Design and Operation of Heap Leach Pads

By:

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Purpose of Presentation

- Summarize advancements made in the design and operation of heap leach pads:
  - Design and construction of leach pads and working with operations over the last 20 years
  - Working with difficult ore material types (saprolite, laterite, agglomerated ore, etc)
  - Construction and operational problems in harsh environments (high rainfall, freezing temperatures, heat, etc).
Subset of Topics Covered

- Leach Pad Configuration
- Liner System Design
- Ore Properties Testing
- Operational Considerations
Leach Pad Configuration
General Overview
Leach Pad Configuration

Considerations:
- Ore material properties (leaching characteristics, durability, etc.)
- Water balance
- Land availability and ground slope
- Project cost (capital and operating)

Pad Configuration Types:
- Dedicated, single use pad ("standard" leach pad)
- On/Off or Reusable Pad
- Valley Fill
- Hybrid
Single Use Pad

- Mine
- Prepare & Place on Pad
- Leach
- Leave in Place/Reclaim
  - or
  - Releach
- Place Additional Lift of Ore
Single Use Pad

- Suitable for variable ore types and leach cycle times.
- Typically large area for leach pad. Pad area based on ore production, leaching cycle time, ore “aging”, etc.
- Flat topography to maintain geotechnical stability.
- Large storm event pond.
- Low initial capital costs.
- Incremental pad expansion costs must be considered in project cost.
On/Off Pad

Reusable Pad Method

- Mine
- Prepare & Place on Pad
- Leach
- Wash/Neutralize Remove
- Dispose in Separate Waste Pile
On/Off Pad

- Suitable for ore with short leach cycles and consistent leaching characteristics.
- Areas with limited flat terrain.
- Requires a rinsed ore site/pad.
- Durable “high-stress” liner system.
- Practiced in wide range of climate conditions.
- Smaller storm pond.
- Costs: double handling of ore, rinsing system, rinsed ore storage.
Valley Fill Pad

- Mine
- Prepare & Place in Valley
- Leach
- Cover with New Ore
- Leach
- Leave in Place
Valley Fill Pad

- Best suited for hard, durable ore with good drainage. Can accommodate extended leach times.
- Used in steep terrain (slopes up to 40%).
- Internal solution storage reduces external pond requirements.
- Robust liner system (high hydraulic head and ore loads).
- Retaining structure for confinement of heap.
- High upfront capital cost.
Hybrid Pads

- Combination dedicated, single use pad with partial internal solution storage
- Single use pad combined with on/off pad
- Valley fill pad with a portion used as an on/off pad
- Side-hill leach pads
- Dump leach (no liner)
Liner System Design
Liner Design Advancements

- Experience with geosynthetics under high loads and harsh conditions
- Operation of heap leach pads with significant ore loads (+130 m)
- Construction and operation of very large leach pads (+ 1.5 billion tonnes and covering 10 km² across varying foundation materials)
- Solution collection pipe performance under high ore load
Liner Design Components

- Foundation materials
- Underliner soils
- Geomembrane liner
- Overliner materials (drainage and/or protection layers)
- Solution collection/air injection piping

Not normally considered liner design

Strong interaction between each component and the overall system.

Construction Quality Assurance program needed to achieve good liner performance
Typical Single Composite Liner

Overliner Layer:
- Drainage/protection layers
- Solution collection pipes
- Air injection pipes

Ore

Geomembrane

Underliner

Foundation
Typical Double Composite Liner

- Primary Geomembrane
- Secondary Geomembrane
- Underliner
- Foundation
- Leak Detection Layer
- Overliner Layer:
  - Drainage/protection layers
  - Solution collection pipes
  - Air injection pipes
- Ore
Foundation Design Considerations

- Heap stability
- Solution drainage/recovery
- Performance of geomembrane
- Performance of solution pipes
Underliner Design Considerations

- Seepage control
  - Environmental impact
  - Economic impact
- Interaction with geomembrane liner
- Prefer compacted native soil with a minimum saturated hydraulic conductivity of $1 \times 10^{-8}$ m/s (World Bank Standard)
- Admixtures maybe considered
- Geosynthetic Clay Liner (GCL) – limited
Underliner

40% slope
Geosynthetics preferred over other liner materials (asphalt, concrete, etc).

Typical: HDPE, LLDPE, and PVC (smooth and textured)

Overall seepage control (environmental & economic issues)

Foundation settlement

Puncture by ore load and trafficking

Heap stability (slippage along interface)
Geomembrane Liner Testing

- **Load Testing**: Compatibility of geomembrane liner with rest of liner system under anticipated ore loads
- **Interface Shear**: Shear strength of interface for heap stability analysis
Geomembrane Liner Puncture
Geomembrane Interface Shear

Overliner

Geomembrane

Underliner

Normal Stress

Shear Stress

Clay soil placed at 70 psf at 32% m.c.

INTERFACE FRICTION TEST RESULTS
ASTM D 5321

CLIENT: GOLDER ASSOCIATES, INC.
CLIENT PROJECT: JCB NO. 043-2189
PROJECT NO.: L05156-01

INTERFACE: SOIL LINER VS 80-MIL SMOOTH LLDE PE ON SCREENED OVERLINER
*The Soil Liner in points 2 and 3 were placed at 87 psf at 27% m.c.
Overliner Design Considerations

- Protect geomembrane (ore loads, mine equipment trafficking, etc)
- Medium for solution collection, air injection, etc
- Protect solution collection/air injection piping (ore loads, mine equipment trafficking, etc)
- Prefer native free-draining sand and gravels – durable materials.
- Hydraulic properties of overliner govern solution collection pipe design.
Overliner Placement

Note: Overliner placed directly over geomembrane and pipes
Ore Properties Testing
Material Test Types

- Geomechanical properties
  - Heap stability
  - Ore compression
  - Settlement
  - Ore durability
- Hydraulic properties
  - Percolation
  - Flow versus ore load
  - Draindown moisture content (water balance and inventory)
- Metallurgical testing (not covered)
Typical Geomechanical Tests

Tests simulate varying stress conditions within heap

- Circular Failure
- Block Failure
- Unconfined Compression
- Triaxial Compression
- Direct Shear

Ore
Typical Hydraulic Tests

- **Column Tests:**
  - Recovery
  - Percolation rates
  - Leaching parameters (time, concentration, etc)
  - Moisture contents (drain down, leaching)

- **Load-Percolation:**
  - Sustainable percolation (unsaturated flow) under load
  - Compression of ore (settlement and density)

- **Load-Permeability:**
  - Saturated hydraulic conductivity under load
  - Ore degradation
  - Overliner characteristics
Hydraulic Testing

Tests simulate varying hydraulic conditions within heap
Operational Considerations
Operational Issues

- Ore stacking and scheduling
- Leach scheduling
- Chemistry control
- Water balance
- Cold or hot climate operation
- Wet or dry climate operation
- Difficult ore types:
  - Low permeability
  - Slow leaching
  - Acid consuming/generating
Select Operational Issues

- **Wet Climates**
  - Positive water balance requiring storage and treatment of excess process solution.
  - Dilution of solution grade.
  - Ore heap instability due to high saturation and erosion

- **Low Permeability Ore**
  - Heap instability due to high saturation
  - Poor or delayed recovery
  - High inventory (lock-up in pore spaces)
Wet Climates
Operational Issues

Solution management/heap stability problem:

- Increase solution and storm pond sizes
  - Capital cost and land constraints
- Pump excess solutions onto the heap ("sponge" effect)
  - Does not reduce excess solution volume
- Rain Skirts / Covers
  - Capital cost
  - Operationally intensive during rainy season
- Excess solution treatment/discharge
Rain Skirts
Rain Skirts
Low Permeability Ore
Operational Issues

Heap stability & recovery problem:

- Ore agglomeration
  - Controlling agglomeration process to provide consistent product (moisture important)
- Maintain low heap height to preserve ore permeability
  - Capital cost and land constraints
- Blending with more durable ore
  - Logistics of blending and control
- Interlift liner systems
  - Capital cost
  - Operationally intensive
THANK YOU FOR YOUR TIME