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Cement Based Stabilization Solutions
Full Depth Reclamation

NWPMA
Portland, Oregon
October 25, 2016

Diane Warner, PE
Northwest Cement Council
Executive Director

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Agenda

Soil-Cement Benefits (sub-base and base)

Full-Depth Reclamation with Cement
Introduction
Design
Construction

Project Examples

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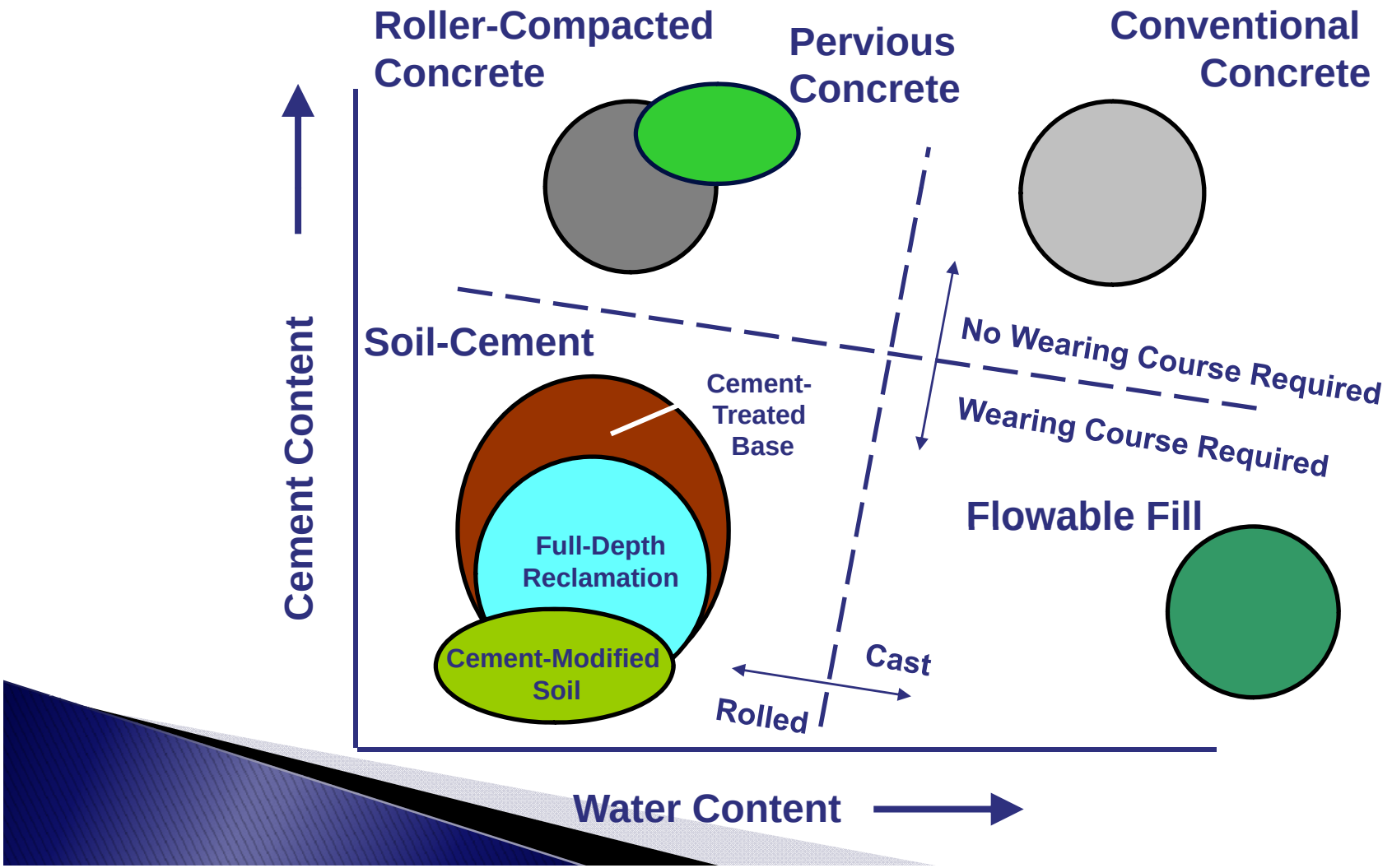
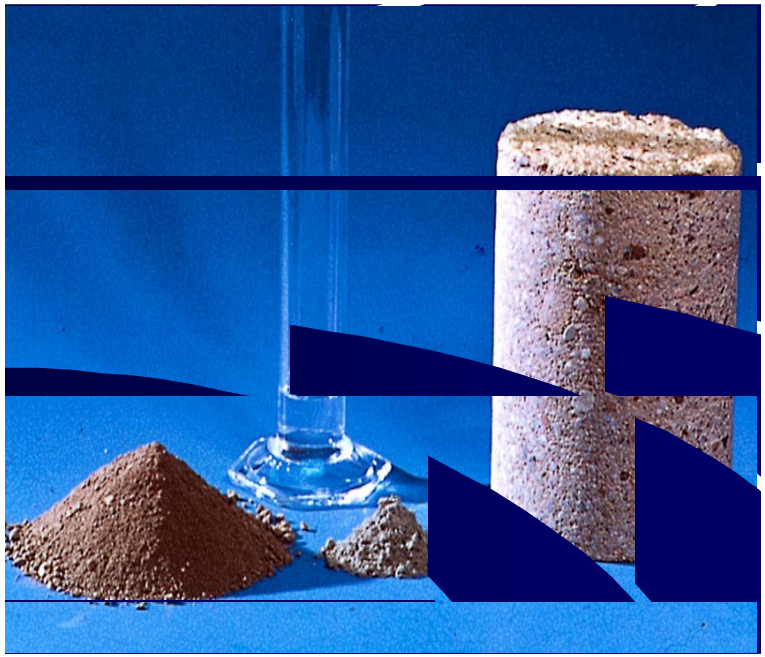
Cement-Based Pavement Materials

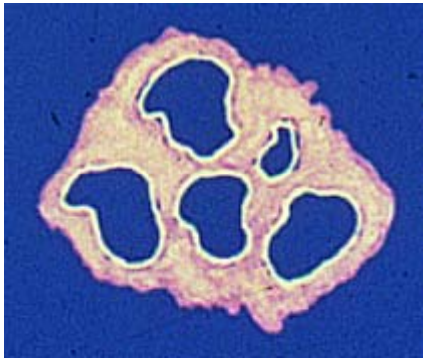


What is Soil-Cement?

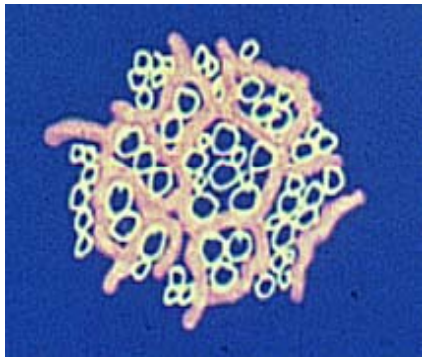
- Mixture of portland cement, soil/aggregate and water
- Pulverized, intimately blended, compacted to high density
- Base or subbase for bituminous and concrete pavement
- Achieves unconfined compressive strengths of 200 to 800 psi
- Provides long term durability



Concrete



Soil-Cement



Cementitious Gel or Paste

- Coat All Particles
- Fills Voids

Hydration Products

- Voids are not Filled
- Calcium-silicate-hydrate and Calcium – aluminum-hydrate act as glue that binds and stabilzes flocculated clay particles

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Why Use Soil-Cement?

- Very economical, durable pavement base
- Eliminates use of virgin aggregates
- Allows thinner pavement sections
- Reduces moisture susceptibility
- Frost resistant
- Decreased base thickness compared to unbound aggregate base
- Structural properties maintained under varying moisture conditions
- High stiffness inhibits fatigue cracking and rutting of asphalt surface.

Applications

- Residential streets
- Medium to high-volume roads
- Airports
- Parking lots
- Industrial storage facilities
- Low volume roadways, where frost depth controls the pavement design, rather than traffic loading

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Soil-Cement Family

- Soil-Cement
  - Cement-Modified Soil
  - Cement-Treated Base
  - Full Depth Reclamation

Cement-Modified Soil (subgrade)

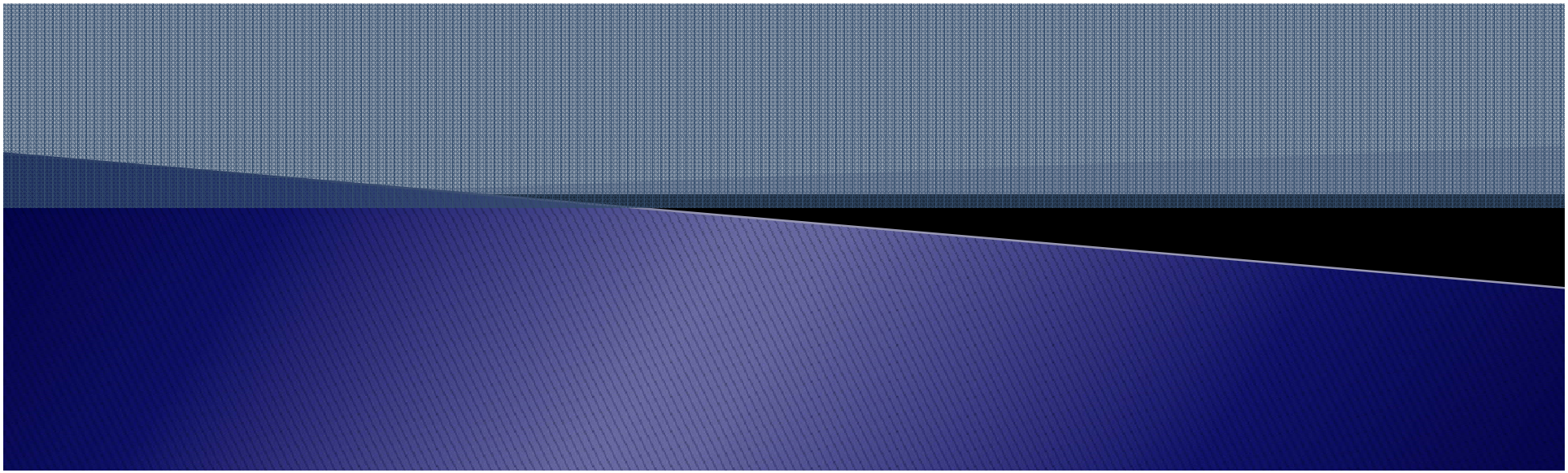
- Eliminates removal/replacement of inferior soils
- Low cost soil improvement
- Improves pavement support
  - Does not contribute appreciably to the structural capacity of the pavement
- Forms weather-resistant work platform
- Creates a pavement section resistant to frost heave

Cement-Treated Base

- Uses local or marginal aggregates
- Can be processed through central plant
- Stronger than typical soil-cement 300-800 psi
- Eliminates rutting
- Spans weak subgrades

Materials That Can Be Cement-Stabilized

- Soils (sand, silt, clay)
- Gravel
- Shell
- Crushed Stone
- Slag
- Recycled HMA
- Recycled Concrete



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Full-Depth Reclamation with Cement

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- Introduction
- Benefits
- Design
- Construction
- Field Testing
- Performance

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Introduction

Definition of Full-Depth Reclamation

- Method of flexible pavement reconstruction that utilizes the existing asphalt, base, and subgrade material to produce a new stabilized base course for a chip seal, asphalt, or concrete wearing surface.

Types of Reclamation Methods

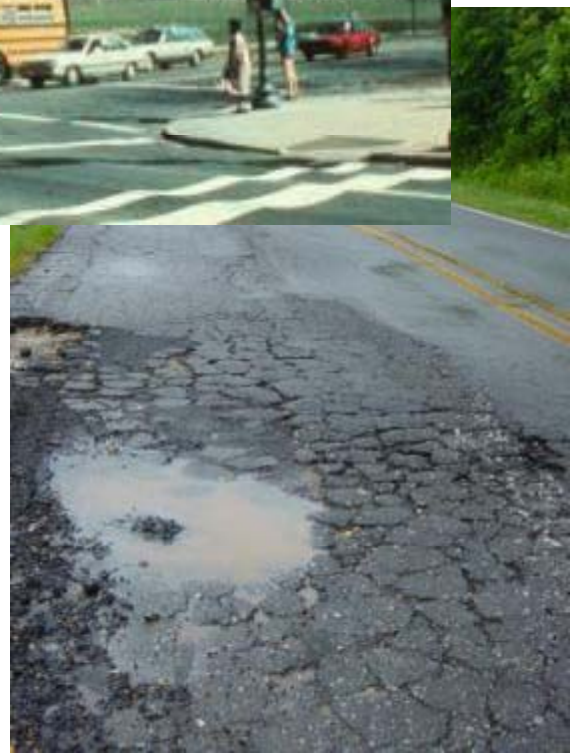
- Mechanical Stabilization
- Bituminous Stabilization
  - emulsified asphalt
  - expanded (foamed) asphalt
- Chemical Stabilization
  - - portland cement
  - - slag cement
  - - fly ash
  - - kiln dust
  - - lime
  - - other

Determining when FDR is Appropriate

- Base / Road Failure
- Reconstruction necessary
- Pavement Distress

Examples of Pavement Distress

- Alligator cracking
- Rutting
- Excessive patching
- Base failures
- Potholes
- Soil stains on surface



Benefits

Advantages of the FDR Process

- Use of in-place materials
- Little or no material hauled off and dumped
- Maintains or improves existing grade
- Conserves virgin material
- Saves cost by using in-place "investment"
- Saves energy by reducing mining and hauls
- Very sustainable process

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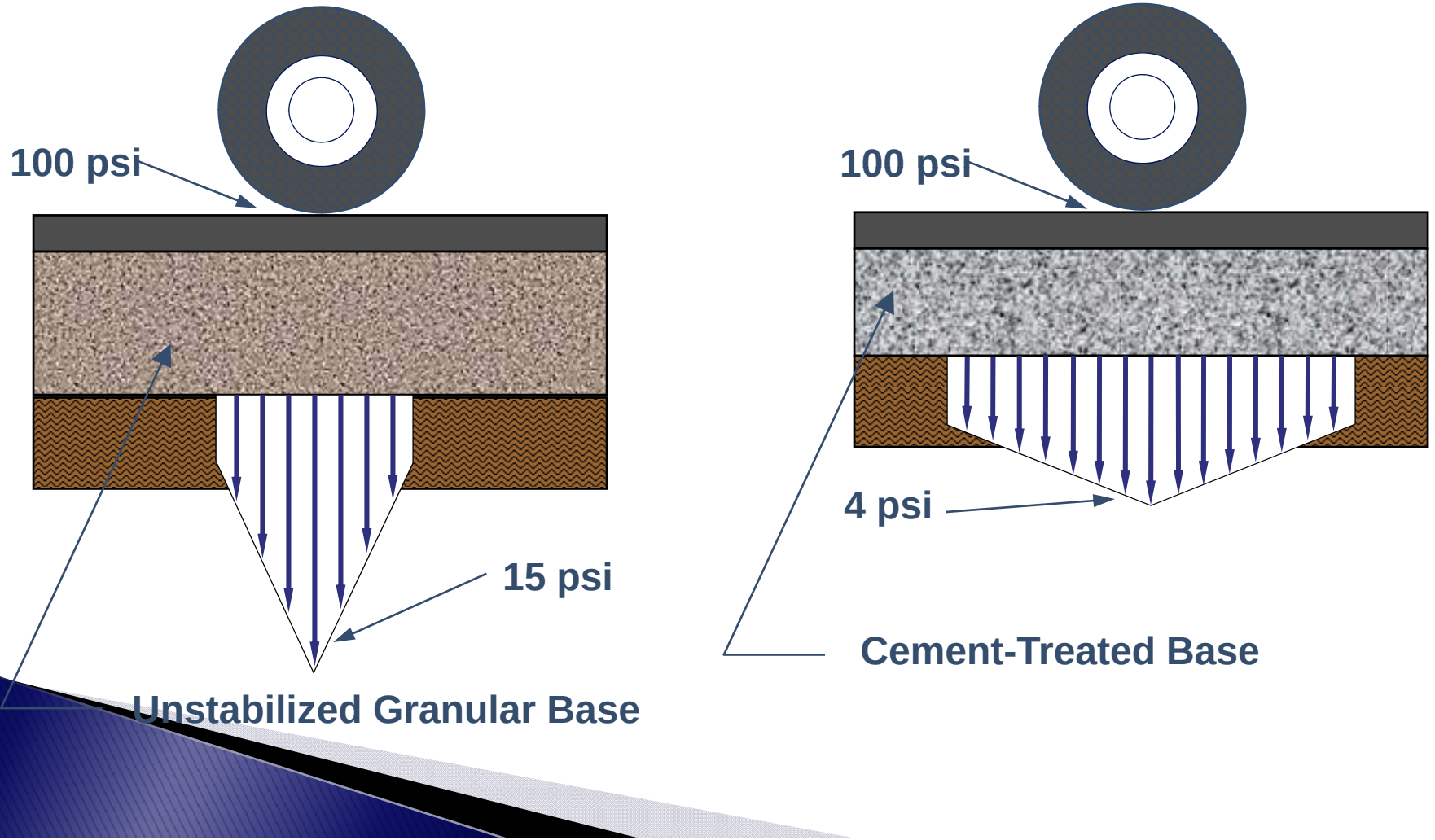
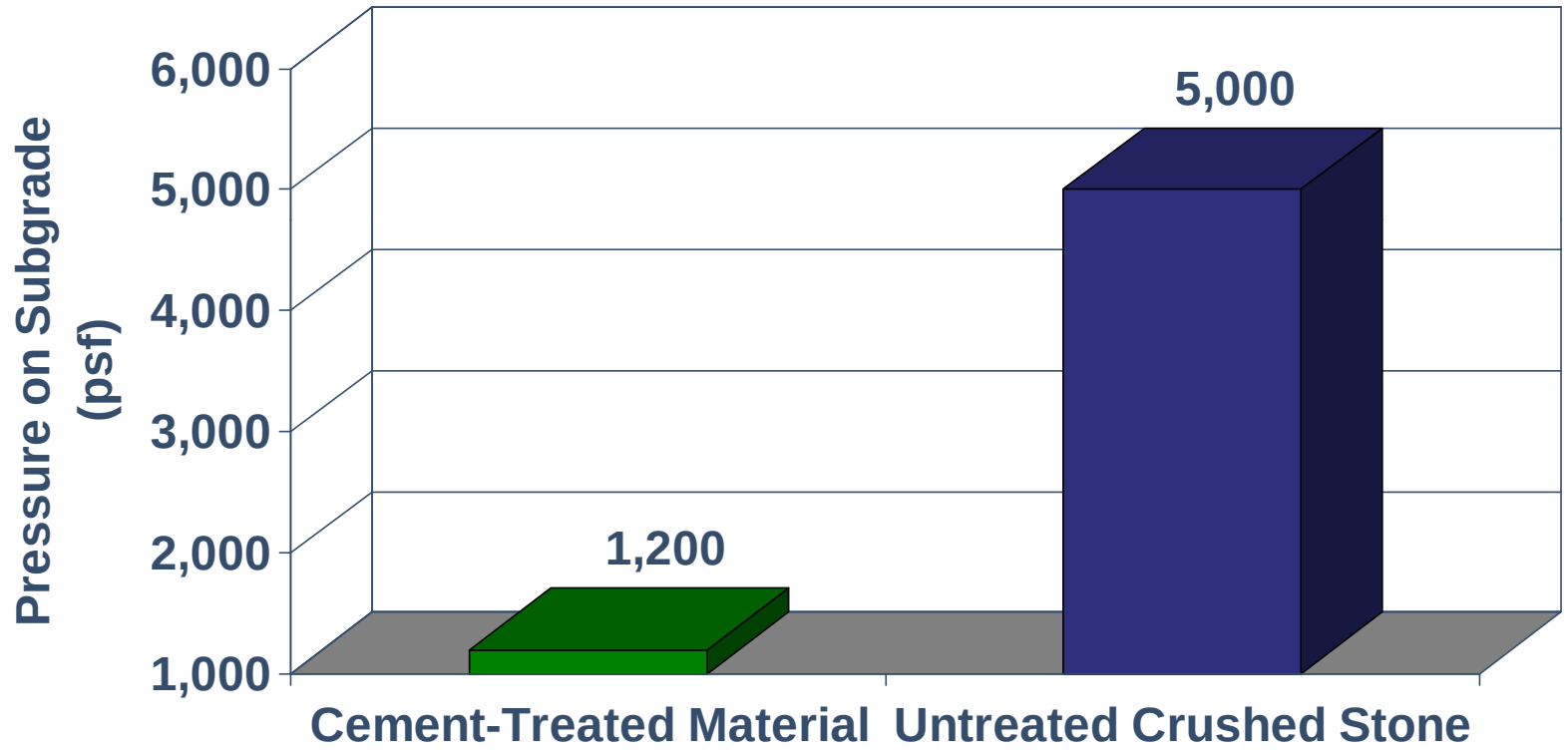
Benefits of FDR with Cement

- Increased rigidity spreads loads
- Eliminates rutting below surface
- Reduced moisture susceptibility
- Reduced fatigue cracking in asphalt surface
- Allows for a thinner pavement section

Improved Performance In Rutting And Fatigue Cracking

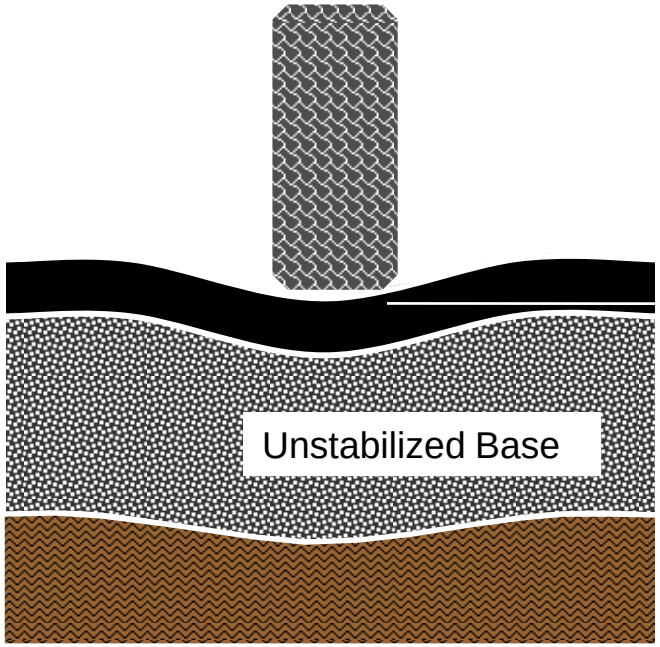


Load-Spreading Capability

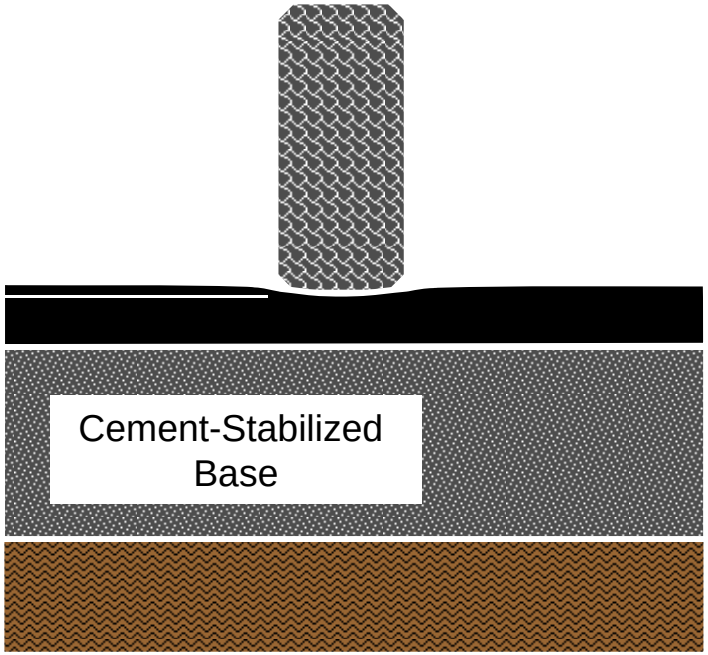


Pressure on subgrade from base with 11,500 psf surface load

Eliminates Rutting Below Surface

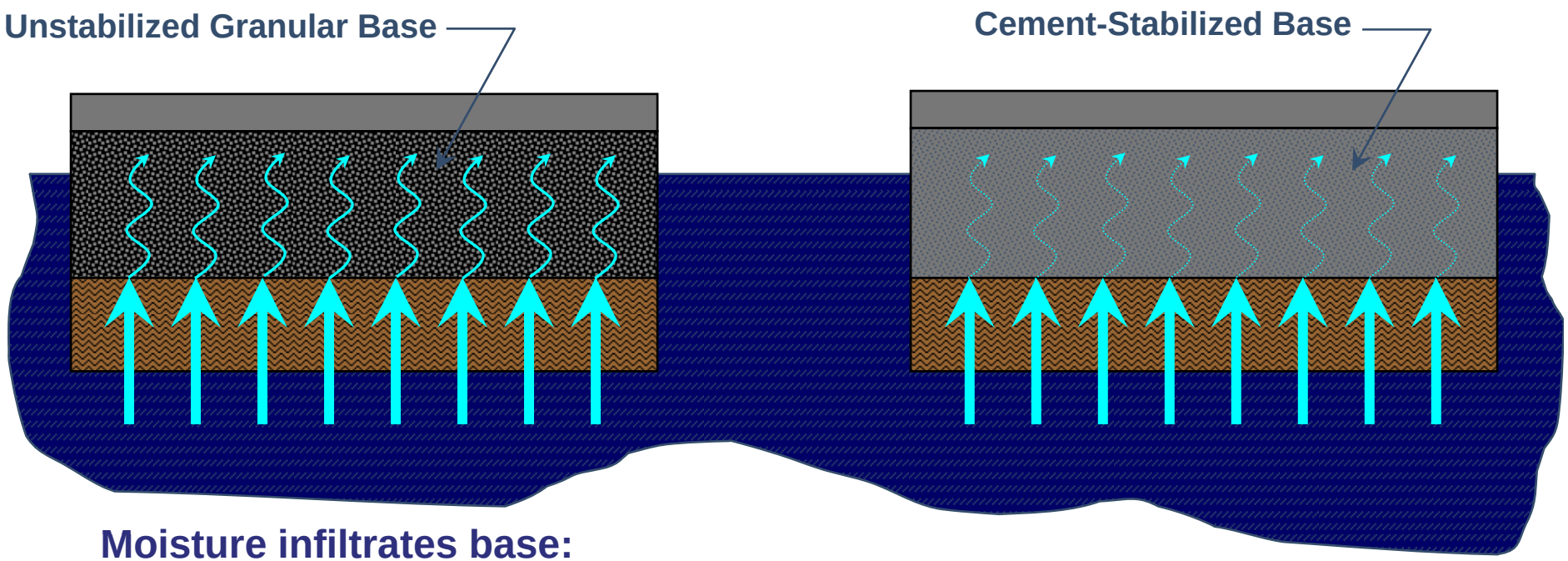


Rutting can occur in surface, base and subgrade of unstabilized bases due to repeated wheel loading



Cement-stabilized bases resist consolidation and movement, thus virtually eliminating rutting in all layers but the asphalt surface.

Reduced Moisture Susceptibility



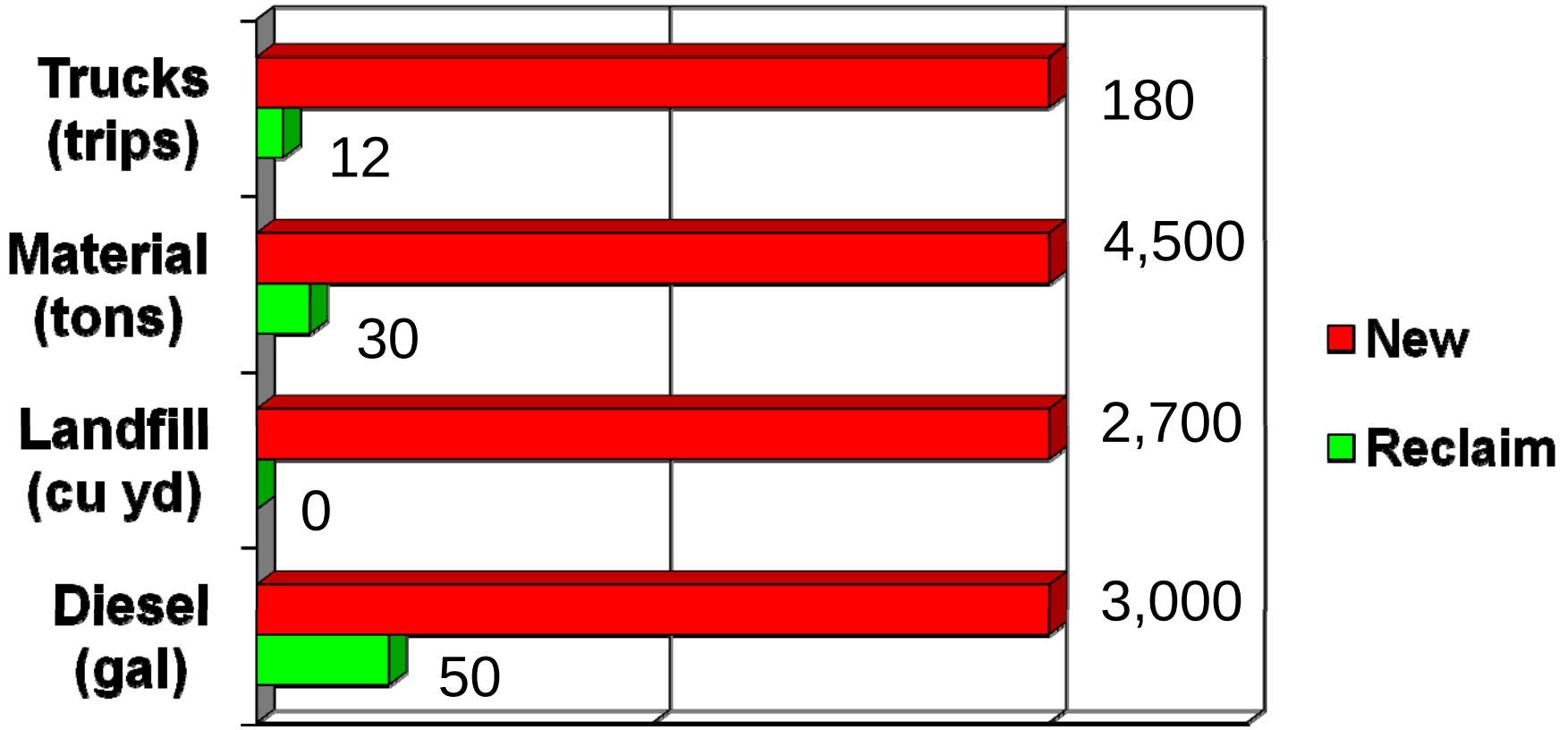
Moisture infiltrates base:

- **Through high water table**
- **Through capillary action**
- **Causes softening, lower strength, and reduced modulus**

Cement stabilization:

- **Reduces permeability**
- **Helps keep moisture out**
- **Maintains high level of strength and stiffness even when saturated**

Sustainable Element of FDR Process



1 mile of 24-foot wide, 2-lane road, with a 6-inch base

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Design

Field Sampling

- Obtain representative samples of roadway material
- Usually about 100 pounds of material is required

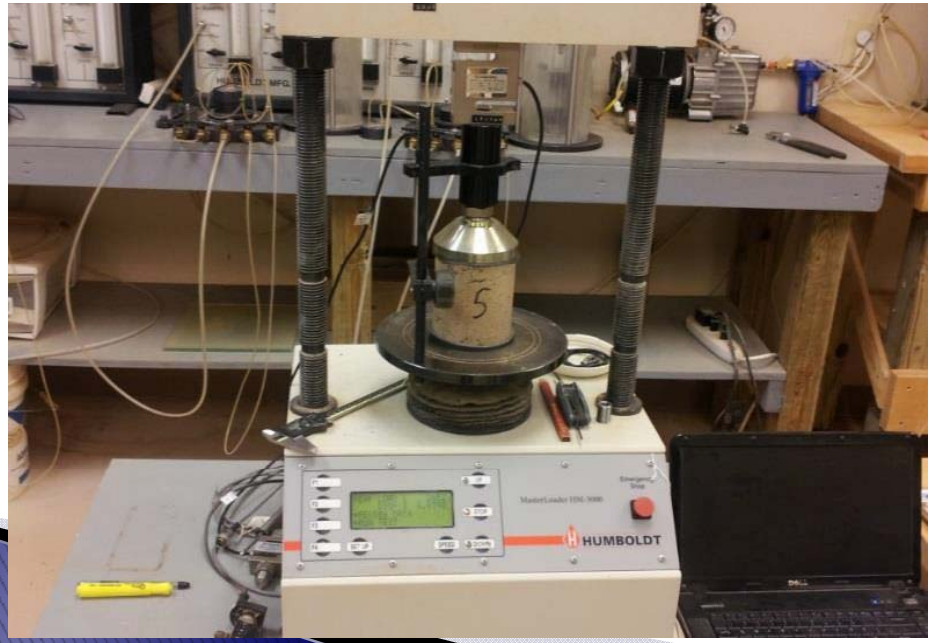
Blending Aggregates

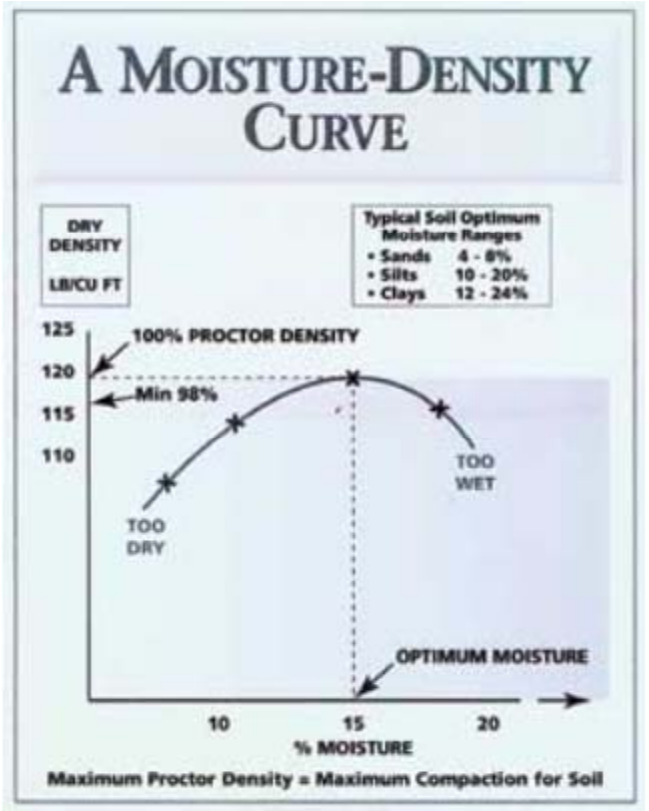
- Breakdown Asphalt
- Sieve Aggregates

Testing

- Standard Proctor ASTM D-558 to determine relationship between moisture and density

- Compressive Strength



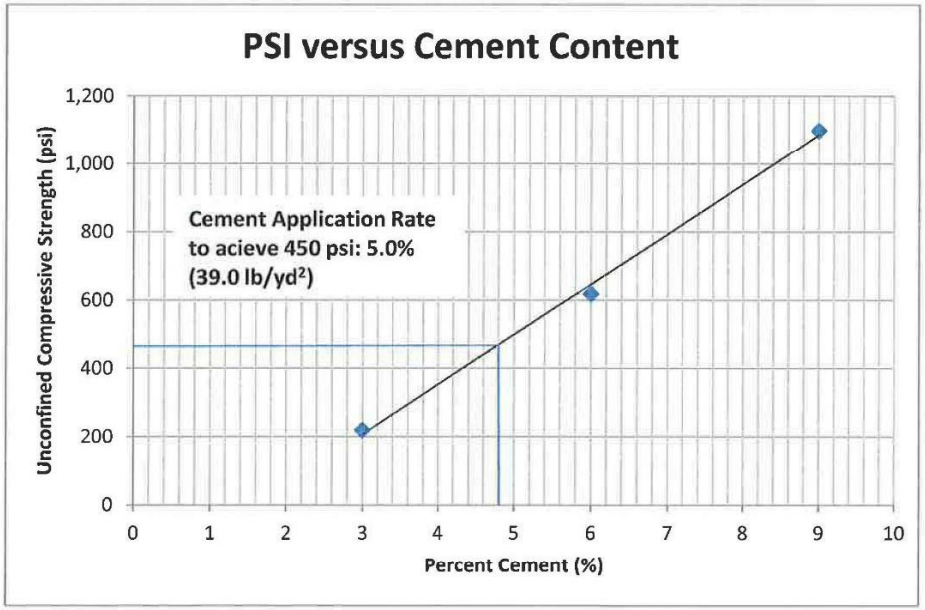


Laboratory Mix Design

- Obtain representative samples of roadway material
- Usually about 100 pounds of material is required
- Determine the maximum dry density and optimum moisture content at various cement percentages (ASTM D558)
- Prepare samples
- Typical designs vary between 2 and 8 percent cement by weight of dry material
- Cure samples
- Break the cylinders

Unconfined Compressive Strength Testing

ASTM D1633

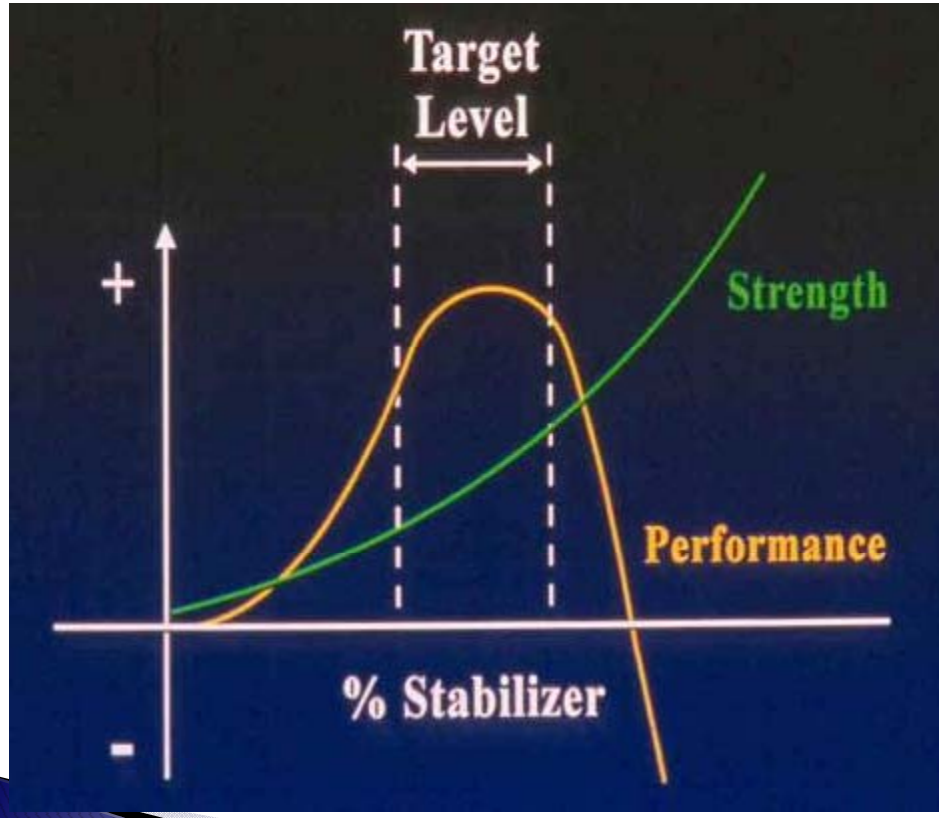


CMRB LABORATORY TEST RESULTS

Project Location: Nichol Street 8" Reclamation
Greenville, South Carolina
Client: City of Greenville
Date: 2/5/2014

Sample ID	Dry Unit Weight (pcf)	Average Moisture (%)	Compressive Load (lbs)	7-Day Compressive Strength (psi)
3% Cement	128.8	8.3%	2,670	210
	126.8		2,670	210
	129.9		3,170	250
Average	128.5	8.3%	2,840	220
6% Cement	131.3	8.3%	7,370	590
	133.1		8,020	640
	132.6		7,910	630
Average	132.3	8.3%	7,770	620
9% Cement	133.7	8.3%	12,580	1000
	130.3		13,880	1100
	132.6		15,270	1210
Average	132.2	8.3%	13,910	1,100

Please keep in mind that strength and performance are NOT the same thing



The purpose of the mix design procedure is to select the correct amount of stabilizer that most closely balances both strength AND performance for the roadway materials!

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Pavement Thickness Design Procedures

- 1993 AASHTO Pavement Design Guide
  - Structural Numbers
  - Layer Coefficients
- Proposed New AASHTO Design Guide
  - Mechanistic-Empirical Design
  - Evaluates effects of pavement materials, traffic loading conditions, environmental factors, design features, and construction practices
- StreetPave

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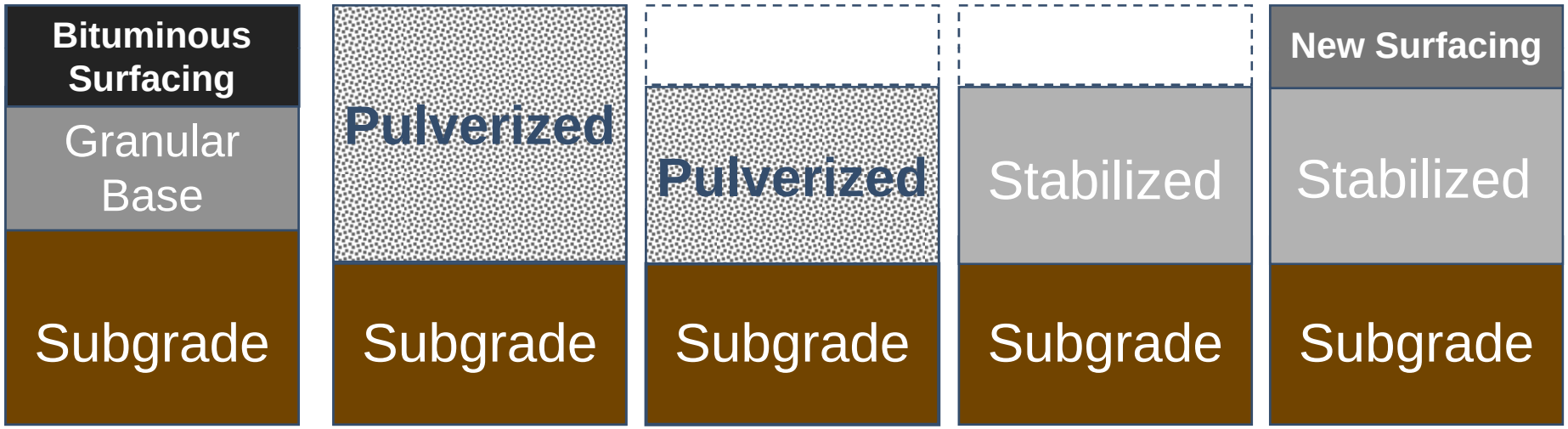
FDR Construction Process

Pulverize, Shape, Add Cement, Mix In Place, Compact, and Surface



Existing road

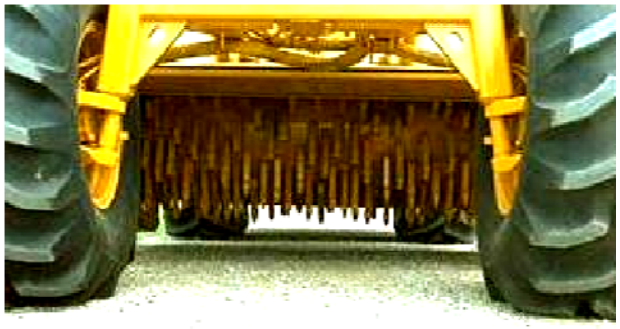
Pulverization to desired depth

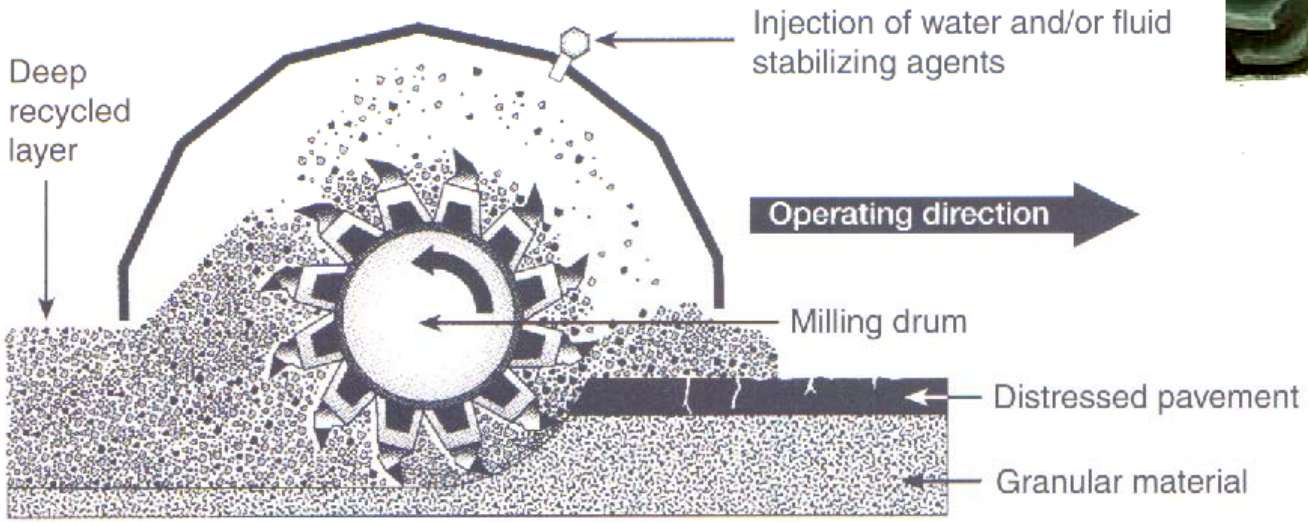
Removal of excess material (if necessary) and shaping

Addition of cement, mixing, reshaping, and compaction

Final surface application

Inside a Reclaimer





Pulverization

- Pulverize mat to appropriate gradation
- Usually, only one pass is required

Cement Spreading

Cement is spread on top of the pulverized material in a measured amount in either a dry or slurry form

Blending of Materials and Moisture Addition

Cement is blended into pulverized, reclaimed material and, with the addition of water, is brought to optimum moisture

Compaction and Grading

Material is compacted to 96 to 98 percent minimum standard Proctor density and then graded to appropriate Plan lines, grades, and cross-sections

Curing

Bituminous Compounds (cutbacks or emulsions)

Water
(kept continuously moist)

Paving

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Field Testing

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Testing Requirements

Gradation/Uniformity

A common gradation requirement is for :
-100 percent to pass a 3-inch sieve,
-a minimum of 95 percent to pass a 2-inch sieve,
-and a minimum of 55 percent to pass a No. 4 sieve
(ASTM C136).

Density

A common density requirement is to be between 96 and 98 percent of the established laboratory standard Proctor density (ASTM D2922).
Nuclear Density Gauge

Moisture

A common moisture requirement is to be within 2 percent of the laboratory established optimum moisture content
(ASTM 4959 Direct Heat
ASTM 4643 Microwave).

FDR processing shall not commence when the soil/aggregate or subgrade is frozen, or when the air temperature is below 40 degrees F

Cement Application

Materials: Square Yard Pan and Balance

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Video

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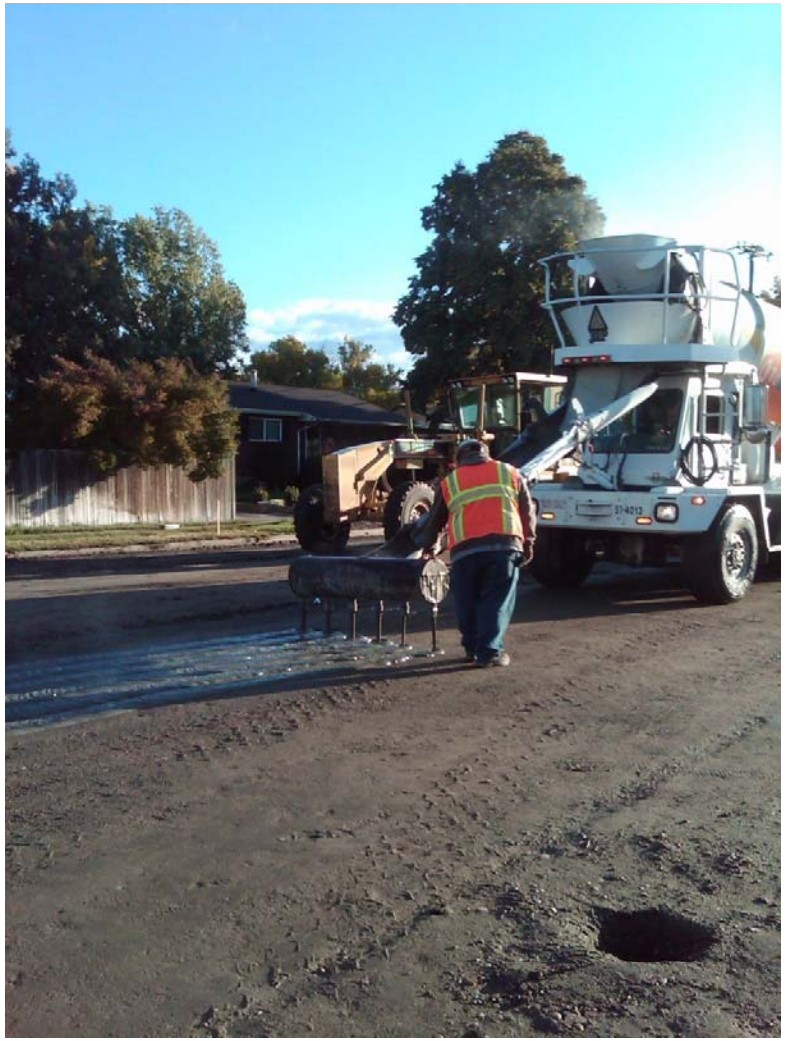
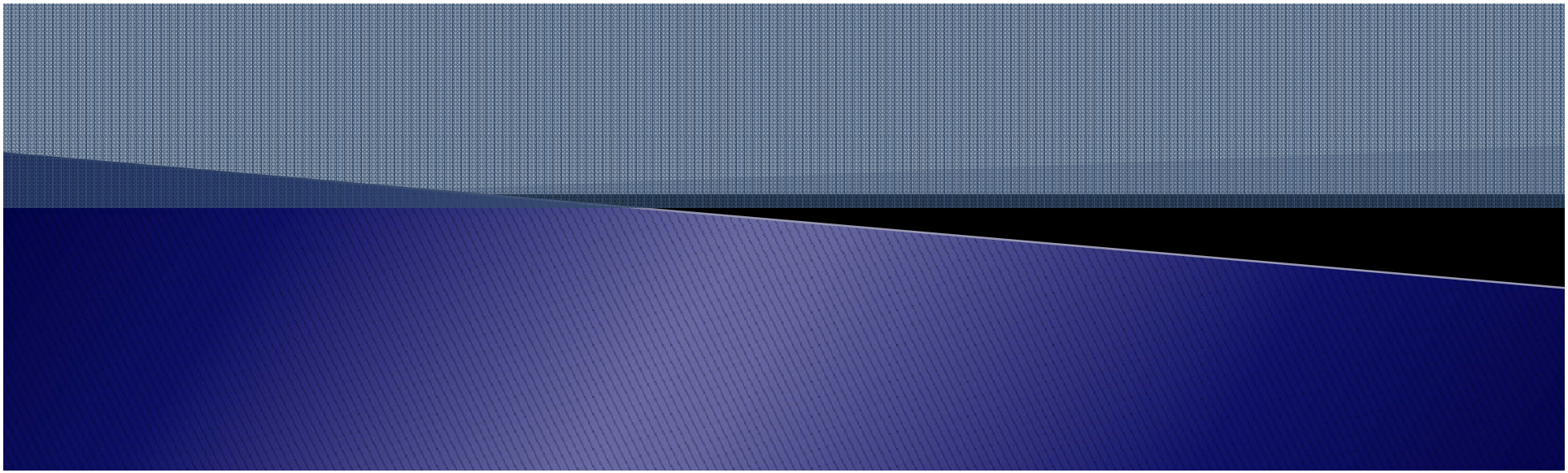
Case Studies

Bonner County, ID

- Constructs about 12 miles of FDR with cement each year
- Started with 8% cement with a 21-day UCS of 900 psi
  - Now they use 3% - 5.5% cement with a 21 UCS of 700 psi
  - Geotextile Fabric between CTB and chip seal



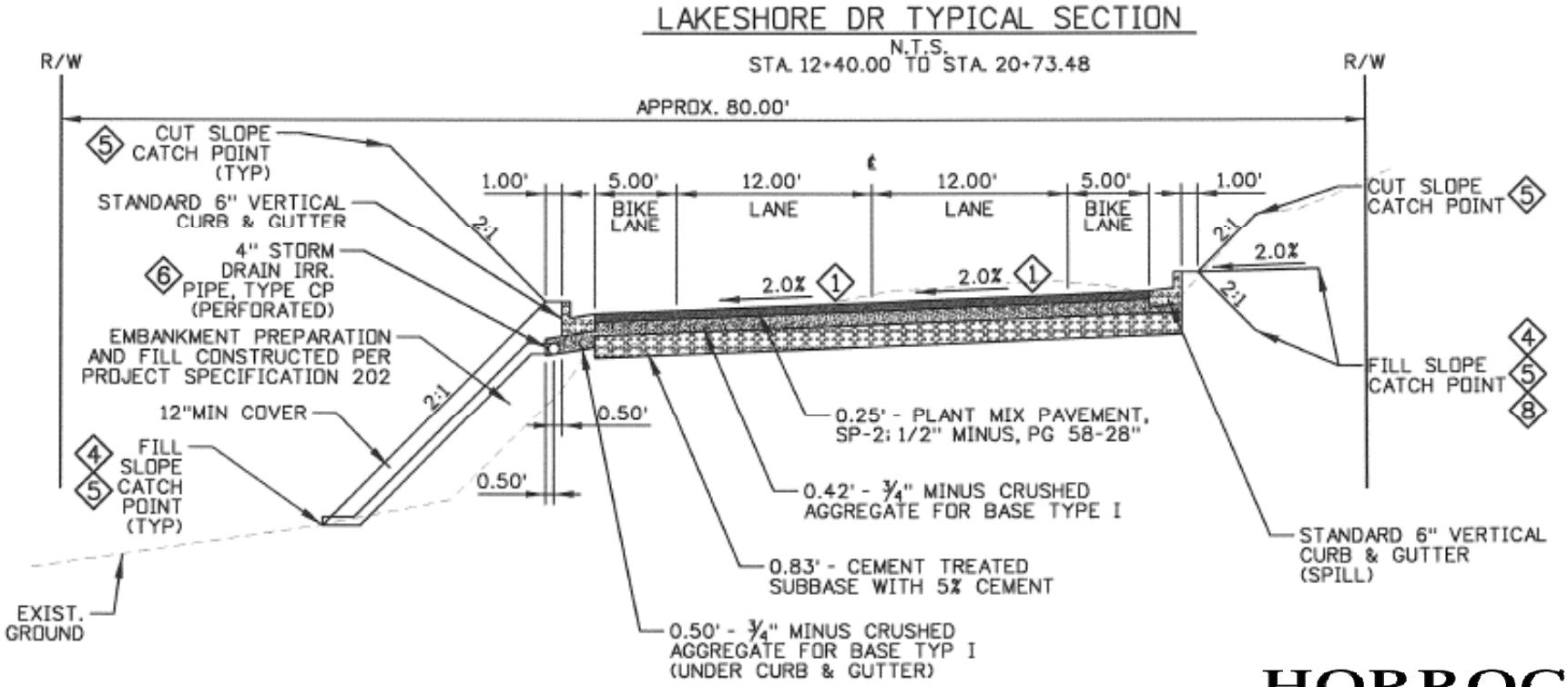


Lakeshore Drive, Cascade Idaho

- Approximately 1300 linear feet on Lakeshore Drive
- FDR chosen to reduce 30” ballast section to 24” and for frost heave protection

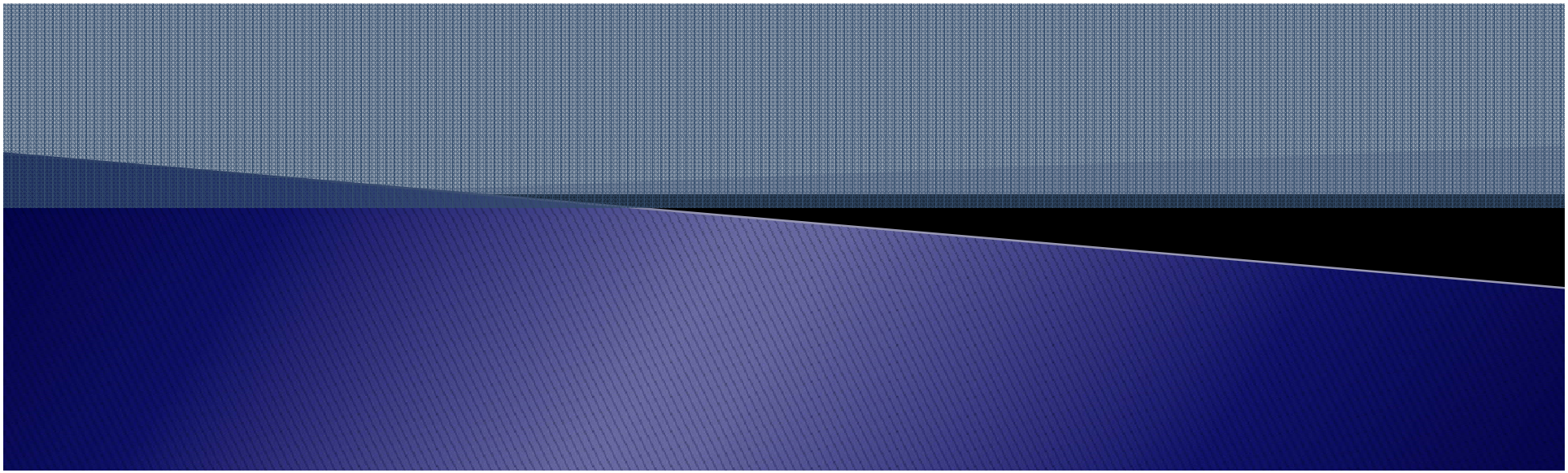
Lakeshore Drive, Cascade Idaho

- Construction sequence:
  - Step 1: Mill and Pulverize 2” of existing asphalt and set it aside
  - Step 2: Reclaim 6” of existing ¾” minus base material and set it aside
  - Step 3: Within the 6” subbase , mix Portland Cement, water and existing pulverized asphalt
  - Step 4: Apply 4” asphalt wearing coarse



Benefits

- Entire FDR process vs. hauling existing material and mining virgin material saved the owner 30%



Case Study: City of Raymond, WA

- **Commercial Street Reconstruction, Raymond WA, 2015**
- **Duryea Street Reconstruction, Raymond WA, 2016**

- **Projects funded by Washington State Transportation Improvement Board**
- **Pavement Services, Inc. supported Lochner, Inc. on these projects**

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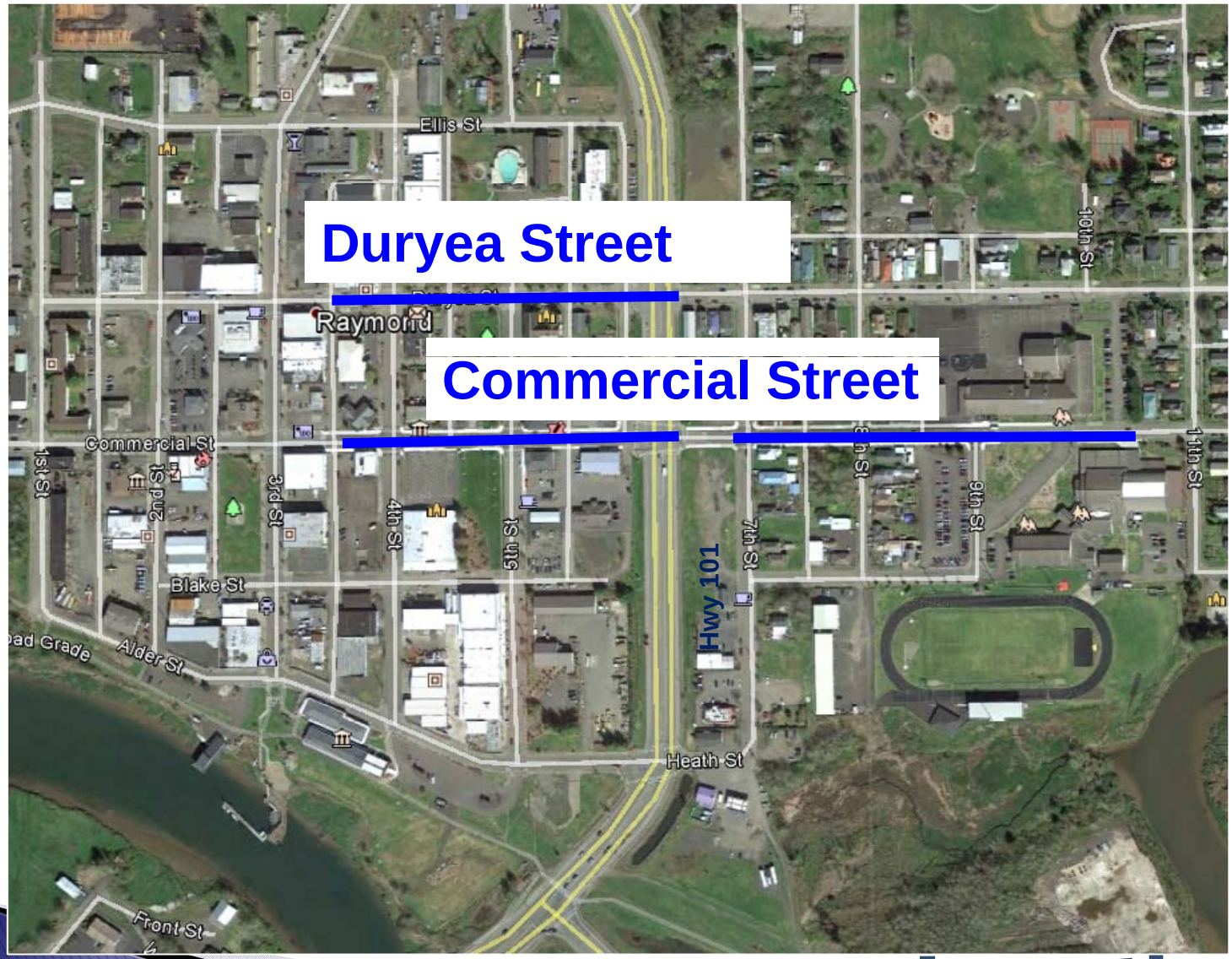

Locations

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Project Details

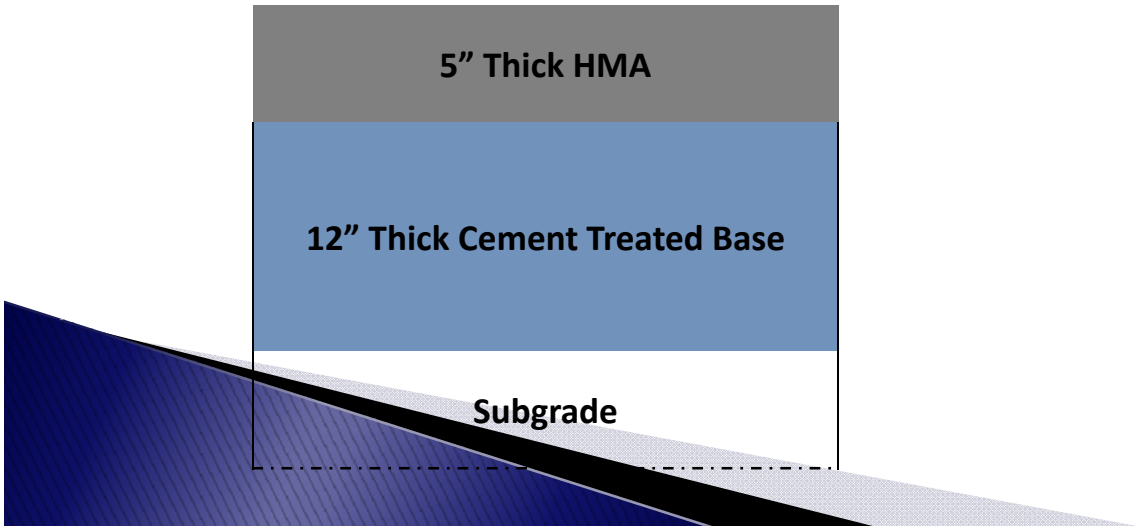
- Commercial Street
  - 3rd St. To 10th St.
  - Existing Pavement Section 4.5” HMA + 6.5” Aggregate Base. Subgrade Classified As Clayey SILT
  - Subgrade CBR ~ 3
  - Traffic Comprised School Buses & FHWA Class 5 Trucks
- Duryea Street
  - 3rd St. To 6th St.
  - Existing Pavement Section 7.75” PCC Over Native Subgrade (Clayey SILT)
  - Subgrade CBR ~ 3
  - Traffic Comprised School Buses & FHWA Class 5 Trucks

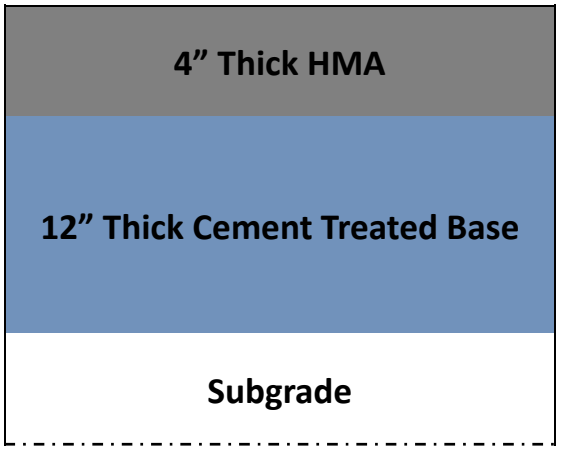
PAVEMENT SERVICES, INC.

Recommendations for New Pavement

- Commercial Street
  - 5-Inch Thick HMA Class ½, PG 64-22 Wearing Course
  - 12-Inch Thick In-Place Cement Treated Base
    - 6” Aggregate + 6” Subgrade

- Duryea Street
  - 4-Inch Thick HMA Class ½, PG 64-22 Wearing Course
  - 12-Inch Thick In-Place Cement Treated Base
    - 6” New Aggregate + 6” Subgrade





Laboratory Testing: Duryea Street

- Duryea Street
  - Moisture-Density Test
    - Composite sample comprised 56% new agg. + 44% native subgrade
    - Specimen molded at 8% cement (by dry weight)
    - Optimum Moisture Content = 18.7%
    - Max. Dry Density = 110.6 pcf.
  - Compressive Strength Tests
    - 3 Soil-Cement specimens molded at 5%, 8% And 11% cement content
    - Cured For 7 Days
    - Cement content of 6% selected for a 7-day strength Of 300 psi

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FDR Construction: Duryea Street

Cement Truck on Duryea Street
Total cement used: 88 Tons

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FDR Construction: Duryea Street

Pulverizer
In operation on Duryea Street

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FDR Construction: Duryea Street

Application of cement to the Soil-Crushed Aggregate blend on Duryea Street October 3, 2016

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FDR Construction: Duryea Street

Water Truck and Pulverizer
In operation on Duryea Street

FDR Construction: Duryea Street

Soil-Cement Stabilized Surface after first pulverization on Duryea Street

FDR Construction: Duryea Street

Vibratory Sheepsfoot Roller compacting the Soil-Cement Stabilized layer on Duryea Street

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FDR Construction: Duryea Street

Dozer In operation grading/profiling the Stabilized Surface On Duryea Street

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FDR Construction: Duryea Street

Vibratory Steel Wheeled Roller compacting the Soil-Cement Stabilized layer on Duryea Street

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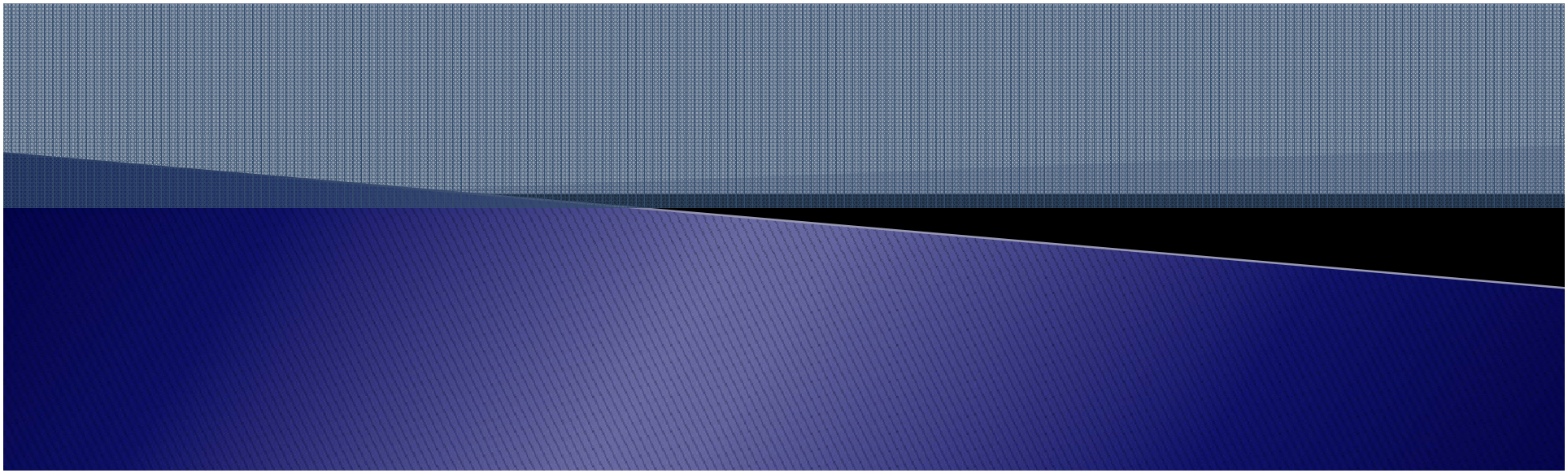
FDR Construction: Duryea Street

Finished Cement-Treated Base on Duryea Street

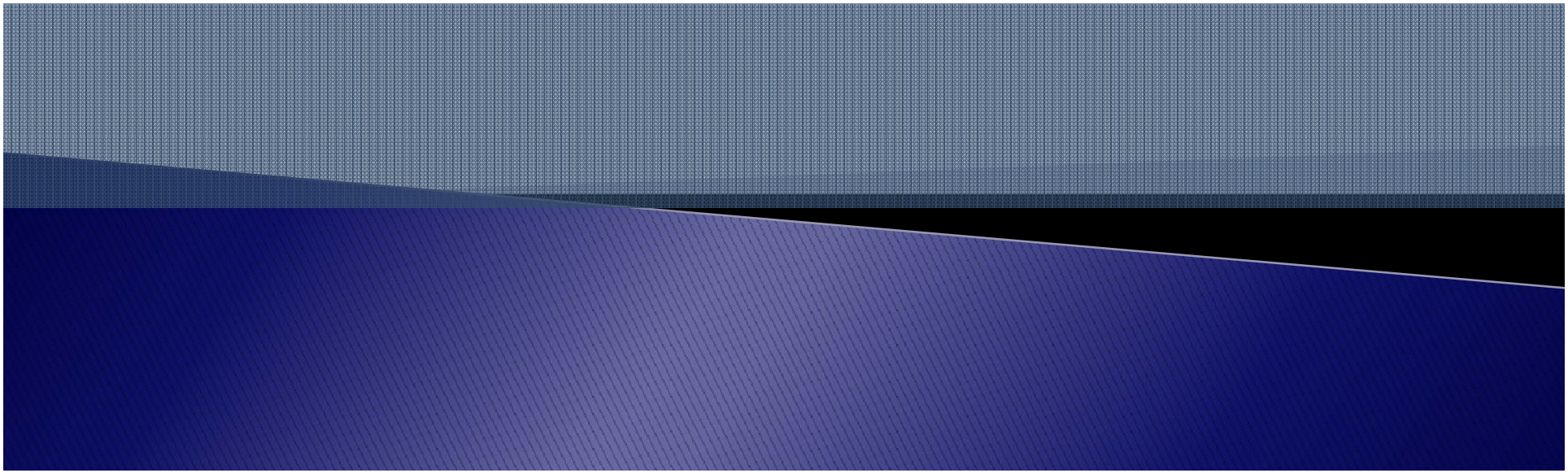
FDR Construction: Duryea Street

HMA Base Course sealing water on Duryea Street October 4, 2016



Harris Street, Eugene OR
FDR with Cement Slurry

- www.youtube.com/watch?v=gtjpmJiYkBM
- www.youtube.com/watch?v=HhYlAA0oqAU



Bear Creek Greenway Trail Reconstruction

- Reconstruct/repair approximately 8 of 17 miles of existing multi-use trail
- Divided into three “Sections”
- Funded with $1.46 M “Non-Highway Readiness” dollars
- Constructed in Summer 2012

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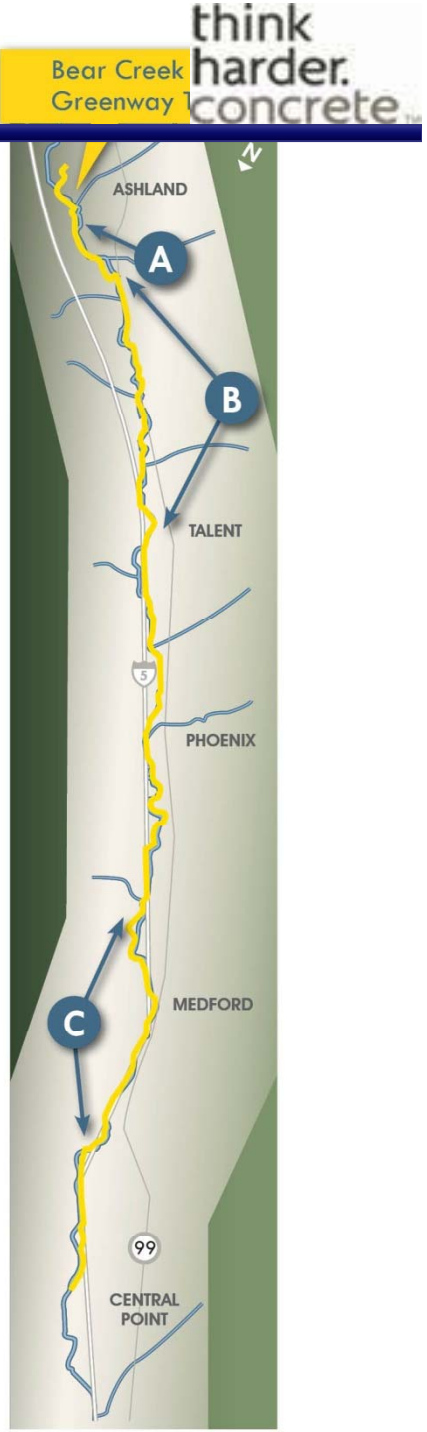
Existing Conditions

- Project construction in three sections: A, B, and C
  - Severe longitudinal cracking – 23 yrs old
  - Root intrusion and distress cracking – 20 to 30 yrs old
  - Root intrusion and pavement failure – more than 35 yrs old



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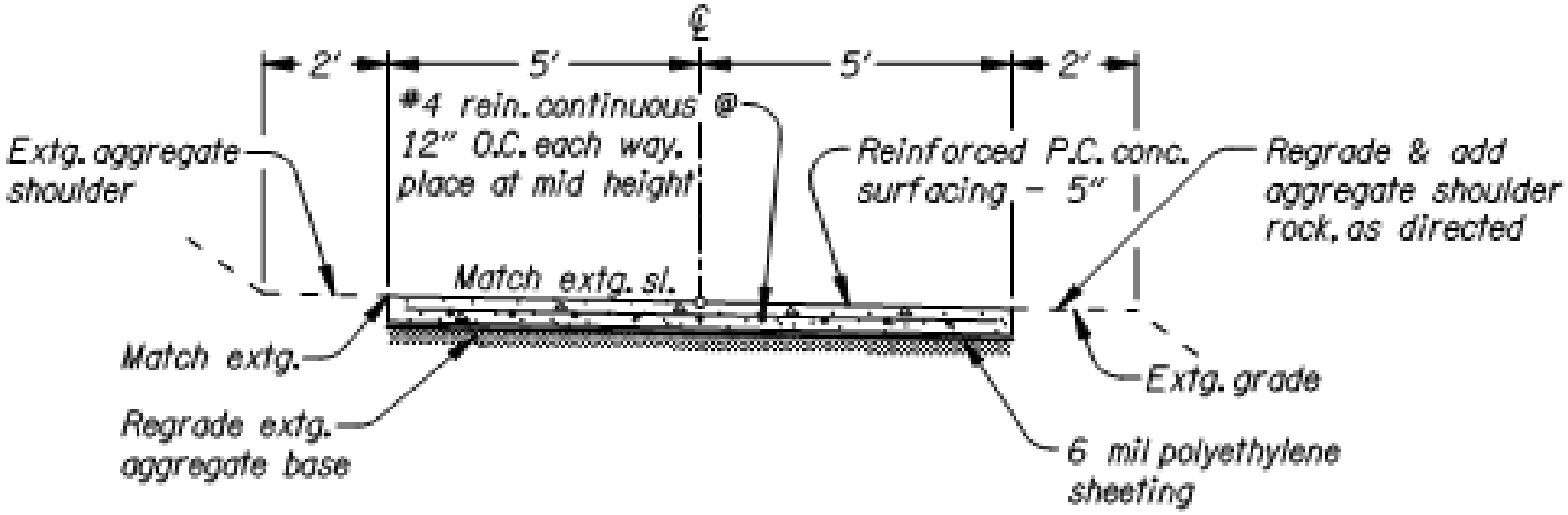
Existing Conditions

FDR Design

- FDR Design Parameters
  - 8-inch treatment depth
  - 4% Portland Cement (by dry weight)
  - Target unconfined compressive strength of 400 psi
- Wearing Surface
  - 3-Inch nominal thickness
  - Level 1 or 2 mix design
- Other requirements:
  - Contractor shall add water to mixture for compaction and curing (+/- 2% of optimum moisture)
  - Keep FDR mixture damp until paving is complete
  - Perform “microcracking” if paving is not started within 12 hours of cement treatment

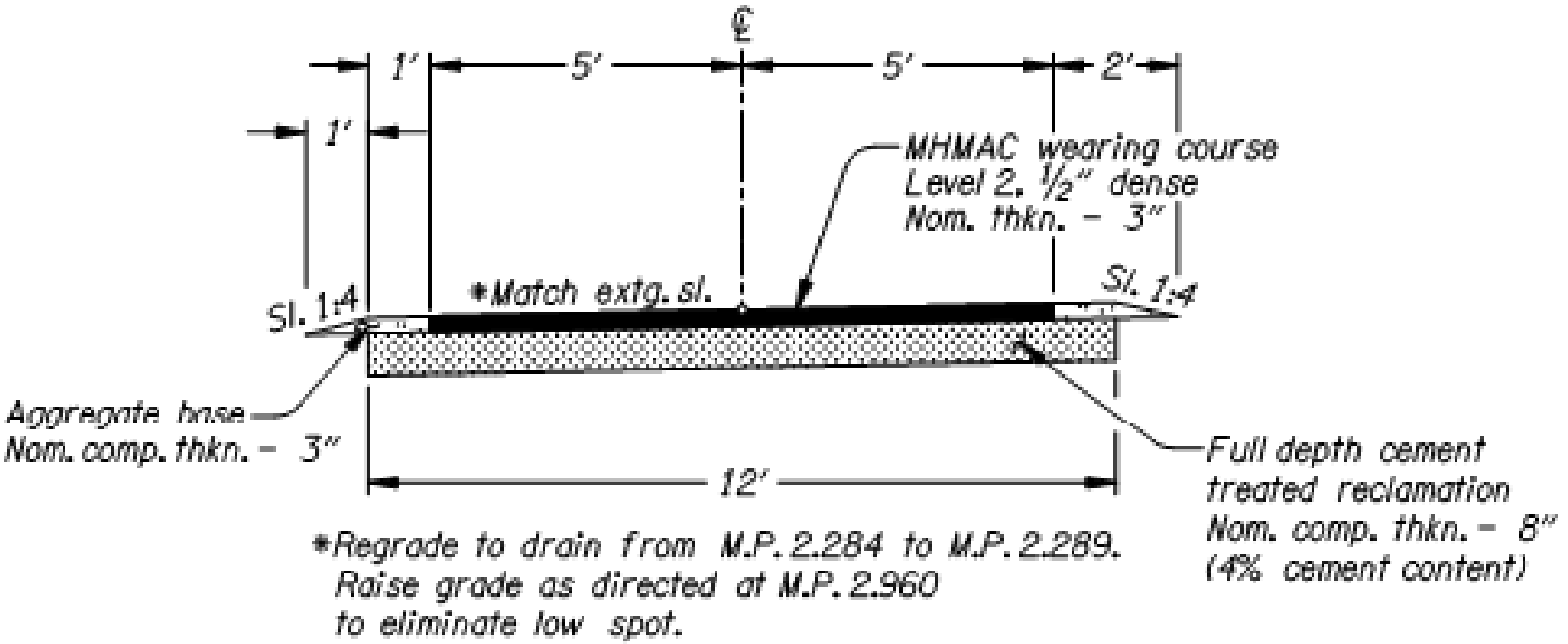
Selected Pavement Designs

- Section A - 5” Reinforced PCC slab



Selected Pavement Designs

- Section B & C - 3” ACP over 8” FDR



FDR Construction Technique

- Step 1 - Pulverizing

FDR Construction Technique

- Pulverizing

FDR Construction Technique

- Mixing (add water)

FDR Construction Technique

- Microcracking (if paving is delayed)

FDR Construction Technique

- Paving

FDR Construction Technique

- Complete!

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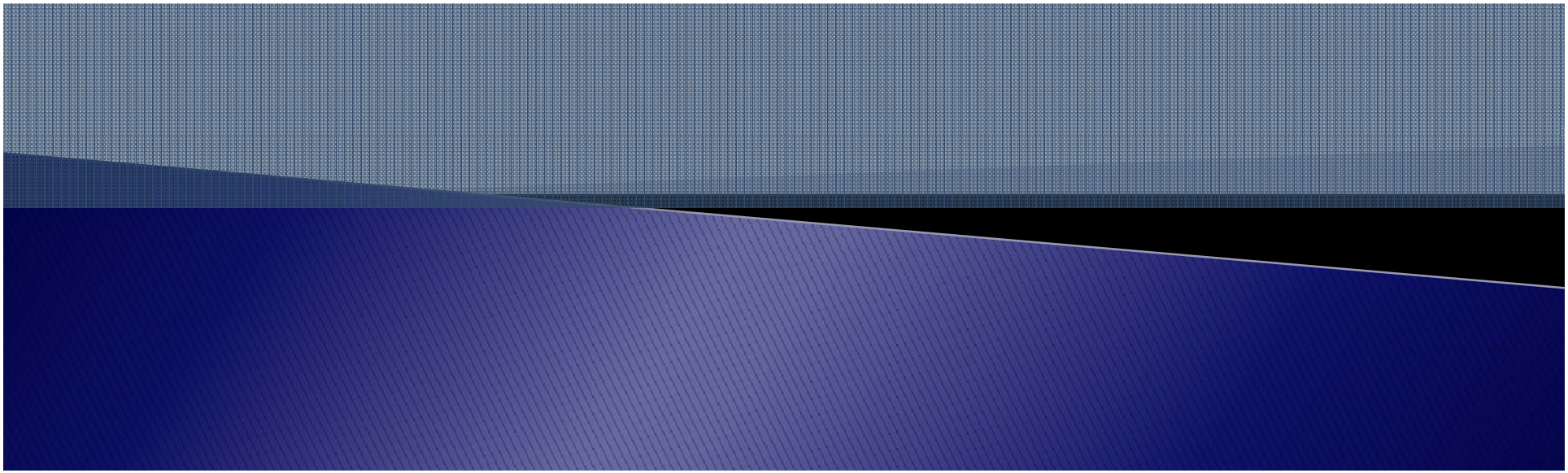
Construction Schedule/ Costs

- Treated approx. 3,000 feet of trail per day
- Nearly 6 miles treated in 10 days on site
- Low Bid (KRM/West Coast Road Recycling)
  - 8” FDR - $4.50/sq. yd.
  - Portland Cement - $110/ton
  - **Total FDR Cost - $6.24/sq. yd.**
- Conventional Methods:
  - 12” Excavation (@ $10/cu. yd) - $3.33/sq. yd.
  - 12” Agg Base (@ $33/ton) - $19.78/sq. yd.
  - Subgrade Geotextile - $1/sq. yd.
  - **Total Conventional Cost - $24.11/sq. yd.**



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PCCP Roundabout with FDR

Mt. Washington/Reed Market/Century Dr. Roundabout Resurfacing

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Why Reconstruct?

- Original construction – 2003
- Failed w/in 8 years
- High volume intersection
- Poor base (cinders & pumice)
- Improve automobile, pedestrian & bicyclist safety
- Increase lifespan & quality of the pavement surface
- Reduce long-term pavement maintenance requirements

Project Description

"Full-depth reclamation of asphalt concrete pavement, base rock, and native materials from an existing roundabout at the intersection of Mt. Washington Drive, Century Drive and Reed Market Road in southwest Bend.

Contract work includes processing reclaimed materials on-site and placing to form a new base course, and offsite disposal of excess material.

Work also includes construction of a non-reinforced portland cement concrete layer, with filled sawcut joints and a tined finish."

Design of Full-Depth Reclamation

- 3% ± 0.50%Type I/II portland cement
- 17” Pulverized & Blended
- Terex RS 800 Reclaimer/Stabilizer
- Leveled with CAT 160H Motor Grader
- 9” removed to maintain grade with PCCP
- 8” Pulverized & Stabilized with 3% cement & water
- Compacted
- Water cure
- Price = $5.60 SY

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Design of Portland Cement Concrete (PCC) Pavement

- 40-year design life
- Traffic Volume = 15,000 – 20,000 ADT (Highest)
- Pavement Thickness: 9”, plain, undowled (ACPA StreetPave)
- Class 5000 – 1 ½ (5000 psi w/ 1 ½ “ Agg.)
- Maximum w/cm ratio of 0.40
- Textured finish – broom finish perpendicular to centerline
- Sealed Joints
- Design strength
  - Flexural beams for paving concrete mix designs shall achieve 650 psi in 14 days.

- Price = $52.50 SY
- 3,980 CY

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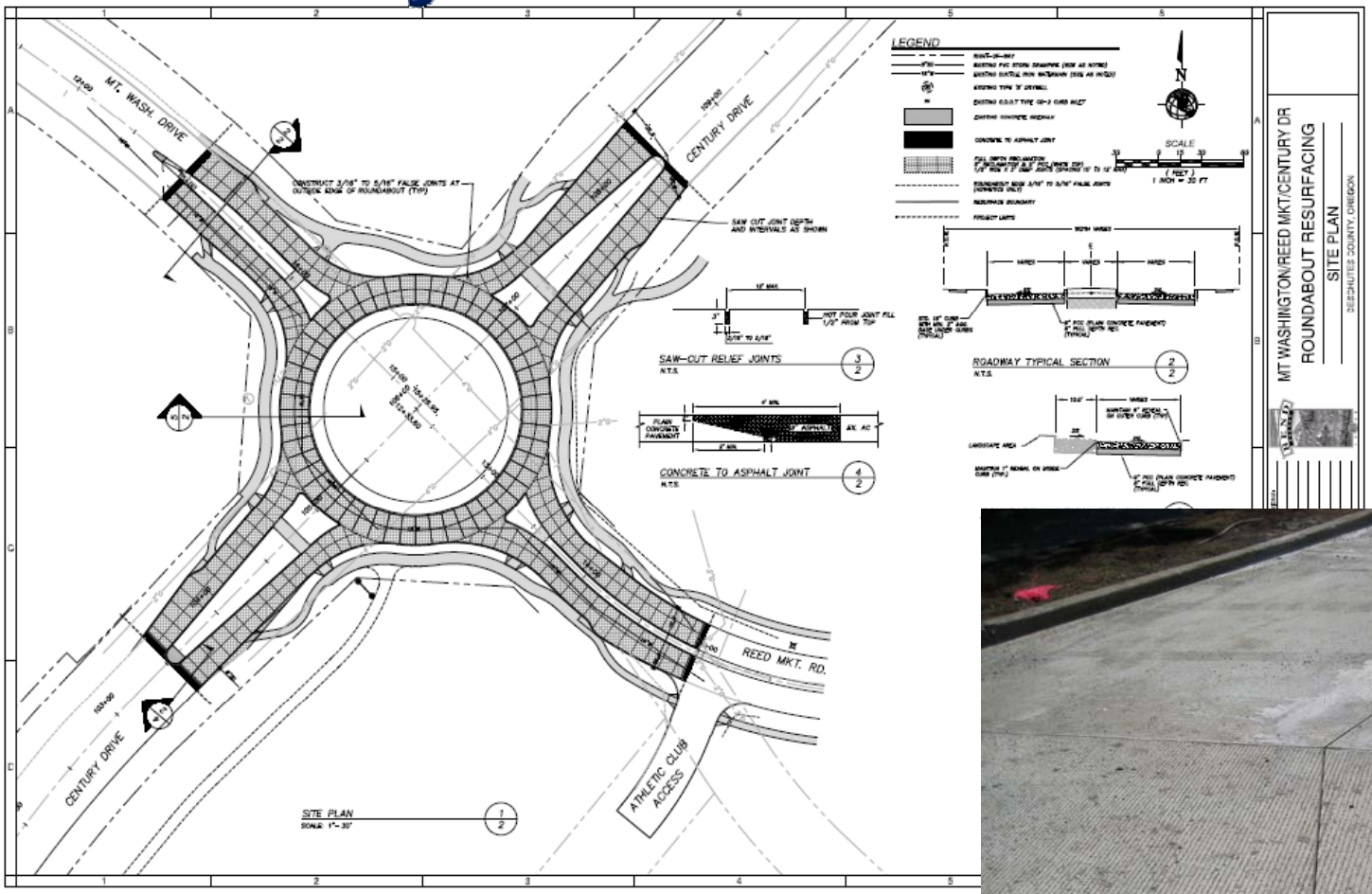
Joint Layout

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Project Team

Project Team:

Owner & Engineer: City of Bend

Hardy Hanson – Street Division Manager, Public Works, City of Bend

Kevin Ramsey – Project Manager/Street Supervisor, City of Bend

Contractor: Taylor Northwest (Jason Lafaver – PM)

Concrete Supplier: Central Oregon Ready-Mix

Concrete Subcontractor: Deschutes Concrete Construction

Concrete Sawing Subcontractor: Diamond Edge Concrete Cutting

- Cement Supplier: Lehigh Northwest Cement Company
- FDR Subcontractor: Porter W. Yett Company

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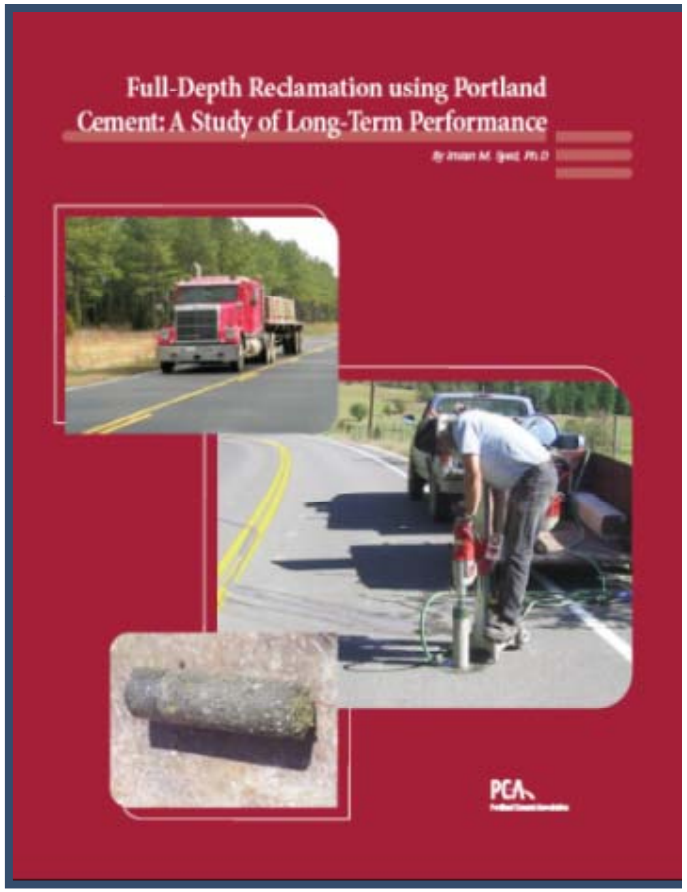
Long Term Performance

LTP Study Conclusions

- Overall, excellent LTP
- Average PCI of 89
- UCS of cores 260 to over 1,000 psi
- Cement contents 2 to 10 percent
- with average being about 5 percent
- Most surface distress was in the asphalt layer
- No major failures attributed to the cement-stabilized base
- Owners are happy with performance and plan to do more in the future



Concluding Comments

- Use of in-place materials
- Very sustainable process
- 30 to 60 percent less expensive than removal and replacement
- Fast operation
- Constructed under traffic
- Can apply local traffic almost immediately
- Structurally better than granular base
- Flexible or PCCP wearing course

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Thank you!