Roadway Foundations

2024 NTRM Symposium

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NORTHERN TRIBAL TECHNICAL ASSISTANCE PROGRAM

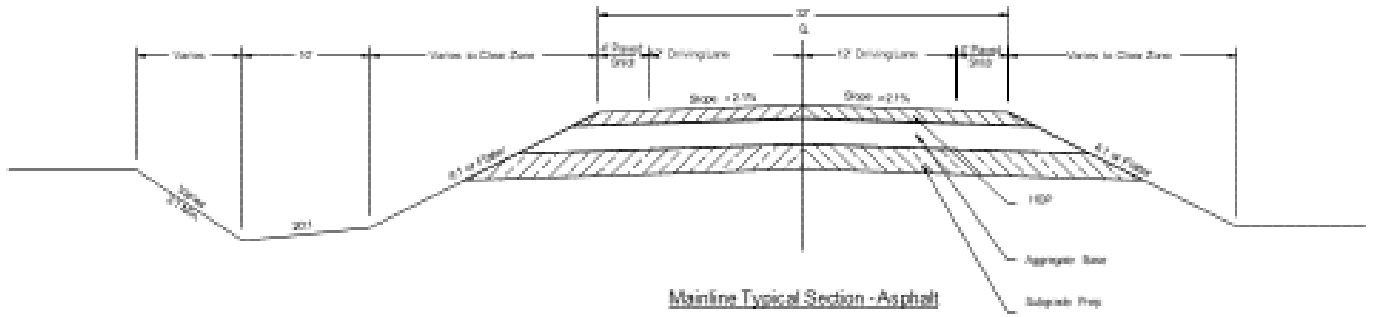
Outline

- Roadway Structure
- Soil Classification
- Subgrade
- Stability – Compaction - Moisture Density
- Vehicle Loads
- Soil Related Failures

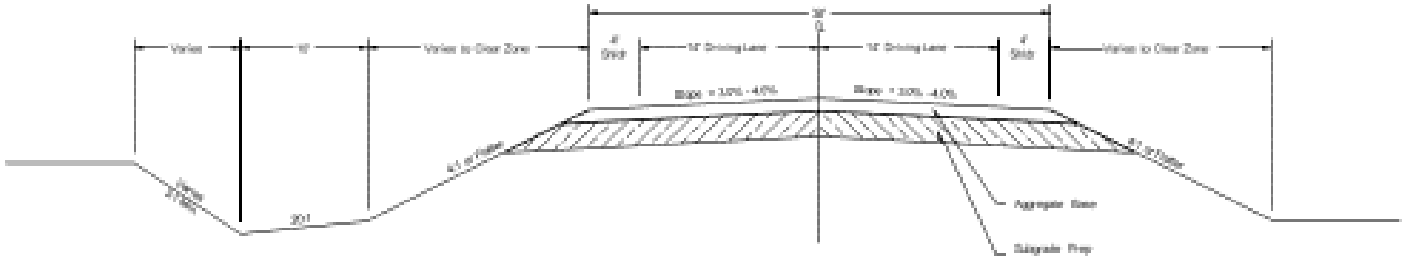
Outline

- Testing
- Geotextiles and Geogrid
- Drainage
- Strategies for Poor Subgrade Soil
- Frost Susceptible Soils
- Surface and Base Course Material

Roadway Structure



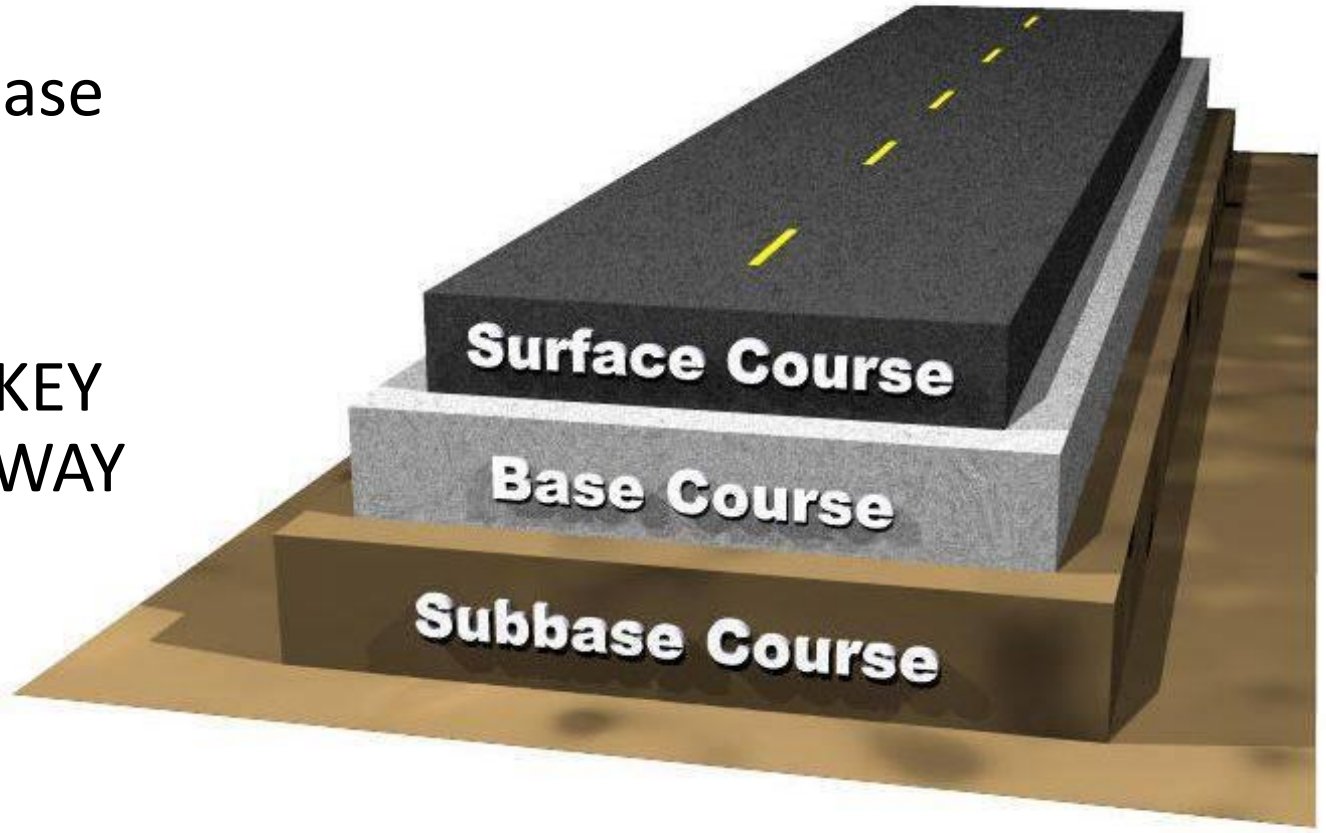
Mainline Typical Section - Asphalt



Mainline Typical Section - Gravel

Roadway Structure Elements

- Surface Course
- Base Course / Stabilized Base Course
- Subbase Course
- SUBGRADE – THIS IS THE KEY COMPONENT TO A ROADWAY STRUCTURE



Roadway Structure

- BUILD FROM THE BOTTOM UP
- Build on a firm base
- Know what soils you are working with
- Test appropriately

Roadway Cross Section

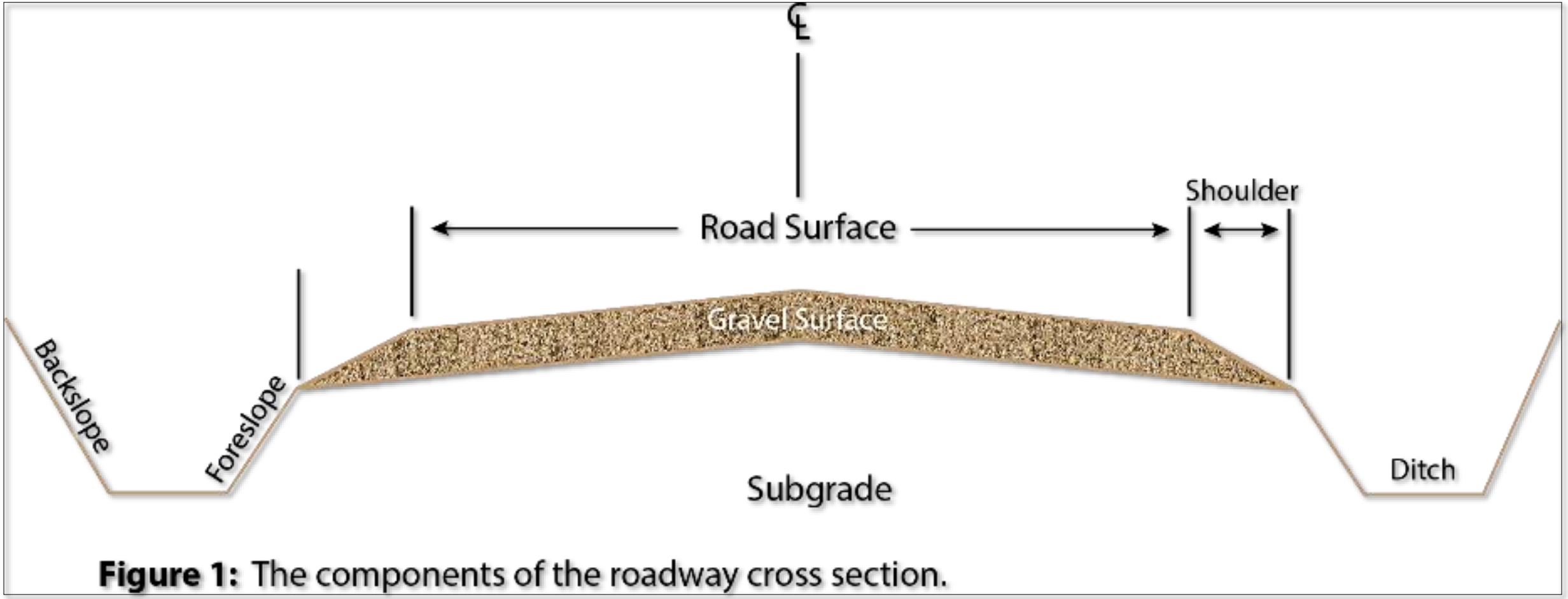
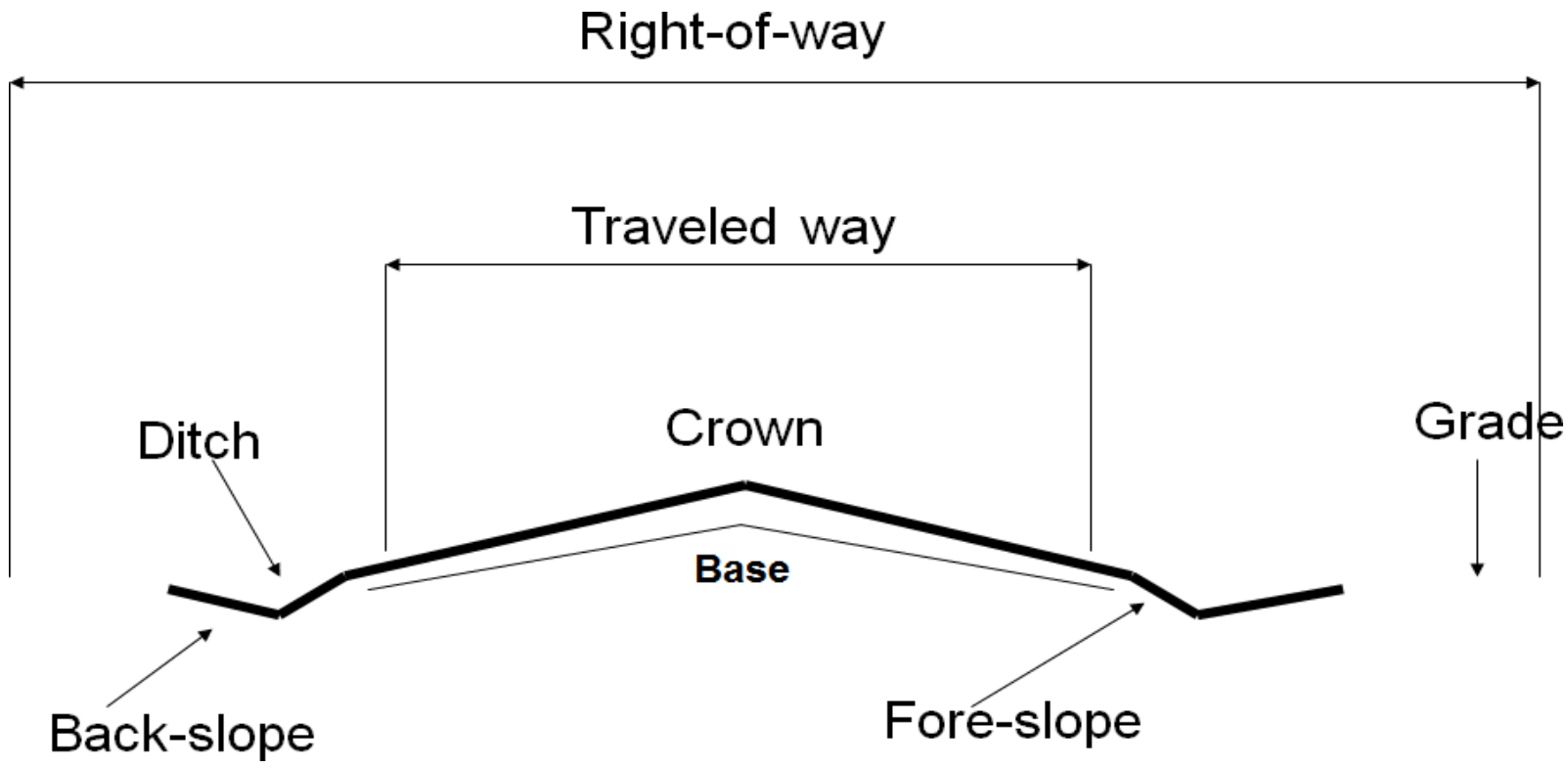


Figure 1: The components of the roadway cross section.

Principles of a Good Road

- When looking at your road don’t just look at the road top, look at the entire cross-section.
- You need to get the water away from the centerline to the shoulder to the ditch and away from the road.



Road and Its Surroundings

- Terrain
- Cross Slope
- Clear Zone
- Drainage
- Ditches
- Bridges/Culverts
- Transitions

Cross Section

- Proper Profile
  - Roof Top
  - Keep Edge
  - **Straight Blades**

Soil Classification

- Classification systems
  - Based on engineering properties of soil that are most pertinent for the purpose for which the classification has been made
    - AASHTO Soil Classification System
    - Unified Soil Classification System (USCS)
    - Indian Standard Soil Classification System (ISCS)
    - Massachusetts Institute of Technology System (MIT)
    - Textural Classification of Soil

Table 5.1. AASHTO Classification System

General Classification	*Granular materials (35% or less passing No. 200 Sieve (0.075 mm)*							*Silt-clay Materials More than 35% passing No. 200 Sieve (0.075 mm)*			
Group Classification	*A—1*		*A—3*	*A—2*				*A—4*	*A—5*	*A—6*	*A—7*
	A—1—a	*A—1—b*		*A—2—4*	*A—2—5*	*A—2—6*	*A—2—7*				*A—7—5 A—7—6*
(*a*) Sieve Analysis: Percent Passing											
(*i*) 2.00 mm (No. 10)	50 max										
(*ii*) 0.425 mm (No. 40)	30 max	50 max	51 min								
(*iii*) 0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
(*b*) Characteristics of fraction passing 0.425 mm (No. 40)											
(*i*) Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
(*ii*) Plasticity index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
(*c*) Usual types of significant Constituent materials	Stone Fragments Gravel and sand		Fine Sand	Silty or Clayey Gravel Sand				Silty Soils		Clayey Soils	
(*d*) General rating as subgrade.	Excellent to Good							Fair to Poor			

* If plasticity index is equal to or less than (liquid Limit—30), the soil is A—7—5 (*i.e.* PL > 30%)
If plasticity index is greater than (Liquid Limit—30), the soil is A—7—6 (*i.e.* PL < 30%)

What is soil?

- Uncemented aggregate mineral grains that are a product of rock weathering as well as decayed organic matter (solid particles) with liquid and gas in the empty spaces between the solid particles.

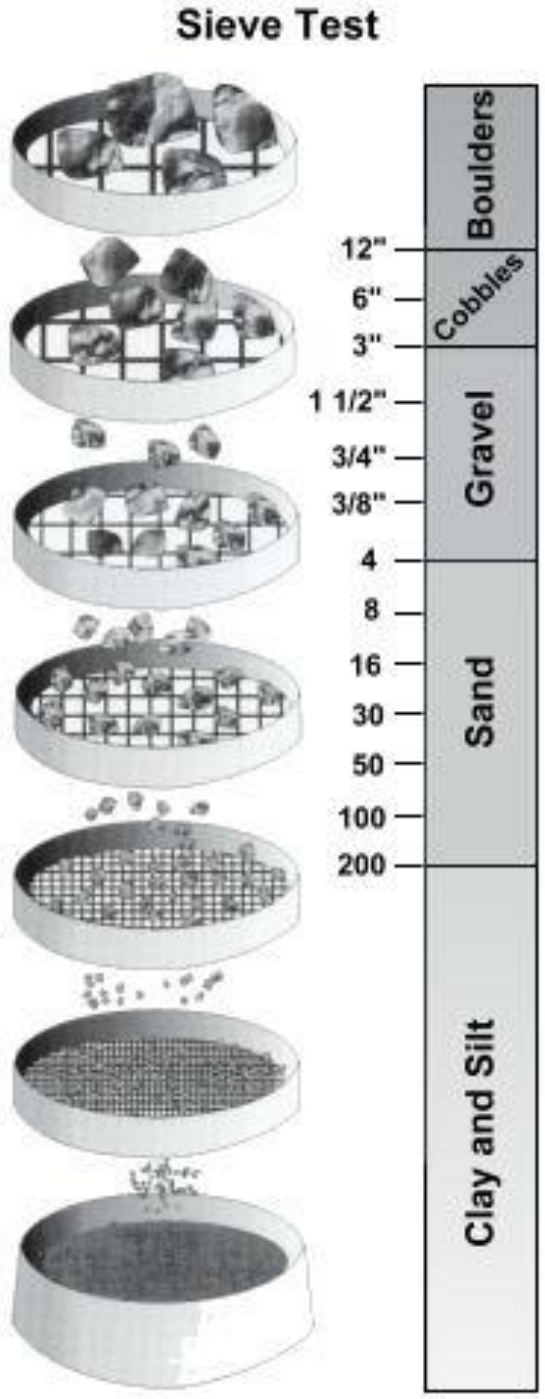
Information from Terracon

Soil Types

- Rock
- Gravel
- Sand
- Silt
- Clay
- Organic
- Peat

Soil Types

- Rock
  - Boulders
  - Cobbles
- Granular Soils
  - Gravel
  - Sand
- Fine-grained/Cohesive Soils
  - Clay
  - Silt



Information from Terracon

Guide to Soil Types

Information from Terracon

What to look for	Appearance/ Feel	Water Movement	When Moist	When Dry
Granular soils, fines sand and silts	Coarse grains can be seen. Feels gritty when rubbed between fingers.	When water and soil are shaken in palm of hand, they mix. When shaking is stopped they separate.	Very little or no plasticity.	Little or no cohesive strength when dry. Soil sample will crumble easily.
Cohesive soils, mixes and clays	Grains cannot be seen by naked eye. Feels smooth and greasy when rubbed between fingers.	When water and soil are shaken in palm of hand, they will not mix.	Plastic and sticky. Can be rolled.	Has high strength when dry. Crumbles with difficulty. Slow saturation in water.

Soil Characteristics

Information from Terracon

	Permeability	Foundation Support	Pavement Subgrade	Expansive	Compaction Difficulty
Gravel	Very High	Excellent	Excellent	No	Very Easy
Sand	Medium	Good	Good	No	Easy
Silt	Medium Low	Poor	Poor	No	Difficult
Clay	Very Low	Moderate	Poor	Low to Very High	Very Difficult
Organic	Low	Not Acceptable	Not Acceptable	Some	Very Difficult

Other Subsurface Conditions

- Groundwater
- Expansive/collapsible soils
- Corrosivity
- Soft Soils
- Contaminated soils
- Mine Subsidence
- Landslides
- Undocumented fill

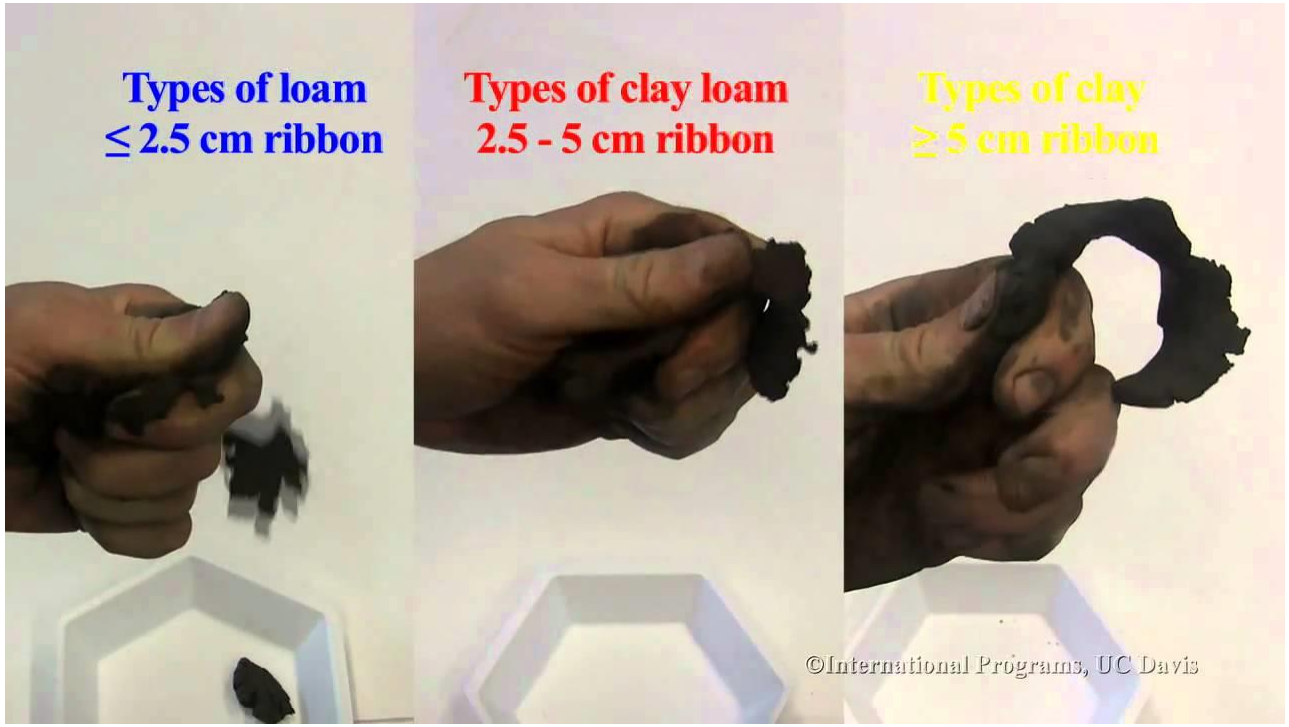
Information from Terracon

Soil Effects

- Permeability
  - Ability of a material to allow fluids to pass through it
- Capillary
  - Movement of water through a porous material, against the force of gravity
- Frost Susceptibility
  - Vulnerability of a material to be damaged by the effects of freezing
- Stability
  - Strength of bearing capacity
- Compaction
  - Exertion of force to squeeze of air or water to increase density
- Moisture Content
  - How much water is in a material

Simple Field Checks

- Dynamic Cone Penetration Test (DCP)
- Ribbon test



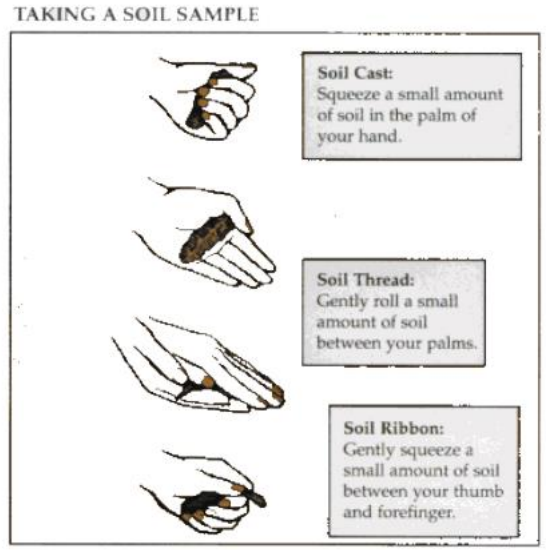


Figure 3. Soil ribbon test.

Soil sample with high sand content. The sample is unable to form a ribbon.

Soil sample with high clay content. The sample is able to ribbon 2 inches.

Simple Field Checks

- Squeeze test
  - Squeeze your handful tightly and then open your hand. If the soil falls apart quickly, you've got sand. If it stays together in a ball, you've got clay. If it feels soft and crumbly and is easy to work then you have loam
- Jar Test
- Visualization
  - Well Graded?
  - Sheen? - Indicates high clay content

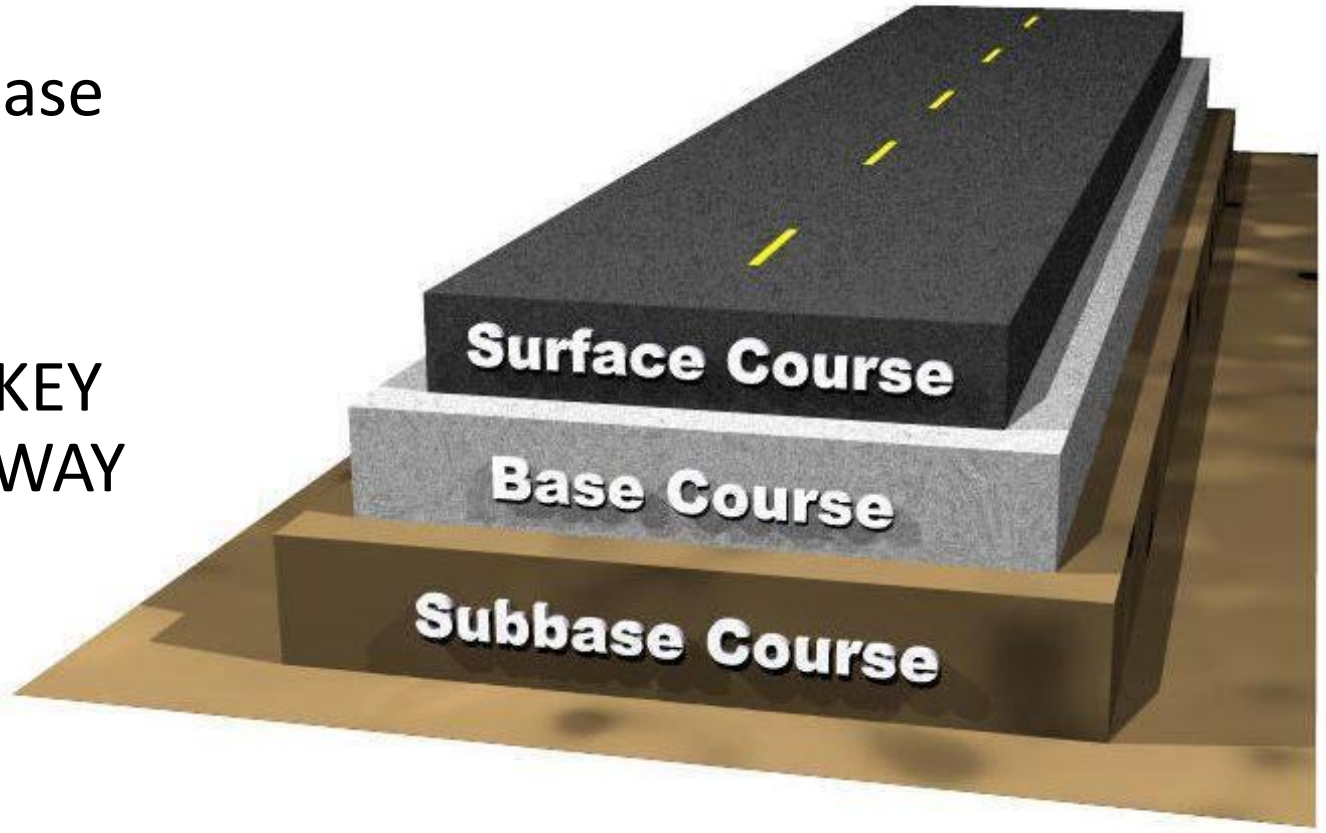
Jar showing the silt layer.
Andrew "Drew" Jeffers, ©2018,
Clemson Extension

Subgrade

- Here is bad day!!

Roadway Structure Elements

- Surface Course
- Base Course / Stabilized Base Course
- Subbase Course
- SUBGRADE – THIS IS THE KEY COMPONENT TO A ROADWAY STRUCTURE



Subgrade

- Definition
  - Referred to as the native material underneath a constructed roadway or can also be referred to imported material brought in to build the embankment under your roadway.

Subgrade

- Supports the subbase, base, and/or gravel surfacing or pavement section
- The subgrade supports everything – **it is your Foundation to build on**

Stability

- Strength of bearing capacity
- Bearing capacity is capacity of the soil to support the loads applied to the ground

Bearing Capacity

Vehicle Tire Pressure

Autos 35 psi or 2.5 T/ft^2

Trucks 75 psi or 5.4 T/ft^2

GROUND TYPE	DENSITY OF STATE	Approximate Ground Bearing Capacity		
		Tons/ft (s)	PSF	PSI
Rock (not shale unless hard)	Bedrock	60	120,000	833
	Layers	15	30,000	208
	Soft	8	16,000	111
Hardpan, cemented sand or gravel		10	20,000	139
Gravel or sand	Compact	8	16,000	111
	Firm	6	12,000	83
	Loose	4	8,000	56
Sand, coarse to medium	Compact	6	12,000	83
	Firm	4.5	9,000	63
	Loose	3	6,000	42
Sand, fine, silty, or with trace of clay	Compact	4	8,000	56
	Firm	3	6,000	42
	Loose	2	4,000	28
Silt	Compact	3	6,000	42
	Firm	2.5	5,000	35
	Loose	2	4,000	28
Clay	Compact	4	8,000	56
	Firm	2.5	5,000	35
	Loose	1	2,000	14

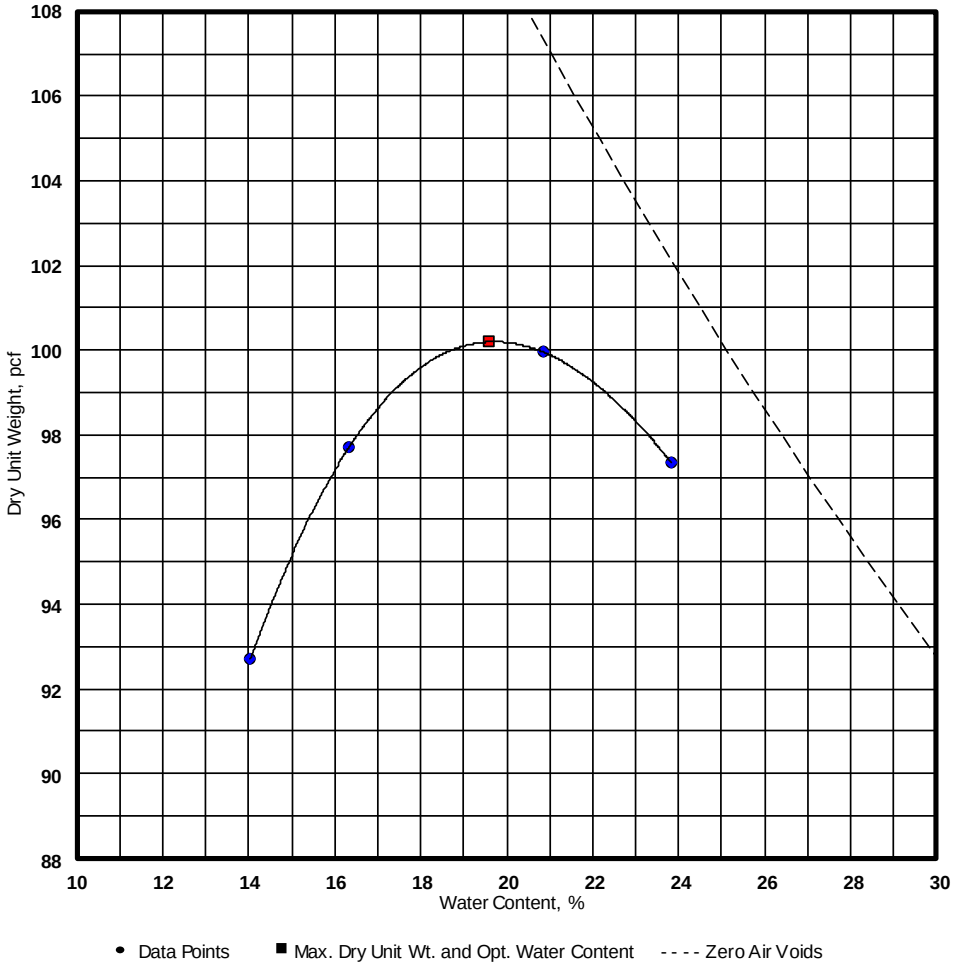
Moisture Content

- Definition
  - ratio (percentage) of the mass of water to the mass of soil
- We can only achieve maximum compaction or density of a soil by using a certain amount of moisture or the optimum moisture content
  - Too little or too much moisture does not allow the soil to achieve maximum density
- A Proctor test is used to plot the relationship between moisture content and the dry density of the soil

Proctor Test

Information from Terracon

- On the dry side
  - High Strength
  - Low compressibility
  - Higher swell Potential
  - Higher Permeability



- On the wet side
  - Lower Strength
  - Higher compressibility
  - Lower swell Potential
  - Lower Permeability

Compaction

- Definition
  - Exertion of force to squeeze of air or water to increase density
- Ensures stable and settlement-free construction or installation
- Increases the bearing capacity of the soil and provides stability by increasing its shear strength
- Helps prevent damage by frost, reduces settlement under dead and live loads, and reduces the permeability of the soil

Constructing the Subgrade

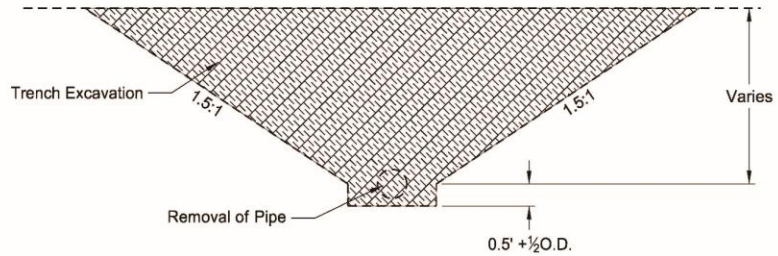
- Compaction Control is required
  - Optimum moisture (variance is given depending on specification used)
  - Specified lift thickness (6” or 12”)
  - 90% or 95% compaction of maximum dry density

Drainage

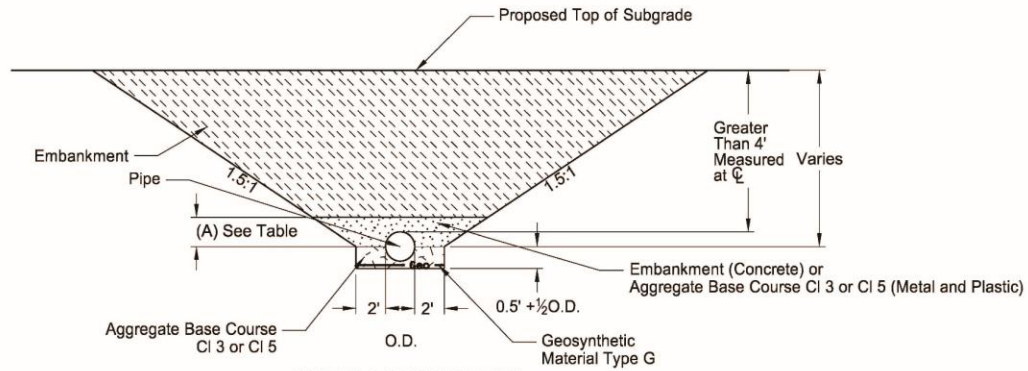
- Structures (bridges)
- Culverts
  - Materials – RCP, CMP, etc.
  - Sizing – Minimum sizes for approach and CL
    - Effectively transport water
    - Reduce plugging of culverts
- Ditching
  - 4:1 slopes or flatter
  - Adequate ditch bottom width (10’)

TRANSVERSE MAINLINE PIPE INSTALLATION DETAIL
PIPES MORE THAN 4 FEET BELOW TOP OF SUBGRADE

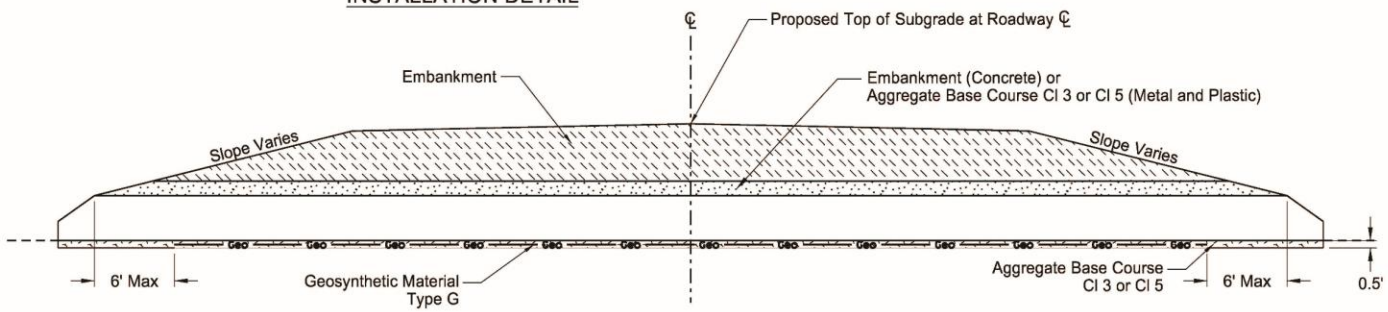
D-714-25



EXCAVATION DETAIL



INSTALLATION DETAIL



CROSS SECTION

Pay Items
1) Pipe*
2) Geosynthetic Material Type G
3) Removal of Pipe (if required)

*Included in Pipe Pay Item
1) Pipe
2) Trench excavation
3) Aggregate Base Course Cl 3 or Cl 5
4) Embankment

NOTES:

1) This drawing applies to new/replaced mainline and paved intersection roadways (including ramps). It does not include pipes in approaches.

2) Embankment may be either Borrow Excavation or Common Excavation - Type A.

Backfill Dimensions	
Pipe Materials	Dimension (A)
Concrete	0.5 O.D.
Metal and Plastic	0.5 O.D. + 1 Foot

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

7-26-13

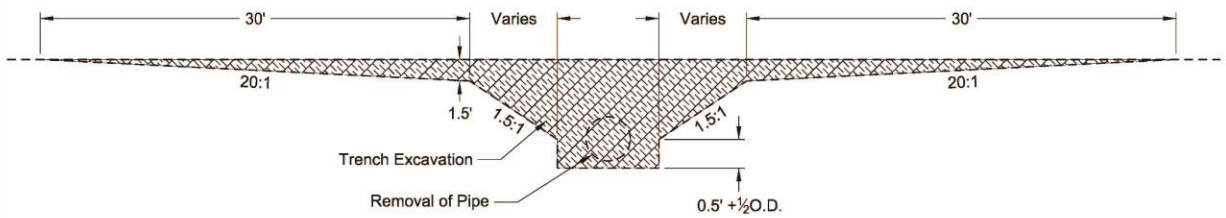
REVISIONS

DATE	CHANGE
10-15-13	Label Formatting
1-21-14	Nomenclature
9-18-15	Title Rewording
12-10-15	Added Plastic Pipe
5-27-20	Replaced R1 Fabric with Geogrid
	Changed bedding depth

REGISTERED PROFESSIONAL ENGINEER
MATTHEW C KURLE
PE-8777
DATE
05/27/20
NORTH DAKOTA
DocuSign

TRANSVERSE MAINLINE PIPE INSTALLATION DETAIL
PIPES 4 FEET OR LESS BELOW TOP OF SUBGRADE

D-714-26



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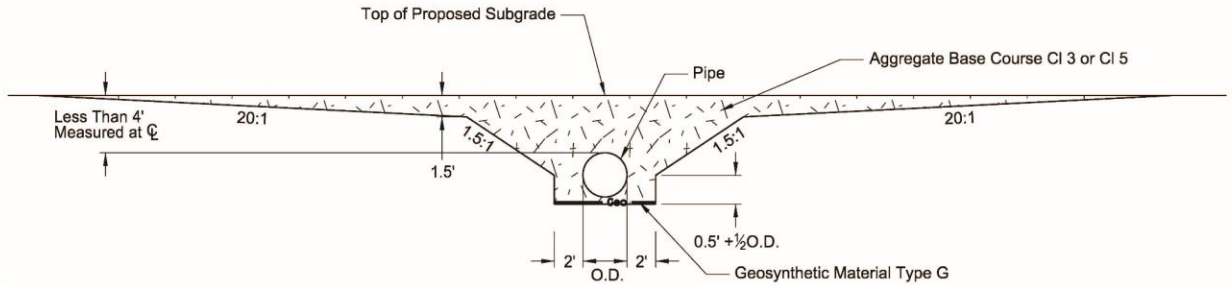

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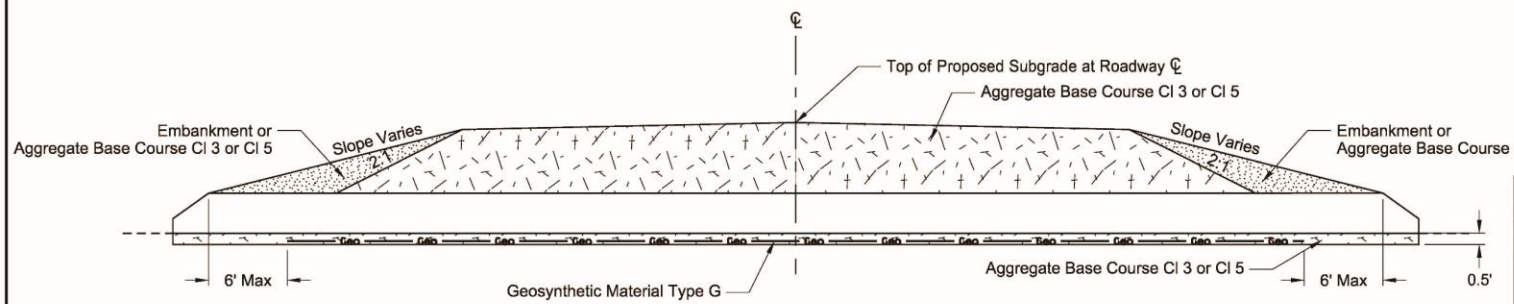

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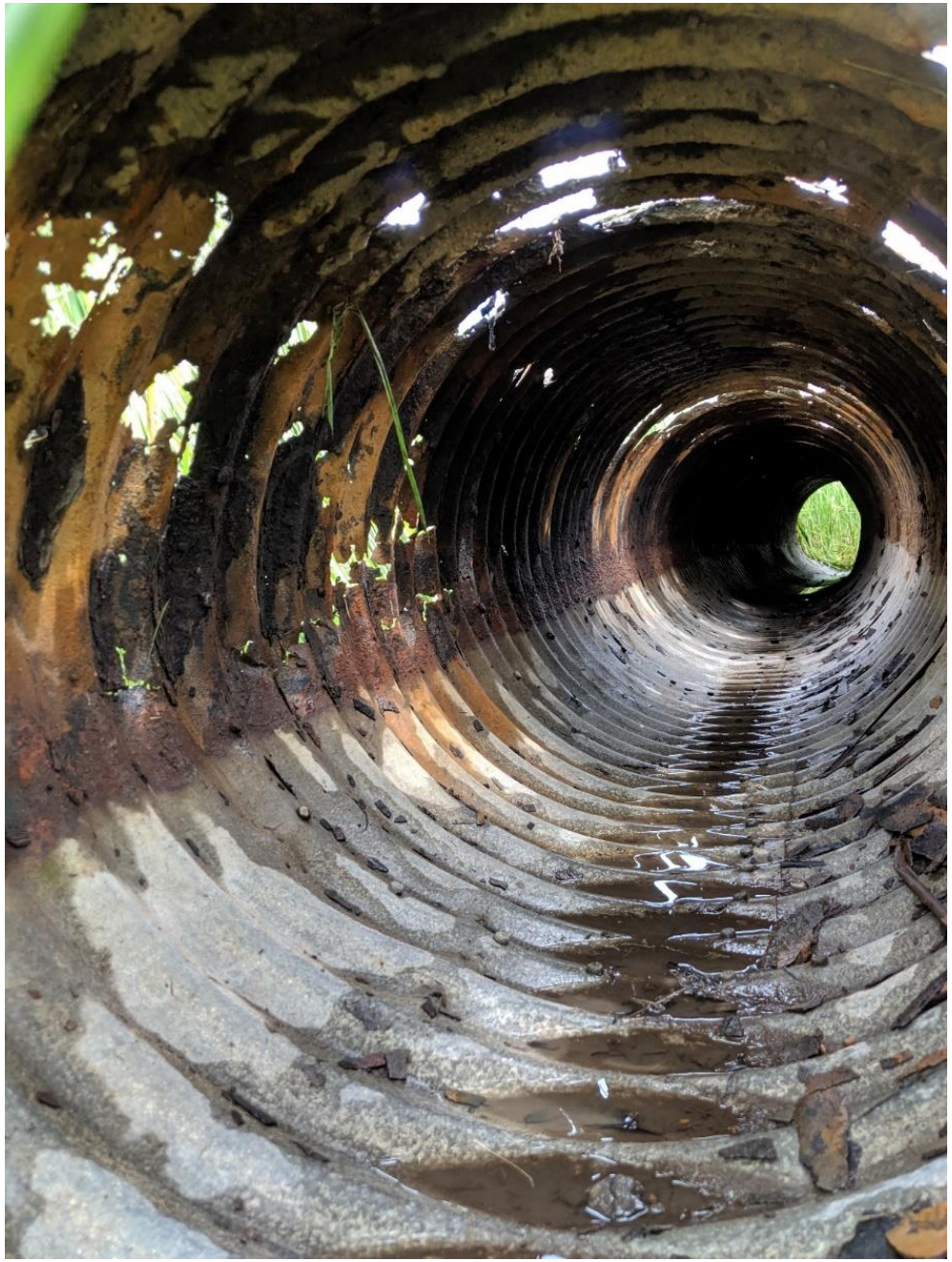

Strategies for Poor Subgrade Soils

- Add Material
- Dig Out
- Blend
- Stabilize
- Geotextiles
- Geogrid / Geocells

- ULTIMATELY it is a combination of Strategies

Adding Material

Digging Out Poor Soils

Blending Materials

- Bring in better quality materials
  - Blend material with existing subgrade
  - Can be less expensive to provide a suitable subgrade

Stabilizing the Subgrade

- Mechanical Soil Stabilization
- Compaction Soil Stabilization
- Chemical Soil Stabilization

Mechanical Soil Stabilization

- Mechanical solutions involve physically changing the property of the soil
  - Affect its gradation, solidity, and other characteristics
  - Dense and well graded material can be achieved by mixing and compacting two or more soils of different grades
- Addition of a small amount of fine materials such as silts or clays enables binding of the non-cohesive soils which increases strength
- Strong and angular particles of sand and gravels, impart internal friction and incompressibility to the mix
- Addition of clay contributes to the binding properties

Mechanical Soil Stabilization

- Factors affecting the mechanical stability of mixed soils may include:
  - The mechanical strength and purity of the inplace materials
  - The percentage of materials and its gradation in the mix
  - The degree of soil binding taking place
  - The mixing, rolling, and compaction procedures adopted in the field
  - The environmental and climatic conditions

Compaction Soil Stabilization

- Uses mechanical means for removing air voids in the soil
  - Results in soil that can bear load subsequently without further immediate compression
- Dynamic compaction is a type of soil stabilization
  - a heavyweight is dropped repeatedly onto the ground at regular intervals to quite literally pound out deformities and ensure a uniformly packed surface.
- Vibratory compaction is a type of soil stabilization
  - another technique that works on similar principles, though it relies on vibration rather than deformation through kinetic force

Chemical Soil Stabilization

- These techniques rely on adding additional material to the soil that will chemically and physically interact with it and change its properties
  - Cement stabilization
  - Fly Ash
  - Calcium Chloride
  - Polymers
  - Enzymes

Stabilizing the Base Material

- Geotextiles
  - Permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain
- Geogrids
  - Geosynthetic material that can be used to provide the functions of reinforcement, stabilization, and filtration

What Are Geosynthetics?

“Plastic products used to solve geotechnical problems”

- PP, HDPE, PET, PVC, rubber

- Numerous categories based on function

  - Soil reinforcement & stabilization
  - Filtration & separation
  - Drainage
  - Erosion control
  - Lining & barrier


NO
PARKING
ANY
TIME

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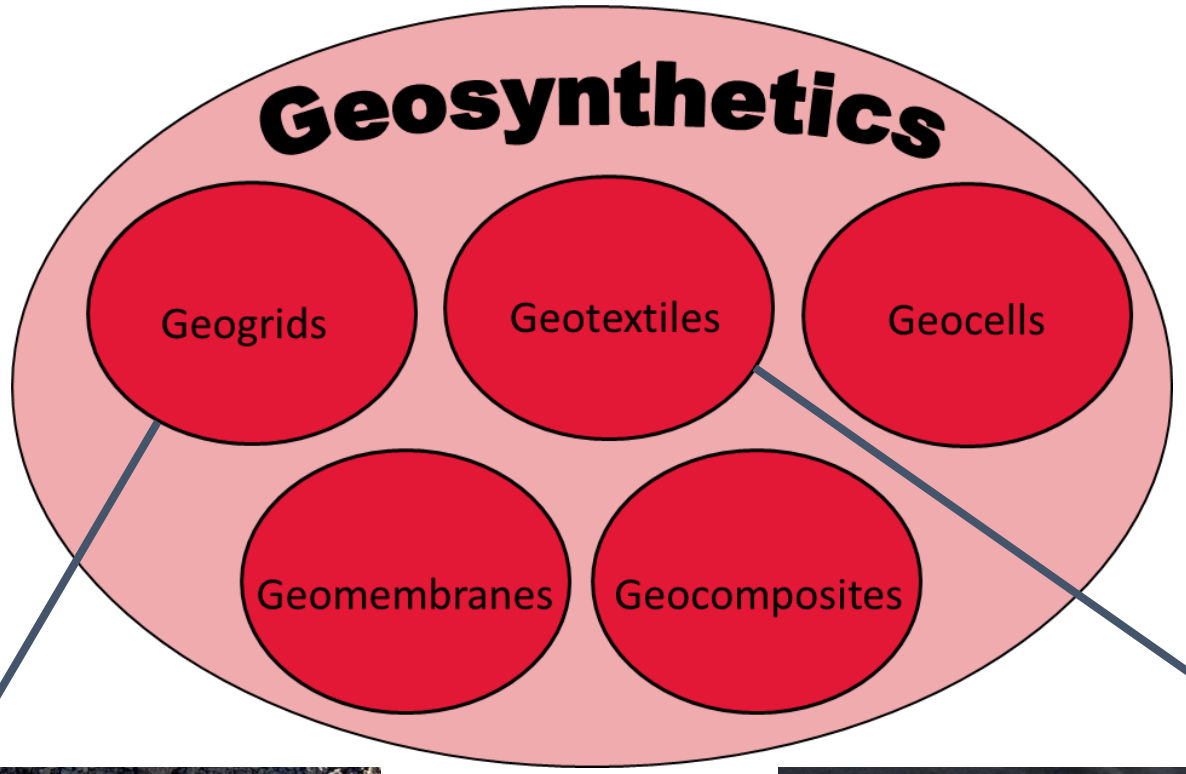

Geosynthetics
Geogrids
Geotextiles
Geocells
Geomembranes
Geocomposites

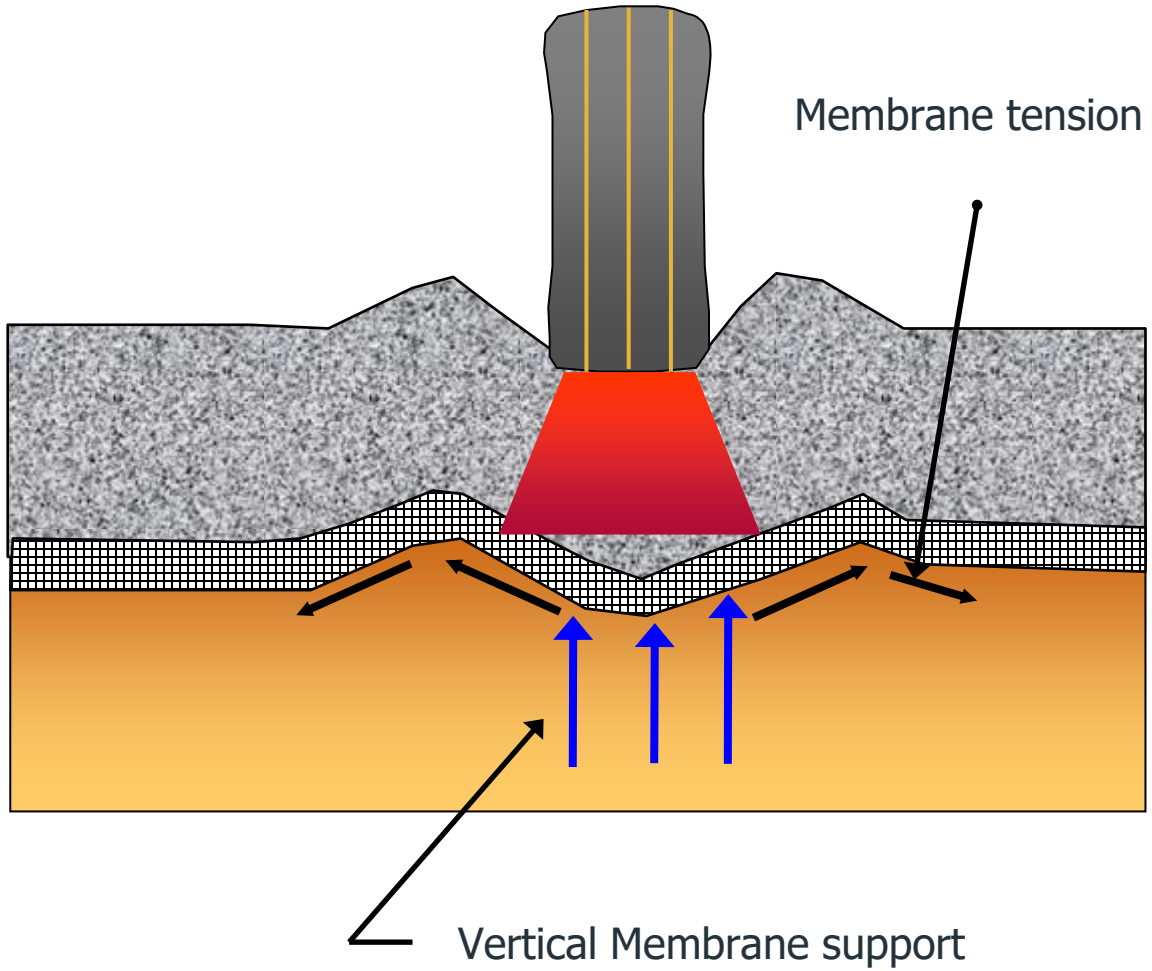
Woven Geotextiles

Non-Woven Geotextiles

Geogrids


HMA Wearing Course
Hot Mix Asphalt (HMA) Layer
Granular Base
Subgrade

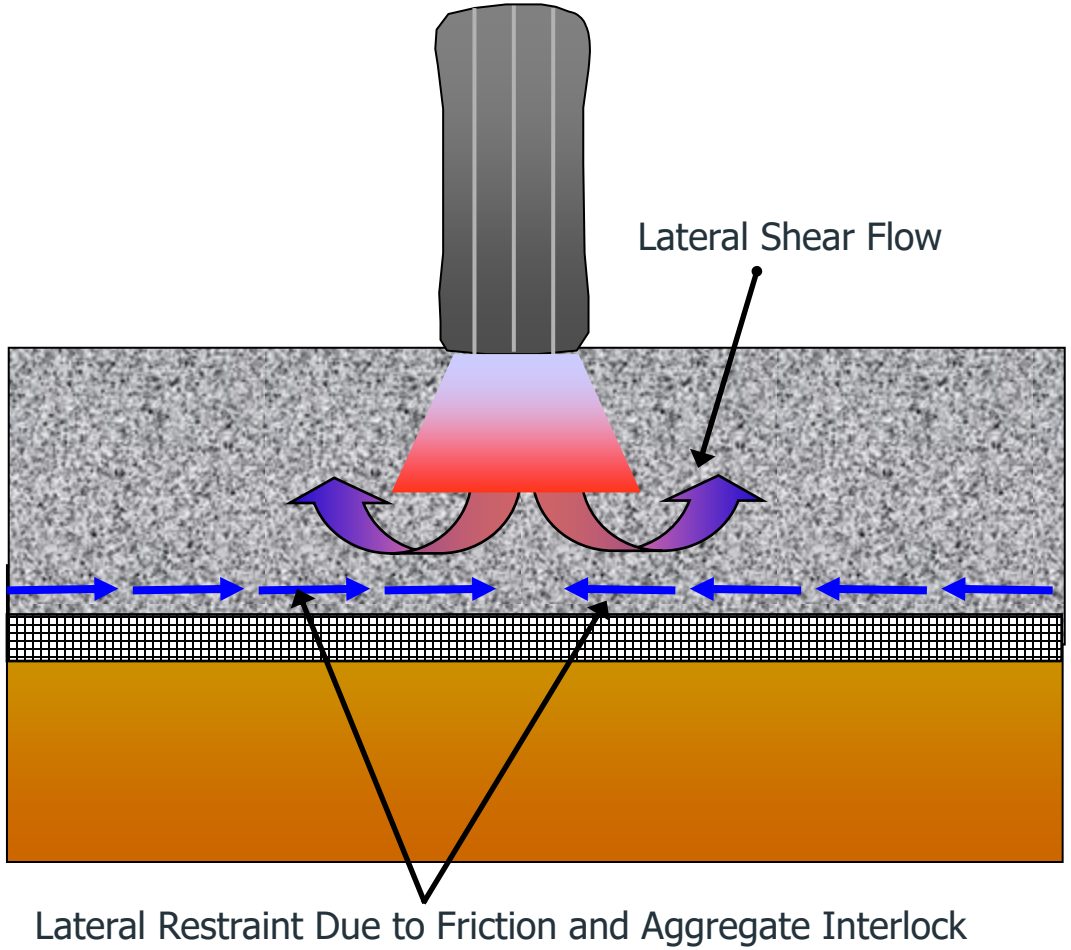
Geotextile Stabilization



Separation and Tensioned Membrane are the mechanisms for geotextile stabilization

Source: USACOE ETL 1110-1-189

Stabilization Geogrids



Lateral Restraint is the most important mechanism for geogrids in stabilization applications

Source: USACOE ETL 1110-1-189

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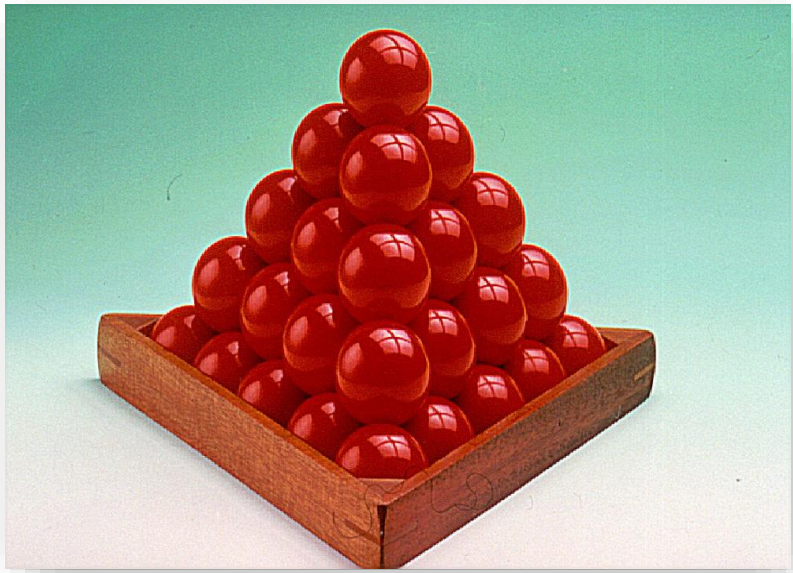
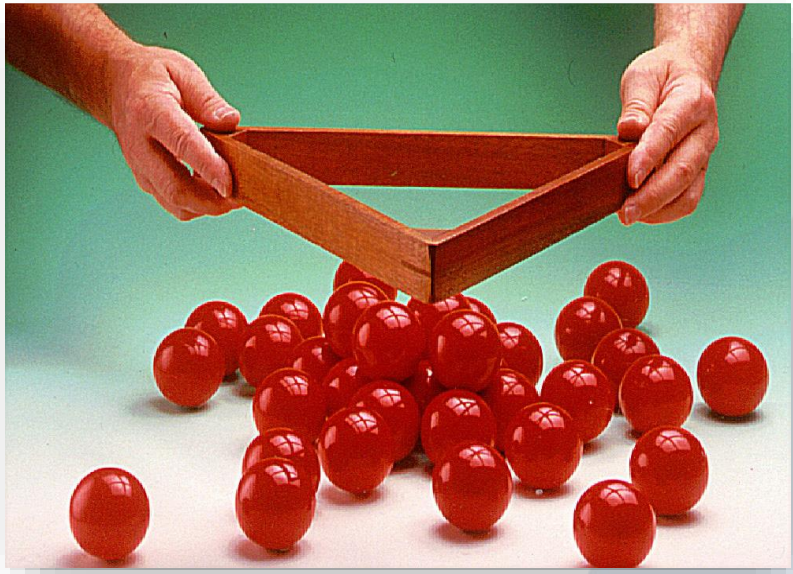
Geogrid Function





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Industrial Site with Woven Geotextile

Industrial Site with Geogrid

“Roads wear out from the top down, but they fall apart from the bottom up.”

National Association of County Engineers

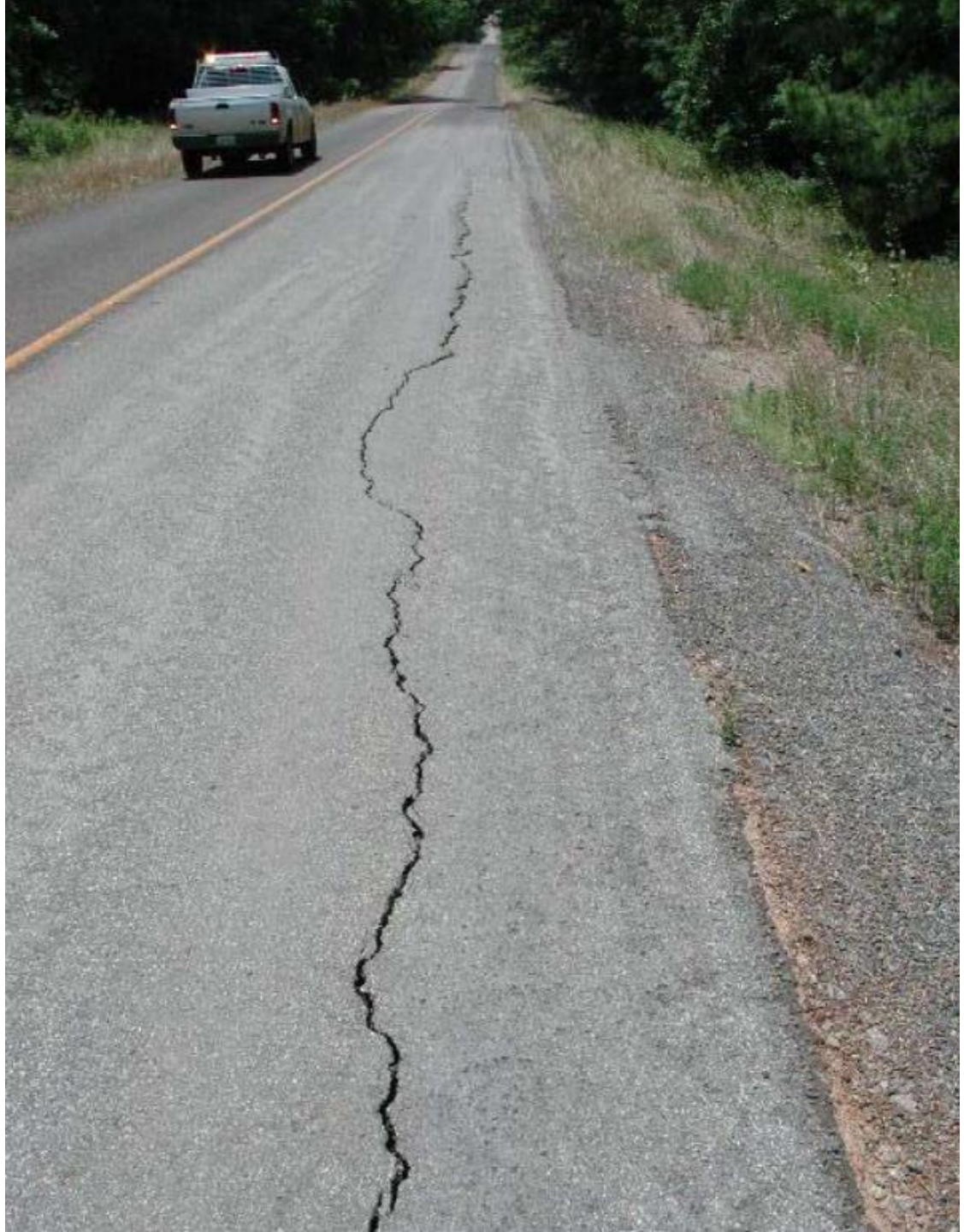
Geosynthetics in Roadway Foundations

- Improve structural capacity to support traffic
- Preserve aggregate integrity and separation from subgrade
- Protect subgrade from overstress and further weakening
- Conserve valuable aggregate resources
- Prevent failure due to loss of subgrade strength

November
2016

4 Months

March
2017



1 = 100 to 300

Geosynthetic Advantages

- Easy to install
- Readily available
- No special equipment, curing time or weather restrictions
- No chemical or weathering degradation

Geosynthetic	Material Cost ($/SY)	Installed Cost ($/SY)
8oz non-woven	$1.00	$2.00
Light woven	$1.00	$2.00
Heavy wovens	$3.00 - $6.00	$4.50 - $7.50
Biaxial (BX) geogrid	$1.25	$2.75
Multiaxial geogrids (NX & HX)	$3.50 - $6.00	$5.00 - $8.00

$1/SY is approximately $7,500 per lane-mile

250 to 500 SY/roll

Tensar

Aggregates

Gravel

Crushed Concrete

Asphalt Millings

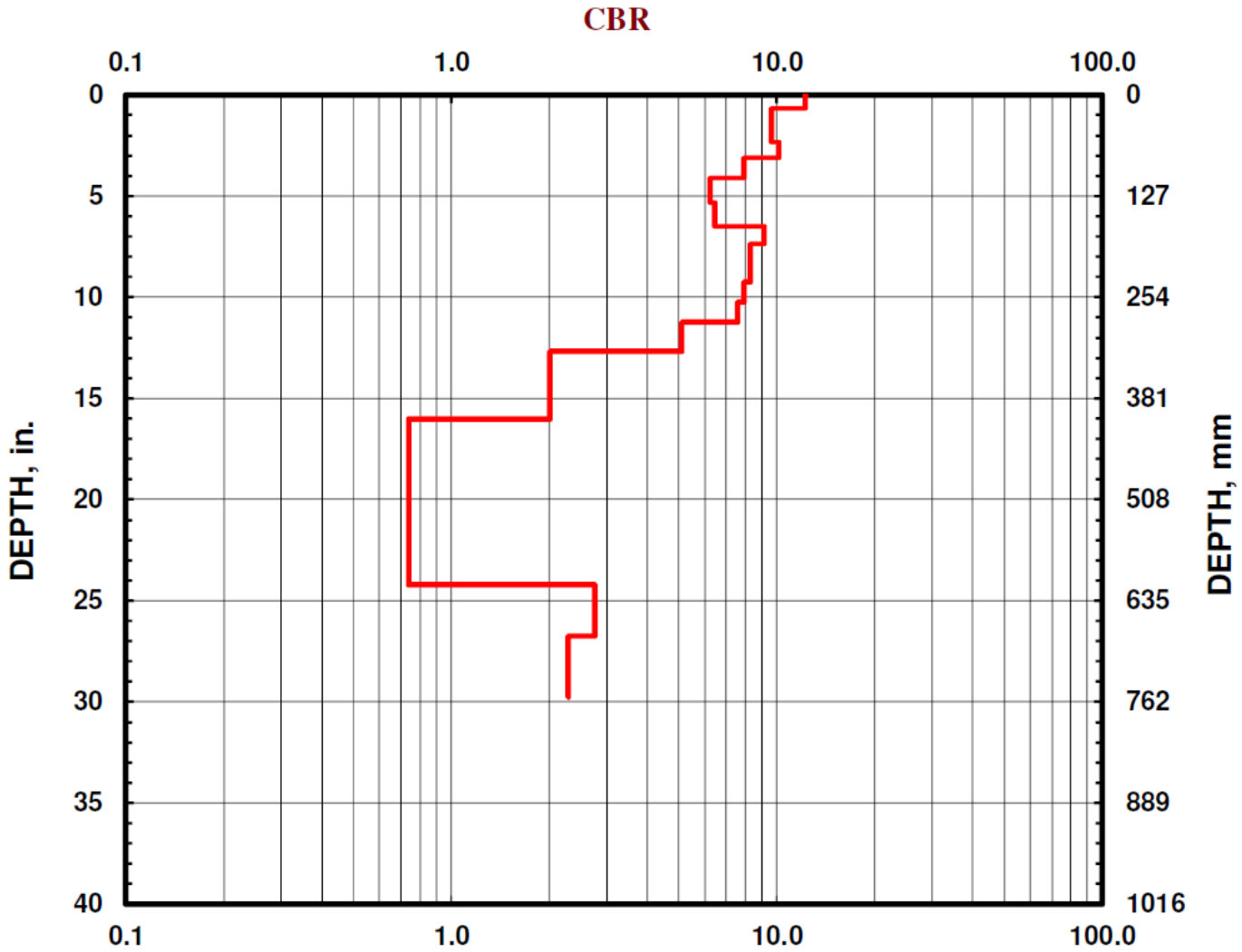
Blended or Salvaged Base Course

Sand

Chemical Additives

How Much Aggregate on the Geosynthetic?

Subgrade Strength



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Paved Roads

Unpaved Roads

Soft Area Reconstruction

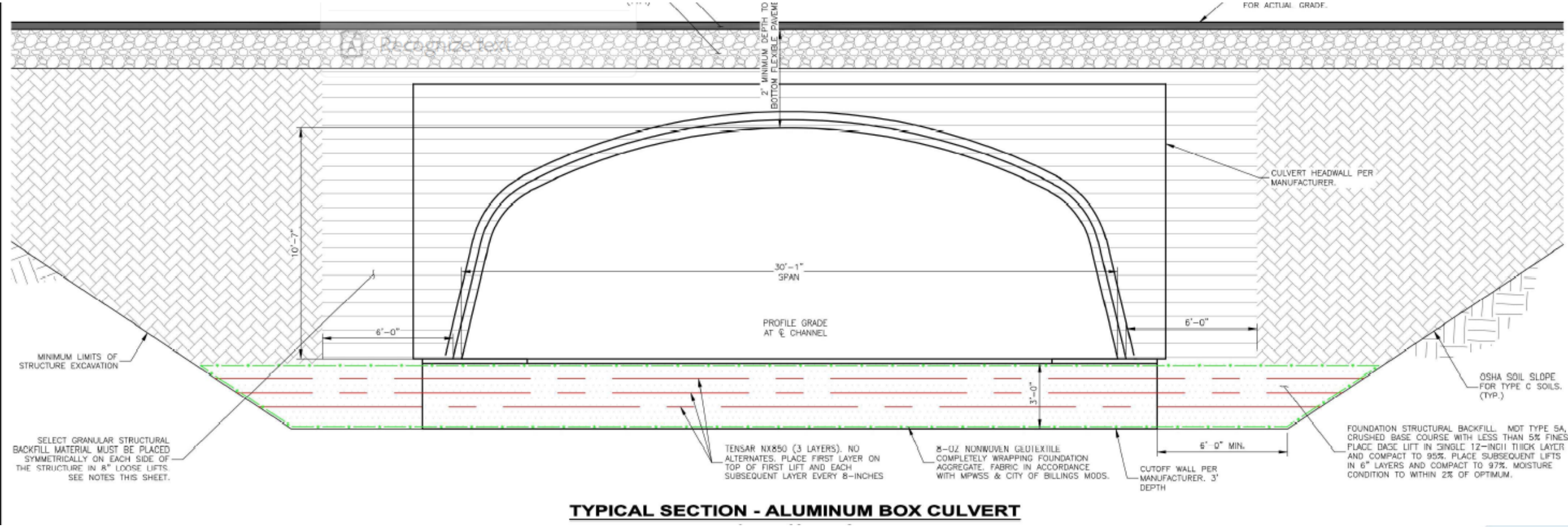

145 St SE
115 Ave SE

Patching Failed Pavement


DEERE


TIRES PLUS

Culverts



TYPICAL SECTION - ALUMINUM BOX CULVERT

Tensar

Low Water Crossings

Tensar

Handling and Installation

Safety and PPE

Tensar

Tensar


CATERPILLAR


CATERPILLAR


SIDUMP


SM38
KENWORTH
KLD 816


SM28
KENWORTH
SCHIELE
VIN FJ454721
KLD 816


LOAD KING


SmithCo
SIDE DUMP
STS


1304

Build America Buy America

The *Build America Buy America Act*, enacted as part of the Infrastructure Investment and Jobs Act on November 15, 2021, established a domestic content procurement preference for all Federal financial assistance obligated for infrastructure projects after May 14, 2022. The domestic content procurement preference requires that all iron, steel, manufactured products, and construction materials used in covered infrastructure projects are produced in the United States.

Geosynthetics in Roadway Foundations

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Frost Susceptible soils

- Three (3) Criteria Needed
  - Frost Susceptible Soil
  - Freezing Temperatures
  - Water Availability

Frost Susceptible Soils

- Permeable soils with capillary actions

- Frost susceptible soils from low to high frost heave potential
  - Gravely soils
  - Sands
  - Clays
  - Silts
  - Very fine silty sands

Frost Susceptible Soils

Frost Group	Degree of Frost Susceptibility	Type of Soil	Percentage Finer than 0.075 mm (# 200) by wt.	Typical Soil Classification
F1	Negligible to low	Gravelly soils	3-10	GC, GP, GC-GM, GP-GM
F2	Low to medium	Gravelly soils	10-20	GM, GC-GM, GP-GM
		Sands	3-15	SW, SP, SM, SW-SM, SP-SM
F3	High	Gravelly Soils	Greater than 20	GM-GC
		Sands, except very fine silty sands	Greater than 15	SM, SC
		Clays PI > 12	-	CL, CH
F4	Very high	All Silts	-	ML-MH
		Very Fine Silty Sands	Greater than 15	SM
		Clays PI < 12	-	CL, CL-ML
		Varied clays and other fine grained, banded sediments	-	CL, ML, SM, CH

Frost Action

- Surface freezes from the top down
- Pulls water up as freezing front migrates downward
- Ice lenses are formed causing the soil to heave
- Spring thaw
  - Thaws from the top down
  - Soil becomes saturated where unfrozen
  - Soil below is frozen so moisture has nowhere to go

Frost Heave Repair

- Identify damaged areas / record repair area
- Repair during dry period
- Make sure repair areas are large enough
- If damaged area appears to be 50’ in length – repair 100’

Frost Heave Repair Methods

- Dig Out Frost Susceptible Materials
- Geotextiles
- Blending Material
- Insulation


CAT

Thank you!

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