GEOSYNTHETICS CONFERENCE

GEOSYNTHETIC MATERIALS ASSOCIATION

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Gannett Fleming

Fundamentals of Geosynthetics: Types, Functions, Selection and Applications

PM – Applications

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PM Session

Gannett Fleming

Thank You to the Following Companies Who Provided Samples for Preparing this Course

Tencate Mirafi
Tensar Corp.
EPI – Environmental Protection Inc.
Typar – Berry Plastics
Terram
Minerals Technology – CETCO
ICA – Insulation Company of America
Enka Solutions – Low and Bonar
GSE Environmental – SOLMAX
Presto Geosystems

Part 4: Functions and Applications

- Proper selection of a geosynthetic
  - Not feasible to cover all possible applications
  - Demonstrate process
  - Emphasis on process and more typical application
  - Will cover examples for most classes of materials covered in Part 3 of this course
  - Sometimes process very straight forward and sometimes more involved
  - Always matching application function and soil with geosynthetic type, fabrication/structure and polymer

Material (Typically Best for Application or Most Cost-Efficient)	Function/Application																
	Filtration	Separation	Stabilization	Reinforcement	Drainage	Impervious Barrier	Weak Subgrade	Load Distribution	Capillary Break	Lateral Drain	Bond Breaker	Protective Layer	Lightweight Fill	Paving	Steep Slope Facing	Compaction Aid	Erosion/Scour Control
Geotextile W-Mono	XX																
Geotextile W-Slit-Film																	X
Geotextile W-Multi-PP			X													X	
Geotextile W-Multi-Mix			X	X													
Geotextile W-Multi-PET				X													
Geotextile NW-NP		XX							XX	XX	XX	X		X		XX	X
Geotextile NW-SB		X									X			X			
Geogrid Uniax-HDPE/PET				XX													
Geogrid Biaxial-PP			XX												X	X	
Geogrid Biaxial-PET				X											X		
Geogrid Biaxial-FG														X			
Geogrid Triaxial/Multiaxial-PP			XX													X	
Geocell-HDPE/SB-PP							XX	XX							X		X
Geomembrane						XX						X					
Geosyn Clay Liner (GCL)						X											
Geofoam								X					XX				
Geocomposite Drains					XX				X	XX							
Paving Composites														XX			
Stabilization Composites			X														
Erosion & Sediment Control (ESC)																	XX

Part 4: Functions and Applications – cost considerations

Notes for table:

- Some materials may be able to provide multiple functions
- Where multifunction capability is indicated, it is not universal but depends upon compatibility with site-specific soil conditions
- Co-function capability may exist, however, broad multifunction capability for individual materials is not typical

- Also – keep in mind that geosynthetics typically (but not always) carry load in tension (there are exceptions)

Part 4: Functions and Applications – cost considerations

- Cost of geosynthetics is tied heavily to polymer cost
- Material that performs a function with equal or better efficiency having lowest polymer cost per square yard, will likely be most cost-effective
- Both weight per square yard and individual polymer cost are factors to be considered
- Structure also enters into efficiency calculus – e.g., geogrid typically more effective as reinforcement than geotextile since:
  - does not rely solely on interface friction, but also bearing of CM ribs on soil
  - grid is more efficient structure (stress transfer with soil)

Interdependency of Geosynthetic Polymer, Structure and Function

- Proper selection of a geosynthetic can be summed up as follows:

- Application – what is controlling function(s)
- Soil (earth material) and water conditions

⇩

Will Dictate

⇩

- Structure – geosynthetic type and fabrication
- Polymer type

Part 4: Functions and Applications

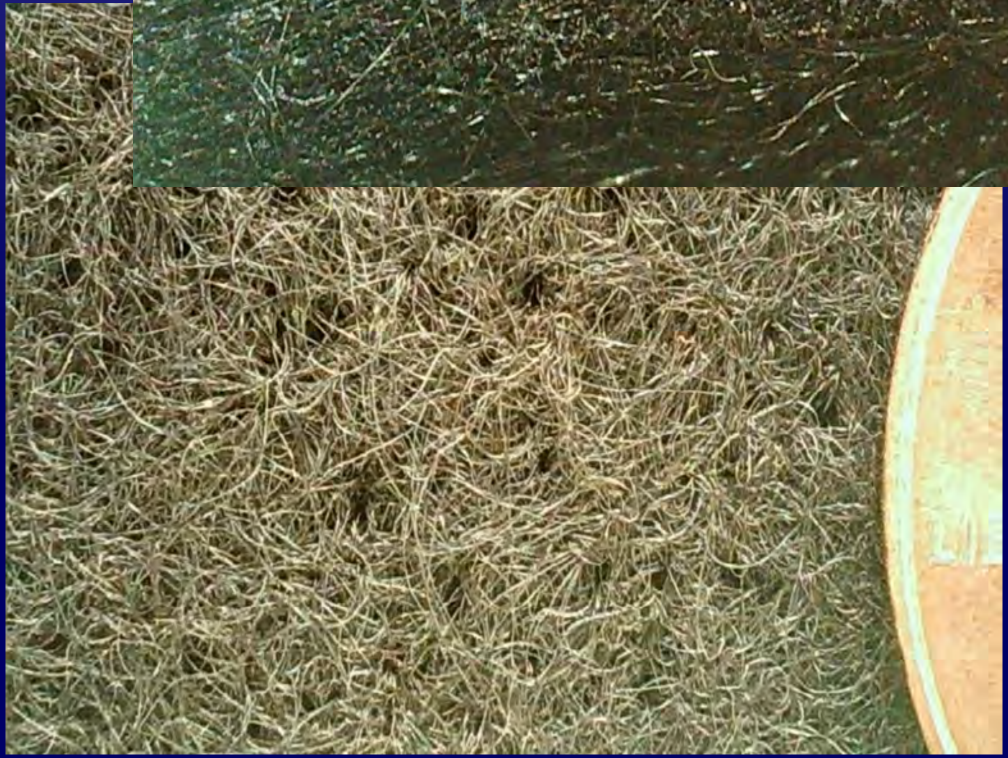
Example: Interdependency of Geosynthetic Polymer, Structure and Function

Material	Geotextile
Structure	Nonwoven Needle Punched
Polymer	Polypropylene
Function	Filtration
Application	Separation

Note: For highway applications this is a versatile multipurpose material
(Equally useful in other engineering environments)

Part 4: Functions and Applications

- Geotextile → Nonwoven Needle-Punched (NWNP-PP)
  - Variety of different functions and applications – extremely versatile
  - Structure makes NWNP geotextiles highly survivable – 50% elongation before failure
  - NWNP fabrics are also relatively inexpensive



Part 4: Functions and Applications – Separation

- Geotextile → Nonwoven Needle-Punched (PP)
  - For geotechnical engineering in highway environments, NWNP geotextile is:
    - Useful
    - Effective
    - Cost Efficient
    - “It is a Simple and Powerful Tool”
  - In my opinion, for a properly designed and constructed pavement section, nothing is more effective than a NWNP geotextile separator in protecting the integrity and increasing the longevity of a roadway. (Protects integrity of coarse aggregate drain layer)

Part 4: Functions and Applications – Separation

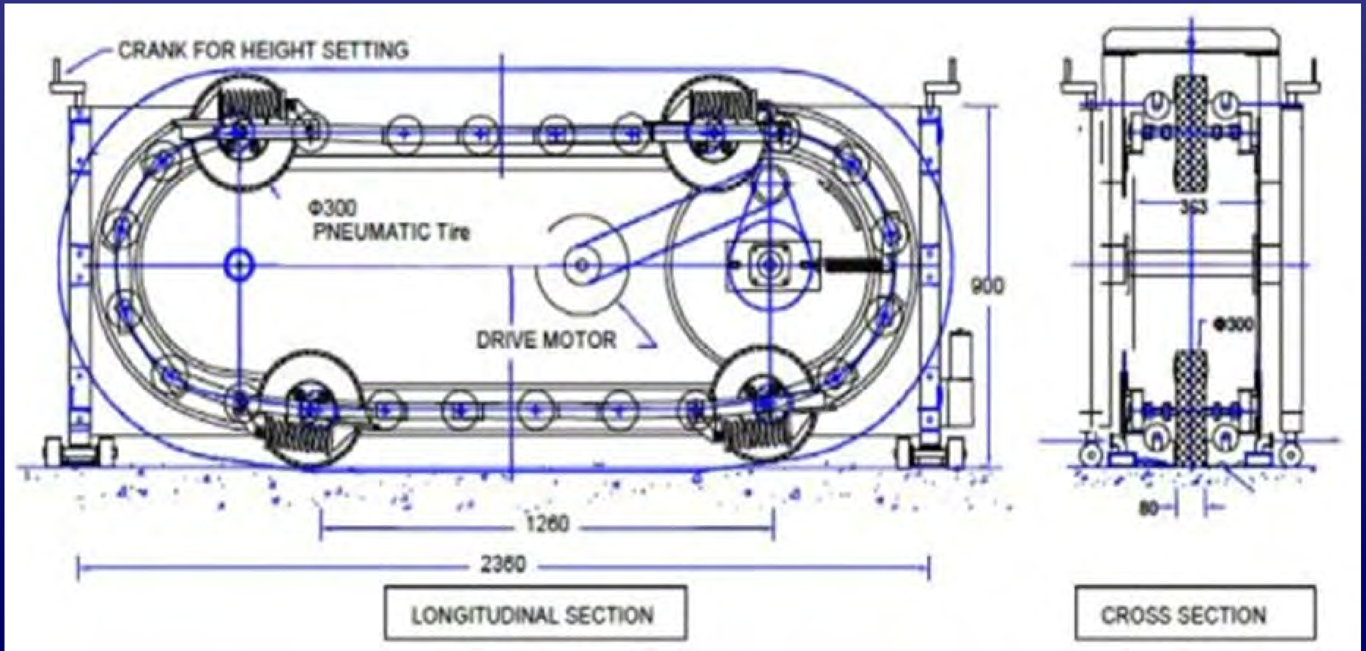
- Geotextile → Nonwoven Needle-Punched (PP)
  - Pennsylvania Subgrade Soils:

    50% Soils > 35% Fines (-200 sieve)

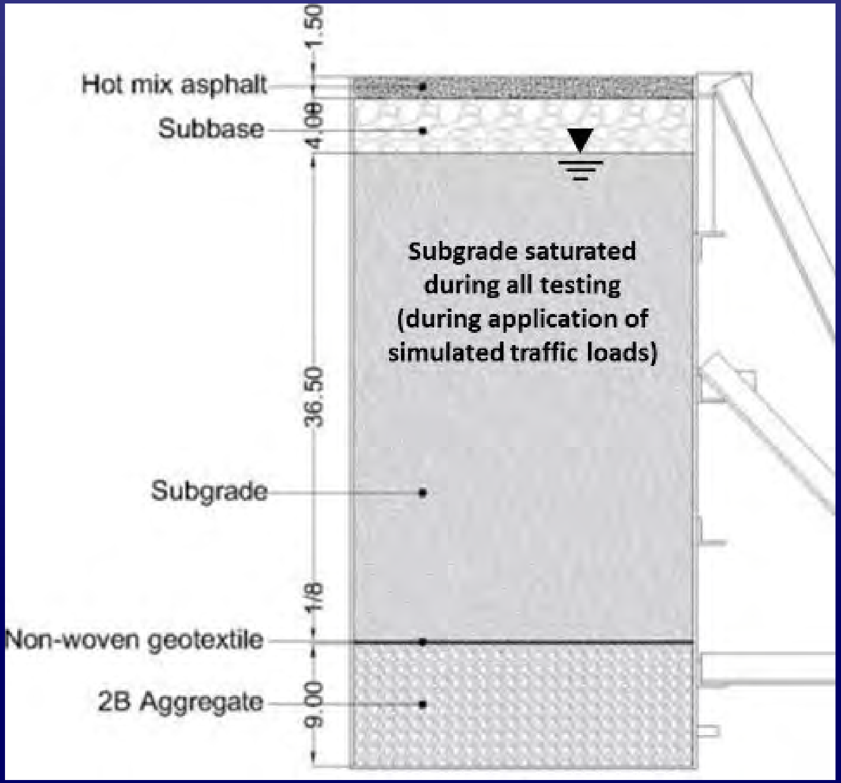
    73% Soils > 20% Fines (-200 sieve)
  - Pumping of fines up into granular subbase is big problem
  - Study to determine effectiveness of NWNP geotextile as separator between subgrade soil and granular subbase to prevent migration of fines

Part 4: Functions and Applications – Separation

- Geotextile → Nonwoven Needle-Punched (PP)
  - Study used 1/3 scale load simulator



Schematic of MMLS3 Load Simulator: Internal Track Mechanism, (units in mm)



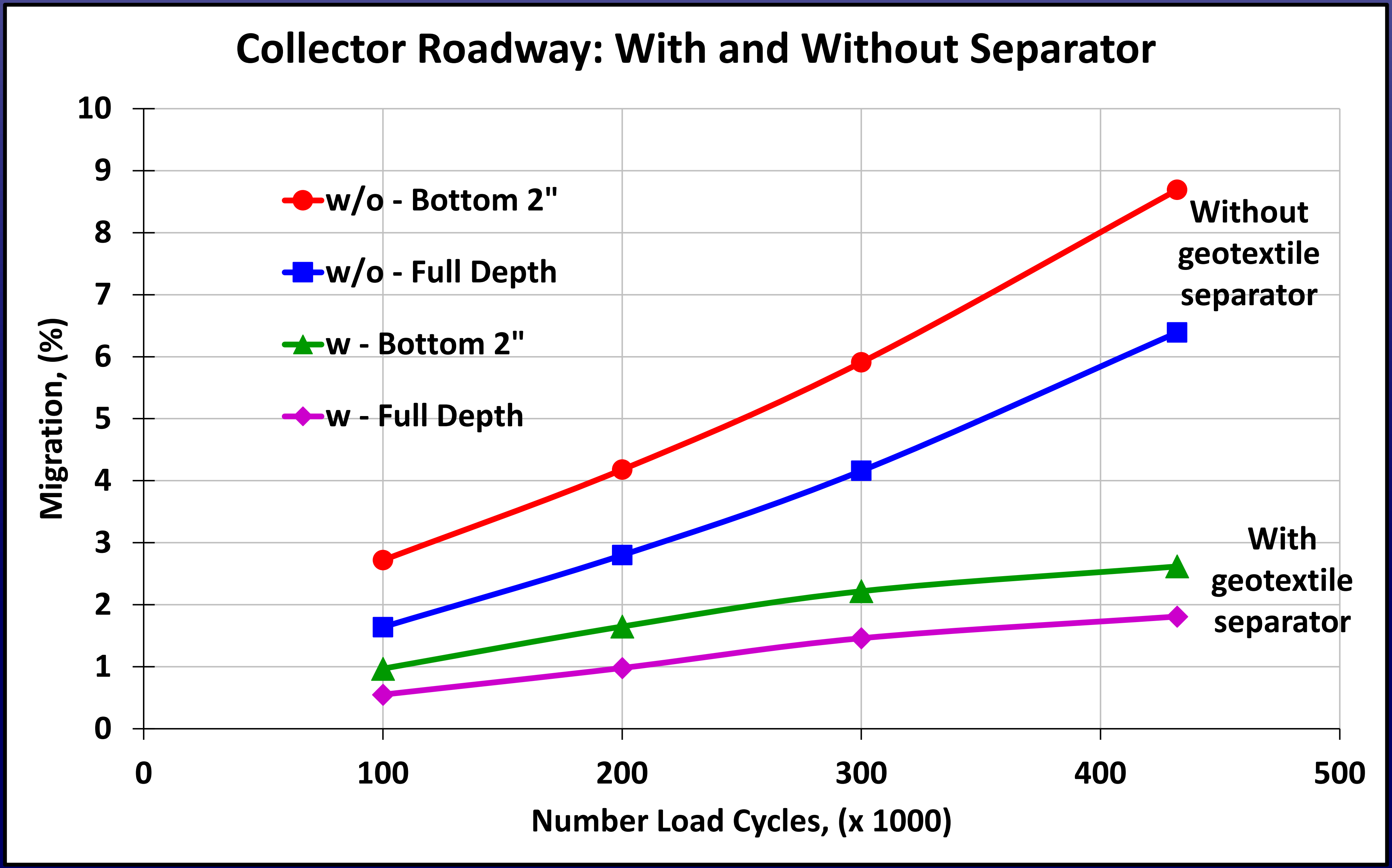
Typical Cross Section of Test Bed, (units in inches)

Part 4: Functions and Applications – Separation

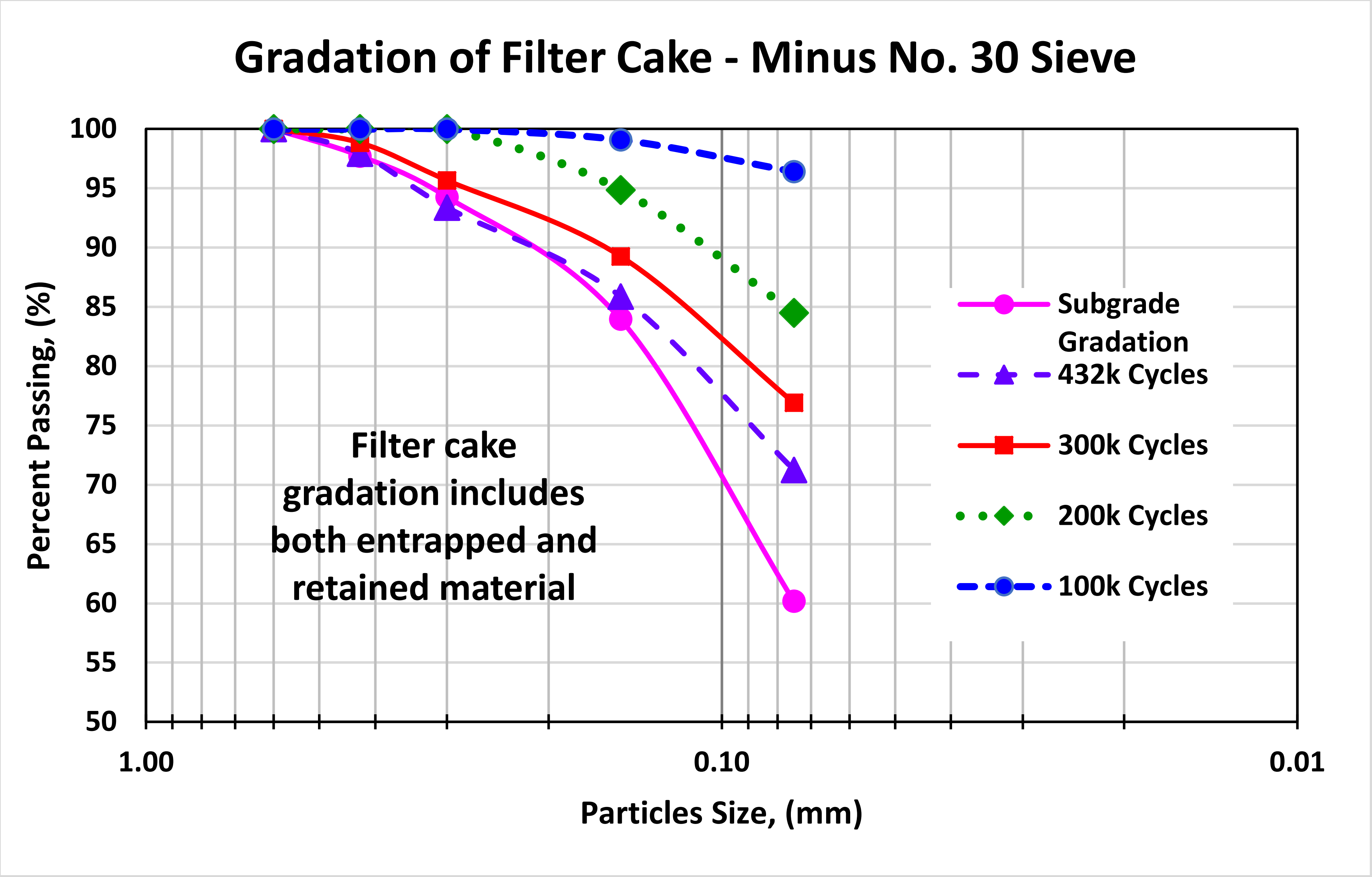
- Geotextile → Nonwoven Needle-Punched (PP)
  - Pavement Configurations Modelled in Study:

Roadway Class Modeled	Pavement Type	Pavement Section	Thickness (in)	ATPB (in)	Total Thickness All Bound Layers, (in)	Subbase (in)	Design Life (years)	ESAL's (millions)	ADT (one direction)
Collector	Flexible	Bituminous Concrete*	8.5	N/A	8.5	6.0	20	1.9	7900
Interstate	Flexible		17.5	N/A	17.5	6.0	20	25.6	25,000
Interstate	Rigid	PCC	13.0	4.0	17.0	4.0	20	36	25,000

Part 4: Functions and Applications – Separation



Part 4: Functions and Applications – Separation



Separation geotextile became more efficient as number load cycles increased (as filter cake developed)

Part 4: Functions and Applications – Separation

Gradation of Filter Cake						
Particle Size		Percent Passing of Minus 30 Matrial				
Sieve No.	Sieve Size, (mm)	Original Subgrade	100k Cycles	200k Cycles	300k Cycles	432k Cycles
30	0.600	100.0	100.0	100.0	100.0	100.0
40	0.425	97.7	100.0	100.0	98.8	97.9
50	0.300	94.3	100.0	100.0	95.7	93.4
150	0.150	84.0	99.1	94.9	89.3	85.9
200	0.075	60.2	96.4	84.5	76.9	71.3

Separation geotextile became more efficient as number load cycles increased (as filter cake developed)

Part 4: Functions and Applications – Separation

- Geotextile → Nonwoven Needle-Punched (PP)
  - Study Test Results:

Filter cake gradation eventually matches subgrade gradation (once filter cake fully developed)

No better proof could you have as to the efficiency of the geotextile separator

Part 4: Functions and Applications – Separation

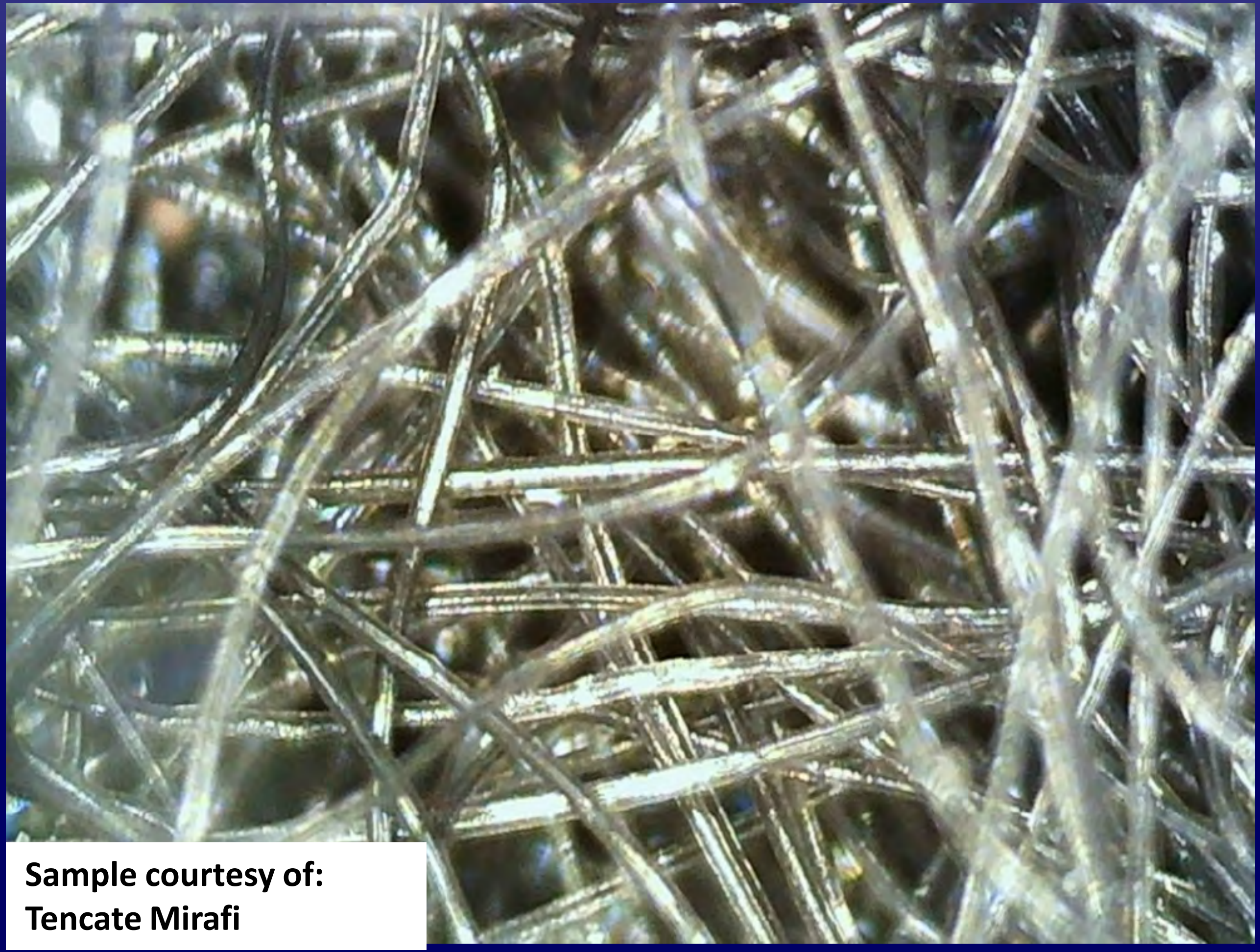
- Geotextile → Nonwoven Needle-Punched (PP)
  - Function: Separation – emphasis on soil retention
  - Geotextile Structure:
    - Felt like fabric
    - 3D matrix of needle-punched fabric provides excellent separation capabilities for wide range of particles sizes (especially for fine-grained soils against coarse open-graded aggregate)
    - Soil particles embed in matrix gradually building up filter cake
    - The thicker (higher oz/sy) the fabric, the greater the separation capacity

Part 4: Functions and Applications – Separation

- Geotextile → Nonwoven Needle-Punched (PP)
  - Function: Separation – emphasis on soil retention
  - Geotextile Structure:
    - Polymer is polypropylene (PP)
    - Effective and cost efficient for application

Part 4: Functions and Applications – Separation

- Geotextile → Nonwoven Needle-Punched (PP)
  - Function: Separation – emphasis on soil retention (3D fiber matrix)



Sample courtesy of:
Tencate Mirafi

Fabric structure of 3D matrix of fibers highly efficient at preventing migration of soil particles while permitting flow of water

Interdependency

Structure: NWNP
Polymer: Polypropylene
Function: Filtration
Application: Separation

Part 4: Functions and Applications – Separation

- Geotextile → Nonwoven Needle-Punched (PP)
  - Since fabric is needle-punched (as opposed to woven), has high elongation prior to failure (typically minimum 50% elongation prior to failure)
  - High elongation translates into excellent survivability during installation and aggressive service conditions
  - 12 oz/sy fabric is efficient separator with fine grained soil and has excellent survivability during installation and in aggressive applications (e.g., rip-rap against soil)
  - PENNDOT standard for all new pavements or complete pavement rehabs

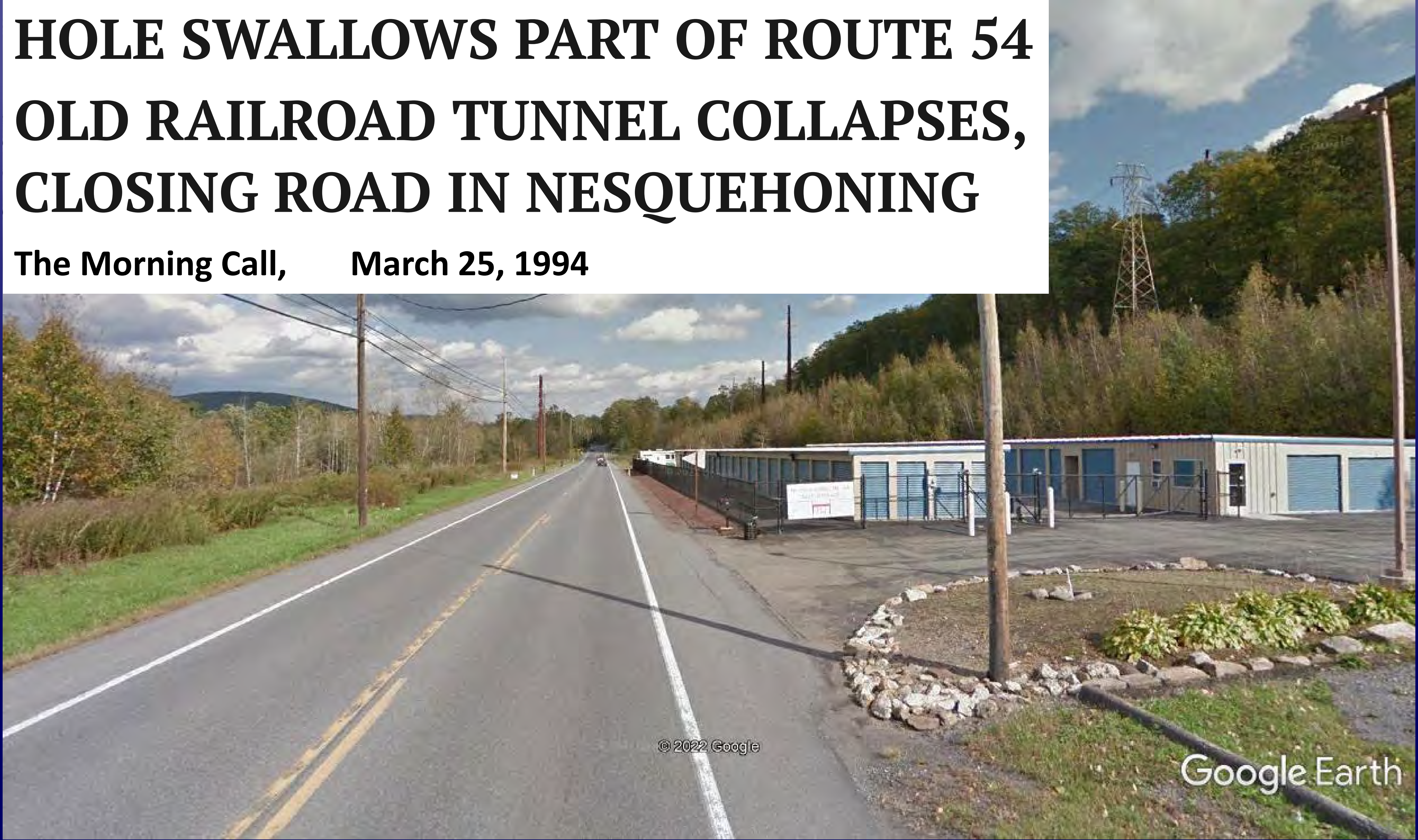
Part 4: Functions and Applications

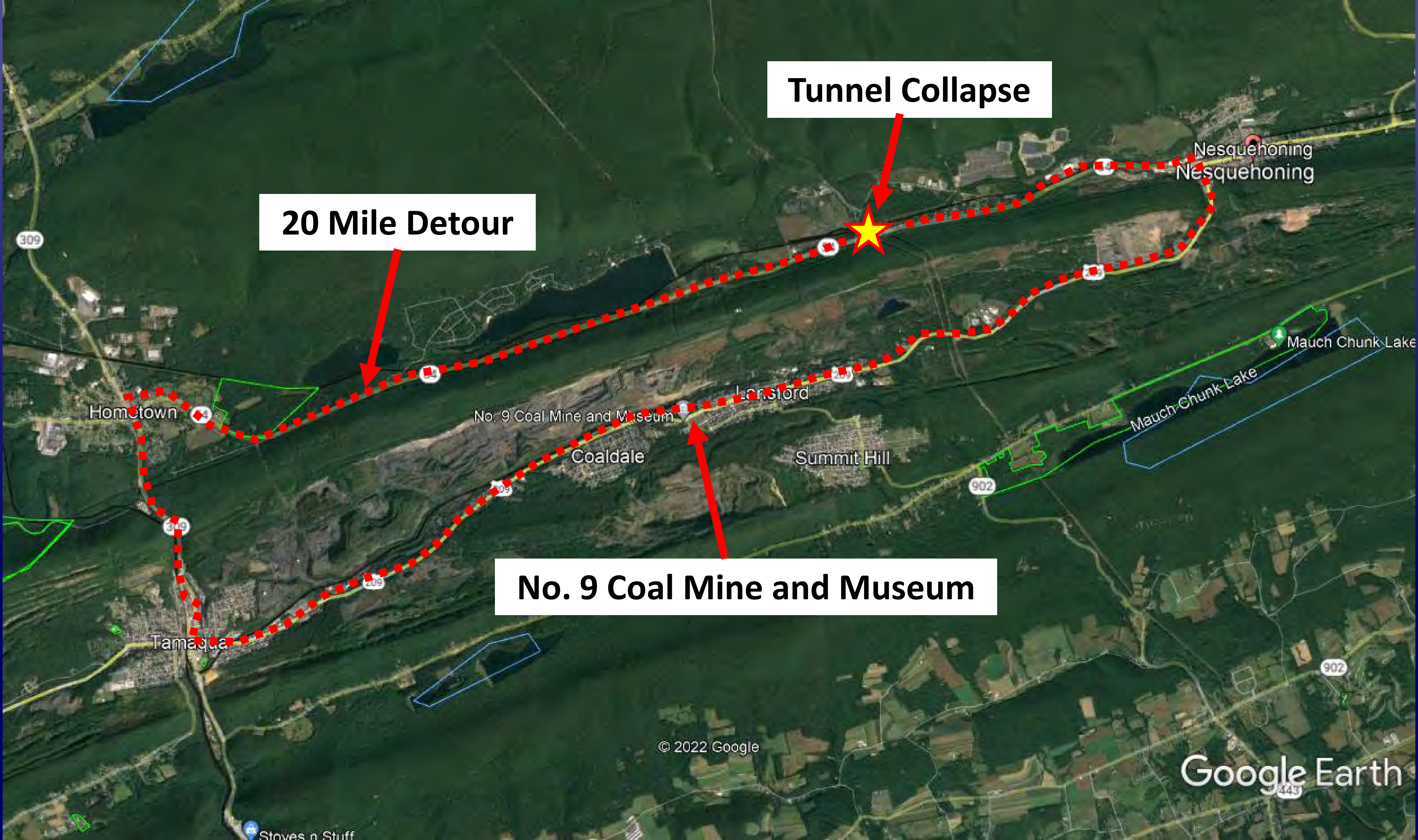
Example: Interdependency of Geosynthetic Polymer, Structure and Function

Material	Geotextile
Structure	Nonwoven Needle Punched
Polymer	Polypropylene
Function	In-plane Flow (Transmissivity)
Application	Drainage

HOLE SWALLOWS PART OF ROUTE 54 OLD RAILROAD TUNNEL COLLAPSES, CLOSING ROAD IN NESQUEHONING

The Morning Call, March 25, 1994




Tunnel Collapse
20 Mile Detour
No. 9 Coal Mine and Museum
Nesquehoning
Hometown
Coaldale
Summit Hill
Tamaqua
Mauch Chunk Lake
309
209
902
© 2022 Google
Google Earth
Stoves n Stuff

Part 4: Functions and Applications – Drainage

- Geotextile → Nonwoven Needle Punched
  - Collapsed zone and adjacent side slope excavated and culvert inserted to carry drainage from abandoned railroad tunnel
  - Native soil sandy clay, very wet
  - High moisture presented problem with proper compaction and potential stability and settlement problems when reconstructing the embankment.

Part 4: Functions and Applications – Drainage

- Geotextile → Nonwoven Needle Punched
  - Imported granular fill to replace the native soil was estimated to be $21/cy ($39.50/cy in 2022). Due to the high cost of replacement materials, decision to use NWNP geotextile to drain native soil during placement and compaction.
  - The polypropylene NWNP geotextile permitted dissipation excess pore pressure developed in the native soil during compaction – accelerating consolidation settlement and increasing strength.
  - Field testing conducted to confirm pore pressure response.

Part 4: Functions and Applications – Drainage

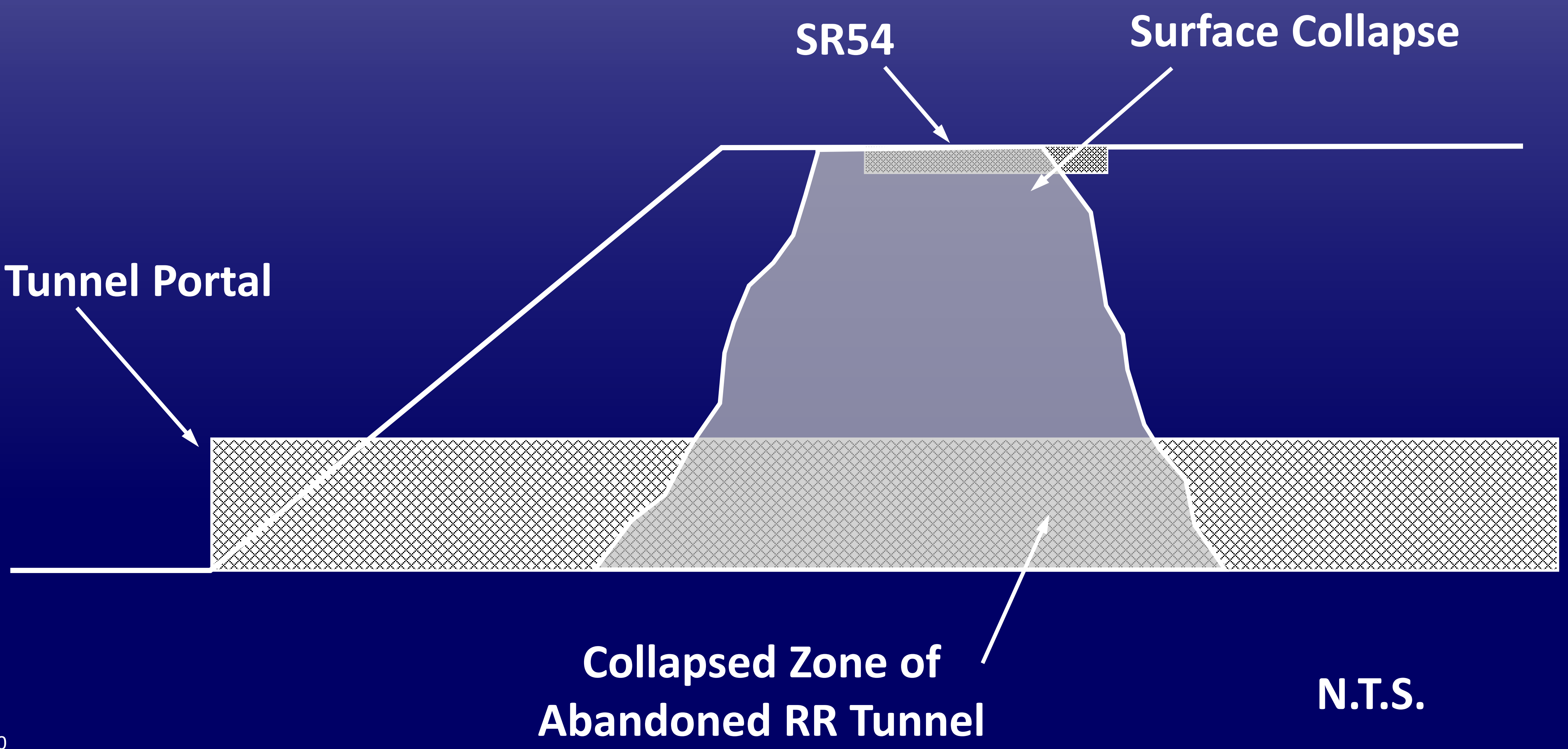
- Geotextile → Nonwoven Needle Punched
  - Field trial with geotextile placed at 12-inch vertical spacing in compacted fill
  - Full pore pressure dissipation achieved in test section in approximately 4 days as compared to approximately 25 percent dissipation without geotextile layers in same time period.
  - Using the geotextile at 1 ft intervals in compacted fill, the effective drainage path was reduced from the full height of the slope of 50 feet to 0.5 foot, a factor of 100. This permitted consolidation of the embankment to be completed under the fills own load, by the end of construction (as opposed to almost a year without the geosynthetic).

Part 4: Functions and Applications – Drainage

- Geotextile → Nonwoven Needle Punched
  - Piezometers placed at the base and middle of the slope during construction, confirmed the field trial test pad results.
  - Material cost of the geotextile was approximately $1/sy ($1.9/sy in 2022).
  - In-place costs of the geotextile, along with the on-site fill averaged just over $3/cy ($5.70/cy in 2022) for a total cost of $70k ($132k in 2022).
  - Savings of approximately $200k over the select-fill alternative, with additional savings from not having to remove the on-site soils from project site (plus significant time savings).

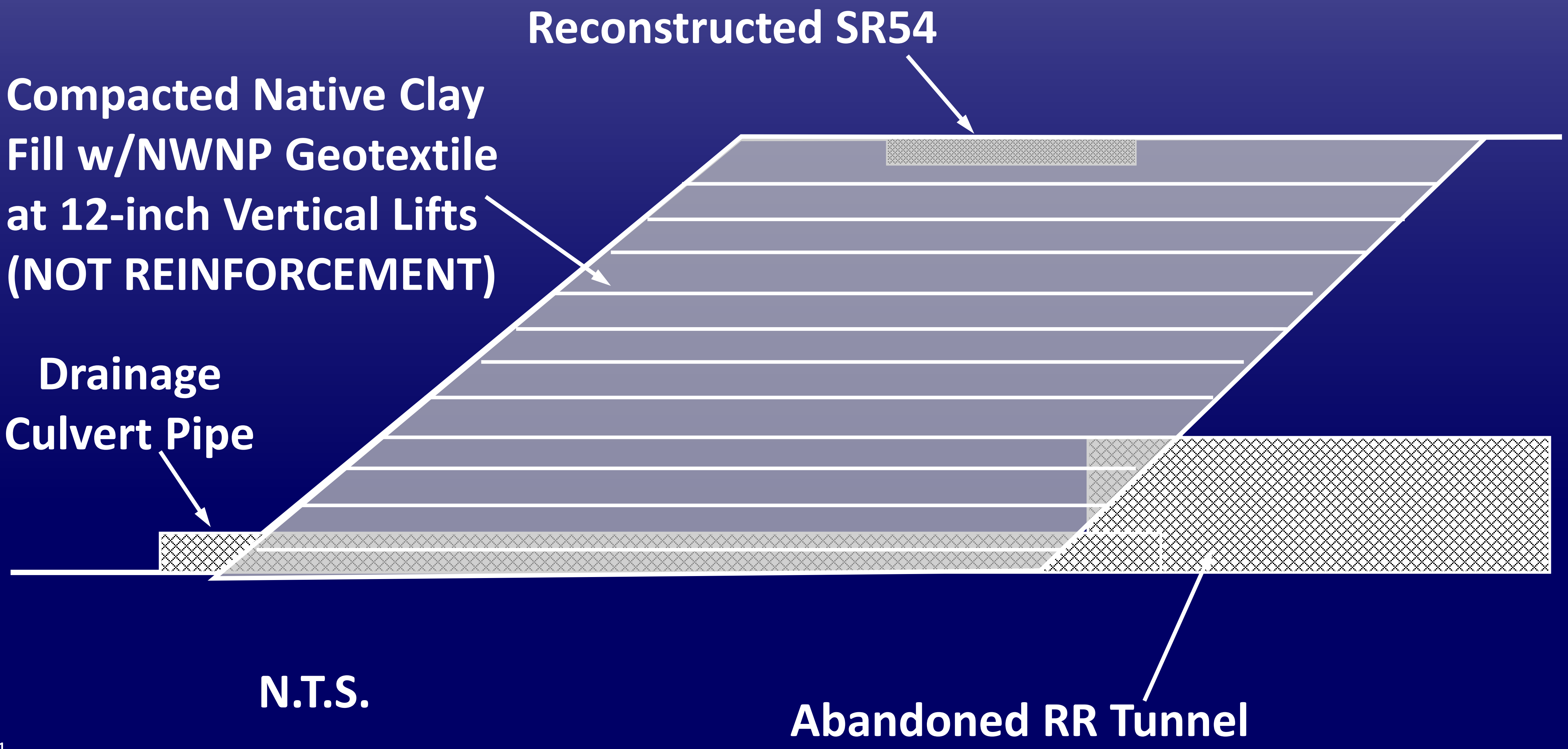
Part 4: Functions and Applications – Drainage

- Geotextile → Nonwoven Needle Punched



Part 4: Functions and Applications – Drainage

- Geotextile → Nonwoven Needle Punched



Part 4: Functions and Applications – Drainage

- Geotextile → Nonwoven Needle-Punched (PP)

Source: FHWA

Part 4: Functions and Applications – Drainage

- Geotextile → Nonwoven Needle-Punched (PP)
  - NW NP fabric can also effectively and efficiently provide several other functions
  - Function: Lateral Drain (similar to capillary break) – in-plane flow (transmissivity – ft^2/sec)
  - Transmissivity – material thickness matters, and therefore compressibility matters
  - If adequate thickness, NW NP has good capacity for in-plane flow
  - Pennsylvania soils are predominantly fine grained (35% A-4 and additional 30% A-2-4 with >20% fines)

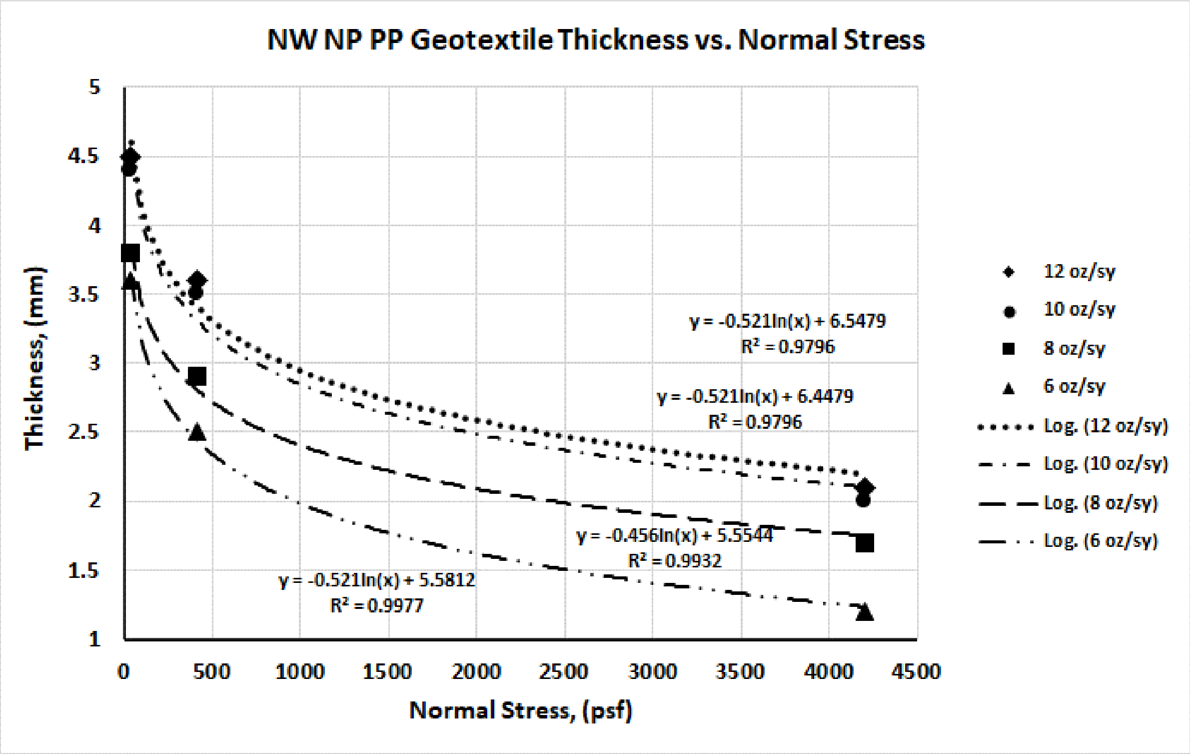
Part 4: Functions and Applications – Drainage

- Geotextile → Nonwoven Needle-Punched (PP)
  - Void space vs. normal stress (compression of fabric)
  - No compression – NW-NP PP ≈ 87% void space
  - 50 percent compression ≈ 75% void space

Void Space in a NW NP PP Geotextile	
Percent of Uncompressed Thickness, (%)	Percent Void Space, (%)
100 (No Compression)	87
75	83
50	75
25	50

Part 4: Functions and Applications – Drainage

- Geotextile → Nonwoven Needle-Punched (PP)
  - Thickness vs. normal stress (compression of fabric)
  - Normal stress 4200 psf (34 feet fill) 12 oz/sy fabric retains 50% thickness
  - At 50% thickness still has 75% void space
  - Good transmissivity (good in-plane flow)



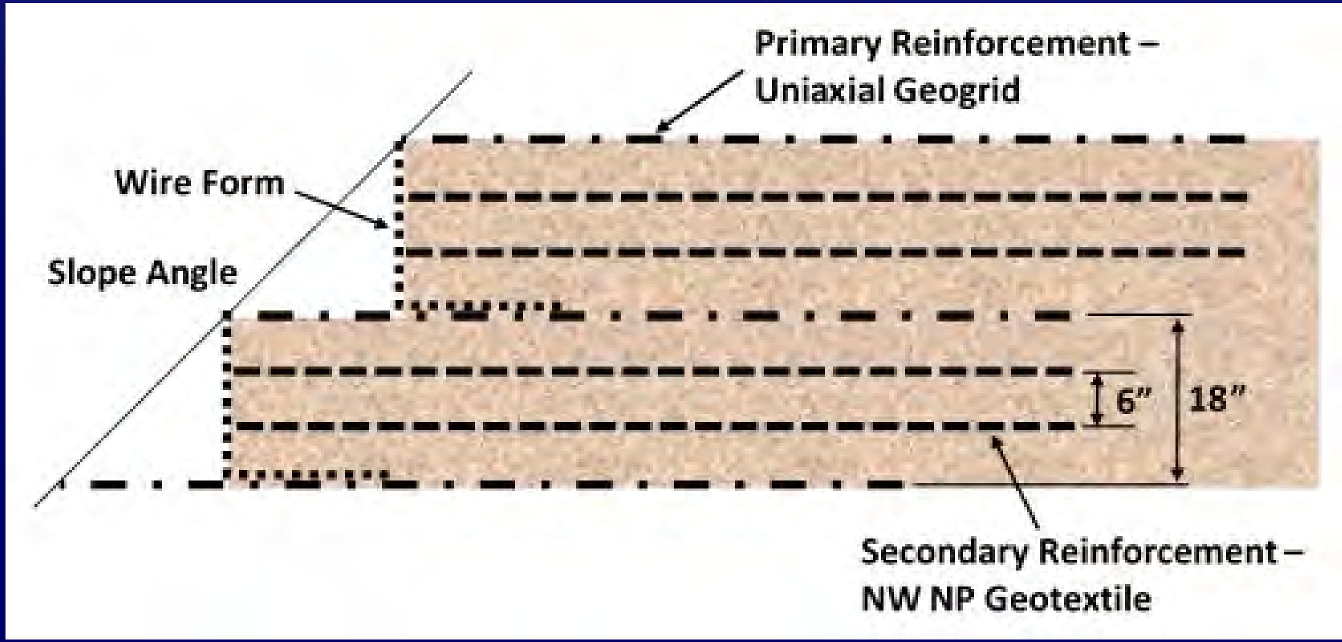
Void Space in a NW NP PP Geotextile	
Percent of Uncompressed Thickness, (%)	Percent Void Space, (%)
100 (No Compression)	87
75	83
50	75
25	50

Source: Dragana et. Al., 2014

Part 4: Functions and Applications – Drainage

- Geotextile → Nonwoven Needle-Punched (PP)
  - NW NP serves three functions in reinforced soil slope (cont.)

1) In-plane drainage permitting use of lower permeable soils for RSS
2) Provides edge confinement serving as compaction aid at unsupported face of RSS during construction and in service
3) With six-inch vertical spacing automatically controls lift thickness of compacted fill



Part 4: Functions and Applications

NWNP Geotextile for Erosion Control – not primary choice for erosion control but used in appropriate situations (dual function)

Material	Geotextile
Structure	Nonwoven Needle Punched
Polymer	Polypropylene
Function	Separation/Filtration
Application	Erosion Control

Part 4: Functions and Applications – Erosion Control

- Geotextile → Nonwoven Needle-Punched (PP)

Source: FHWA

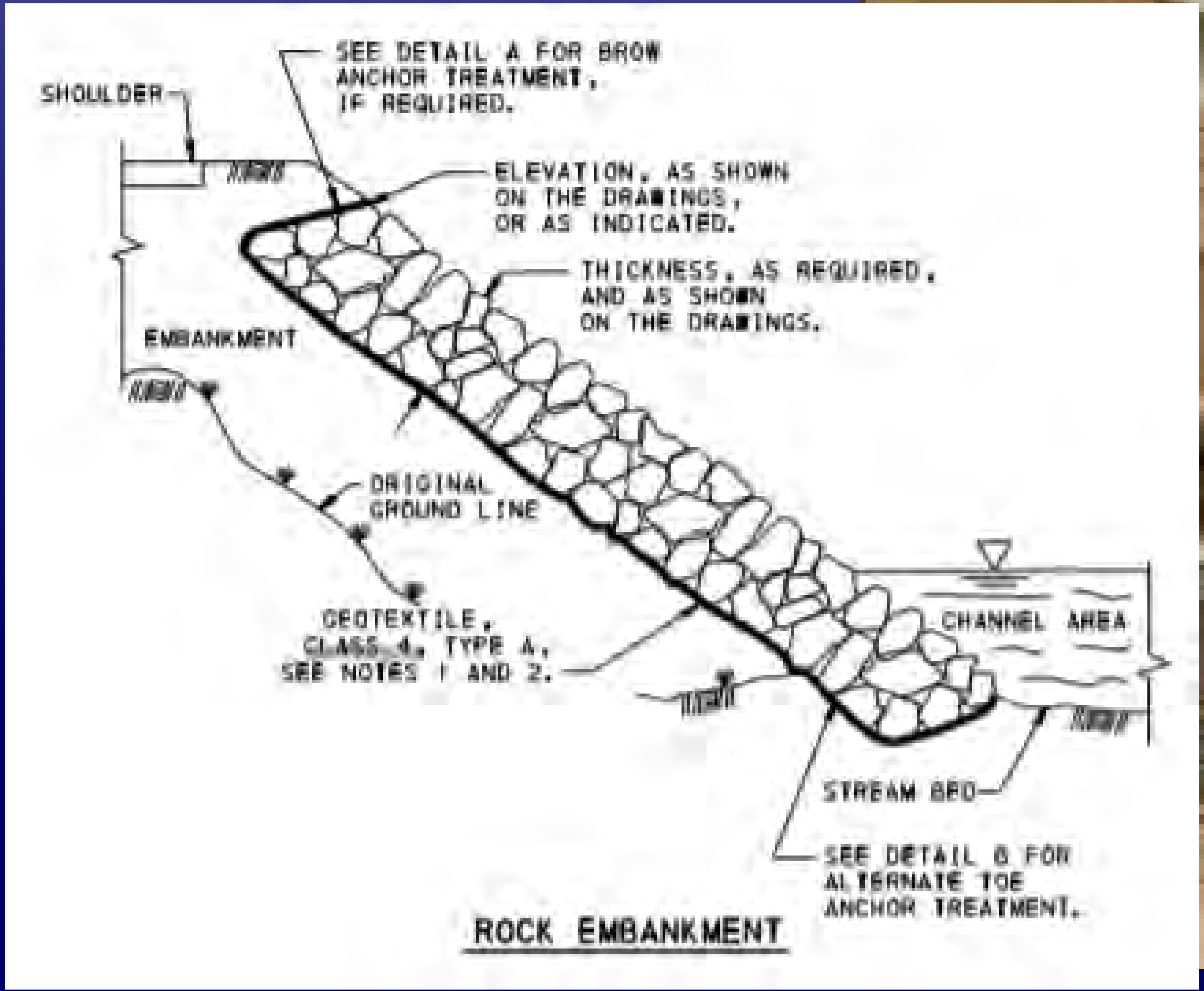
Part 4: Functions and Applications

- Geotextile → Nonwoven Needle-Punched (PP)

Source: PENNDOT

Part 4: Functions and Applications

- **Geotextile → Nonwoven Needle-Punched (PP)**



Source: PENNDOT

Source: Erosion Control Products

Part 4: Functions and Applications

Material	Geotextile
Structure	Nonwoven Needle Punched
Polymer	Polypropylene
Function	Stress Relief/Bond Breaker
Application	Pavement Overlay Interlayer

Part 4: Functions and Applications

- Geotextile → Nonwoven Needle-Punched (PP)
  - Function: Bond Breaker
  - NP fabric results in 3D matrix of loosely bound staple fibers
  - Given adequate thickness, loosely bound fibers prevent bonding of concrete pavement overlays to underlying concrete pavement surfaces

NWNP Geotextile Interlayer

Source: OK/AR Chapter, ACPA

Part 4: Functions and Applications

- Geotextile → Nonwoven Needle-Punched (PP)
  - Function: Bond Breaker

- ≈ ¼ in thick
- 13-15 oz/sy

Source: OK/AR Chapter, ACPA

Part 4: Functions and Applications

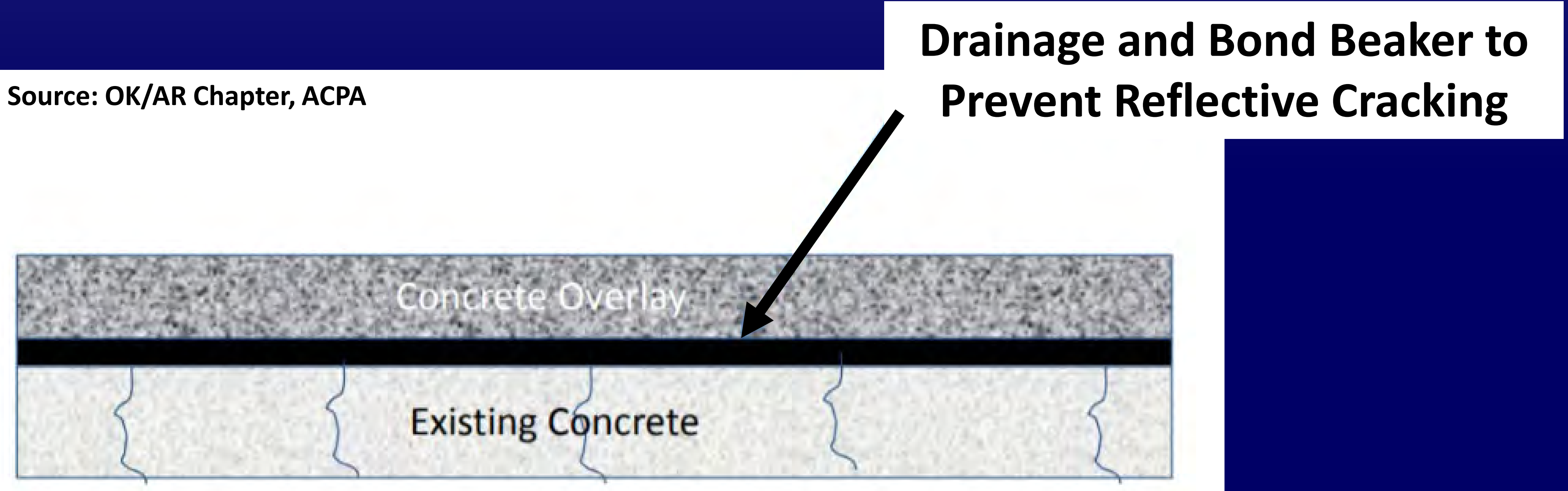
- Geotextile → Nonwoven Needle-Punched (PP)
  - Function: Bond Breaker

Source: OK/AR Chapter, ACPA

Part 4: Functions and Applications

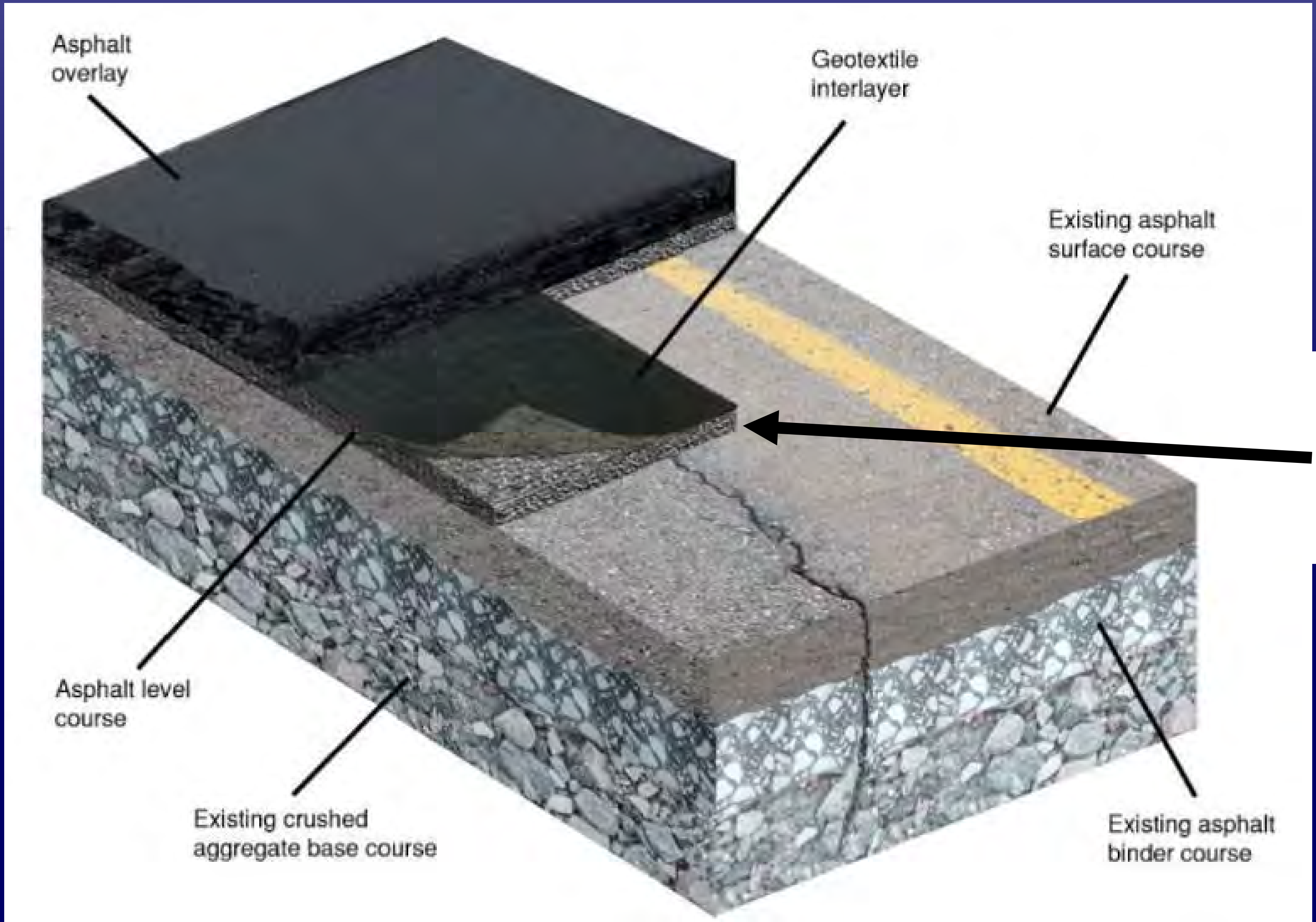
- Geotextile → Nonwoven Needle-Punched (PP) – Bond Breaker
  - University of Munich Study
    - Provides Drainage
    - Prevents Erosion of Cement Treated Base
    - Prevents Reflective Cracking
    - Provides Uniform Bearing Support During Curling/Warping

Source: OK/AR Chapter, ACPA



Part 4: Functions and Applications

- **Geotextile → Nonwoven Needle-Punched (PP)**



Geotextile for prevention of reflective cracking in asphalt overlay

Source: Benchmark, Inc.

Part 4: Functions and Applications

- Geotextile → Nonwoven Needle-Punched (PP)

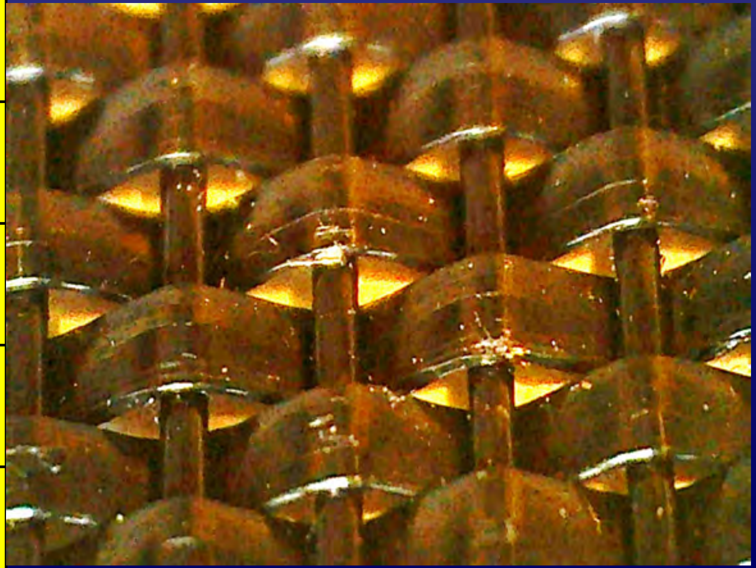
With an asphalt tack coat added, can also serve as membrane waterproofing system

Source: Propex

Part 4: Functions and Applications

Example: Interdependency of Geosynthetic Polymer, Structure and Function

Material	Geotextile
Structure	Woven Monofilament
Polymer	Polypropylene
Function	Filtration
Application	Drainage



Part 4: Functions and Applications

Interdependency of Geosynthetic Polymer, Structure and Function

Woven Monofilament Geotextile			
Product Designation	Percent Open Area (%)	Permittivity (sec^{-1})	Mass per Unit Area (lb/sy)
FW402	10	2.10	0.41
FW403	6	0.96	0.56
FW500	3	0.20	0.53
FW404	1	0.90	0.58

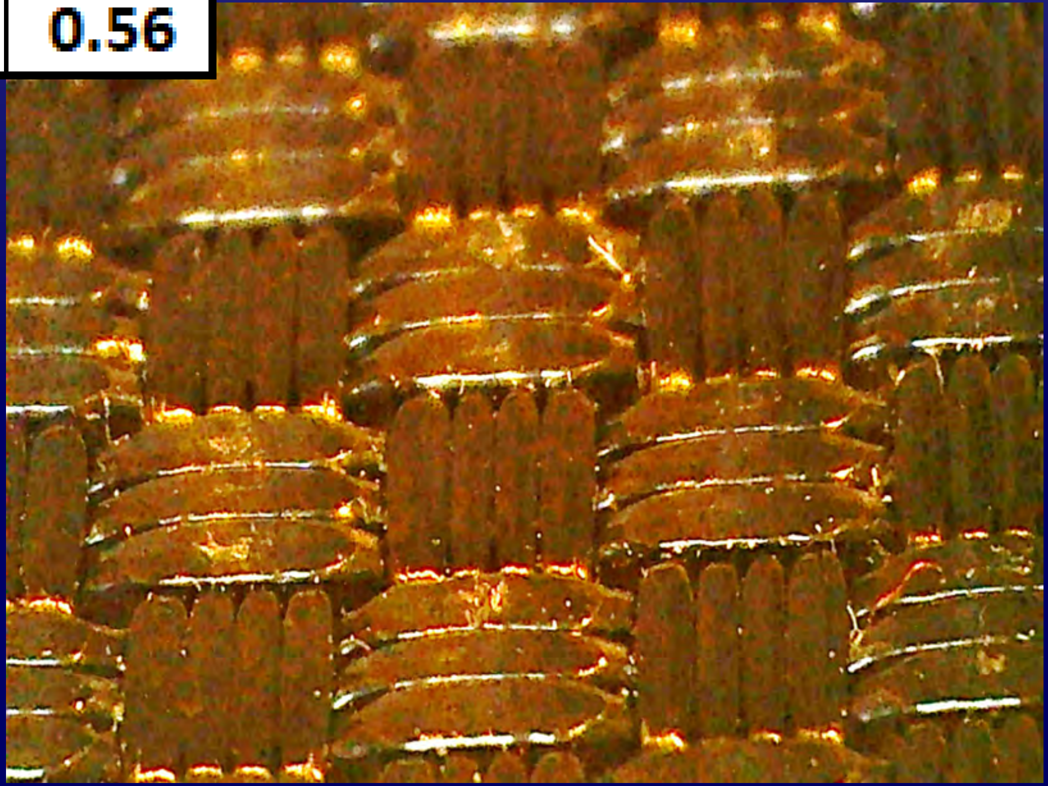
Same mass per unit area but very different POA and Permittivity – controlled by fabric structure

Part 4: Functions and Applications

Interdependency of Geosynthetic Polymer, Structure and Function

FW403	
POA	6
Perm	0.96
lb/sy	0.56

Structure



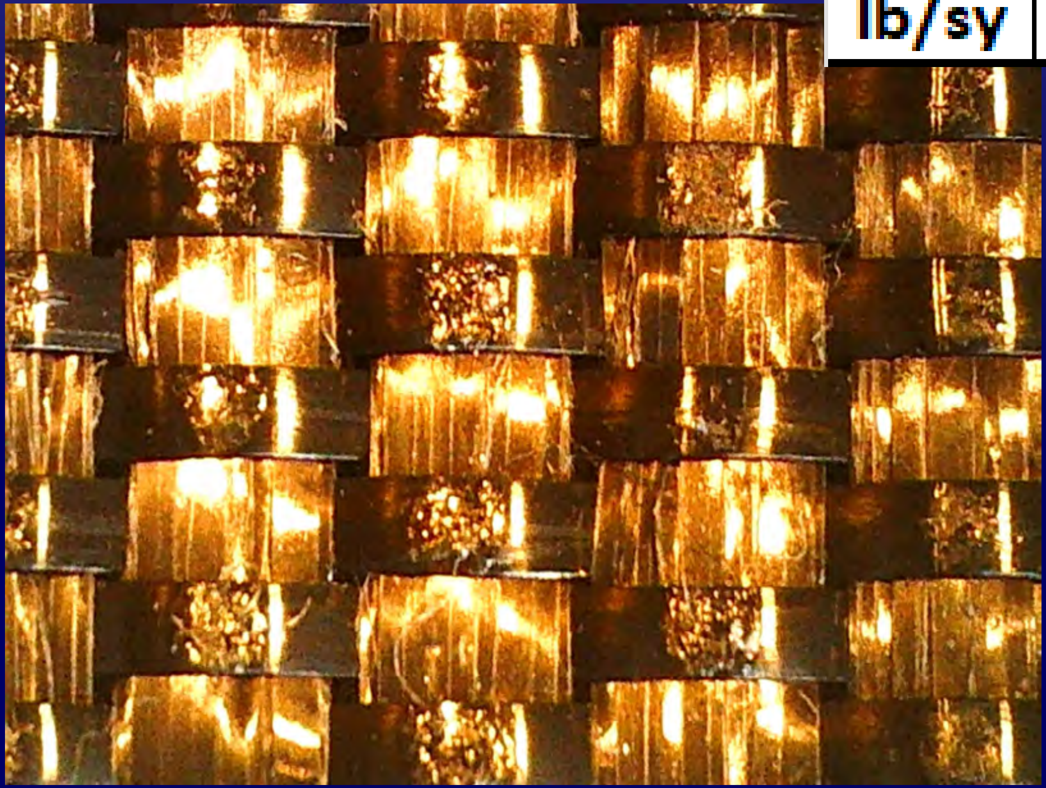
Multiple finer calendered filaments MD and CD

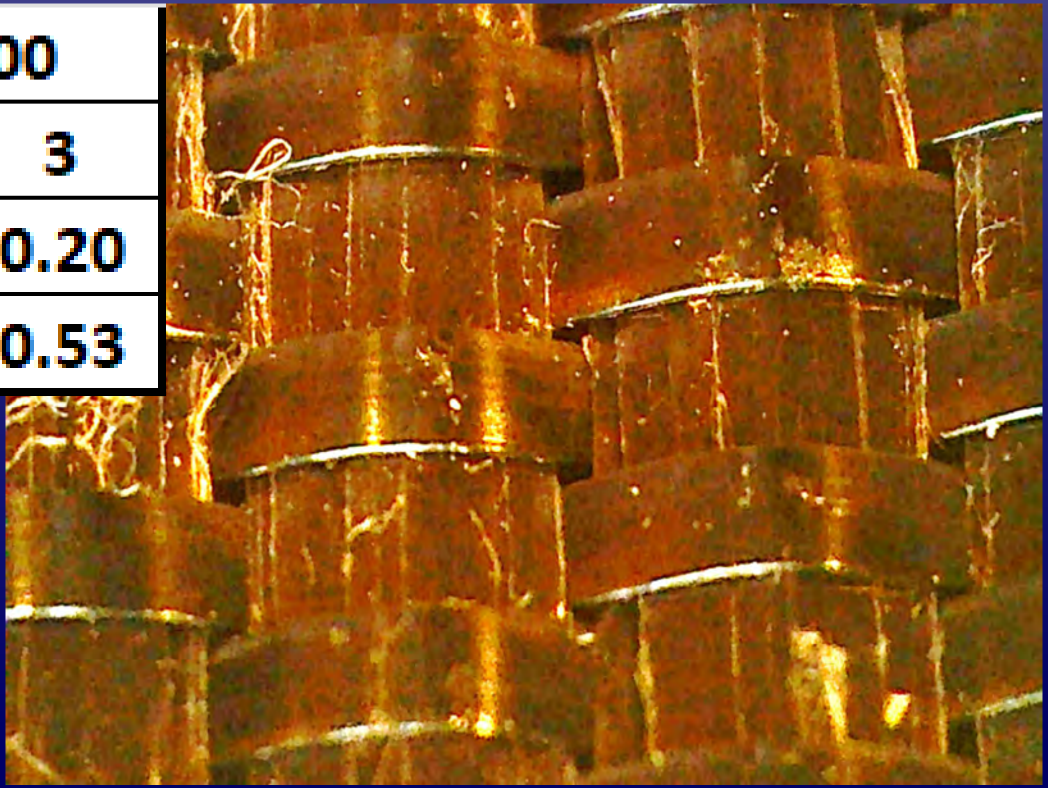
Part 4: Functions and Applications

Interdependency of Geosynthetic Polymer, Structure and Function

Structure

FW500	
POA	3
Perm	0.20
lb/sy	0.53



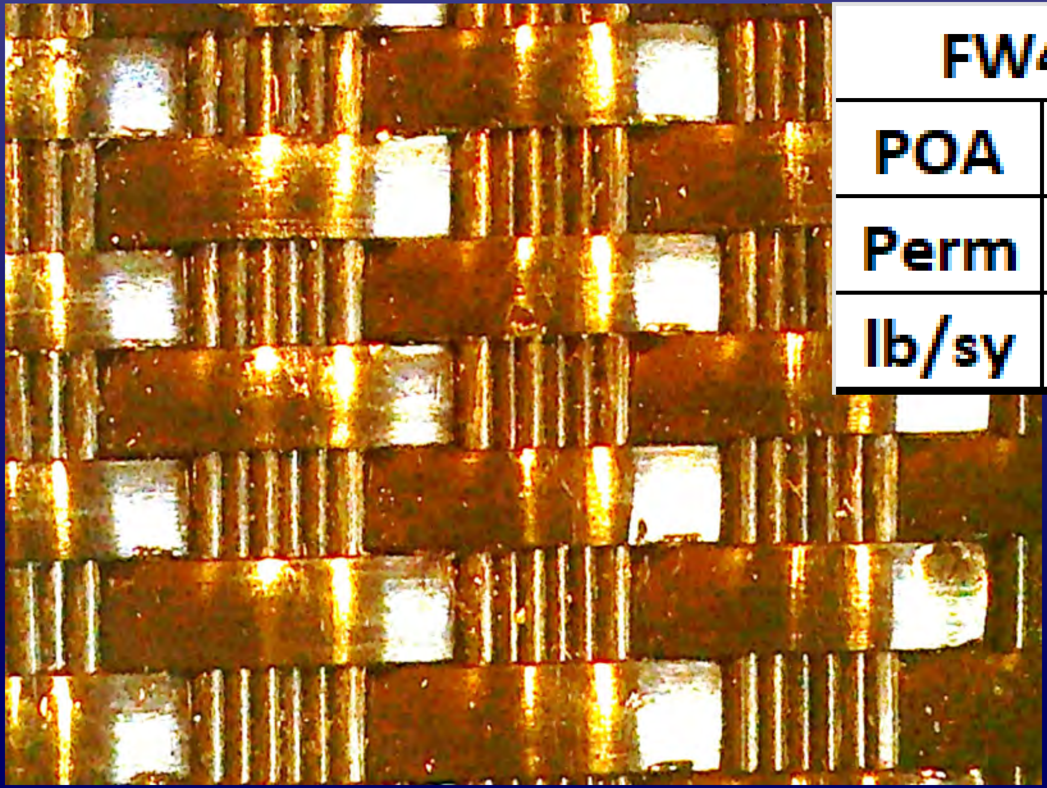


Single calendered filaments one direction, Multiple calendered filaments other direction

1:50PM

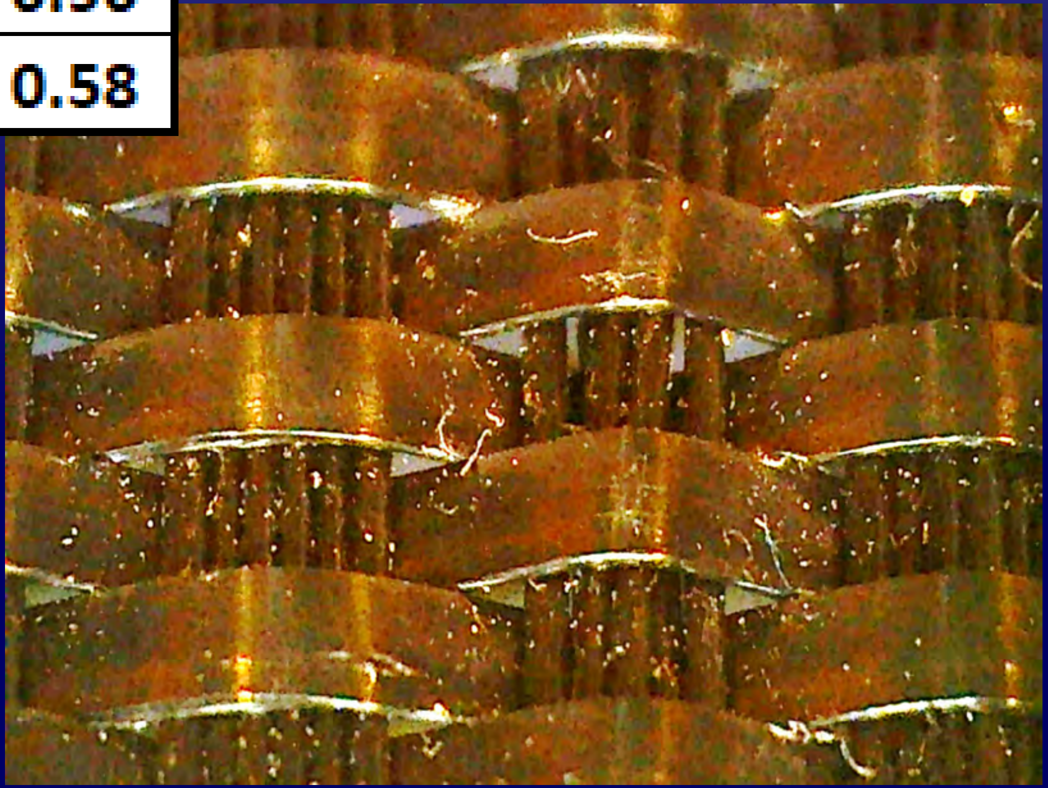
Part 4: Functions and Applications

Interdependency of Geosynthetic Polymer, Structure and Function



FW404	
POA	1
Perm	0.90
lb/sy	0.58

Structure

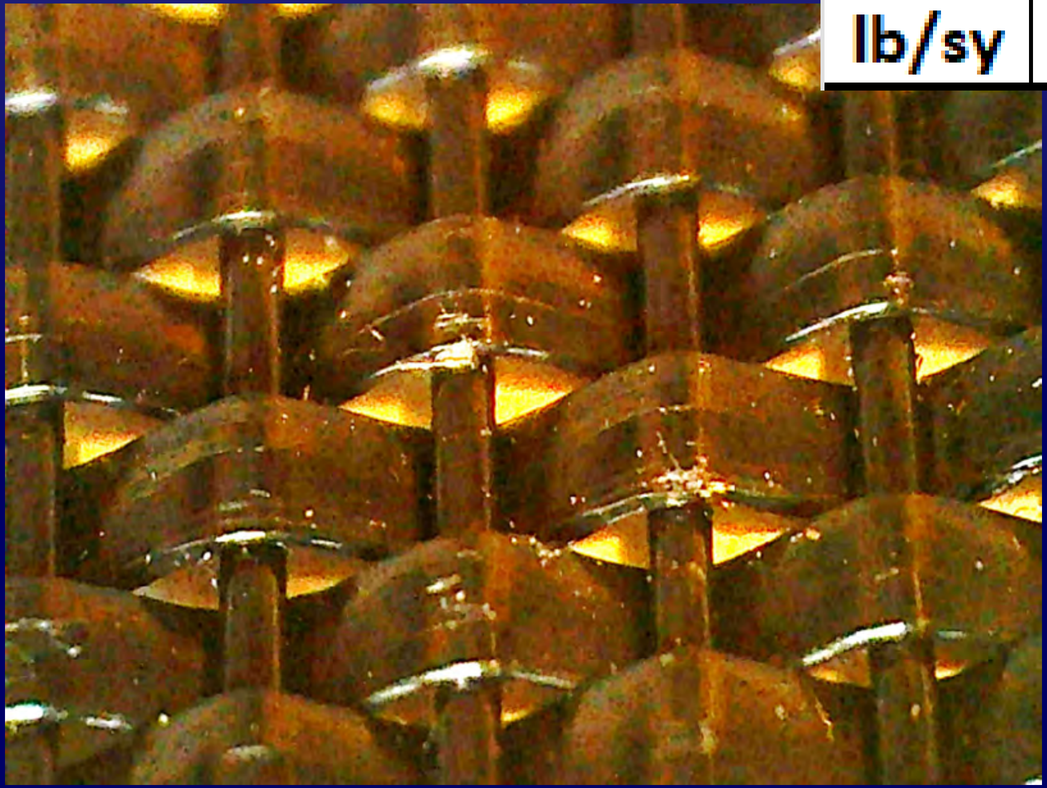


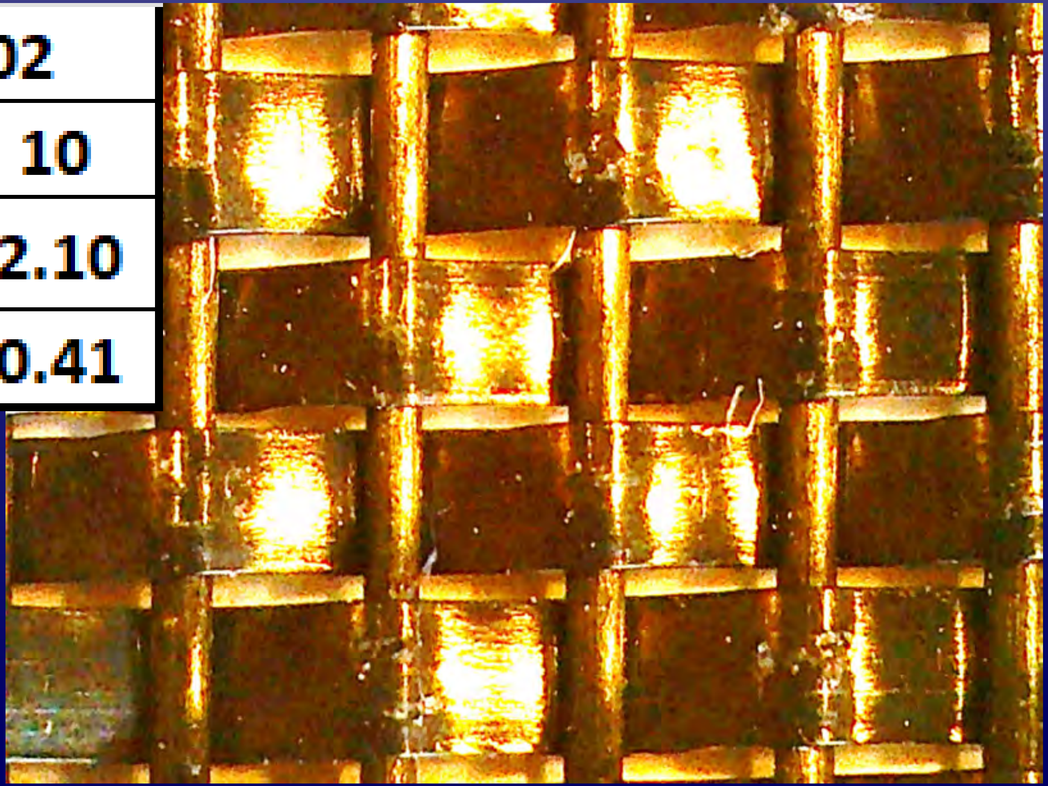
Single calendered filaments one direction, Multiple finer filaments other direction (not calendered)

Interdependency of Geosynthetic Polymer, Structure and Function

Structure

FW402	
POA	10
Perm	2.10
lb/sy	0.41





Single filaments MD and CD, Calendered one direction

Part 4: Functions and Applications

Interdependency of Geosynthetic Polymer, Structure and Function

Woven Monofilament Geotextile			
Product Designation	Percent Open Area (%)	Permittivity (sec^{-1})	Mass per Unit Area (lb/sy)
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Same mass per unit area but very different POA and Permittivity – controlled by fabric structure

Part 4: Functions and Applications – Filtration/Drainage

Example: Interdependency of Geosynthetic Polymer, Structure and Function

- Geotextile → Woven Monofilament
  - Function: Filtration – emphasis on water flow as opposed to material retention
  - Cross-plane flow – permittivity (sec^{-1}) or cross plane flow rate
  - Woven monofilament provides variable AOS and POA depending upon material structure (i.e., filament density and shape – as seen above)

Part 4: Functions and Applications – Filtration/Drainage

Example: Interdependency of Geosynthetic Polymer, Structure and Function

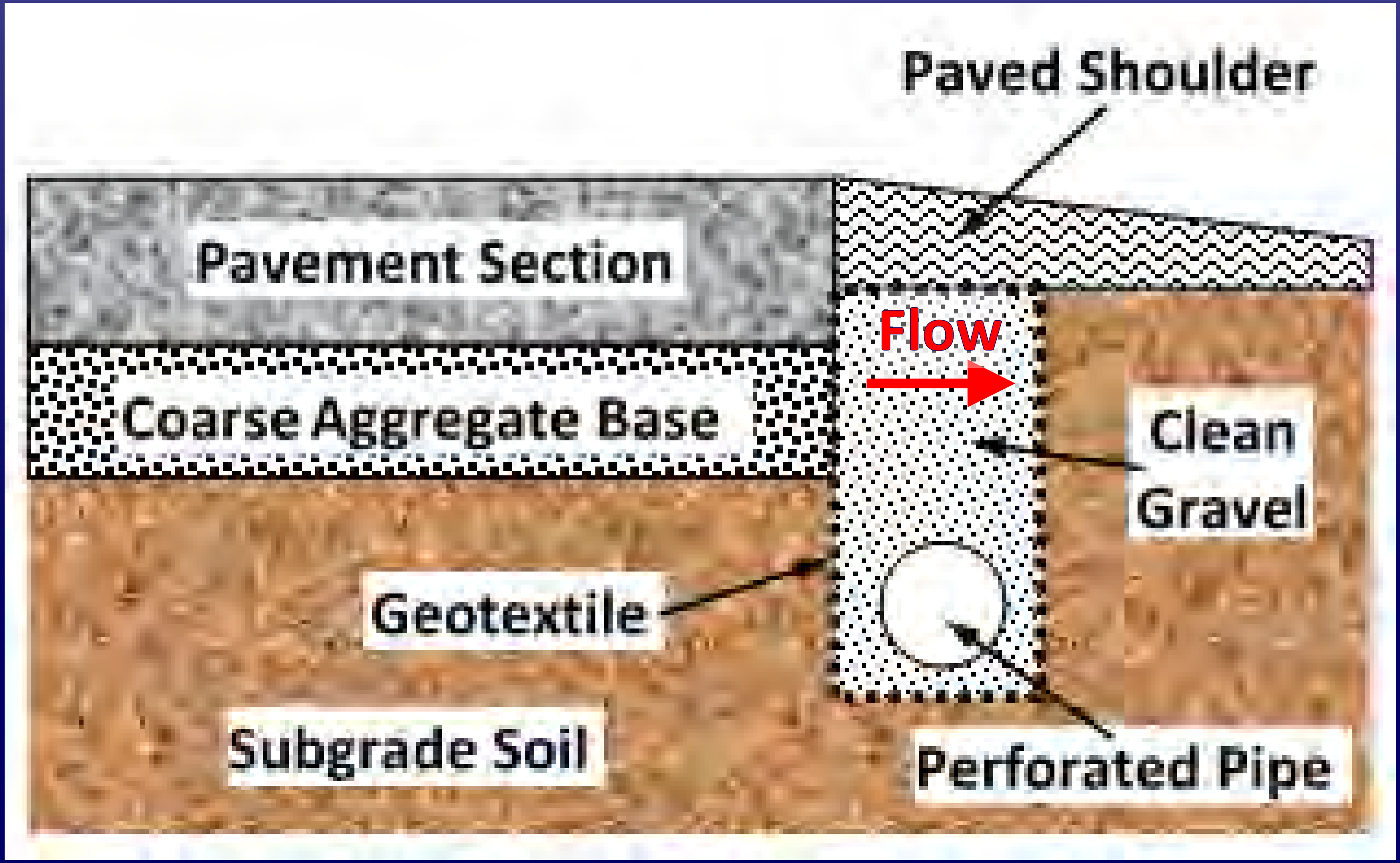
- Geotextile → Woven Monofilament
  - Structure can prevent clogging – fines can pass freely
  - May not be ideal if water flowing <u>from</u> high fines content soil
  - Can also co-function as separator if between fine sand and gravel

Filtration/Drainage – Woven Monofilament Geotextile

- Proper selection of a geosynthetic – a more detailed example
  - Remember - always matching application function and soil with geosynthetic type, fabrication/structure and polymer
  - Sometimes process very straight forward and sometimes more involved
  - The following is an example of a more involved process – but with a very large footprint (material serving as a statewide standard specification)

Part 4: Functions and Applications

- Selection of geotextile filter for pavement base drain

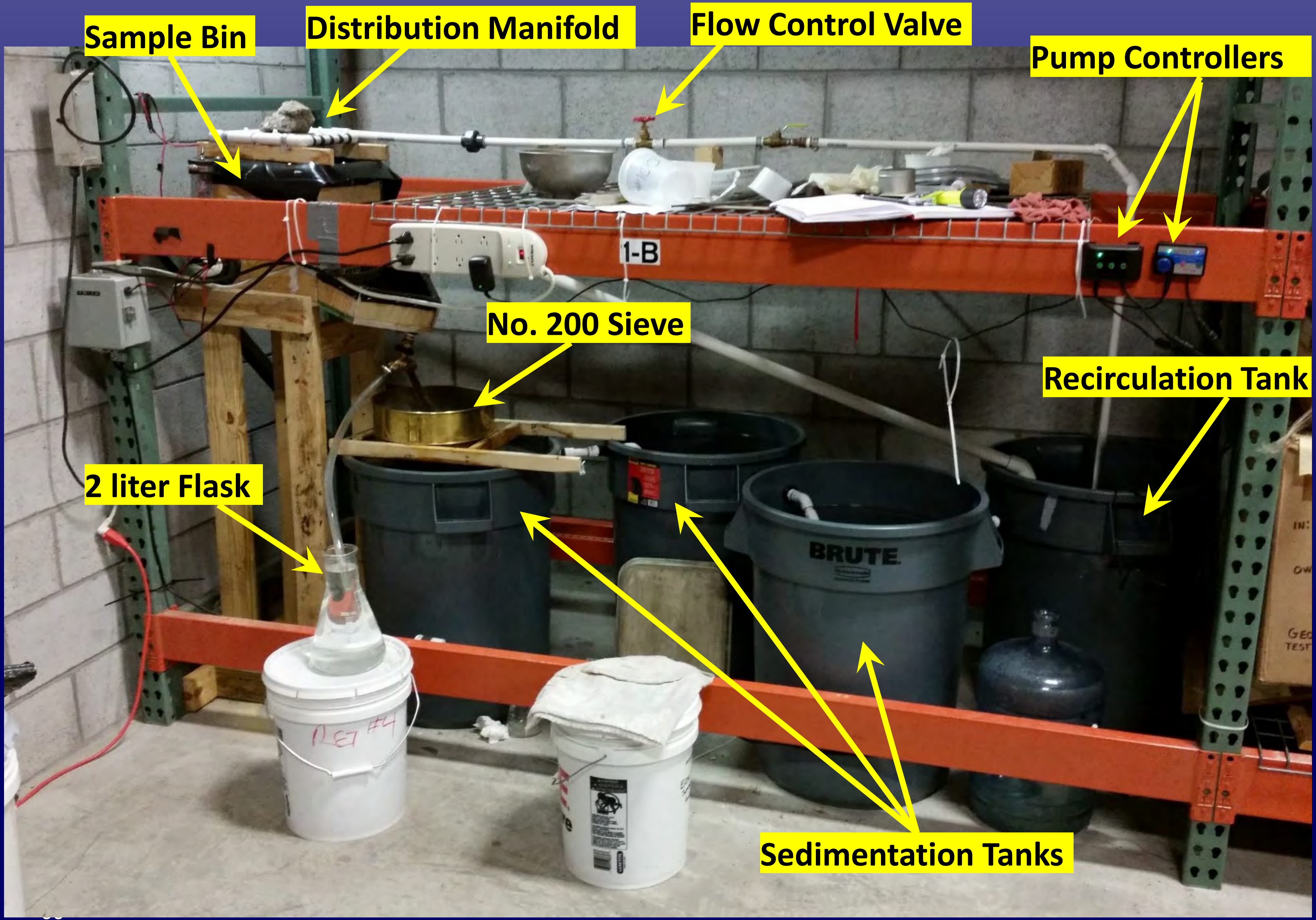


Filtration/Drainage – This application needs to favor water flow over soil retention

Part 4: Functions and Applications

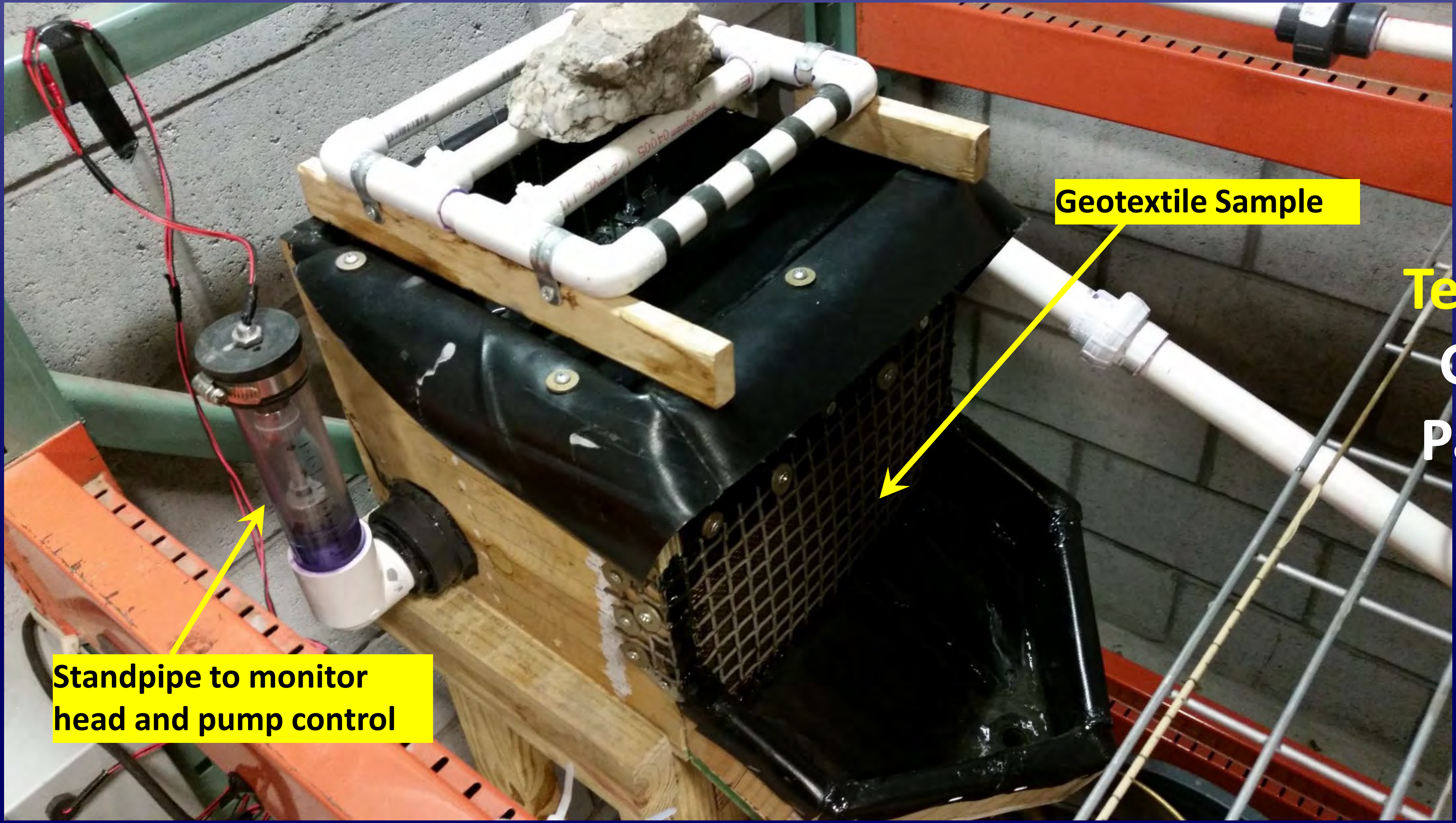
Test Apparatus – Geotextile for Pavement Base Drain

Part 4: Functions and Applications

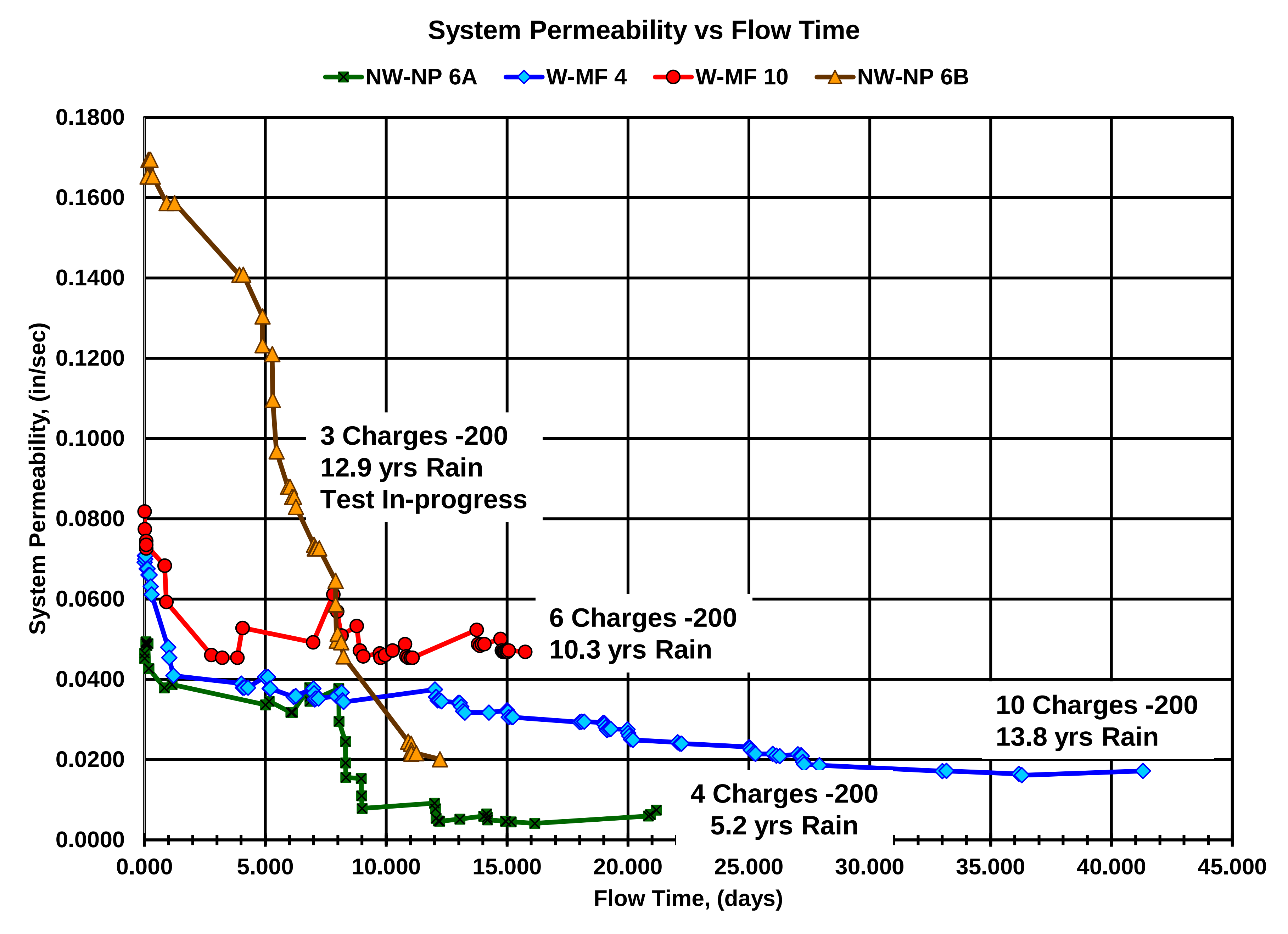


Test Apparatus – Geotextile for Pavement Base Drain

Part 4: Functions and Applications



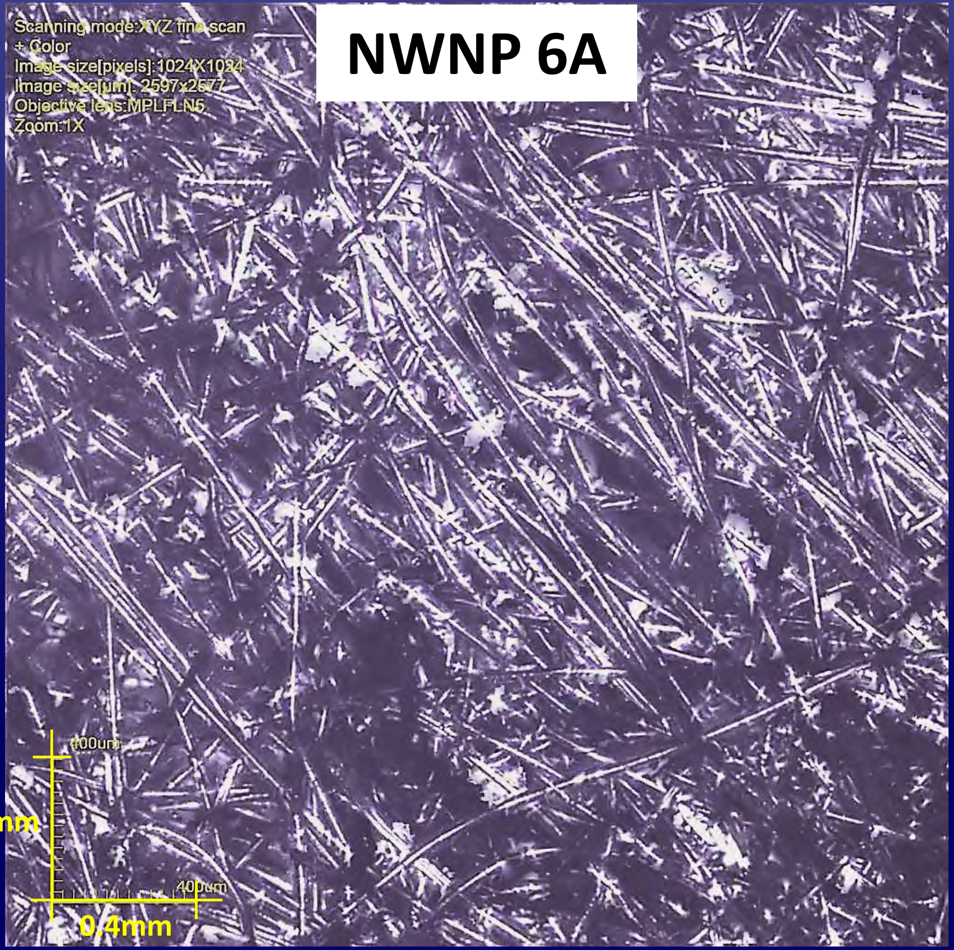
Test Apparatus – Geotextile for Pavement Base Drain



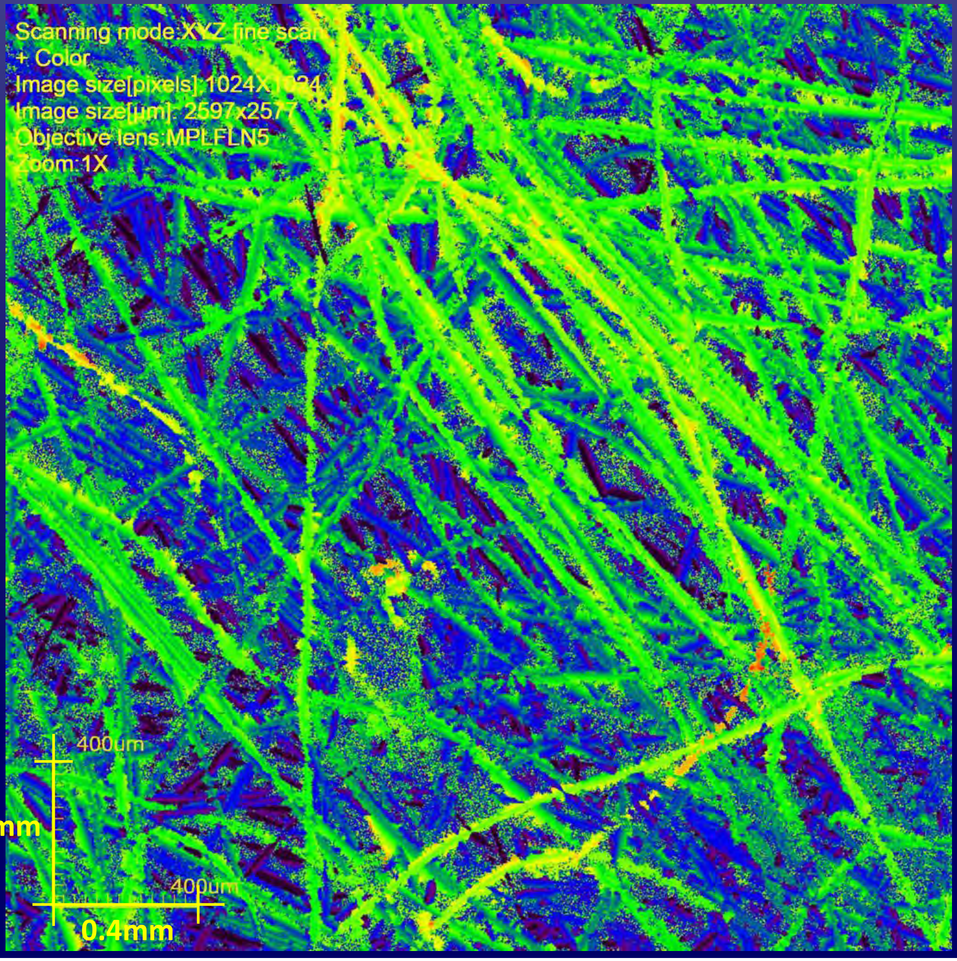
System Permeability vs Flow Time
NW-NP 6A
W-MF 4
W-MF 10
NW-NP 6B
System Permeability, (in/sec)
0.1800
0.1600
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
0.000
5.000
10.000
15.000
20.000
25.000
30.000
35.000
40.000
45.000
Flow Time, (days)
3 Charges -200
12.9 yrs Rain
Test In-progress
6 Charges -200
10.3 yrs Rain
10 Charges -200
13.8 yrs Rain
4 Charges -200
5.2 yrs Rain

Part 4: Functions and Applications – Filtration/Drainage

- Selection of geotextile filter for pavement base drain



Nonwoven Needle-Punched Fabric

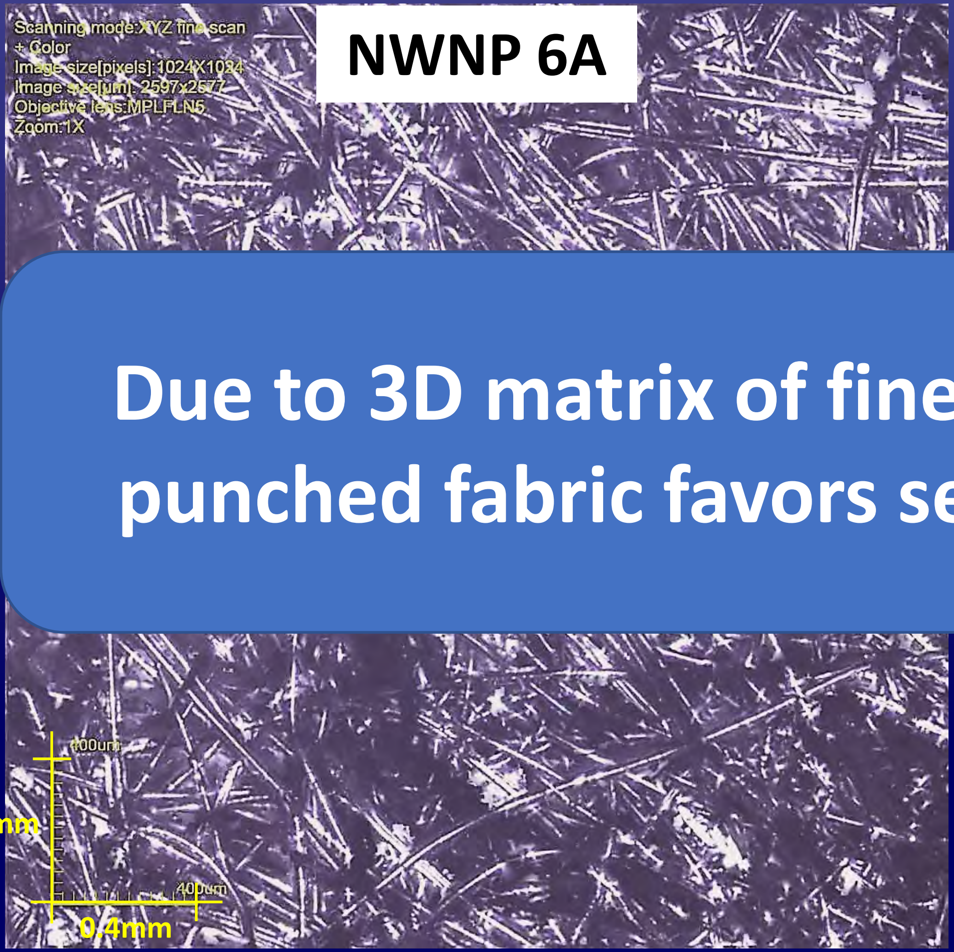


Colorized 3D

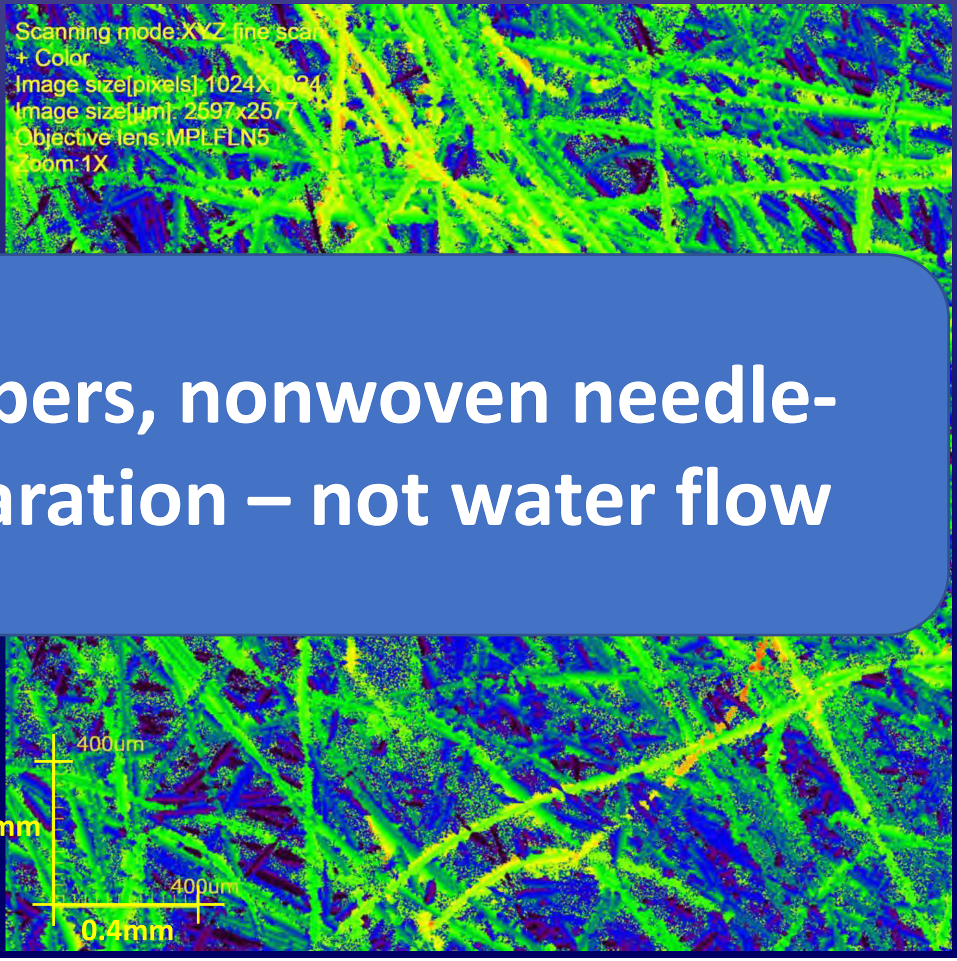
Part 4: Functions and Applications – Filtration/Drainage

- Selection of geotextile filter for pavement base drain

NWNP 6A



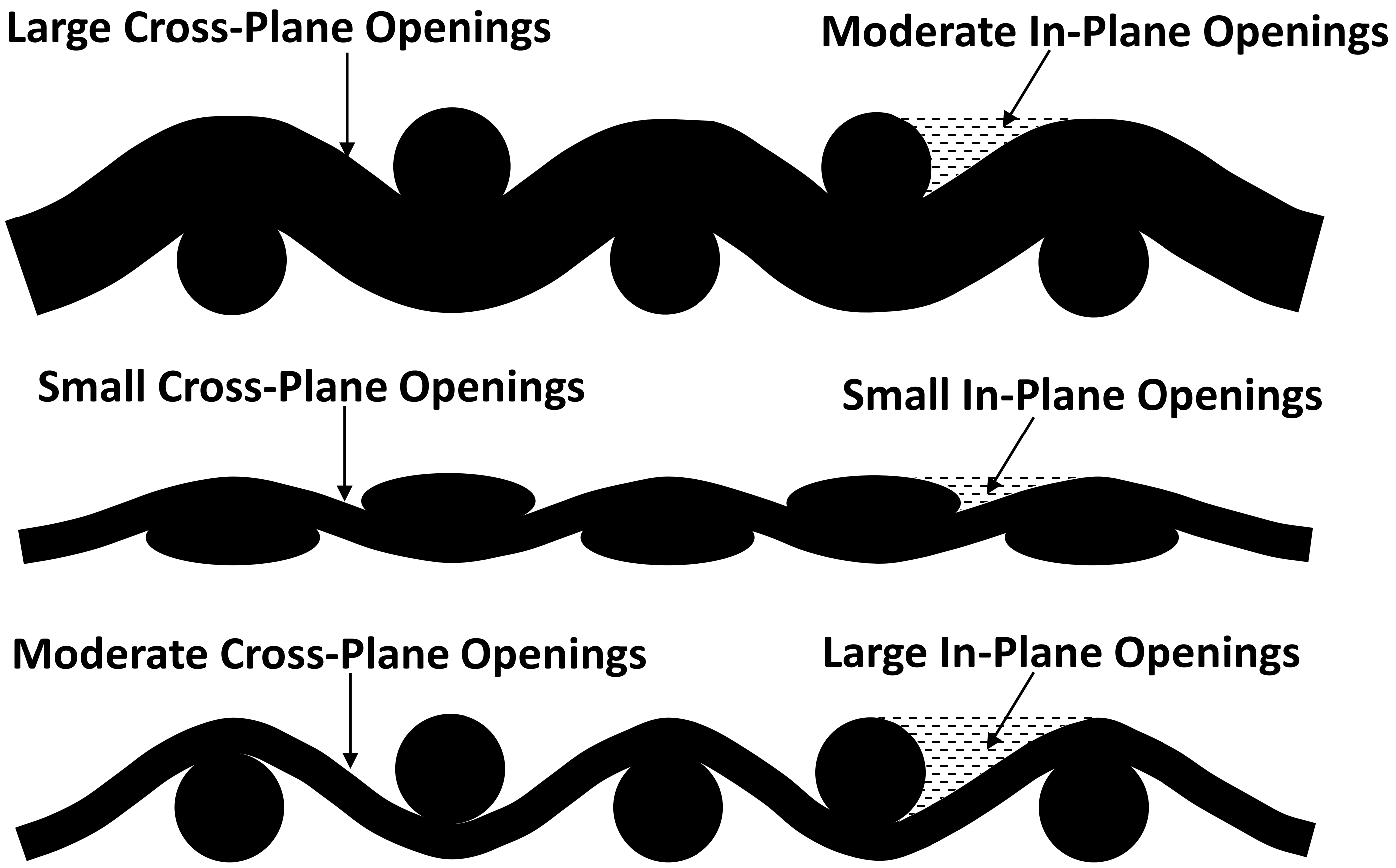
Nonwoven Needle-Punched Fabric



Colorized 3D

Due to 3D matrix of fine fibers, nonwoven needle-punched fabric favors separation – not water flow

Part 4: Functions and Applications – Filtration/Drainage



(a) Filaments Not Calendered

(b) Filaments Calendered Two Directions

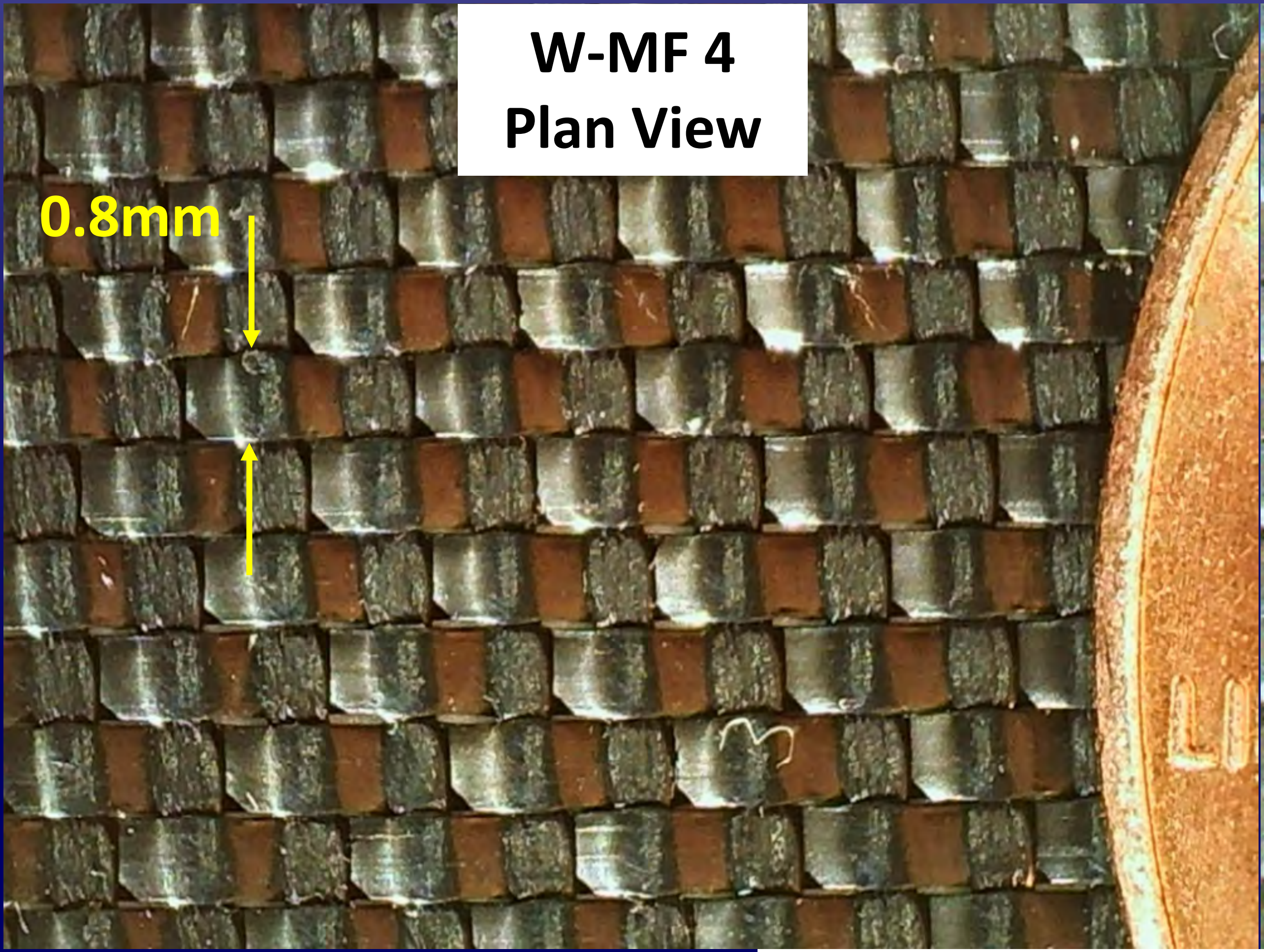
(c) Filaments Calendered One Direction

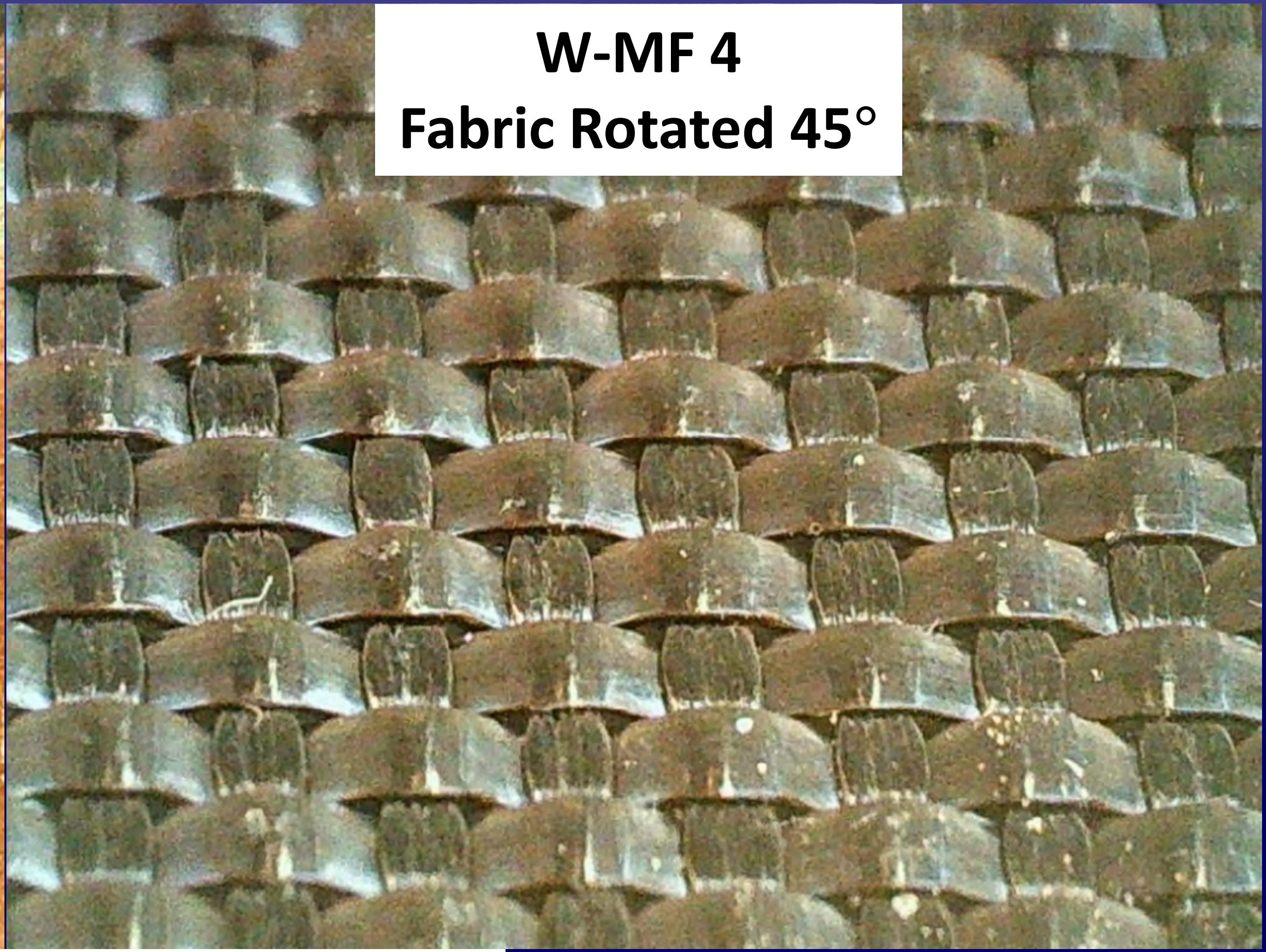
Impact of Calendering Filaments (Equivalent Filament Counts)

Woven Monofilament Geotextile

Part 4: Functions and Applications – Filtration/Drainage

- Selection of geotextile filter for pavement base drain



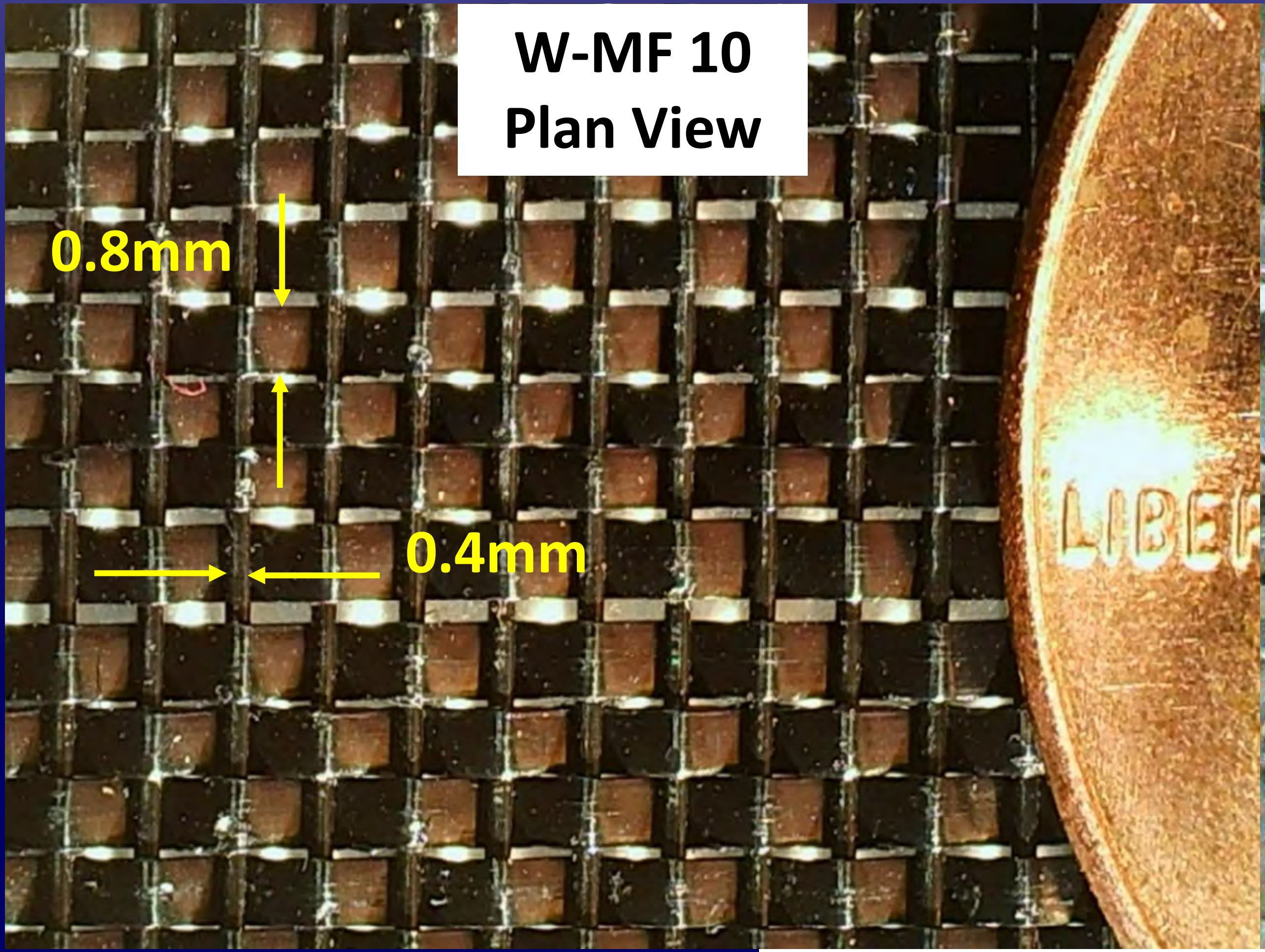


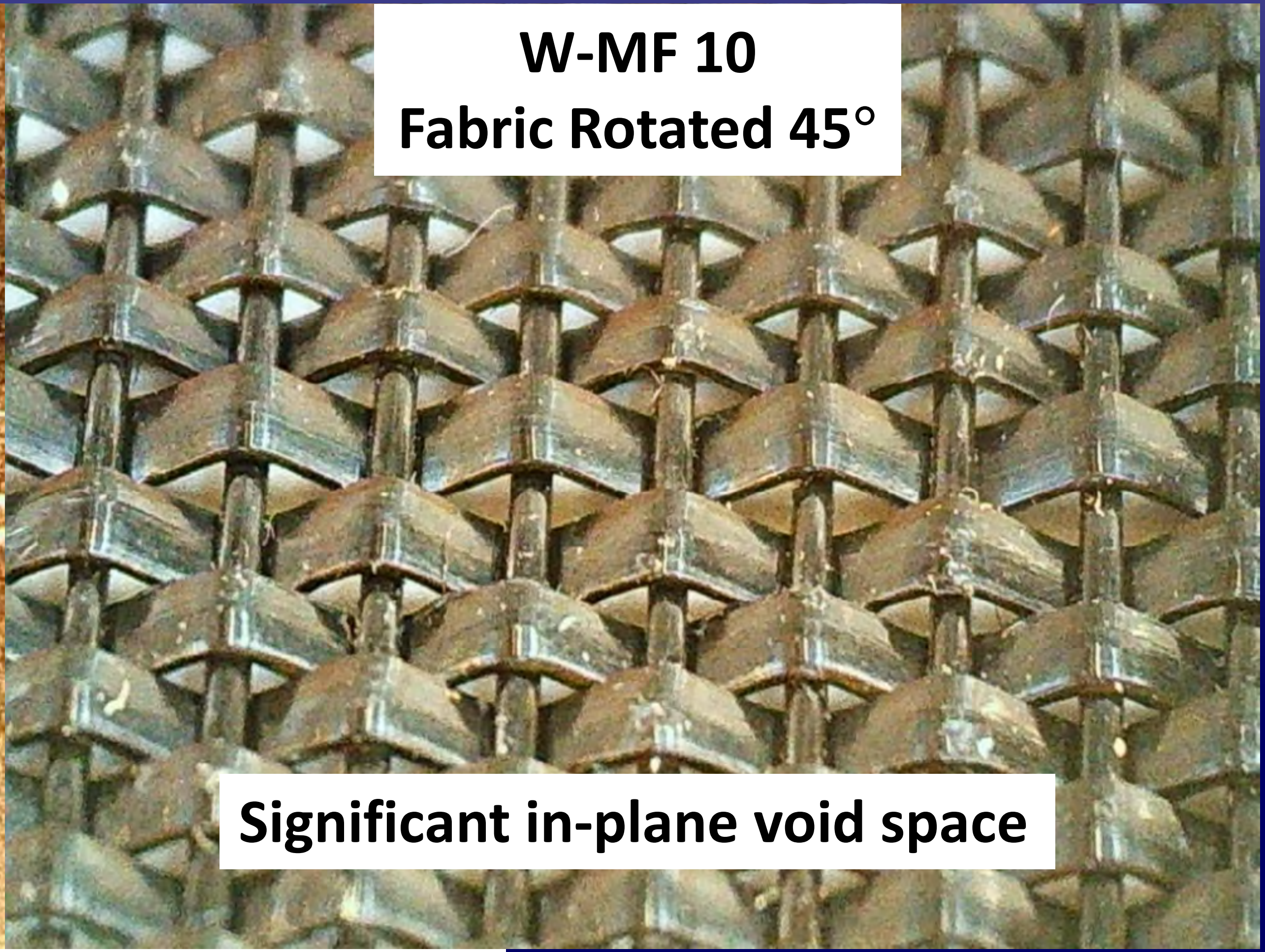
W-MF 4

Woven Monofilament Fabric
Calendered Two Directions, POA = 4

Part 4: Functions and Applications – Filtration/Drainage

- Selection of geotextile filter for pavement base drain

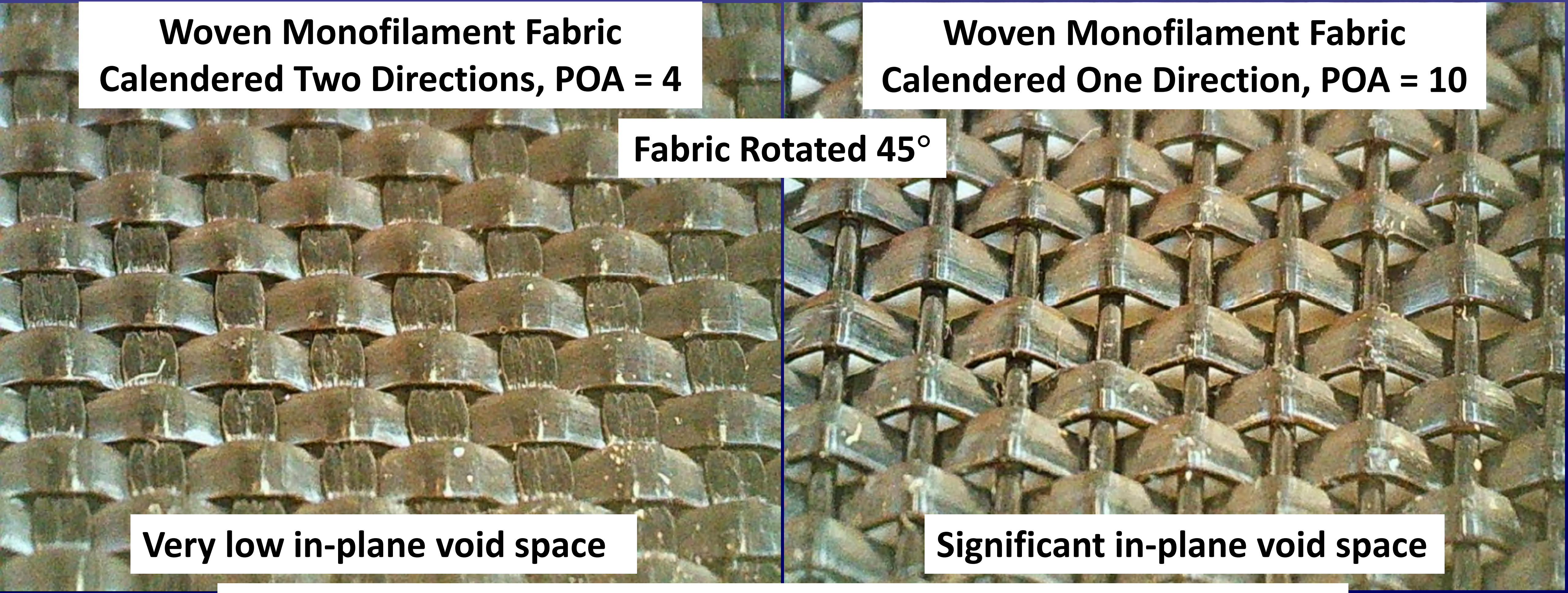




Woven Monofilament Fabric
Calendered One Direction, POA = 10

Part 4: Functions and Applications – Filtration/Drainage

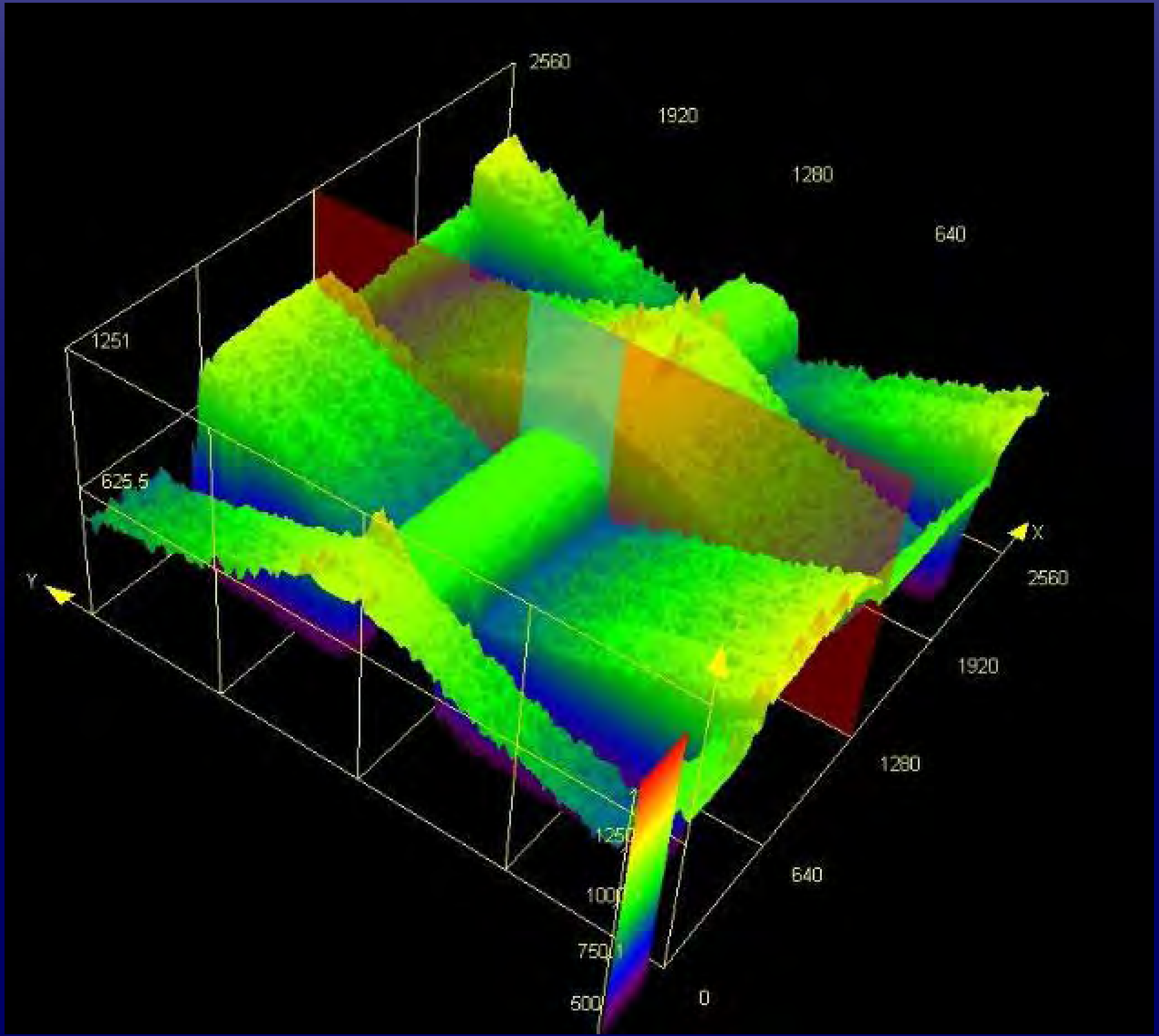
- **Selection of geotextile filter for pavement base drain**



Two materials have same weight, same fiber count, same cost – difference is the structure

Part 4: Functions and Applications – Filtration/Drainage

- **Selection of geotextile filter for pavement base drain**



Woven Monofilament Fabric
Calendered One Direction, POA = 10
Colorized Isometric View

Part 4: Functions and Applications

Material	Geotextile
Structure	Woven Slit Film and Nonwoven Needle Punched
Polymer	Polypropylene
Function	Filtration
Application	Erosion and Sediment Control

Part 4: Functions and Applications – Erosion and Sediment Control

- Erosion and sediment control (ESC) is an area of the geosynthetics industry that has experienced rapid growth and regular innovation
- ESC materials becoming more effective, with increasing product sophistication
- Applications cover broad range of situations from highly aggressive erosional conditions, an aid in establishing vegetation and controlling sediments transported from areas experiencing erosion.

Part 4: Functions and Applications – Erosion and Sediment Control

- Recall that the Geosynthetics industry has its origins in ESC (1958 COE application discussed earlier)
- Erosion occurs when soil particles are dislodged as the result of forces from wind or surface water flow
- Sedimentation occurs when eroded soil particles, or sediments, transported by wind or water, or deposited at another location
- Both erosion and sedimentation have negative consequences

1:50PM

Part 4: Functions and Applications – Erosion and Sediment Control

- Erosion results in loss of vegetation, reduction of infiltration, structural instability and sedimentation
- Sedimentation is a consequence of erosion
- Some impacts of sedimentation are poor water quality and the potential for increased flooding from loss of flow capacity and clogged drains
- Sediment control attempts to address some of the consequences of erosion, while effective erosion control prevents problems from ever developing

Part 4: Functions and Applications – Erosion and Sediment Control

- 1992 paper by Theisen states that cumulative research suggests excessive sediment in our waterways is earth's most prevalent contaminant
- Paper argues erosion and sedimentation are source of ever increasing economic and social losses
- Losses result from reductions in farmland, fishery yields, species diversity and navigable waterways
- And that these losses exceed those caused by other pollutants such as hazardous wastes, smog or ground water contamination

Part 4: Functions and Applications – Erosion and Sediment Control

- January 20, 2022 – Article in The Philadelphia Inquirer
- Headline: Nearly 2,400 more miles of Pennsylvania's streams are impaired now compared to just two years ago
- One-third of all Pennsylvania waterways (nearly 28,000 miles) are now considered polluted enough to harm wildlife, recreation, or drinking water (according to report by PADEP)
- Pollutants include ammonia, nitrates, nitrites, nitrogen, phosphates, calcium, magnesium, chloride, sulfates, and dissolved solids
- These are all runoff pollutants

Part 4: Functions and Applications – Erosion and Sediment Control

- **With this perspective, although less dramatic and visible than many other geosynthetic applications,
it could be argued that applications of geosynthetics in erosion and sediment control,
might be considered among the most important uses relative to their resulting impact**

Part 4: Functions and Applications – Erosion and Sediment Control

- ESC applications can be both temporary or permanent
- For geosynthetics, sediment control applications are often temporary (often until erosion control measures in full effect)
- Erosion control applications can be temporary or permanent
- Applications of geosynthetics in both erosion and sedimentation control can vary considerably

Part 4: Functions and Applications

Material	Geotextile
Structure	Woven Slit Film and Nonwoven Needle Punched
Polymer	Polypropylene
Function	Filtration
Application	Sediment Control

Part 4: Functions and Applications – Sediment Control

- Geotextile → Woven Slit-Film (W-SF)
  - Function: Sediment Control (Silt Fence)
  - Cross plane flow – permittivity (sec^{-1}) or volumetric flow rate
  - Capture sediments to prevent transport
  - AOS ≈ 0.425mm (No. 40 sieve) – Good
  - Permittivity ≈ 0.5 sec^{-1} – Low
  - Flow Rate ≈ 4 gal/min/ft^2 – Low

Thin film = very flexible

Close weave = Low Permittivity

Part 4: Functions and Applications – Sediment Control

- Geotextile → Woven Slit-Film (W-SF)
  - Consequently W-SF capture soil sediments while permitting water to pass
  - Like a soil dam – retain soil sediment while water flows over top of trapped sediments through W-SF fabric
  - High strength, loose weave, very flexible and low cost
  - Material favors soil retention as opposed to water flow

Source: USDA

Source: hewittgeo.com

Part 4: Functions and Applications – Sediment Control

- Wattles and Filter Socks
  - Structurally very similar
  - Wattles consist of a straw or coir tube held together with a fine mesh netting
  - Filter socks consist of a NWNP geotextile sock filled with mulch or other filter media

Source: Arizona Bag Company

Source: cdwconsultant.com

Source: cdwconsultant.com

Part 4: Functions and Applications – Erosion and Sediment Control

- Sediment filter bags (a.k.a. Dewatering Bags)
- Typically manufactured from nonwoven needle-punched (NWNP) geotextile
- Can be manufacture from woven multifilament geotextile if needed, but will increase cost
- Sediment laden water pumped into bag; Sediments trapped in bag as water discharge through filter bag face


Source: geosynthetics.com


Source: Ultratech

Part 4: Functions and Applications – Sediment Control

- Sediment Filter Bags → Nonwoven Needle-Punched (NWNP) Geotextile (Typically)
  - Function: Sediment Control
  - Cross plane flow – permittivity (sec^{-1}) or volumetric flow rate
  - But also soil retention
  - 3D structure of NWNP fabric traps sediments preventing transport
  - Good compromise of AOS (≈ 0.2 mm) and permittivity (≈ 1.2 sec^{-1})
  - Typically 8 or 10 oz/sy NWNP geotextile

Part 4: Functions and Applications

Example: Interdependency of Geosynthetic Polymer, Structure and Function

Material	Geotextile
Structure	Woven Multifilament
Polymer	Polypropylene
Function	Filtration
Application	Erosion Control/Beach Restoration

Part 4: Functions and Applications – Erosion Control

- **Dredging Operation for Beach Restoration**


Source: carolinacoastonline.com


Source: dredgingtoday.com

$18 million sand project to restore 3.5 miles of beach, from Jetty Park to Cocoa Beach Pier


Source: floridatoday.com

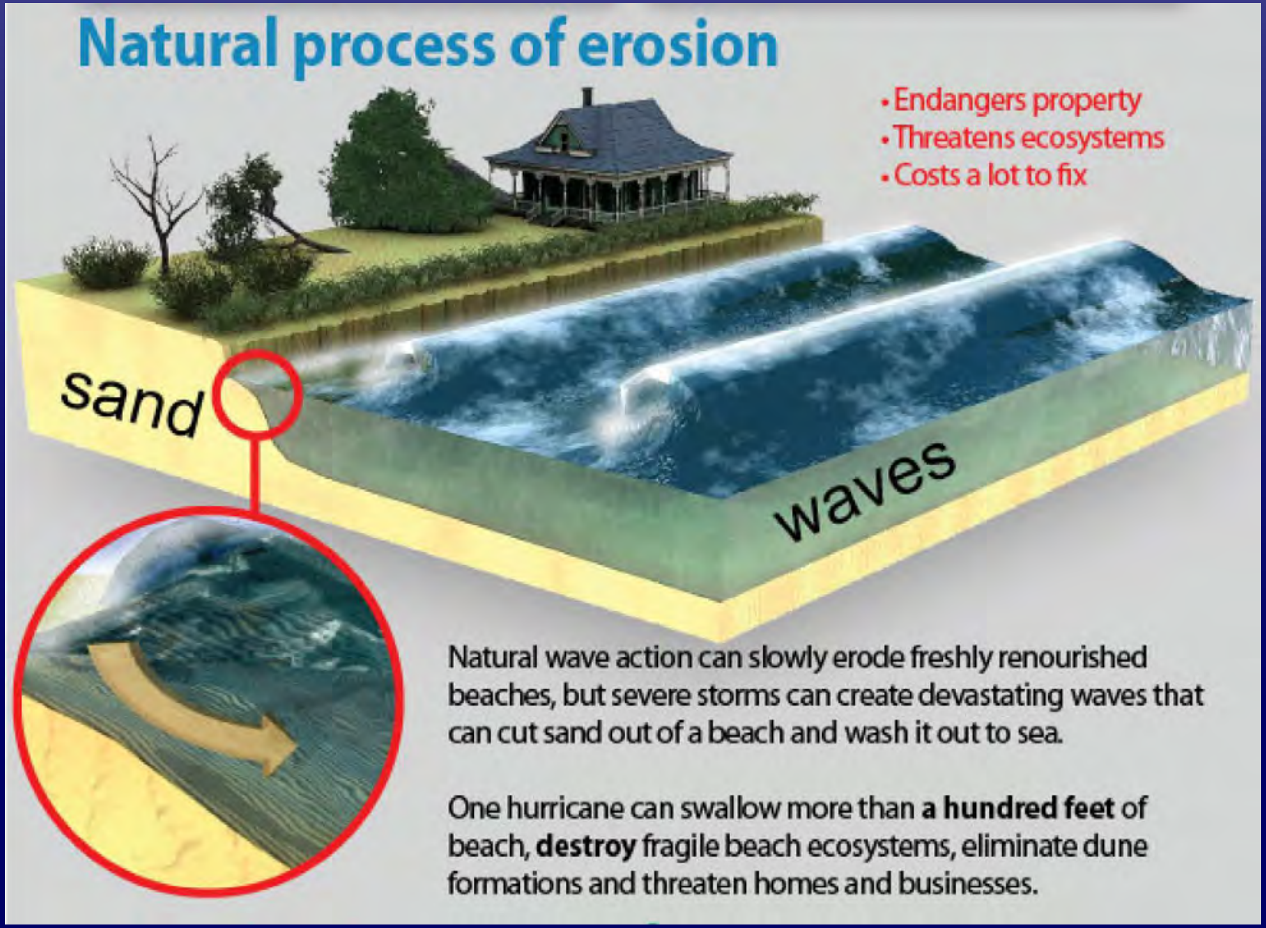
Part 4: Functions and Applications – Erosion Control

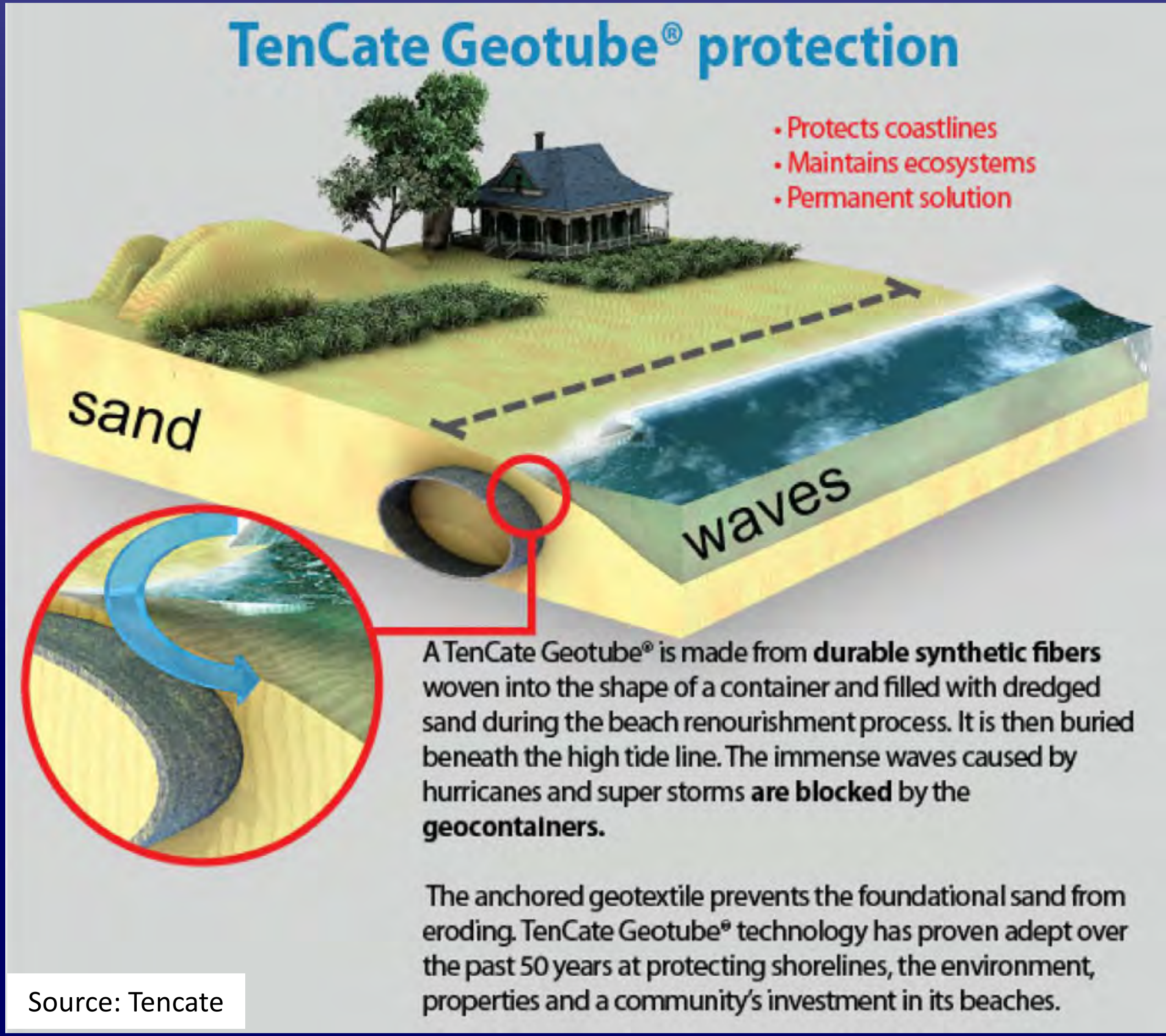
- Geotextile Bags/Tubes → Woven Multifilament Geotextile
  - Primary cost of beach restoration is dredging ("excavation and placement of sand")
  - What if that cost could be eliminated and the process "performed" by nature

Source: Geosynthetics Magazine

Part 4: Functions and Applications – Beach Restoration and Protection

- **Geotextile Bags/Tubes → Woven Multifilament Geotextile**

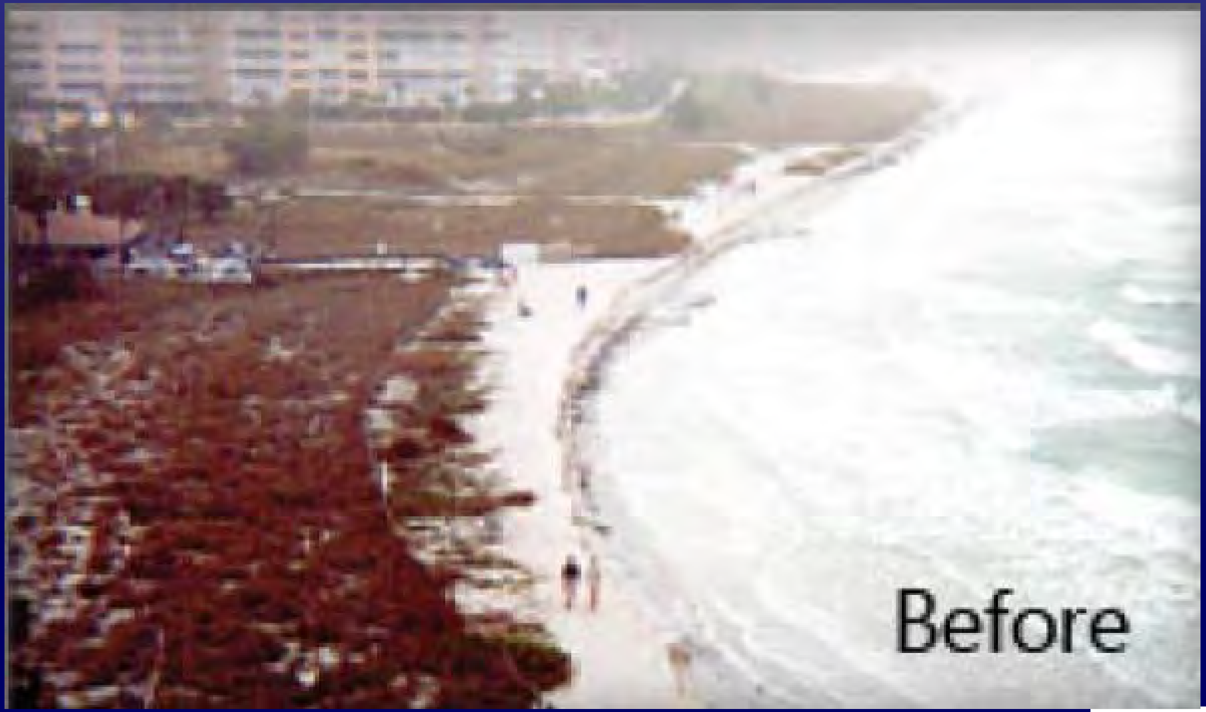




Source: Tencate

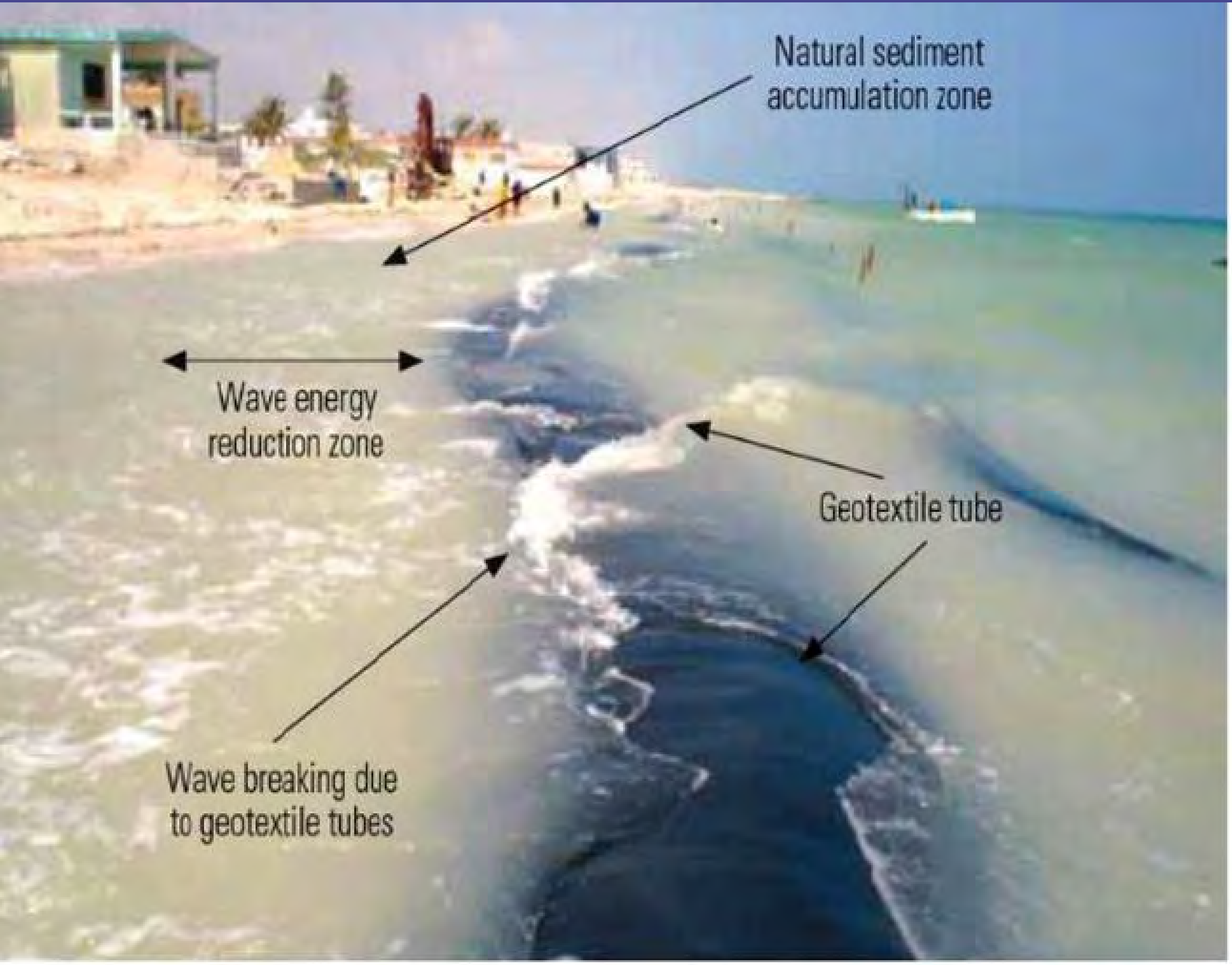
Part 4: Functions and Applications – Beach Restoration

- Geotextile Bags/Tubes → Woven Multifilament Geotextile



Source: Tencate

Part 4: Functions and Applications – Beach Restoration



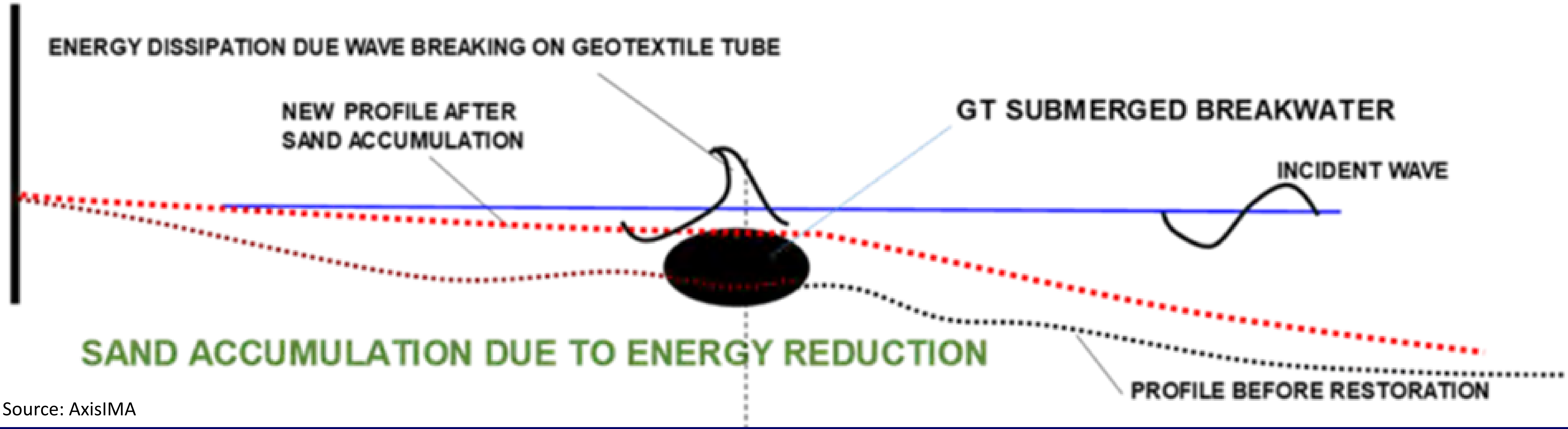
(a)

(b)

Source: International Journal of Sustainable Built Environment

Part 4: Functions and Applications – Beach Restoration

- **Geotextile Bags/Tubes → Woven Multifilament Geotextile**



Source: AxisIMA

Part 4: Functions and Applications – Beach Restoration

- **Geotextile Bags/Tubes → Woven Multifilament Geotextile**

Source: sciencedirect.com

Part 4: Functions and Applications – Beach Restoration

- **Geotextile Bags/Tubes → Woven Multifilament Geotextile**

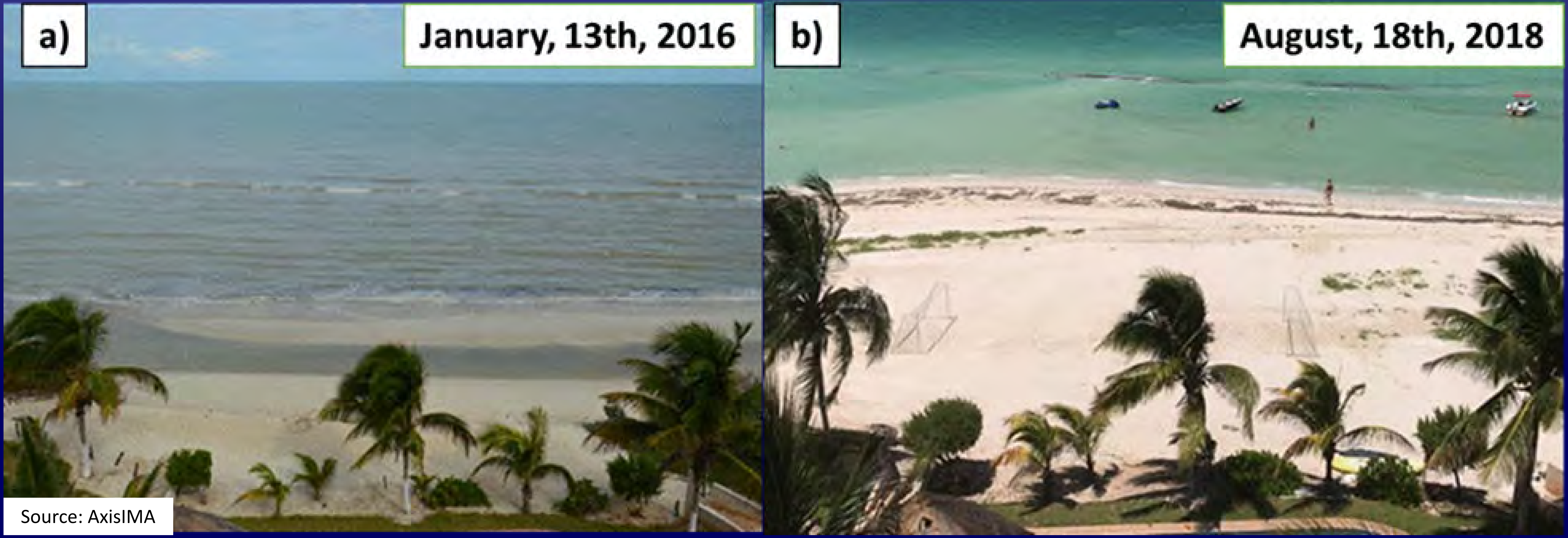
Source: Ace Geosynthetics

Part 4: Functions and Applications – Sediment Control

- **Geotextile Bags/Tubes → Woven Multifilament Geotextile**

Part 4: Functions and Applications – Beach Restoration

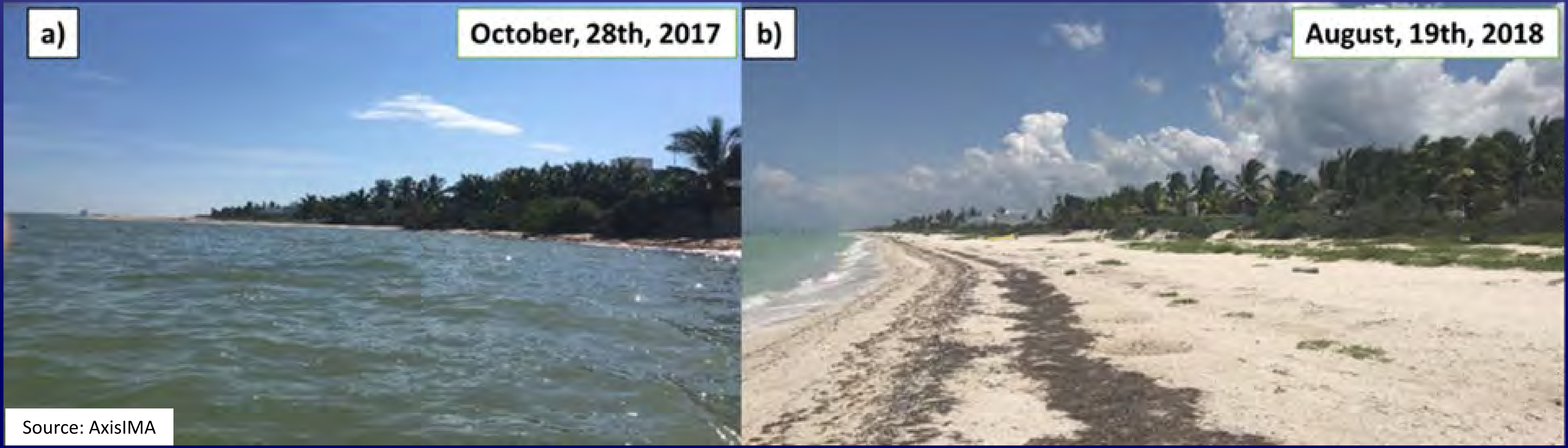
- **Geotextile Bags/Tubes → Woven Multifilament Geotextile**



Source: AxisIMA

Part 4: Functions and Applications – Beach Restoration

- **Geotextile Bags/Tubes → Woven Multifilament Geotextile**



Part 4: Functions and Applications – Beach Restoration

- **Geotextile Bags/Tubes → Woven Multifilament Geotextile**

Source: geosynthetica.com

Part 4: Functions and Applications – Stabilization vs Reinforcement

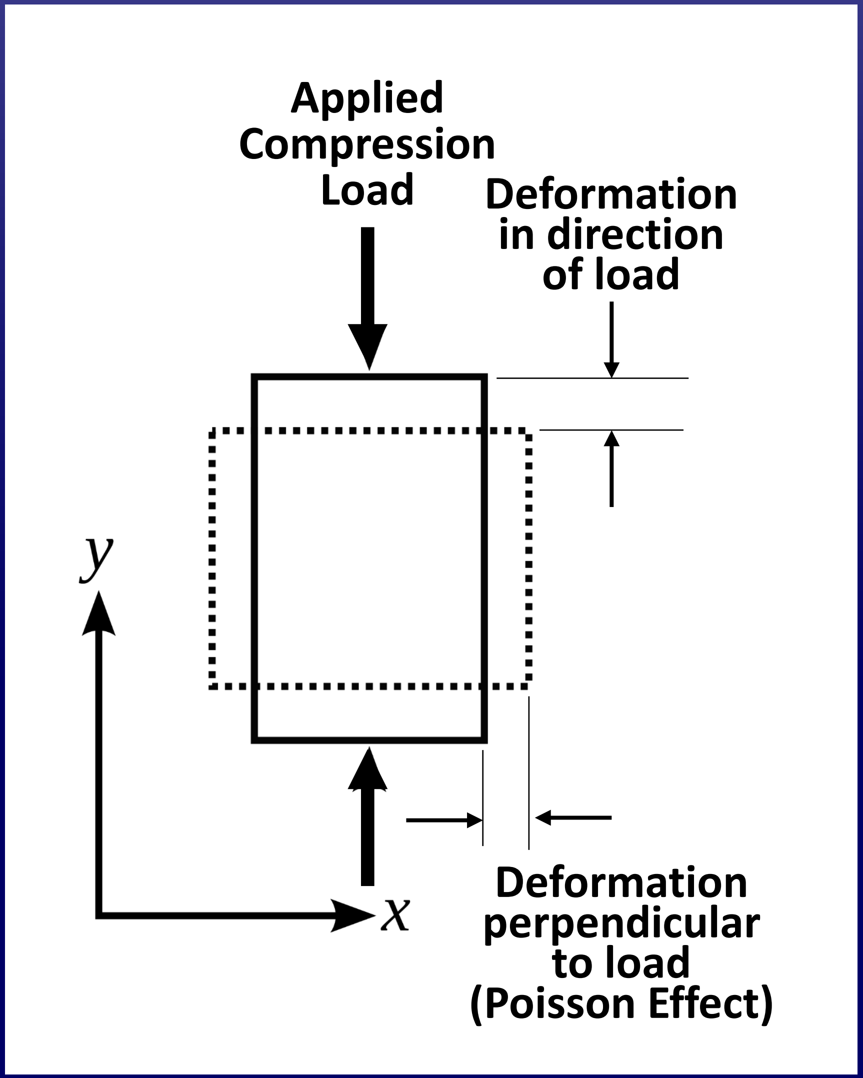
- **Detour – Stabilization versus Reinforcement**

  - Sometimes two terms used interchangeably, but there is difference
  - Function (reinforcement vs stabilization) depends upon structure and polymer type
  - We will refer to stabilization as “passive” and reinforcement as “active”
  - Take a few minutes to differentiate between the two functions

Part 4: Functions and Applications – Stabilization vs Reinforcement

- **Stabilization**

  - Stabilization – "Passive"
  - Action similar to Poisson effect
  - Under a compressive load material deforms in direction of load, expanding perpendicular to load
  - Similarly, under compressive load aggregate wants to spread laterally



Part 4: Functions and Applications – Stabilization vs Reinforcement

- Stabilization
  - Geosynthetic layer resists the lateral deformation
  - Geocell – Cells resist deformation of soil/aggregate in cell being loaded
  - Geogrid – Grid structure resists deformation soil/aggregate (interlock with material embedded in apertures or openings of geogrid)
  - Geotextile – Fabric resists deformation of soil/aggregate in stress transfer at interface of fabric and fill

Part 4: Functions and Applications – Stabilization vs Reinforcement

- **Stabilization**

  - The geosynthetic confines the soil/aggregate resisting lateral movement and enabling more efficient mobilization of soil/aggregate shear strength
  - By resisting lateral movement, confining stress is increased resulting in better mobilization of shear strength

Soil Shear Strength Equation: $S = c + \sigma \tan\phi$

where:

S = shear strength

σ = overburden/confining pressure

ϕ = soil/aggregate friction angle

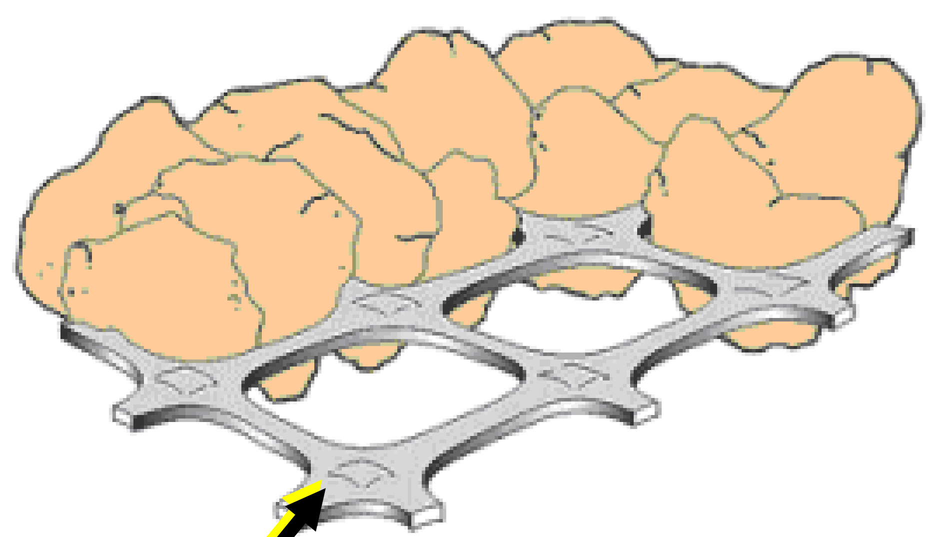
Part 4: Functions and Applications – Stabilization vs Reinforcement

- **Stabilization**

  Soil Shear Strength Equation:

$$S = c + \sigma \tan\phi$$

Mechanism: Confinement



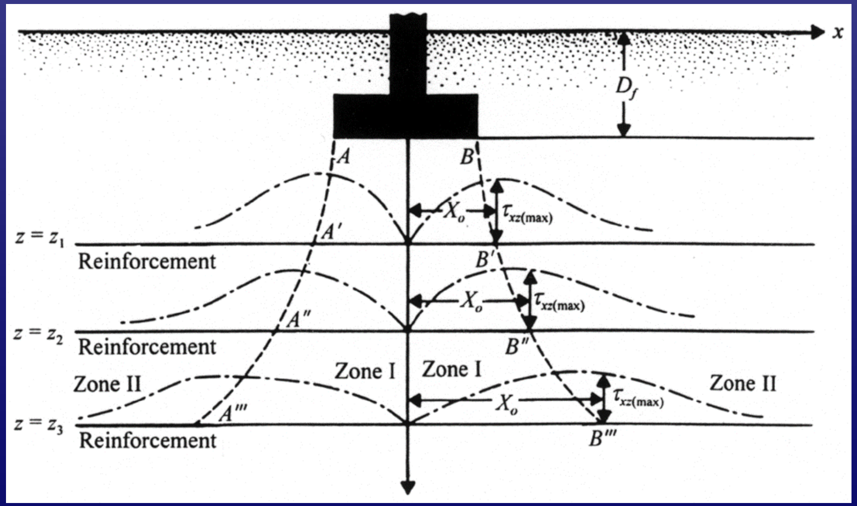
Chen, Cheng & McDowell, & Thom, Nick. (2013). A study of geogrid-reinforced ballast using laboratory pull-out tests and discrete element modelling. Geomechanics and Geoengineering. 8. 10.1080/17486025.2013.805253.

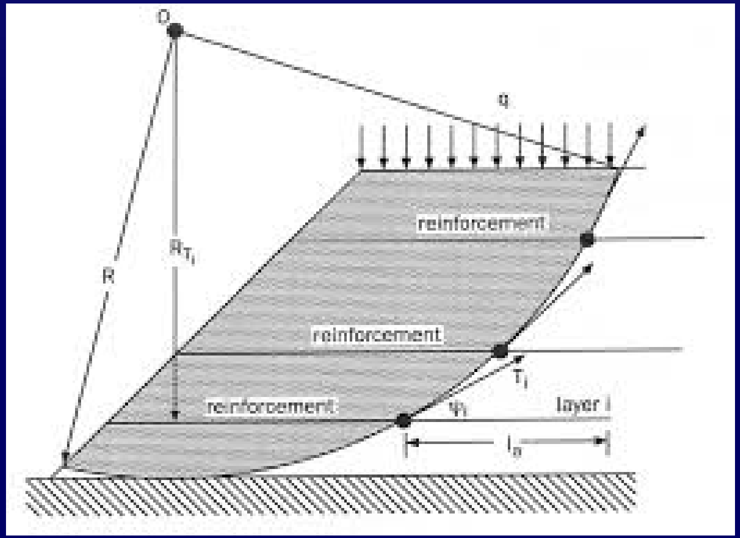
Chen, Cheng & McDowell, & Thom, Nick. (2013). A study of geogrid-reinforced ballast using laboratory pull-out tests and discrete element modelling. Geomechanics and Geoengineering. 8. 10.1080/17486025.2013.805253.

Geosynthetic Layer:
Geocell, Geogrid or Geotextile

Part 4: Functions and Applications – Stabilization vs Reinforcement

- Reinforcement
  - Reinforcement – "Active"
  - Geosynthetic works in conjunction with soil
  - Adds strength to system
  - Localized interlock and friction to mobilize tensile strength of geogrid
  - High Tensile Stress Mobilized
  - High Tensile Strength Required
  - Analogous to reinforced concrete





Part 4: Functions and Applications

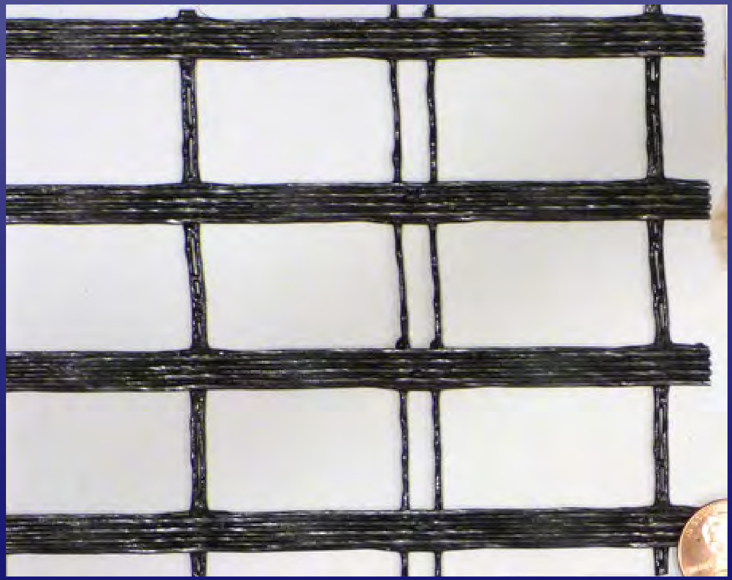
- **Stabilization vs Reinforcement – Summary**

  - Stabilization = “Passive”
    - Confinement
    - Better mobilization of available shear strength
  - Reinforcement = “Active”
    - Independent element
    - Adds strength to system

Likely Both Stabilization
and Reinforcem
Functions Exhib

Part 4: Functions and Applications

Material	Geogrid
Structure	Uniaxial
Polymer	PET/HDPE
Function	Reinforcement
Application	Reinforced Slopes



Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial
  - Function: Reinforcement – supplementing soil shear strength by adding tensile reinforcement
  - Use in slope stability application or foundation reinforcement
  - Provides water proofing membrane
  - Two primary polymers used for uniaxial geogrids are HDPE and PET

Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial – Reinforcement Design Strength
  - Determine the required overall reduction factor (combined factor of safety – like LRFD reduction factors)

$$RF_{OV} = RF_{CR} \times RF_{ID} \times RF_{D}$$

where:

RF_{OV} = combined (overall) reduction factor (dimensionless)

RF_{CR} = creep reduction factor (dimensionless)

RF_{ID} = installation damage reduction factor (dimensionless

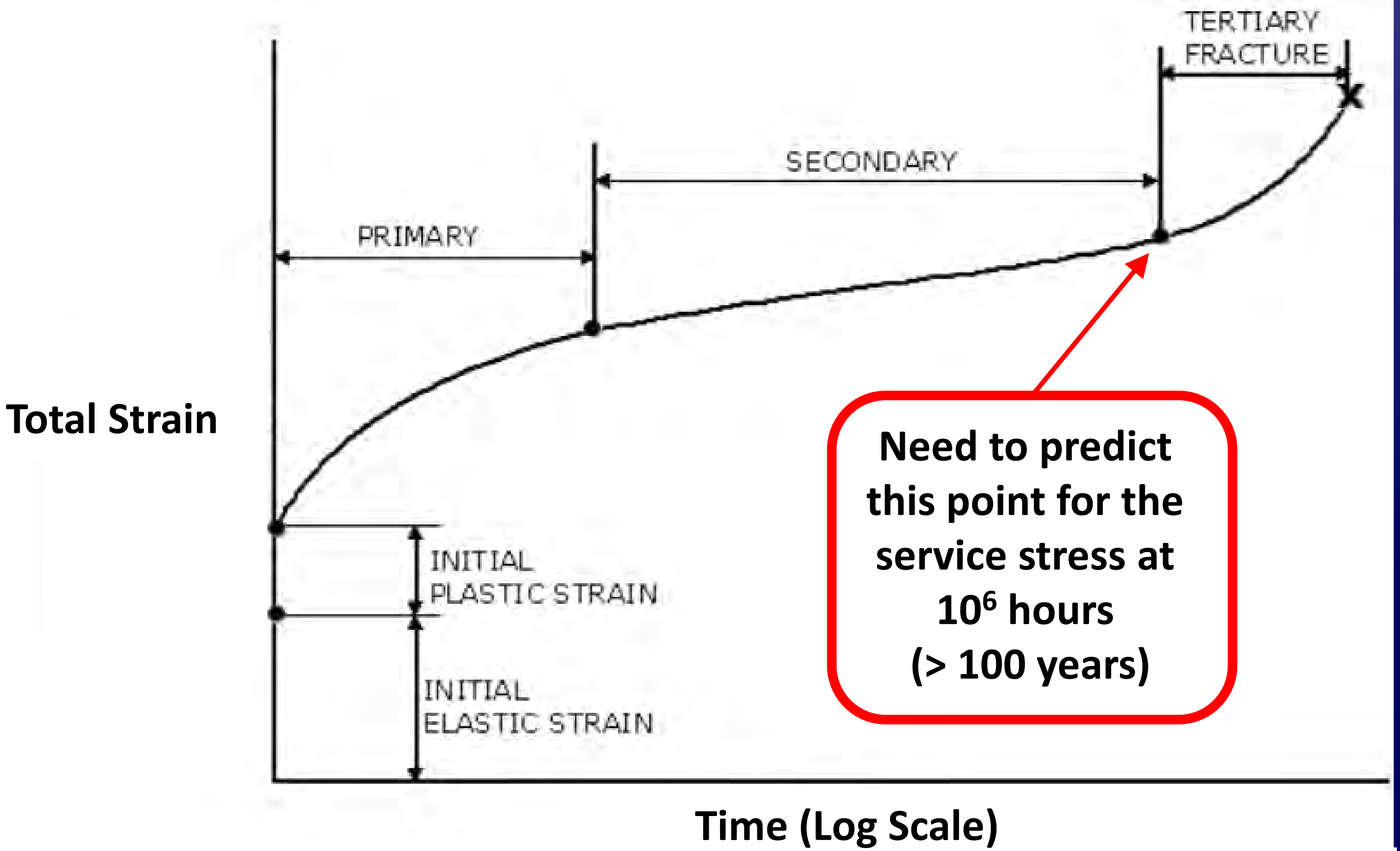
RF_{D} = durability reduction factor (dimensionless)

Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial – Reinforcement Design Strength
  - Determining Creep Reduction Factor (RF_{CR}) – Ratio of T_{ULT} to creep-limiting strength

Time-dependent Strain Curve with Primary, Secondary and Tertiary Stages

Creep Resistance = Need to Predict Start of Tertiary Stage



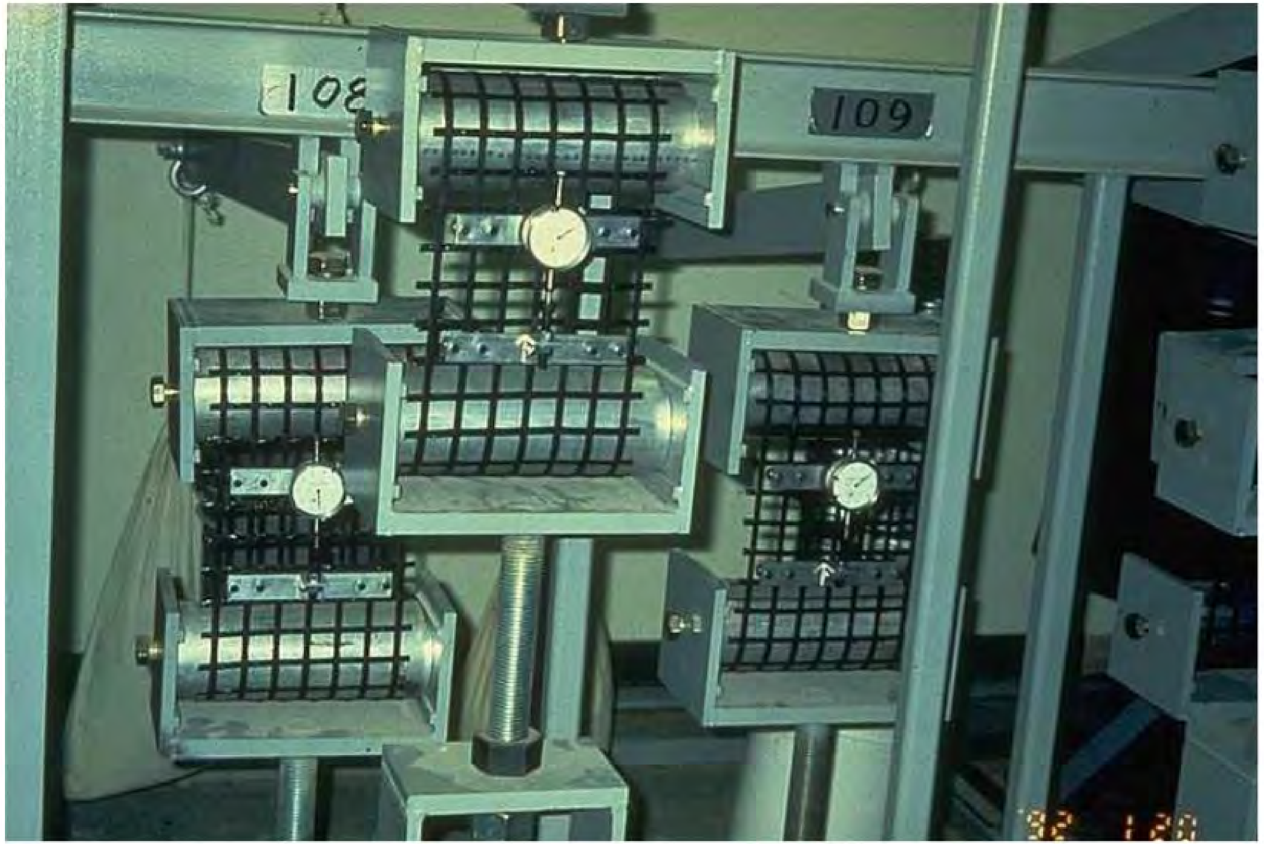
Time-dependent Strain Curve with Primary, Secondary and Tertiary Stages

Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial – Reinforcement Design Strength
  - Determining Creep Reduction Factor (RF_{CR})

Time-Temperature Creep Testing

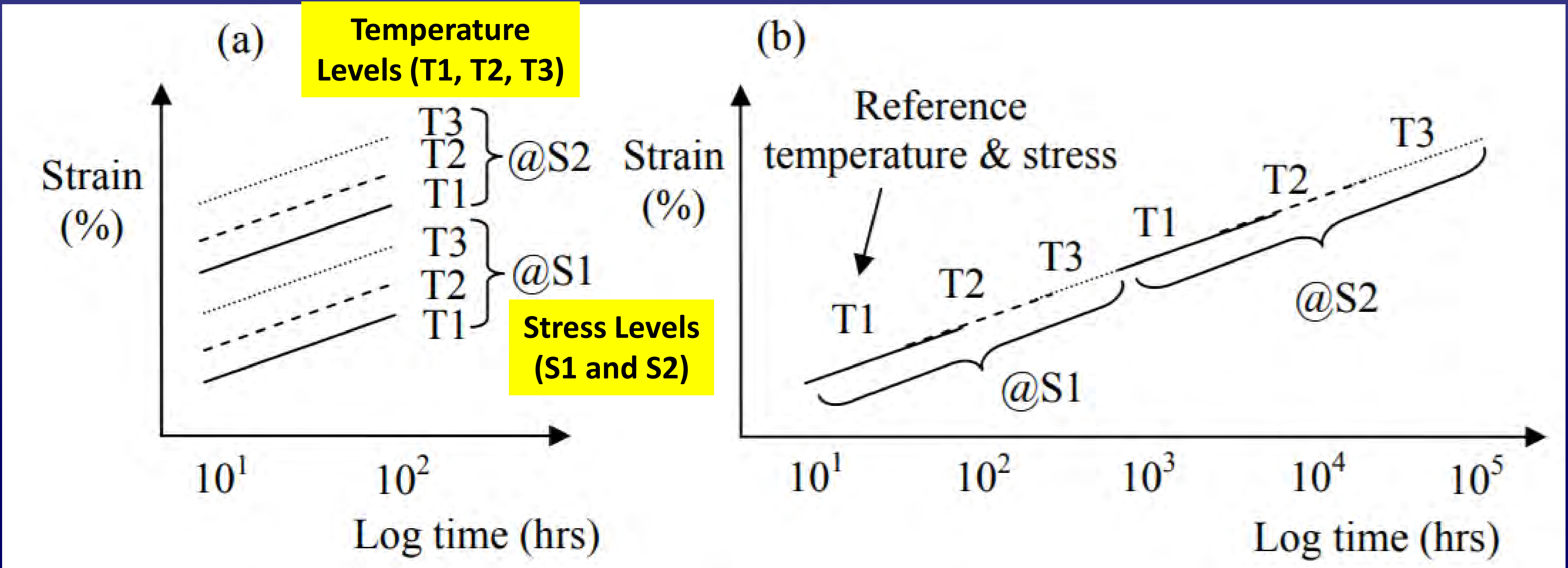
Sustained Load at Stepped Stresses and Temperatures



Creep Testing of Geogrid

Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial – Reinforcement Design Strength
  - Determining Creep Reduction Factor (RF_{CR})

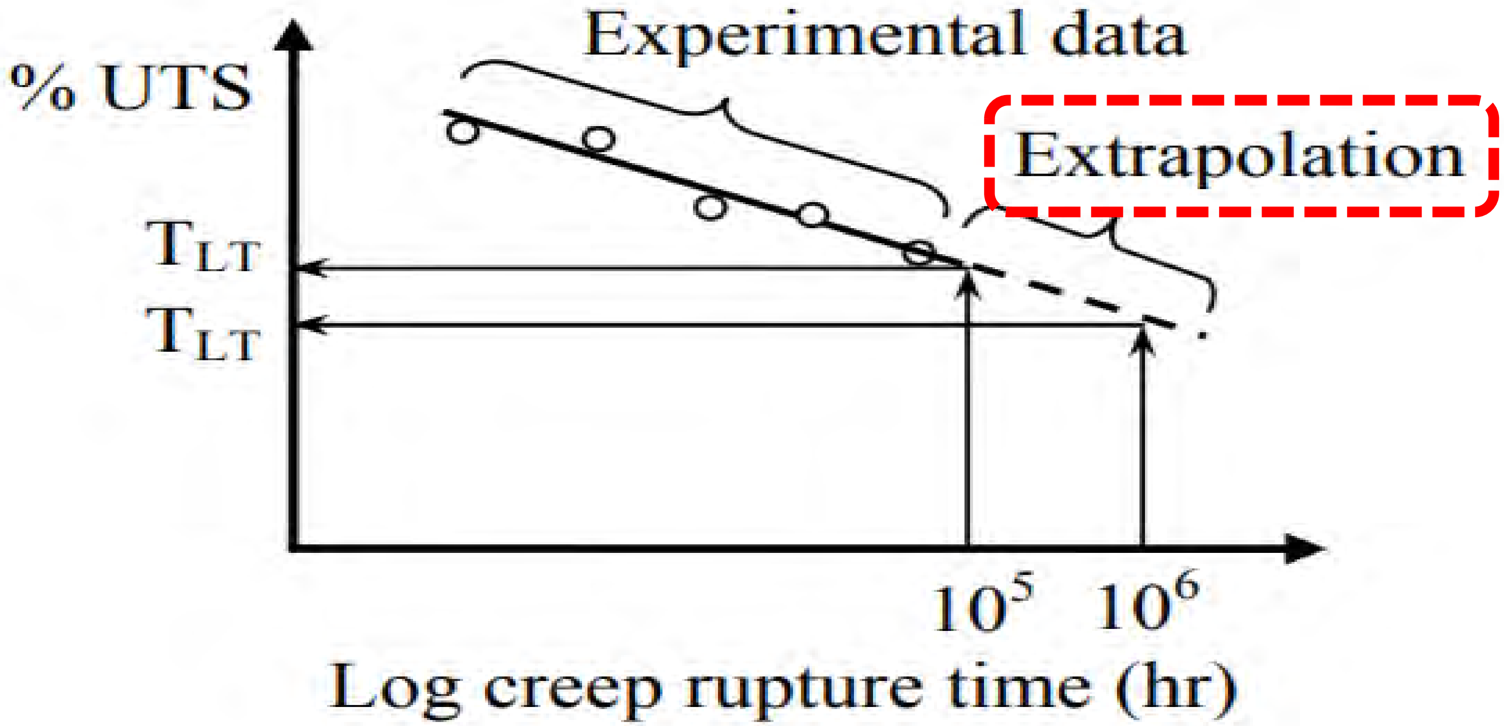


Time-Temperature-Stress Superposition:
(a) Raw Data and (b) Prediction of Creep Behavior with Shifting
(Temperature: T3 > T2 > T1 and Stress: S2 > S1)

Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial – Reinforcement Design Strength
  - Determining Creep Reduction Factor (RF_{CR})

Predict Long Term Allowable Strength (T_{LA}) at 10^6 hours (≈ 110 years)



Method to Determine Creep Reduction Factor Using Creep Rupture Curve for a Tensile Creep Test

Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial

$$T_{LA} = T_{ULT} / RF_{OV}$$

So:

$$RF_{CR} = T_{ULT}/T_{LA} = \text{Creep Reduction Factor}$$

Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial HDPE vs Uniaxial PET
  - Both have high strength
  - HDPE lower cost than PET, but PET RF_{CR} lower than HDPE
  - The two counter each other so that product cost is comparable
  - Typical Roll Sizes: 4.83 x 200 ft HDPE vs. 12 x 150 ft PET
  - HDPE more manageable in handling while PET covers more area – project needs and contractor placement method may dictate preference
  - Note: Overlap of adjacent strips of reinforcement not necessary – just butt edges
  - Slopes as steep as 0.5H:1V (63°) constructed – if steeper, wall design requirements will control
  - Typical maximum vertical spacing is 18 inches

Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial Reinforcement
  - Good application – Bad execution! (Details can be very important)

Active traffic on interstate highway

Failure of temporary shoring failure on bridge construction – temporary shoring used uniaxial geogrid reinforcement with gabion facing

Part 4: Functions and Applications – Reinforcement

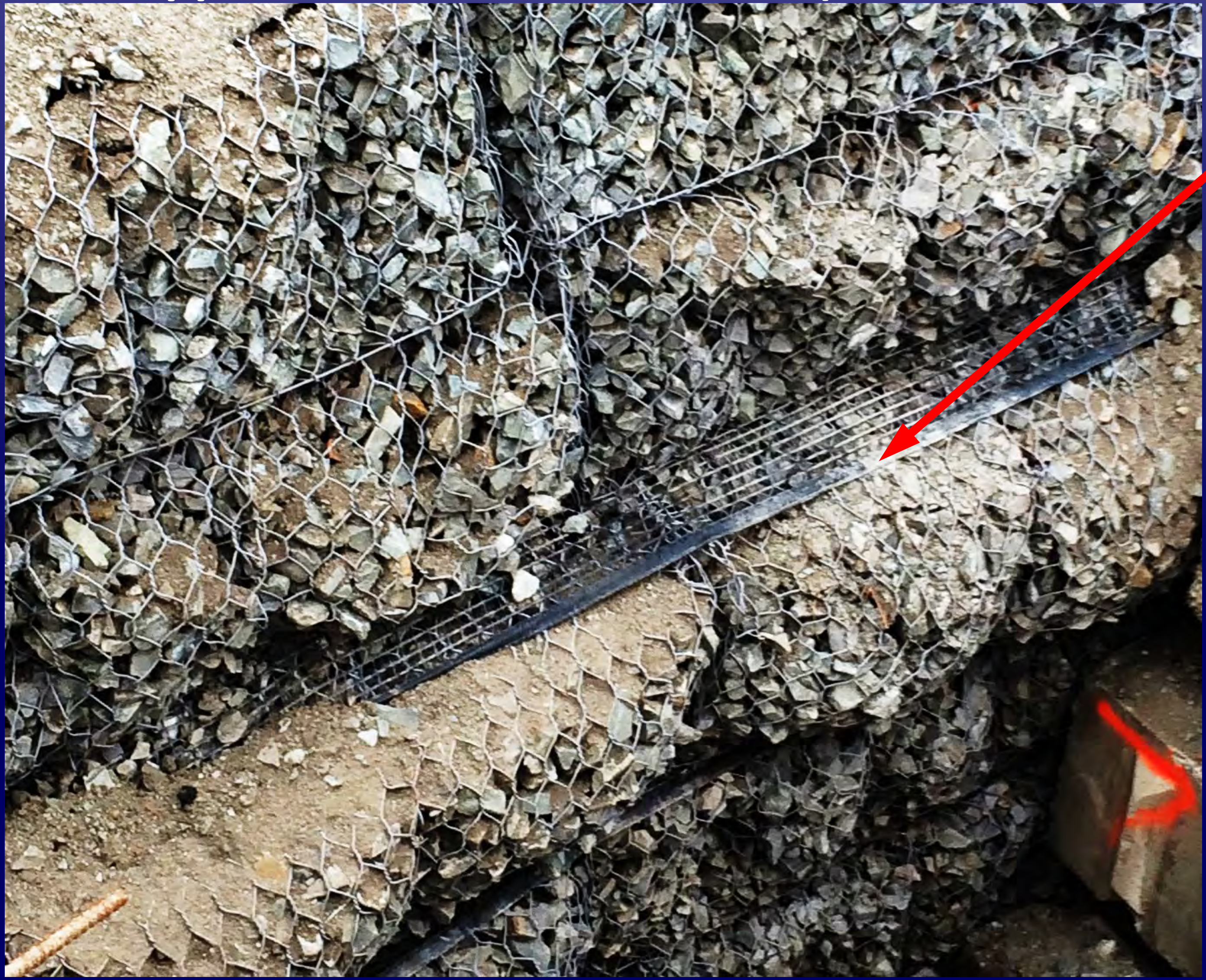
- Geogrid → Uniaxial Reinforcement
  - Good application – Bad execution! (Details can be very important)

Do you see a problem in this photo?

See Next Slide

Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial Reinforcement
  - Good application – Bad execution! (Details can be very important)

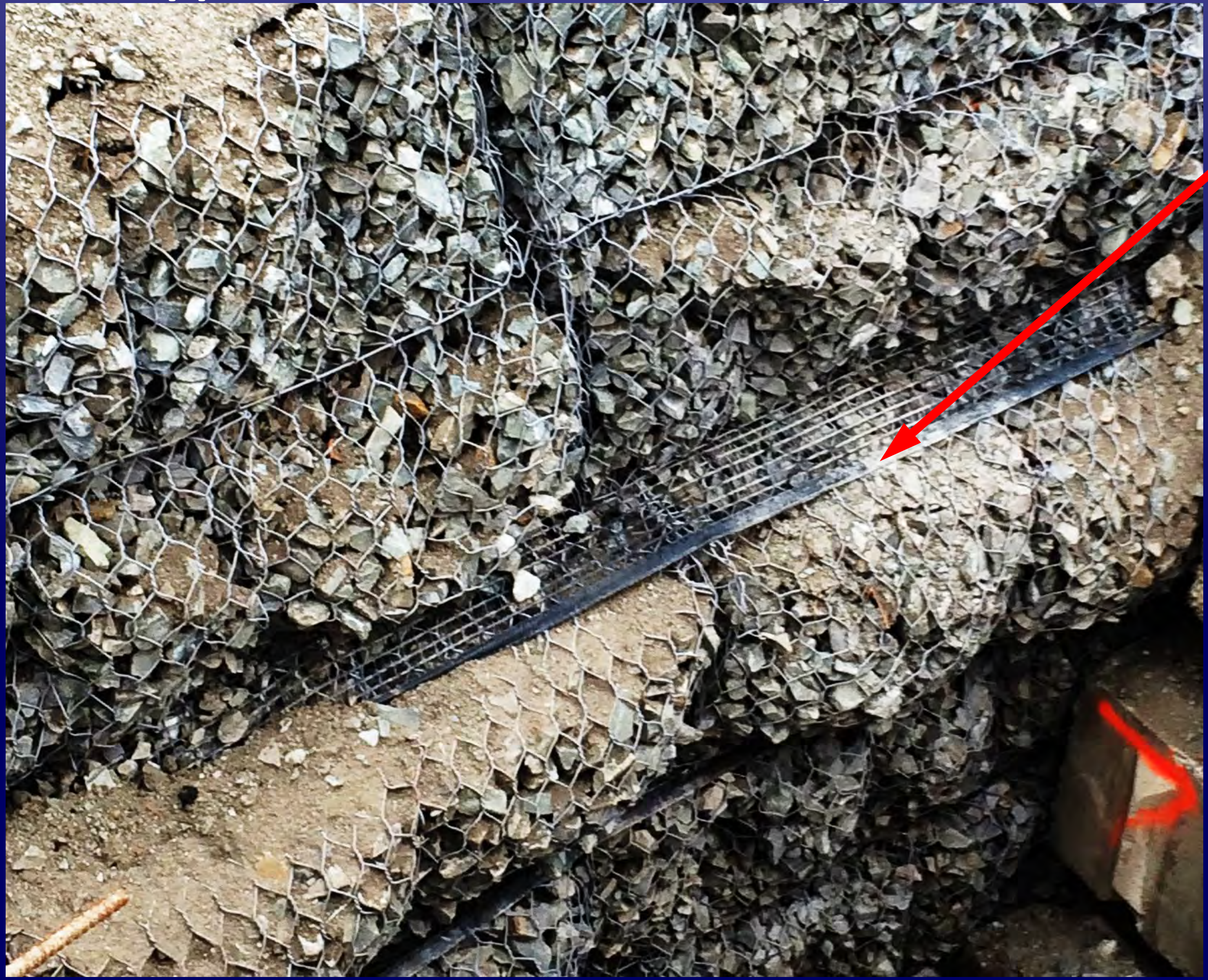


Note selvage of geogrid at face of temporary support

Uniaxial geogrid was placed in the wrong direction. Selvage is machine direction – strong direction. Uniaxial geogrid should have been placed with machine direction perpendicular to shoring face (the gabions)

Part 4: Functions and Applications – Reinforcement

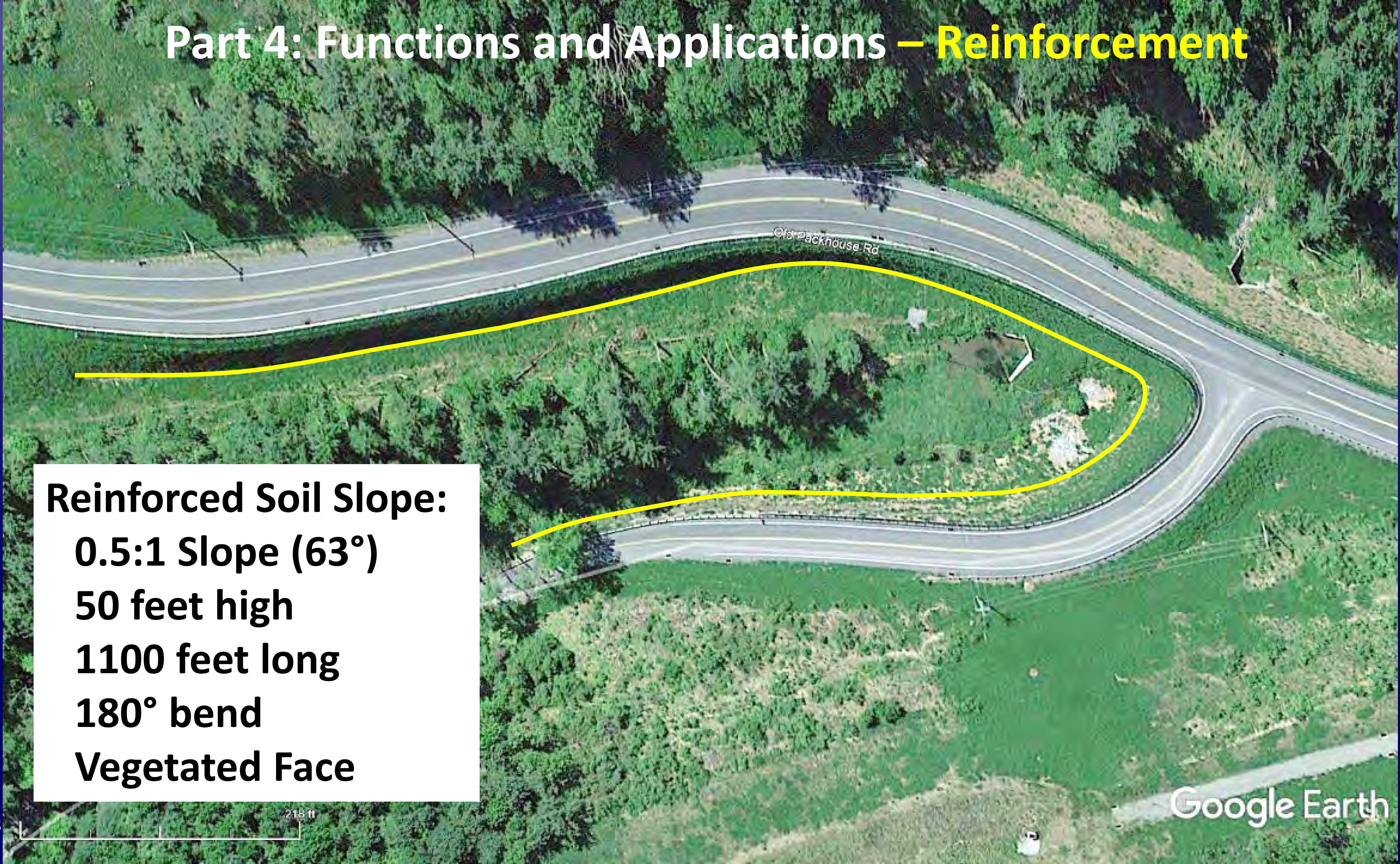
- Geogrid → Uniaxial Reinforcement
  - Good application – Bad execution! (Details can be very important)



Note selvage of geogrid at face of temporary support

Only fraction of strength in cross machine direction as opposed to machine (strong) direction for uniaxial geogrid.

Part 4: Functions and Applications – Reinforcement



Reinforced Soil Slope:
- 0.5:1 Slope (63°)
- 50 feet high
- 1100 feet long
- 180° bend
- Vegetated Face

Part 4: Functions and Applications – Reinforcement

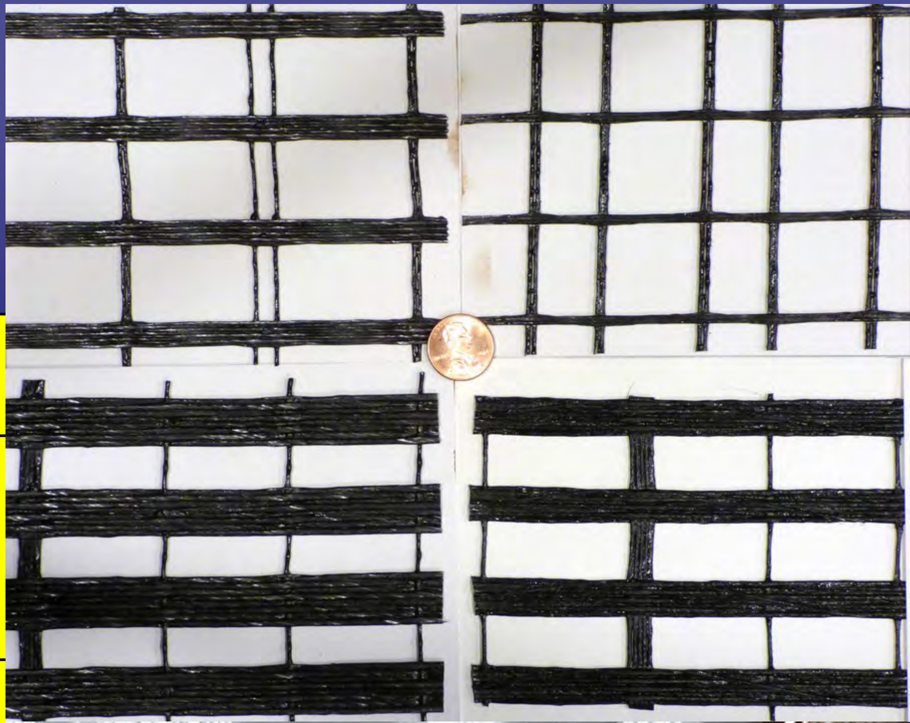
Part 4: Functions and Applications – Reinforcement

Part 4: Functions and Applications – Reinforcement

Part 4: Functions and Applications – Reinforcement

Part 4: Functions and Applications
– Reinforcement

Material	**Geogrid and Geotextile**
Structure	**Uniaxial (Geogrid) and Woven (Geotextile)**
Polymer	**PET**
Function	**Reinforcement**
Application	**Sinkhole Safety Net**



Part 4: Functions and Applications – Reinforcement

- Geogrid → Uniaxial
  - Function: Reinforcement – supplementing soil shear strength by adding tensile reinforcement
  - Application: Sinkhole Safety Net
  - Provide temporary support for roadway section in active sinkhole area
  - Not a solution to the primary problem – sinkhole development
  - Will not prevent sinkhole activity
  - Provides a means of better managing the problem and providing temporary protection

SR422 Sinkhole Safety Net – Site Layout and Sinkhole History

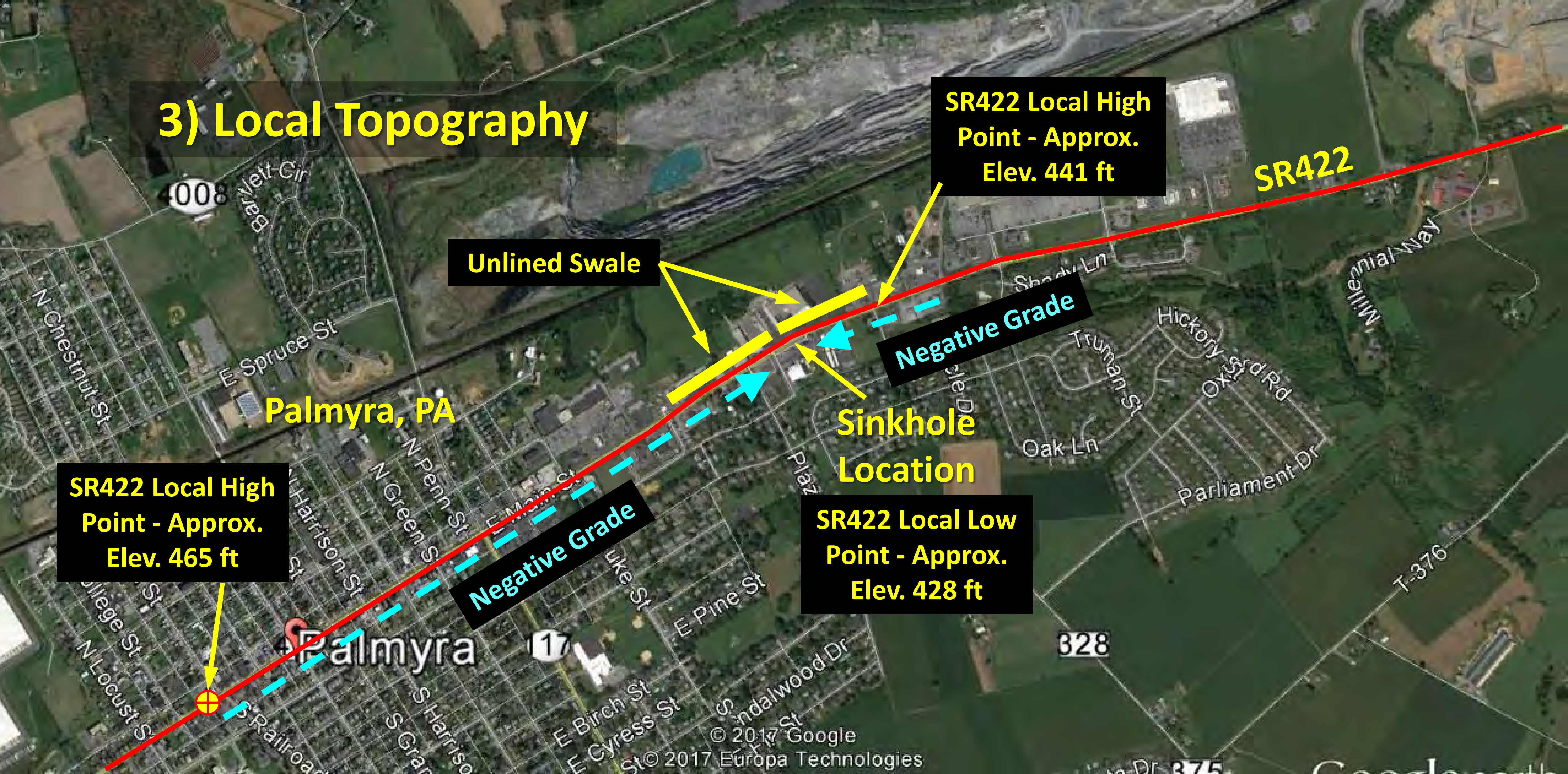
Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Sinkhole Safety Net

- Significant Factors (...understanding of local conditions):
  1) Carbonate Geology
  2) Local Surface Mining Operation (Quarry)
  3) Local Topography
  4) Local Development w/o Adequate Storm Water Control (Control of Surface Water)

SR422 Sinkhole Safety Net – Significant Factors

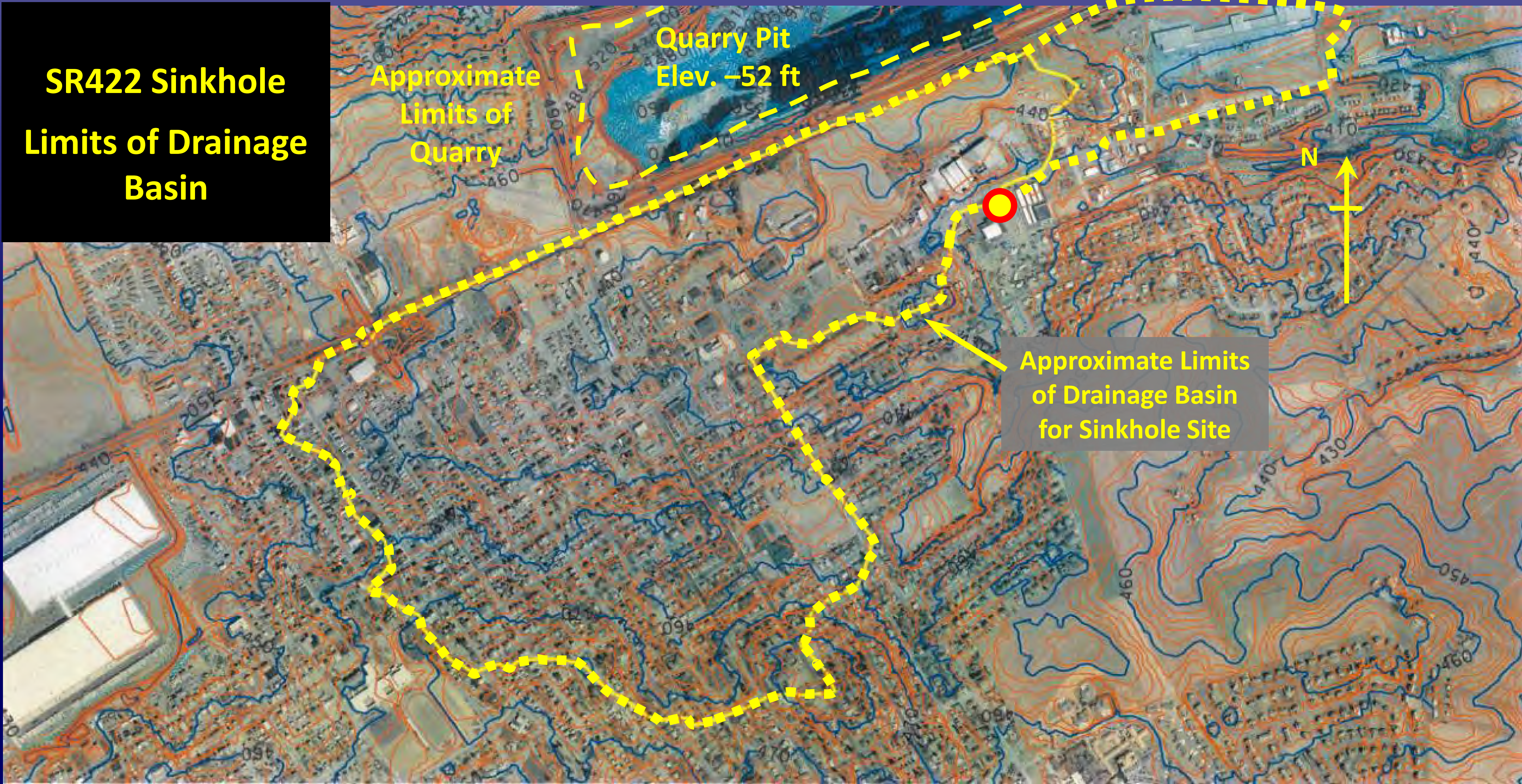
SR422 Sinkhole Safety Net – Significant Factors



SR422 Sinkhole Safety Net – Significant Factors

4) Control of Surface Water (i.e. Storm Drains)

Part 4: Functions and Applications



Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Sinkhole Safety Net

- Design based upon using catenary equation for uniform load
- Design calcs conducted over labor day weekend with internet as primary available technical reference, therefore, a number of (often highly conservative) assumptions were made
- Goal: Estimate required geosynthetic tensile reinforcement to support design load given following criteria:
  - 0.67 foot (8 inch) maximum deflection
  - 8-foot diameter sinkhole
  - Geometry yields 2 percent elongation for geosynthetic reinforcement (Design strength at 2% strain)

Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Sinkhole Safety Net

- Based upon above design assumptions, using catenary formula for 8-foot length and 8-inch (0.67 ft) sag, yielded required tensile strength of 18.1 kips/foot of geosynthetic width

Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Sinkhole Safety Net

- Target design requirements yielded a 2 percent tensile elongation – this significantly reduces tensile force that can be used from the high strength geosynthetics
- Provides system having significant reserve capacity to accommodate subsidence events from anticipated future sinkhole activity

Part 4: Functions and Applications – Reinforcement

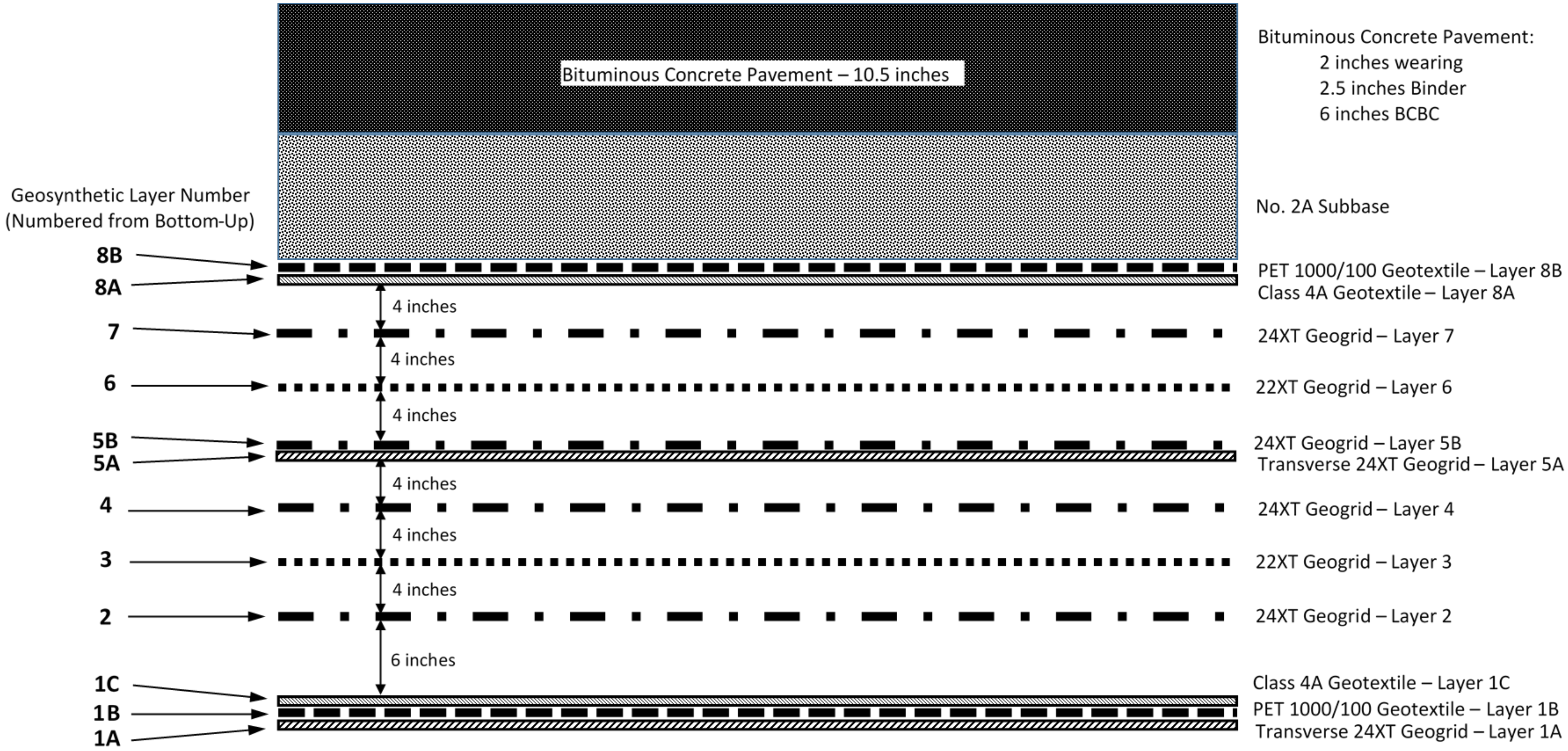
Geogrid → Uniaxial → Sinkhole Safety Net

- Due to limited material availability, three different uniaxial geosynthetic products were used in the reinforced section

Product Type	Designation	Est. 2% Tensile Strength, (k/ft)	No. Layers	Total 2% Tensile Strength, (k/ft)	Ult. Tensile Strength, (k/ft)
High Strength Woven Polyester Geotextile	PET1000/100	5.6	2	11.2	68.5
High Strength Polyester Geogrid	24XT	1.5	4	6.0	27.4
High Strength Polyester Geogrid	22XT	1.4	2	2.8	20.6
		Sum of Layers	8	20.0	-

- **Total 2% tensile strength provided = 20.0 k/ft > 18.1 k/ft required**

Part 4: Functions and Applications – Reinforcement

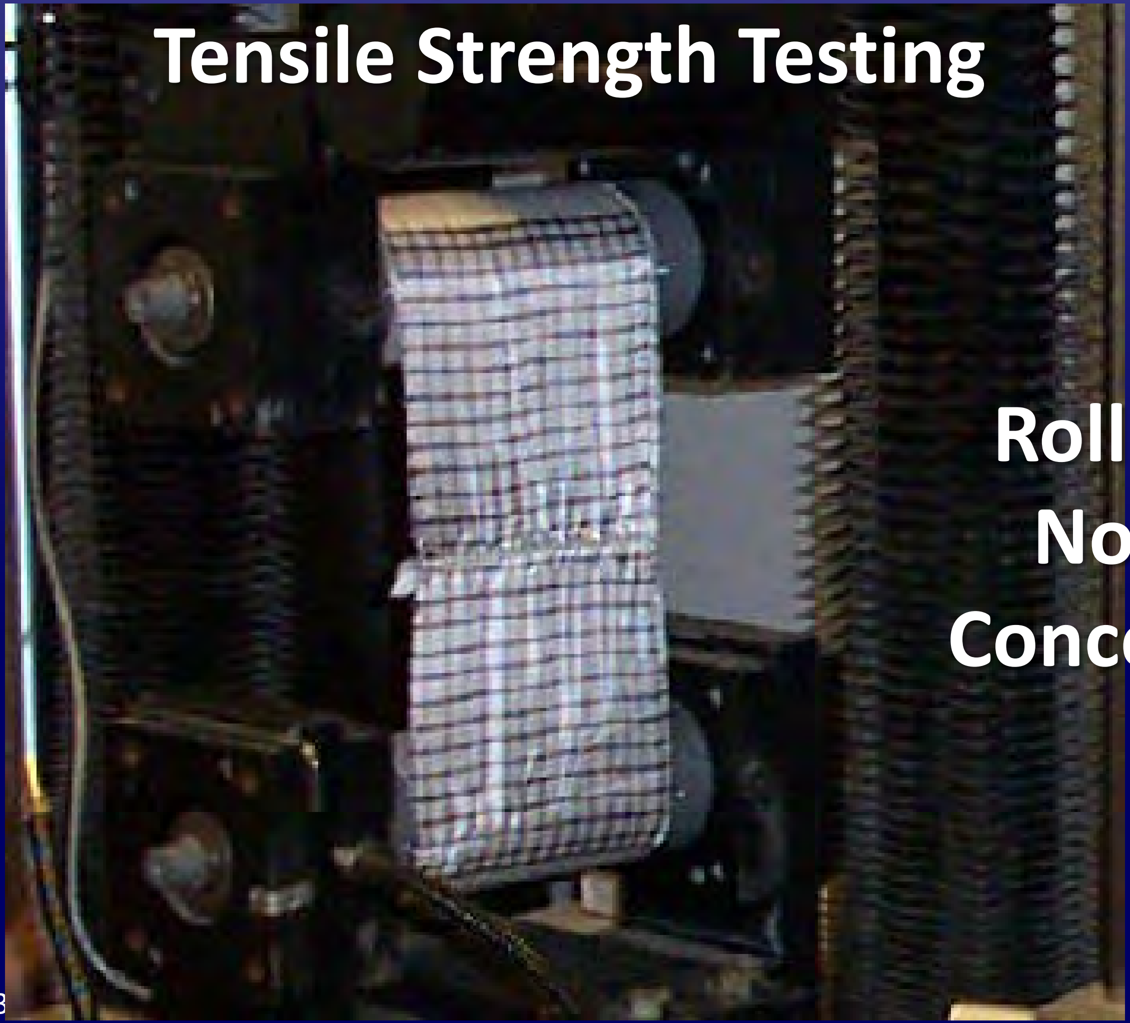


Typical Section – Flexible Sinkhole Safety Net – Roadway
(N.T.S.)

Part 4: Functions and Applications – Reinforcement

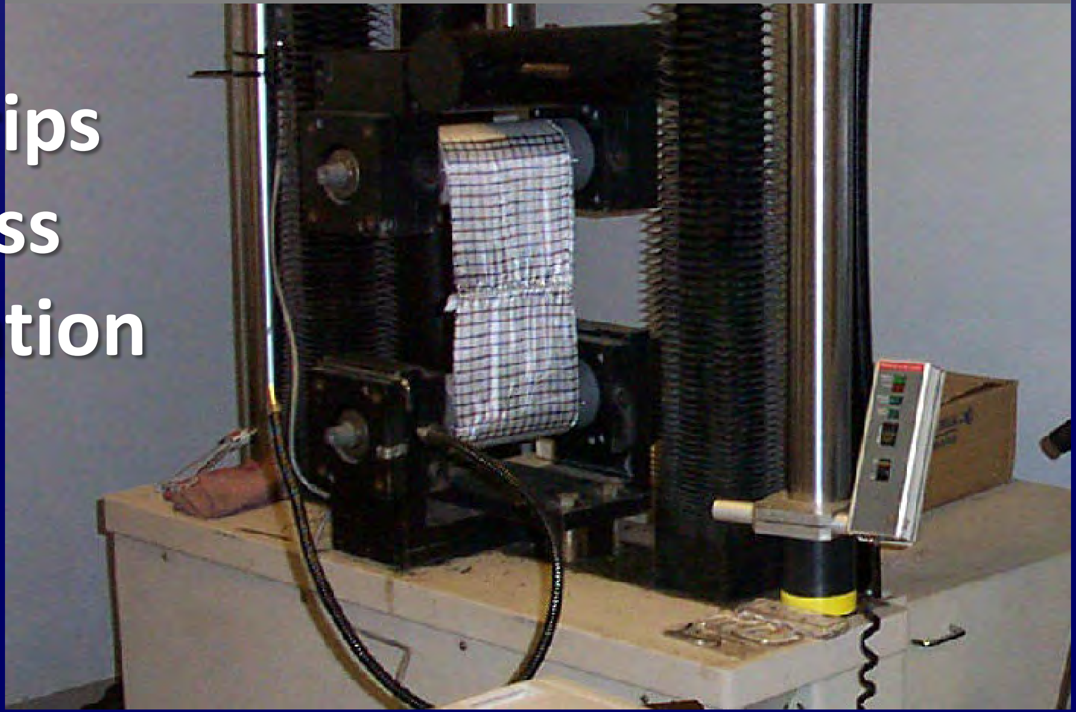
Geogrid → Uniaxial → Sinkhole Safety Net

Roller Grips – Geosynthetic Tensile Strength Testing

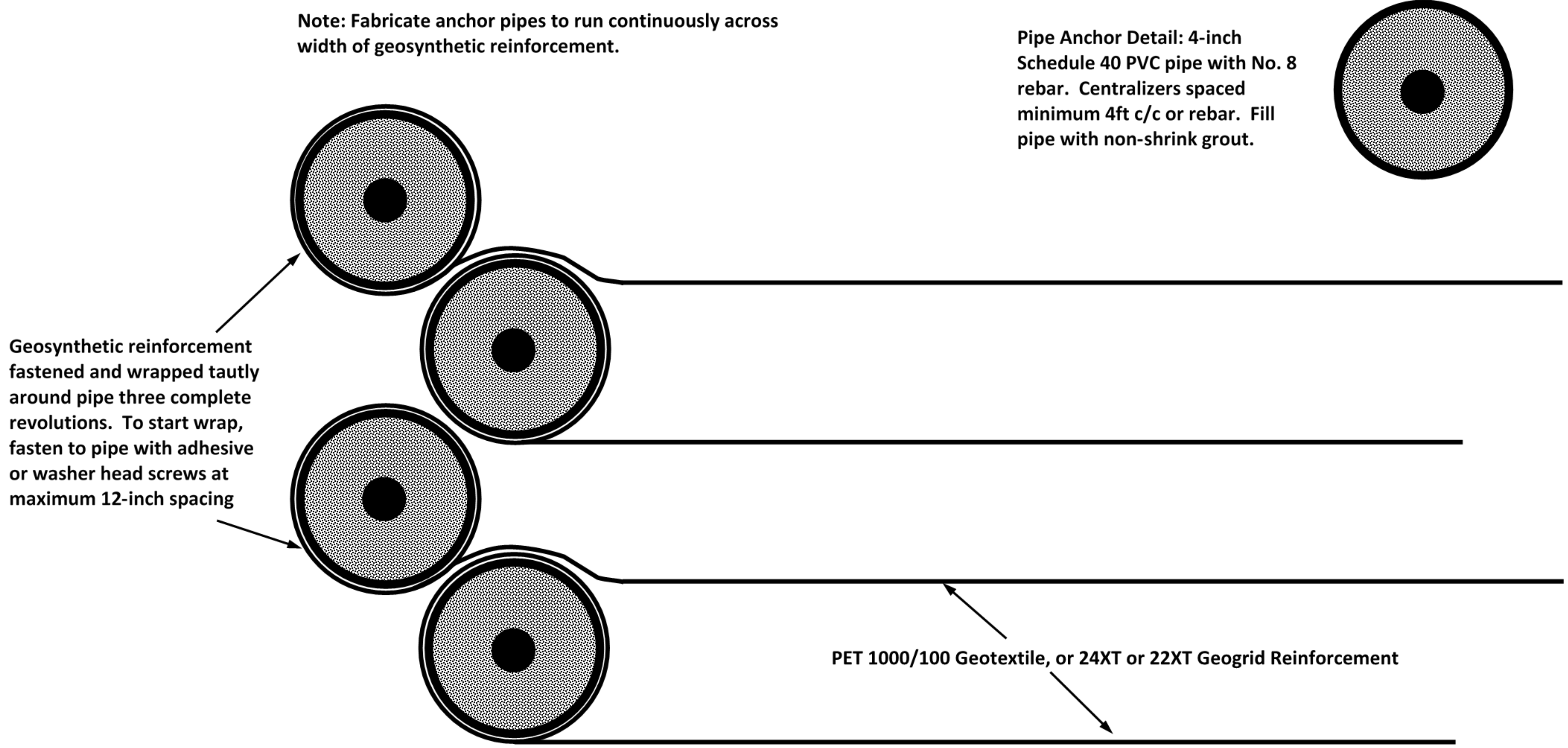


Roller Grip – Geosynthetic wrapped around roller and grips itself by friction – no stress concentration

Roller Grips
No Stress
Concentration



Part 4: Functions and Applications – Reinforcement



Geosynthetic Reinforcement Anchor Adjacent to Existing Structural Slab
(N.T.S.)

Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Sinkhole Safety Net

Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Sinkhole Safety Net

Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Sinkhole Safety Net

Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Sinkhole Safety Net

Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Sinkhole Safety Net

Part 4: Functions and Applications – Reinforcement

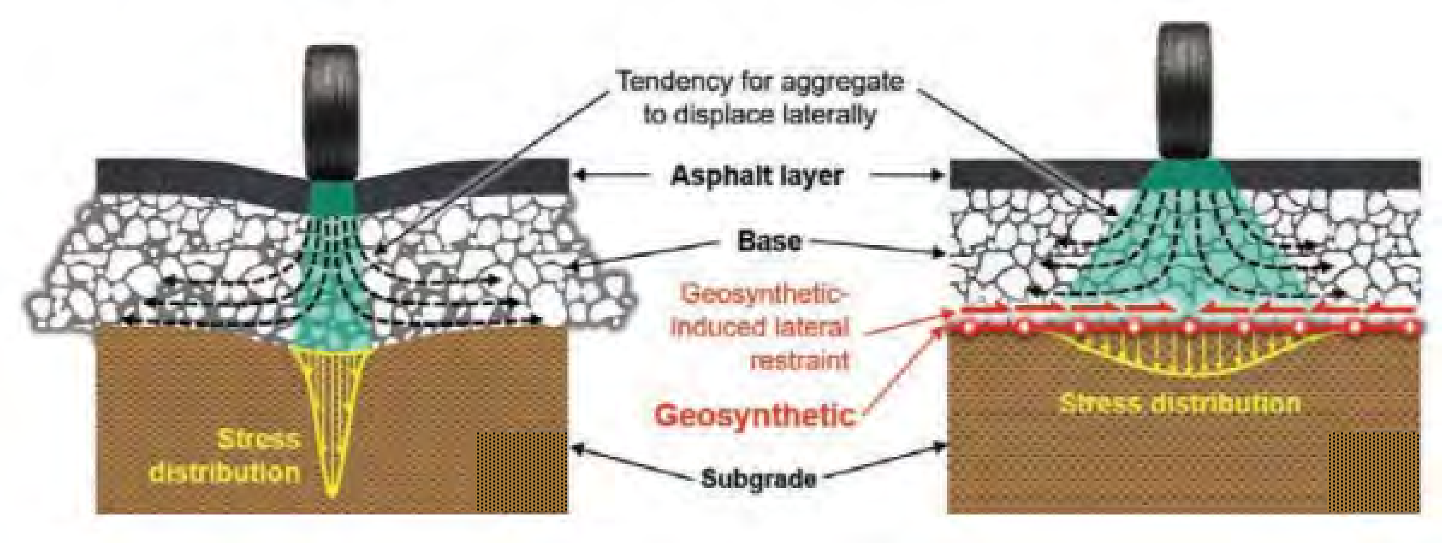
Geogrid → Uniaxial → Sinkhole Safety Net

Part 4: Functions and Applications – Reinforcement

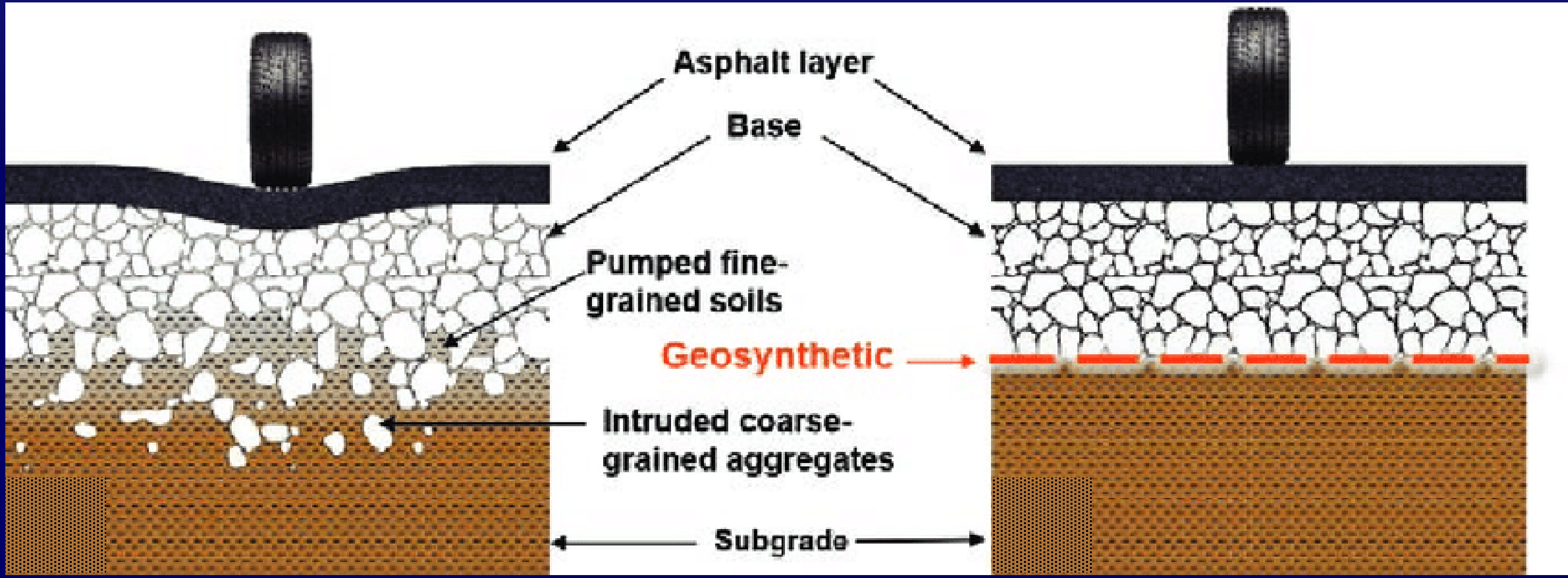
Geogrid → Uniaxial → Sinkhole Safety Net

Part 4: Functions and Applications

- **Stabilization – Geocell, Biaxial/Multiaxial Geogrid or Geotextile**



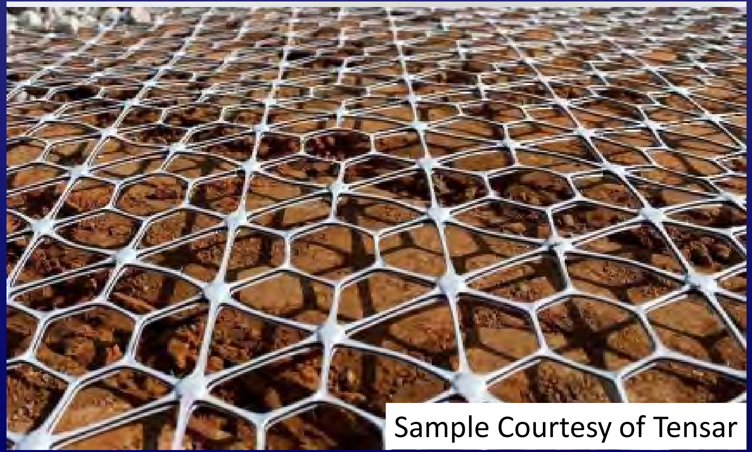
Source: ResearchGate



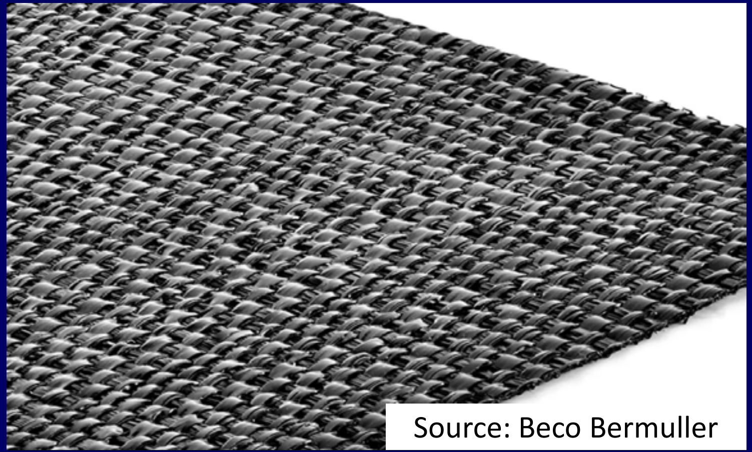
Material	Geocell
Structure	Welded Expanding Cells (Various Depths)
Polymer	HDPE and Polypropylene
Function	Stabilization
Application	Confinement/Load Distribution


Source: Presto Geosystems

Material	Geogrid
Structure	Biaxial/Multiaxial
Polymer	Polypropylene
Function	Stabilization
Application	Confinement/Load Distribution


Sample Courtesy of Tensar

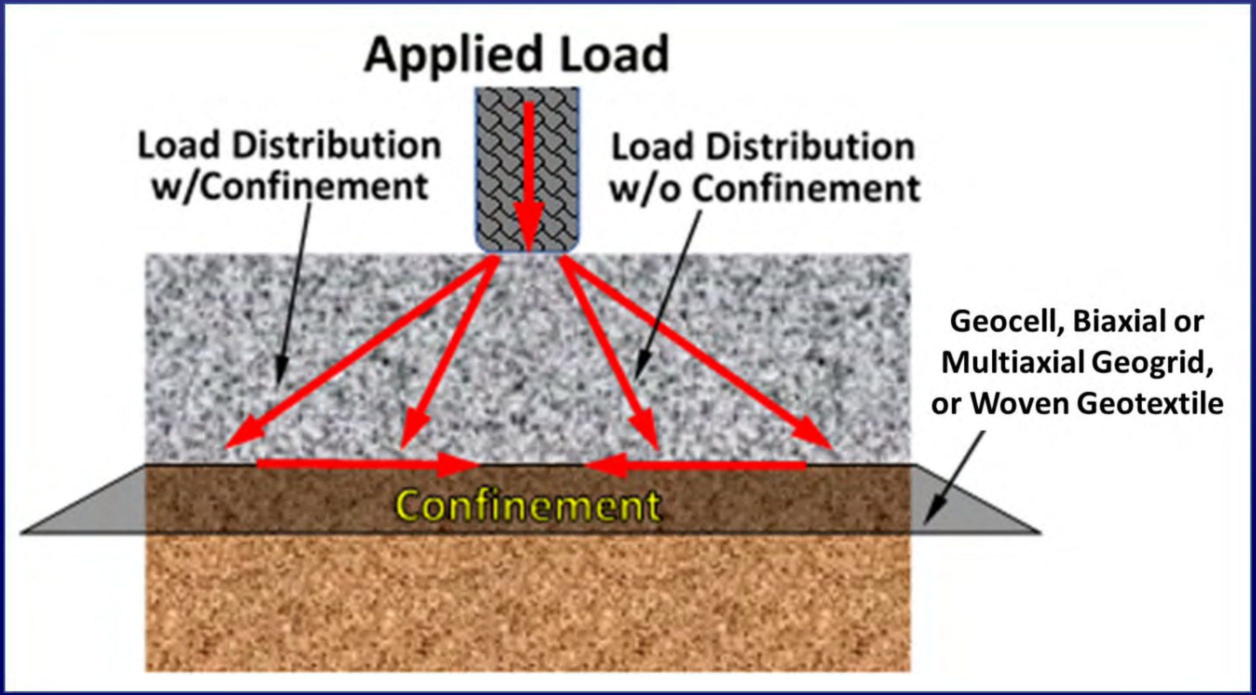
Material	Geotextile
Structure	Woven Multifilament
Polymer	Polypropylene
Function	Stabilization
Application	Confinement/Load Distribution


Source: Beco Bermuller

Part 4: Functions and Applications

- Geocell, Geogrid and Woven Multifilament Geotextile → PP
  - Function: Stabilization
  - These material act to confine fill soil/aggregate
  - Confinement enables better mobilization of fill material shear strength
  - Long-term design strength (i.e., creep) not an issue with confinement applications for PP geosynthetics (low stress application)

Part 4: Functions and Applications – Stabilization/Load Distribution



- Confinement - Lateral Restraint
- Passive Resistance
- Load Distribution
- Low Subgrade Stress
- Low Geogrid Tensile Stress
- Low Geogrid Strain
- No Reinforcement Function

Part 4: Functions and Applications – Stabilization vs Reinforcement

- **Stabilization – Mechanism is Confinement**

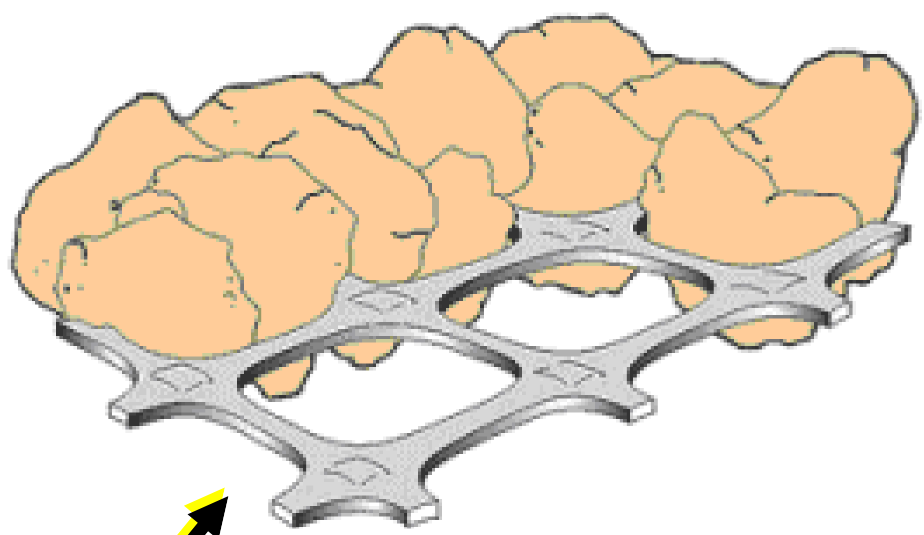
Soil Shear Strength Equation: $S = c + \sigma \tan\phi$

where:

S = shear strength
σ = overburden/confining pressure
ϕ = soil/aggregate friction angle

Better Mobilize Soil/Aggregate Shear Strength

Chen, Cheng & McDowell, & Thom, Nick. (2013). A study of geogrid-reinforced ballast using laboratory pull-out tests and discrete element modelling. Geomechanics and Geoengineering. 8. 10.1080/17486025.2013.805253.



Chen, Cheng & McDowell, & Thom, Nick. (2013). A study of geogrid-reinforced ballast using laboratory pull-out tests and discrete element modelling. Geomechanics and Geoengineering. 8. 10.1080/17486025.2013.805253.

Geosynthetic Layer: Geocell, Geogrid or Geotextile

Part 4: Functions and Applications

- **Stabilization – Geocell, Biaxial/Multiaxial Geogrid or Geotextile**

Material	Efficiency		Relative Cost*	Comments
Geocell	Best	↑ Increasing Efficiency	$$$$	Most efficient; Best for severe conditions; May be most cost effective for same required performance
Multiaxial Geogrid	Very Good		$	Most efficient performance of "sheet" materials; Most cost efficient "sheet" material
Biaxial Geogrid	Better		$$	More cost efficient than geotextile for same performance
Geotextile	Good		$$$	Least performance efficient; Least cost efficient of all materials for required performance

*Material cost – not in place application cost

Part 4: Functions and Applications

Material	Geocell*
Structure	Welded Expanding Cells
Polymer	HDPE/Polypropylene
Function	Load Distribution
Application	Soft Subgrades/Foundations, Pavement Section Reduction

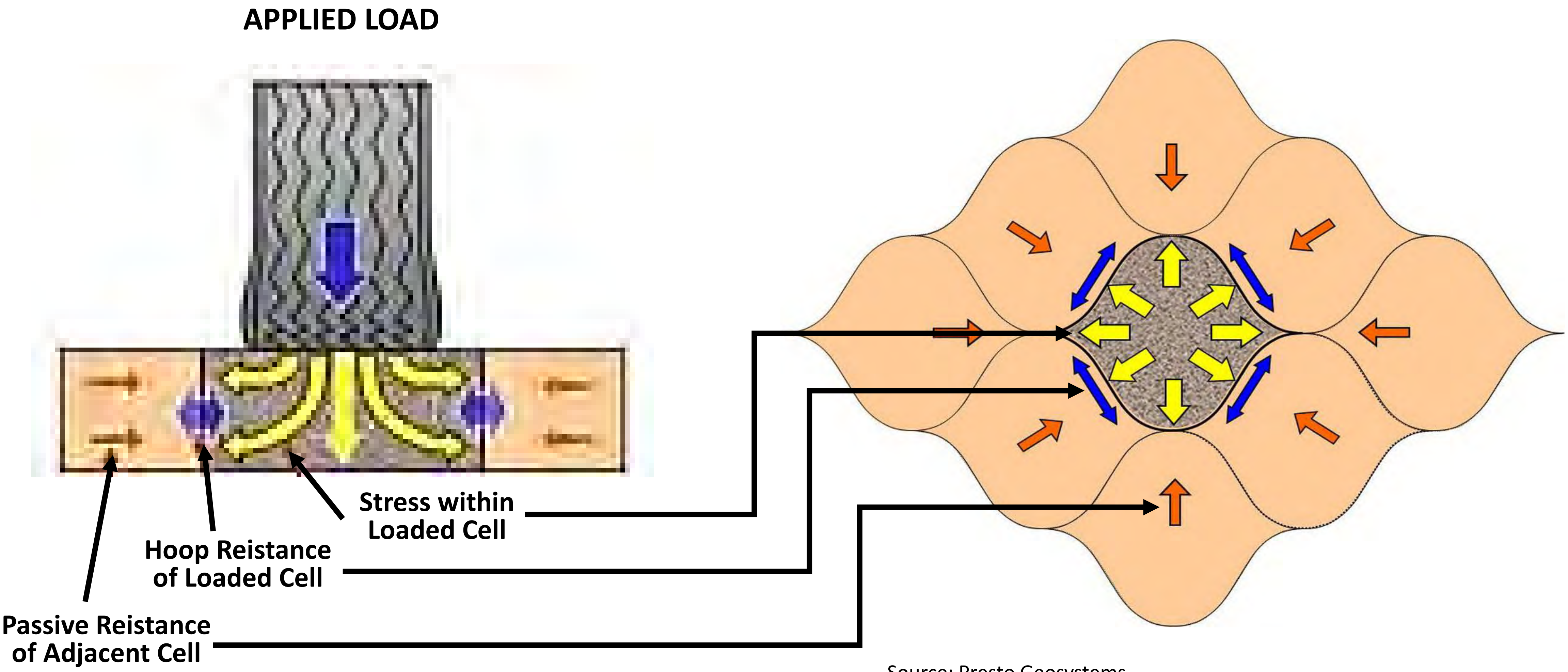
***For less severe conditions, or just base thickness reduction, a multiaxial geogrid may be a more cost efficient.**

Part 4: Functions and Applications – Load Distribution

- Geocell → HDPE and PP Spunbond
  - Function: Load Distribution
  - Ideal for efficient distribution of concentrated loads on soft/weak and/or compressible subgrades and foundations
  - Cells surrounding loaded cell resist lateral deformation efficiently distributing the vertical applied load
  - Concept by military for rapid runway construction
  - HDPE is perforated rigid wall and PP is flexible solid wall
  - Flexible wall may require more care in backfilling – however, although not as rigid as HDPE, found them to be of substantial wall thickness (not light-duty PP spunbond material)

Part 4: Functions and Applications – Load Distribution

- Geocell → HDPE and PP Spunbond



Source: Presto Geosystems

Part 4: Functions and Applications – Load Distribution

- Relocation of local road for Rt 100 bypass in Lehigh County, PA
- Load distribution over deep soft subgrade (> 12-foot depth)
- Extremely soft and wet – consistency of stiff toothpaste
- Combination of NWNP Geotextile and Geocell used to distribute construction and service loads
- Incorporated into extra depth subbase layer
- Highly efficient load distribution
- Permitted construction in very unfavorable conditions and effective performance of roadway section in service

Part 4: Functions and Applications – Load Distribution

Source: Prestogeo

Part 4: Functions and Applications – Load Distribution

Source: Prestogeo

Part 4: Functions and Applications – Load Distribution

Source: Prestogeo

Part 4: Functions and Applications – Load Distribution

Source: Prestogeo

Part 4: Functions and Applications – Load Distribution

- Geocell → Load Distribution
  - St. Davids, PA
  - Reconstruction of Wayne Ave under SEPTA Overpass
  - Limited vertical clearance
  - Locally low area – poor drainage
  - Local business community

Source: Prestogeo

Part 4: Functions and Applications – Load Distribution

- **Geocell → Load Distribution**

Part 4: Functions and Applications – Load Distribution

- Geocell → Load Distribution

Part 4: Functions and Applications – Load Distribution

- Geocell → Load Distribution
  - Soft wet soil subgrade
  - Multiple utilities
  - Rutting of asphalt concrete base course immediately after placement
  - Undercutting not feasible
  - Raising subgrade elevation not feasible
  - Class 4 geotextile separator over subgrade with geocell incorporated into subbase coarse aggregate
  - Permitted reconstruction of asphalt concrete pavement bad to original finished grade

Part 4: Functions and Applications – Load Distribution

- Geocell → Load Distribution

Part 4: Functions and Applications – Load Distribution

- **Geocell → Load Distribution**

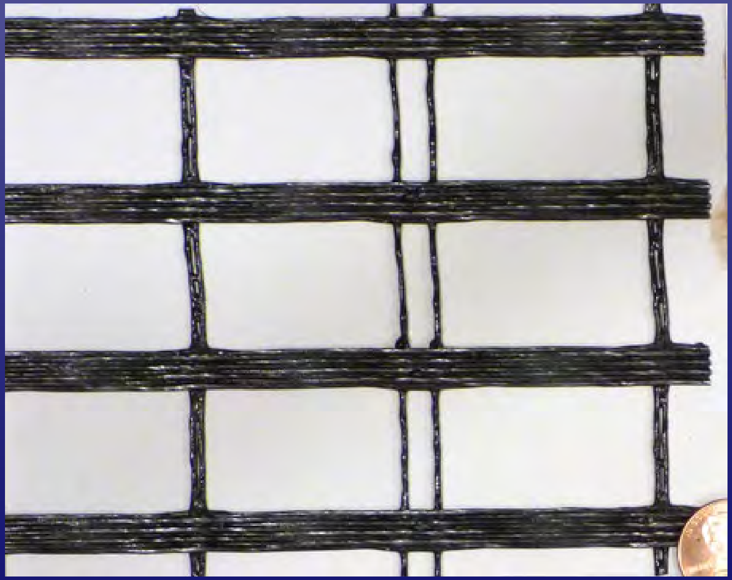
Part 4: Functions and Applications – Some Other Applications

- Geocell → HDPE and PP Spunbond
  - Also effective as steep slope facing for vegetated reinforced slopes
  - Flexible PP may have concerns with UV degradation for this application if stepped wall or slope face (exposed surfaces)
  - Perforated HDPE may require coarse aggregate fill in front face cell unless solid wall geocell is available
  - Geocell can also be used as slope facing for erosion control in more aggressive conditions (e.g., along waterways)
  - Other applications: construction of stable low-volume gravel road, sound barrier, rockfall or avalanche barrier


Likely Both Stabilization and Reinforcement Functions Exhibited
Load Transfer Platform

Part 4: Functions and Applications

Material	Geogrid
Structure	Uniaxial
Polymer	PET/HDPE
Function	Reinforcement
Application	Load Transfer Platform

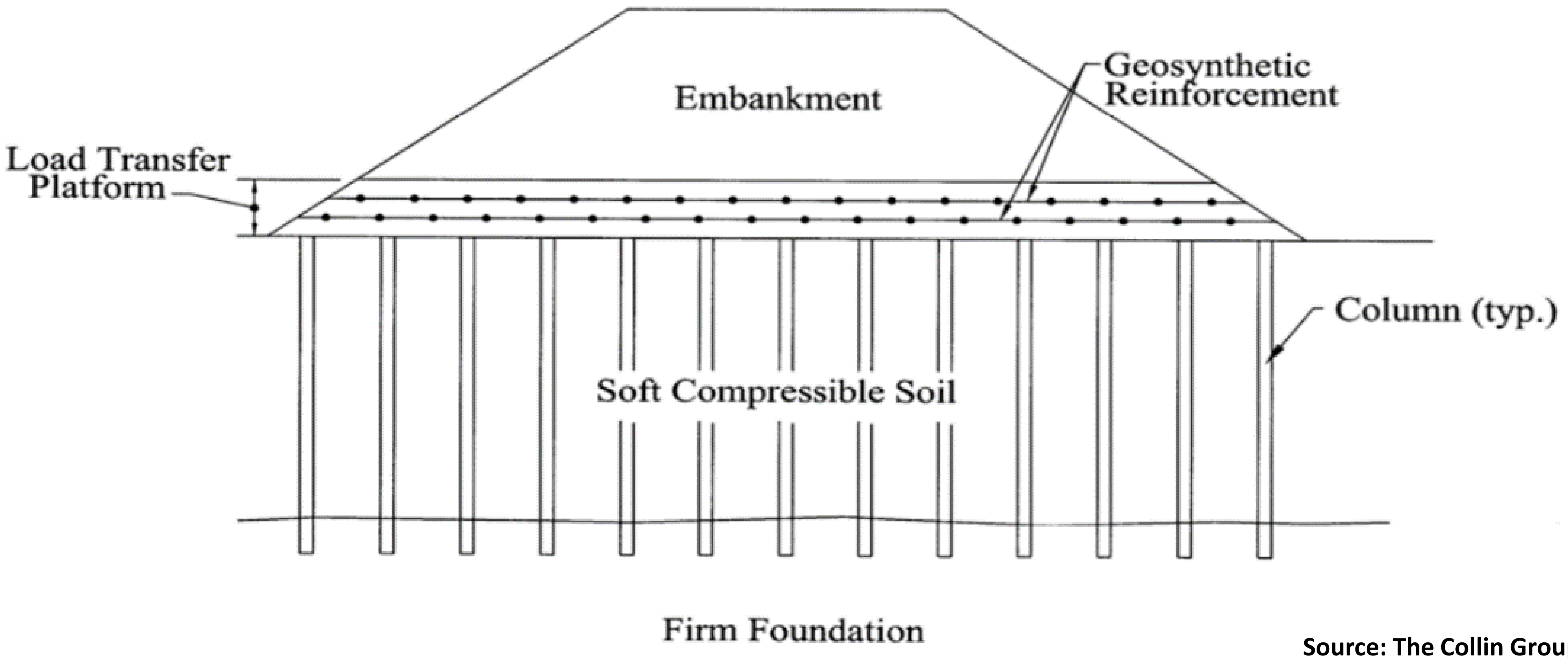


Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Load Transfer Platform

- Uniaxial geogrid primarily serving reinforcement function
- Example: Column supported embankment with geosynthetic reinforcement (Load Transfer Platform)
- Three design/construction options:
    - Uniaxial reinforcement in primary (long) axis with sufficient number layers in secondary (short) axis to prevent lateral spreading – likely most efficient placement for construction
    - Uniaxial reinforcement in alternating directions with each layer (like a two-way reinforced concrete slab)
    - Creep resistant biaxial reinforcement (PET)

Part 4: Functions and Applications



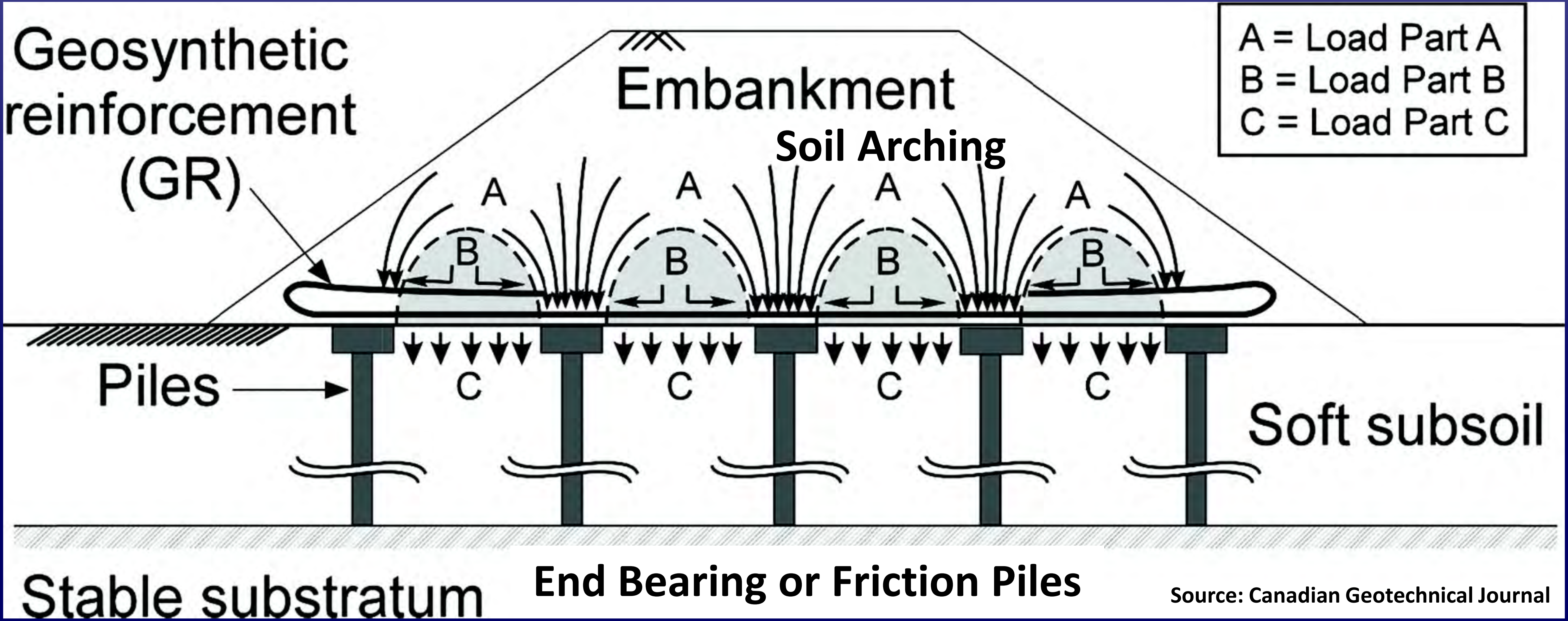
Source: The Collin Group

Column Supported Embankment with Geosynthetic Reinforced Load Transfer Platform

Reference: Geosynthetic-Reinforced Column-Support Embankment Design Guidelines (Collins Method)
On-line: https://www.thecollingroup.com/wp-content/uploads/2020/11/Collin_Han_Haung-NAGS-2005.pdf

Part 4: Functions and Applications – Reinforcement

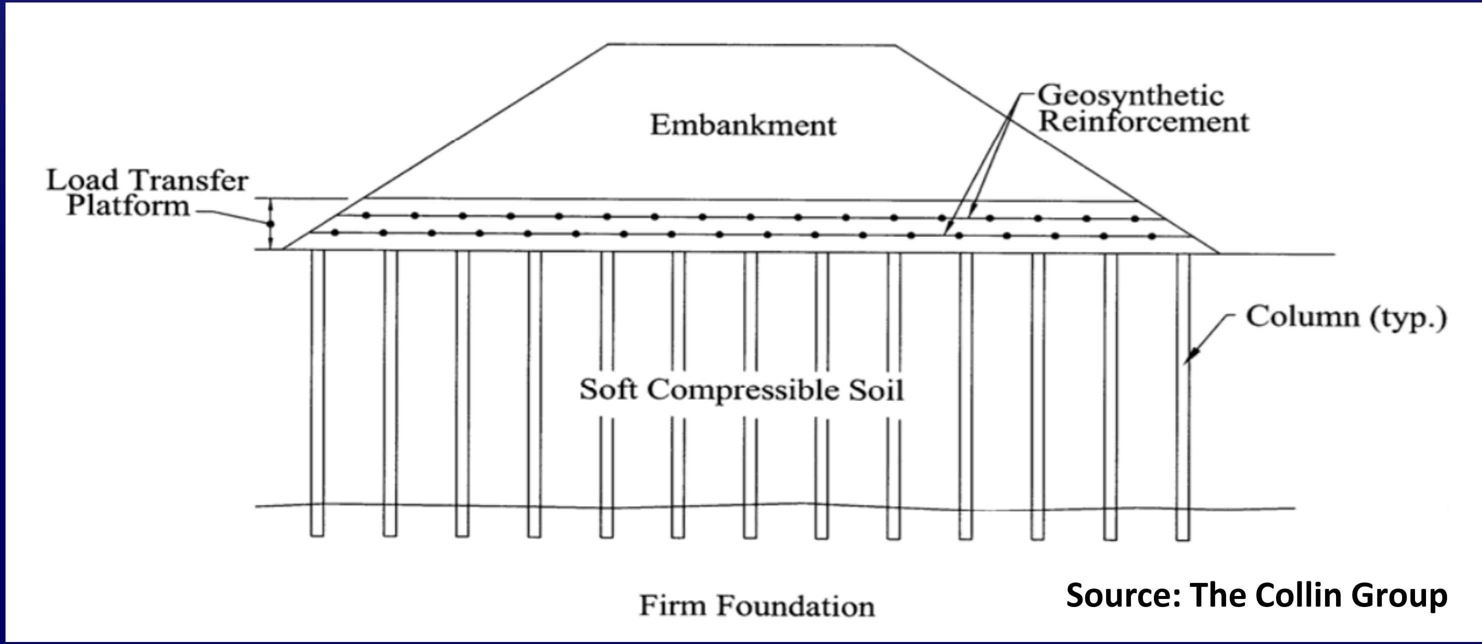
Geogrid → Uniaxial → Load Transfer Platform



Part 4: Functions and Applications – Reinforcement

Geogrid → Uniaxial → Load Transfer Platform

- Since a reinforcement foundation, important that creep resistance geosynthetic be used for the reinforcement
- During construction of platform, may be serving more of a stabilization function – facilitates construction of the platform



Source: The Collin Group

Part 4: Functions and Applications

Material	Geofoam
Structure	Expanded Polystyrene
Polymer	Polystyrene
Function	Load Reduction
Application	Various

Part 4: Functions and Applications

- Geofoam → EPS
  - Function: Lightweight fill
  - Can be good option to reduce load where insufficient foundation soil shear strength or excessive settlement is an issue
  - Very lightweight – densities from 0.7 to 2.85 pcf,
  - Compressive strength at one percent strain from 2.2 to 18.6 psi respectively

Part 4: Functions and Applications

- Geofoam → EPS
  - Soil cover required to protect EPS geofoam from high contact pressure surface loads
  - Compacted soil weighs ≈ 0.85 psi per foot of thickness so the overburden pressure of 4 to 5 ft of soil cover ≈ 4 psi
  - Soil cover overburden pressure controls required EPS type – typically EPS29 top layer (capping) and EPS19 for subsequent layers

Part 4: Functions and Applications

- Geofoam → EPS
  - General concept is to keep post construction overburden stress less than or equal to existing vertical overburden stress, or below project-specific critical overburden stress – load balancing
  - May have to remove sufficient existing material to create final load balanced condition, or net negative final overburden stress

Part 4: Functions and Applications

- Geofoam → EPS
  - Can also significantly reduce lateral loads (horizontal stress) using geofoam since EPS blocks are rigid
  - Must have adequate surface load distribution and adequate EPS compressive strength to prevent excessive short- and long-term compression of geofoam

Part 4: Functions and Applications

- Geofoam → EPS
  - Since EPS density much lower than water, will have to anchor down blocks if used below water table or in areas with tidal fluctuations

Part 4: Functions and Applications

- Geofoam → EPS
  - Significant concern is environments with hydrocarbons (liquid or vapor)
  - In highway applications, fuel spills (gasoline or diesel) are potential problem
  - Must protect EPS from both liquid and vapor using appropriate hydrocarbon-resistant geomembrane (full encapsulation)

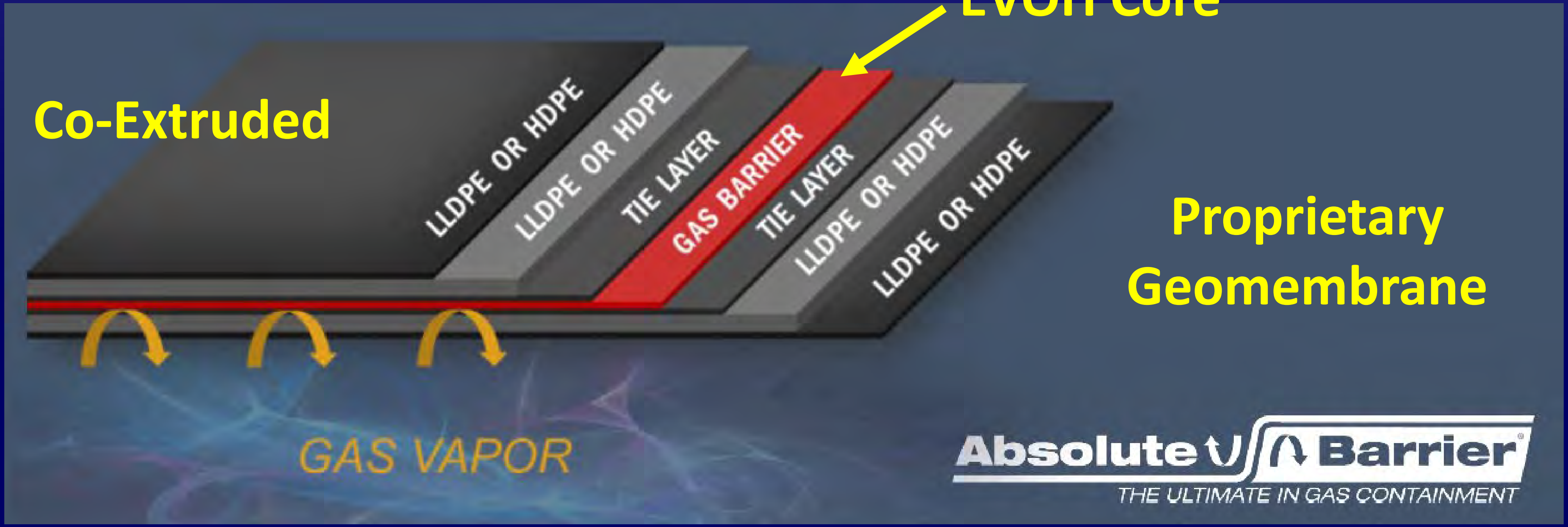
Part 4: Functions and Applications

- Geofoam → EPS
  - Note: current best geomembrane option is an LLDPE with an EVOH copolymer core
  - EVOH = Ethylene Vinyl Alcohol = <u>copolymer</u> of ethylene and vinyl alcohol
  - Copolymer is a polymer formed when two (or more) different types of monomers are linked in the same polymer chain

Part 4: Functions and Applications

- Geofoam → Protective Membrane
  - EVOH is a polar molecule while hydrocarbons such as gasoline and diesel are non-polar molecules – therefore they "repel" one another
  - LLDPE and HDPE are non-polar – resist degradation from hydrocarbons, BUT permeable to vapors

EVOH Core

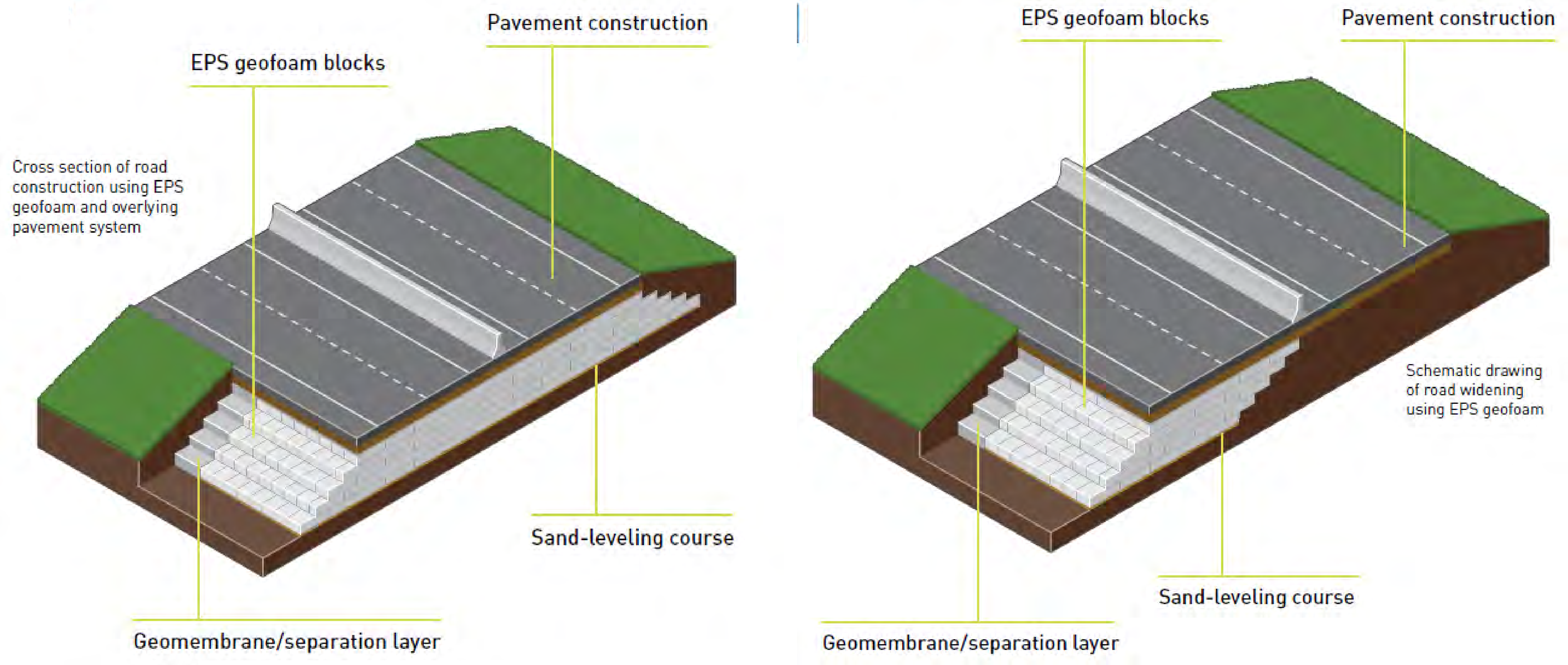


Part 4: Functions and Applications

- Geofoam → Other Applications
  - While very lightweight, EPS is a relatively high-cost fill material, and manufacturing facilities are limited
  - Material, transportation and protection (i.e., geomembrane) costs must all be considered relative to other alternatives
  - In the right circumstances, EPS can be the most cost-effective solution, and with proper protection, risks are low relative to much more complicated foundation or support systems with complex subsurface conditions

Part 4: Functions and Applications

- **Geofoam: Typical Applications**

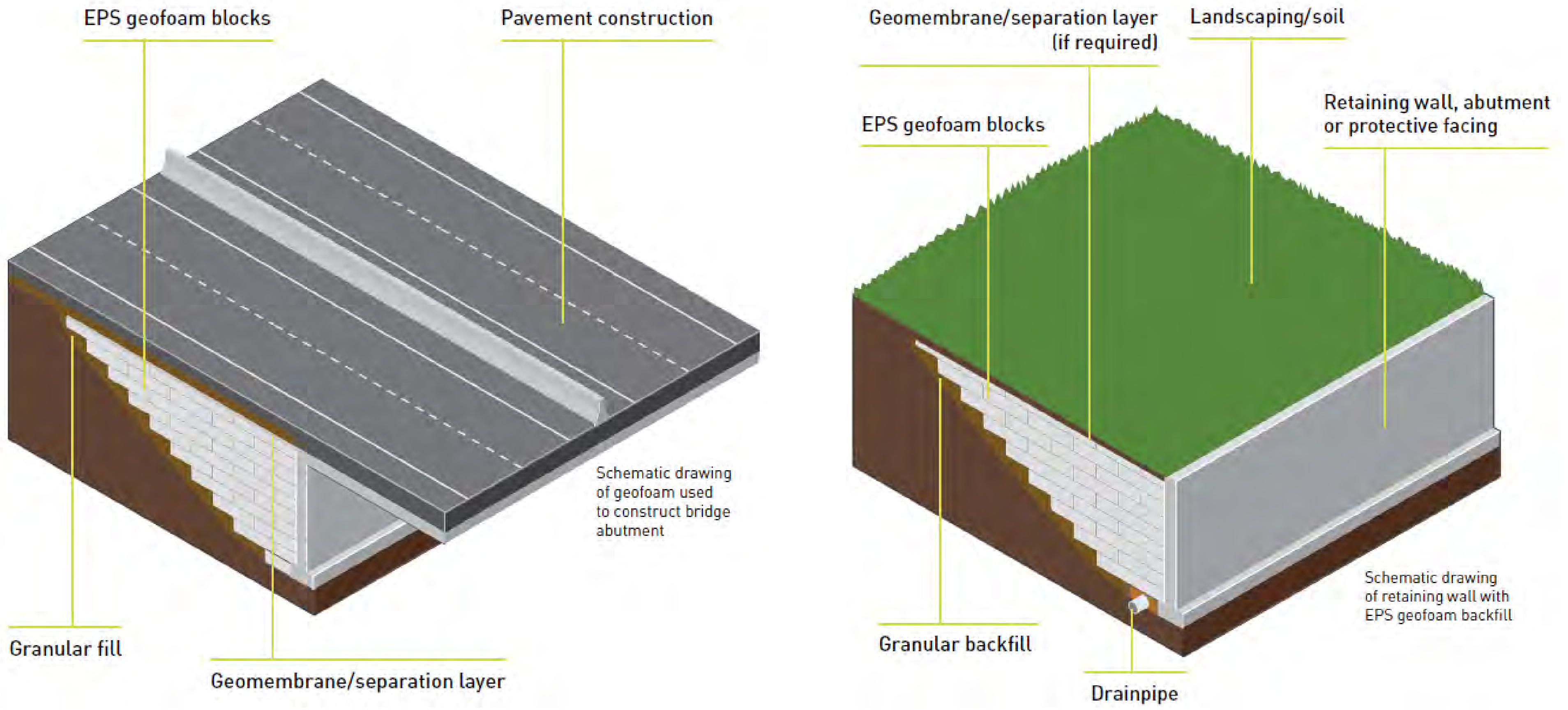


Lightweight Embankment Fill – Full Section or Widening

Source: EPS Alliance

Part 4: Functions and Applications

- **Geofoam: Typical Applications**

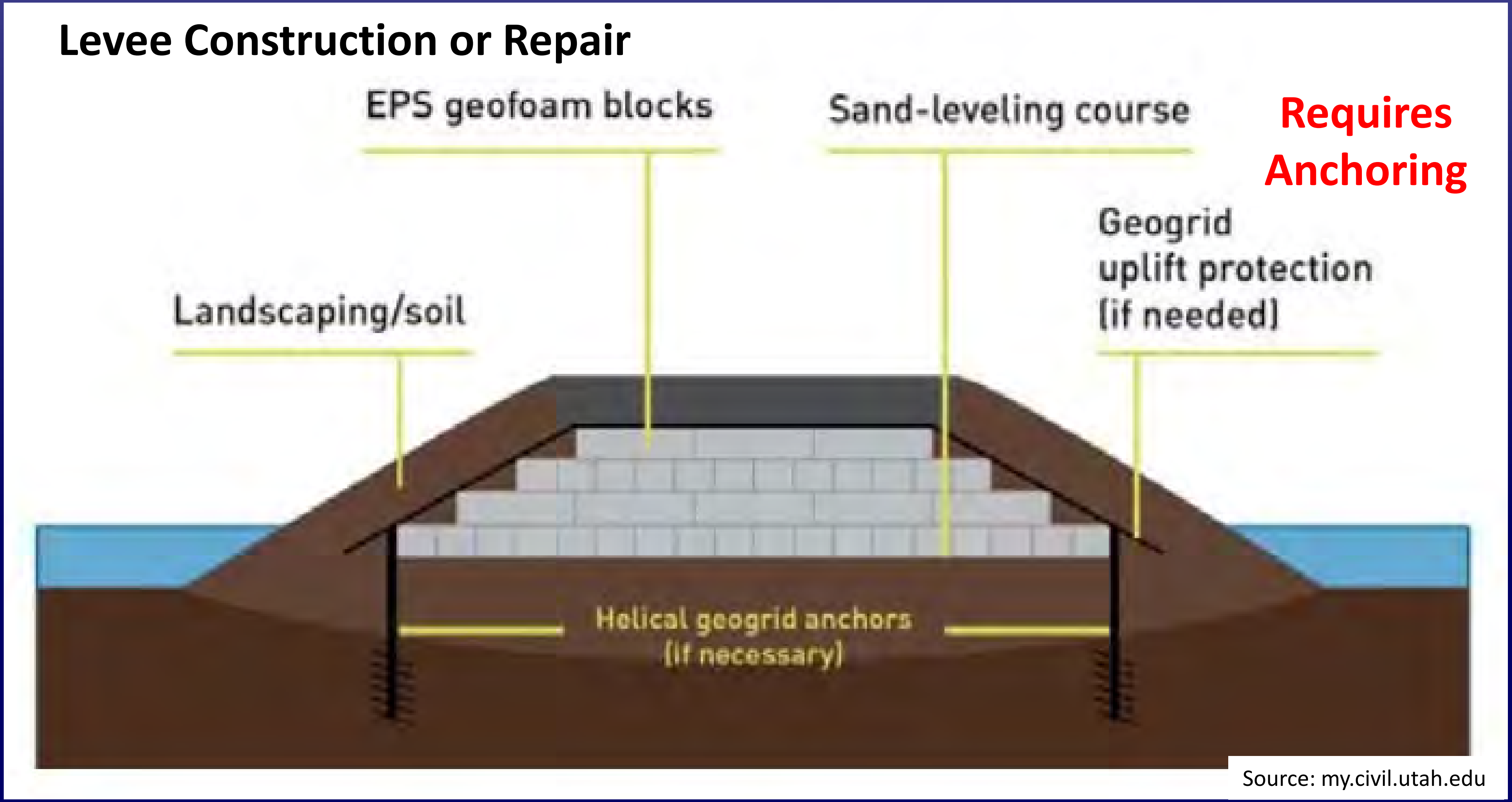


Lightweight Bridge or Retaining Wall Backfill

Source: EPS Alliance

Part 4: Functions and Applications

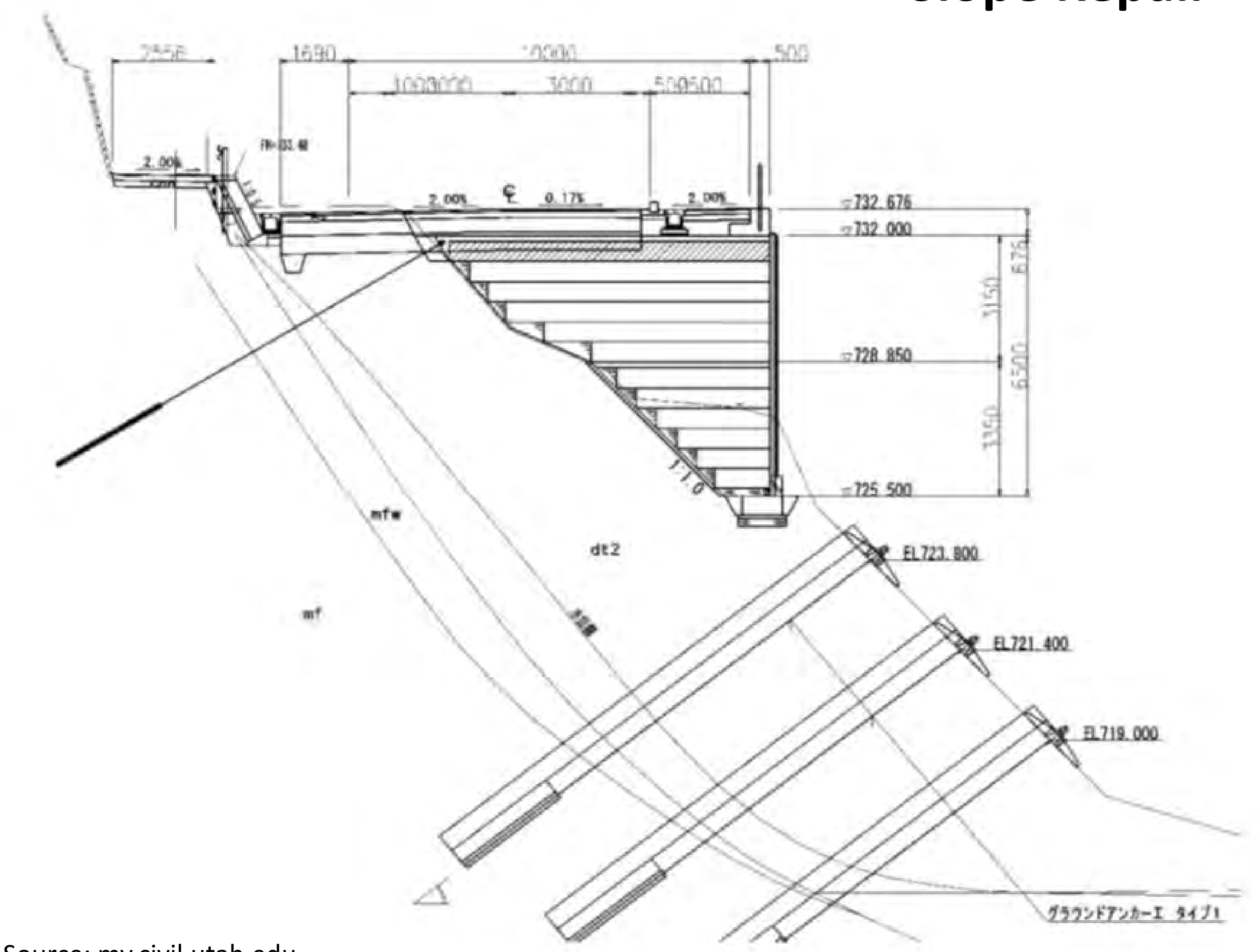
- **Geofoam: Typical Applications**



Part 4: Functions and Applications

- **Geofoam: Typical Applications**

Slope Repair



Source: my.civil.utah.edu

Part 4: Functions and Applications

- **Geofoam: Typical Applications**

Energy Attenuation for Rockfall Protection Tunnel (Turkey)

Source: my.civil.utah.edu

Part 4: Functions and Applications

- **Geofoam: Typical Applications**

Seating Base For Stadium

Source: my.civil.utah.edu

Part 4: Functions and Applications

- **Geofoam: Typical Applications**

Floating Helipad – Vancouver, Canada

Source: my.civil.utah.edu

Part 4: Functions and Applications

Material	Geofoam
Structure	Expanded Polystyrene
Polymer	Polystyrene
Function	Load Reduction
Application	Lightweight Fill – Embankment Construction Over Soft Foundation

Part 4: Functions and Applications

- Geofoam → Expanded Polystyrene
  - Function: Lightweight Fill for Embankment Over Weak Foundation

Source: PENNDOT, District 10-0

Source: PENNDOT, District 10-0

Part 4: Functions and Applications

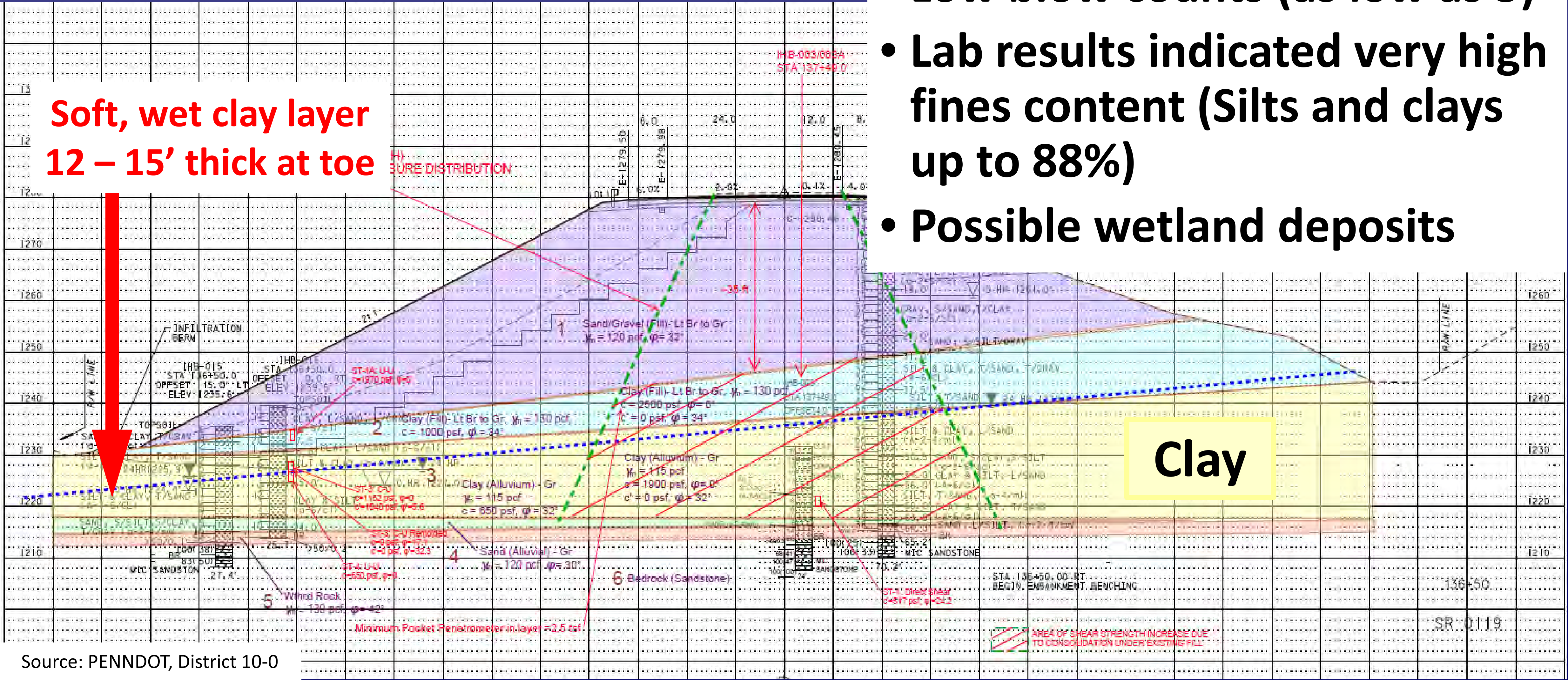
- Geofoam → Expanded Polystyrene

Source: PENNDOT, District 100

- **Removal of 3-span structure over abandoned RR bed/trail**
- **Widening of roadway to accommodate climbing lane**
- **Large embankment fill**
- **Relocated trail**
- **Adjacent wetland**

Part 4: Functions and Applications

- Geofoam → Expanded Polystyrene



- Alluvial clay layer
- Low blow counts (as low as 3)
- Lab results indicated very high fines content (Silts and clays up to 88%)
- Possible wetland deposits

Source: PENNDOT, District 10-0

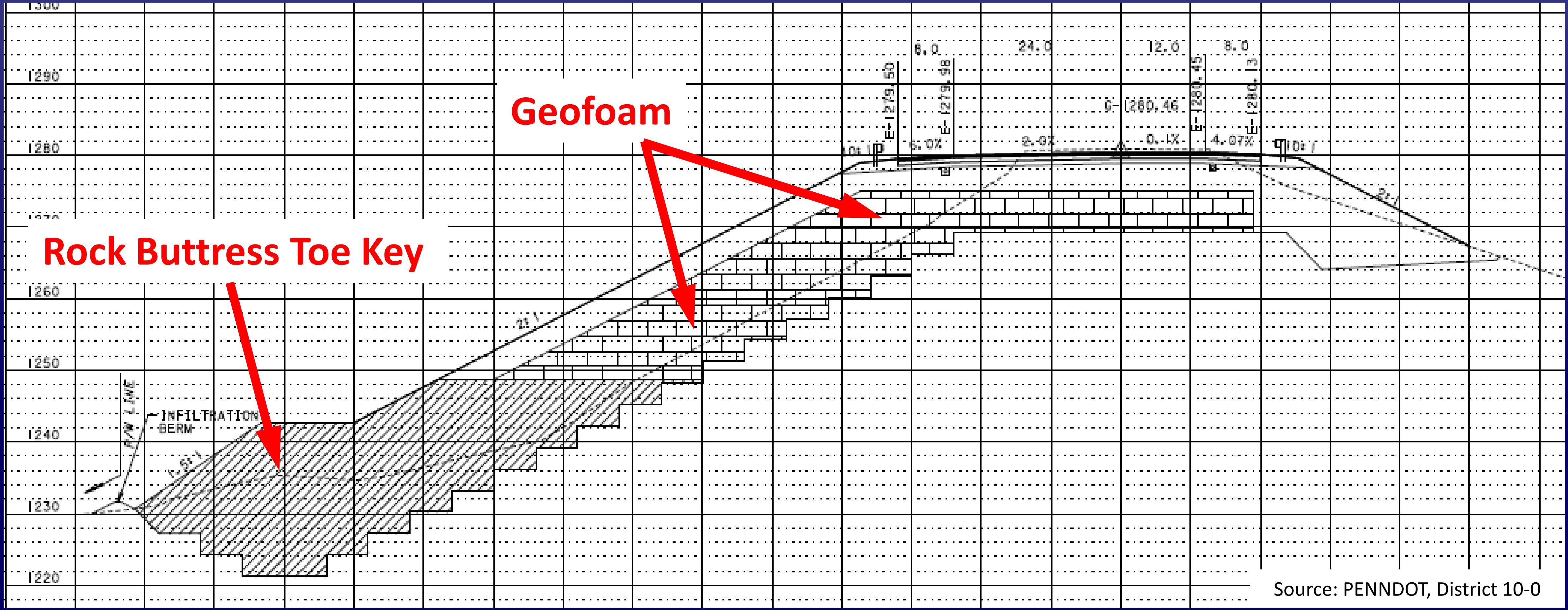
4:10 PM

Part 4: Functions and Applications

- Geofoam → Expanded Polystyrene
  - Alternatives Selected:
    - Geofoam unit weight of 1.35 pcf compared to 120 pcf for soil
    - Geofoam significantly decreased load placed on existing soft foundation soils at base of fill
    - Rock buttress at toe

Part 4: Functions and Applications

- Geofoam → Expanded Polystyrene



Source: PENNDOT, District 10-0

Part 4: Functions and Applications

- Geofoam → Expanded Polystyrene

- **Geofoam completely encapsulated in hydrocarbon resistant geomembrane for protection**

Source: PENNDOT, District 10-0

Part 4: Functions and Applications

- **Geofoam → Expanded Polystyrene**

Source: PENNDOT, District 10-0

Part 4: Functions and Applications

- **Geofoam → Expanded Polystyrene**

Source: PENNDOT, District 10-0

Part 4: Functions and Applications

- Geofoam → Expanded Polystyrene

Source: PENNDOT, District 10-0

Part 4: Functions and Applications

- Geofoam → Expanded Polystyrene

- Geofoam Cap Block = $100/cy (installed)
- Geofoam Fill Block = $160/cy (installed)
- Cap block of higher density (and therefore compressive strength) to resist traffic loads
- 2019 Data
- Note – cap block typically higher unit cost due to higher density

Source: PENNDOT, District 10-0

Part 4: Functions and Applications

- Geofoam → Expanded Polystyrene

- Geomembrane = $65/sy (installed) – high
- Hydrocarbon resistant

Source: PENNDOT, District 10-0

Part 4: Functions and Applications

Material	Geogrid
Structure	Grid
Polymer	Polypropylene
Function	Confinement
Application	Gabion Mattress – Erosion Control Gabion Basket – Stabilization

Part 4: Functions and Applications

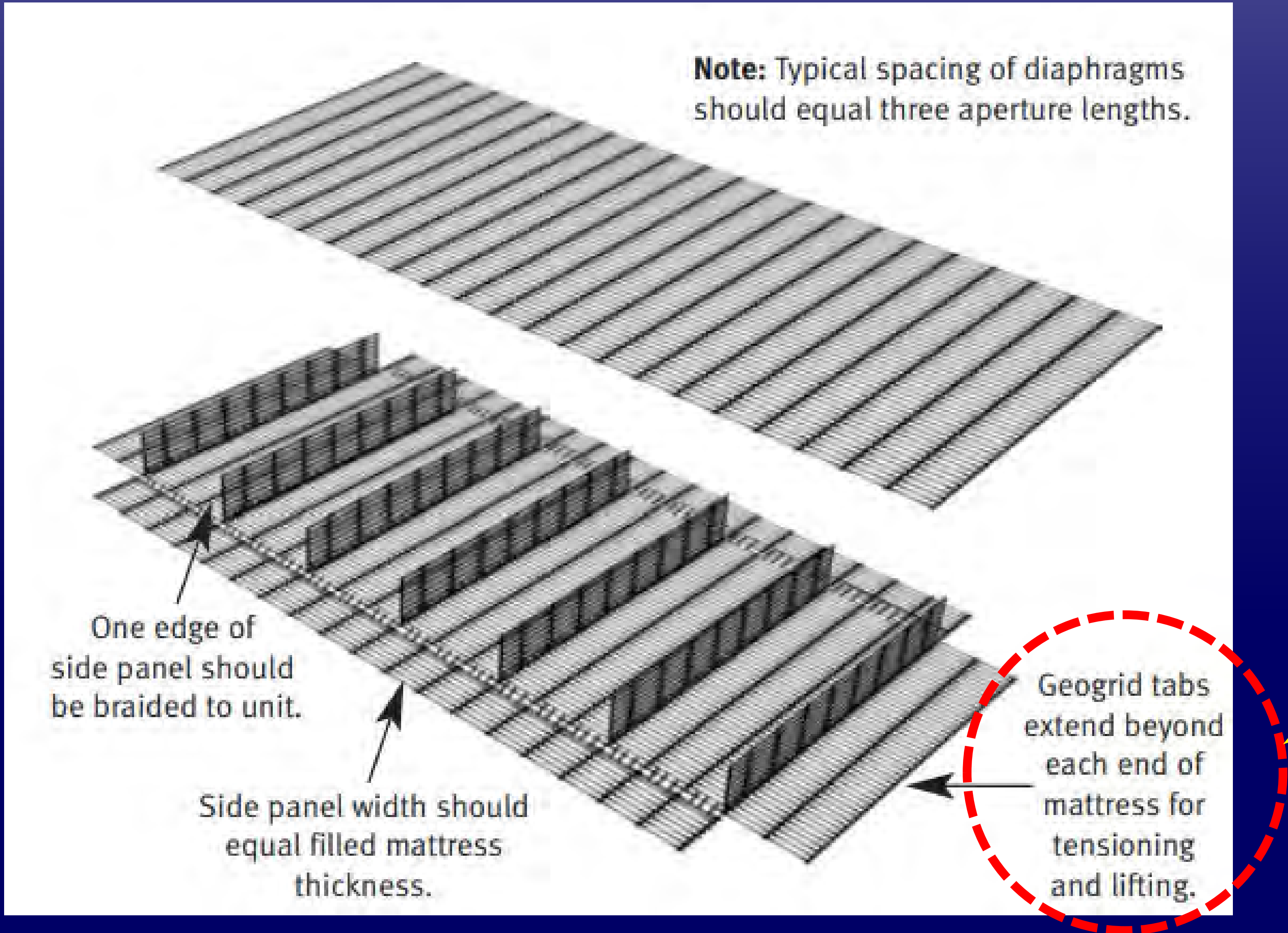
- Geogrid → Gabion Baskets/Mattresses → Polypropylene
  - Use of polypropylene geogrid to fabricate gabion baskets and mattresses
  - Gabion Baskets – Stabilization
  - Gabion Mattresses – Erosion Control (especially high energy environments)
  - Both biaxial and uniaxial geogrid have been used for fabrication
  - Some care required in cold climates – may need to stage filling and assembly in partially heated area (to maintain material pliability)

Part 4: Functions and Applications

- Geogrid → Gabion Baskets/Mattresses → Polypropylene
  - Benefits:
    - Cost (If PP = 1x, Galv. Steel ≈ 2x, Galv./PVC Coated ≈ 2.5x and SS ≈ 7.5x)
    - Flexibility
    - Durability/Corrosion Resistance – especially in a marine environment
    - Typically preassembled except for lid closure
    - Can be lifted in place complete – filled and assembled
    - Greater flexibility is dimensions (up to 13 ft width and 164 ft length)
    - Filled dimensions typically adjustable (if needed)

Part 4: Functions and Applications

- **Geogrid → Gabion Baskets/Mattresses → Polypropylene**



Extra length of grid on each end to facilitate tensioning and lifting

Source: TENSAR

Part 4: Functions and Applications

- Geogrid → Gabion Baskets/Mattresses → Polypropylene

Part 4: Functions and Applications

- Geogrid → Gabion Baskets/Mattresses → Polypropylene

Typical Filling Frames to More Easily Fill Mattresses

Source: TENSAR

Part 4: Functions and Applications

- **Geogrid → Gabion Baskets/Mattresses → Polypropylene**

Source: TENSAR

Typical Filling Operation

Part 4: Functions and Applications

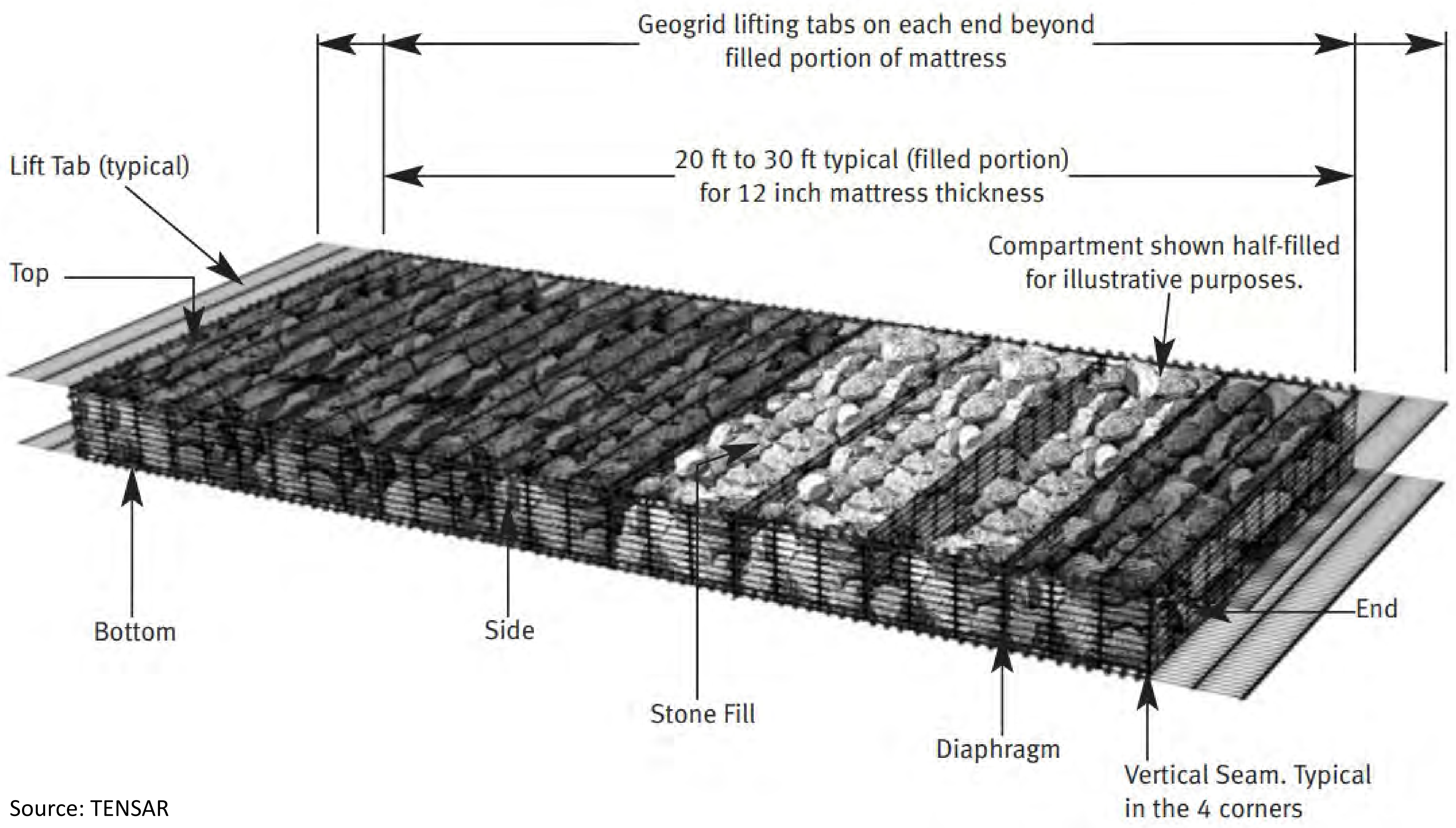
- Geogrid → Gabion Baskets/Mattresses → Polypropylene

Assembled baskets to be filled in place

Source: TENSAR

Part 4: Functions and Applications

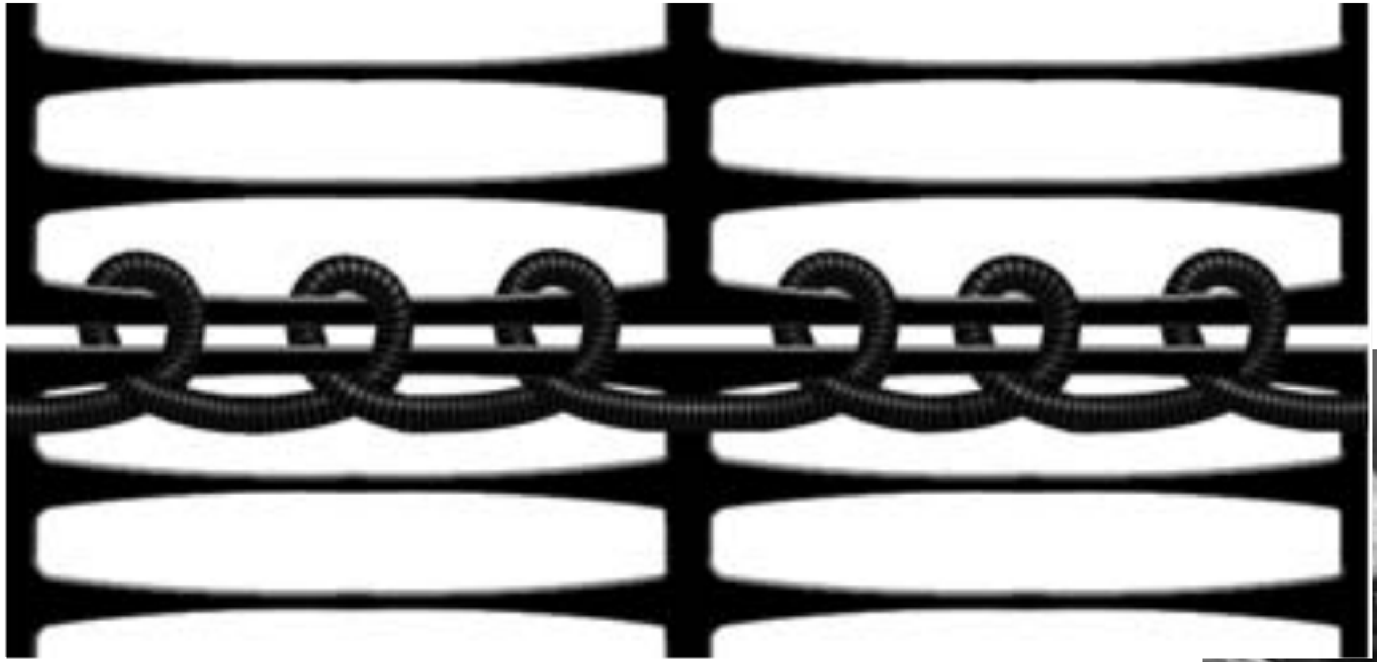
- **Geogrid → Gabion Baskets/Mattresses → Polypropylene**



Source: TENSAR

Part 4: Functions and Applications

- Geogrid → Gabion Baskets/Mattresses → Polypropylene



Lacing for lid closure

Source: TENSAR

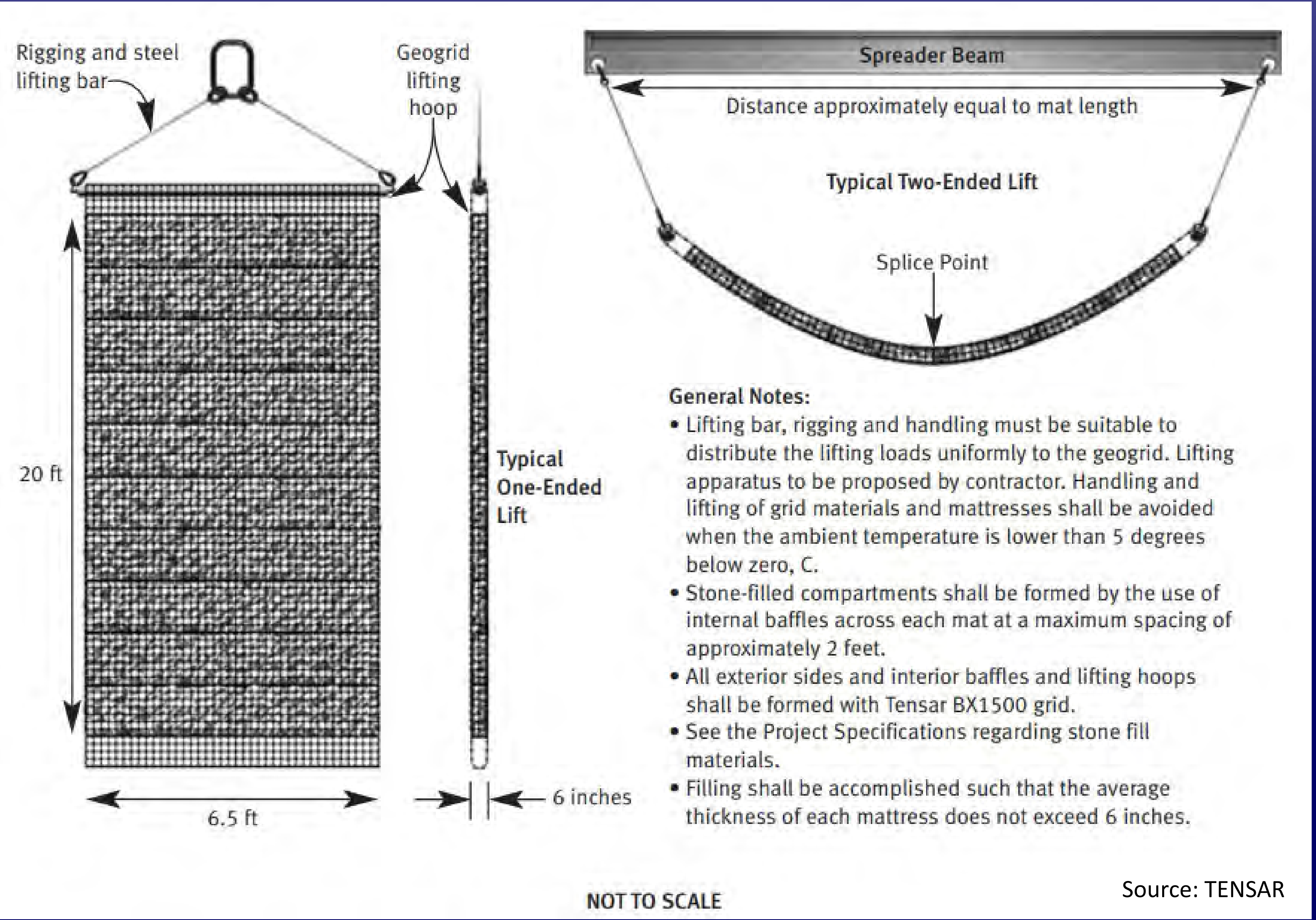
Part 4: Functions and Applications

- **Geogrid → Gabion Baskets/Mattresses → Polypropylene**

Completed mattresses ready for installation

Part 4: Functions and Applications

- Geogrid → Gabion Baskets/Mattresses → Polypropylene



Lifting options – frame or single bar

Part 4: Functions and Applications

- Geogrid → Gabion Baskets/Mattresses → Polypropylene

Lifting completed mattress in place with lifting frame

Source: TENSAR

Part 4: Functions and Applications

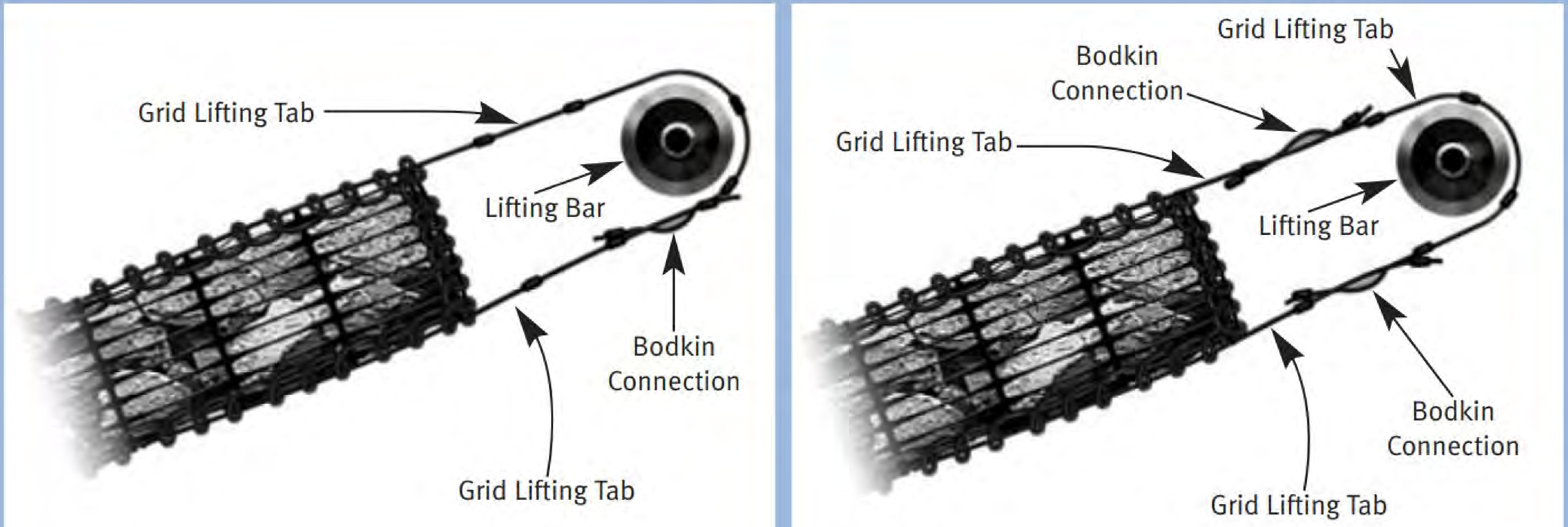
- Geogrid → Gabion Baskets/Mattresses → Polypropylene

Source: TENSAR

Lifting completed mattress in place with end connection

Part 4: Functions and Applications

- **Geogrid → Gabion Baskets/Mattresses → Polypropylene**



Source: TENSAR

Lifting bar connection detail

Part 4: Functions and Applications

- Geogrid → Gabion Baskets/Mattresses → Polypropylene

Mattress being placed in submerged marine application

Source: TENSAR

Part 4: Functions and Applications

- Geogrid → Gabion Baskets/Mattresses → Polypropylene

Mattress being placed for shoreline protection

Source: TENSAR

Part 4: Functions and Applications

- Geogrid → Gabion Baskets/Mattresses → Polypropylene

Shoreline protection

Part 4: Functions and Applications

- **Geogrid → Gabion Baskets/Mattresses → Polypropylene**

Retaining structure in marine application

Source: TENSAR

Part 4: Functions and Applications

- **Geogrid → Gabion Baskets/Mattresses → Polypropylene**

Drainage channel lining

Part 4: Functions and Applications

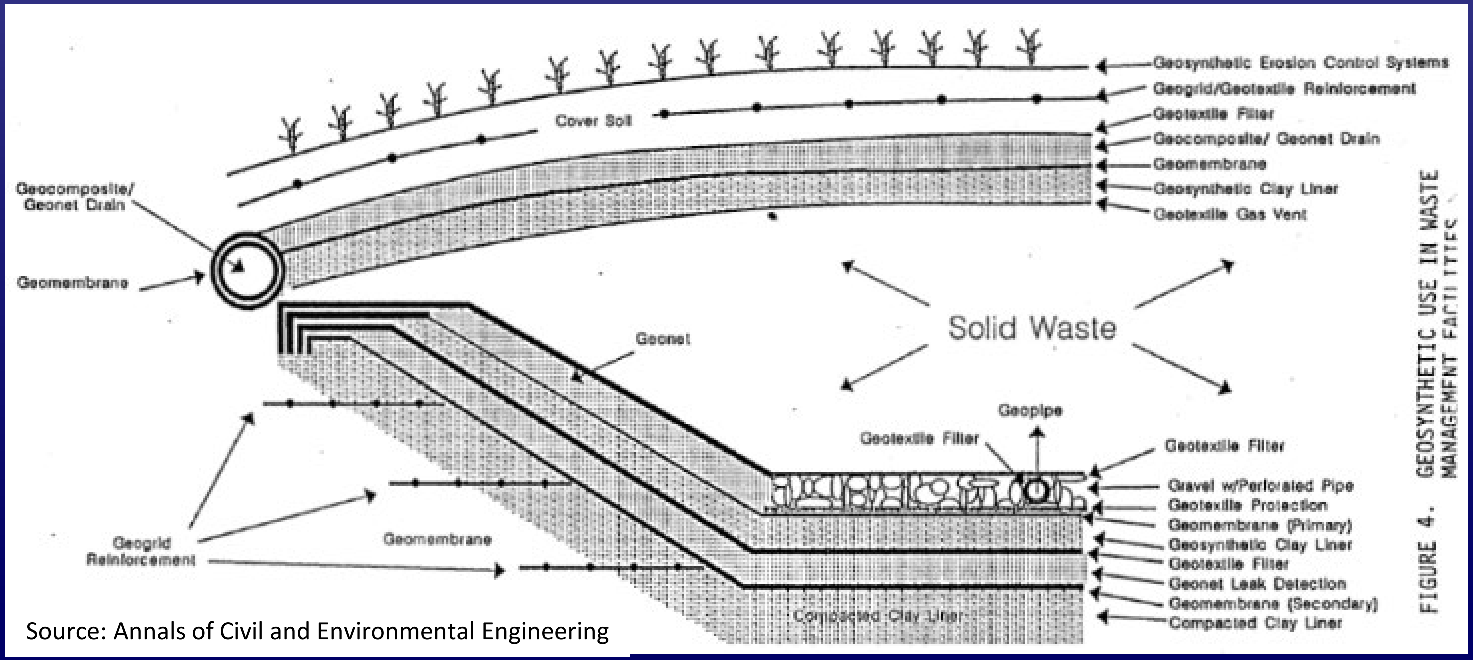
Material	Geomembrane
Structure	Sheet/Membrane
Polymer	Various
Function	Impervious Barrier
Application	Fluid and Gas Containment

Part 4: Functions and Applications

- Geomembrane → Multiple Polymer Types
  - Of various applications of geosynthetics none has likely had the impact and footprint the for environmental applications – especially landfills
  - Landfill types include those for hazardous materials, industrial wastes and municipal solid wastes
  - By far the largest in volume is for municipal solid waste (our trash)
  - Impact in protecting environment and resources (especially groundwater) cannot be overstated
  - And the role that geosynthetics play in containing those wastes and protecting environmental resources is colossal

Part 4: Functions and Applications

- Geomembrane → Municipal Solid Waste Landfill



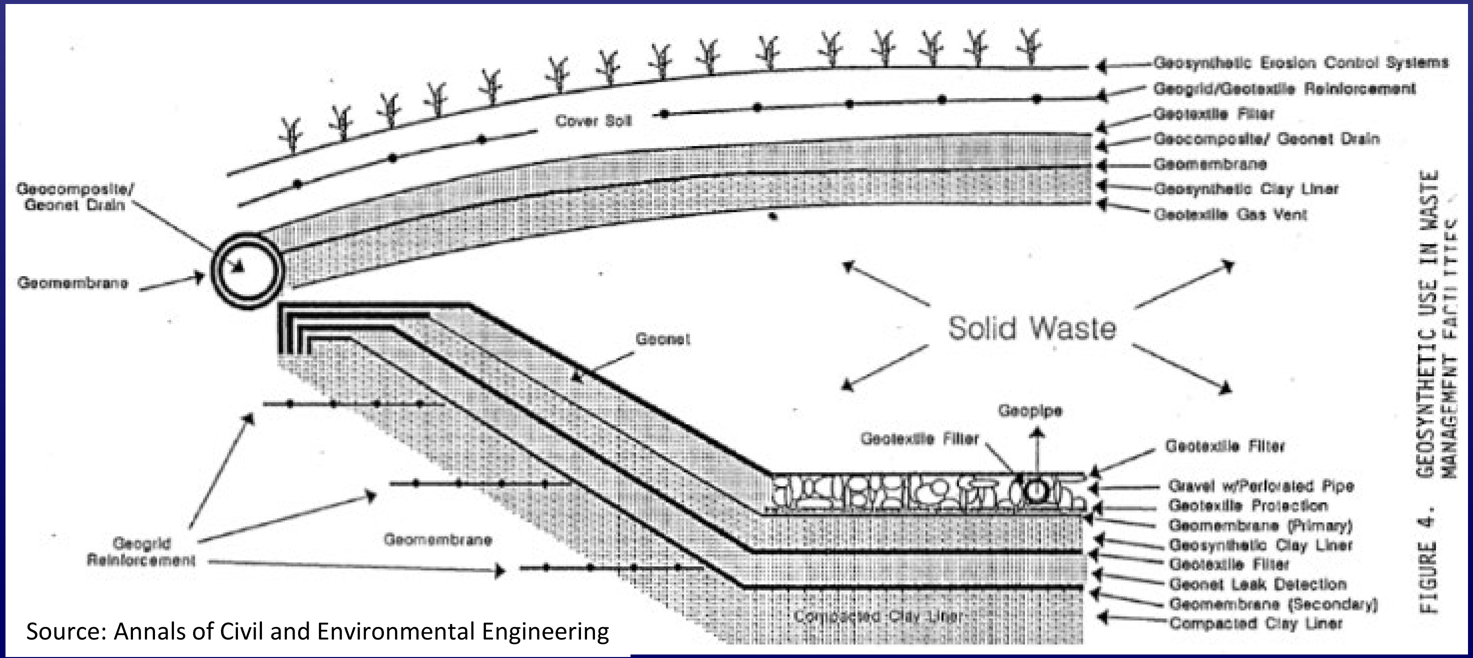
Typical Cross Section Municipal Solid Waste Landfill

Geosynthetic Types Used:

- Geomembranes
- Geotextiles (various)
- Geosynthetic Clay Liner
- Geocomposite Drains
- Geogrids

Part 4: Functions and Applications

- **Geomembrane → Municipal Solid Waste Landfill**



Source: Annals of Civil and Environmental Engineering

Typical Cross Section Municipal Solid Waste Landfill

Geosynthetic Functions:

- Containment (Impervious Barrier)
- Separation
- Filtration
- Drainage
- Fluid Collection (Leachate)
- Gas Collection/Venting

Part 4: Functions and Applications

- **Geomembrane → Municipal Solid Waste Landfill**

Source: Annals of Civil and Environmental Engineering

Part 4: Functions and Applications

- Geomembrane → Example Application: Protection of Acid-Bearing Rock slope Face
  - System developed to cover rock slope face
  - Multiple geosynthetic materials
  - Used NW-NP Geotextile, Geomembrane and Geocell
  - Geocell filled with limestone rock as ballast and to provide alkaline source in event of membrane puncture
  - Thick NW NP geotextile placed top and bottom of geomembrane for protection
  - Geomembrane cuts off oxygen and water to prevent oxidation of rock face and production of acid
  - Geocell ballasts geomembrane – like ballasted roof

Part 4: Functions and Applications

Material	Geomembrane, Geotextile and Geocell
Structure	Sheet/Membrane, Non-Woven Needle Punched and Expanding Cell
Polymer	Various
Function	Impervious Barrier, Liner Protection and Ballast
Application	Acid Producing Rock Slope Protection

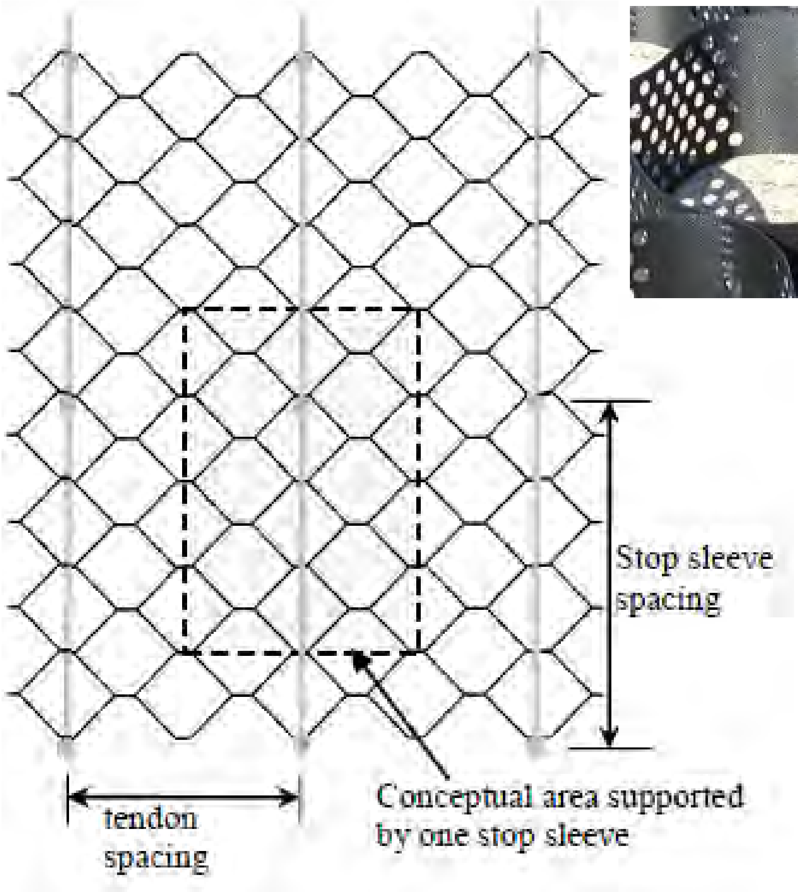
Part 4: Functions and Applications

- **Geomembrane/NWNP Geotextile/Geocell → Example Application: Protection of Acid-Bearing Rock slope Face**

Facing for Acid Bear Rock Slope

Part 4: Functions and Applications

- **Geomembrane/NWNP Geotextile/Geocell → Example Application: Protection of Acid-Bearing Rock slope Face**



Tendon Support Detail

Source: Foye, Kevin; "Armored Geomembrane Cover"; Int. J. Environ. Res. Public Health, 2011, 8, 2240-2264.

Stop Sleeve with Stainless Steel Cable

Filling of Geocell

Part 4: Functions and Applications

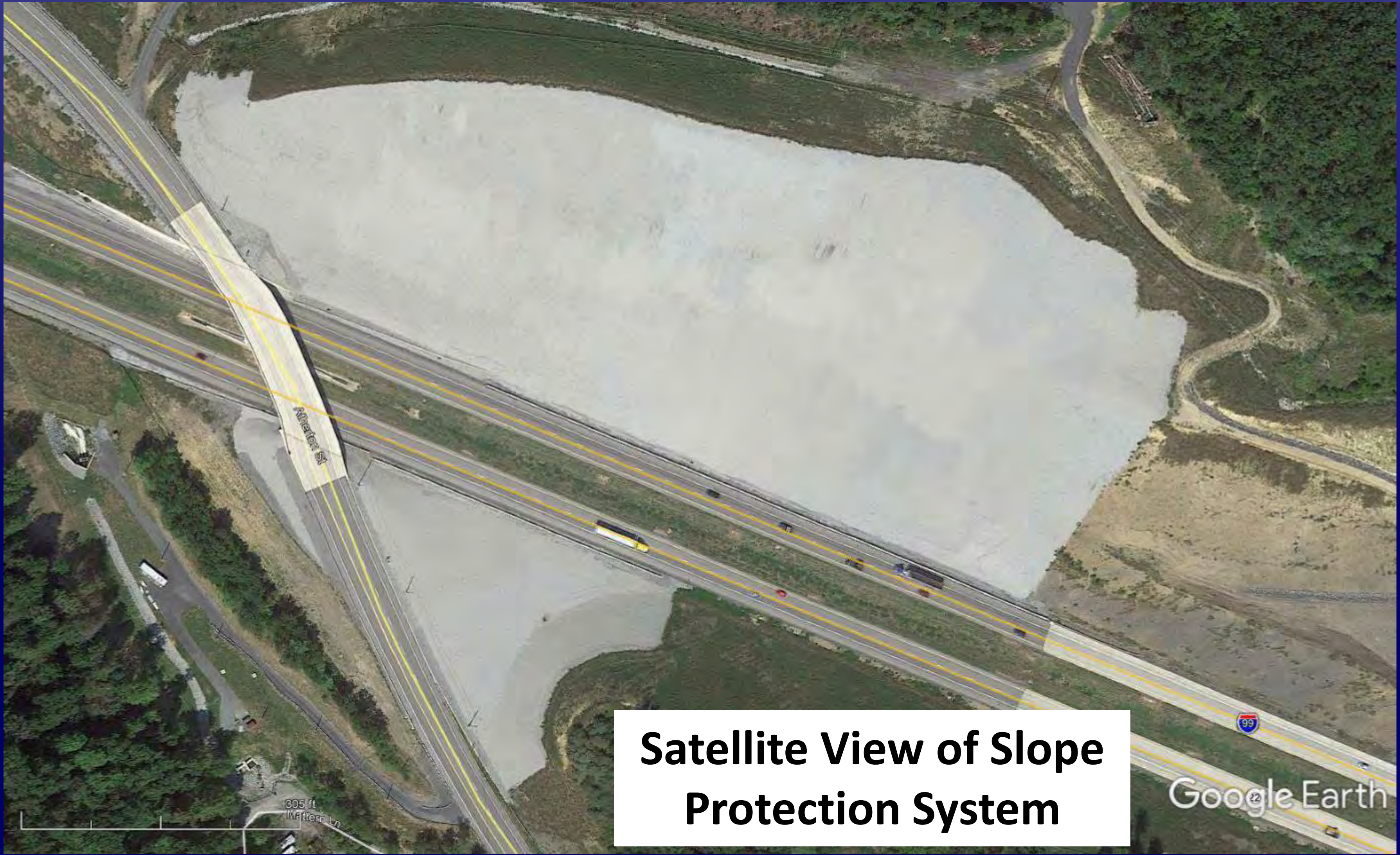
- **Geomembrane/NWNP Geotextile/Geocell → Example Application: Protection of Acid-Bearing Rock slope Face**

Slope Protection System
Deadman Anchor

Source: Foye, Kevin; "Armored Geomembrane Cover"; Int. J. Environ. Res. Public Health, 2011, 8, 2240-2264.

Part 4: Functions and Applications

- **Geomembrane/NWNP Geotextile/Geocell → Example Application: Protection of Acid-Bearing Rock slope Face**



Satellite View of Slope Protection System

Geomembrane is key component of protection system – isolates rock from oxygen and water.

Geotextile protects geomembrane, and geocell is ballast protecting sheet materials

Part 5: Construction Considerations

- Construction Considerations
  - Survivability
  - Installation (roll size and weight)
  - Seaming and connections
  - Contractor Means and Methods/Specifications
  - Material Acceptance – Testing

Part 5: Construction Considerations – Survivability

- Survivability
  - Relative to most other construction materials, geosynthetics can be subject to damage during installation and backfilling
  - This potential for damage needs to be considered in selection of the material (for standard or project specifications) and during design
  - Specifications need to reflect material and strength properties that can survive all short-term applied construction loads, and all long-term service loads and environmental conditions

Part 5: Construction Considerations – Installation

- Installation (roll size and weight)
  - Many geosynthetic materials are manufactured and shipped in rolls
  - Roll size (dimensions – width and length) and weights vary width product type and manufacturer
  - Roll dimensions and weight can impact installation methods and time and therefore can influence product selection
  - Material cost may not be fully reflective of in-place cost

Part 5: Construction Considerations – Seaming and Connections

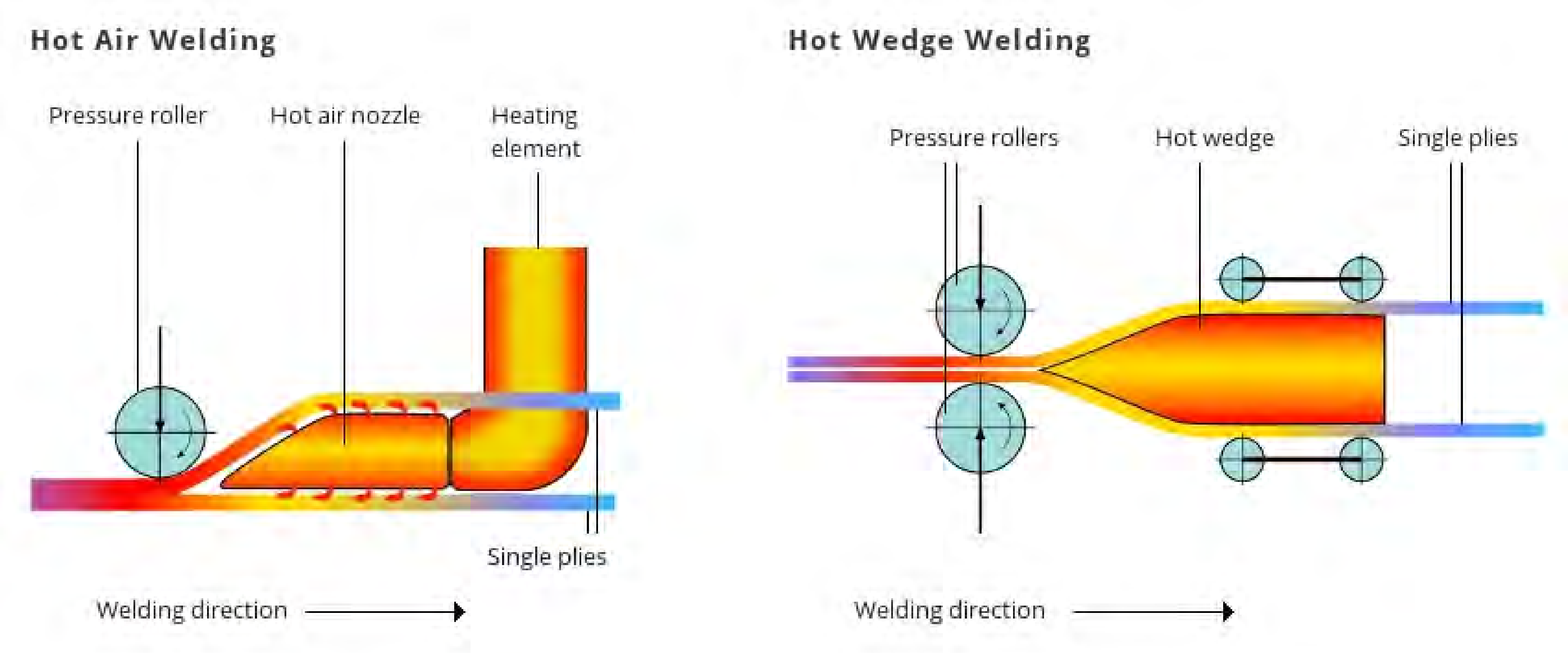
- Seaming and Connections – Welded Seams for Geomembranes
  - Two General Types of Geomembrane Field Seams:
    - Fusion
    - Extrusion
  - Fusion welders melt the surface of the geomembrane which is then fused together with pressure

Part 5: Construction Considerations – Seaming and Connections

- Seaming and Connections – Welded Seams for Geomembranes
  - There are three general types of fusion welders:
    - Hot wedge welder
    - Hot air welder
    - Ultrasonic Welder
  - Hot wedge and hot air fusion welding consists of placing a self-propelled welder between two overlapped panel edges
  - Hot welders heat and melt the surface of the geomembrane and then compress the material between two rollers where the combination of heat and pressure fuses the panels

Part 5: Construction Considerations – Seaming and Connections

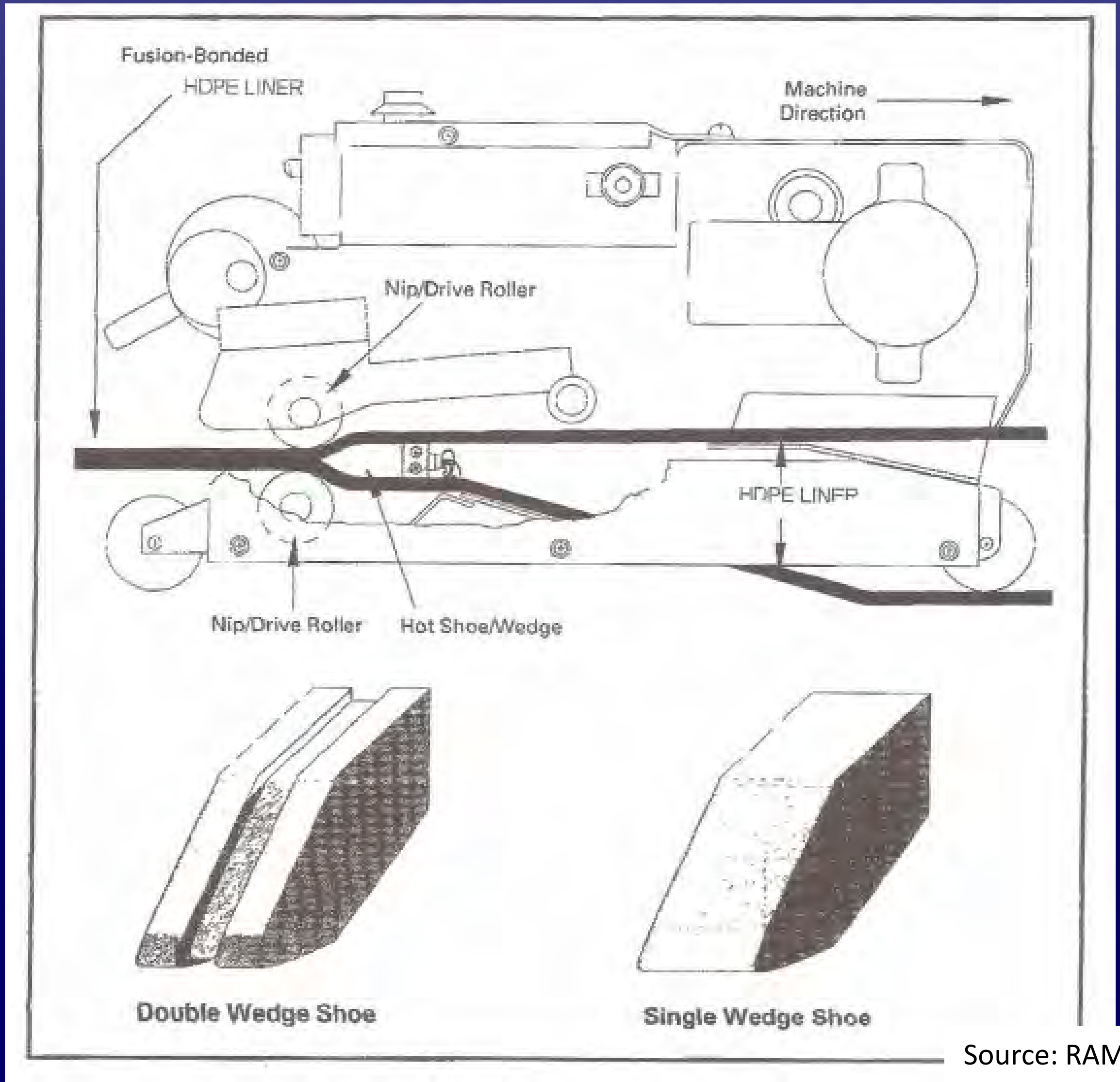
- Seaming and Connections – Welded Seams for Geomembranes
  - Hot wedge welders melt the membrane using a heated metal wedge
  - Hot air welders use a hot air blower to melt the membrane

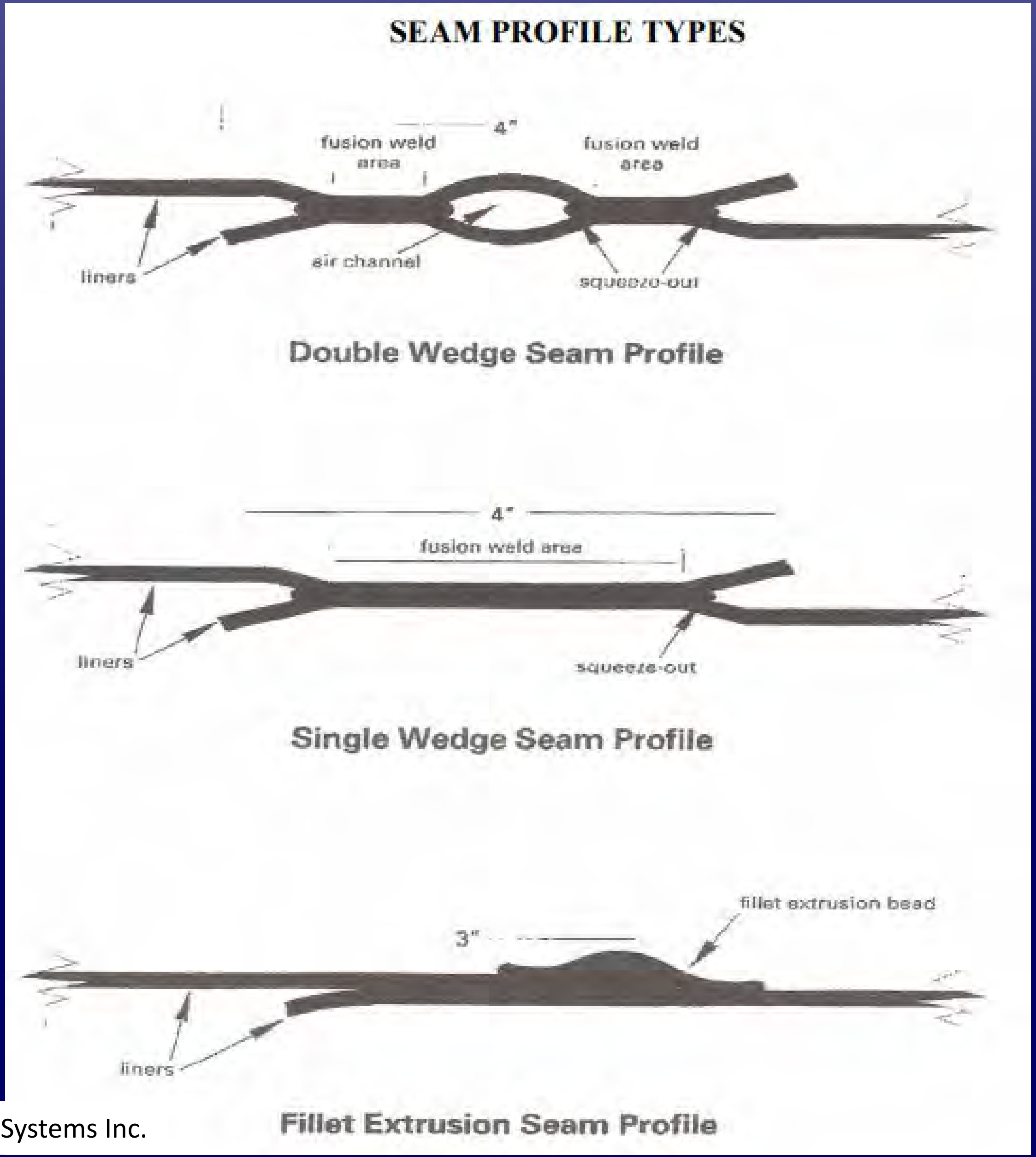


Source: Stanmech Technologies

Part 5: Construction Considerations – Seaming and Connections

- **Welded Seams for Geomembranes**





Source: RAM Lining Systems Inc.

Part 5: Construction Considerations – Seaming and Connections

- Seaming and Connections – Welded Seams for Geomembranes
  - Hot wedge welders melt the membrane using a heated metal wedge

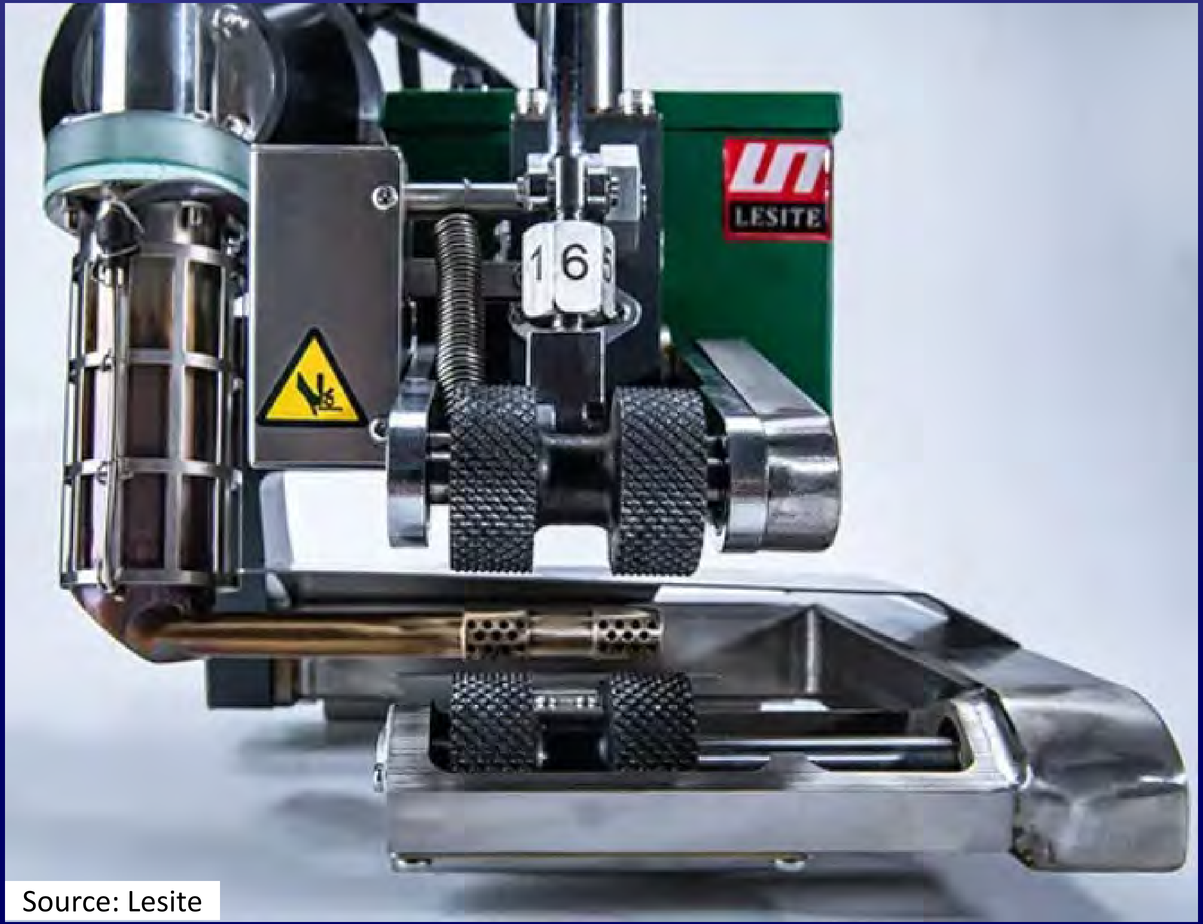
Source: Weldy

Source: Lesite

Part 5: Construction Considerations – Seaming and Connections

- Seaming and Connections – Welded Seams for Geomembranes
  - Hot air welders use a hot air blower to melt the membrane

Source: Lesite



Source: Lesite

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Testing method must accurately model the parameter being measured
    - Testing can be index or performance
    - Index testing – strictly QC/QA – not a performance measure
    - Performance testing – assures meeting critical design parameters

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Strength Testing
    - Variety of test methods for determining the tensile strength of geosynthetics
    - Method required for use depends on type of material being tested and the purpose of the testing

Part 5: Construction Considerations – Material Acceptance (Testing)

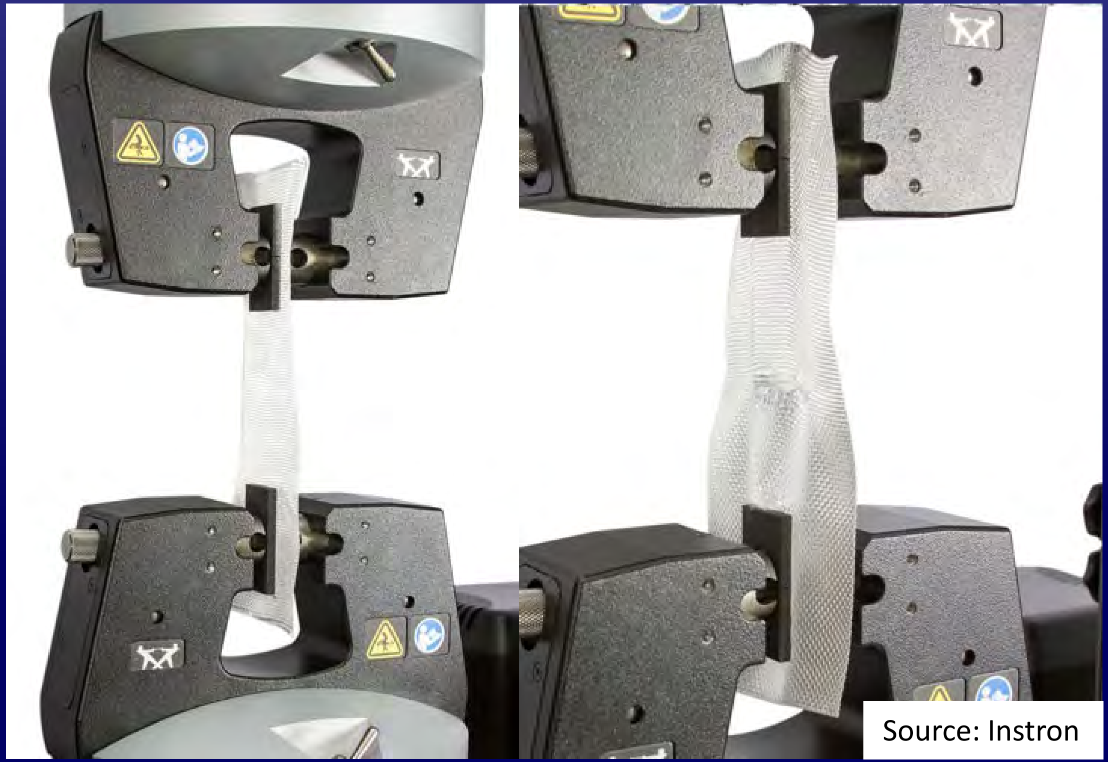
- Material Acceptance – Testing:
  - Strength Testing (ASTM D4632)
    - ASTM D4632 – "Standard Test Method for Grab Breaking Load and Elongation of Geotextiles" – strength index test (QC/QA)
    - ASTM D4595 – "Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method" – design conformance
    - ASTM D6637 – "Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method" – design conformance

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - ASTM D4632 – "Standard Test Method for Grab Breaking Load and Elongation of Geotextiles"

Source: Science Direct

Note edge effect – elevated tensile strength



Source: Instron

Grab Tensile Strength and Elongation – not design strength

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - ASTM D4595 – "Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method"

Wide Width Tensile Strength and Elongation

Source: United Test

Source: Test Resources

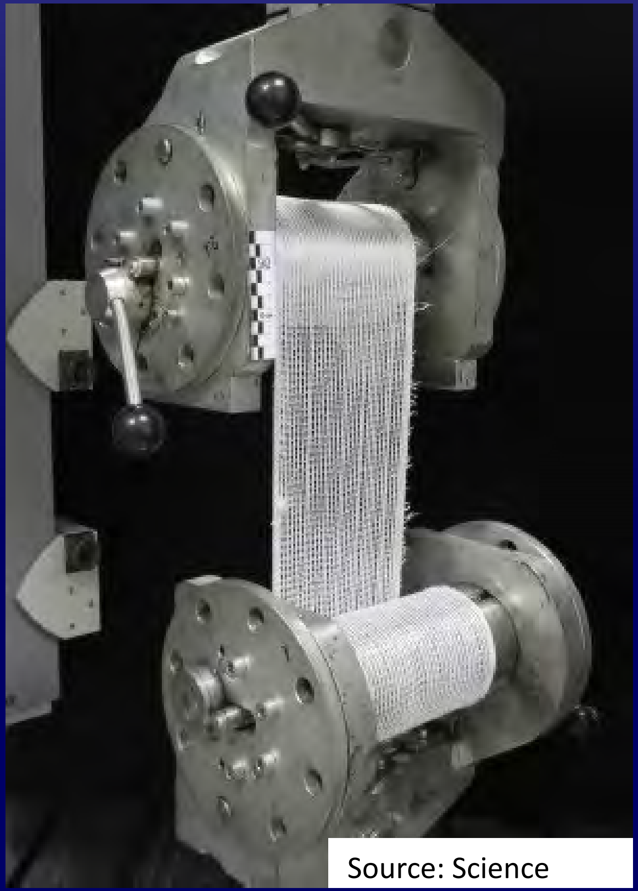
Source: United Test

Stress Concentration at Grip

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - ASTM D4595 – "Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method"

Wide Width Tensile Strength and Elongation

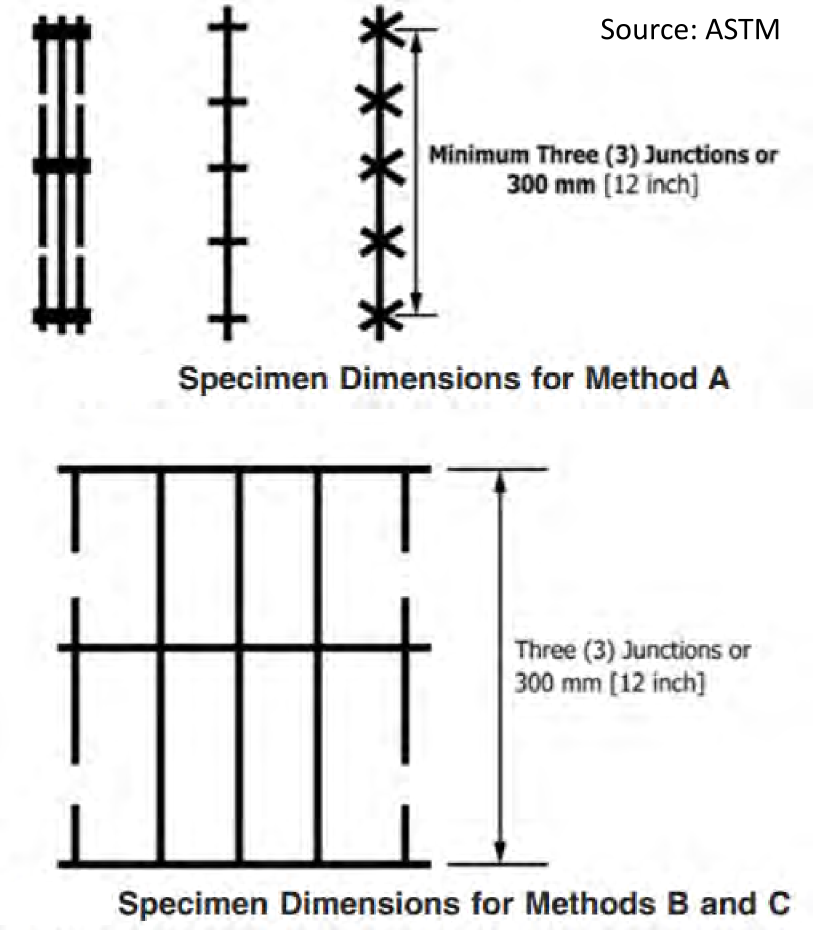


Source: Science Direct

Roller Grips – No Stress Concentration

Part 5: Construction Considerations – Material Acceptance (Testing)

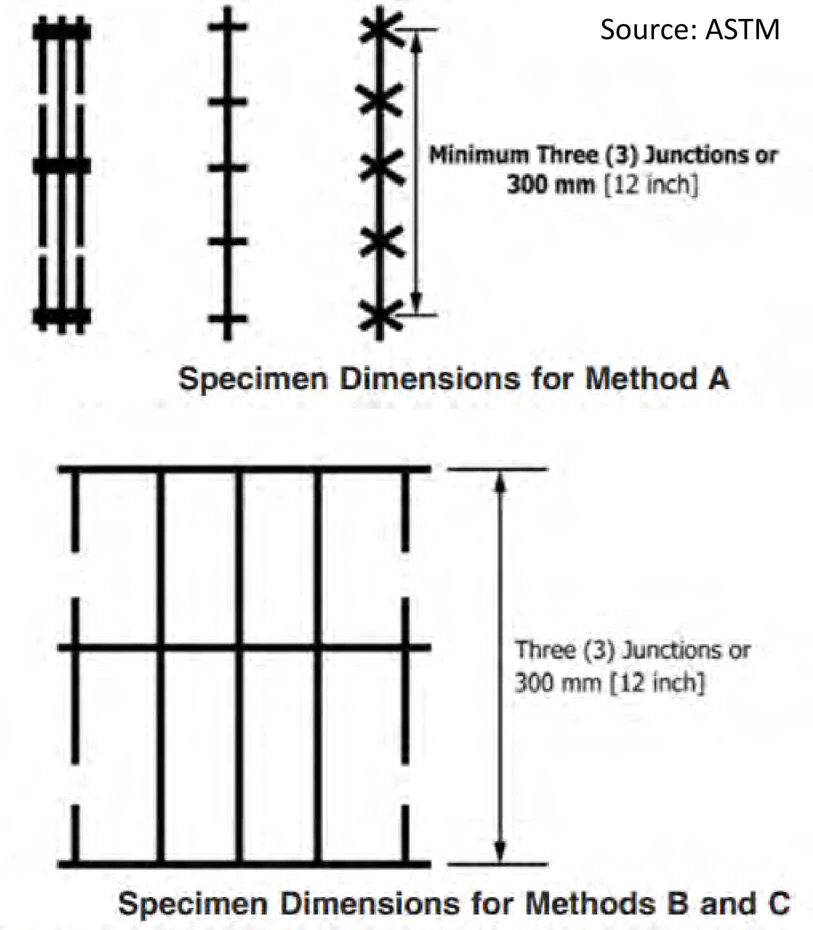
- Material Acceptance – Testing:
  - ASTM D6637 – "Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method"



- Method A – Each specimen to contain at least one intersecting rib (or set of ribs) crossing the test direction with at least three junctions (two apertures) in the direction of the testing
- Methods B and C – Each finished specimen to be a minimum of 200 mm wide and contain five ribs in the cross-test direction wide by at least three junctions (two apertures) or 300 mm [12 in.] long in the direction of the testing

Part 5: Construction Considerations – Material Acceptance (Testing)

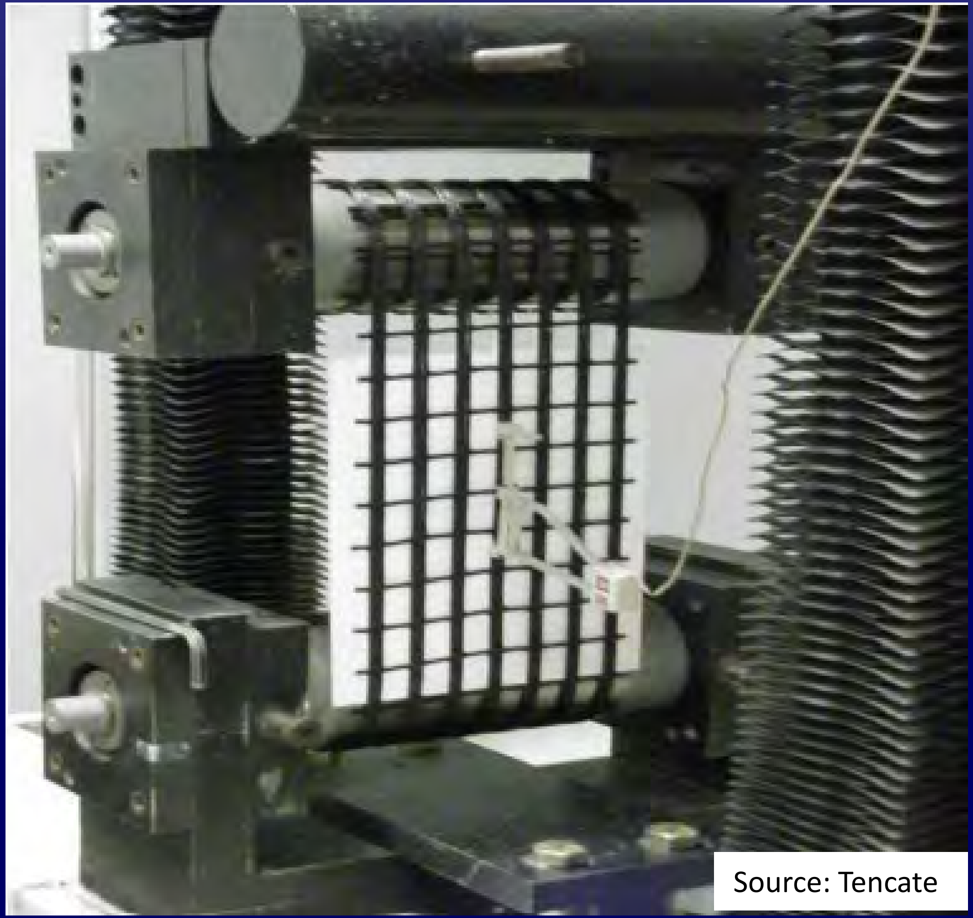
- Material Acceptance – Testing:
  - ASTM D6637 – "Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method"



- Within Test Methods A, B, and C, the outermost ribs are commonly cut prior to testing to permit extra width of material in the clamps to minimize slippage within the clamps. The test results shall be based on the unit of width associated with the number of intact ribs.

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - ASTM D6637 – "Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method"


Source: Tencate


Source: Wiley Online Library

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Testing of Geomembrane Seams (ASTM D7700)
    - ASTM D7700 – "Standard Guide for Selecting Test Methods for Geomembrane Seams"
    - Guide intended for use selecting appropriate test methods and practices necessary to evaluate geomembrane seams
    - Covers many different types of geomembranes, seam methods and test methods
    - ASTM states significant effort was made to be comprehensive, however, list of test methods and seam types should not be considered exhaustive

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Carbon Black Testing
    - Carbon black is additive in geosynthetics used to resist degradation from UV radiation
    - Carbon black produced by incomplete combustion of hydrocarbons (typical fossil fuels and their derivatives)
    - Variety of methods of production and therefore types of carbon black including furnace black, thermal black, channel black, lamp black and acetylene black
    - Furnace black most common production process and type of carbon black

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Carbon Black Testing
    - Two ASTM methods of testing for carbon black for geosynthetics
      - ASTM D1603 – "Standard Test Method for Carbon Black Content in Olefin Plastics
      - ASTM D4218 – "Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique"
    - CAUTION: If get white residue/ash, other material was substituted for carbon black

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Carbon Black Testing – Method Comparison

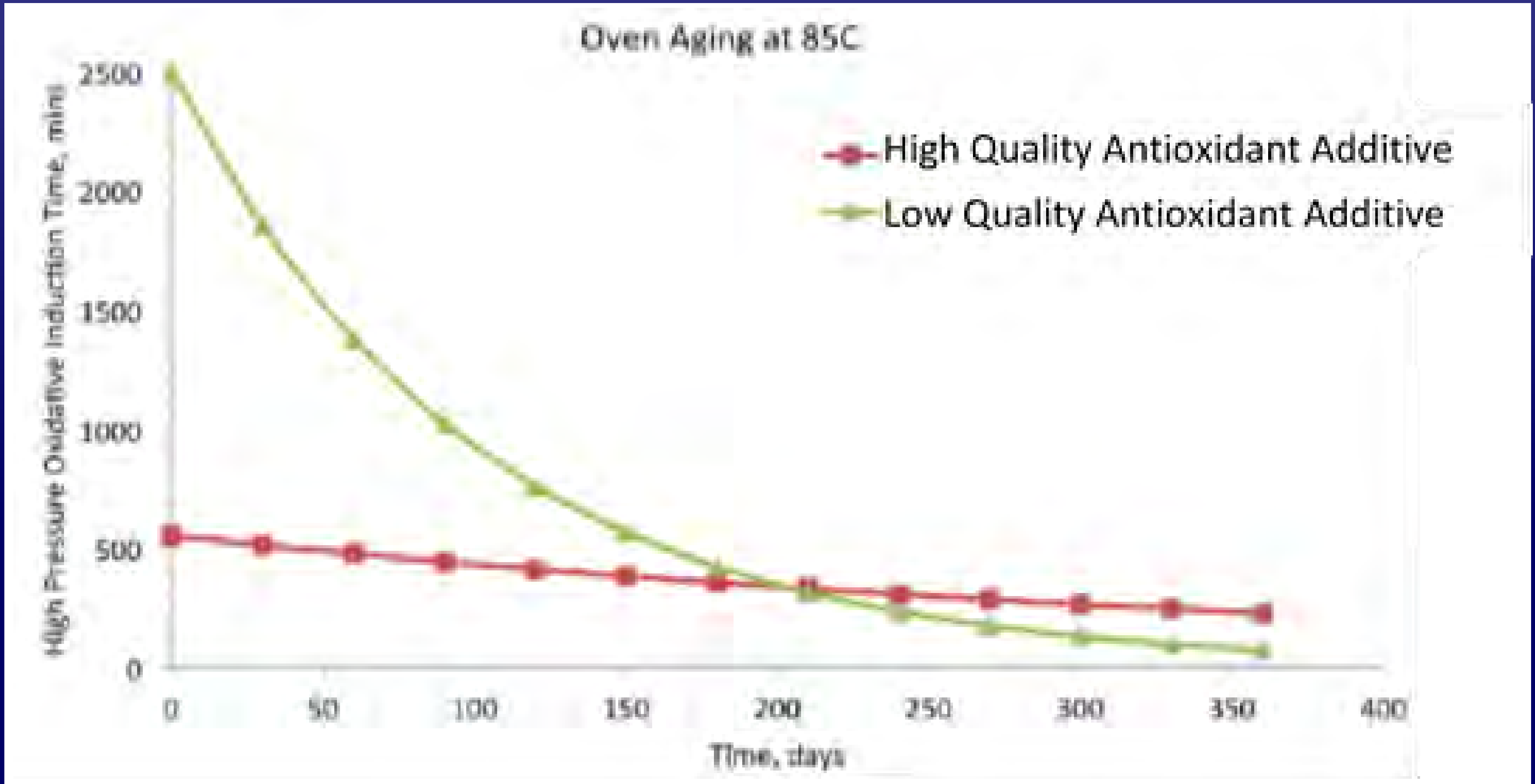
ASTM Designation	Method	Applicability	Limitations
D1603	Tube Furnace with Sample in Nitrogen	Determination of the carbon black content in polyethylene, polypropylene, and polybutylene plastics	Not recommended with acrylic or other polar monomer modifications; Not applicable to compositions that contain nonvolatile pigments or fillers other than carbon black; Not applicable to materials containing brominated flame retardant additives.
D4218	Muffle Furnace	Determination of black polyethylene compounds containing channel or furnace black	Not applicable for thermal black; Not suitable for plastics that char on pyrolysis.

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Oxidative Induction Time (OIT) and Durability Testing
    - Less reputable manufacturers can produce material that meet requirements following both the OIT test methodologies
    - Accomplished by using non-durable food additives which can create a very high standard OIT result
    - But such additives do little or nothing to contribute to the long-term performance of the geosynthetic

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Oxidative Induction Time (OIT) and Durability Testing



Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Oxidative Induction Time (OIT) and Durability Testing
    - Further testing of these materials following GSI test methods GM-13 and GM-17 (oven aging and accelerated UV exposure), shows the high initial OIT levels decrease rapidly with thermal or UV aging
    - Material using the low-quality antioxidant additive fails to meet GRI durability criteria, despite very high initial OIT value
    - GRI testing shows that although may be at much lower initial OIT value, high-quality antioxidant additive remains stable and viable over time

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Oxidative Induction Time (OIT) and Durability Testing
    - When evaluating long-term durability of geosynthetics (geomembranes), important to comprehensively evaluate material considering not only required OIT value, but long-term thermal and UV durability
    - Adequate long-term thermal and UV durability helps assure adequate integrity of antioxidant additive used in the geosynthetic

Part 5: Construction Considerations – Material Acceptance (Testing)

- Material Acceptance – Testing:
  - Oxidative Induction Time (OIT) and Durability Testing
    - For addition information, go to Geosynthetic Institute (GSI) web site and download GSI White Paper #32 "Rationale and Background for the GRI-GM13 Specification for HDPE Geomembranes"
    - Available at:

      www.geosynthetic-institute. org/papers/paper32.pdf

Fundamentals of Geosynthetic: Types, Functions, Selection and Performance

kpetrasic@gfnet.com

END
PM Session

Gannett Fleming

Fundamentals of Geosynthetics: Types, Functions, Selection and Performance

If you have any questions that we were unable to get to or not satisfactorily addressed, please contact me

If interested in hosting this course or providing for your institution, please contact me

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kpetrasic@gfnet.com

Gannett Fleming

Thank You for Visiting . . .

Gannett Fleming