Roadway Foundation Basics

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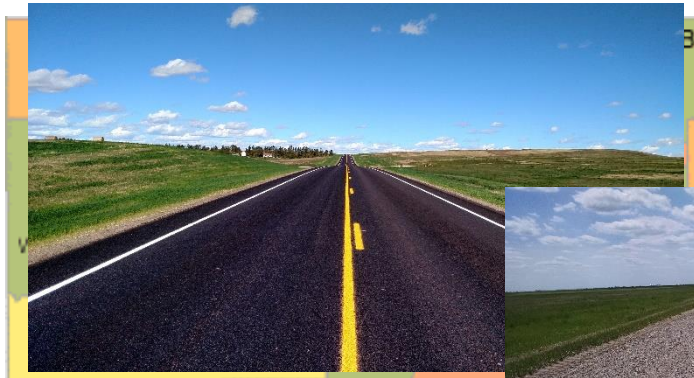
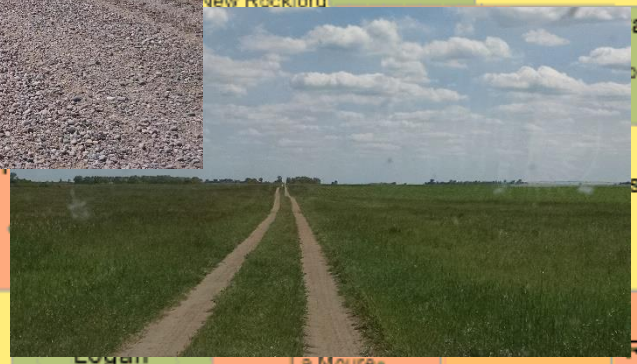
NORTH DAKOTA LOCAL TECHNICAL ASSISTANCE PROGRAM

NORTH Dakota | Transportation
Be Legendary.

U.S. Department of Transportation
Federal Highway Administration

53 counties
1,360 organized townships
357 communities





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AGC
North Dakota

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

National Association of County Engineers

Roadway Cross Section Example

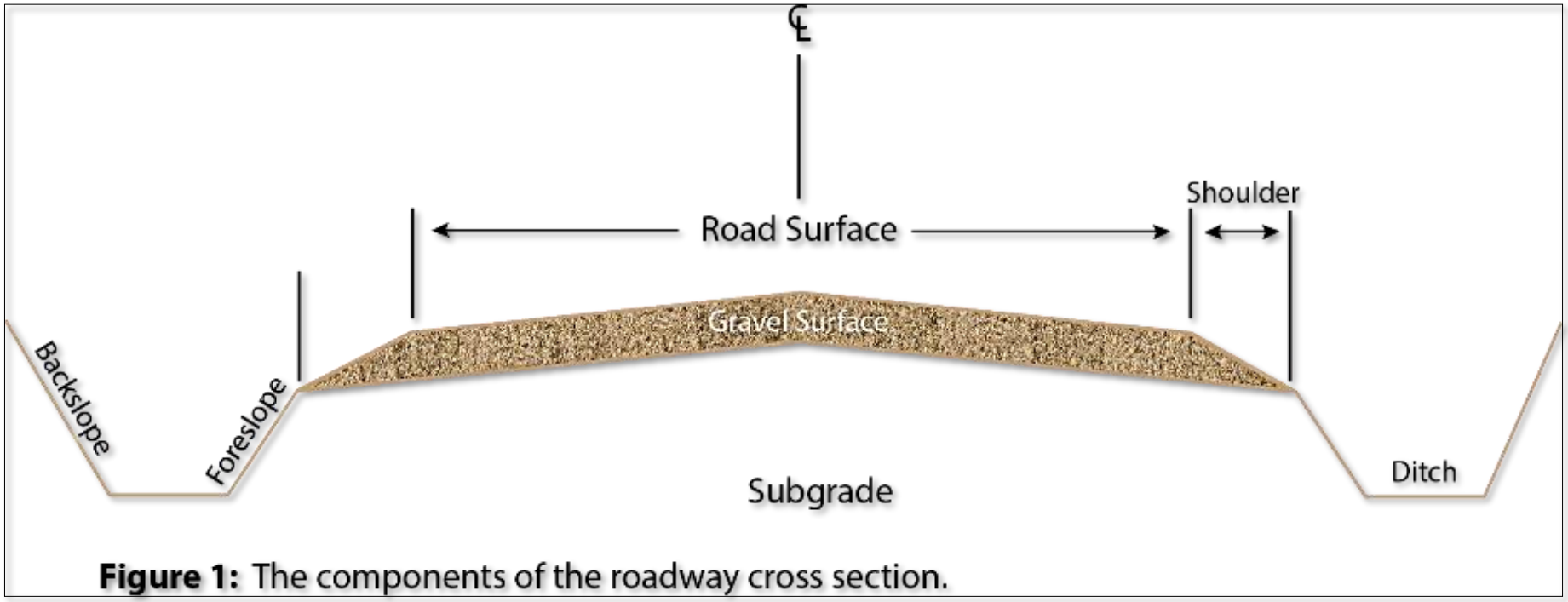
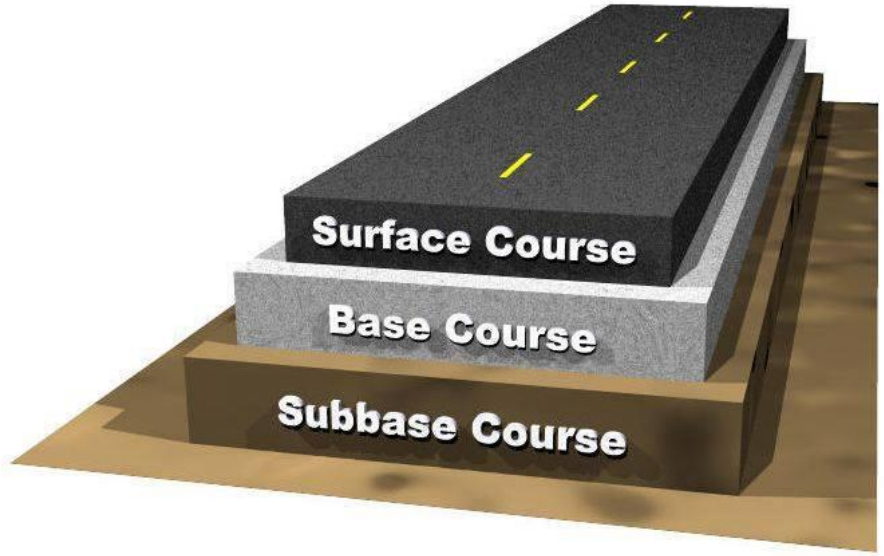


Figure 1: The components of the roadway cross section.

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

Video – Roadway Shape

One of the Biggest Challenges in Road Maintenance

Crown

Lack of crown 2% or less

Crown

Good

Excessive

Road and its Surroundings

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

Soil Effects

- Permeability
  - Ability of a material to allow fluids to pass through it
- 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

Subgrade

- Here is bad day!!

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

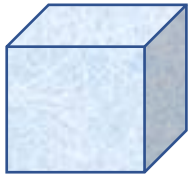
Autos 35 psi or 2.5 T/ft^2

Trucks 75 psi or 5.4 T/ft^2

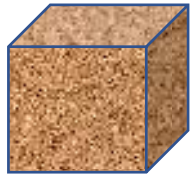
GROUND TYPE	DENSITY OF STATE	Approximate Ground Bearing Capacity		
		Tons/ft (s)	PSF	PSI
Rock (not shale unless hard)	Bedrock	60	120,000	833
	Layers	15	30,000	208
	Soft	8	16,000	111
Hardpan, cemented sand or gravel		10	20,000	139
Gravel or sand	Compact	8	16,000	111
	Firm	6	12,000	83
	Loose	4	8,000	56
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

Density Measurement in Lbs./Cubic Foot (PCF)

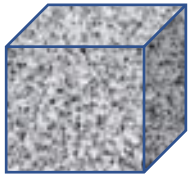
- Examples of “Density”



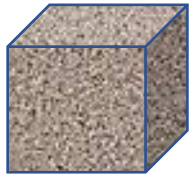
Water:
62 lbs/CF
8.34 lbs/Gal
7.5 Gal/CF



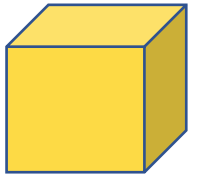
Soil:
90 to 120 lbs/CF



Gravel:
135 lbs/CF



Solid Rock:
165 lbs/CF



Gold:
1200 lbs/CF
$33,000,000

Density testing → nuclear gages
Approximate density or compaction → construction equipment
Moisture content estimate → hand squeeze (fragile cast) method

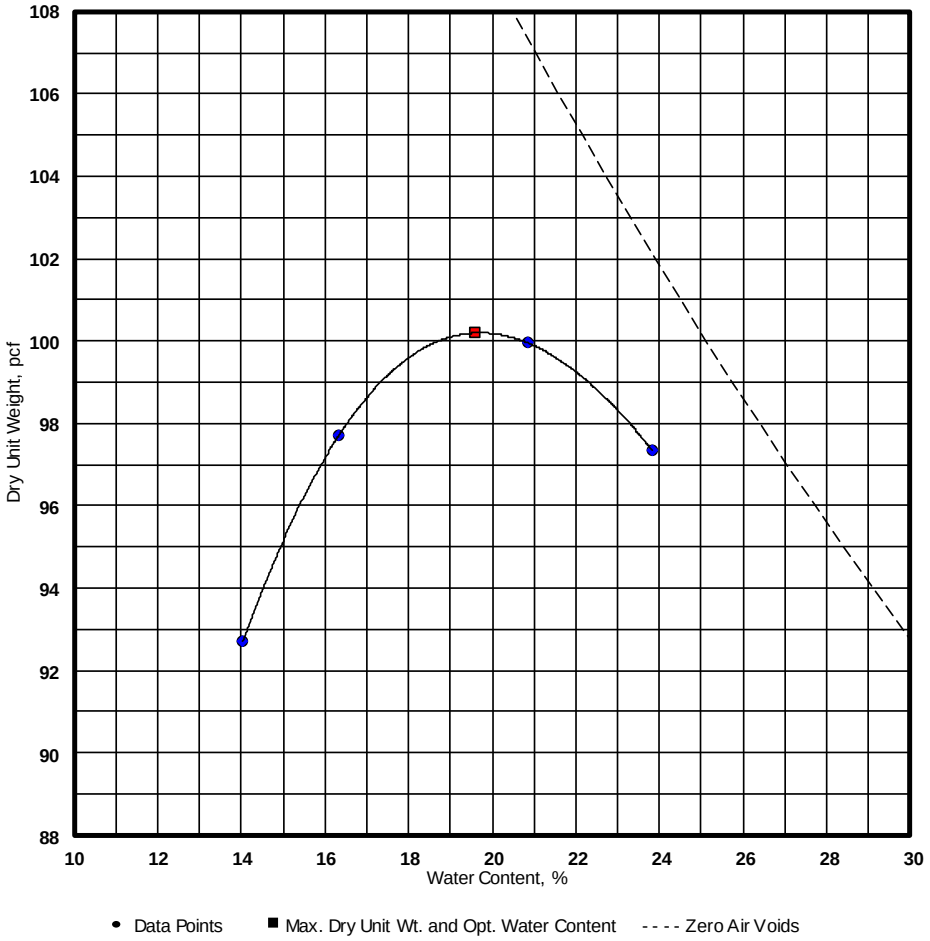
Moisture Content

- 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 the optimum moisture content
- 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

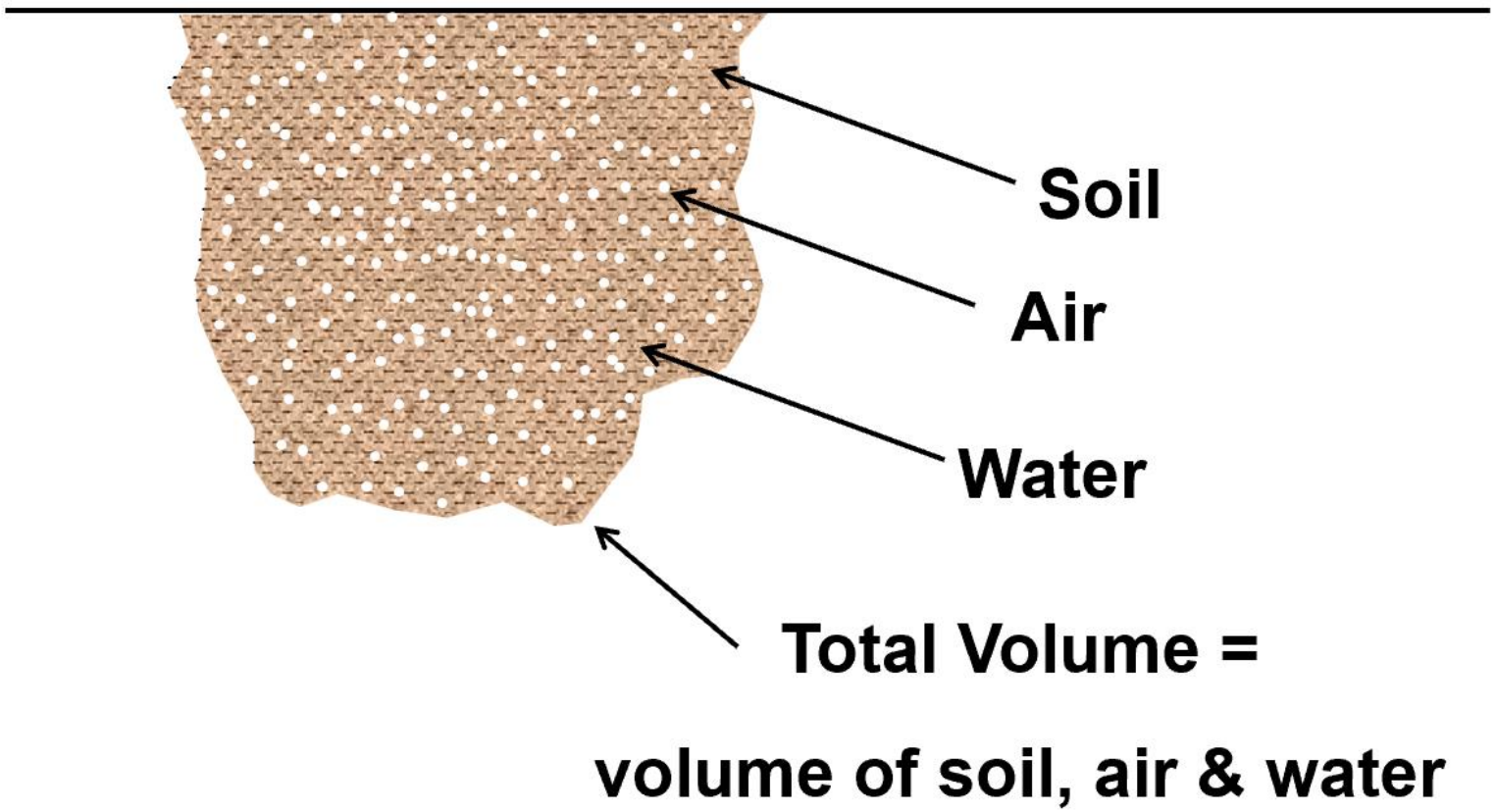


- On the wet side
  - Lower Strength
  - Higher compressibility
  - Lower swell Potential
  - Lower Permeability

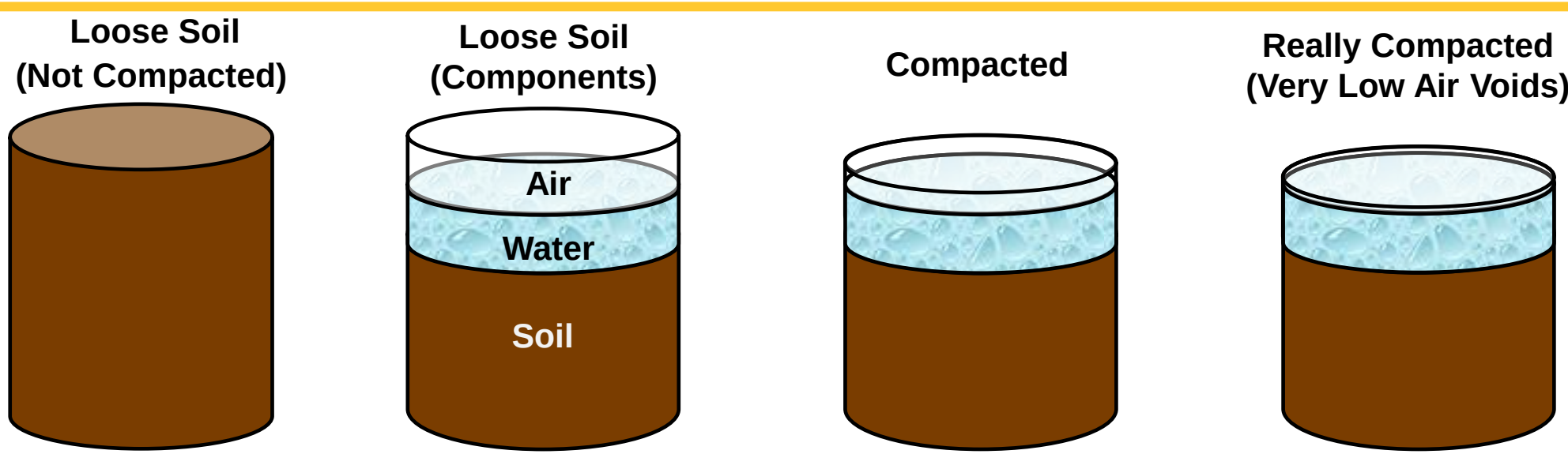
Importance of Compaction

- Compaction → compressing material to higher densities.
- High density benefits
  - Increases bearing capacity – provides stability
  - Reduces settlements
  - Reduces rutting
  - Reduces permeability of the soil
  - Low cost strength improvement - squeeze air out, get better particle contact → higher strength
- Low density can cause very costly repairs to finished work

Soil Components that Influence Compaction



Compacting Loose Soil



What happens when a soil is compacted?

- Only the volume of air voids decreases, i.e.. individual soil particles get closer to each other
- Soil becomes stronger

What controls compaction?

- Compaction effort
- Amount of water

Question: What is the primary reason for not getting good compaction?

Possible Answers:

- Roller too small
- Not enough roller passes
- Roll speed too high
- Low soil moisture content
- Incorrect roller type

Compaction depends on:

- **Best moisture**,
- Slow roller speed,
- Roller size & number of passes,
- Support under the compacted layer

Best (Optimum) Moisture Estimate – Fragile Cast Method

Too dry - crumbling

Good moisture

Too wet – free moisture

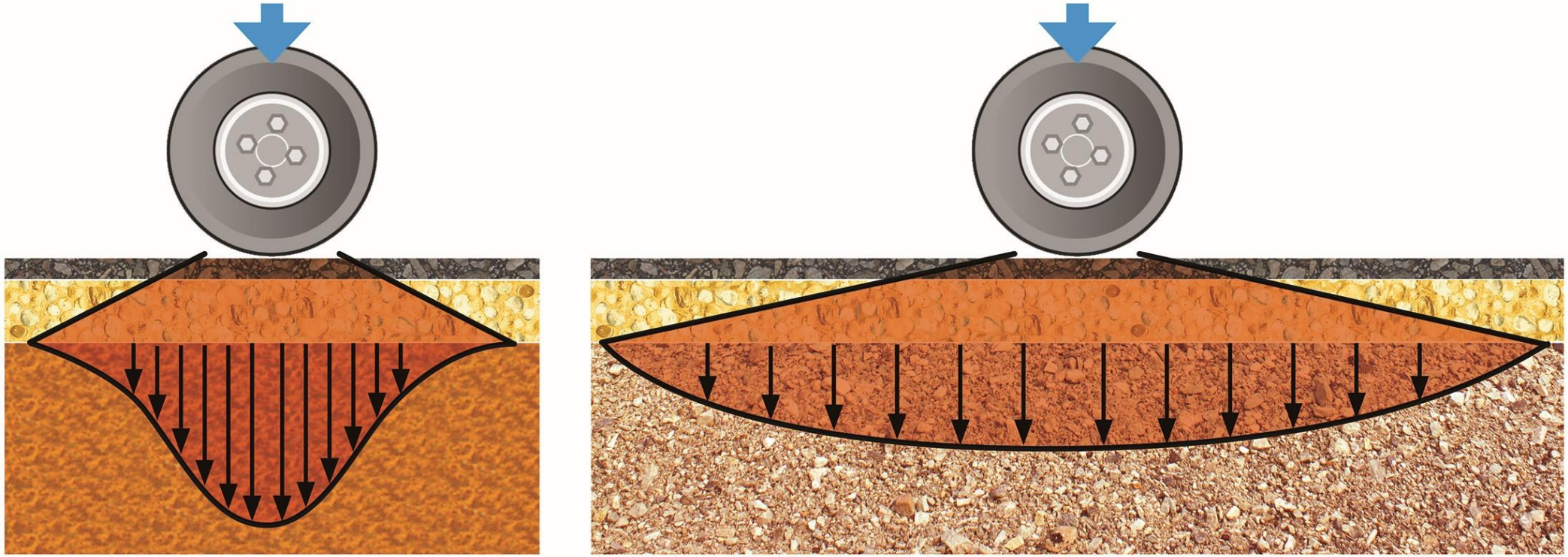
Constructing the Subgrade

- Compaction Control is required
  - Optimum moisture
  - Specified lift thickness (12”)
  - 90% to 95% compaction of maximum dry density

Methods to Reduce Soil Settlement

- Increase soil compaction
- Use granular materials instead of soil
- Treat soil with chemical stabilizers or Geotextiles

Vehicle Loads



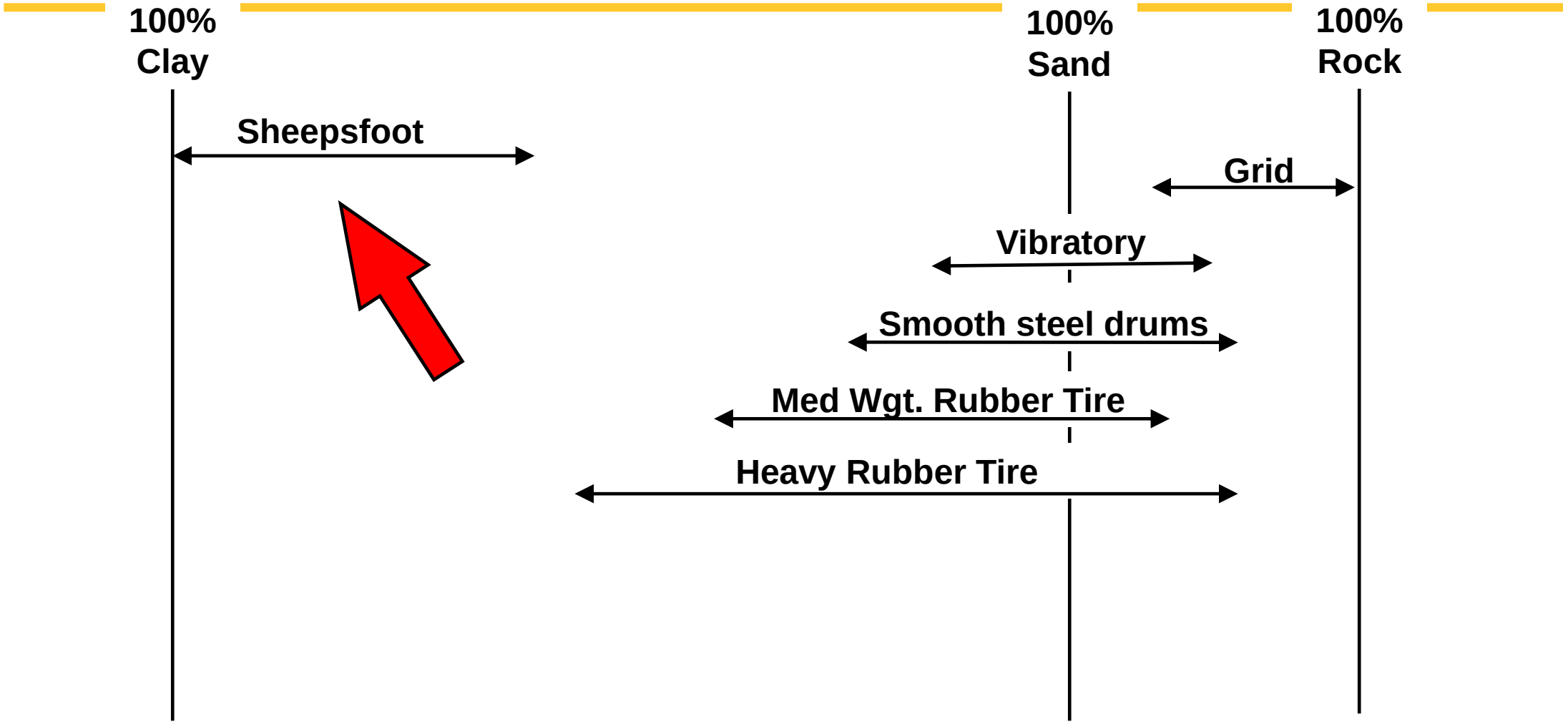
Compaction Testing

- Determine moisture content
- Determine density

Compaction Specs

- Embankment Soil: 95% of std density and nuclear gauge
- Aggregate Base: 95% of modified and nuclear gauge
- Rolling Spec
  - Speed for all rollers: 3 to 5 mph
  - Rubber Tire rollers: minimum tire pressures and wheel loadings

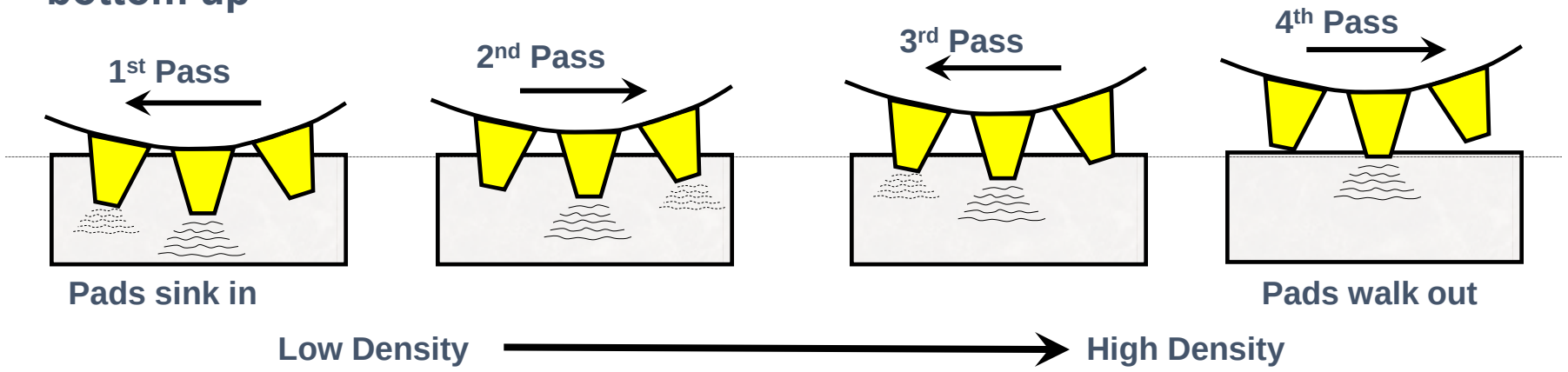
Selecting the Right Roller



Sheep Foot Roller

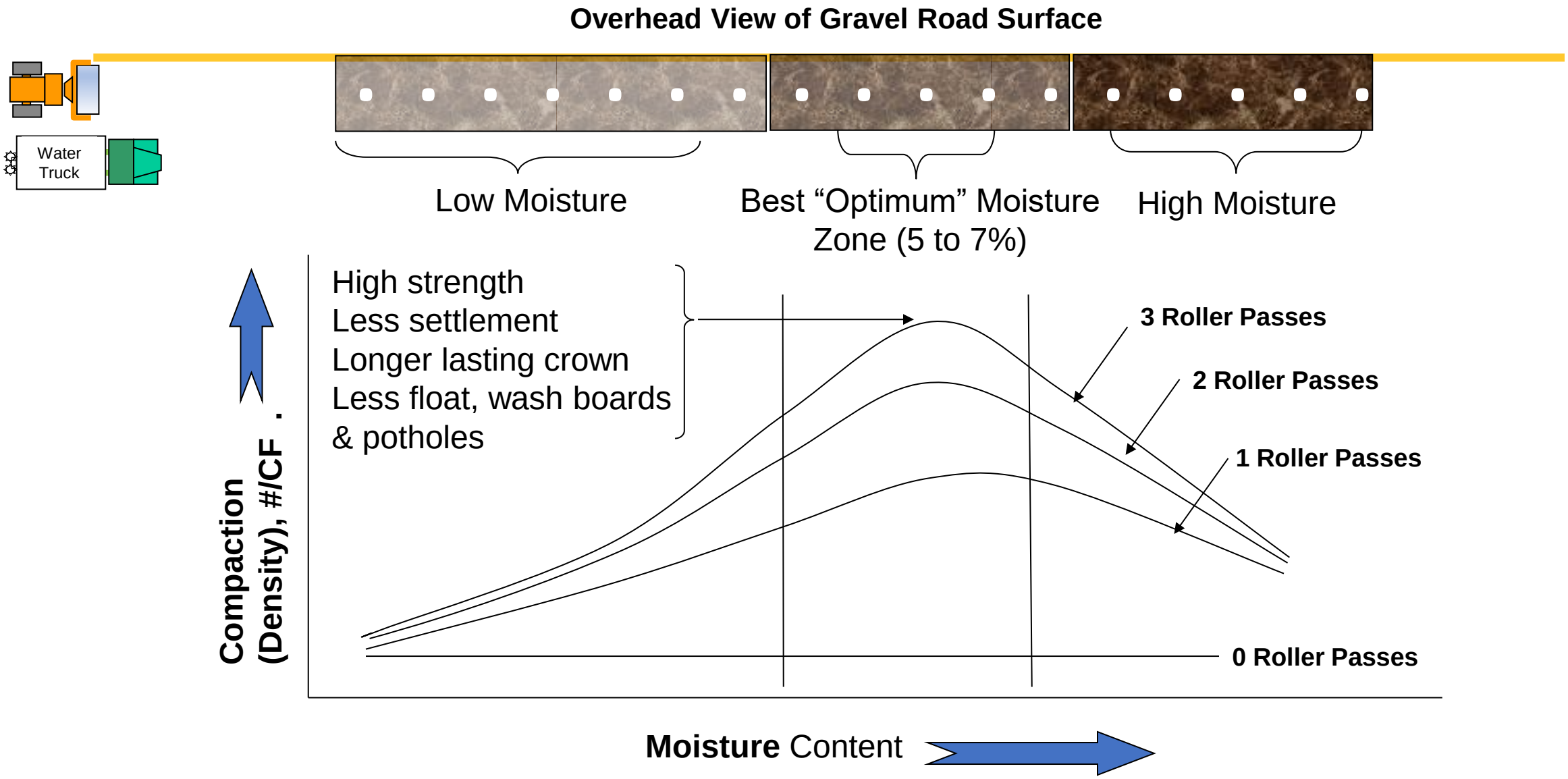
Best for Clay Soils

Compacting from the "bottom up"



Rubber Tire (Pneumatic)

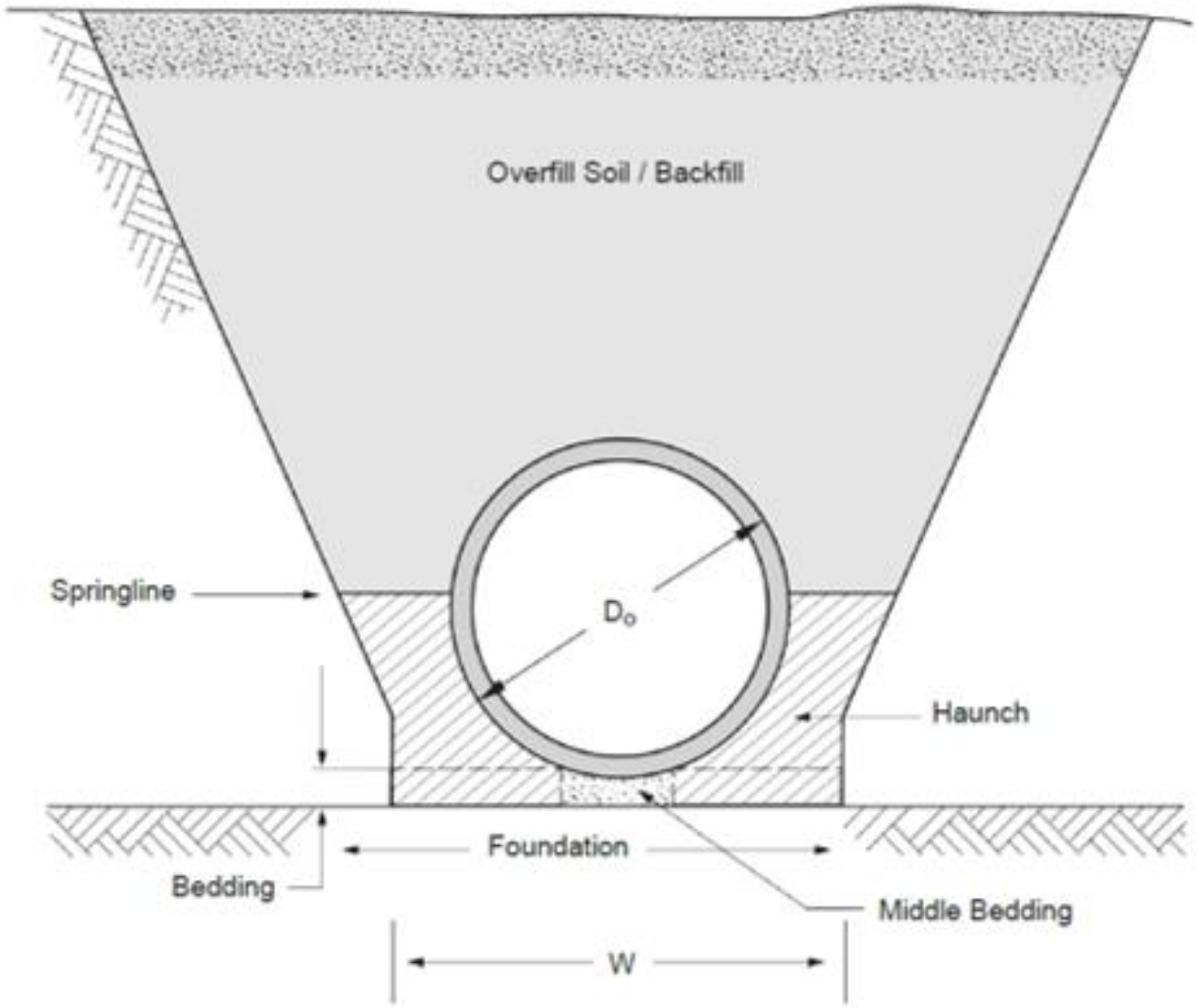
Best Moisture for High Density (Compaction)



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’)

Pipe Installation



Strategies for Poor Subgrade Soils

- Add Material
- Dig Out
- Blend
  - Bring in better quality materials
  - Blend material with existing subgrade
  - Can be less expensive to provide a suitable subgrade
- Stabilize
- Geotextiles / Geogrids

- ULTIMATELY it is a combination of Strategies

Temporary or Permanent Fix?

- Pit run layer in spring is normally temporary fix
- Permanent fixes normally require:
  - Stabilization of area greater than rut area
  - Knowing soft subgrade depth and expected 10 year truck traffic
  - Use of pit run, fabric, grid, portland cement, or ??

The Cause of Subgrade Soft Spots

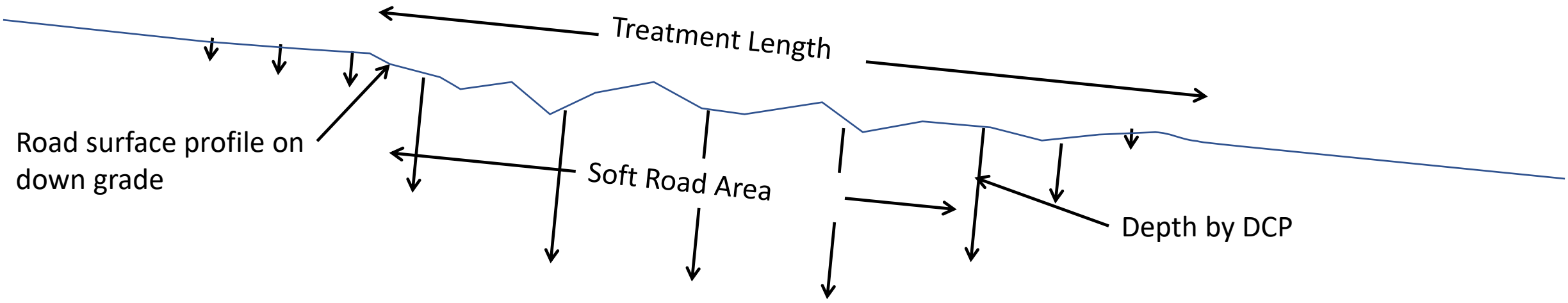
- Poor Surface drainage saturates subgrade
- Excessive **Sub**surface moisture weakens subgrade
- Frost heave and subsequent thaw weakening during mid winter and spring breakup
- Others?

Soft Subgrade Solutions

- Raise road grade, raise crown to improve surface drainage
- Subexcavation & replacement with rock over fabric or grid
- Chemically modify soil with Portland Cement
- Other Solutions?

Soft Spot Length, Depth & Strength

- Ask Blade operator
- Testing to determine length, depth & strength
- Stake it or take GPS tagged photos in the spring

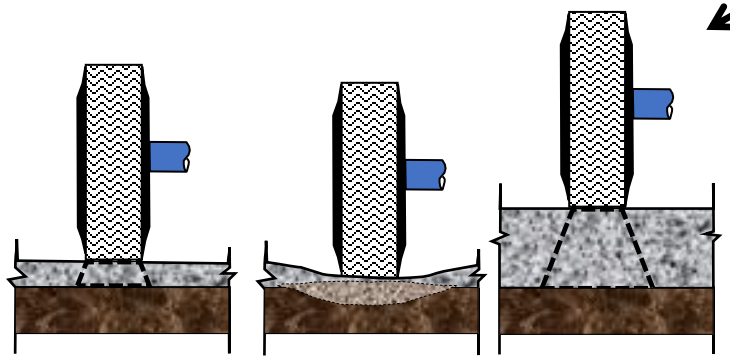


Options for Dealing with Weak Subgrades

Problem

Subgrade too wet

Subgrade overloaded



Subgrade Rutting

Possible Options

- Higher crown
- Gravel with clay
- Better roadside drainage
- Better subsurface drainage
- Increase gravel thickness

- Pit Run
- Pit Run with geosynthetic
- Cement/soil modification

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
  - Dense and well graded material can be achieved by mixing and compacting two or more soils
- Addition of a small amount of clay enables binding of the non-cohesive soils which increases strength
- Angular particles not round rocks increases compactability

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
  -

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
  - Magnesium Chloride or 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

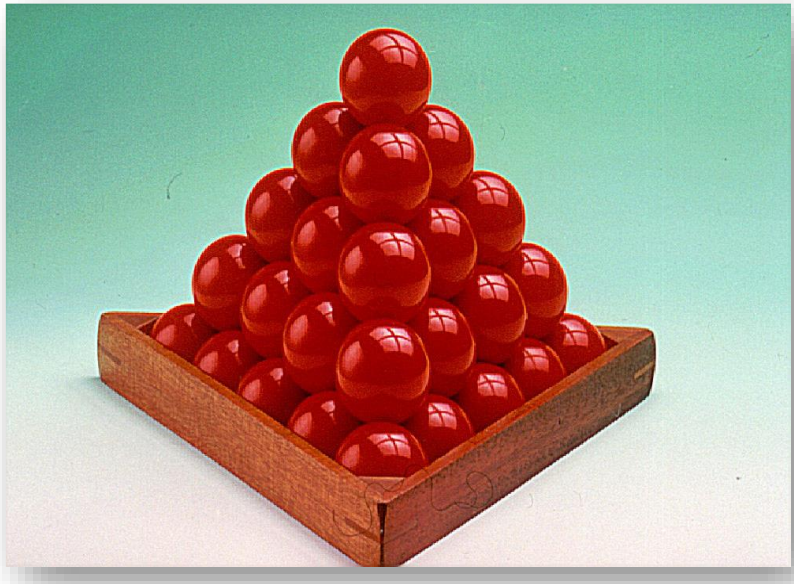
Geosynthetics in Roadway Foundations

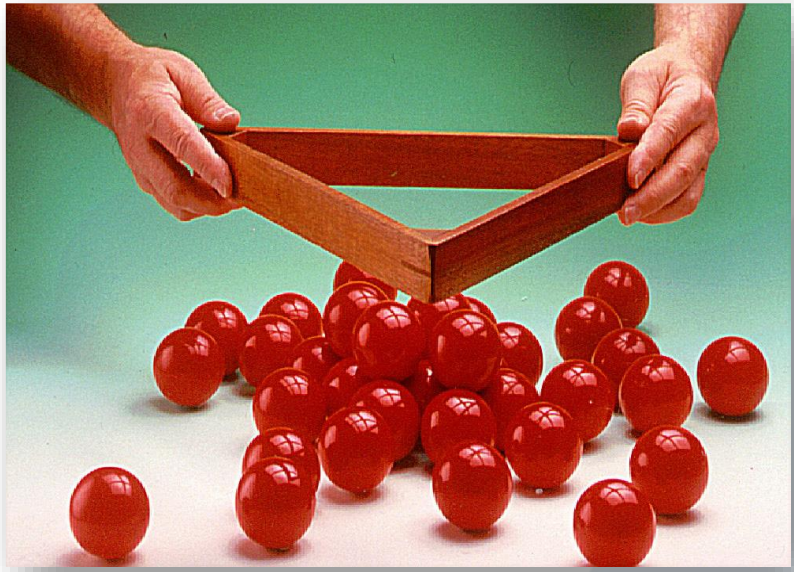
- Improve structural capacity to support traffic
- Preserve aggregate integrity and separation from subgrade
- Protect subgrade from overstress and further weakening
- Conserve valuable aggregate resources
- Prevent failure due to loss of subgrade strength

Geosynthetics

- Geogrids
- Geotextiles
- Geocells
- Geomembranes
- Geocomposites

Geogrid Function



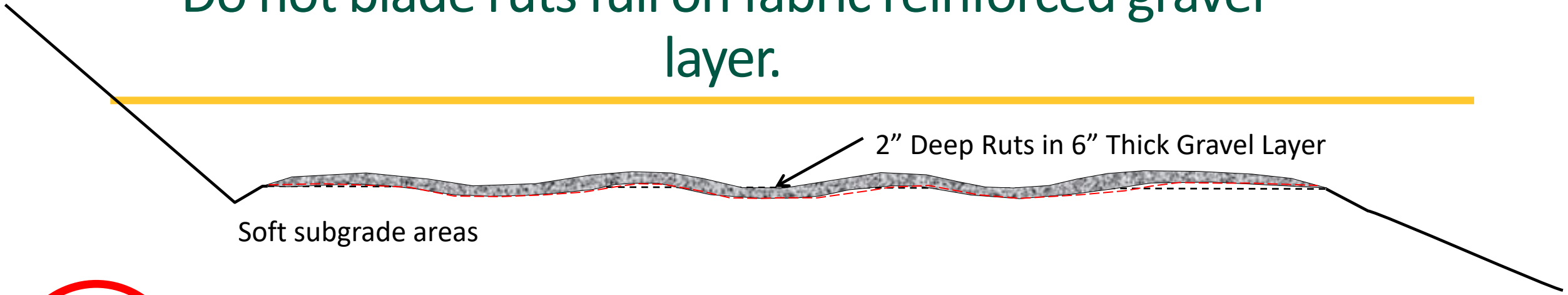


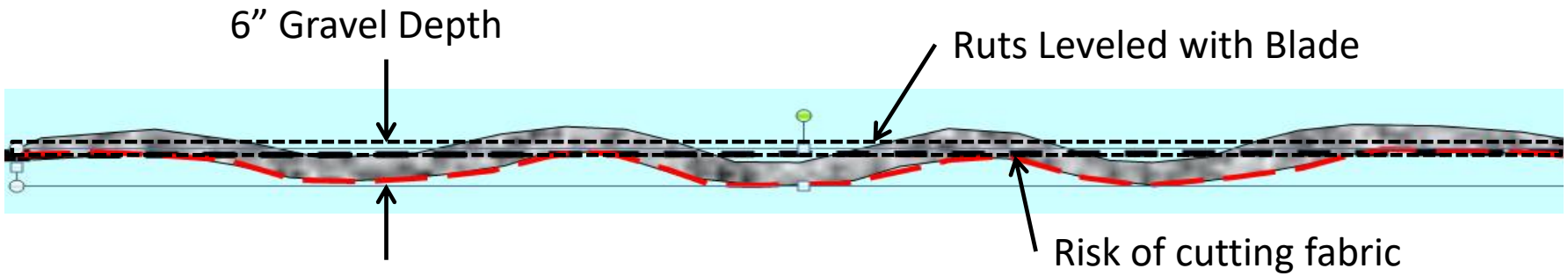
Tensar

Geosynthetic Advantages

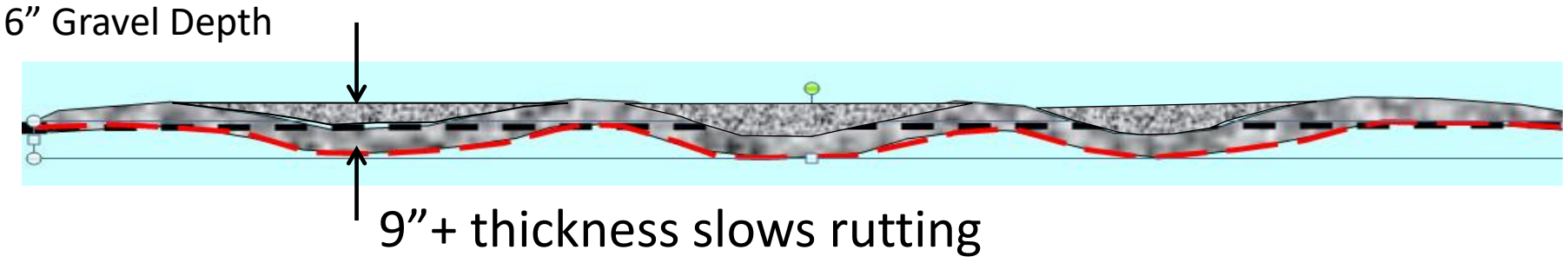
- Easy to install
- Readily available
- No special equipment, curing time or weather restrictions
- No chemical or weathering degradation

Do not blade ruts full on fabric reinforced gravel layer.





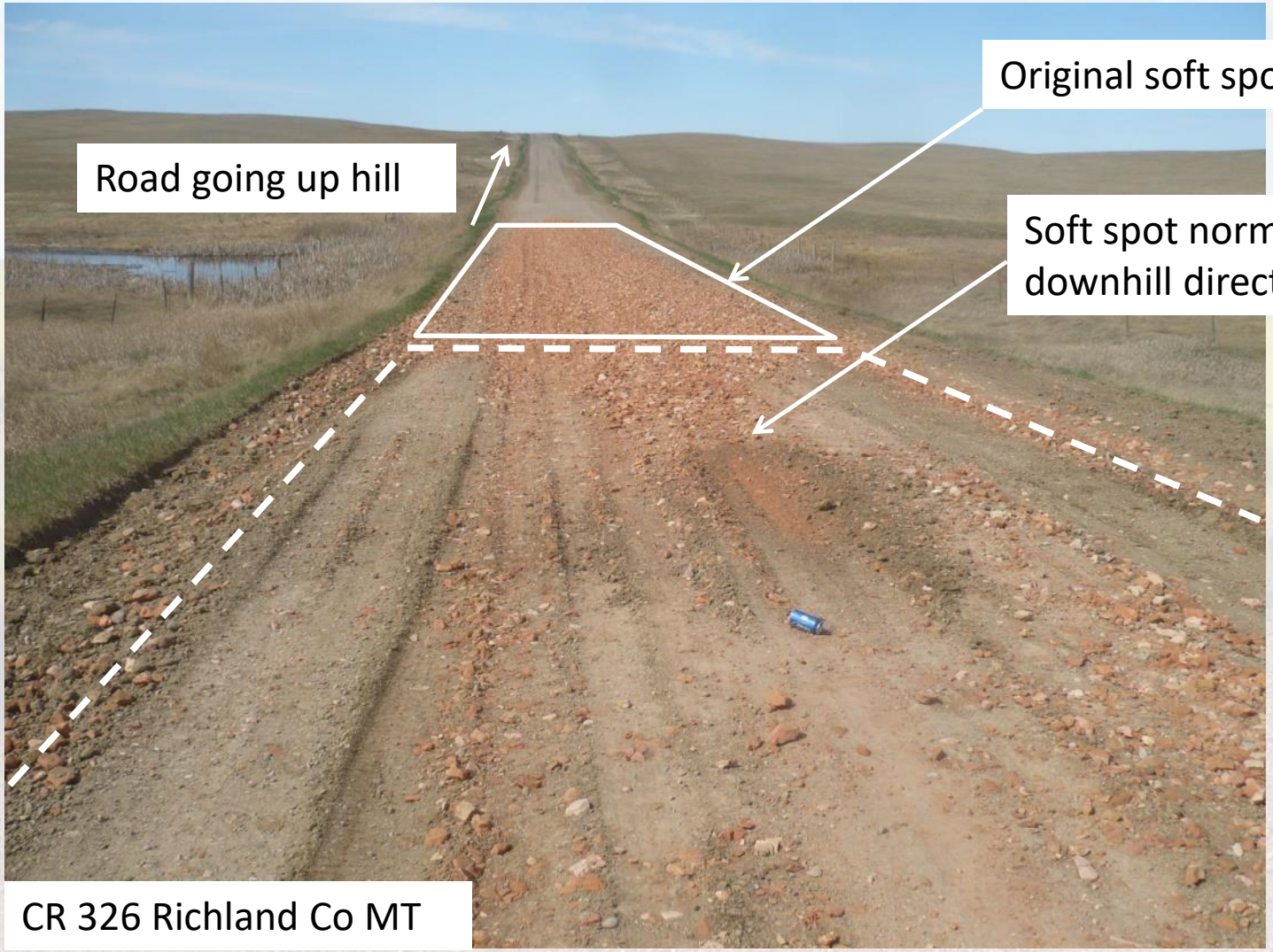
Haul in more gravel to fill ruts



Combination of Strategies

- Ultimately we need to use a combination of these strategies to obtain the desired result!

Wet Soft Spot Treatment with Pit Run



Subgrade Soft Spot Fix – Portland Cement

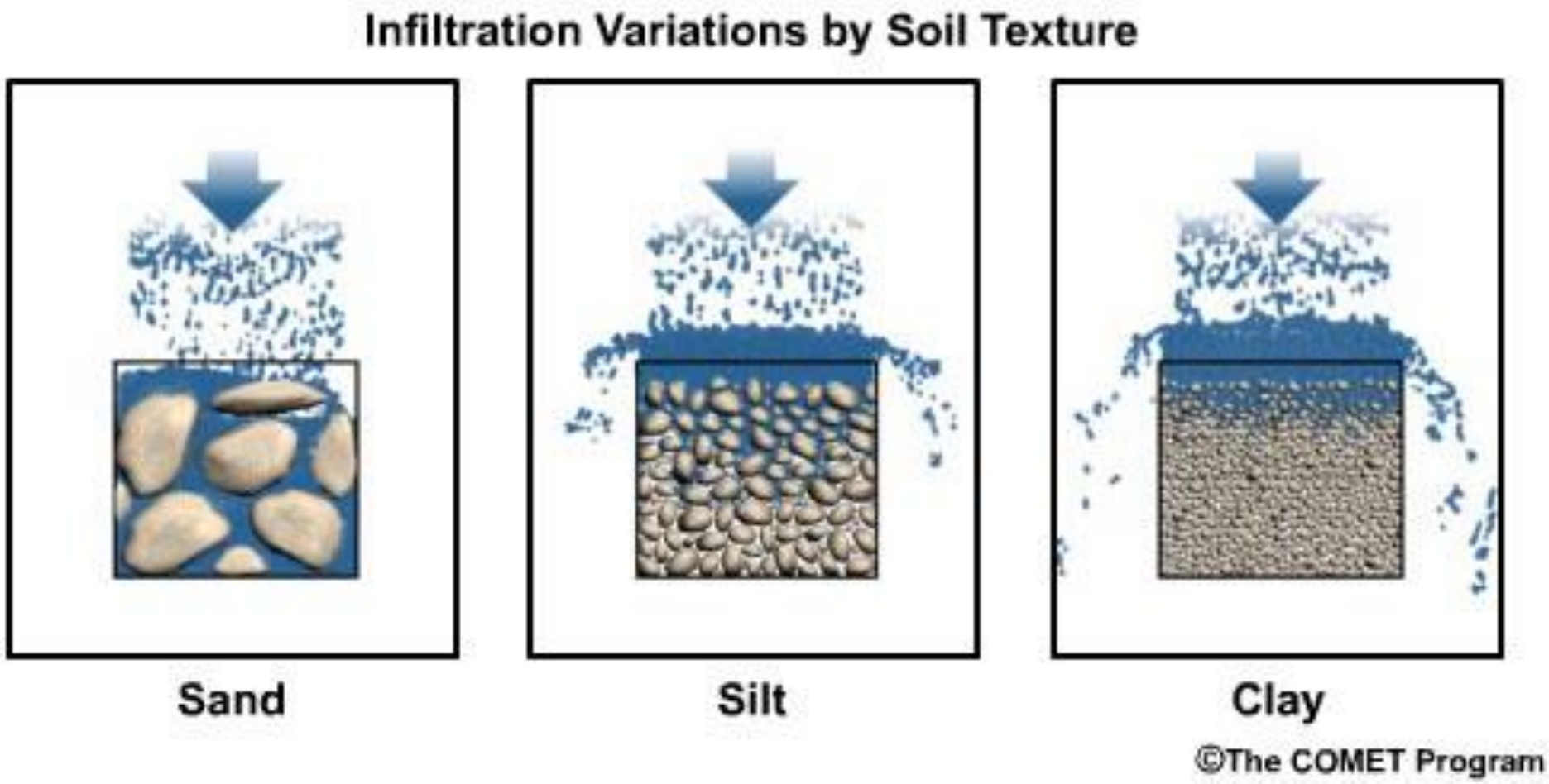
Tips for Getting Good Compaction

- Compact at the best moisture → use fragile cast method
- Heavier rollers can achieve higher densities
- Roll with proper equipment
  - Sheep foot for clays
  - Steel or rubber tire rollers elsewhere
- 3 MPH roller speeds increase compaction
- Watch for sponginess – If deflection and reflection occurs recompact underlying layer(s)
- Compact until no further deformation

Conclusions

- Solve surface drainage problems first
- Consider more permanent fixes to soft spots
- Become more familiar with geosynthetic products and portland cement
- Document performance

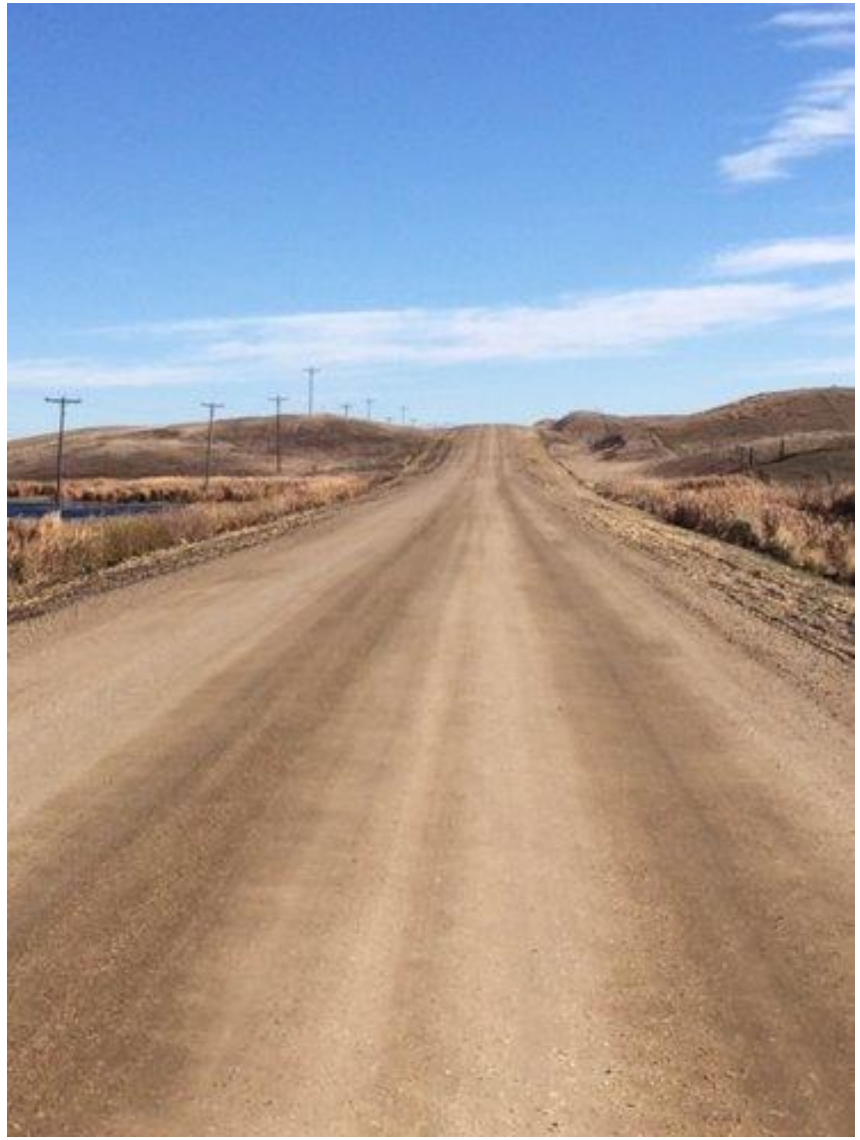
Gravel Quality – Gradation and Binder



Plasticity Index

Clay

The glue that hold the rocks and sand together



Questions?

Thank you!

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