Liner system design for tailings impoundments and heap leach pads

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TAILINGS & MINE WASTE 08, VAIL

Liner Systems

- Liner systems
  - Environmental containment of process solutions
  - Enhances solution recovery and management
- Heap leach pads
  - Dedicated lined pads w/ external solution ponds
  - Valley leach facilities w/ internal solution storage
  - On/off pads w/ active cells and external solution ponds
  - Hybrid pads (internal and external solution storage)
- Tailings impoundments
  - Internal solution collection
  - Enhanced consolidation
  - Solution management

Modern Liner System Design

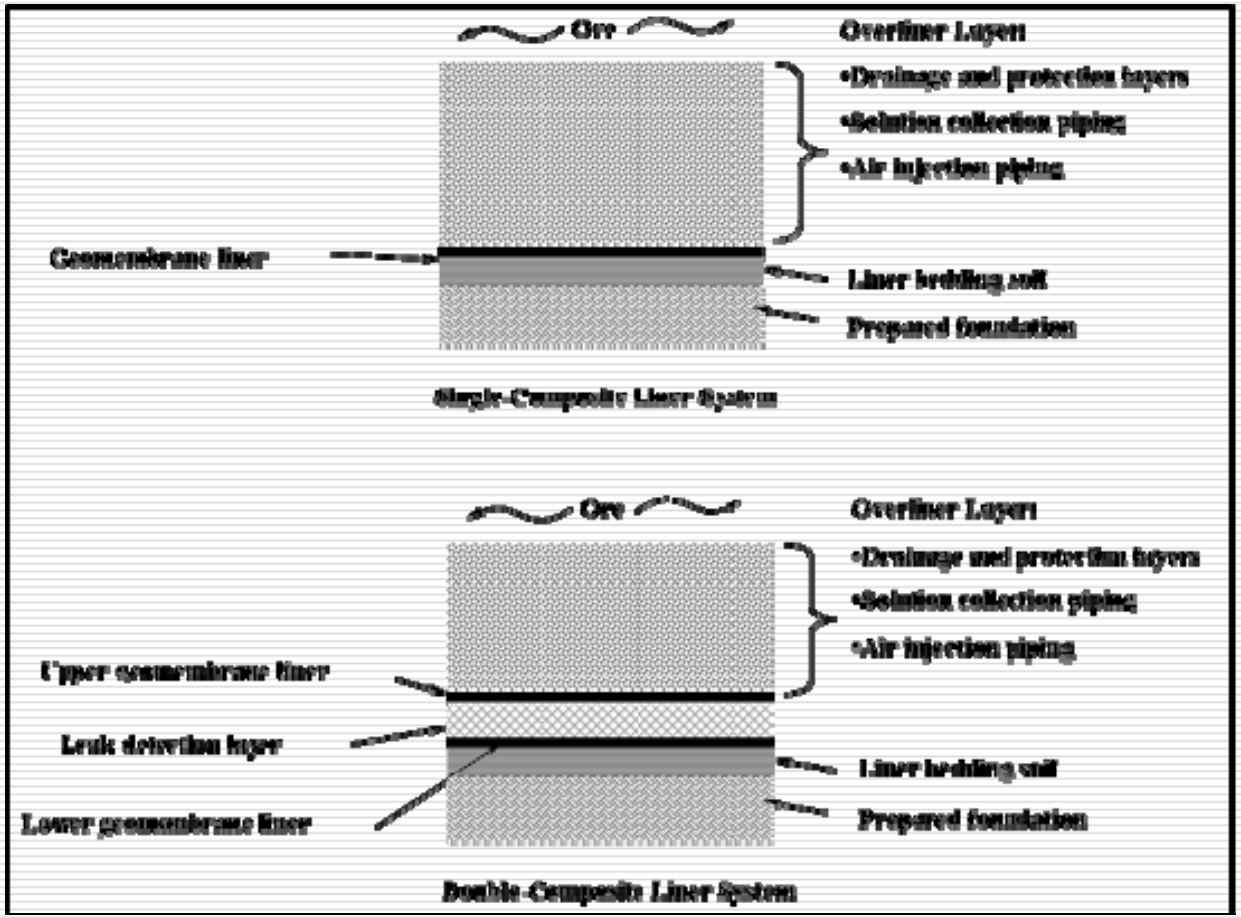
- Blend of natural and synthetic components.
- Integration of geosynthetics
- Designed to achieve desired level of performance under anticipated loads.
- Experience has shown there is close interaction between the various components of the liner system.
- Liner system design approach should focus on the interaction and compatibility between components.

Liner System Design Considerations

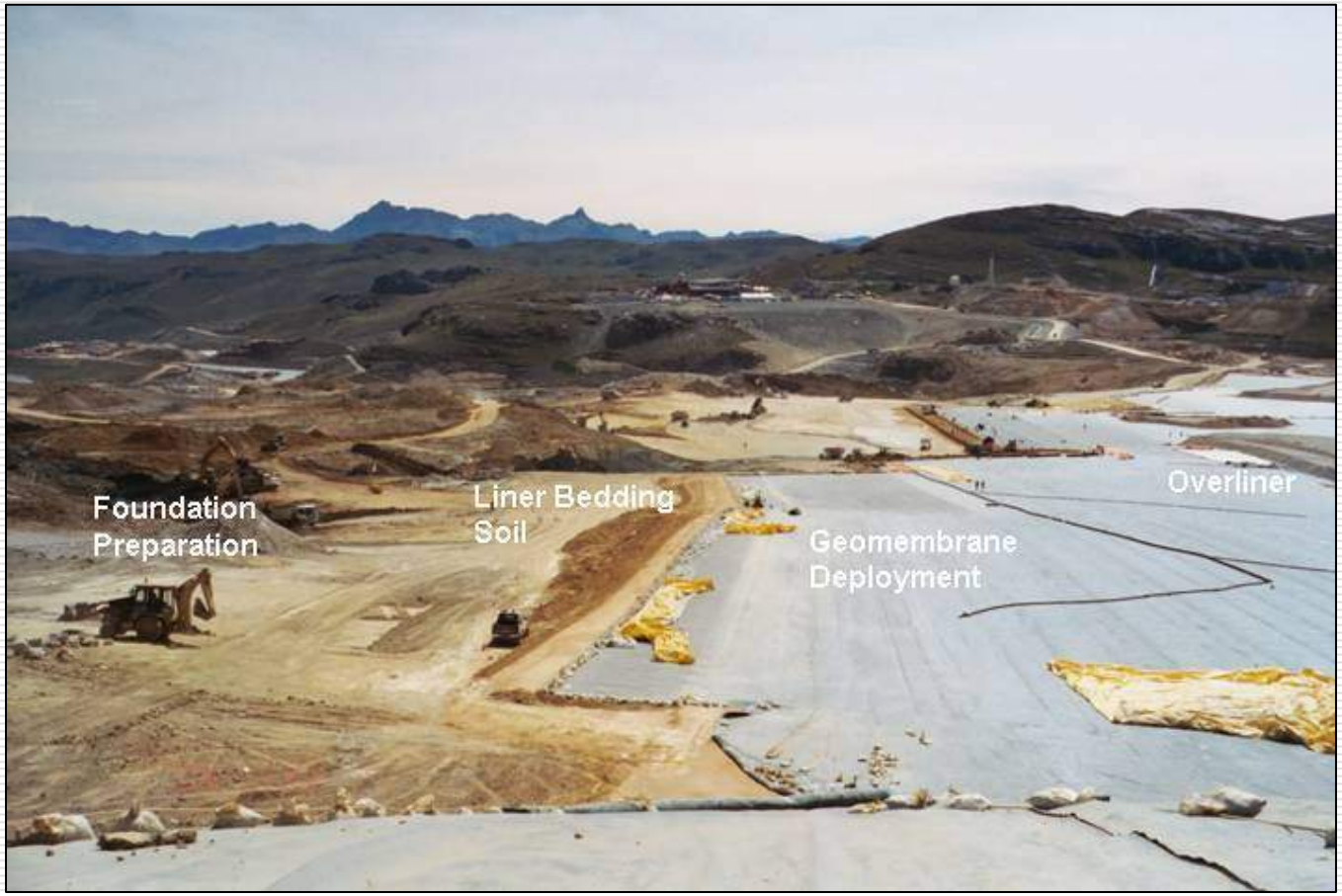
- Lining systems in mining environment exposed to harsh conditions:
  - High loads (HLPs designed to exceed 4 MPa)
  - Solar radiation
  - Steep grades
  - High seismic loads
  - Ore truck traffic
  - Ore processing solutions

HLP Liner System Design

Typical Liner System Components



Liner System Components



Liner System Components

- Foundation
- Liner bedding
- Geomembrane liner
  - HDPE, LLDPE, PVC, etc
- Overliner
  - Protection layer
  - Drainage layer
  - Solution collection pipes
  - Air injection pipes

HLP Inter-Dependent Design

- Environmental containment
- Solution collection
- Heap stability

Environmental Containment

- Liner bedding
  - Hydraulic properties
  - Compaction characteristics
  - Physical characteristics
- Foundation
  - Settlement affecting GM performance
- Geomembrane
  - Mechanical properties
- Overliner
  - Physical characteristics

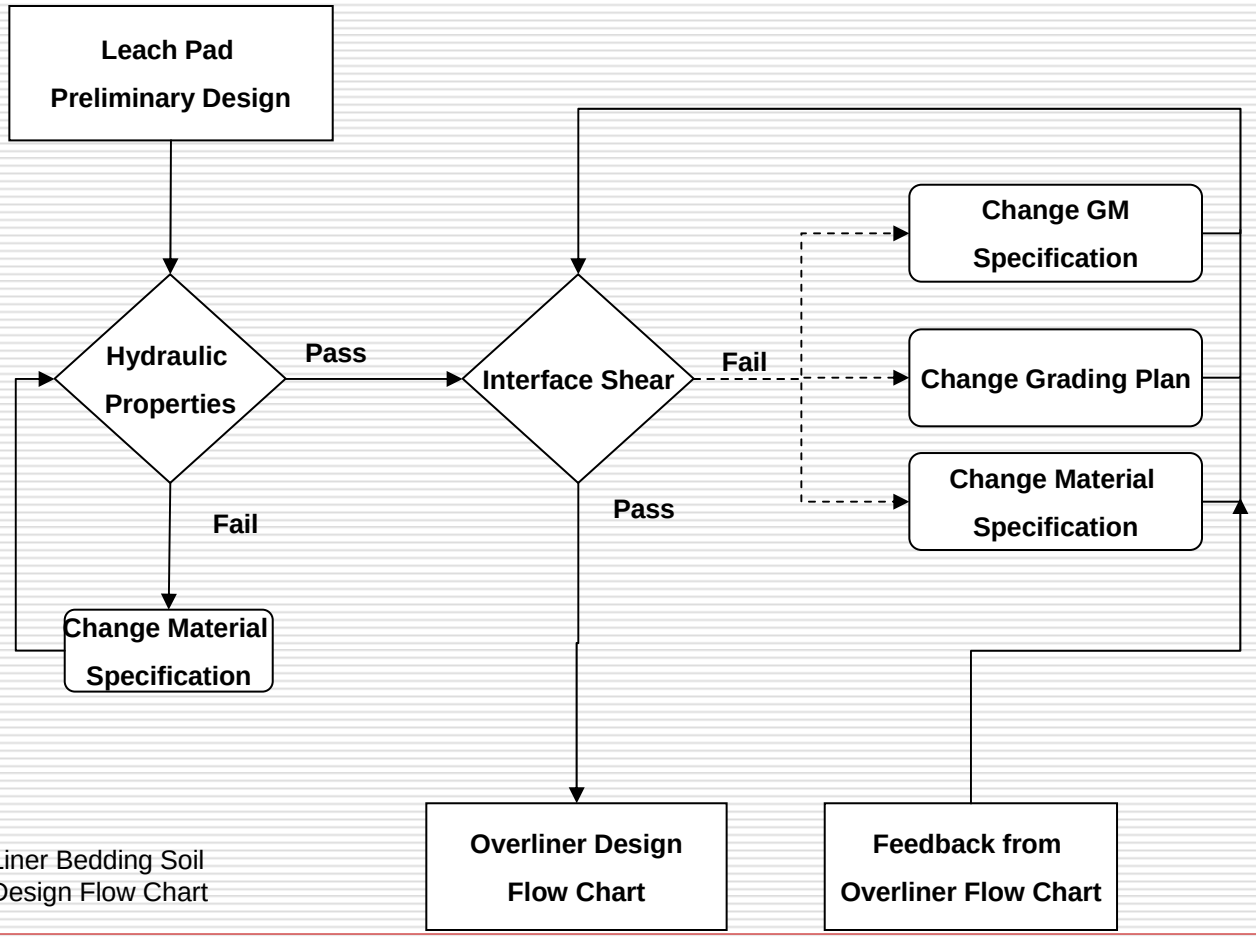
Solution Collection

- Overliner
  - Hydraulic properties (solution flow)
  - Mechanical characteristics under load (solution flow and pipe support)
  - Geochemistry (reaction with leach solutions)
  - Physical characteristics
- Solution Pipes
  - Mechanical properties under load
  - Interaction with drainage materials
- Pad grading
  - Sloped for solution collection and heap stability

Heap Stability

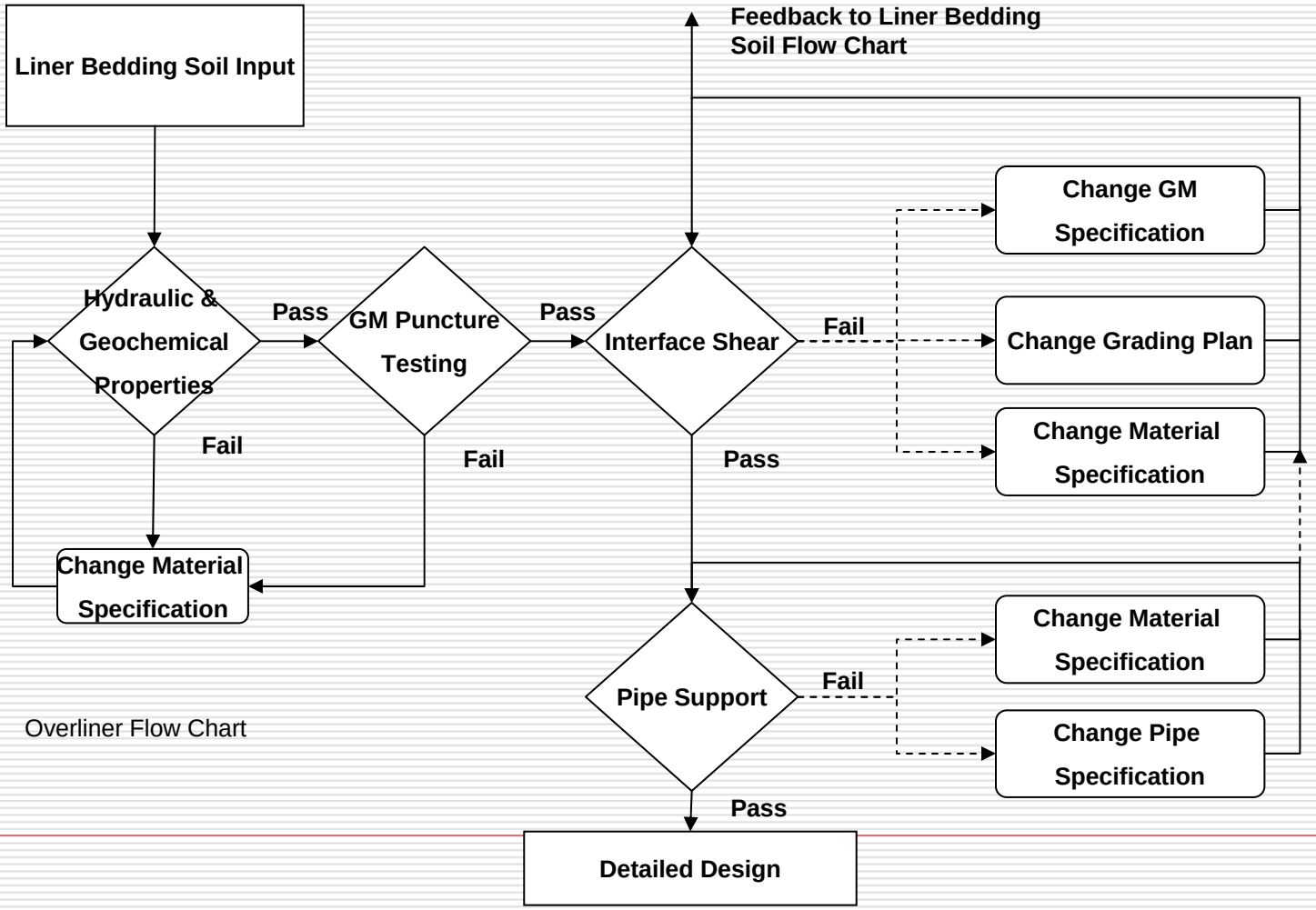
- Liner bedding
  - Residual interface friction between liner and bedding
  - Internal shear strength
- Overliner
  - Residual interface friction between liner and overliner
  - Internal shear strength
- Ore loading
- Pad grading
- Internal solution levels

Design Flow Chart – Liner Bedding



Liner Bedding Soil
Design Flow Chart

Design Flow Chart – Overliner

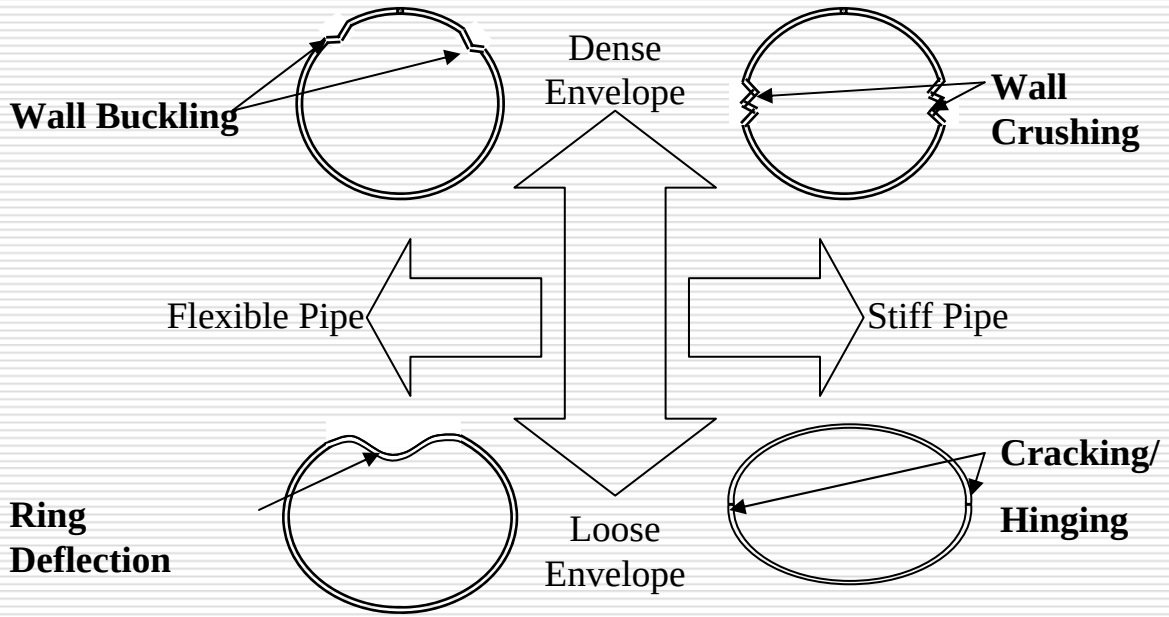


Overliner Flow Chart

Solution Collection Pipes

- Traditionally, design equations based on the performance of “stiff” pipe (e.g. pipe materials have a high stiffness compared to surrounding materials)
- Geopipes are generally less stiff than surrounding materials, therefore traditional equations not really applicable
- Pipe design methods need to consider pipe flexibility and interaction between pipe and surrounding materials

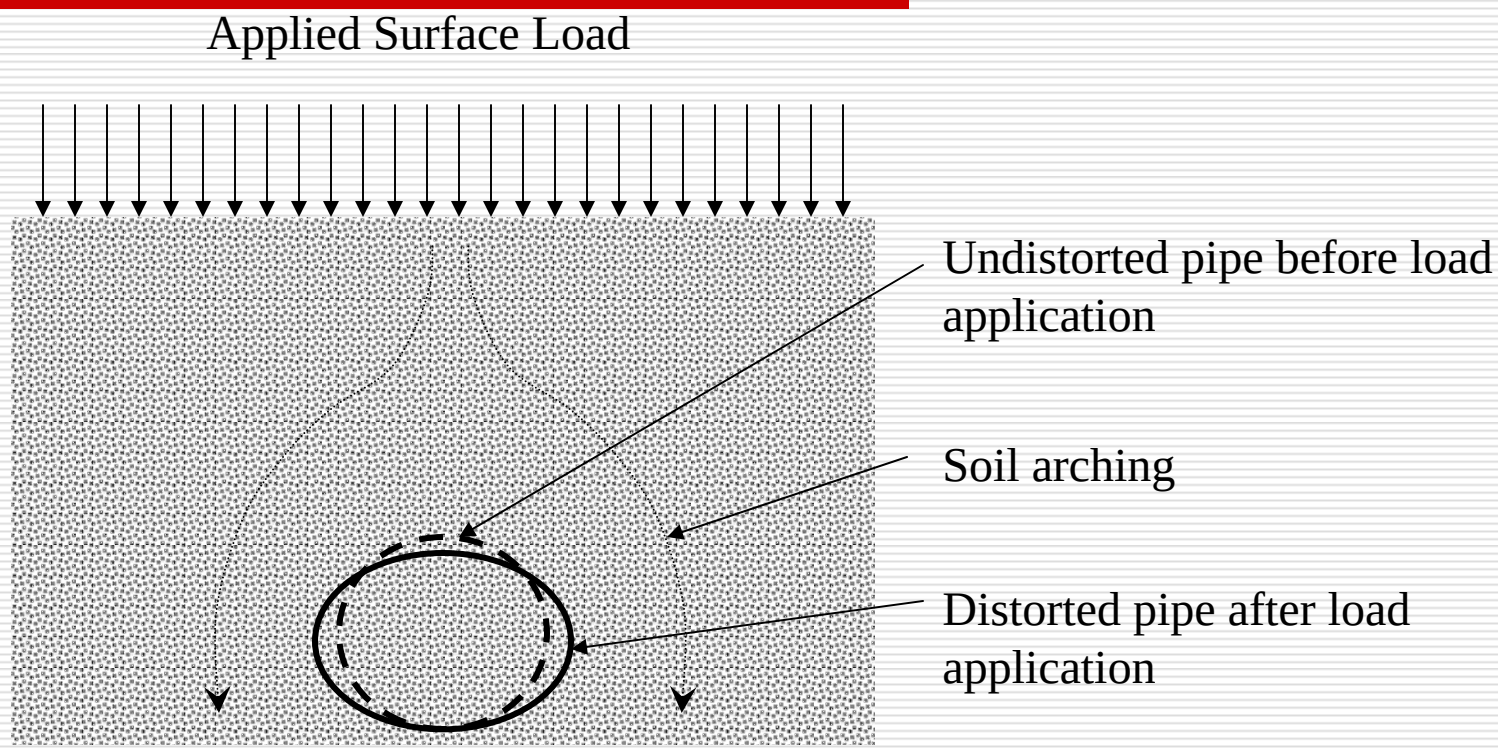
Pipe Deformation



After Watkins and Reeve, 1979

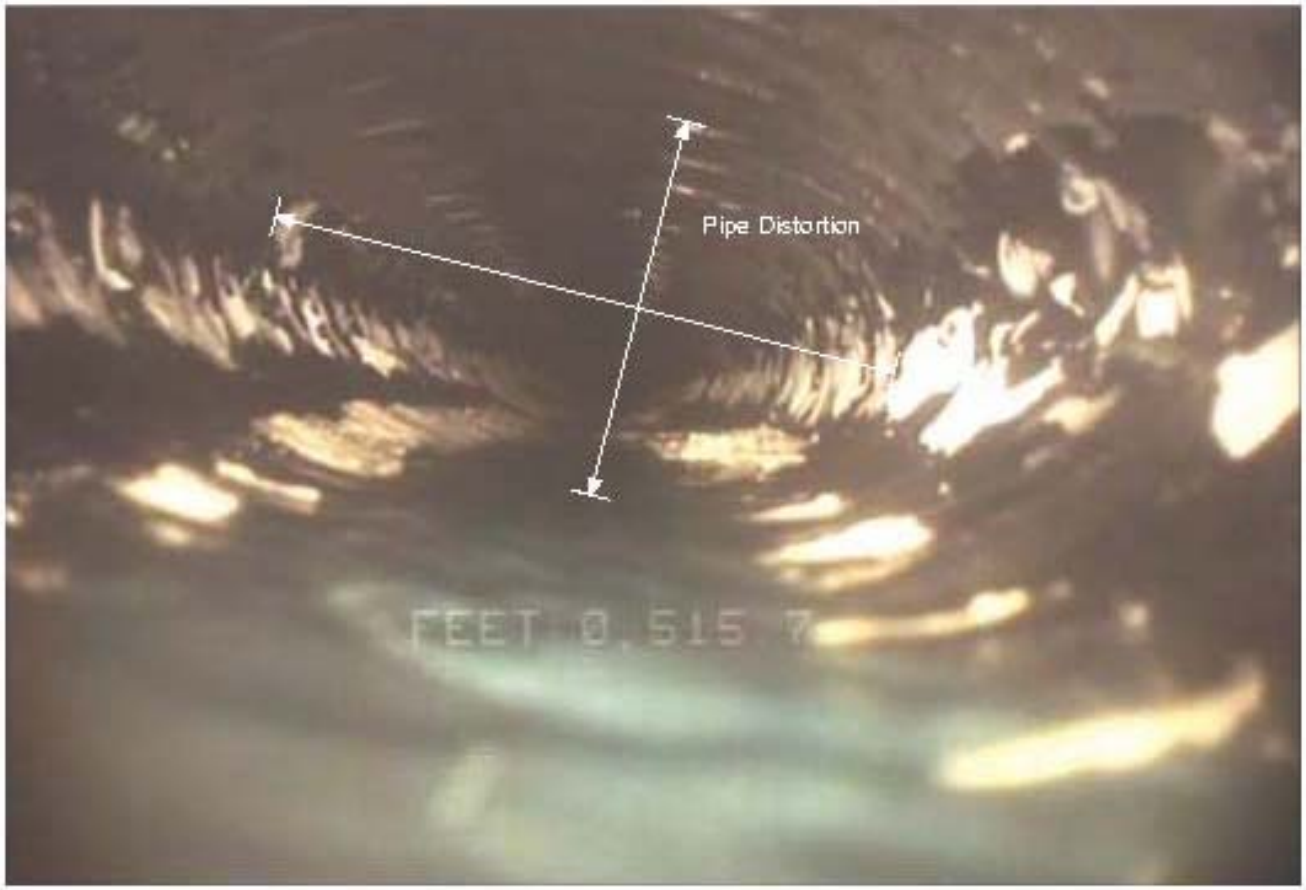
Note: Pipe deformation is a function of both pipe stiffness and envelope quality.

Soil Arching

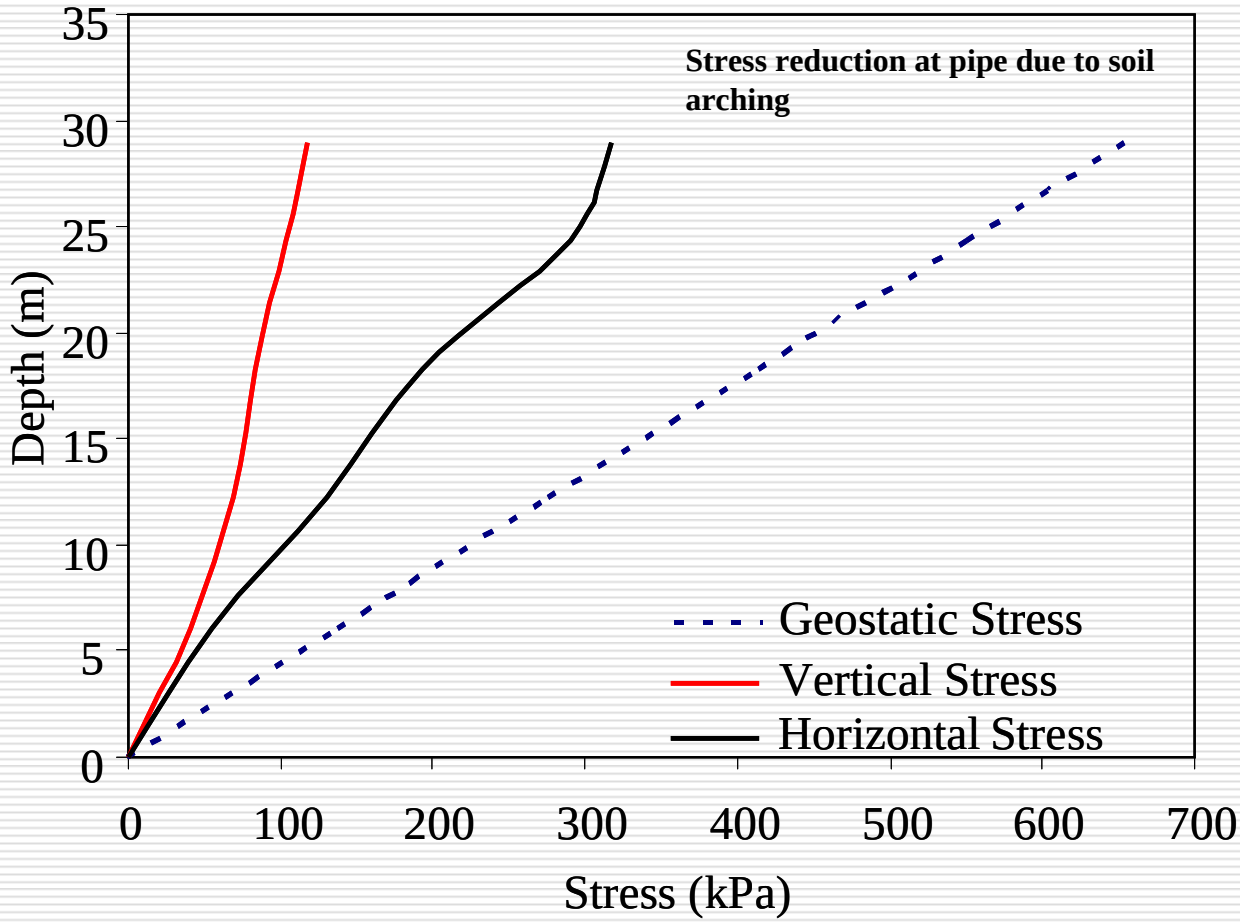


Soil arching reduces stress transfer onto the pipe. The magnitude of the arching affect is a function of the pipe stiffness and pipe envelope properties

Pipe Response



Soil Arching – Stress Reduction



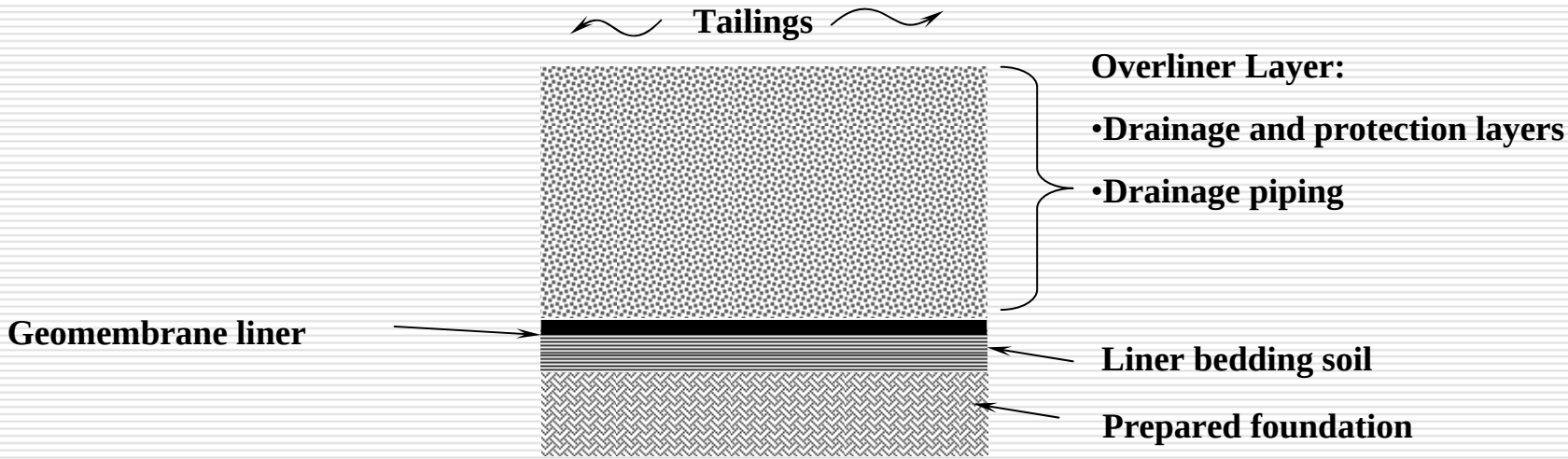
(after Adams *et al.* 1988)

Pipe Design

- Use design methods for flexible conduits [Burns and Richards (1964) and Höeg (1968)]
- Important: Test the one-dimensional compression (stress vs strain) of the drainage material.
  - Governs the stress transfer to the pipe.
- Consider both Corrugated and Solid PE pipe to meet desired performance
- Thickness of drainage layer does affect pipe performance under load

TSF Liner System Design

Typical Liner System Components



Single-Composite Liner System

Liner System Components

- Foundation
- Liner bedding
- Geomembrane liner
  - HDPE, LLDPE, PVC, etc
- Overliner
  - Protection layer
  - Drainage layer
  - Drainage pipes

Important Design Considerations

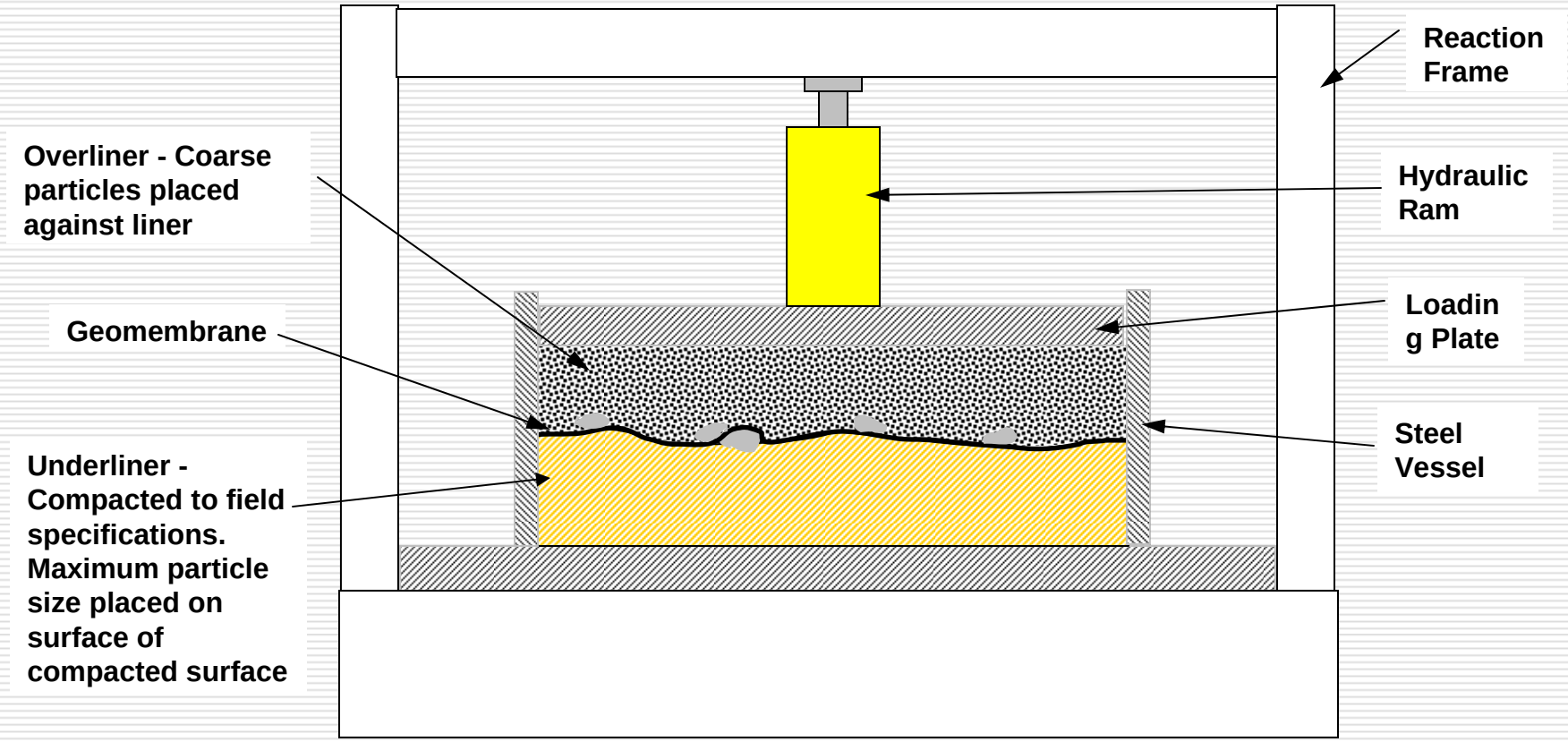
- Strain on GM from loading due to foundation settlement
- Compatibility of liner bedding material with process solution chemistry
- Long-term exposure of GM to solar
- Maximum hydraulic head on liner system
- Leak detection/collection requirements
- Tailings delivery
  - Discharge onto GM may cause damage to liner

GM Selection

GM Performance

- Based on experience
- Rough correlation to liner-load test

Liner-Load Testing



GM Liner Selection Chart

Foundation	Liner Bedding	Overliner	Effective normal stress (MPa)§		
			<0.5	0.5< <1.2	>1.2
Firm or high stiffness	Coarse-grained	Coarse-grained	2mm LLDPE or HDPE	2mm LLDPE or HDPE	2.5mm LLDPE or HDPE
		Fine-grained	1.5mm LLDPE or HDPE	2mm LLDPE or HDPE	2.5mm LLDPE or HDPE
	Fine-grained	Coarse-grained	1.5mm LLDPE or HDPE	1.5mm LLDPE or HDPE	2mm LLDPE or HDPE
		Fine-grained	1mm LLDPE or HDPE	1.5mm LLDPE or HDPE	2mm LLDPE or HDPE
Soft or low stiffness	Coarse-grained	Coarse-grained	2mm LLDPE	2mm LLDPE	2.5mm LLDPE
		Fine-grained	1.5mm LLDPE	2mm LLDPE	2.5mm LLDPE
	Fine-grained	Coarse-grained	2mm LLDPE	2mm LLDPE	2.5mm LLDPE
		Fine-grained	1.5mm LLDPE	2mm LLDPE	2.5mm LLDPE

Conclusions 1/2

- Compatibility between the liner system components important for robust design
  - Performance of one component can affect the performance of other components
- Liner system testing and analysis needs to consider <u>all</u> components under the anticipated loading conditions.
  - Static & dynamic loads
  - Geochemistry of solutions
  - Environmental factors

Conclusions 2/2

- Pipe design must use flexible conduit approach.
- Design of drainage materials (particle size, compressibility, and thickness) does affect pipe performance.
- Foundation settlements affect both geomembrane liner and solution pipe performance.
- With proper design, liner systems can perform under very high loads and harsh conditions.

Questions