated there were several reoccurring meetings that satisfied the requirement.

In April 2012 DGS reported to the PMT that the construction contractor would prepare a presentation regarding a remediation plan. It was also reported that PB had completed their evaluation of the SSTC structural integrity, identifying several deficiencies, and that PB would evaluate the FP remediation plan once the full plan had been submitted.

Recommended actions, including a 2 inch Latex Modified Concrete (LMC) overlay, recommended by Parsons Brinckerhoff, Inc. (PB) and MTA in mid-2012, were proposed during the following months, but meeting minutes indicate "WMATA has not accepted this proposed fix and continues to question the root cause of the cracks."

As stated earlier in this report, Montgomery County contracted with KCE in June 2012, to conduct an evaluation of the in situ conditions of the structural frame of the SSTC based on their independent document review, field investigation observations, and engineering analyses, and WMATA contracted for the services of WDP to determine the condition of the SSTC and to understand whether it satisfies the required strength and durability to meet its intended uses and service life. Those efforts resulted in a March 15, 2013 report by KCE and a May 2, 2013 by WDP, both of which identified similar deficiencies that require remediation.

The expectations of DGS - that PB would ensure the design met all applicable standards, and that FP and its subcontractors would construct the SSTC in accordance with Construction Documents - were not met.

As evidenced in the comparisons of construction data presented in earlier findings in this report, Balter inspectors captured data during the course of construction that evidenced deviation from design and construction specifications, but documents do not indicate that data was ever used to find and raise major concerns to the attention of FP or DGS. Performing that type of analytical review is not a responsibility typically assigned during a construction project and there is no indication that responsibility was assigned in this case.

Conclusions

In response to problems that surfaced during the project, DGS contracted with PB to provide "construction management" services, but that individual was not independent of PB and the functions he was assigned did not allow him to serve as an effective construction manager for this project.

Rather than hiring an individual to supplement DGS staff under a "construction manager" contract, and acquiring the services of KCE after the major construction efforts had concluded, DGS would have benefitted from retaining an objective third party firm at the outset to serve as an independent construction manager. That firm could be selected on the basis of expertise in dealing with structures of unusual design similar to the SSTC.

Typical industry practice is for Construction Managers to be contracted either before or at the same time as the Contractor. Their primary role is to observe the work of the construction contractor for progress, workmanship, and conformance with Construction Documents and existing codes. The CM notifies Owners of any problems and may provide recommendations for resolution. Direction is given to the Contractor from the Owner. However, such a firm could also be utilized if during a project there are concerns about the construction contractor's performance.

Recommendation 8

DGS should develop procedures to identify circumstances under which an independent third party should be employed to serve as Construction Manager on an atypical construction project. The trigger could be a dollar value or uniqueness of the project.

DGS should develop protocols to ensure that controversial issues encountered/problems experienced by or with the construction contractors are promptly and effectively addressed. As an example, DGS could develop and incorporate into its contracts a systematic process that identifies deficiencies and withholds payments pending resolution. This "rolling punch list of deficiencies" control would address construction issues. Once an item is identified as deficient, it would be added to a rolling punch list which is tied to payments. Therefore, the Contractor is motivated to correct issues in a timely manner. FP generated their own internal contract compliance list which was included and discussed at progress meetings, but evidently was not tied to payments.

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Structural Remediation of the Paul S. Sarbanes Silver Spring Transit Center

As stated earlier in this report, Montgomery County contracted with KCE Structural Engineers, (KCE) in June 2012, to conduct an evaluation of the in-situ conditions of the structural frame of the SSTC based on its independent document review, field investigation observations, and engineering analyses. WMATA contracted for the services of Whitlock Dalrymple Poston & Associates, (WDP) to determine the condition of the SSTC and to understand whether it satisfies the strength and durability requirements necessary to meet its intended use and service life.

Those efforts resulted in a March 15, 2013 report by KCE and a May 2, 2013 by WDP, both of which identified similar deficiencies that require remediation. Following the issuance of the KCE report in March 2013, a remediation kickoff meeting was held on April 25, 2013. As a spinoff of that meeting, the Cooperative Remediation Working Group (CRWG) was formed, which consists of professional design engineers from Parsons Brinckerhoff, KCE, Wiss, Janney, Elstner Associates (WJE), Walter P. Moore, and Simpson Gumpertz & Heger (SGH); construction personnel from Foulger-Pratt Contracting (FP), VStructural, Wagman, and Facchina; and WMATA and DGS staff. The charge of that group is to agree upon design and implementation of a remediation plan to resolve all of the issues raised in the KCE and WJE reports to the satisfaction of WMATA and Montgomery County.

By late summer 2013 a remediation plan for pour strips on the 330 level had been agreed to by the CRWG and was being implemented by the contractors. Work on the pour strips consisted of adding beams under the strips and placing new reinforcing and concrete on the surface.

In early December 2013, the Project Management Team was advised that construction activities directly related to remediation of the east and west 330 level pours strips had been completed.

The CRWG also adopted a plan to fill slab cracks and resolve the slab thickness deficiencies by topping the Level 330 and 350 slabs with a Latex Modified Concrete (LMC) overlay that will be applied as a final step once the weather and temperatures permit, and after decisions regarding any remedial actions necessary to address torsion and shearing force issues have been made.

On April 8, 2014, the Director of the Department of General Services updated the County Council on the status of remediation discussions that had been ongoing among the County and its independent consultant, KCE, WMATA, and the Structural Engineer-of-Record, Parsons Brinckerhoff, to review the design calculations.

In his statement, the Director indicated that the KCE recommendation plan and engineering design requires removal of material and drilling into the structure. WMATA "…questioned whether this work needs to be performed or, if it is necessary, may be deferred until evidence of stress occurs, if at all." The Director reported that the County Executive directed DGS to engage in negotiations under which Parsons Brinckerhoff would post a bond in the amount necessary to pay for this work, should it become necessary in the future. He also reported that the County Executive had commissioned an advisory panel to provide him with advice on the final work to be done.

Subsequent Event

On May 8, 2014, the County Chief Administrative Officer advised members of the County Council that the County Executive had directed County contractors to move ahead on remediation work at the Silver Spring Transit Center. That work would address the shear and torsion recommendations contained in the April 21, 2014 report commissioned by the County Executive entitled Report of the Independent Advisory Committee Regarding the Status of the Silver Spring Transit Center.

Image 10: Additional Beams for Remediation of Shear and Torsion Deficiencies per KCE and IAC Recommendations

4:24 pm on 12 Dec 2013 **(sstc-beam10.jpg)**

Source and courtesy of the Montgomery County Maryland Department of General Services.

Chief Administrative Officer's Response

OFFICES OF THE COUNTY EXECUTIVE

Isiah Leggett
County Executive

Timothy L. Firestine
Chief Administrative Officer

MEMORANDUM

May 14, 2014

TO: Edward Blansitt, Inspector General

FROM: Timothy L. Firestine, Chief Administrative Officer

SUBJECT: Final Draft Report, Project Management Deficiencies in Constructing the Paul S. Sarbanes Silver Spring Transit Center

I am in receipt of your memo and final draft report dated April 15, 2014 detailing the review conducted by your office concerning the Silver Spring Transit Center. Your assessment of this issue has been thorough and fair. Please find below specific responses to your audit recommendations.

IG Recommendation 1: DGS should improve its controls for future projects in a manner that is consistent with the lessons learned and additional recommendations contained in Exhibit I, the report "Analysis of Project Controls," in addition to other recommendations made in this report.

CAO Response: This recommendation furthers the thesis of Alpha Corporation's Analysis of Project Controls report which largely states that implementation and refinement of project controls would have prevented many if not all of the construction deficiencies in the Transit Center. The report states, "Therefore, identification of controls that were omitted, deficient or failed is necessary to avoid repeating mistakes due to misplaced confidence in deficient controls." The County set forth specific Project Controls in the Contract Documents. Many of the controls evidenced in the report, particularly those that deal with concrete composition and placement, are clearly identified and set forth in the Contract Documents and place the responsibility for quality assurance and control measures on Parsons Brinckerhoff (PB), Foulger-Pratt (FP), and Robert B. Balter Company (Balter). Those contractors should have employed appropriate quality assurance and control measures to achieve more positive results. PB, FP, and Balter failed to impose quality assurance and control measures to ensure that the concrete complies with the Project requirements. The County agrees that it should continue to improve its project controls so that the mistakes made by the contractors on the Transit Center are not repeated in future construction projects.

Edward Blansitt, Inspector General
May 14, 2014
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IG Recommendation 2: DGS should ensure construction documents clearly establish responsibility for and performance of systematic analysis of data collected and recorded during construction in order to identify possible inconsistencies with specifications, project control weaknesses, and construction deficiencies that should be investigated and resolved.

CAO Response: This section of the report focuses on the addition of excessive amounts of water to the concrete mixture and the subsequent lowering of the concrete compressive strength. FP was responsible for ensuring the composition of the specified and accepted concrete mix met Project requirements. Balter, as the testing agent, was required to inspect, test, and monitor the composition and placement of the concrete for the County. The Contract Documents are very clear on limiting water addition to the concrete mixture. FP and Balter were required to monitor and document the composition of the concrete. FP should have complied with the requirements of the Contract Documents and it should not have poured defective concrete. Balter should have noted the failure of FP to adequately ensure the composition of the concrete and it should immediately have alerted the County of the defective condition so that the County would have had the opportunity to stop the concrete pours until FP was prepared to place concrete that met with the requirements of the Contract Documents. On future complex construction projects, DGS will utilize the services of a Construction Management firm for greater oversight of all construction operations, thereby lessening the likelihood that similar problems will occur.

IG Recommendation 3: In future projects, DGS should ensure that all specification requirements are reviewed and implemented unless a variance is mutually discussed and agreed upon. Temperature limits during curing should be monitored and maintained, and specifications for duration of curing should be strictly observed. Confusion about where to take samples and about cold weather limits should be avoided by clearer language in specifications. Any conflicts between specifications and standards should be resolved in favor of the more conservative of those required by stakeholders (in the case of the SSTC, the stakeholders are DGS, and WMATA).

CAO Response: This section of the report addresses the requirements for cold weather curing and thermal protection as it relates to concrete placement. We agree that the controls are clearly identified and set forth in the Contract Documents. Further, we agree that the records collected by FP and Balter during the project clearly indicate that the details of curing concrete were not addressed in strict accordance with Contract Documents. The contract requirements and applicable building code requirements were clear and FP and Balter knew exactly what the cold weather curing and thermal protections were to be used for the pouring and curing of slabs. Nonetheless, both FP and Balter substantially ignored those requirements. It is clear that observations and evaluations by the County and its contractors and consultants could influence quality of future work. We agree that enforcement of the requirements of the Contract Documents

Edward Blansitt, Inspector General
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serve to avoid or alleviate mistakes made by a general contractor and special inspector. On future complex construction projects, DGS will utilize the services of a Construction Management firm for greater oversight of all construction operations, thereby lessening the likelihood that similar problems will occur with cold weather curing and thermal protection.

IG Recommendation 4: DGS should modify its contract specifications for future construction projects to ensure that concrete test specimens are made as near as possible to the actual point where concrete is placed. Where referenced standards require testing at the point of delivery, DGS should clarify in the specification that such testing is in addition to typical testing.

CAO Response: This section of the report addresses the discrepancy of concrete sampling between the point of delivery and the point of placement. The requirements of the Contract Documents are clear in that the testing cylinders are to be made and stored as near as possible to the point of deposit. Balter failed to comply with the Statement of Special Inspections which references ASTM Standard C31/C31M that indicates that cylinders should be made and stored in or on the structure as near as possible to the point of deposit. It was Balter's responsibility as the special inspector to ensure that the test cylinders were made and stored as near as possible to the point of the concrete deposit. FP was also responsible to ensure that the cylinders were made and stored as near as possible to the point of deposit by construction contract specification section 03300.1.5.B which references ASTM C94. Therefore, we do not agree with this recommendation. The requirements are set forth in the applicable building and material codes as well as set forth in the Contract Documents. Thus, no ambiguity existed in this Project. Balter and FP ignored the applicable standards and the requirements of their respective contracts. On future complex construction projects, DGS will utilize the services of a Construction Management firm for greater oversight of all construction operations, thereby lessening the likelihood that similar problems will occur with concrete sampling.

IG Recommendation 5: In future projects, DGS should ensure its construction contractors utilize a construction method that allows direct measurement of floor thickness so that inspectors can help the Contractor by identifying problems before the concrete is placed. Alternatively, a second, independent survey should be performed. Survey equipment could be utilized by inspectors to continuously monitor concrete thickness during placement, and submit a report of survey results for Owner and SEOR approval.

DGS should hold construction contractors accountable for any remediation and increased maintenance costs that will likely result from the contractor's failure to ensure specified concrete slab thickness was attained during placement.

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CAO Response: This section of the report addresses the issue of slab thickness. The Contract Documents specified a dimension for the slab thickness. We agree that FP should have utilized a method that ensured direct measurement of the floor thickness. We further agree that we should hold FP accountable for any remediation and increased maintenance costs that will likely result from FP's failure to ensure specified concrete slab thickness. On future complex construction projects, DGS will utilize the services of a Construction Management firm for greater oversight of all construction operations, thereby lessening the likelihood that a similar problem with slab thickness would occur.

IG Recommendation 6: Those professionals whose lack of diligence resulted in the pour strip construction deficiencies should be held accountable.

DGS should consider implementation of changes to guard against occurrence of such errors in future projects, for example:

- All shop drawings could be required to be submitted before the pre-installation conference occurs, or
- A pre-installation conference could occur with each new area covered by a recently approved shop drawing, or
- A Submittal Registry should project the number and identity of proposed shop drawings anticipated for all phases. (For example, if only one pre-installation conference occurs at the beginning of the Definable Feature of Work, part of the conference should identify the number of submittals that will be generated for Designer review for the phased construction. Then as construction proceeds discussion should occur whether each of those proposed submittals have been approved during the progress meetings.)

CAO Response: This section of the report addresses the pour strips. We agree that the control measures in place should have prevented the construction deficiencies in the pour strips on Level 330. While we agree with the recommendation that we should hold FP and PB accountable for the pour strip construction deficiencies, we believe that Balter also bears responsibility for its failure to account for the omission of post-tensioning cables in that location.

IG Recommendation 7: DGS should develop procedures to identify circumstances under which an independent peer reviewer should be employed to review and improve the design of unique and challenging construction projects. The trigger for a peer review could be the nature and complexity of the project design.

CAO Response: This recommendation proposes that an independent peer reviewer be employed for unique and complex construction projects. Note that this project was designed during the period that pre-dated the formation of DGS as a department in the

Edward Blansitt, Inspector General
May 14, 2014
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County's government. Since then, the practice of independent peer review for large, complex, or unique projects has become much more commonplace. DGS frequently employs independent peer review on these types projects that feature project review by an independent team. This has had a decidedly positive effect on those projects.

IG Recommendation 8: DGS should develop procedures to identify circumstances under which an independent third party should be employed to serve as Construction Manager on an atypical construction project. The trigger could be a dollar value or uniqueness of the project.

DGS should develop protocols to ensure that controversial issues encountered/problems experienced by or with the construction contractors are promptly and effectively addressed. As an example, DGS could develop and incorporate into its contracts a systematic process that identifies deficiencies and withholds payments pending resolution. This "rolling punch list of deficiencies" control would address construction issues. Once an item is identified as deficient, it would be added to a rolling punch list which is tied to payments. Therefore, the Contractor is motivated to correct issues in a timely manner. FP generated their own internal contract compliance list which was included and discussed at progress meetings, but evidently was not tied to payments.

CAO Response: This recommendation proposes the use of a construction manager for a project like the Transit Center. Since the formation of DGS, the use of construction management expertise has been increasingly emphasized. We agree that were the Transit Center's construction begin today,DGS would use a construction management firm. DGS has currently prepared a solicitation to select construction management firms to be used on future projects.

If you have any questions, please feel free to contact me or Assistant Chief Administrative Officer Fariba Kassiri, who can be reached at (240) 777-2512 or Fariba.Kassiri@montgomerycountymd.gov.

TLF:dd

cc: Fariba Kassiri, Assistant Chief Administrative Officer
David Dise, Director, Department of General Services
Marc Hansen, County Attorney
John Markovs, Deputy County Attorney

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Acronyms & Terminology

ACI	American Concrete Institute. A non-profit technical society that has developed many of the concrete industry's design standards and recommendations.
ASTM	ASTM International (formerly the American Society for Testing and Materials). An international organization that develops and publishes voluntary consensus technical standards.
Balter	Robert B. Balter Company. The company selected as inspector of the SSTC.
Beam	In the SSTC, a secondary, horizontal structural element that withstands load by resisting bending. Loads carried by beams in the SSTC are transferred to girders.
Construction Documents	Final drawings and Specifications containing detailed requirements written in paragraph form that must be satisfied for materials, design, products, or services, that were prepared by the Design Team and approved by Montgomery County Department of Permitting Services in 2008.
DGS	Montgomery County Department of General Services, also referred to as "County"
DPS	Montgomery County Department of Permitting Services. The branch of government that issues building permits.
Facchina	Facchina Construction Company, Inc. The company selected by FP to provide all concrete construction activities for the SSTC covered in this report.
FP	Foulger-Pratt Contracting, LLC. The company selected to implement construction of the SSTC.
Girder	In the SSTC, the primary, horizontal structural element that withstands load by resisting bending. Loads carried by girders in the SSTC are transferred to vertical structural elements such as columns or walls.
KCE	KCE Structural Engineers. The company selected by the County to perform a structural evaluation of the SSTC.
PB	Parsons Brinckerhoff, Inc. and its predecessor affiliates PB Americas, Inc. and Parsons Brinckerhoff Quade & Douglas, Inc. who entered into contracts with Montgomery County. The company who, as Designer of Record, designed the SSTC. See also SEOR.
PMT	Project Management Team - The Management Team comprised of the managers responsible for the transit center project delivery.

Acronyms & Terminology

RFF	Rockville Fuel and Feed Co., Inc. A company who provided most of the ready-mixed concrete in the Level 330 & 350 slabs, beams, and girders of the SSTC.
RFI	Request for Information. Contractors generate RFIs in order to ask the Design Team a question and obtain written information regarding the project. Also, known as a Request for Interpretation.
SEOR	Structural Engineer of Record. On this project the SEOR was an employee of Parsons Brinckerhoff, Inc. Also referenced as SER.
Slab	In the SSTC, a horizontal, steel reinforced concrete structural element serving as the drive lanes and floors. On Levels 330 & 350, slabs set atop beams and girders.
Spalling	Cracking, breaking, chipping, or fraying of a concrete slab's surface, usually confined to a small area.
Specifications	See Construction Documents
SSTC	The Paul S. Sarbanes Silver Spring Transit Center, the subject of this Inspection. See the introduction for a description of the facility.
VSL	VStructural LLC. The company selected by Facchina to provide all post-tensioning for the SSTC.
w/c	Ratio of water to cement in concrete. The *w/c* ratio has a significant influence on the strength and durability of concrete.
WMATA	Washington Metropolitan Area Transit Authority. The agency that agreed to provide maintenance and operations for the SSTC.

Exhibit I

Alpha Corporation Subject Matter Expert Report

ALPHA CORPORATION
1800 Washington Boulevard, Suite 415 Baltimore, MD 21230 410) 646-3044 Fax: (410) 646-3730

March 14, 2014

Montgomery County OIG
51 Monroe Street, Ste 802
Rockville, MD 20850

Attn: Edward L. Blansitt, Inspector General

Reference: Analysis of Project Control

Dear Mr. Blansitt,

As requested and in conformance with our contract, Alpha Corporation has attached our Analysis of Project Controls for the Silver Spring Transit Center.

We appreciate the opportunity to assist the County in this matter and if you have any questions or concerns, please contact us.

Sincerely,
ALPHA CORPORATION

Michael Damron, P.E. LEED AP
Vice President

Enclosure: Analysis of Project Controls

SILVER SPRING TRANSIT CENTER

ANALYSIS OF PROJECT CONTROLS

Prepared for:

Montgomery County, Maryland
Office of the Inspector General
Rockville, Maryland

Prepared by:

ALPHA CORPORATION

March 14, 2014

TABLE OF CONTENTS

I. Terms and Acronyms Used in This Analysis

A/E	Architect/Engineer. The design team also includes professionals from disciplines such as electrical, mechanical, and plumbing. Parsons Brinckerhoff (PB) was the prime/leader of the team on the SSTC Project.
ACI	American Concrete Institute. A non-profit technical society that has developed many of the concrete industry's design standards and recommendations.
AOR	Architect of Record. The registered, licensed professional on this project was Zimmer Gunsul Frasca Architects LLP (ZGF).
ASI	Architect's Supplemental Instruction. ASIs are used when the designer would like to modify the Construction Documents.
ASTM	American Society for Testing and Materials. An international organization that develops and publishes voluntary consensus technical standards.
Concrete Cover	The least distance between the surface of embedded reinforcement and the surface of the concrete. Concrete cover is required to prevent corrosion and damage to the reinforcement.
Construction Contract	Contract between Montgomery County and Foulger-Pratt Contracting, LLC to construct the SSTC facility.
Construction Documents	Final drawings and Specifications prepared by the Design Team and approved by DPS in 2008.
CM	Construction Manager is responsible for management of project planning, design, and construction from inception to completion to controlling time, cost, and quality.
Construction Manager Contract	Contract between Montgomery County and Parsons Brinckerhoff to provide Construction Project Management Services. The contract is reproduced in KCE Exhibit M1 beginning on page 296.
Construction Team	Foulger-Pratt Contracting, LLC and subcontractors (See Figure 1).
Contractor	Foulger-Pratt Contracting, LLC. The company selected via competition to implement the construction of the SSTC.
CQC	Contractor Quality Control. Quality Control (see description under QC in this list) implemented by the Contractor on construction efforts. Compare to DQC.
Definable Features of Work	A task that has limits which can be separate from other tasks and has control requirements and crew unique to that task. Installation of the fire alarm system for the second level is a Definable Features of Work.
Design Contract	Contract between Montgomery County and Parsons Brinckerhoff, Inc. to design the SSTC facility.
Design Team	Parsons Brinckerhoff, Inc.
DGS	Montgomery County Department of General Services, the branch of government that acts as the Owner of the SSTC until the completion of construction.
DOR	Designer of Record. For this project the DOR is Parsons Brinckerhoff, Inc.
DPS	Montgomery County Department of Permitting Services. The branch of government that issues building permits.
DQC	Design Quality Control. Quality Control (see description under QC in this list) implemented by the Design Team on design efforts. Compare to CQC.

EOR	Engineer of Record. The registered, licensed professional responsible for a design, on this project Doug Lang of PB served as EOR.
Facchina	Facchina Construction Company, Inc. The company selected by FP to provide all concrete for the SSTC.
FP	Foulger-Pratt Contracting, LLC. The company selected to implement construction of the SSTC.
GPR	Ground Penetrating Radar. Used to scan the existing concrete to detect reinforcing.
IBC	International Building Code. A model document that becomes the building code when adopted by a government.
Inspection Contract	Contract between Montgomery County and Robert B. Balter Company to perform third-party inspections including field testing during the construction efforts for the SSTC.
KCE	KCE Structural Engineers. The company selected by the County to perform a structural evaluation of the SSTC.
KCE Report	Report prepared by KCE of their findings dated March 15, 2013.
MOU	Memorandum of Understanding. On this project, it refers to a document called the Silver Spring Technical Plan dated January 26, 2008 found in KCE Exhibit M1 beginning on page 555.
OLO	Montgomery County Office of Legislative Oversight. The report: *Managing the Design and Construction of Public Facilities: A Comparative Review* was developed by the OLO.
O&M	Operations and Maintenance
PB	Parsons Brinckerhoff. The company who designed the SSTC. See also DOR and SEOR.
PT	Post-Tensioned. A technology where cables called tendons are pulled in tension to provide strength for a concrete assembly.
QC	Quality Control. A system of efforts directed at maintaining standards and procedures
RBB	Robert B. Balter Company. The company selected as inspector of the SSTC.
RFF	Rockville Fuel and Feed Co., Inc. A company who provided ready-mixed concrete in the floors of the SSTC. (Some of the concrete in other elements such as walls, columns and foundations were provided by Lafarge Concrete).
RFI	Request for Information. Contractors generate RFIs in order to ask the Design Team a question and obtain written information regarding the project.
R&R	R&R Reinforcing, Inc. The company selected by Facchina to install reinforcing for the SSTC.
SEOR	Structural Engineer of Record. On this project the SEOR was Parsons Brinckerhoff, Inc. See also DOR and EOR.
SI	Special Inspections
SSI	Statement of Special Inspections
Specification	Detailed requirements written in paragraph form that must be satisfied for materials, design, products, or services. In this analysis refers to a specific document as developed by Parsons Brinckerhoff and included in Construction Documents.

SSTC	Silver Spring Transit Center, the subject of this analysis. See the introduction for a description of the facility.
Variance	Alternatives submitted to the original Design Team during the submittal process.
VSL	VSTRUCTURAL LLC. The company selected by Facchina to provide all post-tensioning for the SSTC.
w/c	Ratio of water to cement in concrete. The *w*/c ratio has a significant influence on the strength and durability of concrete.
WMATA	Washington Metropolitan Area Transit Authority. The agency that owns the building site and will provide maintenance and operations for the SSTC.

II. Executive Summary

The Silver Spring Transit Center (SSTC) is a new ground transportation hub in Silver Spring, Maryland. It accommodates bus and taxi movements while loading and unloading passengers, and is located immediately beside an existing station for rail passengers. Bus loops are located on both the ground and second floors, while private vehicles and taxis use the third, smaller level. The second and third levels are made of concrete reinforced with both mild steel reinforcing bars and post-tensioned tendons embedded in the floors to provide strength.

The land upon which the Silver Spring Transit Center is situated has two owners: Montgomery County Maryland and Washington Metropolitan Area Transit Authority (WMATA). Under a formal Memorandum of Understanding (MOU) between Montgomery County and WMATA, Montgomery County is the project owner authorized to take any actions necessary for the successful construction of the SSTC. Under the MOU, upon completion of construction, WMATA is to become the owner and will be responsible for future maintenance and operations. Construction participants also include the Design Team (lead by Parsons Brinckerhoff), the Construction Team (lead by Foulger-Pratt), and the third-party inspector (Robert B. Balter Company).

During construction, small pieces of concrete above a few tendons broke away making the tendons visible and demonstrating that the amount of concrete over the tendons was not sufficient. The series of investigations that followed produced a report by KCE Structural Engineers (KCE) in March of 2013 which identified multiple deficiencies with the Silver Spring Transit Center. Some of the deficiencies result from construction activities that deviate from the design. To correct the deficiencies, a working group was formed to design and implement a remediation plan. At the writing of this analysis, design and implementation of the remediation plan for one of the deficiencies (the pour strips discussed below) had been completed while plans to address other deficiencies are in progress.

This analysis focuses on project controls, those actions intended to prevent problems that result in such deficiencies. The Silver Spring Transit Center project implemented many project controls that if properly designed and implemented should have identified deviations from project plans early enough to allow corrective action during initial construction. In spite of the many controls, some of the deficiencies identified by KCE in the mostly-completed structure were not identified and/or not corrected during construction. This analysis examines available documents to understand the design, implementation and effectiveness of controls implemented during the construction of the SSTC and provides information relating to the activities made by construction participants in conjunction with the deficiencies.

During the course of this analysis we reviewed the Construction Documents, Requests for Information (RFIs) and their responses, Architectural Supplemental Instructions (ASIs), and numerous sketches and field changes. As is typical for construction projects, an Owner's needs are communicated in written form via Specifications and drawings depicting an intended design which directs the creation of document submittals by a Contractor. Typical submittals include concrete mix designs, trade-specific shop drawings, and quality control programs. Submittals are reviewed by the Owner's representative to confirm that needs and design has been correctly interpreted. Coordination between all parties is promoted by requiring meetings before specified events and at specified time intervals.

The three construction deficiencies discussed within this analysis are: the pour strips (narrow sections of concrete floor cast later than adjacent portions of the floors) in which some of the required reinforcing was omitted; the concrete composition, which has lower compressive strength than is required by the Construction Documents; and, concrete placement issues that resulted in slabs of insufficient thickness and with insufficient concrete cover over reinforcing steel and post-tensioned tendons. Controls on post-tensioning were also analyzed. This analysis mentions deficiencies in design cited in the KCE report, such as design stresses related to post-tensioning, but does not specifically examine the design deficiencies cited in the KCE report or the controls intended to identify and correct design deficiencies.

Pour Strips

The SSTC structure includes three pour strips, one on the top level and two on the second level. Both pour strips at the second floor are 10' by 80' rectangles which were purposely installed at least 60 days later than the rest of the floor. KCE found that concrete in one of the second level pour strips has less reinforcing steel than is required by Construction Documents, and neither of the second level pour strips have post-tensioned tendons. This structural deficiency resulted from failure of the reviewers to detect the absence of specified reinforcing steel in shop drawings for one of the pour strips, and failure to question the absence of any drawings for the two pour strips in the post-tensioning shop drawing set.

Construction drawings appear to require post-tensioned tendons in all the pour strips. The absence of post-tensioned tendons in the pour strips is consistent with the absence of post-tensioning shop drawings for the pour strips. The mild steel reinforcing that was detected by KCE coincides with the reinforcing shop drawings. Both sets of shop drawings were created by the Construction Team and reviewed by the Design Team. As a control measure, the manager of the construction quality control plan was required to review each submittal, including shop drawings, and note any variances from the construction drawings, but no differences were noted. Further, the RFI process existed to address any apparent inconsistencies or ambiguities, but that process was not used regarding the pour strips. These controls, as designed, should have been effective, but implementation of these controls failed in regards to the construction of the pour strips.

The shop drawings are among the items that were discussed in a pre-installation conference for post-tensioning. At the time this meeting was held, not all post-tensioned shop drawings were available because on this project the shop drawings were submitted in phases. Having these shop drawings available during the pre-installation conference might have facilitated the work of the reviewers in identifying the differences between the construction drawings and the shop drawings. Phased submissions are not prohibited, but steps were not taken to enable reviewers to clearly understand and track which submittals were outstanding or when delivery of submittals should have been expected.

Concrete Composition

Concrete strength measured by KCE in cores taken from the mostly-completed structure was in many cases considerably less than that of test cylinders collected during construction activities. Concrete properties can be affected by many variables, so many controls were evaluated. Some were found to have functioned largely as intended, such as selection of the concrete's components and vibration of the fresh concrete to remove entrapped air. Other controls suffered from poor implementation, such as not inspecting two of the batch plants or failing to correct a trend of low quantities of entrained air. Slump limits and curing practices met typical industry practice but not the higher standard requested by WMATA. Confusion about where to take samples and about cold weather limits existed that could have been avoided by clearer language in the Specifications. Although the proper records were kept and submitted regarding the amount of water in the concrete mix, KCE testing indicates that in many cases water was added without permission or documentation.

Concrete Placement

The Design Team, Contractor, and Owner moved quickly to resolve the problem of surfacing post-tensioned tendons upon its discovery during construction, so controls on tendon location as implemented at the end of the project are considered to have been effective. However, the issue of slab thickness continued until the project's end even though it was identified about halfway through construction of the floors. Minutes from a meeting which included all parties in November of 2010 note that, "Area around popped tendons was surveyed for slab thickness. Slab came in thin in some areas." Thickness maps of the entire slab surface at both floors that were later created by KCE show how widespread the problem was, even in work completed after the aforementioned meeting. Since controls are supposed to allow corrective action on identified deviations from project plans, the controls on slab thickness were not effective.

Construction records do not document direct measurements of the thickness of the concrete floor slabs. The top surface was given the desired shape based on measurements taken by survey equipment operated while concrete was being placed. Thickness was realized as the difference between formwork position and concrete top surface, and inspectors could not independently check thickness except at the perimeter. This construction method, selected by the Contractor, depended upon his own implementation being correct. No redundant measurements were taken, despite repeated reminders from the engineer of record. Future construction efforts should either utilize a construction method that allows direct measurement of floor thickness so that inspectors can help the Contractor by identifying problems before the concrete is placed, or the inspectors should perform a second, independent survey during construction.

This analysis reviewed records kept during construction to evaluate the controls associated with the three slab deficiencies described above. KCE identified other deficiencies, such as reinforcing bar cover in columns and cracks in beams and girders. Although these deficiencies were not reviewed as part of this analysis, some of the conclusions and recommendations relating to controls for the slab deficiencies will apply to the column, beam and girder deficiencies. "Lessons learned" from the experience of the SSTC construction will improve effectiveness of remedial actions and will benefit both future projects and the ongoing remediation efforts. Table 1 on page 10 summarizes results of the control analysis with regard to the control's design, implementation, and effectiveness.

Table 1

Control	Design	Implementation	Effectiveness
Pour Strips			
RFIs and meetings	no deficiency	no deficiency	not utilized to clarify PT
submittal review	no deficiency	deficient	deficient
pre-installation conference	phased submittals not anticipated	no deficiency	PT shop drawings expected at pour strips but not produced
daily reports	no deficiency	no deficiency	inconsistent follow-up
Concrete Composition			
pumped concrete samples	ambiguous	no deficiency	weakened
batch plant inspections	vague	inconsistent	weakened
concrete mix design	no deficiency	no deficiency	no deficiency
water added at site	no deficiency	no deficiency	KCE petrographic data suggests water additions
slump measurements	inconsistent with WMATA	no deficiency	no deficiency
cold weather curing	inconsistent with WMATA	confusion regarding referenced standard	weakened
surface curing	inconsistent with WMATA	few records	no deficiency
entrapped air	no deficiency	no deficiency	no deficiency
entrained air	no deficiency	QC missing	pump effect unknown
Concrete Placement			
PT tendon placement	no deficiency	deficiency fixed	some popped tendons
steel rebar placement	no deficiency	few records	unknown
floor thickness	no redundant measurements	ineffective, even after deficiencies identified	ineffective
Post Tensioning			
stressing records	no deficiency	no deficiency	no deficiency
concrete stresses	questionable	none documented	ineffective
grout strength	no deficiency	records unavailable	unknown
time to grouting	not specified	inconsistent	unknown except for limited destructive evaluation by KCE
strength at stressing	drawings stricter than Specification	followed the Specification	no impact
age at stressing	no deficiency	late once	no impact

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III. Introduction and Purpose

The Silver Spring Transit Center is located in downtown Silver Spring, Maryland, adjacent to the existing Washington Metropolitan Area Transit Auhorty (WMATA) pasenger rail station. The SSTC's primary purpose is to serve as a bus terminal, but the SSTC also provides accommodations for passenger drop-off and pick-up for private vehicles and taxis. Under a formal Memorandum of Understanding (MOU) between the two owners of the land being used for this project, Montgomery County Maryland and Washington Metropolitan Area Transit Authority (WMATA), Montgomery County is authorized to manage the development and construction of the SSTC. Upon completion of the project and WMATA's acceptance, WMATA will control, operate and maintain the facility.[1]

A contract to construct the SSTC was signed in 2008. During the construction efforts in October 2010, tendons became visible in a completed floor when small pieces of concrete above a few tendons broke away. Concerns about the visible tendons coupled with visible evidence of extensive cracking of concrete prompted immediate review by the entire construction team, as well as an investigation by both present and future owners. Montgomery County ultimately retained the services of KCE Structural Engineers, PC (KCE) to perform a structural evaluation of the SSTC structure and to conduct an extensive document review. KCE prepared a report of their findings dated March 15, 2013 which is herein referred to as 'KCE Report'.

The SSTC is comprised of three floors which are referred to as Levels 305 (sometimes referred to in the KCE report as Level 300), 330, and 350. Level 305 is constructed at ground level while both Levels 330 and 350 are elevated. The SSTC is primarily constructed from reinforced cast-in-place concrete. The elevated floors are constructed from concrete and reinforced with mild steel and post-tensioned (PT) tendons. Post-tensioning is a method of strengthening concrete or other materials with high-strength steel strands or bars, typically referred to as tendons.[2] Concrete posts, beams and girders support the above grade floors. At the East and West ends of the facility on Level 330 there are ten foot wide strips of slab (pour strips) which encompass the full width of the slab and join the adjacent sections to create a continuous surface. The concrete in the pour strips was required to be placed a minimum of sixty days after both adjacent sections of concrete. See Appendix C for drawings showing how the floors were sequenced by the Contractor.

Objectives, Methodology, and Scope

Management actions intended to prevent problems are called project controls. Management of construction requires flexibility since each project is different, but construction managers have found success when they implement systems to control time, cost, scope and quality. Effective controls identify deviations from project plans early enough to allow corrective action. This project implemented many controls, but some of the deficiencies identified by KCE in the mostly-completed structure were not

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[1] Amended and Restated Memorandum of Understanding between Washington Metropolitan Area Transit Authority and Montgomery County Maryland dated September 25, 2008, page 9. (KCE Report, Exhibit M1 pdf page 496).

[2] "What Is Post-Tensioning?" Post-Tensioning Institute, December, 2000.

identified and/or not corrected during construction. Therefore, identification of controls that were omitted, deficient or failed is necessary to avoid repeating mistakes due to misplaced confidence in deficient controls.

This analysis has three objectives:

- to review the construction project controls which were established particular to this project;
- to evaluate control implementation with regards to selected deficiencies; and,
- to identify any controls that were either omitted or ineffective and the causes of such deficiencies.

The methodology used in this analysis is to evaluate records kept during construction beginning with the KCE report including its exhibits and attachments. As specific records are found to be lacking in this primary resource, such records are requested individually. Our knowledge of the construction industry and of structural design is then applied to interpret records and make appropriate recommendations.

This analysis discusses project controls related to three components for which deficiencies are identified in the KCE report. The first component in the scope of this analysis was the pour strips. The investigation performed by KCE identified that the as-built West pour strip on Level 330 does not have temperature and shrinkage reinforcing steel required by Construction Documents and that both as-built pour strips on Level 330 do not have post-tensioning tendons. The second component discussed is the concrete composition. Based on in-situ testing performed by KCE, the cast-in-place concrete in areas of the structure does not meet compressive strength requirements set in the Construction Documents. The third component discussed is concrete placement. The KCE report identified that concrete cover over reinforcing is less than required, and the thickness of the concrete floors does not comply with Construction Documents. Project controls relating to reinforcing cover and thickness of the concrete in the floors are similar, thus, the two deficiencies are addressed in one section.

During the course of this analysis we reviewed the Contract Documents, Requests for Information (RFIs) and their responses, Architectural Supplemental Instructions (ASIs), and numerous sketches and field changes. However, this analysis does not specifically examine the design deficiencies cited in the KCE report or controls intended to identify design deficiencies. The design issues noted by KCE include:

- a lack of coordination during design between elements, such as electrical and other embedded items interfering with reinforcing and post-tensioning, slab geometry and sloping to drains relative to specified slab thickness;
- failure to take into account various required limitations on stress induced during initial post-tensioning;
- induced forces that overbalanced the structure due to post-tensioning forces that exceeded the actual weight of the slabs, beams, and girders, inducing cracks in the structure;
- failure to accommodate the stress caused by restraint forces due to the as-designed integral concrete walls, columns, and girders, which induced cracking in the slabs and in those elements themselves;

- failure to incorporate into the Contract Documents all of the required WMATA Manual of Design Criteria and the WMATA Standards; and,
- under-design of certain elements of the structure to resist shear forces and torsion forces.

IV. SSTC Background and Project Controls

SSTC Background

Within DGS, the Division of Building Design and Construction is responsible for planning, designing, and constructing Montgomery County's public buildings. DGS serves as the Owner during construction of the Project.[3] Preliminary planning for the SSTC began in the 1990's and required the relocation of the neighboring WMATA station before plans could be formalized for the SSTC. Under the terms of the MOU between Montgomery County and WMATA, DGS would lead the construction effort and WMATA would maintain the structure upon construction completion. The MOU required that WMATA design standards be incorporated into the design of the SSTC.

Montgomery County entered into contract with Parsons Brinckerhoff, Inc (formerly known as Parsons Brinkerhoff Quade and Douglas, Inc. and PB Americas, Inc.) in 2004 to design the facility. Herein, this contract is referred to as "Design Contract." Parsons Brinckerhoff, Inc (PB) was/is the Designer of Record (DOR) as well as the Structural Engineer of Record (SEOR) for the project and hired sub-consultants to perform design work associated with other disciplines such as architectural design services.[4] For the SSTC project, the term Architect/Engineer (A/E) refers to PB since they hold the prime design contract with Montgomery County. Per the Montgomery County Contract with PB, the Design Team was required to prepare progress documents for three phases: Schematic, Design Development, and Construction Documents. At each phase, PB was required to submit progress drawings, Specifications, and cost estimates for DGS review, comment, and approval.[5]

Specifications are detailed requirements written in paragraph form that must be satisfied for materials, design, products, or services. For example, specifications include explicit material, composition, and performance requirements for concrete mixes as well as other materials utilized in construction. Specifications also provide direction, expectations, and minimum requirements for all parties involved in the construction process. Specifications are divided into sections with each section focused on one topic or material.[6] Herein, the use of the word "Specification" refers to the specific document developed by PB and incorporated into the Construction Documents.

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[3] In the Construction Contract between Montgomery County and Foulger-Pratt, signatures representing the Owner are those of the director of DGS and of the chief of the Division of Building Design and Construction. (KCE Report, Exhibit M1 pdf page 17).

[4] The Architect of Record, Zimmer Gunsul Frasca Architects LLP (ZGF), performed sub-consulting architectural services for Parsons Brinckerhoff, Inc.

[5] Design Contract, sections 3.3.1.1 and 6.2. (KCE Report, Exhibit M1 pdf pages 146 and 157).

[6] The Specifications are organized into sections that are numbered according to the industry standard called MasterFormat, as set forth by the Construction Specifications Institute. In this system, the prefix number 01 gives general construction direction such as submittal procedures or testing requirements while sections with prefix numbers of 02 through 16 provide information for specific material types.

All construction projects must be designed to the minimum requirements dictated in building codes. Montgomery County has adopted the use of the International Building Code (IBC), which requires compliance with several other standards prepared by independent committees or industry agencies. For example, the American Concrete Institute (ACI) develops the standards for concrete and IBC requires all concrete design to be in conformance with ACI requirements. Another example is the American Society for Testing and Materials (ASTM) which provides standards for test methods, material performance requirements, as well as other recommended guides and best practices. The IBC and those standards referenced by it were utilized by PB in the preparation of the SSTC's design documents. Since specific standards are typically revised and updated over time, the standards referenced during the design were those that were in effect at the time the structure was designed.

The final drawings and Specifications prepared by PB are dated 2008 and are herein called "Construction Documents." These were approved by Montgomery County Department of Permitting Services (DPS) with the issue of a building permit in 2009. DPS enforces standards that control what goes on before, during and after construction through a mandatory permitting process. The Building Construction Division of DPS is responsible for ensuring public safety through the enforcement of construction codes and zoning standards. This is accomplished through engineering plan review and construction inspection related to the administration and enforcement of building, structural, electrical, mechanical, fire-safety, energy conservation, and accessibility codes. DPS is independent from DGS, the county branch that handled construction of the SSTC.[7]

Montgomery County contracted with Foulger-Pratt Contracting, LLC (FP) in 2008 to construct the facility. Herein, this contract is referred to as "Construction Contract" and FP is referred to as "Contractor." The Construction Contract incorporated the Construction Documents developed by PB. As is typical construction procedure, the Specifications required FP to interpret the Construction Documents and prepare trade-specific drawings called shop drawings and to submit product information that communicates FP's intended construction methodology and understanding of the proposed construction.

Specifications require the designer of record (PB) to review and approve the shop drawings and submittals to confirm that FP's intended construction is in conformance with the design intent. Examples of required submittals include FP's intended concrete mix designs as well as their intended quality control (QC) program.

FP subcontracted all concrete-related aspects of the project work to Facchina Construction Company, Inc. (Facchina). Facchina in turn entered into a contract with VSTRUCTURAL LLC (VSL) to provide design, shop drawings, hardware, and on-site consultation for post-tensioned aspects of the concrete work. At the same time, Gerdau Ameristeel provided shop drawings and materials for the mild steel reinforcing aspect of the concrete work. R&R Reinforcing, Inc. (R&R) provided installation for Facchina of both the mild steel reinforcement and the post-tensioning elements. Lafarge Concrete and Rockville Fuel and Feed Co., Inc. (RFF) are the companies that supplied ready mix concrete for the SSTC project.

[7] Row 11 (Cont'd) of undated, tabulated responses by DGS to WMATA comments on the CQC plan submitted by FP says, "It is important to realize that the County is not a monolithic organization. The County team managing this project ... [is] DGS, and they submitted their permit application ... [to] DPS. DGS must satisfy DPS requirements" in order to obtain permission for occupancy.

Montgomery County Special Inspections Program

The building code requires certain inspections for all construction projects. Montgomery County's Special Inspection Program procedures applicable to the SSTC are those required by Montgomery County Building Code, and in accordance with the International Building Code (IBC).

Owners of buildings and structures whose elements are subject to special inspections must submit, as part of the permit application, a Statement of Special Inspections (SSI) prepared by the Structural Engineer of record (SEOR) as a condition for permit issuance and pre-construction meeting. This statement must include a complete list of materials requiring special inspections, the inspections to be performed and a list of the individuals, approved agencies and firms intended to be retained for conducting such inspections.

The Special Inspector (SI) is the registered design professional retained by an owner to provide special inspections and material testing services as specified by appropriate design professionals of record and approved by the DPS. The SI must provide construction observation and testing services of required scope and frequency to offer a professional opinion that the constructed project was built in accordance with the DPS-approved construction documents, and that construction has been tested and inspected in accordance with the SSI and applicable codes and standards. The SI may be an agent of, or independent of the Inspection and Testing agency or the project's SEOR.

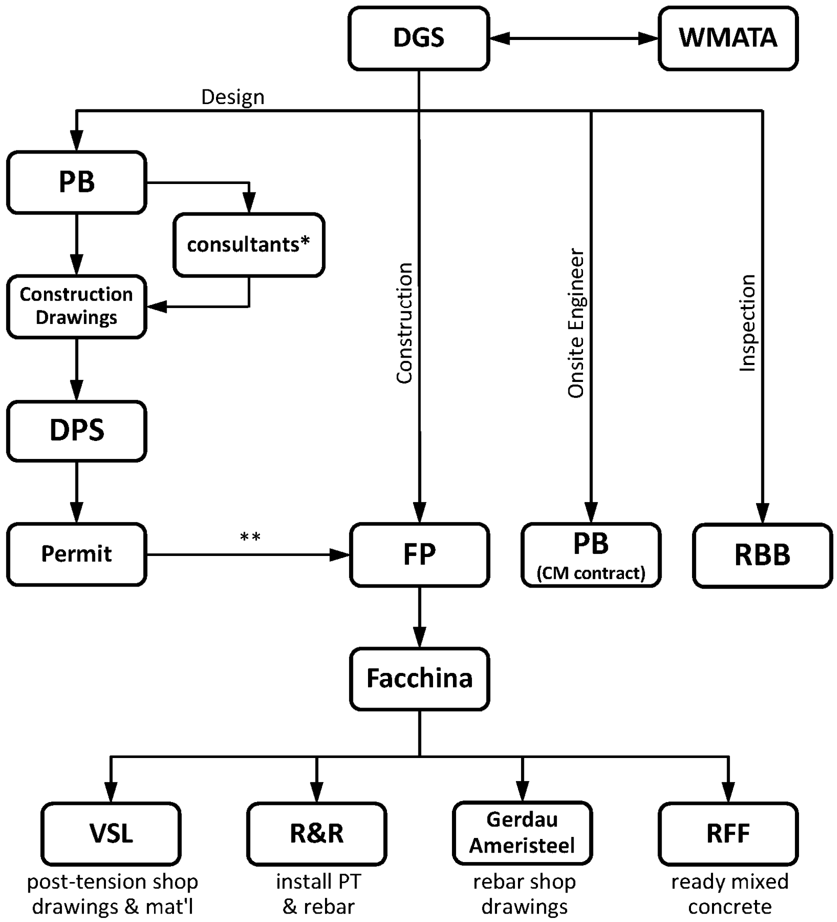
The Special Inspector is required to keep records of specified inspections and testing and is required to furnish specified inspection and test reports to the DPS building official, and to the registered design professionals of record. All discrepancies are required to be brought to the attention of the contractor for correction or, if not corrected, to the attention of the code official and to the registered design professionals of record, as appropriate. Interim reports shall be submitted as required by the special inspection program manual. A Final Report of Special Inspections documenting completion of all required special inspections and correction of documented discrepancies shall be submitted prior to the issuance of an occupancy permit.

Montgomery County contracted with Robert B. Balter Company (RBB) to perform all of the third-party inspections and field testing under the SSI during the construction efforts.[8] Herein, the contract with RBB is referred to as "Inspection Contract."

PB was contracted by Montgomery County in 2009 to provide Construction Project Management Services. Herein, this contract is referred to as "Construction Manager Contract." The Scope of Services for PB indicates that they provide a full-time on-site project engineer to work under the direction of the County's Contract Administrator or his designee, which in this case is DGS.

[8] Contract for Inspection and Materials Testing Services between Montgomery County, Maryland and The Robert B. Balter Company, County Contract No. 6504510207-AA, signed 10/24/2006. (KCE Report, Exhibit M1 pdf page 333-405).

Figure 1 depicts the sequence of some of selected relationships between parties involved in the construction of the SSTC.



*Consultants to PB include Zimmer Gunsul Frasca Architects LLP (ZGF), A B Consultants, Inc., Coastal Resources, Inc., Gallop Corporation, Remline Corporation, Rosborough Communications, Inc., and Staiano Engineering, Inc.

**The Permit was officially granted to DGS. For practical purposes, however, it authorized FP to proceed.

Figure 1 – Sequence of SSTC Relationships

Many project controls are associated with the design and construction of the SSTC. Controls are identified and established via the Design Contract, Construction Contract, Inspection Contract, and the Construction Manager Contract. As is typical for all design and construction efforts, additional project controls are established for the project during permit review.

Quality control programs are required for both PB and FP as established in their respective contracts. Project conferences and the design submittal process are also established in the Design Contract. The Construction Documents generated by PB include Specifications and drawings, both of which are incorporated into the Construction Contract. The Specifications establish minimum project controls that FP is required to execute including document control, daily quality control reports, shop drawing generations and review criteria, inspections, and conferences. The various controls established for the

SSTC relating to the three deficiencies reviewed in the analysis are described more specifically in the following paragraphs.

Design Project Controls

The Design Contract included language requiring PB to execute a Design Quality Control (DQC) program and to initiate early and continuous reviews and coordination with the appropriate government entities for permits and approvals.[9] The Design Contract also required project conferences throughout all phases of the Project including work sessions as required during the submittal review meetings.[10] Phases included Concept, Schematic, Design Development, and Construction Documents. Exhibit A of the Design Contract indicates the required scope of services including requirements per discipline for documents submitted in each phase. Exhibit L of the Design Contract indicates requirements for the DQC, which are summarized in the next paragraph.

PB was required to submit a DQC plan within 30 calendar days after receipt of a Notice to Proceed. The Plan was required to include staff names and qualifications for each person assigned a DQC function including the Design Quality Control Manager who must report directly to a Principal of the firm and have minimum 10 years of experience in architectural or engineering design with 5 of those years involving DQC functions. The plan was also required to include a submittal tracking plan, coordination plan, design review plan, design schedule, and a cost estimate and analysis form. An orientation meeting was required and opportunities were provided throughout the Design Contract duration to reconfirm mutual understanding of the Plan. During the Design Development, Construction Document, and the Construction Bid phases of design, the DQC Manager must maintain the Plan and submit checklists for submittal tracking, coordination, design review, and design schedule. During the Construction Administration Phase, the DQC Manager was required to submit the submittal tracking checklist, a RFI/Issue tracking checklist, and a review of the Critical Path Method schedule and any related General Contractor's claims for delay.[11]

The copy of the DQC program submitted by PB that was provided to this analysis did not show evidence of having been maintained after submission. The DQC plan has staff names, but does not provide qualifications. It includes procedures for tracking documents supplied by third parties, but does not specifically address submittals. The DQC plan describes coordination and design review without identifying design elements. Therefore, the DQC program does not meet many of the requirements given in the Design Contract as explained in the preceding paragraph.

During the course of this analysis we reviewed the Construction Documents, Requests for Information (RFIs) and their responses, Architectural Supplemental Instructions (ASIs), and numerous sketches and field changes. However, this analysis does not specifically examine the design deficiencies cited in the KCE report or controls intended to identify design deficiencies. This analysis reviewed design documents only to determine whether specific requirements were presented for Contractor implementation,

[9] Contract for Architectural/Engineering Services between Montgomery County, Maryland and Parsons Brinckerhoff Quade & Douglas, Inc. for Design of Silver Spring Transit Center, County Contract #4504510121-AA, page 13-14. (KCE Report, Exhibit M1, pdf page 141-142).
[10] ibid, page 21. (KCE Report, Exhibit M1, pdf page 149).
[11] ibid, pages L-1 – L-3

because the deficiencies reviewed stemmed from activities which occurred during construction. Therefore, the controls surrounding design were not directly relevant to the deficiencies. Accordingly, evaluation of the implementation or effectiveness of design controls is not considered within this analysis. Where appropriate, this analysis does include a few recommendations to the designers specifically related to the slab deficiencies.

Construction Project Controls

Designer Controls

Per the Design Contract, PB was obliged to perform one Pre-Construction Conference and attend construction progress meetings on a bi-weekly basis. Emergency field meetings were also required and were to be held at DGS request to resolve urgent problems. Also, the Design Contract required PB to attend any meetings necessary to properly coordinate the design and construction administration effort including without limitation, meetings with government agencies, code officials, and applicable utilities. PB was required to review field coordination and provide written field reports within three working days of each site review.[12]

Montgomery County Personnel

DGS personnel performed many of the tasks typically assigned to a Construction Manager, and had primary responsibility for document control activities and to perform Quality Assurance functions.[13] Quality assurance can be described very briefly as continuously reviewing all operations and auditing all test reports. Quality control, on the other hand, consists of inspecting, testing and checking the products of construction activity. Quality control responsibilities on this project were shared by FP and RBB according to the Test Matrix included in Appendix A.

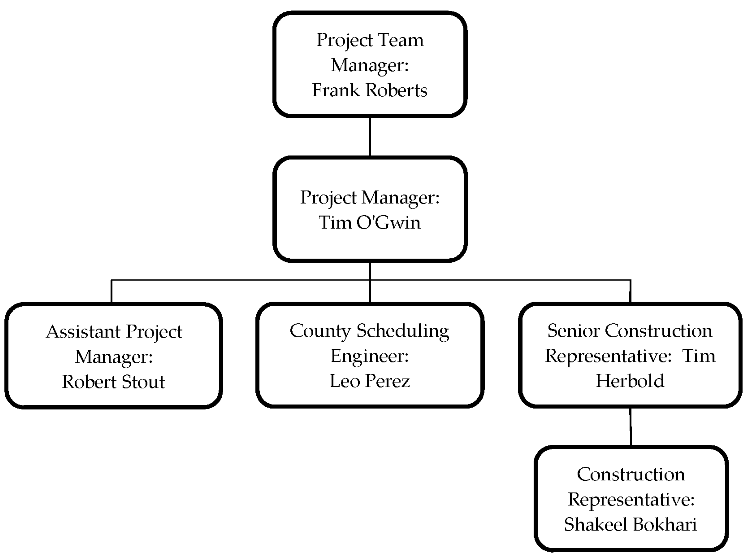


Figure 2 – Organizational Chart of DGS Personnel

[12] ibid, page 21-22. (KCE Report, Exhibit M1, pdf page 149-150)
[13] Foulger Pratt Quality Control Plan Revised Submission 4/17/09; DGS response to question 11

Several DGS personnel were involved in the construction administration of the SSTC. A full description of the duties and functions of each person as provided by DGS can be found in Appendix B. The organization of personnel is summarized in Figure 2 on page 18 and was developed based on duty and function descriptions from Appendix B. The organizational relationships were and continue to be in effect throughout the duration of the construction activities.

Construction Manager

The Construction Management Contract was initiated after construction began to provide on-site construction project management services. The Background section of the Construction Management Contract indicates that during the first part of the construction effort substantial redesign was necessitated by large scale underground utility relocation and several unforeseen conditions. Due to the significant delay relating to the redesign, Montgomery County determined it necessary to have a full-time project engineer from PB's staff on-site to coordinate the redesigns and review process activities.

John Anderson serves the role of onsite project engineer. The scope of services in the Construction Management Contract indicate that Mr. Anderson's responsibilities include coordination of project design activities and issues with various outside agencies, production of required progress reports to outside agencies, coordination of document reviews, documentation and assistance to DGS staff in negotiating Construction Contract changes, identification and resolution of project design issues, participation in progress meetings, and assistance to DGS's Capital Projects Manager and other County personnel with other duties that may be necessary to expedite and assure satisfactory coordination with WMATA and other agencies involved in project.[14]

While the contract with PB was called a Construction Management Contract, responsibilities of Mr. Anderson do not correlate to typical industry Construction Manager roles. Without an independent Construction Manager engaged for the project, DGS was expected to function in the typical CM role, which is described in an industry publication as "conducting periodic progress meetings, document control, cost tracking and management, evaluation of payment requests, change order management, quality management, schedule control, monitoring of Contractor's safety efforts, commissioning and generation of the punchlist."[15] Mr. Anderson was in a support staff position to DGS as they provided construction management. Additional discussion relating to the role of Construction Manager can be found in the *Considerations* section of this analysis.

Contractor Quality Control Plan

Provisions in the Design Contract require PB to include certain quality control provisions in the Construction Documents. These provisions would require the Contractor to submit a Contractor Quality Control (CQC) Plan.[16] Review of the Plan FP submitted indicates that it identifies requirements for personnel organization, document control, RFI procedures, submittal control, testing, phased inspections,

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[14] Agreement for On-Site Project Engineering Services between Montgomery County, Maryland and P.B. Americas, Inc. for On-Site Construction Project Management Services for the Silver Spring Transit Center Contract No. 0363200005-AA, page 2-3. (KCE Report, Exhibit M1, pdf page 298-299)

[15] An Owner's Guide to Project Delivery Methods by the Construction Management Association of America, August 2012, page 15

[16] Contract for Architectural/Engineering Services between Montgomery County, Maryland and Parsons Brinckerhoff Quade & Douglas, Inc. for Design of Silver Spring Transit Center, County Contract #4504510121-AA, page L3 – L-15.

deficiency correction, commissioning, and material handling. Also included in the Plan is the inspection processes including concealed elements of work, special inspections per the Montgomery County Statement of Special Inspections, substantial completion inspections and final inspections. The CQC Plan applies to aspects of the work both on-site and off-site. The primary focus is on the early identification and resolution of potential problems before they impact the project. A more detailed description of the CQC Plan is found in Appendix A.

Shop Drawing & Submittal Review

Per the Specifications in Section 01330.1.4.H, a standard submittal review cycle requires four copies of the shop drawing be submitted from the Contractor to PB. PB keeps one reviewed copy and transmits one copy to the Owner and two copies to the Contractor. During the October 29, 2008 Progress Meeting, a modification to the review cycle was presented, "FPC will distribute submittals to each party, (1 to MC, 3 to WMATA, and 6 to PB). PB will distribute as required for internal review. PB will return submittals to each party (1 to MC, 1 to WMATA, 1 to ZGF, 1 to FPC). FPC's copies will be fedexed unless they are reviewed 2 days prior to a progress meeting which case they will be delivered to the meeting."

A flow chart of the review process is depicted in Figure 3 below.

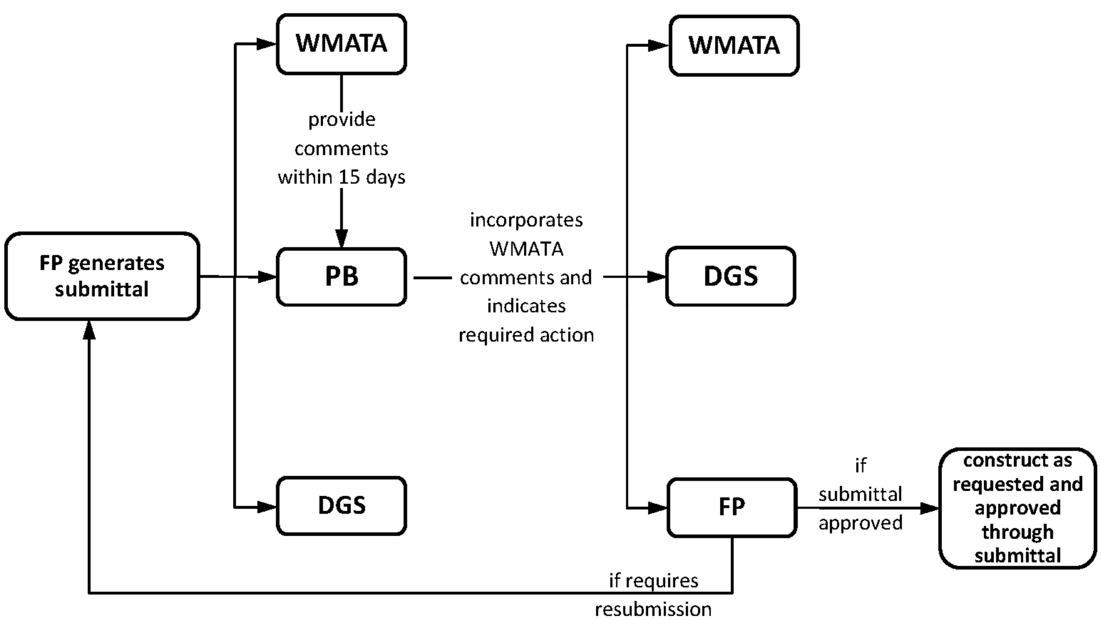

Figure 3 – SSTC Submittal Review Process

Per Specification Section 01330.1.4.G, FP is required to review and approve all submittals for compliance with Construction Documents and field dimensions prior to submission to A/E. FP's approval should be noted on the label or title block. The A/E is required to return any un-reviewed submittal not bearing notation of the Contractor's approval. DORs indicate results of their review of the shop drawings, product data, and samples by use of a rubber stamp, as shown in Figure 4, which usually has some exculpatory language in fine print plus some options which can be exercised by use of check marks. The stamp used by PB provided the options of Approved; Approved as Noted; Return No Action Taken; Revise and Resubmit; and Rejected, See Comments.

PARSONS BRINCKERHOFF
100 South Charles Street
Tower 1, 10th Floor
Baltimore, Maryland 21201-2727

PROJECT.	Silver Spring Transit Center
DIVISION NO.	3
SPECIFICATION NO.	03381
SUBMITTAL NO.	03381 – 011 - 01
DESCRIPTION	Level 330 Partial Pour 1A & 1B Elongation and Effective Force Calculations

APPROVED ☐
APPROVED AS NOTED ☒
(Revise, but no resubmittal required if noted items are modified as indicated.)
RETURN NO ACTION TAKEN ☐
REVISE AND RESUBMIT *(Noted items only. Resubmittal review will be limited to noted items only.)* ☐
REJECTED, SEE COMMENTS ☐

Review is only for general conformance with the design concept of the project and general compliance with the information given in the contract documents. The contractor is responsible for conformation with all requirements of the plans and specifications, including, but not limited to, dimensions which shall be confirmed and correlated at the job site, for information that pertains solely to the fabrication process or to the means, methods, techniques, sequences and procedures of construction, and for coordination of the work of all trades.

BY: Douglas Lang
DATE: 04/12/10

Figure 4 – Representative Submittal Stamp used by PB on the SSTC project

Meetings and Conferences

PB conducted bi-weekly meetings at the Project site as required by Specification 01310.1.7. Copies of minutes from these meetings are included in KCE Exhibit P. Additional meetings were held as required before or after various Definable Features of Work. For instance, a pre-installation conference for post-tensioning is required by Specification 03381.6.E.1-8. This analysis reviewed minutes of the meeting, which was held July 13, 2010. As required, discussion included schedule, onsite storage, structural load limitations, coordination of PT installation drawings, mild reinforcing steel drawings, tolerances, marking and measuring of elongations, submittal of stressing records, and removal of formwork. A pre-installation conference for concrete is required by Specification 03300.1.5J. This analysis reviewed minutes of two such meetings, held April 28, 2010 and August 25, 2010. As required, discussion included mix design and procedures for field quality control, cold and hot weather, finishing and curing.

Testing

Department of Permitting Services

As previously described, the Special Inspections Program for Montgomery County requires Special Inspections (SI) to be performed on projects for verification of compliance of specific items listed on the Statement of Special Inspections (SSI) which is a condition of the building permit. In the SSI, the SEOR identifies those components that require special inspections, and names the inspection and testing agency retained by the owner to perform the inspections. The Inspection Contract required RBB to perform the third-party testing.[17] RBB was required to furnish copies of their inspection reports to the building official at DPS within ten business days of each inspection.

Contractor

Administrative and procedural requirements for quality control and quality assurance are established in the Specifications in Section 01400. The Section requires that FP engage an Independent Testing and Laboratory Agency (different than the one utilized by the Owner) to provide inspection services not specified as Owner's responsibility. The section also references Section 01440, *Contractor's Quality Control (CQC)*, which requires FP to submit a plan for execution of a CQC Program. As contained in Section 01440.3.7, *Tests*, FP is to perform tests to verify control measures are adequate to provide a product conforming to Construction Documents. Contractor required testing is shown herein in the Testing Matrix included in Appendix A.

The Special Inspections Program requires the Contractor to secure and deliver to A/E or its testing agency samples of proposed material which are required to be tested, submit through the testing agency to the A/E the proposed concrete mix design for approval, furnish labor as necessary to obtain and handle samples, advise testing agency in advance of operations for completion of quality tests, and furnish copies of mill test reports of all shipments of cement and reinforcing steel to Architect and testing agency. Based on the documents reviewed, it appears the Contractor provided the appropriate submittals.

Testing Agency

Per the Specifications in Section 03300, *Cast-in-Place Concrete*, Paragraph 3.17 indicates field quality control requirements for concrete work associated with the project. Subparagraph 3.17(A) indicates that the Owner will engage a qualified testing and inspecting agency to perform test and inspections and prepare test reports. Montgomery County entered into the Inspection Contract with RBB in accordance with the Specification requirements. Section C of the Specification Section provides requirements for the concrete testing including how the samples are to be obtained, frequency, which tests to perform on the samples, how the tests are to be performed, how the testing results are to be communicated, what is considered to be acceptable results, and what is required if testing indicates deficiencies. Slump, air content, concrete temperature, and compressive-strength tests are all required to be measured. Direction relating to slump indicates that one test must be performed at point of placement for each composite sample. Direction on location where samples must be obtained is not included for other tests.

[17] Contract for Inspection and Materials Testing Services between Montgomery County, Maryland and The Robert B. Balter Company, County Contract No. 6504510207-AA, page 2. (KCE Report, Exhibit M1 pdf page 336).

For the compressive-strength test, Section 03300 Subparagraph 3.17 (C)(6)(a) requires a test of one set of two laboratory-cured specimens at 7 days and one set of two specimens at 28 days. Additionally, one set of two field-cured specimens are to be tested at 2 days for evaluation of the concrete for acceptability to begin post-tensioning, one set of field specimens to confirm concrete placed in post-tensioned members has reached strength required for completion of stressing, and two cylinders for evaluation at 28 days to compare to laboratory cured cylinders. The tests are to be performed in accordance with ASTM C 39. The number of sets was expanded by mutual agreement during construction to include a set at 56 days.[18]

The Special Inspection Program documentation included in the Inspection Contract includes requirements for testing of cast-in-place concrete as well as other components of a construction project. RBB was required to perform slump tests; fabricating, sorting, transporting, curing, and testing of compression test cylinders; test of fine and coarse aggregate; preparation and distribution of test and other pertinent reports; review of mill test certificates for specification conformance; and report findings to Architect and Contractor. The Program does not require RBB to test reinforcing steel, wire fabric, or mill tests on cement and steel.[19]

Inspections

The Special Inspection Program requires inspectors to hold current certifications by the Maryland Chapter of the American Concrete Institute or the Ready Mix Concrete Producers Technical Committee.[20] Also, the inspectors must have a minimum of five years of experience in test inspection for construction projects of similar scope and size.[21] Per the Specifications in Section 03300, *Cast-in-Place Concrete*, Section 3.17 indicates field quality control requirements for concrete work associated with the project. Section A indicates that the Owner will engage a qualified testing and inspecting agency to perform test and inspections and prepare test reports. Montgomery County initiated the Inspection Contract in accordance with the Specification requirements.

The Special Inspection Program documentation included in Exhibit E of the Inspection Contract includes requirements for inspection of cast-in-place concrete as well as other components of a construction project. Concrete structures require:

- inspection of formwork and reinforcing prior to placement of concrete,
- authorization in writing for the stripping of formwork and reshoring only after the criteria approved by the Structural Engineer of Record (SEOR) is met,
- inspection of the batching tickets and delivery operations for compliance with project Specifications, and
- performance of compression tests.

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[18] Item 4.2 in FP Preinstallation Conference minutes dated 4/28/2010

[19] Contract for Inspection and Materials Testing Services between Montgomery County, Maryland and The Robert B. Balter Company, County Contract No. 6504510207-AA, Exhibit D, page 32. (KCE Report, Exhibit M1 pdf page 366).

[20] ibid, Exhibit D, page 33. (KCE Report, Exhibit M1 pdf page 367).

[21] ibid, Exhibit D, page 28. (KCE Report, Exhibit M1 pdf page 362).

Post-tension concrete structures require:

- inspections of formwork, tendons, and reinforcing prior to placement of concrete,
- inspection of all concrete placement,
- inspection of all tensioning,
- retention of elongation records, and
- provision of permission to Contractor to burn, cut, or cap pre-stressing anchorage only after the criteria approved by SEOR has been met.[22]

The Special Inspection Program documentation included in Exhibit D of the Inspection Contract indicates that inspection of the plant (including batching) of all concrete and field inspection of concrete before, during, and after placement is required. However, the design or inspection of formwork and the supervision of the placing of reinforcing steel are excluded.[23] SSTC Specifications delegate design and implementation of formwork to the Contractor. The third-party inspector RBB was required to inspect the final placement of reinforcing steel, but not the day-to-day operations relating to placement.

Administrative and procedural requirements for quality control and quality assurance are established in the Specifications in Section 01400. The section references Section 01440, *Contractor's Quality Control (CQC)*, which requires FP to submit a plan for execution of a CQC Program. As contained in Section 01440.3.8, *Substantial and Final Completion Inspections*, when work or a designated portion thereof is determined to be substantially complete by FP, then the CQC System Manager shall conduct an inspection of the work and develop a "punch list" of items which do not conform to the approved plans and Specifications. An additional inspection and list is also required at final completion. The Special Inspection Program requires that the Contractor schedule and coordinate the required inspections such that they are conducted and approved prior to proceeding with work.

Considerations

The report *Managing the Design and Construction of Public Facilities: A Comparative Review* (OLO Report) prepared by the Office of Legislative Oversight (OLO) reviewed the management practices used within Montgomery County Government and found that the practices largely align with the models and practices used by other jurisdictions and with "best practice" literature.[24] Elaboration on controls discussed within the OLO Report and the presentation of additional future considerations for project controls are discussed herein.

Construction Manager

The role of a Construction Manager (CM) can vary widely between construction projects so the scope of CM services must be agreed by contract based on the owner's needs. For the SSTC project, DGS had a dedicated staff that performed many duties and functions (see Appendix B). Review of the Construction Manager Contract for SSTC and the project description for the project engineer indicates that PB had a limited role as CM and was engaged after problems arose in order for the Design Team to have addi-

[22] ibid, Exhibit E, page 46-47. (KCE Report, Exhibit M1 pdf page 380-381).
[23] ibid, Exhibit D, page 32. (KCE Report, Exhibit M1 pdf page 366).
[24] Managing the Design and Construction of Public Facilities: A Comparative Review, Office of Legislative Oversight, OLO Report 2013-8, July 30, 2013, page i.

tional field presence during construction. It appears the additional field presence was intended to foster more cohesive lines of communication between the Design Team and DGS field personnel, Contractor, and other agencies involved/impacted by the project such as WMATA or utility providers.

As a clarification, the CM services provided by PB were handled separately from the same company's other roles in this project as DOR and SEOR. A single staff member, John Anderson, was assigned by PB to fulfill their CM contract on the SSTC project. For the duration of CM activities, Mr. Anderson was under the direct supervision of DGS project manager and had no decision making authority.[25] A different PB engineer, Douglas A. Lang, sealed the Construction Documents, reviewed shop drawings and provided site observations as designer's representative.

Examples of duties that, in general, can be handled by the CM are listed by the Construction Management Association of America in its publication Quality Management Guidelines.[26] Of these items, DGS took responsibility for: bid packaging and contracting strategy, permitting, public relations, and project commissioning. Items that were delegated to FP include: master schedule, resource planning, and safety considerations.

Of particular interest are items in which responsibility seems to have been shared between DGS and FP, such as document control, because these items have the potential for contributing to confusion. At the beginning of the project, DGS anticipated having "primary responsibility for document control activities. These activities include tracking and obtaining responses to RFIs, submittals and proposals for extra work from FPC, and maintaining an up-to-date set of Construction Documents."[27] The submittal logs and RFI logs that are included in the record,[28] however, were all contributed by FP. It was also FP who maintained the up-to-date set of Construction Documents.[29]

The lack of clarity in project roles caused comment during review of the CQC submittal. "QA and QC roles and responsibilities are split between [DGS], [RBB], [FP], and [FP]'s subcontractors, and the division seems unclear to WMATA. WMATA doesn't fully understand who is responsible for what. Any confusion regarding roles and responsibilities can lead to lapses and mistakes, so this lack of clarity is troubling."[30] Future projects would benefit from well-defined allocation of responsibility between project participants. Performance of project participants in each area of responsibility could be confirmed by an independent agency carrying out the function of quality assurance. For example, if CM services are obtained by contract from an independent organization, DGS can supervise the CM.

[25] Memorandum dated June 16, 2009 attached to Construction Manager Contract (KCE Report, Exhibit M1, pdf page 309).
[26] Page 6, 2000 edition, section contributor: Darryl Dunn of Construction Dynamics Group, Inc., Allentown, Pennsylvania.
[27] Row 11 (Cont'd) of undated, tabulated responses by DGS to WMATA comments on the CQC plan submitted by FP.
[28] Minutes from numerous PB Construction Progress Meetings (KCE Report, Exhibit series P).
[29] June 14, 2010, email regarding Contract Drawings attached to RBB letter dated August 29, 2012 (for letter see KCE Report, Exhibit Q1, pdf page 3)
[30] Row number 1 of undated comments attached to the CQC plan submitted by FP.

Document Control
FP utilized *Prolog Manager*[31] for RFI tracking and submittal tracking, with such logs usually included in weekly progress meeting minutes.[32] Minutes also include lists of action items, deficiencies, non-conformances, and drawing changes. Revisions were tracked using spreadsheets maintained by FP. Due to the complexity of the project, a drawing log is a necessity to enable the entire project team to use the same version of the Construction Documents. While it is beneficial to the team to have a Contractor who is utilizing the latest edition of construction software, it is equally important for the Owner to have access for use of the same documents.

Web-based software programs such as *Prolog Converge* or *Primavera Contract Management* allow a records custodian to maintain the document database on a real time basis and allow real time access by stake-holders across the project to these documents. In most cases an Owner can set restrictions to access to these documents appropriate. An Owner has the option to request access into the Contractor web-based software (access could be granted as read only) or to maintain their own database which the Contractor utilizes. For future projects, additional control can be obtained through the use of an Owner established web-based construction contract management database which is maintained by the Contractor or CM in order to effectively manage the project's administration, analysis, and reporting.

Shop Drawing Review
The PB approval stamp on shop drawings, such as in Figure 4 on page 21, were typically only applied to the first (top) drawing of each set/batch of submitted shop drawings. Therefore, shop drawings that were not the first drawing in a set/batch do not specifically bear evidence of PB approval, although the PB stamp on the first page does list the other pages that were reviewed. While the application of the stamp on the first drawing does not contradict Specification requirements, confusion may occur as to which version of the drawing is the final, approved drawing. To avoid possible confusion, the requirement of stamping each drawing could be incorporated into either future project specifications or into DGS Special Inspection program. Stamping every drawing in a set is currently being implemented by many engineers in the industry. Additionally with the advent of full size scanners, the loss of manpower due to the repetition of stamping every sheet can be avoided by scanning and printing the shop drawings.

Additional project control can be obtained through the clear communication amongst all parties during the submittal review process. Figure 5 on page 27 depicts a flow chart generally based on the submittal review process implemented by a government agency to clearly define roles and responsibilities within the submittal review process. Generation of a similar flow chart to identify and foster lines of communication may be beneficial to DGS.

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[31] Prolog Manager is a construction project management computer application sold by Meridian Systems, a Trimble Company.
[32] For an example, see PB Construction Progress Meeting #55, February 27, 2011 minutes. (KCE Report, Exhibit P4, pdf pages 10 through 17).

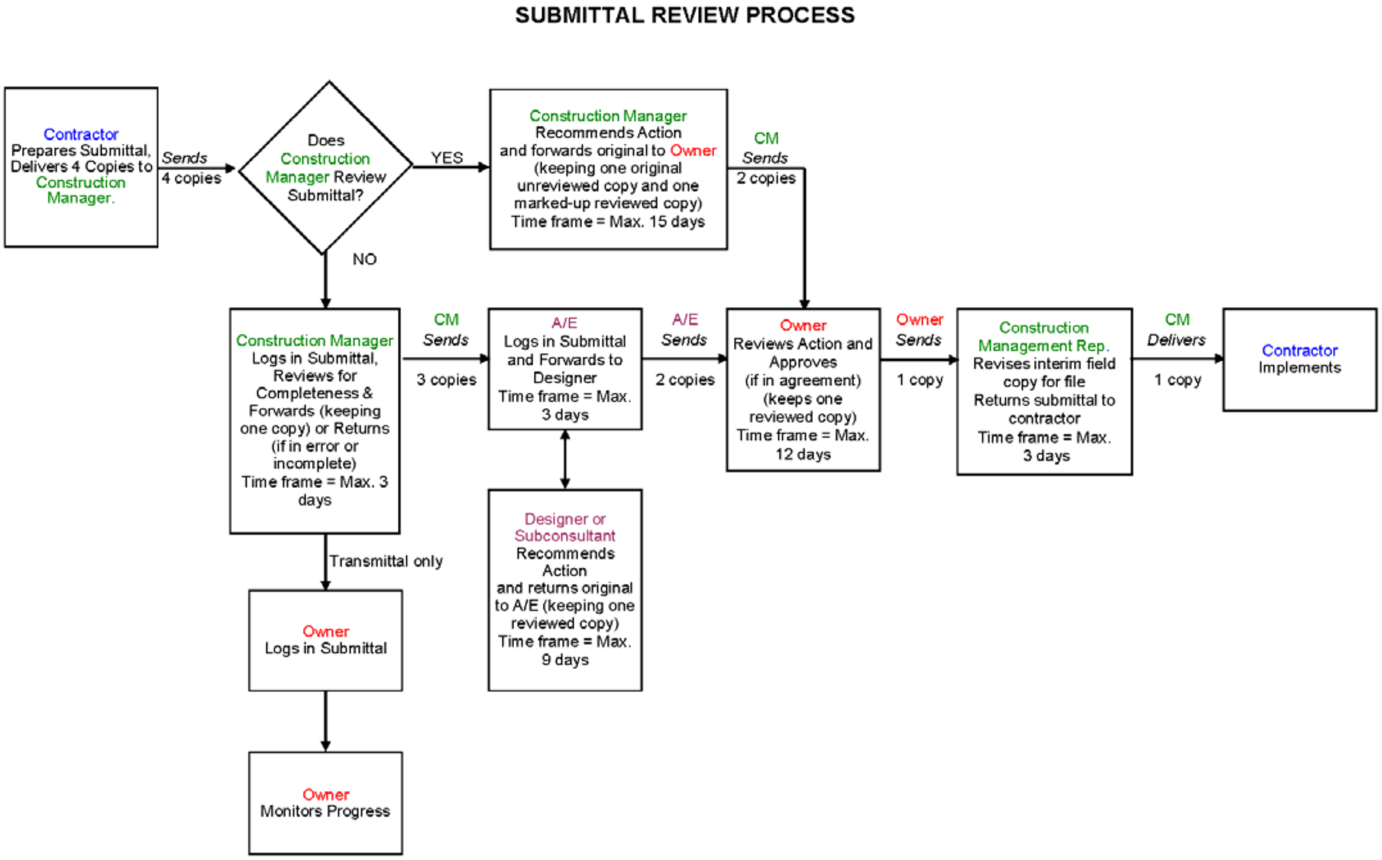

Figure 5 – Representative Federal Agency Submittal Review Process

V. Pour Strips

Deficiency Identified in KCE Report

KCE utilized ground penetrating radar (GPR) to scan the constructed pour strips in order to detect the presence of reinforcing. Two pour strips were required on the 330 level, one at each the east and the west end. One pour strip was required on the shorter 350 level at the east end. The results indicated that neither the east nor the west pour strip on Level 330 was constructed with post-tensioning tendons. Additionally, the west pour strip on Level 330 did not have mild steel reinforcing in the North-South direction.[33] The pour strip constructed on the east end of Level 350 was constructed with both the mild steel reinforcing and post-tensioning tendons.

KCE opined that drawings in the Construction Documents required mild steel and post-tensioning tendons within the pour strips on the 330 level. No explanation has been offered for the missing mild steel, but a response from Facchina to the KCE report stated that VSL disagreed that drawings require

[33] KCE Report, page 46.

post-tensioning tendons in the Level 330 pour strips,[34] and asserts that their shop drawings were intentionally prepared without such tendons. All of the shop drawings submitted by VSL were approved by PB, although no VSL shop drawings were submitted for Level 330 pour strips.[35] A VSL shop drawing, approved by PB, does exist for the pour strip on the 350 level which indicates post-tensioning cables in conformance with Construction Documents.

Shop drawings from VSL were submitted in phases, and each phase had a key plan such as the one in Figure 6, below, to indicate the scope of the shop drawing. It is possible that the shop drawing reviewer expected that shop drawings of the pour strips would be submitted after other shop drawings since these areas would have been poured last; however, none of the key plans in shop drawings submitted by VSL include the pour strip. Facchina asserts that VSL shop drawings identify pour strips containing no post tensioning because of a blank area that is depicted in shop drawing PT-02.[36] The area surrounding the East pour strip is shown in Figure 7 on page 29, which is taken from the same shop drawing page as the sample key plan in Figure 6.

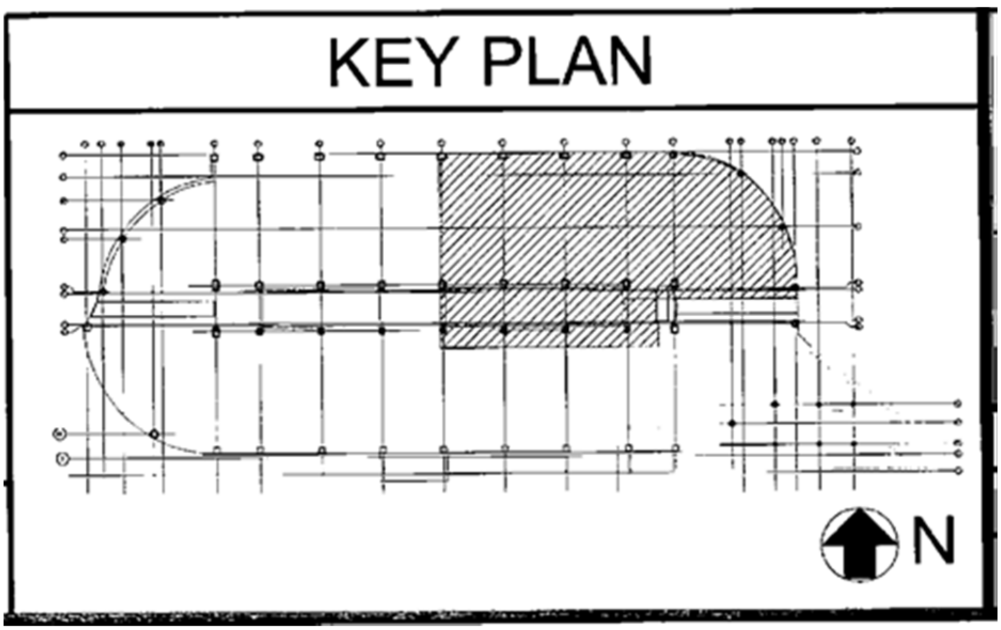

Figure 6 – Representative Key Plan used by VSL on the SSTC project

[34] Facchina letter dated August 30, 2012, item 4, page 2, (KCE Report, Exhibit J3, pdf pages 259).
[35] "Based on a review of our shop drawing files, no post-tensioning shop drawing submittals were provided for the Level 330 delayed pour strip areas." PB letter dated August 24, 2012, page 3 (KCE Report, Exhibit K1, pdf page 70).
[36] Facchina letter dated August 30, 2012, item 6, page 3, (KCE Report, Exhibit J3, pdf pages 260).

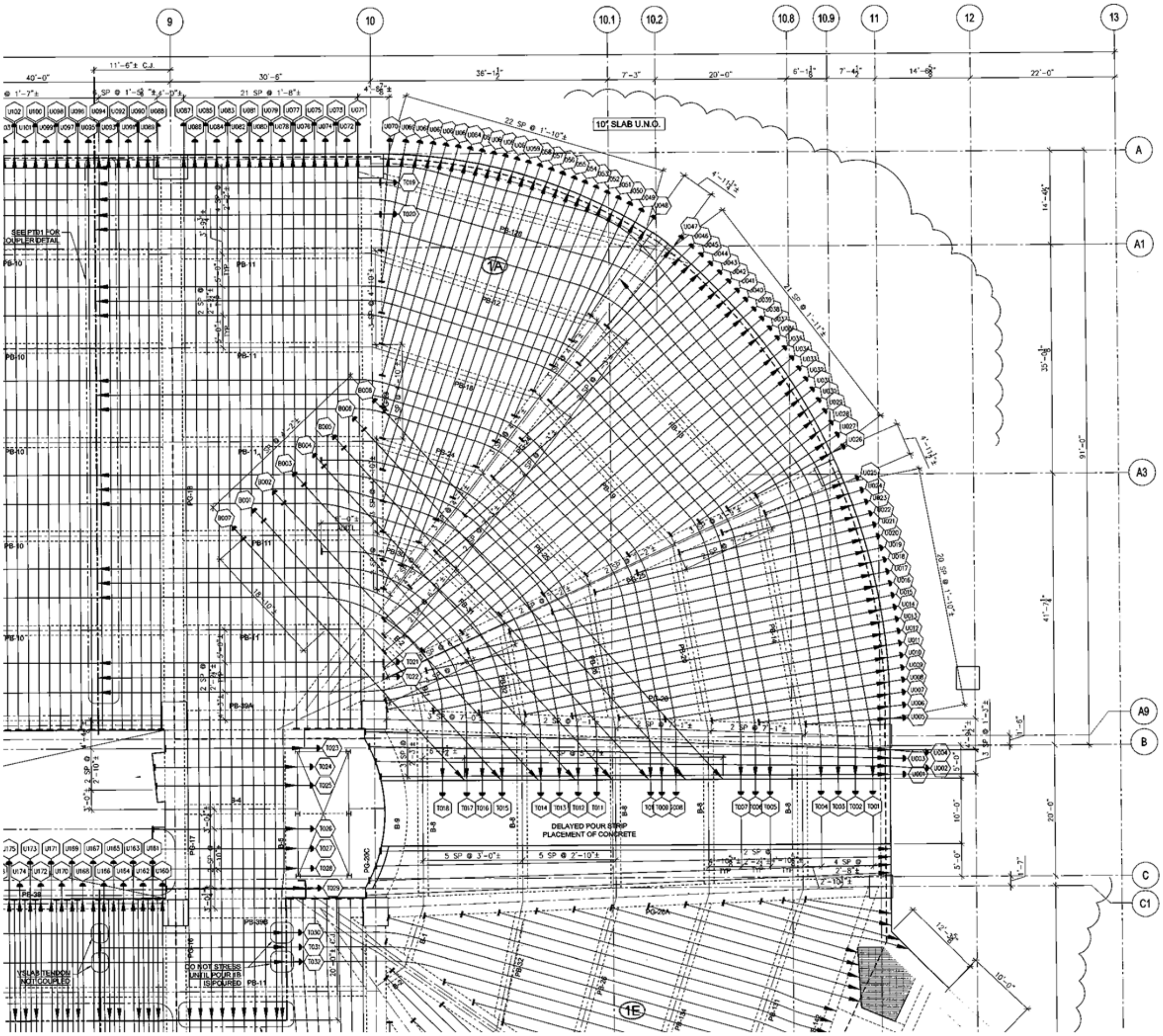

Figure 7 – Portion of VSL shop drawing PT-02

The required extent of post-tensioning is indicated in the Construction Documents using callout notations on drawing S2.01 which reference a schedule. Of the callouts located near pour strips, three are inside the pour strips while nine are located to one side or the other. VSL and FP claimed the variability in callout locations were reasonably interpreted to mean that "drawings did not require the inclusion of PT in the pour strips on level 330."[37] The RFI process, available to address and clarify any interpretation issues, was not utilized.

[37] Letter from Facchina Construction Company to Foulger-Pratt Contracting dated August 30, 2012, Item 4 on pages 2-3 (KCE Report, Exhibit J3, pdf pages 259-260).

Project Control Deficiencies contributing to this defect:

RFIs and Meetings

Questions regarding interpretation of the Construction Documents may be discussed at meetings or answered via the RFI process.[38] If the callout notation for locations of post-tensioning tendons near pour strips was confusing, then FP and their subcontractors had multiple opportunities to ask for clarification. This project utilized regularly scheduled meetings to encourage communication, but the issue of post-tensioning in pour strips at Level 330 was not raised until the KCE Report findings were presented. The methodology surrounding the RFI and meeting process was in conformance with Specification requirements and is typical industry protocol. No deficiencies are noted in design or implementation of project controls for RFIs and meetings. Adequate channels of communication were available to the Contractor, although they were not utilized in regard to pour strip reinforcing.

Submittal Review

The CQC Plan directs that "the QC System Manager will certify contract compliance [of all submittals] or note any variances."[39] The QC System Manager is another name for the CQC Manager that is discussed in Appendix A of this document. In general, submittals are used to coordinate those details of a project that are outside the scope of Construction Documents as well as present the Contractor's understanding of required construction. Design professionals review all submittals in order to check for conformance with the design concept.

In addition to the review by the A/E, this project required FP to "review and approve all submittals for compliance with Construction Documents and field dimensions."[40] The approval stamp from FP states, "This submittal has been reviewed for general compliance with the plans and specifications. This review and the response indicated below do not relieve the subcontractor or supplier of any contract responsibilities including the furnishing of all items required by the documents and the confirmation of all quantities and dimensions." The stamp from Facchina certifies "that the specification requirements have been met and all dimensions, conditions and quantities have been verified as shown and/or as corrected in these drawings."

The PB shop drawing review stamp says, "Review is only for general conformance with the design concept of the project and general compliance with the information given in the construction documents. The Contractor is responsible for conformation with all requirements of the plans and specifications, including, but not limited to, dimensions which shall be confirmed and correlated at the project site, for information that pertains solely to the fabrication process or to the means, methods, techniques, sequences and procedures of construction, and for coordination of the work of all trades." As communicated by these review stamps, shop drawings are considered to integrate all relevant requirements of Construction Documents and are intentionally used to direct construction efforts.

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[38] Item 1.8.A of Specification 01310 reads, "Immediately on discovery of the need for interpretation of the Contract Documents, and if not possible to request interpretation at Project meeting, prepare and submit an RFI in the form specified."

[39] FP Quality Control Plan Revised submitted 4/17/09, item 3.D "Submittal Control," page 11.

[40] Item 1.4.G of Specification 01330

We noted that both mild steel shop drawings and post-tensioning shop drawings were submitted in multiple packages consisting of several drawings each, versus being submitted as one complete package. There is no Construction Contract language or language in the Specifications which prevents FP from submitting the shop drawings for a Definable Feature of Work in multiple submissions. It is possible that phased submission of shop drawings contributed to the reviewers' failure to notice the missing reinforcing and tendons in the pour strips. For future projects, changes to submittal procedures should be implemented to make it less likely that reviewers will fail to notice and correct omissions. For example, requiring a log of anticipated submittals would improve detection of missing items. A requirement that submittals associated with each Definable Feature of Work be delivered in one shipment should also reduce this vulnerability but may not be practical in all cases.

In the case of the pour strips, mild steel reinforcing shop drawings show reinforcing for level 330 in the East/West direction[41] but not in the North/South direction[42] at the west pour strip. At the east pour strip, shop drawings show reinforcing in both the East/West[43] and North/South[44] directions. Mild steel reinforcement in both directions is depicted in pour strip detail 10 of drawing S4.02 in the Construction Documents. All shop drawings by Gerdau Ameristeel bear approval stamps from Facchina and from FP. The shop drawings were approved as noted by PB. Approved shop drawings by Gerdau Ameristeel were used to direct placement of mild steel reinforcing and were also the standard referenced by RBB inspectors.

If the Contractor who prepared the post-tensioning shop drawings believed that post-tensioning should not be included in the pour strips for level 330, the independent review by the QC manager should have highlighted this difference from the Construction Documents and should have flagged it as a variance. Since no variances were noted on the post-tensioning submittal, the CQC manager's initial review was ineffective. The review of post-tensioning shop drawings by PB also failed to detect this difference from the Construction Documents.

The submittal review process was performed in accordance with the Contractor Quality Control Plan, the Specifications and industry practice. Although further control, such as an additional review by another individual, could be implemented to help guard against human error, that is not standard for the industry. Design of the control for submittal review should have been adequate because it required two independent reviews, and both reviews required by the control were implemented, but the control was ineffective in the case of the pour strips because both reviewers failed to notice reinforcing omissions in pour strips and PB failed to request clarification about whether a shop drawing for the pour strips was forthcoming.

It should be noted that one page in the KCE copy of shop drawings still bears the mark "Revise and Resubmit." The page with this notation is Gerdau Ameristeel drawing R30-1A-2,[45] which shows part of

[41] Gerdau Ameristeel drawing R30-1D-1 (KCE Report, Exhibit Y5, pdf page 16).
[42] Gerdau Ameristeel drawing R30-1D-2 (KCE Report, Exhibit Y5, pdf page 17).
[43] Gerdau Ameristeel drawing R30-1E-1 (KCE Report, Exhibit Y5, pdf page 18).
[44] Gerdau Ameristeel drawing R30-1A-2 and R30-1E-2 (KCE Report, Exhibit Y5, pdf pages 13 and 19).
[45] KCE Report, Exhibit Y5, pdf page 13. Revise and Resubmit comment is dated October 7, 2009. A newer version of this drawing with Approved as Noted comment dated March 29, 2010 was provided upon request.

the steel reinforcing in Pour 1A, adjacent to the east pour strip. Normally records should only include approved versions, but this copy was included by KCE because their exhibits were intended to record what was available to inspectors.

Inspections of work in progress based on unapproved drawings can lead to errors in the field. The EOR's comments on this particular drawing did not directly contribute to any of the deficiencies observed by KCE, however an indirect connection could be construed with reinforcing missing from the west pour strip. Only approved drawings should be utilized. FP was responsible for distribution of shop drawings as described in Appendix A. Implementation of document control was deficient in the case of shop drawing R30-1A-2.

Pre-Installation Conference

A pre-installation conference for post-tensioning was held on July 13, 2010 to fulfill the Specification requirements discussed in Section IV of this analysis. The methods and procedures discussed included post-tensioning mobilization (schedule, shop drawings, delivery and storage of materials), placement of reinforcement and tendons in the slab (layout of formwork, rebar sequence, horizontal and vertical tolerances and spacing) , stressing of tendons- inspections and testing (calibration, inspection and installation coordination, stressing sequence and timing, elongation measuring, stressing procedures), grouting of tendon duct (installation methods, testing, grout type), removal of formwork (timing, sequence), and general safety.[46] At the time of the pre-installation meeting, not all shop drawings had been submitted and approved.[47] The shop drawings were submitted prior to each pour rather than submitted as a single package. As a result, the pre-installation conference for the post-tensioning in its entirety was held prior to approval of all shop drawings in their entirety. It is preferable that when practicable, all submittals associated with a Definable Feature of Work be submitted in one shipment prior to pre-installation meetings. If the Definable Feature of Work is extensive, then at a minimum a log of anticipated submittals should be generated and reviewed at the pre-installation conference.

Daily Reports

Daily reports do not mention any anomalies prior to placement of concrete in the pour strips. The Level 330 east pour strip was poured on January 12, 2011. The FP daily report from this date mentions "pour strip between pours 1A & 1E" as work performed by Facchina.[48] In advance of the concrete pour, the FP daily report on January 11 has no mention of any preparatory meetings or discussions between FP and Facchina. The RBB daily report for January 12 noted that "Facchina placed approx. 50 cy of 8000 psi concrete for pour strip between concrete deck pour 1A and 1E."[49]

The Level 330 west pour strip was poured on April 19, 2011, and available evidence makes clear that the Contractor and sub-contractors were not aware of the deficiencies. Neither the FP daily report nor the RBB daily report mention any concerns or deficiencies on the day of this concrete pour, while the April 18 report notes that "Facchina worked on cleaning and finishing up installing reinforcing steel for

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[46] SSTC Preparatory Meeting and Preinstallation Conference Meeting Minutes, 7/13/10. (KCE Report, Exhibit Q1, pdf page 7)
[47] SSTC Preparatory Meeting and Preinstallation Conference Meeting Minutes, 7/13/10, Item 4.2. (KCE Report, Exhibit Q1, page 10.)
[48] FP Daily CQC Report dated January 11, 2011 (KCE Report, Exhibit A4, pdf page 231).
[49] RBB Daily Report by John Welk, 1/12/11. (KCE Report, Exhibit B5, pdf page 83).

concrete pour strip area 330 between concrete deck pours 1H and 1D. A final inspection was done for the pour strip area and it was approved for concrete placement tomorrow 4-19-11 (Tues)."[50]

The quality control plan for this project includes the following list of instructions for deficiencies:[51]

> Upon determination during any course of the work, or during any part of the three phased CQC Inspection Process of the existence of a deficiency the following procedures will be followed:
>
> - Identification and documentation of the noted deficiency in the Contract Compliance Notice Log.
> - Review of deficiency with Subcontractor or Supplier party to the deficiency.
> - Investigation of the cause of the nonconforming work. Documentation of any significant findings.
> - Determination and documentation of corrective action.
> - Coordination and/or approval of corrective action as needed with Architect, Engineer, and/or Owner.
> - Develop, implement and document procedures and/or controls to prevent recurrence by having a new Initial Phase Inspection, re-inspection to confirm and document adequacy of corrective measures.

The above project control was not activated with regard to the pour strips because available evidence indicates that the team believed that the mild steel layout indicated in the shop drawings was correct. Workers and inspectors also had no reason to believe that there was post-tensioning required to be installed in the pour strip since post tensioning shop drawings did not exist. A comparison might be made with the Level 350 pour strip, for which post tensioning was provided. Although the three pour strips, two on Level 330 and one on Level 350, serve the same function and were built and inspected by some of the same people, the width of the upper pour strip and the configuration of supporting girders are different. SSTC is a complicated and unique project, so workers and inspectors would not have been guided by intuition or experience. VSL, who has experience in similar structures,[52] had to resubmit many of their shop drawings after review by PB due to the complexity of the project. Therefore, no deficiencies are noted in controls on daily reporting with regard to pour strips. However, some issues noted in RBB daily reports are not documented to have received follow up. See the section of this analysis that discusses unhydrated cement for more details.

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[50] RBB Daily Report by John Welk, 4/18/11. (KCE Report, Exhibit B6, pdf page 66).
[51] FP Quality Control Plan Revised submitted 4/17/09, item 3.F "Phased Inspection and Deficiency Control," pages 14-15.
[52] Facchina letter dated August 30, 2012, item 2, page 2, (KCE Report, Exhibit J3, pdf pages 259).

VI. Concrete Composition

Deficiencies Identified in KCE Report

Based on in-situ sampling and testing performed by KCE, the concrete within the SSTC structure has several deficiencies:

- First, the concrete in some areas of the floors has lower compressive strength than required by Construction Documents. The compressive strength is also lower than that reported by construction period testing and sampling.
- Second, petrographic analysis of coring samples taken by KCE indicates between 5-12% of the Portland cement and 16-18% of the slag was unhydrated.
- Third, petrographic analysis of coring samples taken by KCE indicates the presence of entrapped air.

Lower compressive strength than is required by Construction Documents contributes to an inability of the structure to support the intended loading. The deficiencies noted in the concrete composition also provide evidence of concrete that had not gained sufficient strength at the time stressing of post-tensioning tendons occurred, which contributed to the excessive cracking visible in the slabs, beams and girders.

Compressive Strength

KCE documentation includes results of laboratory testing of concrete sample cylinders obtained by RBB during concrete pouring operations,[53] which show that concrete compressive strength was tested per the Specification requirements during construction. The documents reflecting RBB laboratory test results indicate that the strength of the laboratory specimens exceeds the minimum value required in Construction Documents.

However, results of the tests performed by KCE on the samples taken from the in-situ concrete forming the floors are less than required in the Construction Documents.[54] The concrete compressive strength test results on the samples obtained by KCE also show considerable variance, indicating to KCE that quality control was insufficient.[55] Discussion of the project controls relating to several aspects of concrete quality follows.

Project Control Deficiencies

Pumped Concrete Samples

The purpose of a concrete pump is to move fresh concrete via hose from the truck chute (near the pump hopper, at a fixed location) to the hose end, which may be easily moved as needed and is typically a great distance away from the delivery truck. Through the use of a pump, all delivery trucks can unload at one location and the concrete is efficiently distributed throughout the project. In order for the concrete to

[53] KCE Exhibits R1 through R4.
[54] KCE report, Table 4, page 40.
[55] ibid, page 26.

move easily through the pump, lower viscosity helps as long as the concrete remains cohesive. Therefore, it is not uncommon for workers to add water or chemical admixtures which improve these properties. Excessive water in the mix has performance ramifications and should, therefore, be monitored closely.

Review of project documentation relating to the location where sample cylinders were to be created when concrete is pumped indicated contradiction and ambiguity. The Inspection Contract[56] and the Statement of Special Inspection indicate that the sampling location should be the point of placement, which, during pumping operations, is the discharge end of the hose. This does not agree with industry guidance from ASTM. Specification section 03300.1.5.B references ASTM C 94 and that standard states that slump samples should be taken from the point of delivery, which is the truck chute.

Meeting minutes from July 2010 indicate that the question was discussed during the pre-installation conference[57] and at some point soon after RBB was directed to make a limited number of comparison cylinders at the end of the concrete pump hose while conducting the majority of testing at the truck chute.[58] The minutes do not indicate who directed that course of action or why that direction was given.

Taking most of the samples at the truck chute increased the risk that the concrete samples taken would not be representative of the in-situ concrete. Since the contradiction between standards and Specifications was raised in the appropriate forum, and since RBB documents indicate that testing followed the protocol established therein, the control was implemented as directed. However, the control was weakened and failed to fully achieve its purpose. The design of this control should be clarified so that future projects require testing at the point of placement, because air content and other properties can change during pumping.

Inspection of Batch Plants

RFF provided the concrete for the floors from two of their batch plants.[59] Batch plants are the location where the components of concrete are dispensed into a ready mixed concrete truck. Batch plant inspections are required as indicated in Section IV of this analysis. There are no specifics given as to what items at the batch plant should be inspected. Inspections do not attempt to confirm the accuracy or calibration of measurement devices used at the plant. Rather they are intended to confirm setup and maintenance in accordance with industry standards and project specifications. An industry publication says, "While the professional inspection does add to cost, the continuing education of the suppliers and concrete subcontractors in the areas of quality control should ultimately create better concretes of all strengths and result in better and more economical use of materials."[60]

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[56] Contract for Inspection and Materials Testing Services between Montgomery County, Maryland and The Robert B. Balter Company, County Contract No. 6504510207-AA, Exhibit D, page 34. (KCE Report, Exhibit M1, pdf page 368).
[57] SSTC Preparatory Meeting and Preinstallation Conference Meeting Minutes, 7/13/10. (KCE Report, Exhibit Q1, pdf page 9).
[58] RBB Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, page 7. "As directed by Montgomery County and as agreed to by WMATA and PB at the pre-pour meeting, [RBB] cast sets of 6 'comparison' cylinders on the deck at the end of the concrete pump hose."
[59] Item 1.8 in FP minutes reads "concrete will be shipped from both Rockville plant and the College Park plant," Preparatory Meeting 8/25/2010 regarding 03300 Concrete Placement Methods, Logistics, and Testing
[60] ACI publication number 363-R92 section 7.6, page 43.

RBB inspected the batch plant at Lafarge concrete in May of 2010,[61] but batch plants belonging to RFF were never inspected.[62] PB meeting minutes from July of 2010 note that "concrete plant inspection can occur anytime, [DGS] and [RBB] to coordinate a time."[63] Based on available documentation, the inspection was not performed. The project control to inspect concrete batch plants was vague and was not consistently implemented.

Batch plants owned by RFF are certified by the National Ready Mix Concrete Association.[64] Certification indicates that the batch plant maintains a documented quality management system and has been audited by a third party independent of the batch plant. Aggregate moisture content is measured at least once per each day of production and water addition to batches is adjusted accordingly. Measuring devices on truck water tanks may be either sight gages accurate to ±1 gallon or water meters accurate to ±2%. Procedures for verifying accuracy of measuring devices are described in the company's quality manual. Certification of RFF batch plants does not replace the inspection required by Specifications, but shows that the concrete producer is in accordance with industry standard quality control measures.

Concrete Mix Design

Concrete is a mixture of Portland cement, water, aggregates, and admixtures. Combining water with cement initiates a chemical reaction called hydration where the cement turns to paste and, in effect, glues the aggregate together. The quantity of each component affects performance, so mixture formulations must be customized to each application. Construction Documents give the required performance and mandate that FP submit proposed mixes for PB review approval. The mix designs for each application were submitted early in the project and discussed often at progress meetings.[65]

The concrete mix design used for the floors was identified on submittals and batch tickets as 8K2DC2NL. The mix submittal was revised to address comments made by both PB and WMATA, after which it was approved by PB. A modification of admixture quantities submitted by FP was approved separately by PB. Since the mix was reviewed and approved by all parties required by Construction Documents and according to industry practice, no deficiency is evident in implementation or design of the control for approval of the concrete mix design.

Water to Cement Ratio

The ratio of water to cement (*w*/*c*) in concrete has a great influences on concrete's behavior. A low water to cement ratio yields a stronger, more durable mixture while a greater value allows for easier flow and placement. KCE tested the *w*/*c* ratio in hardened samples taken from the in-situ concrete and tabulated the results in the KCE Report.[66] Values for *w*/*c* ratio are expressed as a range or with a tolerance because

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[61] RBB Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, pages 168-169.

[62] RBB Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, page 8. "[RBB] requested inspection of Rockville Fuel and Feed's plant several times, but authorization was never granted."

[63] PB Construction Progress Meeting #43, July 15, 2010 minutes. (KCE Report, Exhibit P3, pdf page 196). Item 3.1 of FP Preinstallation Conference minutes dated April 28, 2010 is similar and reads, "Mike Bailey indicated there is a requirement for [RBB] to inspect the concrete plant. John Hershey indicated any of us could call and come by anytime."

[64] Certificates from NRMCA were submitted with Concrete Mix Design Submittal. (KCE Report, Exhibit V1, pdf pages 73-74).

[65] Minutes from various PB Construction Progress Meetings. (KCE Report, Exhibit P2, pdf pages 29, 105, item 18.2 on pdf pages 154, 190 and 234),

[66] KCE Report, Table 3, page 40.

they are estimates which are made based on evaluation of polished samples under microscopes.[67] An article in the ASTM Journal found that petrography estimates are routinely accepted by the concrete industry.[68] That same article gave four different methods upon which such estimates can be based, and said there are few studies that can attest to the accuracy of the *w/c* ratio estimates. In all cases the *w/c* ratio reported by KCE exceeds the value approved in the mix design. The petrographic test results together with compressive strength test results suggest that water was added to the mixture without documentation.

Motives for adding water to the mixture include pump protection and workability during placement. The *w/c* ratio of fresh concrete cannot be directly tested, so the quantity of water added is controlled via records from both the batch plant and the project site. These records are intended to control the three locations where water can typically be added to concrete mixtures: at the batch plant, in the delivery truck, or at the pump hopper.

Batch plants measure how much of each ingredient is used in every load, and a computer records these quantities on the delivery ticket. The amount of water already present in wet sand or gravel is subtracted from the amount of plain water provided. Often, batch plants purposefully provide less than the full amount of water so that this "withheld" or "holdback" water can be added later to fine-tune consistency. The lower right-hand corner of RFF delivery tickets indicates the amount of withheld water, which is the maximum amount that is supposed to be added to the mixture at the project site. An example concrete batch ticket is included in Appendix E – Sample Reports.

Ready mixed concrete trucks have a water reservoir used for cleanup which also provides water for adjusting mixture consistency. The truck driver can dispense water into the mixer drum at the touch of a button, which the driver is only supposed to do when authorized by the appropriate person. Available documents do not clearly identify who was responsible for providing such authorization. KCE says "it is generally the concrete superintendent" who determines if water is to be added (KCE Report, page 20). RBB asserts that "the QC manager from [Facchina] directed the water to be added."[69] We were unable to determine from documents reviewed whether or not all parties at the time of construction were aware who had the authority to direct additive amounts.

Water meters on delivery trucks can range in simplicity from a clear tube mounted beside the water tank to a digital meter mounted on the pipe leading to the mixer drum. This project used the clear tube type of water level indicators. Field reports from RBB indicate how much water they observed being added to the concrete mixture at the project site. A comparison of this number with the amount of withheld water indicates that documented water additions at the project site were not in excess of allowed amounts on

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[67] "The water/cement ratio of the concrete was estimated by viewing a thin section of the concrete under an Olympus BH-2 polarizing microscope at magnification up to 1000x. Thin section analysis was performed in accordance with APS Standard Operating Procedure 00 LAB 013, 'Determining the Water/Cement of Portland Cement Concrete, APS method.' The samples are first highly polished, then epoxied to a glass slide. The excess sample is cut from the glass and the slide is polished until the concrete reaches 25 microns or less in thickness." American Petrographic Services, Inc. report dated October 29, 2012, page 4 (KCE Report, Attachment 47, pdf page 127).

[68] Erlin, Bernard (2006). "Catching the Elusive Water-Cement Ratio Using Petrographic Methods—and Their Evaluation." *Journal of ASTM International*, Volume 5, Issue 7.

[69] RBB Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, page 7.

loads for which records exist. However records exist for only one in five trucks. It is assumed that batch tickets for other trucks were discarded after review by RBB. It is helpful to retain all batch tickets through completion of the project so that project records are complete. This is not standard practice, but easily implemented for future projects.

RBB asserts that they also monitored "loads which were not sampled, to observe that the amount added did not exceed the holdback amount."[70] The inspector recorded the amount of water he observed to be added, so control of water additions to concrete mixes was implemented according to Specifications. However, water additions by truck drivers can occur unnoticed by the inspector. Therefore, the design of this control could be improved in future projects by specifying the use of meters on the water lines that lead to mixer drums, not just level indicators on the water tank (which can also be used for cleaning purposes). This is practical, and sometimes happens, although it is not yet standard.

Water additions at the pump hopper are not mentioned in the project documents, either to confirm or refute this practice. Any water additions at the pump hopper would likely have been observed by the RBB inspectors stationed nearby. Since these inspectors were confirming that water additions did not exceed holdback amounts (as asserted above), it is expected they would have objected to such a practice. The water additions implied by KCE's petrographic evaluation are approximately 10 gallons per cubic yard of concrete.[71] It is highly unlikely that such a quantity could have been added at the pump hopper without notice, or that such a quantity could be thoroughly mixed into the fresh concrete by the pump.

Water is sometimes added to the concrete surface during finishing. A soft surface layer[72] was noted by KCE petrographers in some cores,[73] so water additions at the concrete surface may be one explanation for the occurrence of a soft surface layer. However, it is possible for water to "bleed" to the surface of fresh concrete, and such bleed water may explain the soft surface layer. Adding water during concrete finishing is never recommended because it decreases the durability of the surface layer. The addition of water at the surface during finishing was discussed and declared unacceptable during the preconstruction meeting.[74] Concrete finishing includes the processes called screeding (which removes concrete from high areas and fills in low areas), floating (which embeds large aggregate and moves a small amount of cement paste upward) and either troweling or brooming (which provide a smooth or textured surface, respectively). Finishing operations do not deeply stir the concrete, so water additions at the surface would not explain the *w/c* ratio found by KCE inside the concrete slabs.

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[70] RBB Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, page 6.

[71] As shown on the RFF delivery ticket in Appendix D, the design W/(C+P) ratio was 0.26 and the design quantity of water at this ratio was 31.0 gallons per cubic yard. To reach a ratio of 0.35 (the low end of the range reported by KCE), water content would have to be: (31 gallons) x (0.35) / (0.26) = (41 gallons), a 10 gallon per cubic yard increase.

[72] "The immediate top surface of the core samples is soft and easily removed rendering the surface lacking sufficient wear resistant. The inferior paste properties observed surficially can be attributed to an elevated water-cementitious materials ratio, possibly [due to] applied water." Universal Construction Testing, Ltd. report dated February 19, 2013, page 3 of 65 (KCE Report, Attachment 51, pdf page 214).

[73] "The water/binder ratio was approximately 0.35, but the 0.40 to 0.45 near the top surface which indicated more water at the surface which could be a sign of re-tempering." RJ Lee Group report dated December 4, 2012, page 6 of 19 (KCE Report, Attachment 51, pdf page 393).

[74] Item 2.3 in FP minutes reads "No water used to aid in finishing. Eucobar finishing aid is approved," Preparatory Meeting 8/25/2010 regarding 03300 Concrete Placement Methods, Logistics, and Testing.

Water additions without documentation are implied by KCE, who writes:[75]

> We also believe the .24-.26 range [of *w/c* ratio] is not consistent with the slumps as RBB reported, presumably after a high range water reducer was added per the approved mix design. In fact if the water/cement ratio was .24-.26, it is our opinion the concrete would have been very difficult to pump and even harder to finish and would not have permitted complete hydration to occur.

Slump Measurements

The slump test is used on fresh concrete mixtures to measure workability. Slump measurements are influenced by mixture proportions, water content, and admixtures. Water-reducing admixture WRDA 35 and superplasticizer EXP 950 were approved on this job,[76] and the quantity of each admixture added at the batching plant was recorded under rows labeled WRDA and SUPER, respectively, in the RFF delivery tickets (see Appendix E – Sample Reports). A low slump value indicates a stiff mixture while higher values correspond to thinner mixtures. Slump measurement values were recorded by RBB once for every 50 cubic yards, in accordance with Construction Document requirements. The approved submittal limits slump to 8 inches, and slumps were consistently within the range of 7 and 8 inches at slab pours. Since documents indicate that slump limits are in accordance with the approved submittal, no deficiency in control implementation relating to slump is noted. However, WMATA Specifications limit slump to 2 – 4 inches[77] so the design of this control was inconsistent with WMATA requirements.

Unhydrated Cement

If concrete does cure not properly, cement in the mixture can remain unhydrated (uncombined with water). Portland cement must combine with water in order to bind the other components together. Ground blast-furnace slag (an industrial byproduct that improves the strength and quality of concrete) was combined with Portland cement on this job, so the term "cementitious materials" is used to refer to all active ingredients. The presence of unhydrated cementitious material is attributed by KCE to delayed placement and/or early removal of thermal protection during cold weather.[78] The paragraphs that follow discuss these ideas and present another possible source of unhydrated cementitious material.

Ambient temperature affects the chemical reaction between cement and water; therefore newly placed concrete needs protection during cold weather. Cold weather is defined as a period when the average of expected daily high and low temperatures falls below 40°F for three successive days. Specifications provide limits on the temperature of delivered concrete and on surface temperatures for the next several days. Documents indicate that these limits were not clear to project participants[79] since the Specifications reference ACI 306.1 for such limits. Photocopies attached to the cold weather meeting minutes are taken from ACI 306R, the Guide to Cold Weather Concreting rather than the Specification for Cold Weather Concreting. Tables in ACI 306R repeat some of the limits given in ACI 306.1, but other requirements are

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[75] KCE Report, page 22.

[76] Concrete Mix Design Submittal, (KCE Report, Exhibit V1 pages 25 and 27).

[77] WMATA specification 03300 section 3.02 C.1.c (KCE Report, Exhibit E1, pdf page 1115).

[78] KCE Report, pages 23-25.

[79] Item 4.1 of FP preparatory meeting 03300 Cold Weather Concrete minutes dated 11/4/2010 reads, "Facchina believed the cold weather protection requirement to be 3 days. Subsequent research of ACI leads the group to believe that 3 days cold weather cure time is proper."

not duplicated. Some details of cold weather protection were affected by this confusion in document retrieval, resulting in incorrect implementation of the cold weather project control as discussed below.

Cold weather specification ACI 306.1 sets minimum surface temperature at 55°F while concrete is protected, and also notes that temperature of fresh concrete is not to exceed the minimum by more than 20°F. WMATA Specifications provide for a minimum surface temperature of 55°F, with no upper limit. Cold weather protection measures required by the Specifications were implemented by the Contractor for eight of the floor pours. Plastic sheeting and blankets were placed on top surfaces just after the concrete was poured, and the area below the pour was enclosed and heated. RBB monitored concrete surface high and low temperatures at several locations. Based on RBB temperature readings,[80] lower limits were frequently exceeded in the days following placement of concrete for the floors. It may be that none of the parties who reviewed RBB's daily reports to DGS noticed that temperatures were outside of the range allowed by the referenced standard.

Prevention of sudden temperature changes is also the reason for another limit in both ACI and WMATA Specifications. ACI 306.1 Table 3.2.1 requires a gradual decrease in surface temperature limited to 50 degrees per day, while WMATA Specifications limit temperature drop to 20°F per day. A gradual decrease in surface temperature cannot be confirmed on this project since RBB did not monitor concrete temperatures after area heat was discontinued,[81] which typically occurred after 3 days. Three days is the minimum thermal protection period required by ACI 306.1 Section 3.4.4, while WMATA Specifications require that curing protection should last 7 days.[82]

Controls for cold weather concrete as designed were less restrictive than WMATA Specifications. This project should have clearly conveyed temperature limits during cold weather curing, and the duration of these limits should have been coordinated with those set by WMATA. The Contractor should have procedures for correcting any temperatures that were outside of these limits. The Construction Manager should have taken action when temperatures measured by their Inspector exceeded project limits.

Another potential source of unhydrated cementitious material is drying. To limit water loss during concrete finishing operations, Specification 03300 3.13.B indicates that evaporation retarding chemicals be applied when "hot, dry, or windy conditions cause moisture loss approaching 0.2 pounds per square foot per hour." RBB asserts that evaporation retarding chemicals were used as specified,[83] although RBB daily reports do not discuss this topic. Eucobar, an evaporation retardant, was discussed before concrete placement,[84] and a representative from Eucobar visited the project.[85] After concrete finishing, Specification 03300 3.13.E requires one of three methods to prevent moisture loss: wet curing, moisture retaining covers, or curing compounds. The use of moisture retaining covers was observed during cold

[80] Various RBB Daily Reports, (KCE Report, Exhibit B4 pdf pages 391, 397, 405, 411 and 415 are related to pour 2B).
[81] RBB Daily Report, 12/14/10. (KCE Report, Exhibit B4, pdf page 415). "Heat turned off under deck, stopped monitoring temps."
[82] WMATA specification 03300 section 3.06 B.1.c (KCE Report, Exhibit E1, pdf page 1123, KCE Report, Exhibit N2, pdf page 80).
[83] RBB Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, page 5.
[84] Item 2.3 in FP minutes reads, "No water used to aid in finishing. Eucobar finishing aid is approved." Preparatory meeting held August 25, 2010 regarding 03300 Concrete Placement Methods, Logistics and Testing.
[85] "EUCOBAR rep onsite," FP Daily CQC Report dated December 10, 2010 (KCE Report, Exhibit A4, pdf page 151).

weather,[86] but RBB reports do not otherwise document the curing method used by Facchina. Implementation of controls to prevent drying is poorly documented based on reviewed information. Design of these controls is less restrictive than WMATA Specifications, which require wet curing except where application of moisture would be impractical.[87]

A third potential source of unhydrated cementitious material is a type of drying called self-desiccation. Self-desiccation can arise with mixtures having *w/c* ratios around 0.40 or less[88] when the water initially incorporated into the concrete is insufficient to completely hydrate all the cementitious materials. Self-desiccation can be prevented by using saturated, porous aggregate to provide internal curing. Since internal curing was not specified on this project, the unhydrated cementitious material found by KCE may be explained by self-desiccation rather than by any construction deficiency. Indeed, low *w/c* ratio is linked to unhydrated particles in one of KCE's petrographic reports.[89] The presence of self-desiccation is not detrimental to concrete as long as performance objectives such as strength, stiffness and durability are met. For future projects, if the A/E believes that self-desiccation will affect the structure's performance, project requirements should be modified to include internal curing.

Entrapped Air

Entrapped air was noted in some of the concrete samples taken from the in-situ concrete by KCE.[90] The only project control on entrapped air given in the Construction Documents is a requirement for the vibration of fresh concrete. One of the four RBB inspectors that were present during concrete pours monitored concrete placement in the slab. In his report regarding pour 1B, an RBB inspector writes, "Concrete was properly vibrated, 2 vibrators were used."[91] Based on this comment made early in the slab pours, inspectors did verify that the vibration control was implemented.

The presence of entrapped air in the core samples is not surprising because an industry guide states, "complete removal of entrapped air is rarely feasible."[92] Lack of additional project controls for entrapped air does not indicate a deficiency in control design because monitoring and testing for entrapped air is not possible. The same industry guide says, "Presently, there is no quick and fully reliable indicator for determining the adequacy of consolidation of the freshly placed concrete. Adequacy of internal vibration is judged mainly by the surface appearance of each layer."[93] Therefore, no deficiencies are noted in controls relating to entrapped air.

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86 "Slab was covered with poly sheets followed by insulated blankets." RBB Daily Report by Tony Lord, 12/7/10, (KCE Report, Exhibit B4, pdf page 384).

87 Item 3.05 of section 03300 (KCE Report, Exhibit E1, pdf page 1121).

88 American Concrete Institute, ACI 308R-01, Section 1.3.2 (KCE Report, Exhibit Z1, pdf page 12).

89 "[Samples] show a superabundance of residual portland cement and slag particles evidencing restricted hydration as would be anticipated due to the low *w/cms*." Figure 13 in Petrographic Examinations of Cores from the SSTC dated February 14, 2013 by The Erlin Company (KCE Report, Attachment 50, pdf page 204).

90 KCE Report, Table 16, page 70.

91 RBB Daily Report by Tony Lord, 10/02/10, (KCE Report, Exhibit B3, pdf page 847).

92 American Concrete Institute, ACI 309R-96, Section 7.2.

93 American Concrete Institute, ACI 309R-96, Section 7.6.2.

Entrained Air

Entrained air refers to microscopic cells of air distributed throughout the concrete paste. Entrained air voids are much smaller than entrapped air, and are beneficial because they improve concrete's resistance to damage caused by freezing. The approved mix design required between 4 and 7 percent of entrained air. The entrained air content in hardened cores taken from the in-situ concrete on this project was identified by KCE[94] and in some cases was outside the approved range. Differences may be due to the presence of a concrete pump, which can alter the air-void system. However, apparent differences may not be statistically significant due to the limited number of hardened samples which were evaluated and the variability inherent in test methods. Also, the comparison of the post-hardened values directly to Construction Document requirements is disputed by another engineer.[95]

The entrained air content of fresh concrete was sampled by RBB once for every 50 cubic yards, in accordance with Construction Documents. Batches with low air content were treated with Fritz-Pak (an approved[96] admixture), and RBB asserts that the subsequent load or two were also tested.[97] Pour 1Ea "showed a pattern of low entrained air content spanning the majority of concrete sampled. For the concrete trucks sampled this condition was rectified by the addition of air packs."[98] The pattern of low entrained air content was not recorded as an issue in the FP quality control log.[99] The inspector implemented testing for entrained air at the frequency given in Specifications, but the pattern of low values thus detected was not dealt with as a deficiency according to the CQC plan. Design of controls on entrained air is in accordance with industry standards, but implementation was deficient because it lacked quality control.

The amount of entrained air at the point of concrete placement was only measured three times per floor slab pour. Entrained air can be lost as concrete is conveyed through a pump,[100] an effect that was not quantified on this project. Air entrainment solutions used on future projects should take into account the presence of a concrete pump.

VII. Concrete Placement

Deficiency Identified in KCE Report

The two deficiencies relating to concrete placement are concrete cover and thickness of the structural floors. Based on GPR testing and coring samples by KCE, the required amount of concrete over reinforcing (concrete cover) is not provided in some areas. In these areas, placement of reinforcing is not

[94] KCE Report, Table 15, page 69.

[95] "Technical specifications did not include performance requirements for air-void characteristics of the hardened concrete, and the technical specifications permitted concrete finishing techniques attributed by CTL [Group, Inc.] for the reduction of air in the near surface." by Simpson Gumpertz & Heger dated June 21, 2012, page 3, (KCE Report, Exhibit L1, pdf page 50).

[96] Concrete Mix Design Submittal, (KCE Report, Exhibit V1 page 23).

[97] RBB Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, page 10.

[98] RBB Daily Report by Brian Flickinger, 11/12/10, (KCE Report, Exhibit B4, pdf page 264).

[99] PB Construction Progress Meeting #52, December 9, 2010 minutes (KCE Report, Exhibit P3, pdf page 342).

[100] "It is normal to find a loss of about 0.5 to 1.0 percent air as concrete is conveyed through a pump. … Certainly, air loss through a pump doesn't occur every time. However, it does occur often enough to be considered seriously until better solutions are developed." Publication CIP 21, 2005, by the National Ready Mixed Concrete Association.

in accordance with Construction Documents or industry standards. The significance of this defect is explained by KCE, who states, "The durability of a concrete structure is reduced as the depth of concrete cover over reinforcement is decreased. This relationship is a result of the fact that there is a smaller distance through which chlorides must penetrate to reach the depth of the reinforcing steel to initiate corrosion."[101]

Further, there are many locations where the thickness of the concrete floors does not meet the minimum requirements as indicated in the Construction Document. The significance of this defect is explained by KCE, who states, "Our analysis of the as-built post-tensioned slabs indicates slab areas with thicknesses below approximately 9 inches and with compressive strengths at or below 6,970 psi do not have adequate shear capacity in certain locations to support the design loads (the areas less than 9 inches thickness are limited in extent and therefore do not limit overall load-carrying capacity). In addition, the as-designed analysis indicates the initial and service level stresses were exceeded."[102]

The insufficiency of concrete cover on tendons was identified as an issue on October 28, 2010 when three ducts became exposed to view through the surface of Pour 1A shortly after being grouted.[103] The Design Team was immediately notified, and "new procedures for tendon placement have been installed to prevent them from surfacing after grouting/stressing."[104] The new procedure[105] helped, but not all tendon cover values measured by KCE in slabs cast after this date met Construction Document provisions.[106]

Project Control Deficiencies

Post-Tensioned Tendon Placement

Discussions during the post-tensioned pre-installation conference included vertical tolerance on tendon placement.[107] Checklists used by RBB before each pour included an item for "duct high and low points (profiles) at the correct elevation with sufficient cover."[108] The engineer of record observed general alignment of tendons a few days before at least nine of the pours.[109] The efforts by various parties to control tendon alignment did not prevent some cover deficiencies, but it is quite possible that insufficient cover at tendons was caused by insufficient concrete thickness rather than by incorrect tendon placement. Controls on location of post-tension tendons, including pre-installation meetings and pre-pour checklists, were implemented correctly, but did not prevent some popped tendons. No deficiency is noted in the design of these controls since solutions were quickly created when problems arose.

[101] KCE Report, page 97.
[102] KCE Report, page 6.
[103] RBB Daily Report by Tony Lord, 10/28/10. (KCE Report, Exhibit B4, pdf page 151).
[104] PB Construction Progress Meeting #51, November 16, 2010, minutes (KCE Report, Exhibit P3, pdf page 317).
[105] PB Field Observation Comments, 10/30/10. (KCE Report, Exhibit C1, pdf page 10). "the top of the duct should not be closer than 1 3/8 inch below the top of the slab. FP has made a template to check that this dimension is held."
[106] KCE Report, Attachment 33.
[107] FP Preinstallation Conference Minutes, 7/13/2010. (KCE Report, Exhibit Q1, pdf page 8).
[108] RBB Daily Report by Tony Lord, 12/3/10. (KCE Report, Exhibit B4, pdf page 369).
[109] PB Field Observation Comments, various dates. (KCE Report, Exhibit C1).

Mild Steel Reinforcing Placement

RBB asserts that concrete clear cover was verified on mild steel reinforcing bars,[110] although results of such measurements were not documented in their reports. The concrete cover found by KCE at slab bottom bars and at beams and girders meets requirements for fire ratings.[111] (Wide variations found in the cover of mild steel reinforcing at columns[112] was not reviewed as part of this analysis.) Per Specification 03381.3.6D, reinforcing was to be secured against displacement, and an inspector verified that it was not disturbed during concrete placement.[113] Inspection of reinforcement placement which is required by Specification 03300 3.17.B.1 was provided,[114] although some inspections were possibly hurried based on statements made in RBB daily reports.[115] No deficiencies are noted in either implementation or design of project controls on mild steel reinforcing bar locations.

Thickness of Concrete Floors

Thickness of concrete floors was not directly measured during concrete pours. The method selected by the Contractor to establish floor thickness was to give the top surface the desired shape based on measurements taken by survey equipment operated while concrete was being placed.[116] The bottom surface was established by formwork positions. Thickness was realized as the difference between formwork and top surface, with no redundant system to prevent floor thickness problems.

Slab thickness deficiencies were identified in portions of the incomplete project as early as November 2010,[117] when less than half of the slab concrete had been placed. Thickness deficiencies were discovered during the investigation into popped tendons, and WMATA immediately requested a survey to identify other thin areas. WMATA's survey was followed by other surveys,[118] which show that thin areas also

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[110] RBB Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, page 5.

[111] KCE Report, page 89.

[112] KCE Report, page 48.

[113] RBB Daily Report by Tony Lord, 10/18/10. (KCE Report, Exhibit B4, pdf page 7). "I monitored concrete placement on deck. Tendons and reinforcing steel were maintained in their proper positions."

[114] Inspector Tony Lord (typical of multiple inspectors and occasions) writes, "I continued to inspect the placement w/ VSL and structural drawings. I logged all items requiring correction that were found in my inspections. Placement is ongoing and will continue tomorrow." RBB Daily Report, 12/2/10. (KCE Report, Exhibit B4, pdf page 361).

[115] RBB Daily Report by John Welk, 10/16/10. (KCE Report, Exhibit B3, pdf page 2). "Work & corrections were still not completed today. Therefore sign-off for concrete pour [1C] card was not done today. I will arrive @ 2:00 AM Monday morning 10-18-10 to do final inspection of completed work, at which time, if all work is completed as per specifications, I will sign-off on completed work (concrete pour card)." Records for pour 2A are missing after KCE Report, Exhibit B4, pdf page 201. RBB Daily Report by Tony Lord, 11/11/10. (KCE Report, Exhibit B4, pdf page 256). "At day's end, placement was approx 90% complete. Placement [for pour 1Ea] is scheduled for tomorrow at 4 am. Concrete placement will begin in the areas where reinforcement has been approved. Incomplete areas will be done ahead of concrete placement." RBB Daily Report by John Welk, 12/6/10. (KCE Report, Exhibit B4, pdf page 376). "Work is still not completed. I will come in tonight @ 11:00 [PM] and do a final walk through inspection. When work is completed I will sign-off on pour card." Pour 2B was begun at 1:00 AM on 12/7/10. RBB Daily Report by John Welk, 12/9/10. (KCE Report, Exhibit B4, pdf page 393). "Work is still not completed. I will come in tomorrow morning @ 5:00 AM & do a final walk through inspection. When work is completed I will sign-off on pour card."

[116] Entry 1.13 of FP minutes from meeting held 8/25/2010 regarding 03300 Concrete Placement Methods, Logistics and Testing: "How will grades and elevations be established on finished concrete surface? Facchina's surveyor/ layout man will shoot all elevations of top of concrete as placed during the pour for use by W concrete to rake out and screed to established top of concrete elevations."

[117] PB Construction Progress Meeting #51, November 16, 2010, minutes. (KCE Report, Exhibit P3, pdf page 317-318.) "Area around popped tendons was surveyed for slab thickness. Slab came in thin in some areas."

[118] Project Management Team Meeting #13, September 15, 2011 minutes item 6.1. "Slab Thickness Survey. WMATA's survey was confirmed by both MC's surveyor and Faccina's surveyor."

exist in concrete placed following this discovery. The results of the Greenhorne thickness survey are reproduced in Appendix C, which shows measured thickness by color code. The method selected by the Contractor to establish thickness depended upon his own correct implementation. The inspector did not (according to the response from RBB to the KCE report, the inspector could not) independently check thickness except at the perimeter.[119] However, wet depth checks using a simple rod inserted vertically into the fresh concrete would have been practical. The engineer of record repeatedly included reminders to "all parties" in comments noted in October and November 2010 field reports[120] to maintain thickness, but no independent method to check thickness was developed.

Construction Documents indicate several controls related to floor thickness:

- Tolerance on finished floor elevation was required to be discussed in the concrete pre-installation conference as indicated in Specification section 03300.1.5J, but the topic is not found in this meeting's minutes.[121]
- Specification section 03300.3.1B references ACI 117 for formwork tolerances, which sets a limit of ¾ inch on form surface elevations. The RBB checklist includes formwork shape, location, and dimensions and RBB is listed among those testing correct installation of formwork in the FP Test/ Inspection Matrix[122] (included as Appendix A of this analysis). However, the Inspection Contract specifically excludes inspection of formwork,[123] so it is unclear whether this tolerance was actually verified.

Thus two project controls related to concrete thickness were not implemented, and concrete thickness was not directly measured due to the construction method utilized. Future projects would benefit from selecting a construction method that allows direct measurement of floor thickness, or at least from having redundant verification of formwork and surface elevations.

VIII. Post Tensioning

Concrete is very strong in compression but easily cracks when loaded in tension, so reinforcing is typically cast into it. Steel, which is strong in tension, is positioned where tensile forces are expected to occur. The reinforcing can be conventional or an alternative is to reinforce concrete with high strength steel strand, to which tension has been externally applied. When this tension is applied after the surrounding concrete has hardened, the system is known as post-tensioned concrete.

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[119] "Thickness of the slab at points away from the perimeter could not be measured without survey equipment." RBB Letter regarding Response to KCE Report Dated March 15, 2013, April 22, 2013, page 5.

[120] PB Field Observation Comments, 10/15/10, 10/30/10, 11/11/10. (KCE Report, Exhibit C1, pdf pages 5, 8, 22) "Elevations of formwork, system for maintaining required design elevations at the top of the concrete, and system for maintaining typical concrete thickness at 10 inches should be verified by all parties."

[121] Item 6.1 in FP Preinstallation Conference minutes dated 4/28/2010 reads, "How will top of slab / thickness be determined? This will be discussed at a future meeting." The meeting held 8/25/2010 regarding 03300 Concrete Placement Methods, Logistics and Testing did not discuss tolerances or thickness; surface profile in item 1.13 is the most similar item of discussion.

[122] Foulger-Pratt QC Plan-Appendix E.

[123] Contract for Inspection and Materials Testing Services between Montgomery County, Maryland and The Robert B. Balter Company, County Contract No. 6504510207-AA, Exhibit D, page 32. (KCE Report, Exhibit M1, pdf page 366).

Steel used for post-tensioning commonly takes the form of high strength wires braided into a flexible strand. This strand goes inside corrugated plastic tubes called ducts, as shown in Figure 8, below. Ducts are held in place above formwork on rows of disposable supports called chairs. Chair sizes are selected so that the center of gravity of steel ("CGS" in the figure) matches the height specified by the engineer. Components called anchors are located at each end of the duct to transfer forces from the strand into the concrete. The assembly of strand, anchors and duct is referred to as a tendon.

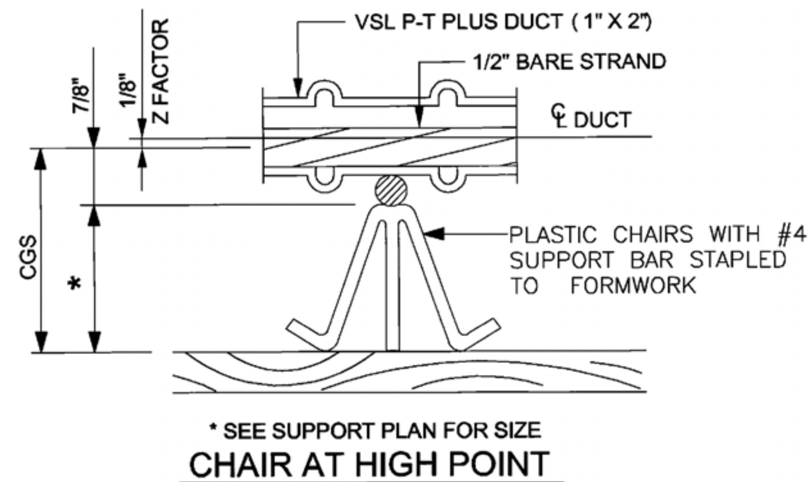

Figure 8 – Post-Tensioning Elements[124]

A hydraulic machine called a jack is used to apply tension to one or both ends of each strand. The action of applying tension using a jack is called stressing. Stressing cannot commence until the concrete is strong enough to support the jacking forces. Jacking forces are measured with calibrated gauges, and the actual force is compared to the required force as given in the approved shop drawings. Strand elongations are also measured and are compared to predicted elongations as a method of quality control. Once everything checks out, then strands are permanently fixed in place by pumping a liquid into the void surrounding them. This liquid is called grout, and it later becomes a solid by the chemical reaction of the water and cement from which it was made.

Controls in Construction Documents

The SSTC was designed utilizing post-tensioning tendons, and several controls on this activity were established in the Specifications. Structural drawings give the required forces and profiles of post-tensioning tendons, but do not identify controls specific to post-tensioning. The CQC plan also does not include controls specific to post-tensioning. The primary applicable Specification Section is 03381, Bonded Post-Tensioned Concrete, which includes requirements for the design, supply, and construction of post-tensioning tendons and all associated items. The design, implementation and effectiveness of some of these controls are analyzed below.

Specification 03381.3.3.B gives requirements for support of post-tensioning ducts. VSL submitted shop drawings and detailed supports for tendons that were selected to achieve these profiles. Actual tendon profiles were verified by RBB, and any tendons that did not meet construction criteria were added to a

[124] Typical tendon support detail, VSL shop drawing number PT03.

pre-pour checklist. Each item on the checklist was initialed after being corrected, prior to placement of concrete. In spite of these efforts, a few popped tendons did occur (that is, the post-tensioning ducts became visible when the concrete cover cracked off and fell away). Popped tendons and controls on post-tensioned tendon placement are discussed in the Concrete Placement section of this analysis. Please see that section for an evaluation of the control's effectiveness.

Stressing Records

Specification 03381.1.4.A indicates that the Contractor is to "provide effective forces and profiles shown on the drawings." VSL submitted shop drawings that detailed tendons selected to achieve the required effective forces. The effective force is distinct from the force applied by the stressing ram to the tendon because some of the applied force dissipates. Loss of stressing force occurs both immediately (due to elastic shortening, friction, and anchorage slip) and over the life of the structure (due to creep, shrinkage, and relaxation). Effective forces were calculated by VSL engineers taking into account the expected sum of all these losses. The results of these calculations were provided to field crews before post-tensioning operations in the form of expected elongations for each tendon.

Specification 03381.1.5.J indicates the elements to be included in stressing records. Stressing records having the requested elements are included in KCE Exhibits C, D and H. Specification 03381.3.7.H indicates that the stressing records are to be submitted and that elongations that deviate from the expected value by more than 5 percent should be resolved to satisfaction of the EOR. This tolerance was modified by PB during construction to plus or minus 7 percent,[125] which is the tolerance given for post-tensioned construction in section 18.20.1 of the ACI 318 concrete building code.

Sometimes the actual elongations were outside allowable tolerances.[126] Each such instance was evaluated by the responsible engineer at VSL, and associated calculations were submitted to PB and are included in Exhibit H of the KCE report. Out-of-tolerance elongations were reviewed by PB, and records of approval are also included in Exhibit H. For example, one such evaluation is found in Exhibit H4 page 100, where regarding pour 1A girders PG-26 and PB-39A, PB writes, "Final effective post-tensioning force of 1363 kips has been calculated by VSL. This effective force is lower than the 1450 kip effective force identified for these members in the Construction Documents (ASI #11), however, the members noted will still have a capacity that is more than adequate for the design loading. Based on the final effective forces determined by VSL, and PB's review of the design, I recommend that the post-tensioning of these members be accepted." No deficiency is noted in the design, implementation, or effectiveness of the control on stressing records.

Concrete Stresses

Stress in concrete is typically calculated rather than measured. The calculation starts with the forces acting on a structural element, and then divides by the area of that element. A large force on a large element may thus cause the same stress as a small force on a small element. The greatest stress is caused by large forces acting on small elements.

[125] RFI number 657 dated November 10, 2010 (KCE Report, Exhibit U3, pdf page 699).
[126] KCE summarized elongation results in attachment 55 to the KCE Report, beginning in Volume 3 on pdf page 473.

Structural elements can experience different forces on opposite sides, for example compression on the top and tension on the bottom. In these cases, somewhere between the two sides there is always a dividing line at which there is neither compression nor tension. This line is called the neutral axis. The part of the element that is farthest away from the neutral axis is called the extreme fiber. Building codes limit the stress at the extreme fiber because that is the place on the element where cracks begin to form, thus decreasing the strength and durability of the element.

Specification 03381.1.4.C indicates, "Comply with ACI 318 limits on stresses at transfer of prestress and under service load." Stress limits at the time of post-tensioning are found in section 18.4.1 of ACI 318, which says that the extreme fiber stress is not to exceed $0.60f_{ci}'$ in compression or $3\sqrt{f_{ci}'}$ in tension. Under service loads, ACI 318 section 18.4.2 limits compression stress to $0.45f_c'$ while section 18.3.3 creates a serviceability group for concrete with tensile stress of less than $7.5\sqrt{f_c'}$. WMATA is more restrictive than ACI at service loads, limiting tension stress to $6\sqrt{f_c'}$.[127]

To check whether these limits are met, one must calculate the concrete extreme fiber stress. This calculation is complex in post-tensioned members and is usually done only by the engineer who designs the post-tensioned building elements. For the SSTC, PB provided the member sized and specified reinforcing geometry. Engineers from VSL selected the tendons needed to achieve the effective forces specified by PB and evaluated stressing operations.

Since decisions by PB controlled the extreme fiber stress, it seems misplaced for them to place a control on concrete stress in the SSTC Specification. Sample specifications for post-tensioned concrete structures as produced by MasterSpec® contain a provision worded very similar to Specification 03381.1.4.C, but the context of these sample specifications is for buildings in which the design services have been delegated to a specialty engineer. Since design services were not delegated to the Contractor, inclusion of a Specification provision providing limits on concrete stresses may have been inadvertent. The design of this control is questionable because it delegates a check that PB should have performed.

KCE observes that, "Review of the Contract Documents and the PB calculations presented show that PB attempted to comply with WMATA's 6√f'c extreme fiber tension stress limit for service loads. However, no initial stress review appears to have been performed."[128] The success of these attempts was challenged in the structural investigation by outside engineer Simpson Gumpertz & Heger.[129] No documentation is found that any member of the Construction Team performed the calculations necessary to implement the control on concrete stresses given in Specification 03381.1.4.C. The ineffectiveness of this control may be responsible for some of the cracking observed in the SSTC. KCE notes that exceeding the initial extreme fiber stress limit "could lead to concrete cracking during initial stressing. The initial cracking would affect the distribution of service level stresses, but does not impact the ultimate strength of the structure."[130]

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[127] Section 5.09.C.3.a.3 of the WMATA Manual of Design Criteria. (KCE Report, Exhibit E1, pdf page 331).
[128] KCE Report, page 33.
[129] "We analyzed PB's original structural design using ADAPT-PT 2010 (Build 2010.2) with PB's input load files. We found service level stresses exceeded PB's stated 6√f'c criteria with the specified compressive strength of 8,000 psi." by Simpson Gumpertz & Heger dated March 14, 2012, page 6, (KCE Report, Exhibit L1, pdf page 14).
[130] Ibid.

Grout Strength

Specification 03381 sections 2.5 and 2.10 give requirements for the grout inside of ducts, and provide restrictions in addition to those in ACI 318 section 18.18. Strength is supposed to be 8,000 psi at 7 days, which apparently was not always obtained based on meeting minutes from the post tensioning summit held in November 2010.[131] KCE Exhibits do not include sufficient documentation of grout strength break results to evaluate the control's effectiveness. Specification 03381 Sections 3.9 and 3.10 give grouting requirements, with the frequency of sampling modified by RFI 624.[132] Records indicating that grout strength specimens were created are included in the KCE Exhibits, and it is apparent that PB reviewed results of these tests because they authored a letter recommending acceptance of grout strengths.[133] Independent evaluation of control effectiveness is limited by access to records.

Time to Grouting

During the post-tensioning preparatory meeting, "it was discussed that the expected maximum time limit to grout tendons after placement is 30 days. If tendons are left ungrouted after 60 days VSL can apply a corrosion inhibitor product into the duct."[134] The Specifications do not provide any limit on time before grouting. An industry guide suggests 20 days as the permissible interval between tendon installation and grouting unless corrosion protection is used.[135] Grouting operations were initiated 39 days after the first pour, and grouting equipment broke immediately[136] and repeatedly.[137] By 46 days after the first pour, all but a "small section of pour 1A not under pour 2A"[138] had been grouted, with six blocked tendons grouted after 88 days.[139] Both the grout and the slab required external heat sources for pours 1C and 1D.[140] No explanation was noted for the delay of grouting tendons at other pours, which have elapsed times as shown in Table 2, below. No records were found documenting the use by VSL of the corrosion

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[131] Item 1.13 in PB minutes reads, "Monitor closely next grouting operation to ensure proper mixing and sampling is taking place – concern about low 28-day breaks,"and item 1.16 reads, "Facchina to evaluate why grout numbers are coming in low," post tensioning summit held November 30, 2010 (KCE Report, Exhibit C1 page 29).

[132] RFI number 624 dated October 18, 2010 (KCE Report, Exhibit U3, pdf page 538). "One test is to be taken at the beginning of the mixing of grout each day, every 2 hours during the operation, and at the conclusion of grouting each day."

[133] "The purpose of this letter is to confirm that Parsons Brinkerhoff has reviewed the grout strength comparison test results performed on three batches of post-tensioning duct grout." Letter dated February 4, 2011 from Douglas A. Lang to Timothy O'Gwin. (KCE Report, Exhibit B5, pdf page 289).

[134] Item 4.2 in FP minutes, Preparatory Meeting 7/13/2010 regarding 03381 Bonded Post Tensioned Concrete (KCE Report, Exhibit Q page 10).

[135] Post-Tensioning Manual, sixth edition by the Post-Tensioning Institute (2006), Table 4.7 (page 86).

[136] RBB Daily Report by Brian Flickinger, 10/22/10. (KCE Report, Exhibit B4, pdf page 93). "The 1st mixer/pump used ceased to operate after 1 hour. Inspector informed of a clog in mixer at pump inlet. 2nd mixer attempted to be placed in service and inspector informed that this mixer is in a non-functional state."

[137] RBB Daily Report by Brian Flickinger, 10/26/10. (KCE Report, Exhibit B4, pdf page 112). "Grout placement for post tensioned elements of concrete pour 1A resumes today… mixing equipment again clogged then broken in afternoon about 4pm." RBB Daily Report by Brian Flickinger, 10/29/10. (KCE Report, Exhibit B4, pdf page 186). "Grout operations started early in the afternoon, the delay caused by the contractors primary grout mixer/pump having ceased functionality, and the contractors back up mixer/pump being long term inoperative."

[138] RBB Daily Report by Brian Flickinger, 10/29/10. (KCE Report, Exhibit B4, pdf page 186).

[139] RBB Daily Report by John Welk, 12/10/10. (KCE Report, Exhibit B4, pdf page 399). "Contractor also resumes grouting operation for (6) blocked PT tendons for pour 1A, level 330'."

[140] RBB Daily Report by Brian Flickinger, 1/11/11. (KCE Report, Exhibit B5, pdf page 75). "Today's grouting is started in morning due to overnight heating of deck sections 1C and 1D, and the heating of materials to bring temperature of liquid grout and surrounding concrete up to spec's required for job. Without these heating efforts grout placement could not have been able to be accomplished within job specs today."

inhibitors mentioned above. KCE exposed a limited number of tendons during their destructive testing program,[141] and did not remark about their condition.

Table 2 – Time Elapsed to Grouting of Post Tensioning Ducts

		Grouting Date		Days Elapsed	
Pour Name	Pour Date	Begin	End	Begin	End
1A	9/13/2010	10/22/2010	12/10/2010	39	88
1B	10/2/2010	11/3/2010	12/3/2010	32	62
1C	10/18/2010	1/5/2011	1/11/2011	79	85
2A	11/2/2010	1/20/2011	2/4/2011	79	94
1Ea	11/12/2010	2/14/2011	3/7/2011	94	115
2B	12/7/2010	2/2/2011	2/4/2011	57	59
1D	12/20/2010	1/11/2011	1/28/2011	22	39
1F	12/30/2010	2/17/2011	3/4/2011	49	64
2C	1/14/2011	3/7/2011	3/15/2011	52	60
2D	1/31/2011	3/9/2011	3/15/2011	37	43
1G	2/8/2011	3/16/2011	3/22/2011	36	42
1H	2/18/2011	3/16/2011	3/23/2011	26	33
2Ia	3/29/2011	4/20/2011	4/20/2011	22	22
350' Pour Strip	6/1/2011	7/28/2011	7/28/2011	57	57

Strength and Age of Concrete at Time of Stressing

Specification 03381.3.7.C indicates that concrete strength at time of stressing was supposed to exceed 4000 psi or 6000 psi, depending on specifics given in that section. KCE notes a discrepancy[142] between this provision and drawing S1.00, which has a single value for minimum concrete strength at time of stressing corresponding to 6000 psi. As discussed in the section of this analysis related to Pour Strips, discrepancies in Construction Documents are to be discussed at meetings or answered via the RFI process. The Specification requirements were repeated during the post-tensioning pre-installation conference,[143] but minutes have no mention of the requirement from the drawing. An RFI was issued regarding PT stressing order,[144] but no clarification of concrete strength at time of stressing was requested or given through the RFI process. The design of the control on concrete strength at time of stressing exhibits inconsistency between drawings and specifications which was not explicitly clarified during construction; therefore, the control is found to be deficient in design.

When a discrepancy is noted between drawings and specifications, the more stringent requirement was to have been followed.[145] Based on comments in RBB daily records,[146] the Construction Team followed

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[141] "We exposed post-tensioning tendons in 36 of the 49 inspection openings. … After we collected grout samples from inside the duct and documented general conditions (including concrete cover dimension and grout and strand condition), we replaced the grout and repaired both the duct and opening." KCE Report, page 51. Results of inspection openings are included as attachment 42 to the KCE Report, beginning in Volume 3 on pdf page 103.

[142] KCE Report, page 16.

[143] Items 3.7 and 3.8 in FP minutes, Preparatory Meeting 7/13/2010 regarding 03381 Bonded Post Tensioned Concrete (KCE Report, Exhibit Q page 9).

[144] RFI number 594 dated September 24, 2010 (KCE Report, Exhibit U3, pdf page 394).

[145] Item H.3 in the Construction Contract between Montgomery County and Foulger-Pratt. (KCE Report, Exhibit M1 pdf page 5).

the Specification, which is less restrictive. Actual strength at time of stressing is shown in Table 3, below. In 9 of 14 pours, the strength at time of stressing would not have met the more restrictive requirements given in the drawings, but the strength did meet the Specification requirements. An example specification from the Post Tensioning Institute requires 3000 psi concrete strength at time of stressing.[147] Since the Specification and the drawings were more restrictive than industry recommendations, implementation of the Specification instead of the drawing requirements had no noticeable impact on the control's effectiveness.

Table 3 – Strength and Age of Concrete at Time of Stressing

		Initial Stressing				
		4000 psi	6000 psi		Days Elapsed	
Pour Name	Pour Date	Concrete	Concrete	Date	Begin	End
1A	9/13/2010	RBB, KCE		10/22/2010	3	18
1B	10/2/2010	RBB		11/3/2010	4	11
1C	10/18/2010	RBB		1/5/2011	3	9
2A	11/2/2010	RBB, KCE		1/20/2011	3	13
1Ea	11/12/2010	RBB, KCE		2/14/2011	4	11
2B	12/7/2010	RBB, KCE		2/2/2011	3	9
1D	12/20/2010	RBB, KCE	KCE	1/11/2011	3	8
1F	12/30/2010	RBB, KCE	KCE	2/17/2011	4	11
2C	1/14/2011	KCE		3/7/2011	4	10
2D	1/31/2011	KCE		3/9/2011	4	8
1G	2/8/2011	RBB, KCE	RBB, KCE	3/16/2011	3	8
1H	2/18/2011	RBB, KCE	RBB, KCE	3/16/2011	4	8
2Ia	3/29/2011	RBB, KCE		4/20/2011	3	8
350' Pour Strip	6/1/2011	KCE	KCE	7/28/2011	3	5

"RBB" in this table indicates that an RBB inspector made a comment confirming concrete strength in the corresponding daily report. "KCE" in this table indicates that strength was verified based on data from the KCE exhibits. KCE exhibits do not include data necessary for verification of pours 1B and 1C.

Specification 03381.3.7.D indicates that concrete age at time of initial stressing was supposed to be less than 96 hours. An example specification from the Post Tensioning Institute says stressing should be completed "within 72 hours after the concrete is placed to minimize early age concrete shrinkage cracking."[148] Considering the high concrete strength specified at time of stressing as discussed above, a slightly longer period of time is reasonable in order to allow the material to gain strength. Some increase in shrinkage cracking can be expected in association with this longer delay in applying initial post-tensioning stress. Early age shrinkage cracking did in fact occur, although project participants attributed it to other causes.[149] Therefore, no deficiency is noted in the control's design.

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[146] See for example RBB Daily Report by Tony Lord, 4/1/11. (KCE Report, Exhibit B6, pdf page 3). "Concrete test cylinder results representing pour 2I-A exceeded 4000 psi, stressing of U-slab tendons is permitted."
[147] Post-Tensioning Manual, sixth edition by the Post-Tensioning Institute (2006), section 6.4.1 (page 120).
[148] ibid
[149] Follow up Meeting for Concrete Finishing Pour 2B, 12/16/10, minutes item 2.2. "The group agrees the windy conditions contribute to shrinkage cracking and Facchina indicated it is suspected that the minimal use of Eucobar may contribute to shrinkage cracking."

Concrete age at the time of initial stressing is discussed in the KCE Report on page 16. A review of Table 3 for the elapsed time in days to the beginning of initial stressing confirms that all pours received initial stressing at either three or four days after the pour. In one instance, RBB commented that more than 96 hours had passed,[150] apparently because the pour was cast early in the morning and stressing was implemented on the fourth day, but not as early in the morning. Such an occurrence is considered to have no significant influence on the performance of a post-tensioning system, so the effectiveness of the control is not impacted.

IX. Conclusions

Project control deficiencies identified in this analysis stem from either evidence that project controls for the SSTC were not implemented properly or evidence that additional controls were required, as discussed in the four preceding sections. The intent is, in part, to consider the "lessons learned" from evaluating controls related to the deficiencies identified by KCE in the SSTC structure.

East and West Pour Strips on Level 330

As required in the CQC Plan for the SSTC, the CQC Manager is required to highlight any proposed variances from the Construction Documents in the submitted shop drawings. The variances should be noted on the shop drawings and discussed in the progress meetings. A log maintained by FP of requested variances is also recommended. The log should include a description of the variance, the submittal number which demonstrates the proposed variance, the date requested by FP, the date of PB approval, and the date of DGS approval.

Due to phased shop drawing submittal process used, the pre-installation conference occurred before all shop drawings were reviewed. While this process was not prohibited in the Specifications, it allowed for ambiguity regarding outstanding submittals. Several changes to this procedure could occur. First, if possible and practical, all shop drawings could be required to be submitted before the pre-installation conference occurs. Second, a pre-installation conference could occur with each new area covered by a recently approved shop drawing. At a minimum the Submittal Registry should include the number of proposed shop drawings anticipated for the phases. For example, if only one pre-installation conference occurs at the beginning of the Definable Feature of Work, part of the conference should cover how many submittals will be generated for DOR review for the phased construction. Then as construction proceeds discussion should occur whether each of those proposed submittals have been approved during the progress meetings.

In the case of the mild reinforcement steel, PB approved shop drawings which omitted some of the reinforcing shown in Construction Documents. Since the A/E is responsible that shop drawings correctly convey the design intent, PB should carefully consider Contractor interpretations. FP should also be

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[150] RBB Daily Report by Tony Lord, 2/22/11. (KCE Report, Exhibit B5, pdf page 379). "NON-COMPLIANT ISSUES: Pour 1H: 96 hours elapsed after concrete placement before tendons were stressed."

diligent in the future when reviewing submittals from its subcontractors. Pre-installation meetings should confirm that all construction personnel are using approved versions of shop drawings.

Concrete Composition

Specifications should be reworded to require that testing of concrete occur at the point of placement. Where referenced standards require testing at the point of delivery, clarify in the specification that such testing is in addition to typical testing. Concrete batch plants are required to be inspected by the Specifications, and the Construction Manager should verify that this has occurred. Results of the in-situ concrete testing indicate water may have been added to the fresh concrete mixture without documentation, so additive water requires close monitoring in the future. One possibility is to require meters on water lines leading to mixer drums, in order to better monitor and document the amount of water added to concrete by the delivery truck driver.

Agreements with WMATA required the SSTC project to meet WMATA design requirements. All WMATA Specification requirements should have been reviewed and implemented unless a variance was mutually discussed and agreed upon. The specific items where differences were noted from WMATA standards (and their suggested resolution) are: slump limits during concrete pouring operations (a variance should be requested for use with pumped concrete), temperature limits during curing (should be coordinated and clearly conveyed rather than included by reference), and wet curing (Specifications for moisture retaining covers should be revised). Specifications should require the Contractor to develop procedures for active monitoring and correction of temperatures during cold weather. The Construction Manager should be notified when independent temperature measurements made by the inspector are outside of project limits for corrective action.

As Designer of Record, PB should review performance of the concrete mixture and specify internal curing if self-desiccation is found to be the reason that in-situ compression strength is less than that of laboratory cured cylinders. Due to the presence of entrapped air found by KCE in the completed structure, a review of vibration and finishing methodologies is also needed. The DOR should also consider if any changes are required in Construction Documents to improve air-void performance when concrete is pumped.

Construction documentation such as daily logs indicates the addition of entrained air to the concrete mixture was not administered consistently. It is recommended, therefore, that monitoring and documenting the quantity of entrained air be implemented. The effect of pumping operations on entrained air content should be taken into account.

Concrete Placement

Placement of reinforcement and tendons were addressed during the pre-installation conference, and were discussed again when it was discovered that adequate cover was not being maintained, but the issue of insufficient top cover continued to occur and corrective action by FP was not effective. Reinforcing and tendon locations were established relative to the bottom, formed surface because the concrete top surface did not yet exist while reinforcing was being placed. Inspectors also measured reinforcing and tendon locations relative to the bottom of slab, calculating top cover by assuming that the minimum slab thickness would be provided. It is assumed that concrete cover issues would be resolved when adequate slab thickness is obtained as discussed below.

Construction Documents and approved shop drawings require a minimum concrete thickness for the floors was not achieved in all installed locations. RBB asserts that concrete thickness could not be checked without survey equipment. Direct measurement was not possible except at the perimeter due to FP's use of survey equipment for establishing the slab's top surface. It is recommended that construction methods should be any of several methods that are available which allow direct measurement of floor thickness, or alternatively, that redundant survey equipment should be utilized to monitor concrete thickness, with a report of survey results submitted for Owner and PB approval.

X. Qualifications

Alpha Corporation

Alpha Corporation (Alpha) is a full-service consulting firm offering a wide array of engineering and program/construction management and construction consulting services. Since 1979, we have provided these services to a broad spectrum of clients, including government agencies, municipalities, institutions, private enterprises, developers and contractors.

Alpha Corporation's diverse staff of more than 182 includes professional engineers, project and construction managers, inspectors, cost estimators, schedulers, and risk managers. Each brings a solid background of technical knowledge and experience to every project, earning Alpha Corporation an outstanding reputation in a very competitive industry. Alpha's personnel are registered as Professional Engineers (P.E.); LEED Specialists through U.S. Green Building Council; Certified Construction Managers (CCM) through CMAA; Certified Professional Estimators (CPE); Planning and Scheduling Professionals (PSP) through the Association for the Advancement of Cost Engineers; and Project Management Professionals (PMP) through PMI.

J. Michael Damron, P.E., LEED AP

Mr. Damron is an experienced professional engineer and manager with more than 20 years of experience in the building construction industry. He has performed audits, evaluations, and analysis for various building systems and clients. He has expertise in review of procedures and processes, building evaluations and load analysis, structural design and analysis, team coordination, construction and contract documentation, and construction administration for government, educational, institutional, office, medical and residential buildings. Mr. Damron has provided services for government, institutional, and commercial clients. Mr. Damron is also a LEED accredited professional.

State Registrations:	MD, VA, PA, NY, ME, NJ
Education:	Bachelor of Science in Building Construction Virginia Polytechnic Institute and State University
Professional Affiliations:	ACI, SAME, ACEC

Mary Billings, P.E., LEED AP $^{BD+C}$

Ms. Billings is an experienced senior engineer with more than 13 years of experience in the performance of peer and constructability reviews of construction documents as well as preparation of construction documents for new or repair construction projects. She has expertise in building evaluations and load analysis, design construction and construction documents for government, industrial, and heavy infrastructure projects. Ms. Billings is a LEED accredited professional.

State Registrations:	MD, VA, WV, DC
Education:	Master of Science, Civil Engineering
	Virginia Polytechnic Institute and State University
	Bachelor of Civil Engineering
	Georgia Institute of Technology
Professional Affiliations:	SAME

XI. Appendices

Appendix A – Contractor Quality Control Plan

Appendix B – Duties and Functions of DGS Project Management Team

Appendix C – Plans of SSTC Floors

Appendix D – Cited Standards

Appendix E – Sample Reports

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Appendix A – Contractor Quality Control Plan

Note: All the information in this appendix is paraphrased from the CQC plan submitted by FP. Descriptions represent what was supposed to happen according to that plan and have not been confirmed unless specifically noted. This summary was produced as part of the analysis to show the type and extent of controls that were utilized on the SSTC project.

This appendix describes the document control, submittal control, and quality control aspects that are implemented by the SSTC project CQC Plan. Doug Goetz is responsible as CQC Manager for overall implementation of the CQC Plan in conjunction with trade focused QC Project Engineers. The Manager is also responsible for monitoring of off-site QC activities to the extent necessary to meet the specific Construction Contract requirements and those of the CQC Plan. The Manager is an onsite, fulltime employee who has day-to-day responsibility for onsite administration of the Plan including submittal review, phased inspections, and overall CQC coordination. The CQC Manager also has authority over Construction Contract compliance, stop/reject work, order correction of defective work, and direct and coordinate activities of all QC personnel.

Document Control

The CQC Plan addresses document control as a critical function of the Contractor and indicates use of proprietary software, Prolog Manager, as the primary means of document control. The types of documents included within the Document Control Plan are Construction Documents and constructability review, Request for Information (RFI) generation and tracking, Construction Drawings revision logs, and Construction Drawings distribution logs. As questions arise on a project or if the Contractor would like to construct something differently than as shown in Construction Documents, contractors generate RFIs in order to ask the DOR the question. Response to questions or clarifications may alter the Construction Documents. Also, if the DOR would like to modify the Construction Documents, they may issue an Architect's Supplemental Instruction (ASI) in the form of a supplemental drawing. As a result, the Construction Document revision log is maintained to reflect the current revision level of each drawing and the current set of Construction Documents with all changes initiated by RFIs or ASIs are called "field set of Construction Documents." Detailed changes for Drawing and Specification are tracked in Microsoft Excel and are accessible to the project team at all times.

All Construction Documents distributed to subcontractors and vendors are sent with a transmittal showing the drawing numbers and current revision dates. Upon receipt, the CQC System Manager, posts all revisions on the field set of Construction Documents to allow dissemination of the most current information. The CQC System Manager conducts periodic inspections of the field set of Construction Documents to verify they are being kept up to date by all trades. The field set of Construction Documents are maintained throughout the duration of the project and are the basis for the Record Set of documents provided at project completion. A Plan Distribution Log is maintained in the project database management system, Prolog, to enable subcontractors and vendors to verify they have received current Construction Documents. Subcontractors Field Drawings are inspected by the CQC Manager on a weekly basis and verified against the Plan Revision Log.[151]

Upon discovery or notification by Subcontractor/Supplier of a question or conflict in the Construction Documents, existing conditions, and/or conflicts with the work to be installed; FP is required to generate an RFI using the Request for Information form. The CQC Manager reviews all RFI's to confirm accuracy of the clarification being requested, that an appropriate plan or other reference data is included, and in

[151] Foulger-Pratt Quality Control Plan Revised 4/17/09 section B.4 page 5

order to coordinate with Project Staff to determine a possible solution if necessary. After review, the RFI is distributed to the A/E and DGS. Upon receipt of an RFI response, the CQC Manager and the Superintendent along with subcontractor field staff reviews the response to check for completeness and accuracy. If the response is complete and accurate, the CQC Manager posts the RFI to the Record Documents, logged into the tracking system, and distributed to the affected trades. If the RFI response does not completely or accurately answer the question, a subsequent RFI numbered with the Original RFI number supplemented by a Revision number is issued and the RFI tracking process begins again. The CQC Manager assures that the Subcontractors work with the current set of RFI responses.

Submittal Control

The CQC System Manager is responsible for managing and controlling the submittal review process.[152] Submittals are required to be reviewed in a sequence that does not cause delay in the work, the work of the Owner, or third-party contractors. In addition to compliance with Construction Contract requirements, all submittals are required to be checked for accurate dimensions and coordination with other trades prior to submission for review. Any variations from the Construction Documents are clearly indicated in the submittal. The processing of submittals is initiated and controlled by FP, in coordination with the QC System Manager. All submittals are numbered by FP upon receipt. Submittals are forwarded by FP's Project Manager, Brett Harton, to the QC System Manager. Foulger-Pratt's Project Manager certifies to the QC System Manager that the submittal has been reviewed by the Foulger-Pratt project staff with respect to drawing and trade coordination, that it can be constructed or installed in the space allocated, and that it meets the technical requirements of the Construction Contract. Upon completion of QC review, the QC System Manager certifies Construction Contract compliance or notes any variances, and the submittal is returned to FP's Project Manager who forwards it to the A/E and others per the agreed upon distribution.[153]

Upon receipt of the returned submittal, it is reviewed by the QC Manager and Foulger Pratt Project Manager for action noted by reviewer and any comments made on the submittal. The submittal is forwarded to the appropriate Subcontractor and/or Supplier and is also forwarded to appropriate trades whose work must be coordinated with the work indicated in the submittal. All original and reviewed/returned submittals are kept on file with Foulger Pratt for future reference by the QC Manager and Foulger Pratt project staff. In the event that the action by the reviewer results in a rejection or requirement to revise and resubmit, the appropriate logs are updated, the submittal returned to the Subcontractor, and resubmission is tracked. The Submittal Register is the primary tool used in managing the submittal control process. The register lists the submittals as identified in the Specifications by section and type (shop drawing, product data, certificates, test data, close out requirements, warranties, instructions, O&M data, and spare parts).

[152] Foulger-Pratt Quality Control Submittal Section 3.D page 11

[153] Per direction from PB in Progress Meeting dated Oct 29, 2008 "FPC will distribute submittals to each party, (1 to MC, 3 to WMATA, and 6 to PB. PB will distribute as required for internal review. PB will return submittals to each party (1 to MC, 1 to WMATA, 1 to ZGF, 1 to FPC). Exhibit P1 pages 39/59 section 1.1 Submittal Schedule and Logs

Ongoing periodic review of the register occurs in conjunction with the schedule to maintain timely submissions. As subcontracts and purchase contracts are awarded, the individual subcontractor/supplier sends a letter outlining specific submittal requirements including a list of items to be submitted, number of copies, any other administrative requirements set forth in the Specifications, and a timetable for submission. Submittal dates are scheduled in accordance with Foulger-Pratt's project schedule. The CQC System Manager and Project Manager monitor the status of submittals to confirm satisfactory progress. If a submittal becomes delinquent, it is to be addressed by verbal contact with the responsible party followed by written correspondence and other actions necessary to avoid impact to the project.[154]

The Submittal Log is a continuous and ongoing update of the submittal packages that have been submitted. The submittal packages are comprised of submittals as listed in the Submittal Register. The Submittal Log is maintained in Prolog which allows the CQC System Manager to effectively manage the process by using the various reporting functions of the database management system. The status of submittals is updated in the database as they are received and processed and presented in the regularly scheduled progress meetings with the Project Team or at other intervals as may be required by the Project Owner. The Submittal Log is kept current throughout the project and a final record copy is provided to the Owner at project completion.

Quality Control

The CQC Plan requires all testing and inspection during construction to be conducted in accordance with the Specifications and in compliance with the Construction Contract. As part of the Plan, a Test Matrix was created and is reproduced at the end of this appendix. The Test Matrix identifies each test and inspection required by type and the Specification paragraph as related to each Definable Feature of Work. The matrix also indicates the frequency of each test/inspection and the person or the certified independent testing agency responsible for performing each test/inspection. The Test Matrix is reviewed by the CQC Manager and coordinated with the Construction Schedule and planned work in the field. Additionally, the Test Matrix is coordinated with the Owner's Independent Testing Agent, RBB, as well as with the testing requirements of the Special Inspections Program.

The Test Matrix is maintained by the QC System Manager. Upon receipt of the written certified test report from the testing agency, the QC System Manager records the results in the Test Matrix. DGS is notified of any non-conforming test results within 24 hours of receipt of the information. Any non-conforming results are addressed prior to further work progressing relative to the non-conformance. After corrective actions are taken, re-testing is performed to confirm satisfactory results/acceptance have been achieved. The Quality Control Manager verifies that testing procedures comply with the requirements of the Construction Documents, verifies that facilities and testing equipment are available when needed and comply with applicable testing standards, checks test instrument calibration against certified standards, and verifies that recording forms and test identification control number system have been prepared. Results of all tests taken are recorded on the Quality Control Daily Report. The QC Manager's implementation of the Contractor's required Testing and Inspection process is integrated with

[154] Foulger Pratt Quality Control Plan Submittal Revised 4/17/09

the Independent Testing & Inspection provided by the Owner and as required by the Special Inspections Program. Daily communication, both written and verbal, with the Owner's Independent Testing agent(s) occurs so that the Independent Testing results are tracked, monitored, and have satisfactory results. In the event a test does not produce satisfactory results, the QC Manager verifies the re-inspection and/or re-test has been performed and satisfactory results have been achieved.

The CQC Plan utilizes a three-phased QC inspection process, incorporating Preparatory, Initial and Follow-Up control phases. These three phases are required to be scheduled, conducted, and documented by the QC System Manager in conjunction with the assigned QC Project Engineer and Trade Foreman. Each distinct trade activity/task that requires separate control procedures is assigned as a Definable Feature of Work.

The preparatory phase is to be performed prior to beginning work on each Definable Feature of Work and includes a check that the portion of the CQC System for the work to be performed has been accepted by the Owner, a review of the Construction Documents by the CQC System Manager with the construction personnel responsible for carrying out the construction, a check to assure that all materials and/or equipment have been tested, submitted, and approved, a check to assure that provisions have been made to provide required control inspection and testing, an examination of the work area, and a physical examination of required materials, equipment, and sample work to assure that they conform to approved shop drawings or submitted data and are properly stored. For each Definable Feature of Work, the QC System Manager is required to conduct a Preparatory Phase Meeting and Inspection at least 24 hours prior to the start of work. Where multiple Definable Features of Work are provided by the same subcontractor and are commencing at the same time, a preparatory meeting is required to be held with the Subcontractor to cover the multiple definable features. A minimum of 72-hour notice is required to allow attendance by all appropriate parties including respective trade supervisory personnel.

The CQC Plan requires the QC System Manager to conduct an Initial Phase Inspection with the respective trade crew and foremen as a specific Feature of Work starts for the first time. The purpose of this inspection is to confirm that the initial segment of work complies with all Construction Contract requirements. The QC System Manager documents the results of this inspection in the daily QC Report. Any issues encountered are documented and tracked. Included in the Initial Inspection Phase is a check of preliminary work for compliance with Construction Documents, a review of the minutes of the preparatory meeting, verification of full Construction Contract compliance, verification of required control inspection and testing, establishment of a level of workmanship and verification that it meets minimum acceptable workmanship standards, comparison with sample panels or mock-ups as appropriate, a check of conditions to include compliance with applicable safety regulations, and a review of safety issues with each construction personnel.

Minutes of the Initial Phase Inspection are prepared by the CQC System Manager and attached to the daily CQC report submitted to the Owner's Construction Representative. Exact location of the Initial Phase must be indicated for future reference and comparison with follow-up phases. The Initial Phase is required to be repeated for each new crew to work on-site, or whenever quality standards are not being met. The Follow-up Phase Inspection is performed by the QC System Manager on a periodic basis to verify continued Construction Contract compliance for a specific Feature of Work until the work is complete. The quality of the workmanship is compared to that which was established in the Preparatory and Initial Inspections. Testing is monitored and reviewed for proper performance and satisfactory results. Any re-work items are verified as being corrected. As with the previous inspections, the QC System Manager documents the results in the QC Daily Report. Any issues encountered are documented and tracked for timely resolution. Follow-up Inspections are documented in the Quality Control Managers Daily Report.

Test Matrix

The test matrix that follows is copied from the CQC plan submitted by FP.

FOULGER-PRATT

#10
#11

QC PLAN-APPENDIX E

SILVER SPRING
TRANSIT CENTER

51-0037

TEST/INSPECTION MATRIX

Silver Spring Transit Center

Testing Inspection Matrix
FPC Job #51-0037

FOULGER-PRATT

SPEC. SECTION	FEATURE of WORK	PARAGRAPH	STANDARD	REQUIREMENTS	FREQUENCY	TEST BY
		Division 2				
02205	Planting Soil	1.3	ASTM - USDA AASHTO	Soil Tests	Once for each three types	Balter / QC Manager
02270	Tieback Anchors	1.2, D	ASTM C 109	Standard test method for compressive strength of hydraulic cement mortars	As required	Sub / QC Manager
02270	Tieback Anchors	1.5		Alignment Tolerances. 1.5 degrees of required inclination. Within 2" of required loc	Each anchor	Berkel / ECS / QC Manager
02270	Tieback Anchors	3.5, A, K,L,M	PTI	Anchor Testing	Each Anchor	Berkel / ECS / QC Manager
02271	Tie-Down Anchors	1.4,	ASTM C 109	Standard test method for compressive strength of hydraulic cement mortars	As required	Sub / QC Manager
02271	Tie-Down Anchors	1.7	ASTM D 1586	Standard penetration testing for borings	As required	Sub / QC Manager
02271	Tie-Down Anchors	3.5	PTI	Anchor Testing	Each anchor	Sub / QC Manager
02271	Tie-Down Anchors	3.5, K	PTI	Performance Testing	10 % of anchors for foundation tie-down	Sub / QC Manager
02300	Earthwork	3.19	ASTM D - 1556	Subgrades, fills, backfills - compactions	Per 3.19, D -1, 2, 3	Balter / QC Manager
02300	Earthwork	3.8		Proof - roll	As required	Balter / QC Manager
02310	Controlled Blasting	1.9, D	BATF - COMAR - CFR - WMATA	Pre-Blast Inspection Survey	Prior to blasting	Balter / QC Manager
02310	Controlled Blasting	1.9, A, 4	BATF - COMAR - CFR - WMATA	Test Blasts / Production Blasts	Daily	Balter / QC Manager
02310	Controlled Blasting	1.9, E	BATF - COMAR - CFR - WMATA	Vibration Overpressure Monitoring	During blasting	Balter / QC Manager
02466	Drilled Piers	3.2	ACI-336.1	Test Borings	Prior to pier excavation	Balter / QC Manager
02466	Drilled Piers	3.9, A	ACI-336.1	Inspection of Excavations	Each Excavation	Balter / QC Manager
02466	Drilled Piers	3.9, C	ACI-336.1	Pier Inspection	Each Pier	Balter / QC Manager
02466	Drilled Piers	3.15, A	ACI-336.1	Crosshole Sonic Logging	All piers	Balter / QC Manager
02466	Drilled Piers	3.05, B	ACI-336.1	O-Cell Load Test	Demonstration Piers	LOADTEST
02466	Drilled Piers	3.16	ACI-336.1	Pier report, soil/rock testing, concrete testing	As required	Balter / QC Manager

Silver Spring Transit Center

Testing Inspection Matrix
FPC Job #51-0037

FOULGER-PRATT

SPEC. SECTION	FEATURE of WORK	PARAGRAPH	STANDARD	REQUIREMENTS	FREQUENCY	TEST BY
02510	Water Distribution System	3.15, C		Hydrostatic Test - pressure - leak test for water pipes	After backfill	WSSC / Ross / QC Manager
02510	Water Distribution System	3.15, D		Hydrostatic test of thrust restraint system	After valve installation and testing of water main	WSSC / Ross / QC Manager
02510	Water Distribution System	3.15.F		PVC Pipe Continuity Test	Once after installation of pipe	WSSC / Ross / QC Manager
02510	Water Distribution System	3.7		Chlorination	Per WSSC 02511	WSSC / Ross / QC Manager
02530	Sanitary Sewer	3.8, B		Gravity Sewer - except for 42" and larger RCP	After completion of backfill	WSSC / Ross / QC Manager
02530	Sanitary Sewer	3.8, C		Gravity Sewer - 42" and larger diameter RCP	Once after installation of pipe	WSSC / Ross / QC Manager
02530	Sanitary Sewer	3.8, C, 2		Final Sewer Testing	Once	WSSC / Ross / QC Manager
02530	Sanitary Sewer	3.8, D		Mandrel Test	Once after installation of pipe	WSSC / Ross / QC Manager
02530	Sanitary Sewer	3.8, E		Force Mains - pressure / leak test	Once after installation of pipe	WSSC / Ross / QC Manager
02530	Sanitary Sewer	3.8, F		CCTV Sewer House Connection	Once after installation of pipe	WSSC / Ross / QC Manager
02530	Sanitary Sewer	3.8, G		Manholes	As required	WSSC / Ross / QC Manager
02630	Storm Drainage	3.18, B		Pressure Test Piping	Once after installation of pipe	WSSC / Ross / QC Manager
02630	Storm Drainage	3.11	ASTM C 172	Concrete Testing	One sample of each mixture exceeding 5 cu. Yd.	Balter / QC Manager
02741	Hot-Mix Asphalt	3.11	SHA	Asphalt Testing / Thickness, Smoothness, Density	After placement	Balter / QC Manager
02742	Stamped Asphalt	1.9, C	SHA	Asphalt Testing / Thickness, Smoothness, Density - Stamping Depth	After placement	Balter / QC Manager
02780	Unit Pavers	3.2, C		Proof Roll	As required	Balter / QC Manager
02780	Unit Pavers	3.3, F		Tolerances: lippage - 1.6-mm unit to unit nor 3mm in 3m from level	As required	Balter / QC Manager
02812	Irrigation	2.2		Coverage Test	After installation	Engineer / QC Manager
02920	Lawns & Grasses	2.3	ASTM D 5268	Topsoil Soil Testing	Each 50 cubic yards	Sub / QC Manager
02920	Lawns & Grasses	1.02, E		Inspect Plant Material	Prior to digging and at arrival on site	Engineer / QC Manager

Silver Spring Transit Center

Testing Inspection Matrix
FPC Job #51-0037

FOULGER-PRATT

SPEC. SECTION	FEATURE of WORK	PARAGRAPH	STANDARD	REQUIREMENTS	FREQUENCY	TEST BY
03331	Cast-In-Place Architectural Concrete	3.5	ASTM C 39 C - 39 M	Compressive Strength Test: One set of two field cured specimens at 2 days for evaluation of the concrete for acceptability to begin post-tensioning, test one set of field specimens to confirm concrete in post-tensioned members has reached required strength	For each pour	Balter
03331	Cast-In-Place Architectural Concrete	3.5	ASTM C 231	Air Content: One test for each sample	At Placement	Balter / QC Manager
03331	Cast-In-Place Architectural Concrete	3.5	ASTM C 1064 C 1064 M	One test hourly when air temp. is 40 deg.F or lower and when 80 deg. and higher. One test for each composite sample	At Placement	Balter / QC Manager
03331	Cast-In-Place Architectural Concrete	3.5	ASTM C 31 C / 31M	Compression Test Specimens: Five sets of two standard cylinders for each composite sample. Laboratory cure two sets of cylinders and field cure three sets of cylinders	For each pour	Balter
03331	Cast-In-Place Architectural Concrete	3.5	ASTM C 39 C - 39 M	Compressive Strength Tests: One set of two laboratory cured specimens at 7 days and one set of two specimens at 28 days	For each pour	Balter
03381	Bonded Post-Tensioned Concrete	2.9	ACI 304 R	Testing for Concrete and Grout Mixes: Comply with requirements of Division 03300	As required	Balter / QC Manager
03381	Bonded Post-Tensioned Concrete	3.10, A, 1		Inspection of Duct after installation	After installation	Sub / Balter / QC Manager
03381	Bonded Post-Tensioned Concrete	3.6	ACI 5.3.2	Inspection of Concrete Placement	During placement	Sub / Balter / QC Manager
03381	Bonded Post-Tensioned Concrete	3.7		Tendon Stressing	After concrete strength reaches 4000 psi	Sub / Balter / QC Manager
03381	Bonded Post-Tensioned Concrete	3.10, A		Field Quality Control: Refer to Specification Requirements	As required	Sub / Balter / QC Manager
03381	Bonded Post-Tensioned Concrete	3.4		Inspect duct for damage, ensure ducts are watertight with no voids	After installation	Sub / Balter / QC Manager
03381	Bonded Post-Tensioned Concrete	3.10, A, 2		Contractor Inspections and Records: See Field Quality Control Test Reports	As required	Sub / Balter / QC Manager
03408	Segmented Retaining Wall	2.7	ASTM D 422 - 4318-698	Reinforced Soil Inspection	After Backfill	Balter / QC Manager
03408	Segmented Retaining Wall	3.3	Per 3.8	Compaction Testing: Infill soils	After wall installation	Balter / QC Manager
03408	Segmented Retaining Wall	3.4				

Silver Spring Transit Center

Testing Inspection Matrix
FPC Job #51-0037

FOULGER-PRATT

SPEC. SECTION	FEATURE of WORK	PARAGRAPH	STANDARD	REQUIREMENTS	FREQUENCY	TEST BY
02930	Trees & Shrubs	3.08		Acceptance Inspection	Once	Engineer / QC Manager
		Division 3				
03300	Cast -In-Place Concrete	3.9	ACI 301-10	Verify correct installation of formwork, reinforcement, embeds	Each Pour	Sub / Balter / QC Manager
03300	Cast -In-Place Concrete	3.9	ACI 5.3.2	Inspection of Concrete Placement	As required	Sub / Balter / QC Manager
03300	Cast -In-Place Concrete	3.17	ACI 304 R	Concrete Tests and Inspections	As required	Sub / Balter / QC Manager
03300	Cast -In-Place Concrete	3.17, C, 1	ASTM C 172	Concrete Samples: one composite sample for each days pour of each mixture exceeding 5 cu. Yd. plus one set for each additional 50 cu. Yd	At Placement	Balter / QC Manage
03300	Cast -In-Place Concrete	3.17, C, 2	ASTM C 134/C 143 M	Slump: one for each sample	At Placement	Balter / QC Manage
03300	Cast -In-Place Concrete	3.17, C, 3	ASTM C 231	Air Content: One test for each sample	At Placement	Balter / QC Manage
03300	Cast -In-Place Concrete	3.17, C, 4	ASTM C 1064 C 1064 M	One test hourly when air temp. is 40 deg.F or lower and when 80 deg. and higher. One test for each composite sample	At Placement	Balter / QC Manage
03300	Cast -In-Place Concrete	3.17, C, 5	ASTM C 31 C / 31M	composite sample. Laboratory cure two sets of cylinders and field cure three sets of cylinders	For each pour	Balter
03300	Cast -In-Place Concrete	3.17, C, 6	ASTM C 39 C - 39 M	Compressive Strength Tests: One set of two laboratory cured specimens at 7 days and one set of two specimens at 28 days	For each pour	Balter
03300	Cast -In-Place Concrete	3.17, C, 6, a	ASTM C 39 C - 39 M	Compressive Strength Test: One set of two field cured specimens at 2 days for evaluation of the concrete for acceptability to begin post-tensioning, test one set of field specimens to confirm concrete in post-tensioned members has reached required strength	For each pour	Balter
03331	Cast-In-Place Architectural Concrete	3.5	ASTM C 231	Air Content: One test for each sample	At Placement	Balter / QC Manager
03331	Cast-In-Place Architectural Concrete	3.5	ASTM C 1064 C 1064 M	One test hourly when air temp. is 40 deg.F or lower and when 80 deg. and higher. One test for each composite sample	At Placement	Balter / QC Manager
03331	Cast-In-Place Architectural Concrete	3.5	ASTM C 31 C / 31M	Compression Test Specimens: Five sets of two standard cylinders for each composite sample. Laboratory cure two sets of cylinders and field cure three sets of cylinders	For each pour	Balter
03331	Cast-In-Place Architectural Concrete	3.5	ASTM C 39 C - 39 M	Compressive Strength Tests: One set of two laboratory cured specimens at 7 days and one set of two specimens at 28 days	For each pour	Balter

Silver Spring Transit Center

Testing Inspection Matrix
FPC Job #51-0037

FOULGER-PRATT

SPEC. SECTION	FEATURE of WORK	PARAGRAPH	STANDARD	REQUIREMENTS	FREQUENCY	TEST BY
08912	Structural-Sealant-Glazed Curtain Walls	3.4, B, 4	AAMA 501.2	Water Spray Test: A minimum area of 50 ft. by one story	Before installation of interior finishes. As directed by architect	Independent Agency QC Manager
08960	Sloped Glazing Assemblies	3.4, B, 1	ASTM C 1401	Structural Sealant Adhesion Test	As installation proceeds	Independent Agency QC Manager
08960	Sloped Glazing Assemblies	3.4, B, 2	ASTM E 783	Air Infiltration Test: 1.5 times rate specified, but not more than 0.50 cfm/sq. ft. at min. static pressure differential of 12 lbf/sq. ft. Test area: one bay wide, not less than 30 ft by one story	As installation proceeds	Independent Agency QC Manager
08960	Sloped Glazing Assemblies	3.4, B, 3	ASTM E 1105	Water Penetration Test: 0.67 times the static-air-pressure differential, not less than 6.24 lbf/sq. ft. Test area: one bay wide, not less than 30 ft by 30 feet of sloped glazing assembly	As installation proceeds	Independent Agency / QC Manager
08960	Sloped Glazing Assemblies	3.4, B, 4	AAMA 501.2	Water Spray Test: A minimum area of 30 by 30 ft.	Before installation of interior finishes. As directed by architect	Independent Agency / QC Manager
		Division 13				
13110	Cathodic Protection	3.8, C, D		Bond resistance testing, Theoretical joint and bond resistance, Insulation continuity	As Required	Sub / QC Manager
13110	Cathodic Protection	3.8, D		Test each insulating joint for continuity of insulation	Prior to Backfill	Sub / QC Manager
13110	Cathodic Protection	3.8, E		Test continuity, pipe to soils potential	After Backfill	Sub / QC Manager
13760	CCTV	3.4, C, E		Pre - Testing and Operational Testing	Operational: After system has been in normal function for 14 days	Mfg. Rep. / Sub / QC Manager
13760	CCTV	3.6, D		Pre - Testing and Final Testing	Final Testing after acceptance of pre-testing	Mfg. Rep. / Sub / QC Manager / WMATA
13852	Fire Alarm And Intrusion Detection System	3.4,B, D		Pre - Testing and Final Testing	Final Testing after acceptance of pre-testing	DPS / Sub / QC Manager
13930	Wet Pipe Fire Suppression System	3.11		Leak Test, Controls and Safeties, Flush, pumps, Fire Alarm Coordination	As required	Fire Marshall / DPS / Sub / QC Manager
13935	Dry Pipe Fire Suppression System	1.6, G		Fire Hydrant Flow Test	Once	Fire Marshall / DPS / Sub / QC Manager
13935	Dry Pipe Fire Suppression System	3.11		Leak Test, Controls and Safeties, Flush, pumps, Fire Alarm Coordination	Upon Completion of Installation	Fire Marshall / DPS / Sub / QC Manager
	Clean Agent Extinguishing	3.7, A B, C,				

Silver Spring Transit Center

Testing Inspection Matrix
FPC Job #51-0037

FOULGER-PRATT

SPEC. SECTION	FEATURE of WORK	PARAGRAPH	STANDARD	REQUIREMENTS	FREQUENCY	TEST BY
03410	Plant-Precast Structural Concrete	3.3	ASTM E 165-709	Inspection of Field Welds	Each weld	Balter / QC Manager
		Division 4				
04200	Masonry	1.5, A, 1		Placement: Do not place when temp. falls below 40 degrees or when temperatures below 40 degrees are likely after mortar is placed.	During placement	Sub / QC Manager
04200	Masonry	1.5, A,2		Placement: Heat and maintain temp. of mtrls. At not less than 40 degrees - not more than 160 degrees	During placement	Sub / QC Manager
04200	Masonry	1.5, B		Placement during hot weather: cover work for 3 days, when ambient temp. is over 95 degrees protect work for 72 hrs.	During placement	Sub / QC Manager
04200	Masonry	3.3		Placing Tolerances: Average thickness of any three consecutive joints 3/8" to 1/2"	During placement	Sub / QC Manager
04810	Unit Masonry	3.9, A, 1		Spacing, Grades, Sizes, Reinforcement	Prior to Grout	Balter / QC Manager
04810	Unit Masonry	3.9		CMU Test, Mortar Test, Grout Test, Prism Test	Each 5000 sq. ft. of wall	Balter / QC Manager
04815	Glass Unit Masonry	1.6		Weather Limitations: Install when temps. Are 40 deg. Or higher	As required	Sub / QC Manager
04815	Glass Unit Masonry	2.3	ASTM C 270	Mortar Mixes: Type S mortar	As required	Sub / QC Manager
04815	Glass Unit Masonry	3.2, E,		Place pointing mortar in 3/8" layers	During placement	Sub / QC Manager
04860	Stone Masonry	1.6, B, C	ACI 530.1	Cold Weather Requirements: Comply with ACI 530.1 / ASCE 6 / TMS 602	As required	Sub / QC Manager
04860	Stone Masonry	3.4		Tolerances: variation from level: 1/8" in 5 ft. Slope: 1/8" from back of tread to nose of tread	During placement	Sub / QC Manager
		Division 5				
05120	Structural Steel	2.8		Shop Tests and Inspections	Fabrication	Balter
05120	Structural Steel	3.5, B	ASTM A 325 - A 490	Shop-bolted connections	As required	Balter
05120	Structural Steel	3.5, C	AWS D1.1	Field Welded Connections	As required	Balter / QC Manager
05310	Steel Deck	3.4, B	AWS D1.3	Inspection of Field Welds	After installation	Balter / QC Manager
		Division 7				
07131	Sheet Waterproofing	3.1	ASTM D 4263	Capillary Moisture Test	Prior to installation	Sub / QC Manager

Silver Spring Transit Center

Testing Inspection Matrix
FPC Job #51-0037

FOULGER-PRATT

SPEC. SECTION	FEATURE of WORK	PARAGRAPH	STANDARD	REQUIREMENTS	FREQUENCY	TEST BY
15181	Hydronic Piping	3.9, C		Performance Test	Prior to operating system	DPS / Sub / QC Manager
15410	Plumbing Fixtures	3.4		Verify installation for compliance with Contract requirements and operation	After Installation	DPS / Sub / QC Manager
15415	Drinking Fountains and Water Coolers	3.5		Performance Tests	After powering	DPS / Sub / QC Manager
15446	Sump Pumps	3.4		Check Mechanical Operation	Start up	DPS / Sub / QC Manager
15485	Electric Water Heaters	3.3, A, B, C		Leak Test, Operational Test, Controls and Safeties	After Installation	DPS / Factory Rep / Sub / QC Manager
15629	Scroll Water Chillers	3.3		Operation Testing	Start up	Factory Rep / Sub / QC Manager
15725	MIC - AHU's	3.4, A, B, C		Leak Test, Refrigerant Leak Test, Fan Operation Test	Start up	Factory Rep / Sub / QC Manager
15731	Packaged Terminal AC	3.3, A		Compliance with Requirements, Operational Test, Controls and Safeties	Start up	DPS / Sub / QC Manager
15732	Rooftop AC Units	3.4, A, B, C		Compliance with Requirements, Operational Test, Controls and Safeties	Start up	DPS / Sub / QC Manager
15778	Heat Tracing	3.3		Continuity, Insulation Integrity, Cable Rating and Power	Before application of coverings	DPS / Sub / QC Manager
15815	Metal Ducts	3.6	SMACNA	Air Duct Leak Test	After Installation	DPS / Sub / QC Manager
15820	Duct Accessories	3.2		Operate Dampers, Access Door Location, Inspect Turning Vanes	After Installation	DPS / Sub / QC Manager
15836	Axial Fans	3.3		Fan Operation, Damper Linkage and Operation, Motor Rotation	After Installation	DPS / Sub / QC Manager
15840	Air Terminal Units	3.3	ARI 880	Compliance with Requirements, Operational Test, Controls and Safeties	After Installation	DPS / Sub / QC Manager
15950	TAB			See Commissioning Plan		
		Division 16				
16055	Overcurrent Protection	3.5		Voltage Drop Study: Not to exceed 2% at rated capacity, Max. voltage drop 3%	As required	Sub / QC Manager
16060	Grounding and Bonding	3.5		Ground Resistance Test	After Installation	Sub / Independent Agency / QC Manager
16124	Medium Voltage Cables	3.2		Visual, Mechanical, Electrical per NETA ATS	As required	DPS / Sub / Independent Agency / QC Manager
	Lighting Control					

Silver Spring Transit Center

Testing Inspection Matrix
FPC Job #51-0037

FOULGER-PRATT

SPEC. SECTION	FEATURE of WORK	PARAGRAPH	STANDARD	REQUIREMENTS	FREQUENCY	TEST BY
13974	Fire Suppression Standpipes	1.3, B, 1		Fire Hydrant Flow Test	Upon Completion of Installation	Fire Marshall / DPS Sub / QC Manager
13974	Fire Suppression Standpipes	3.1	NFPA 14	Leak Test, Controls and Safeties, Flush, pumps, Fire Alarm Coordination	Upon Completion of Installation	Fire Marshall / DPS Sub / QC Manager
		Division 14				
14200	Hydraulic Elevators	3.02		Acceptance and Elevator Tests (Full Load Run Test - Speed Test)	As required: One hour continuous run	DPS / Sub / QC Manager / Engr.
14300	Heavy duty Escalator	3.04		Load Test, Overspeed Test, Handrail Tension, Broken Chain Protection	After Installation	DPS / Sub / QC Manager / Engr.
		Division 15				
15073	Vibration and Seismic Controls for Plumbing	3.5		Performance Tests: Four of each type to 90% of rated load	After Installation	DPS / Sub / QC Manager
15074	Vibration and Seismic Controls for HVAC	3.5		Performance Tests: Four of each type to 90% of rated load	After Installation	DPS / Sub / QC Manager
15082	Plumbing Insulation	3.1		Insulation	Once - random locations	DPS / Sub / QC Manager
15083	HVAC Insulation	3.5,B,1		Ductwork Inspection	One location for each duct system	DPS / Sub / QC Manager
15083	HVAC Insulation	3.5, B, 2		Pipe, fittings, strainers and valves	Three locations of straight pipe	DPS / Sub / QC Manager
15140	Domestic Water Piping	3.9, A		Rough-in Inspection, Final Inspection	Rough-in and Final	DPS / Sub / QC Manager
15140	Domestic Water Piping	3.9, B		Domestic Water Piping	Prior to concealment / 50 psgi for 4 hrs.	DPS / Sub / QC Manager
15140	Domestic Water Piping	3.11	AWWA C651 / AWWA C652	Disinfection of Domestic Water Piping	50 ppm chlorine for 24 hrs	DPS / Sub / QC Manager
15145	Domestic Water Piping Specialties	3.3		Vacuum Breaker and Backflow Preventer	After Installation	DPS / Sub / QC Manager
15150	Sanitary Waste and Vent Piping	3.8, A, C		Rough-in and Final: Leaks and defects	After Installation	DPS / Sub / QC Manager
15150	Sanitary Waste and Vent Piping	3.8, D		Force Main: Static water pressure of 50 psig for four hours	Prior to concealment	DPS / Sub / QC Manager
15160	Storm Drainage Piping	3.7, A, D		Rough-in and Final: Leaks and defects	Prior to concealment	DPS / Sub / QC Manager

Silver Spring Transit Center

Testing Inspection Matrix
FPC Job #51-0037

FOULGER-PRATT

SPEC. SECTION	FEATURE of WORK	PARAGRAPH	STANDARD	REQUIREMENTS	FREQUENCY	TEST BY
16211	Electricity Metering	3.2	NECA 1	Meter Load Test	Once for eight hours	Sub / QC Manager
16231	Packaged Engine Generator	3.4		NETA Acceptance Testing, NFPA 110 Acceptance Tests	Coordinate with tests for transfer switches	Factory Rep / Sub / QC Manager
16269	Frequency Controllers	3.8		Insulation resistance, continuity, visual	Prior to acceptance	Sub / Independent Agency / QC Manager
16289	Transient Voltage Suppression	3.3	NETA ATS	Compliance, Start up Checks, Visual - Mechanical	Once - After surge protection, before energizing circuitry	Sub / Independent Agency / QC Manager
16341	Medium Voltage Switchgear	3.5	NETA ATS	Electrical - Mechanical Acceptance Tests per NETA ATS	Prior to acceptance	Factory Rep / Sub / QC Manager / Independent Agency
16410	and Circuit Breakers	3.5	NETA ATS	Connections, Switch-Relay Type, Fuse Rating, Visual - Mechanical	As required	DPS / Factory Rep / Sub /QC Manager
16415	Transfer Switches	3.3	NEMA ICS 1	Compliance, Visual - Mechanical per NETA ATS, Insulation Resistance	As required	DPS / Factory Rep / Sub /QC Manager
16420	Enclosed Controllers	3.8	NETA ATS	Insulation Resistance, Continuity, Controllers, Components, Equipment	As required	DPS / Factory Rep / Sub /QC Manager
16441	Switchboards	3.5	NETA ATS	Insulation Resistance, Continuity, Electrical - Mechanical per NETA ATS	As required	Sub / Independent Agency / QC Manager
16442	Panelboards	3.4	NETA ATS	Electrical - Mechanical Acceptance Tests per NETA ATS, Load Balancing	As required	Sub / Independent Agency / QC Manager
16443	Motor Control Centers	3.7	NETA ATS	Insulation Resistance, Continuity.	After Installation	Sub / Independent Agency / QC Manager
16461	Low Voltage Transformers	3.4	NETA ATS	NETA Acceptance Testing	After Installation	Sub / Independent Agency / QC Manager
16511	Interior Lighting	3.2		Test Emergency Lighting	After Installation	DPS / Sub / QC Manager
16521	Exterior Lighting	3.7	IESNA LM	Measure Light Intensity	After Installation	Sub / QC Manager
16601	AEMS	3.03		System Start Up, Verify Operation	After Installation	Sub / QC Manager
16670	Lightning Protection	1.1, B		Ground Resistance Test	After Installation	Sub / Independent Agency / QC Manager
16724	Emergency Speakerphone	3.2		Components - Equipment, Operational Test	After Installation	DPS / Sub / QC Manager
16740	Structured Cabling System	3.4	ANSI/TIA/EIA	Test for product capability, OTS, continuity, polarization and shorts, OTDR	After Installation	Sub / QC Manager

Appendix B – Duties and Functions of DGS Project Management Team

Note: The information provided in this appendix was provided by DGS. It has been reformatted slightly to fit this document but is otherwise not a product of this analysis. The descriptions provided have not been verified and are provided for information purposes only.

Several County personnel are involved in the construction administration of the SSTC. The Montgomery County Special Inspections Program outlines the duties and functions required by the owner or owner's representatives.[155] The following outlines each individual's duties and functions, which fulfill the requirements.

The description of Mr. Anderson's duties and functions as supplied by DGS include:

- Works under the lead of the Project Manager Tim O'Gwin primarily to supports County with interface with WMATA for All submittals – review and acceptance issues, coordination with PB in the resolution of All submittal issues
- As time evolved on the project this support grew to include coordination of the Safety & Security Certification process (WMATA close out/checklist program), Commissioning and Closeout; which are now his major activities since submittals are down to a minimum
- Spends time in the site office and in the field to support the daily construction activities
- Coordination with MTA with all QA/QC inspections and issues on the project
- Support County activities in major settlement with the Contractor and their caisson sub-contractor to optimize DGS's payment for extra caisson work on the project
- Support DGS in other cost related (no time-related) PCOs
- Attends progress meetings, construction prep meetings, Commissioning meetings, Closeout meetings, Safety & Security meetings, some MTA coordination meetings

Frank Roberts serves as Project Team Leader and his duties and functions include:

- Performing all the functions of a Team Leader of the on-site SSTC County personnel to manage their day to day activities as well as reporting to the Division management on a day to day basis
- Coordination with WMATA, MTA, FTA management of all project issues
- Performing all the lead functions associated with managing the Prime Contract for both Contractor and A/E, together with coordination and adherence to WMATA requirements as defined in the MOU for the project. Additionally coordinates with MTA, FTA and DGS management team to ensure that the work is proceeding according to agreements.
- Coordinating with FP on-site and home-office management team including monthly MC/FP management team meetings in which major problems are jointly flushed out ; works very closely with PM on Field Orders and Change Orders with FP/PM to manage the fairness and accuracy of that process
- Spending time in the site office and in the field to support the daily construction activities
- Coordinating with the PM on RFIs, ASIs and All project issues and problems to the level of detail needed to get resolution and eliminate project delays
- Assisting the PM with work associated with Review, negotiation and resolution of PCO by Field Order or Change Order instrument
- Attending all progress meetings, some construction prep meetings, project SWAT 3-person team meeting (FP/PB/County) PMP meetings (Chairs this meeting), FTA/MTA meetings, SSTC briefing meetings, weekly team meetings, and prepares input to the respective meetings, and quarterly MTA meeting as-required

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155 Montgomery County Special Inspections Program, Section 1.7.1 Owner (Owner's Representatives), Page 4 of 26, Revised 10/26/2012

- Keeping DGS Division management personnel well informed of all issues critical and pending that will affect the success of the project, on a daily basis
- Coordinating with Tim Herbold on daily urgent construction issues that need PM resolution
- Monitoring the project website content and updates accordingly
- Attending Safety & Security, Commissioning , Closeout meetings
- Attending monthly schedule review meetings and reviews the schedules and Notices of Delay proposed by the Contractor for input to County response and evaluation of those delay claims.

Tim O'Gwin serves as Project Manager and his duties and functions include:

- Performing all the lead functions associated with managing the Prime Contract for both Contractor and A/E, together with coordination and adherence to WMATA requirements as defined in the MOU for the project. Additionally coordinating with MTA, FTA and DGS management team to ensure that the work is proceeding according to agreements.
- Spending time in the site office and in the field to support the daily construction activities
- Reviewing, negotiating the Contractor's PCOs for settlement (together with DGS's cost estimating contractor) and prepares all the documentation – Field Orders or Change Orders, for settlement inclusive of meetings with the CRC (for Change Orders)
- Reviewing all the contract RFIs & A/E responses for clarification for accuracy and agreement ; has the final word in direction for closure of RFIs
- Reviewing all the contract ASIs & A/E responses for clarification for accuracy and agreement ; has the final word in direction for closure of RFIs
- Attending all progress meetings, some construction prep meetings, PMP meetings, FTA/MTA meetings, SSTC briefing meetings, weekly team meetings, and prepares input to the respective meetings
- Coordinating with Bob Stout in the running of the weekly A/E Design Team meetings
- Coordinating monthly meetings with WMATA's site construction personnel
- Supporting the Project Team Leader in the resolution of All issues related to the execution of both the A/E Contract and the Construction Contract
- Acting as lead in the supervision of work done by PB's on-site construction management engineer (John Anderson)
- Coordinating with Tim Herbold on daily urgent construction issues that need PM resolution

Robert Stout serves as Assistant Project Manager and his duties and functions include:

- Assisting the Project Manager -Tim O'Gwin and the Project Team Leader – Frank Roberts as-needed in the execution of all functions to support the management of the SSTC project; but within those functions has some fixed roles such as All project Financial and Invoicing, and Reports
- Spending time in the site office and in the field to support the daily construction activities
- Preparing All project Reports including monthly reports to MTA and FTA, and EOB Briefings
- Coordinating the monthly PMP meetings that include the presence of FTA/MTA/WMATA/PB/County and prepares minutes and agenda
- Updating DGS input to the MTA Quarterly meetings on the project
- Processing All the Invoices on the project – verification through payment, keeps an update on the project financial balances
- Administering PB Contract including assignment of task orders and ASIs
- Assisting the PM in the review and execution of RFIs on the project so that DGS stays current and in-control of clarifications and potential changes

- Coordinating and runs weekly meetings with the Design Team (PB/ZGF) and biweekly meetings with MTA
- Performing other duties as assigned by the PM and the Team Leader to assist with coordination documentation with WMATA, FTA and MTA.

Leo Perez serves as County Scheduling Engineer and his duties and functions include:

- Performing all the functions of an on-site scheduling engineer including and not limited to daily photos of All ongoing construction on the site in order to maintain records and to help to validate the monthly schedule updates from the Contractor
- Spending time in the site office and in the field to support the daily construction activities
- Coordinating the monthly schedule reviews of the project which are attended by MTA and their scheduling consultant, County and the Contractor
- Assisting in preparation of letter responses to the contractor of schedule updates as well as Notices of Delay
- Assisting in review and preparation of DGS settlement with the Contractor for time lost in the early phases of construction on the project – Change Order #8.
- Attending all progress meetings, PMP meetings, some site prep meetings, schedule review meetings and County biweekly management team meetings.
- Supporting the activities of A/E in their review of project Notices of Delay from the Contractor; TC26 schedule through the current TC42 schedule
- Supporting the PM and Team Leader in numerous and miscellaneous activities involved with a better understanding of construction slippage in time and issues that may be driving the Contractor's PCO submittal
- Supporting the cost estimating efforts of the team as-required

Tim Herbold serves as Senior Construction Representative and his duties and functions include:

- overseeing the daily functions of Shakeel Bokhari
- Spending majority of time on the site
- Reporting daily construction activities, issues, problems, and look-ahead conditions of the construction activities to the Team Leader and Project Manager
- Inspecting all site construction installations by General Contractor and Subcontractors including but not limited to the major items of Earthwork, Sediment & Erosion Control, Caisson drilling & concrete, Concrete, Steel, Post-tensioning, Formwork, Finishes, Electrical & Mechanical installations, Glazing , Escalator & Elevator installations, Paving, Underground & Above ground Utility installations, Miscellaneous Metals installations
- Coordinating and documents daily inspection performed by RBB in the execution of all the work categories listed above; prepares daily Construction Representative reports for County use and records
- Reviewing RFIs, ASIs and other change instruments on the project and follows through inspection with the Contractor on implementation of those Construction Documents
- Attending construction preparatory meetings, biweekly progress meetings, superintendents' meetings, subcontractor meetings, safety meetings, weekly SSTC project meetings, Commissioning meetings, Closeout meetings, safety & Security meetings
- Attending biweekly project Briefing meetings in the EOB and presents work status activities to the SSTC management team
- Reviewing RBB daily and monthly inspection reports
- Reviewing and okays RBB's monthly Invoices with corrections as-needed

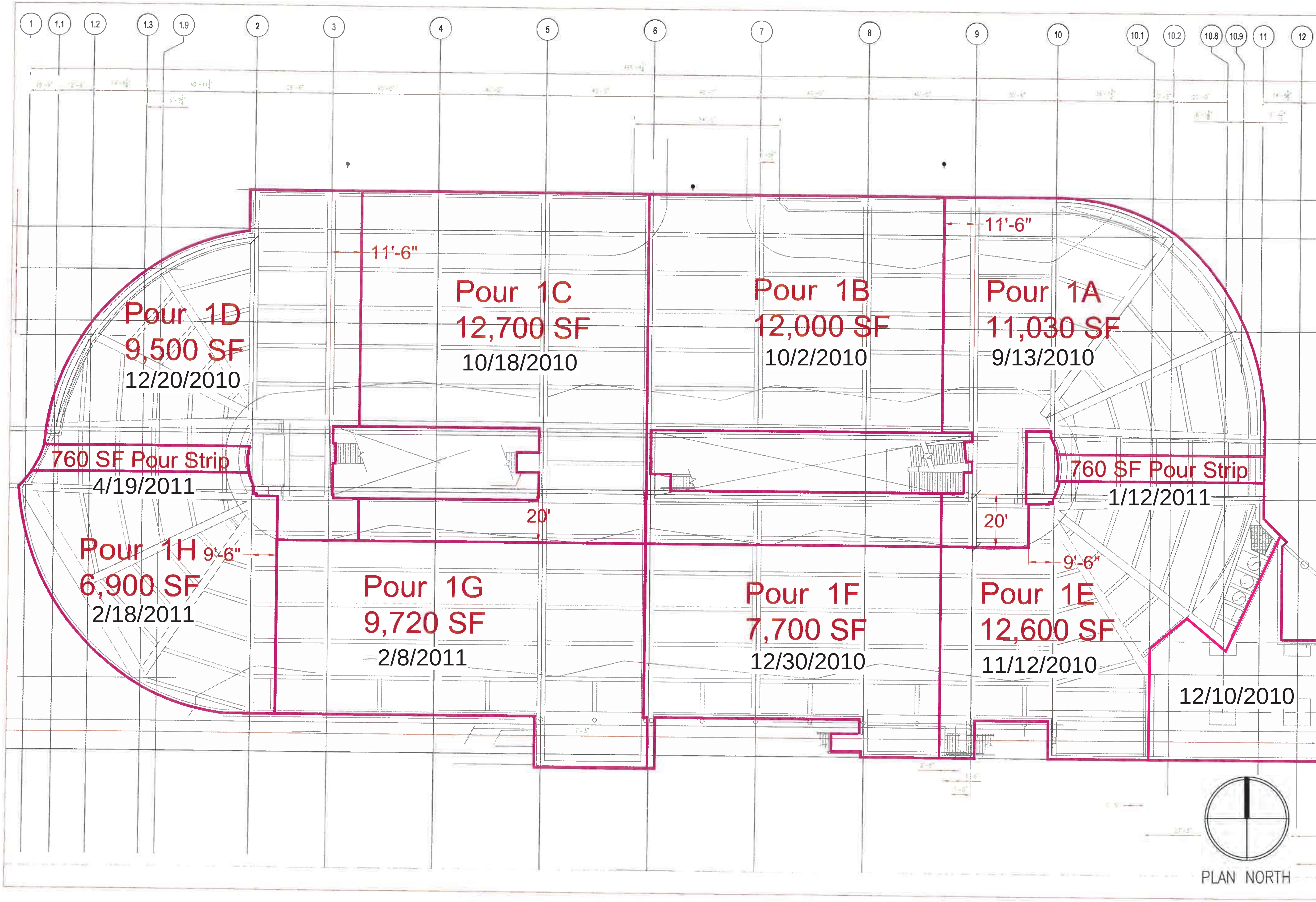
- Reviewing the Contractor's monthly Payment Applications, line by line, for accuracy and inspects materials being billed for in the monthly Payment Applications
- Maintaining a presence on the site during after –hours or weekend construction presence by the General Contractor or their subs

Shakeel Bokhari serves as Construction Representative and his duties and functions include:

- Reporting to the Senior Construction Representative, Tim Herbold for definition of daily functions
- Spending majority of time on the site
- Inspecting all site construction installations by General Contractor and Subcontractors including but not limited to the major items of Earthwork, Sediment & Erosion Control, Caisson drilling & concrete, Concrete, Steel, Post-tensioning, Formwork, Finishes, Electrical & Mechanical installations, Glazing , Escalator & Elevator installations, Paving, Underground & Above ground Utility installations, Miscellaneous Metals installations
- Coordinating and documents daily inspection performed by RBB in the execution of all the work categories listed above; prepares daily Construction Representative reports for County use and records
- Reviewing RFIs, ASIs and other change instruments on the project and follows through inspection with the Contractor on implementation of those Construction Documents
- Attending construction preparatory meetings, biweekly progress meetings, superintendents' meetings, subcontractor meetings, safety meetings, weekly SSTC project meetings, Commissioning meetings, Closeout meetings, safety & Security meetings
- Reviewing RBB daily and monthly inspection reports
- Reviewing the Contractor's monthly Payment Applications, line by line, for accuracy and inspects materials being billed for in the monthly Payment Applications
- Maintaining a presence on the site during after –hours or weekend construction presence by the General Contractor or their subs

Appendix C – Plans of SSTC Floors

Note: The information provided in this appendix is taken from KCE Attachments 11 and 26. It has been reformatted slightly to fit this document but is not otherwise a product of this analysis. The content has not been verified and is provided for information purposes only.



PROJECT NO : 490

DATE: July 17, 2009

SCALE: N.T.S.

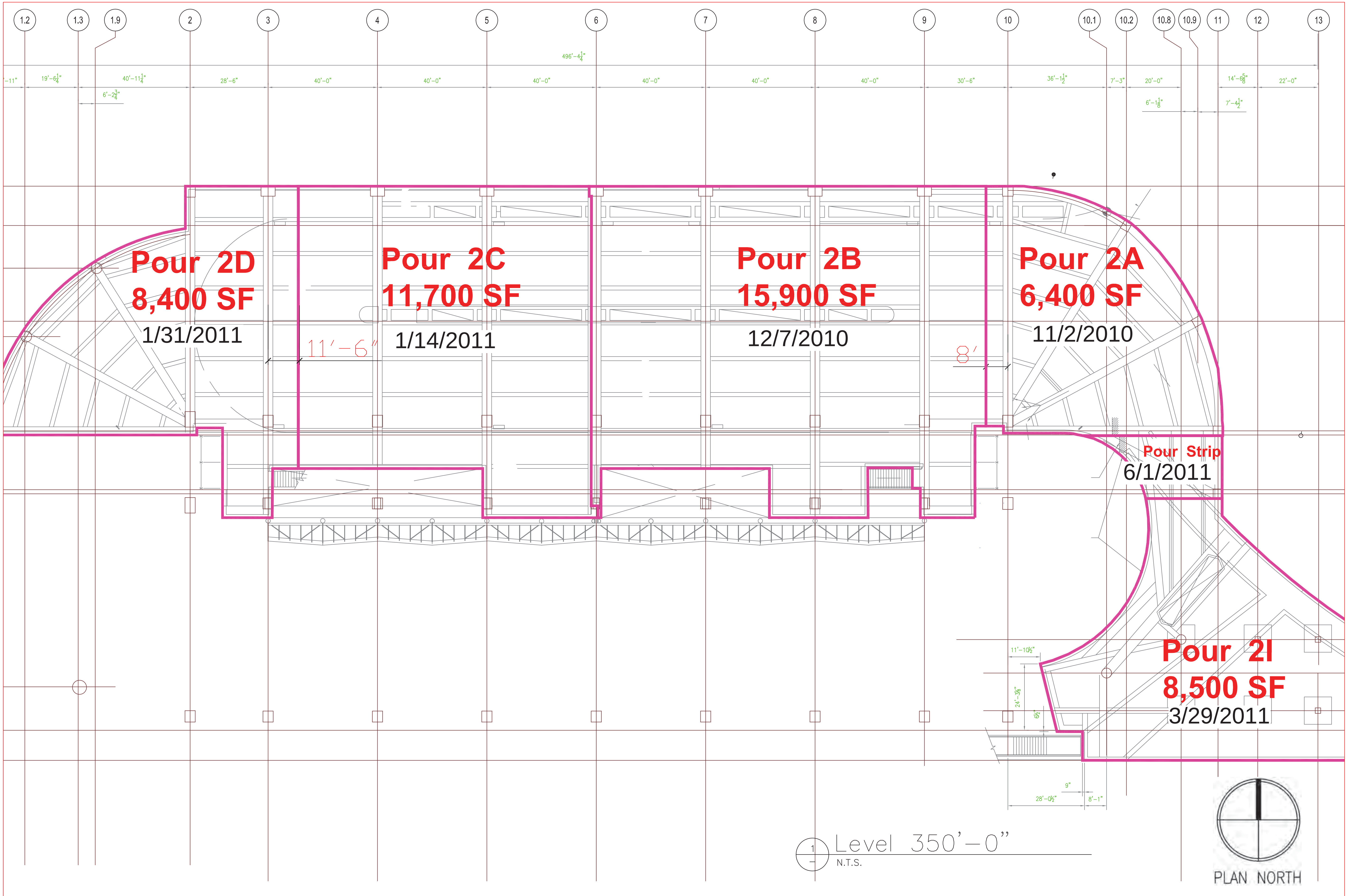
Silver Spring Transit Center

Ramsey Avenue & Bonifant Street
Silver Spring, Maryland

Construction Joints 330 Level

Facchina
CONSTRUCTION COMPANY, INC.

DWG NO: CJ - 100



PROJECT NO : 490

DATE: 04/15/2010

SCALE: N.T.S.

Silver Spring Transit Center

Ramsey Avenue & Bonifant Street
Silver Spring, Maryland

Construction Joints 350 Level

Facchina
CONSTRUCTION COMPANY, INC.

DWG NO:
CJ - 200

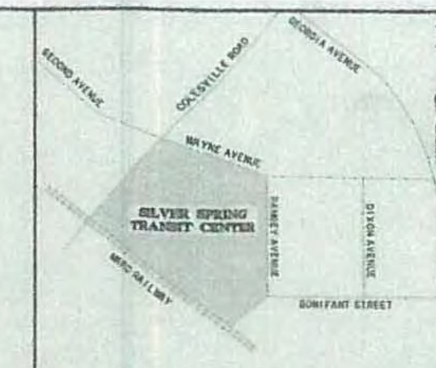
Concrete Slab Thickness (inches)				
Number	Minimum Elevation	Maximum Elevation	Color	Surface Area (sq.ft.)
1	7.00	8.00		30.6
2	8.00	9.00		2938.9
3	9.00	9.76		9737.2
4	9.76	10.38		17870.3
5	10.38	11.00		12317.6
6	11.00	13.00		4486.7

N

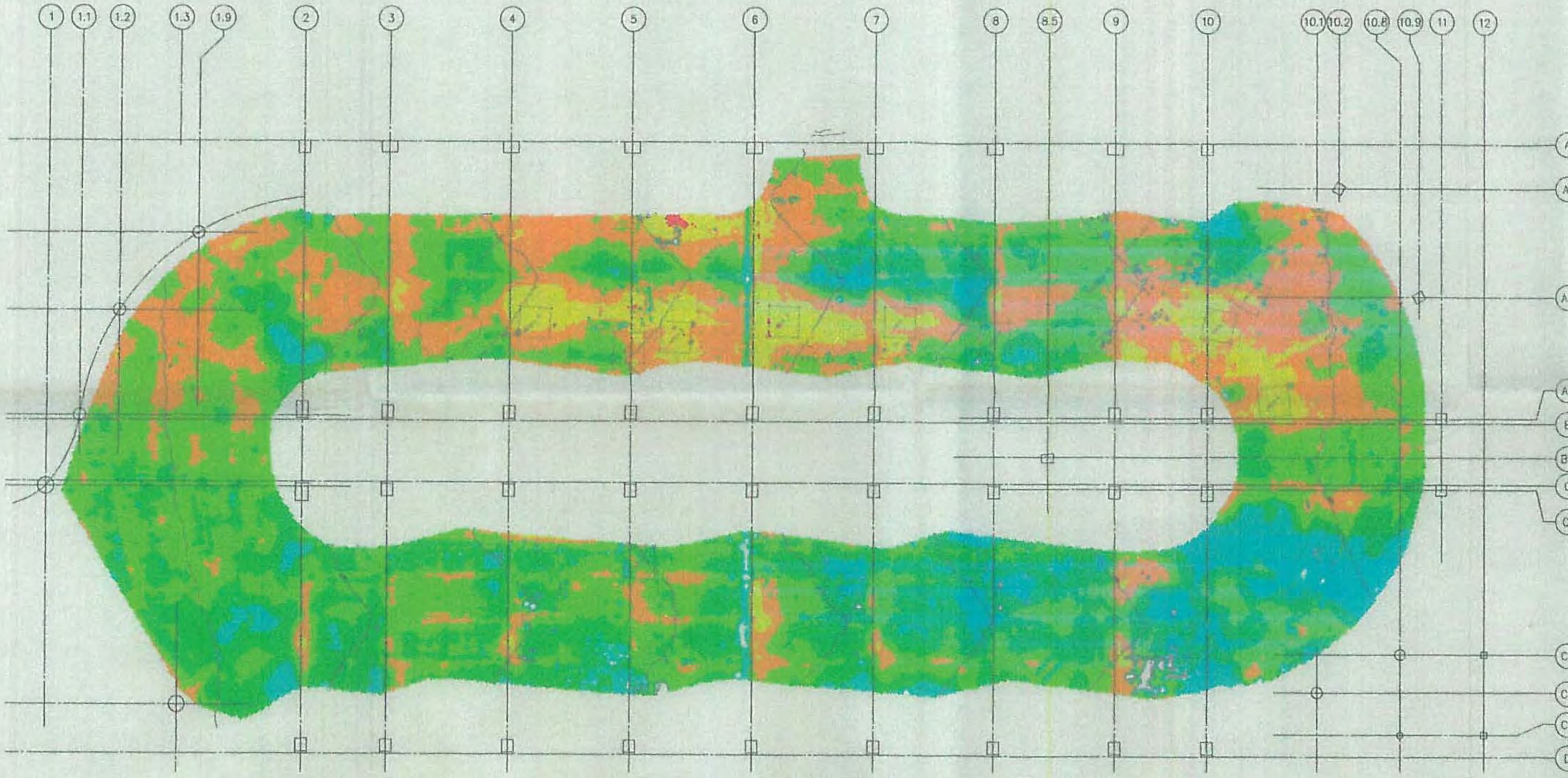
20 10 0 20 40
GRAPHIC SCALE
FEET

LEGEND:

&	AND
LB	LICENSE BUSINESS
NO.	NUMBER
SQ.FT.	SQUARE FEET



LOCATION MAP
NOT TO SCALE



CONCRETE SLAB BETWEEN LEVEL 305 AND 330

SCALE: 1"=20'

REPORT OF ASBUILT SURVEY:
THE SURVEY SHOWN HEREON IS A FORENSIC SURVEY OF THE SILVER SPRING TRANSIT CENTER'S LOWER AND UPPER CONCRETE SLABS BEING BETWEEN FLOORS 305 AND 330 AND FLOORS 330 AND 350, LOCATED IN SILVER SPRING IN MONTGOMERY COUNTY, MARYLAND. THE FIELD SURVEY WAS COMPLETED NOVEMBER 1 THROUGH 8, 2011, UNDER THE DIRECTION OF JOHN H. ADLER III, PROFESSIONAL SURVEYOR AND MAPPER (PSM). THIS SURVEY IS VALID ONLY WHEN THE SIGNATURE AND RAISED EMBOSSED SEAL ARE FOUND AT THE END OF THIS REPORT.

ACCURACY:
HORIZONTAL, VERTICAL CONTROL, AND BUILDING GRID LINES WERE PROVIDED BY WMATA VIA A SURVEY CONTROL PLAN SET. ALL EQUIPMENT UTILIZED FOR THIS SURVEY HAS BEEN CALIBRATED WITHIN ONE YEAR OF THE DATE OF THE FIELD SURVEY AS RECOMMENDED BY THE MANUFACTORERS.

DATA SOURCE:
SILVER SPRING TRANSIT CENTER, WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY SURVEY CONTROL SET, DRAWING NO.B6-8713-SP001, DATED 8/2011

A STAR*NET DATA FILES PROVIDED: 8713-CONTROL.DAT, 8713-TRAV-FINAL.DAT, AND 8713-TRAV-VIKA_PNTS-FINAL.DAT.

MEASUREMENT METHODS:
ADDITIONAL HORIZONTAL CONTROL WAS SET UTILIZING A TOTAL STATION. ALL HORIZONTAL ANGLES WERE TAKEN EIGHT (8) TIMES AND AVERAGED. ADDITIONAL VERTICAL CONTROL WAS ESTABLISHED FOR FLOOR SST305 UTILITZING A DIGITAL LEVEL RUNNING A CLOSED BENCH LOOP FROM "BM1" TO A SCRIBE ON A SOUTHEAST CONCRETE RETAINING WALL. ADDITIONAL VERTICAL CONTROL WAS ESTABLISHED FOR FLOOR SST330 UTILIZING A DIGITAL LEVEL RUNNING A CLOSED BENCH LOOP FROM "BM2" BACK TO "BM2". ADDITIONAL VERTICAL CONTROL WAS ESTABLISHED FOR FLOOR SST350 UTILIZING A DIGITAL LEVEL RUNNING A CLOSED BENCH LOOP FROM "BM3" BACK TO "BM3". SURVEY DATA WAS COLLECTED UTILIZING A LEICA HDS3000 HIGH DEFINITION LASER SCANNER. THE CEILING OF THE SST305 FLOOR WAS SCANNED FROM EIGHTEEN (18) LOCATIONS. THE CEILING AND FLOOR OF THE SST330 FLOOR WERE SCANNED FROM FIFTEEN (15) LOCATIONS. THE FLOOR OF THE SST350 FLOOR WAS SCANNED FROM SIX (6) LOCATIONS. ALL SCANS WERE REGISTERED USING LEICA CYCLONE v7.1.1. REGISTRATION FOR ALL SCANS ACHIEVED A MAXIMUM MEAN ABSOLUTE ERROR OF 0.018 FEET FOR ALL TARGET CONTROL POINTS. LEVEL SST305 CEILING IS BASED ON A POINT CLOUD OF 7,017,762 POINTS. LEVEL SST350 FLOOR IS BASED ON A POINT CLOUD OF 13,930,867 POINTS. LEVEL SST350 CEILING IS BASED ON A POINT CLOUD OF 13,930,867 POINTS. LEVEL SST350 IS BASED ON A POINT CLOUD OF 2,689,734 POINTS. A MESH WAS CREATED FROM EACH UNIFIED FLOOR OR CEILING AND A SAMPLE SIX (6) INCH BY SIX (6) INCH GRID WAS EXPORTED INTO AUTOCADD CIVIL 3D. ELEVATION BANDINGS ARE BASED ON THIS SAMPLE GRID. ONE FOOT CONTOURS ARE BASED ON FLOOR SURFACE MODEL ONLY.

LIMITATION:
SCANS WERE LIMITED TO THE ROADWAY AREAS ONLY. AREAS OUTSIDE OF THE CURB LINE WERE NOT EVALUATED.

NOVEMBER 25, 2011
Date of Signature

John H. Adler III
Professional Surveyor and Mapper
Florida License Number 4693

NOTE: 1 FOOT CONTOURS ARE BASED ON TOP OF CONCRETE SLAB ONLY.

© LATEST DATE HEREON

SURVEYOR'S NOTES

1. ATTENTION IS DIRECTED TO THE FACT THAT THIS MAP MAY HAVE BEEN REDUCED IN SIZE BY REPRODUCTION. THIS MUST BE CONSIDERED WHEN OBTAINING SCALED DATA.
2. GREENHORNE & O'MARA, INC. AND THE CERTIFYING SURVEYOR ACCEPT NO RESPONSIBILITY FOR RIGHT-OF-WAYS, EASEMENTS, RESTRICTIONS OR OTHER MATTERS AFFECTING TITLE TO THE LANDS SURVEYED.

REVISIONS:	DATE:

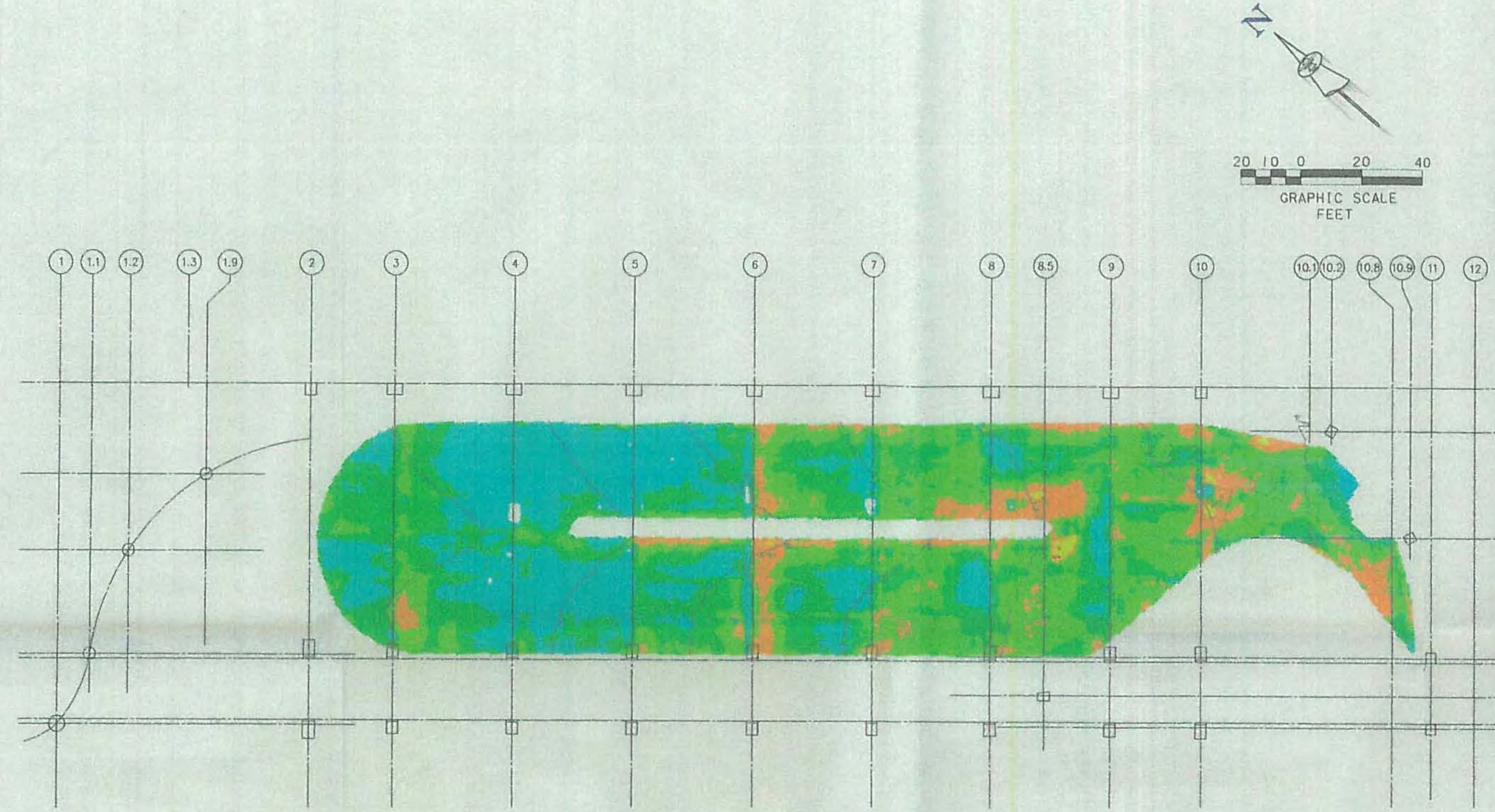
ENGINEERS • ARCHITECTS • PLANNERS • SCIENTISTS • SURVEYORS • PHOTOGRAMMETRISTS
GREENHORNE & O'MARA, INC.
3223 COMMERCE PLACE, SUITE 100
WEST PALM BEACH, FL 33407
(561) 686-7707
ANNAPOLIS, MD • FAIRFAX, VA • FREDERICKSBURG, VA • LAUREL, MD
MECHANICSBURG, PA. • RALEIGH, NC • ROCKVILLE, MD • ST. PETERSBURG, FL • WALDORF, MD

FORENSIC SURVEY FOR:

SILVER SPRING TRANSIT CENTER
CONCRETE FLOOR SLABS

SILVER SPRING, MARYLAND

DESIGN	1" = 20' SCALE
RITZEL DRAWN	1 OF 2
ADLER CHECKED	
11/25/2011 DATE	030931.053.ADLE.459 DRAWING NO.



CONCRETE SLAB BETWEEN LEVEL 330 AND 350

SCALE: 1"=20'

WMATA HORIZONTAL SURVEY CONTROL IS BASED ON AN ADJUSTMENT USING BUILDING GRID CONTROL POINTS PROVIDED BY VIKA AND SHOWN ON REFERENCE DRAWING ENTITLED "GRID CONTROL WORKSHEET"

WMATA VERTICAL SURVEY CONTROL IS BASED ON AN ADJUSTMENT HOLDING VERTICAL BENCHMARK "B" PROVIDED BY VIKA AND SHOWN ON DRAWING ENTITLED "BENCHMARK1 EXHIBIT".

WMATA HORIZONTAL SURVEY CONTROL

POINT ID	NORTHING	EASTING	DESCRIPTION
100	483411.1848	1303853.7307	25MM MINI PRISM
101	483330.3931	1303925.5100	25MM MINI PRISM
102	483187.4617	1304015.2959	25MM MINI PRISM
103	483103.2294	1303923.4118	25MM MINI PRISM

WMATA VERTICAL SURVEY CONTROL

POINT ID	ELEVATION	DESCRIPTION
BM1	306.9714	BERNTSEN RS30 PLASTIC SMART TARGET
BM1A	301.0633	PK NAIL
BM1B	300.8369	BERNTSEN RS30 PLASTIC SMART TARGET

WMATA HORIZONTAL SURVEY CONTROL

POINT ID	NORTHING	EASTING	DESCRIPTION
200	483438.0481	1303837.1604	25MM MINI PRISM
201	483463.6393	1303814.2208	25MM MINI PRISM
202	483481.2826	1303766.9228	25MM MINI PRISM
203	483356.9601	1303850.5444	25MM MINI PRISM
204	483143.9050	1303836.6066	25MM MINI PRISM

WMATA VERTICAL SURVEY CONTROL

POINT ID	ELEVATION	DESCRIPTION
BM2	327.8824	BERNTSEN RS30 PLASTIC SMART TARGET

WMATA HORIZONTAL SURVEY CONTROL

POINT ID	NORTHING	EASTING	DESCRIPTION
301	483257.3121	1304002.6350	25MM MINI PRISM
302	483362.0978	1303904.7843	25MM MINI PRISM
303	483473.1899	1303782.5505	25MM MINI PRISM
304	483471.2749	1303687.3312	25MM MINI PRISM
305	483383.8157	1303728.6814	25MM MINI PRISM
306	483183.2417	1303904.1828	25MM MINI PRISM

WMATA VERTICAL SURVEY CONTROL

POINT ID	ELEVATION	DESCRIPTION
BM3	348.7744	BERNTSEN RS30 PLASTIC SMART

Concrete Slab Thickness (inches)

Number	Minimum Elevation	Maximum Elevation	Color	Surface Area (sq.ft.)
1	7.00	8.00		6.5
2	8.00	9.00		84.9
3	9.00	9.76		1675.8
4	9.76	10.38		6751.9
5	10.38	11.00		7040.1
6	11.00	13.00		6678.0

NOTE: 1 FOOT CONTOURS ARE BASED ON TOP OF CONCRETE SLAB ONLY.

SURVEYOR'S NOTES

1. ATTENTION IS DIRECTED TO THE FACT THAT THIS MAP MAY HAVE BEEN REDUCED IN SIZE BY REPRODUCTION. THIS MUST BE CONSIDERED WHEN OBTAINING SCALED DATA.
2. GREENHORNE & O'MARA, INC. AND THE CERTIFYING SURVEYOR ACCEPT NO RESPONSIBILITY FOR RIGHT-OF-WAYS, EASEMENTS, RESTRICTIONS OR OTHER MATTERS AFFECTING TITLE TO THE LANDS SURVEYED.

REVISIONS: DATE:

ENGINEERS • ARCHITECTS • PLANNERS • SCIENTISTS • SURVEYORS • PHOTOGRAMMETRISTS
GREENHORNE & O'MARA, INC.
3223 COMMERCE PLACE, SUITE 100
WEST PALM BEACH, FL 33407
(561) 686-7707
ANNAPOLIS, MD • FAIRFAX, VA • FREDERICKSBURG, VA • LAUREL, MD
MECHANICSBURG, PA. • RALEIGH, NC • ROCKVILLE, MD • ST. PETERSBURG, FL • WALDORF, MD

FORENSIC SURVEY FOR:

SILVER SPRING TRANSIT CENTER
CONCRETE FLOOR SLABS

SILVER SPRING, MARYLAND

© LATEST DATE HEREON

DESIGN	SCALE 1" = 20'
RITZEL DRAWN	2 OF 2
ADLER CHECKED	
11/25/2011 DATE	030931.053.ADLE.459 DRAWING NO.

Appendix D – Cited Standards

ACI 117	Specification for Tolerances for Concrete Construction and Materials
ACI 318	Building Code Requirements for Structural Concrete
ACI 306R	Guide to Cold Weather Concreting
ACI 306.1	Specification for Cold Weather Concreting
ACI 308R-01	Guide to Curing Concrete
ACI 309R-96	Guide for Consolidation of Concrete
ASTM C 39	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C 94	Standard Specification for Ready-Mixed Concrete

Appendix E – Sample Reports

This appendix contains examples of some of the records that were reviewed during the analysis. It is not intended to be complete, because several thousand pages of construction records were created for the SSTC project. These sample pages are included for the benefit of the reader who does not have access to the full KCE Exhibits. The samples selected for inclusion in this appendix are associated with concrete pour 1Eb which was cast on December 10, 2010. This pour was chosen arbitrarily and illustrates cold weather provisions.

Page	Description	KCE Exhibit Source
80	FP daily CQC report	A4 pages 150, 151
82	RBB inspector's daily report	B4 pages 401, 403
84	concrete slab temperature report	B4 page 405
86	concrete cylinder test specimen ticket	S1 *
87	concrete cylinder test log	S1 page 588
88	concrete cylinder break report	R3 page 150

* The KCE Exhibit contains pages similar to the sample, but this particular page was missing from the KCE Exhibit and was provided by RBB as page 187 of their April 22, 2013 letter.

Note: The information provided in this appendix is taken from the noted KCE Exhibits. It has been reformatted slightly to fit this document but is not otherwise a product of this analysis. The content has not been verified and is provided for information purposes only.

Daily CQC Report

Project **Silver Spring Transit Center** **51-0037**	Day: 743 **Fri, 10-Dec-10** Weather; Temp. (AM/PM): clear 27-445

NO.	FOULGER PRATT PERSONNEL	NO.	FOULGER PRATT PERSONNEL	NO.	OWNER / ARCHITECT
1	Project Executive	2	Assistant Superintendent	1	Architect
1	Project Manager	1	CQC Assistant Manager	1	Owner Representative
1	CQC Manager		Field Engineers / Surveyors		Developer Representative
1	Superintendent	1	Safety officer		Consultants
2	Assistant Project Manager	4	Laborers	1	Project Admin. Asst.

NO.	SUBCONTRACTOR / TRADE	CPM Activity	WORK PERFORMED
5	Ross	02230	excavate grade beam for pedestrian bridge, test pit for duct bank, backfill at A-line and radius wall
5	Ross Colesville Road	02530	excavate towards SS1, load contaminated soil
1	CHS		traffic control
2	W&R	Div 15	layout, install drain pour 1D
5	Freestate	Div 15	layout, install conduit pour 1D
1	American Automatic	13935	install sleeve pour 1Eb
3	Berkel	02260	drill piles 10, 11, place concrete piles 1, 8, 9
	Consolidated	07170	
	Facchina	03300 03381	place concrete pour 1Eb
			grout blocked tendons in pour 1A & 2A
			install non corrosive material in pour 1Ea tendon ducts

NO.	INSPECTION / TESTING AGENCY	TEST / INSPECTION PERFORMED	SPEC SECTION	Para / Dwg	COMMENTS	LOCATION
4	Balter	visual / PT / grout	03300 03381		see report	various
	Balter	visual	02260		see report	Box culvert
2	FPC	visual	03300 03381		inspected material and installation	various
	FPC	visual	02260		inspected material and installation	Box culvert

Daily CQC Report

Project
Silver Spring Transit Center
51-0037

MATERIAL RECEIVED (see attached)	Approved (Y/N)	SUB RESPONSIBI	COMMENTS

No.	DEFICIENCIES IDENTIFIED	SPEC SECTION	SUB RESPONSIB	CORRECTIVE ACTION	LOCAT

DEFICIENCIES CORRECTED

SUBMITTALS REVIEWED	SUBMITTAL #	SPEC SECTION	REVIEWED BY	ACTIO

GENERAL NOTES / OBSERVATIONS /SAFETY

no safety violations

Monitoring of soldier piles / lagging: visual

7:45 QC mtg. discussion items: 1.) PT stressing procedures. 2.) use of EUCOBAR. 3.) use of air entraned concrete at trowled 4.) FCC indicated that no salts are to be used on slabs for one year after placement.

FPC held meeting for revised multi strand stressing procedures

EUCOBAR rep onsite

DIRECTION PROVIDED BY THE OWNER / ARCHITECT

Contractor's Verification Statement: Workmanship and all equipment and materials incorporated into the SSTC project comply with the Contract Documents

CQC Representative: [signature]

Brook Foster (NAME) 10-Dec-10 (DATE)

THE ROBERT B. BALTER COMPANY

DAILY REPORT

Project: Silver Spring Transit Center Contract No.: 16027-0

Client: Montgomery County Date: 12/10/2010

Contractors: Foulger-Pratt Weather: Mostly cloudy Temps: ~~28~~-35

Type of Inspections: Inspection of post-tensioning system installation

Tests Performed:

Samples Sent for Testing:

Contacts: Shak B., Brook Foster, Scott Hamilton, Doug Goetz

Summary of today's work: Facchina: 1. Attended meeting regarding revised multistrand and monostrand stressing procedures. Procedures were devised by Facchina and VSL, and have been approved by Doug Lang / PB. See procedure documents for details.

2. Stressed tendons of pour 2B. Uniform tendons were stressed (50% of total); temperature tendons were stressed (all). Willie Lewis of VSL supervised operations.

3. Concrete test cylinder strength of pour 2B exceeded 4000 psi @ 3 days.

4. Continued placing tendons and associated reinforcement for pour 1D. Placement is ongoing and will continue next working day.

NON-COMPLIANT ISSUES:

PARTIES NOTIFIED:

RESOLUTION:

Verification: Hours: Reg 8 OT 4 Inspector: Tony Lord

INFORMATION IS SUBJECT TO FINAL REVIEW: Supervisor: PE:

THE ROBERT B. BALTER COMPANY

DAILY REPORT

Project: Silver Spring transit ctr. Contract No.: 16027-G

Client: Montgomery county Date: 12-10-10

Contractors: Facchina Weather: Cloudy/Snow Temps: 28°-35°

Type of Inspections: concrete quality assurance

Tests Performed:

Samples Sent for Testing:

Contacts:

Summary of today's work: Facchina: placed approx 150 cubic yards of 8,000 psI concrete for deck pour. IEB elevation 330' Level. I assisted tom w. with sampling and testing of concrete. Concrete placement was monitored. Concrete test cylinders were made, slump test, aE-contents, and concrete temps were taken. All per spec.

NON-COMPLIANT ISSUES:

PARTIES NOTIFIED:

RESOLUTION:

Verification: Hours: Reg 8 OT Inspector: [signature]

INFORMATION IS SUBJECT TO FINAL REVIEW: Supervisor: PE:

THE ROBERT B. BALTER COMPANY
Geotechnical Engineers

410-363-1555
18 Music Fair Road, Owings Mills, MD 21117

CONCRETE SLAB TEMPERATURE REPORT

Project: Silver Spring Transit

Contract No. 16027-0

Date: 12-10-10

Placement ID:

Time	Location in placement	Concrete Temperature	Weather/Ambient Temperature
7:03AM	DECK POUR 2B 350' 1ST LOCATION	No thermometer	CLEAR, 19°
7:06AM	DECK POUR 2B 350' 2ND LOCATION	94° / 76°	CLEAR, 19°
7:11AM	UNDER 2B 350' FORMWORK TEMP	76°	CLEAR, 19°
7:19AM	UNDER STEPS (FIELD CURE AREA)	78° / 46°	CLEAR, 19°
7:08AM	CURING BOX ON DECK 350'	56° / 42°	CLEAR, 19°
7:20AM	CURING SHED	88° / 82°	CLEAR, 19°
4:00PM	Deck pour 2B level 350', 1st loc.	93°/74°	Clear 35°
4:02PM	Deck pour 2B level 350', 2nd loc.	90°/72°	" "
4:08PM	Underside 2B level 350' formwork	75°	" "
4:05PM	Curing box on deck 350' FC	55°/43°	" "
4:10	Curing Shed	75°/72°	" "

4

THE ROBERT B. BALTER COMPANY
Geotechnical Engineers

18 Music Fair Road
Owings Mills, Maryland 21117

COMPRESSIVE STRENGTH TEST SPECIMEN DATA

Project: SST Ctr Proj. No.: 16027-0-MD
Client: Montgomery Co.
Contractor: Facchina
Sample Location: DECK POUR 1EB 330' LEVEL BETWEEN COLUMN LINE 10.2 & 10.8 and C9 & F
Method of Placement: Concrete Pump
Slump: 7.5" inches
Water added at site? ☐ Yes, ______ gallons ☒ No
Specimen made by: TOM W & JOSH M
Concrete Temperature: 60° °F
Air Content: 4.6% ☐ N/A
Specimen Set No.: 463

Supplier: Rockville Fuel & Feed Co
Ticket No.: 91444 Truck No.: 26
Water-Cement Ratio: 0.26
Mix Number: 8K2DC2NL
Mix Design: 8000psi
Time Batched: 10:45AM
Batch Size: 10 cu yds
Date Molded: 12-10-10 Time: 12:19pm
Date Delivered to Lab: ______
Unit Weight: ______ PCF ☒ N/A
Weather: CLOUDY
Air Temperature: 27° °F

Test Req'd: ____ At ____ Days; 2 At 7 days; ____ At 14 Days; 3 At 28 Days; ____ Reserved

Remarks: Revolutions = 89, 2=56-day Breaks (Lab Cured), 2=3-day Breaks (Field Cured), 2=5-day Breaks (Field Cured), 3=28-day Breaks (Field Cured)

ROCKVILLE FUEL AND FEED
PLANT #1 & #2

10Dec10
10:45AM

Flop Gate:.. DRY
Batch:. 2 of 2

Volume:10.00 yd3 Mix ID: 8K2DC2NL
Truck #:... 26 MAXWELL AKOTO

Mix Desc:.8000 PSI #8 ST AIR/2DCI
Ticket # 91444
FACCHINA CONSTRUCTION CO., INC.
SILVER SPRING TRANSIT CENTER-750

W/(C+P) Ratio: 0.26

Material		Design	Moist		Target	Actual	Free H2O	Status
CON_SAND		1000 Lb	5.5%	0.0%	5291 Lb	5260 Lb	291 Lb	Done
STONE8		1850 Lb	0.5%	0.0%	9296 Lb	9260 Lb	46 Lb	Done
CEMENT		550 Lb	0.0%		2750 Lb	2740 Lb	0 Lb	Done
SLAG		360 Lb	0.0%		1800 Lb	1790 Lb	0 Lb	Done
AEA	*1	9.0 oz	100.0%		23 oz	24 oz	2 Lb	Done
WRDA		41.0 oz	0.0%		205 oz	204 oz	0 Lb	Done
SUPER		54.6 oz	100.0%		273 oz	272 oz	18 Lb	Done
DCI		256.0 oz	100.0%		1280 oz	1312 oz	85 Lb	Done
WATER	*1	31.0 Gal	100.0%		88 Gal	88 Gal	733 Lb	Done

Ice/Batch 0 Lb Water allowed by mix design:. 310 Total Water 280
Moisture compensation water:. 104 Water allowed at jobsite: 30 Gal

14th Mix ...

ROCKVILLE FUEL & FEED COMPANY, INC.

READY MIXED CONCRETE

Rtws: 87°

[illegible]

KEEP OUT OF REACH OF CHILDREN

P.O. Box 1707 12-10-10
Rockville, MD 20849-1707

(4)

PLANT LOCATIONS:
Rockville, MD
College Park, MD
Columbia, MD

Air temp: 27°
Conc temp: 60°
Slump: 7.5"
Air: 5.4%
Time @ 12:11 pm

301-762-3988
1-877-847-RMIX

14 CYL made

DATE: [illegible]

CUSTOMER # / CUSTOMER NAME: [illegible] CONSTRUCTION CO., INC.

PROJECT NAME: SILVER SPRING [illegible]

DELIVERY ADDRESS: [illegible] COLESVILLE ROAD, SILVER SPR

INSTRUCTIONS: [illegible]
[illegible] WEST [illegible] COLESVILLE [illegible] TO JOB ON RIGHT.
[illegible] DRUM ROTATION COUNTER MUST BE WORKING [illegible]

PLANT: 1 | TRUCK #: [illegible] | DRIVER: [illegible]

LOAD TIME: [illegible] | START POUR: | ARRIVE JOB SITE: | FINISH POUR:

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IS AT CUSTOMER'S RISK.
WATER ADDED ON JOB AT CUSTOMER'S REQUEST ______ GAL
WATER ADDED TO THIS LOAD BY AUTHORITY OF X ______

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UNIT OF MEASURE	UNIT PRICE	AMOUNT
10.00	140.00	170.00	[illegible]	5000 PSI [illegible]	[illegible]		
NOTE: CUMULATIVE QUANTITY VALUES MAY NOT REFLECT ACTUAL YARDS DELIVERED ON JOB.							

SUB TOTAL
TAX
TOTAL

CON_SAND	1800 Lb	AEA	#1	[illegible] oz
STONE	1550 Lb	WRDA		[illegible] oz
CEMENT	550 Lb	[illegible]		236.6 oz
WATER #1	31.0 Ga	DCI		236.0 oz
SLAG	350 Lb			

[illegible]

Deck pour 1EB 537' level Ahead Column B... [illegible]

CUSTOMER ACKNOWLEDGES AND UNDERSTANDS ALL OF TERMS AND CONDITIONS CONTAINED ON BOTH SIDES OF THIS DOCUMENT.

RECEIVED BY: X ______

[illegible]

THE ROBERT B. BALTER COMPANY

Silver Spring Transit Center Project

CONCRETE TESTING INFORMATION

Specimen set #	Date	Truck #	Ticket #	Slump	Air %	Concrete Temp.	Air Temp
460 ( )	12-10-10	27	91399	8"	6.2%	60°	24°
461 ( )	12-10-10	30	91403	8"	5.1%	60°	24°
462 ( )	12-10-10	83	91423	8"	4.5%	60°	27°
463 ( )	12-10-10	26	91444	7.5"	4.6%	60°	27°
464 ( )	12-9-10	43	91329	7.5"	6.1%	65°	28°
465 ( )	12-9-10	410	91340	4"	6.4%	67°	32°
466 ( )	12-16-10	3600216	65349618	8"	6.5%	60°	20°
467 ( )	12-17-10	3600046	65349644	8"	4.9%	65°	30°
468 ( )	12-20-10	67	91818	6.5"	5.1%	55°	19°
469 ( )	12-20-10	67	91818	7.5"	5.3%	57°	19°
470 ( )	12-20-10	74	91821	7.5"	6.2%	55°	19°
471 ( )	12-20-10	79	91826	7.5"	6.5%	58°	18°
472 ( )	12-20-10	84	91832	7.5"	4.1%	55°	19°
473 ( )	12-20-10	77	91837	7"	6.2%	55°	20°
474 ( )	12-20-10	77	91837	8"	5.7%	58°	19°
475 ( )	12-20-10	83	91843	8"	5.5%	55°	21°
476 ( )	12-20-10	79	91849	7"	5.6%	61°	21°
477 ( )	12-20-10	32	91855	7.5"	5.9%	61°	21°
478 ( )	12-20-10	37	91862	8"	6.9%	61°	22°
479 ( )	12-20-10	56	91881	6"	4.0%	62°	22°
480 ( )	12-20-10	79	91883	7"	5.7%	60°	22°
481 ( )	12-20-10	79	91883	7.5"	5.9%	61°	22°
482 ( )	12-20-10	43	91889	7.5"	5.5%	61°	23°

REPORT OF CONCRETE CYLINDER TEST
THE ROBERT B. BALTER COMPANY
Silver Spring Transit Center
Report Date: 1/7/11

Project Number: 16027-0
Report Number: 515
Project: Silver Spring Transit Center
Client: Montgomery County DPW&T/DCD/CS
Address: 1110 Bonifant Street,
Silver Spring, Maryland 20910
Attn: Mr. Timothy O'Gwin

FIELD TEST CONDITIONS AND RESULTS (AASHTO T 23))

Contractor: Facchina
Date Placed: 12/10/2010
Time Sampled: 12:19 PM
Number of Specimens: 14
Reserves: 0
Location of Sample: Deck Pour 1EB, 330' Level, Between Column Lines 10.2 & 10.8 and C9 & E.

Supplier: Rockville Fuel & Feed Co.
Truck Number: 26
Mix Number: 8K2DC2NL
Design Strength: 8000
Time Batched: 10:45 AM
Batch Size: 10.0
Slump: 7.5" (AASHTO T 119)
Concrete Temp: 60 (ASTM C 1064)
Water Added: NO

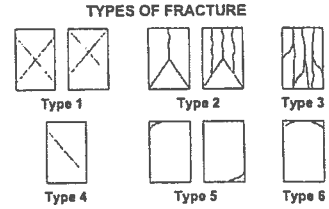
Method of Placement: Concrete Pump Truck
Method of Curing: Field Cured & Moist Cured
Ticket Number: 91444
Time Placed: 12:19 PM
Unit Weight: N/A (ASTM C 138)
Air Content: 4.6% (AASHTO T 152)
Ambient Temp: 27
Technician: Tom W & Josh M

LABORATORY TEST RESULTS (AASHTO T 22)

Specimen	Test Date	Age	Load	Diameter	Area	Strength	Percent of Design	Type of Fracture
FC 5488	12/13/2010	3	127800	4.00	12.57	10170	127%	3
FC 5488	12/13/2010	3	125960	4.00	12.57	10020	125%	3
FC 5488	12/15/2010	5	127780	4.00	12.57	10170	127%	5
FC 5488	12/15/2010	5	127960	4.00	12.57	10180	127%	5
5488	12/17/2010	7	146060	4.00	12.57	11620	145%	5
5488	12/17/2010	7	147120	4.00	12.57	11710	146%	5
5488	1/7/2011	28	156250	4.00	12.57	12430	155%	2
5488	1/7/2011	28	155040	4.00	12.57	12340	154%	2
5488	1/7/2011	28	152270	4.00	12.57	12120	152%	2
FC 5488	1/7/2011	28	154880	4.00	12.57	12330	154%	2

Remarks: W/C Ratio: 0.26
Revolutions = 89; 2 = 56 Day Breaks (Lab Cured);
2 FC = 3 Day Breaks; 2 FC = 5 Day Breaks;
3 FC = 28 Day Breaks *** FC = Field Cured ***

TYPES OF FRACTURE



Copies to:

Reported by: ______________________

Vincent Gerard V. Pineda
Engineering Technician

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Alpha Corporation
1800 Washington Boulevard, Suite 425
Baltimore, MD 21230
Tel: (410) 646-3044 Fax: (410) 646-3730

www.alphacorporation.com

Exhibit II: Objectives, Scope, and Methodology

The objective of our Inspection was to identify and document any project management deficiencies during the construction of the Silver Spring Transit Center. In achieving our objectives, we attempted to determine which project management controls failed, how these controls should have functioned, why they failed, and what measures should be taken to ensure controls will be effective in future projects undertaken by Montgomery County.

The SSTC project implemented many controls, but some significant deficiencies identified by KCE Structural Engineers (KCE) and Whitlock Dalrymple Poston & Associates, P.C. (WDP) in the structure were not identified and/or not corrected during construction. Our review examined the key project controls that were in place during construction of the SSTC in order to determine:

- how the structural deficiencies occurred,
- the design and implementation of each construction project control specific to the SSTC,
- which, if any project control failed during the construction, resulting in a deficiency,
- the cause of the project control failure, and
- whether necessary actions are being taken to ensure that project controls will be effective during remediation.

In order to address these questions, a report on the Silver Spring Transit Center entitled "Analysis of Project Controls" was prepared at our request by the Alpha Corporation. That report, along with recommendations, lessons learned, and the appendices referenced in their analysis, is contained in its entirety in Exhibit I of this report. Work papers supporting information contained in Exhibit I have been independently assembled and referenced, and the report extensively considered by OIG staff.

We consulted with the subject matter expert we retained to provide professional expertise, Alpha Corporation, to ensure the accuracy of the technical aspects of the analysis prepared by the OIG staff.

We conducted this review from May 2013 through March 2014, in accordance with the Quality Standards for Inspection and Evaluation issued by the Council of the Inspectors General on Integrity and Efficiency. Those standards require that we plan and perform our work to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our objectives.

Exhibit II: Objectives, Scope, & Methodology

We relied heavily on the data supporting the KCE report that is publically disclosed on the DGS website, but also reviewed meeting minutes, and other information developed during the construction process. We retained copies only of those documents used by us in direct support of our analysis. When additional data was needed for us to develop an opinion, or when available data referenced other data that was not reviewed by KCE, we requested that information and have incorporated it into our work papers.

Our review methodology included:

- Review of the evaluation report and evidence prepared by KCE Structural Engineers on behalf of Montgomery County Maryland
- Review of the evaluation report prepared by Whitlock Dalrymple Poston & Associates (WDP) on behalf of the Washington Metropolitan Area Transportation Authority
- Review of Montgomery County Council committee and regular meeting minutes and analyst packet relating to Capital Improvement Program submissions and changes.
- Identification of construction deficiencies reported in KCE and WDP reports that would likely have been subject to project or management control.
- Determining potential controls that should be tested to confirm the existence, success, or failure of the control during the inspection process.
- Identification and contracting with a Subject Matter Expert to assist in in assessing the sufficiency and adequacy of the controls.
- Evaluation of construction project vendor contracts and construction and performance specifications.
- Evaluation of construction project design, structural, and technical drawings.
- Close review of our subject matter expert's analysis and supporting documentation
- Close consultation with our subject matter expert regarding engineering construction and related materials methods techniques, industry standards, and related technical issues.
- Review of meeting minutes of the various oversight groups engaged in the construction project.
- Review of other construction documents.
- Review of industry standards and building codes that related to the project.
- Review of the Montgomery County Special Inspections Program.

Exhibit III: Standards

The following standards were either used in the design criteria for the SSTC, or were referenced within this report:

American Concrete Institute (ACI), Farmington Hills, Michigan

- ACI 117 - *Standard Tolerances for Concrete Construction and Materials*.
- ACI 214R - *Evaluation of Strength Test Results of Concrete*
- ACI 301 - *Specifications for Structural Concrete for Buildings*
- ACI 302.1R - *Guide for Floor and Slab Construction*
- ACI 304 - *Recommended Practice for Measuring, Mixing, Transporting and Placing Concrete*
- ACI 304R - *Guide for Measuring, Mixing, Transporting and Placing Concrete*
- ACI 305R - *Hot Weather Concreting*
- ACI 306R - *Cold Weather Concreting*
- ACI 306.1 - *Standard Specification for Cold Weather Concreting*
- ACI 308 - *Standard Specification for Curing Concrete*.
- ACI 308R - *Guide to Curing Concrete*
- ACI 311.1R - *Manual for Concrete Inspection*
- ACI 311.4R - *Guide for Concrete Inspection*
- ACI 318 - *Building Code Requirements for Structural Concrete*.

American Institute of Steel Construction (AISC) – Chicago, Illinois

- Specifications for Design, Fabrication, and Erection of Structural Steel for Buildings

ASTM International (formerly American Society for Testing and Materials), West Conshohocken, Pennsylvania.

- ASTM C31/C31M - *Standard Practice for Making and Curing Concrete Test Specimens in the Field*
- ASTM C39/C39M - *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*
- ASTM C94/C94M - *Standard Specifications for Ready Mixed Concrete*
- ASTM C125 - *Standard Terminology*

Exhibit III: Standards

- ASTM C172 - *Standard Practice for Sampling Freshly Mixed Concrete*
- ASTM C1064C/C1064M - *Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete*

Concrete Reinforcing Steel Institute (CRSI), Schaumburg, Illinois

- MSP2 - *Manual of Standard Practice*

International Code Council (ICC) - Washington, District of Columbia

- 2003 International Building Code.

Post-Tensioning Institute (PTI) - Farmington Hills, Michigan

- Specifications for Bonded Single Strand or Multi-Strand Tendons for use in Corrosive Environments.

Washington Metropolitan Area Transit Authority (WMATA) - Washington, District of Columbia

- WMATA Manual of Design Criteria – Release 6.

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Exhibit IV: Comparison of KCE In-Situ Compressive Strength & Petrographic Test Pairing to Balter Construction Inspection Tests

The following chart isolated areas in the SSTC where we determined close adjacencies between Balter and KCE compressive strength and composition analysis testing that allowed for a relatively close comparison of the testing results. Tests made at (or nearly at) the same concrete location at the time of construction and after completion of the structure should exhibit the nearly same compressive strength. Records maintain by Balter during construction and the KCE testing firms during core collection both noted the approximate location of the sample in terms of a column and row grid matrix in use at the SSTC. This grid matrix is indicated on most structural drawings.

How to Read:

Chart 1: Comparison of KCE In-Situ Compressive Strength & Petrographic Test Pairings to Balter (RBB) Construction Inspection Tests

Average KCE psi as % of RBB: 62%

Pour Information		Testing Information		Strength	Grid Location		Concrete Attributes				KCE psi as %	KCE psi as %
Date	#	Core #	KCE Tset Type	(psi)	Row	Column	Entrained	Entrapped	w/c	unhydrated	of 1st RBB	of 2nd RBB
7-Dec-10	2B	121	Compressive Strength	**11,040**	A3 - A8	8 - 9					81% Δ	80% Δ
		122	Petrographic		A3 - A8	8 - 9	6.00%		.35 - .40			
		123	Petrographic		A2 - A3	7 - 8	5.20%	0.70%	.35 - .45	7% - 11%		
		124	Compressive Strength	10,060	A2 - A3	7 - 8					74%	73%
KCE-Reported average compressive strength - Pour 2B				8,810							65%	64%
56-day RBB Test Cylinder Batch 91111: Test Report # 486				13,575	A2.8 - A3	8 - 9	5.50%		.26			
56-day RBB Test Cylinder Batch 91160: Test Report # 495				13,740	A1 - A2	7 - 8	5.30%		.24			

In the sample above for Pour 2 B, a first comparison set was located for KCE testing extracted in the area between Rows A3 and A8 at Columns 8 to 9. Two testing cores were extracted adjacent to each other. One core (#121) was used to conduct a compressive strength test, and the second (#122) was used to conduct the petrographic analysis. By reference to Balter inspection tickets, we found that the concrete specimen cylinder represented in Balter test report # 486 was for the concrete that was placed at the location where the KCE cores had been extracted. Comparison of the of the KCE and Balter test results should complement each other as the tests were conducted on the same batch of concrete.

For core # 121, we note that the KCE reported compressive strength was 11,040 psi, while Balter reported a compressive strength of 13,575 psi. The first of the two rightmost columns indicate that the KCE sample demonstrated 81% of the strength reported by Balter (and 80% of the second Balter sample reported by test #495). For all of the compressive strength tests it conducted on Pour 2B, KCE determined that the average strength was 8,810 psi.

KCE's petrographic analysis conducted on core # 122 indicates that the in-situ concrete at this location exhibited a water to cement ratio (*w/c*) between .35 and .40, while Balter reported that *w/c* at this area was .26. KCE reported entrained air of 6%, while Balter reported 5.5%.

Exhibit IV: Comparison of KCE In-Situ Compressive Strength & Petrographic Test Pairing to Balter Construction Inspection Tests

Chart 1: Comparison of KCE In-Situ Compressive Strength & Petrographic Test Pairings to Balter (RBB) Construction Inspection Tests

Average KCE psi as % of RBB	62%

Pour Information		Testing Information		Strength	Grid Location		Concrete Attributes				KCE psi as %	KCE psi as %
Date	#	Core #	KCE Tset Type	(psi)	Row	Column	Entrained	Entrapped	w/c	unhydrated	of 1st RBB	of 2nd RBB
18-Oct-10	1C	6	Compressive Strength	6,690	A2 - A4	3 - 4						46% ↓
		47	Petrographic		A2 - A4	3 - 4	5.00%		.38 - .43			
		48	Petrographic		A2 - A4	3 - 4	1.40%	6.10%	.35 - .45	5% - 10%		
KCE-Reported average compressive strength - Pour 1C				6,210								43% ▼
56-day RBB Test Cylinder Batch 87901: Test Report # 387 *				14,470	A1 - A3	3.3 - 4	4.20%		.25			
20-Dec-10	1D	72	Compressive Strength	7,100	A2 - A4	2 - 3						49%
		71	Petrographic		A2 - A4	2 - 3	6.00%		.35 - .40			
KCE-Reported average compressive strength - Pour 1D				6,780							▼	47% ▼
56-day RBB Test Cylinder Batch91832: Test Report # 522				14,400	A2 - A4	2 - 3	4.10%		.26			
12-Nov-10	1E	95	Compressive Strength	9,370	C1 - C6	10 - 10.1					66%	68%
		96	Petrographic		C1 - C6	10 - 10.1	6.00%		.35 - .40			
		99	Petrographic		C1 - C6 (c5)	10 - 10.1	2.60%	3.00%	.35 - .45	7% - 13%		min
		100	Compressive Strength	**5,070**	C1 - C6 (c5)	10 - 10.1					36% ↓	37% ↓
KCE-Reported average compressive strength - Pour 1E				6,740							47% ▼	49% ▼
56-day RBB Test Cylinder Batch 89739: Test Report # 462				14,270	C6	10.1	5.10%		.25			
56-day RBB Test Cylinder Batch 89748: Test Report # 463				13,735	C6	10.1	4.40%		.26			
30-Dec-10	1F	105	Petrographic		C1 - C6	7 - 8	7.00%		.35 - .40			
		106	Compressive Strength	9,350	C1 - C6	7 - 8						69%
		107	Compressive Strength	9,000	C1 - C6	7 - 8						67%
		108	Petrographic		C1 - C6	7 - 8	6.30%	0.30%	.35 - .45	8% - 13%		
KCE-Reported average compressive strength - Pour 1F				6,990								52%
56-day RBB Test Cylinder Batch 92297: Test Report # 551				13,495	C3 - C8	7 - 8	5.20%		.26			
8-Feb-11	1G	79	Petrographic		C1 - C6	5 - 6	7.00%		< .38			
		80	Compressive Strength	7,990	C1 - C6	5 - 6					60%	64%
		85	Compressive Strength		C1 - C6	3 - 4						
		86	Petrographic	7,770	C1 - C6	3 - 4	6.30%	3.90%	.35 - .45	8% - 12 %	58%	62%
KCE-Reported average compressive strength - Pour 1G				6,490							48% ▼	52%
56-day RBB Test Cylinder Batch 93856: Test Report # 642				13,410	C - C5	5 - 6	5.50%		.26			
56-day RBB Test Cylinder Batch 93860: Test Report # 644				12,505	C - C5	5 - 6	5.50%		.26			
2-Nov-10	2A	111	Compressive Strength	7,920	A2 - A3	10.2 - 10.9					57%	57%
		112	Petrographic		A2 - A3	10 - 10.2	4.50%		.35 - .45			
		115	Compressive Strength	8,160	A2 - A3	10.2 - 10.9					58%	59%
		116	Petrographic		A2 - A3	10.2 - 10.9	2.00%	1.60%	.35 - .45	8% - 13%		
KCE-Reported average compressive strength - Pour 2A				6,440							46% ▼	47% ▼
56-day RBB Test Cylinder Batch 88958: Test Report # 436				13,965	A2	10.3	4.30%		.26			
56-day RBB Test Cylinder Batch 88980: Test Report # 439				13,815	A3	10.7	4.50%		.25			
7-Dec-10	2B	121	Compressive Strength	**11,040**	A3 - A8	8 - 9					81% Δ	80% Δ
		122	Petrographic		A3 - A8	8 - 9	6.00%		.35 - .40			
		123	Petrographic		A2 - A3	7 - 8	5.20%	0.70%	.35 - .45	7% - 11%		
		124	Compressive Strength	10,060	A2 - A3	7 - 8					74%	73%
KCE-Reported average compressive strength - Pour 2B				8,810							65%	64%
56-day RBB Test Cylinder Batch 91111: Test Report # 486				13,575	A2.8 - A3	8 - 9	5.50%		.26			
56-day RBB Test Cylinder Batch 91160: Test Report # 495				13,740	A1 - A2	7 - 8	5.30%		.24			
14-Jan-11	2C	127	Petrographic		A4 - A9	5 - 6	7.00%		< .38		max	
		128	Compressive Strength	10,710	A4 - A9	5 - 6					86% Δ	74%
		131	Petrographic		A4 - A9	3 - 4	5.90%	1.00%	.35 - .45	7% - 12%		
		132	Compressive Strength	5,330	A4 - A9	3 - 4					43% ↓	37% ↓
KCE-Reported average compressive strength - Pour 2C				6,870							55%	48% ▼
56-day RBB Test Cylinder Batch 93009: Test Report # 590				12,480	A3 - B	3.3 - 4	4.50%		.26			
56-day RBB Test Cylinder Batch 93019: Test Report # 591				14,390	A3 - B	3.3 - 4	5.40%		.26			
31-Jan-11	2D	141	Petrographic		A4 - A9	2 - 3	6.60%	0.60%	.35 - .45	8% - 13%		
		142	Compressive Strength	8,460	A4 - A9	2 - 3					72%	57%
KCE-Reported average compressive strength - Pour 2D				8,070							69%	54%
56-day RBB Test Cylinder Batch 93512: Test Report # 615				**11,750**	A4 - B	2 - 3	6.10%		.25			
56-day RBB Test Cylinder Batch 93517: Test Report # 616				**14,905**	A4 - B	2 - 3	4.70%		.26			

Pours 1 A, 1 B, and 1 D were not part of the sample set used for data calculations, and 1 H presented no adjacent compressive strength and petrographic test locations.

- ↓ KCE Core sample less than 50% strength of proximate RBB-tested strength
- ▼ KCE all sample average for pour area less than 50% strength of proximate RBB-tested strength
- Δ KCE Core sample at least 80% strength of proximate RBB-tested strength
- * All 56-day RBB test results are the average of two specimen cylinders

Average Unhydrated Cementitious Material	
Low	Hi
7	12

Exhibit V: Comparison of Same Batch, Inspection Station to Surface Deck Field Cured Strength Results

The following charts capture compressive strength test results for those sets of comparison specimens cast from the same batch of concrete. One set of cylinders was cast at the inspection station. The second set was cast on the deck after the concrete had been pumped from the truck to the surface. Up to three comparison sets (a total of 6 specimen cylinders) were cast for each pour that exceeded 50 cubic yards of concrete.

How to Read:

Locate the first box below for Pour 1 A. Three comparison sets were cast for this pour – Set 1 from truck # 65, Set 2 from truck # 68, and Set 3 from truck 411.

For truck 65, the tests conducted on the specimens that were cast at the inspection station 26 minutes after leaving the concrete plant were reported in Robert B. Balter Company's Report of Concrete Cylinder Test, report number 283, while results for the specimens collected on the deck 41 minutes after batching were contained in report number 284. Note that if this batch of concrete exceeded the 90 minute maximum batch age, it would be indicated in this column. If water had been added to the mix after the specimen was collected at the inspection station, it would be reported in the column "Added H_2O (gal)".

Three days after the specimens were cast, two cylinders from each specimen set were tested for compressive strength. Specimens from the inspection station were measured at 5,860 and 4,730 psi, while the specimens from the deck were measured at 6,130 and 6,120 psi. In this example, KCE records did not include twenty-eight day inspection station strength test results.

Concrete Batch			Sample	RBB Strength Test		Slump	Air	Added	Revs	W/C	Time	3-Day Strength		28-Day Strength	
Pour	Truck #	Ticket #		#	Location		Content	H_2O (gal)		ratio	Lapse	Sample 1	Sample 2	Sample 1	Sample 2
1 A	65	85320	Set 1	283	Inspection Station	8.0	6.0%	0.0	125	0.25	26	5,860	4,730	Data Not Avialable (DNA)	
				284	Deck	8.0	5.0%	0.0	133	0.25	41	6,130	6,120		
	68	85354	Set 2	291	Inspection Station	8.0	5.7%	0.0	110	0.26	65	5,750	5,900		
				292	Deck	7.3	4.4%	0.0	181	0.26	90	6,270	6,690		
	411	85413	Set 3	299	Inspection Station	8.0	6.8%	0.0	232	0.27	65	7,870	8,130		
				300	Deck	7.3	5.9%	0.0	265	0.27	75	7,920	7,610		
1 B	56	86785	Set 1	334	Inspection Station	8.0	6.9%	0.0	115	0.26	37	Data Not Avialable			
				335	Deck	7.5	6.4%	Data Not Available							
	67	86827	Set 2	342	Inspection Station	8.0	6.5%	0.0	105	0.26	63				
				343	Deck	8.0	6.0%	Data Not Available							
	32	86859	Set 3	349	Inspection Station	8.0	5.9%	0.0	187	0.26	59				
				350	Deck	7.0	6.0%	Data Not Available							
1 C	67	87816	Set 1	373	Inspection Station	8.0	4.5%	0.0	125	0.25	50	Data Not Avialable			
				374	Deck	8.0	5.4%	0.0	DNA	0.25	65				
	78	87855	Set 2	381	Inspection Station	8.0	4.2%	0.0	129	0.25	68				
				382	Deck	7.5	4.0%	0.0	DNA	0.25	86				
	69	87901	Set 3	387	Inspection Station	8.0	4.2%	0.0	73	0.25	51				
				388	Deck	7.5	4.7%	0.0	DNA	0.25	81				

Exhibit V: Comparison of Same Batch, Inspection Station to Surface Deck Field Cured Strength Results

Concrete Batch			Sample	RBB Strength Test		Slump	Air	Added	Revs	W/C	Time	3-Day Strength		28-Day Strength	
Pour	Truck #	Ticket #		#	Location		Content	H_2O (gal)		ratio	Lapse	Sample 1	Sample 2	Sample 1	Sample 2
1 D	67	91818	Set 1	518	Inspection Station	6.5	5.1%	20.0	71	0.25	53	10,480	10,220	13,100	13,440
				519	Deck	6.5	5.3%	20.0	71	0.25	74	5,140	5,020	10,620	10,890
	77	91837	Set 2	523	Inspection Station	7.0	6.2%	0.0	112	0.26	45	9,190	9,580	12,100	11,820
				524	Deck	8.0	5.7%	0.0	112	0.26	65	3,820	3,930	7,550	7,410
	79	91883	Set 3	530	Inspection Station	7.0	5.7%	0.0	250	0.26	53	9,910	10,190	11,470	11,460
				531	Deck	7.5	5.9%	0.0	250	0.26	73	4,460	4,130	9,120	9,510
1 E (a)	68	89704	Set 1	454	Inspection Station	7.5	5.5%	10.0	100	0.27	52	9,240	9,060	10,020	10,070
				455	Deck	7.5	5.7%	10.0	DNA	0.29	67	5,470	5,200	11,630	11,560
	29	89730	Set 2	460	Inspection Station	7.0	5.0%	10.0	175	0.27	41	5,530	5,030	11,430	11,530
				461	Deck	7.5	5.5%	10.0	DNA	0.29	46	8,710	8,320	10,080	10,070
	69	89793	Set 3	468	Inspection Station	8.0	4.6%	0.0	83	0.25	69	5,380	5,450	12,390	12,500
				469	Deck	8.0	5.0%	0.0	**DNA**	0.25	87	9,920	10,280	12,020	11,850
1 F	77	92269	Set 1	543	Inspection Station	7.5	5.0%	0.0	116	0.26	19	6,560	6,730	12,220	11,700
				544	Deck	7.0	4.7%	0.0	150	0.26	44	6,910	6,960	8,780	9,340
	62	92282	Set 2	547	Inspection Station	8.0	6.3%	0.0	120	0.26	45	7,930	7,810	12,690	12,660
				548	Deck	7.5	5.8%	0.0	153	0.26	75	6,120	6,670	9,160	9,250
	32	92316	Set 3	554	Inspection Station	8.0	6.1%	0.0	128	0.25	52	5,700	5,310	12,040	11,910
				555	Deck	7.5	5.9%	**15.0**	160	0.27	**101**	7,190	7,550	8,680	8,730
1 G	67	93856	Set 1	642	Inspection Station	7.0	5.5%	0.0	185	0.26	44	8,150	8,380	12,140	12,260
				643	Deck	7.3	5.0%	0.0	211	0.26	66	7,200	7,080	10,260	10,870
	69	93889	Set 2	649	Inspection Station	8.0	4.5%	0.0	33	0.25	65	9,690	9,950	13,630	13,510
				650	Deck	7.5	4.3%	0.0	33	0.25	80	6,230	6,080	11,630	11,500
	61	93913	Set 3	654	Inspection Station	7.5	4.9%	0.0	250	0.26	51	10,060	9,680	12,210	12,400
				655	Deck	7.0	4.8%	0.0	250	0.26	67	6,130	6,750	11,350	10,950
1 H	65	94393	Set 1	667	Inspection Station	7.5	4.9%	12.0	120	0.26	49	7,610	7,710	11,550	11,780
				668	Deck	8.0	4.4%	0.0	131	0.26	59	6,320	6,520	8,590	9,750
	84	94422	Set 2	674	Inspection Station	8.0	4.9%	15.0	119	0.26	34	7,650	7,860	12,030	11,530
				675	Deck	8.0	4.6%	10.0	137	0.26	47	7,770	7,580	11,490	11,170
	411	94476	Set 3	682	Inspection Station	7.5	4.8%	0.0	156	0.26	43	7,380	6,870	10,840	10,910
				683	Deck	7.0	4.5%	0.0	170	0.26	49	7,380	7,350	10,120	10,000
2A	67	88929	Set 1	428	Inspection Station	8.0	4.8%	0.0	98	0.26	59	5,150	5,520	12,550	13,470
				429	Deck	8.0	4.8%	0.0	98	0.26	74	7,620	7,610	12,480	12,870
	37	88953	Set 2	434	Inspection Station	8.0	4.2%	0.0	188	0.26	58	5,540	5,700	12,790	12,650
				435	Deck	8.0	4.7%	0.0	188	0.26	78	6,640	6,610	11,410	11,550
2 B	67	91088	Set 1	481	Inspection Station	8.0	6.3%	0.0	195	0.25	41	4,080	4,150	11,150	10,670
				482	Deck	8.0	5.1%	0.0	195	0.25	62	4,270	4,590	9,280	8,840
	69	91152	Set 2	493	Inspection Station	7.5	5.1%	0.0	119	0.26	77	6,840	6,910	12,680	12,790
				494	Deck	8.0	4.6%	0.0	119	0.26	**101**	5,990	6,060	11,180	11,310
	37	91251	Set 3	507	Inspection Station	7.0	4.7%	0.0	88	**DNA**	78	4,300	3,960	11,240	10,130
				508	Deck	7.0	4.2%	0.0	88	**DNA**	**94**	5,750	5,740	10,100	10,260
2 C	67	92950	Set 1	578	Inspection Station	7.0	4.5%	0.0	176	0.26	57	7,060	6,490	11,400	11,600
				579	Deck	8.0	4.3%	**20.0**	195	0.30	67	7,080	7,170	11,200	11,140
	81	92978	Set 2	585	Inspection Station	8.0	5.6%	0.0	110	0.26	60	5,380	5,300	12,890	13,120
				586	Deck	8.0	5.4%	0.0	110	0.26	75	8,030	8,060	12,830	12,700
	61	93053	Set 3	594	Inspection Station	7.0	4.8%	0.0	250	0.26	**95**	6,380	6,590	13,170	12,650
				595	Deck	8.0	5.1%	0.0	250	0.26	**109**	5,390	5,160	9,620	9,110
2 D	67	93509	Set 1	613	Inspection Station	7.0	6.2%	0.0	105	0.25	50	6,360	6,530	10,820	11,410
				614	Deck	8.0	6.0%	**15.0**	131	**DNA**	64	6,890	6,580	10,900	10,970
	82	93538	Set 2	620	Inspection Station	7.5	5.4%	0.0	240	0.25	**91**	6,980	7,470	12,340	12,110
				621	Deck	8.0	5.0%	**15.0**	280	**DNA**	**113**	5,850	6,420	13,550	13,660
	57	93600	Set 3	627	Inspection Station	8.0	7.0%	25.0	252	0.25	56	7,270	6,790	11,360	11,290
				628	Deck	7.0	6.7%	0.0	279	**DNA**	75	6,400	6,520	10,670	10,490
2 I (a)	78	96174	Set 1	767	Inspection Station	7.0	5.0%	0.0	126	0.25	40	5,830	5,830	11,720	11,800
				768	Deck	8.0	4.8%	**15.0**	140	0.27	51	5,170	5,190	9,230	9,120
	79	96187	Set 2	770	Inspection Station	7.5	4.9%	0.0	255	0.25	48	6,730	6,330	12,790	13,020
				771	Deck	7.0	4.5%	**37.0**	291	0.28	**123**	4,160	4,050	7,780	7,590

Source: Robert B. Balter Company Report of Concrete Cylinder Test and Rockville Fuel and Feed Company, Inc. job batching and delivery tickets.
3-Day Strength results for Pour 1 F were actually tested on Day 4.
For Set 2 of Pour 1 H, truck numbers differ (84 & 86), an apparent transcription error by the inspector as the batch ticket # is the same for both comparative specimens.

Exhibit VI: Chief Administrative Officer's Statement to County Council

Statement by Chief Administrative Officer Tim Firestine

On Moving Ahead with Final Fix to Silver Spring Transit Center

May 8, 2014

County Executive Ike Leggett has directed County contractors to move ahead on remediation work at the Silver Spring Transit Center to address shear and torsion issues and ensure that the Center will not only be safe but also meet its projected 50-year life span – consistent with our Memorandum of Understanding with the Washington Metropolitan Transit Authority (WMATA).

The County Executive has directed KCE, the County's contract engineering team, to meet on Monday with Parsons Brinckerhoff, the project's engineer of record, to finalize the remediation plan consistent with concerns raised in the Augustine report. The County Executive has given the go-ahead to bring equipment on site to begin preparation for the remediation work.

WMATA, the "customer" for whom the facility is being built, is in agreement with the County Executive to undertake the remediation to address concerns raised about the possible effects of shear and torsion on the structure.

The County Executive has made it clear that he would not open the Transit Center until it was safe to do so. The County will deliver a facility to Metro that is safe and will meet its projected 50-year life. The County will ensure that any additional costs incurred because of faulty construction, design, or inspection by private contractors will be the responsibility of those contractors, not the County taxpayer.

In 2012 – when the facility was 95 percent complete, the County Executive rejected a proposal to simply "cover over" cracks in the concrete with a thin layer of poured concrete and "move on." That would have been wrong.

Instead, the County Executive hired KCE to conduct an in-depth review of the project. As a result of that review, KCE found significant flaws beyond the cracks in the concrete. KCE determined that these flaws would affect the maintenance and durability of the facility and would require repairs to address shear and torsion issues.

Because concerns remained about costs and scheduling, during the winter "weather window" when the overlay could not be done due to low temperatures, the County Executive asked former Lockheed Martin CEO Norman Augustine to undertake an independent review of the project. Mr. Augustine's report supported KCE's proposed remediation plan and introduced, for the first time, concern that the facility could experience safety issues.

The County is grateful to Mr. Augustine for his work and those associates whose expertise he solicited. Not only did they deliver a report at no cost to the taxpayers, but this report has also proved pivotal in helping to advance a consensus for remediation with WMATA and Parsons Brinckerhoff.

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