Design of Geofoam Embankment for the I-15 Reconstruction

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I-15 Reconstruction - Quick Facts

- Single Largest Highway Contract in U.S.
- 17 Miles of Urban Interstate
- $1.5 Billion Design-Build
- 4 Year Construction Duration (Summer 2001)
- 144 Bridges/Overpass Structures
- 160 Retaining Walls (mostly MSE Walls)
- 3.8 Million m^3 of Embankment Fill
- 100,000 m^3 Geofoam Embankment

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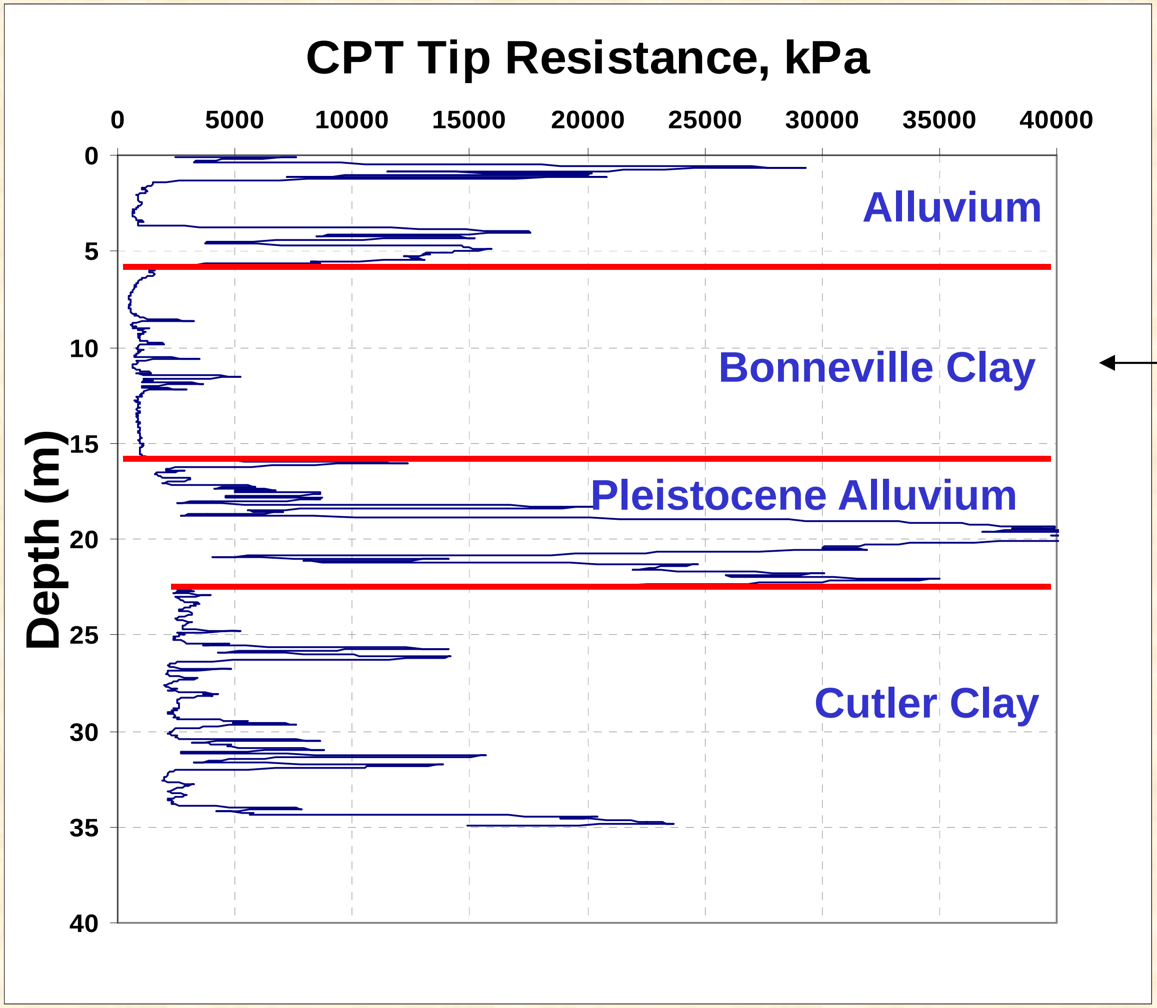
Primary Uses of Geofoam on the I-15 Project

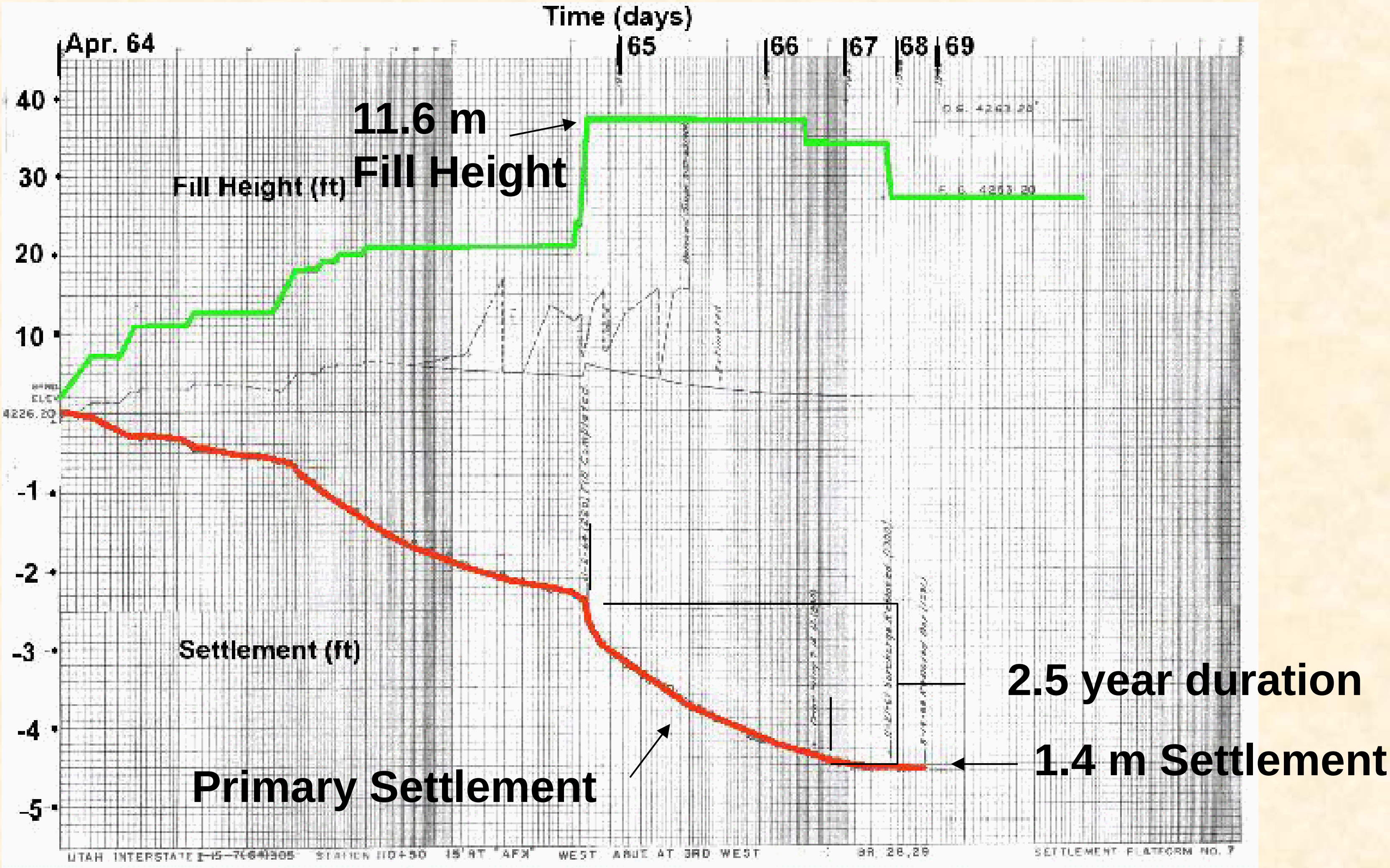
- Reduce Settlement to Protect Buried Utilities
- Improve Slope Stability of Embankments
- Rapid Construction in Time Critical Areas

Settlement Reduction (continued) Subsurface Profile in Salt Lake Valley

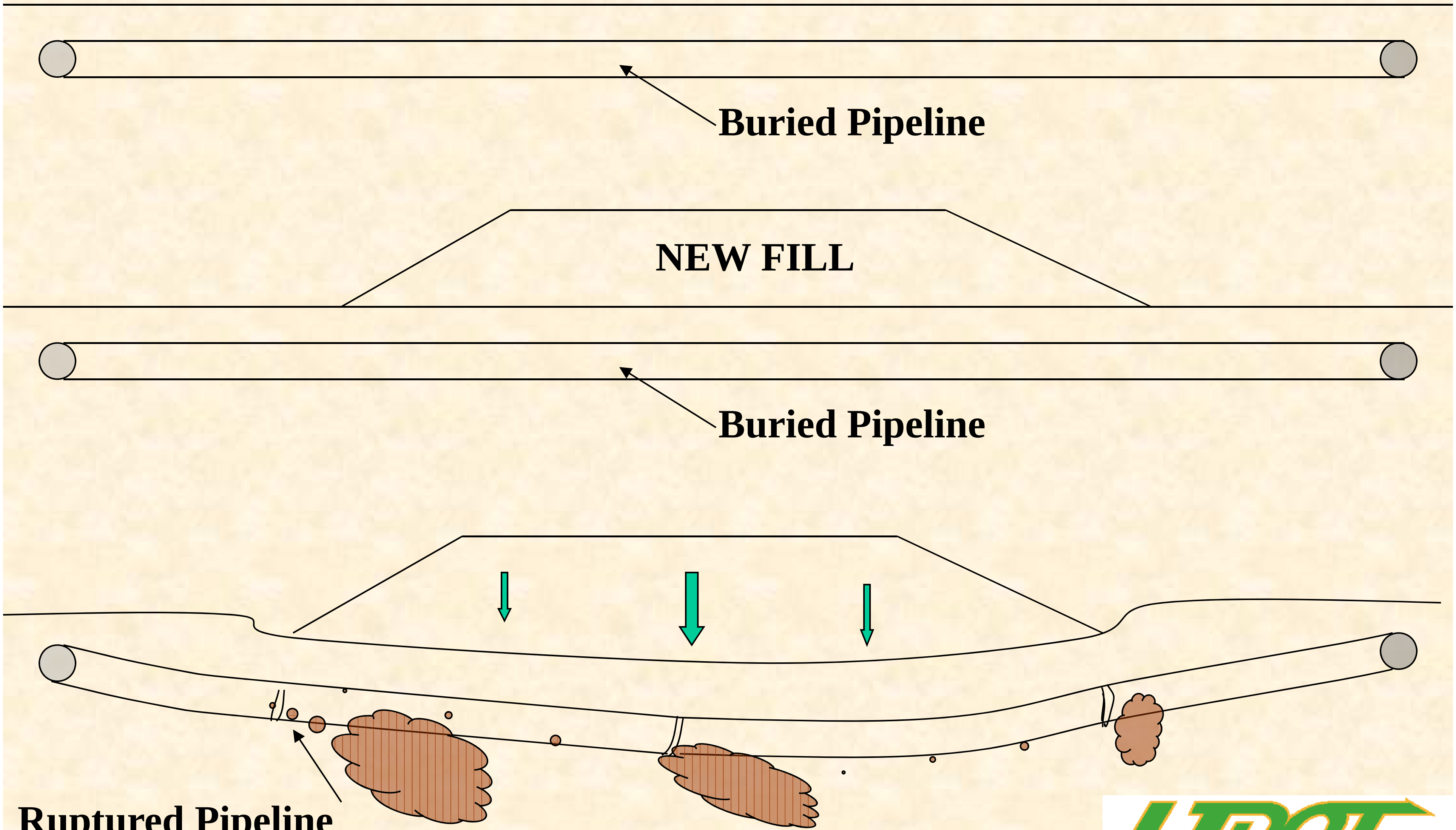


Soft Clay (10-m thick)

Settlement Reduction (continued)
Settlement on I-15, Salt Lake City (1964 - 1968)



Settlement Reduction (continued)
Buried Utilities



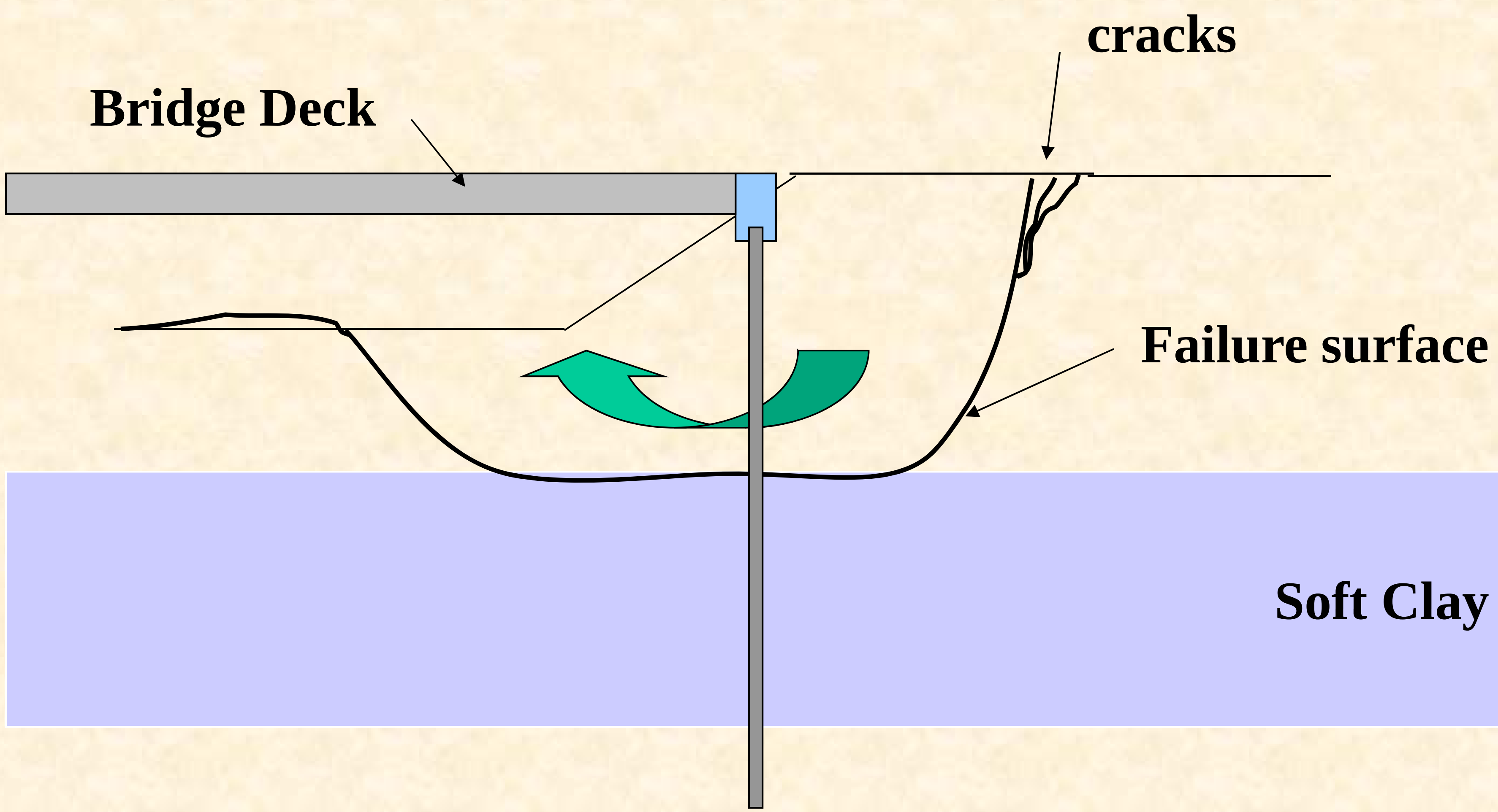
Settlement Reduction (continued)
Buried Utilities along Roadway

Buried Utilities

Geofoam Embankment from State St. to 200 W. Along Interstate I-80, Salt Lake City, Utah

Improve Slope Stability (continued)

Diagram of Potential Instability at Bridges

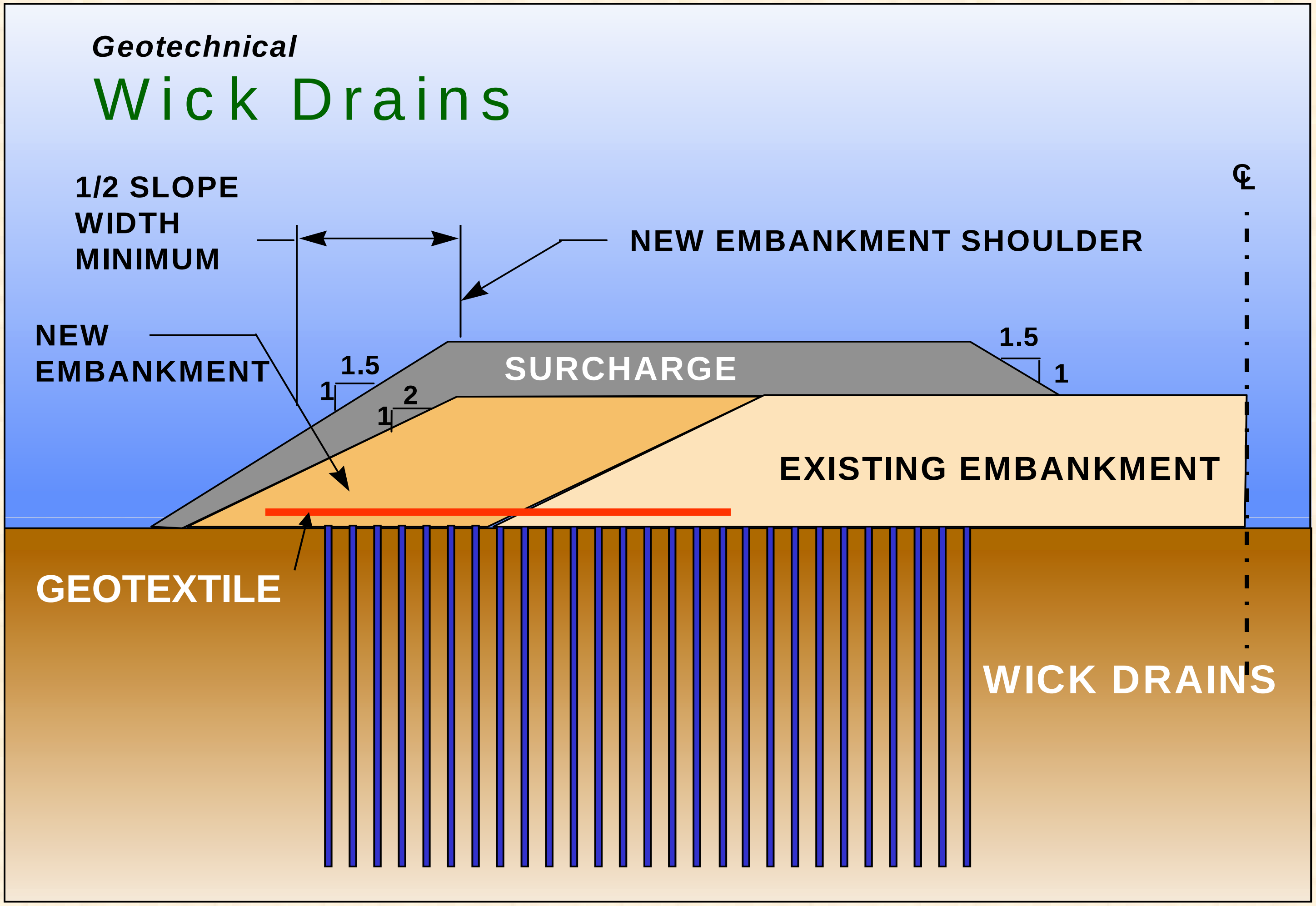


Improve Slope Stability

Details of Geofoam Construction at Bridge Abutments

Rapid Construction

(Typical Embankment Construction for I-15)



Rapid Construction

(Typical Embankment Construction for I-15)

Wick Drain Installation (4 weeks)

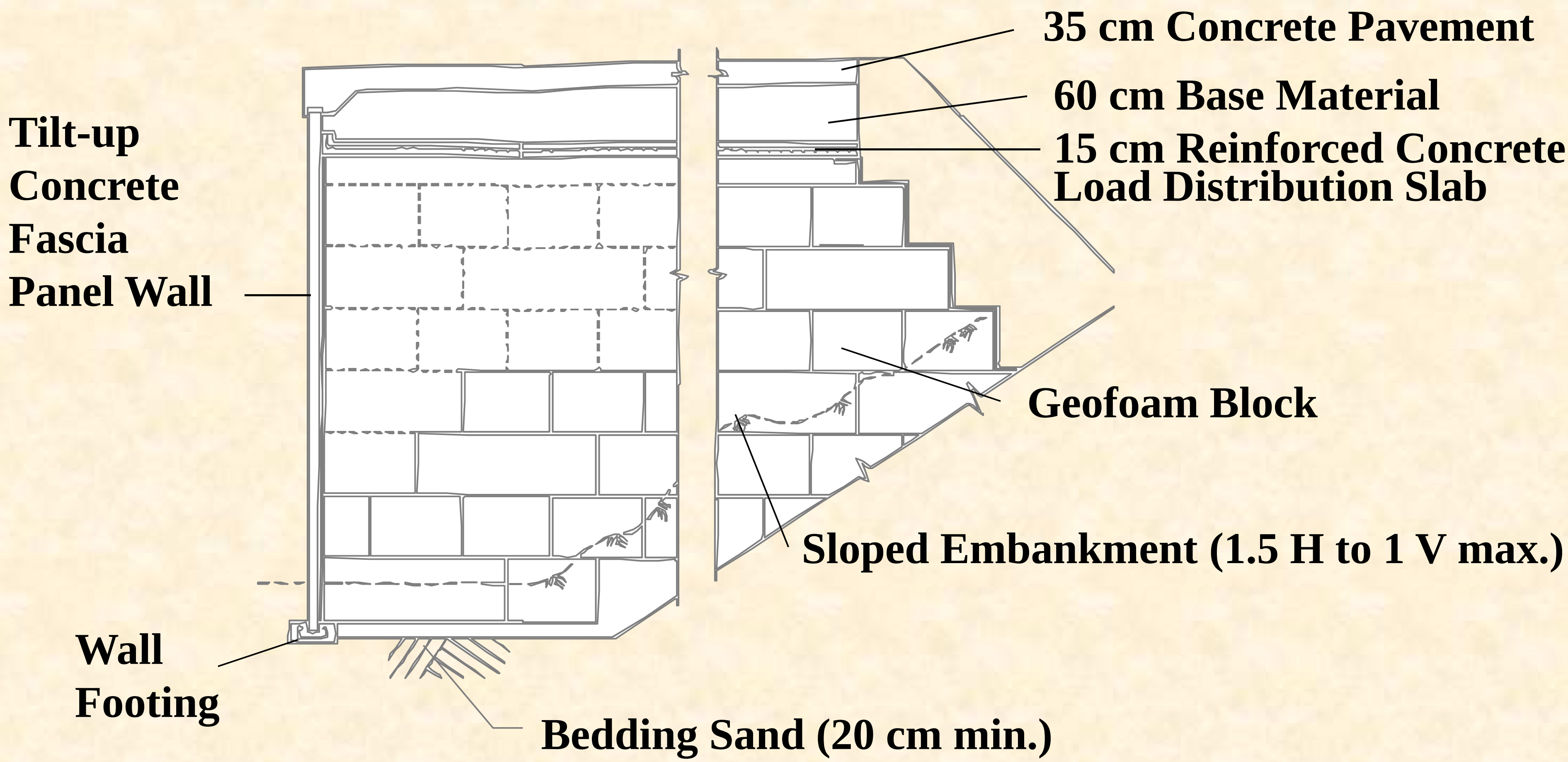
Grading and Geotextile (4 weeks)

Wall Construction + Settlement Time (6 weeks + 24 weeks)

Concrete Panel Placement (2 weeks)

Rapid Construction

(Typical Geofoam Construction for I-15)

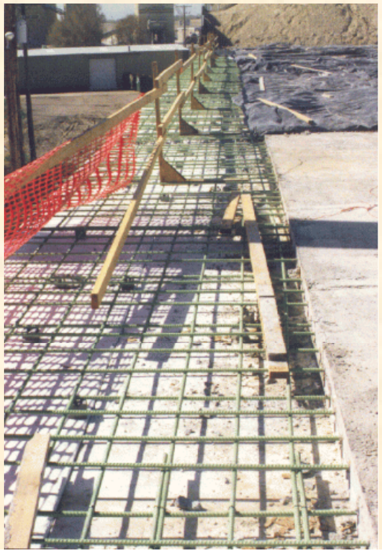


Rapid Construction

(Typical Geofoam Construction for I-15)

Grade Preparation (1 week)

Block Placement (3 weeks)

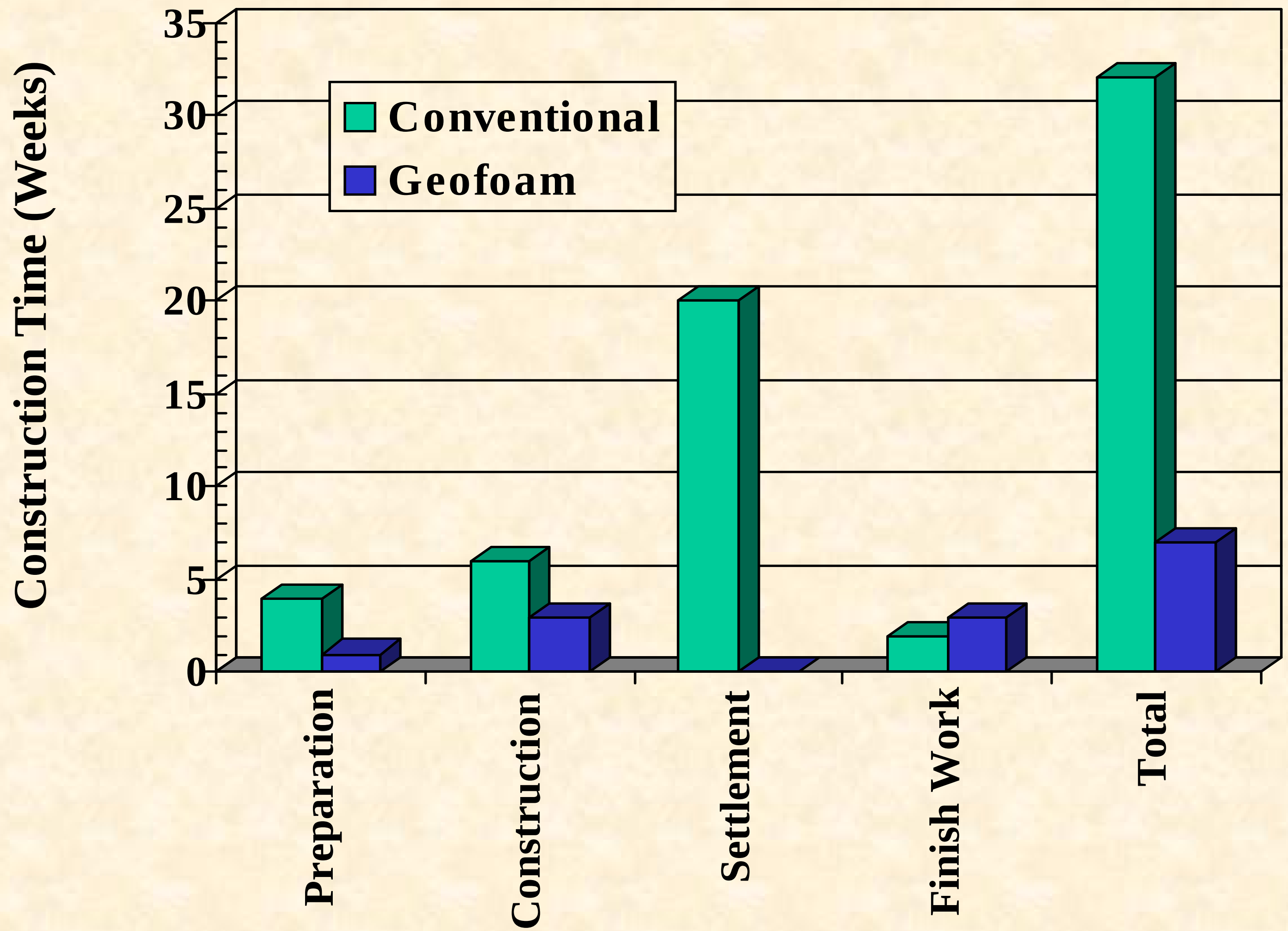


Load Distribution Slab Construction (2 weeks)

Panel Wall Construction (1 Week)

Rapid Construction

(Comparison of Construction Time)



Design Considerations

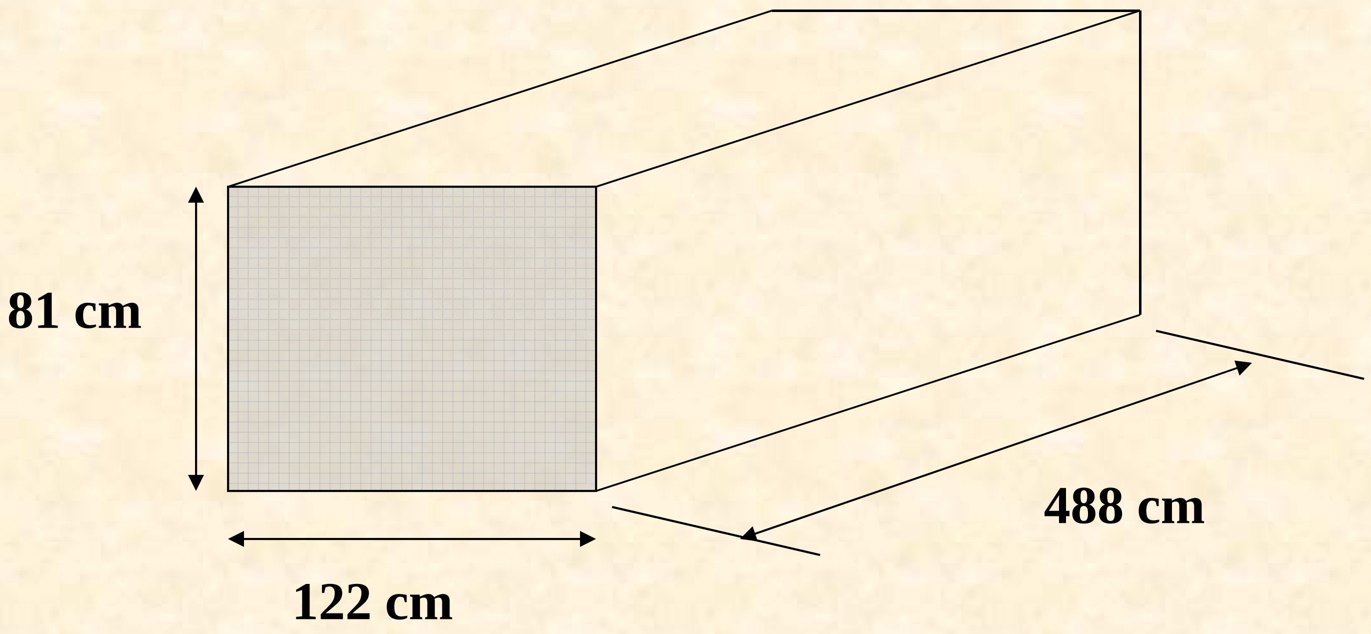
- Material Type
- Dimensions
- Density
- Compressive Strength
- Allowable Load & Creep
- Interface Friction
- Stability of Internal Slope
- Bedding Material & Compaction
- Concentrated Loads
- Moisture Absorption
- Buoyancy
- Thermal Resistance
- Differential Icing
- Chemical Attack
- Flammability
- Insect Infestation
- Ultra Violet Degradation
- Durability

Design Considerations (Material Type)

- Expanded Polystrene (EPS)*
  - virgin feedstock
  - maximum of 5 percent regrind content

* Extruded Polystrene (XPS) is also available, but was not used on the I-15 project

Design Considerations (EPS Block Dimensions)



Dimension tolerance 0.5 percent

- **If tolerance is met, no trimming is necessary**
- **If tolerance is not met, shop trimming is necessary**

Design Considerations (EPS Density)

Property	ASTM Test C 578	Type XI	Type I	Type VIII*	Type II	Type IX
Nominal Density (kg/m^3)	C303 / D 1622	12	16	20	24	32
Minimum Density (kg/m^3)	C303 / D 1622	11	15	18	22	29

* Type VIII was used for I-15 Reconstruction

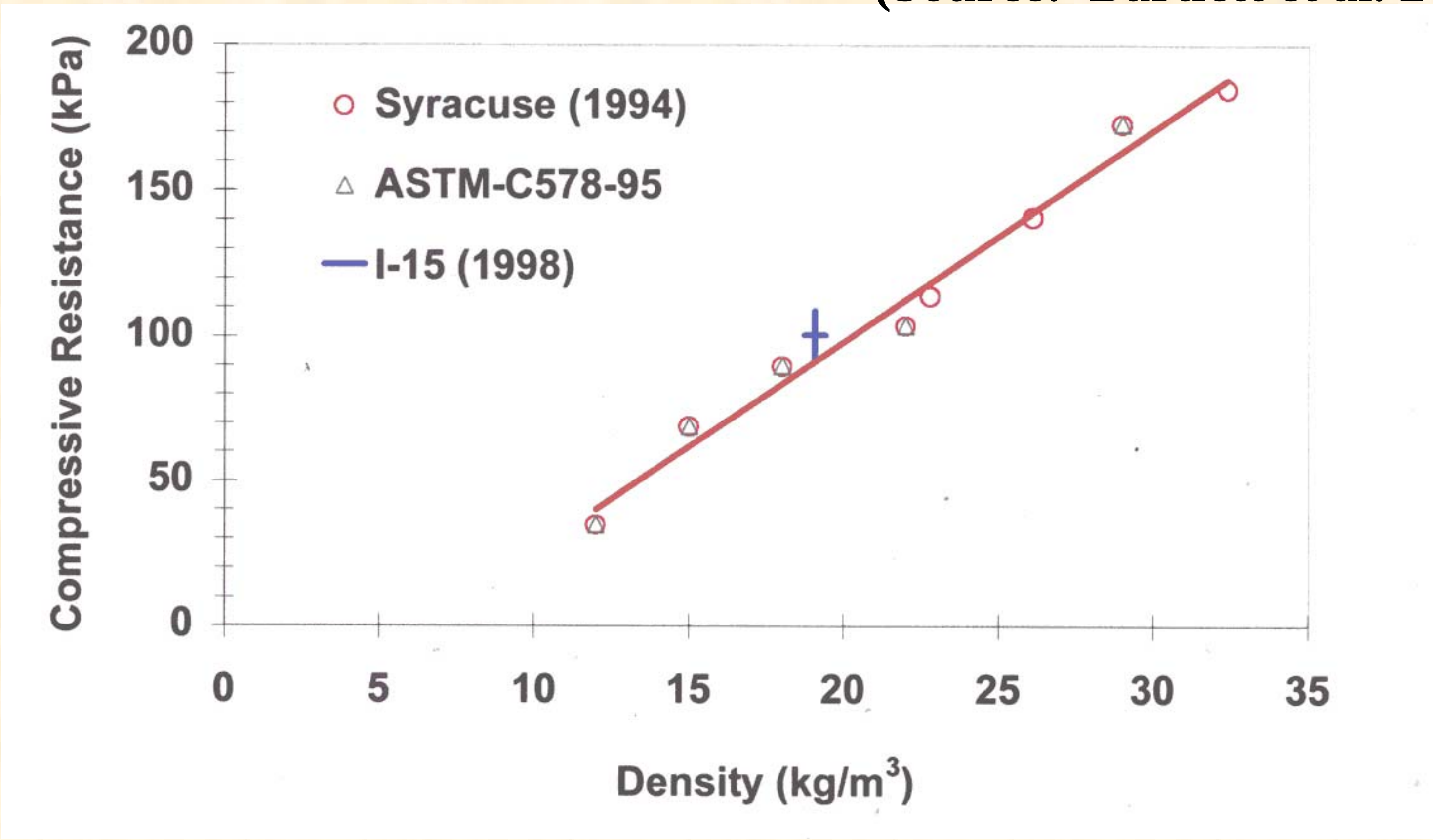
Design Considerations
(EPS Minimum Compressive Strength)

Property	ASTM Test	Type XI	Type I	Type VIII	Type II	Type IX
kPa (10% Strain)	C 165 / D 1621	35	69	90*	104	173

* Type VIII was used for I-15 Reconstruction
Strain Rate for Testing = 5 mm / minute

Design Considerations (EPS Minimum Compressive Strength Versus Density)

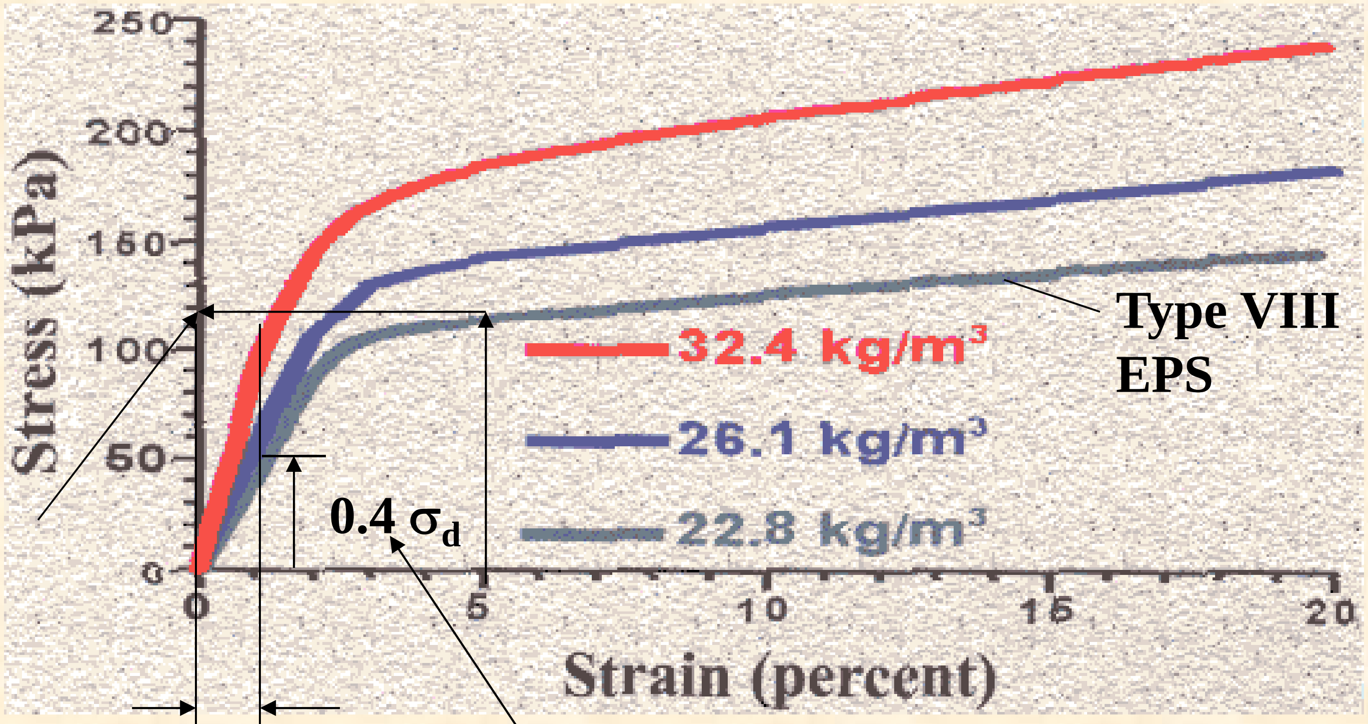
(Source: Bartlett et al. 2000)



σ_d = 7.3 * D - 47 where D = Density in kPa.

Design Considerations (Allowable Stress and Creep)

Source: Negussey (1997)



σ_d = stress @ 5% strain

* Allowable Stress Must Maintained Below 1% Axial Strain to Minimize Long-Term Creep

***Simplified Formula*:**

Allowable Stress = 0.4 σ_d

Allowable Stress = 0.4 x 120 = 48 kPa

Design Considerations
(Allowable Stress and Creep)

Allowable Stress

(Dead Load + Live Load) $\leq$ 0.4 σ_d

Dead Load = Weight of Load Distribution Slab + Weight of Base Material + Weight of Pavement.

Dead Load = 30 % of σ_d = 0.3 σ_d

Live Load = Traffic Loads

Live Load = 10 % of σ_d = 0.1 σ_d

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Design Considerations
(Creep Data from Norway)

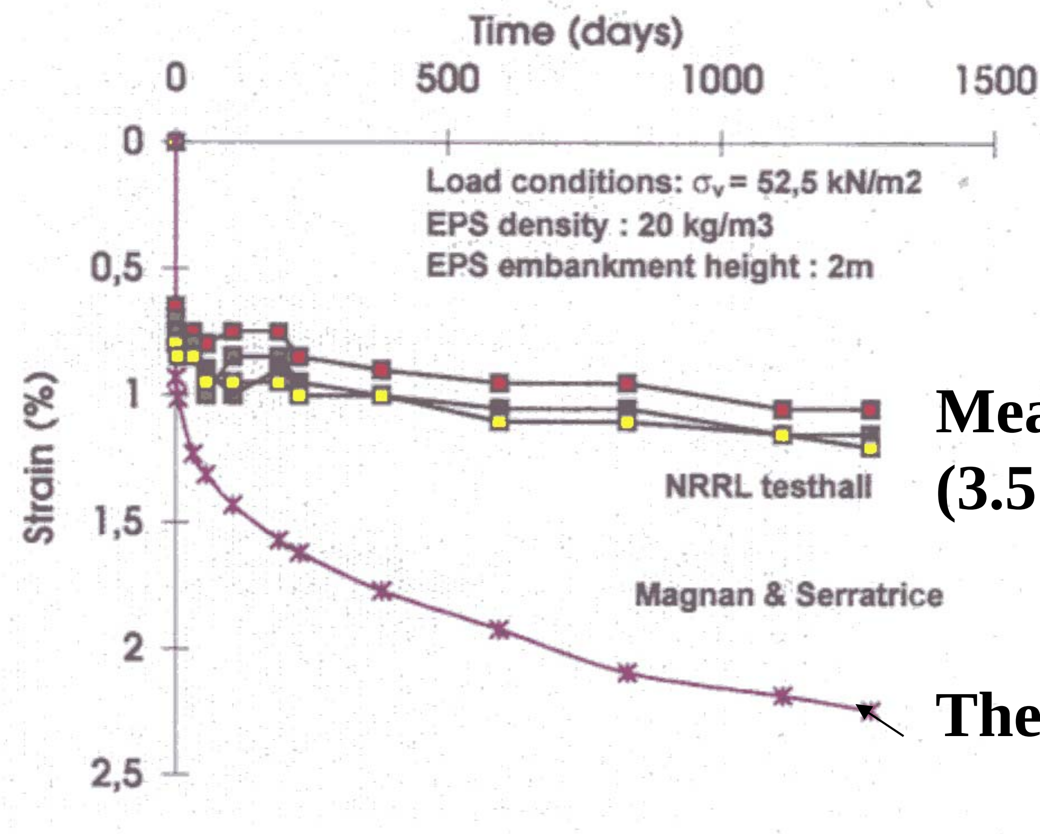


Fig. 7 Deformation / creep in the test fill

Measured Data (3.5 years)

Theoretical Model

(Source: Aaboe, 2000)

Design Considerations (Creep Data from Norway)

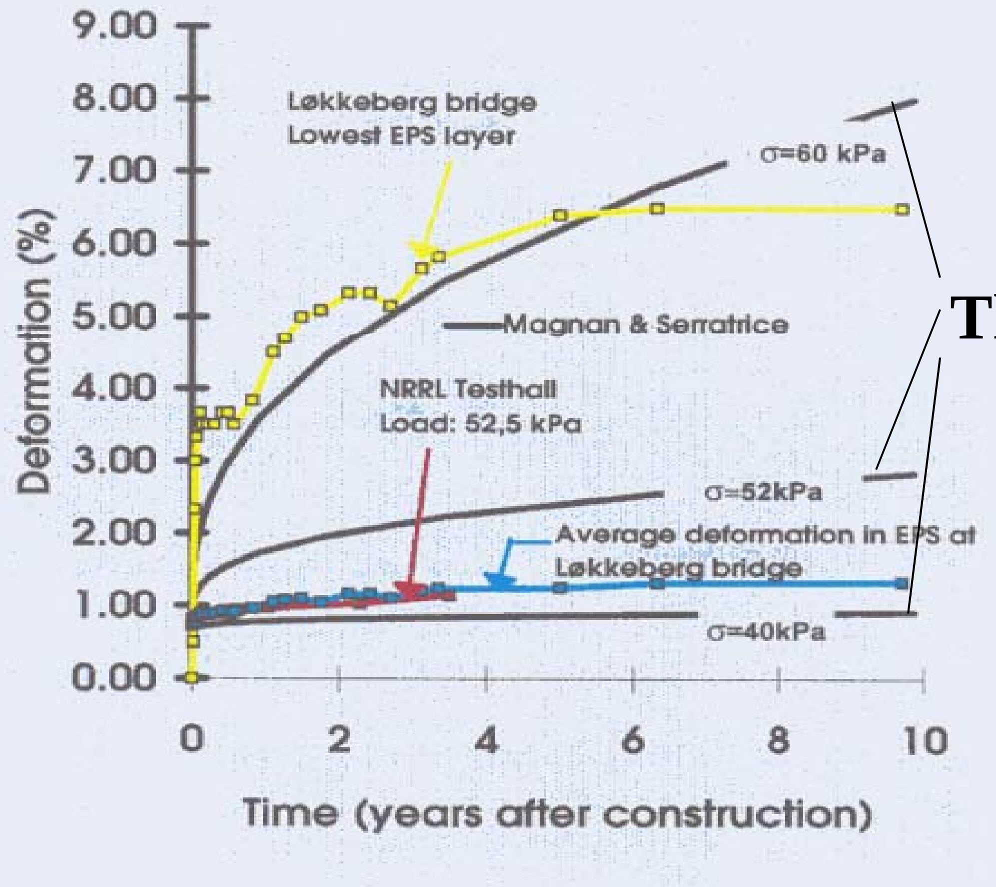
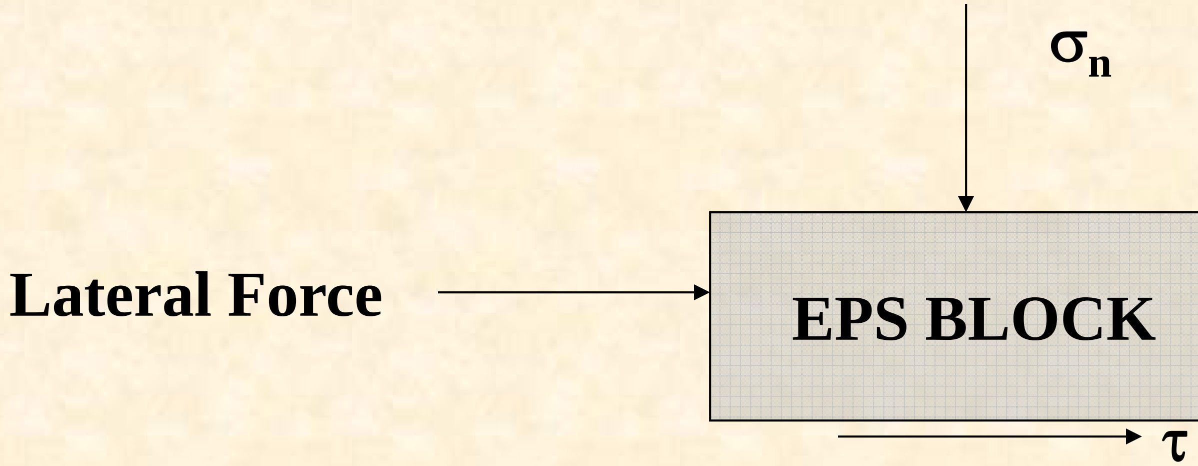


Fig 13. Creep deformations in EPS.

Theoretical Model

(Source: Aaboe, 2000)

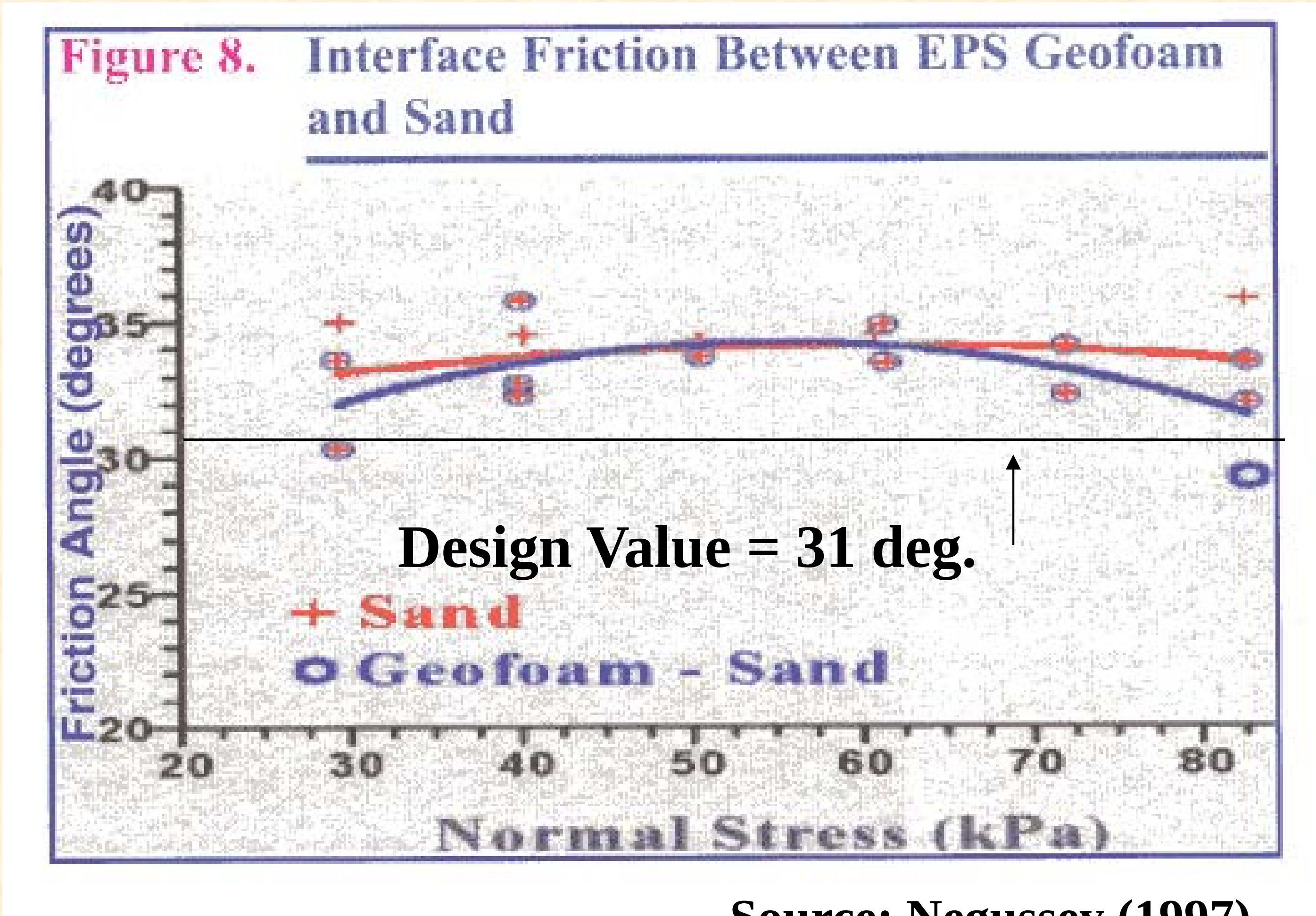
Design Considerations (Interface Friction)



- **Interface Friction Need for Design Against Sliding**

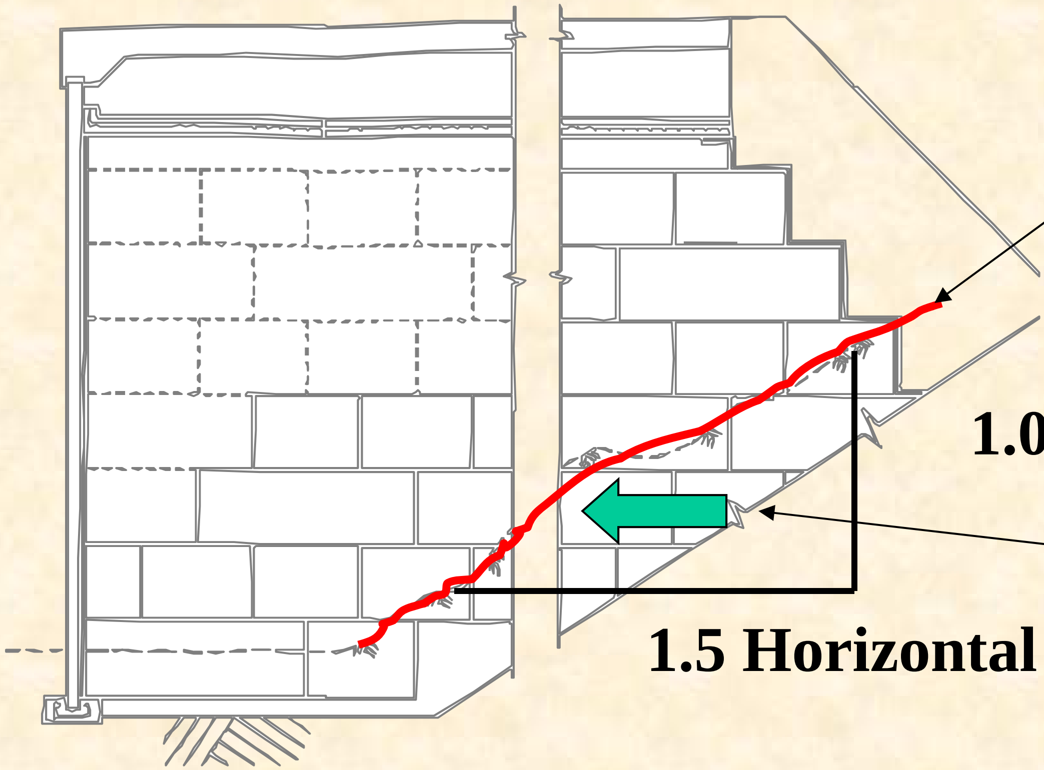
$\tau = \sigma_n \tan \phi$
τ = sliding shear resistance
σ_n = normal stress
$\tan \phi = 0.6$ (Design Value)
$\phi = 31$ degrees (Design Value)

Design Considerations (Interface Friction)



Source: Negussey (1997)

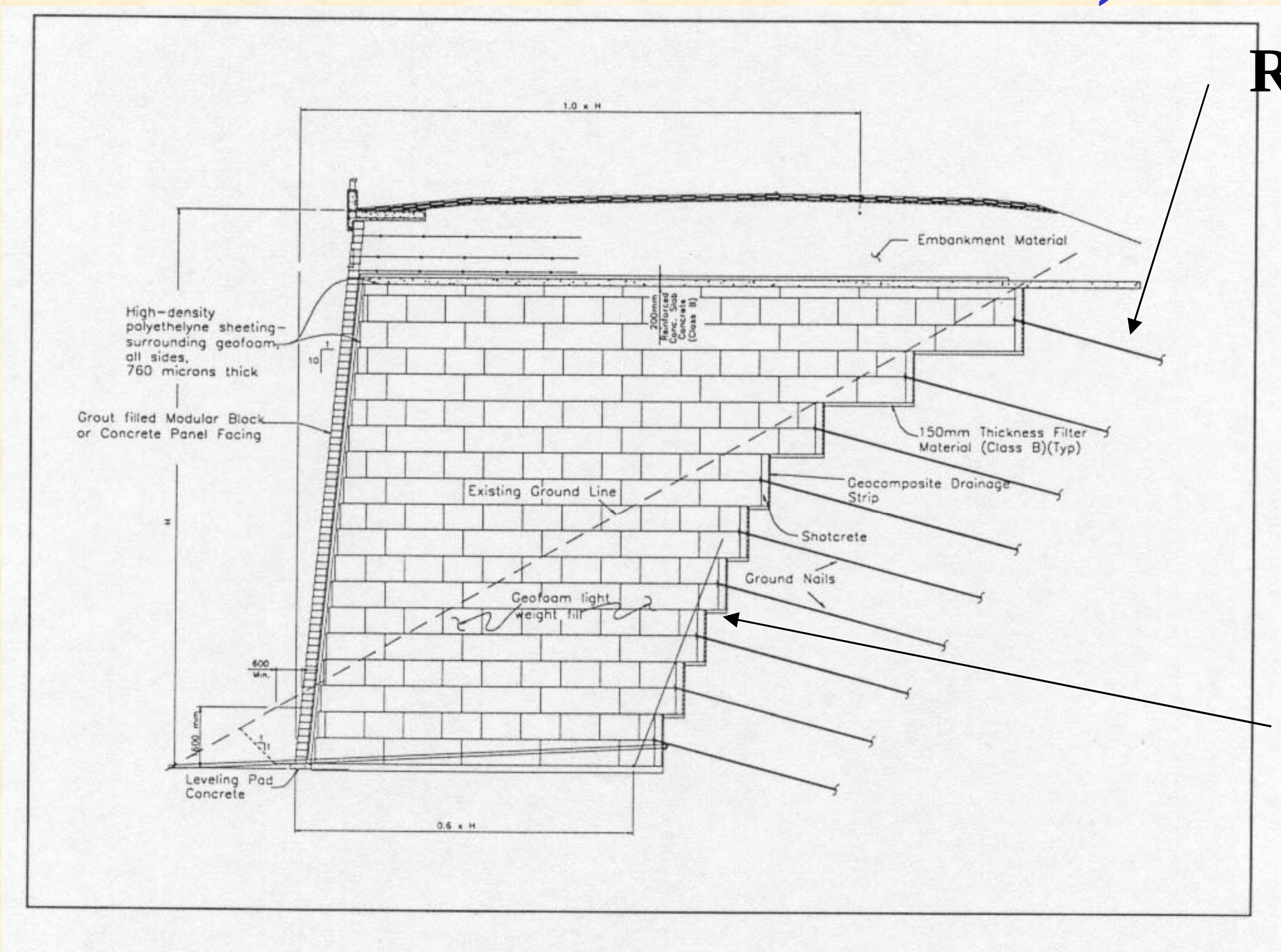
Design Considerations (Stability of Internally Sloped Embankments)



(Do Not Allow Transfer of Horizontal Force)

Maximum Back Slope = 1.5 H to 1.0 Vertical for Embankment to Guarantee Internal Slope Stability

Design Considerations (Stability of Internally Sloped Cuts and Hillsides)



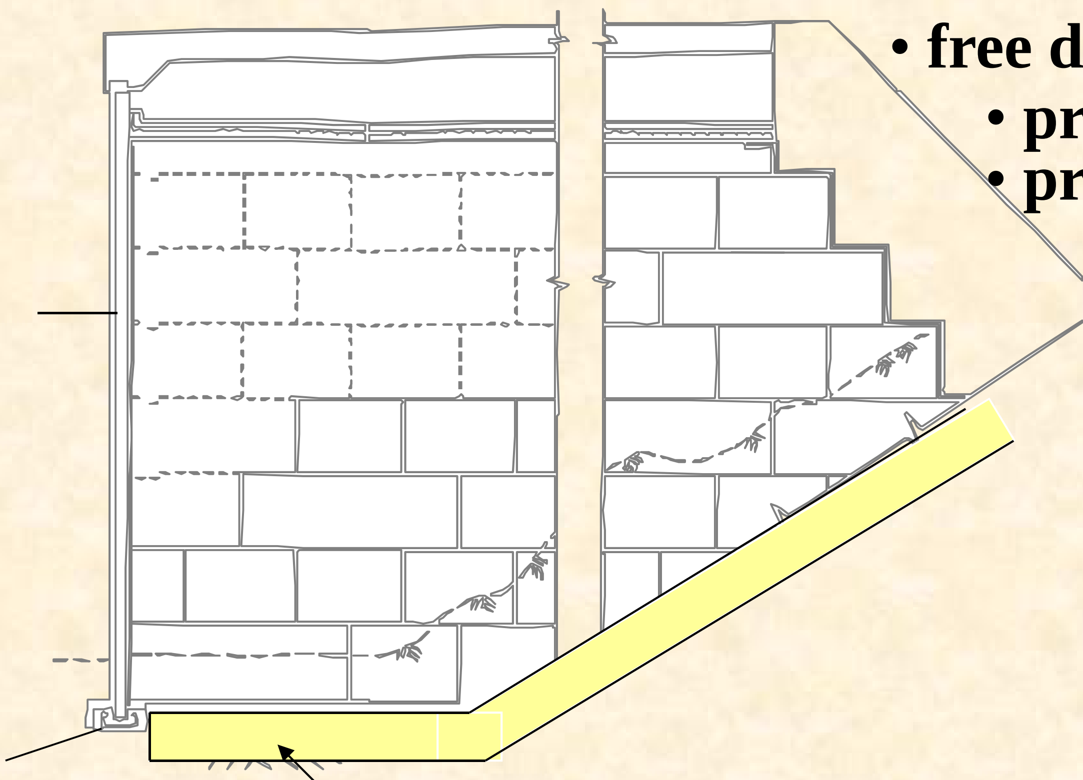
Reinforced Slope Soil Nails, Soil Anchors, or Other Reinforcement

Cut Slope or Landslide

Design Considerations (Bedding Material and Compaction)

Bedding Sand Function

- free draining sand or fine gravel
  - provides leveling course
  - provides drainage



Bedding Sand (20 cm min.)

Design Considerations
(Bedding Material and Compaction)

Gradation Specification for Bedding Sand

Sieve Size	50mm	13mm	6mm	2mm	0.425mm	0.075 mm
% Passing (Percent Passing)	95 - 100	65-100	50-100	40-70	10-40	0-5

*** Materials with more than 20 percent of the samples containing between5 and 7 percent minus 0.075 mm material shall not be accepted for use.**

Design Considerations
(Bedding Material and Compaction)

Grade Preparation and Leveling

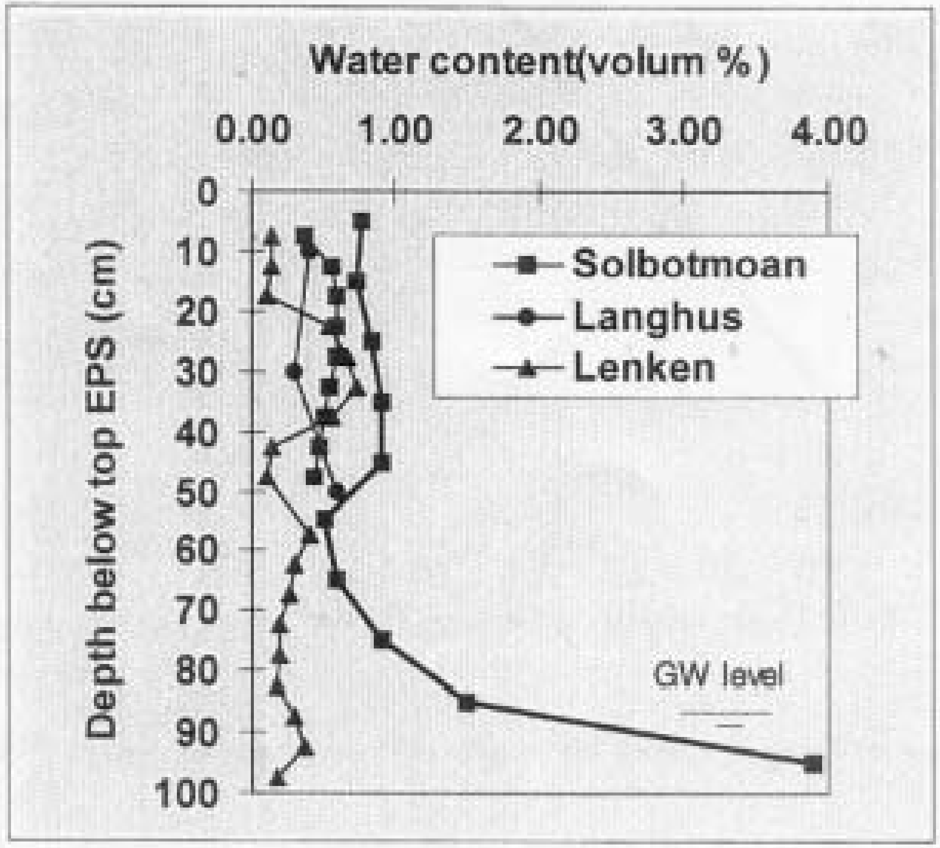
(*Maximum lift thickness = 20 cm)

Light-Weight Compaction Equipment

Design Considerations (Concentrated Loads)

- Uncovered geofoam damages easily from tire loads
- Do not use heavy equipment atop geofoam until the load distribution slab is placed
- Use light-weight construction equipment
- Protect with plywood sheeting

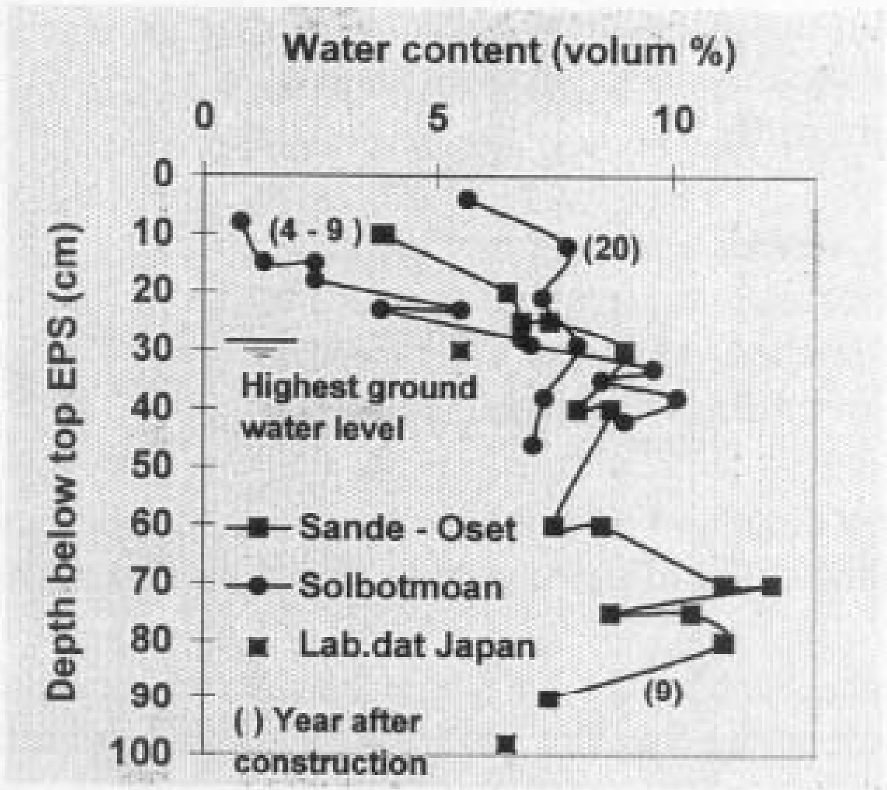
Design Considerations (Moisture Absorption - Above High Groundwater Elevation)



Figur 5. Typical drained situation from 3 EPS fills

(Source: Aaboe, 2000)

Design Considerations (Moisture Absorption - Below Groundwater)



Figur 7. Typical water content in submerged EPS blocks

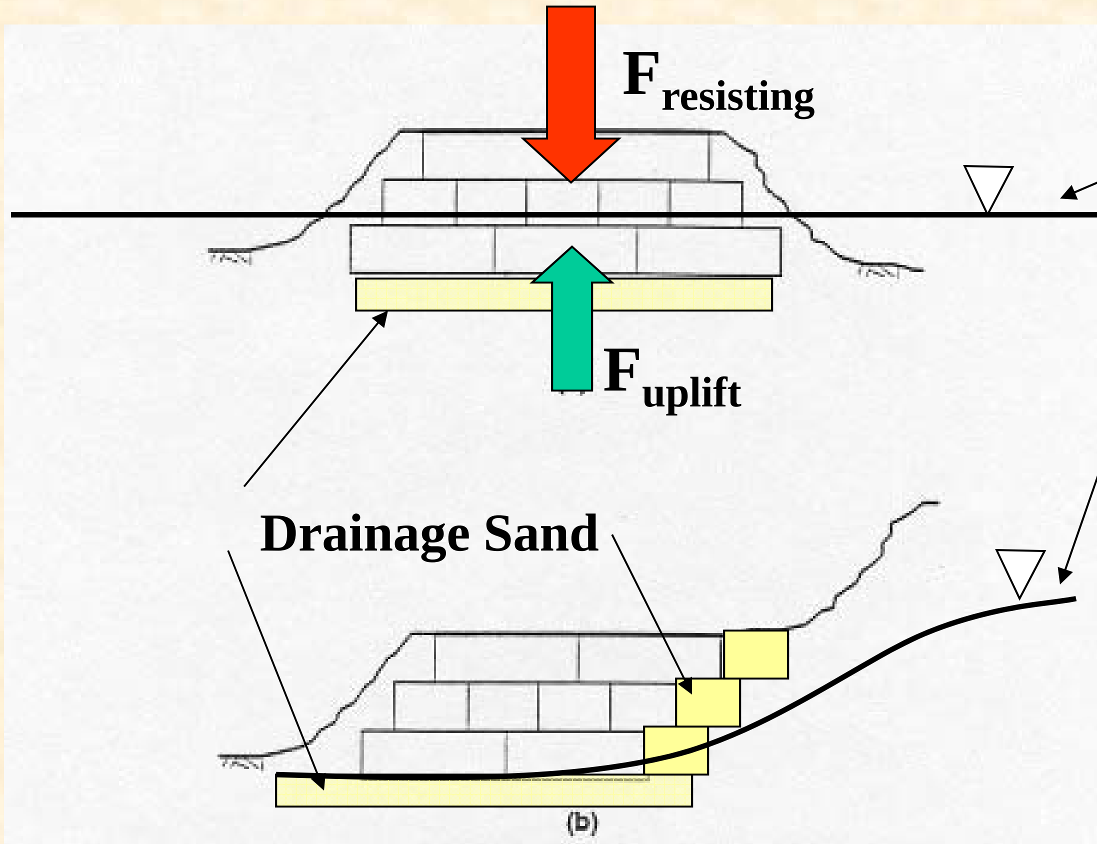
(Source: Aaboe, 2000)

Design Considerations (Moisture Absorption - Design Values)

- Installation of EPS above high groundwater
  - Design Moisture Content = 1 percent by volume
- Installation of EPS that is periodically submerged
  - Design Moisture Content = 5 percent by volume
- Installation of EPS below groundwater
  - Design Moisture Content = 10 percent by volume

Design Considerations (Buoyancy)

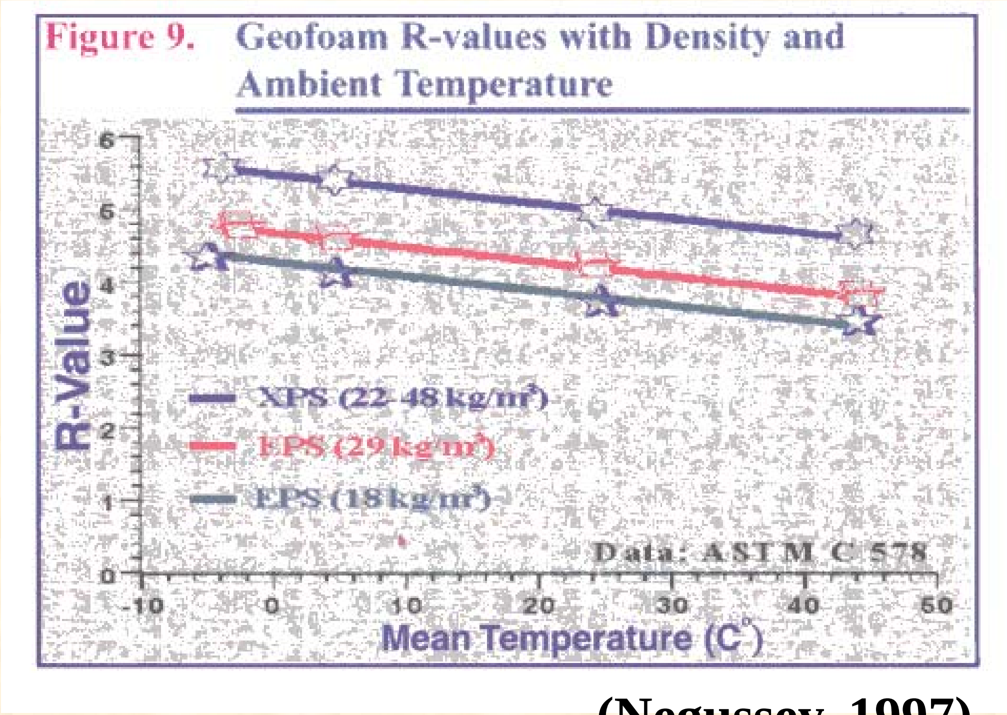
100-year design flood event



groundwater

$$F_{resisting} = 1.3 \times F_{uplift}$$

Design Considerations (Thermal Resistance)

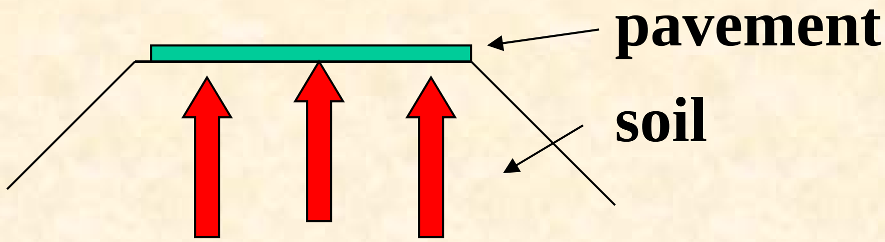


(Negussey, 1997)

- R-value = heat flow through a unit width of material.
- R-value for geofoam is about 4 (18 kg/m^3 density).
- R-value for soil and concrete is less than 1.

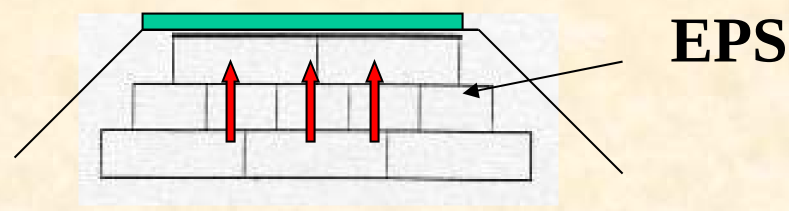
Design Considerations (Differential Icing - Cold Regions only)

No Icing



Good Heat Transfer

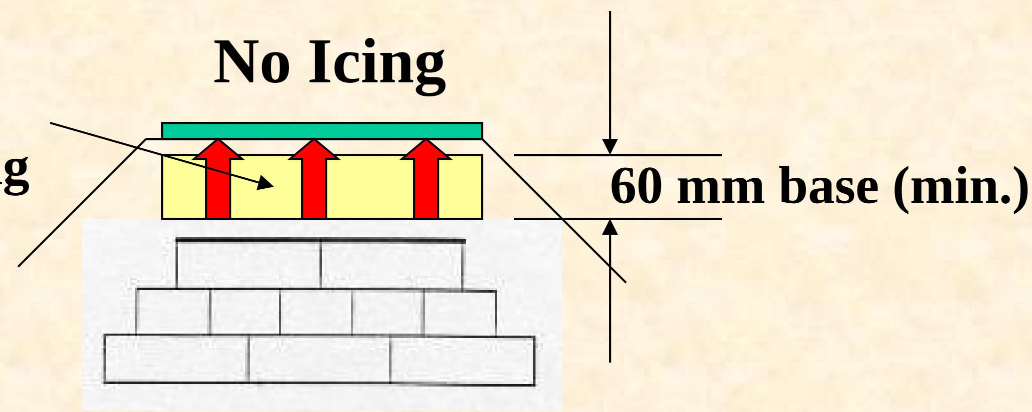
Icing



Poor Heat Transfer

No Icing

Base material has heat capacity and prevents pavement from icing as rapidly.



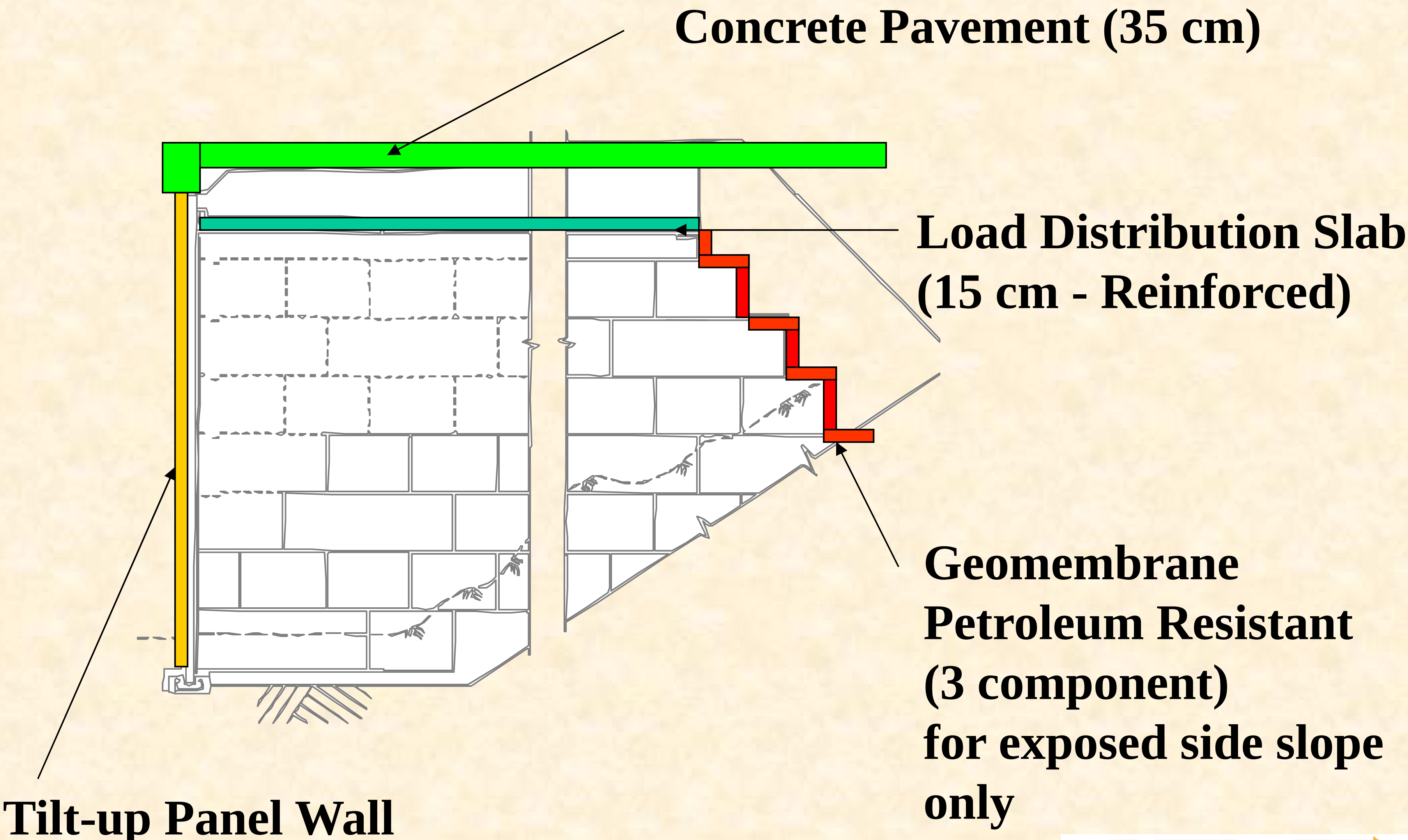
Proper Design to Prevent Icing

Design Considerations (Chemical Attack)

- **Solvents that Dissolve Geofoam**
  - **Gasoline**
  - **Diesel**
  - **Other Petroleum Based Fuels**
  - **Organic Fluids**

- **Protection Against Accidental Spills**
  - **Concrete Load Distribution Slab**
  - **Geomembrane**
  - **Fascia Panel Wall with Coping**

Design Considerations (Chemical Attack - Protective Barriers)



Design Considerations
(Chemical Attack - Protective Barriers)

- Tripolymer Geomembrane
  - Polyvinyl Chloride
  - Ethylene Interpolymer Alloy
  - Polyurethane
- 9 mm thickness minimum (total)

Design Considerations (Flammability)

- Geofoam is Combustible and Must Be Protect Against Open Flame or Heat
- Material Specification should include:

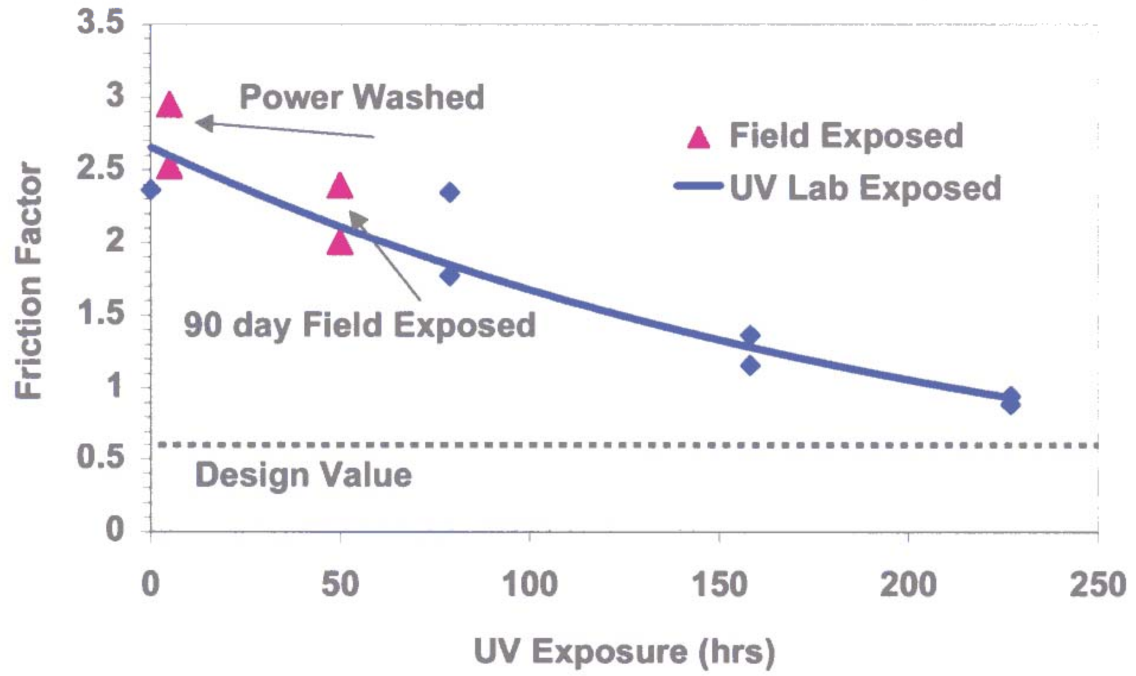
  "Flame Retardant Additive and a UL Certification of Classification as to External Fire Exposure and Surface Burning Characteristics."

Design Considerations (Insect Infestation)

- Chemical (Borate) can be added to stop termite or insect infestation.

Design Considerations (UV Degradation)

(Bartlett et al., 2000)

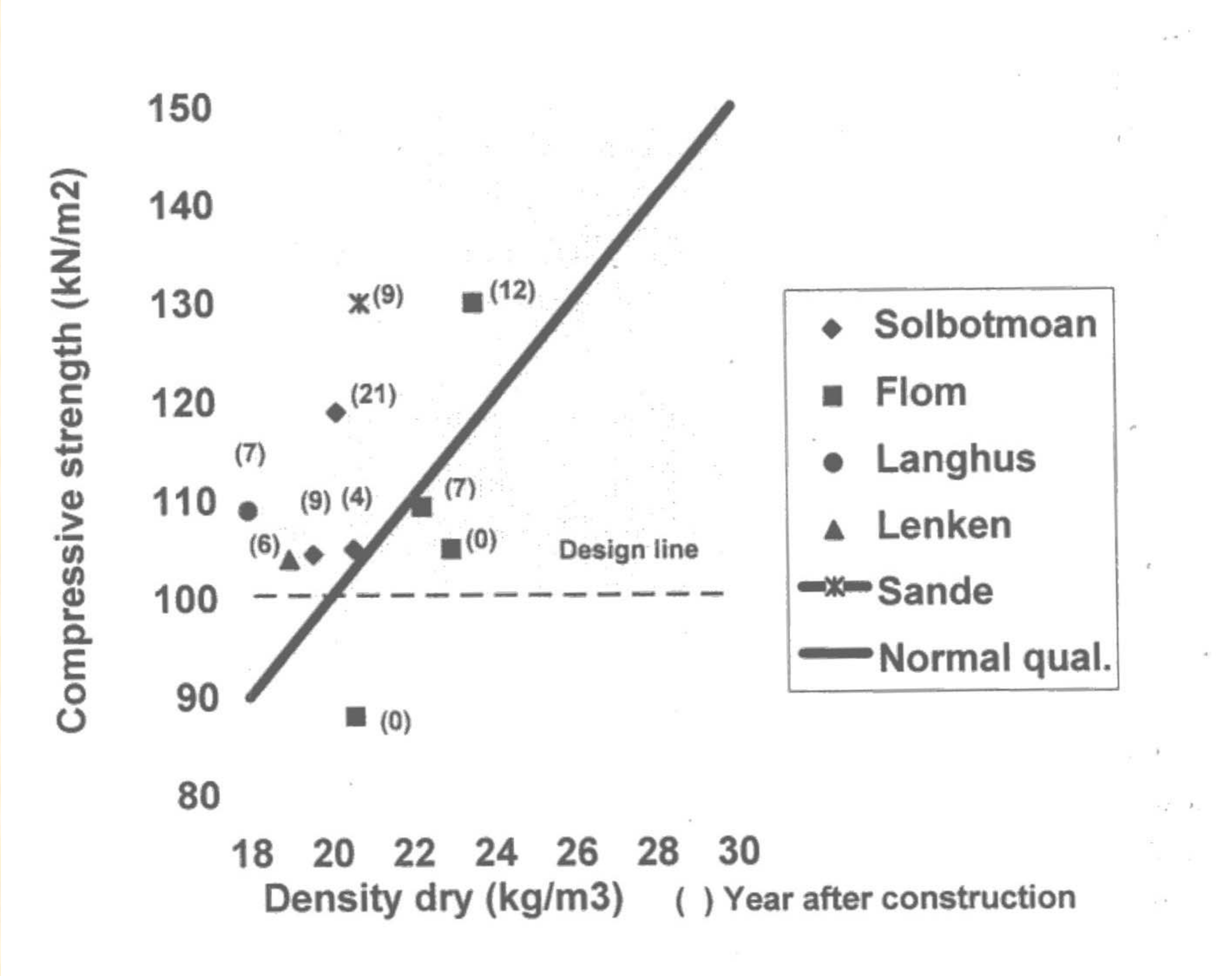


Prolonged Exposure (> 90 days) to sunlight can lead to discoloration of geofoam and decrease in the internal angle of friction on the surface of the geofoam.

Design Considerations (UV Degradation)

- Geofoam should not be left uncovered more than 90 days.
- UV exposure times greater than 90 days require "power-washing" to remove degraded geofoam surface where the load distribution slab is placed
- Side surface where tilt-up panel wall is placed do not require power-washing.

Design Considerations (Durability Data from Norway)



Note: No loss of compressive strength with time is evident (Source: Aaboe, 2000).

(Questions ? ? ?)