



Responsible Renewal. Reliable Results.

Fundamentals for Stabilization Process, Additive Selection and Design

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Stabilization

- Stabilization has become a very important tool roadway engineers can employ when rehabilitating their pavement structures.
- Stabilization can improve the pavement structure in many ways including:
 - **Shear strength** – the ability to resist shear stresses due to traffic loading.
 - **Modulus (stiffness)** – the ability to respond elastically and minimize permanent deformation when subjected to traffic loading.
 - **Resistance to moisture** – the ability to resist the absorption of water to maintain shear strength and modulus.
 - **Stability** – the ability to maintain its physical volume and mass when subjected to traffic or moisture.
 - **Durability** – the ability to maintain material and engineering properties when exposed to environmental conditions such as moisture and temperature changes to extend service life.
 - **Resistance to fatigue** – the ability to extend pavement surface fatigue life by addition of a more flexible crack resistant component to the overall pavement structure.
 - **Resistance to rutting** – the ability to withstand the accumulation of the permanent deformation when subjected to traffic.
 - **Grade change restrictions** – reduction the need of thicker HMA overlay by strengthening the underlying layer in areas where specific grade needs to be met such as curb and gutters.



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Stabilization vs. Modification

- **Stabilization** refers to base/subgrade soil improvement that includes significant, long-term reactions which result in a bound layer.
- A laboratory mix design is recommended to be performed for stabilization: to find the optimum stabilization additive and additive content that allows the mixture to pass mix design performance requirements.
- Performance requirements/tests vary between stabilization processes and stabilization additives.
- Performance tests are used to assure the material placed in the field is represented by the mix design so pavement life is extended by meeting key performance attributes.



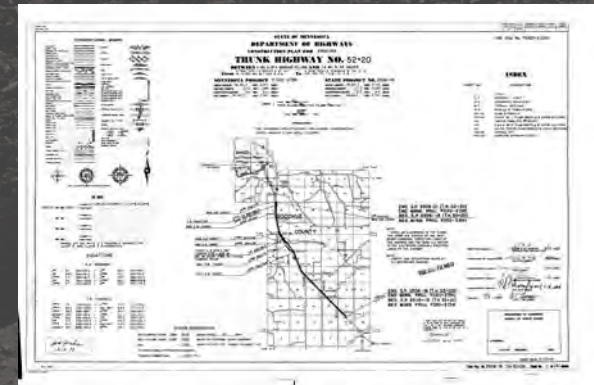
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Stabilization vs. Modification (Contd.)

- **Modification** refers to base/subgrade improvements that occur in the short term, usually as a compaction aid during construction or for short-term strength improvement that occurs shortly after mixing (within hours).
- Since no long-term reaction takes place in base modification, the stabilized base layer will remain unbound.
- Soil/base modification requires no laboratory mix design or performance testing.

Pavement Assessment

- Pavement assessment is the first step in making good decisions.
- The condition of the existing pavement is assessed through:
 - Pavement History
 - Pavement Condition/Distress Survey
 - Pavement Strength Evaluation
 - Surface, Base and Subgrade Analysis (GPR, Coring, Boring)
 - Surface and Subsurface Drainage Review
 - Others? (Ride & Safety)



Pavement Surface Evaluations

- What is a pavement condition survey?
 - A detailed visual inspection of the pavement surface
 - A link to key insights into the causes of deterioration
 - Project level and network level
 - Various methodologies (PASER, PCI, PQI)
 - Bituminous and concrete





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Pavement Strength Evaluation

- Evaluation of the structural capacity of an existing pavement can be determined by Falling Weight Deflectometer testing:
 - Identify spring load capacity
 - Identify potential pavement failures
 - In-site R-value for use in pavement design
 - Design overlay thickness
 - Evaluate feasibility of repair options that leave material in-place



Evaluation of In-place Materials

- Evaluation of in-place materials can be determined destructively (coring or borings) or non-destructively (GPR):
 - Identify thickness of in-place materials
 - Identify underlying conditions (stripping?)
 - Provide options for repair
 - Preliminary binder selection



Evaluation of In-place Materials (Contd.)



Evaluation of In-place Materials (Contd.)





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Ground Penetration Radar (GPR)



Quickly cover large flat open areas, such as lawns, roads and sidewalks.

GPS optional

DVL

Quick release and angle adjustable mount

Integrated cable system for signal, power and odometer

Fold down handle

Tough fibre glass cart - no metal, to eliminate interference

Interchangeable brackets allow any Noggin to be attached

12V battery

New battery 9Ah, 3.9 kg. (8.6 lb) lighter, smaller, 12V gel cell

Optical encoded odometer

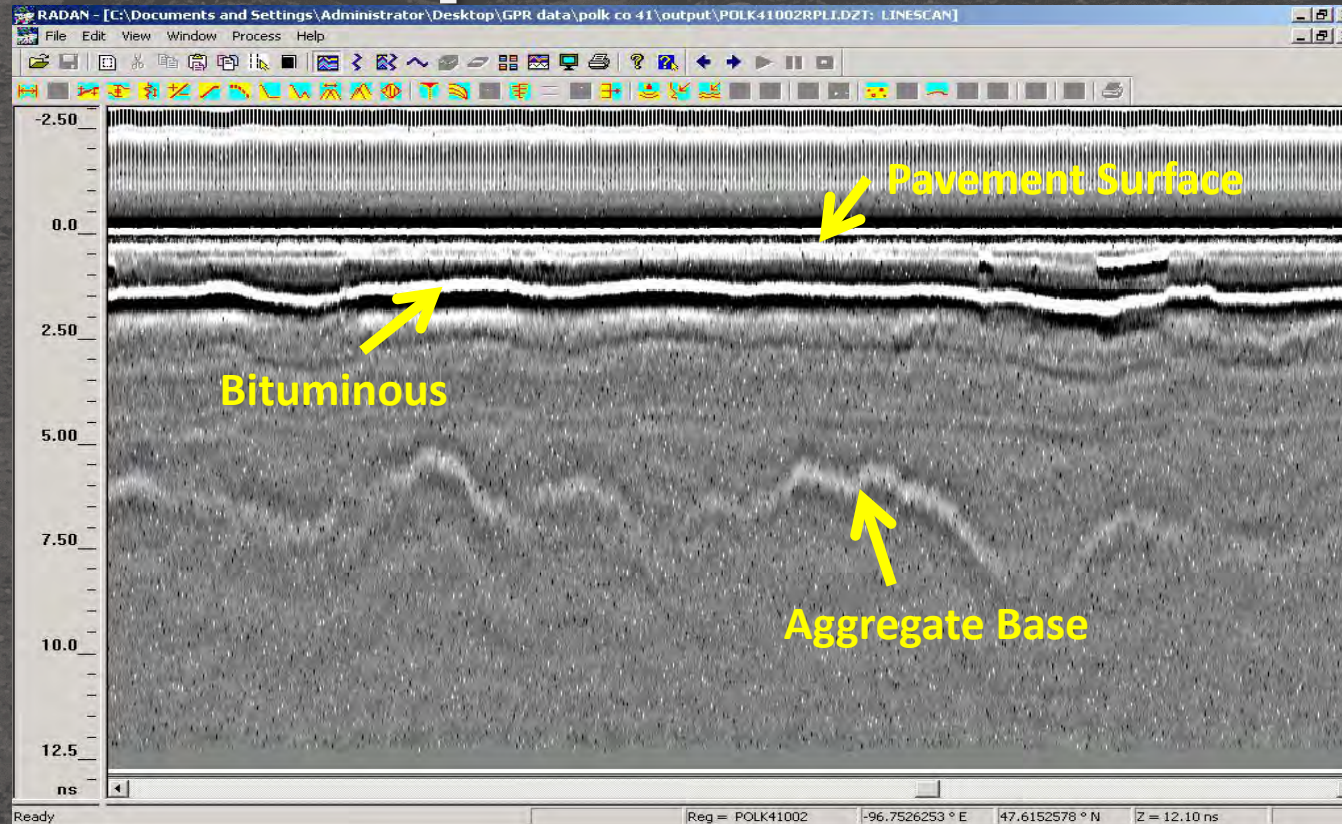
(Noggin^{plus} 250 shown here)



Air-coupled GPR

Ground-coupled GPR

Typical GPR Output File



Repair Recommendations

- Preventive Treatments (microsurfacing, sealing)
- Overlay/Mill & Overlay
- Full depth remove and replace
- Cold in place Recycling (CIR)
- Full Depth Reclamation (FDR)
- Stabilized Full Depth Reclamation (SFDR)
- Cold Central Plant Recycling (CCPR)





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Stabilized Full Depth Reclamation (SFDR)

- Renews upper 6-12 inches of pavement structure (asphalt, aggregate base and subbase) through direct reclamation
- Typically combined with asphalt emulsion, Portland cement or other additive to increase structural capacity, then overlaid
- Cost and time savings over conventional reconstruction/rehab and typical design life of 20-30 years or greater
- Becoming a common rehab strategy across the US



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SFDR Construction Process

- **Pulverization:** A reclaimer pulverizes existing pavement to a predetermined depth. New aggregates can also be added
- **Introduction of additive:** The base stabilizer is injected into (bituminous)/spread over (chemical) the reclaimed materials and the reclaimed materials are thoroughly mixed.
- **Compaction:** Compaction usually starts with vibratory pad foot roller and continues with a pneumatic roller and finishes with vibratory or static smooth drum.
- **Application of an overlay**

SFDR Construction Process (Contd.)

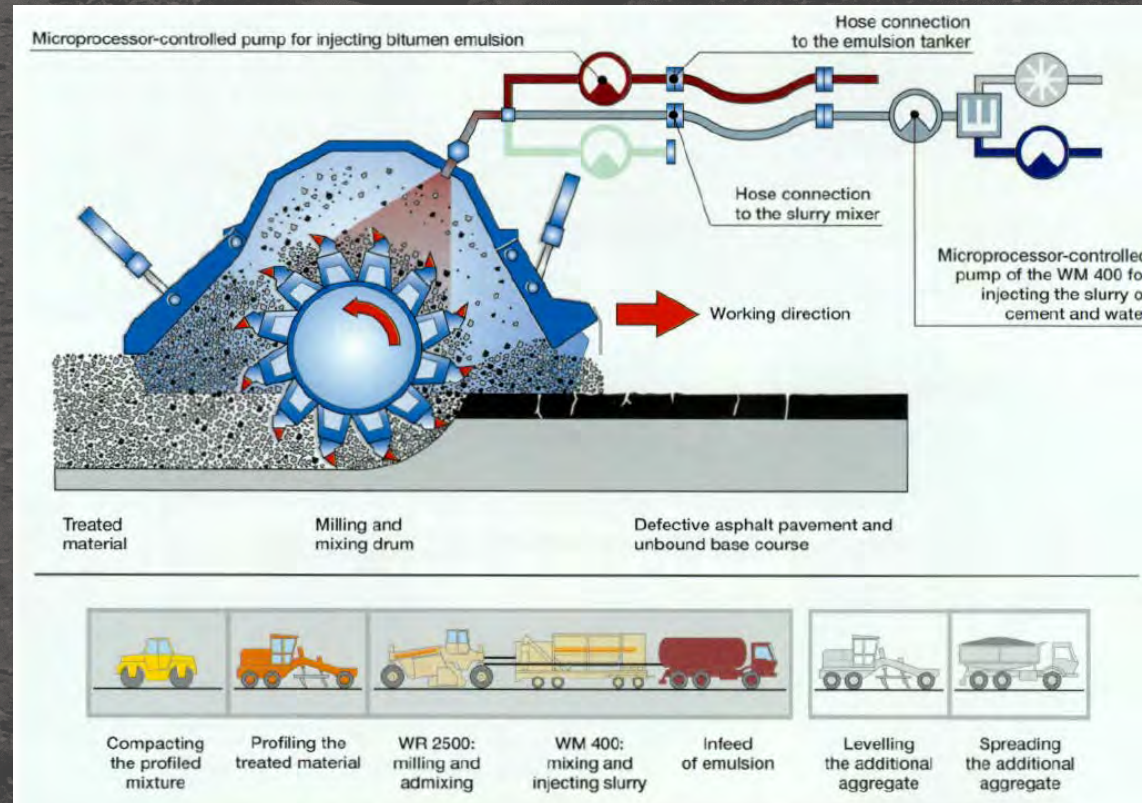


Photo obtained from "USDOT Pavement Recycling Guidelines for State and Local Government, Reference Manual (1997)"



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Base Stabilization

- **Chemical stabilization:** the stabilizers either react chemically with the material being stabilized (e.g., lime reacts with clays) or react on their own to form cementing compounds (e.g. cement):
 - **Cement:** Portland or hydrated
 - **Lime:** hydrated or quick lime
 - **Fly-ash:** by-product of coal combustion and can be in the form of self-cementing Class C or Class F (when used in combination with other additives)
 - **Cement Kiln Dust (CKD):** by-product of cement production
 - **Lime Kiln Dust (LKD):** by-product of lime production

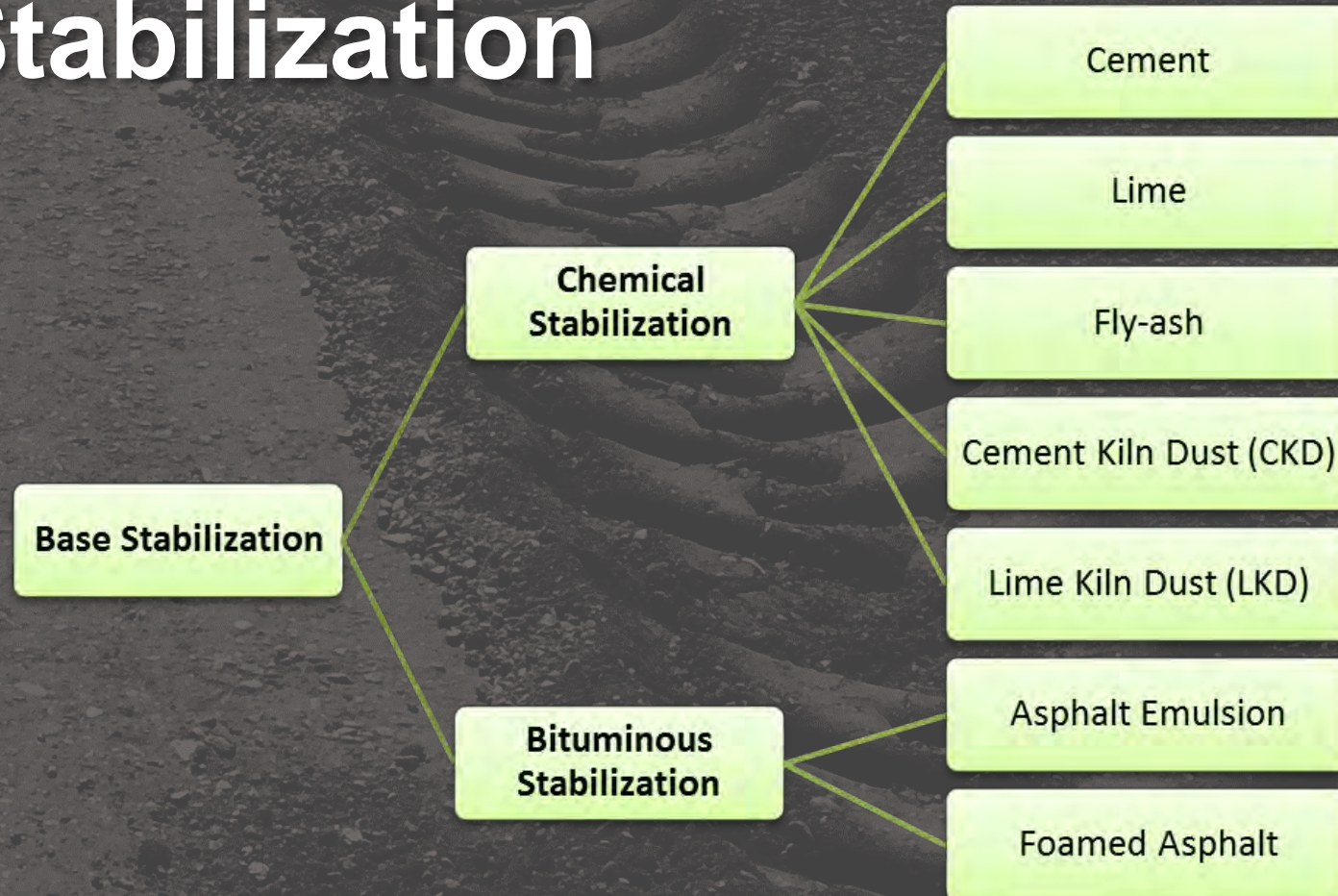


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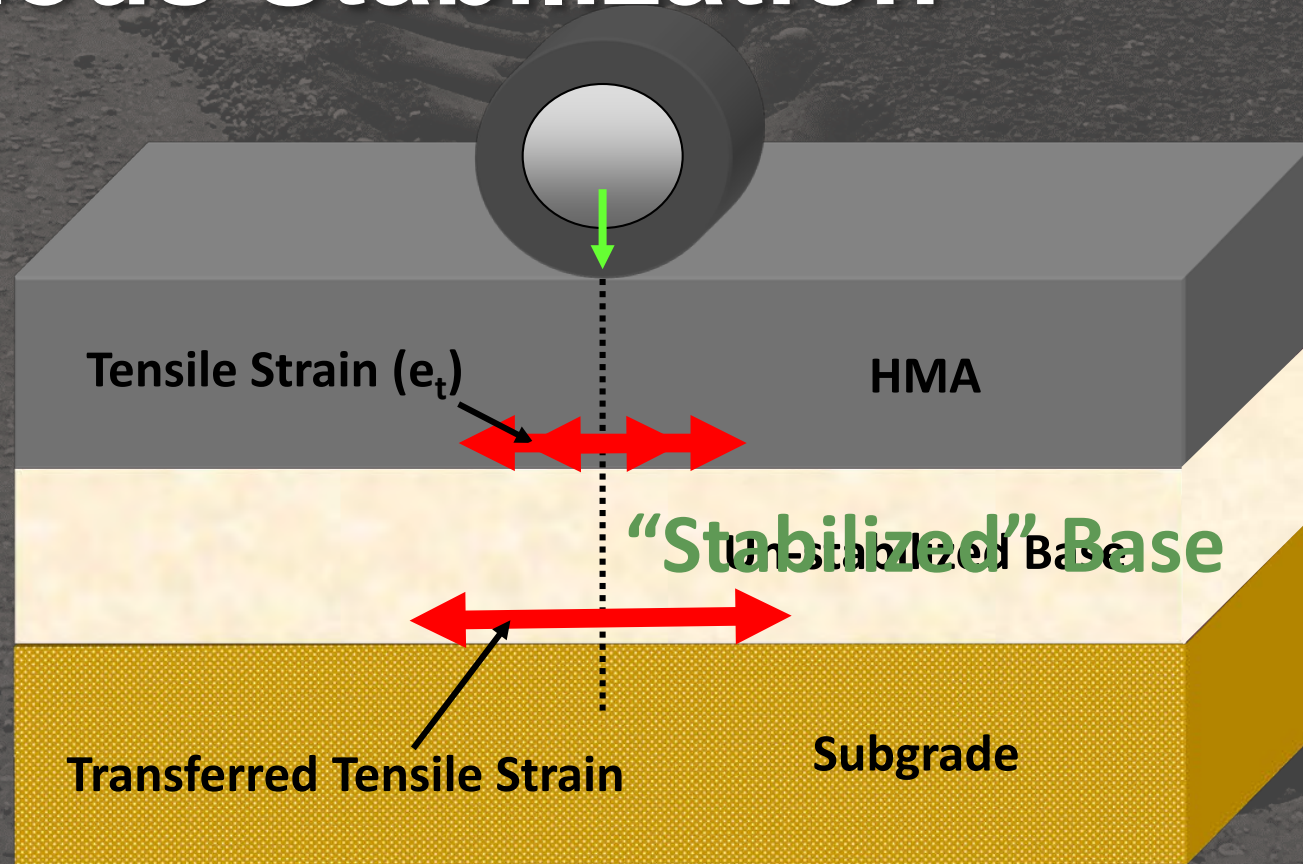
Base Stabilization

- **Bituminous Stabilization:** Bituminous does not react chemically with the base materials to produce a product that alters the surface chemistry of the particle, but develops an adhesive bond among the particles and the binder:
 - **Asphalt emulsion** which is an emulsion of asphalt binder, water, and emulsifier.
 - **Foamed (expanded) asphalt** which is a mixture of air, water, and hot asphalt binder. Foamed asphalt adhere to fine particles (mainly passing No. 200 sieve) and create an asphalt bound filler that acts as mortar which binds the coarse aggregate together.

Base Stabilization



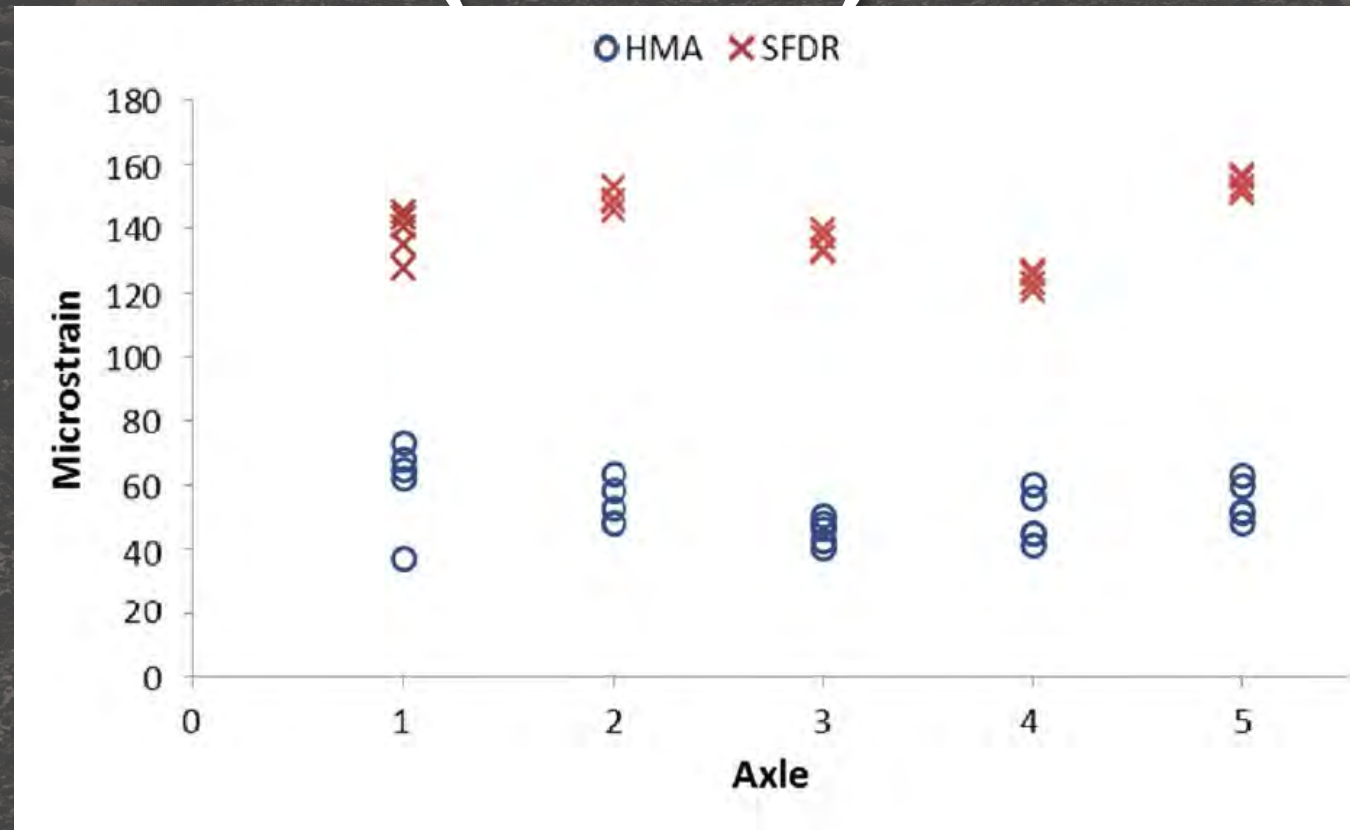
Bituminous Stabilization



Bituminous Stabilization (Contd.)

- MnDOT Cell 2 , 3, and 4
- Exceptional performance!!!
- 150% of the design life ADT with only two minor cracks in 2 sections!

Graph obtained from Johanneck L. and Dai S. (2013), "Responses and Performance of Stabilized Full-Depth Reclaimed Pavements at the Minnesota Road Research Facility," TRR.

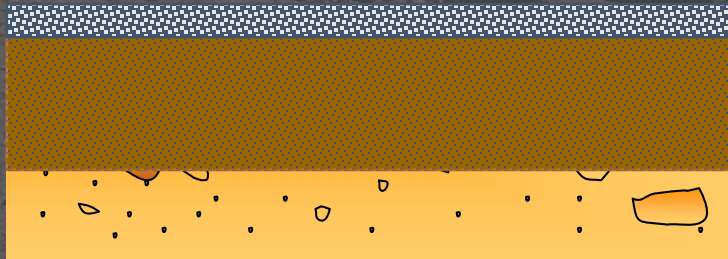




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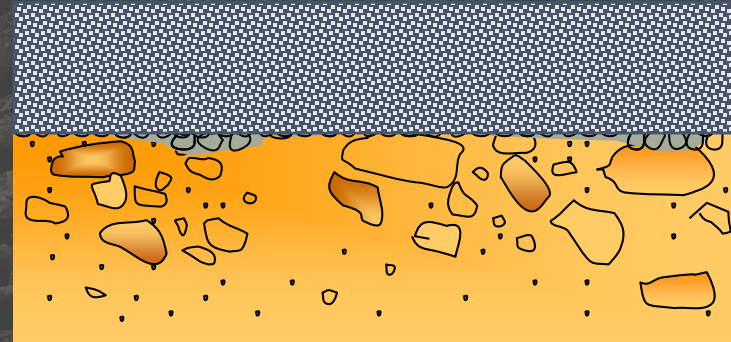
Base Stabilization vs. HMA Overlay

Stabilized Base
Flexible Overlay



Base Stabilization

- Strengthens base
- Reduces Overlay Thickness
 - Flexible
 - Better Fatigue Resistance
- Ready for
 - **Staged construction**
 - Future growth



4-6" HMA Overlay

- Over existing base
- Poor base = overlay failure
- Requires widening, curb, gutter, slope corrections



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Emulsion vs. Foamed Asphalt

- Emulsion has different coating characteristics than foamed asphalt.
- The significant difference in temperature of the binding additives during placement, makes emulsion a much safer product than foamed asphalt.
- In foamed asphalt, binder goes through a short-term aging which could adversely affect the mixture fatigue performance
- Some fine particles (approximately between 5 to 20 percent passing 200 sieve) are required in foamed asphalt stabilization



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Chemical Stabilization

- Chemical stabilization can be used on a wide range of materials, but the stabilized layer will be less flexible, and therefore, less fatigue resistant.
- Chemical stabilization is recommended when the base materials are not clean (infiltrated by marginal silty and/or clayey subgrade material).
- Cement, Cement Kiln Dust (CKD), and fly-ash typically are limited to reclaimed materials in which the plasticity index is less than 20.
- In the case of materials with high plasticity ($PI > 20$) Lime and/or Lime Kiln Dust (LKD) are more often used.

Chemical Stabilization (Contd.)

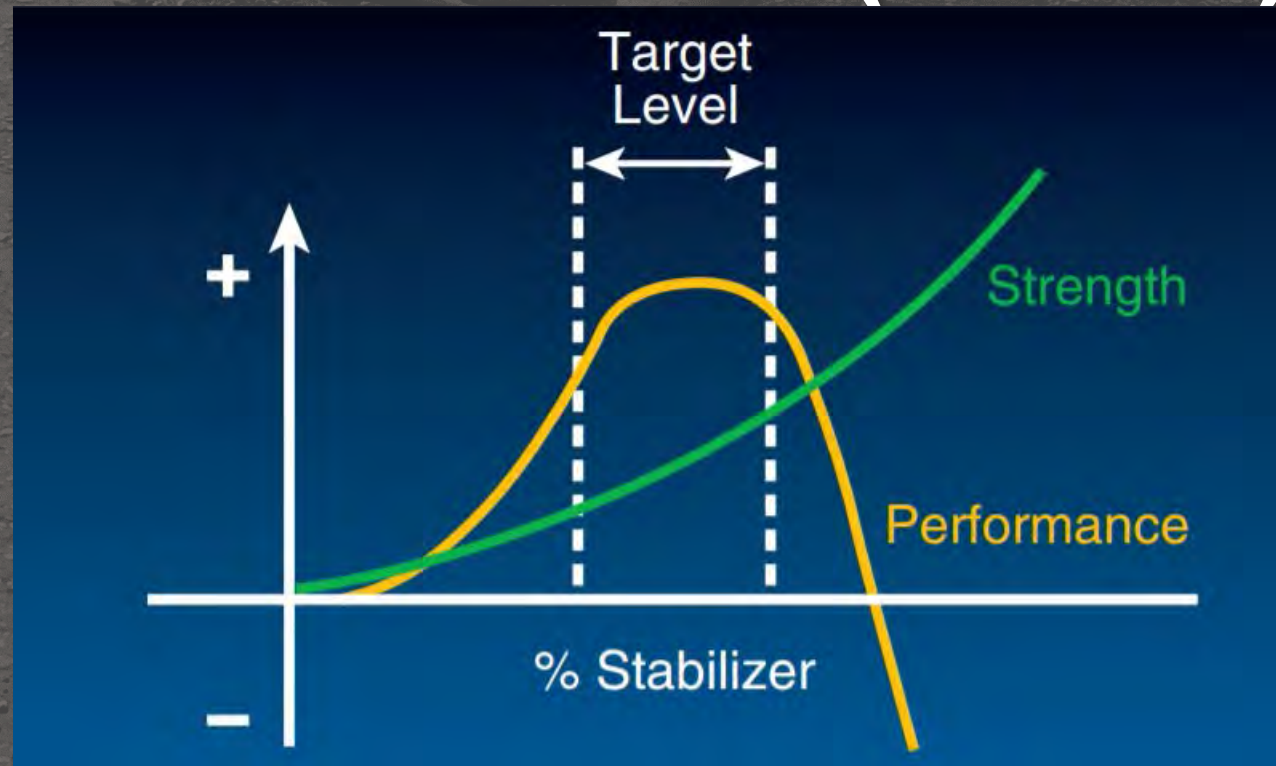
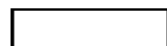


Photo obtained from "PCA Study of Long-Term Performance (2007)"

Stabilization Additive Selection

Reclaimed Material Type	Well-Graded Gravel	Poorly Graded Gravel	Silty Gravel	Clayey Gravel	Well-Graded Sand	Poorly Graded Sand	Silty Sand	Clayey Sand
USCS ⁽¹⁾ Classification	GW	GP	GM	GC	SW	SP	SM	SC
AASHTO ⁽²⁾ Classification	A-1-a	A-1-a	A-1-b	A-1-b A-2-6	A-1-b	A-3 A-1-b	A-2-4 A-2-5	A-2-6 A-2-7
Asphalt Emulsion SE ⁽³⁾ >30 or PI ⁽⁴⁾ <6 P200 ⁽⁵⁾ <20%	Highly recommended	Highly recommended	Recommended	Recommended	Recommended	Recommended	Not recommended	Not recommended
Foamed Asphalt PI<10 5%<P200<20%	Not recommended	Not recommended	Highly recommended	Highly recommended	Not recommended	Not recommended	Recommended	Not recommended
Cement, CKD, and Fly-ash PI<20	Recommended	Recommended	Highly recommended	Highly recommended	Highly recommended	Highly recommended	Highly recommended	Highly recommended
Lime, LKD PI>20 P200<25%	Not recommended	Not recommended	Not recommended	Recommended	Not recommended	Not recommended	Not recommended	Highly recommended



Not recommended



Recommended

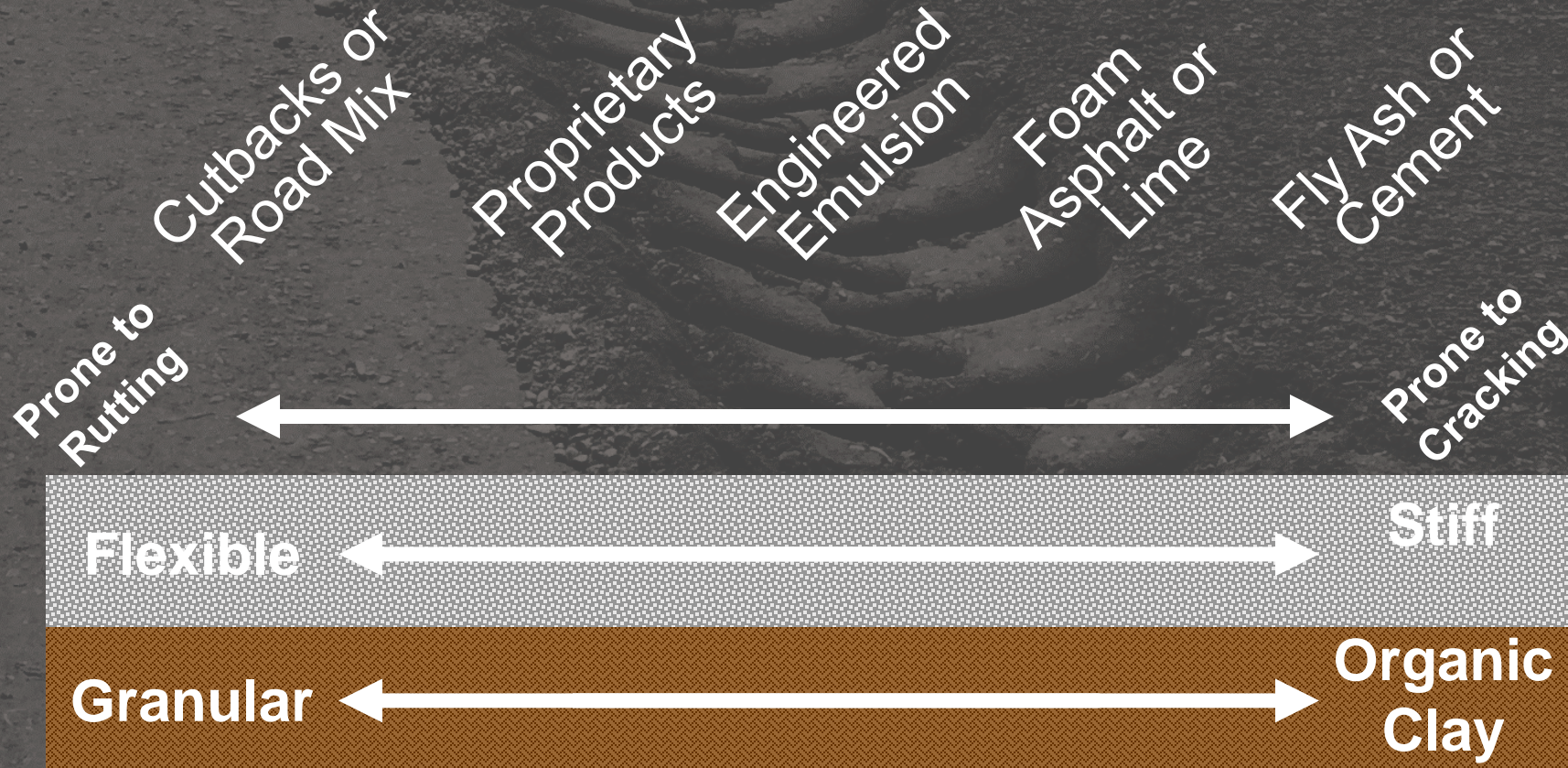


Highly recommended



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Stabilization Considerations





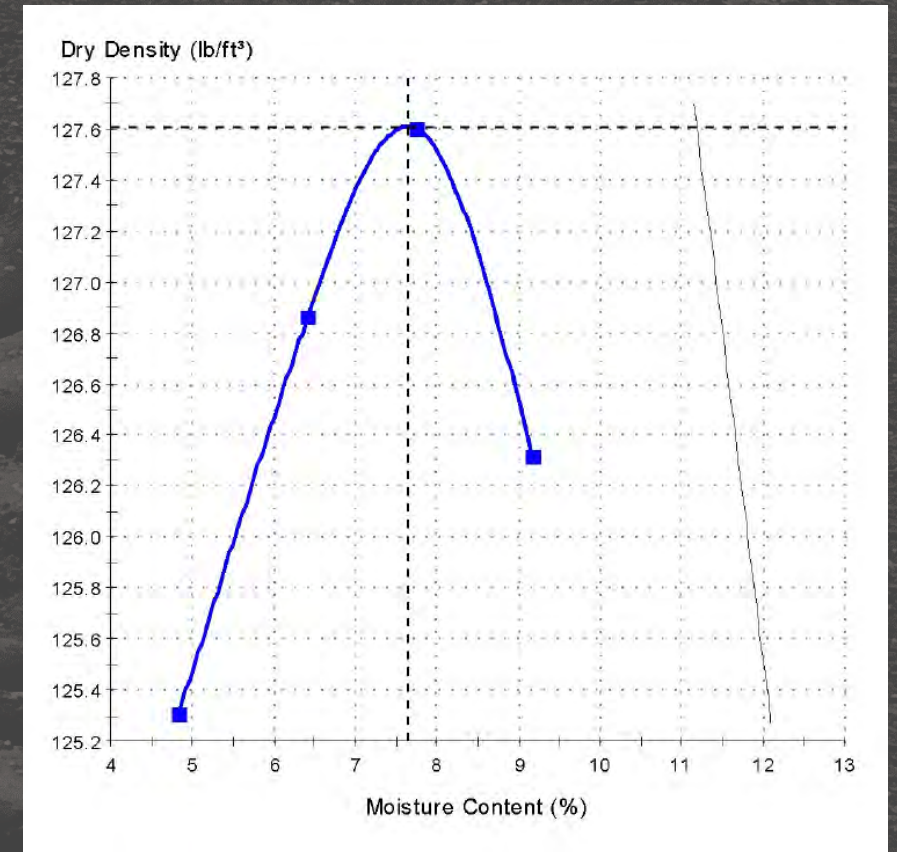
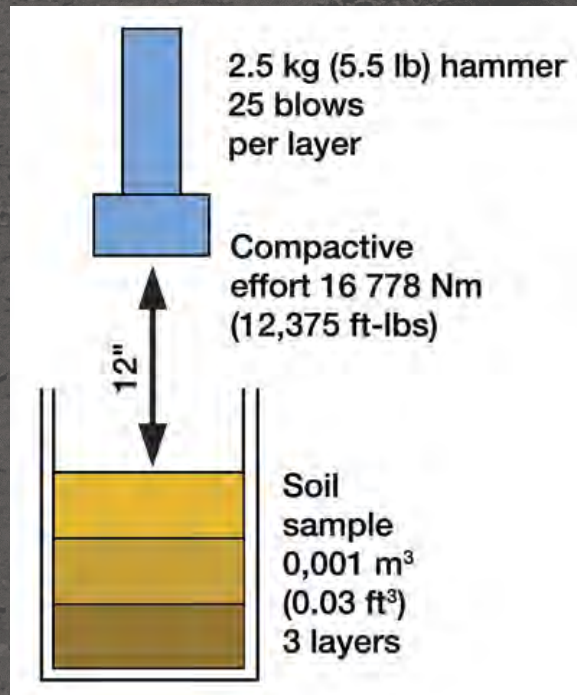
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Stabilization Additive Selection (Contd.)

GW/GP	<ul style="list-style-type: none">• Emulsion
GM/GC	<ul style="list-style-type: none">• Foamed Asphalt• Cement/CKD/Fly-ash
SW/SP/ SM	<ul style="list-style-type: none">• Cement/CKD/Fly-ash
SC	<ul style="list-style-type: none">• Lime/LKD• Cement/CKD/Fly-ash

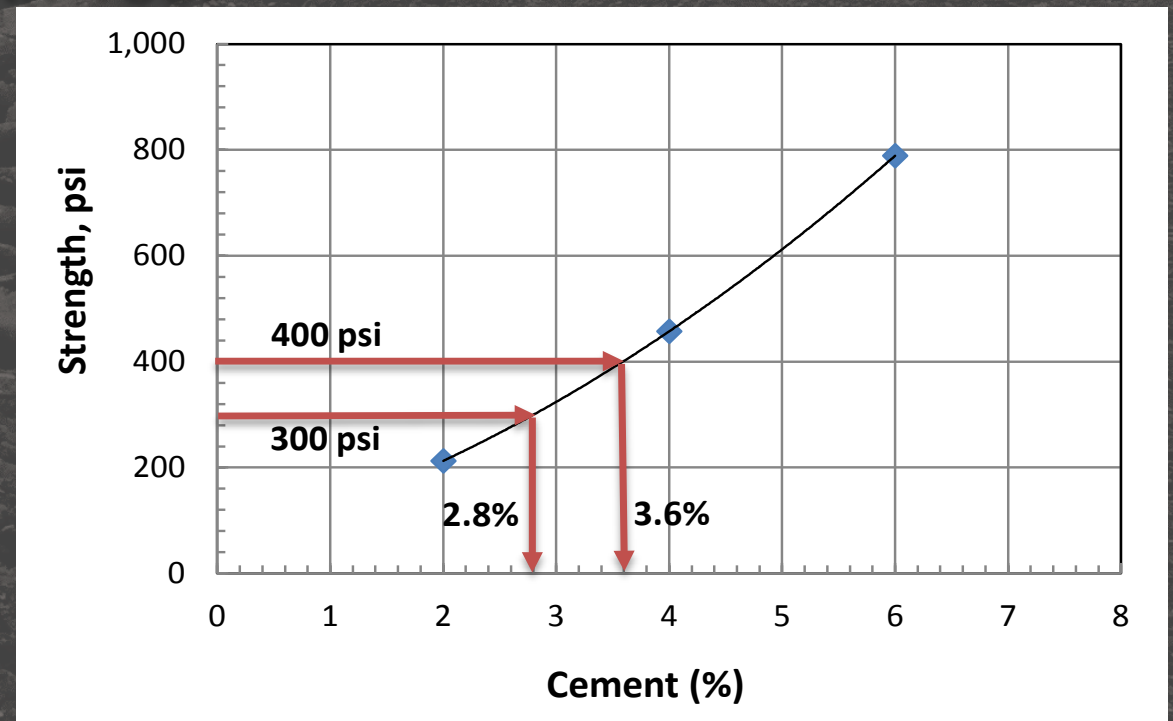
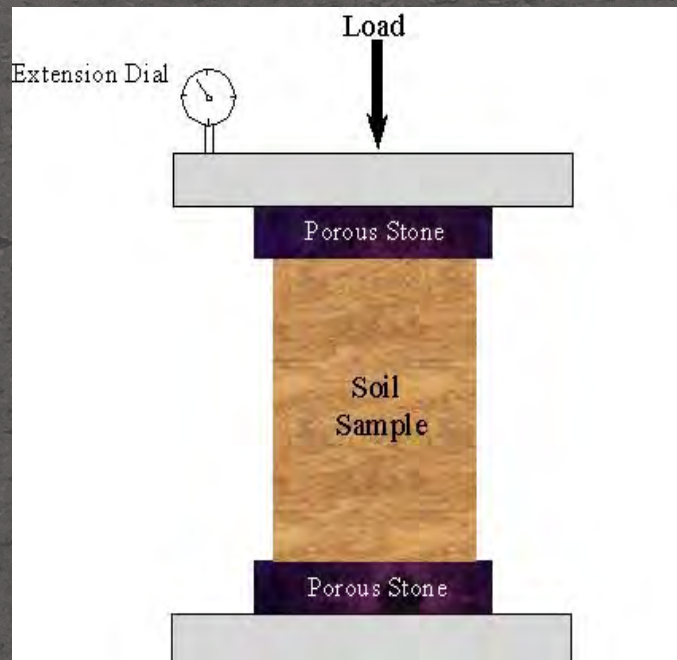
Chemical Stabilization

- Proctor Compaction Test



Chemical Stabilization (Contd.)

- Unconfined Compressive Strength Test





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Chemical Stabilization

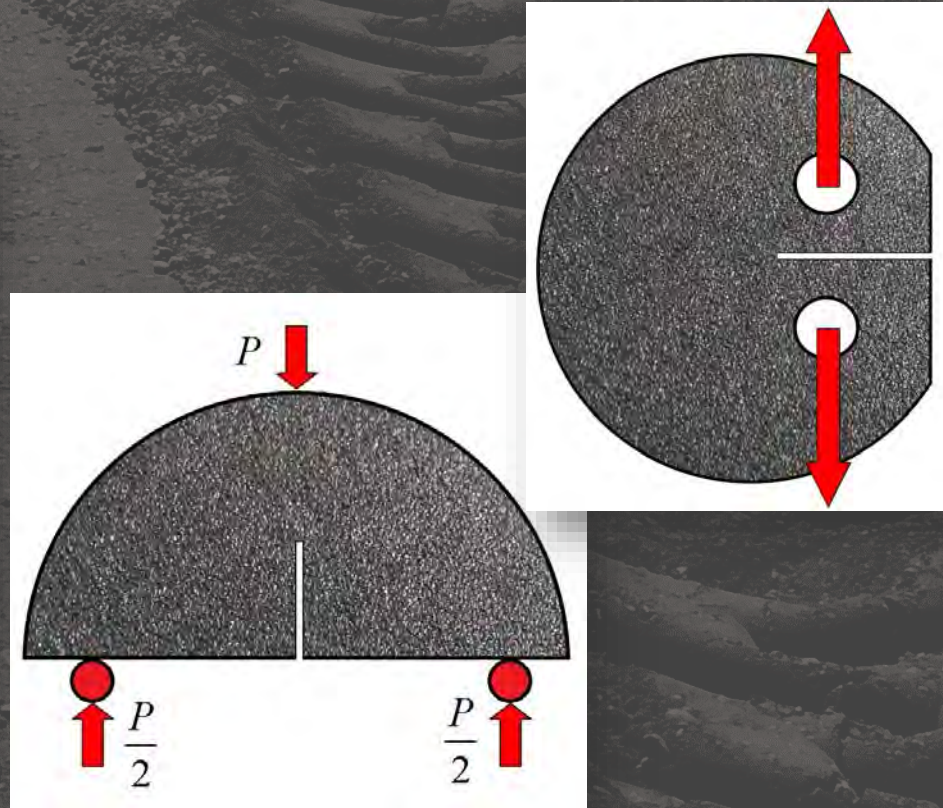


Bituminous Stabilization

- Short term strength
- Indirect Tensile Strength (ITS)
- Conditioned ITS
- Resilient Modulus
- Thermal Cracking (IDT)
- Fracture Testing (DCT, SCB)



Bituminous Stabilization Performance Testing





Dickinson, ND



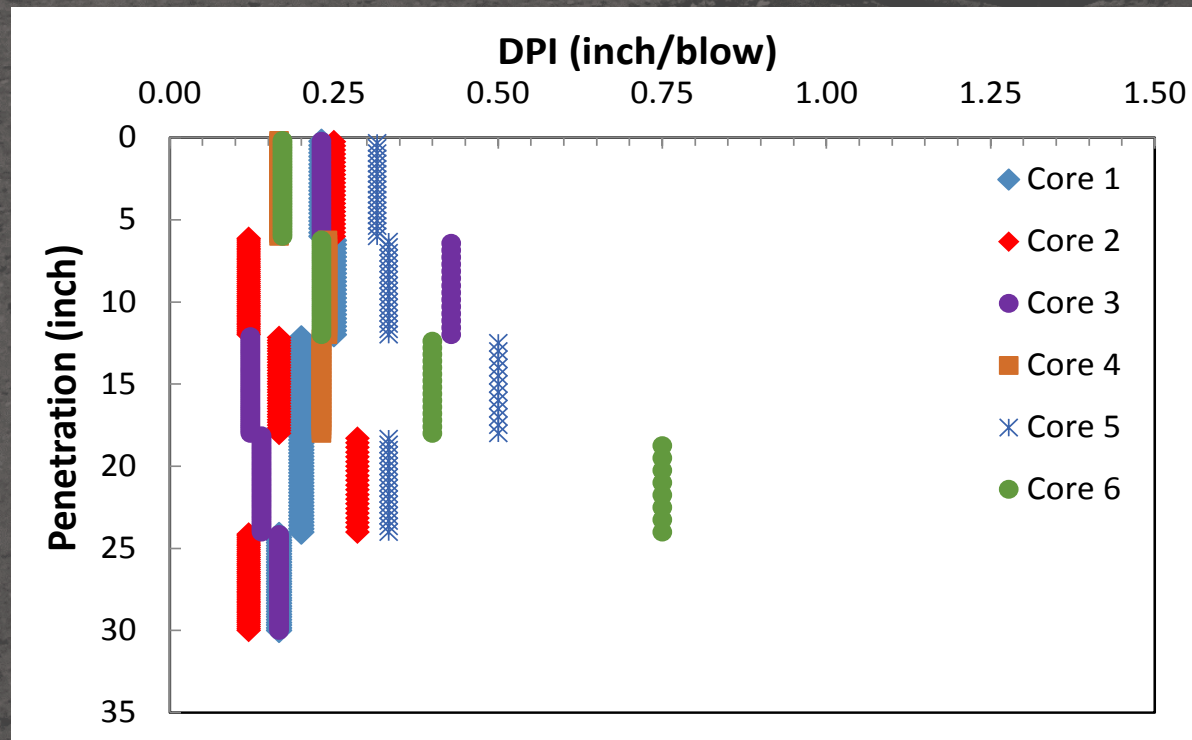


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Dickinson, ND

Exploration ID	Location	BIT Thickness (inches)	Base Thickness (inches)	Subgrade Soil Type	CBR (DCP)	R-Value (DCP)
C-1	EB	7	1	Silty Sand (SM)	46	50
C-2	WB	9	< 1	Lean Clay (CL)	58	60
C-3	EB	10	< 1	Silt (ML)	54	55
C-4	WB	5	12	Silt (ML)	45	50
C-5	EB	6	2	Lean Clay (CL)	25	35
C-6	WB	7 ½	2	Lean Clay (CL)	32	40

Dickinson – DCP Testing Results



All DCP measures from top of subgrade

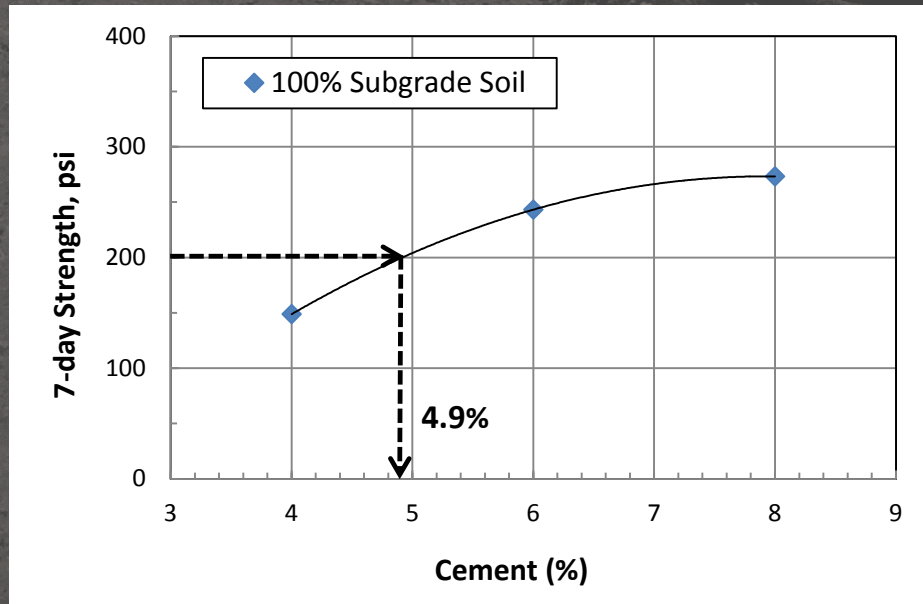


Dickinson – Mix Designs

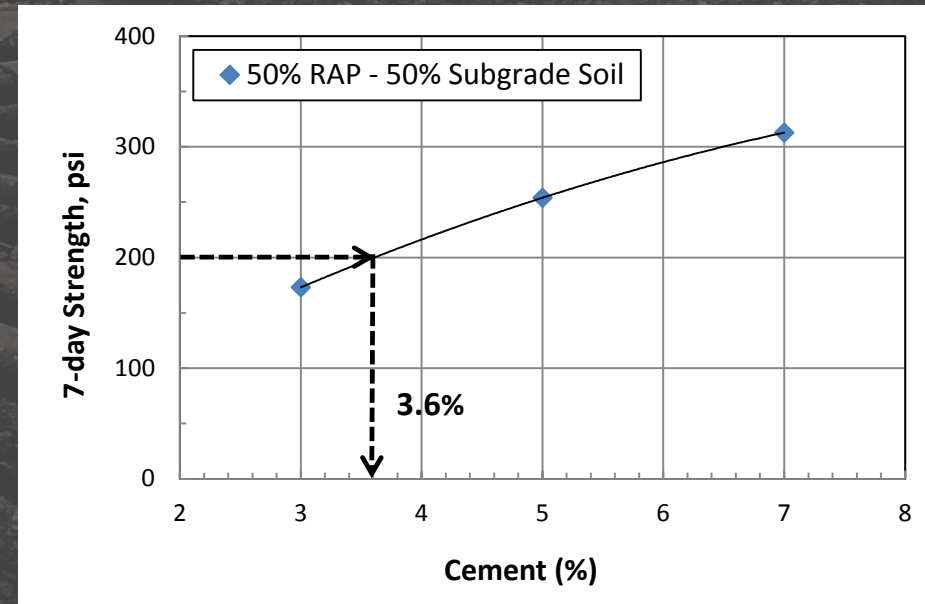
- Subgrade soil with cement
- SFDR with cement (50% RAP, 50% subgrade soil)
- SFDR with emulsion (High-yield)

#	Design	RAP to soil ratio	Additive	Additive Trial Percentages
1	Soil cement	0/100	Cement	4, 6, and 8
2	SFDR with cement	50/50	Cement	3, 5, and 7
3	RAP with emulsion	100/0	Emulsion	1.25%, 1.75%, and 2.25%

Dickinson – Mix Designs



Soil – Cement



SFDR with Cement



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Dickinson – Mix Designs

- TRR High Yield Emulsion
- Trials at 1.25, 1.75, and 2.25%
- 100% RAP
- Selected Emulsion Content = 1.75%
- Optimum Moisture Content = 4%



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Dickinson – Mix Designs

Test	@ 1.75% Emulsion	MnDOT Grading and Base Manual Requirement
Short-Term Strength, g/25 mm height	226	175 g/25mm
Indirect Tensile Strength (ITS), psi	39	40 psi
Conditioned ITS, psi	18	25 psi
Resilient Modulus, ksi	138	150 ksi
Thermal Cracking (IDT), °C	- 40	Report



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Questions?

Thank You!

