Quality Base Material Produced Using Full Depth Reclamation on Existing Asphalt Pavement Structure

DTFH61-06-C-00038
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S. Bang, L. Roberts, D. Huft, **D. Johnston**, P. Sebaaly

South Dakota School of Mines and Technology
South Dakota Department of Transportation

North Dakota Asphalt Conference
Bismarck, North Dakota
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Project Technical Panel

- Randy Battey, Mississippi DOT
- Todd Casey, Base Construction Co. (ARRA)
- John Epps, Granite Construction, Inc.
- Joe Feller, SDDOT
- Gary Goff, FHWA ND Division
- David Gress, Univ. of New Hampshire
- Gregory Halsted, PCA (ARRA)
- Brett Hestdalen, FHWA SD Division
- John Huffman, Terex Roadbuilding (ARRA)
- Tim Kowalski, Wirtgen America
- David Lee, Univ. of Iowa
- Chuck Luedders, FHWA Direct Federal Lands
- Ken Skorseth, SDSU
- Ken Swedeen, Dakota Asphalt Pavement Association
- Todd Thomas, Road Science LLC (ARRA)
- Mike Voth, Central Federal Lands Division, FHWA

Research Tasks

1. Literature Review
2. Document State Specifications & Construction Experiences
3. Condition Survey of Existing Test Sections
4. Develop FDR Mix Design Guide
5. Develop Standardized Laboratory Testing Method
6. Field Procedures to Produce Base Material Meeting Asphalt Content and Gradation Specifications
7. Basic Construction Details for Field Test Strip
8. Monitor Construction of Test Sections
9. Establish Laboratory Testing and Design Procedures
10. Information Exchange
11. Final Report

Current Status

- Task 1 (Literature Review) Completed.
- Task 2 (Document State Specifications & Experiences) Completed.
- Task 3 (Condition Survey of Existing Test Sections) Under review by FHWA.
- Task 4 (FDR Mix Design Guide) 100% completed. Report under internal review.
- Task 5 (Lab Testing Methods) 75% completed.
- Tasks 6 and 7 (Test Sections) Completed.
- Task 8 (Test Section Monitoring) Ongoing.
- Task 9 (Design Guide) Started.

Task 4

Task 4-Development of FDR Mix Design Guide

- The objective of this task is to develop a mix design procedure for the various types of FDR.

- Determine what works and what does not work as far as laboratory testing procedures for FDR mixes.

- Each type of FDR has a separate mix design.

Task 4–Development of FDR Mix Design Guide

Mix Design Combinations:

- Mechanically Stabilized

Chemically Stabilized

- Portland Cement
- Fly Ash

Bituminous Stabilized

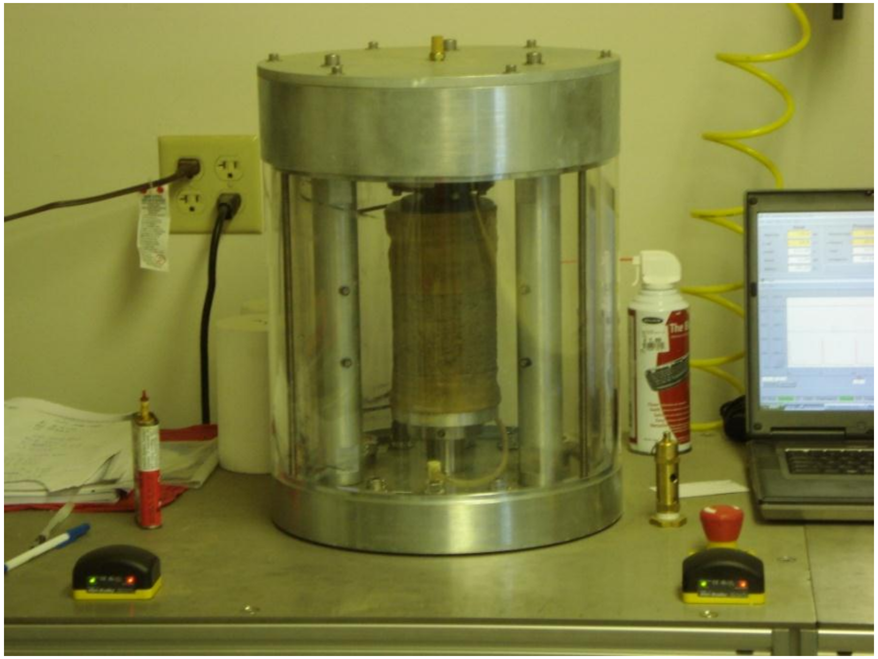
- Asphalt Emulsion
- Asphalt Emulsion with 1% Lime
- Foamed Asphalt with 1% Portland Cement

Composition of FDR

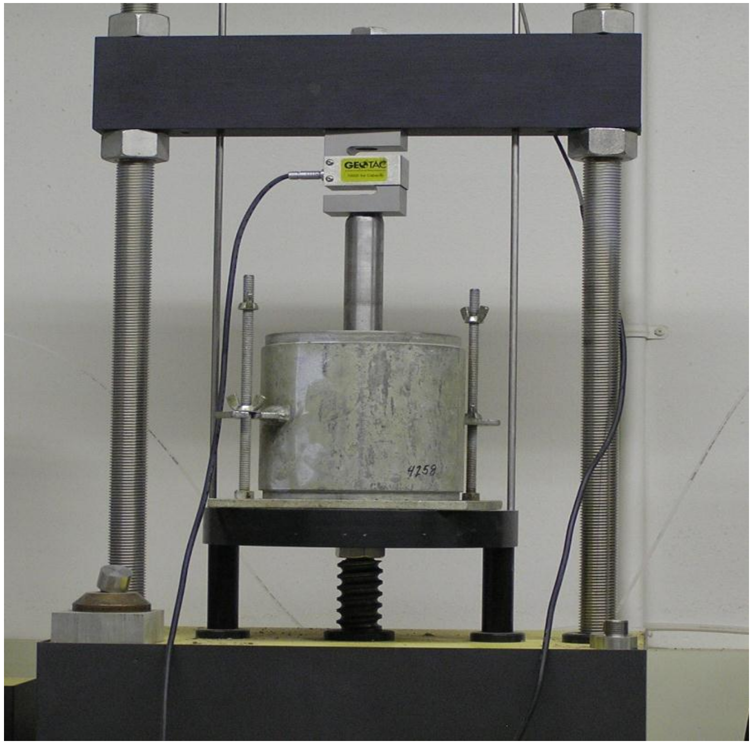
- Good Clean (GC) – Good source crushed aggregate with less than 10% of the material passing the #200 US standard sieve.
- Good Dirty (GD) – Good source crushed aggregate with 14.7% passing the #200 US standard sieve.
- Poor Clean (PC) – Poor source rounded aggregate with less than 10% of the material passing the #200 US standard sieve.
- Poor Dirty (PD) – Poor source rounded aggregate with 14.7% passing the #200 US standard sieve.
- RAP: 0, 25, 50, and 75%

FDR Source	Gradation	FDR Type					
		Unstabilized	Stabilized with PC (3, 5, 7 %)	Stabilized with Fly Ash (10, 12, 15 %)	Stabilized with Asphalt Emulsion (3, 4.5, 6 %)	Stabilized with Asphalt Emulsion (3, 4.5, 6 %)+ Lime	Stabilized with Foamed Asphalt (2.5, 3, 3.5 %) + PC
Poor	Dirty	-Moisture-density curve -Mr and CBR	-Moisture-density curve - Compressive strength -Moisture sensitivity	-Moisture-density curve - Compressive strength -Moisture sensitivity	-Superpave Gyratory - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning	-Superpave Gyratory - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning	-Superpave Gyratory - Moisture-density curve (use results of unstabilized) - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning
	Clean	-Moisture-density curve -Mr and CBR	-Moisture-density curve - Compressive strength -Moisture sensitivity	-Moisture-density curve - Compressive strength -Moisture sensitivity	-Superpave Gyratory - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning	-Superpave Gyratory - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning	-Superpave Gyratory - Moisture-density curve (use results of unstabilized) - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning
Good	Dirty	-Moisture-density curve -Mr and CBR	-Moisture-density curve - Compressive strength -Moisture sensitivity	-Moisture-density curve - Compressive strength -Moisture sensitivity	-Superpave Gyratory - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning	-Superpave Gyratory - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning	-Superpave Gyratory - Moisture-density curve (use results of unstabilized) - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning
	Clean	-Moisture-density curve -Mr and CBR	-Moisture-density curve - Compressive strength -Moisture sensitivity	-Moisture-density curve - Compressive strength -Moisture sensitivity	-Superpave Gyratory - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning	-Superpave Gyratory - Bulk density using Corelok - Maximum density using Corelok -Moisture s conditioning	-Superpave Gyratory - Moisture-density curve (use results of unstabilized) - Bulk density using Corelok - Maximum density using Corelok -Moisture conditioning

Testing of Mechanically Stabilized FDR Mixes



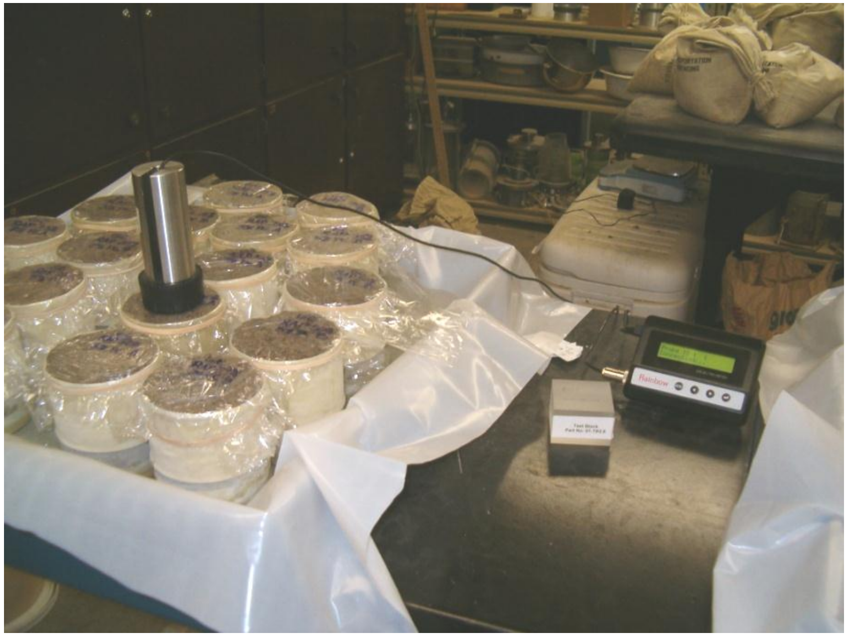
Resilient Modulus Testing



California Bearing Ratio (CBR) Testing

Testing of Portland Cement/Fly Ash Stabilized FDR Mixes

Unconfined Compression Testing



Tube Suction Testing

Testing of Portland Cement/Fly Ash Stabilized FDR Mixes

Moisture Sensitivity Testing with Wire Brush Method

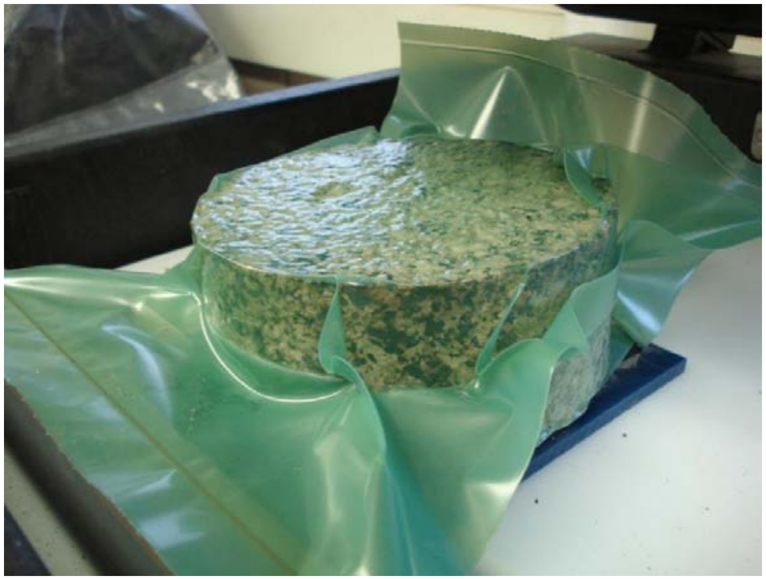
Tested Samples

Testing of Asphalt Emulsion/ Foamed Asphalt FDR Mixes

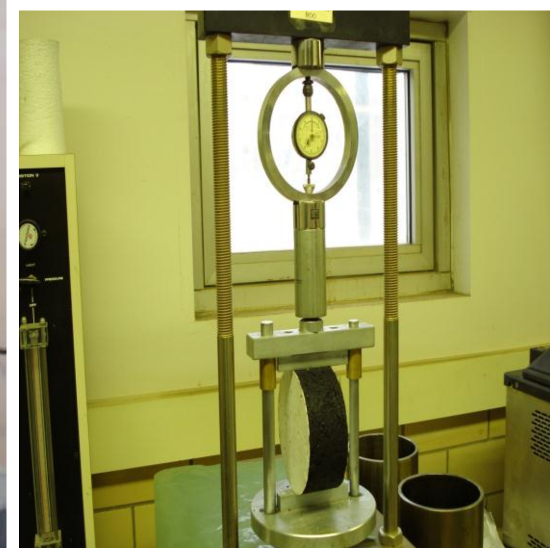
SuperPave Gyratory Compactor

Foamed Asphalt Lab

Testing of Asphalt Emulsion/ Foamed Asphalt FDR Mixes

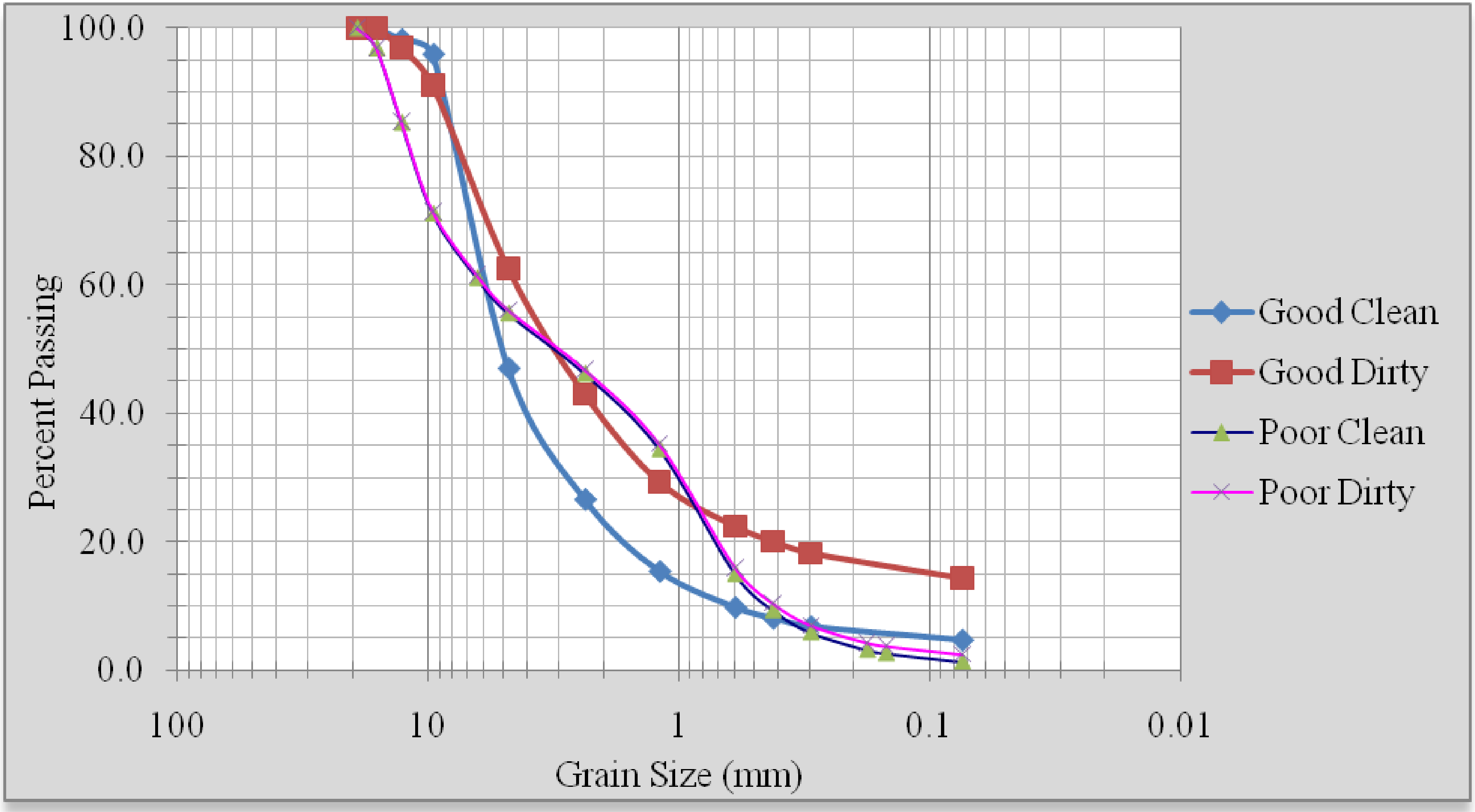


CoreLok Device

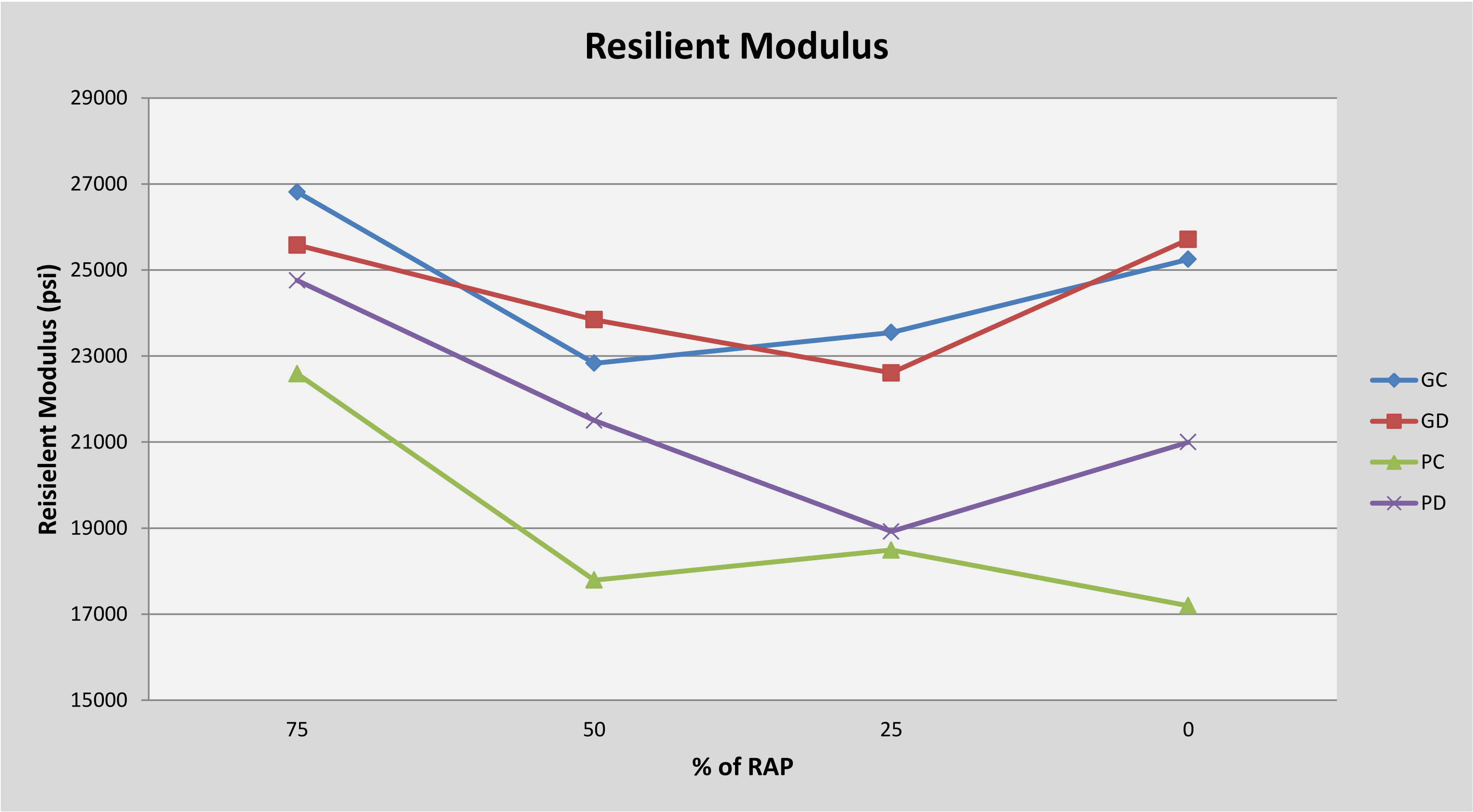


Indirect Tensile Strength (ITS) Testing

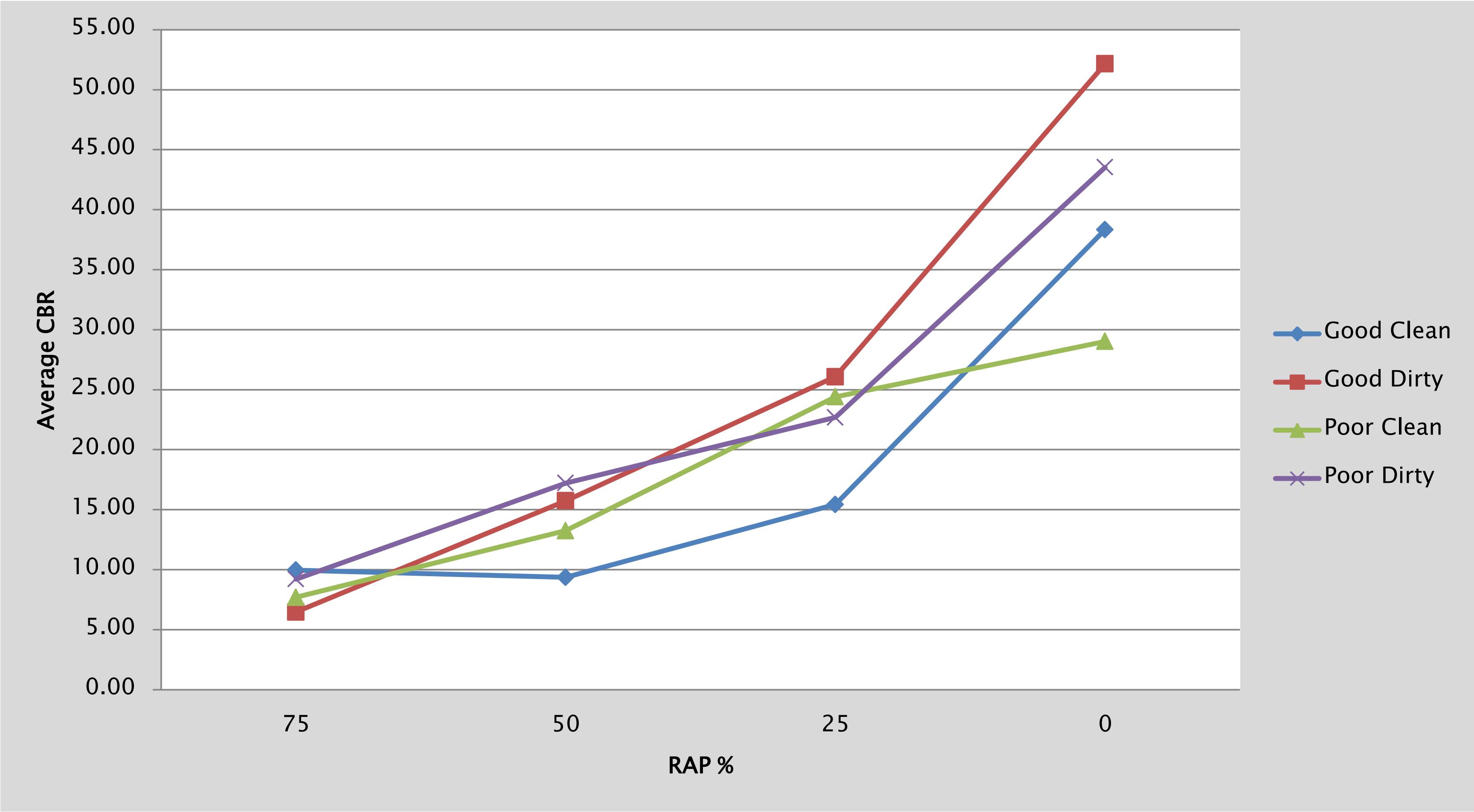
Gradation of Virgin Aggregates



Mechanically Stabilized FDR



Mechanically Stabilized FDR



Mechanically Stabilized FDR

- RAP 25% and 50% content did not significantly impact the Mr.
- The 75% RAP improved the Mr of the Poor source.
- Relationship between Mr and CBR is not reliable for FDR: Recommend to use Mr.

Mix Design Criteria

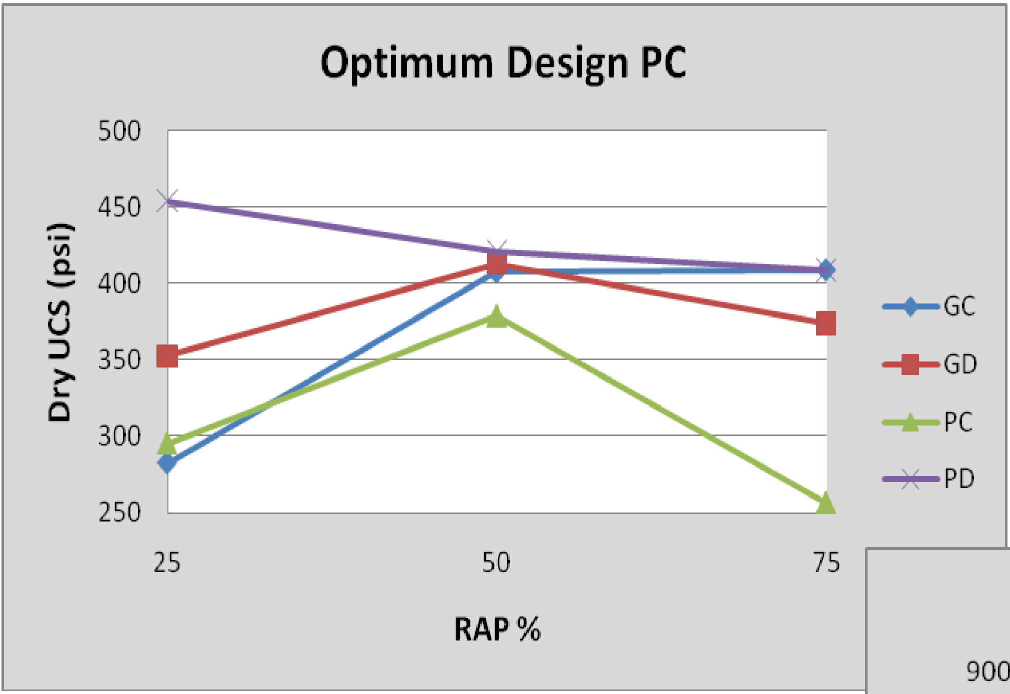
FDR+PC & FDR+FA

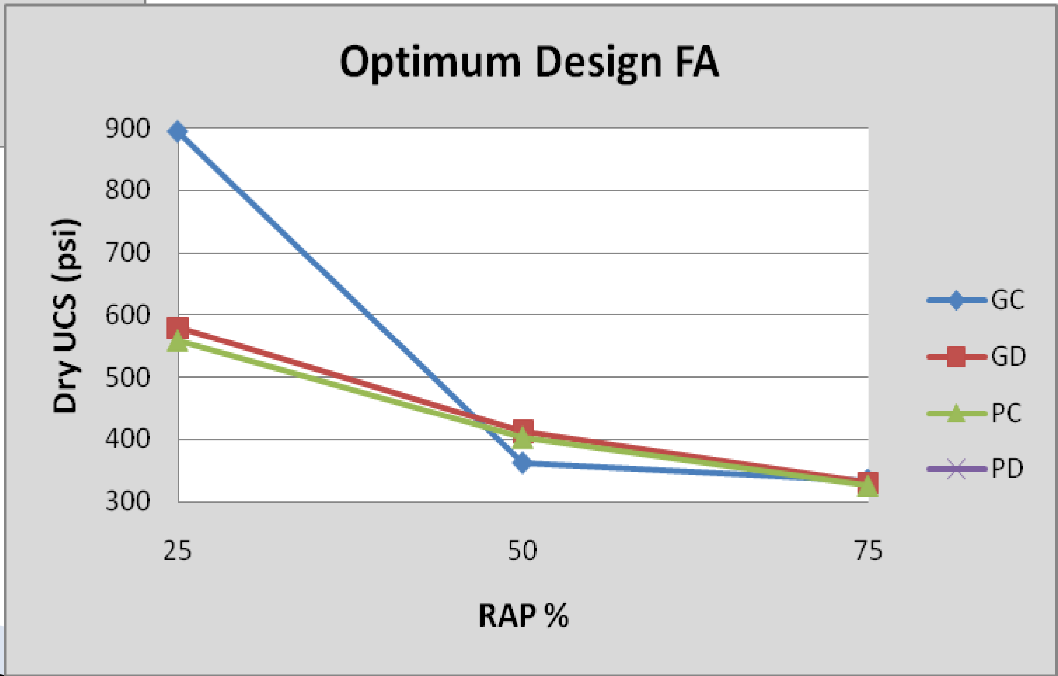
- Dry UC: 300 – 400 psi
- Tube Suction: max 9

FDR+Foamed & FDR+Emulsion

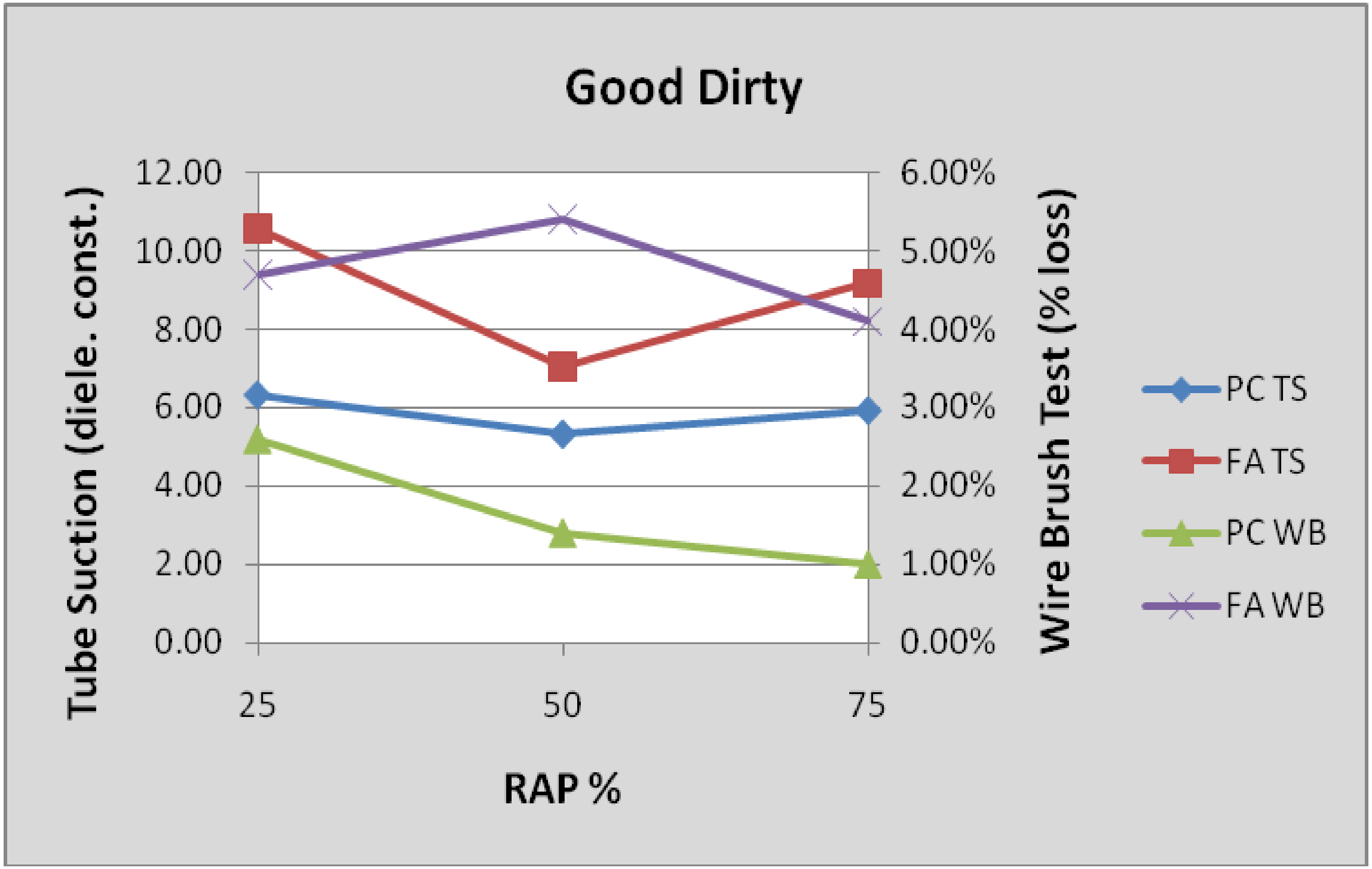
- Dry TS at 77F: min 30 psi
- TS Ratio: min. 70%

Optimum Mix Designs: FDR+PC and FA





Optimum Mix Designs: FDR+PC and FA



Stabilized with PC

- UC strength between 300 and 400 psi is achievable in most cases.
- Higher UCS with higher PC content in all cases.
- Variability of the UCS test is acceptable.
- Tube suction test may be applicable.

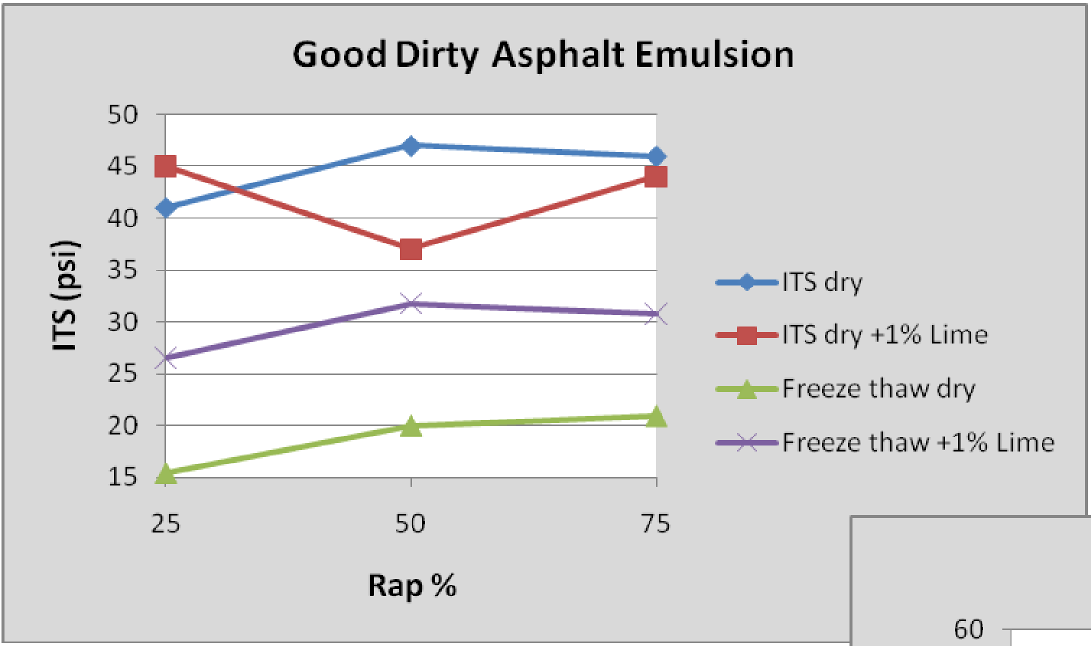
Stabilized with FA

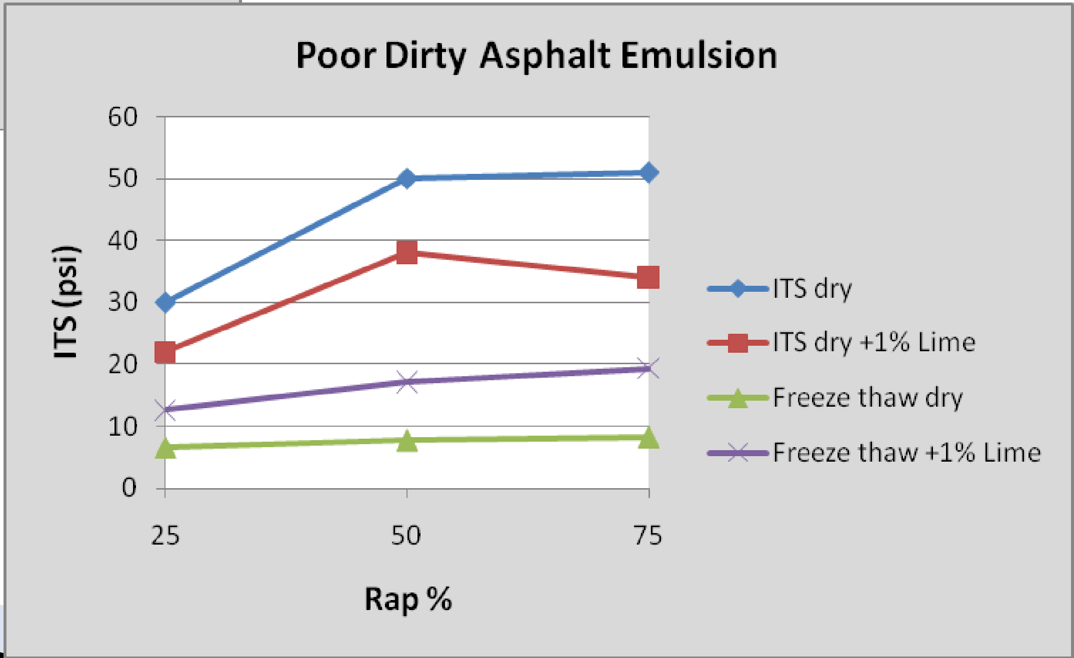
- UC strength between 300 and 400 psi is achievable except for the Poor-Dirty material.
- Higher UCS with higher FA in most cases.
- Variability of the UCS is acceptable.
- Tube suction test may be applicable.

Optimum Mix Designs: FDR+ Emulsion

Material	%Emulsion	Dry TS(psi)	Wet TS(psi)	TSR (%)
NO LIME				
GD-25%	4.5	41	15	37
GD-50%	4.5	47	20	43
GD-75%	4.5	46	21	46
PD-25%	4.5	30	Disintegrate	
PD-50%	4.5	50	Disintegrate	
PD-75%	4.5	51	Disintegrate	
1% LIME				
GD-25%	4.5	45	27	60
GD-50%	4.5	37	32	86
GD-75%	4.5	44	31	70
PD-25%	4.5	22	13	59
PD-50%	4.5	38	17	45
PD-75%	4.5	34	19	56

Asphalt Emulsion ITS (Dry and Wet)





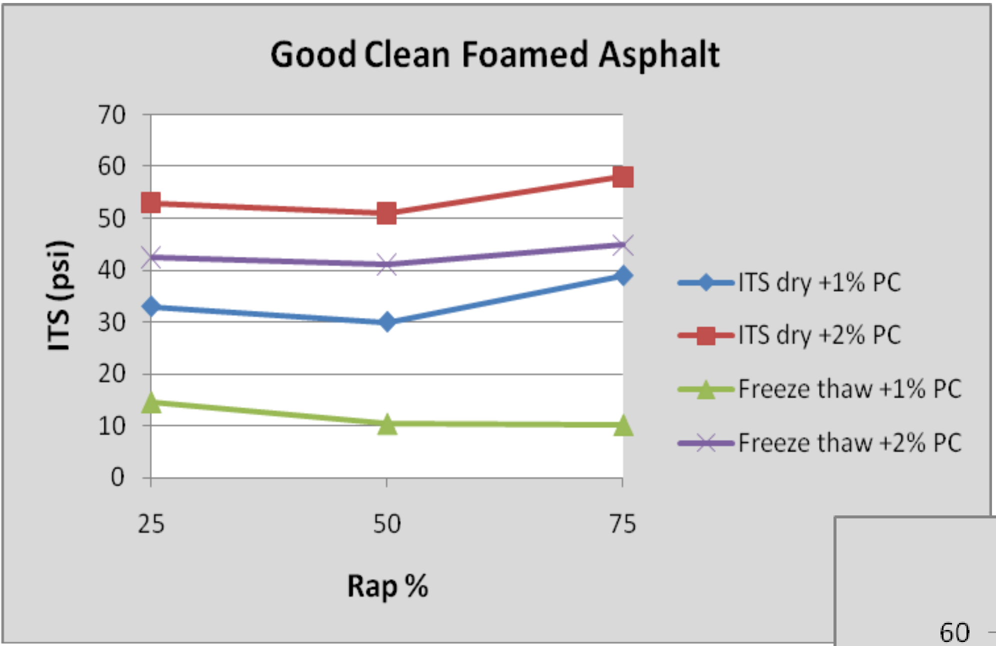
Stabilized with Emulsion

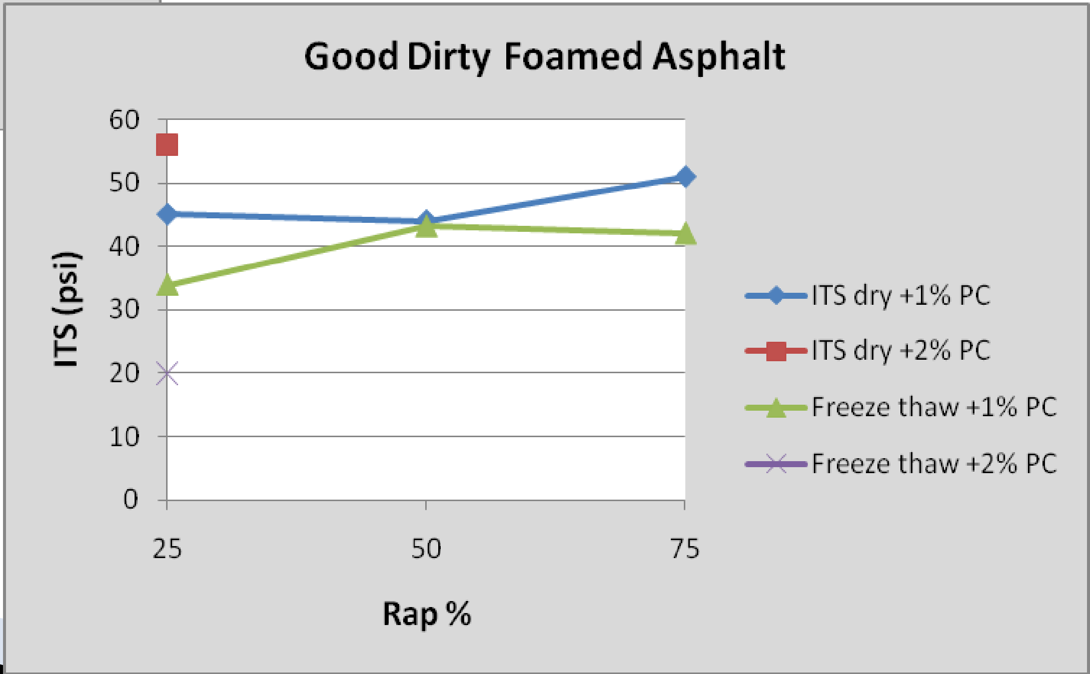
- Could not produce a design using the clean materials: too little fines.
- The ITS is a good indicator.
- The repeatability of the ITS is very good.
- Lime was effective.

Optimum Mix Designs: FDR+Foamed Asphalt+1%PC

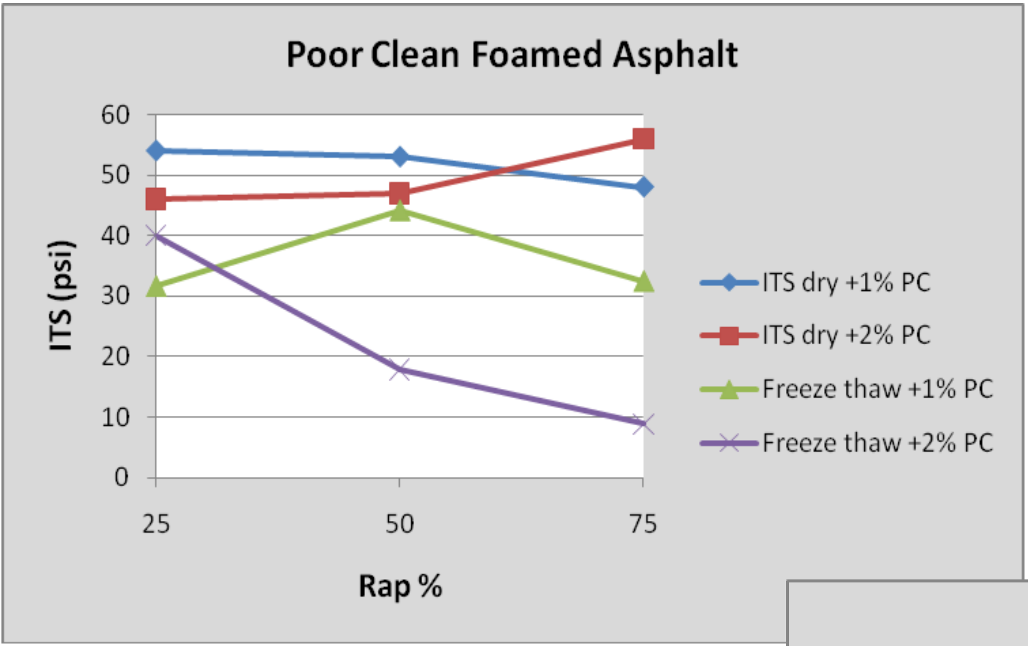
Material	%AC	Dry TS(psi)	Wet TS(psi)	TSR (%)
GC-25%	3.0*	53	43	81
GC-50%	3.0*	51	41	80
GC-75%	3.0*	58	45	78
GD-25%	3.5	45	34	76
GD-50%	3.5	44	43	98
GD-75%	3.5	51	42	82
PC-25%	3.5	54	32	59
PC-50%	3.5	53	40	75
PC-75%	3.5	48	33	69
PD-25%	3.0	43	26	60
PD-50%	3.0	48	29	60
PD-75%	3.0	55	35	64

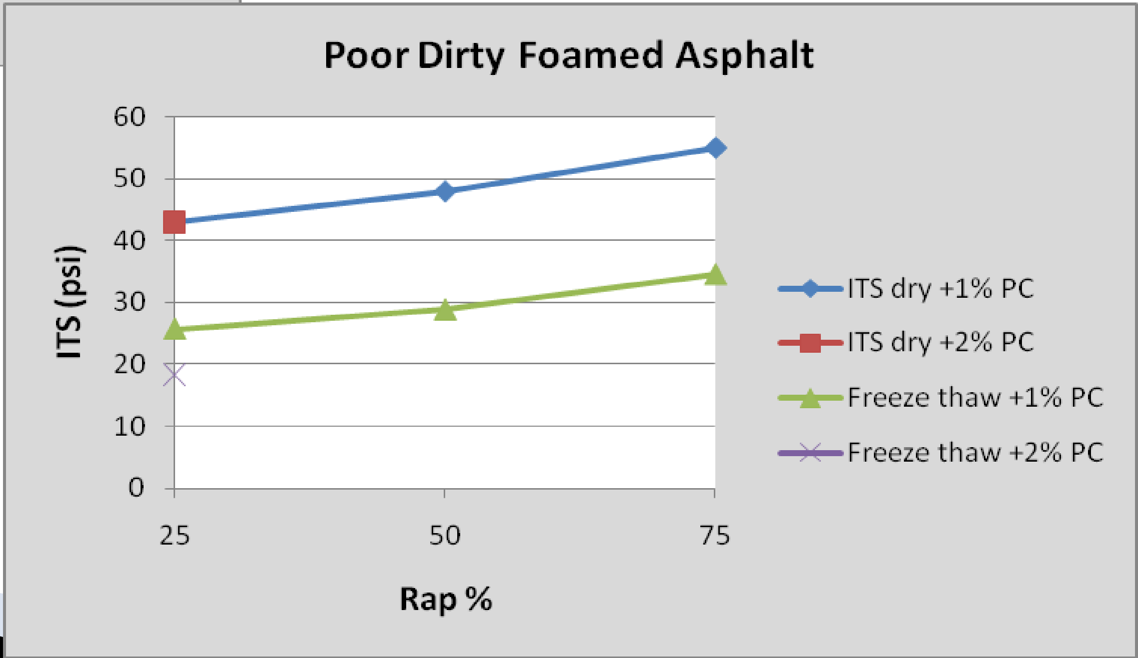
Foamed+1%PC & 2%PC ITS (Dry and Wet)





Foamed+1%PC & 2%PC ITS (Dry and Wet)





Stabilized with Foamed Asphalt

- Could not design without the PC.
- The ITS is a good indicator.
- The repeatability of the ITS is very good.

Task 5

Task 5 – Development of Standard Laboratory Testing Method

- The objective of this task is to develop a laboratory testing procedure to address material properties needed to support practical pavement design. The focus will be on developing standard test methods to be used specifically for AASHTO related pavement designs.
- The FDR process produces a layer that will be modeled as a base course within the structure of a flexible pavement.

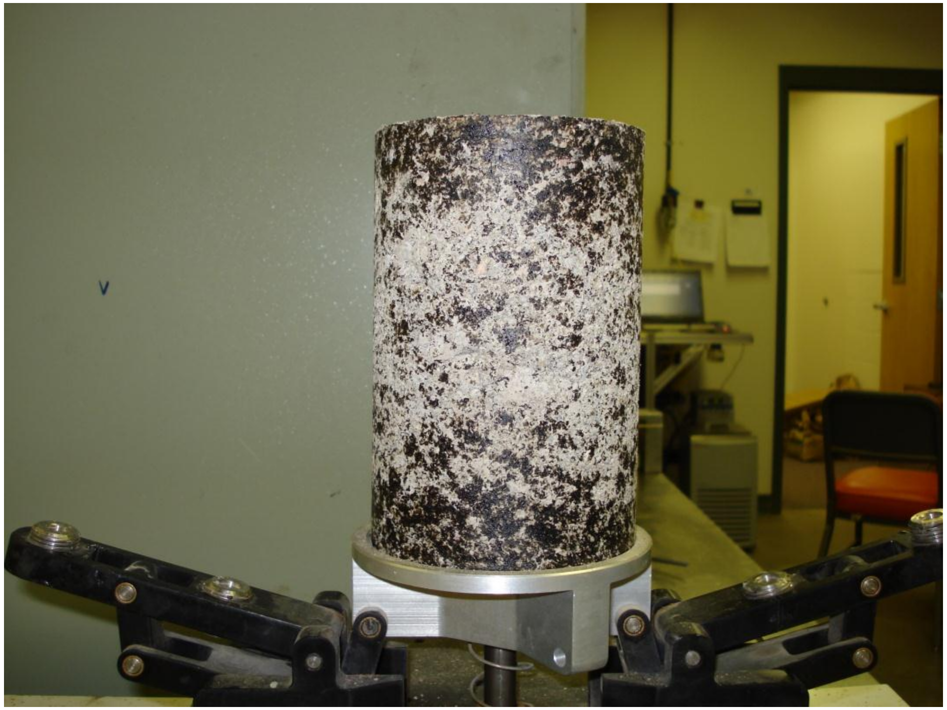
FDR Source	Gradation	FDR Type					
		Mechanically Stabilized/	Stabilized with PC at optimum %	Stabilized with Fly Ash at optimum %	Stabilized with Asphalt Emulsion at optimum %	Stabilized with Asphalt Emulsion (at optimum %)+ Lime	Stabilized with Foamed Asphalt (at optimum %) + PC
Poor	Dirty	- Resilient Modulus - CBR	- Compressive Strength - Modulus of Rupture	- Compressive Strength - Modulus of Rupture	- E* Master Curve - Repeated Load Triaxial	- E* Master Curve - Repeated Load Triaxial	- E* Master Curve - Repeated Load Triaxial
	Clean	- Resilient Modulus - CBR	- Compressive Strength - Modulus of Rupture	- Compressive Strength - Modulus of Rupture	- E* Master Curve - Repeated Load Triaxial	- E* Master Curve - Repeated Load Triaxial	- E* Master Curve - Repeated Load Triaxial
Good	Dirty	- Resilient Modulus - CBR	- Compressive Strength - Modulus of Rupture	- Compressive Strength - Modulus of Rupture	- E* Master Curve - Repeated Load Triaxial	- E* Master Curve - Repeated Load Triaxial	- E* Master Curve - Repeated Load Triaxial
	Clean	- Resilient Modulus - CBR	- Compressive Strength - Modulus of Rupture	- Compressive Strength - Modulus of Rupture	- E* Master Curve - Repeated Load Triaxial	- E* Master Curve - Repeated Load Triaxial	- E* Master Curve - Repeated Load Triaxial

Modulus of Rupture

Simple Performance Tester (SPT)

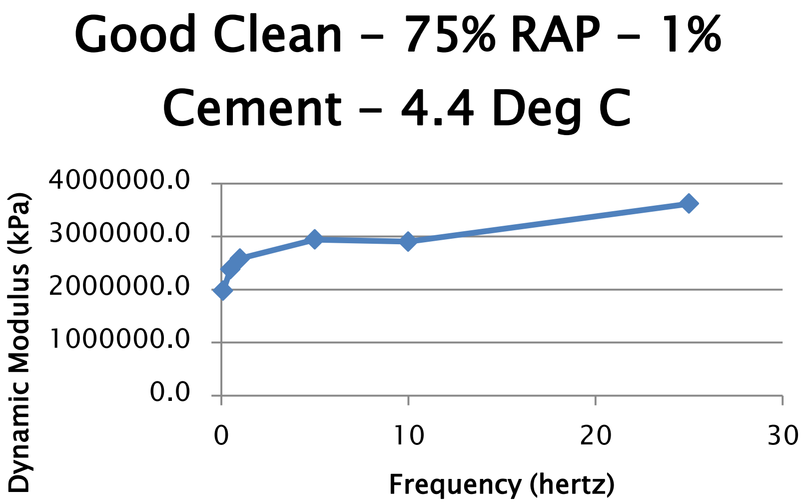
- Resilient Modulus
- Dynamic Modulus
- E* Master Curve
- Repeated Load Triaxial

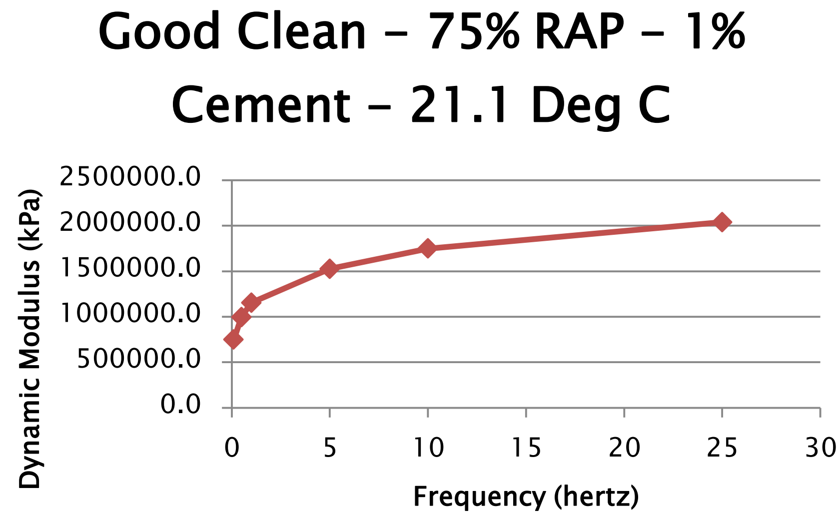
Testing of Asphalt Emulsion/ Foamed Asphalt FDR Mixes

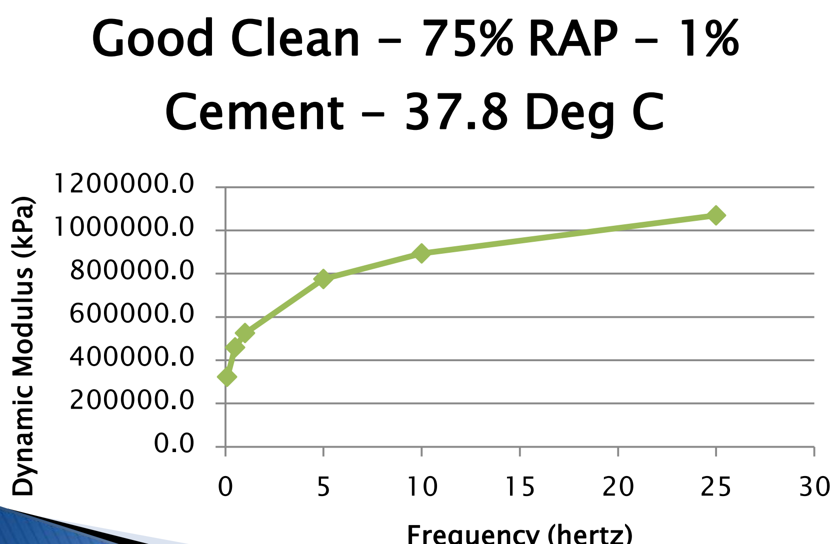


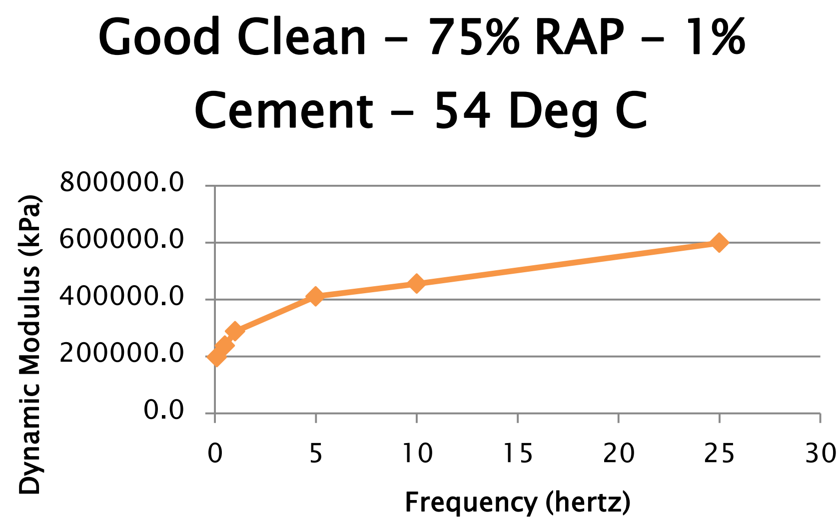
Foamed Asphalt Specimen:
Poor Dirty Gradation with 75% RAP.

CoreLok for specific gravity determination.


Good Clean – 75% RAP – 1% Cement – 4.4 Deg C
Dynamic Modulus (kPa)
4000000.0
3000000.0
2000000.0
1000000.0
0.0
0
10
20
30
Frequency (hertz)


Good Clean – 75% RAP – 1% Cement – 21.1 Deg C
Dynamic Modulus (kPa)
2500000.0
2000000.0
1500000.0
1000000.0
500000.0
0.0
0
5
10
15
20
25
30
Frequency (hertz)


Good Clean – 75% RAP – 1% Cement – 37.8 Deg C
Dynamic Modulus (kPa)
1200000.0
1000000.0
800000.0
600000.0
400000.0
200000.0
0.0
0
5
10
15
20
25
30
Frequency (hertz)


Good Clean – 75% RAP – 1% Cement – 54 Deg C
Dynamic Modulus (kPa)
800000.0
600000.0
400000.0
200000.0
0.0
0
5
10
15
20
25
30
Frequency (hertz)

Task 8

Task 8 – Monitor Performance of Test Sections

- The objective of this task is to monitor the performance of the test sections over a period of two years:
  - Ground Penetrating Radar (GPR) in Summer 2009.
  - Falling Weight Deflectometer (FWD) in Spring and Fall 2009, 2010 and 2011.
  - Rutting and profile measurements in Spring and Fall 2009, 2010 and 2011.
  - Periodic visual surveys.

Test Section Location

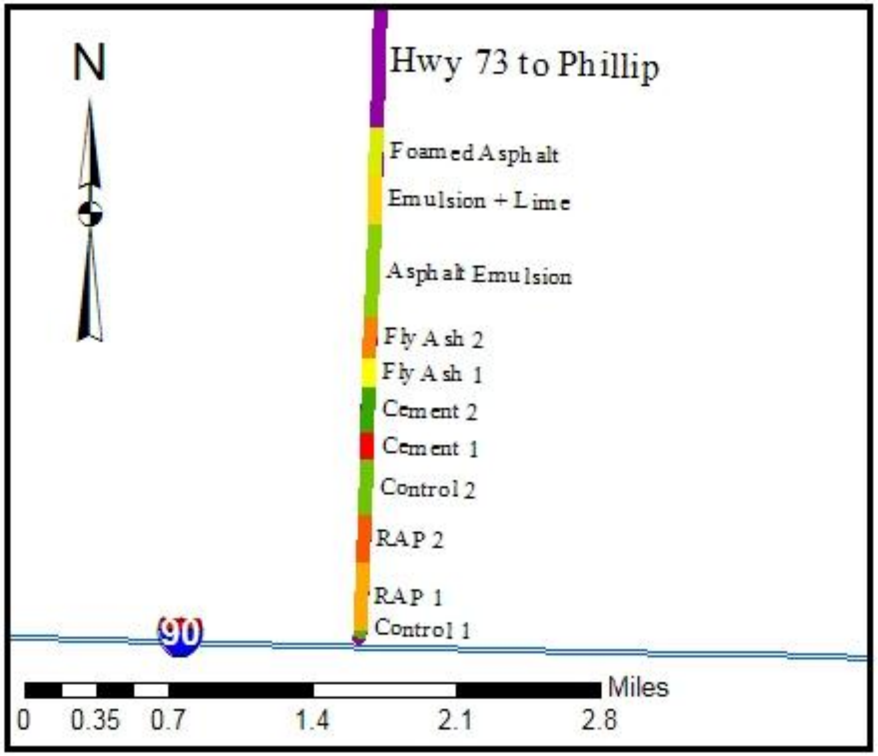


Figure A: Graphical Breakdown of Test Sections.

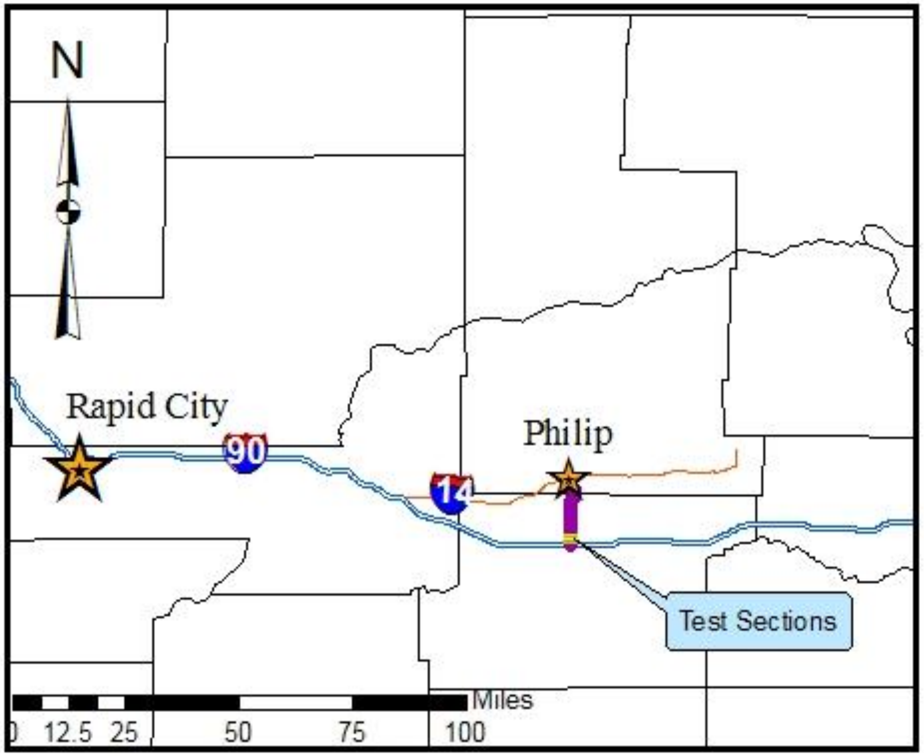
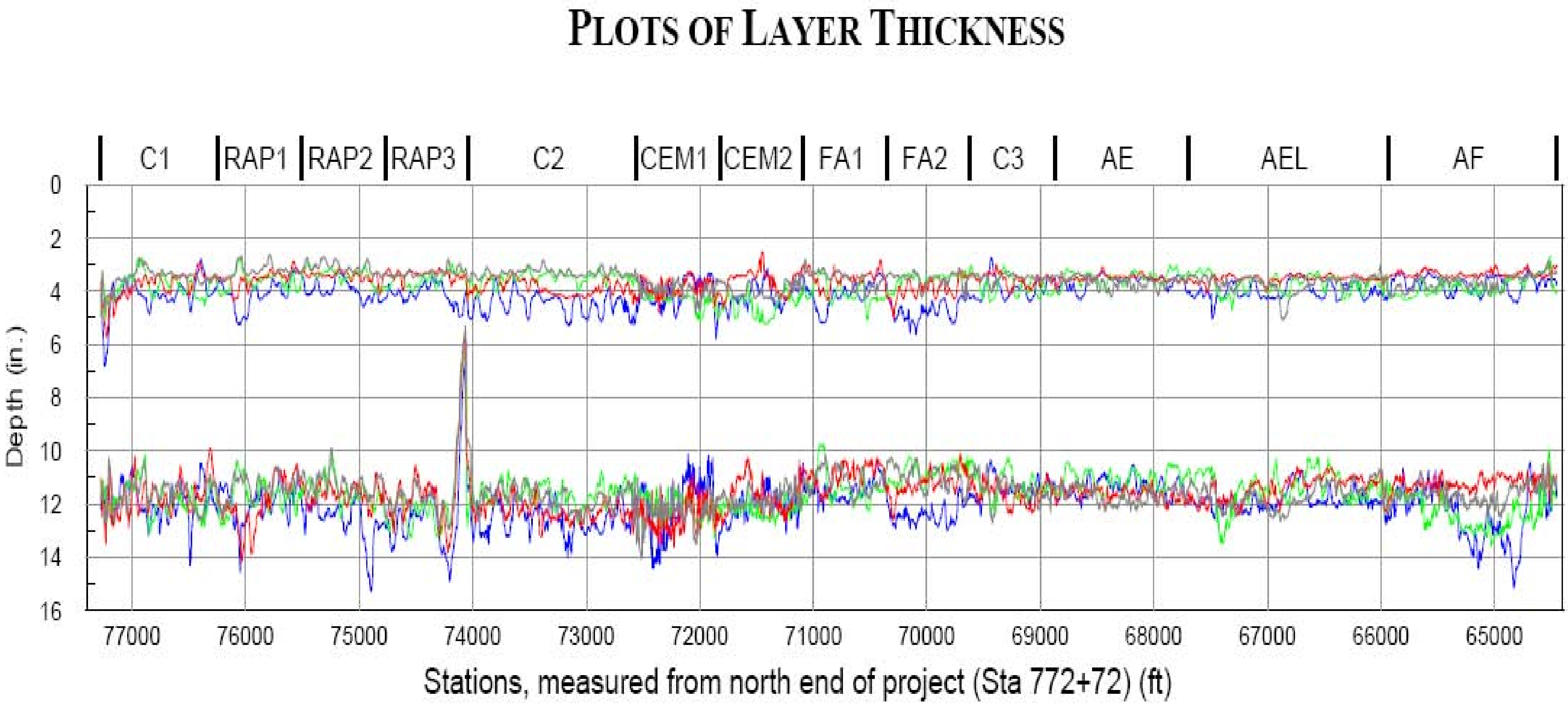


Figure B: Location of Test Section in Respect to Rapid City

Ground Penetrating Radar (GPR) Profile

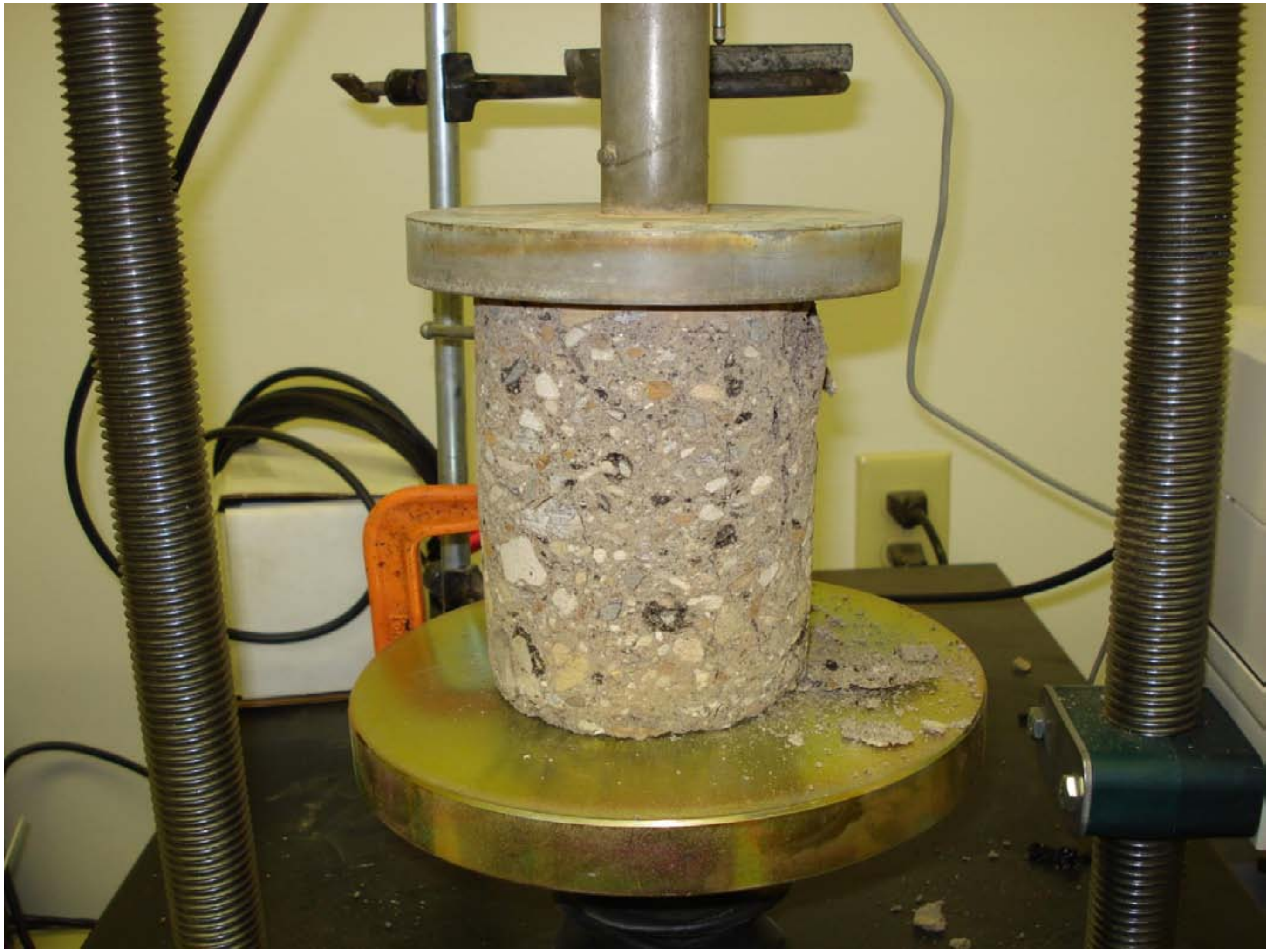


Falling Weight Deflectometer (FWD)

Coring of Base Material


ACE
Marking Paint

Unconfined Compression Testing



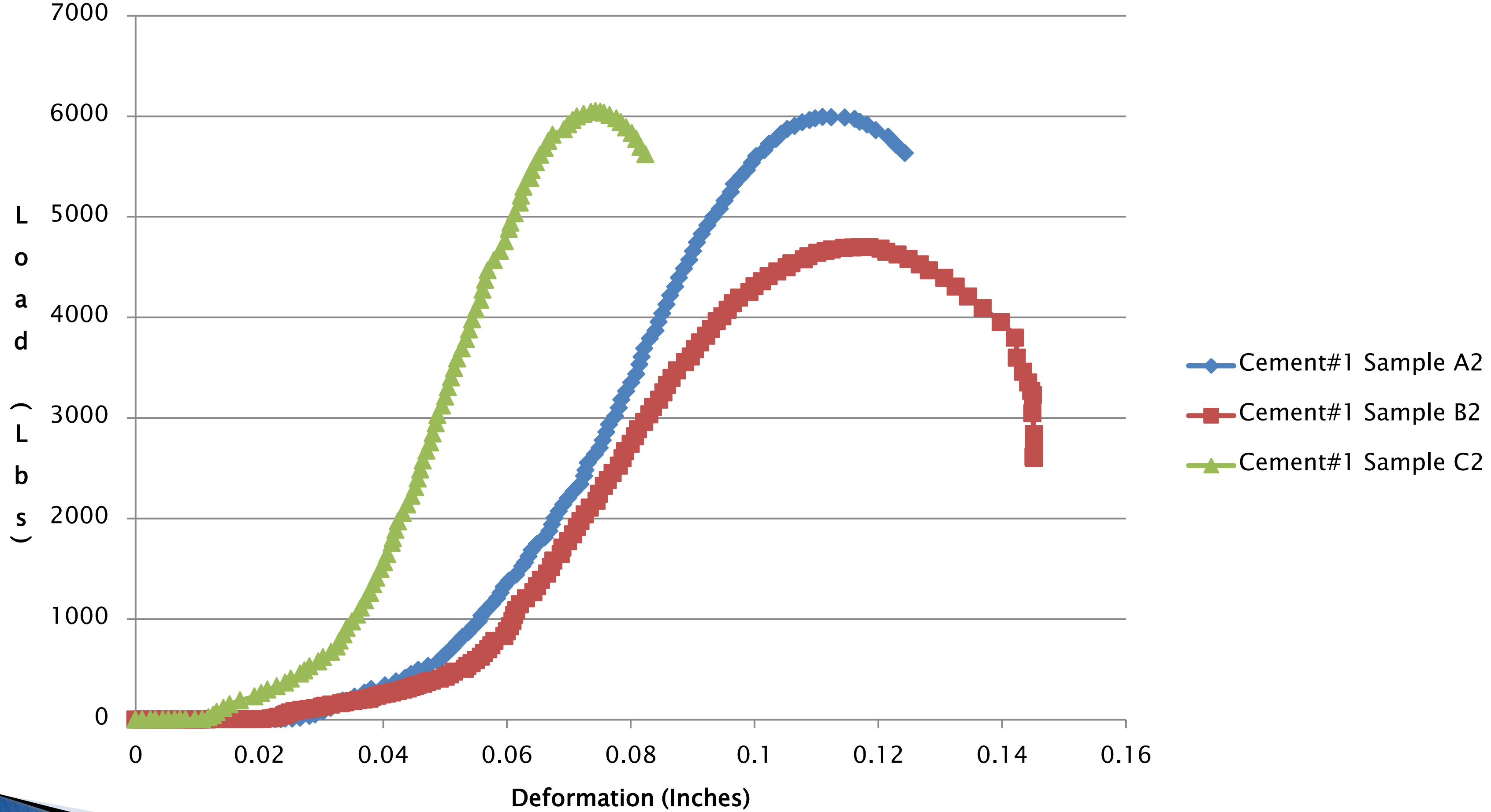
Cement Stabilized – UCS Test Results

- During mix design, a targeted UC strength of 350 psi was used which resulted in an optimum of 3% cement and 14% fly ash.

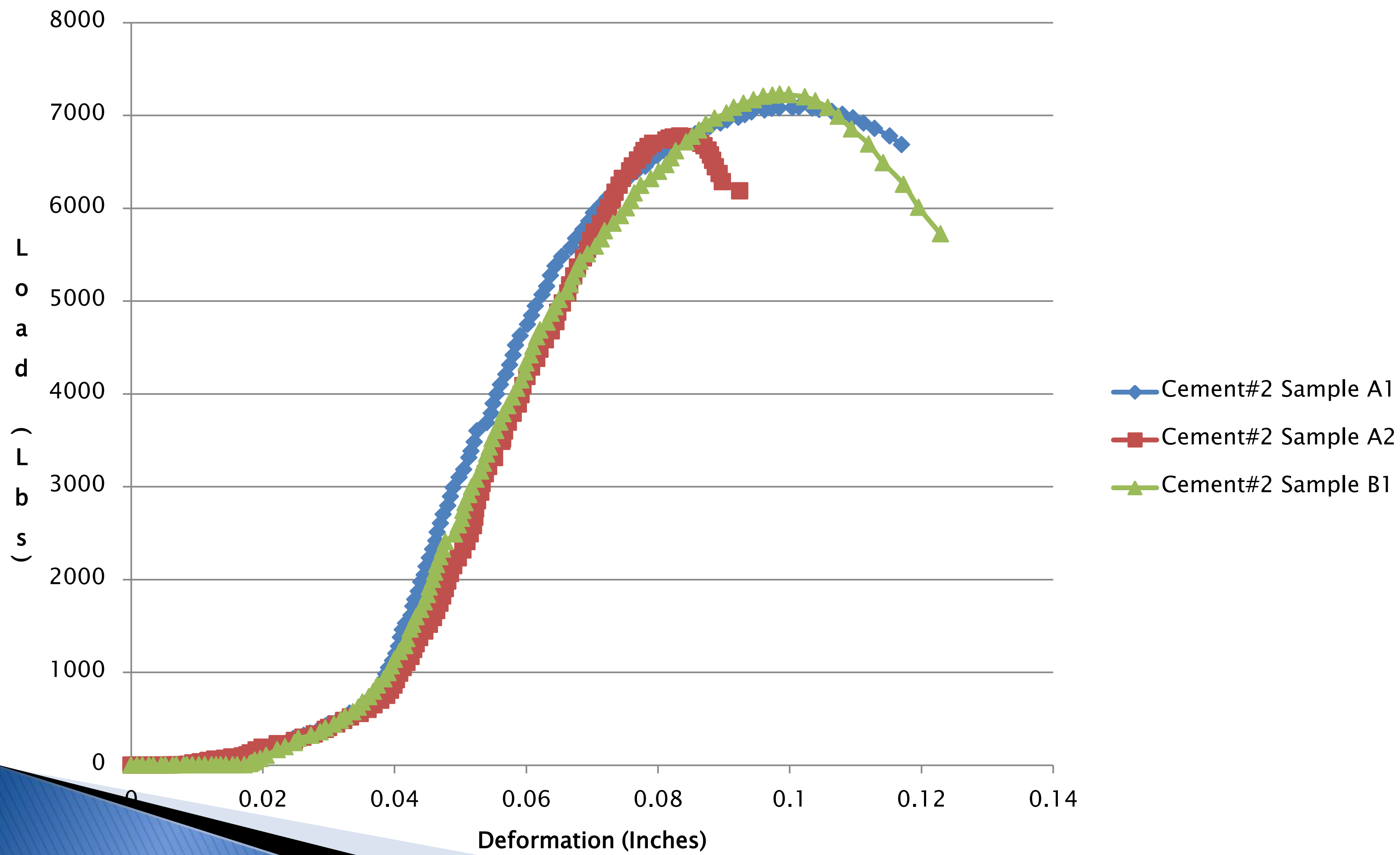
- However, for the field samples, the average UC strength was approximately 500 – 600 psi.

- Transverse cracking has been observed in the cement and foamed asphalt sections.

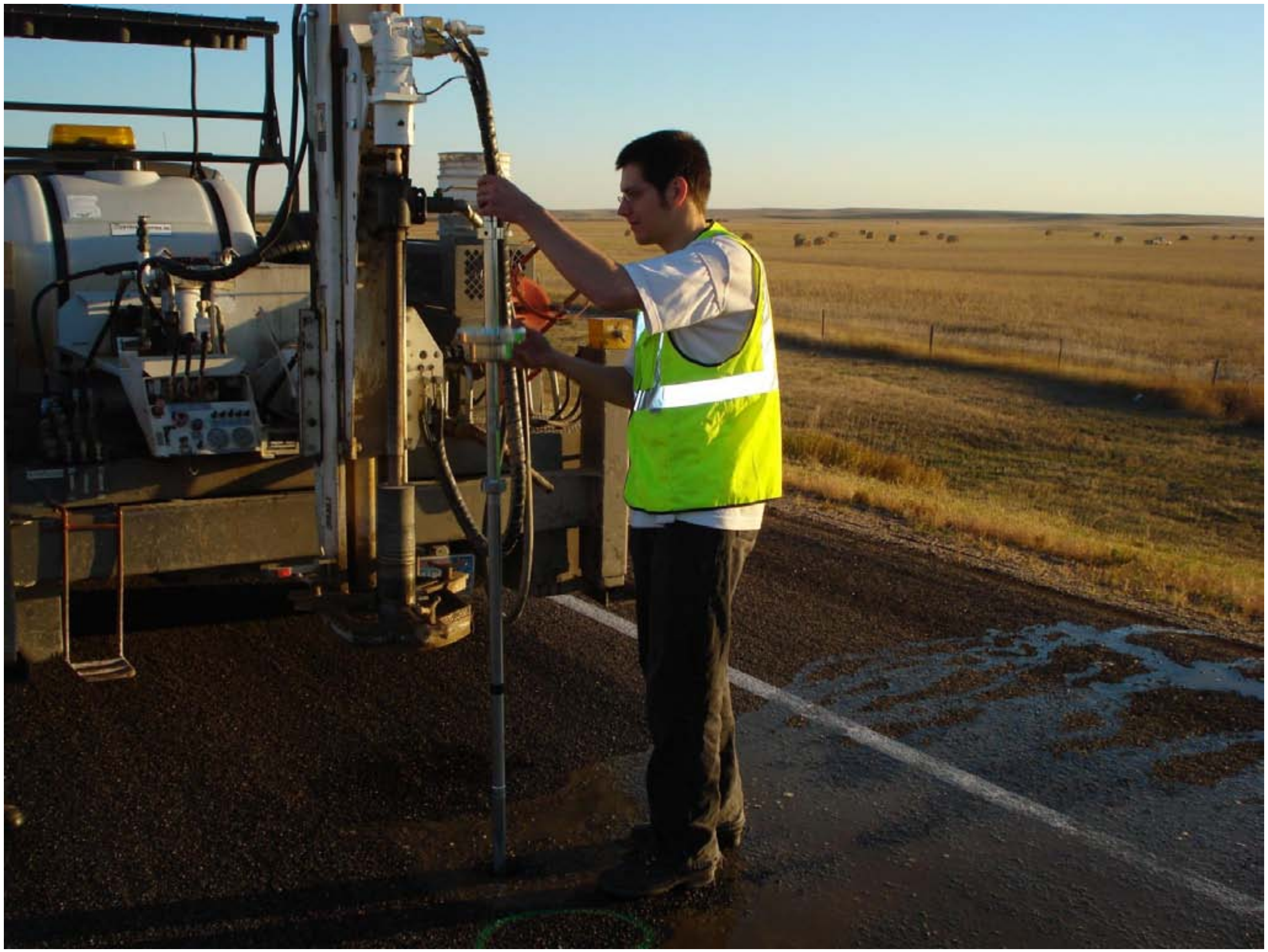
CEM 1 – UCS Test Results



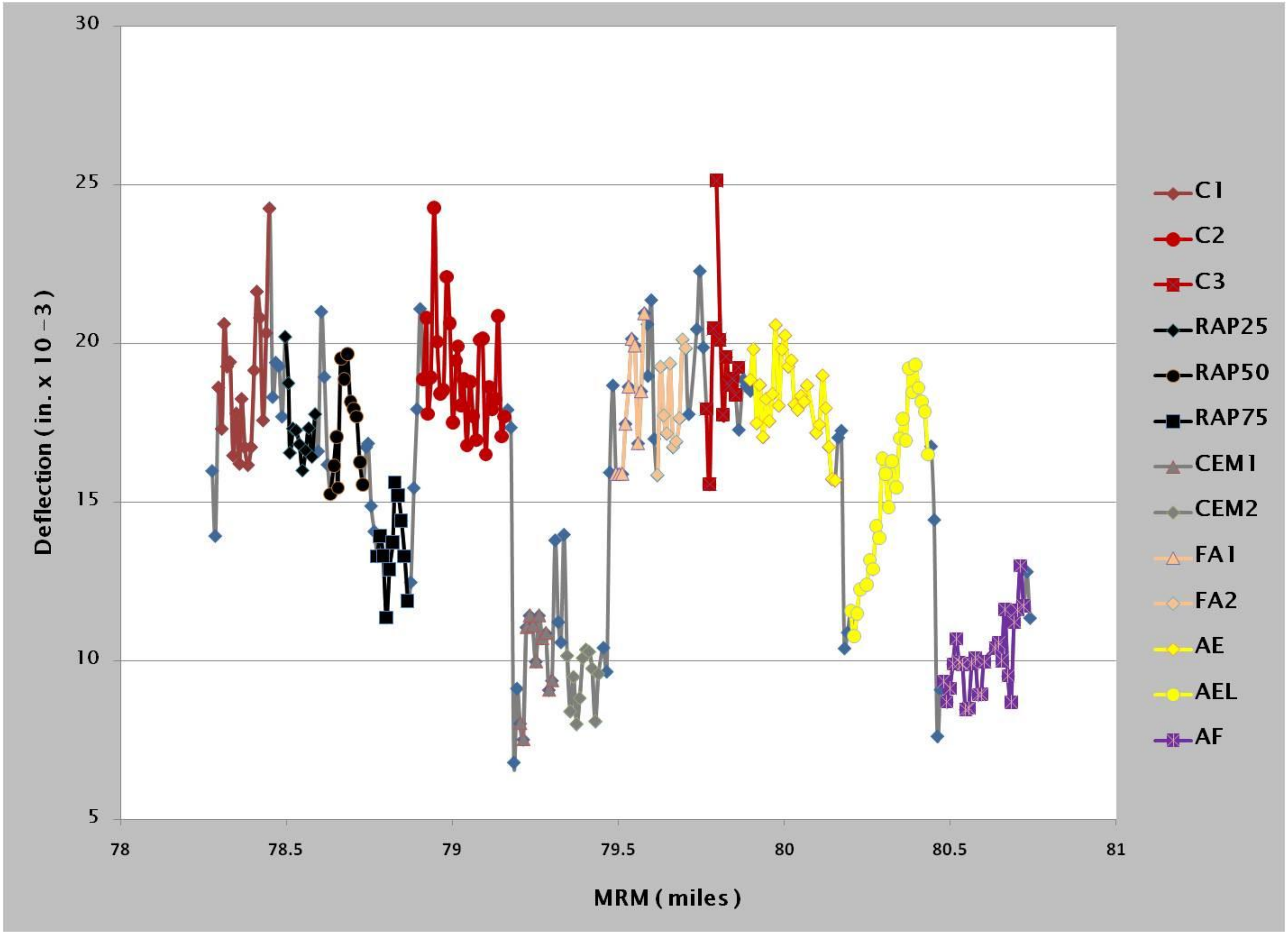
CEM 2 – UCS Test Results



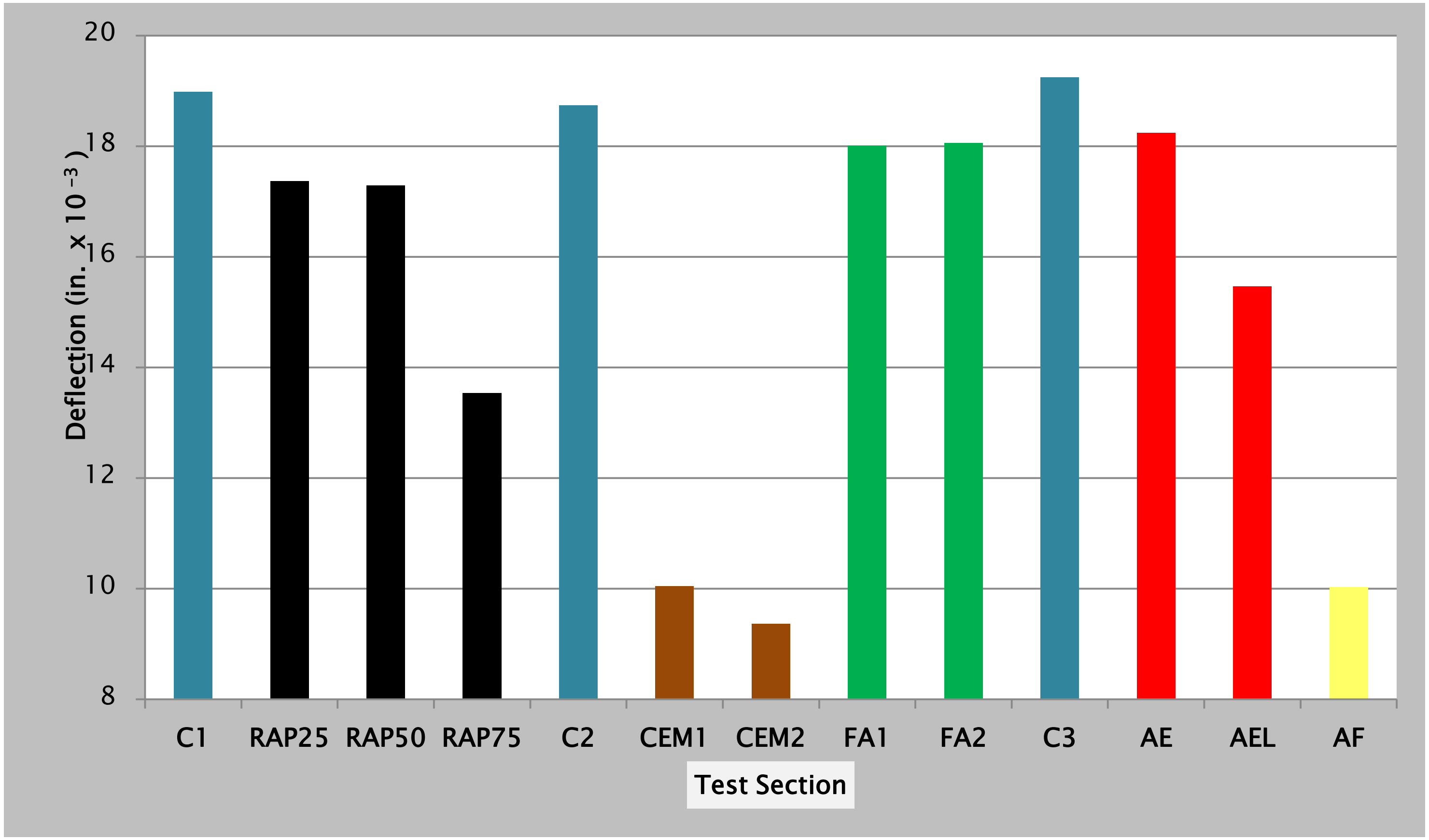
Dynamic Cone Penetrometer (DCP)



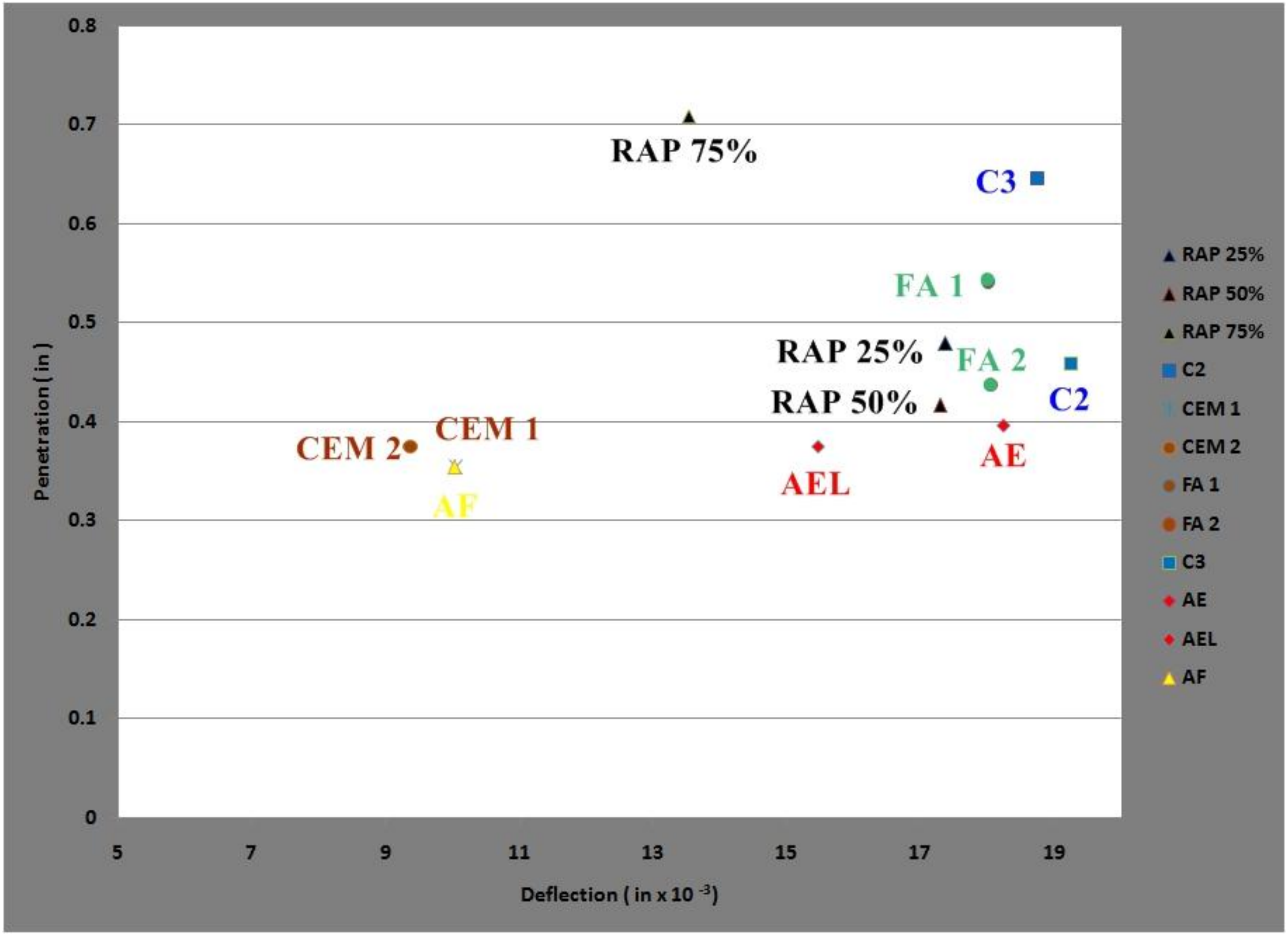
FWD Deflection Profile



Average Deflection Comparison



Deflection Basin and DCP Values



Crack count for the test sections

Test Section	Total Cracks	North Bound only	South Bound only	Spanning both lanes
AF	39	17	7	15
Transition to FA2 in C3	2	1	1	0
FA2	11	0	4	7
FA	13	2	0	11
CEM2	33	16	10	7
CEM1 *	46	16	14	16

* Includes a north bound longitudinal crack about 25 feet in length


12/06/2008

SOUTH DAKOTA
SCHOOL OF MINES
& TECHNOLOGY

Lance A. Roberts, Ph.D., P.E.
Assistant Professor
Civil and Environmental Engineering

501 E. Saint Joseph St.
Rapid City, SD 57701
www.sdsmt.edu

Phone: 605-394-5172
Fax: 605-394-5171
Lance.Roberts@sdsmt.edu

http://fdr.sdsmt.edu/