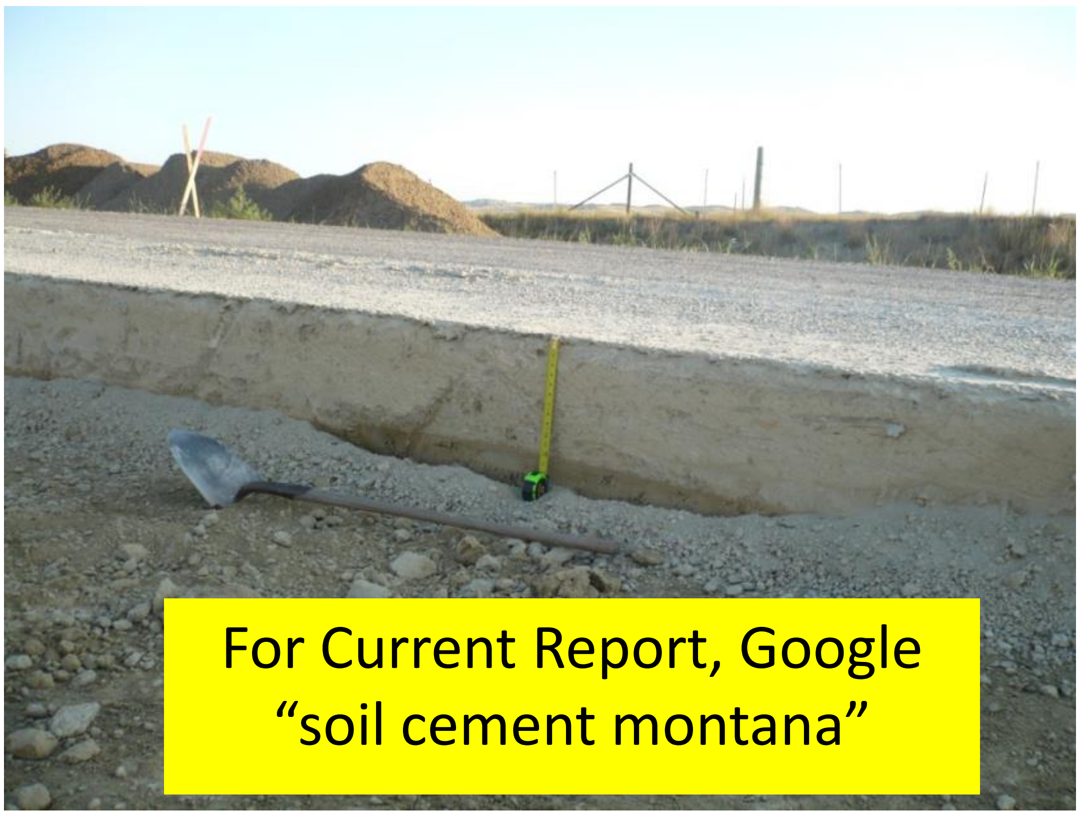
# Soil Cement Roads
## Richland County MT




20th Annual NRRA
Pavement Conference
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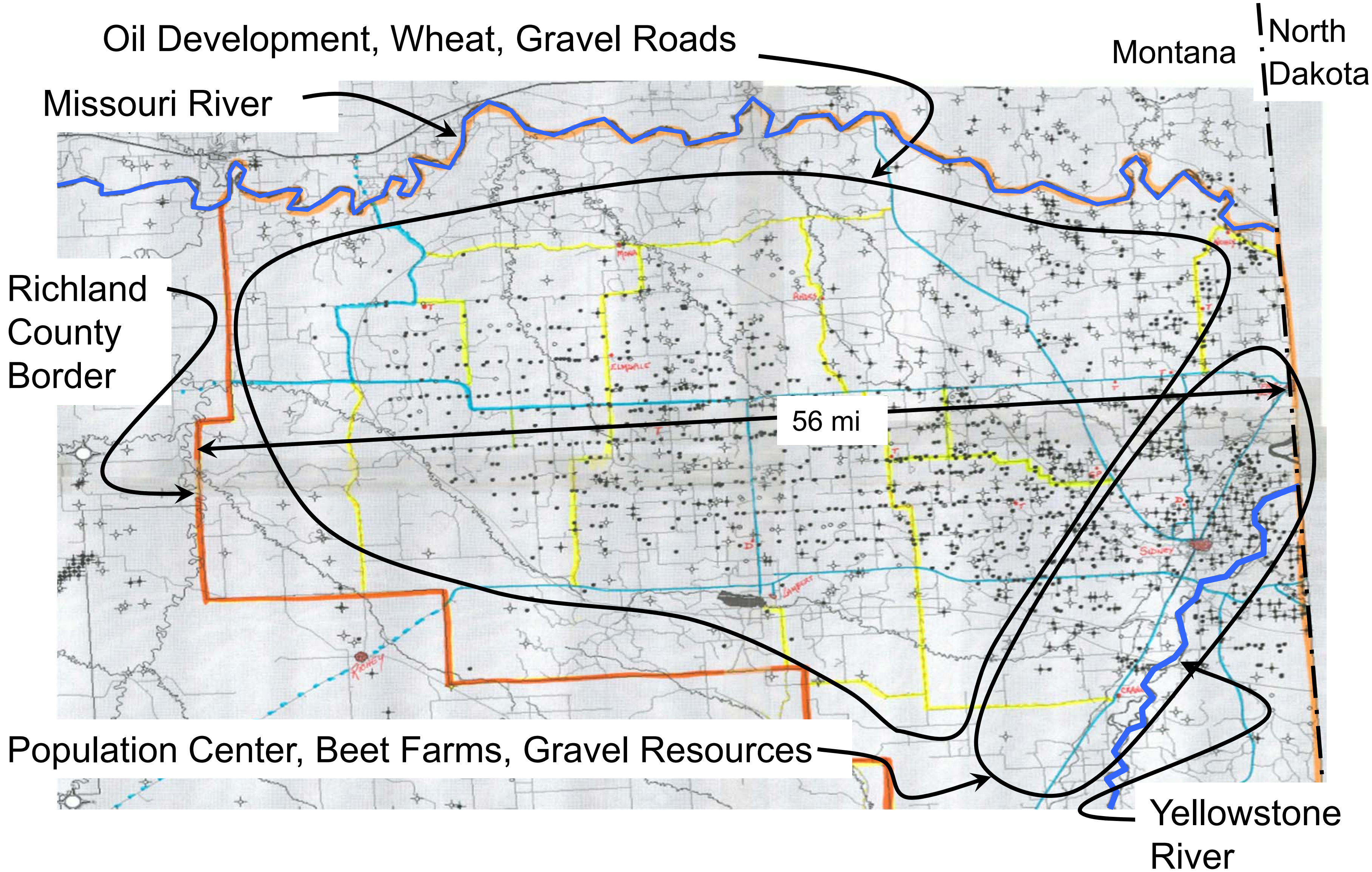
# Presentation Topics

- The Problem:
- Structural Design Options
- Performance Measurements
- Life Cycle Cost Comparisons
- Soil Cement Construction & Repair
- Conclusions & Recommendations

# The Problem

- Heavy Truck Traffic on Weak Soil Roads
  - 50,000 ESAL's per well (development, fracking, crude and produced water haul)
- Truck ADT & Weight Unknown
- Over 100 miles of oil field arterials
- Limited Budget
- Limited Rock Resources

# Richland Co Road Network & Resource Impacts



# Approach to Problem

- Staff a Group to develop options
- Design structural sections
  - Subgrade strengths
  - Truck traffic
  - Available materials
- Build trial sections that have low initial cost
  - Falling Weight Deflectometer (FWD) Test (Montana Non-Destructive Test Unit)
  - Back calculate ESAL life, develop thickness design process (William Vischer, USFS Retired)
  - Develop repair options for problems that develop

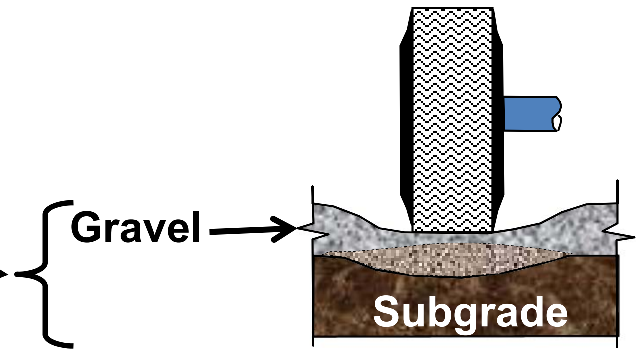
# Weak Soils (CBR of 1 to 3 typical)

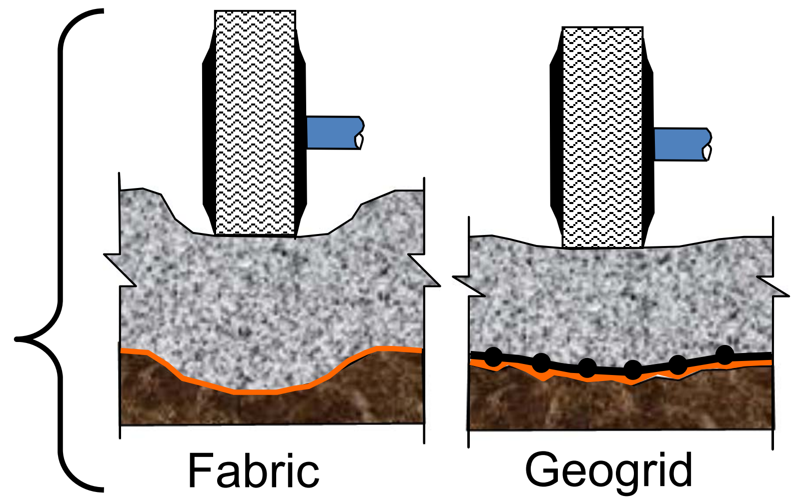

**5" Asphalt, + 8" Base (15 yrs old)**

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

# Weak Clay/Silt Subgrade Soils

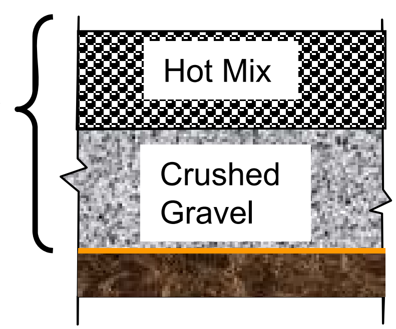
Thin gravel layers mix with subgrade



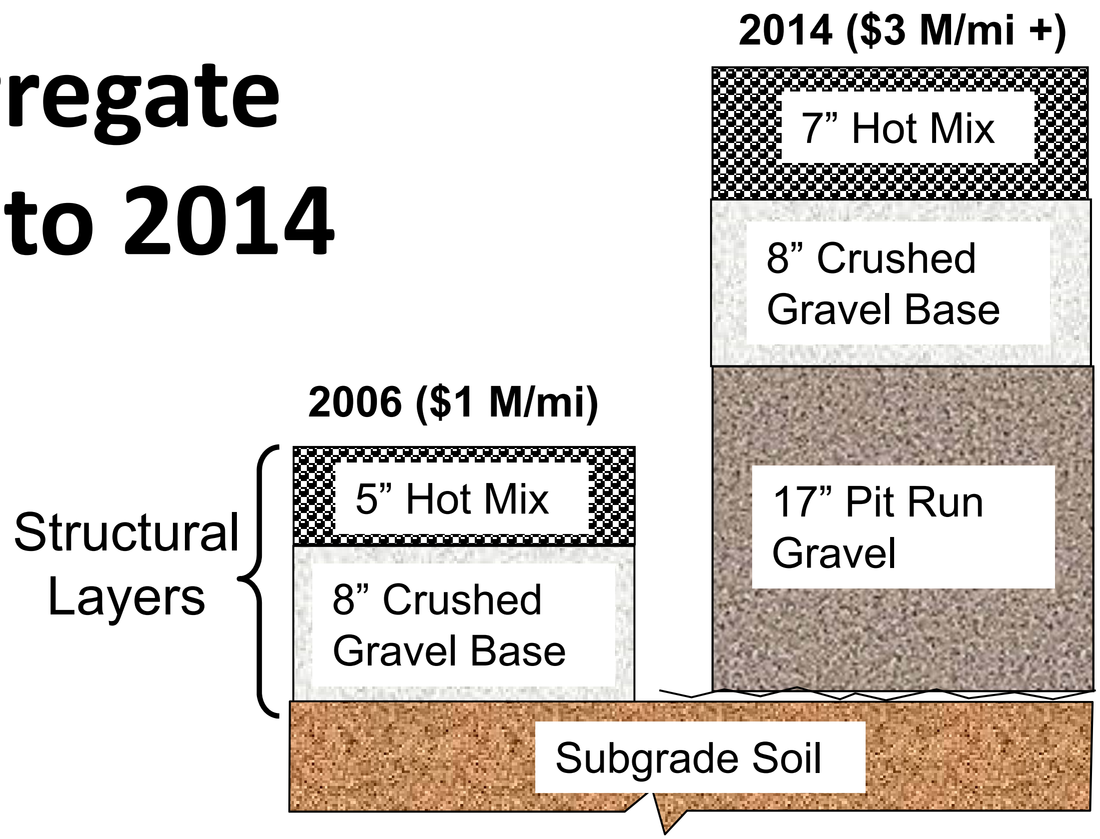

**Gravel $ Too High**

- Gravel with Fabric & Geogrid
- Standard Pavement Design

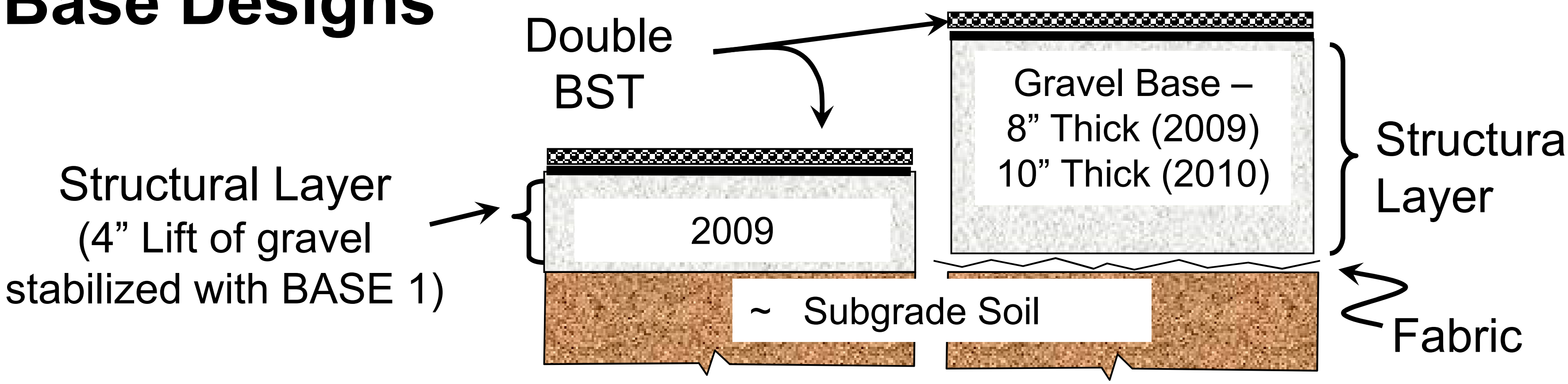


# Asphalt & Aggregate Designs ~ 2006 to 2014

## Standard Hot Mix Designs



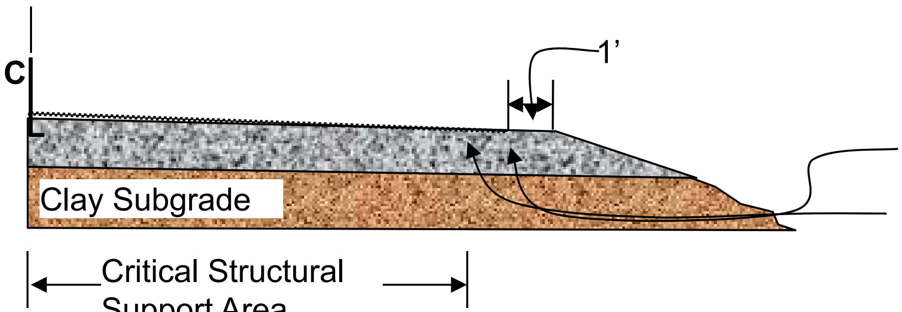

## Thin BST on Base Designs



# 2010 Designs

## BST over 10” Gravel Base

**$400,000/mile**



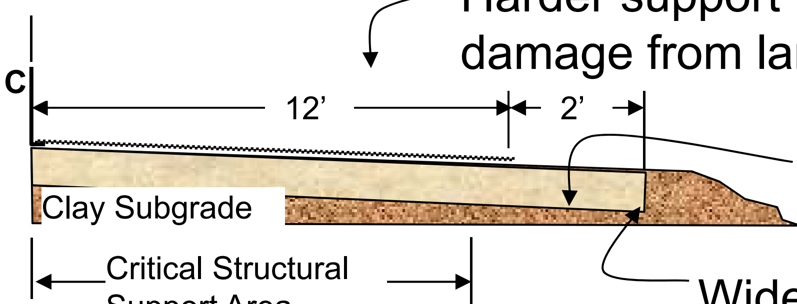

Water infiltration to Clay Subgrade is close to structural support area

Edge cracking & break off mtc. problems

## BST over 8” Soil Cement

**$250,000 /mile**

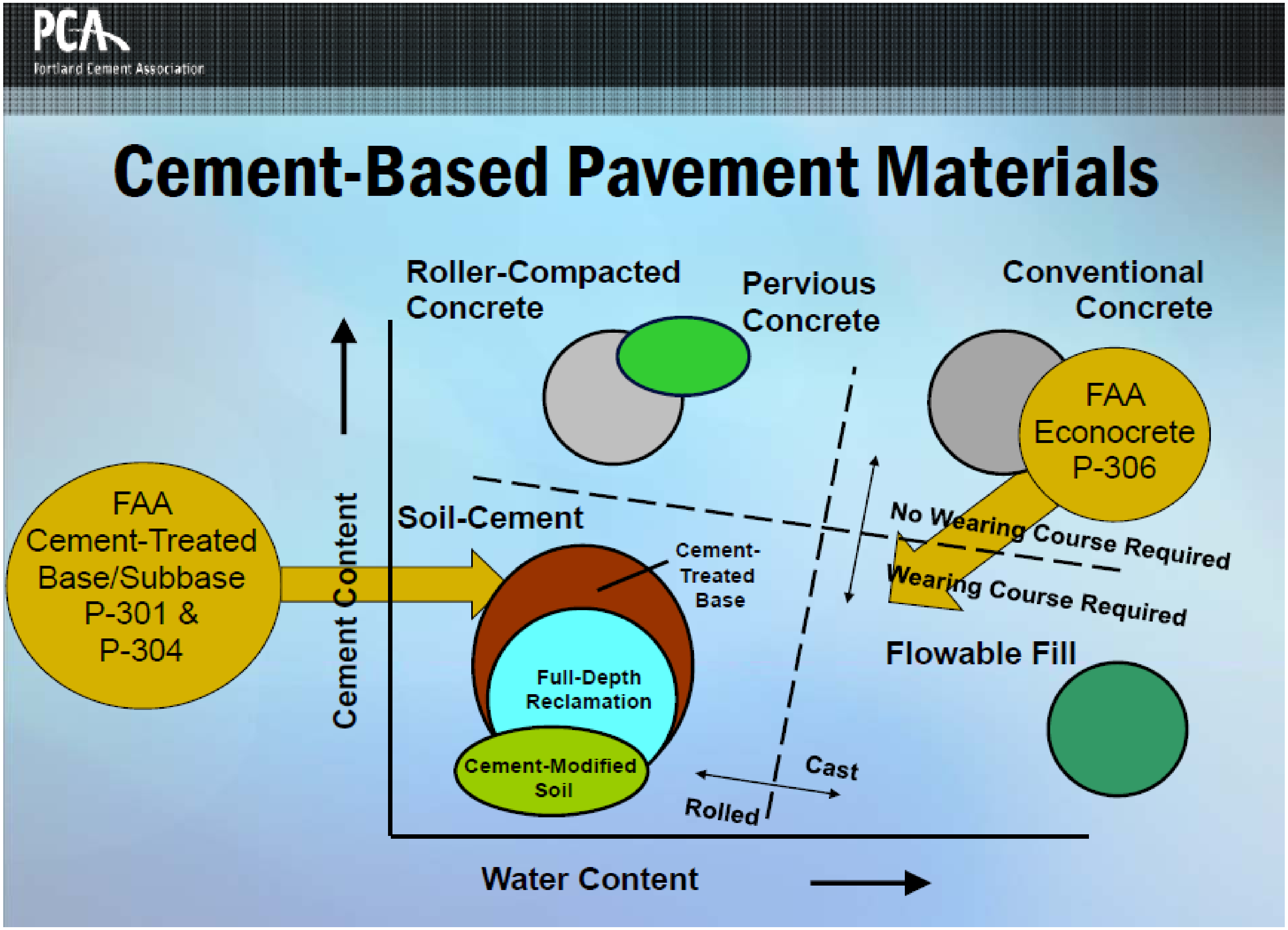
Harder support from soil cement reduces damage from large rock punctures




Flatter wider shoulder is less of a hazard

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

# What is Soil Cement?

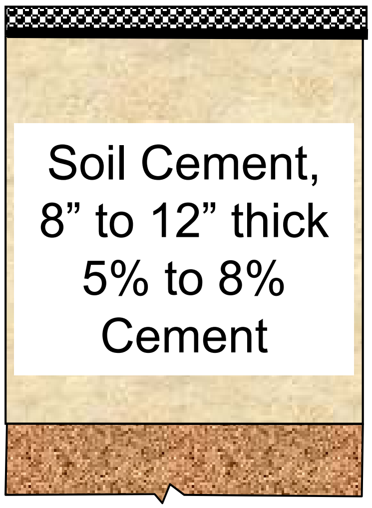


# Concerns with Clay Soil Cement

- Life
- Low cost driving surface
- Repair methods for semi-rigid layer
- Accurate thickness design process
- Clay pulverization
- Deep layer compaction
- Curing in windy climate

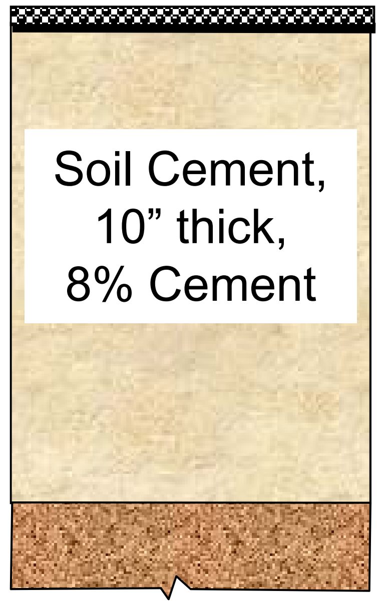
# Soil Cement Designs – Typical Sections

**2010**

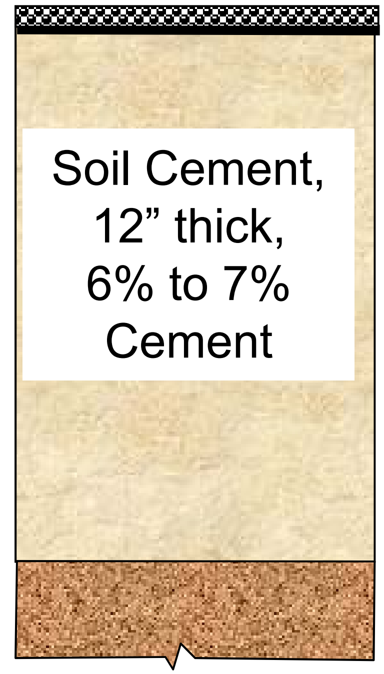



Designs modified after FWD testing in spring and fall

**2011**

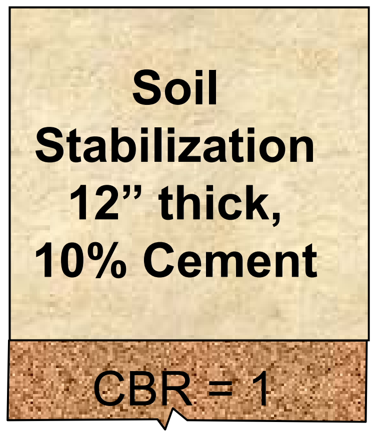



**2012-13**

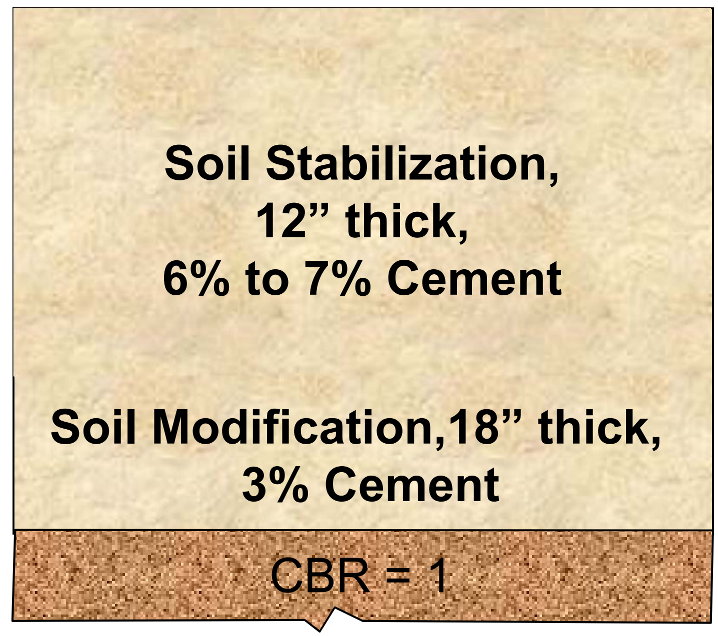


# Soft Subgrade Designs

**2011**




**2012 & 2013**



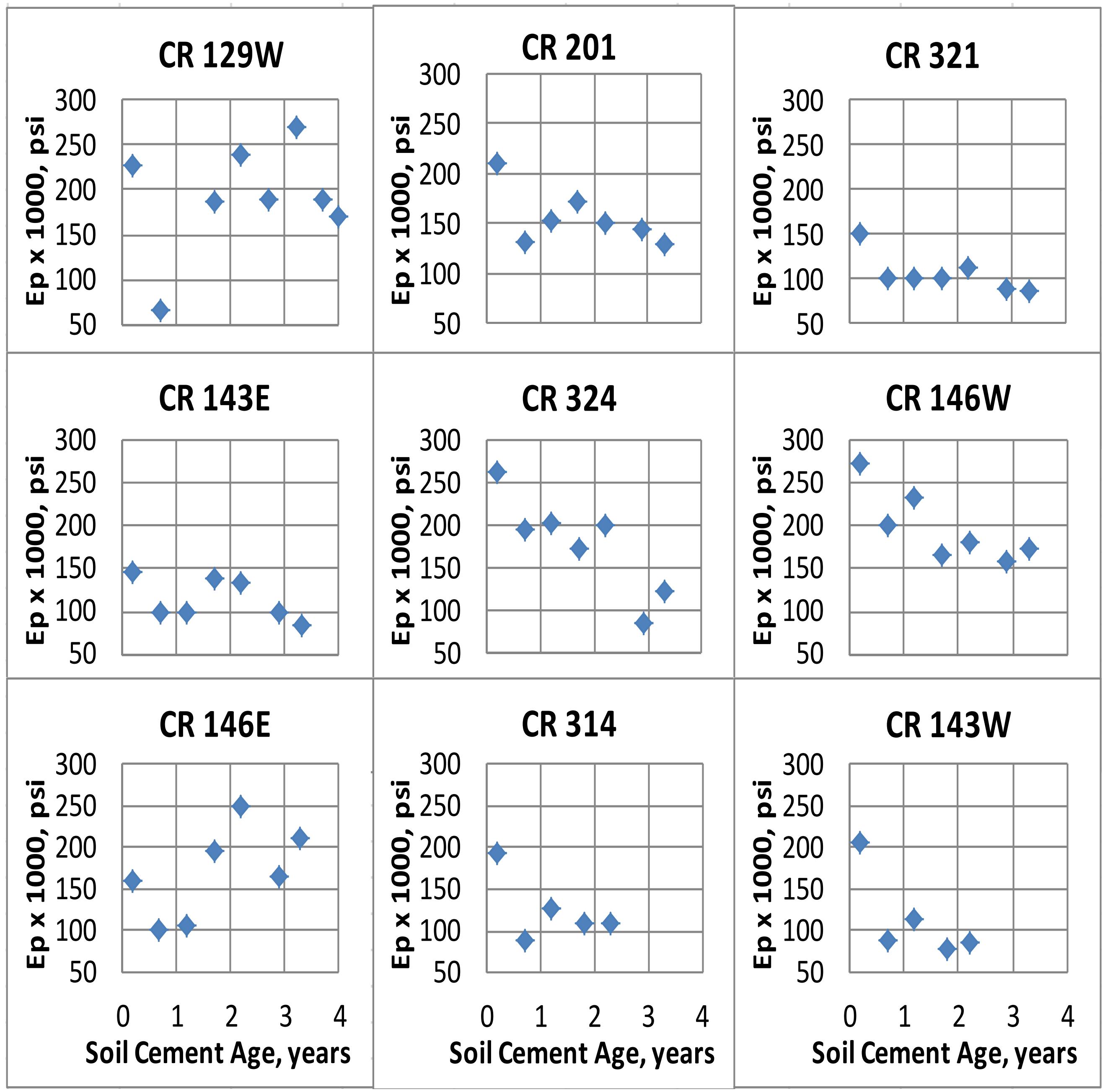

## Soft Spot Location

2011: (5%) Proof Rolling & DCP

2012: (15%) Intelligent Compaction Roller & DCP

2013: (15%) Ground Penetrating Radar & DCP

# Long Term Strength of Soil Cement




Designs should assume Ep will be reduced by 20% to 40% over time (Bill Vischer, Nov 2014)

# Soil Cement Thickness Design (Bill Vischer)

**Appendix E1 - Thickness Design Curves - Soil Cement with BST Surface (4/2/2014)** Page 1

**Thickness Design Outline:** Page one provides and example solution with a step by step process that uses graphs shown on page two and three. Page 4 is a blank form of page one that should help keep the process organized.

| **Thickness Design Steps with an Example** | **Design Data** | |
|---|---|---|
| **Step 1**: Assume a design traffic ESAL value. | ESAL: | 1,000,000 |
| **Step 2**: Determine subgrade modulus. Use either a DCP and charts, or FWD & DCP (preferred option) for the average deflection directly under a 6,000 lb load ($D_o$) from tests conducted in the Spring season. Use Graph 1 to determine Subgrade Mr from FWD maximum deflection, $D_o$ | Subgrade Mr, psi: | 3000 |
| | FWD $D_o$, mils: | 160 |
| **Step 3**: Use Graph 2 to determine allowable subgrad ... design ESAL. | Max Subgrade Microstrain: | 480 |
| **Step 4**: Use Graph 3 to determine ma ... nit for the Soil Cement layer based on design tra ... | Max Stress Ratio | 0.60 |

Design Process will be field validated and refined 2016-17

**Sep 5**: Use Graph 4 and the **maximum** subgrade strain to identify options of soil cement layer thicknesses possible for the design Subgrade Mr. Thicknesses correlating for Esc between 100 and 200 are suggested.

... aximum stress ratio to determine which options from Step 5 are acceptable based on the design Subgrade Mr

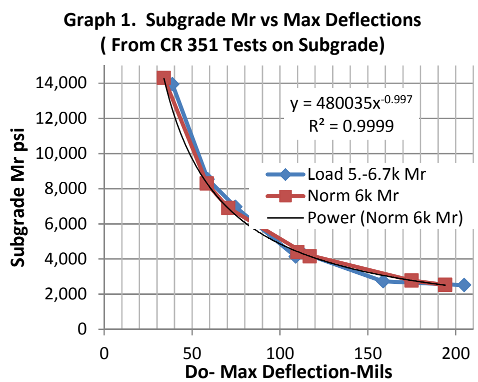
... raph 6 to determine the minimum cement content for each acceptable design option

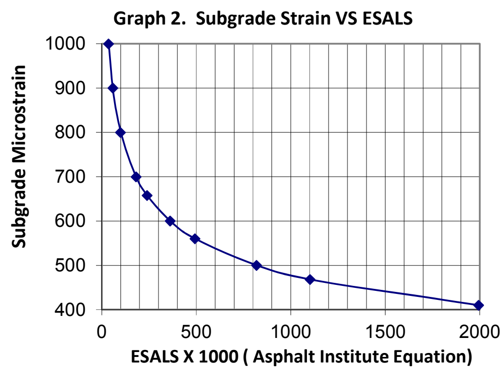
**Step 8**: Selecting the best option requires engineering judgment when consideration of the following criteria

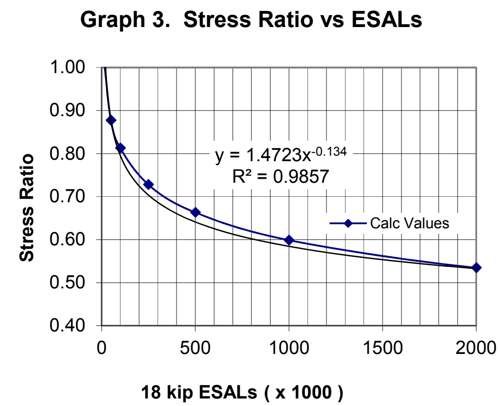
| Design Option | Thickness, inches | $E_{sc}$, psi | (Step 6) | (Step 7) | Cement content for Lean Clay Soils: 6% min for Frost | Cement content for Lean Clay Soils: 8% max for shrinkage cracking | Maximum One Layer depth equals 12". Two layers increase cost |
|---|---|---|---|---|---|---|---|
| 1 | 16 | >100 | OK at any $E_{sc}$ | 5.3 | 6% | OK | Two Layers |
| 2 | 14 | >140 | OK at any $E_{sc}$ | 6.8 | 6% | OK | Two Layers |
| 3 | 12 | >170 | OK at any $E_{sc}$ | 8.8 | OK | No | Single Layer |
| 4 | <12 wont work | | 8" won't work | No | 8" won't work | | |
| 5 | | | | | | | |

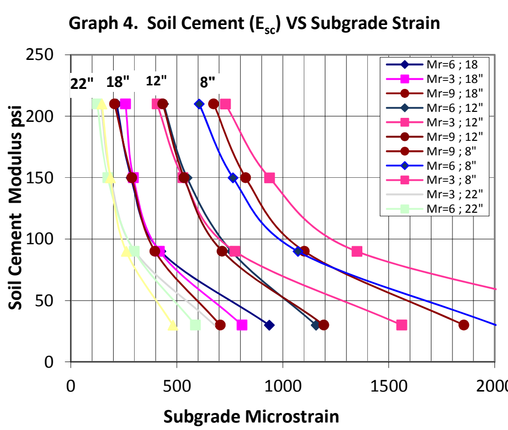
**Step 9**: **Recommendations**: **Alternative A:** Pretreat all known weak areas with 3% cement to 18" depth to raise the average subgrade Mr, followed by 12 % treatment @ 8% Cement. **Alternative B:** Treat 12" depth at 8% Cement and Lower Design Traffic ESAL value from 1,000,000 to 750,000

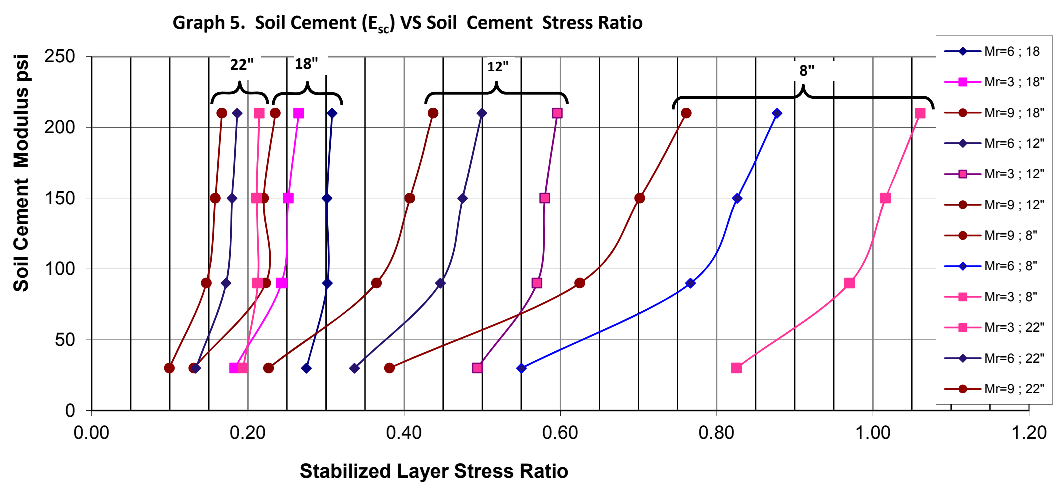
# Soil Cement Thickness Design (Con't)

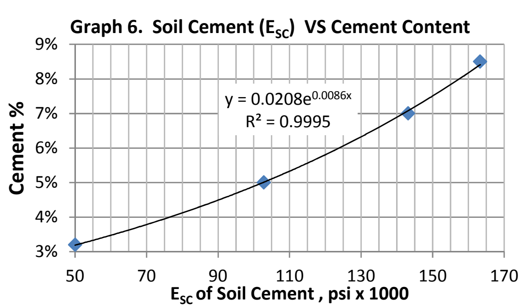


# Estimated Annual Cost Comparisons

| Road Design Option | | Average Estimated Life from FWD Data | | Approximate Cost per Mile (a) | | |
|---|---|---|---|---|---|---|
| **Road Surface** | **Support Structure** | **ESAL Life** | **Years (b)** | **Construc-tion** | **Average Annual Mtc** | **Annual Cost** |
| 5" Hot Mix | 8" Base | 1,150,000 | 8 | $900,000 | $16,000 | $149,000 |
| Double BST | 10" Base | 100,000 | 1 | $400,000 | $20,000 | $606,000 (c) |
| Double BST | 12" Soil Cement | 500,000 | 3 | $300,000 | $18,000 | $115,000 |
| Double BST | 3" Gravel on 12" Soil Cement | 2,000,000 | 13 | $350,000 | $16,000 | $48,000 |
| 4" Treated Gravel | 12" Soil Cement | 2,000,000 | 13 | $400,000 | $26,000 (d) | $63,000 |

(a) Costs are very project specific

(b) Based on 200 trucks/day, 50,000/yr (150,000 ESAL/yr)

(c) Classic case of under designed structural section for the selected ESAL/year traffic

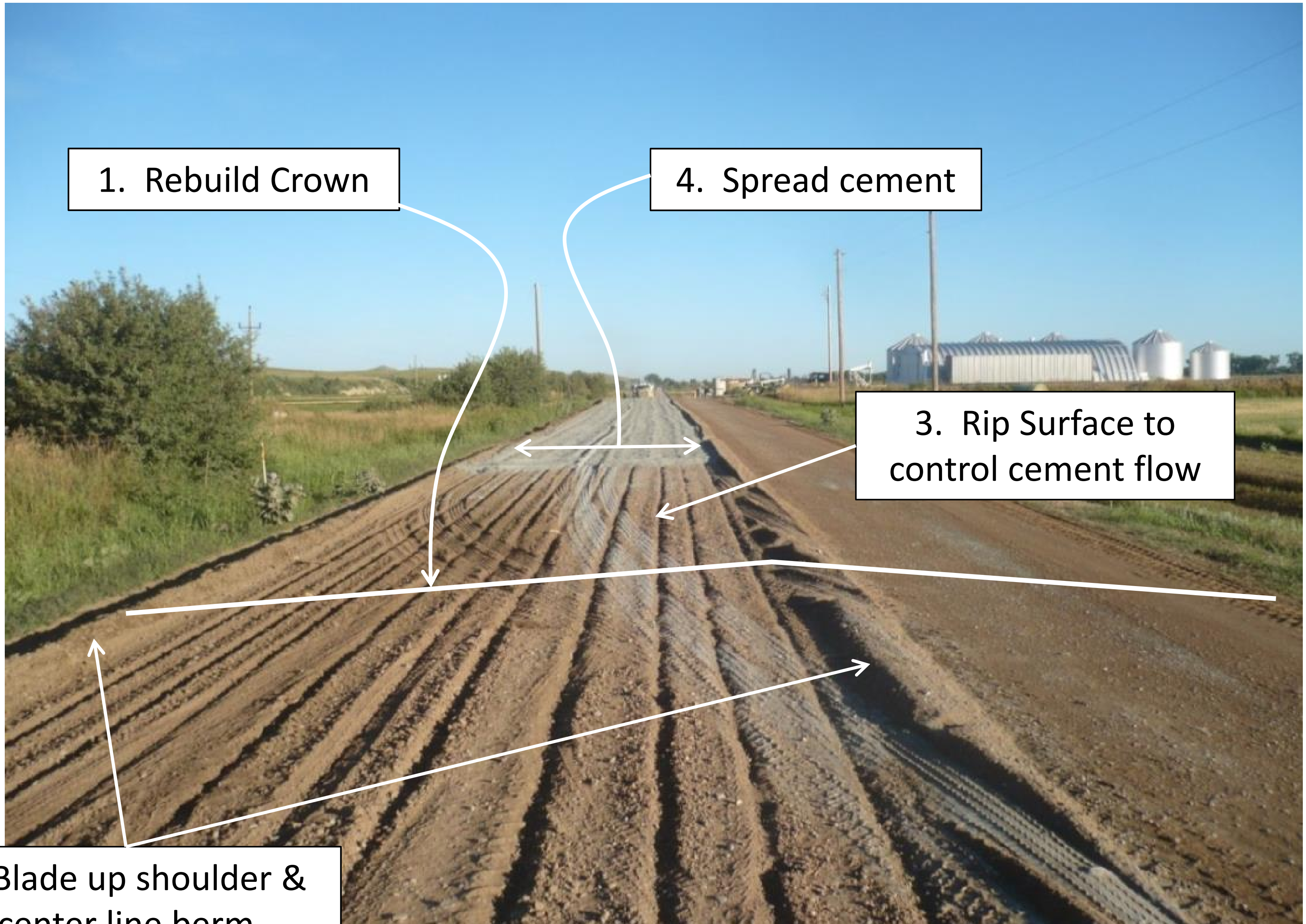
(d) Primarily gravel replacement - WAG

Consider other issues with the Soil Cement option

# Soil Cement Construction

- Road Preparation
- Cement Spreading
- Mixing Cement & Water
- Compaction
- Final Shaping & Compaction
- Curing & Surface Construction

# Road Prep & Cement Spread



# Mixing, Compaction & Finishing

Water to Hydrate Cement

Reclaimer to pulverize soil and mix soil, water & cement

Pad Foot Roller for Compaction

Blade Rebuilds Crown

25 Ton Rubber Roller for Finish

Spread Cement

# Uneven Moisture/Compaction

Problem solved in 2013 by mix chamber cleaning after each cement spread


# Clay Pulverization Problems

Pulverization increased by:
slower ground speed,
multiple passes,
higher drum speeds, and
closing mix chamber doors

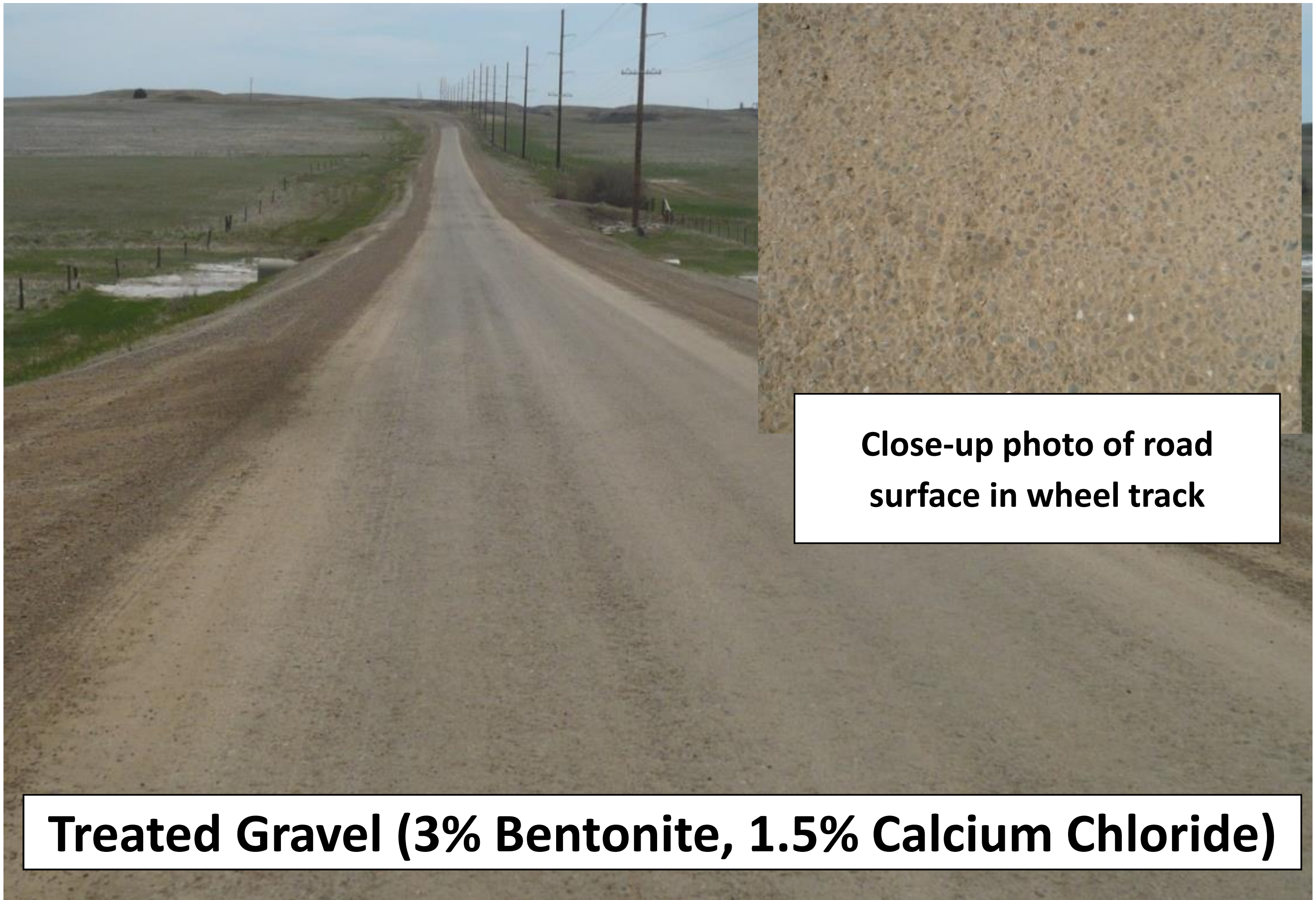
# Double Chip Seal (2011-12)


# Surfacing on Soil Cement

| Year | Surfacing Type, Miles | | | |
|---|---|---|---|---|
| | **Double BST** | **BST on 3" Gravel** | **3" HMA on 3" Base** | **4" Treated Gravel** (Bentonite & $CaCl_2$) |
| **2010** | 1.75 | 0 | 0 | 3 |
| **2011** | 24 | 0.8 | 0 | 0 |
| **2012** | 12 | 0 | 0.4 | 12 |
| **2013** | 0 | 4.8 | 0 | 8 |

| | | | | |
|---|---|---|---|---|
| **Build $** | Low | Moderate | Highest | Moderate |
| **Est. Mtc. $** | Moderate | Low | Lowest | Moderate (Blading, Chloride, Rock) |
| **Estimated Life Cycle $** | Moderate ? | Low? | Low? | Moderate? |

# Treated Gravel Surfacing (1 yr. old)




**Bentonite reduces chloride leaching, chloride reduces Bentonite dusting**

# Soil Cement Quality Assurance

**QA Costs depend on Contractor, site conditions, weather, etc**

- Cement application rate
- Pulverization
- Depth of mixing
- Moisture content during mixing
- Compaction
- Surface finish crown and profile
- Curing

# Extent of Soil Cement Structural Repairs

| | 2011 (24 miles) | 2012 & 13 (30 Miles) |
|---|---|---|
| Total Surface Area, SY | 394,240 SY | 492,800 SY |
| Total Repair Surface Area | 9,878 SY | 1,418 SY |
| % of Total work (1) | 2.5 % | 0.3% |

(1) Note that the relative amounts of truck traffic are unknown

Repairs for 2012 & 2013 work is less because

- Better control of cement flow/content
- Better control of pulverization and moisture content
- Increased design thickness – 10” vs. 12”
- Soft Spot Treatment ~ more treated (15% vs 5% of road area), deeper treatment (12” vs. 18”)

# Problems with 2011 Work

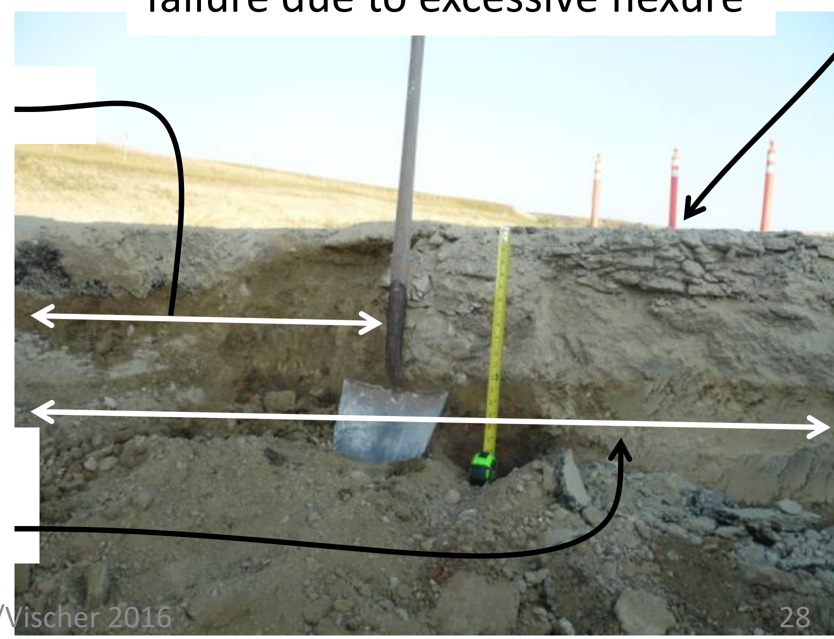
## Otta Seal Bleeding

## Compression Failures

## QA/QC – Soil Pulverization & Cement Uniformity

Soil cement compression failure due to excessive flexure

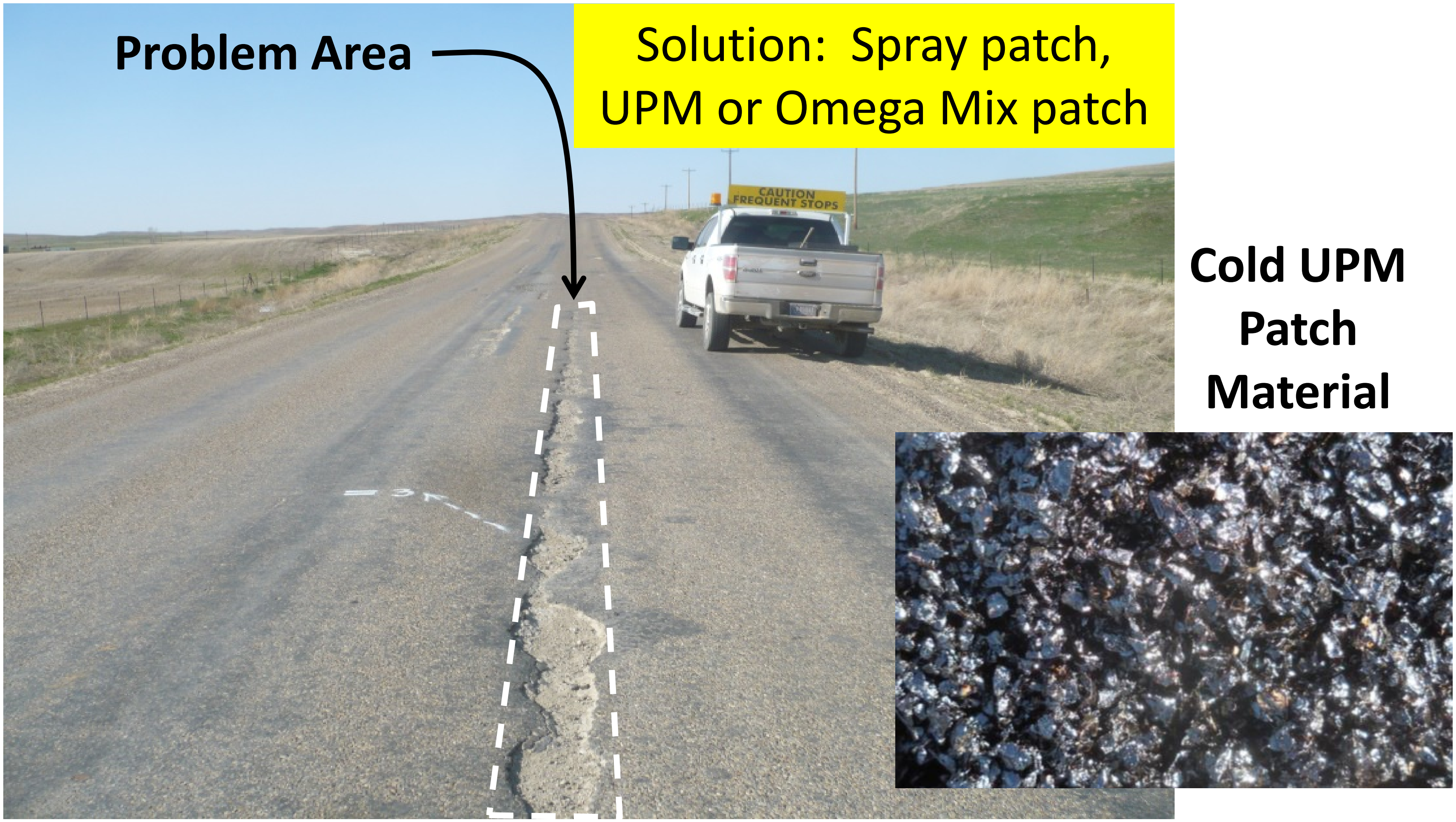
Low cement content on 5 ft shoulder



Note: Repair patch of 5” Hot mix & 15” Base rutted after 6 months

12 inch stabilization depth inadequate for very soft subgrade

# BST "Pick-up" Problems (2011)
## (caused by stopping vehicles on bleeding BST)




**Cold UPM Patch Material**

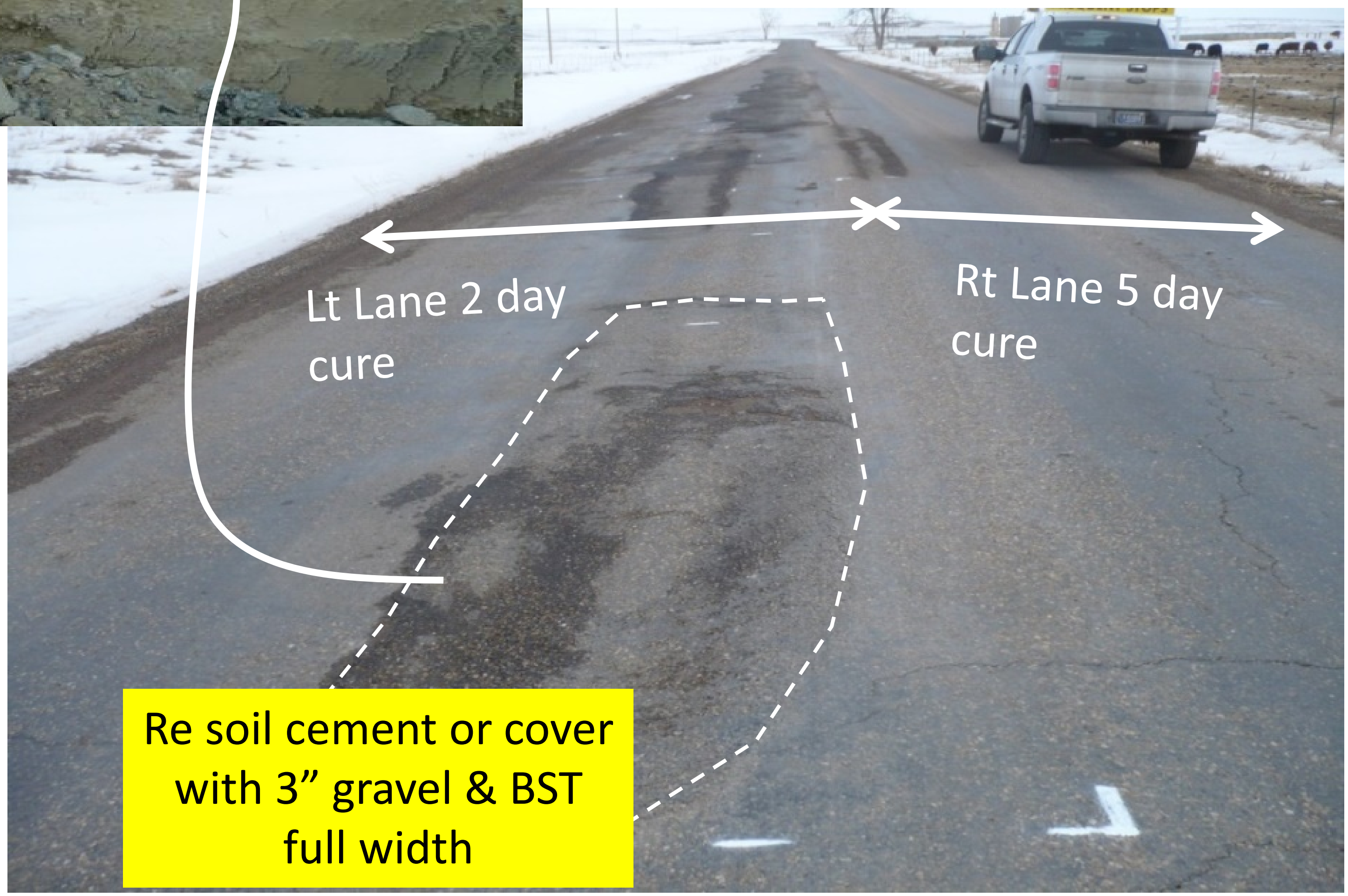
# Road 321 BST Shoving/Tearing (2011)


**Repair Methods:**

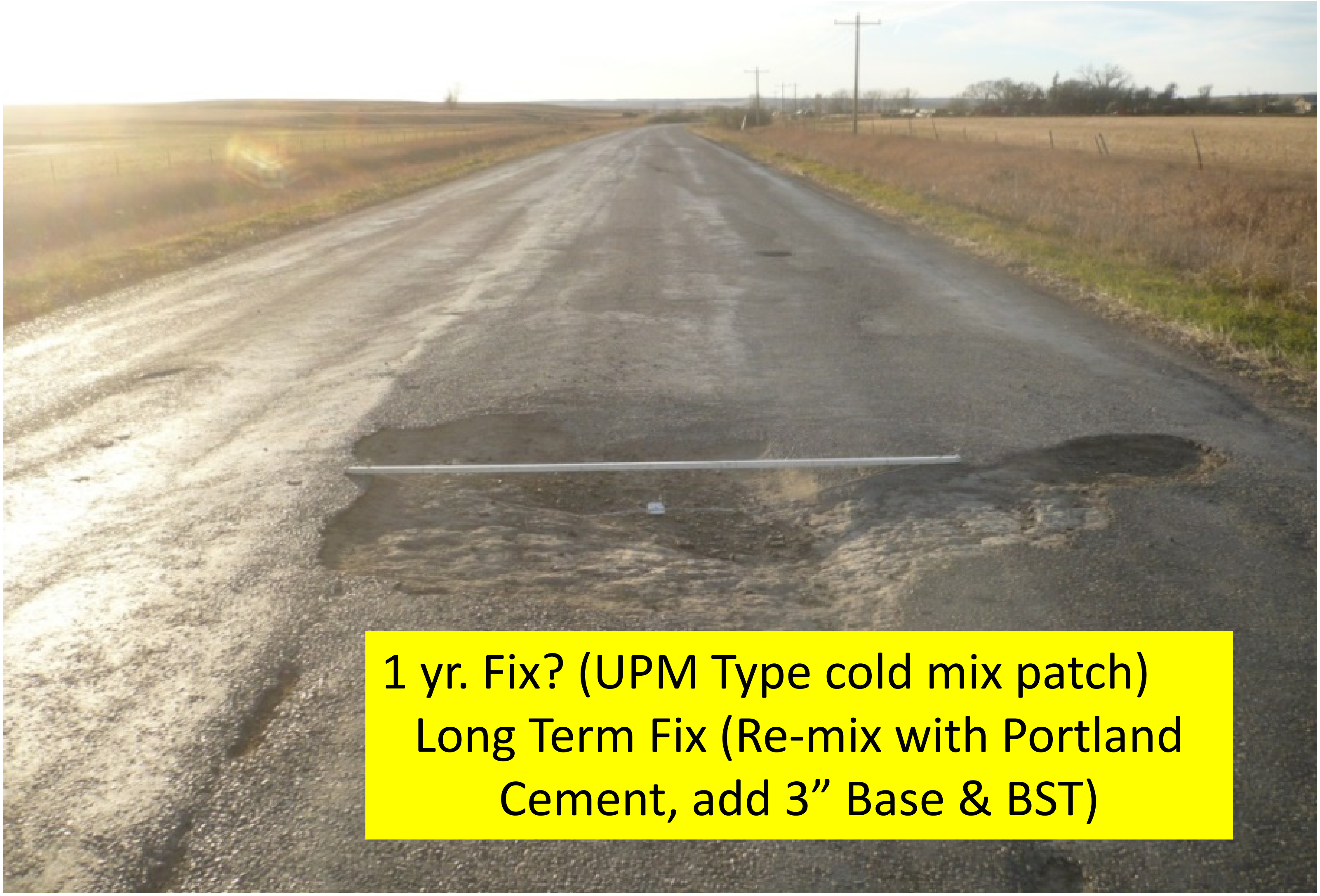
**No Depression Area:** Remove BST & fabric, new BST full width

**Depression Area:** Re-soil cement, 3” Gravel & BST Full width

# Damage by 200 Ton Oil Rig Movement (2011)

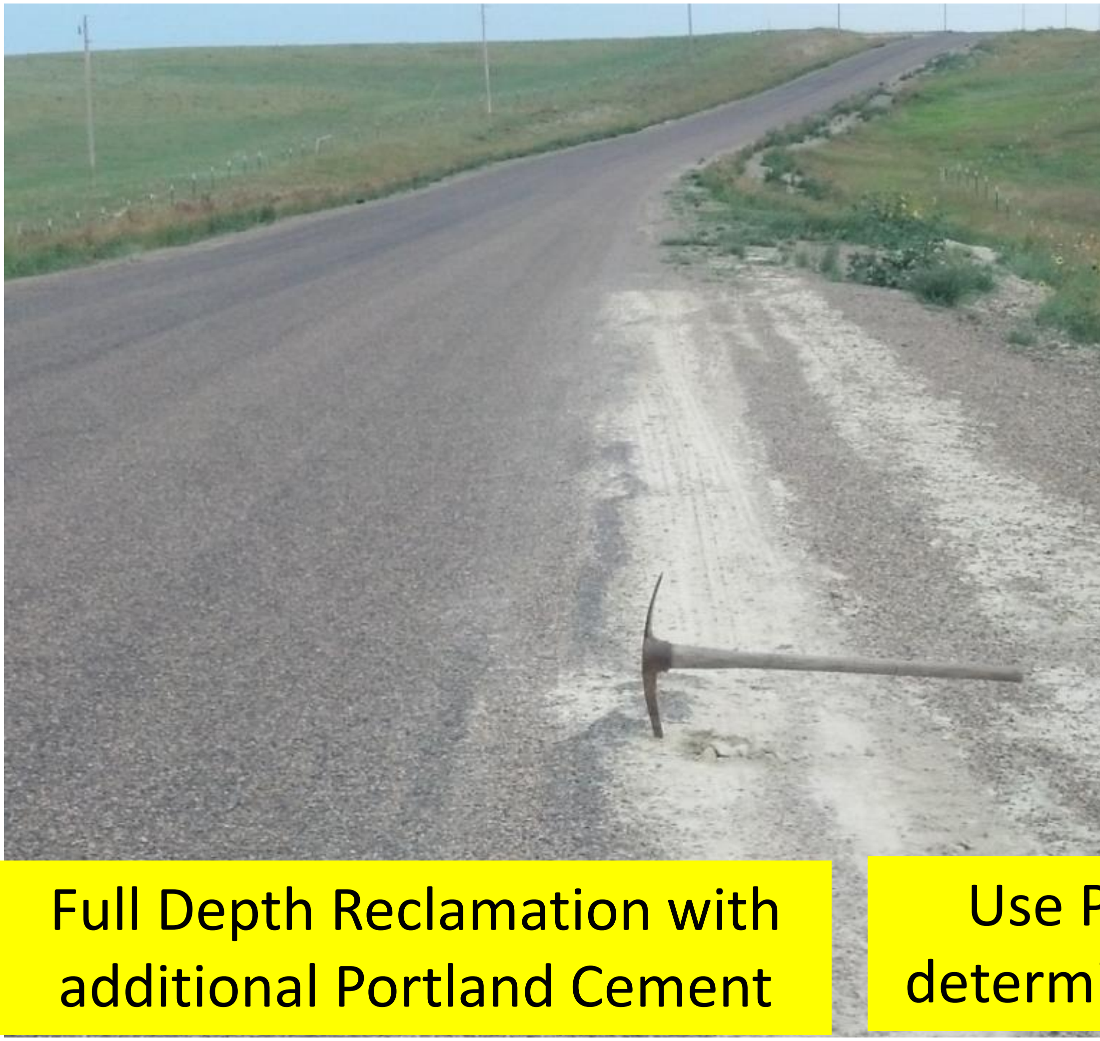


# Pot Hole at Soil Cement Transverse Joint (2011)
## (Caused by low cement content)



1 yr. Fix? (UPM Type cold mix patch)
Long Term Fix (Re-mix with Portland Cement, add 3” Base & BST)

# Depressed/Rutted Areas (2011)
# (Caused by low cement content)



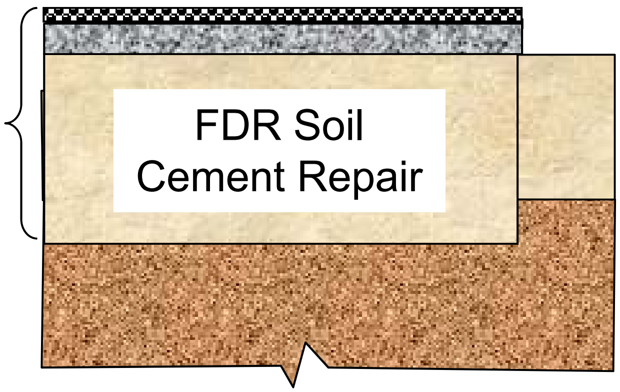
Full Depth Reclamation with additional Portland Cement

Use Pick Axe to determine FDR area

# Repair Options for Structural Problems

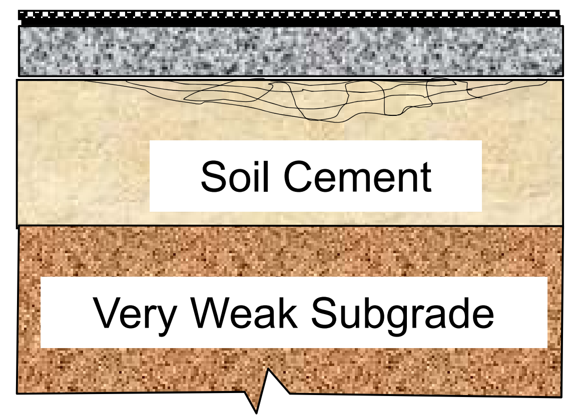
Depressions caused by low cement content

Full Depth & Width Reclamation with more cement, gravel base and BST



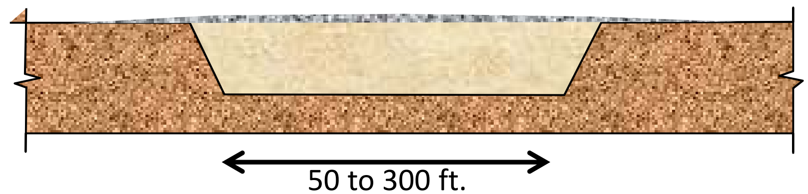

Compression Failures from Flexure

Reinforce with 4” Gravel Base & BST

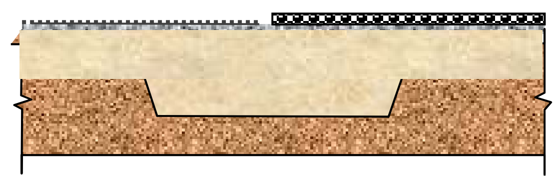


# Proposed Strategy for Improving Unpaved Arterial Roads

- Year 1: Cement stabilize soft spot areas on gravel roads
  - 18 inch treatment depth
  - 3 inch gravel surfacing




- Year 2: After all soft spots stabilized
  - Cement stabilize 12 inch depths,
  - Add 3 inch base
  - Double chip seal or 3 inch hot mix asphalt

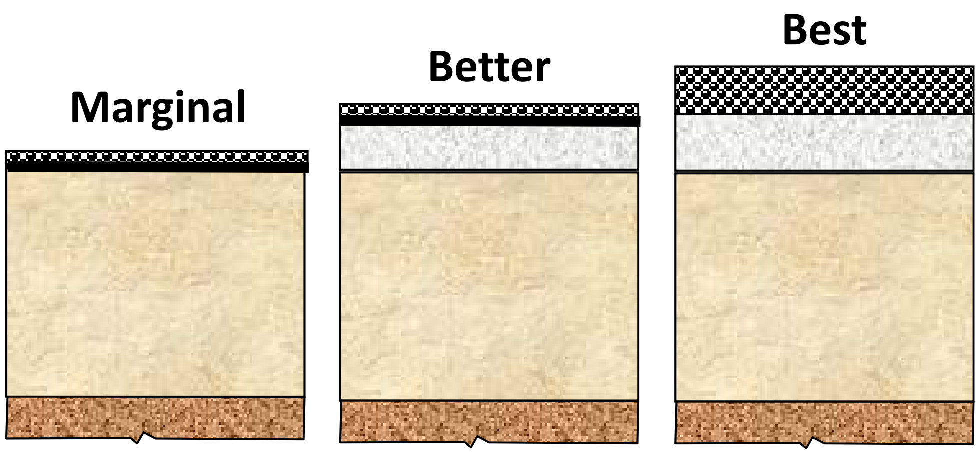


- Re-stabilize any failed areas with at least 5% more cement

# Conclusions/Recommendations

**Costs:** **Soil Cement cost effective where:**
**Rock costs are high,**
**Soils are suitable,**
**Road widths are marginal**

**Design**




**Design thicknesses based on truck traffic, subgrade strength, etc.**

# Conclusions/Recommendations

- Construction and Maintenance

  **Google: “Soil Cement – Montana”**

- Other Resources

  Wirtgen Cold Recycling Technology Manual

  TRB – “Recommended Practice for Stabilization of Subgrade Soils and Base Materials”

  Soil Stabilization for Pavements UFC 3-250-11 (TM 5-822)
  Transportation Research Board publications

  Non-Standard Stabilizers(FS): “Stabilization Selection Guide for Aggregate and Native Surfaced Low Volume Roads”

# Thank You!

Questions or Comments?