Geosynthetic Reinforcement in Landfill Design

Reinforcement applications include:

• ‘Conventional’ reinforced soil structures
• Reinforced steep veneers:
  – Reinforcements parallel to slope
  – Randomly distributed fibers
  – Horizontally placed reinforcements
'Conventional' Reinforced Soil Structures

Toe Buttress Wall
(OII Superfund site)

a) Downslope Outside
   OII Property Line
   Property Line
   Toe Buttress
   Waste
   Sedimentary Rock
   Concrete Pier

b) Property Line
   Toe Buttress
   Waste
   Sedimentary Rock
Numerical Simulation of Toe Buttress Wall

- Monitored 1996 Settlements
- Predicted Final Settlements
- Body Forces to Simulate Earthquake Loading
- Sandy Gravel Backfill
- Displacements Imposed to Induce Final Settlements
Reinforced Veneers

• Design alternatives for steep veneer slopes:
  – Unreinforced veneer
  – Uniaxial reinforcements along the slope
  – Fiber reinforcement
  – Uniaxial reinforcements placed horizontally

• Focus on infinite slope configuration

• Definition of Factor of Safety (FS):
Unreinforced Veneer

Unreinforced Veneer

\[ FS = \frac{Available \text{ soil shear strength}}{Soil \text{ shear stress required for equilibrium}} \]
General Slope Stabilization

Slope-parallel Reinforced Veneer

- Advantages:
  - Well established approach
  - Comparatively easy construction

- Disadvantages:
  - Requires anchorage at the top of the slope
  - Typically requires reinforcements of high tensile strength
  - Unsuitable for long, steep slopes

Source: Zornberg (2005)
Slope-parallel Reinforced Veneer

FS = \frac{\text{Available soil shear strength}}{\text{Soil shear stress required for equilibrium}}
Slope-parallel Reinforced Veneer

Courtesy: Flavio Montez, Huesker
Case History: McColl Superfund Site

Project overview:
- Twelve unlined sumps
- Acidic refinery waste
- Located in Fullerton, California
- Adjacent to residences, golf course
- Non-engineered earthen covers
- Steep topography
McColl Superfund Site: History

- Wastes Placed During WW II
- “Lower Ramparts” Flooded with Bentonite Drilling Mud in 1950’s
- Residential and Country Club Construction in Early to Mid-1970’s
- Tar Seeps, Odors Complaints
- Placed on NPL in 1982
McColl Superfund Site: Waste Characteristics

- Refinery Wastes
  - Very Low pH (sometimes less than 1.0)
  - Mobile (Tar) and Non-Mobile (Char)
  - Low Volatility, but $\text{H}_2\text{SO}_4$, $\text{SO}_2$, Thiophenes (Methyl Mercaptan) Present

- Drilling Mud
  - Diesel Oil - Based
  - Highly Compressible

Case History: McColl Superfund Site

A Problem: You and your next-chair colleague are retained by a group of PRPs to evaluate the final closure system for a Superfund site. The site includes 12 unlined pits filled with highly acidic waste sludge. The bearing capacity on top of the sumps is very low, and semi-liquid sludge has been observed to seep through the soil both laterally and vertically. The Superfund site is located in a densely populated area. The groundwater level is deep.

Seeking a Solution: As a geosynthetic specialist, your task is to conceive a conceptual closure system for the site. Take 10 min. to:

(1) make sure you understood the problem,
(2) identify the main design issues in this project,
(3) identify at least one conceptual closure system that deserves further evaluation, and
(4) list a series of advantages and disadvantages of the identified alternative
McColl Superfund Site: Design Issues

The final closure system should:
• Minimize infiltration of liquids into waste
• Minimize vertical and horizontal exfiltration of waste
• Provide adequate bearing capacity
• Remain stable under static and seismic conditions
• Provide gas control
• Provide adequate chemical compatibility

McColl Superfund Site: Conceptual Design

• Soil-Bentonite Vertical Barrier
• Lightweight Cap w/ Gas Collection Layer
  – Geocell Reinforcement on Lower Ramparts
  – Geogrid Reinforcement on Los Coyotes
  – Geomembrane/GCL Composite Barrier Layer
  – Mechanical Barrier in Golf Course Areas
• Reinforced Soil Walls for Slope Stabilization
RCRA Equivalent Cover:
Golf Course Cap

- Cushion Geotextile
- HDPE Geomembrane
- Geosynthetic Clay Liner
- HDPE Geomembrane Backing
- HDPE Gas Extraction Pipes
- Reinforcing HDPE Geogrid
- Vegetative Cover Soil
- Protection Layer
- Mechanical Barrier/ Drainage Layer
- Barrier Layer
- Gas Collection/ Foundation Sublayer
- Reinforced Foundation Sublayer
- Unreinforced Foundation Layer
- Sand
- Cobbles Filled With Sand
- Existing Cover
- Sand
- Reinforced Foundation Sublayer
- Unreinforced Foundation Layer
RCRA Equivalent Cover:
Open Space Cap

- RCRA Equivalent Cover:
  - Open Space Cap

Diagram:
- Geocomposite
- HDPE Geomembrane
- Geosynthetic Clay Liner
- HDPE Geomembrane Backing
- HDPE Gas Extraction Pipes
- Geotextile (for construction purposes only)
- Vegetative Cover Soil
- Protection Layer
- Drainage Layer
- Barrier Layer
- Gas Collection/Foundation Sublayer
- Reinforced Foundation Sublayer
- Unreinforced Foundation Layer

Existing Ground
- Sand
- HDPE Reinforcing Geocell Filled With Sand

Vegetative Cover Soil
- Protection Layer
- Drainage Layer
- Barrier Layer
- Gas Collection/Foundation Sublayer
- Reinforced Foundation Sublayer
- Unreinforced Foundation Layer
McColl Superfund Site: Compatibility Testing

- Develop “Contact Scenarios”
- Perform EPA 9090 Testing with “Waste Derived Liquid” and Tar
- Perform ASTM D 5084 Testing with “Waste Derived Liquid”
- Develop Special Intrusion Test for Tar

Geomembrane Exposure Tests
Reinforced Soil Retaining Wall

- Cap Cover Grade
- Drainage and Protection Layers
- Property Line
- Reinforced Slope
- Geocell
- Low-Permeability Soil Backfill
- Cutoff Wall
- Abandoned Soldier Pile
- Sump
- Barrier, Gas Extraction and Foundation Layers

Drainage and Protection Layers

Barrier, Gas Extraction and Foundation Layers

Abandoned Soldier Pile

Sump
McColl Superfund Site

- Design and Construction Completed in Two Years (October 1997)
- Cooperation Between PRPs and Agencies Set New Standard of Practice
- First Round of Golf in Summer 1998
- “De-Listing” has been completed

Los Coyotes Country Club Golf Course
Fullerton, California
SUPERFUND SUCCESS.
SUPERFAST

After years of indecision, unprecedented cooperation closed the McColl site in record time and set a new standard for Superfund site closure.

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On Aug. 31, 1996, with a ceremonial chipping shot into the green at the seventh hole, the McColl Superfund site was officially transferred from a National Priorities List (NPL) hazardous waste site into a valued community recreation facility and wildlife oasis.

The 30-month period from when the Environmental Protection Agency (EPA) issued the final groundwater barrier of thầnent (HOCs)—May 13, 1994—to when the treatment completed the closure commission set a new standard for EPA Region 9 which encompassed the western U.S. This final site closure, facilitated by unprecedented cooperation between regulatory agencies, community activist groups and the potentially responsible party (PRP), followed on the heels of 15 years of indecision.

The McColl site, located in Bakersfield, Calif., consisted of an 88-acre hazardous waste disposal site with 12 lined cell pits, or sumps, containing approximately 65,000 cu yd of semi-fines waste sludge generated in the production of high-purity aviation fuel. The waste sludge, disposed of during and just after World War II, is being acidic enough to pH less than 1.0 and, owing to the proximity of airborne compounds, emits a strong, objectionable odor.

During the 1980s and 1990s, in an attempt to control odors from the site, engineers considered covering the sumps in the area known as the Kern River site with diesel oil, instead of lining with peat from peat production. In the late 1990s, an owner of the adjacent land of the property in the area known as the Kern River site, thought that the Kern River golf course had