Richland County "Oil Field" Road Problems, and Various Solutions 2006-2011

NDDOT/NDLTAP
Conference with Oil and Gas Producing Counties

Mandan ND

November 30, 2011

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Outline

- Richland Co Background Information
- Approach to Solution
- Pavement Designs and Alternatives Considered
- Preliminary Life Cycle Costs
- Thin BST 'Pavements'
- Construction and Quality Assurance (Separate Presentation)
- Construction and Maintenance Strategies
- Concerns
- Conclusions

County 2008 Mission

- Ensure Public Safety on Road System
- Meet Public Expectations
- Address air quality and DEQ concerns
- Adhere to GRAVEL stewardship for the next generations
- Find surfacing alternatives with better **cost/benefit**

The Problem

- Heavy Truck Traffic on Weak Soil Roads
- Extensive Road Network
- Limited Budget
- Limited Rock Resources

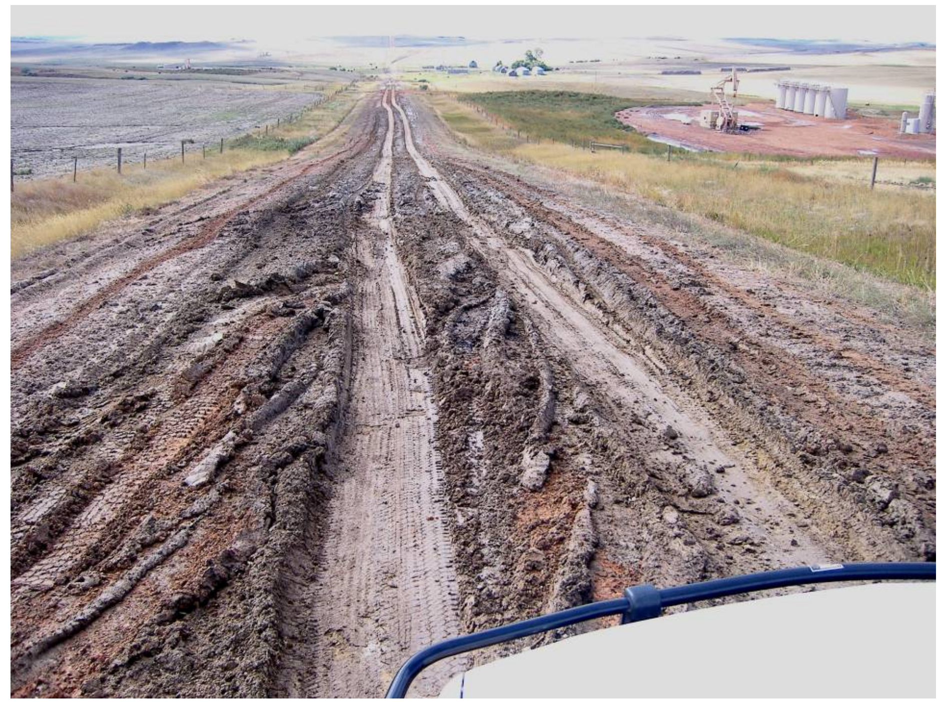
Local Standard

- 5” Asphalt, 8” Base Gravel
- 4” Gravel (New construction)
- Spot Graveling

(Haul 90 to 110,000 cy / year)

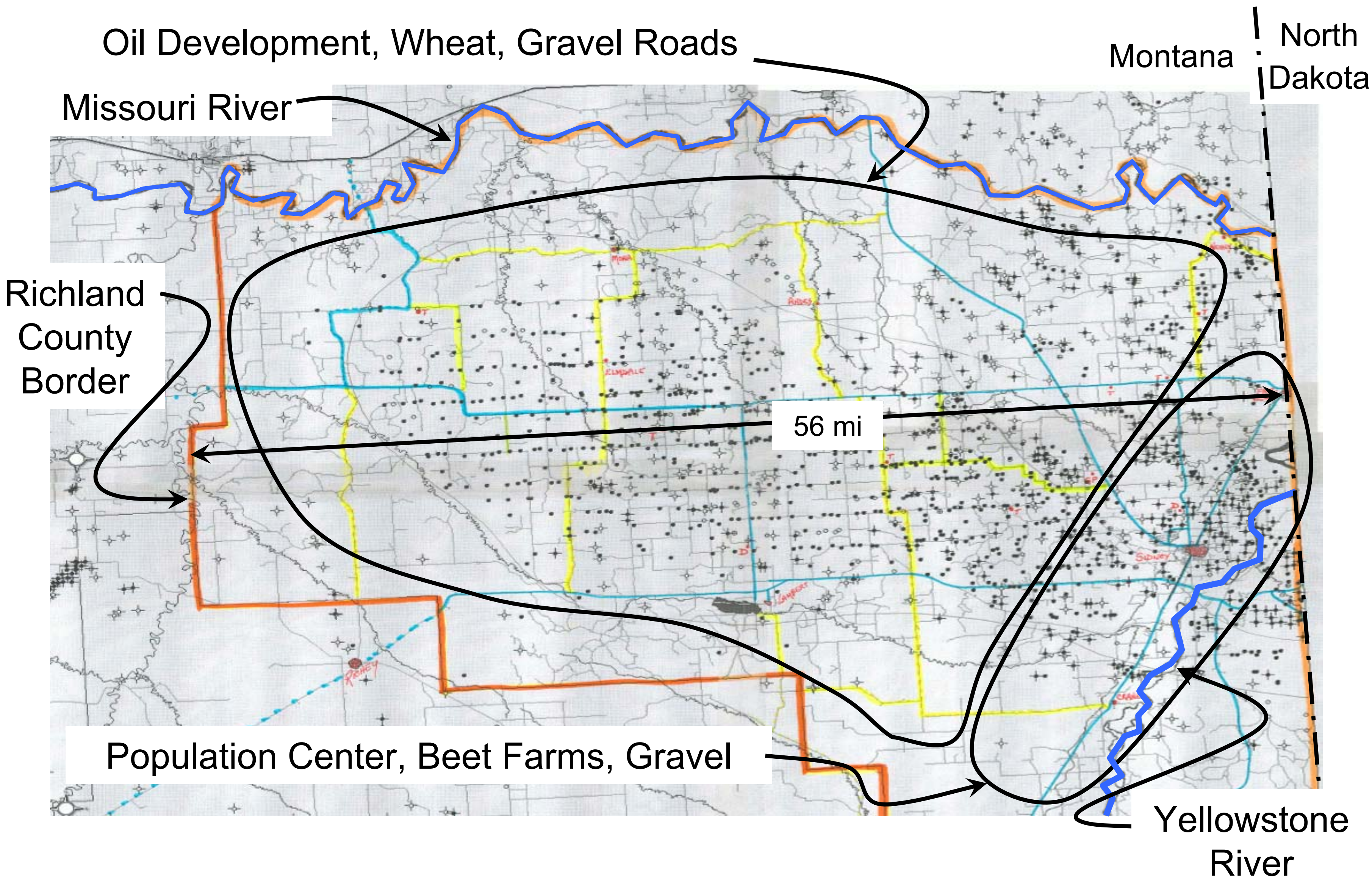
Weak Soils (CBR= 3 or 4 typical)

5" Asphalt, + 6" Base (15 yrs old)



3" Scoria, old gravel base (after 3 months)

Richland Co Road Network & Resource Impacts



Road Network Miles & ADT

- Function Class Miles: 1132 (341 Bus Routes)

Arterials:	86
Major/Minor Coll:	232
Local:	701
Trails:	113

Hot Mix:	40
Surface Treat:	10
Gravel:	968
Dirt :	235

- CI Plan: Collectors (with) Bus Routes = 131.2 mi
  : Improve 20-25 mi. / year
- Truck Traffic
  - Ag Traffic: Beets (Sept & Oct), Cattle, & Grain hauling
  - Oil Field:
    - Well development: 1200 trucks over 3 months (each well)
    - Crude & Water Haul: 3 to 5 trucks/day for 25 years

Structural Thickness Design

		Inches of Gravel			
Soil Strength	Excellent	4	7	9	12
	Good	7	9	12	16
	Fair	9	12	16	20
	Poor	12	16	20	24
Trucks/Day→		**50**	**100**	**150**	**200**

Gravel Thicknesses are based on:

- **Soil Strengths**
- **Truck Traffic**
- **AASHTO 93 Guide**

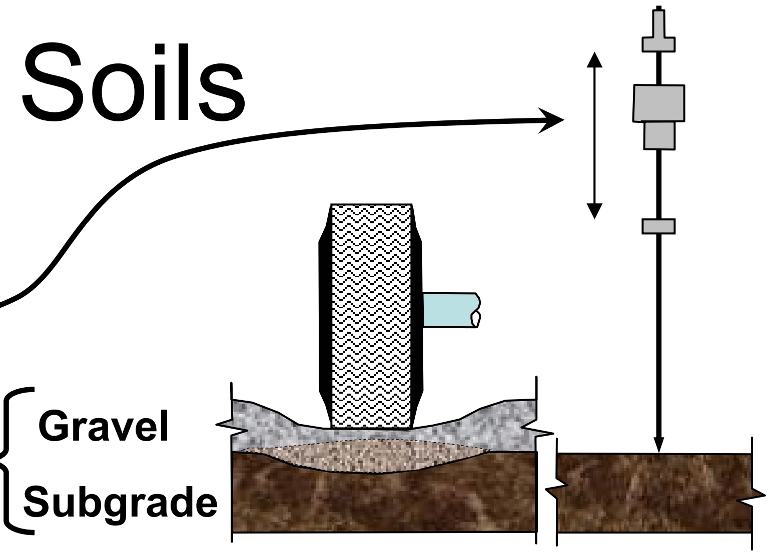
For Example: Rd 127 had 71 Trucks per Day ~ Thickness required is 14

Risk	Factor, %	Route Type
Low	60%	Feeders, detour route available
Moderate	80%	Collectors, detour route available
High	100%	Arterials, no detour, school bus routes

Weak Clay Subgrade Soils

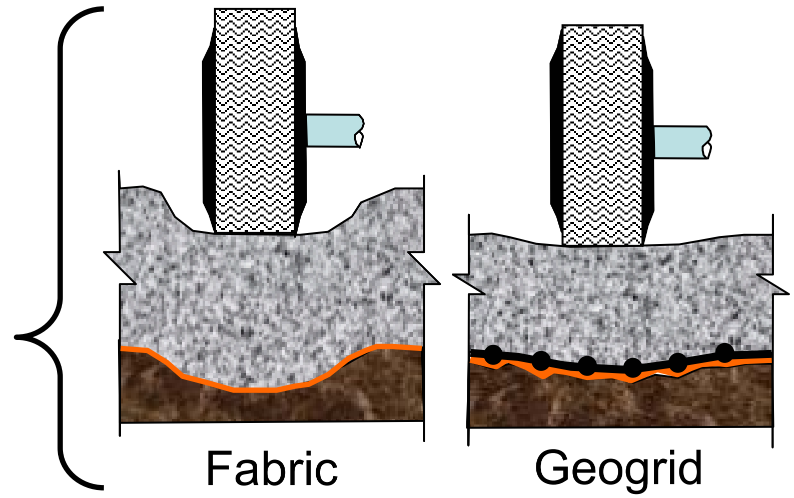
Soil Strength by DCP:
CBR of 1 to 6

Thin gravel layers mix with clay

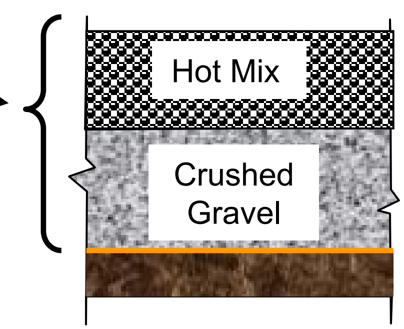


Gravel $ Too High

Gravel with Fabric & Geogrid



Standard Paving Design



Approach to Solution

- Outside Assistance
  - Construction Management Contract (Century Companies)
  - Engineering Consultants (Interstate Engineering, Boesh, Monlux, Holman)
- Design structural sections based on subgrade strengths, truck traffic and available materials
- Consider all alternatives and materials available
- Build trial sections that have low initial cost
  - Test to estimate life and life cycle costs
  - Rebuild isolated areas that fail

Structural Design & Cost Info

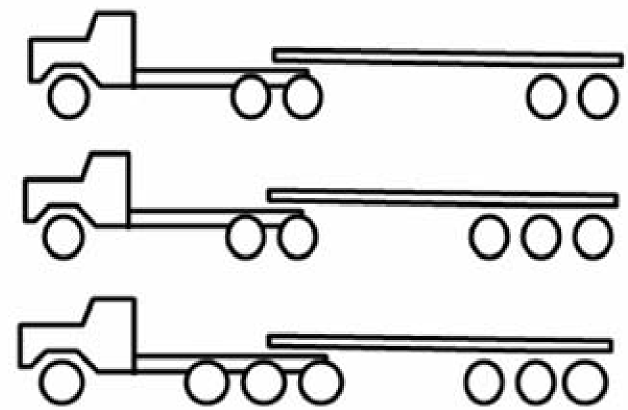
- Subgrade
  - Predominant soil type – Lean Clay
  - Design Strengths ~ CBR of 3 to 6
- Truck Traffic
  - ADT – Variable, unpredictable, increase after improvements
  - Loads normally exceed legal limits
  - No load limit enforcement during winter/spring thaw
- Economics
  - Aggregate – very costly due to haul and shortages
  - Maintenance Costs – unknown for some alternatives
  - Funding – inadequate for scope of problem

Truck Loading & Pavement Life

Truck ESAL Calculations *

Heavy Weight Tandems

Gross Wgt, lbs	Number of Truck Axles		
	5	6	7
40,000	0.40	0.38	0.36
80,000	3.37	2.30	1.22
100,000	6.2	4.2	2.1
120,000	13.9	8.7	3.6
140,000	26.6	16.6	6.5
160,000	51	31	12
180,000	91	55	19
200,000	147	89	32



*From AASHTO 93 Guide, with p_t = 2.0 and SN = 4

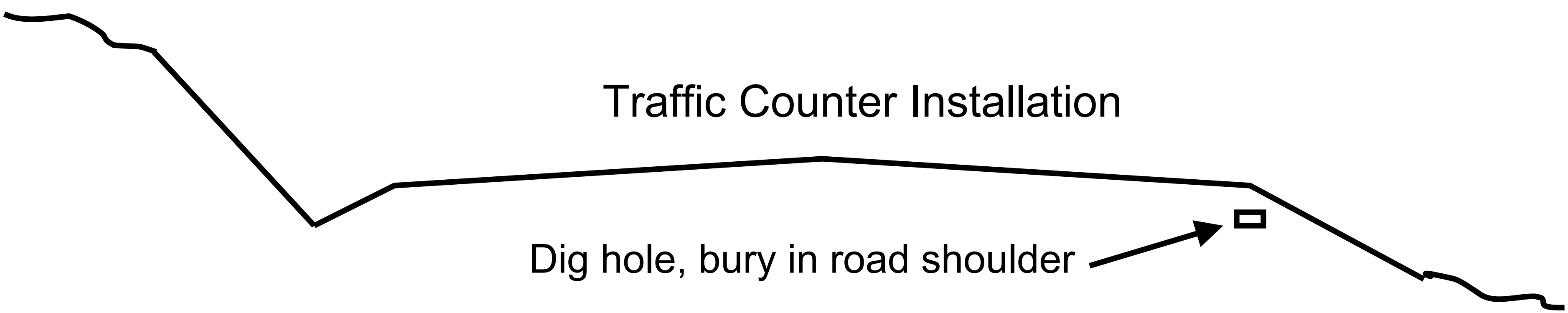
Winter/Spring Breakup Issues

- Frost depth prediction – thermal conductivity (Solid Rock > 3.5)
  - Hot Mix & Base Layer ≈ 1.7 to 2.1
  - Soil Cement and Soil ≈ 0.9 to 1.2
- Tools for predicting time of thaw and length of time for reduced load limits http://www.fs.fed.us/eng/pubs/pdf/00771805.pdf

Traffic Counting and Classification

- Traffic Counts
  Critical for route priority
- Classification (% Trucks)
  Critical for structural designs

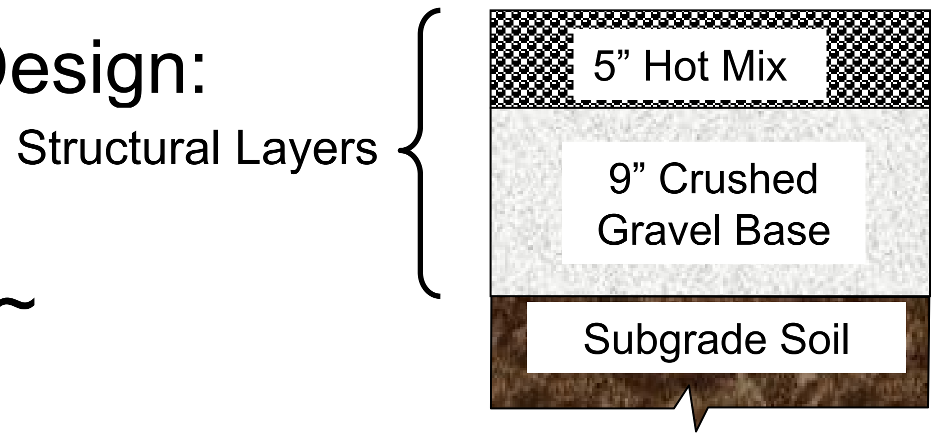
Magnetic Sensor Traffic Counter (www.trafx.net) ~ works 14 months on 3 'C' cell batteries



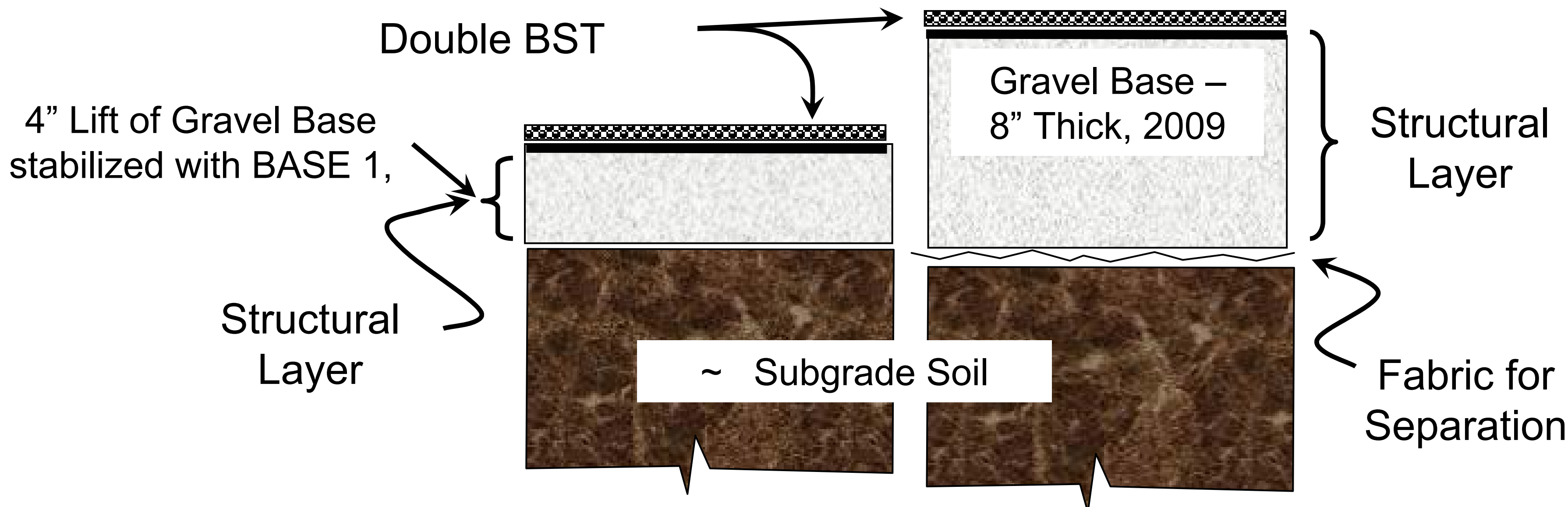
GRM D4

2006-2009 Designs

Traditional Pavement Design:
Rd 328 (2006)



Low Initial Cost Design ~
Thin BST on Base



Alternatives Considered ~ 2010 & 2011

- Improve Subgrade
  - Increased Subgrade Compaction → minor benefit
  - Stabilization
    - **Portland Cement** → Lab mix designs promising
    - **Fly Ash** → Billings & Sidney fly ash had low strengths
    - Lime → Cement preferred for low Plasticity soils
    - Bottom Ash, Sugar Beet Lime, Enzymes, etc → unsure, inconsistent benefits
- Base Rock
  - **Fabric** → prevents clay contamination
  - Geogrid → unsure benefits with high truck traffic
  - BASE 1, Enzymes, etc → unsure, inconsistent benefits
- Asphalt Surface
  - Hot Mix
  - **BST**

2010 Trial Sections

BST (1.5 miles)

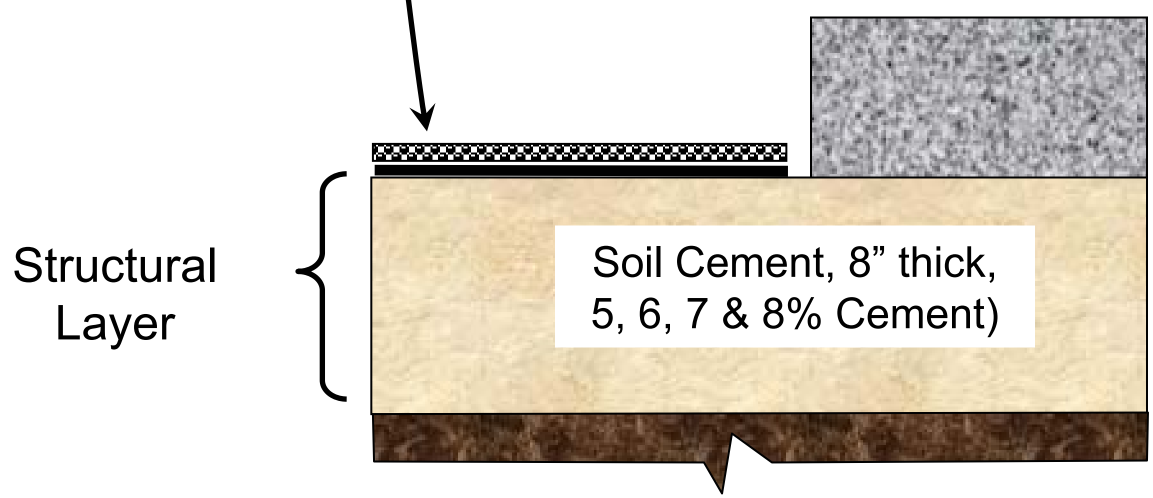
Chips with AC & MC over Fabric (0.25 mi)

& Gravel with HF Emulsion (1.0 mi)

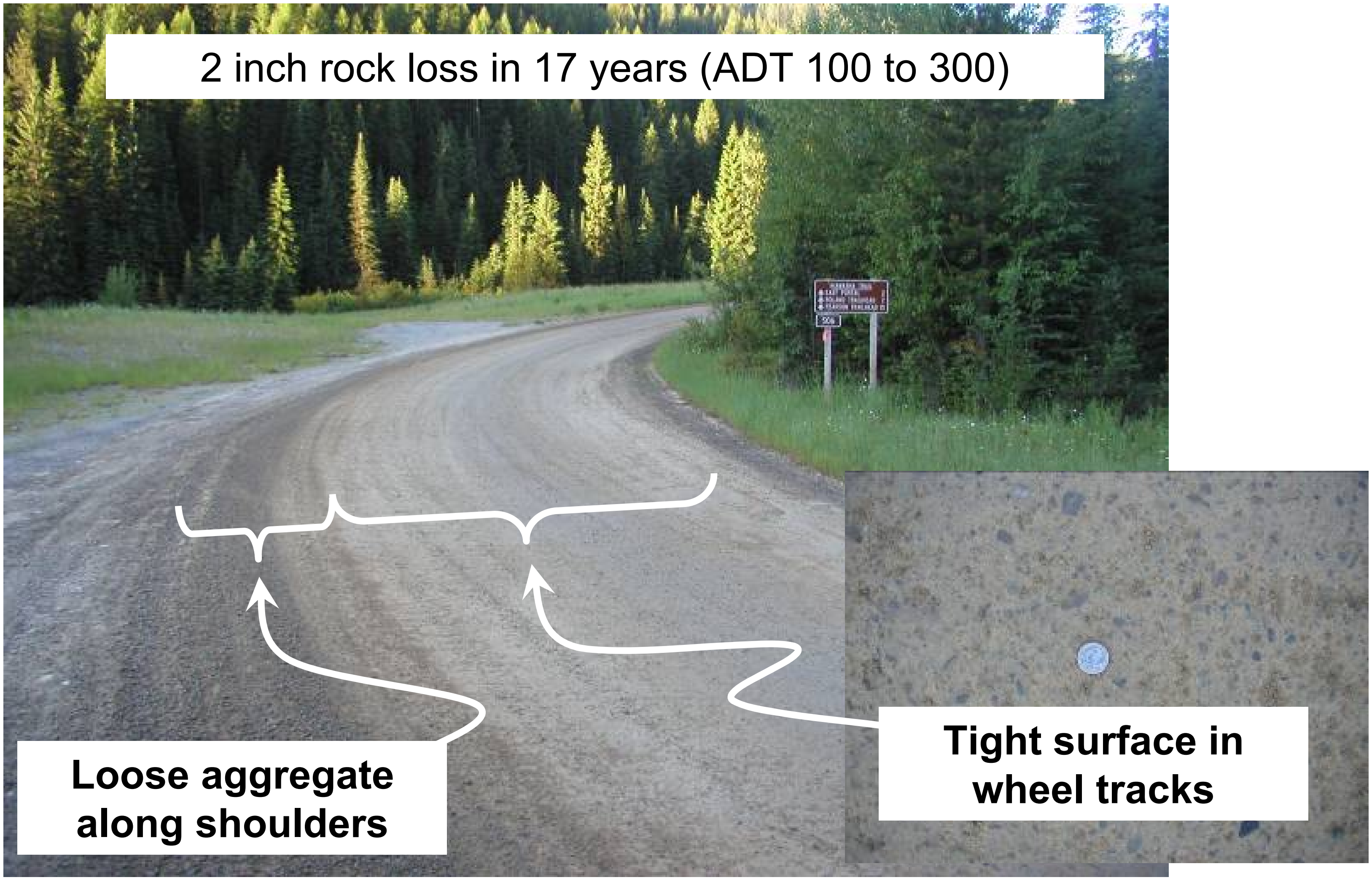
Treated Gravel (3.5 miles)

Additives: 3% Bentonite &

1.5% Calcium Chloride

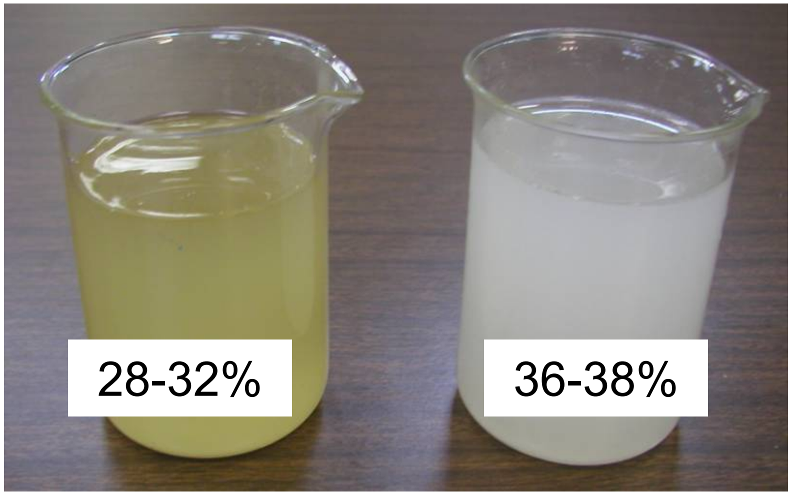


USFS, Rainy Creek Road

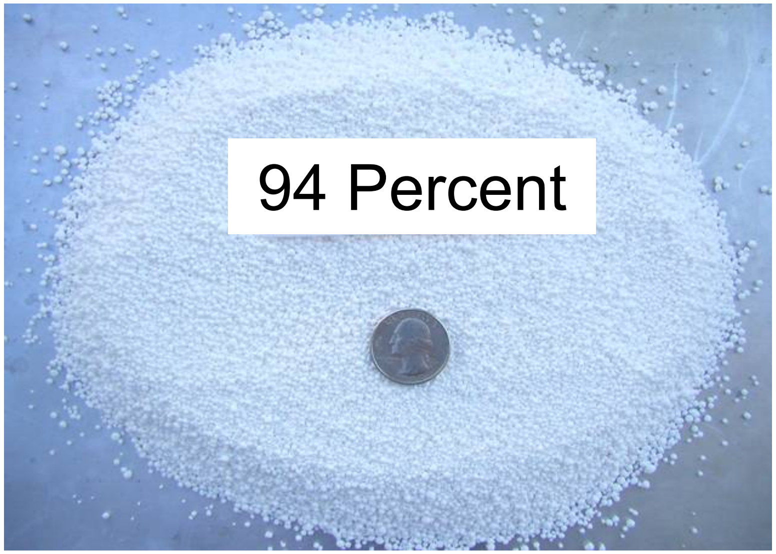


Chloride Salt Dust Control

Magnesium & Calcium Chloride Liquid



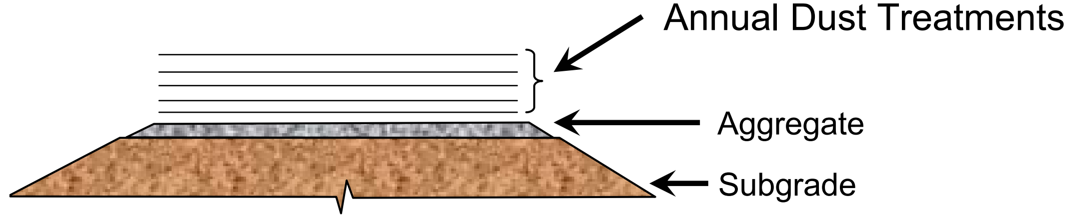
Dry Calcium Chloride Solid



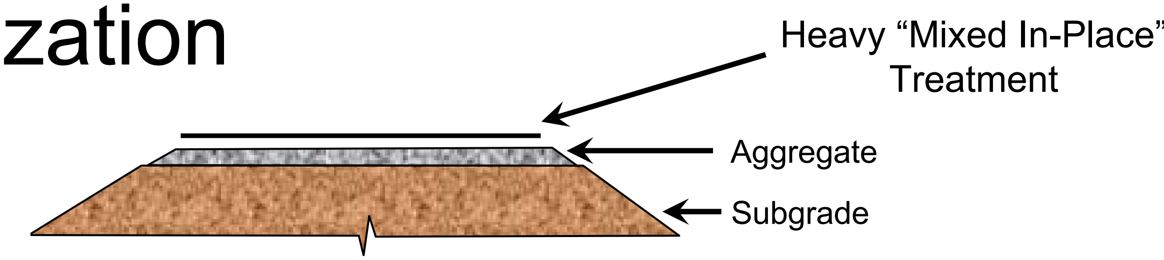
Chloride Treatment Techniques

- Purpose
  - Reduce dust
  - Reduce rock resource depletion
  - Reduce costs (less blading & rock replacement)

- Annual Dust Treatments



- Heavy Stabilization Treatment



Dust Treatments vs Stabilization

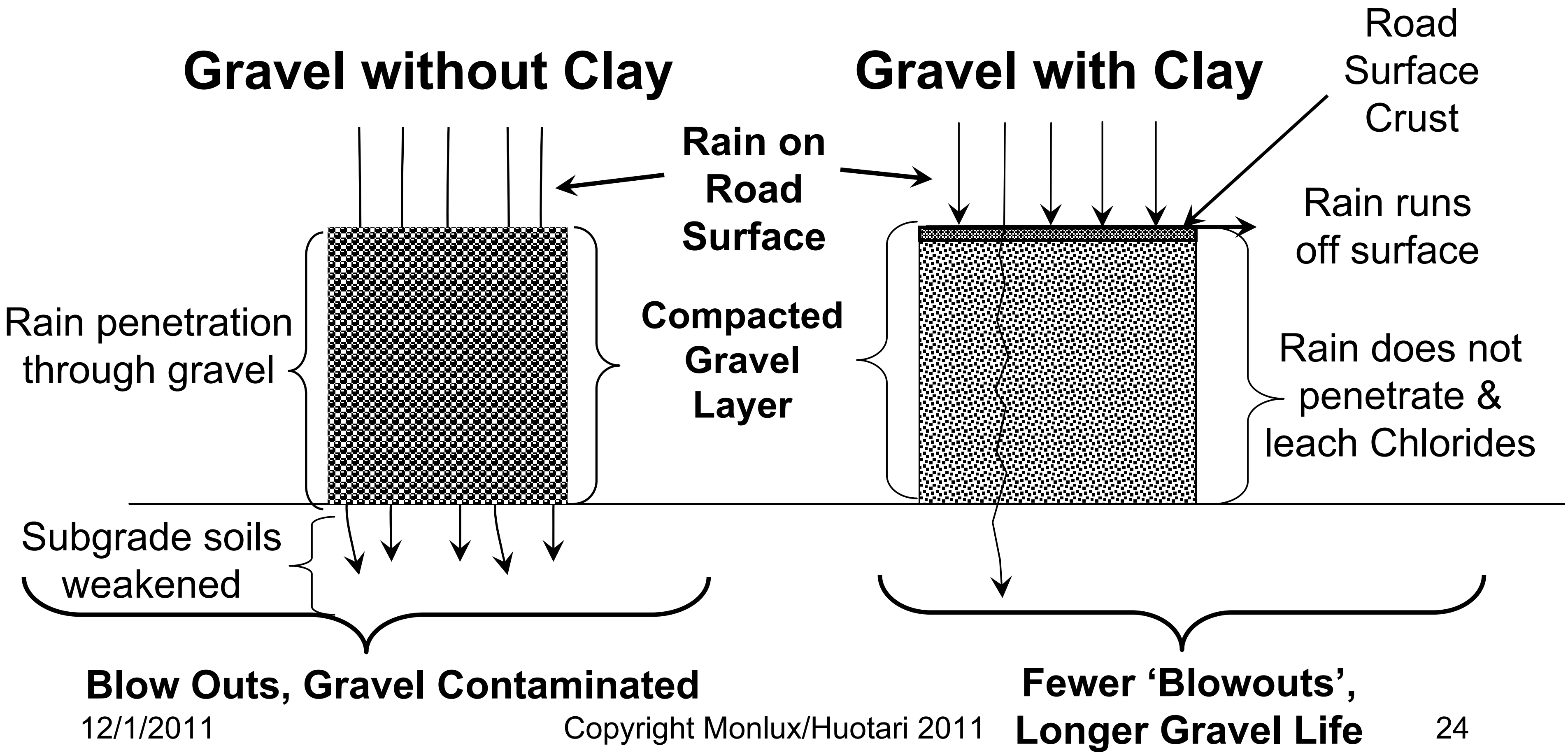
- Gravel suitability
  - Run chloride retention prior to stabilization
- Annual dust treatment
  - Pro: More chloride at road surface
    Good for light traffic
  - Con: Greater long term cost
- Stabilization with light treatment every 3 to 5 yrs
  - Pro: Less dusting, raveling, wash boarding
    Good for heavy haul roads – saves money
    Less blading and rock replacement
    Greater public satisfaction
  - Con: High initial cost.
    Only suitable for good gravel gradations

Additives/Fillers for Clean Gravels

- Purpose:
  - Reduce permeability
  - Improve chloride retention
- Bentonite Clay
  - Envirogel 12, Wyo-Ben
  - Similar to Cat Liter
- Bag House Fines (mineral filler)
  - By-product of asphalt mix manufacture
  - 70 to 80 % pass #200
  - Non Plastic
- Others
  - Crusher Reject
  - Roadside Soil, Pulverized
  - Fly Ash and Bottom Ash
  - Lime Kiln Dust
  - Etc, etc

Clay Binder

- Fills voids in gravel, forms road crust, sheds rain, retains chloride
- Chloride keeps clay from dusting

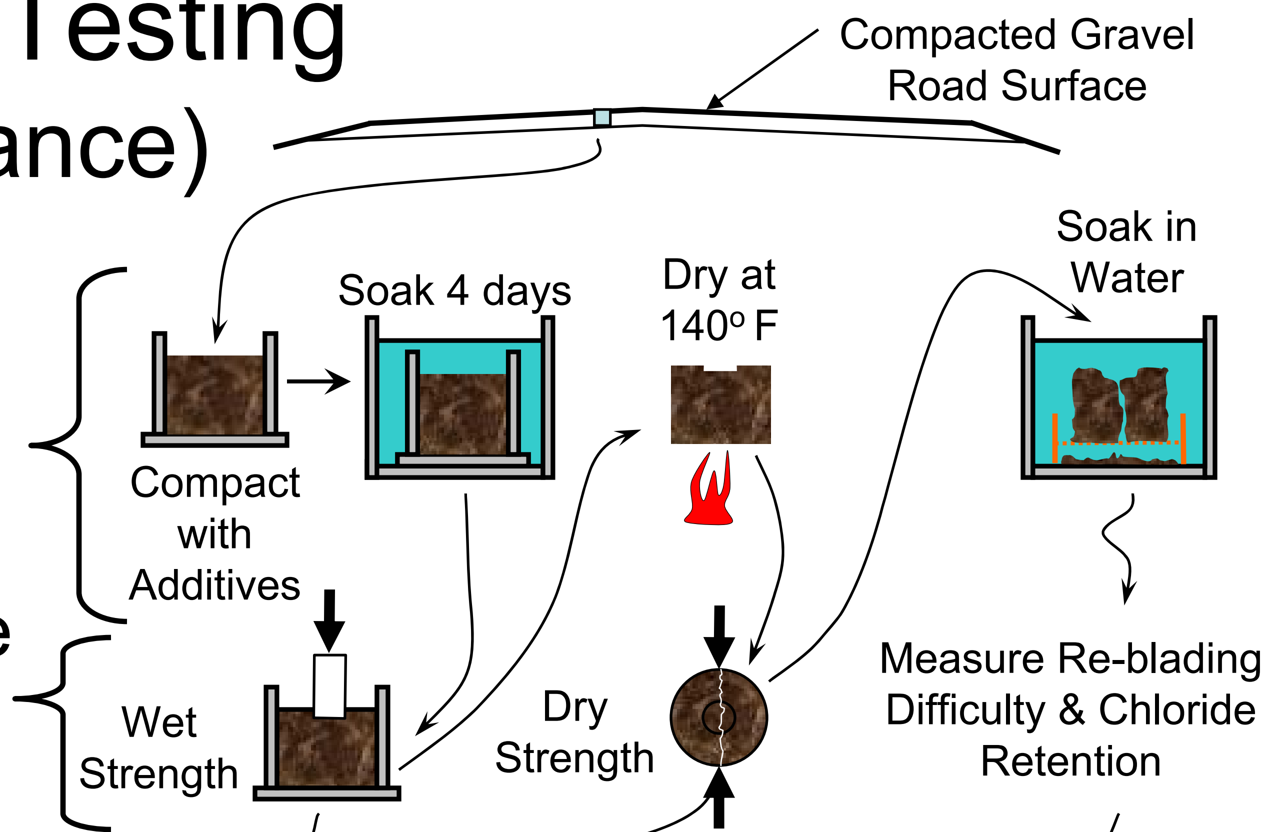


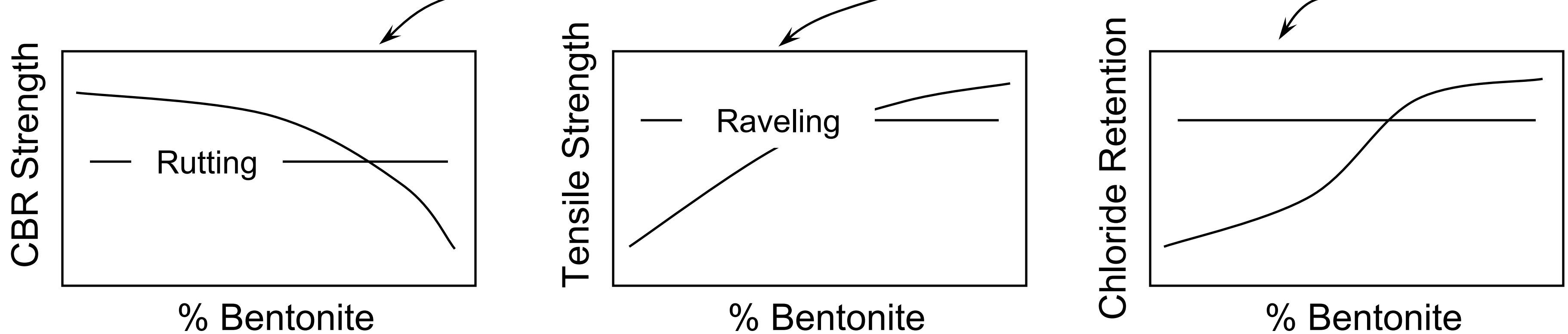
Mix Design Testing (cheap insurance)

Duplicate field conditions in lab

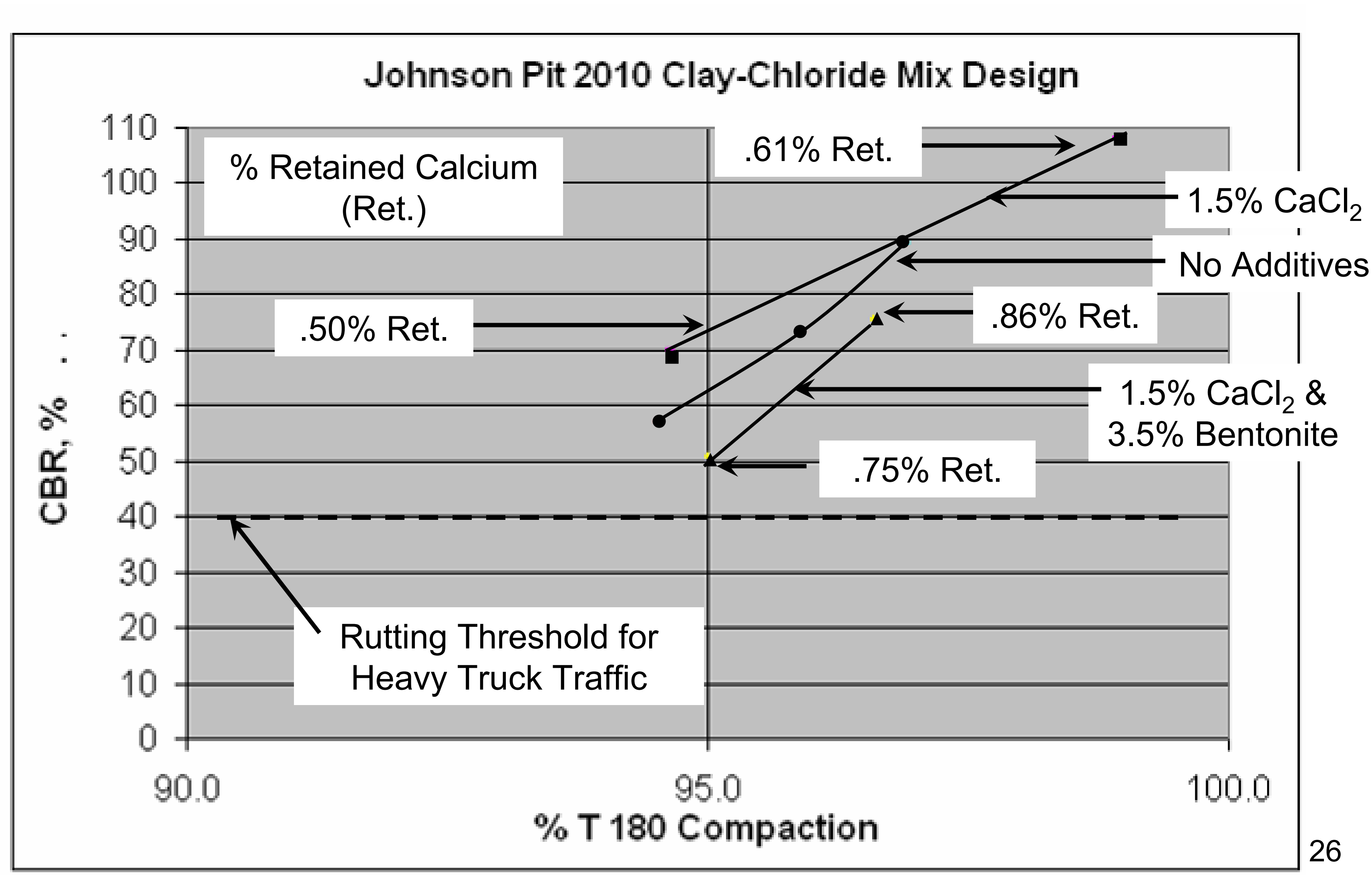
Test to measure properties

Plot curves





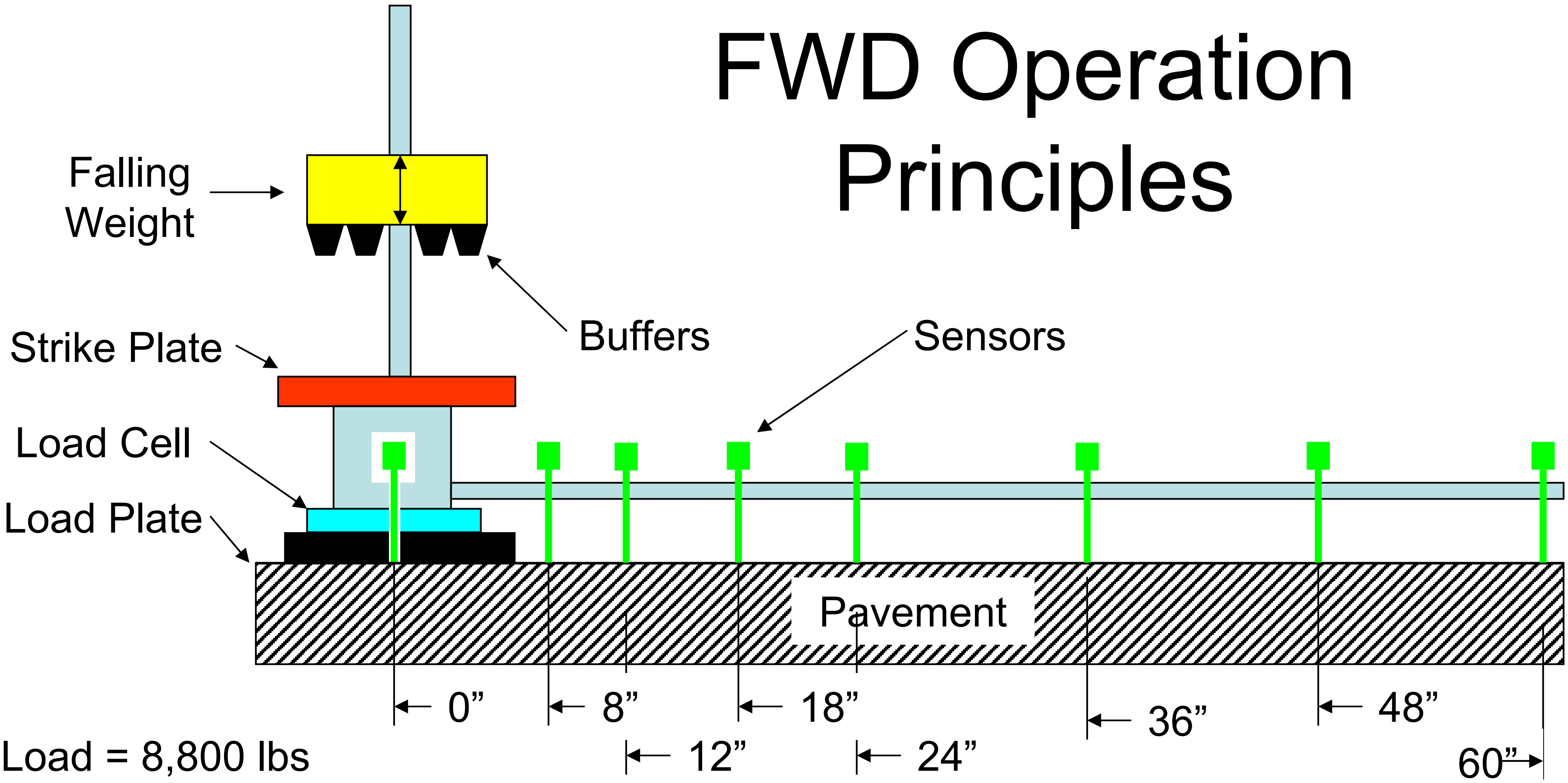
Lab Mix Design
Gravel, Bentonite & Calcium Chloride



Performance Measurement (Strength Testing)

~ MDT Falling Weight Deflectometer (FWD) ~

FWD Operation Principles

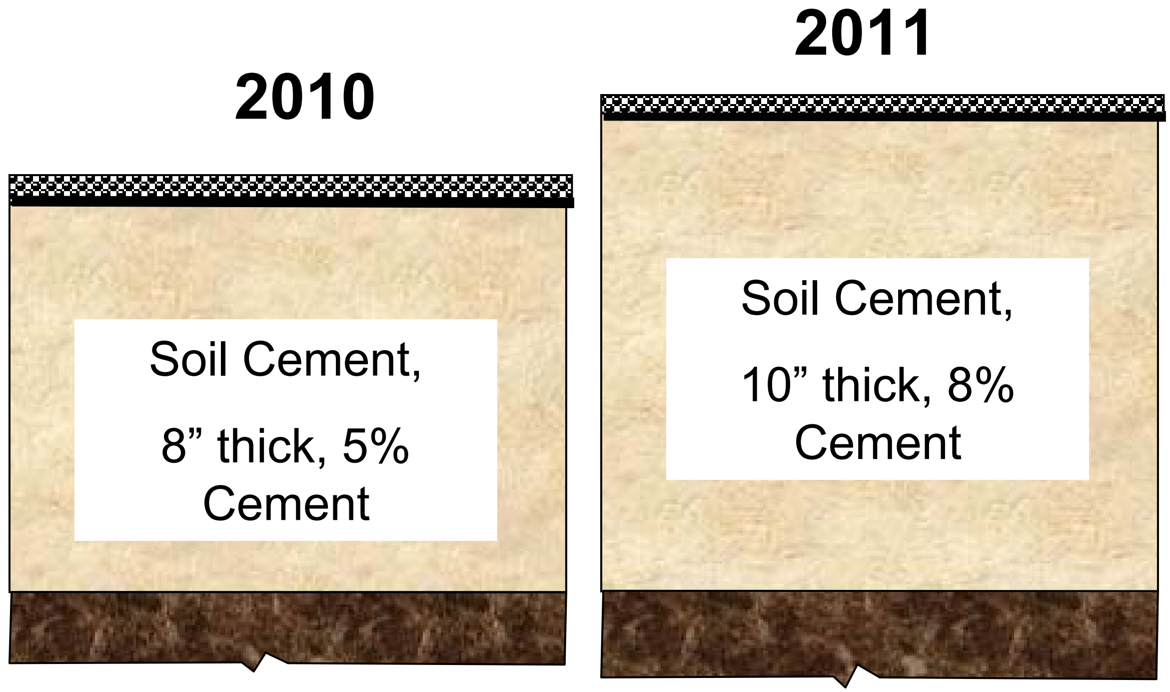


Load = 8,800 lbs

Distance from Load	0”	8”	12”	18”	24”	36”	48”	60”
Deflection, mils	23.1	16.1	13.3	9.9	7.9	4.7	3.5	2.8
Subgrade M_R, Ksi	na	16.4	13.2	11.9	11.2	12.4	12.5	12.0

M_R = 0.24 x Load/(deflection x distance from load) Note M_R of 12 = CBR of ≈ 8

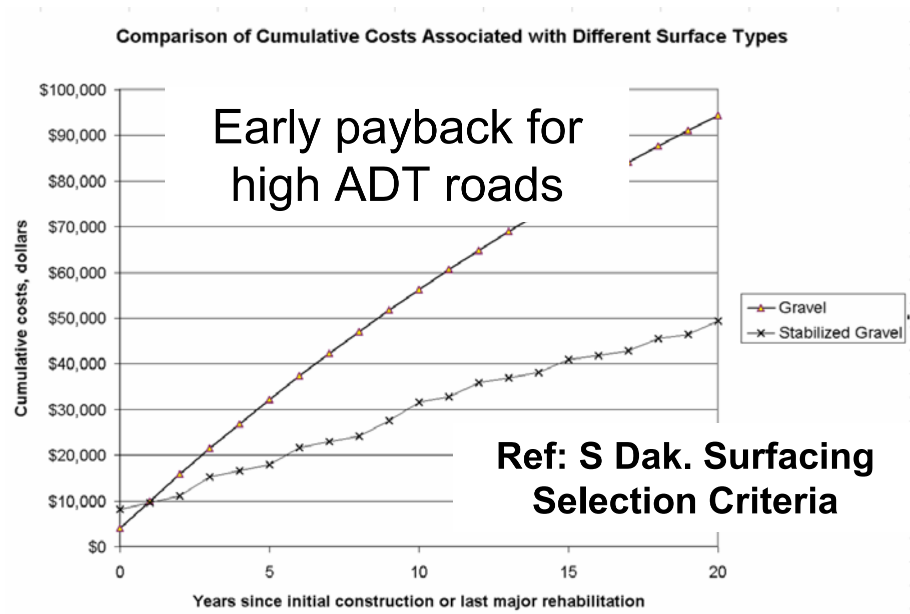
2010 & 2011 Soil Cement Designs



Compressive Strength	225 psi	300 psi
Freeze Thaw Durability	Marginal	Good
Flexural Strength		56% Increase

Life Cycle Costs

- Primary Cost Inputs
  - Construction
  - Maintenance
  - Road User
- Life Prediction
  - Empirical thickness design methods
  - FWD back calculation
- Cumulative life cycle costs per mile
- Cost per ESAL/mile or Truck/mile



Preliminary Cost Comparison

Option		Life by FWD (80,000 GVW trucks) (a)	Costs/Mile (b)		
Surface	Support Structure		Construc tion	Ann Mtc	Per Truck
5" Hot Mix	9" Base on Fabric	600,000	$900,000	?	$1.50

(a) Based on Spring 2011 FWD back-calculation, better info available in 2012 (Note that 75 Trucks/day ≈ 20,000/yr)

(b) Costs are very project specific

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Double Chip BST	10” Base on Fabric	100,000	$400,000	?	$4.00(c)

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(c) Base thickness inadequate – see next slide

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Double Chip BST	10” Base on Fabric	100,000	$400,000	?	$4.00(c)
Double Chip BST on Fabric	10” Soil Cement (8% Cement)	1,000,000	$300,000	?	$0.30
Double Otta Seal BST			$285,000	?	$0.29
Treated Gravel		2,000,000	$400,000	? (d)	$0.20

(a) Based on Spring 2011 FWD back-calculation, better info available in 2012 (Note that 75 Trucks/day ≈ 20,000/yr)

(b) Costs are very project specific

(c) Base thickness inadequate – see next slide

(d) Gravel replacement & treatment costs are likely high, replacement frequency variable

Structural Requirements for BST Pavements (WSDOT - LE)

Max Traffic (80,000 GVW Trucks)	Subgrade Condition	Base Thickness, inches
50,000	Poor	18
	Average	13
	Good	12
125,000	Poor	21
	Average	16
	Good	12
250,000	Poor	24
	Average	18
	Good	13

WSDOT Flexible Pavement Layer Thicknesses Design Table for New or Reconstructed Pavements - LOW ESAL LEVELS
(English Version)

Design Period ESALs	Subgrade Condition	Layer Thickness[1] (feet)			
		HMA Surfaced		BST Surfaced	
		Reliability = 75%		Reliability = 75%	
		HMA Surface Course	Crushed Stone[2]	BST	Crushed Stone[2]
< 100,000	Poor	0.25	0.85	0.08	1.50
	Average	0.25	0.75	0.08	1.10
	Good	0.25	0.75	0.08	0.90[5]
100,000 to 250,000	Poor	0.30	0.95	0.08	1.75
	Average	0.30	0.70	0.08	1.30
	Good	0.30	0.70	0.08	1.00
250,000 to 500,000	Poor	0.35	1.00	0.08	2.00
	Average	0.35	0.65	0.08	1.50
	Good	0.35	0.65	0.08	1.10

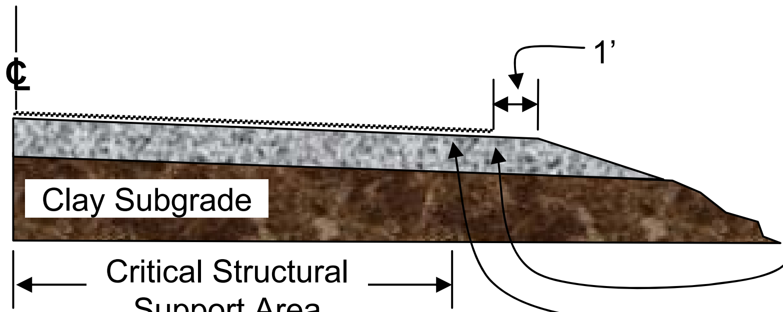
1. Based on the 1993 AASHTO *Guide for Design of Pavement Structures* for flexible pavements with the following inputs:
   $\Delta PSI = 1.7$ $a_{BST} = 0.20$
   $S_D = 0.50$ $a_{crushed\ stone} = 0.13$
   $m = 1.0$
   Subgrade condition (effective modulus):
   Poor: M_R = 35 MPa (5,000 psi)
   Average: M_R = 70 MPa (10,000 psi)
   Good: M_R = 140 MPa (20,000 psi)
2. Gravel borrow may be substituted for a portion of crushed stone when the required thickness of the crushed stone is at least 245 mm. The minimum thickness of crushed stone is 105 mm when such a substitution is made.
3. The assumed elastic modulus for BST (EBST) is 690 MPa (100,000 psi)
4. The assumed thickness for all BST layers is 25 mm (1 inch).
5. Crushed stone thickness increased to a total pavement structure of approximately 305 mm (1.00 ft) based on moisture and frost conditions.

Subgrade Condition	Modulus M_R, psi	CBR
Poor	5,000	3.5
Average	10,000	7
Good	20,000	13

Gravel Base or Soil Cement?

BST over 10” Gravel Base

$ 400,000/mile, $4/Truck (*)



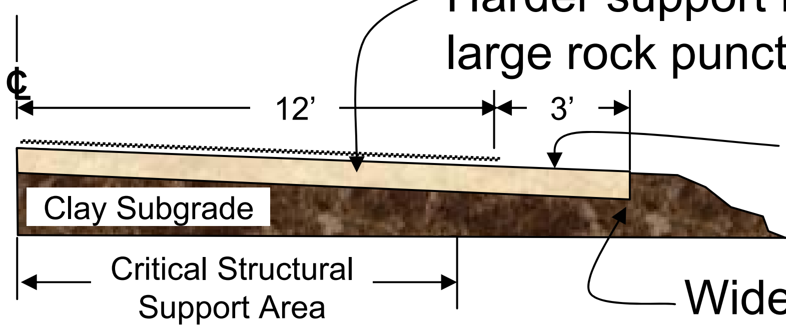
Water infiltration to Clay Subgrade is close to structural support area

Edge cracking & break off mtc. problems

BST over 10” Soil Cement

$250,000 /mile, $0.30/Truck(*)

Harder support from soil cement reduces damage from large rock punctures, turning movements, etc



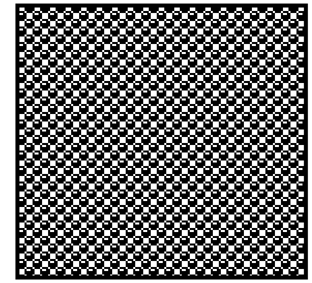
Flatter wider shoulder is less of a hazard

Wide impermeable shoulder keeps surface water further away from critical structure support area.

(*) Maintenance Cost ??

Thin vs. Thick Asphalt Layers

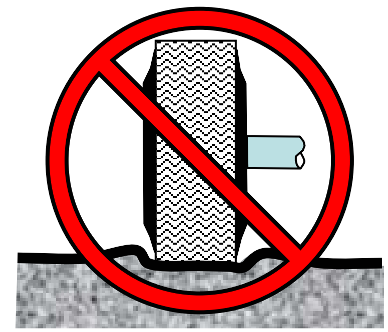
3” Hot Mix



- Thin BST/Otta Seals (3/4” thick)

¾” BST

  - Lower costs for construction, maintenance, recycling & replacement
  - Suited for low traffic & cold climates ~ more flexible & less cracking
  - Good wear surface, no structural strength
  - Quick failure from overloads during thaw



Overloads cause Failures

- Thick Asphalt Pavements (>3” thick)
  - Stronger ~ supports greater loads
  - Poor option directly on top soil cement
- Warning – Both thick & thin options must have good structural support and drainage

Rock Used for Double BST

5/8” & 3/8” Clean Chips

Cost/Mile ≈ $75,000 (Double Shot with Fabric)

AC (PG-58-28): 0.85 gal/SY

MC-3000: 0.40 gal/SY:

Total Chip #/SY: 45#/SY & 27 #/SY

5/8” Gravel – Otta Seal

Cost/Mile ≈ $60,000 (Double Shot)

Total HF 125S: 0.82 gal/SY

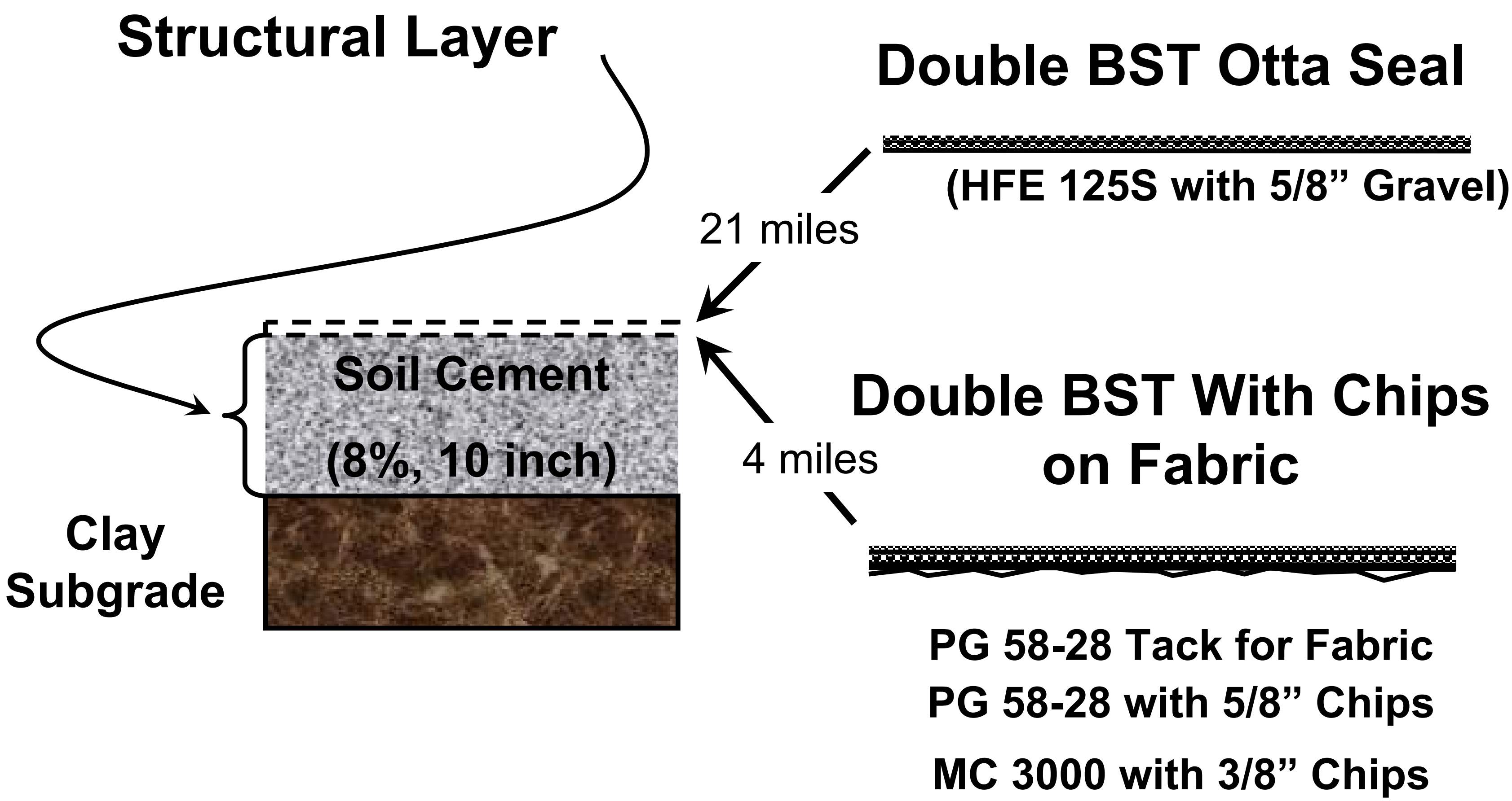
Total Gravel: 70 #/SY

Double BST Options

Otta Seal BST
with Gravel

Clean Chip
BST

2011 Work ~ BST on Soil Cement



Otta Seal Materials Specs

High Float Emulsion Spec (5-4-2011)

Requirement	HF125S (Note A)	
Tests on Emulsion	**Min**	**Max**
Viscosity, Saybolt Furol, Seconds at 50° C	35	150
Residue by Distillation, % by Mass	65	
Demulsibility, %, 50 ml 0.1 N $CaCl_2$	75	
Oil Portion of Distillate, volume/Mass, %	1.0	4.0
Sieve Test, % by Mass		0.1
Storage Stability Test, 24 hr, % by Mass		1
Coating Test	Note B	
Coating ability & water resistance ASTM D244:		
Coating, dry aggregate	good	
Coating, after spraying	fair	
Coating, wet aggregate	fair	
Coating, after spraying	fair	
Adhesion Agent, % by Weight of Residue	Note C	
Tests on Distillation Residue		
Penetration at 25°C, 5s, 100g	125	225
Solubility Trichloroethylene % by Mass	97.5	
Float Test at 60°C, s	1200	
Apparent Specific Gravity at 60°C, Pa.s		
Ductility, 25°C, 5cm/min, cm	40	

Note A: Certificate of Compliance and test reports are required.

Note B: Follow ASTM D244, except that the mixture of limestone and emulsified asphalt shall be capable of being mixed vigorously for 5 minutes, at the end of which period the stone shall be thoroughly and uniformly coated. The mixture shall then be completely immersed in tap water and the water poured off. The stone shall not be less than 90% coated.

Note C: The emulsion must include an adhesion agent and suppliers should cover costs for such in their bids. The actual amount of adhesion agent must be determined by ASTM D 244 with aggregate from the planned source after contract award."

Proposed Gradation Limits (5-4-2011)

Sieve Size	Richland Co Spec		MN Otta Seal Spec	
	Min	Max	Min	Max
3/4"			100	
5/8"	100	100		
1/2"	82	94	84	100
3/8"	69	86	70	98
#4	48	67	44	70
#16	23	38	15	38
#40	14	26	7	25
#200	4	10	3	10

Soil Cement Construction Spec

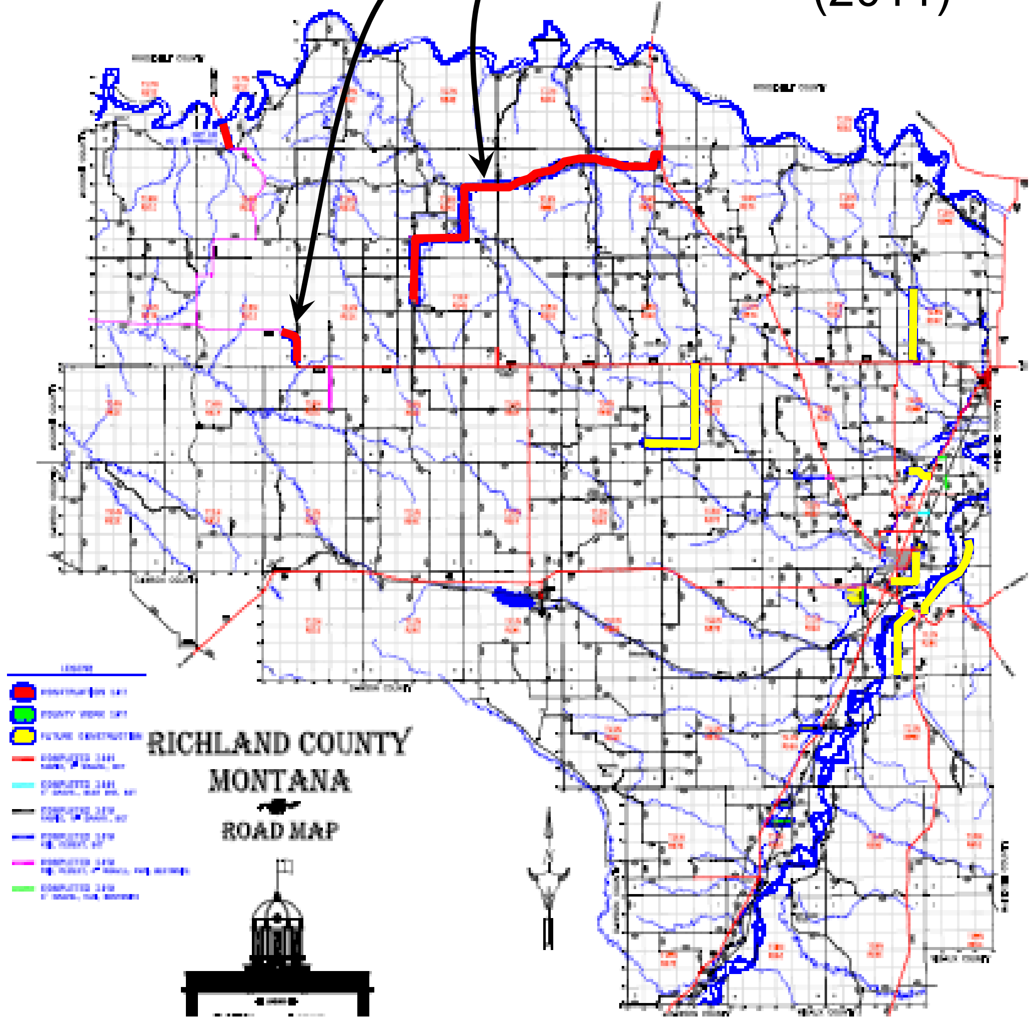
- Made from PCA, DOT, FHWA specs
- Reviewed by five stabilization contractors
- Sections
  - Materials
  - Equipment
  - Quality Control & Assurance
  - Construction (12 subsections)
  - Measurement & Payment

2011 & 2012 Projects

BST over Soil Cement 25 miles (2011)

2011 Work

Future Construction (tentative)

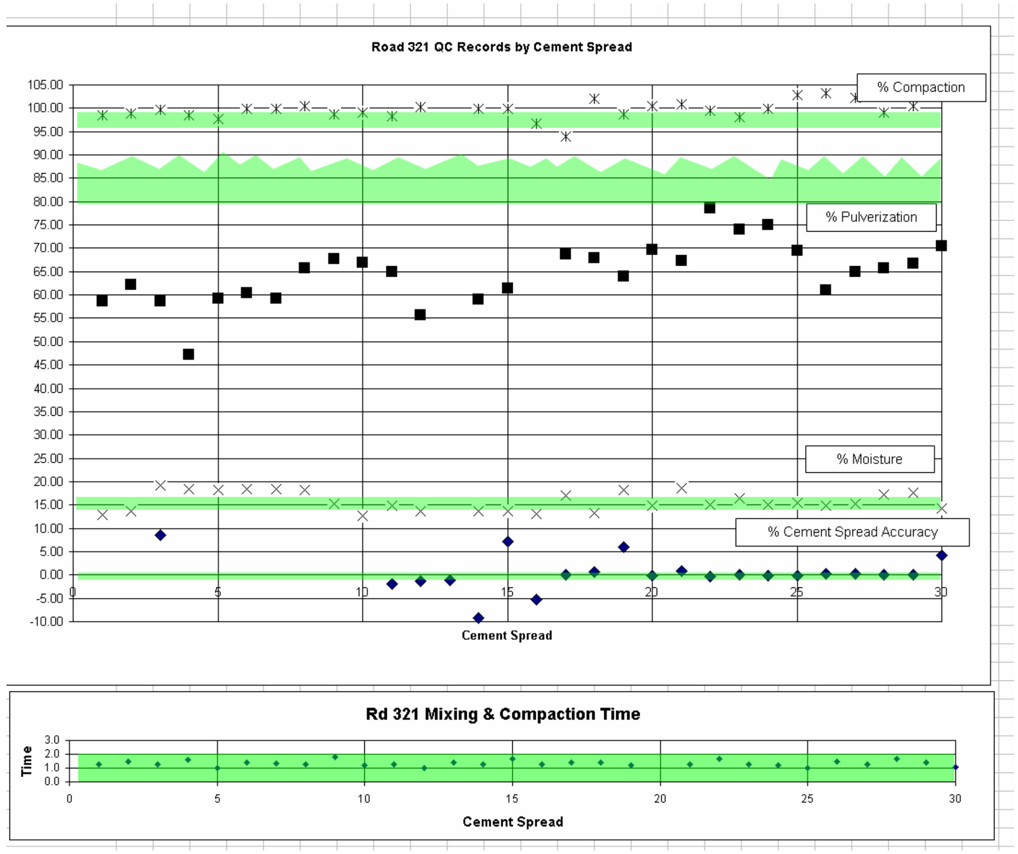


Soil Cement Construction

- Test Strip
- Road Preparation
- Reinforcement of Weak Subgrade
- Cement Spreading
- Mixing Cement & Water
- Compaction
- Final Shaping & Compaction
- Curing
- Traffic Control

Soil Cement Quality Assurance

- Cement application rate
- Pulverization
- Depth of mixing
- Moisture content during mixing
- Compaction
- Surface Finish
- Curing



BST Quality Assurance

- Application Rate Design
- Road Surface Prep
- Sampling asphalt and aggregate
- Distributor & Spreader Uniformity Tests
- Yield Tests
- Adjustment of Application Rates
- Brooming

Construction & Maintenance Strategies

- Construction
  - All Roads:
    - Remove all secondary ditches and roadside vegetation
    - Modify soft spots with cement
  - Arterials
    - Rebuild to proper geometric standards
    - Stabilize soil with cement and BST
- Maintenance & Repair: Arterials
  - Surface wear: Seal coat
  - Structural problems
    - Grind up failed areas
    - Mix in new cement, asphalt emulsion, gravel, or ?
    - Build new BST surface

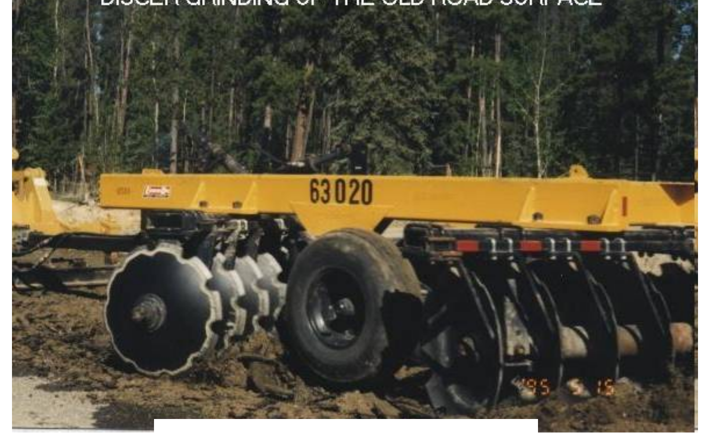
BST over Base ~ Rehab Strategy

- Rip and disc or grind up failed BST pavements
- If BST was rutting, add more base (or cement)
- Rebuild BST

RIPPER AND DISCER TEAR UP THE OLD ROAD SURFACE

Johnson Co WY, Courtesy, Oxford Inc, Moyie Springs ID

DISCER GRINDING UP THE OLD ROAD SURFACE



Yukon Territory

Suggestions for Soil Cement/BST Construction

- Rebuild arterials to proper geometric standards
- Indicate ride will not be as good as hot mix – ride depends on blade operator skills
- Utilize detailed spec
- Mandatory prebid meeting
- Project foreman must attend prework meeting
- Plan to spend 5% on QA
- Build and maintain “As Built” plans

Concerns/Unknowns

- Structural Designs
  - No ability to predict truck traffic volumes
  - No control of heavy loads
  - No control during winter/spring breakup
- Soil Cement
  - Long term freeze/thaw durability and cracking
  - Repair and reconstruction costs/techniques
- BST: Maintenance seal frequency
- Funding: May not keep pace with network destruction

Conclusions

- Costs
  - Although there are unknowns with soil cement, it appears to be a promising cost effective alternative
  - Consider soil stabilization if rock costs are high
  - Gravel stabilized with clay & chloride can be cost effective
  - Estimated life cycle costs are useful
  - BST and Otta seal cost less to build and maintain than hot mix **if** structural support and drainage are adequate
- Technical assistance on soil cement
  - Don’t rely on PCA, Consultants, Contractors
  - Locate qualified independent personnel
  - Utilize TRB publications

Conclusions

- Testing
  - FWD testing of soil cement strength and durability for life prediction is critical
  - Amount of QA/QC needs depend on contractor, site conditions, weather, etc
- Design
  - BST over soil cement is better option than hot mix due to cracking
  - Fabric under chip seal reduces cracking & increases life
- **Document performance and share information**

Richland County Task Force

- **Russ Huotari - Richland Co**
- **Josh Johnson - Interstate Engineering**
- **John Twedt, Troy Kelsey - Century Companies**
- **Steve Monlux – LVR Consultants**

Questions/Comments