Thank you to our Patrons

We will begin our presentation in a few minutes...
L31 N Seepage Barrier
(8.5 SMA Segment)

Miami-Dade County, Florida
By Juan H. Vázquez, PE, PH, BCEE

06/07/2023

2023 Excellence in Environmental Engineering and Science Competition
Honor Award - Environmental Sustainability
Owner: South Florida Water Management District

Design Team:
• R.J. Behar & Company, Inc. – Prime (Civil Engineers)
• WSP (fka Wood Environmental & Infrastructure) – Geotechnical Engineers
• McVicar Consulting, Inc. – Hydrogeological Modeling
• Tierra South Florida, Inc. – Geotechnical Exploration
• Whidden Surveying and Mapping Inc. - Land Surveyors

Construction Management: TSFGeo

Contractor: Geo-Solutions, Inc.
AGENDA

1. Background
2. Location
3. The Problem
4. Design Process
5. Construction
6. Questions and Answers
BACKGROUND – PROJECT DATA

8.5 SMA Limited Curtain Wall
  • Length - 2.3 miles
  • Project Start - 4/26/2021
  • Project Bid - $13,923,000
  • Contract days - 360

CEPP New Water Seepage Barrier
  • Length - 4.9 miles
  • Project Bid - $42,258,000
  • Contract days - 790
The elevation change is only 12 to 14 feet from the maximum near Lake Okeechobee to sea level at the southern extent of the Everglades.

https://www.nps.gov/ever/learn/nature/hydrologicactivity.htm
L31N Seepage project is part of the Comprehensive Everglades Restoration Plan (CERP)

The construction and operation of the historic system disturbed the natural flow of water into the park, leaving Western Shark River Slough unnaturally wet and NE Shark River Slough unnaturally dry.

General Surface Flow Patterns in South Florida
LOCATION

8.5 SMA Limited Curtain Wall – 2.3 miles

L-357 Levee

C-357 Canal

New CEPP Water Seepage – 4.9 miles

L-31N
THE PROBLEM

From Akintunde Owosina, PE, Bureau Chief Hydrology and Hydraulics SFWMD, Presentation Consideration on Moving Water to Shark River Slough 11/14/2019
THE PROBLEM

L-357W Levee

Residential Side

ENP Side
DESIGN PROCESS – GEOTECHNICAL EXPLORATION

- 55 borings - 70 feet in depth
- 5-foot core barrel, with 4” diameter cores retrieved for thirty-two (32) locations and for twenty-seven (27) locations, approximately 2” diameter cores
- (28) boring locations were used for geophysical testing
- Five (5) locations had single-depth monitoring wells installed following geophysical testing.

- Stratum 1: GRAVELLY SAND (EMBANKMENT/LEVEE FILL) – borings were advanced through unconsolidated materials to the top of consolidated limestone materials.

- Stratum 2: VERY SOFT TO VERY HARD LIMESTONE INTERBEDDED WITH SAND, SHELL AND SILT: Gray to light gray, brownish gray, to white limestone interbedded with varying thicknesses of sand and silt representative of the Miami Limestone and Fort Thompson Formations.

- Stratum 3: SAND WITH SHELL; PARTIALLY CEMENTED SANDSTONE WITH SHELL: light to dark brown, light gray sand with clay representative of the Tamiami Formation.
Geophysical logging includes:

A.) electromagnetic induction resistivity and conductivity (EM)
B.) natural gamma ray (GR)
C.) spontaneous potential (SP)
D.) single-point resistivity (SPR)
E.) caliper
F.) water quality
   a. temperature
   b. fluid conductivity
   c. fluid resistivity
G.) full waveform sonic (SONIC)
H.) optical digital borehole image logs (OBI)
I.) flow meters (FM)
   a. heat pulse (HPFM)
   b. spinner flow meter (SFM)
J.) pH
K.) dissolved oxygen
L.) redox (WQ2)
M.) acoustic borehole image logs (ABI)
JLA estimated transmissivity values range from approximately 105,300 to 1,047,100 ft²/day.

summary report provides cross sections depicting the various lithologic, geophysical, and hydrogeologic data and interpretations.
Purpose - The modeling evaluation considers the effectiveness of constructing a seepage barrier at different depths to allow water levels to increase in ENP without negatively impacting the 8.5 SMA.

- Computer model was created utilizing the MODFLOW program developed by the USGS.
- The period 2016 - 2018 was simulated with specific emphasis on the very wet summer and fall of 2017.
DESIGN PROCESS – HYDROGEOLOGIC MODELING

Calibration
Figure 8. Seepage Flowline Locations

- Flowline A is from the eastern terminus of the south leg of the wall to approximately one half mile further to the east.
- Flowline B is from the eastern terminus of the south side of the wall to the southwestern corner of the wall near LPG1.
- Flowline C is from the southwestern corner of the wall to the northwestern corner of the wall.
- Flowline D is from the northwestern corner of the wall to the eastern terminus of the north leg of the wall.
- Flowline E is from the eastern terminus of the north leg of the wall north approximately 1 mile.

Flow Lines

A and E are path at the ends of the proposed (8.5 SMA segment) seepage wall.
Fourteen different model simulations were performed.

Table 4. Seepage Summary Table  Blue text indicates a reduction in seepage into Las Palmas and red text indicates an increase.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Seepage - October 2017 (actf/day)</th>
<th>Seepage reduction from Base - October 2017</th>
<th>Conditions at LPG2</th>
<th>Days Flooded</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>Base</td>
<td>141</td>
<td>201</td>
<td>164</td>
<td>35</td>
</tr>
<tr>
<td>Base_W7</td>
<td>149</td>
<td>160</td>
<td>148</td>
<td>32</td>
</tr>
<tr>
<td>Base_W9</td>
<td>151</td>
<td>140</td>
<td>140</td>
<td>34</td>
</tr>
<tr>
<td>Base_W10</td>
<td>167</td>
<td>17</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Base13</td>
<td>133</td>
<td>193</td>
<td>156</td>
<td>37</td>
</tr>
<tr>
<td>Base13_W10b</td>
<td>151</td>
<td>86</td>
<td>109</td>
<td>30</td>
</tr>
<tr>
<td>Base13_W10b_K10x0.5</td>
<td>129</td>
<td>60</td>
<td>84</td>
<td>25</td>
</tr>
<tr>
<td>Base_W9_K10x2</td>
<td>191</td>
<td>182</td>
<td>186</td>
<td>37</td>
</tr>
<tr>
<td>Base_W9_K10x0.5</td>
<td>129</td>
<td>108</td>
<td>112</td>
<td>30</td>
</tr>
<tr>
<td>CEPP</td>
<td>199</td>
<td>459</td>
<td>309</td>
<td>95</td>
</tr>
<tr>
<td>CEPP_W9</td>
<td>212</td>
<td>206</td>
<td>205</td>
<td>62</td>
</tr>
<tr>
<td>CEPP_W10</td>
<td>231</td>
<td>6</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>CEPP13</td>
<td>190</td>
<td>446</td>
<td>301</td>
<td>93</td>
</tr>
<tr>
<td>CEPP13_W10b</td>
<td>211</td>
<td>113</td>
<td>143</td>
<td>43</td>
</tr>
</tbody>
</table>
Seepage Barrier through Layer 10
DESIGN PROCESS – HYDROGEOLOGIC MODELING

CALIBRATED BASE

October 2017 Average Water Levels – Base (ft, NGVD)

October 2017 Average Water Levels – Layer-10 Wall (ft, NGVD)
The cutoff wall is constructed by filling the trench with a mixture of native soil and bentonite [Soil Bentonite (SB) wall], or cement and bentonite [Cement Bentonite (CB) wall], or soil, cement, and bentonite [(SCB) wall]]. For this application, with very little on-site soil available due to the limestone being close to ground surface, the CB wall is the best alternative. In addition, the rock has large voids and solution cavities, especially in the high flow zones, and the cement in the backfill mix will penetrate these voids and plug them as the cement sets up.

3-foot penetration into the Tamiami Formation
DESIGN PROCESS - PLANS

- Define alignment
- Define Construction limits
- Define/estimate staging areas
PART 1 - GENERAL

1. SCOPE:

Summary of Work: The CONTRACTOR shall furnish all labor, materials, and equipment for the construction of Cement-Bentonite Wall (CB Wall) as shown on the Drawings or as specified herein. The CB Wall shall be constructed at the location showing in the Plans, and from a foundation grade determined by the CONTRACTOR to provide trench stability and reach the bottom elevation of the wall shown on the drawings. Soil boring profiles are provided on the Drawings, as well as in the Design Geotechnical Report.

2. APPLICABLE STANDARDS AND REFERENCES

ASTM INTERNATIONAL

ASTM C 150 Standard Specification for Portland Cement
ASTM D1633 Standard Test Methods for Compressive Strength of Molded Soil-Cement Cylinders
ASTM D-4832-16el Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders
ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort

AMERICAN PETROLEUM INSTITUTE (API)

API RP 13B-1 Recommended Practice for Testing Water-Based Drilling Fluids
API Spec 13A Specification for Drilling Fluid Materials

2. DEFINITIONS

A. Cement Bentonite Wall (CB Wall): The Cement-Bentonite (CB) Wall consists of a vertical trench filled with a specified viscous fluid mixture of Portland cement and Bentonite clay as shown on the plans and in the Specifications. The CB Wall is a minimum twenty-eight (28) inches thick curtain of low permeability material. The trench will be excavated through the prepared foundation grade to the specified bottom elevation using a method proposed by the CONTRACTOR and approved by the DISTRICT. The CB wall construction involves placement of CB slurry into the trench to approximately foundation grade, as shown in the project drawings and described in this specification. The cured Cement Bentonite will form the CB low permeability wall in the desired location.

H. Proof of Concept: Demonstration by CONTRACTOR that means and methods utilized will accomplish the intended goals of the project, meet the quality control aspects of the project, and establish protocols for survey controls, communication of schedule, inspections, and documentation of the work. Proof of Concept for the CB Wall shall successfully demonstrate all aspects of the CB Wall construction, including the Working Pad, and CB Wall. The first 500-feet of the wall may be utilized for the Proof of Concept.

| Table 1: Cement - Bentonite Slurry Trench Quality Control Testing Plan |
|-----------------|-----------------|-----------------|-----------------|
| Property | Requirement | Minimum Test Frequency | Test Method | Comment |
| Bentonite Powder | By Manufacturer | 1 per shipment | API 13A | Wyoming type (90 bbl/ton) |
| a. Certification | 1 per shipment | | | |
| Cement Powder | By Manufacturer | 1 per shipment | ASTM C 150 | Portland Type I or I-II |
| a. Certification | 1 per shipment | | | |
| Water for Slurry Mixing | ASTM C 989 | | | |
| a. pH | 6 to 9 | 1 per week | Hach Kit | Site Source |
| b. Hardness | < 250 ppm | 1 per week | Hach Kit | |
| c. Alkalinity | < 250 ppm | 1 per week | Hach Kit | |
| d. Total Dissolved Solids | < 1500 ppm | 1 per source | Hach Kit | |
| e. Permeability | < 9 x 10^{-6} cm/sec | 1 set per 200 ft, per each sample depth interval | ASTM D5084 | Based on 28-days of curing. Each set consists of 8 samples (4 out of the 8 samples to be provided to the District for QA testing). |

< 9 x 10^{-6} cm/sec
DESIGN PROCESS

Federal Permits:
- USACE Section 404 - Impacts to wetlands
- USACE Section 408 - to alter the Central & Southern Florida (C&SF) Flood Control Project

State Permits:
- Modification of the Comprehensive Everglades Restoration Plan Regulation Act (CERPRA) under 373.1502 F.S.
- FDEP NPDES Construction Generic Permit (CGP)
- SFWMD Dewatering Permit

Local Permits (Miami-Dade County)
- Blasting Permit
- MOT for any temporary street closings
CONSTRUCTION - SUBMITTALS

- Parking & Office
- Batch Plant
- Fuel/Storage
- Equipment Staging
- Batch Plant
- Batch Plant
- Batch Plant
- Owner Trailer
CONSTRUCTION – STAGING AREAS
CONSTRUCTION – PROOF OF CONCEPT
CONSTRUCTION

BENTONITE

A sample of premium grade powdered bentonite was obtained from Cotco located in Lovell, WY. This bentonite complies with American Petroleum Institute 13A, Section 9 requirements.

CEMENT

The cement used for the laboratory design mix was a standard Portland Type I/II powdered cement provided by Lehigh Hanson.

3.0 SAMPLE PREPARATION

BENTONITE SLURRY MIXING

The bentonite slurry mixtures were made using Saint Petersburg, FL tap water, and the premium grade powdered bentonite. The bentonite slurry mixtures were prepared using a high-speed mixer until the bentonite and water were fully mixed. Tests conducted on bentonite slurry were viscosity and density.

MEASURING VISCOSITY AND DENSITY

The results of the bentonite slurry tests are as follows:

<table>
<thead>
<tr>
<th>Mix #</th>
<th>B/W Ratio</th>
<th>Marshall Pinned Viscosity</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>6.53 %</td>
<td>34.4 sec</td>
<td>65.0 pcf</td>
</tr>
<tr>
<td>3</td>
<td>5.99%</td>
<td>33.7 sec</td>
<td>65.0 pcf</td>
</tr>
<tr>
<td>4</td>
<td>6.49%</td>
<td>34.0 sec</td>
<td>65.0 pcf</td>
</tr>
</tbody>
</table>

CEMENT-BENTONITE SLURRY MIXING

The hydrated bentonite slurry was then used to make the CB slurry mixes. Cement was added and mixed with the high speed mixer until the mix was homogeneous.

MIXING AND TESTING CB SLURRY

The results of the CB slurry tests are as follows:

<table>
<thead>
<tr>
<th>Mix #</th>
<th>B/W Ratio</th>
<th>C/V Ratio</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>6.53%</td>
<td>20.01%</td>
<td>72.0 pcf</td>
</tr>
<tr>
<td>3</td>
<td>5.99%</td>
<td>18.00%</td>
<td>71.5 pcf</td>
</tr>
<tr>
<td>4</td>
<td>6.49%</td>
<td>22.04%</td>
<td>73.25 pcf</td>
</tr>
</tbody>
</table>

4.0 CURED CB SAMPLE RESULTS

The molded samples were capped and cured. For mixes #2, 3 & 4 UCS and permeability were tested at 14, 21, and 28 days. The results of the laboratory testing are as follows:

<table>
<thead>
<tr>
<th>Mix #</th>
<th>UCS [psf]</th>
<th>Permeability [cm/sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14 day</td>
<td>21 day</td>
</tr>
<tr>
<td>2</td>
<td>3.2</td>
<td>11.6</td>
</tr>
<tr>
<td>3</td>
<td>5.6</td>
<td>7.5</td>
</tr>
<tr>
<td>4</td>
<td>13.7</td>
<td>14.6</td>
</tr>
</tbody>
</table>

5.0 CONCLUSION/RECOMMENDATION

Based on the results of this program and our previous data from working in this area, a CB slurry mix with increased bentonite and cement will meet the requirements for the completed wall.

As indicated by the lab data, additional bentonite in the CB slurry will provide better permeability results, and more cement will provide higher strengths. It is our intention to begin the barrier wall installation in the field using mix #4 and adjust, based on lab results, to achieve the project objectives.
CONSTRUCTION - BLASTING

Loaded blast holes

LPG2
CONSTRUCTION - BLASTING
CONSTRUCTION - TRENCHING
CONSTRUCTION - TRENCHING

Trencher Capabilities:

- **Power Unit**
  - Capable of working on a 4 to 5.2 Hz cycle, with a maximum of 1.5 hours per cycle.
  - Engine: 1560 HP (1170 kW) Caterpillar 3512 C12 engine, 5000 rpm (3750 kW) at 2100 rpm.
  - Oil capacity: 90 liters (23.75 gallons).
  - Coolant capacity: 177 liters (47.5 gallons).

- **Trenching Capacity**
  - Depth: 3.5 feet (1.07 meters).

- **Drive and Steering**
  - Electric drive and hydraulic steering.

- **Ripper Feed**
  - Capable of handling up to 3000 kg (6600 pounds) per hour.

- **Ripper Blades**
  - Standard with adjustable blades for various trenching conditions.

- **Frame and Structure**
  - Steel frame with adjustable support legs.

- **Control System**
  - Fully adjustable for operator comfort.

R.J. Behar & Company, Inc.
Engineers, Planners, Constructors
CONSTRUCTION – CB PLANT

Batch Plant

Force line
CONSTRUCTION – CB WALL
CONSTRUCTION – CB WALL

Long reach excavator
CONSTRUCTION – SAMPLING

CB Wall sounding
CONSTRUCTION – WALL CAP

Cap Excavation

Cap backfill

Cap compaction
CONSTRUCTION – COMPLETED VIEW

Southern Segment

New levee
CONSTRUCTION – COMPLETED VIEW

Area completed

ENP Wet
CONSTRUCTION – COMPLETED VIEW
CONSTRUCTION – COMPLETED VIEW
CONSTRUCTION – COMPLETED VIEW

LPG2
CONSTRUCTION – LESSONS LEARNED
CONSTRUCTION – LESSONS LEARNED

Cracked levee

Grouted crack
CONSTRUCTION – LESSONS LEARNED

Verification boring, phenolphthalein reagent

Grouted crack - slag-cement-bentonite mix
Questions and Answers
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Questions?
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