DESIGN AND CONSTRUCTION OF A MSE BERM OVER VERY SOFT SOIL

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PROJECT OVERVIEW

• Delaware Solid Waste Authority – DSWA
  • Disposal of waste from the Wilmington, Delaware area in the near future
  • Feasibility → ~20 million cubic yards
  • Approximately 20 years of life
  • Due to site location, Horizontal Expansion was not an option
  • Vertical Expansion
PROJECT OVERVIEW

Previous river edge (1920)

Current Landfill Area (over former dredge disposal area)

Current USACE Disposal Area

DELAWARE RIVER

CHRISTINA RIVER

“new” waste

“old” waste
PROJECT OVERVIEW
GEOTECHNICAL EXPLORATION

- Field tests
  - CPT
  - SPT
  - Vane Shear tests

- Laboratory tests
  - Triaxial Test
  - Direct Simple Shear tests
  - Direct Shear
IDEALIZED STRATIGRAPHY

NOTE:
1. CPT profile labels are shortened from full name (i.e. C060 is P3-02-C060).
2. Data has been clipped to fit on the graph.
3. For offset of CPTs, see Figure 4-2.

FIGURE 4-X
IDEALIZED STRATIGRAPHY (CONTINUED)

Waste (40 to 100 ft thick)

Soft Dredge
K = 10^{-7} cm/s
(60 to 100 ft thick)

Natural Liner (Saturated)

Columbia Formation (Sand)

97 pcf
Su/σ'v = 0.29
φ = 34°

sand and gravel with silt
125 pcf
φ = 40° and no cohesion
ANALYSIS OF INITIAL SOLUTION

• Best option to obtain the required airspace with the available footprint
  • 60-ft high mechanically stabilized earth (MSE) berm

• Foundation improvement was required

• Deep soil mixing initially considered

• Advantage: Strong foundation (i.e., reduced settlements)

• Disadvantage: COST! ($170 million at the time of construction)
Initial Solution: Deep Soil Mixing to improve foundation
Target strength: 3,200 psf
Cost: $170 million for DSM only

Deep soil mixing
ALTERNATIVE SOLUTION

• Use the weight of the MSE berm to improve the foundation strength

• Build MSE berm using well known Stage Construction techniques

• Use prefabricated vertical drains (PVDs)
  – PVDs – Wick Drains
  – PVDs installed beneath the MSE Berm
  – Drains excess pore pressures from the soils
  – Accelerates the consolidation of the dredge/alluvium
  – Increases material strength

• Use High strength geotextile at the base of the berm

• So far so good……
PREFABRICATED VERTICAL DRAINS

- MSE Berm
- Dredge/Alluvium (saturated)
- Drainage Layer
- PVD (typ)
ALTERNATIVE SOLUTION (CONTINUED)

Mechanically Stabilized Earth (MSE) Berm (single and double tier)

Settlement compensation berm: (Unreinforced berm to compensate settlements)

Additional Disposal Volume Gained by MSE berm Construction

Existing Disposal Volume

Dredge disposal

Zone Where Strength Increase is Most Needed

Area with Wick Drains

Soft Soils

Sands

Existing Disposal Volume

Area with Wick Drains

Soft Soils

Sands

Zone Where Strength Increase is Most Needed

Dredge disposal

Existing Disposal Volume

Mechanically Stabilized Earth (MSE) Berm (single and double tier)

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Soft Soils

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Zone Where Strength Increase is Most Needed

Dredge disposal

Existing Disposal Volume

Mechanically Stabilized Earth (MSE) Berm (single and double tier)

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ARE PVDs FEASIBLE?

- Remember: a 60-ft high MSE berm is needed to obtain a ~20 mcy increase in airspace.

- PVDs are typically installed to accelerate consolidation (i.e., undrained).

- Is the undrained strength of the dredge/alluvium enough?

- Preliminary analysis indicated 3,200 psf.
Shear Strength

Undrained

\[ \frac{S_u}{\sigma_o} = 0.29 \]

Drained

\[ \frac{\tau}{\sigma_o} = \tan \phi = 0.67 \]
Shear Strength (with MSE berm)

- MSE berm applied load: 6,000 psf
- Undrained contribution:
  \[ 6,000 \times 0.29 = 1,740 \text{ psf} \]
- Drained contribution:
  \[ 6,000 \times 0.67 = 4,047 \text{ psf} \]
ARE PVDs FEASIBLE?

- Standard design procedures
  - Accelerate consolidation → increase shear strength
  - Use of PVDs is **not** a feasible solution

- If dredge/alluvium assumed undrained
  - Shorter MSE berm height → lower volume
HOW TO MAKE PVDs FEASIBLE

Hybrid Drained-Undrained (HDU) Model

- Paradigm shift
- Drained zone, near the PVDs
- Undrained zone farther from the PVDs
- “Drained radius” calculated based on rate of loading and site-specific soils
- Drained $\rightarrow \varphi = 34^\circ$
- Undrained $\rightarrow \frac{S_u}{\sigma'} = 0.29$
ASSESSMENT OF DRAINED CONDITIONS

• Virtual Sand Piles
  – Pore Pressure generation model for the expected loading conditions
    – MSE Berm Construction
    – Waste Placement
  – Consider both shear and compression
  – Used lab data to estimate pp parameters
  – Pore pressure dissipation model
  – Definition of virtual sand piles diameter
ASSESSMENT OF DRAINED CONDITIONS…

• For the expected MSE construction rates:
  – Analysis showed that 50% of the dredge/alluvium could be considered drained during berm construction
  – Used pilot test to verify dissipation model
MSE BERM DESIGN

- Short Term Conditions (FS>1.3)
- Dredge/alluvium with PVDs modeled as hybrid drained-undrained soil (i.e., 50% drained, 50% undrained)
- Calculate pore pressure
- Geometry and Reinforcement calculated using SLIDE
PREP SUBGRADE FOR PVD INSTALLATION

- Cut/Fill to prepare ground surface
- Crest of compensation berm
- PVD Area
BUILD BASE OF MSE BERM

- Install high strength geotextile (140-ft long) followed by a drainage layer

2-ft drainage layer

High strength geotextile (80,000 lb/lf)
STAGED CONSTRUCTION OF MSE BERM

- Build MSE berm in 10-ft high lifts
- Monitor geotechnical instruments
MONITORING DURING CONSTRUCTION

The graph shows the monitoring data over time for MSE construction (height) and various elevation sensors. The x-axis represents dates from 10/10/06 to 4/1/12, while the y-axis represents the elevation in feet above mean sea level (ft-msl). The graph includes lines for MSE construction (height), P3-PZ-17-1A [Elevation = 17 ft-msl], P3-PZ-17-1B [Elevation = -12 ft-msl], and Settlement Sensor (P3-SS-17-1).
FEM & MONITORING DURING CONSTRUCTION

[Graphs showing cumulative deflection along different directions with depth and deflection axes.]
MSE BERM CONSTRUCTION

Other topics of concern:

• Coordinating geotechnical review with construction

• Helping the contractor understand the implications of settlement on construction and measurements

• Stormwater control
  – MSE berm fill is very erodible

• Concrete pipe supply
MSE BERM CONSTRUCTION
PERMANENT STORMWATER

- Perimeter Drainage Channel
- Perimeter Access Road
- Concrete Outfall Culvert
- Concrete Drop Inlet
- MSE Wall Face
- Counterberm Face
- Headwall
- Mechanically Stabilized Earth Berm

Geosyntec consultants
MSE BERM CONSTRUCTION
CONCRETE PIPE INSTALLATION
MSE Berm Construction

Mirafi 20 XT geogrid

Mirafi Mesh facing

08/13/2007

08/13/2007
MSE Berm Construction
**CONCLUSIONS**

- Basics
- Subsurface Information
  - Key to project success
- Understanding of analytical tools strengths/shortcomings
- FEM model and Field Monitoring
  - Predictions allowed faster construction
  - Response guided decisions
- Communication
  - Client, contractor, engineer
- Engineering and Onsite CQA - $10 million
- Construction - $96 million
CONCLUSIONS

- $11 million foundation improvement