INFILTRATOR
water technologies




The Environment Beneath the Skid-Steer
Soil Engineering Basics for Onsite System Installers

Disclaimers

- NOWRA's Disclaimer: The materials being presented represent the speaker's own opinions and do NOT reflect the opinions of NOWRA.

- Speaker's Disclaimer: The information and situations shown and discussed in this presentation are hypothetical, are provided to improve the audience's awareness of selected potential subsurface conditions, and do not represent actual situations. Workers must consider applicable regulatory requirements and site-specific conditions to determine safe working practices.

Early 1900s Manufactured Gas Plant

http://www.rockawayparkmgpsite.com/site_descr_rock.html

https://www.abcdrilling.com/environmentaldrilling

Manufactured Gas Plant Contamination

https://oto-env.com/blog/new-book-manufactured-gas-plant-remediation-a-case-study/

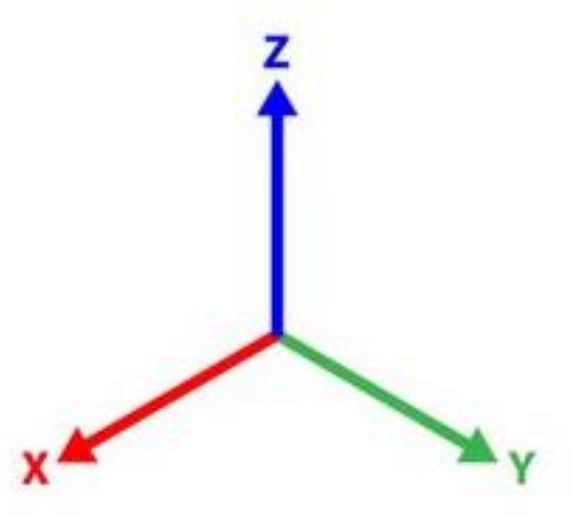
NY & NJ Pass Gateway Development Commission Act - New Jersey Business Magazine (njbmagazine.com)

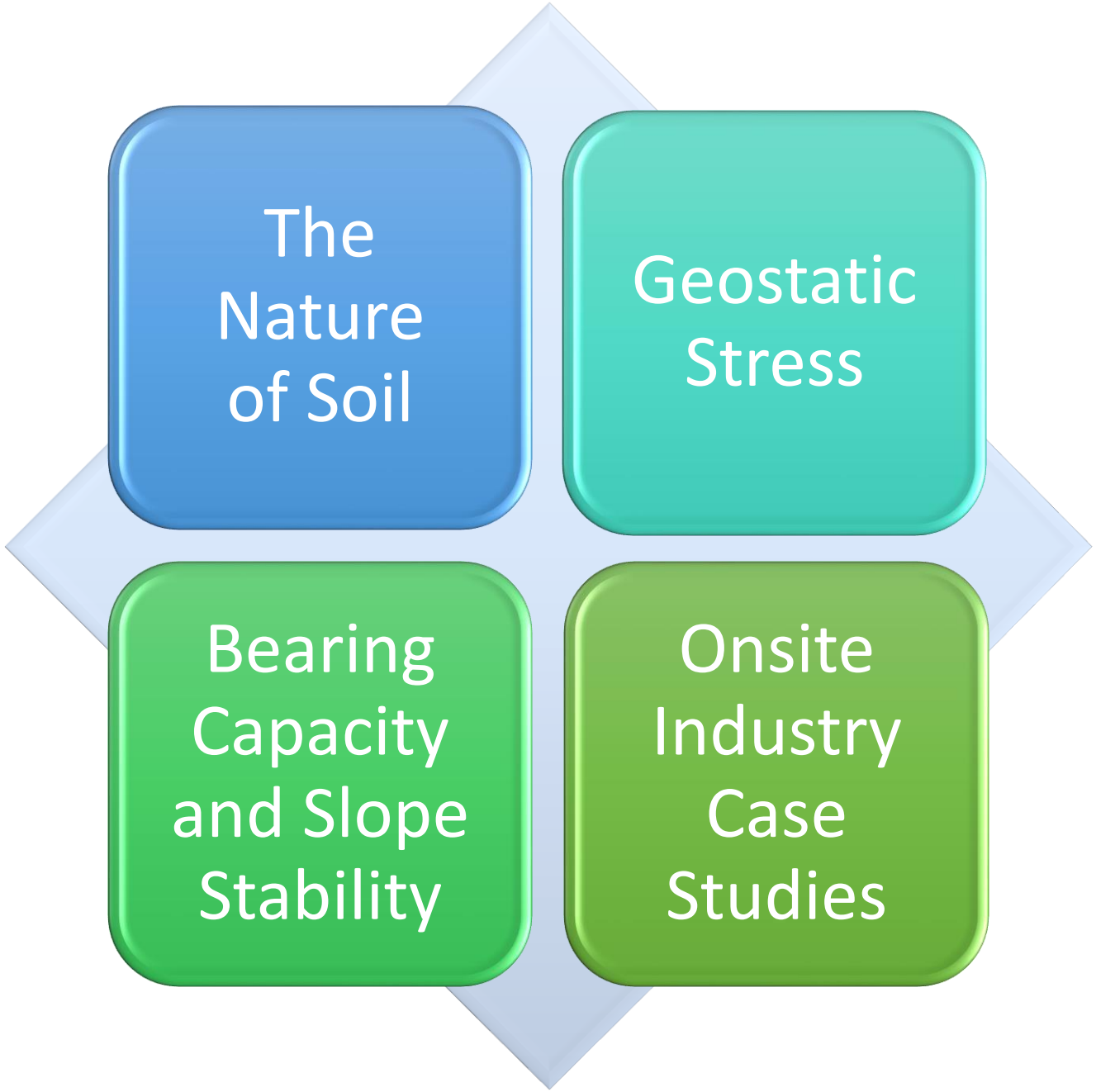
NY & NJ Pass Gateway Development Commission Act - New Jersey Business Magazine (njbmagazine.com)

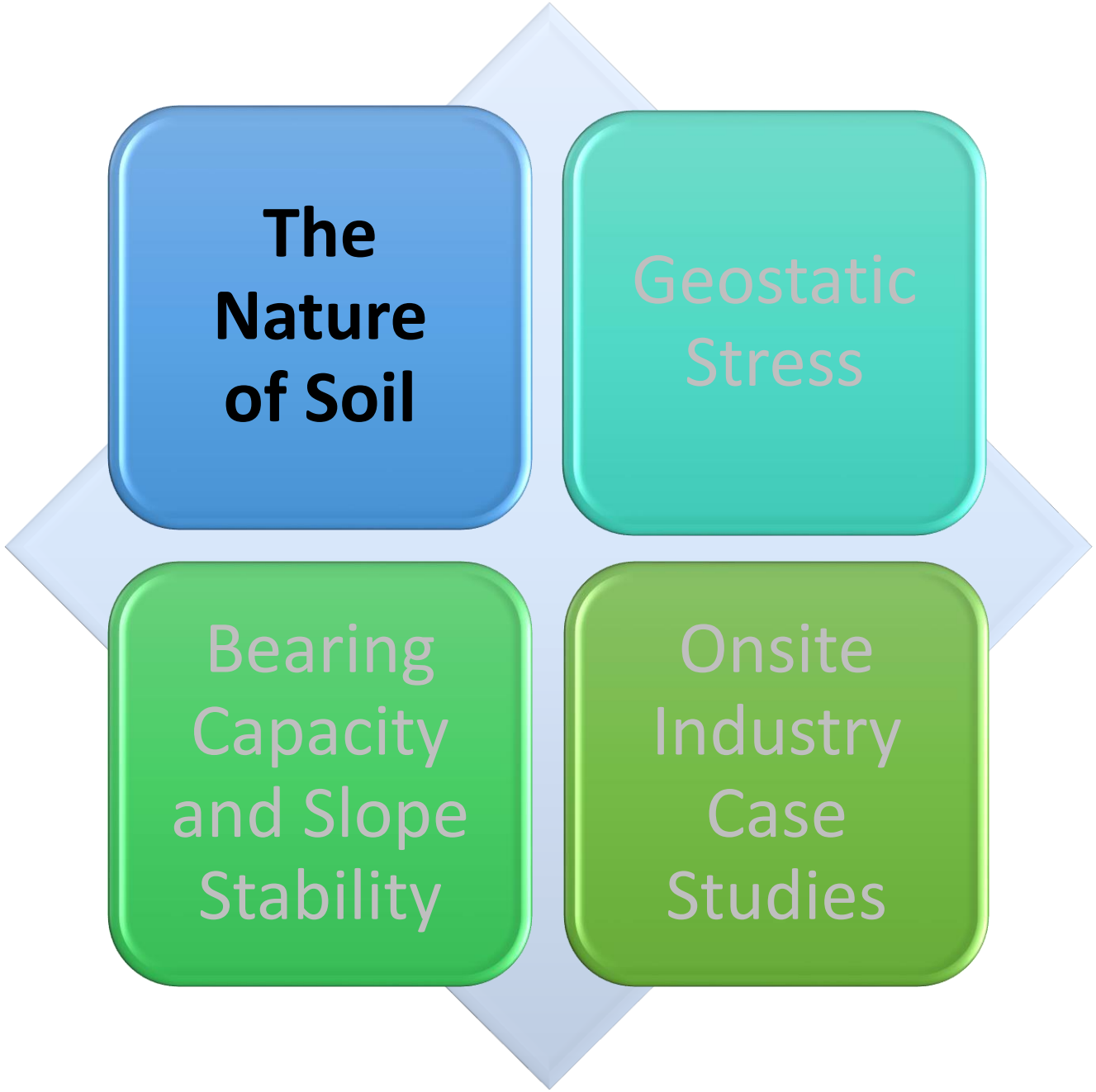
New York City Below Street Level

Worth Street reconstruction NYC - MFM Contracting Corp MFM Contracting Corp.

Thinking underground in three dimensions




The Nature of Soil
Geostatic Stress
Bearing Capacity and Slope Stability
Onsite Industry Case Studies


The Nature of Soil
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Onsite Industry Case Studies


Gravel
> 2 mm
Coarse Sand
0.2 to 2 mm
Fine Sand
0.02 to 0.2 mm
Silt
0.002 to 0.02 mm
Clay
< 0.002 mm

https://premierequestrian.com/horse-arena-footing/coarse-medium-fine-sand-795x500/?hcb=1

Angular sand

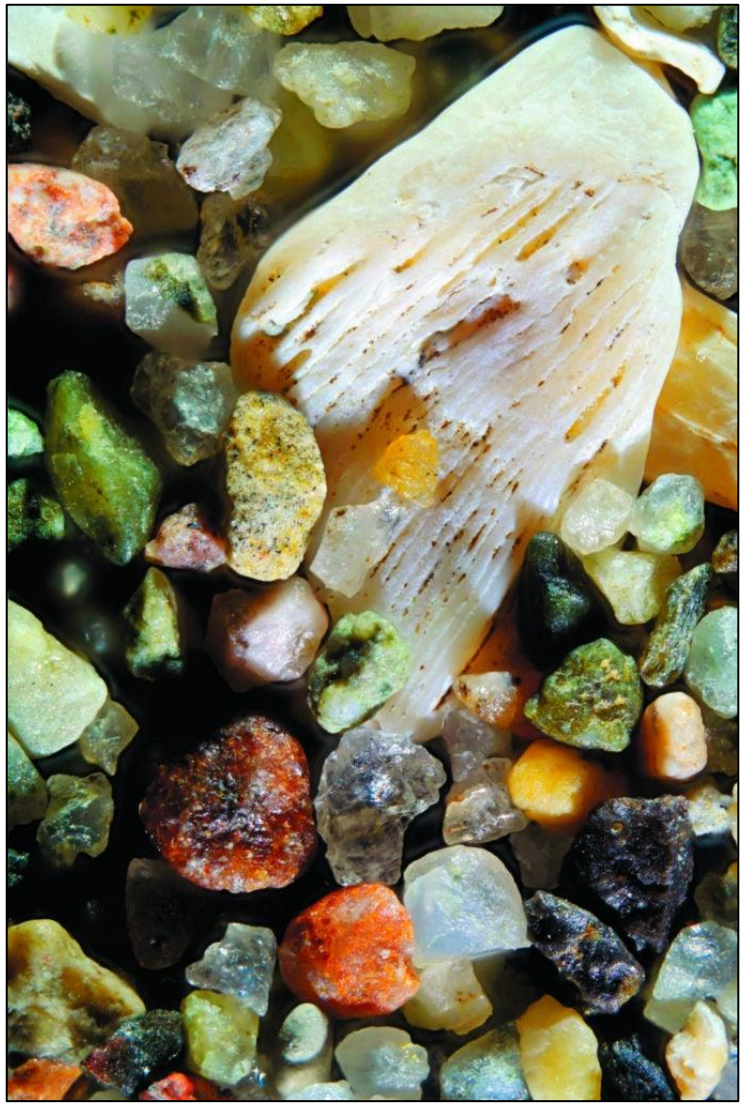
https://www.sandatlas.org/sand-that-remembers-the-rock-it-once-was/

Fine rounded sand

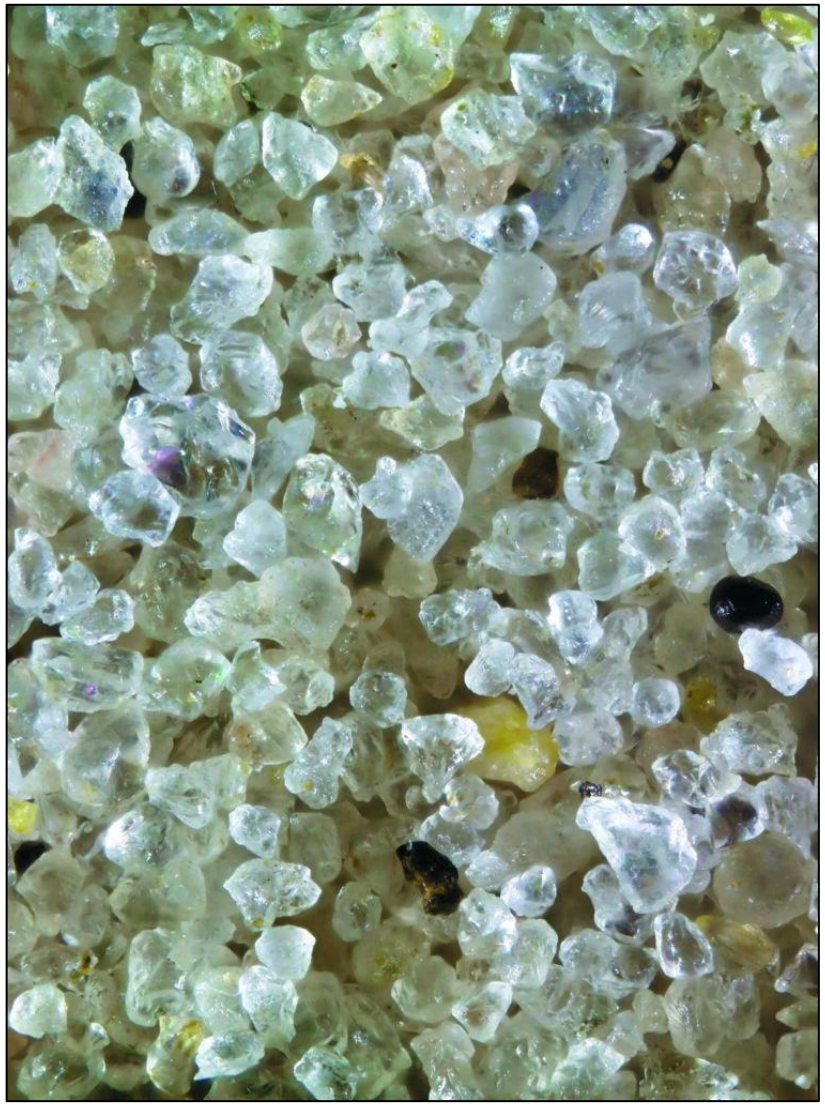
https://www.sandatlas.org/desert-sand/

Sand Particles

Puget Sound, WA



Hilton Head, SC



Great Salt Lake, UT

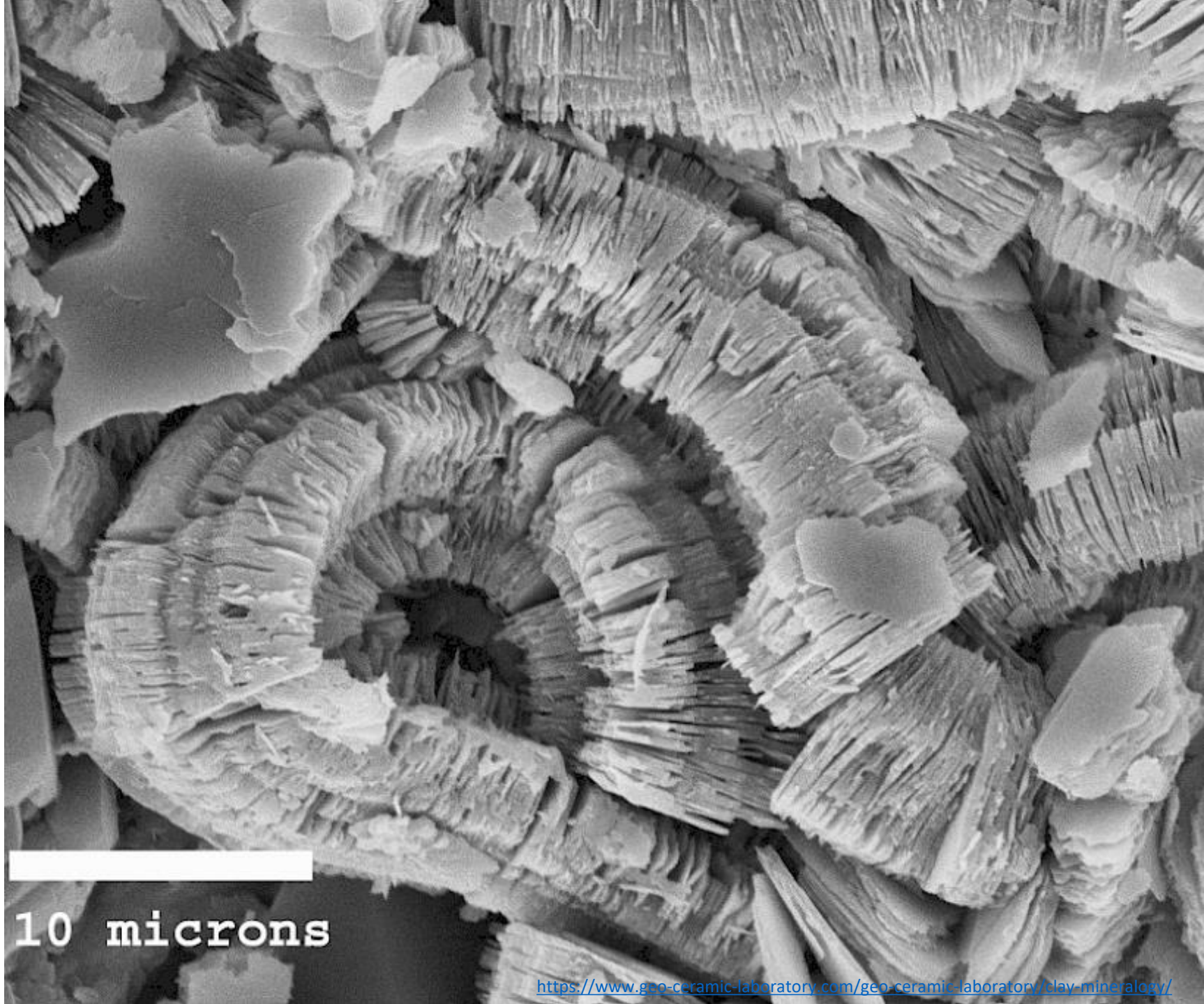
https://www.popsci.com/sand-like-youve-never-seen-it-before/

Kaolinite clay

Scanning electron microscope image

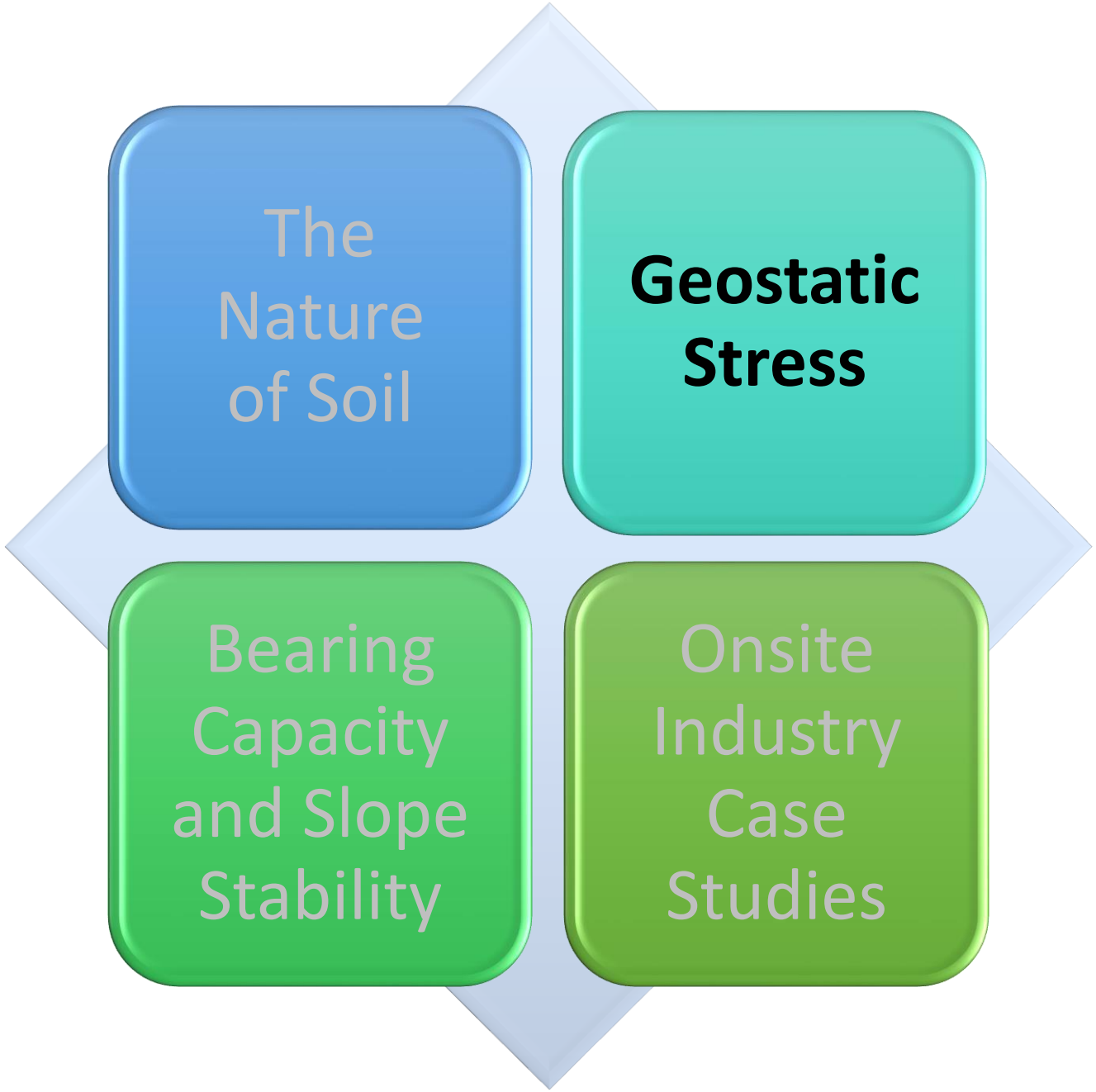
Particles are platy

Platy structure inhibits particle interlock



https://www.geo-ceramic-laboratory.com/geo-ceramic-laboratory/clay-mineralogy/

https://practicalselfreliance.com/making-clay/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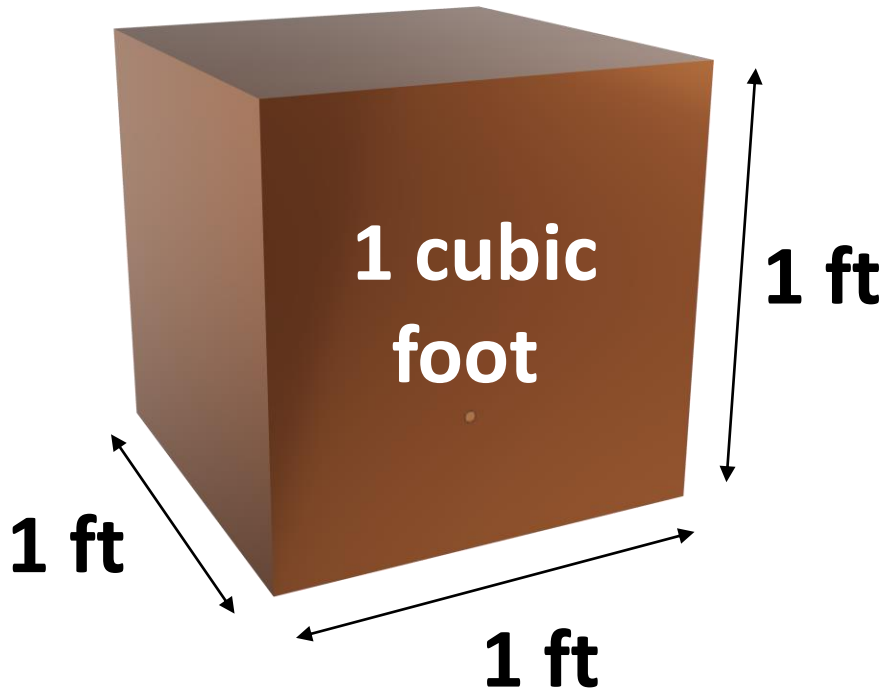
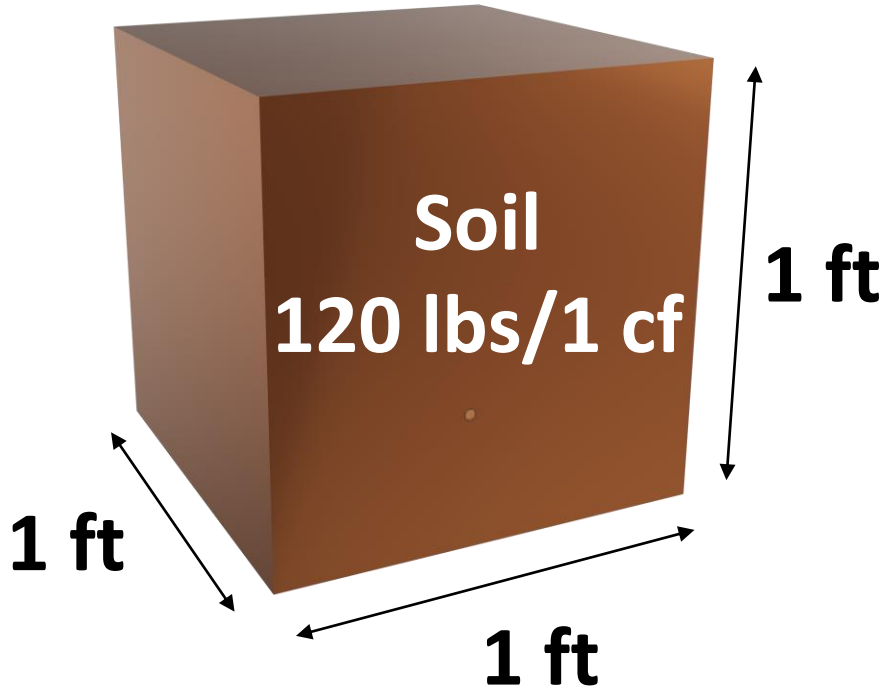
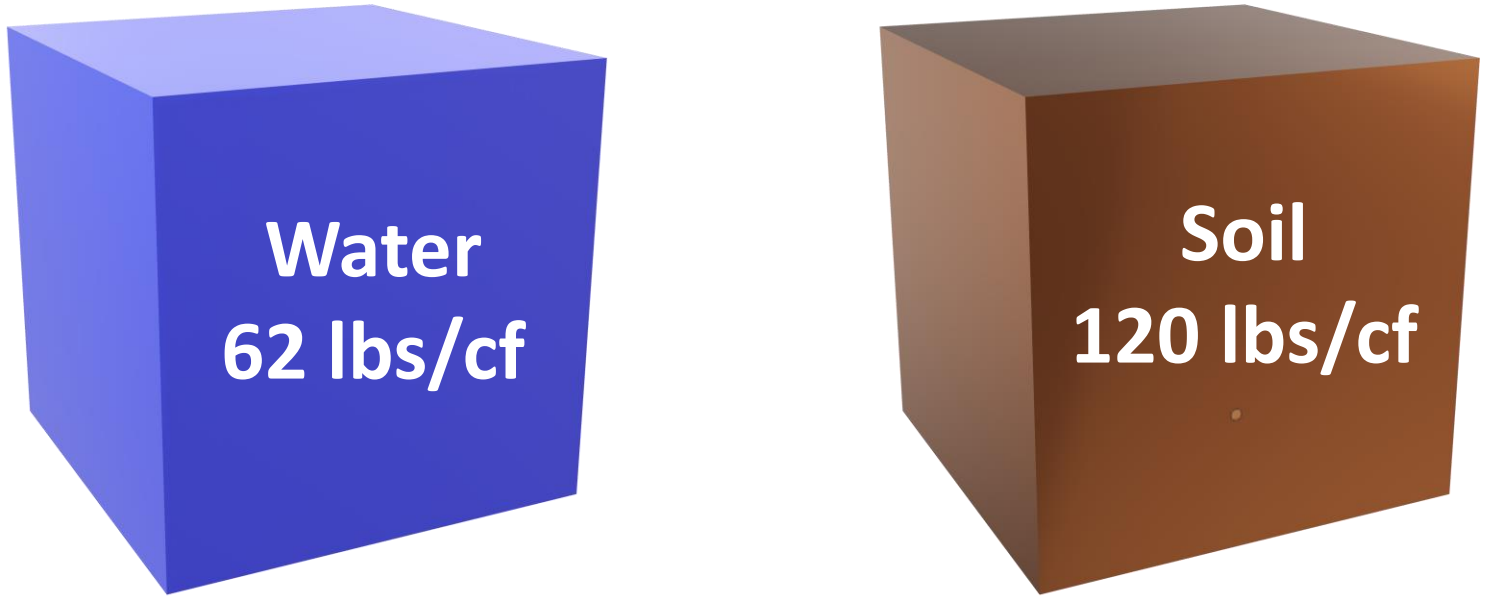

1 cubic foot
1 ft
1 ft
1 ft

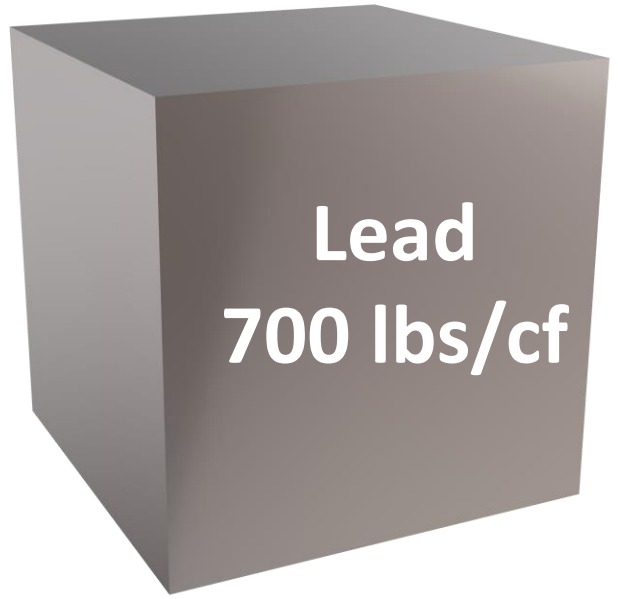

Soil
120 lbs/1 cf
1 ft
1 ft
1 ft

Water unit weight is about half that of soil



~0.5 times soil

Lead unit weight is almost 6 times greater than that of soil



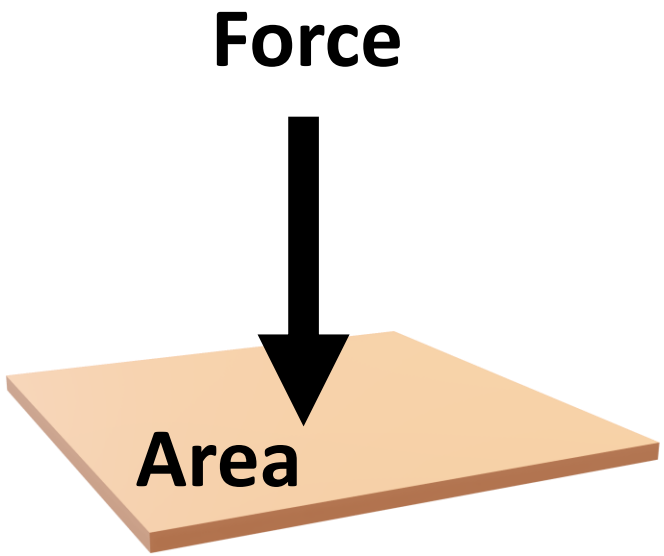
0.5 times soil

~6 times soil

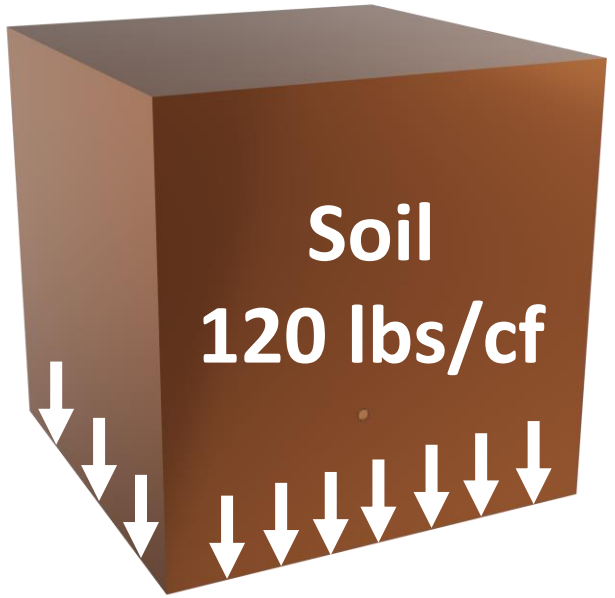
What is Stress?

Stress is force per unit area

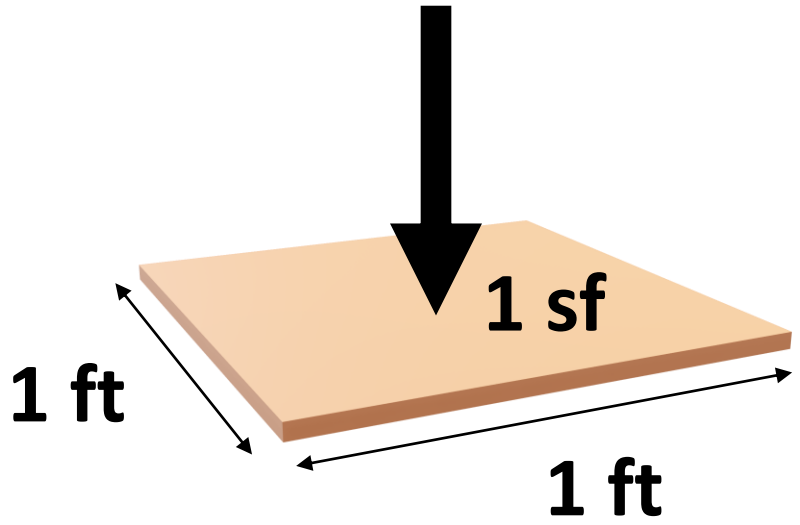
Stress = Force / Area



What is the stress at the base of a cubic foot of soil?



120 pounds of soil occupying one square foot of area

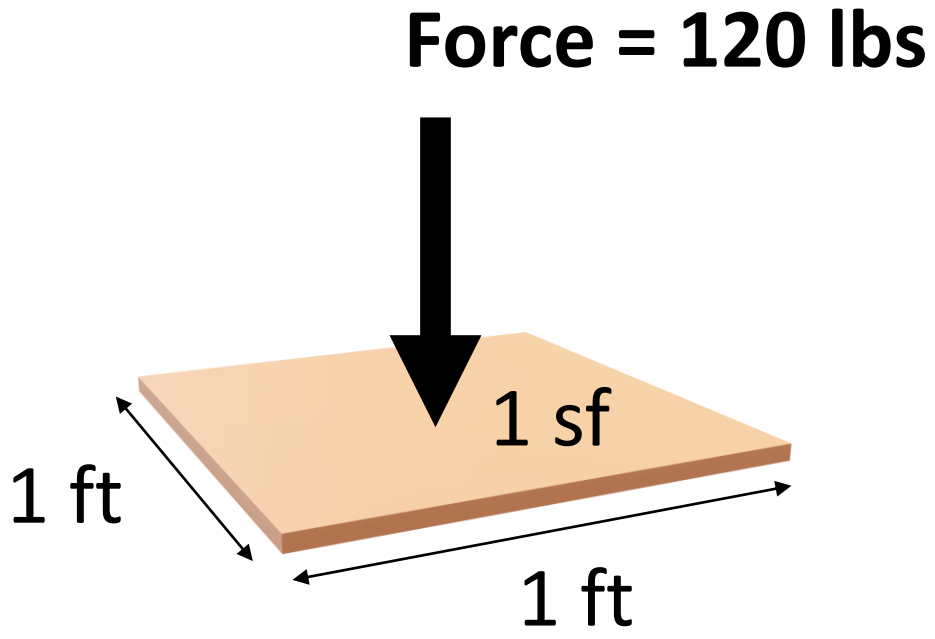


How to Calculate Vertical Geostatic Stress

Vertical geostatic stress = Force / Area

Vertical geostatic stress = 120 lbs / 1 sf

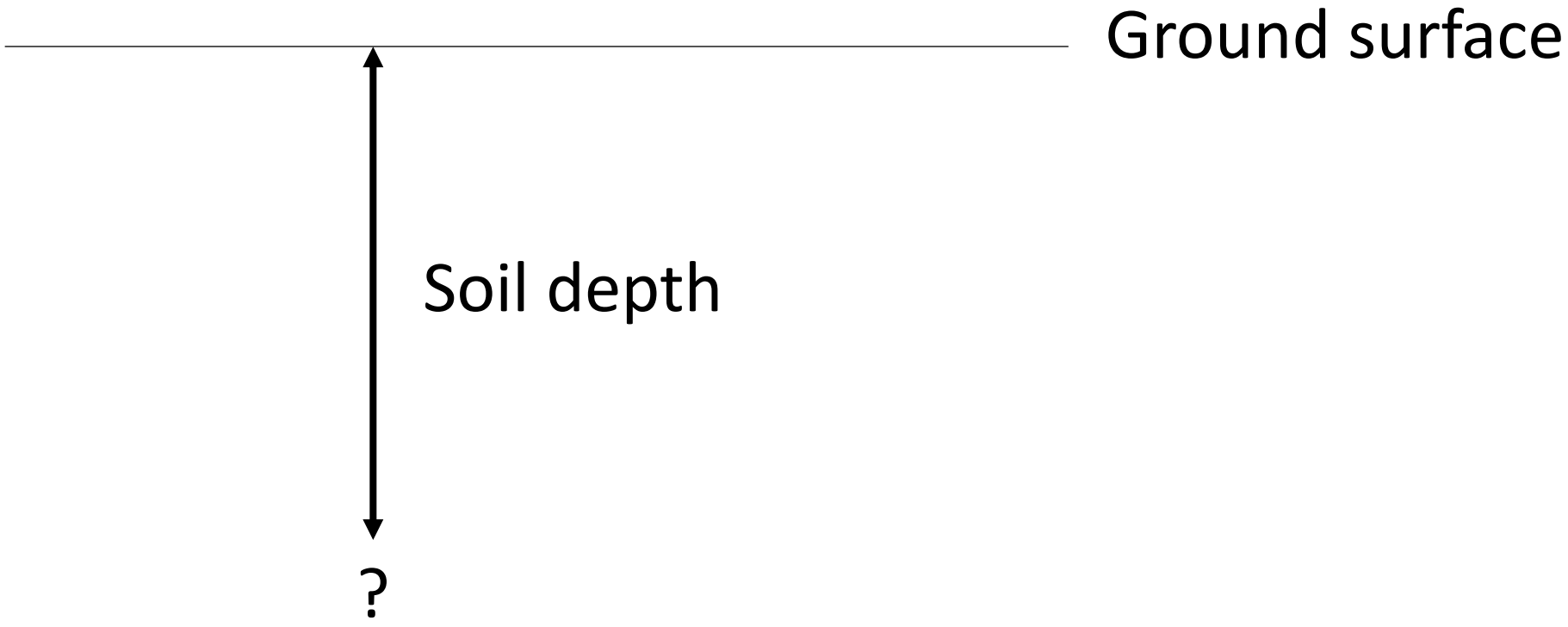
Vertical geostatic stress = <u>120 psf</u>



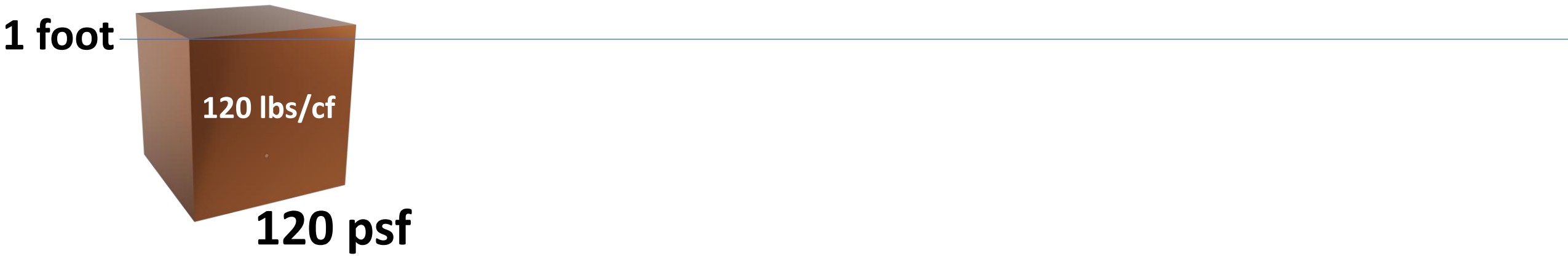
Area = 1 ft x 1 ft = 1 sf

How to Calculate Vertical Geostatic Stress at Depth

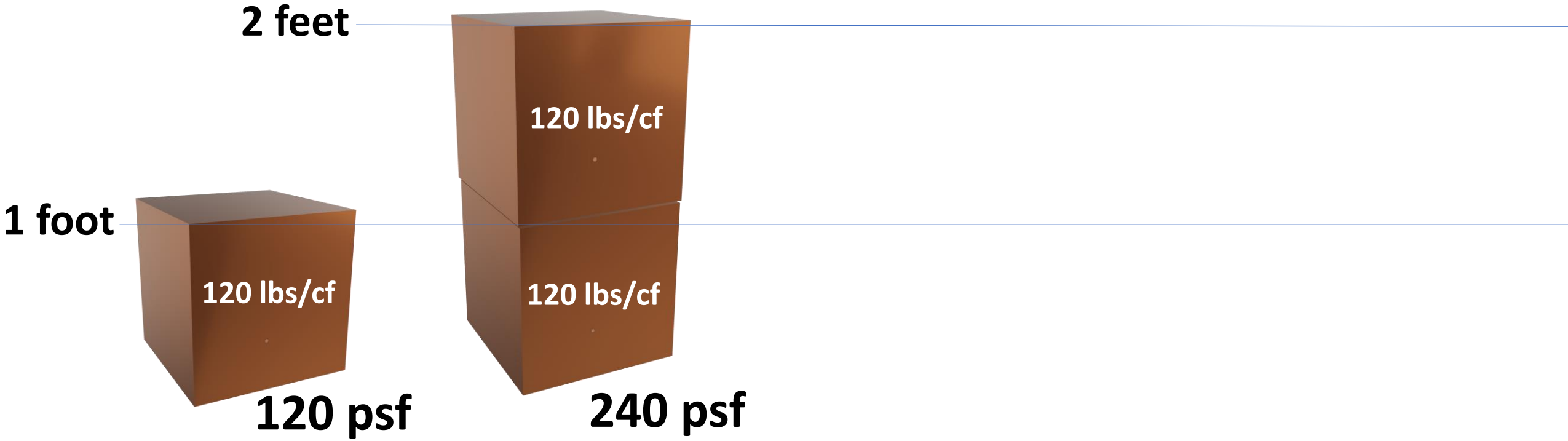
Vertical geostatic stress = Soil unit weight x depth of soil



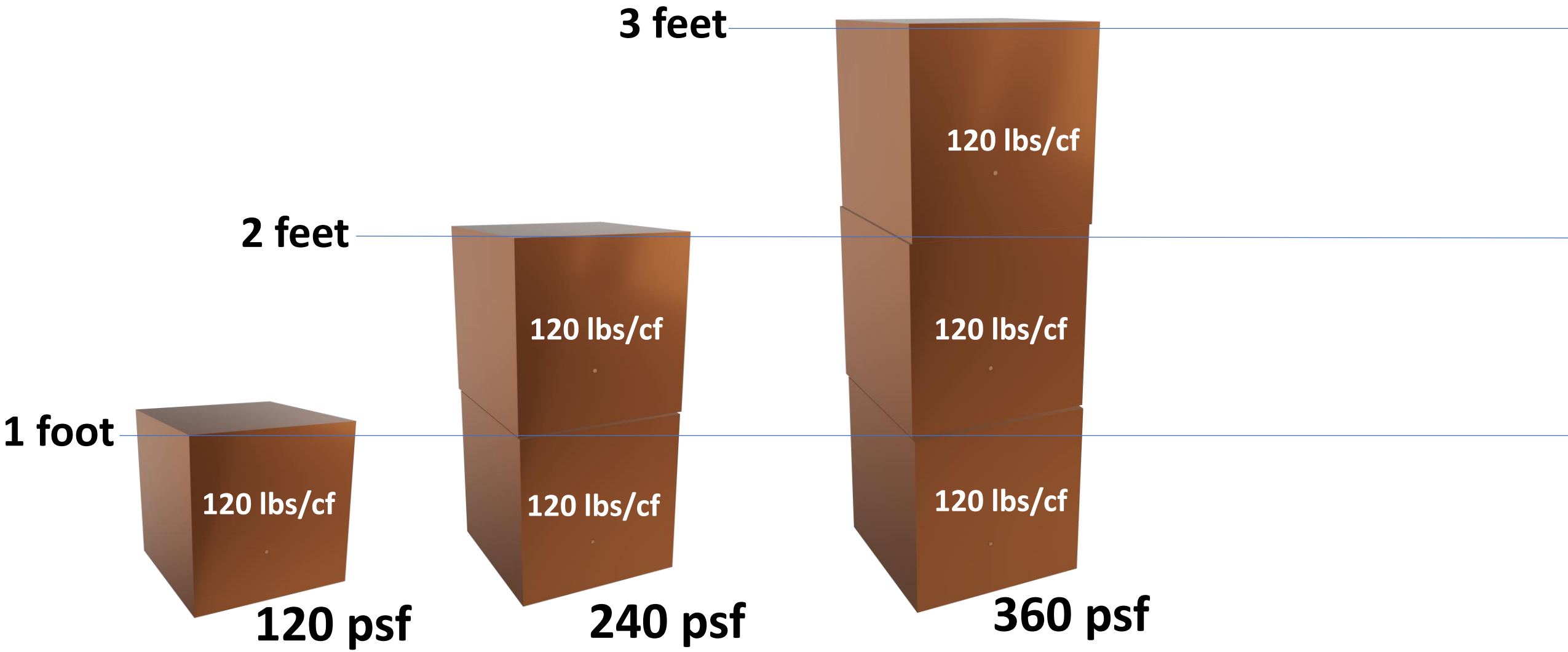
Vertical stress = 120 lbs/cf x 1 ft depth = 120 psf



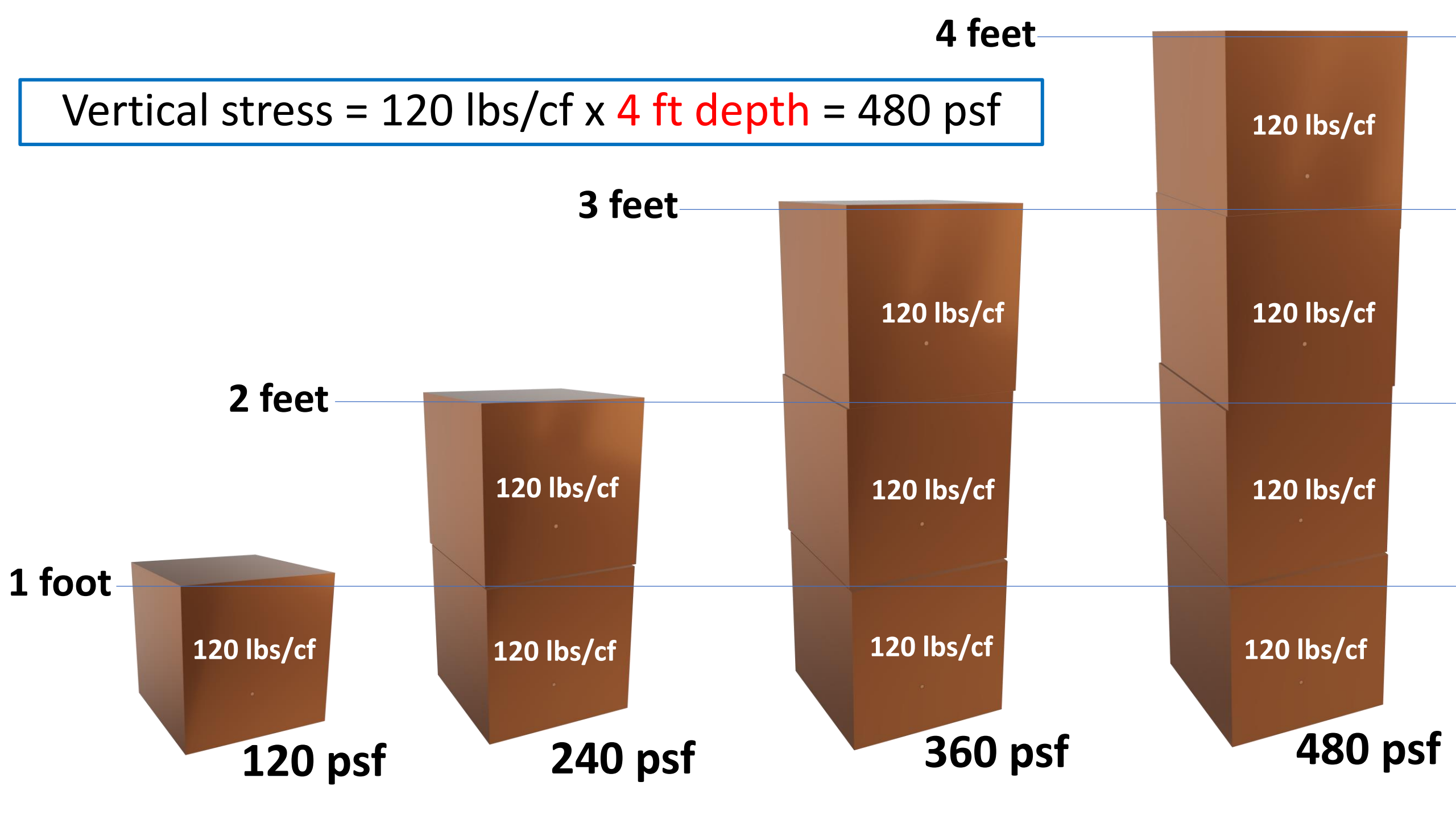
Vertical stress = 120 lbs/cf x 2 ft depth = 240 psf



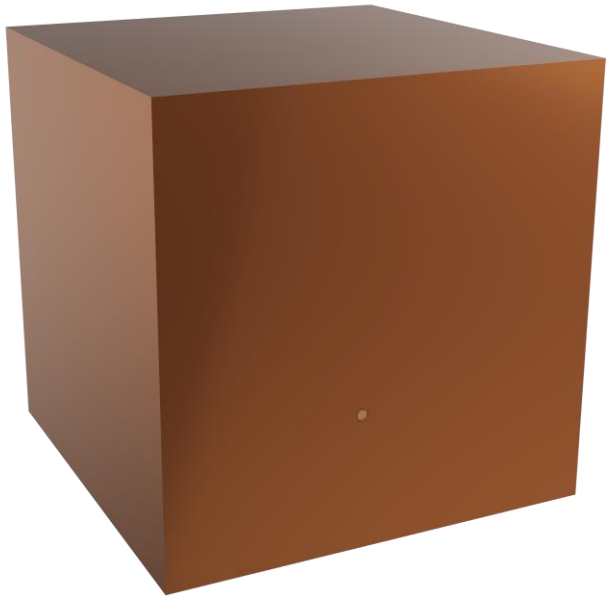
Vertical stress = 120 lbs/cf x 3 ft depth = 360 psf



Vertical stress = 120 lbs/cf x 4 ft depth = 480 psf



Is geostatic stress exerted the same in all directions?



Effect of Lateral Earth Pressure

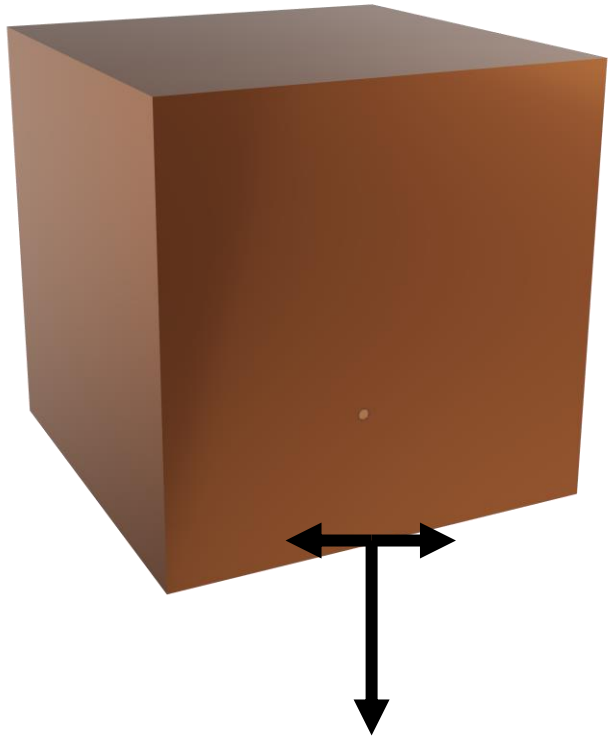
https://www.youtube.com/watch?v=PRHr_91qB74

Effect of Lateral Earth Pressure

Effect of Lateral Earth Pressure

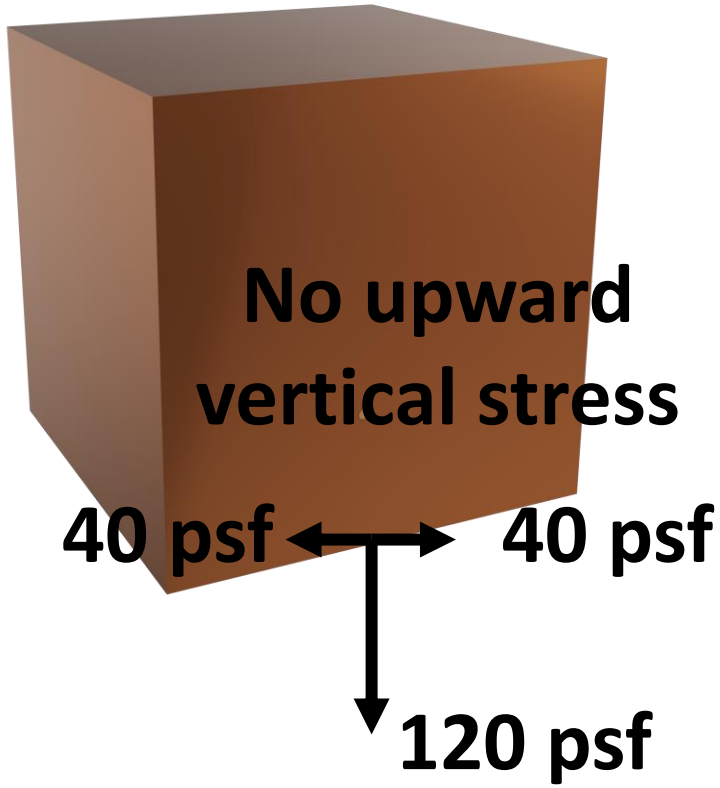
Geostatic stress is NOT the same in all directions

For granular soil, horizonal geostatic stress ~ $\frac{\text{Vertical stress}}{3}$

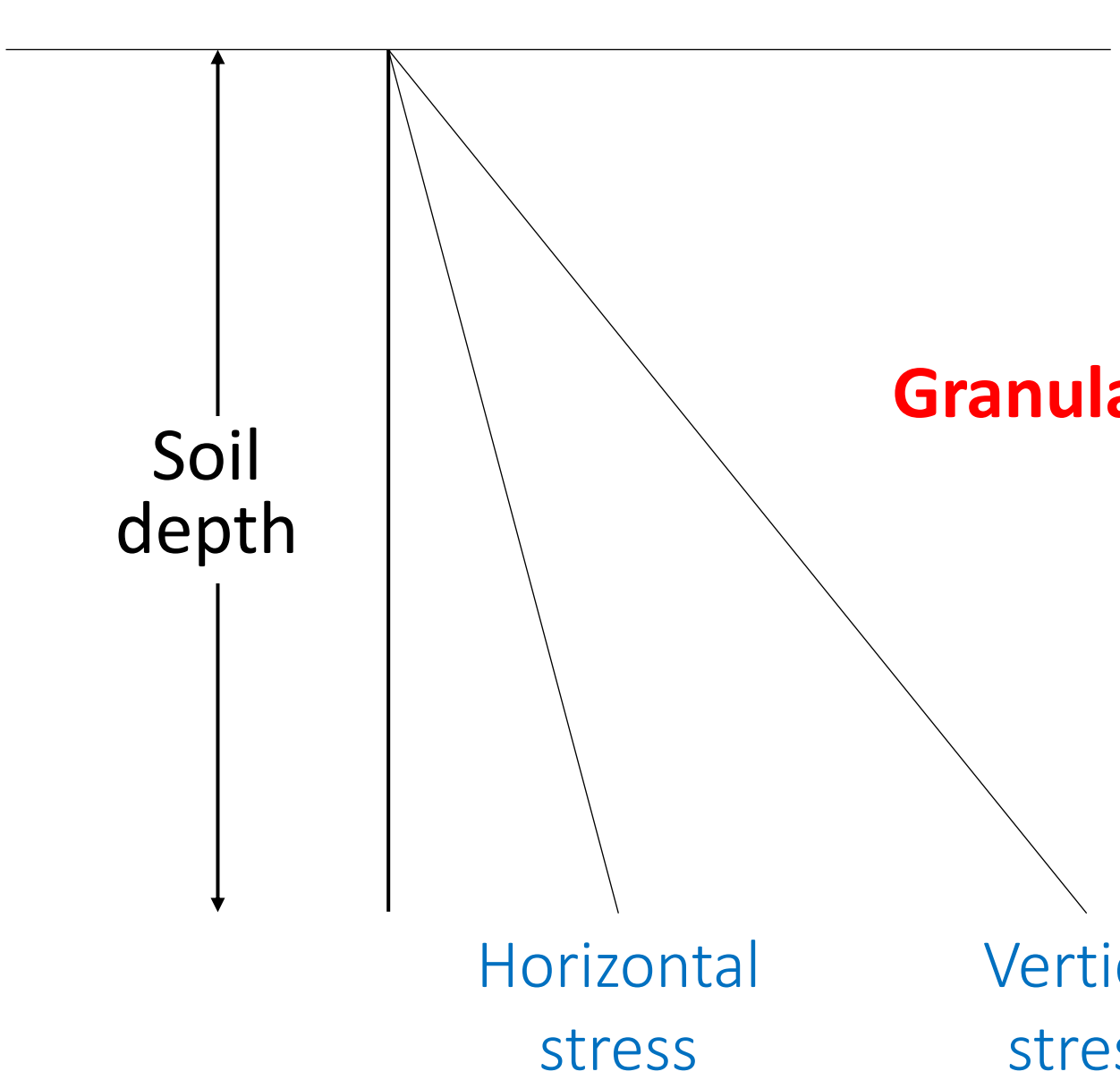


Geostatic stress is NOT the same in all directions

For granular soil, horizonal geostatic stress ~ $\frac{\text{Vertical stress}}{3}$

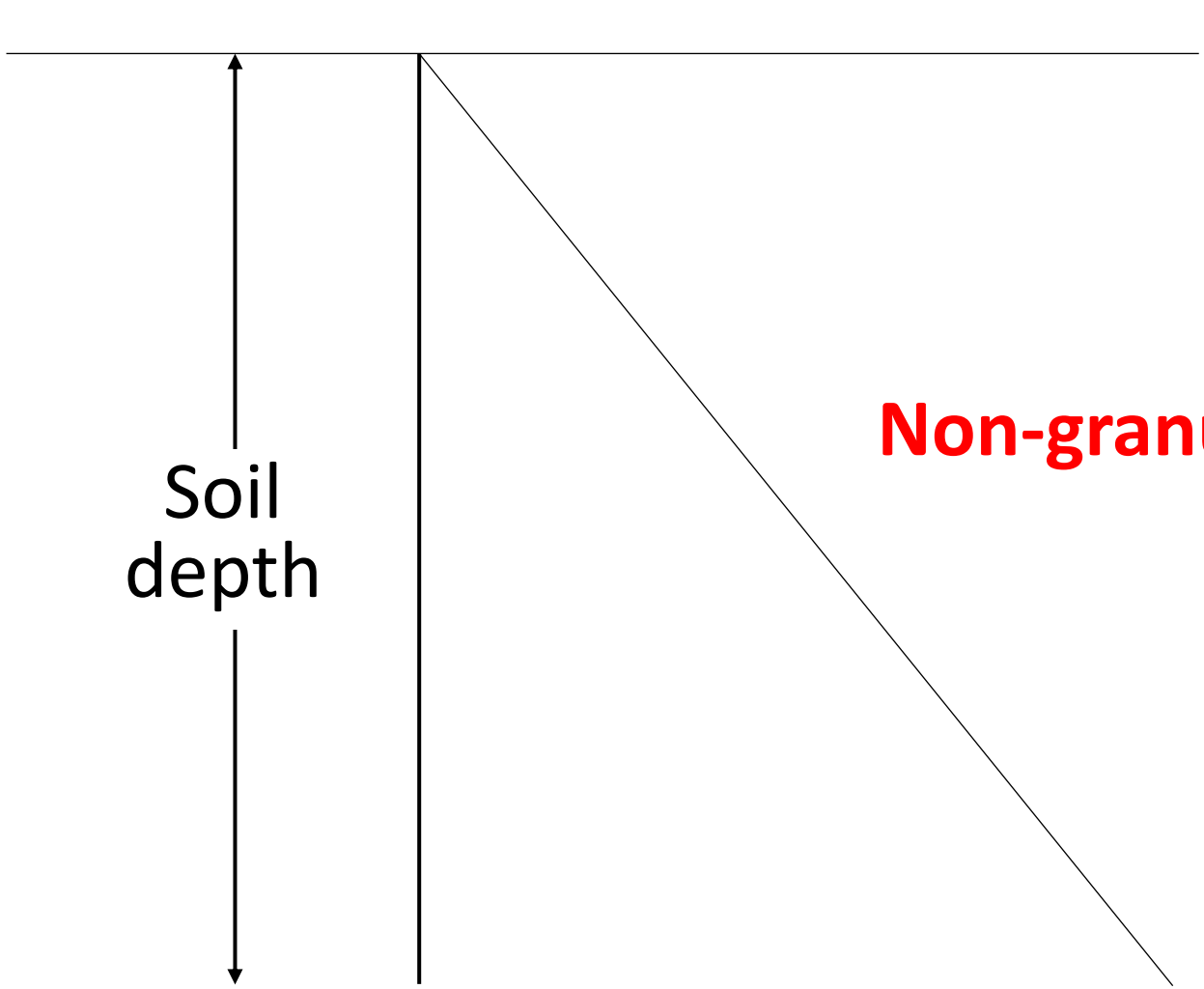


Geostatic Stress at Depth – Granular Soil



Granular soil

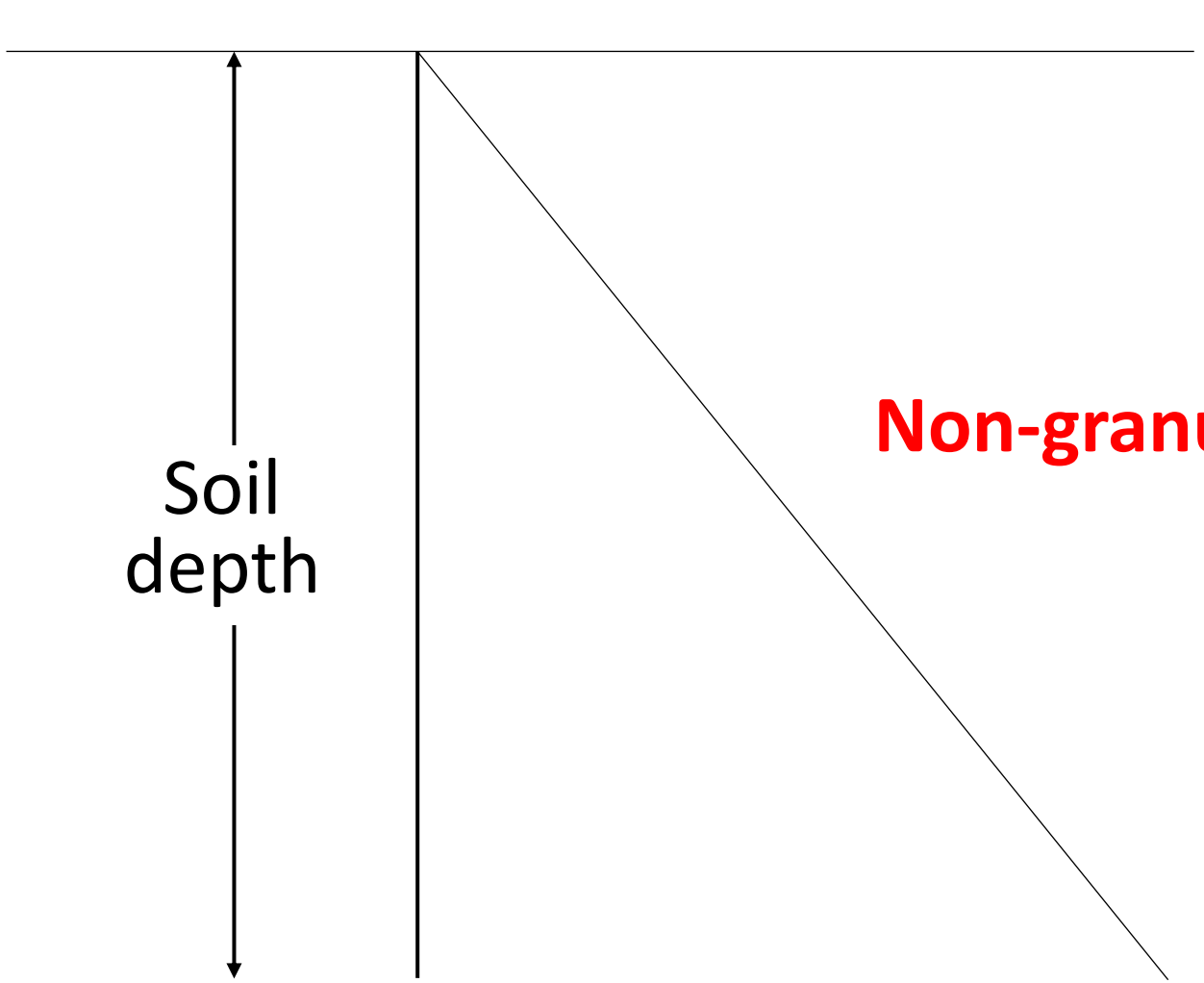
Geostatic Stress at Depth – Non-Granular Soil



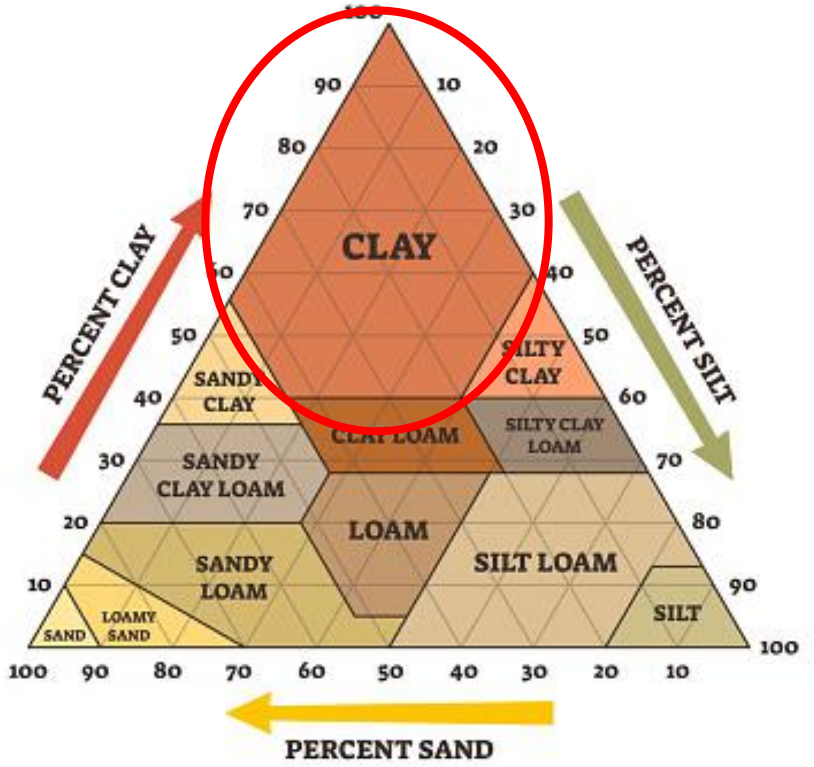
Non-granular soil

Horizontal stress = Vertical stress

Geostatic Stress at Depth – Non-Granular Soil



Non-granular soil



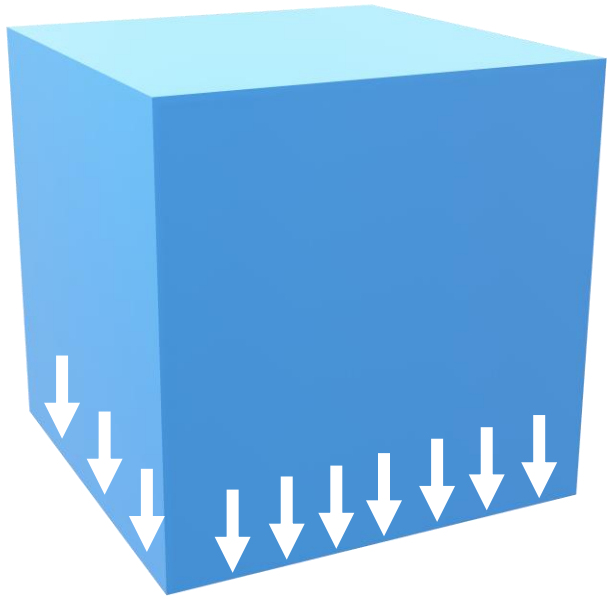
Horizontal stress = Vertical stress

Water pressure

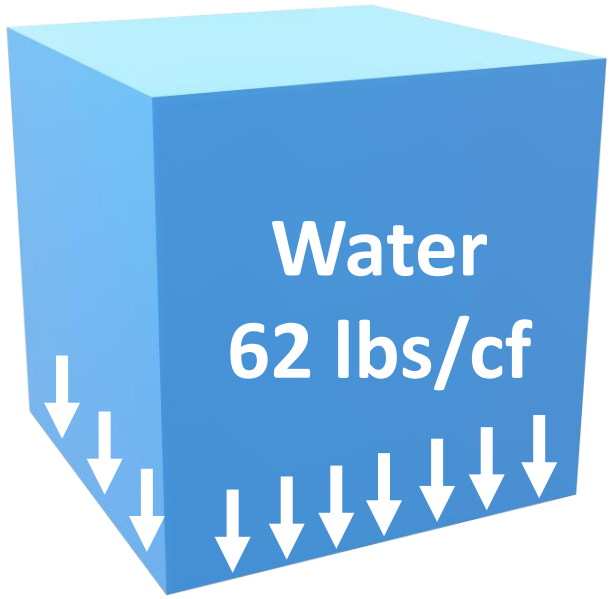
Home - Pool & Hot Tub Alliance (phta.org)

Hydrostatic stress = water pressure

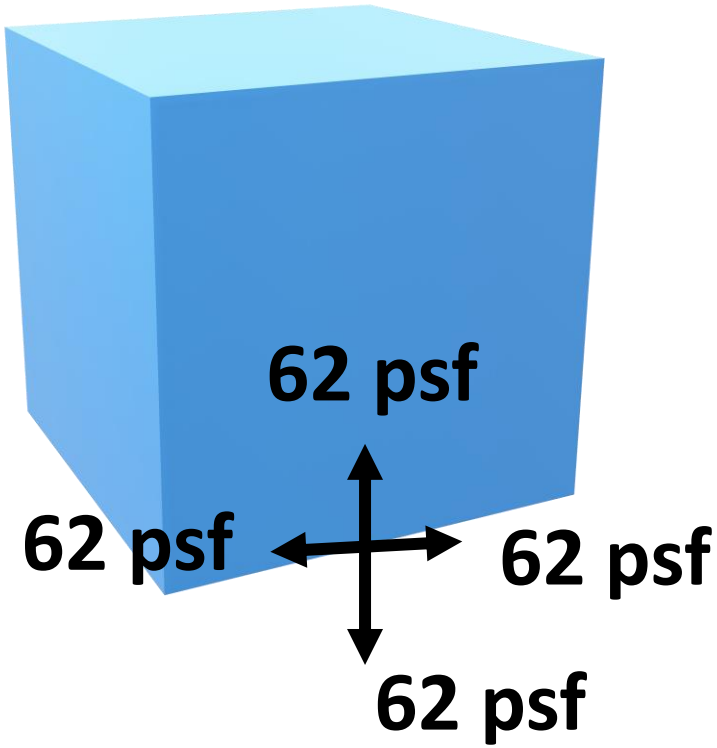
What is the hydrostatic stress at the base of a cubic foot of water?



Hydrostatic stress = 62 lbs/cf x 1 ft depth = 62 psf



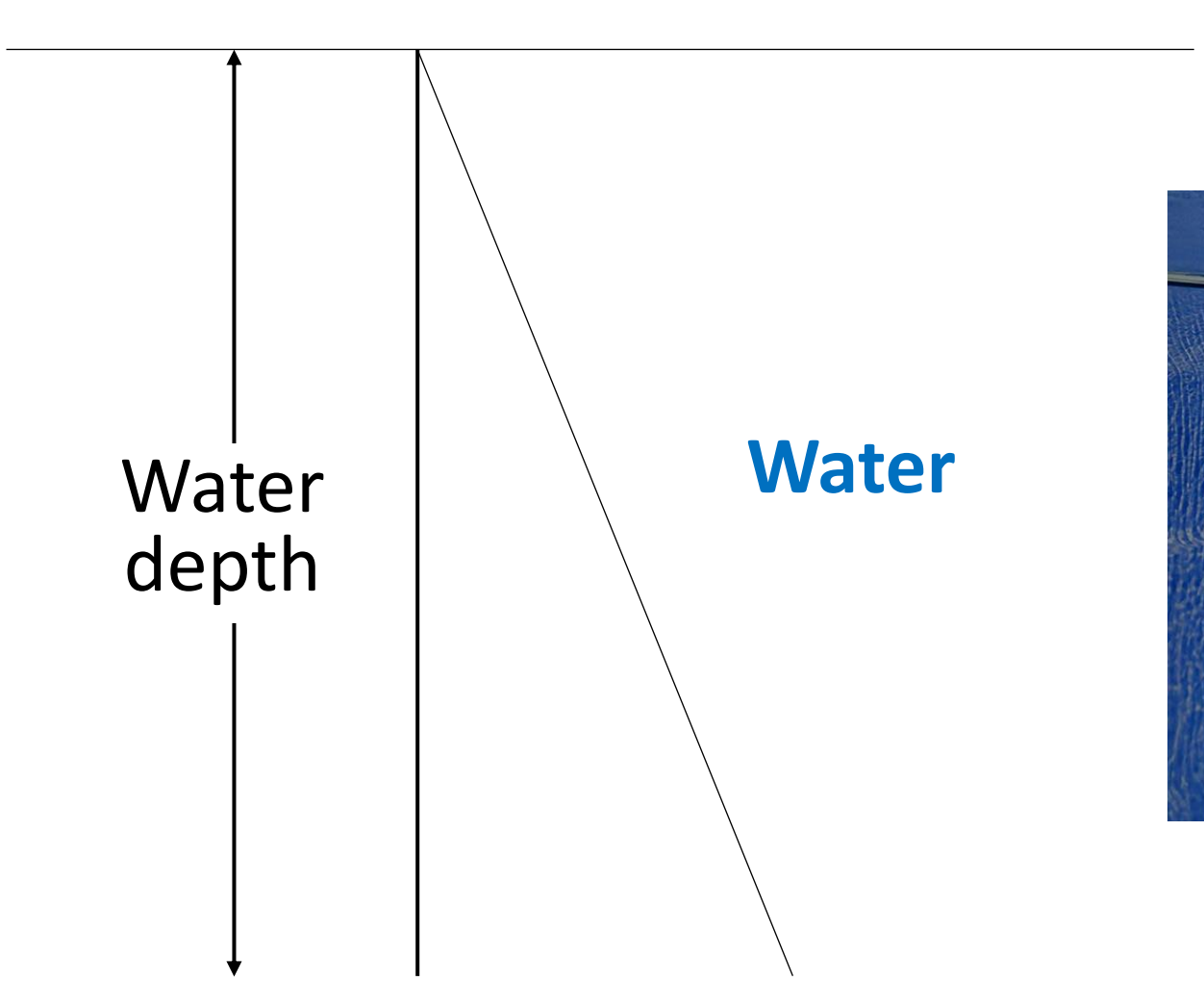
Hydrostatic stress is exerted equally in all directions

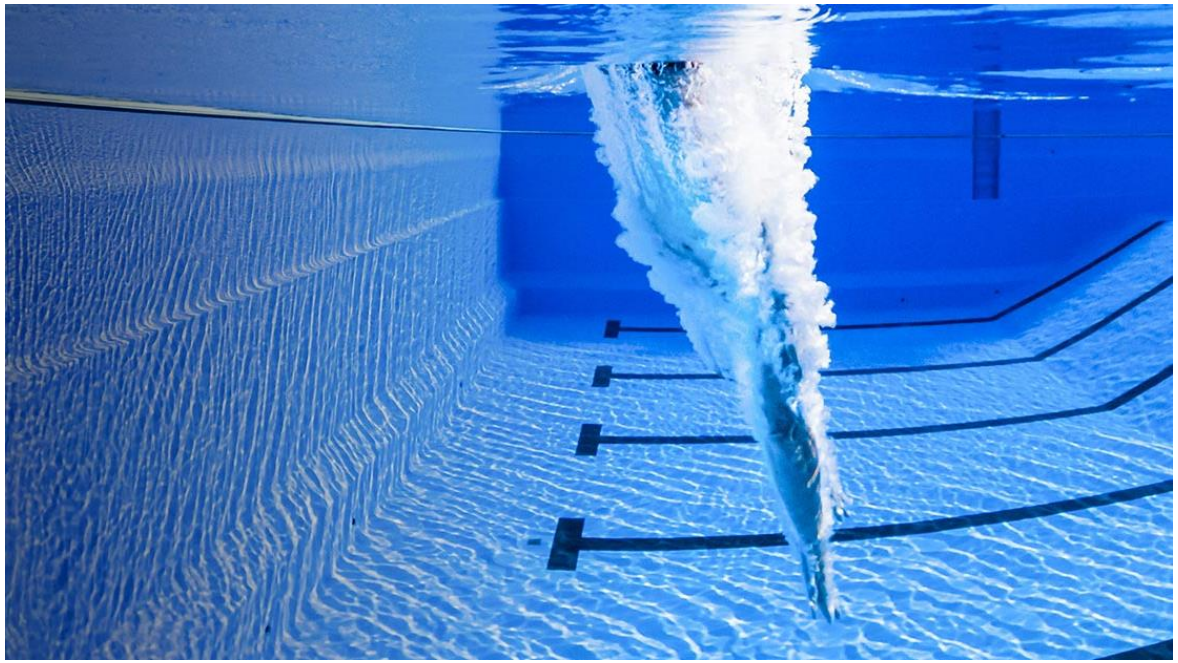


Water pressure

Home - Pool & Hot Tub Alliance (phta.org)

Hydrostatic Stress at Depth

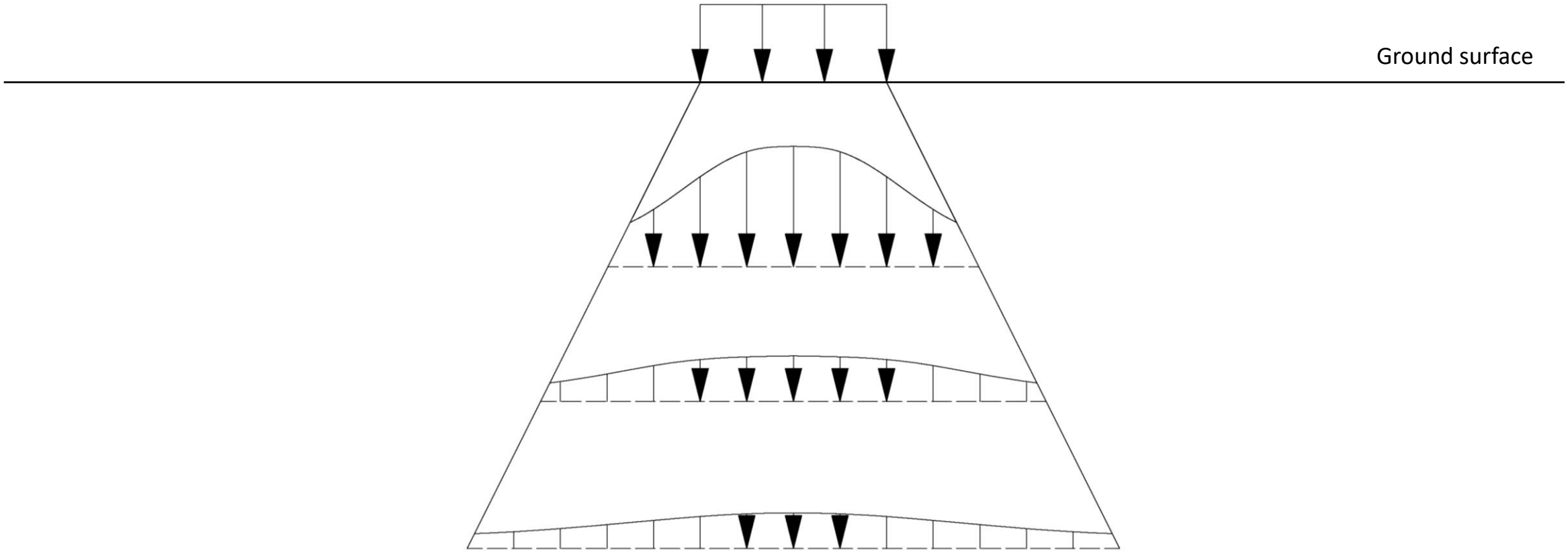




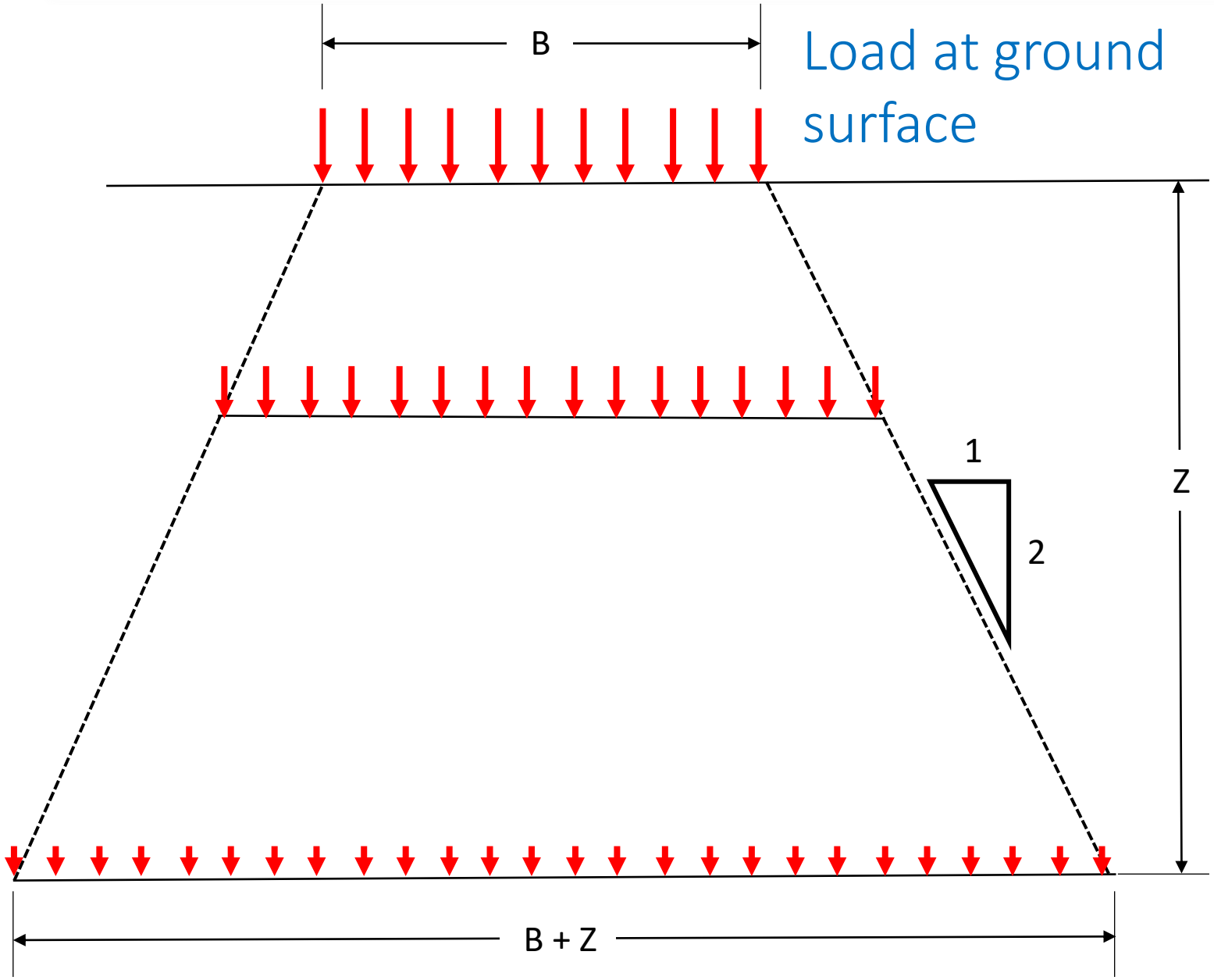
Horizontal stress = Vertical stress

Soil Stress with Depth

Equipment Load
Example: Wheel



2:1 Method for Estimating Vertical Stress at Depth

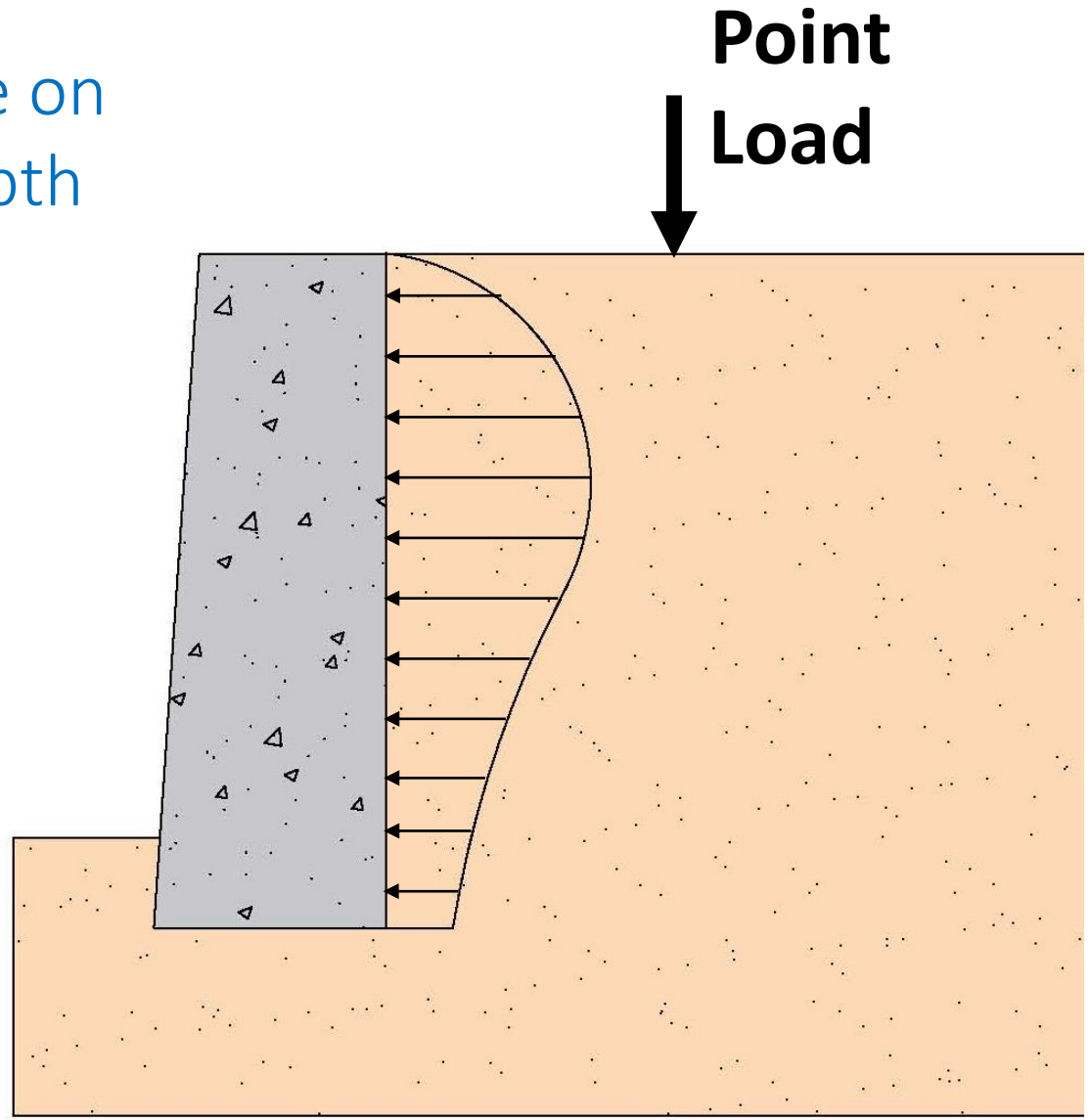


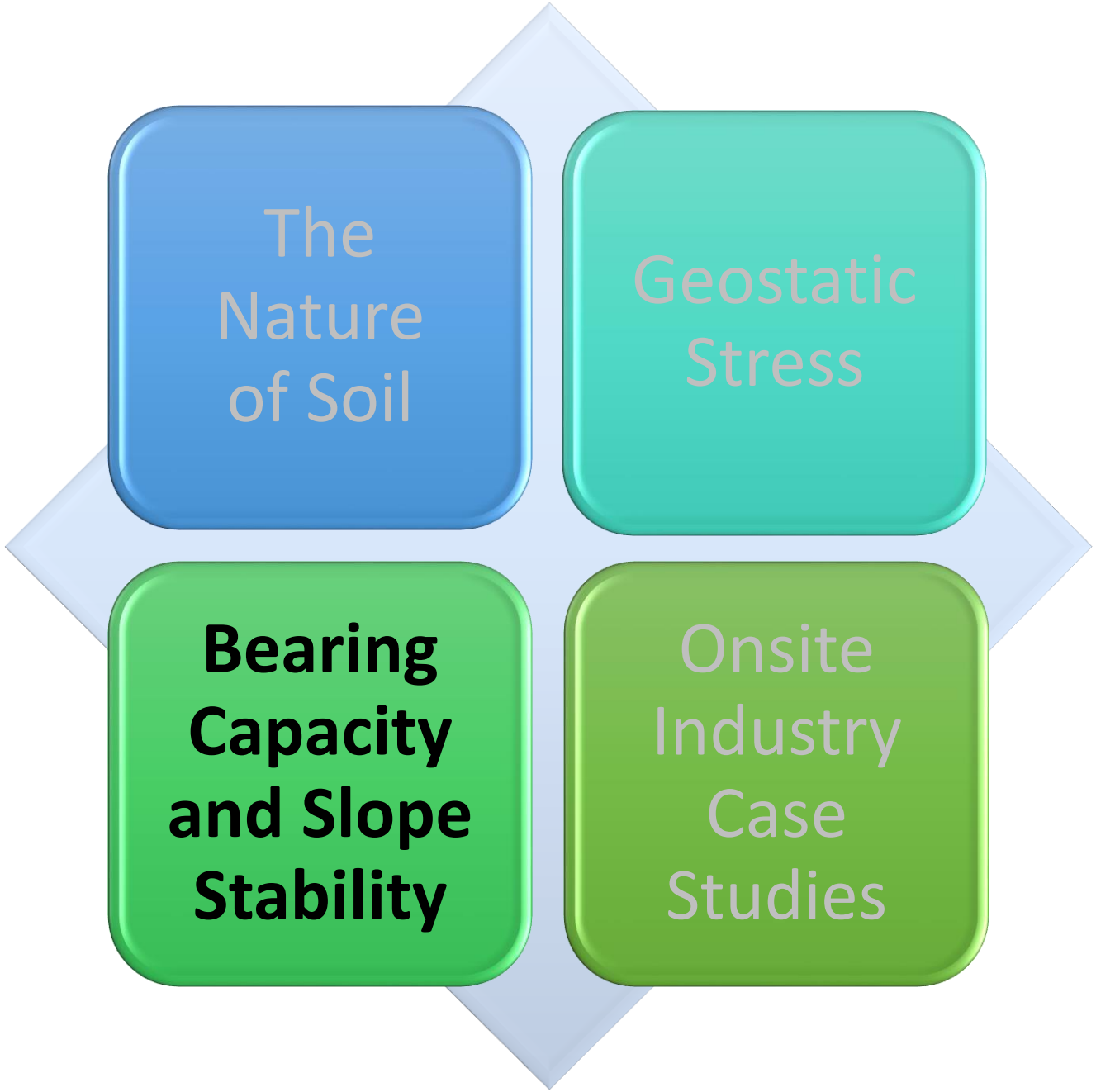
Assume: Square load at ground surface

Depth (Z)	Width (B+Z)	Stress Reduction at Z
0	B	0%
B	2B	50%
2B	3B	67%
3B	4B	75%

Horizontal Stress at Depth Due to Point Load

Horizontal pressure on wall varies with depth

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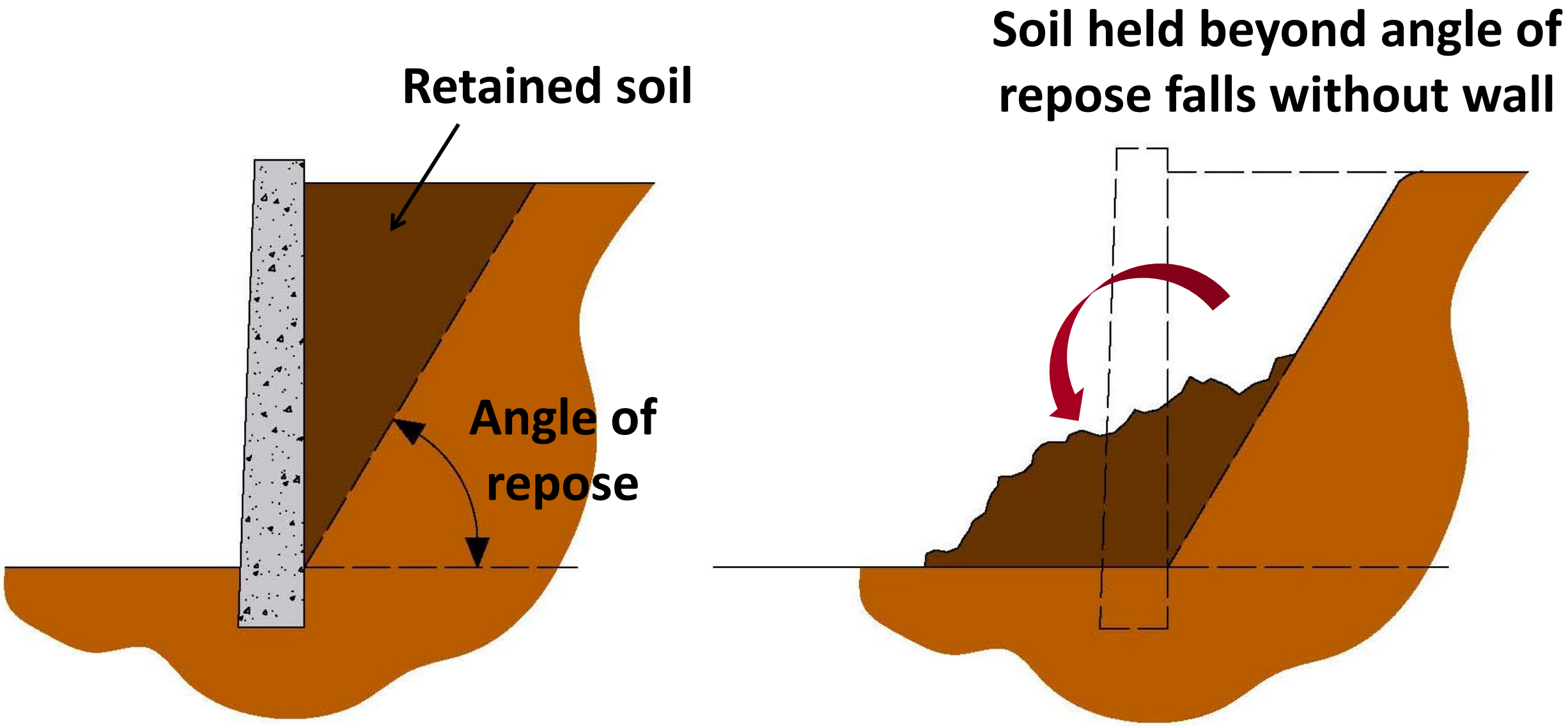
Soil Angle of Repose

Steepest angle of descent relative to the horizontal plane to which a material can be piled without slumping

https://stock.adobe.com/images/isolated-sand-pile-of-fine-light-yellow-sand-isolated-on-white-background/28787455

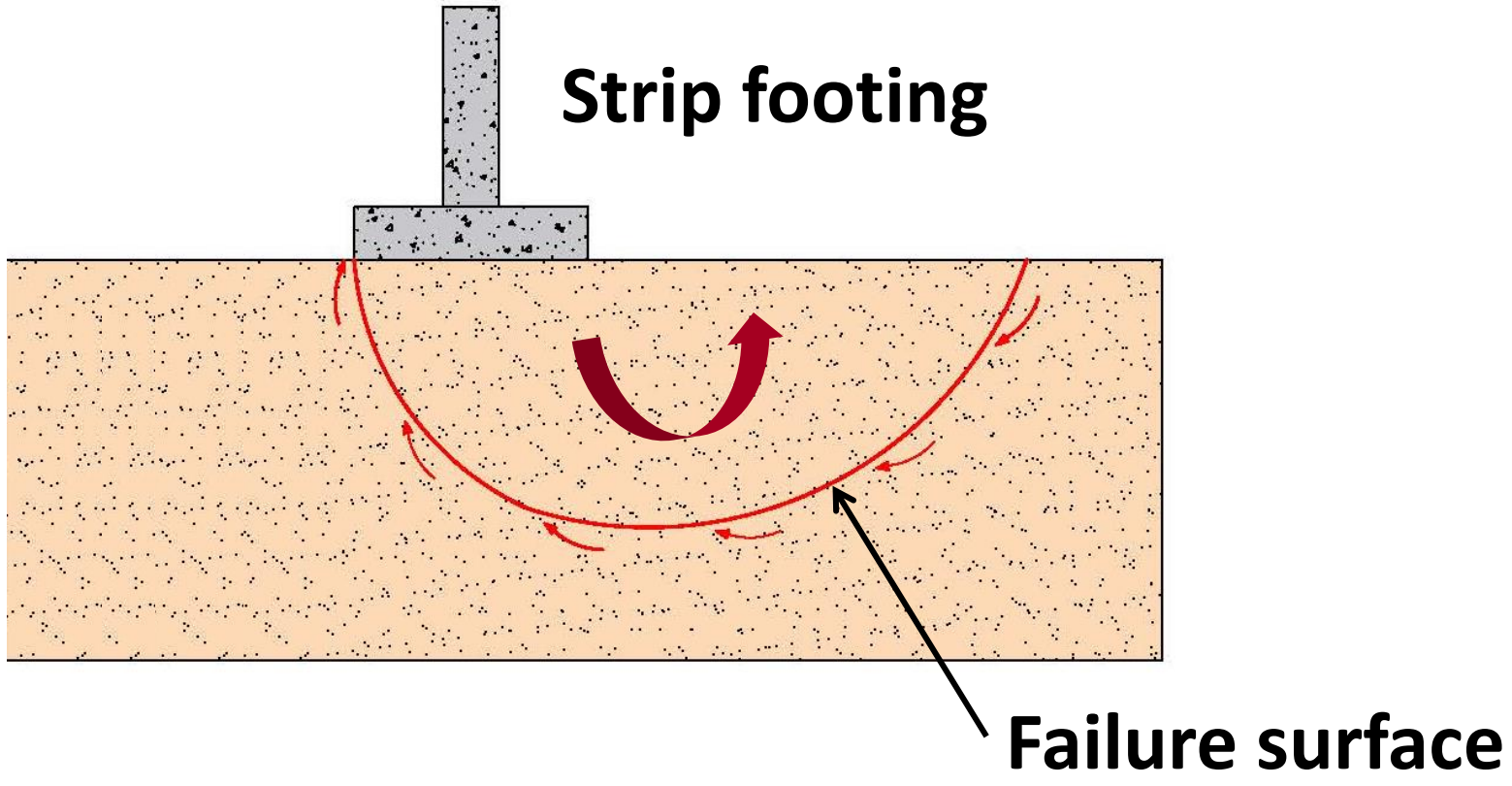
Soil Angle of Repose



https://sites.google.com/site/metroforensics3/causes-of-retaining-wall-failure-or-collapse

Shear Failure

Soil generally fails in shear along a surface



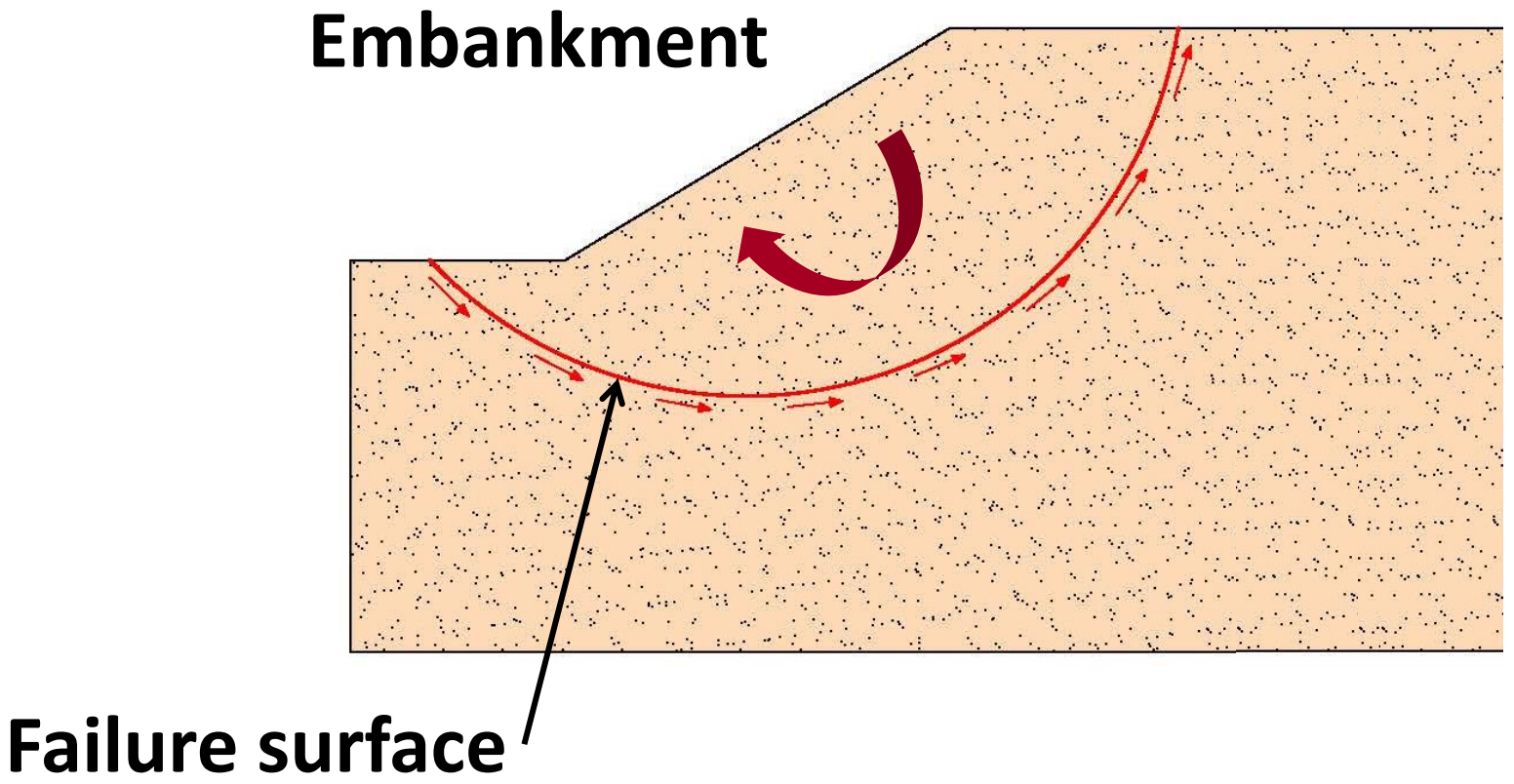
Manitoba - Transcona Grain Elevator

http://www.mhs.mb.ca/docs/sites/northtranscona elevator.shtml
https://apps.peer.berkeley.edu/publications/turkey/adapazari/phase1/site_b/site_b_ph_3_high.jpg

Grain Elevator Weight Exceeds Soil Strength

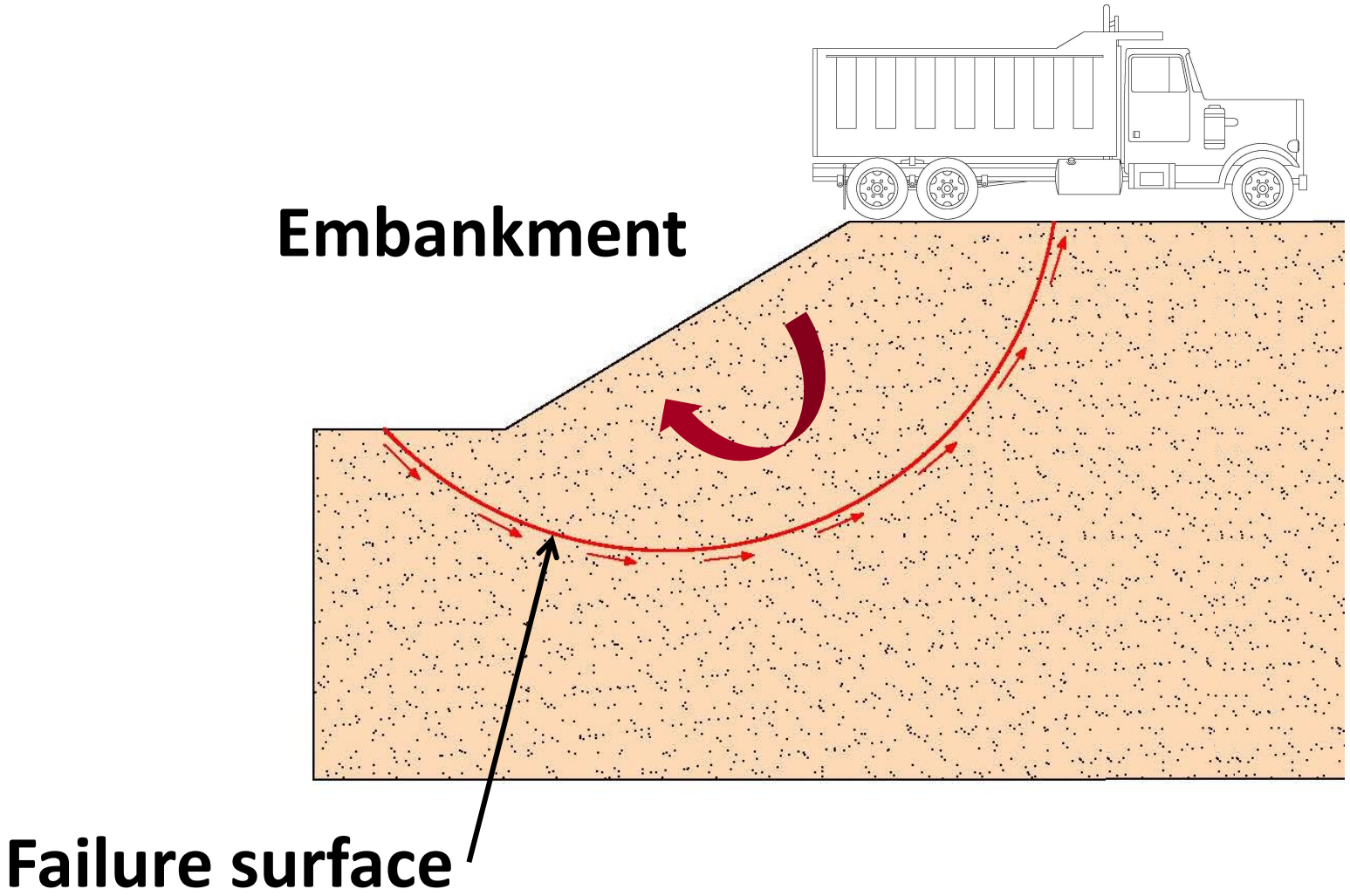
Shear Failure

Soil generally fails in shear along a surface



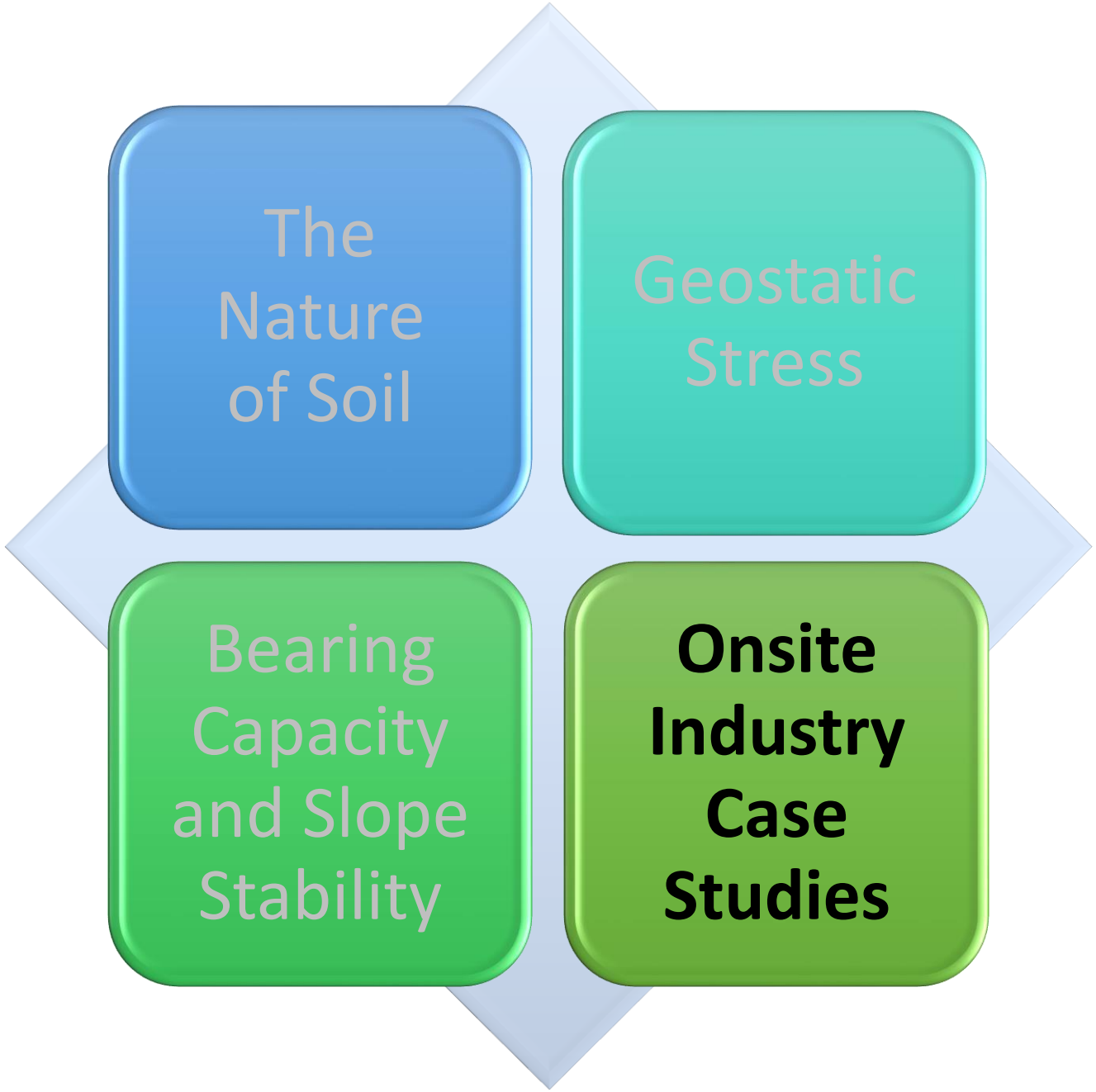
Shear Failure

Soil generally fails in shear along a surface



Slope Failure

https://support.goldsim.com/hc/en-us/articles/360048832194-May-2020-Reliability-of-an-Embankment-Dam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Soil Particle Behavior

Subsurface Structures

Buried Tanks

Slope Stability

Onsite Industry Case Studies

Soil Particle Behavior

Subsurface Structures

Buried Tanks

Slope Stability

Soil Particle Behavior Case Study 1: Chamber Installation Procedures

Angular sand

https://www.sandatlas.org/sand-that-remembers-the-rock-it-once-was/

Fine rounded sand

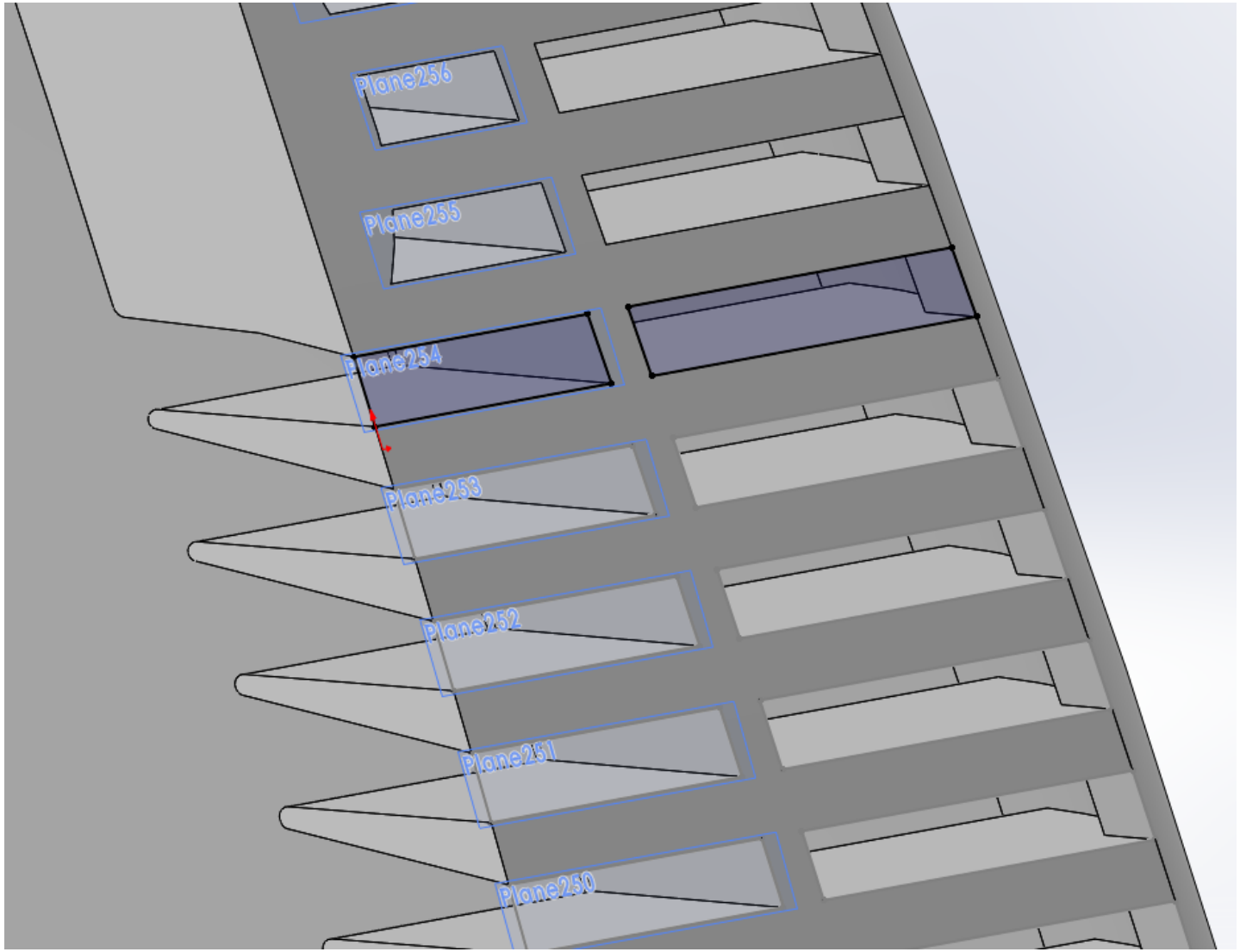
https://www.sandatlas.org/desert-sand/

Chamber Installation

Louvered Sidewall

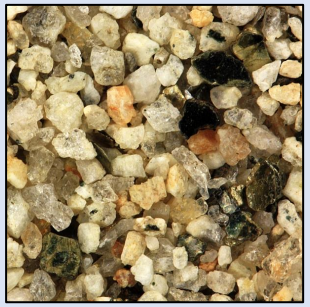
Chamber Installation

Typical Louvered Sidewall



“Walking in” chamber sidewall backfill

Situation: Angular particles with varying size and shape



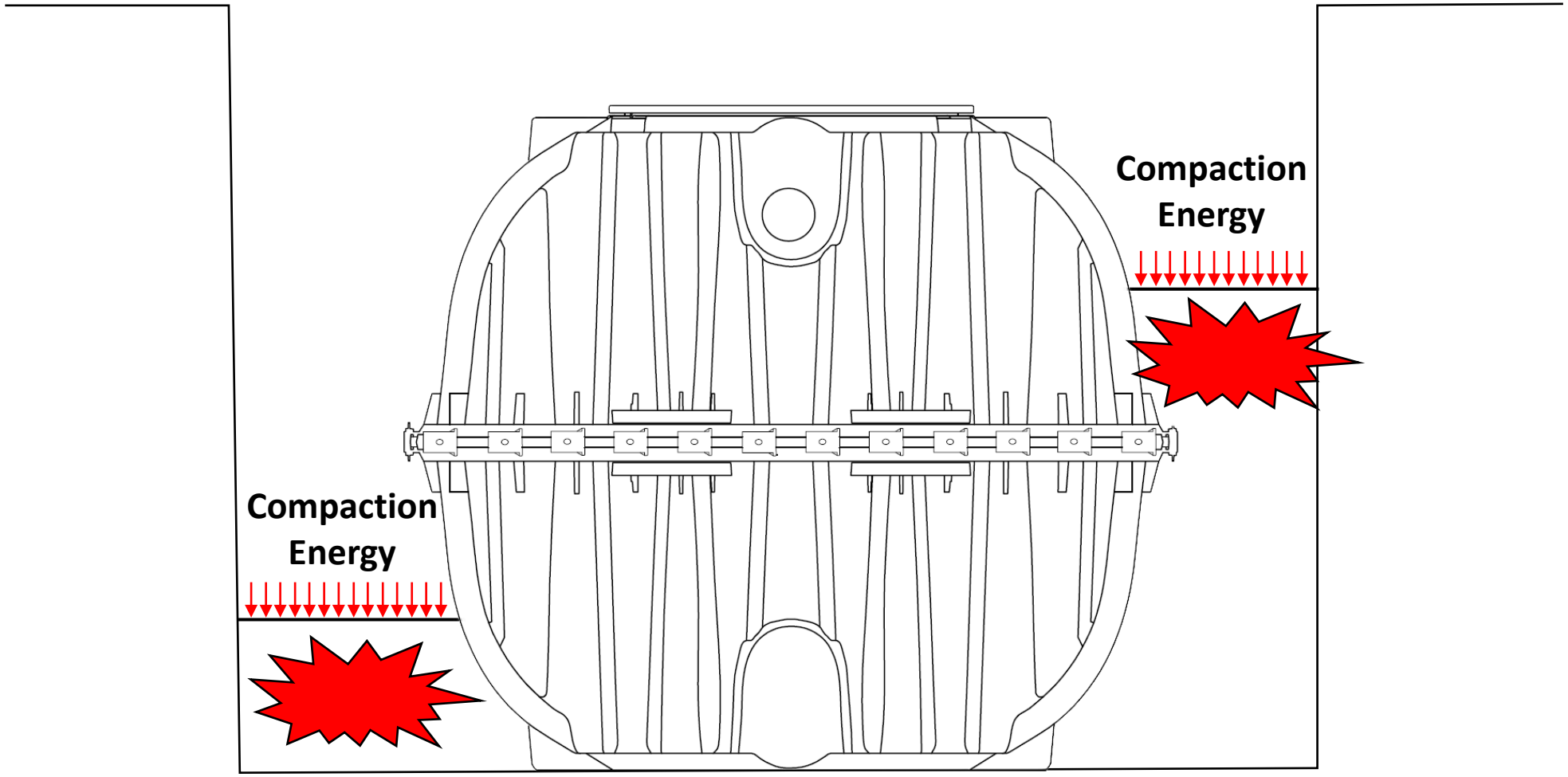
- Place soil in lifts
- “Walk in” sidewalls with feet
- Consolidate particles with foot pressure
- Interlock soil particles against louvers to prevent movement

Preventing uniform soil grain migration

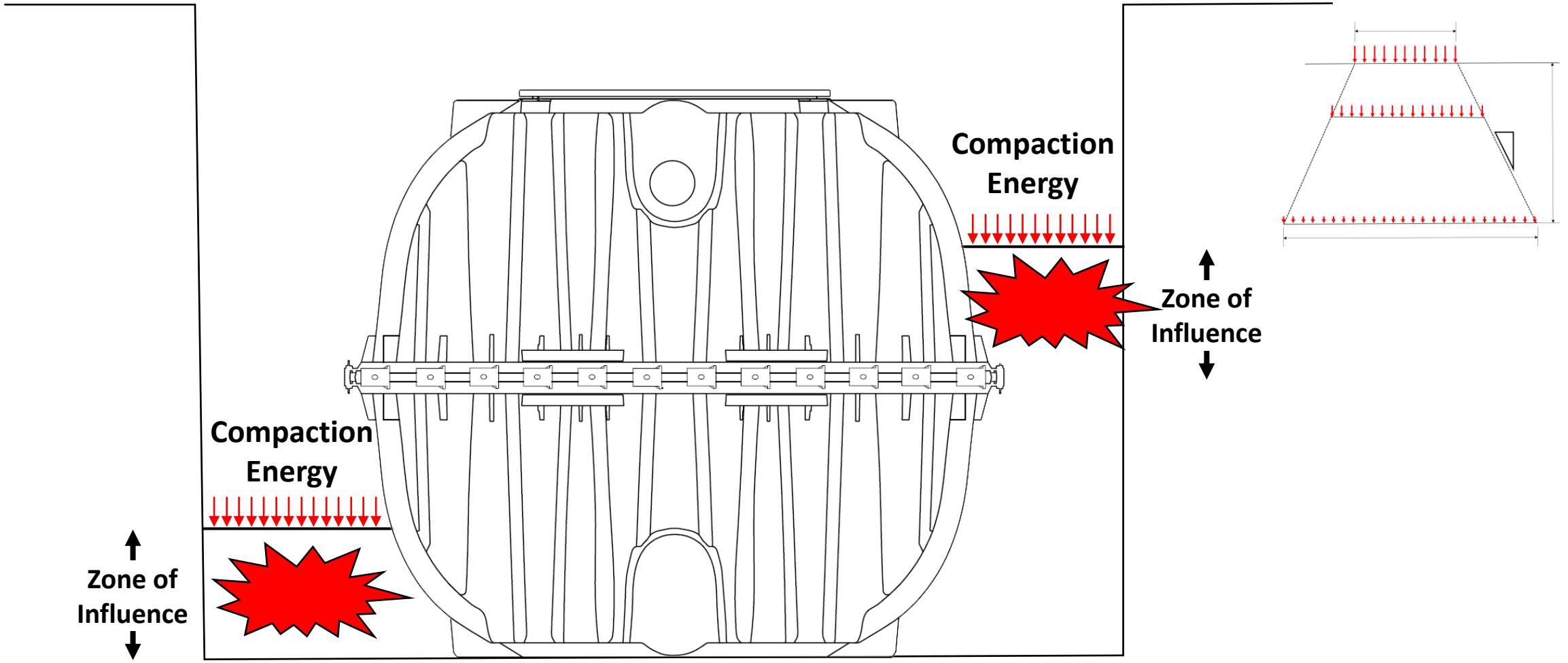
Situation: Rounded particles with uniform size and shape

- Place geotextile over chamber sidewalls
- Place backfill on top of geotextile
- Geotextile separates soil particles from chamber

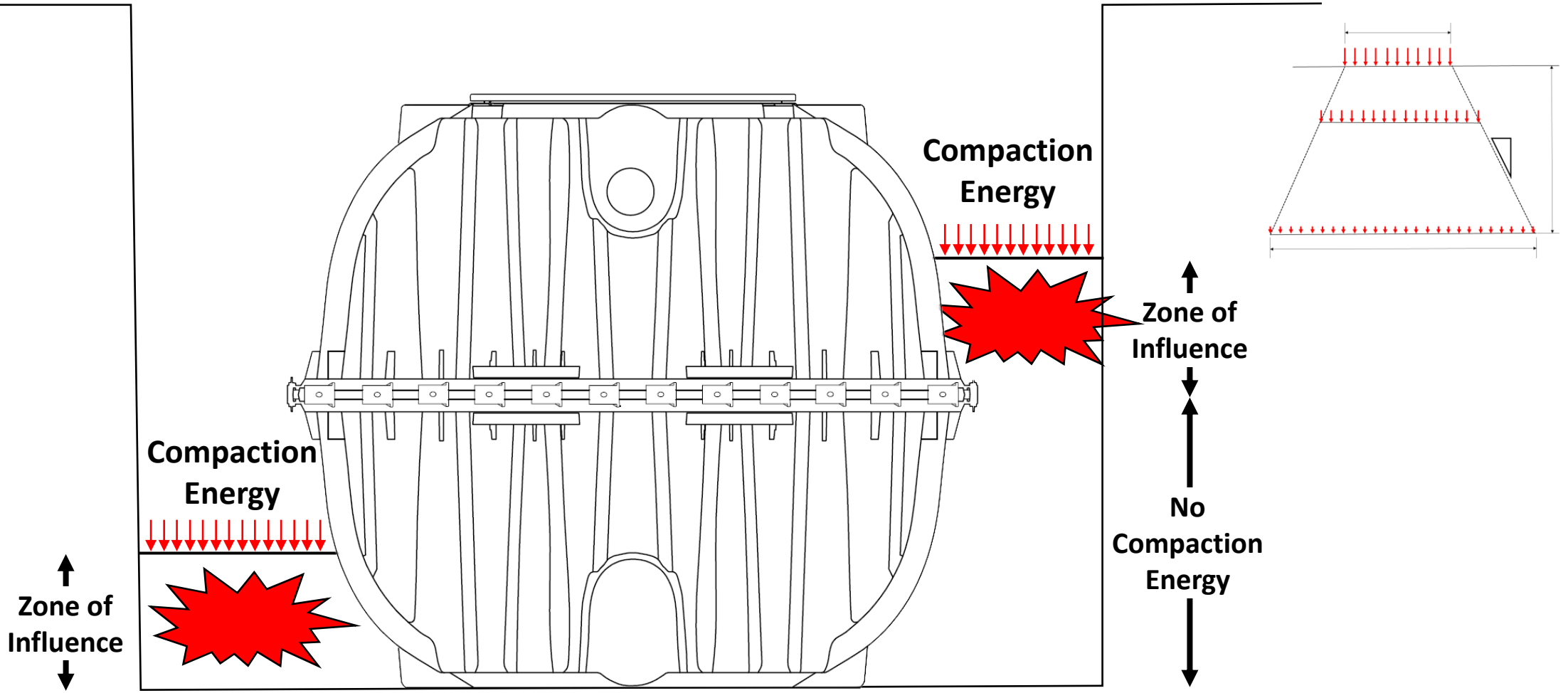
Soil Particle Behavior Case Study 2: Backfilling in Lifts



Compaction energy depth penetration is limited



Compaction energy depth penetration is limited



Soil Particle Behavior Case Study 3: Tank Backfill Materials

Backfill specifications are manufacturer-specific

Must be Pea Stone

Pea Stone Prohibited

Onsite Industry Case Studies

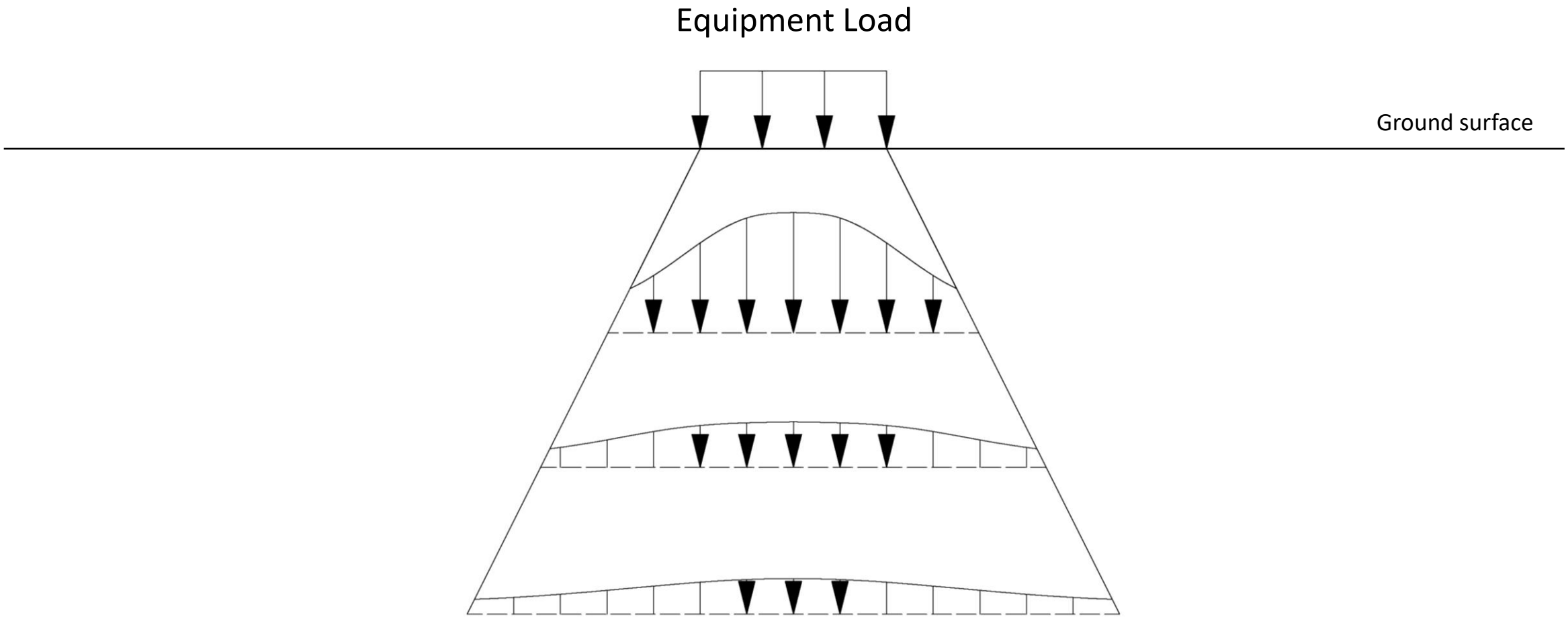
Soil Particle Behavior

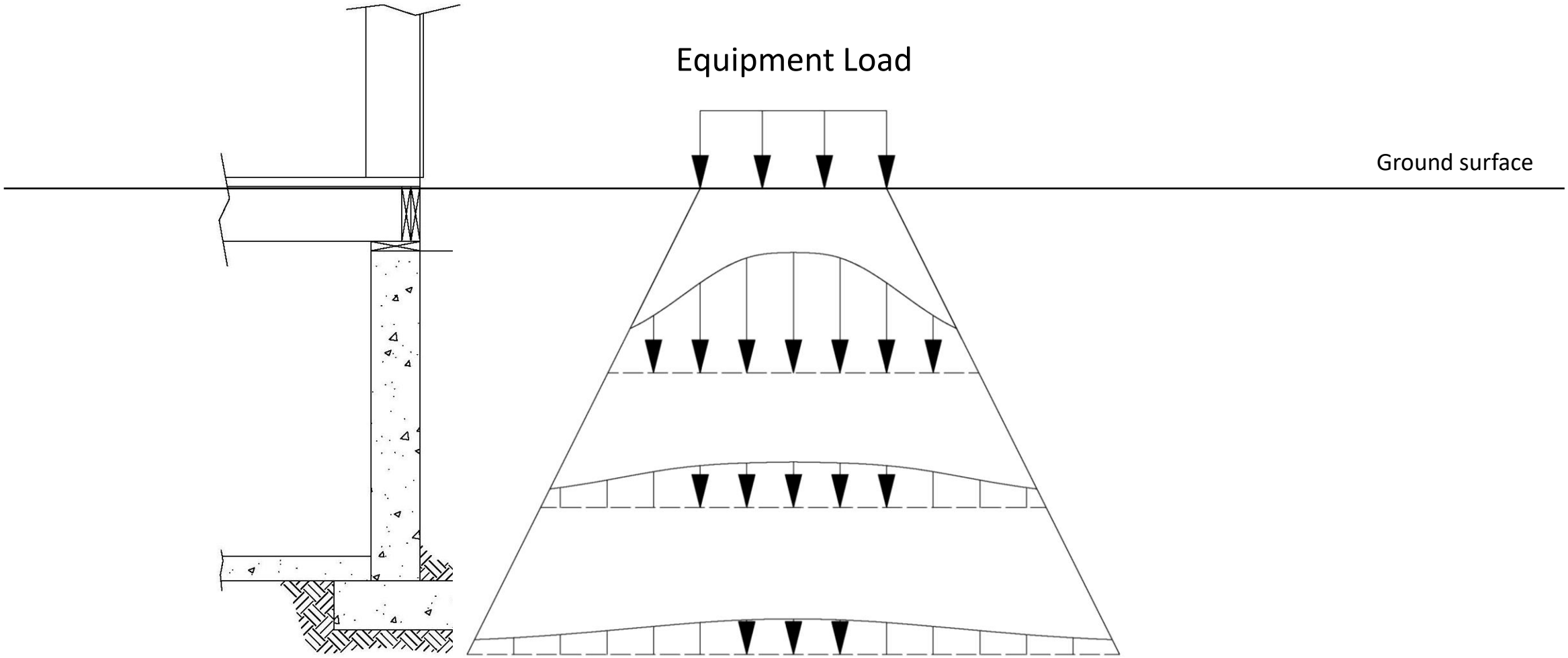
Subsurface Structures

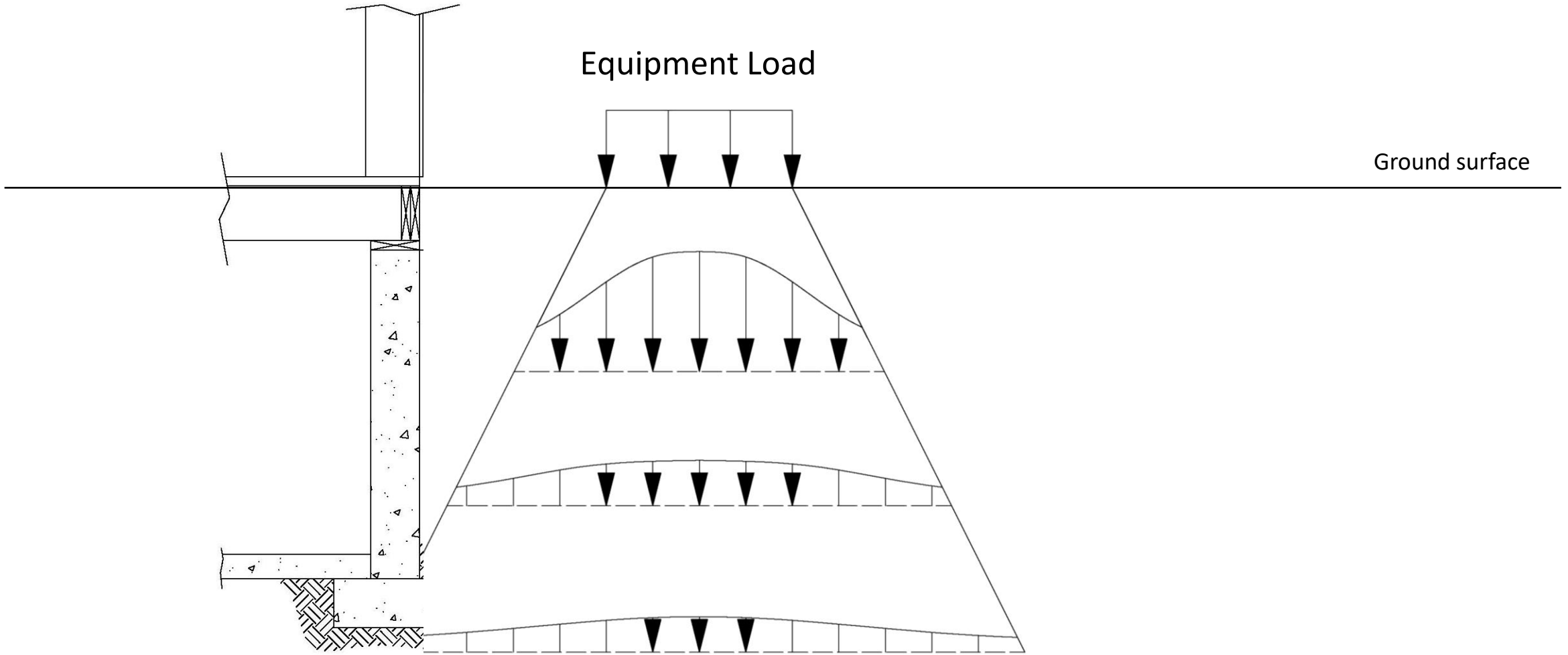
Buried Tanks

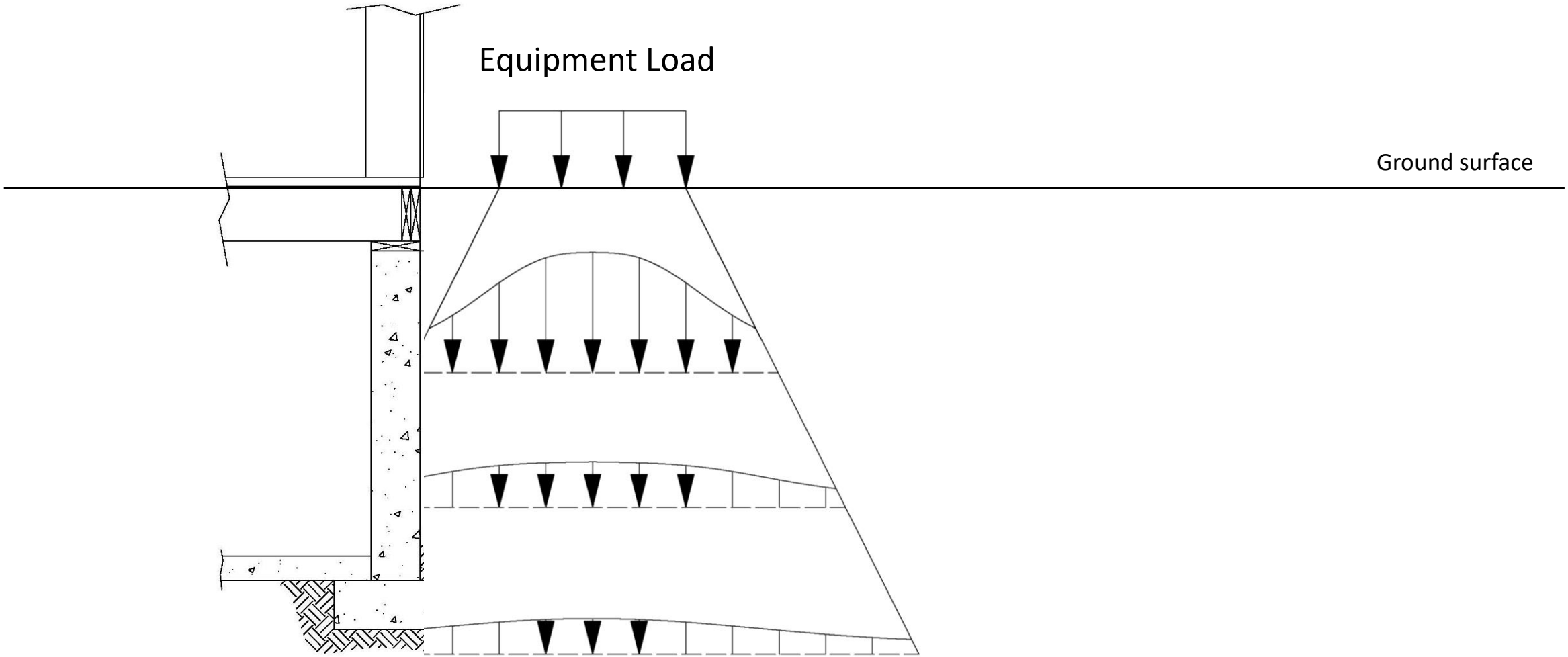
Slope Stability

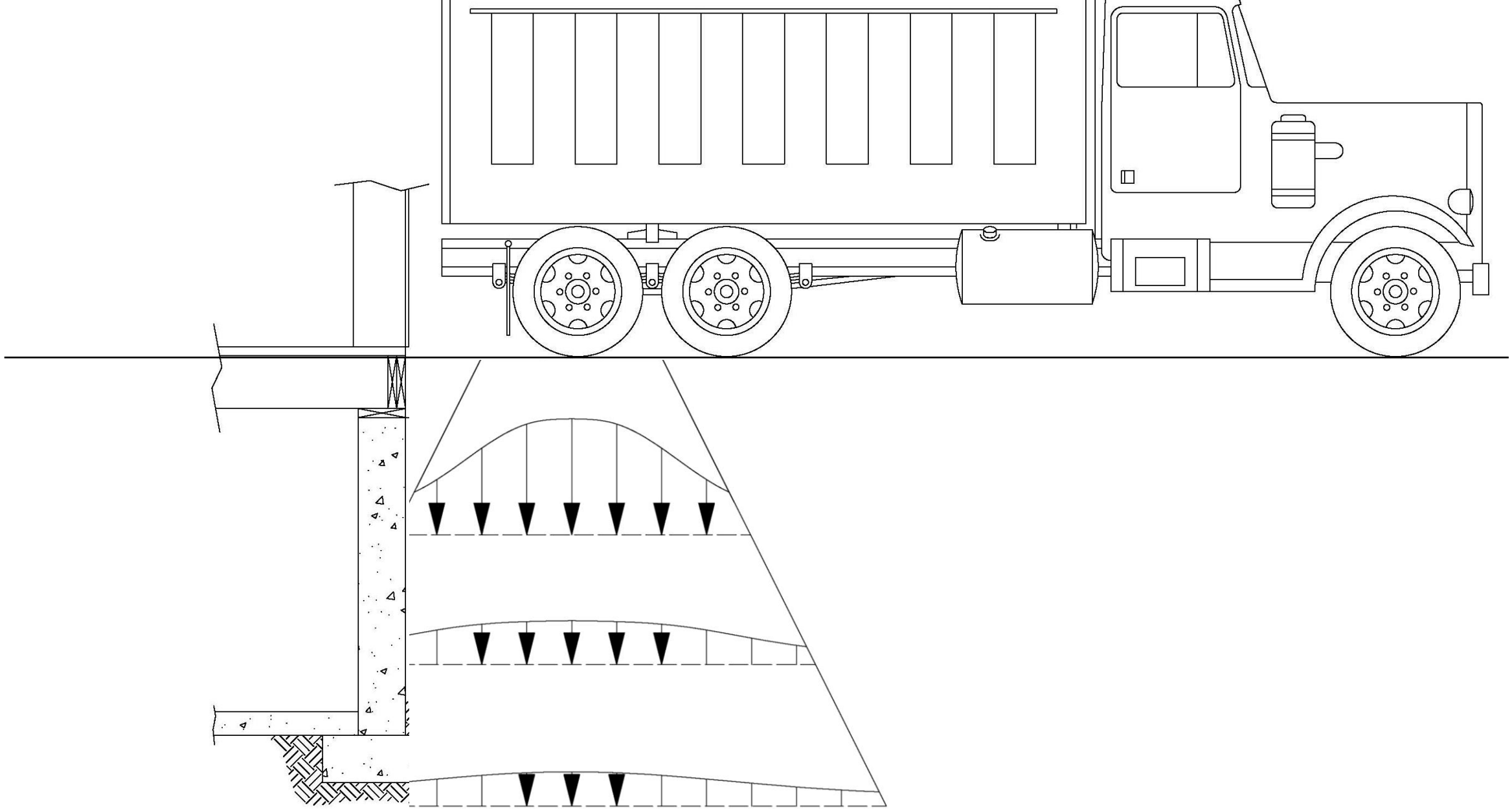
Subsurface Structures Case Study 1: Construction Equipment-Generated Stress




Equipment Load
Ground surface

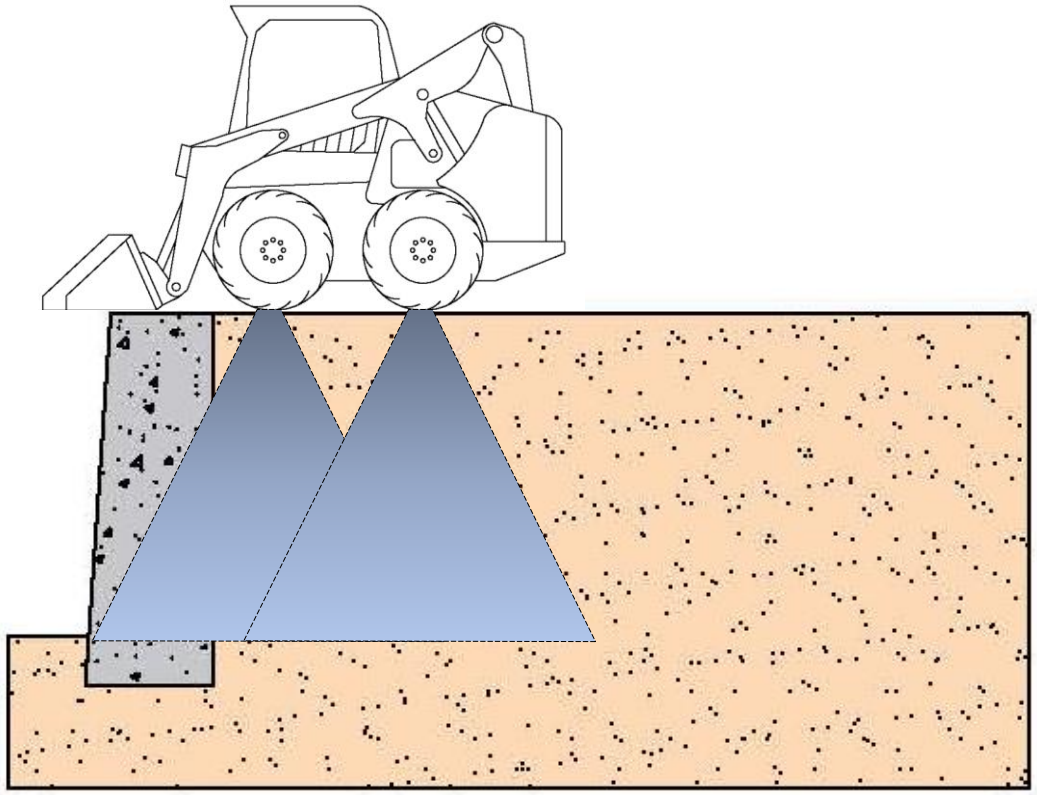

Equipment Load
Ground surface


Equipment Load
Ground surface




Good Idea?

Will the skid steer load move the wall or retained soil?



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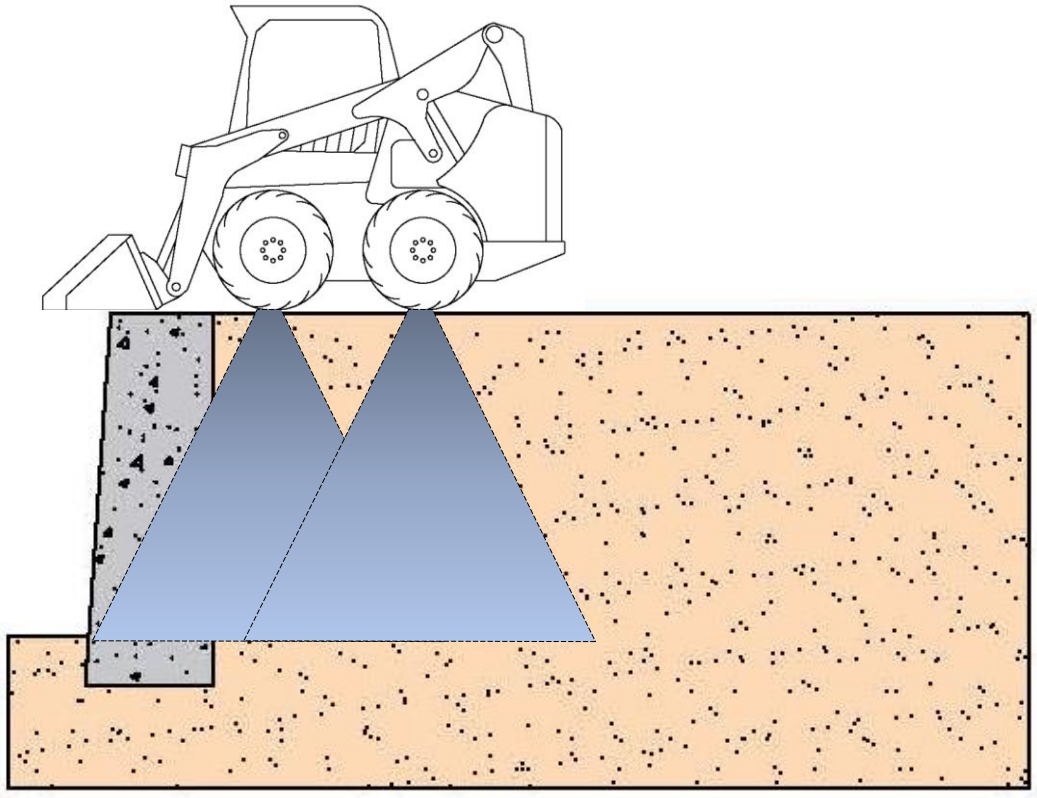
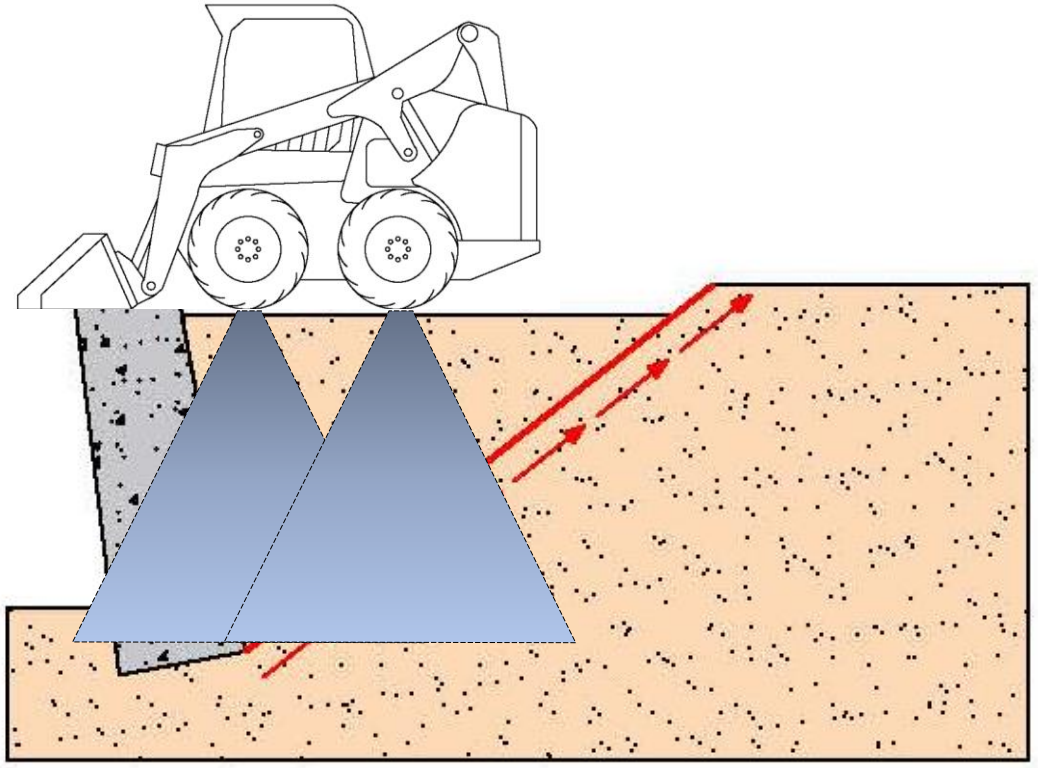
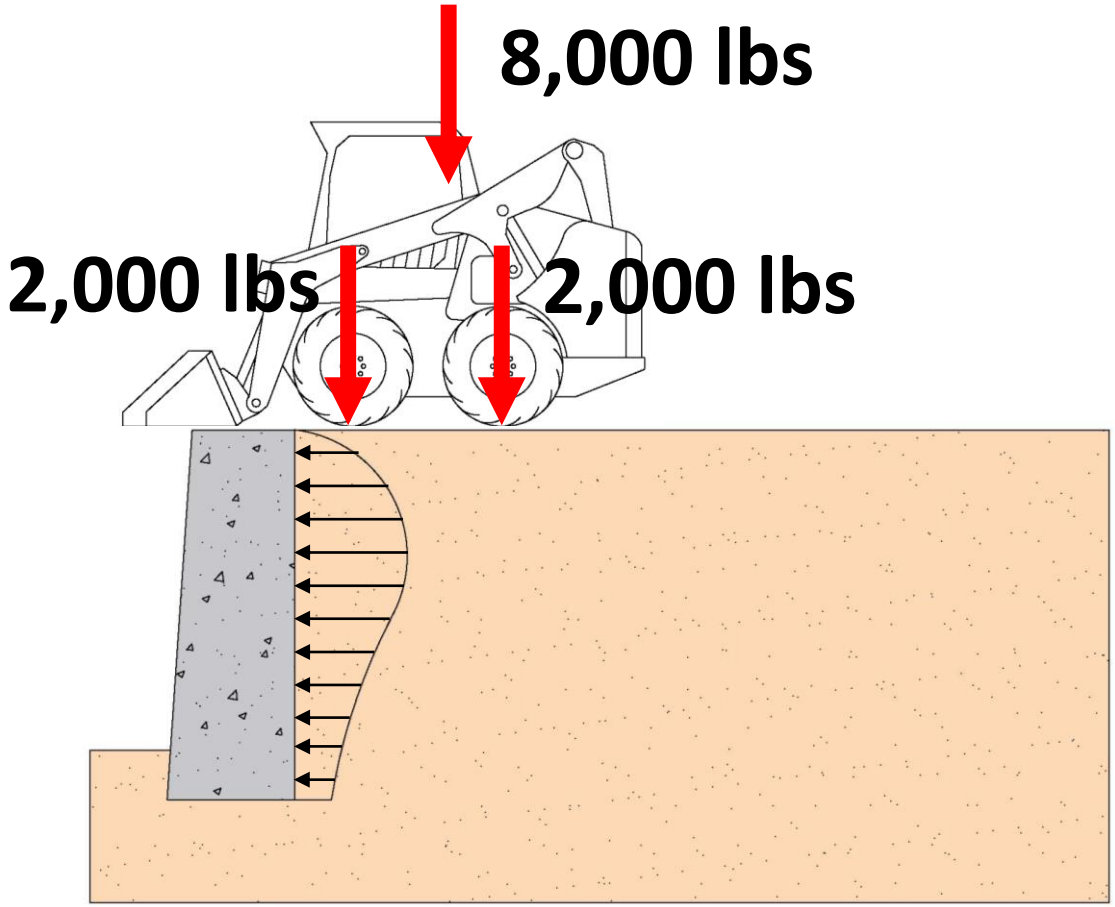


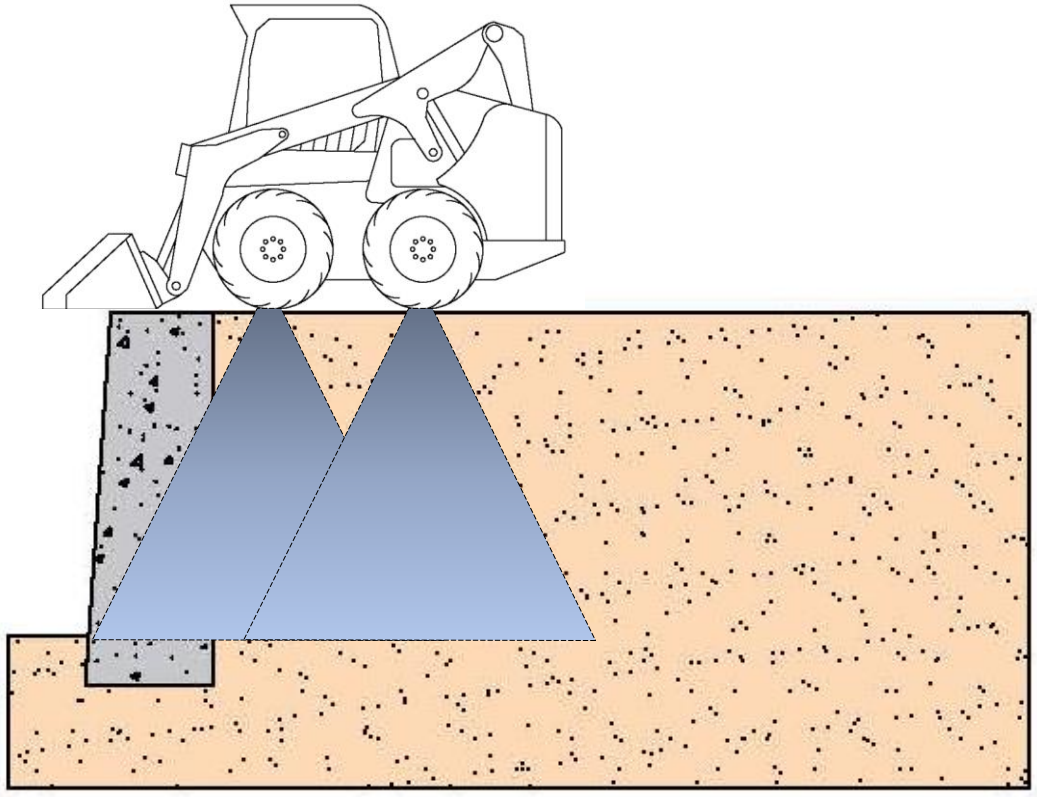


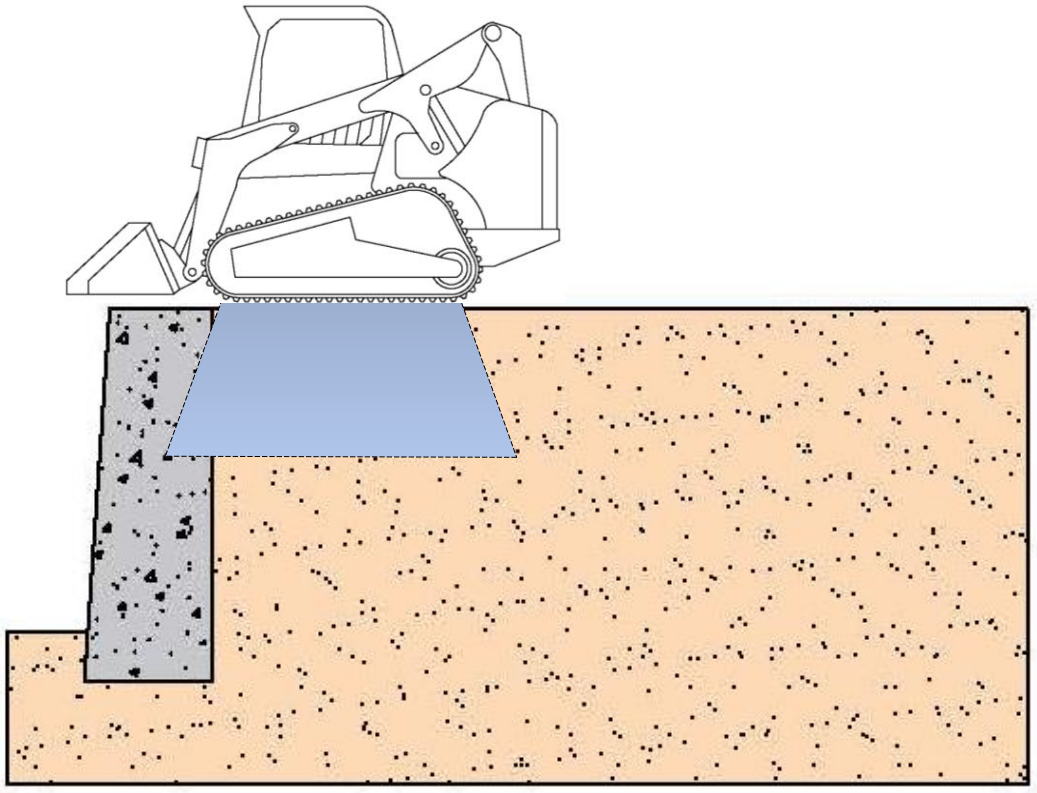
Will the skid steer load move the wall or retained soil?




Good Idea?

Is tracked machinery a better option for site work?

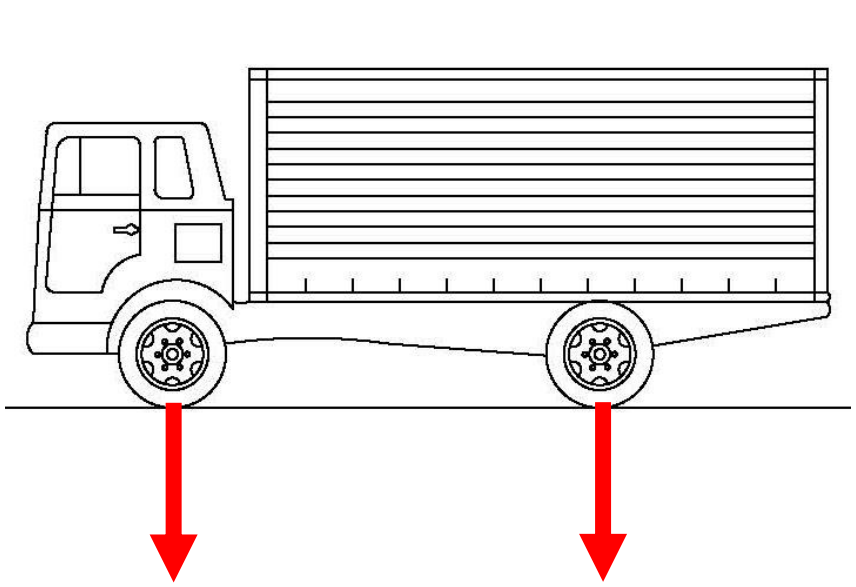




Subsurface Structures Case Study 2: AASHTO H-10 vs. H-20 Loads

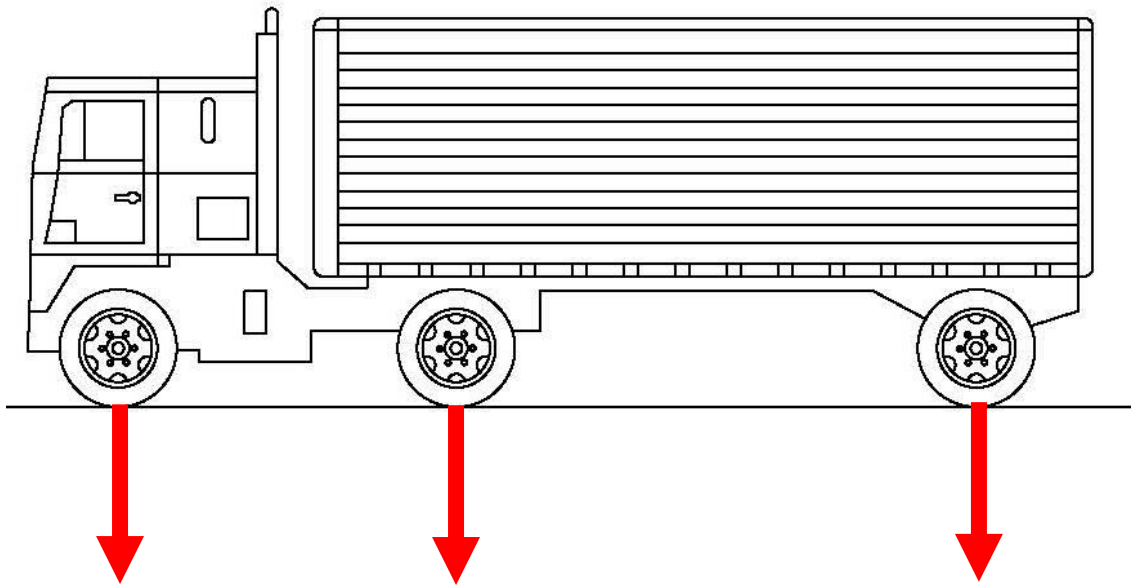
H-10

16,000 lb axle load



H-20

32,000 lb axle load



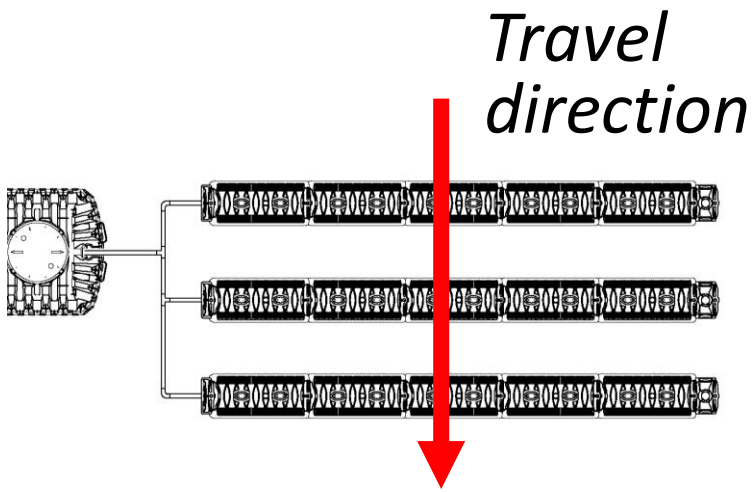
Load ratings of common buried structures

Non-Traffic Rated

Load ratings of common buried structures

Non-Traffic Rated

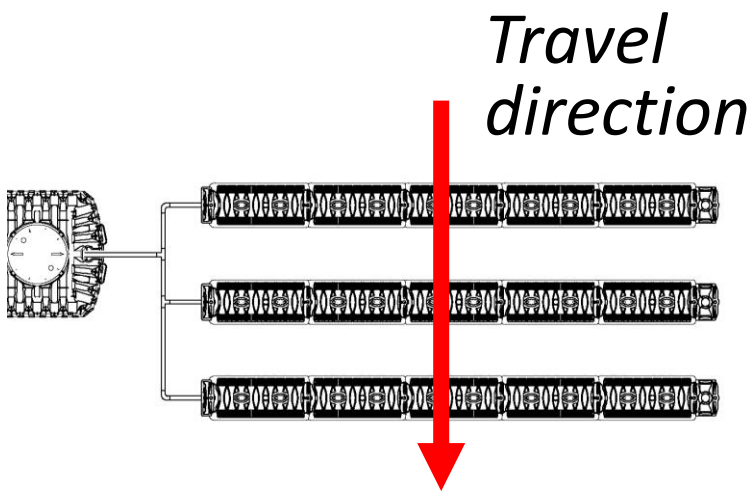
H-10 with 12” cover



Load ratings of common buried structures

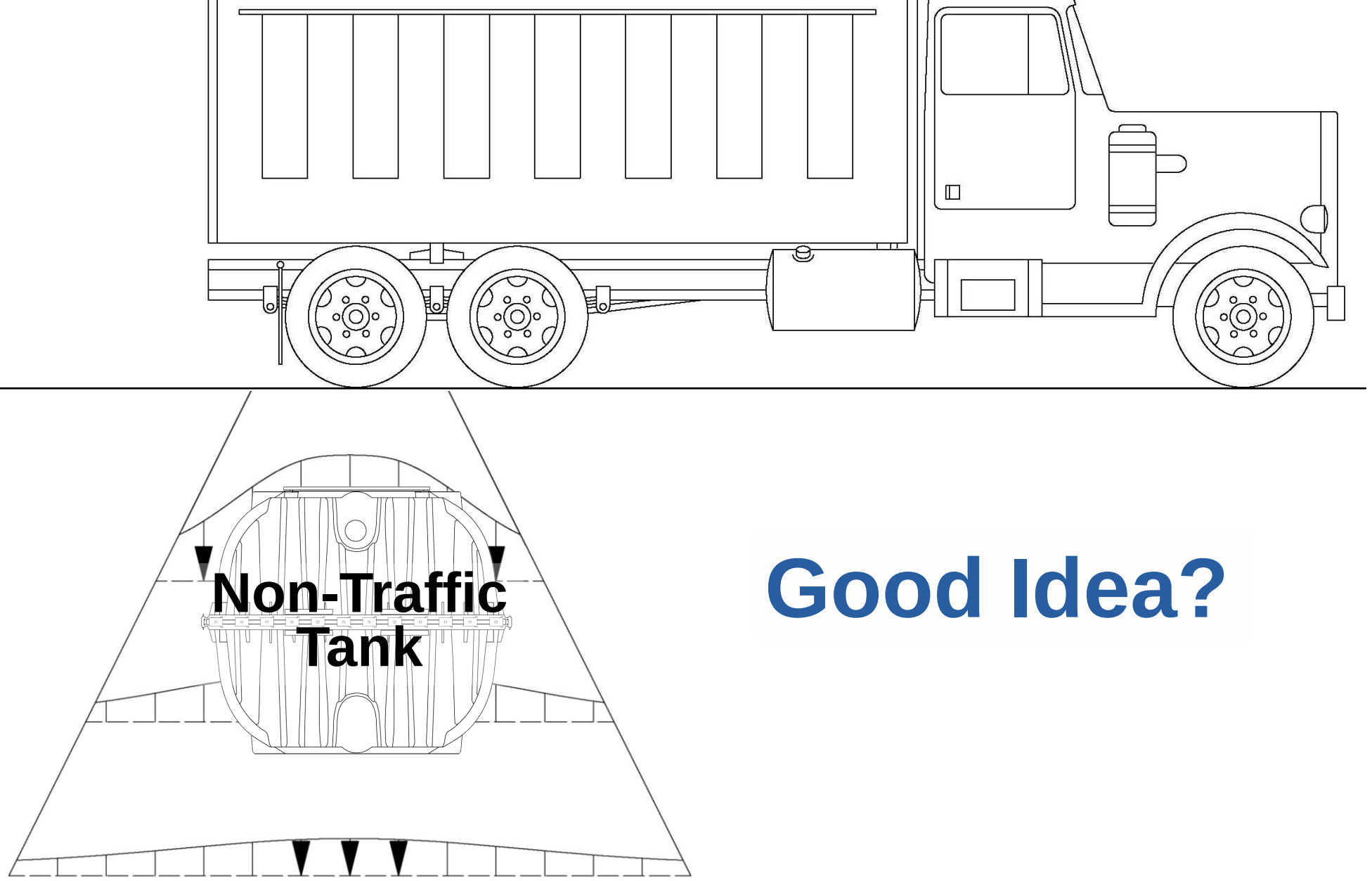
Non-Traffic Rated

H-10 with 12” cover



H-20

Must be designed and installed for H-20 load



Good Idea?

Subsurface Structures Case Study 3: Crane Outrigger Stability

https://www.youtube.com/watch?v=PhaBAMyUbdk

https://www.youtube.com/watch?v=PhaBAMyUbdk

https://www.youtube.com/watch?v=PhaBAMyUbdk


https://www.youtube.com/watch?v=PhaBAMyUbdk


https://youtu.be/tIWpdsV78Fc

Onsite Industry Case Studies

Soil Particle Behavior

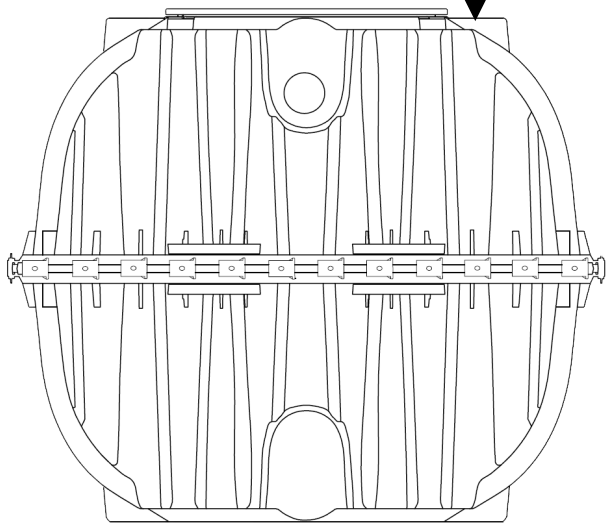
Subsurface Structures

Buried Tanks

Slope Stability

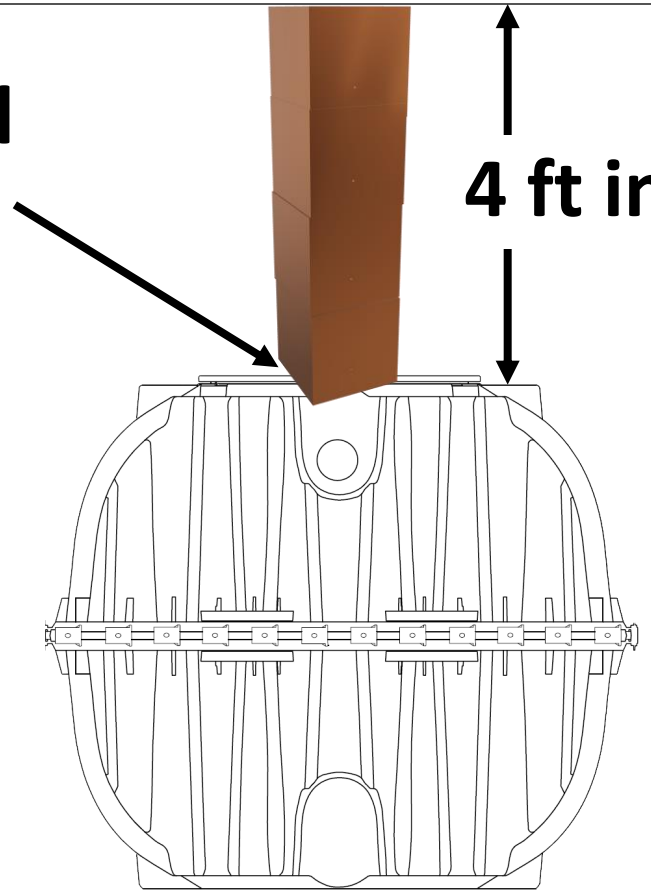
Buried Tanks Case Study 1:
Maximum Septic Tank Burial Depth

Manufacturer's maximum installation depth

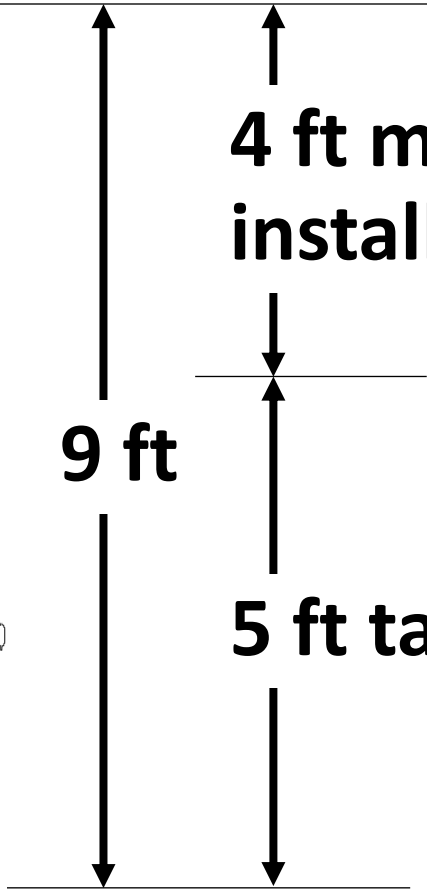


Almost 500-pound soil load on every square foot of tank top

For a 10 ft x 5 ft tank top, each foot of soil cover adds 6,000 lbs

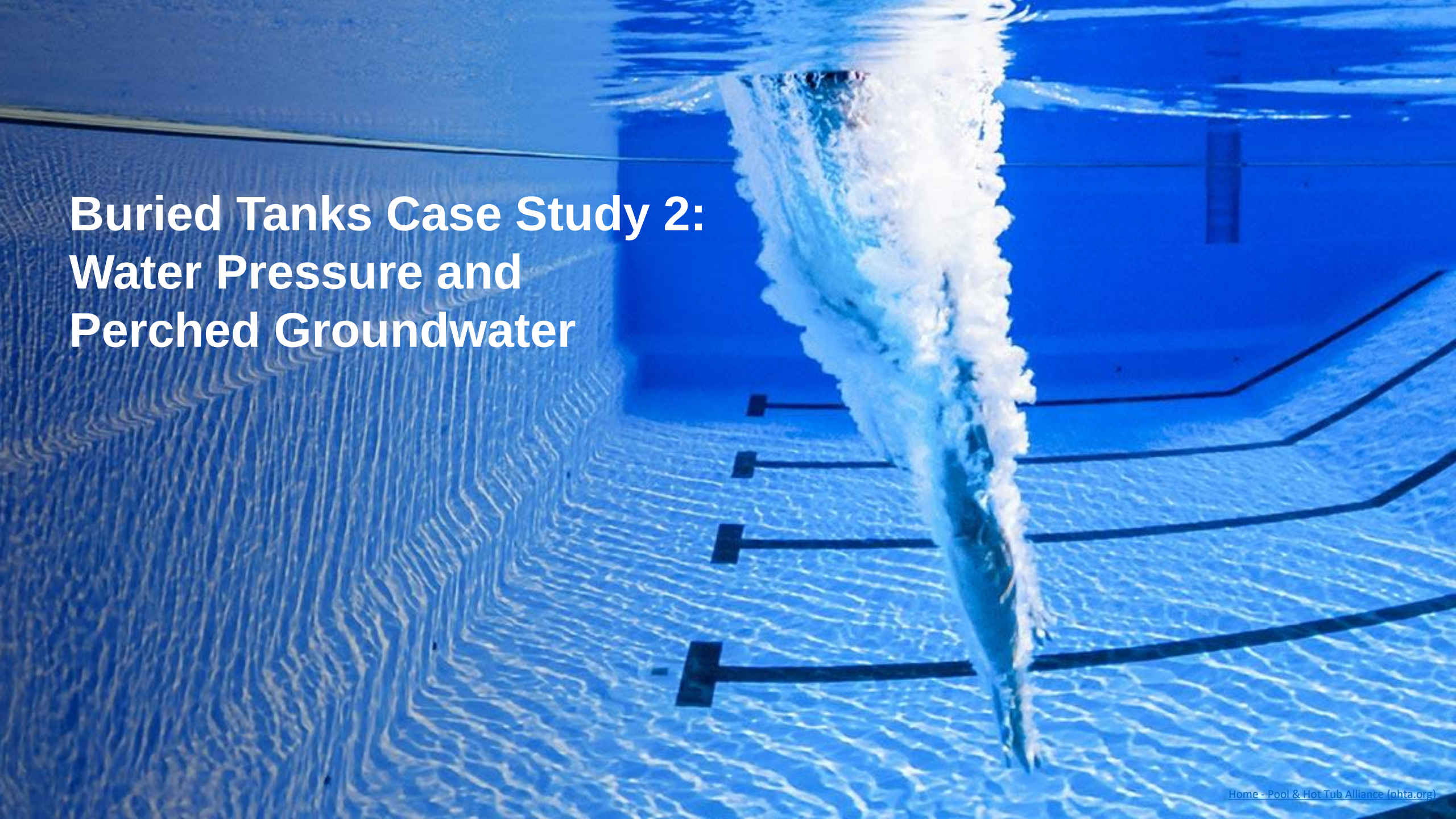


4 ft installation depth



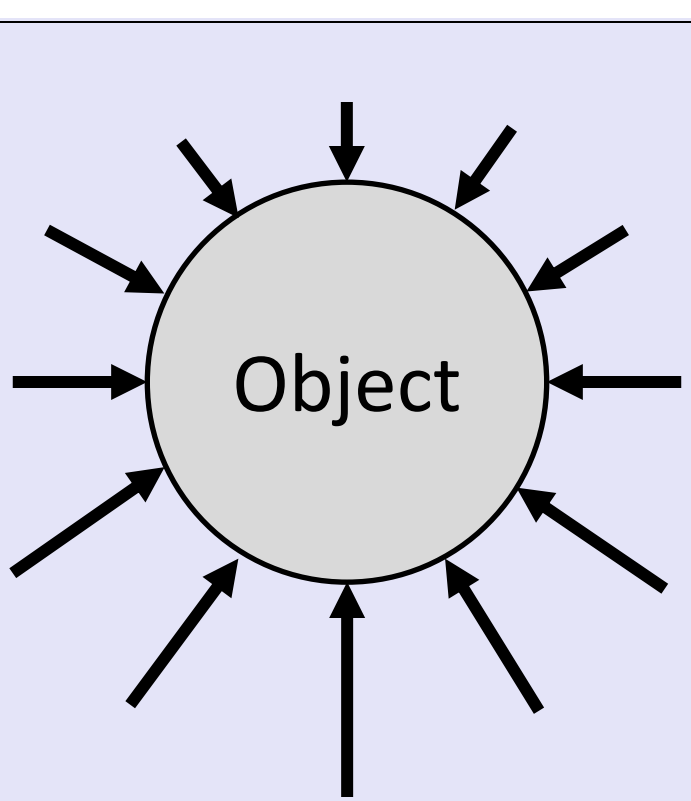
Vertical stress at 9 ft = 1,080 psf

Buried Tanks Case Study 2: Water Pressure and Perched Groundwater



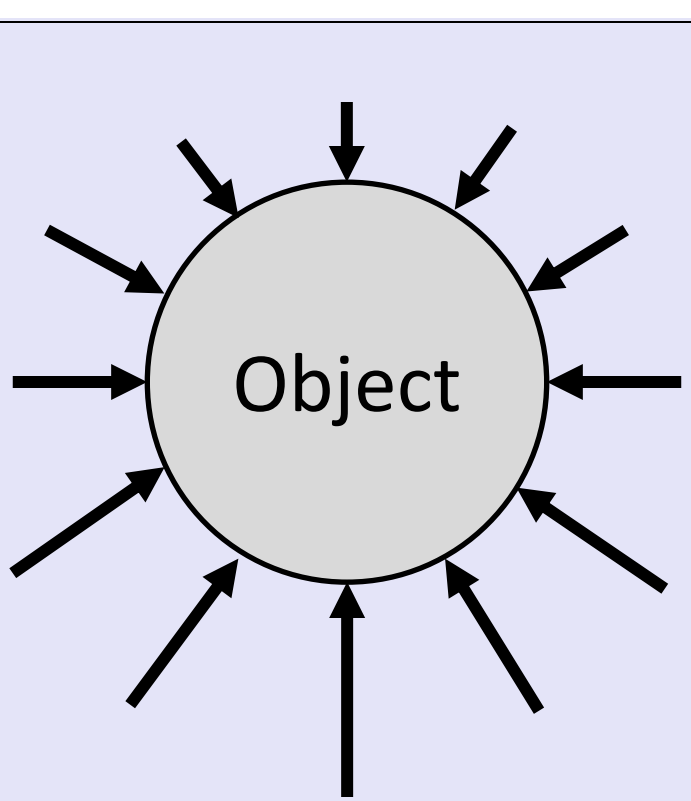
Home - Pool & Hot Tub Alliance (phta.org)

Hydrostatic (water) pressure



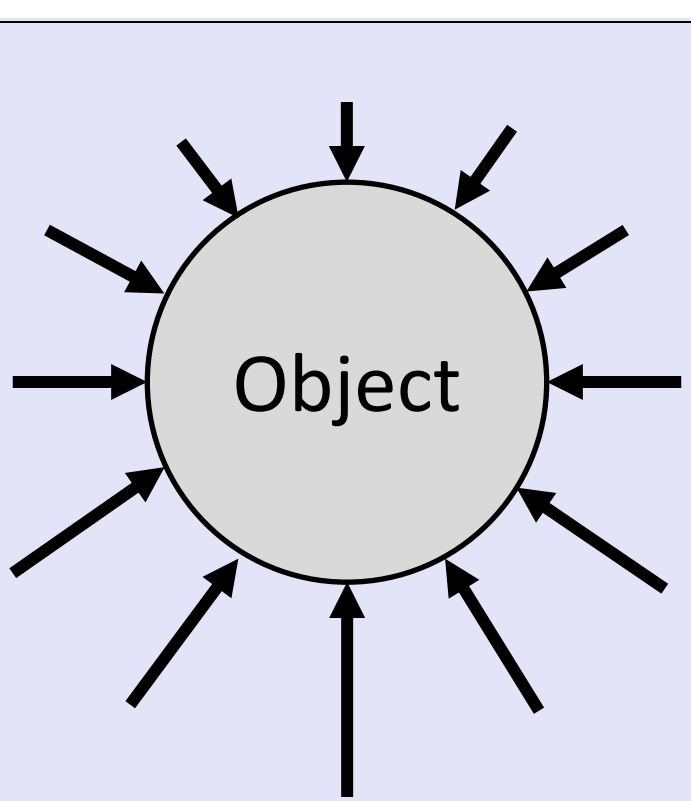
Hydrostatic (water) pressure

Pressure increases with depth



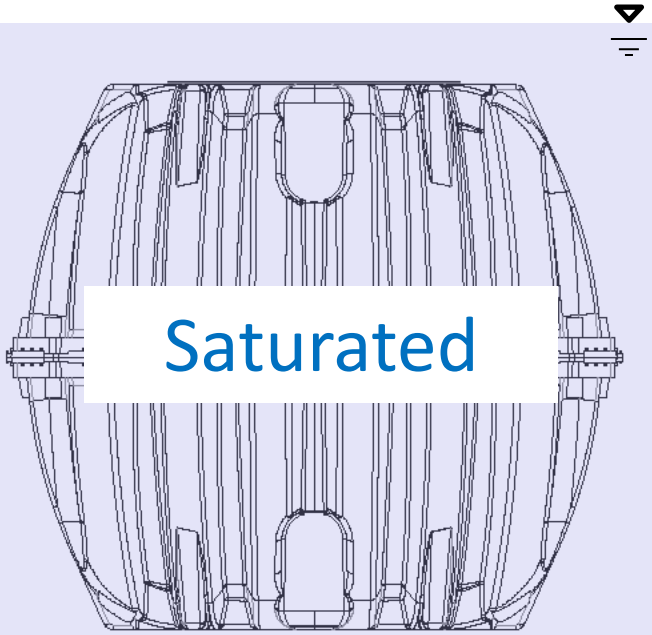
Hydrostatic (water) pressure

What happens for a buried tank?

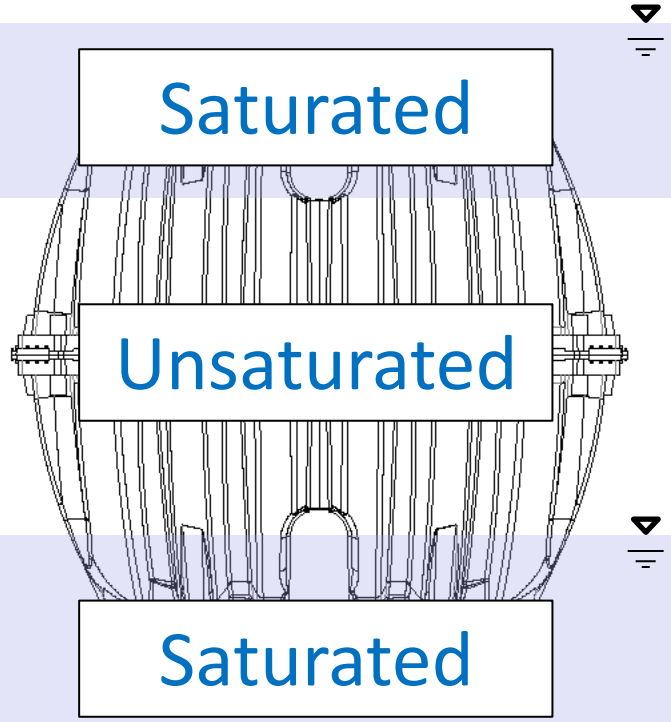


Hydrostatic (water) pressure

Submerged tank
Continuous saturation

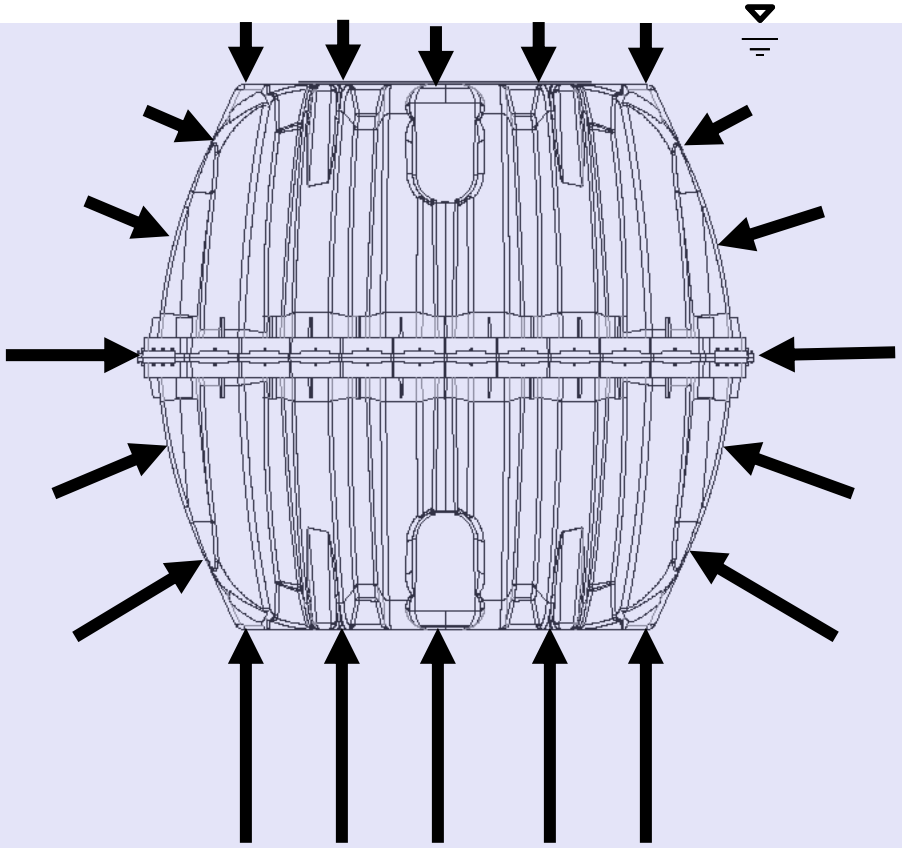


Perched groundwater
Stratified saturation

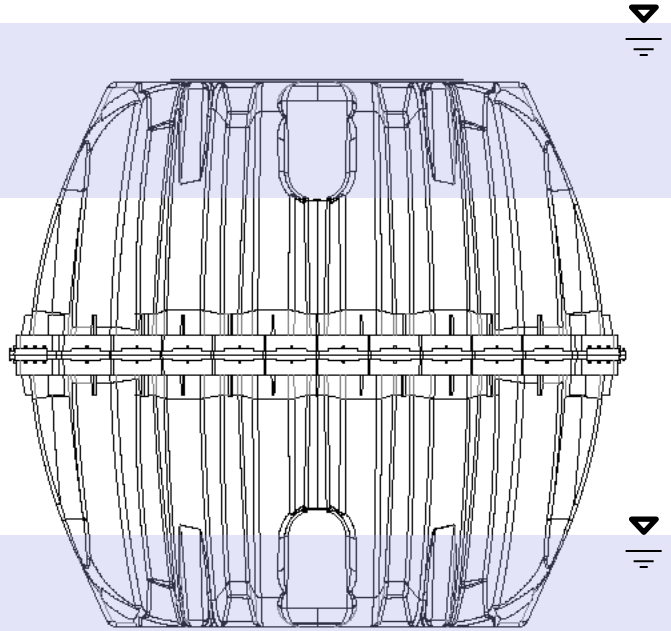


Hydrostatic (water) pressure

Submerged tank
Continuous saturation



Perched groundwater
Stratified saturation



Hydrostatic (water) pressure

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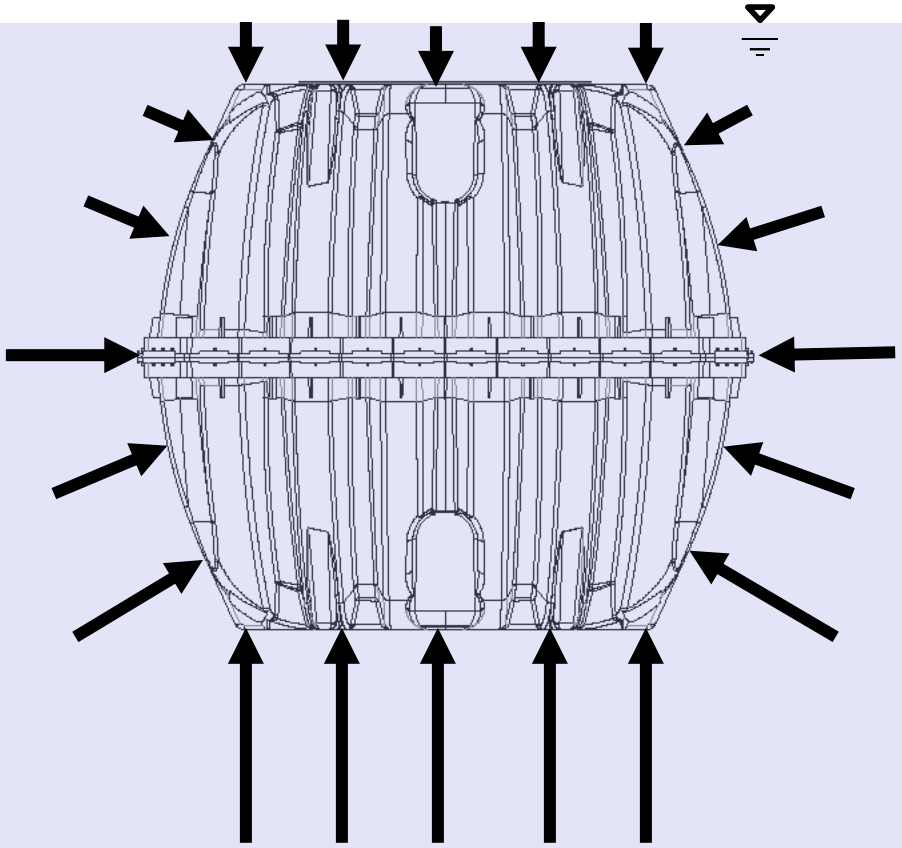

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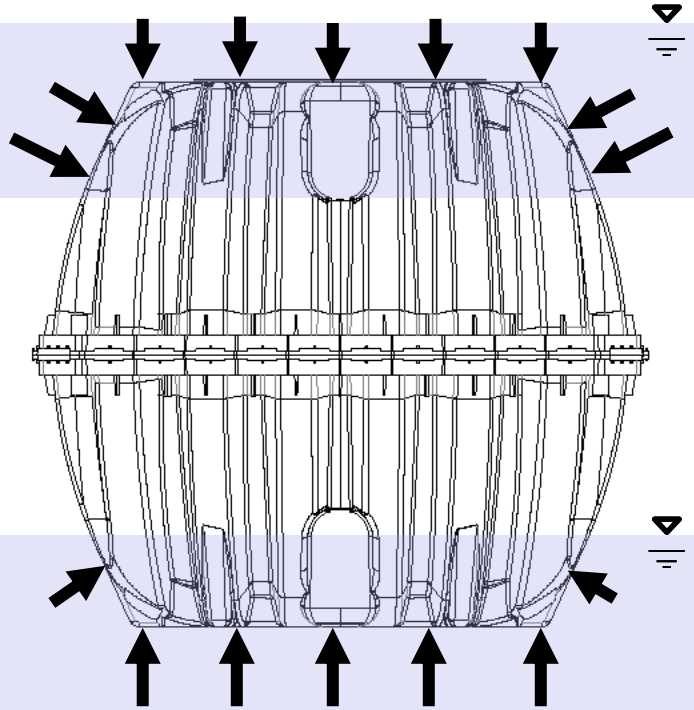
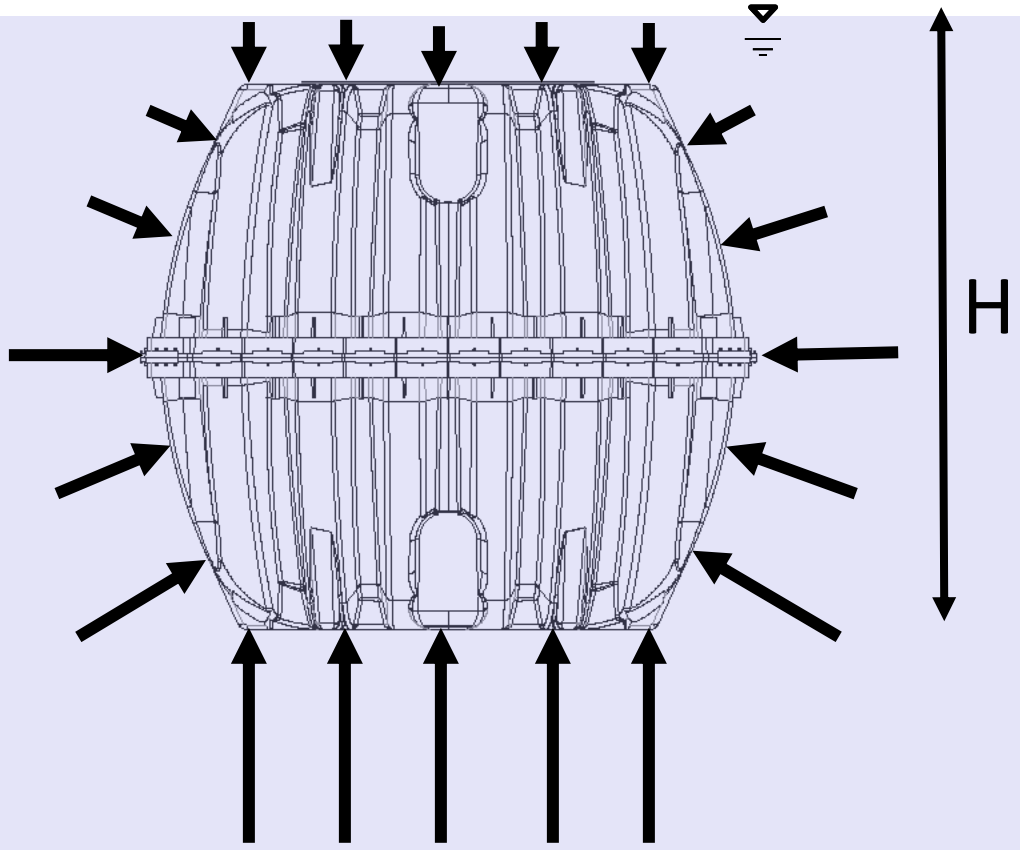
Stratified saturation

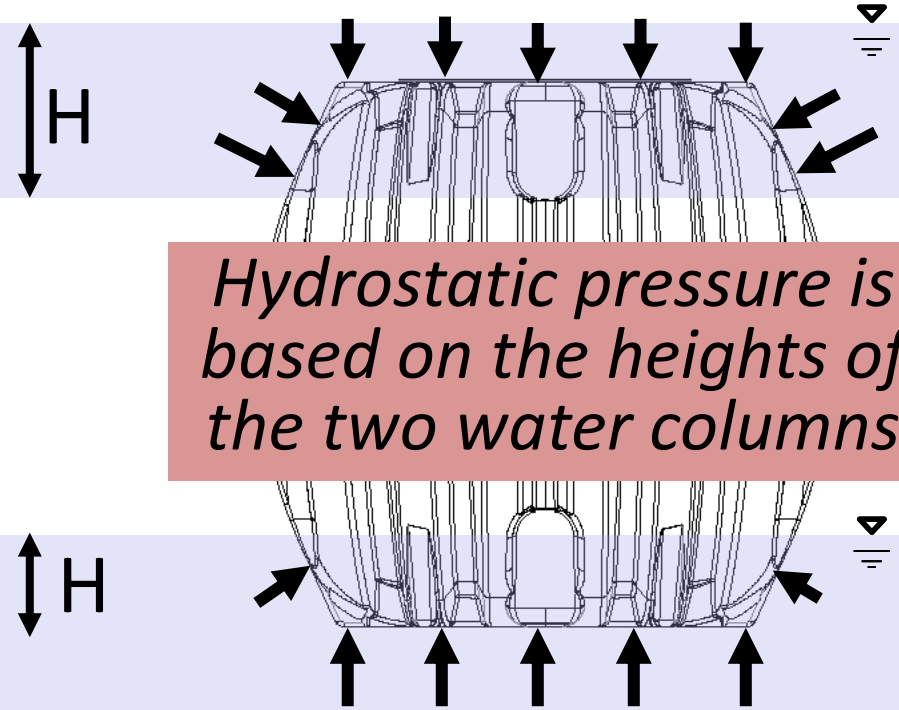


Hydrostatic (water) pressure

Submerged tank
Continuous saturation



Perched groundwater
Stratified saturation



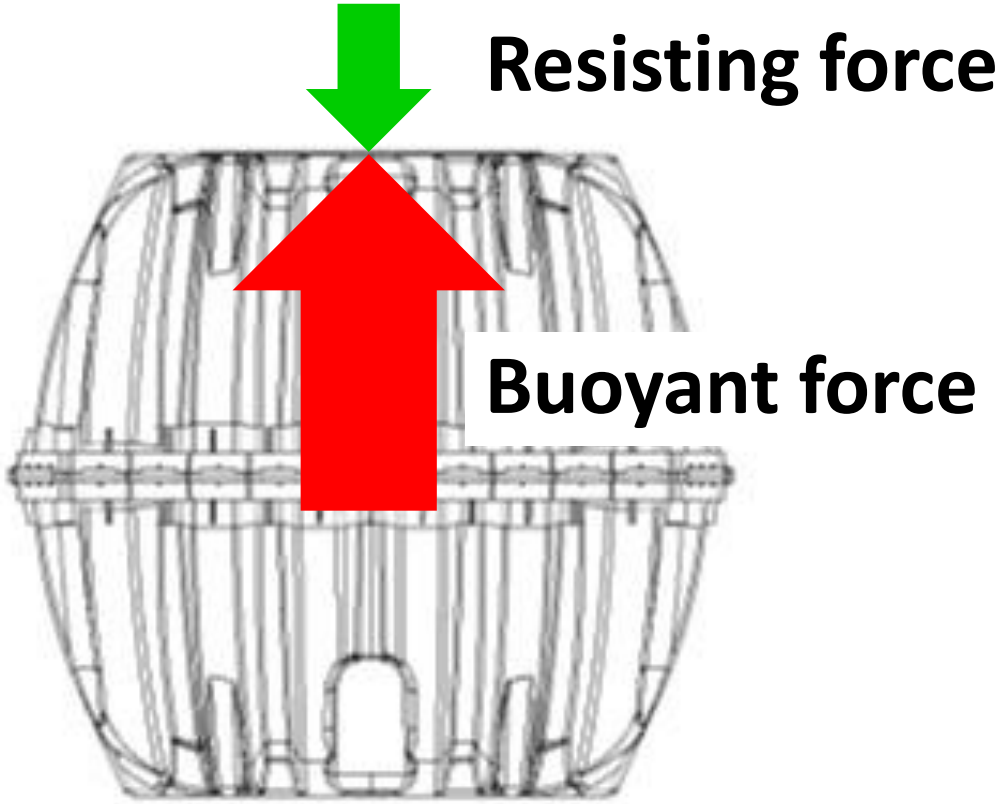
Hydrostatic pressure is based on the heights of the two water columns

Buried Tanks Case Study 3: Buoyancy Control

Buoyant Force > **Resisting Force**

With a Net Upward Force,

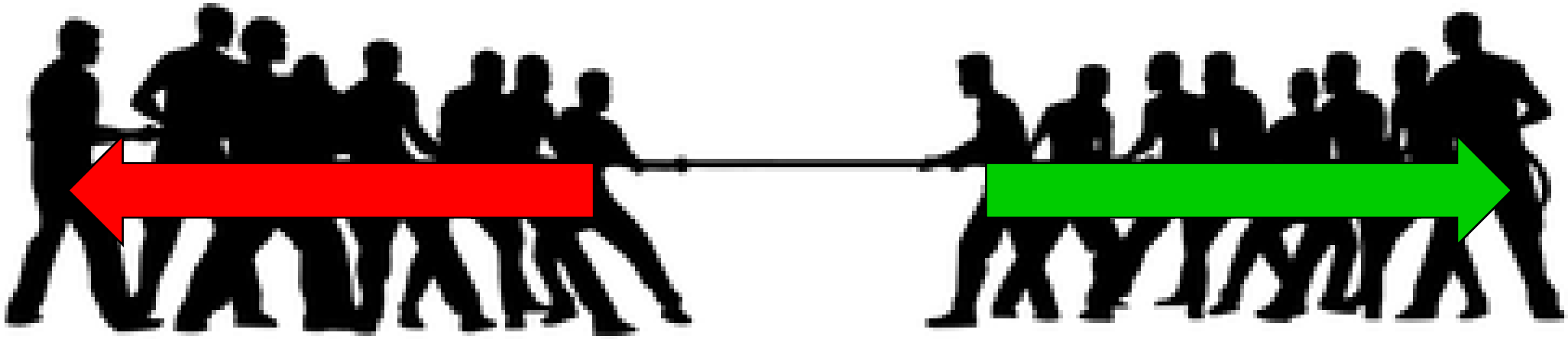
Buoyancy Controls Required



Nobody Wants This...

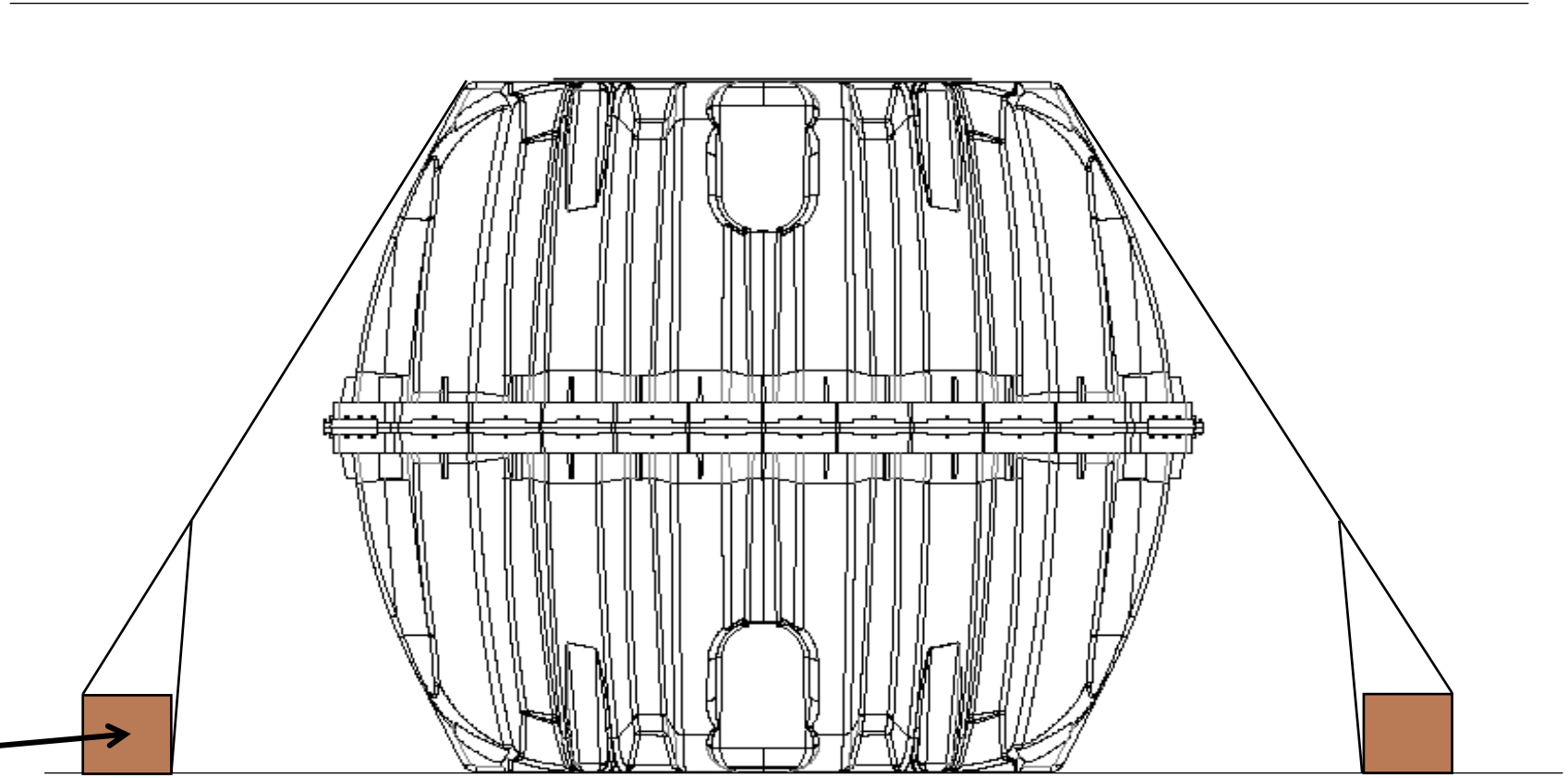
Or This…

Buoyancy is like a tug of war, except vertical



Upward buoyant force vs. Downward resisting forces

Use Pressure Treated Wood Anchor Ballast System

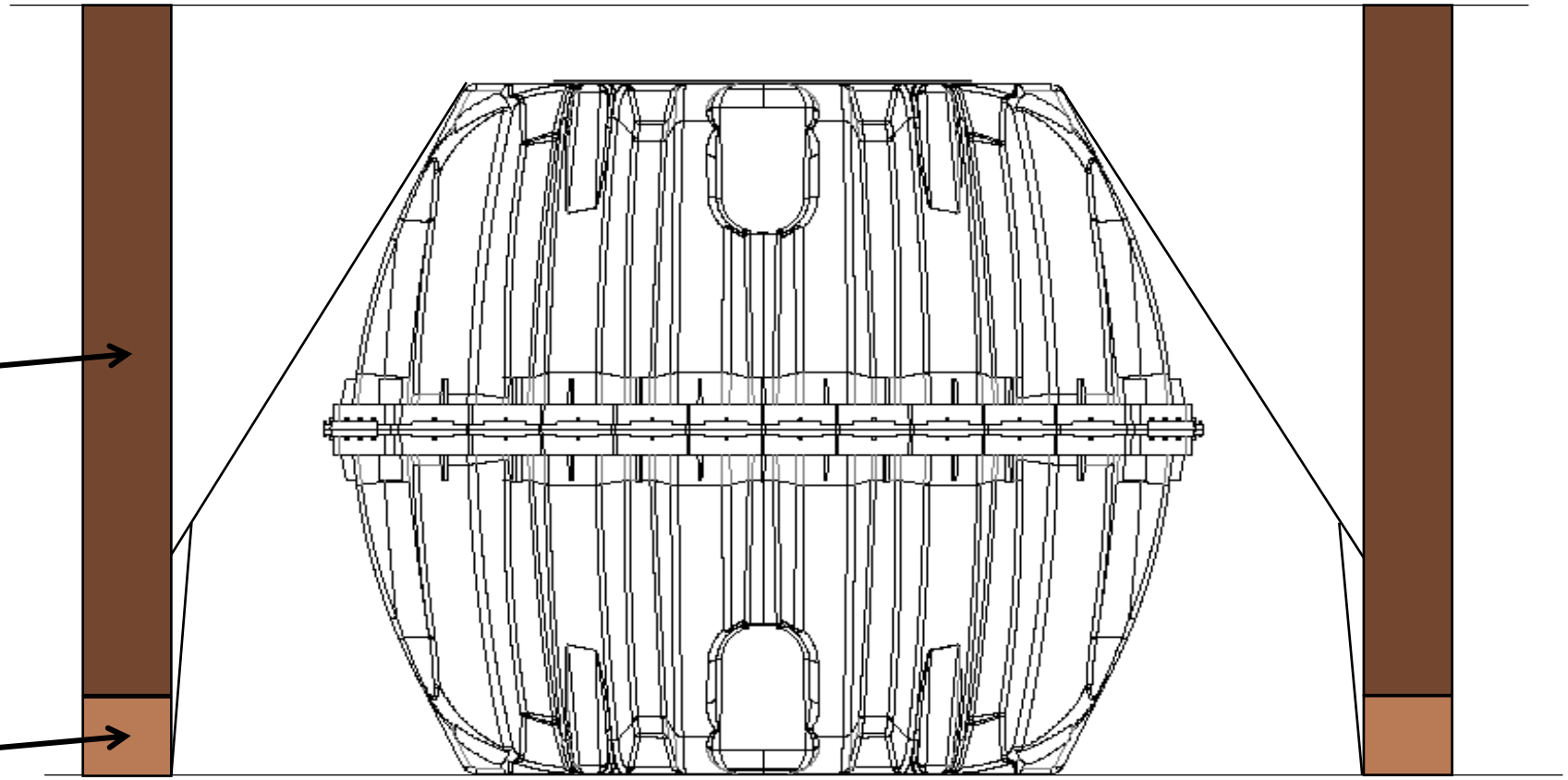


Pressure Treated Wood Beam Anchor Ballast

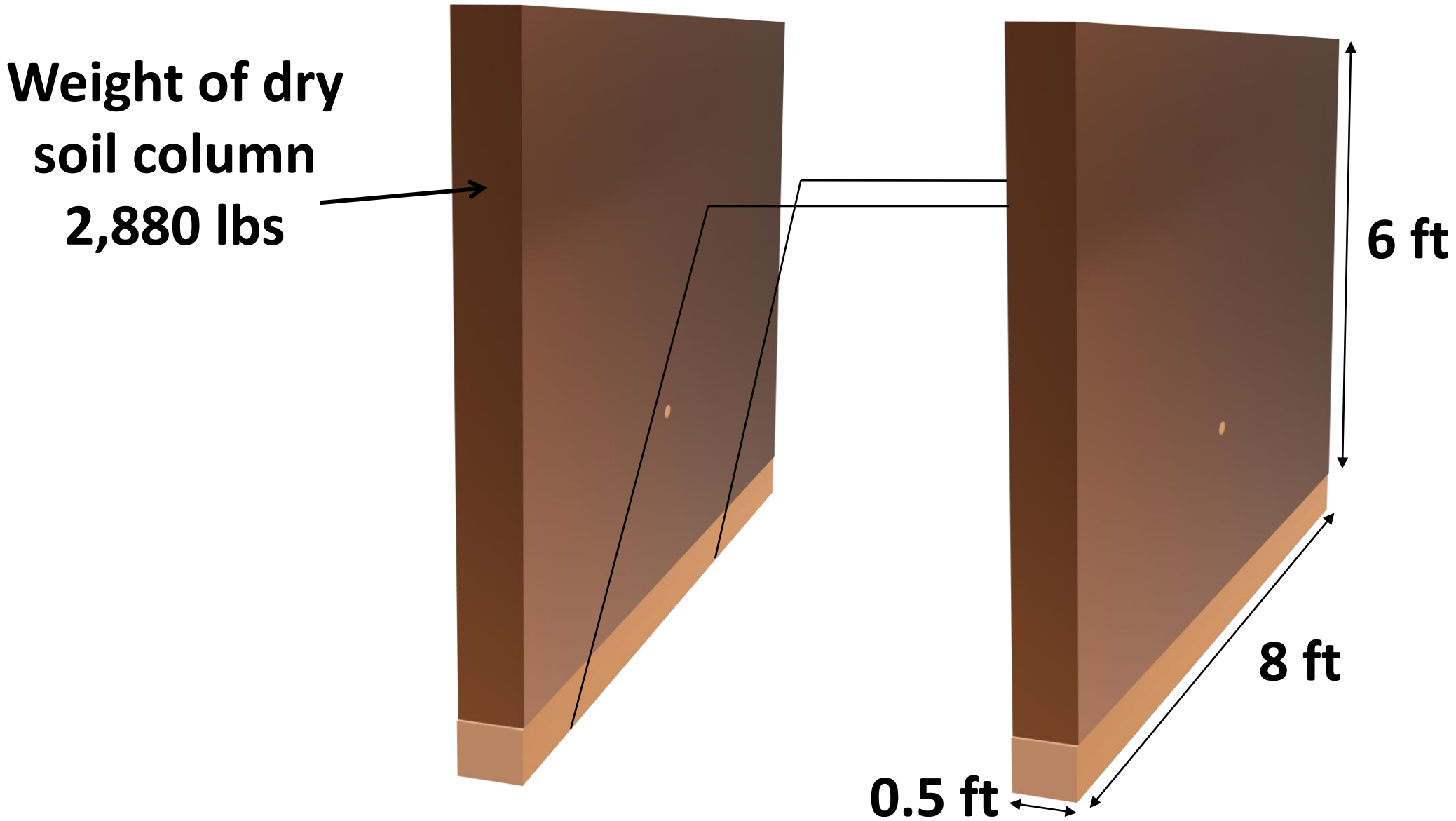
Use Pressure Treated Wood Anchor Ballast System

Soil Column Above Anchor Ballast

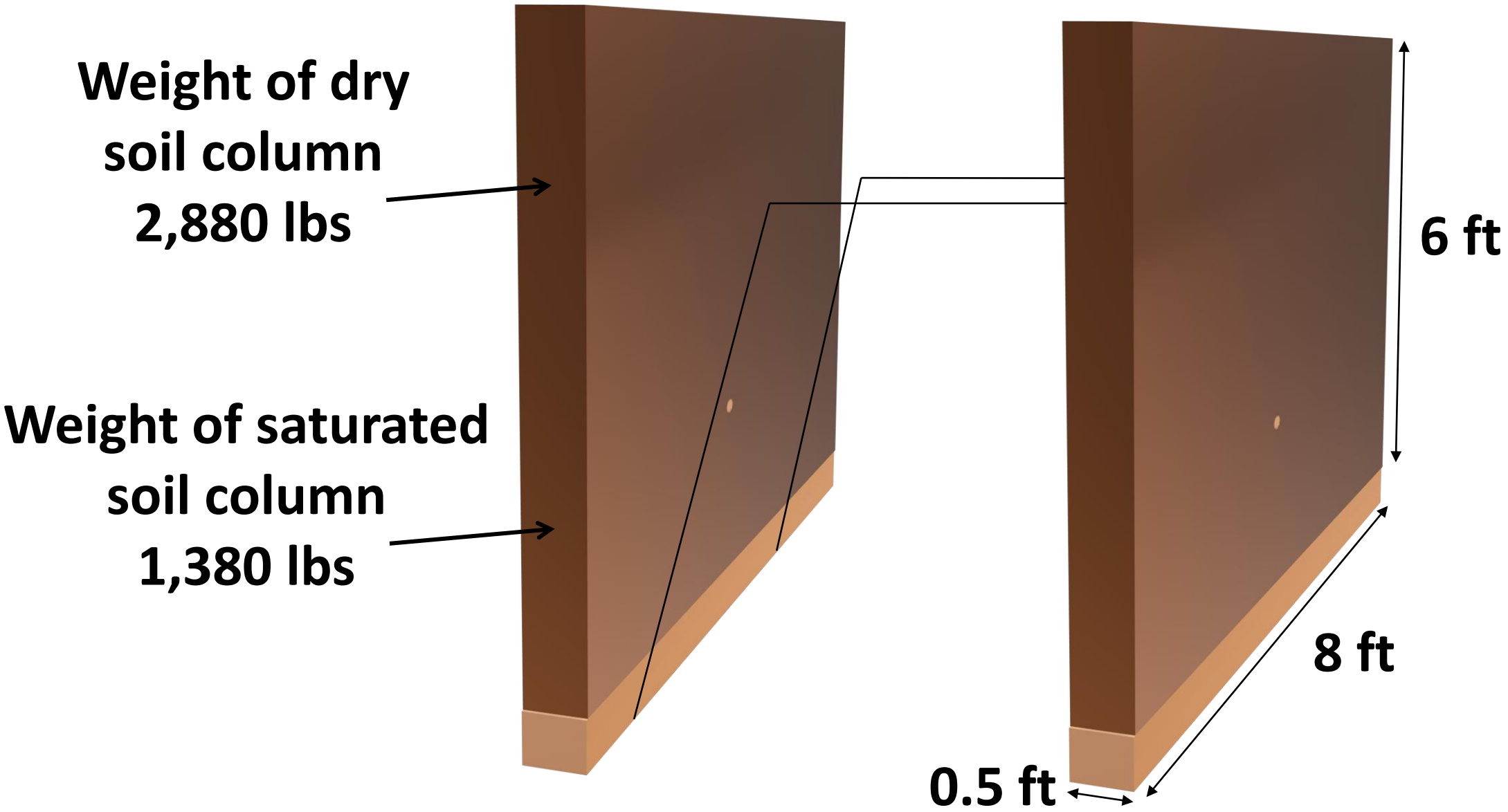
Pressure Treated Wood Beam Anchor Ballast



3-D View of Anchor Ballasts and Overlying Soil Columns



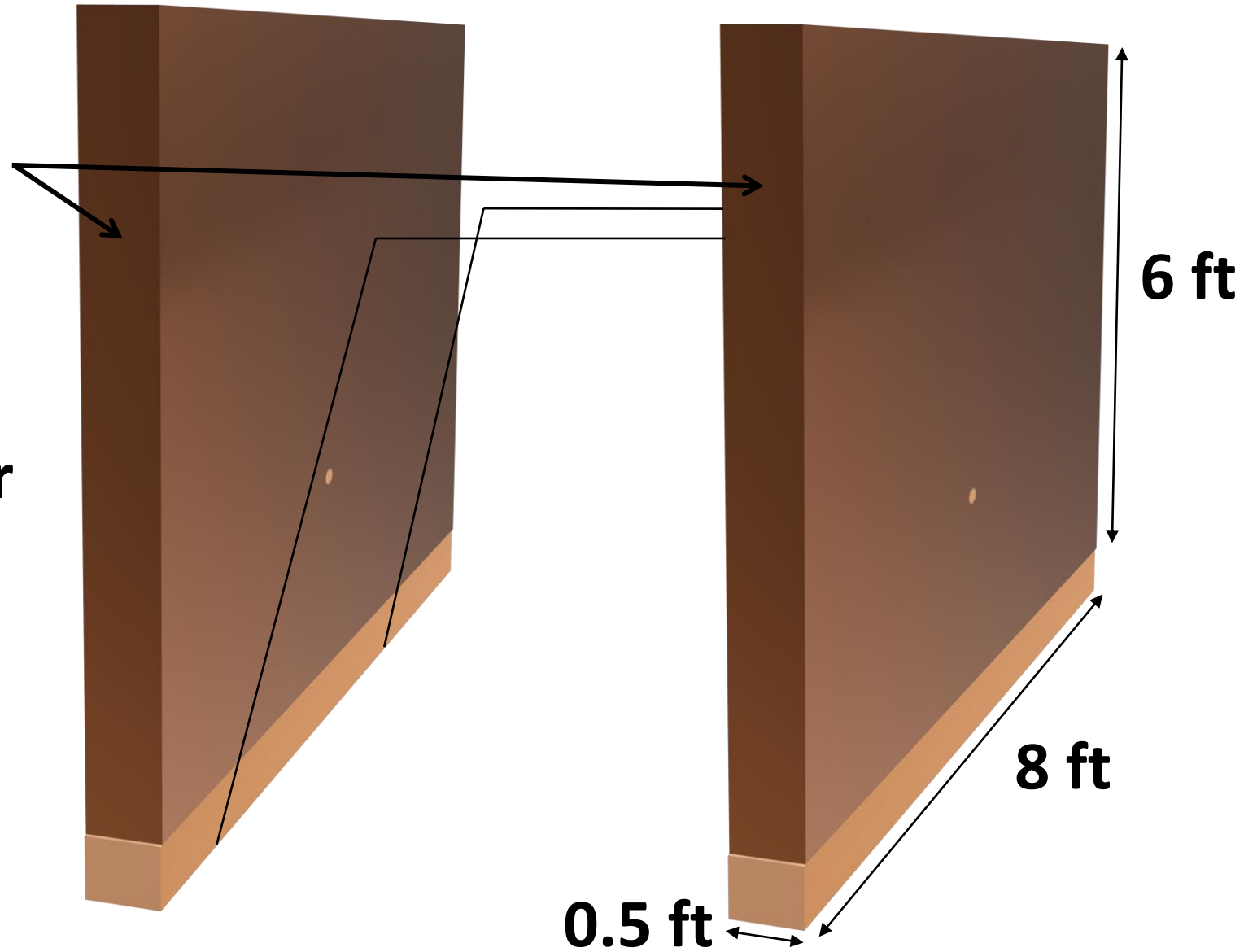
3-D View of Anchor Ballasts and Overlying Soil Columns



3-D View of Anchor Ballasts and Overlying Soil Columns

Total weight for two saturated soil columns
2,760 lbs

Weight of wood anchor ballasts
60 lbs




Anchor ballasts
must be offset from
tank footprint

Onsite Industry Case Studies

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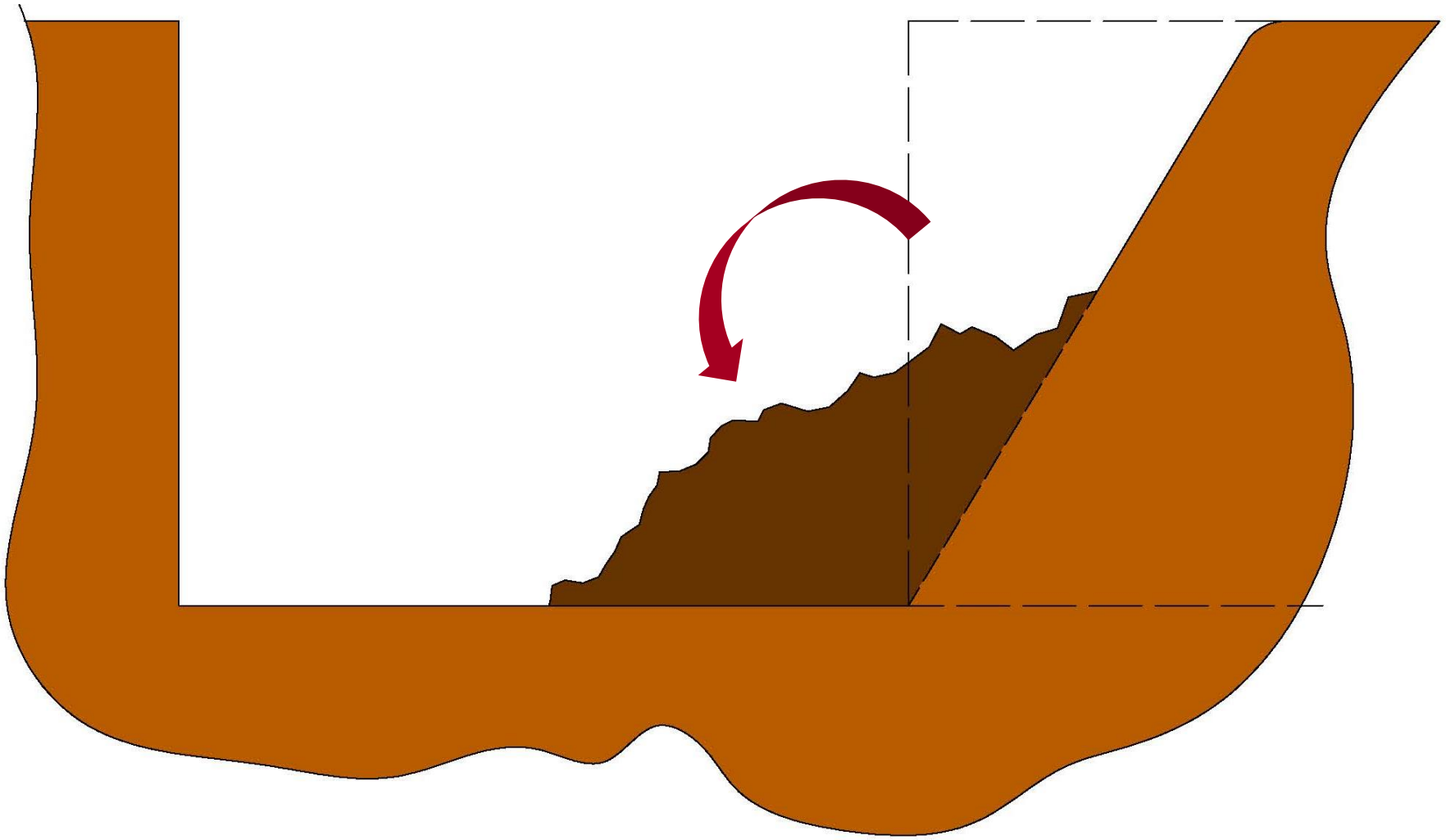
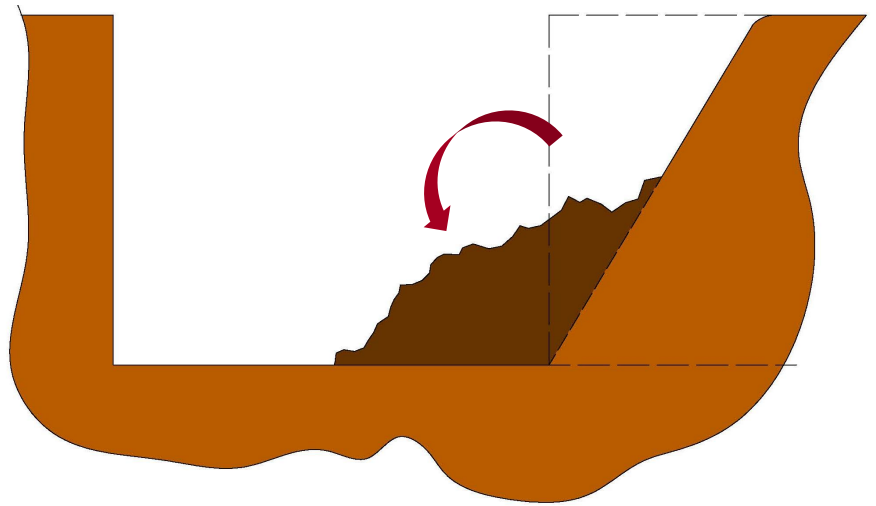
Slope Stability Case Study 1: Excavation Sidewall Stability




Notice the angle of repose and the lack
of setting back the spoil pile.

Situation: Excavation sidewall collapse



- Sidewall height = 4 ft
- Volume of collapsed soil wedge = 6 cf
- Unit weight of soil = 120 pcf
- Weight of collapsed soil per foot of trench = 6 cf x 120 pcf
- Weight of collapsed soil = 720 lbs / 1 ft of trench

6-ft sidewall collapse = 4,300 lbs of soil


newsflare

Example warning signs of an unstable excavation

- Tension cracks and fissures on adjacent ground surface
- Cracked or sagging sidewalls
- Outward bulging areas of sidewall
- Sliding or sluffing sections of sidewall
- Heaved or displaced bottom surface

How to use this information

- Think in three dimensions – above and below ground
- Evaluate the site conditions before starting work
- Look for cracked, bulging, and displaced soil as warning signals of possible movement
- Operate knowing wheel and track loads extend well beyond and below machinery
- Understand manufacturer installation instructions
- Be safe!

480 psf

INFILTRATOR
water technologies

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