Foundry Sands as Structural Fill for Embankments and Retaining Walls

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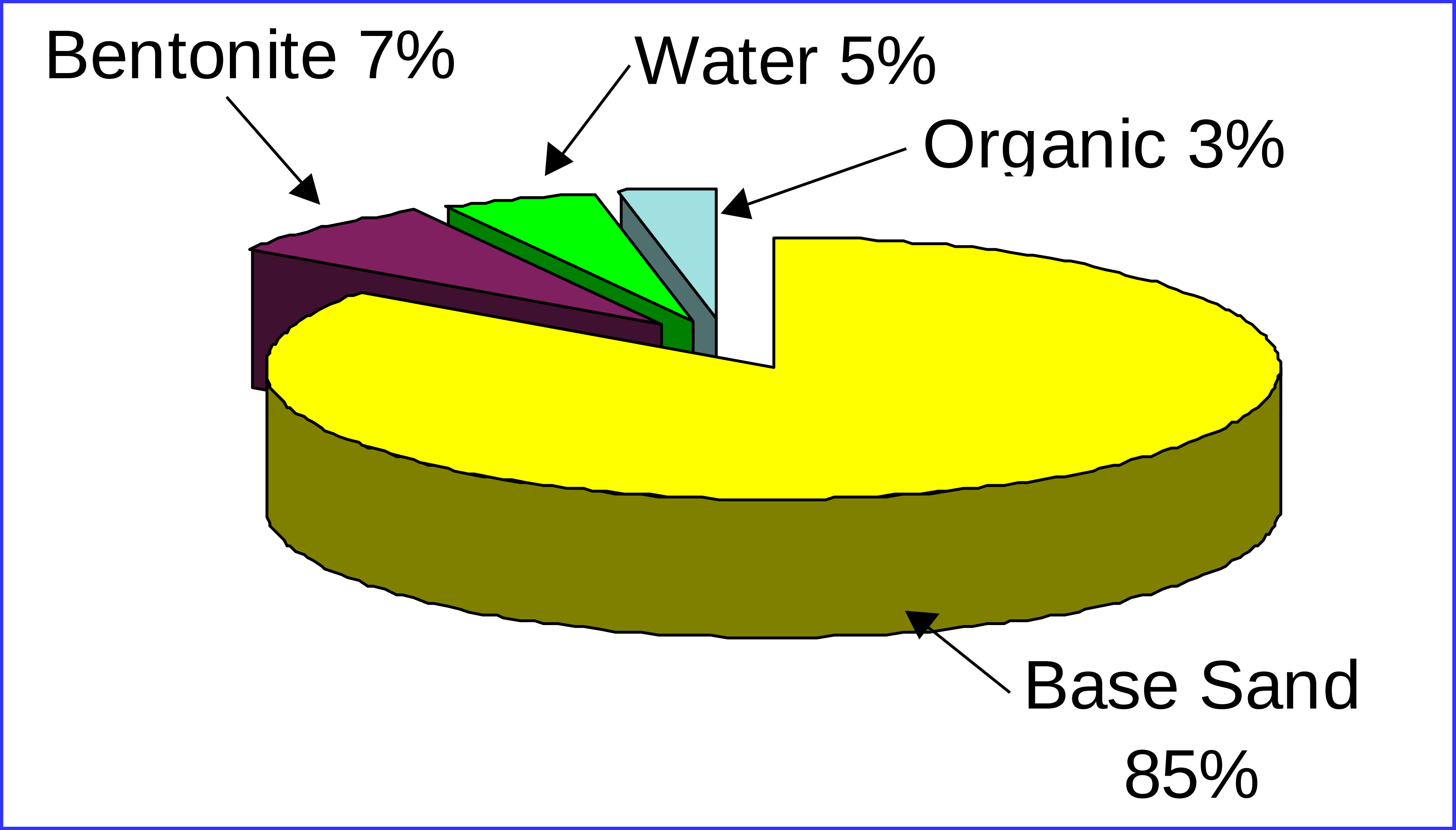
What is foundry sand?

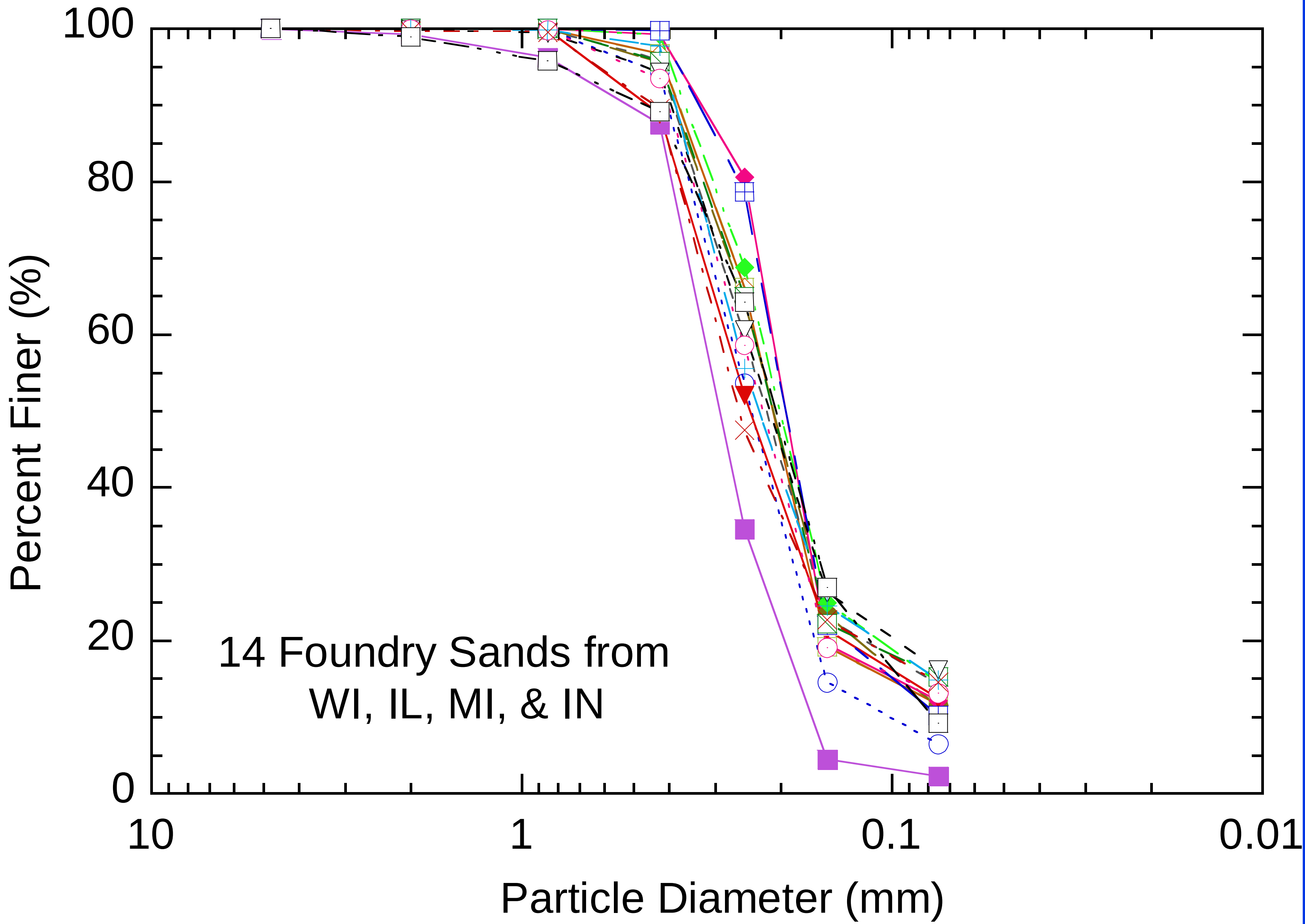


Foundry sands are sand-bentonite mixtures.

Index Properties

- Fine Sand
- Fines: typically 10 – 12%
- 2 μm Clay: typically 3 to 10%
- PI: typically NP-5
- SC, SP, or SP-SM or A-2-4 or A-3
- G_s: 2.52 to 2.73 (Base Sand = 2.66)
- Roundness: Subrounded to subangular (R = 0.5 to 0.7)

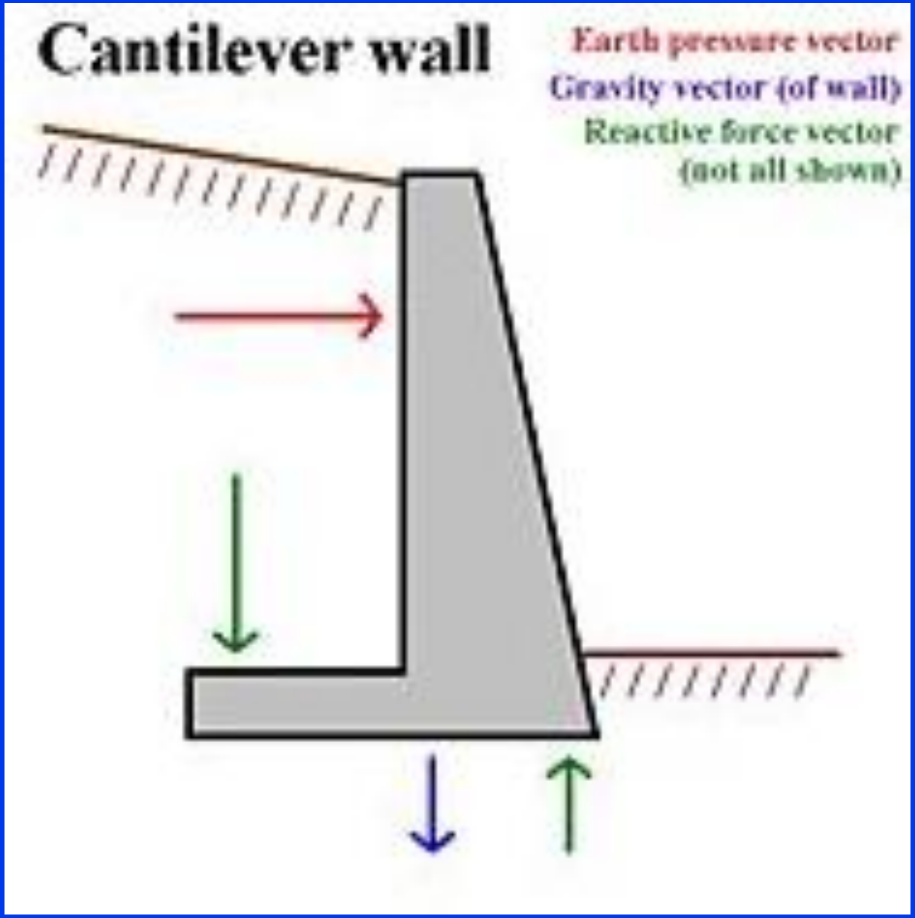
Particle Size Distribution



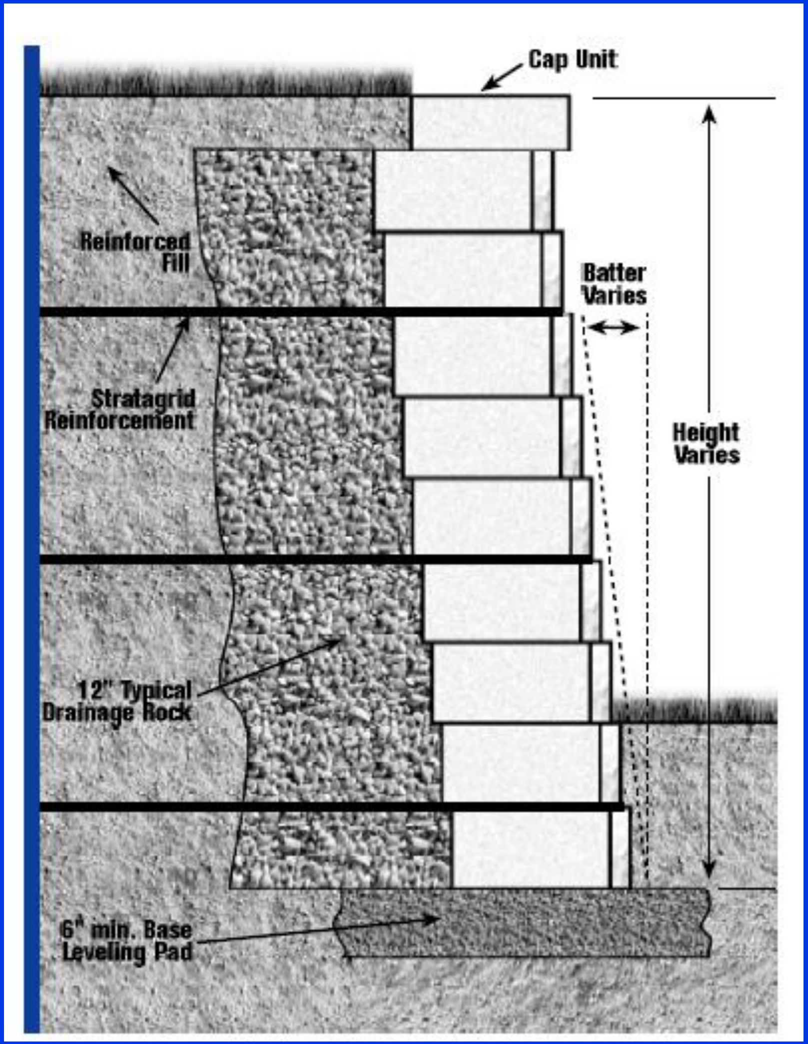
Foundry sand being spread as sub-base at STH 60 field site.

Foundry sand being compacted at STH 60

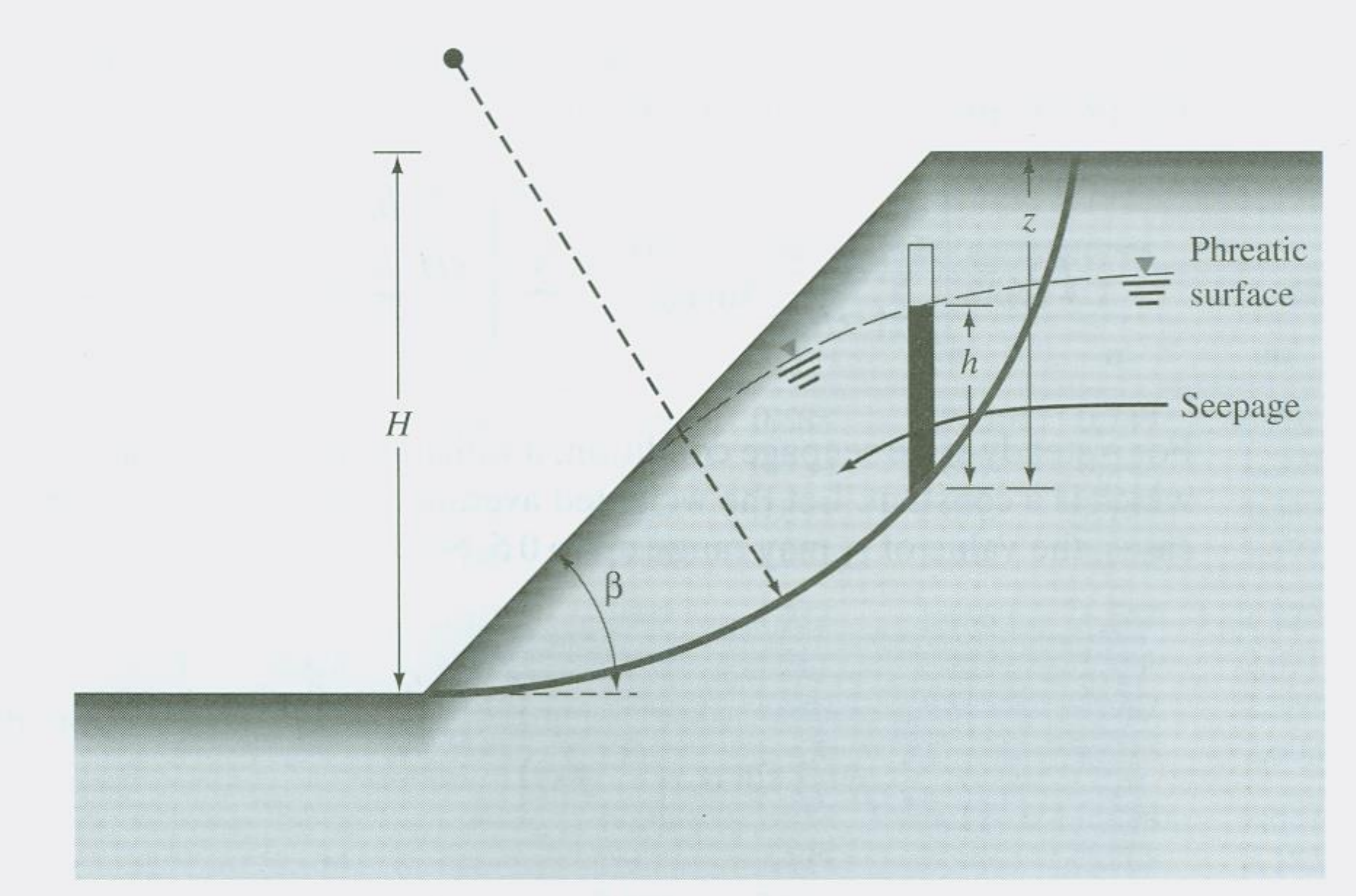
Conventional Wall



MSE Wall



Embankments



Engineering Analyses for Retaining Walls and Embankments

- Overturning (RW)
- Sliding (RW)
- Global stability (RW and embankment)
- Settlement (RW and embankment)
- Practical issues (drainage, raveling, etc.)

Methodology: same approach used with conventional earth fills

Issues for the Engineer

- What is the shear strength of foundry sand?
- What is the interface shear strength with geosynthetics?
- What are the pullout characteristics of geotextiles and geogrids?
- What is the compressibility?

Direct Shear Strength of Foundry Sands

<u>Unsoaked</u>

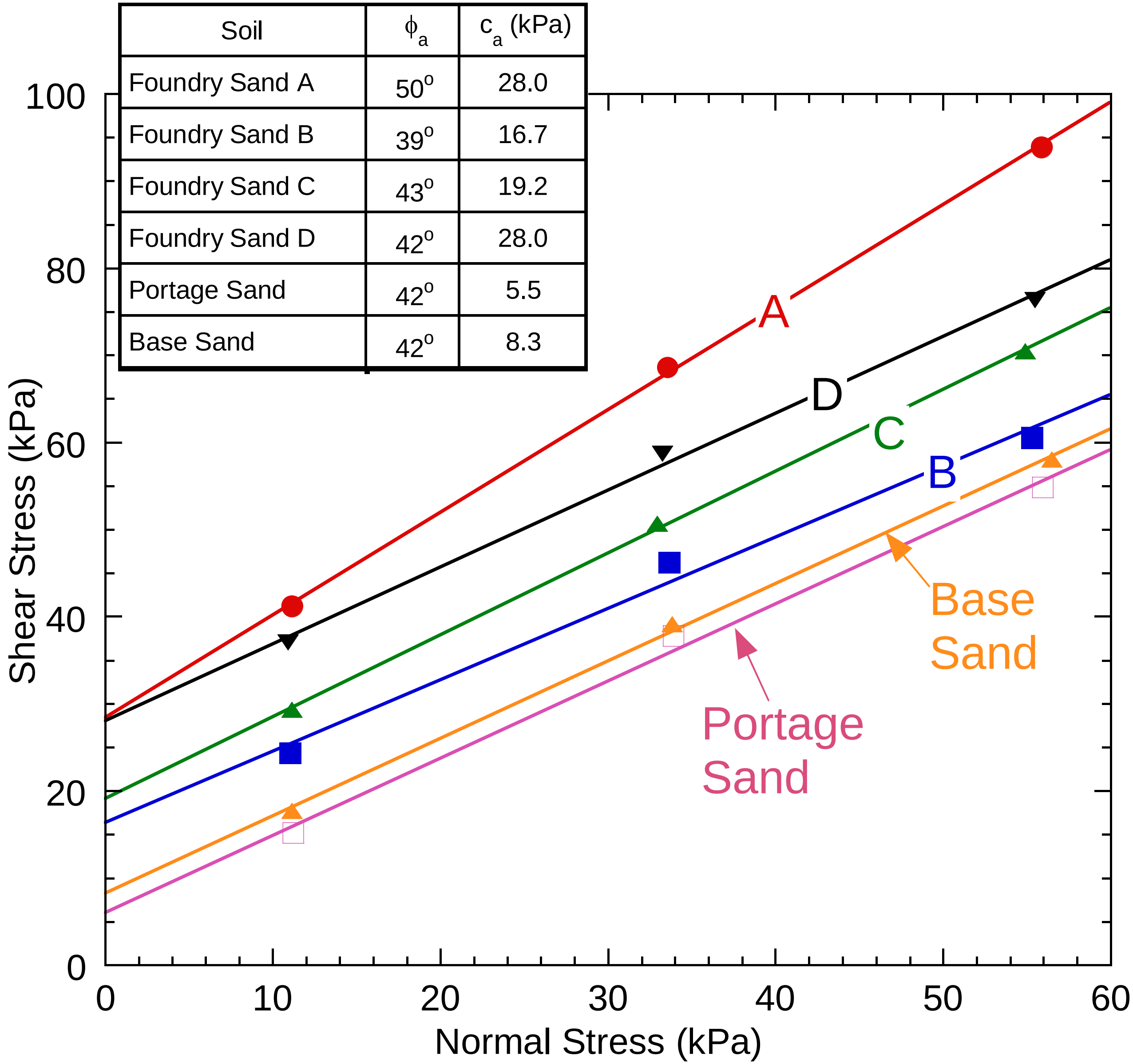
$\phi \sim 40^o$

c’ varies

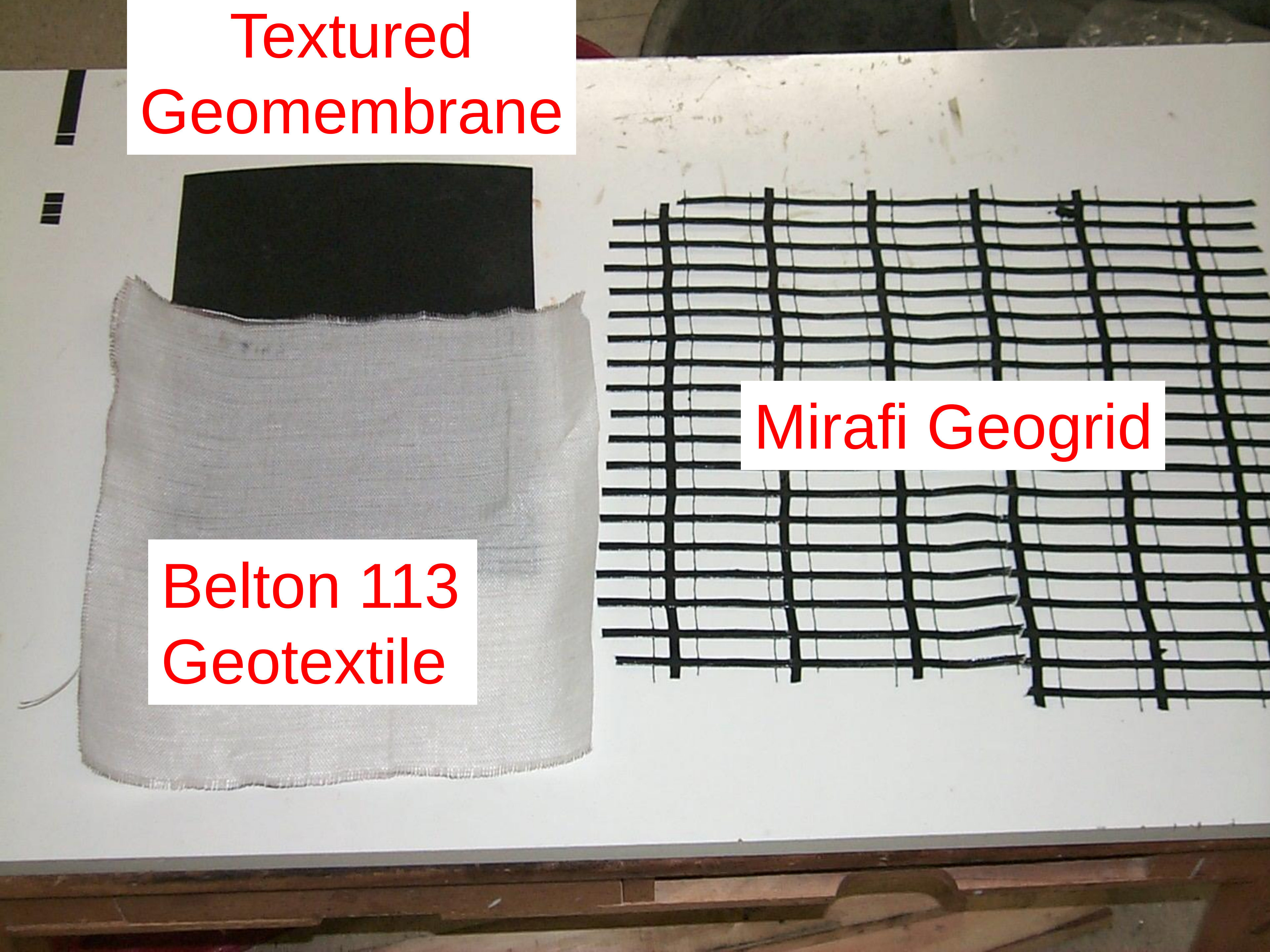
<u>Soaked</u>

$\phi \sim 40^o$

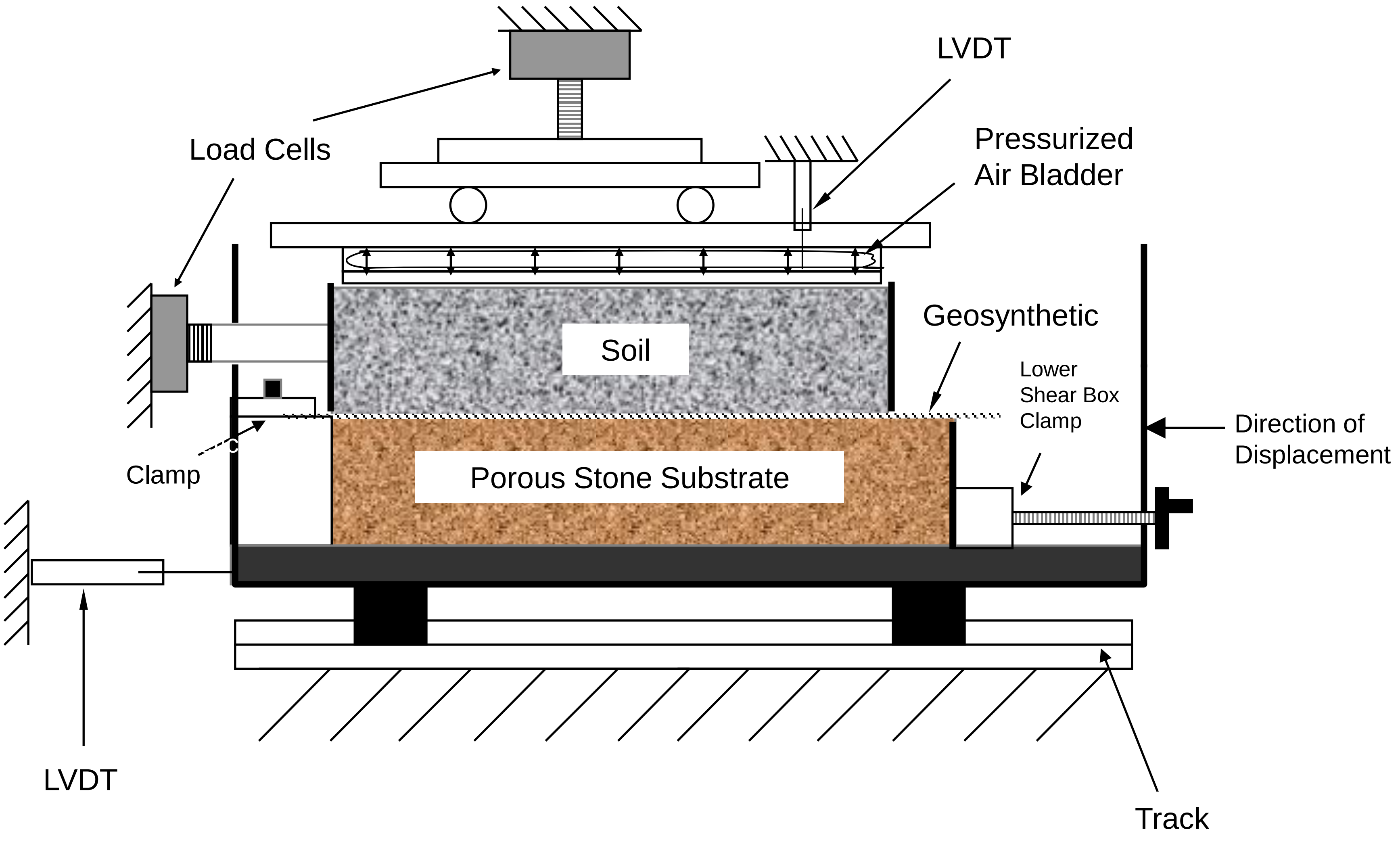
c’ ~ 0



Soil	ϕ_a	c_a (kPa)
Foundry Sand A	50°	28.0
Foundry Sand B	39°	16.7
Foundry Sand C	43°	19.2
Foundry Sand D	42°	28.0
Portage Sand	42°	5.5
Base Sand	42°	8.3


Textured Geomembrane
Mirafi Geogrid
Belton 113 Geotextile

Large-Scale (D 5321) Direct Shear Machine



Interface Direct Shear Box (300 mm x 300 mm)

Frictional Efficiencies

Geotextile:

Base Sand - 83%

Foundry Sands - 61 to 74%

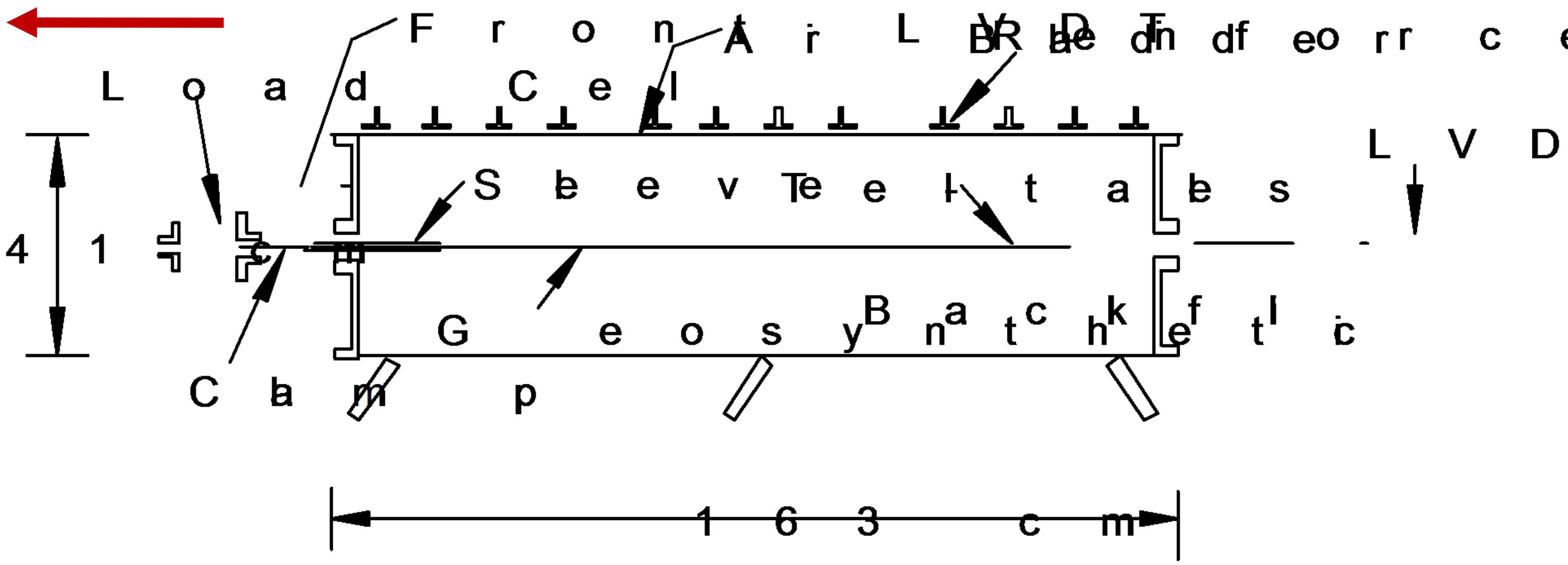
Geogrid:

Base Sand - 96%

Foundry Sands - 51 to 71%

$$E(\%) = \tan\delta/\tan\phi' \times 100$$

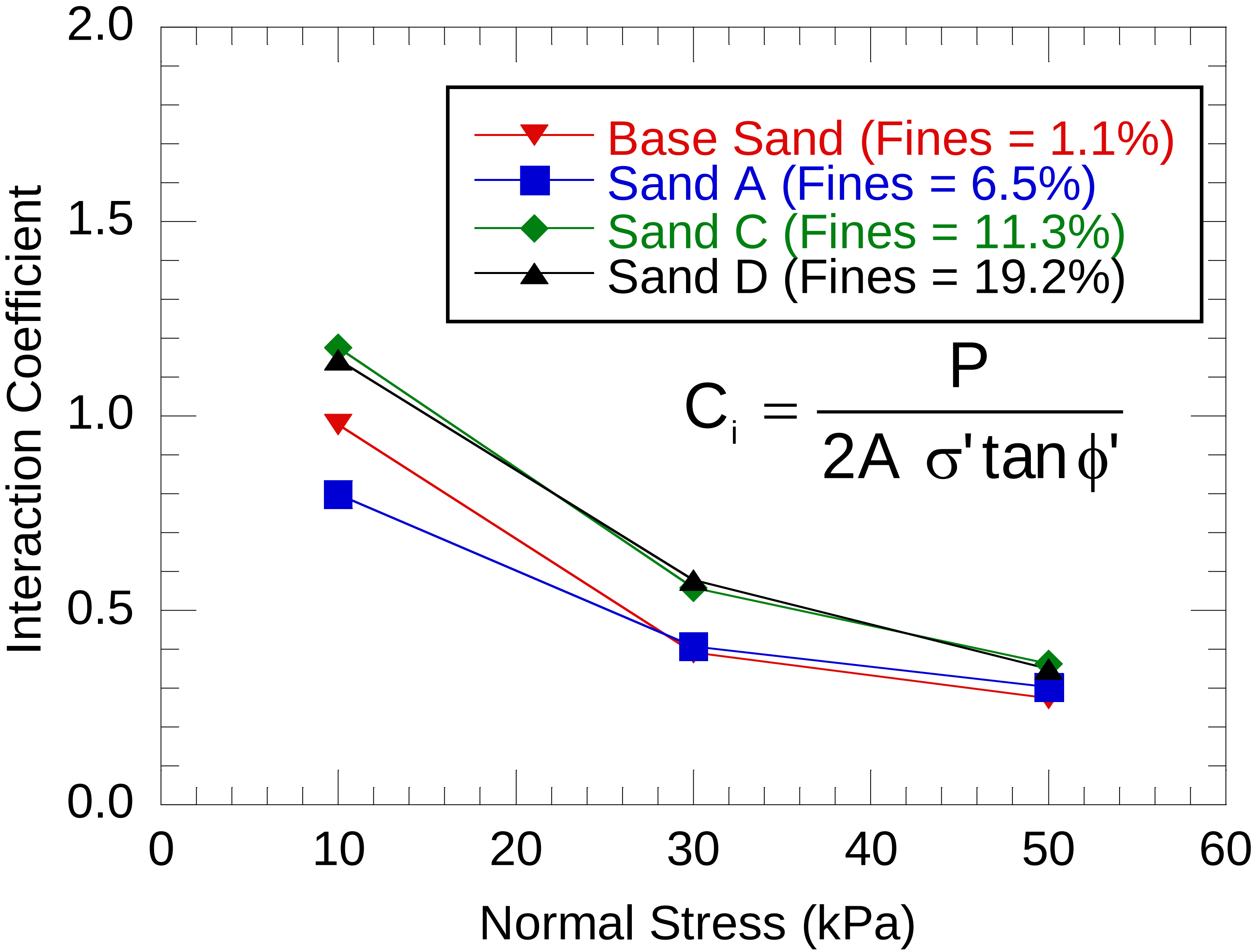
Geosynthetic Pullout Tests



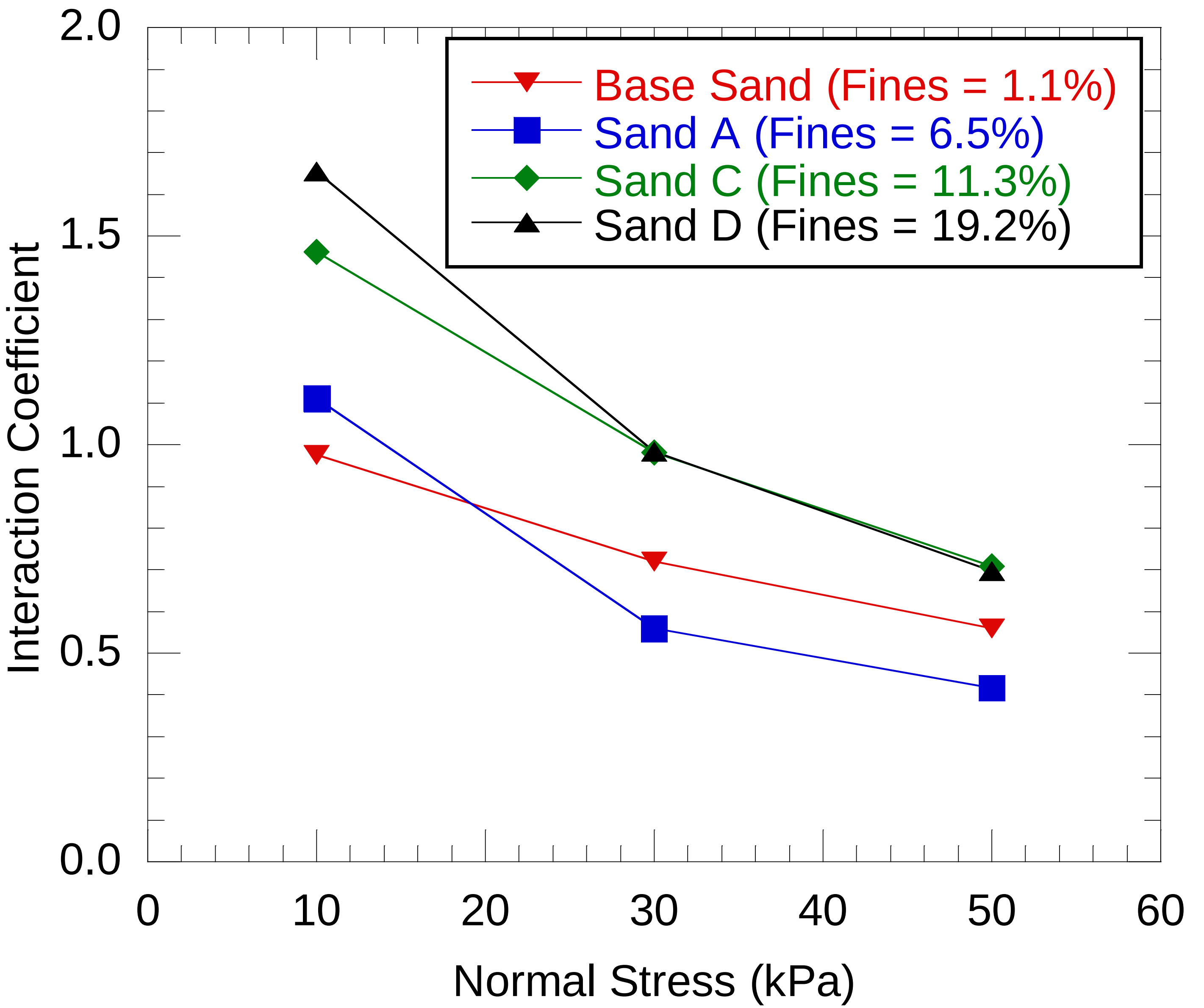
Pullout behavior measured in a pull-out box.

Geosynthetic Pullout Box

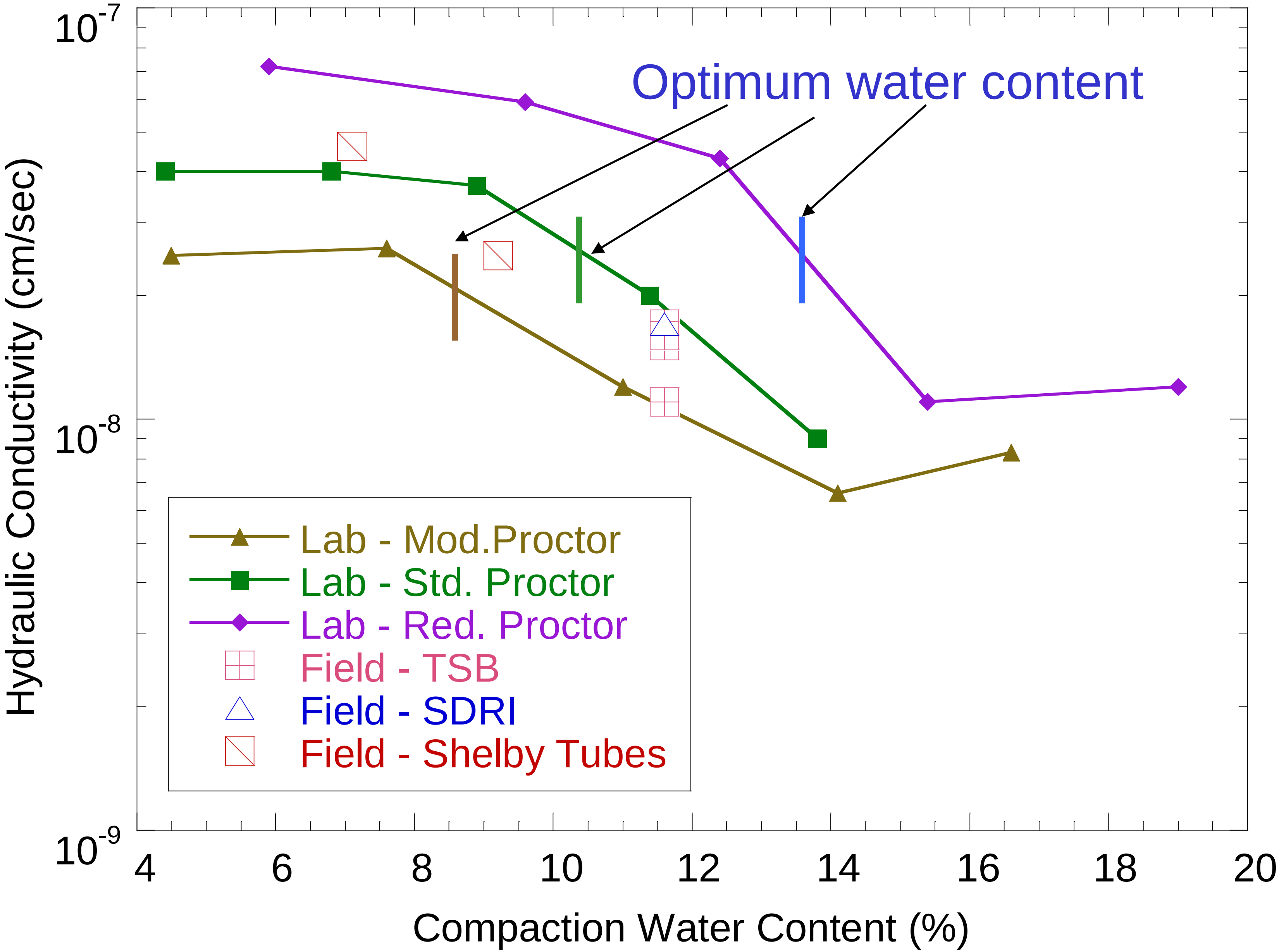
Interaction Coefficients - Geotextile



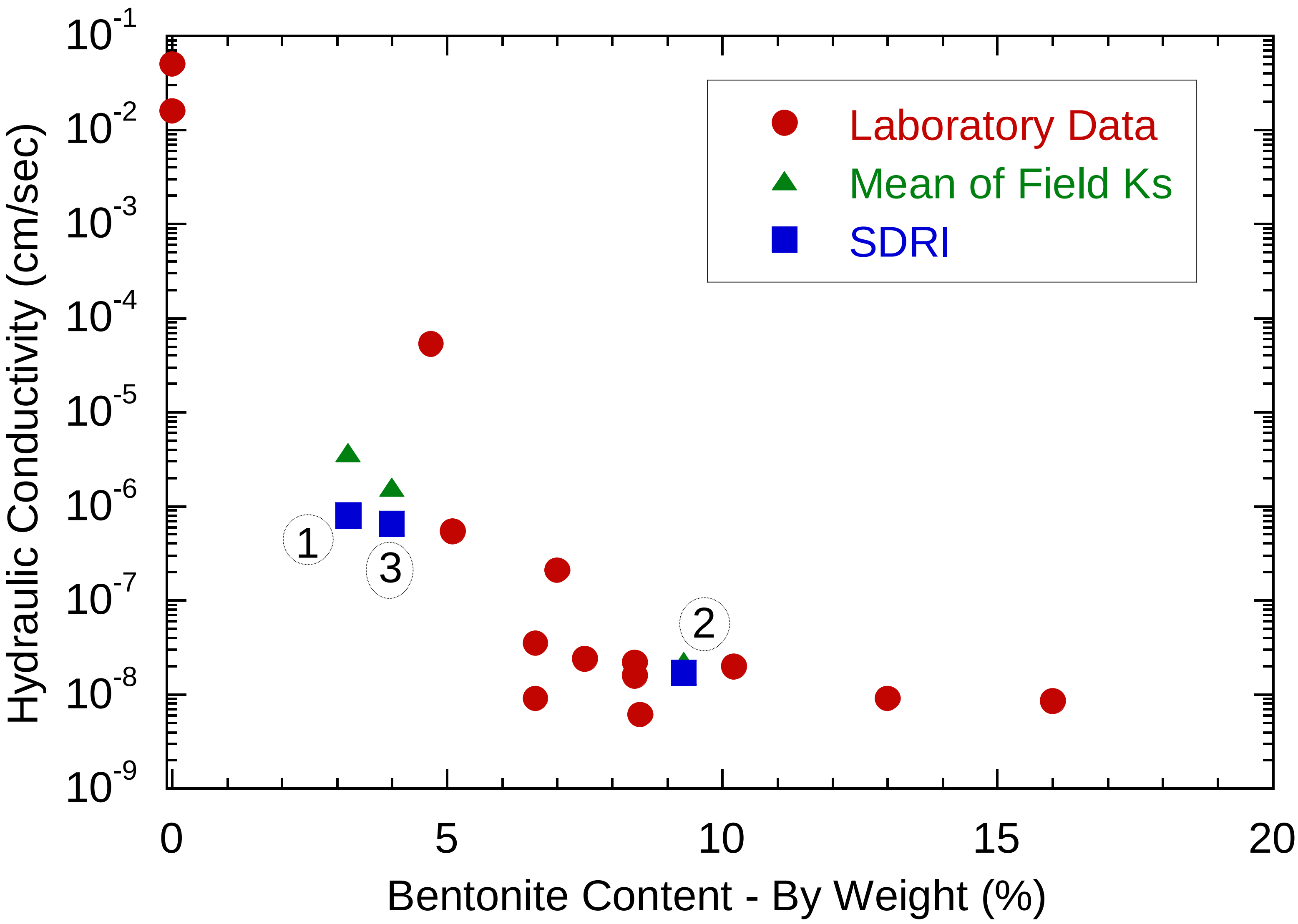
Interaction Coefficients - Geogrid



Hydraulic Conductivity of Foundry Sands



Effect of Bentonite Content



Drainage Issues - 1

- Green sand backfills will not drain like a clean sand backfill. Core sand usually will drain satisfactorily.
- For retaining structures, provide drainage along the back face of the retaining wall to prevent pore pressure build up. Use geosynthetic drainage material.
- Check filtration criteria for geotextile separating drainage layer and foundry sand.

Conventional (AASHTO) Filter Criteria

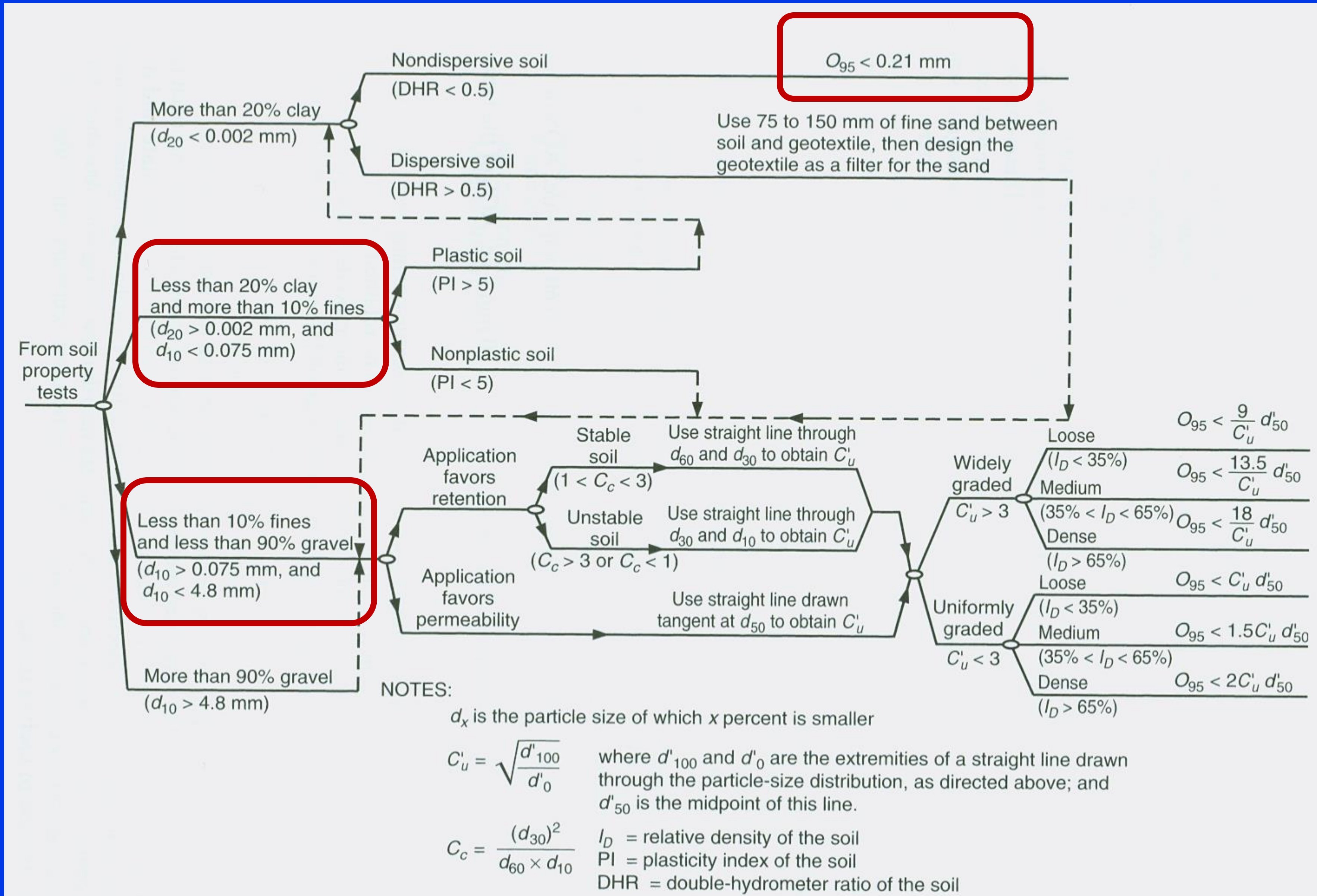
For soils with < 50% fines (nearly all foundry sands):

O_{95} (GT) < 0.6 mm

AOS (GT) > No. 30 sieve size

where O_{95} or AOS is provided by geotextile manufacturer.

Luettich's Filter Criteria



Drainage Issues - 2

- Compact green sands dry of optimum water content to increase hydraulic conductivity.
- Compaction dry of optimum will also result in higher undrained strength and lower compressibility.
- Select sands with lower bentonite content if practical.

Raveling and Erosion

- Green sands will erode internally and externally in the presence of flowing water.
- Geotextile filters on drainage mats will prevent internal erosion in retaining walls.
- Foundry sand surfaces should be covered with surface layer soils and vegetated to minimize surface erosion.

Retaining Wall and Structural Fill Design Recommendations

- ϕ' = 34°, c' = 0 (conservative)
- E = 50% (geogrid) or 60% (geotextile)
- C_i = 1.0 (low normal stresses)
- C_i = 0.5 (higher stresses)
- Compact dry of optimum
- Provide drainage on the back face of retaining walls. Evaluate stability with moist & saturated unit weight in calculations.

Construction Issues

Foundry sands behave like natural sands with fines.

Foundry sands can be very dry when delivered. Adding moisture improves compaction and reduces dust.

Foundry sands can be contaminated with other debris. Be sure the foundry follows good waste separation practices.

Conventional moistening methods work well. Stockpiling over winter season particularly effective.

Disking or roto-tilling sand improves moisture distribution significantly, but is only required if strict control on water content is required.

Compacting green sand with a footed roller improves compaction. Padfoot compactors work best.

Vibration is not required or beneficial unless working with core sand.

Moistened sand tracks in and compacts well. However, wet sand will compact poorly and rut significantly. Avoid standing water by grading surface at close of work day. A smooth drum seal is very beneficial.

Concluding Comments

- Check with sand supplier beforehand to determine typical characteristics of sand and known ranges for key sand properties: d_{50}, C_u, fines content, bentonite content. Compare against data in this presentation.
- Run a drained direct shear test (ASTM D 3080) on the sand if concern exists regarding sand quality.
- Run a compaction test (ASTM D 698 or D 1557) to define maximum density and optimum water content for compaction control.

Concluding Comments

- Measure water content of sand (ASTM D 2216) from supplier to determine level of moisture conditioning required in the field.
- Compare water contents measured during construction using the nuclear gage (ASTM D 6938) to oven-dry water contents (ASTM D 2216) to check suitability of nuclear gage for sand being used in the field. Conduct this test at the start of construction to validate nuclear method.

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