Engineering Evaluation of Concrete Condition
and Steel Sheet Pile Wing Wall Thickness
St. Johns River Water Control Structure S-96B
Indian River County, Florida

Ardaman & Associates, Inc.

OFFICES

Orlando – 8008 S. Orange Avenue, Orlando Florida 32809 – Phone (407) 855-3860
Alexandria – 3609 Mac Lee Drive, Alexandria, Louisiana 71302 – Phone (318) 443-2888
Bartow – 1525 Centennial Drive, Bartow, Florida 33830 – Phone (863) 533-0858
Baton Rouge – 316 Highlandia Drive, Baton Rouge, Louisiana 70884 – phone (225) 752-4790
Cocoa – 1300 N. Cocoa Blvd., Cocoa, Florida 32922 – Phone (321) 632-2503
Fort Myers – 9970 Bavaria Road, Fort Myers, Florida 33913 – Phone (239) 768-6600
Miami – 2608 W. 84th Street, Hialeah, Florida 33016 – Phone (305) 825-2683
Monroe – 1122 Hayes Street, West Monroe, Louisiana 71292 – Phone (318) 387-4103
New Orleans – 1305 Distributors Row, Suite I, Jefferson, Louisiana 70123 – Phone (504) 835-2593
Port St. Lucie – 460 Concourse Place NW, Unit 1, Port St. Lucie, Florida 34986 – Phone (772) 878-0072
Sarasota – 78 Sarasota Center Blvd., Sarasota, Florida 34240 – Phone (941) 922-3526
Shreveport – 7222 Greenwood Road, Shreveport, Louisiana 71119 – Phone (318) 636-3673
Tallahassee – 3175 West Tharpe Street, Tallahassee, Florida 32303 – Phone (850) 576-6131
Tampa – 3925 Coconut Palm Drive, Suite 115, Tampa, Florida 33619 – Phone (813) 620-3389
West Palm Beach – 2200 North Florida Mango Road, Suite 101, West Palm Beach, Florida 33409 – Phone (561) 687-8200

Ardaman & Associates, Inc.

Geotechnical, Environmental and
Materials Consultants

June 25, 2014
File No. 14-6318
Revised July 9, 2014

St. Johns River Water Management District
P.O. Box 1429
Palatka, Florida 32178

Attention: Mr. Wayne Dempsey, P.E.

Subject: Engineering Evaluation of Concrete Condition and Steel Sheet Pile Wing Wall Thickness
St. Johns River Water Control Structure S-96B
Indian River County, Florida

Dear Mr. Dempsey:

As authorized by you, Ardaman & Associates, Inc. has completed an engineering evaluation of the subject control structure with respect to concrete condition and the steel sheet pile wing walls. The purposes of our evaluation were to observe and evaluate the concrete condition, determine the thickness of the existing steel sheet pile wing walls and provide recommendations for remediation. This report documents our findings and presents our engineering recommendations.

SITE LOCATION AND DESCRIPTION

The subject control structure is located near the northwest corner of the Stick Marsh/Farm 13 reservoir near Fellsmere, Indian River County, Florida. The GPS coordinates obtained from Google Earth indicate that the longitude and latitude of the structure are N27.825177^{o}, W-80.741604^{o}, respectively.

We understand that the existing structure was constructed in 1993, and the concrete main structure and the steel sheet pile have not been modified except for periodic painting of the steel sheet pile wing walls.

Based on review of “As-Built” record drawings, the single gate hydraulic control structure is 20 feet in width. The concrete gate monolith is 37.0 feet in length having an upstream top of crest weir elevation of +13.1 feet dropping abruptly over an approximate horizontal distance of 9.0 feet to the downstream top of slab elevation of +11.8 feet. The structure is constructed entirely of reinforced concrete except for the metal gates and anchored steel sheet pile wing walls located at the upstream and downstream edges of the structure. According to the “As-Built” drawings, both the upstream and downstream sheet pile wing walls consist of 35 sections of Type Z-27 sheet pile having a total wall length of 52.5 feet. Type Z-27 (now known as PZ-27) sheet pile has a nominal web and flange thickness of 0.375 inch. We note that on the upstream sheet pile walls, only 26 of the 35 sections of sheet pile were observed. The remaining sections were below the water level.

8008 S. Orange Avenue (32809), Post Office Box 593003, Orlando, Florida 32859-3003 Phone (407) 855-3860 FAX (407) 859-8121

Florida: Bartow, Cocoa, Fort Myers, Miami, Orlando, Port St. Lucie, Sarasota, Tallahassee, Tampa, West Palm Beach
Louisiana: Alexandria, Baton Rouge, Monroe, New Orleans, Shreveport

SITE OBSERVATIONS

Site observations of the portion of the structure above the water level were made on March 21, 2014 (downstream portion) and April 9, 2014 (upstream portion) by Ardaman and Associates engineer Mr. Jason Parker, P.E. At the time of our observations, the upstream and downstream water levels were approximately at +20.6 feet and +16.4 feet, respectively, based on readings made from the on-site staff gauges. Based on the water staining marks, the water levels typically fluctuate approximately 6 inches on the upstream side and 3.5 feet on the downstream side. It is generally known that water levels during extreme hydrological events fluctuate more than typical.

Upstream Structure Observations

For the upstream side of the structure, our observations indicated that the concrete appeared to be in "very good" condition. Pitting within the water floatation zone and below the water surface was minimal. We were unable to observe the concrete structure below a depth of approximately 6 inches due to water clarity. No spalling, significant cracking, rust staining or other indicators of potential structural defects or corrosion were observed.

Relative to the steel sheet pile wing walls, the upstream walls appeared to be exhibiting greater corrosion than the downstream wing walls near the water line, especially the joints. The portions of the steel sheet pile walls that were below the water surface could not be observed relative to their condition.

Representative photographs of our observations are included in Appendix I.

Downstream Structure Observations

For the downstream side of the structure, our observations indicated that the concrete appeared to be in "good" condition; however, there appeared to be somewhat more advanced concrete erosion than the upstream portion of the structure. Pitting within the water floatation zone and below the water surface was observed to be ¼ to ½ inch. We were unable to observe the concrete structure below a depth of approximately 6 inches due to water clarity. No spalling, significant cracking, rust staining or other indicators of potential structural defects or corrosion were observed.

Relative to the steel sheet pile wing walls, the downstream walls appeared to be in "good" condition. We note that the coating paint was peeling on the southwest wingwall. The portions of the steel sheet pile walls that were below the water surface could not be observed relative to their condition.

FIELD EXPLORATION PROGRAM

The field exploration program consisted of performing a series of non-destructive and destructive testing/sampling at selected locations to evaluate the concrete and steel sheet pile wing wall thickness on the upstream and downstream sides of the structure. The following describes the field exploration program in detail.

Rebound Hammer Readings

Rebound hammer testing was performed in general accordance with ASTM C 805, "Standard Test Method for Rebound Number of Hardened Concrete". A rebound hammer is a non-destructive device that consists of a plunger rod and an internal spring loaded steel hammer and a latching mechanism. When the extended plunger rod is pushed against a hard surface, the spring connecting the hammer is stretched to an internal limit and then released, causing the energy stored in the stretching spring to propel the hammer against the plunger tip. The hammer strikes the shoulder of the plunger rod and rebounds a certain distance. On the outside of the unit is a slide indicator which records the distance traveled during the rebound. This indication is known as the rebound number (R-number).

At selected locations, rebound hammer readings were obtained to assess the uniformity of the in-place concrete within and above the water fluctuation zone and to delineate regions of potentially deteriorated concrete for further testing. In general, the rebound hammer testing was performed approximately 12 inches above the water level at the time of our evaluation and a second set of readings was obtained on the concrete approximately 48 inches above the water level at the time of our evaluation. The average results of 10 readings performed at each of the six (6) selected locations are presented on Table 1.

The approximate plan view locations where the readings were obtained are shown on Figure 1.

As shown on Table 1, the average value of the rebound number within the zone of typical water fluctuation is 3.3 and 4.0 for the downstream and upstream walls respectively. The average rebound number value above the zone of typical water fluctuation is 4.5 and 4.3 for the downstream and upstream wall respectively. Though the average rebound number readings obtained above the water typical fluctuation zone is higher than the average rebound number within the typical fluctuation zone, it is our opinion that the lower rebound numbers in the zone of typical fluctuation are primarily due to the surface condition (i.e., pitting present within the zone of typical water level fluctuation). No significant areas of "softer" or "harder" concrete were distinguishable.

Concrete Coring

The field exploration program also included obtaining a series of concrete cores for evaluation. Two (2) 3-inch diameter cores were obtained from six (6) selected locations for a total of twelve (12) core samples. The cores were obtained from approximately 0.5 foot above the water level at the time of our exploration. The cores were drilled horizontally to a depth of at least 3.5 inches or until reinforcing steel were encountered in the core sample. The core samples were visually inspected and measured for length in the field and transported to our laboratory for additional testing. When reinforcing steel was encountered, observations relative to the condition of the reinforcing steel were made within the core hole. Upon completion of the coring program, all core holes were patched with high strength, rapid setting concrete patch.

A summary of the concrete core data including their length and general observations is presented as Table 2. The approximate core locations are schematically illustrated on a site plan shown on Figure 1. These locations were determined by estimating distances from existing site features and should be considered accurate only to the degree implied by the method of measurement used.

Ultrasonic Thickness Readings

Non-destructive ultrasonic thickness readings were performed at selected locations along the upstream steel sheet pile wing walls. At each of the sheet pile wing walls, evenly spaced locations were tested and readings were obtained across the sheet pile section. The readings were obtained approximately 0.5 foot above the water level at the time of the readings. The thickness readings were obtained utilizing a Krautkramer DMS Ultrasonic Thickness Gauge. A summary of the readings for the sheet pile wing walls is included as Table 3A and 3B.

In general, the thickness readings for all walls exceeded the as-built sectional thickness of 0.375 inch. We note that readings may have been influenced by the corrosion.

Water Sampling

A sample of the creek water was obtained on March 21, 2014 downstream of the weir within the stilling basin and near the north wall. This sample was transported to our laboratory for analysis relative to corrosive properties (i.e.; pH, conductivity, chlorides and sulfates).

LABORATORY PROGRAM

Visual Evaluation of Concrete Core Samples

Selected core samples were chosen for examination to assess the depth of the erosion and examine for evidence of corrosion of embedded reinforcing steel. The selected core samples were saw-cut longitudinally and polished for examination.

In general, evidence of erosion (pitting) was measured to be ¼ to ½ inch on the downstream side and negligable on the upstream side. This was consistent with our visual observations. Within the cores we observed no evidence of rust bleeding (as would be expected from corroding reinforcing steel) or leaching of paste due to acid attack. These results also are consistent with our field observations.

Representative photographs depicting the polished core samples are included in Appendix II.

Chemical Evaluation of Concrete Core Samples

Selected core samples were also tested for carbonation and pH to assess the potential for corrosion. The pH of new concrete is typically within the range of 12 to 13 mostly due to calcium hydroxide, which is a normally occurring by-product of cement hydration. As a concrete surface reacts with carbon dioxide in air or water, the pH of the surface gradually is reduced to about 7 to 8 through a process called carbonation. Gradually the process penetrates deeper into the concrete. Once the internal pH drops below 10, the reinforcing steel passivation is disolved promoting corrosion.

To verify the pH, the top 1-inch of selected cores were cut horizontaly from the core samples. The 1-inch sections were crushed into a powder and mixed with distilled water and tested with a pH meter. The following Table summaries the results of the pH testing.

Location	Tested pH
Core 2A	12.1
Core 4A	12.1
Core 5A	12.2
Core 6B	12.2

The affected depth of carbonation from the surface can be readily shown by the use of phenolphthalein indicator solution. The phenolphthalein indicator solution is applied to the fresh cut surface of the concrete core. If the indicator solution turns purple, the pH is above 10.

The results of the indicator solution and pH testing indicate that carbonation is negligible and that the pH of the concrete cores remains high and consistent with depth. These characteristics indicate that concrete within the areas explored has not undergone significant chemical attack.

Representative photographs depicting the carbonation testing using the phenolphthalein are included in Appendix II.

Concrete Compressive Strength Testing

The core samples were trimmed and capped in accordance with ASTM C-42 for compressive strength testing. The results of the compressive strength testing are presented in the following table:

Location	Original Length (in)	Trimmed and Capped Length (in)	Corrected Compressive Strength (psi)
Core 1B	3.9	3.7	6,050
Core 2B	3.5	3.6	5,980
Core 3B	3.9	3.7	5,920
Core 4B	3.6	3.4	5,000
Core 5B	3.1	2.6	7,140
Core 6A	3.0	2.9	4,990

The results indicate that the minimum and maximum compressive strength range from 4,990 to 7,140 psi. The average and median compressive strength are 5,715 and 5,950 psi, respectively.

Chemical Analyses of Water

A water sample collected from the downstream stilling basin was tested for its corrosion properties. Properties tested included pH, resistivity, chloride and sulfate content. The properties and their classification according to the FDOT Structures Design Manual are presented below.

Tested Property				Environmental Classification	
Chloride (ppm)	pH	Resistivity (ohm-cm)	Sulfate (ppm)	Steel	Concrete
140	7.2	1200	78	Extremely Aggressive	Extremely Aggressive

The environmental classification criteria are based on Table 1.3.2-1 for Substructure Environmental Classification from the Florida Department of Transportation Structural Design Manual dated January, 2012. It is noted that the Florida Department of Transportation Substructures Environmental Classification system includes three categories (i.e.; slightly aggressive, moderately aggressive and extremely aggressive). Therefore, the water test results fall into the most aggressive category.

CONCLUSIONS AND RECOMMENDATIONS

Based on our visual observations and the results of our field exploration and laboratory testing programs, it is our opinion that the structural integrity of the concrete and the steel sheet pile wing walls has not been significantly compromised and, in fact, is in good general condition exhibiting normal physical erosion characteristics typical for a hydraulic structure of this age and use. With relatively routine remediation procedures, the facility can remain structurally functional from an erosion and corrosion standpoint for many more years. We note that the remedial recommendations presented herein do not need to be implemented urgently. While the rate of erosion can be expected to increase due to pitting, the condition of the structure considering the years of service suggests that there should be sufficient time to plan and budget the remediation.

The concrete degradation that is present appears to be confined to the outer approximate ¼ to ½ inch of the concrete within the water fluctuation zone on the downstream side of the structure only. The type of degradation observed is consistent with long-term erosion. Erosion is defined in this report as the progressive disintegration of a solid by cavitation, abrasion or chemical action. We saw no visual evidence of excessive concrete cracking, spalling or chemical damage such as leaching or rusting that would indicate that the structural integrity of concrete or reinforcing steel would be otherwise compromised.

Our observations and testing relative to the steel sheet pile wing walls indicate that there is corrosion occurring on the upstream wingwalls. Based on observations, corrosion is occurring at the section joints and at the water line. However, wall thickness readings indicate that the section thickness has not been compromised. Considering the relatively narrow water fluctuation zone on the upside portion of the structure, the concentration of the corrosion within this zone is logical.

The following sections provide additional detail relative to our findings and present our recommendations for continued use.

Concrete Remediation

As previously stated, the majority of the erosion was observed on the downstream portion of the structure walls where the turbulence associated with the flow and the apparent height of water level fluction are the greatest. Therefore it our conclusion that the pitting that has occurred is the result of physical deterioration caused by cavitation and abrasion/impingement erosion. The evidence does not suggest that chemical erosion (i.e.; severe acid attack, carbonation, chloride-related deterioration and/or sulfate attack) is occurring. The following is a brief description of the physical deterioration causes.

<u>Cavitation Erosion</u>

Cavitation attack involves the explosive collapse of gas entrapped bubbles in liquids when there is turbulent or disruptive flow of the liquid. The resultant pressures impact the concrete, causing pitting and erosion. This generally affects the cement paste first and then works on the aggregate. Once the aggregate is carried away, newly exposed paste continues to be attacked. Once erosion has begun, the rate of erosion may be expected to increase because protruding pieces of aggregate become new generators of vapor cavities. The erosion rate is often accelerated further by the high water velocities striking the irregular surface.

<u>Abrasion and Impingement Erosion</u>

Abrasion erosion damage results from the abrasive impacts of waterborne silt, sand, gravel, rock and debris impinging on a concrete surface. The rate of erosion is dependent on a number of factors including the size, shape, quantity and hardness of the particles being transported, the velocity of the water and the quality of the concrete.

Water flowing over or impinging on concrete inevitably leads to erosion of the cement paste, aggregate exposure and removal of the concrete surface. The rate of erosion depends on the velocity, temperature, pH and suspended solids levels of the impinging or flowing water. The size, concentration and hardness of the suspended solids also affect the erosion or “water-blasting” effects on the concrete.

<u>Repair Alternatives</u>

It is generally desirable to eliminate the cause of erosion whenever possible. However in this case, that will likely not be possible. A variety of materials and material combinations can be used for repair of hydraulic concrete structures undergoing the type of deterioration observed. Consideration should be given to the time available, access points, logistics in material supply, ventilation, nature of work, equipment available, and skill and experience of the local labor force. ACI Report 210R-93 provides remedial recommendations for steel plating, epoxy resins, acrylics and other polymer systems. Also included are more conventional fiber reinforced concretes, silica-fume concrete, and shotcretes.

Steel Sheet Pile Remediation

Based on our observations and thickness readings, it is our opinion that the steel sheet pile wing walls have not experienced excessive erosion or corrosion due to physical or chemical conditions. It appears that the wing walls have been treated with corrosion inhibiting paint/coatings in the past. We note that the coating on the southwest wingwall is peeling. Routine periodic applications of additional paint/coatings are expected.

Relative to the upstream steel sheet pile wing walls, we recommend that the corrosion occurring at the joints and at the water level be pressure washed and/or sand blasted to remove the corrosion and then repaint/coat the prepared surface as needed.

Other Considerations

The remedial concrete repair and sheet pile remediation contractor should specialize in remedial contracting of this nature and have at least 10 years of experience with similar projects, and should have successfully completed at least 10 hydraulic structure remedial projects similar to this project.

CLOSURE

The analyses and recommendations submitted herein are based on our observations and on the data obtained from our field and laboratory programs. This report does not reflect any variations which may occur adjacent to or between the test locations, or in the areas that could not be observed.

This report has been prepared for the exclusive use of St. Johns River Water Management District in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made.

We are pleased to be of assistance to you on this phase of the project. When we may be of further service to you or should you have any questions, please contact us.

Very truly yours,
ARDAMAN & ASSOCIATES, INC.
Certificate of Authorization No. 5950

Jason M. Parker, P.E.
Senior Project Engineer
Florida License No. 65928

Charles H. Cunningham, P.E.
Orlando Branch Manager
Florida License No. 38189

JMP/CHC/ksb/nfm
14-6318 Water Control Structure S-96B (2014 Geo)

TABLE 1
Summary of Rebound Hammer Data
Water Control Structure S-96B
SJRWMD, Indian River County, Florida

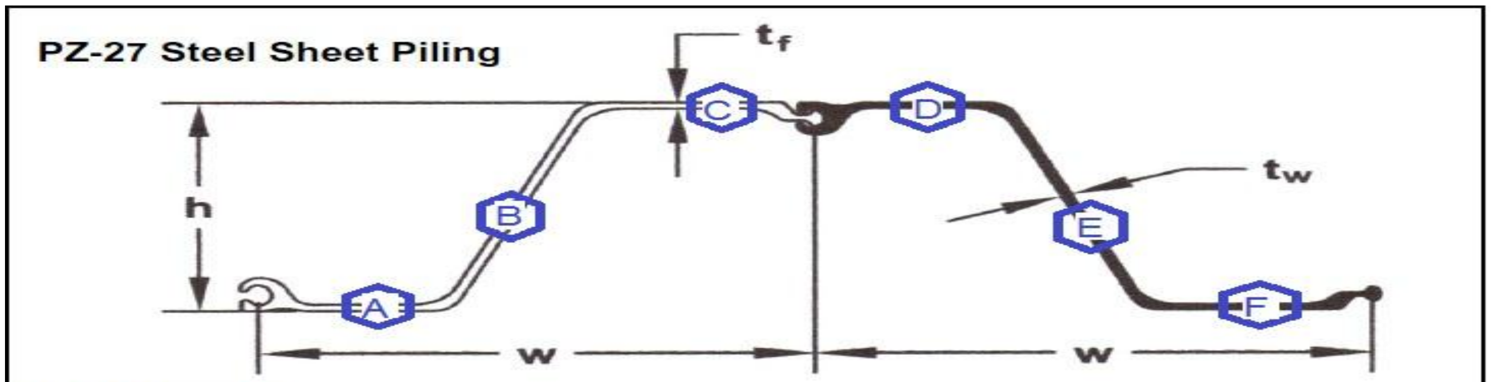
R-Number Location	Description	Average R-Number	
		Within Zone of Typical Water Fluctiation	Above Zone of Typical Water Fluctuation
R1	Downstream - South Wall, West Half	3.0	4.4
R2	Downstream - South Wall, East Half	3.2	4.4
R3	Downstream - North Wall, East Half	3.2	4.8
R4	Downstream - North Wall, West Half	3.8	4.5
R5	Upstream - North Wall	4.0	4.2
R6	Upstream - South Wall	4.1	4.4
	Average (Downstream/Upstream)	3.3/4.0	4.5/4.3

TABLE 2
Summary of Concrete Coring
Water Control Structure S-96B
SJRWMD, Indian River County, Florida

Location	Core Designation	Length (in)	Rebar Encountered	General Condition/Observations
Downstream - South Wall, West Half	C-1A	3.5	N	
	C-1B	3.7	N	
Downstream - South Wall, East Half	C-2A	2.3	Y	Rebar in good condition. No corrosion observed.
	C-2B	3.5	N	
Downstream - North Wall, East Half	C-3A	3.8	N	
	C-3B	3.9	N	
Downstream - North Wall, West Half	C-4A	2.5	Y	Rebar in good condition. No corrosion observed.
	C-4B	3.5	N	
Upstream - North Wall	C-5A	3.2	Y	Rebar in good condition. No corrosion observed.
	C-5B	4.0	N	
Upstream - South Wall	C-6A	4.0	N	
	C-6B	3.8	N	

TABLE 3A
Ultrasonic Thickness Readings
Steel Sheet Pile Wing Walls
Water Control Structure S-96B
SJRWMD, Indian River County, Florida

Reading Designation	Wing Wall Average Thickness Reading (inches)							
	North Wall (Upstream)				South Wall (Upstream)			
	1	2	3	4	1	2	3	4
A	0.401	0.380	0.396	0.389	0.396	0.399	0.390	0.383
B	0.415	0.383	0.379	0.360	0.411	0.395	0.399	0.390
C	0.423	0.425	0.404	0.402	0.374	0.391	0.370	0.367
D	0.440	0.390	0.396	0.380	0.401	0.391	0.390	0.391
E	0.414	0.363	0.369	0.396	0.384	0.389	0.389	0.387
F	0.405	0.404	0.399	0.385	0.377	0.377	0.377	0.374
Maximum Value	0.440	0.425	0.404	0.402	0.411	0.399	0.399	0.391
Minimum Value	0.401	0.363	0.369	0.360	0.374	0.377	0.370	0.367
Average Value	0.416	0.391	0.391	0.385	0.391	0.390	0.386	0.382
Median Value	0.415	0.387	0.396	0.387	0.390	0.391	0.390	0.385



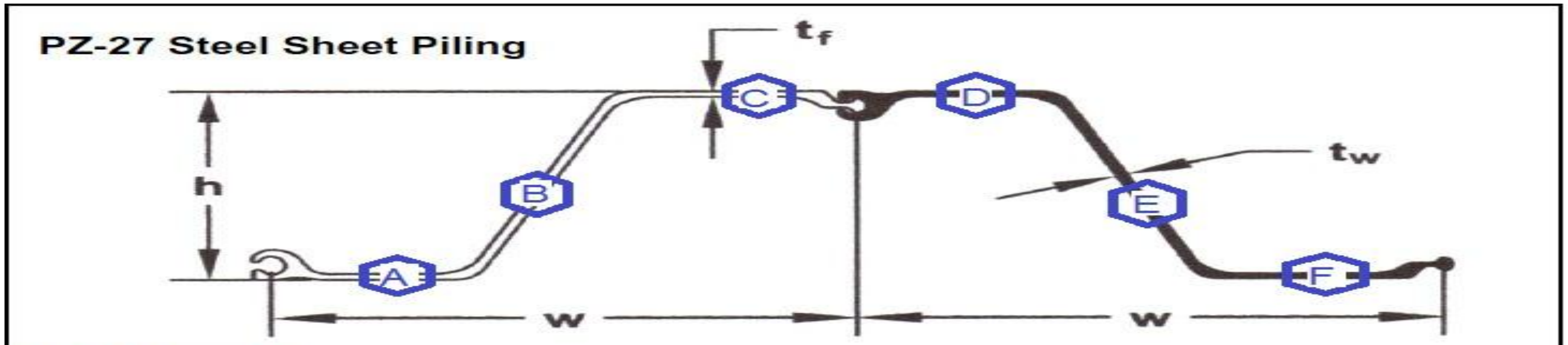
ASTM A572 Grade 50

Section	Width w in (mm)	Height h in (mm)	Thickness tw in (mm)	Cross Sectional Area in^2/ft (cm^2/m)	Weight: Pile lb/ft (kg/m)	Weight: Wall lb/ft^2 (kg/m^2)	Section Modulus in^3/ft (cm^3/m)	Moment of Inertia in^4/ft (cm^4/m)	Coating Area Both Sides ft^2/ft (m^2/m)	Coating Area ft^2/ft^2 (m^2/m^2)
PZ-27	18.00 457	12.00 305	0.375 9.53	11.91 252.10	40.50 60.30	27.00 131.82	30.20 1620	184.20 25200	4.48 1.37	1.49 1.49

Approximate Reading Designation Location

TABLE 3B
Ultrasonic Thickness Readings
Steel Sheet Pile Wing Walls
Water Control Structure S-96B
SJRWMD, Indian River County, Florida

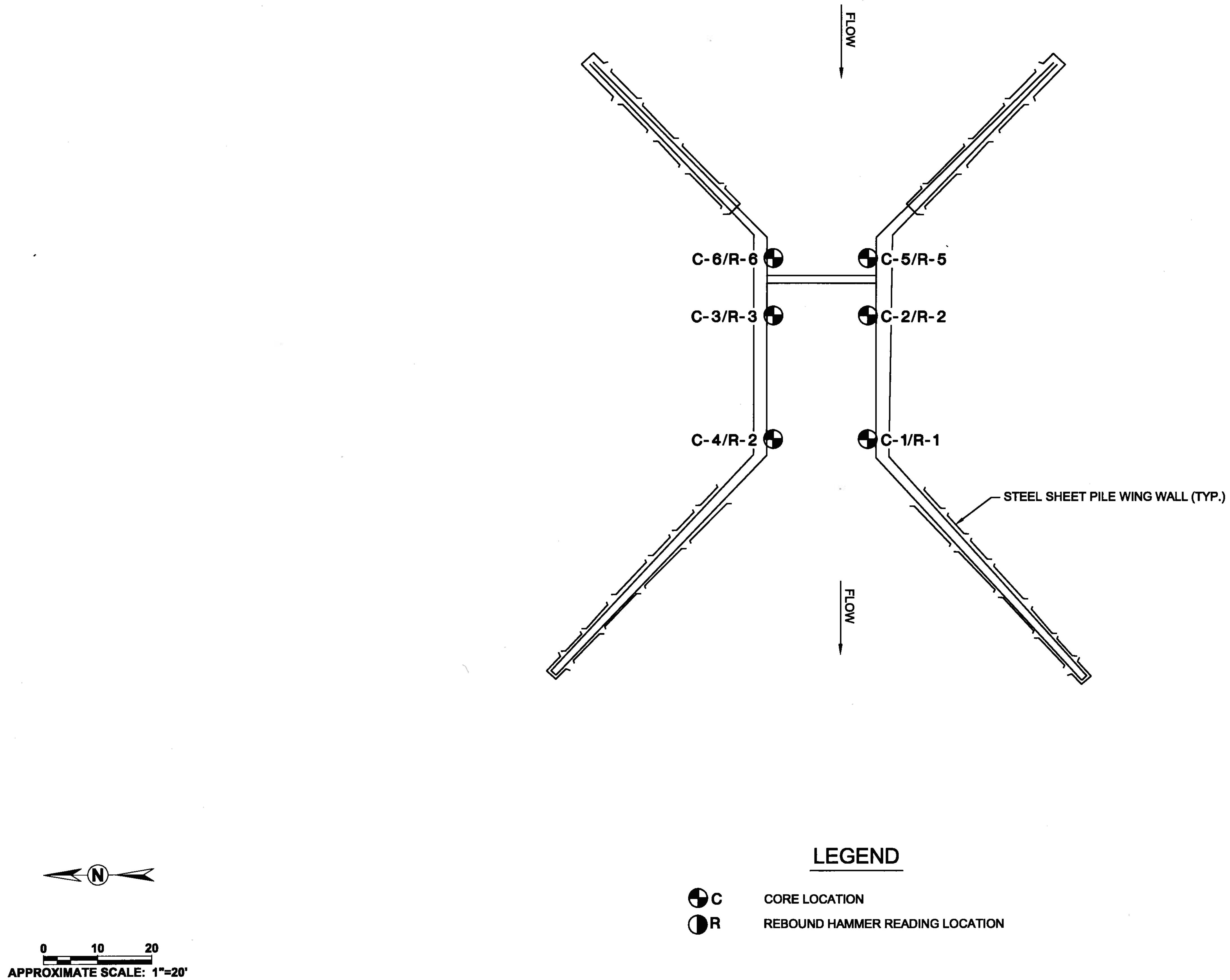
Reading Designation	Wing Wall Average Thickness Reading (inches)									
	North Wall (Downstream)					South Wall (Downstream)				
	1	2	3	4	5	1	2	3	4	5
A	0.408	0.405	0.399	0.411	0.433	0.390	0.416	0.398	0.419	0.395
B	0.399	0.399	0.396	0.421	0.418	0.380	0.411	0.405	0.422	0.381
C	0.414	0.429	0.426	0.439	0.418	0.410	0.429	0.404	0.429	0.420
D	0.387	0.435	0.399	0.404	0.438	0.417	0.421	0.417	0.414	0.418
E	0.432	0.393	0.401	0.413	0.421	0.405	0.381	0.402	0.378	0.405
F	0.409	0.435	0.397	0.419	0.412	0.426	0.412	0.395	0.427	0.408
Maximum Value	0.432	0.435	0.426	0.439	0.438	0.426	0.429	0.417	0.429	0.420
Minimum Value	0.387	0.393	0.396	0.404	0.412	0.380	0.381	0.395	0.378	0.381
Average Value	0.408	0.416	0.403	0.418	0.423	0.405	0.412	0.404	0.415	0.405
Median Value	0.409	0.417	0.399	0.416	0.420	0.408	0.414	0.403	0.421	0.407



ASTM A572 Grade 50

Section	Width w in (mm)	Height h in (mm)	Thickness tw in (mm)	Cross Sectional Area in²/ft (cm²/m)	Weight: Pile lb/ft (kg/m)	Weight: Wall lb/ft² (kg/m²)	Section Modulus in³/ft (cm³/m)	Moment of Inertia in⁴/ft (cm⁴/m)	Coating Area Both Sides ft²/ft (m²/m)	Coating Area ft²/ft² (m²/m²)
PZ-27	18.00	12.00	0.375	11.91	40.50	27.00	30.20	184.20	4.48	1.49
	457	305	9.53	252.10	60.30	131.82	1620	25200	1.37	1.49

Approximate Reading Designation Location



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LEGEND

C	CORE LOCATION
R	REBOUND HAMMER READING LOCATION

CORE LOCATION PLAN

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

ENGINEERING EVALUATION OF SJRWMD STRUCTURE S-96B BREVARD COUNTY, FLORIDA

DRAWN BY: CD	CHECKED BY:	DATE: 06/14/14
FILE NO. 14-6318	APPROVED BY:	FIGURE: 1

APPENDIX I

Photographs of Site Observations

APPENDIX I
Water Control Structure S-96B
SJRWMD, Indian River County

Downstream - View of Structure and Wing Walls.

Downstream - North Structure Wall.

APPENDIX I
Water Control Structure S-96B
SJRWMD, Indian River County

Downstream - South Structure Wall.

Downstream -South Structure Wall.

APPENDIX I
Water Control Structure S-96B
SJRWMD, Indian River County

Upstream - Structure and Wing Walls.

Upstream - South Wing Wall and Structure.

APPENDIX I
Water Control Structure S-96B
SJRWMD, Indian River County

Upstream - North Wing Wall Corrosion at Joint.

Upstream - North Structure Wall.

APPENDIX I
Water Control Structure S-96B
SJRWMD, Indian River County

Upstream - South Structure Wall.

Upstream - South Wing Wall.

APPENDIX II

Petrographic and Carbonation Examination Photographs

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

3925 Coconut Palm Dr.
Suite 115
Tampa, Florida 33619
Florida CA 00005950

Report of Petrographic Examination of Concrete
ASTM C-856

Project:	**Structure 96B**	**Date:**	**May 9, 2014**
Location:			
Client:	**SJRWMD**	**Project No.**	**14-60-6318**

Sample Nos. 1A
3A

Sample Size: 2 ½ in. wide, 3 ½ in. long
2 ½ in. wide, 3 ¾ in. long

Core 1A

Core 3A

Coarse Aggregate

- White to tan to crushed fossiliferous limestone and siliceous limestone.
- Nominal maximum particle size is ¾ inch graded down to ⅛ inch.
- The particles are equidimensional with a sub-rounded to sub-angular texture.
- Volume of coarse aggregate appears reasonable.
- Coarse aggregate relatively well distributed.
- Aggregate paste bond is good.
- No indications of cement-aggregate reactions were noted within the coarse aggregate.
- One aggregate piece in Sample 3A was found to contain a crack partially through the piece. This does not appear to be the result of a reactive aggregate. (Photo 9)

Fine Aggregate

- Natural sand, gray, white and clear quartz.
- Maximum particle size ⅛ inch, graded down to fine sand sizes.
- Particles have sub-rounded texture.
- No indications of cement-aggregate reactions were noted within the fine aggregate.

Matrix (cement paste)

- Paste is light to medium gray with some dark gray zones through the depth of the cores. Sample 3A has a light tan layer at the surface which can be attributed to carbonation which was measured to be on the order of $^{1}/_{16}$ inch deep at the surface as determined by the application of a phenolphthalein indicator solution.
- Paste moderately hard when scratched with steel point.
- Paste to aggregate bond appears good.

Air Voids

- Air voids are spherical to irregular in shape and are not well distributed, visually estimated at 2 to 3 percent.

Surface

- The surface of the sample is eroded. Photo 6 shows one coarse aggregate pice becoming exposed to a point where it will mostly pop out.

Cracking

- No cracking observed, except for the crack observed in the coarse aggregate piece. The piece of aggregate was well embedded in the concrete and is not considered to be an issue at this time.

Embedded Items

- No embedded reinforcing steel was observed.

Conclusions:

1. Quality of concrete is relatively good.
2. The paste is moderately hard to hard when scratched with a steel point.
3. Concrete is not air entrained but does contain entrapped air.
4. The exposed surface of the core is eroded.

William R. Goodson, PE
Senior Materials Engineer
Florida License 37935

Photo 2 – Sample 1A – end view, note surface erosion.

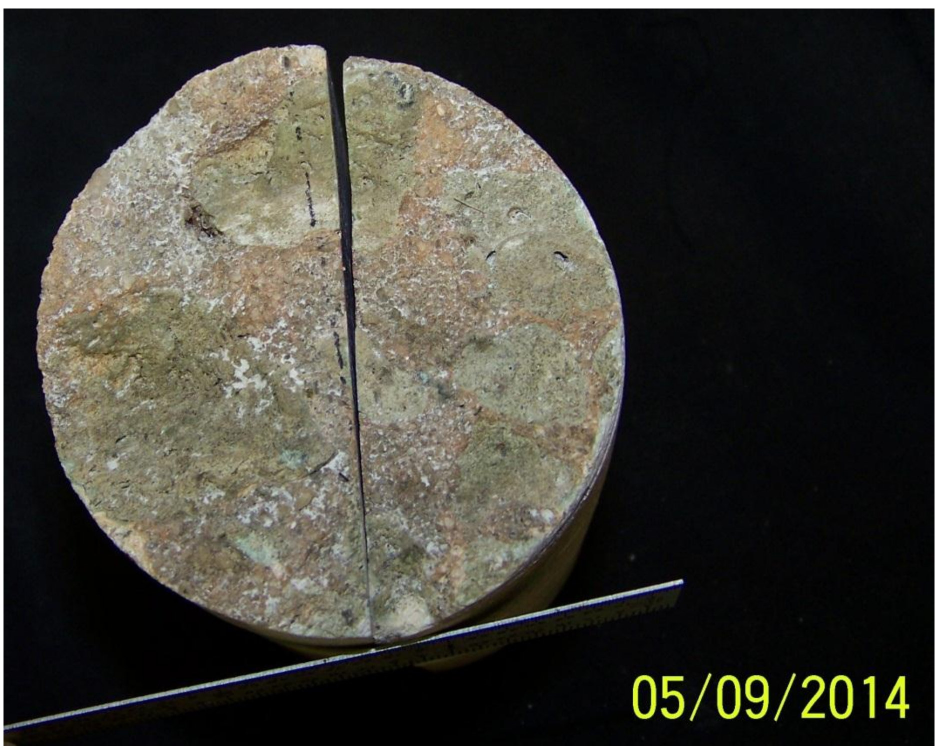

Photo 3 – Sample 3A – end view, note surface erosion.

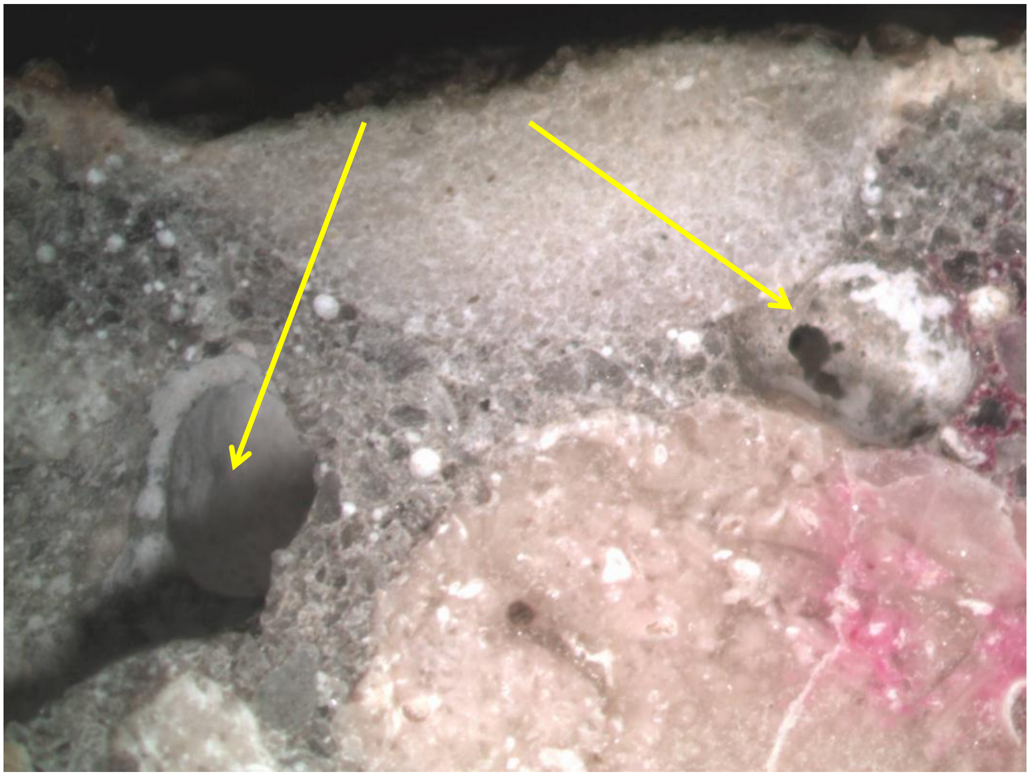

Photo 4 – Sample 1A – entrapped air voids near surface.

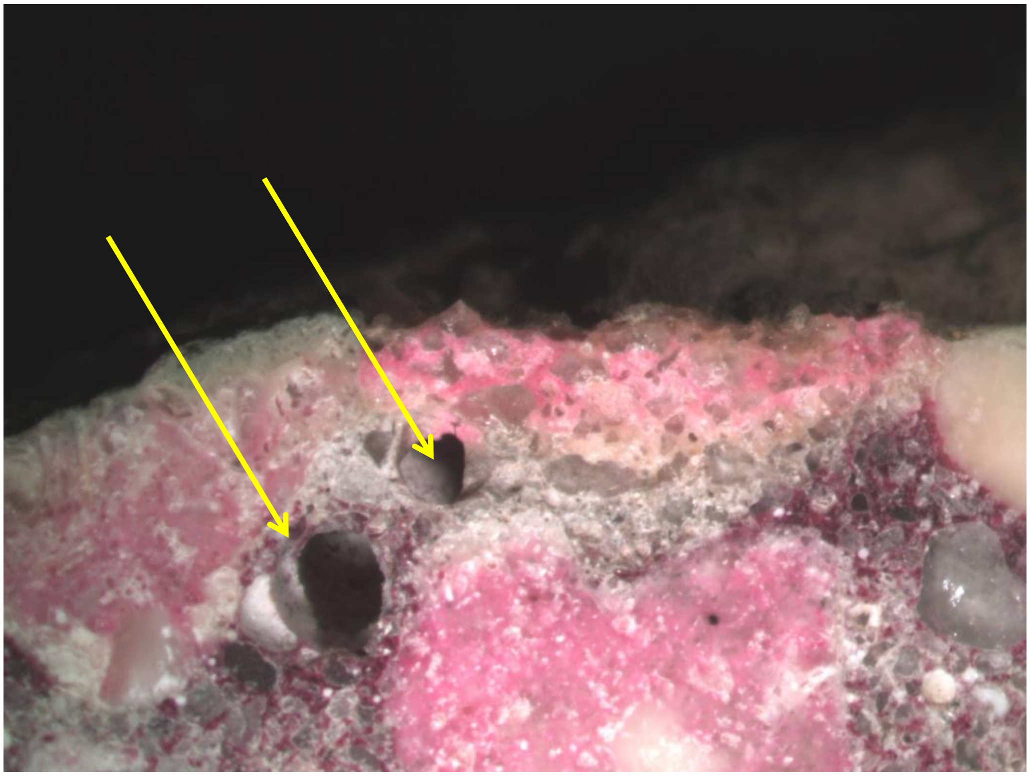

Photo 5 – Sample 1A – entrapped air voids near surface.

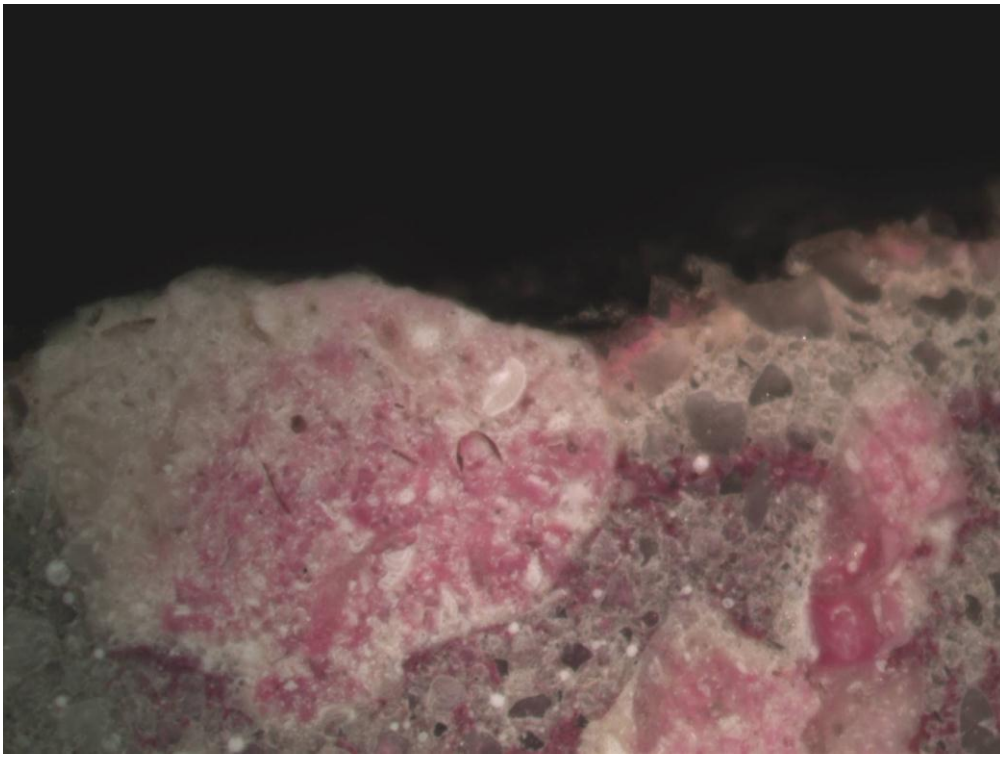

Photo 6 – Sample 3A – magnified view of eroded surface

Photo 7 – Sample 3A – variation in paste coloration, tan near surface to darker gray between coarse aggregate.

Photo 8 – Sample 3A – large entrapped air void

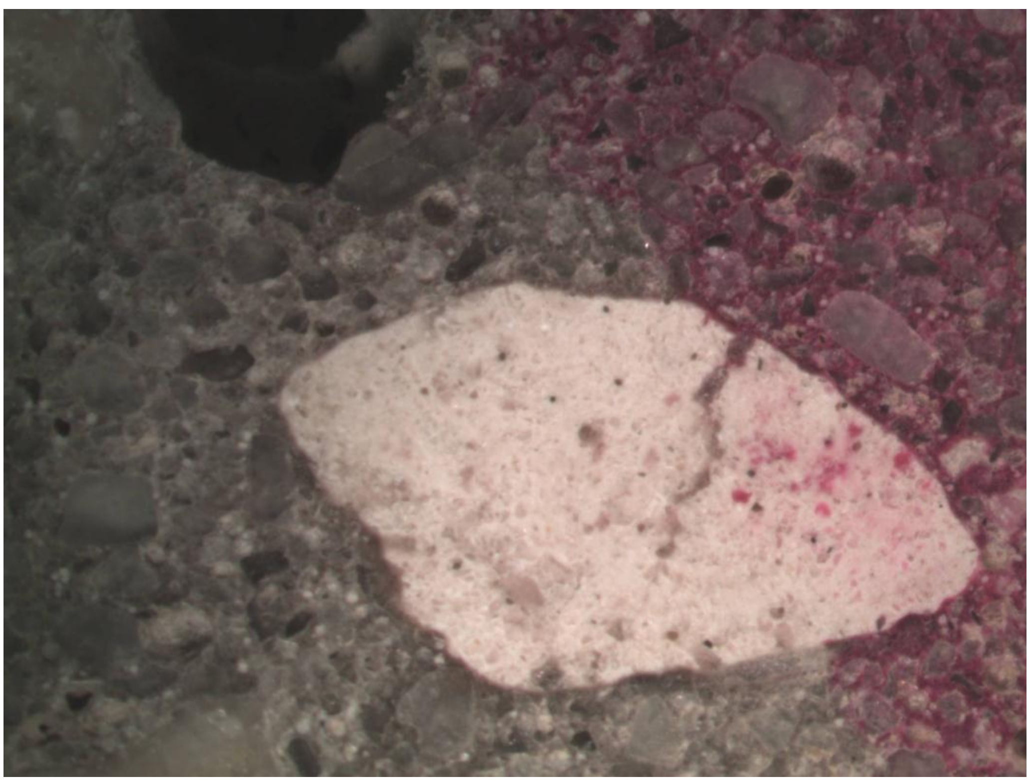

Photo 9 – Sample 1A – crack extending partially through coarse aggregate piece.