Utilization of Cementitious High Carbon Fly Ash to Stabilize Reclaimed Asphalt Pavement as Base Course

Phase II Update

April 16, 2008

THE UNIVERSITY of WISCONSIN MADISON

High Carbon Fly Ash Study

- Sponsor: U.S. DOE
- Research Team: University of Wisconsin at Madison and Bloom Companies
- Partner: Minnesota DOT

Team

- DOE Project Manager: Robert Patton
- PI: Haifang Wen (UW)
- Team: Tuncer Edil and Craig Benson (UW), and Swapna Danda (Bloom)
- MnDOT: Maureen Jensen, Ben Worel, Tim Cylne, Roger Olson, Ed Johnson, Bob Edstrom, Leonard Palek, John Siekmeier

Phases of Study

- Phase I – Laboratory Feasibility Study: Aug. 2005 – Mar. 2006
- Phase II – Field Demonstration: Aug. 2006 – Dec. 2008

Phase II Study

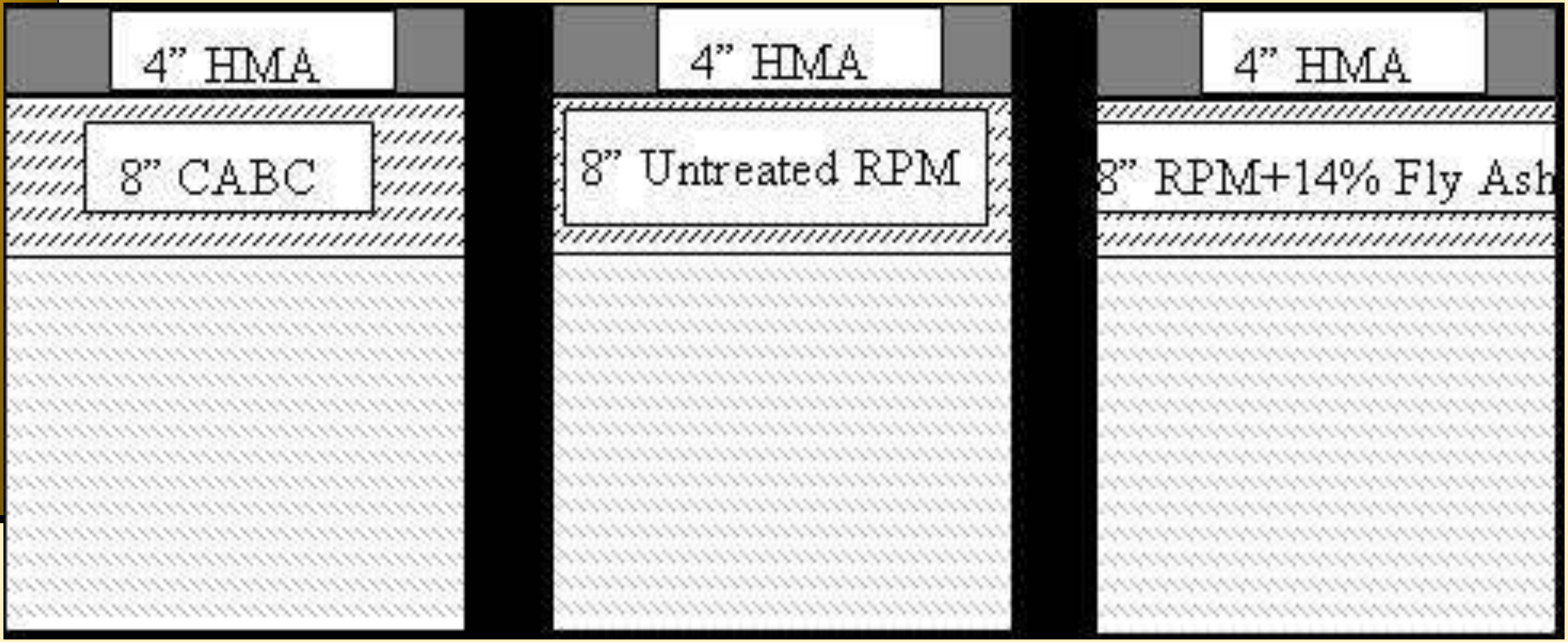
- Full-scale Test Road: MnROAD
- Well-controlled
- Well-instrumented
- Real life application
- Live truck

Phase II Study

- MnROAD Facility

Phase II Study

- Pavement Structures at MnROAD



Phase II Study

- Using Riverside 8 Fly Ash from Xcel Energy
- 14.6% LOI (Carbon)
- 22% CaO
- 14% Application Rate

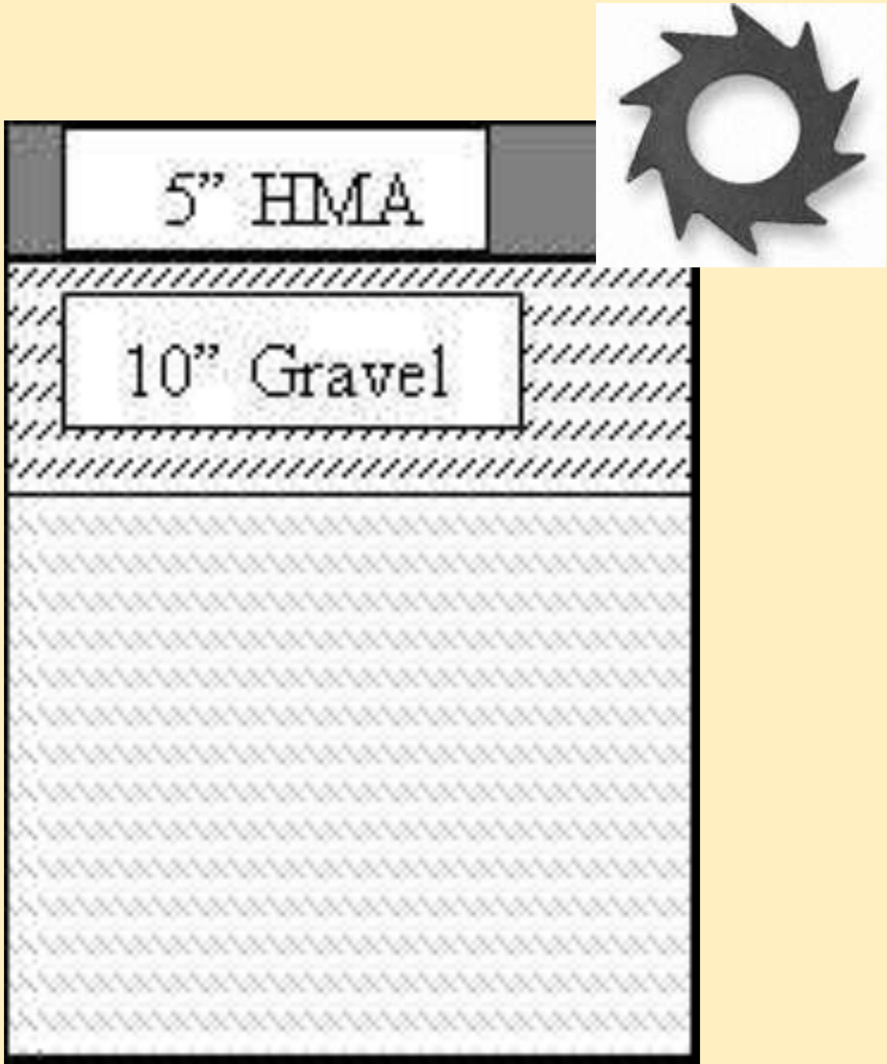
Phase II Study

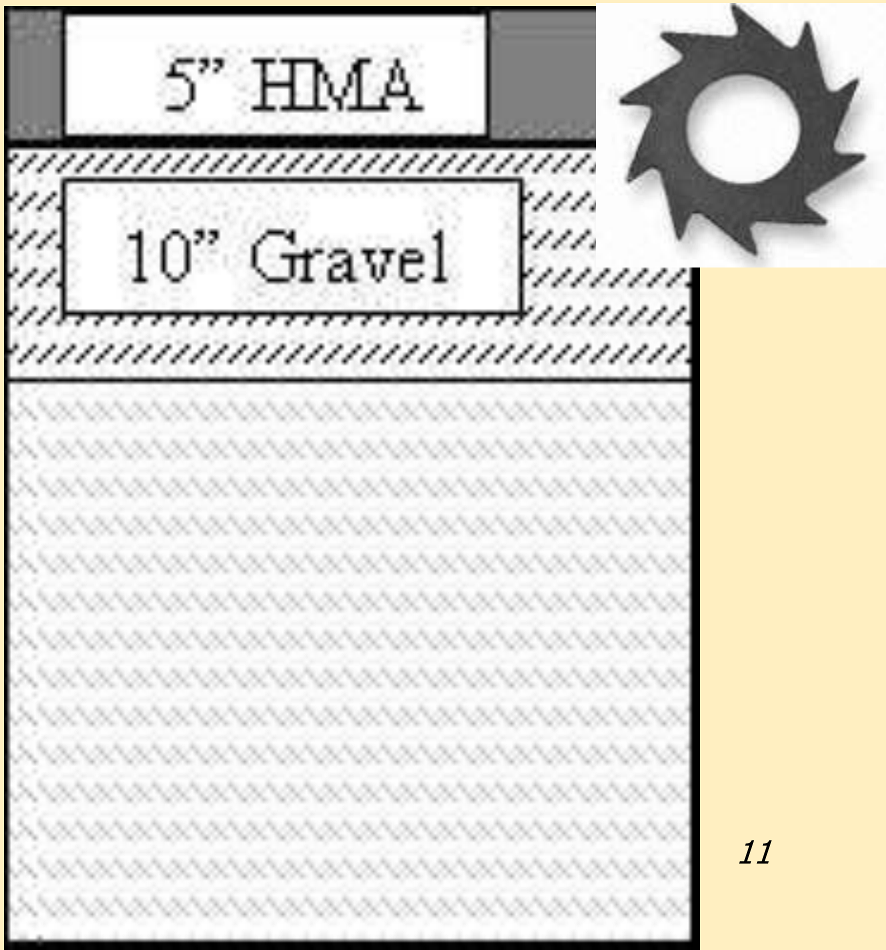
- MPCA considers Riverside 8 Fly Ash a non-compliant materials
- An agreement was made on June 20, 2007 in which MPCA permitted the use of Riverside 8
- MPCA requested continuous monitoring

Phase II Construction

- MnDOT let the project on June 8, 2007
- Midwest Asphalt won the bid.
- Construction started on July 23rd, 2007.

Recycle Asphalt





RPM Base Course Placement

Crushed Aggregate

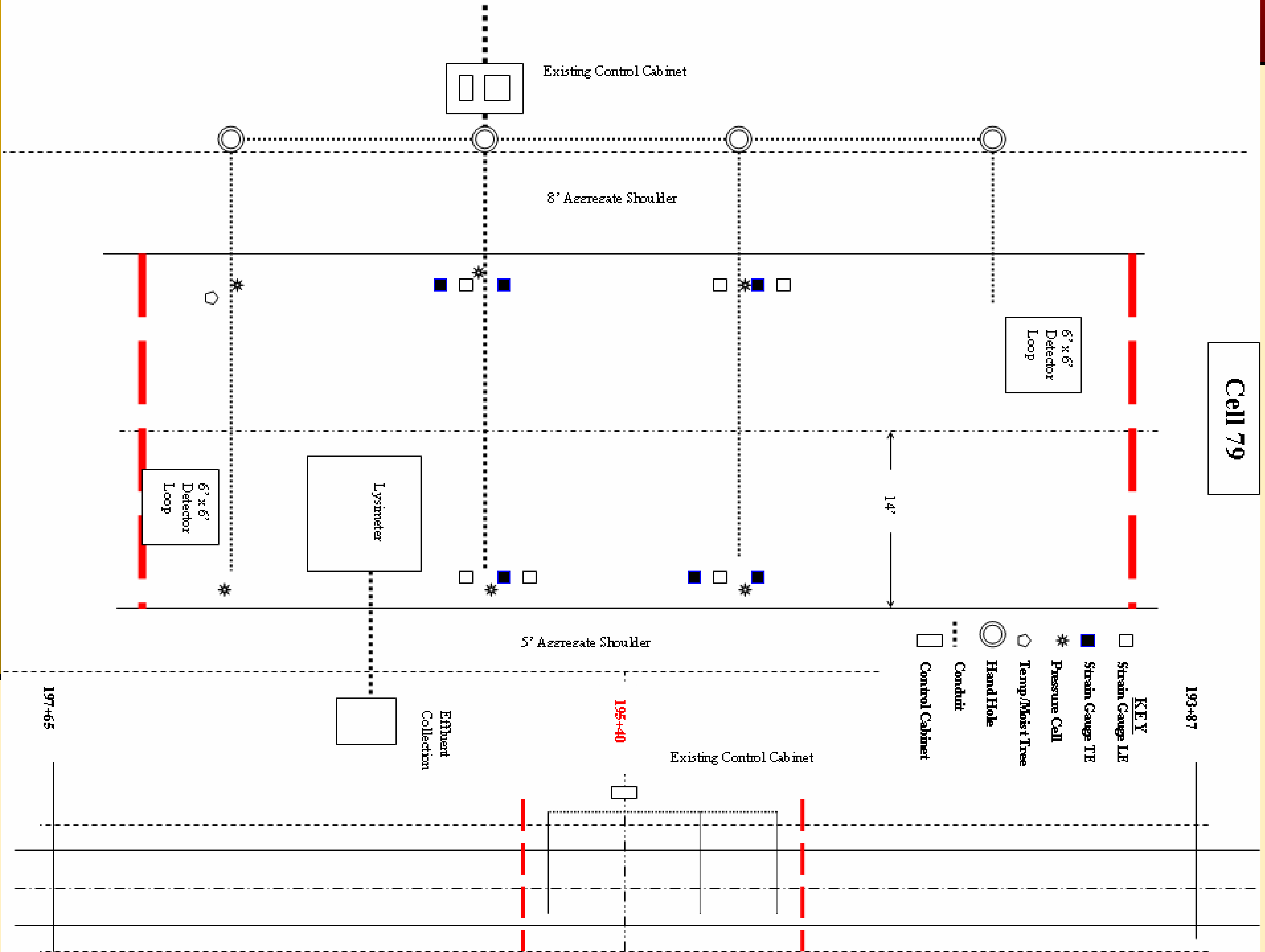
High Carbon Fly Ash Placement

RPM/Fly Ash Mixing

RPM/Fly Ash Mixing

Instrumentation

- Pressure Cell, Strain Gauges, Deformation in Base, Temperature, Moisture (MnDOT)
- Lysimeters for leaching (UW)

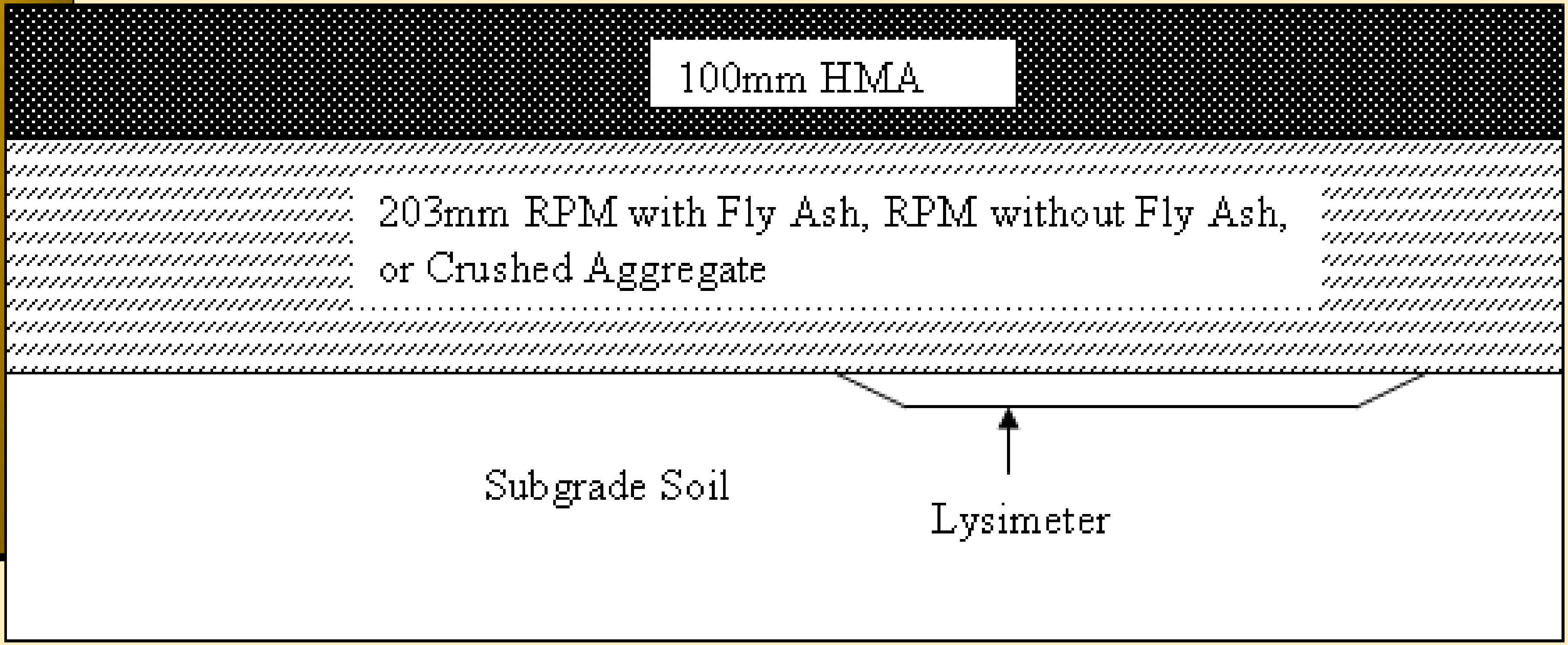


Existing Control Cabinet
8' Aggregate Shoulder
6' x 6' Detector Loop
Lysimeter
6' x 6' Detector Loop
14'
Cell 79
5' Aggregate Shoulder
KEY
Strain Gauge LE
Strain Gauge TE
Pressure Cell
Temp/Moist Tree
Hand Hole
Conduit
Control Cabinet
197+65
Effluent Collection
195+40
Existing Control Cabinet
193+87

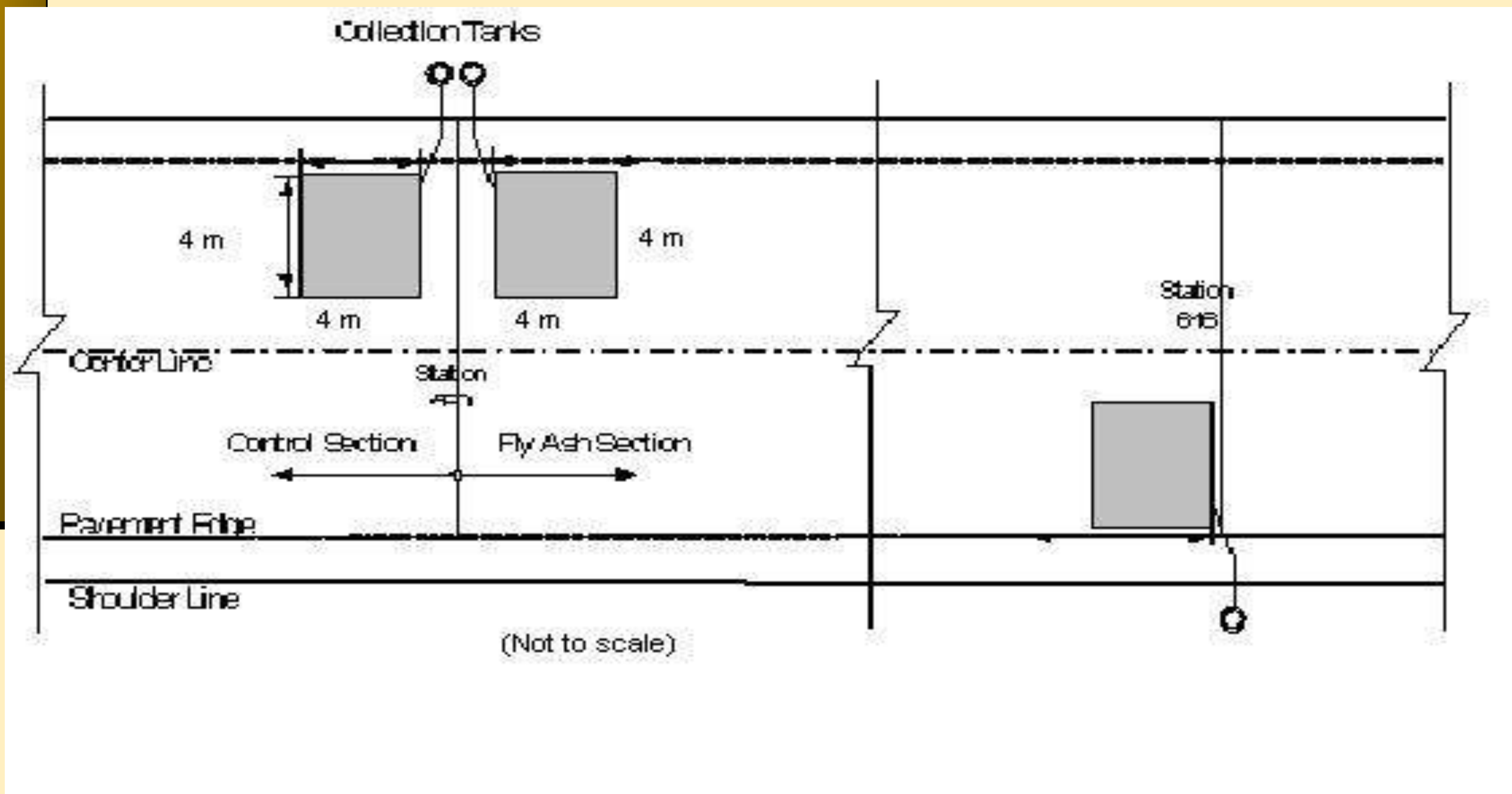
Infrastructure Construction

Instrumentation – Strain Gauge

Lysimeter


100mm HMA
203mm RPM with Fly Ash, RPM without Fly Ash, or Crushed Aggregate
Subgrade Soil
Lysimeter

Plan View of Lysimeter



Installation of Lysimeter


2007 8 1

Collecting Tank

Collecting Tank

HMA Paving

Too wet for paving

Finally..

Open to traffic, Nov 2007

Field Tests

- Subgrade: Dynamic Cone Penetrometer (DCP), Lightweight Deflectometer (LWD)
- Base Course: DCP, LWD, Falling Weight Deflectometer (FWD), Soil Stiffness Gauge (SSG)
- HMA: FWD

Dynamic Cone Penetrometer

- Calculate DCP Penetration Index and Estimate Modulus

$$DPI_i = \frac{Reading_{i+5} - Reading_i}{5}$$

$$\log(E_i) = 3.04758 - 1.06166 \cdot \log(DPI_i)$$

Soil Stiffness Gauge

- Automatically read the material modulus

Lightweight Deflectometer

$$E = \frac{2P}{A}(1-\nu^2).R.a.D_o$$

P=Peak load

A=Contact area

R=Plate radius

α=Rigidity factor

D_0=Center Deflection

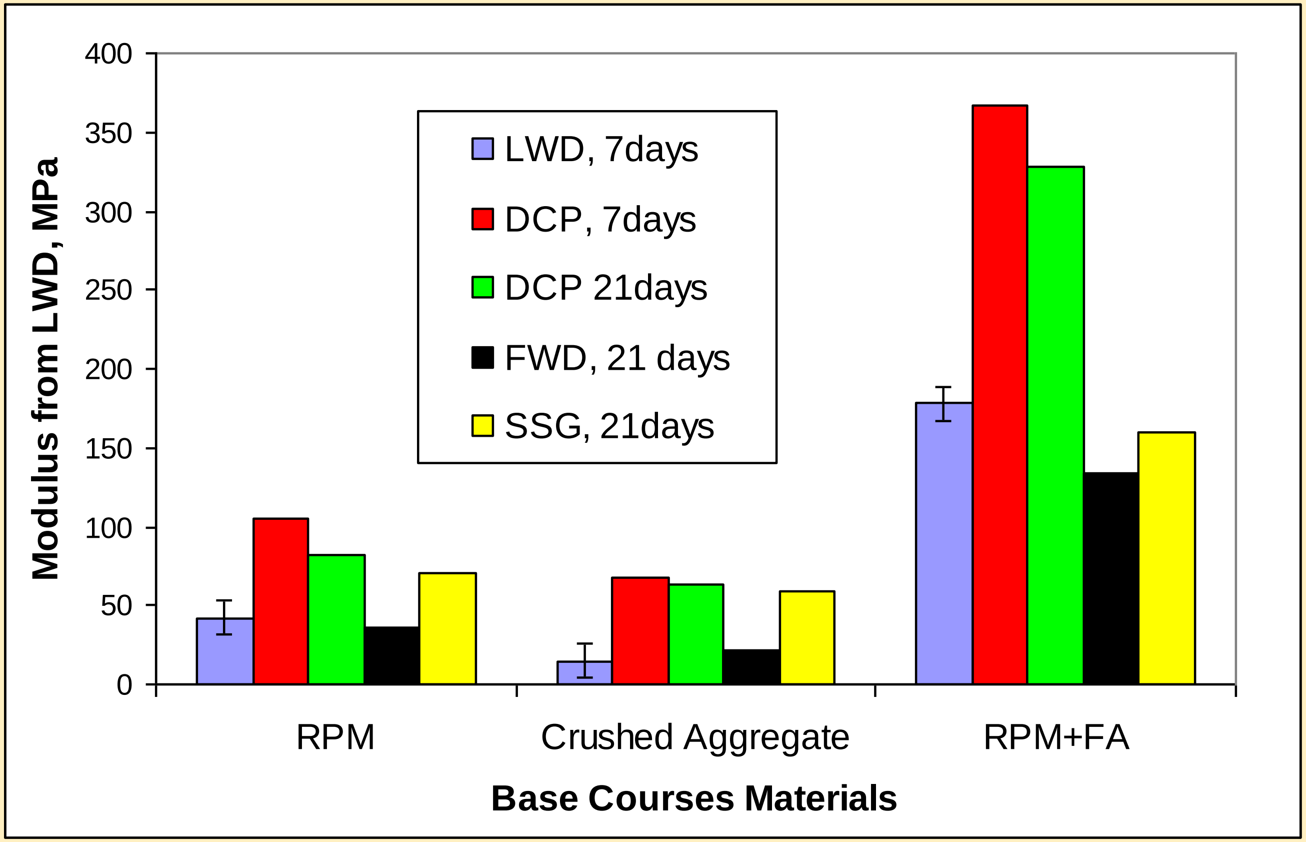
*Dynatest, 2006

Falling Weight Deflectometer

- Backcalculate the modulus of layers

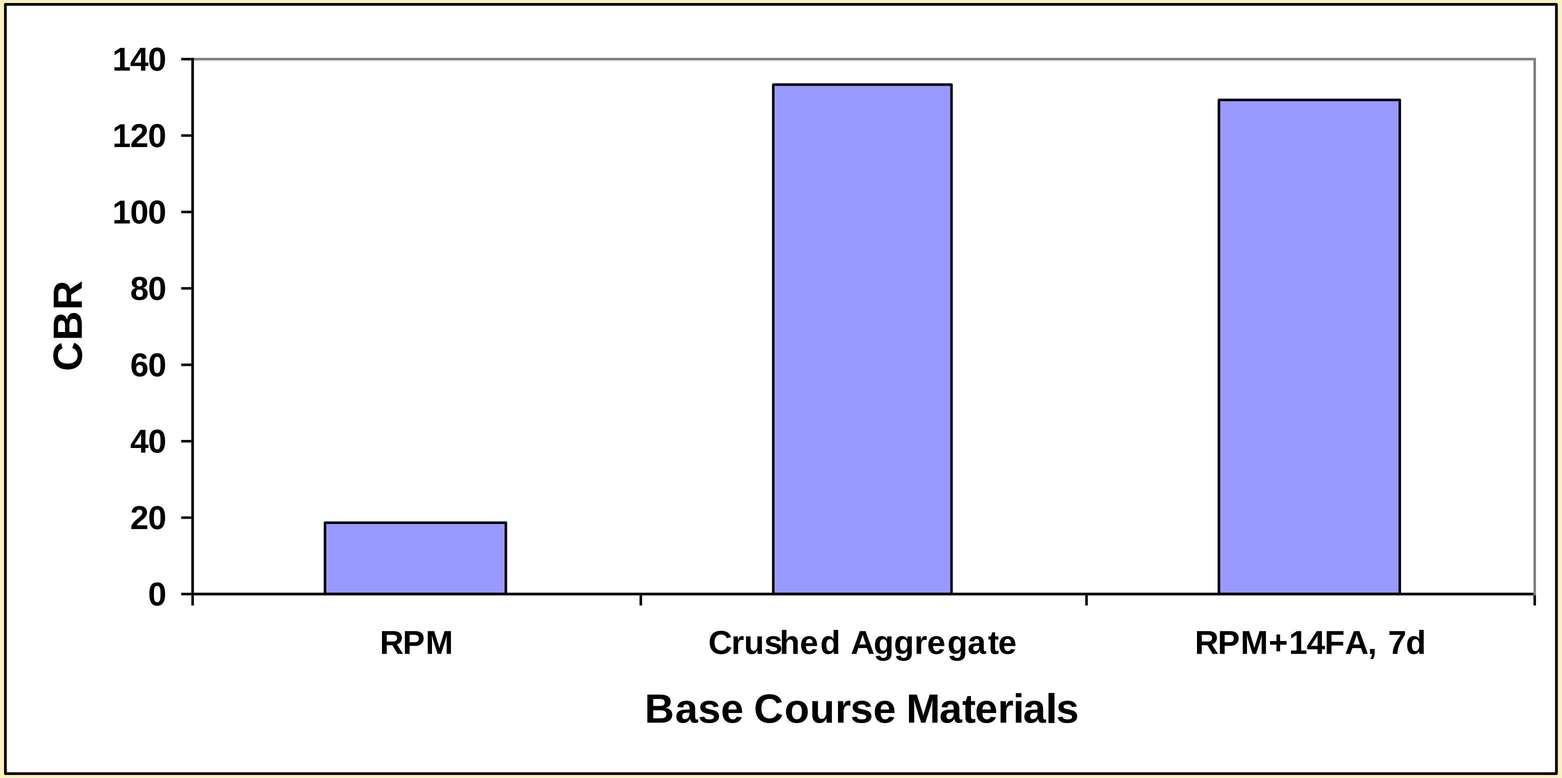
Field Tests

- Modulus



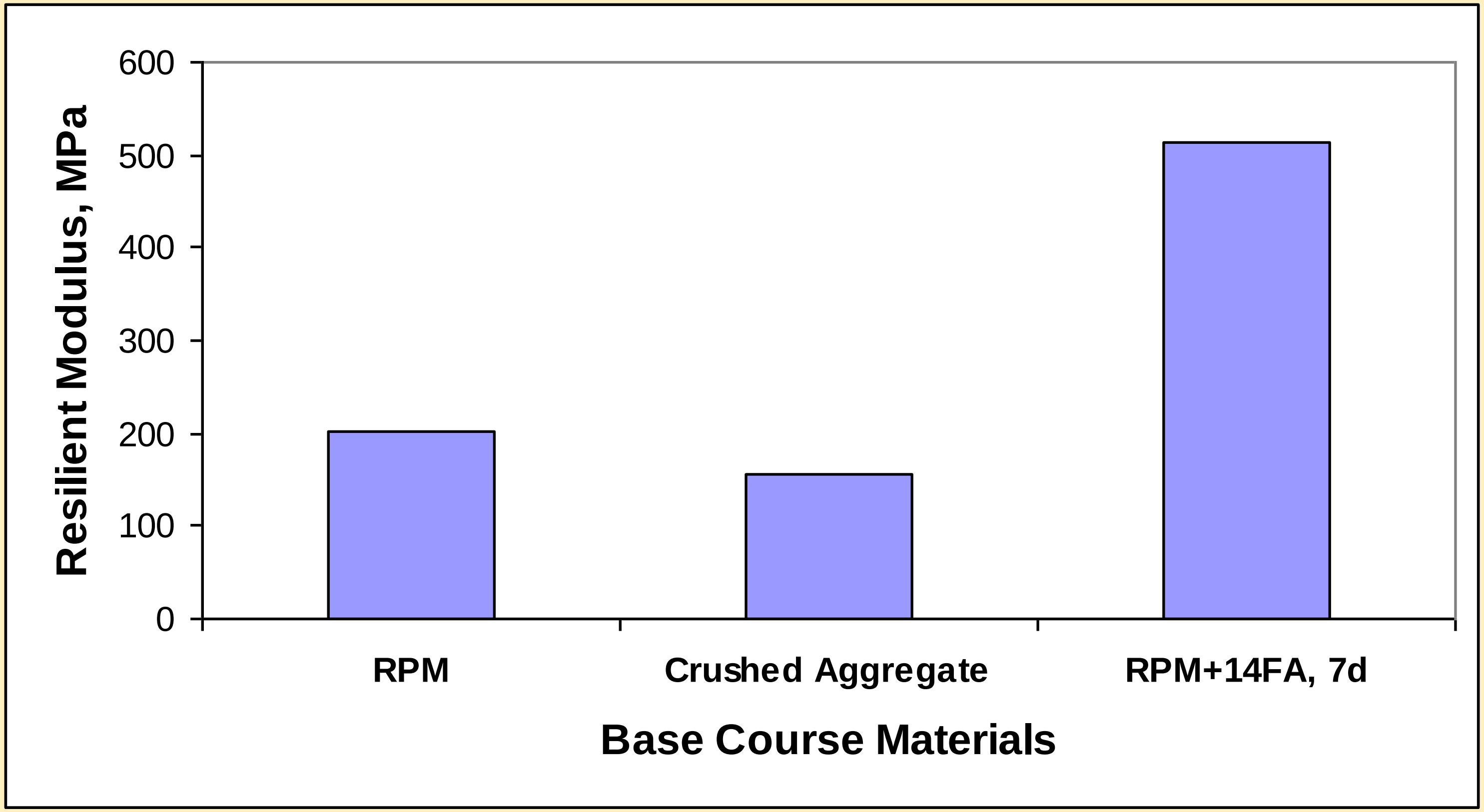
Lab Tests

- CBR



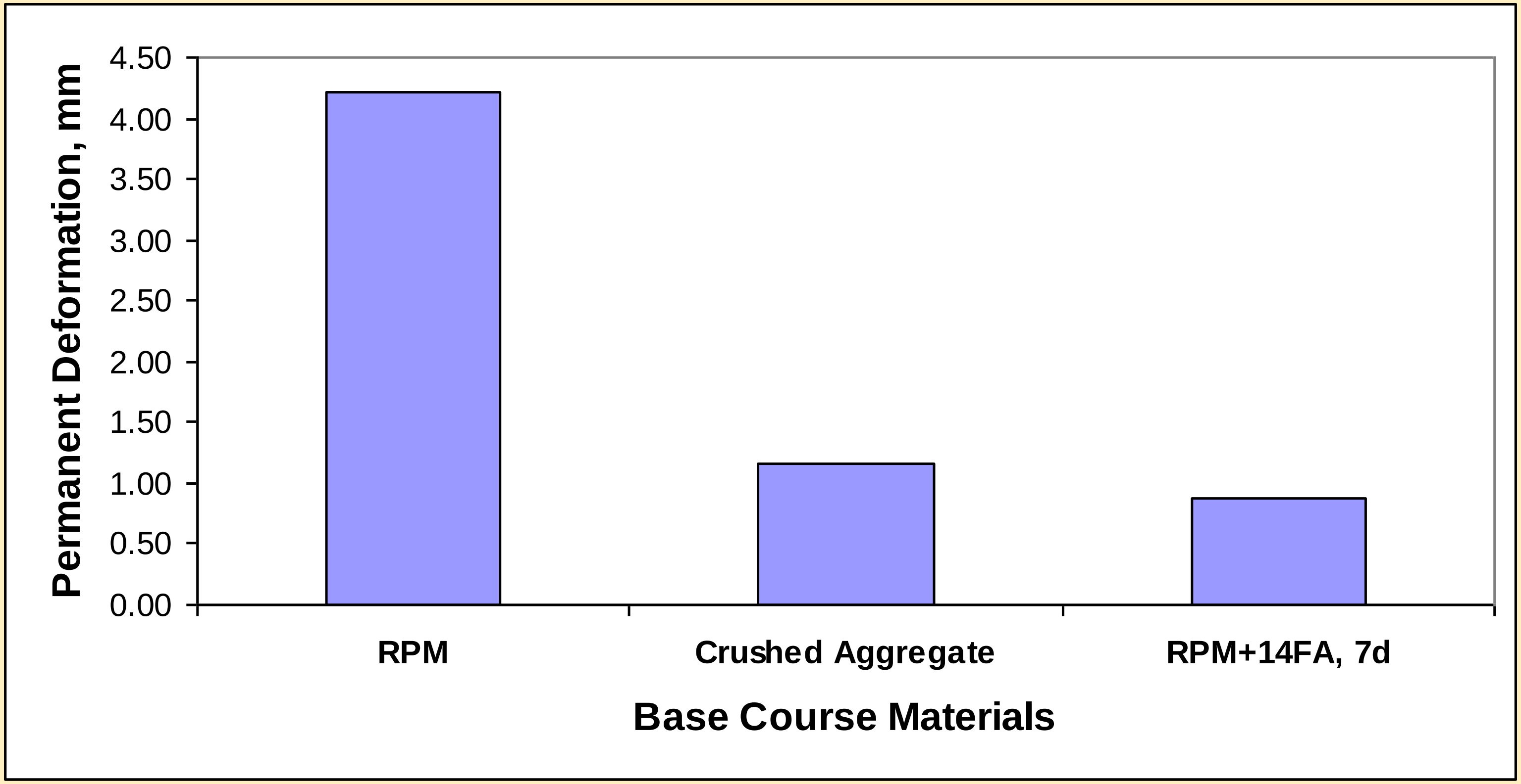
Lab Tests

- Resilient Modulus



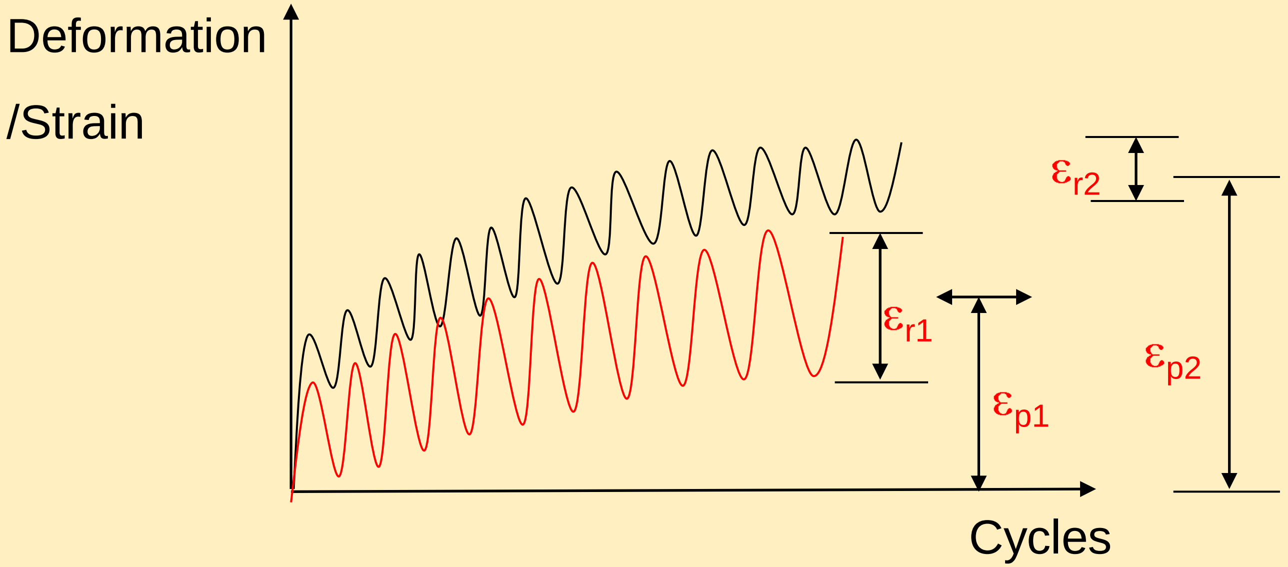
Lab Tests

- Permanent Strain after Mr Tests



Phase II Study – Test Results

- Permanent Deformation

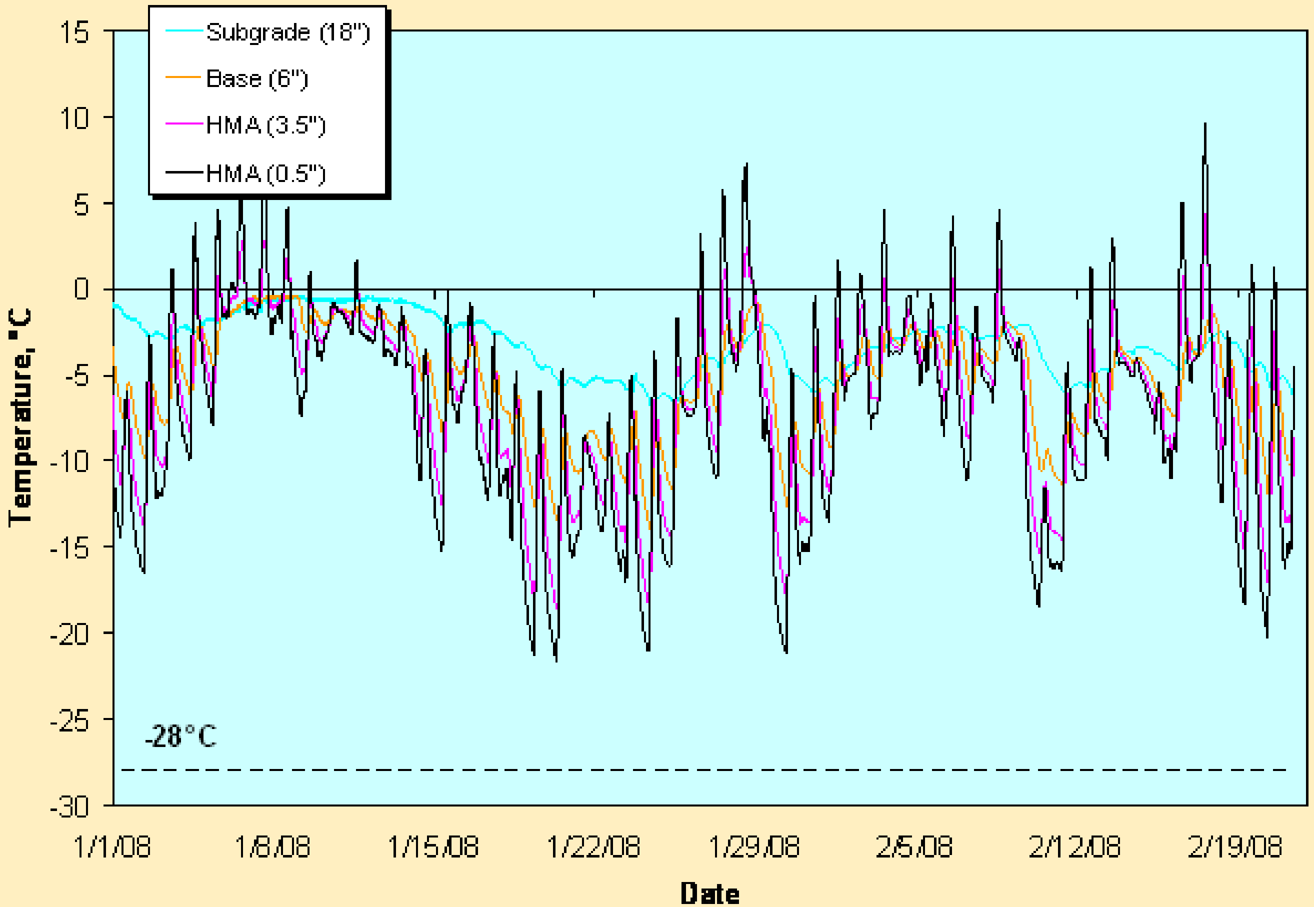


Phase II Study – Test Results

- Anticipated pavement field performance, based on lab test results:
  - Fatigue (from best to worst):
    - RPM/Fly Ash→RPM→Crushed Aggregate
  - Rutting (from best to worst):
    - RPM/Fly Ash→Crushed Aggregate →RPM
- Long-term implication:
  - Deterioration of fly ash base course?
  - Moisture effects on other base course?

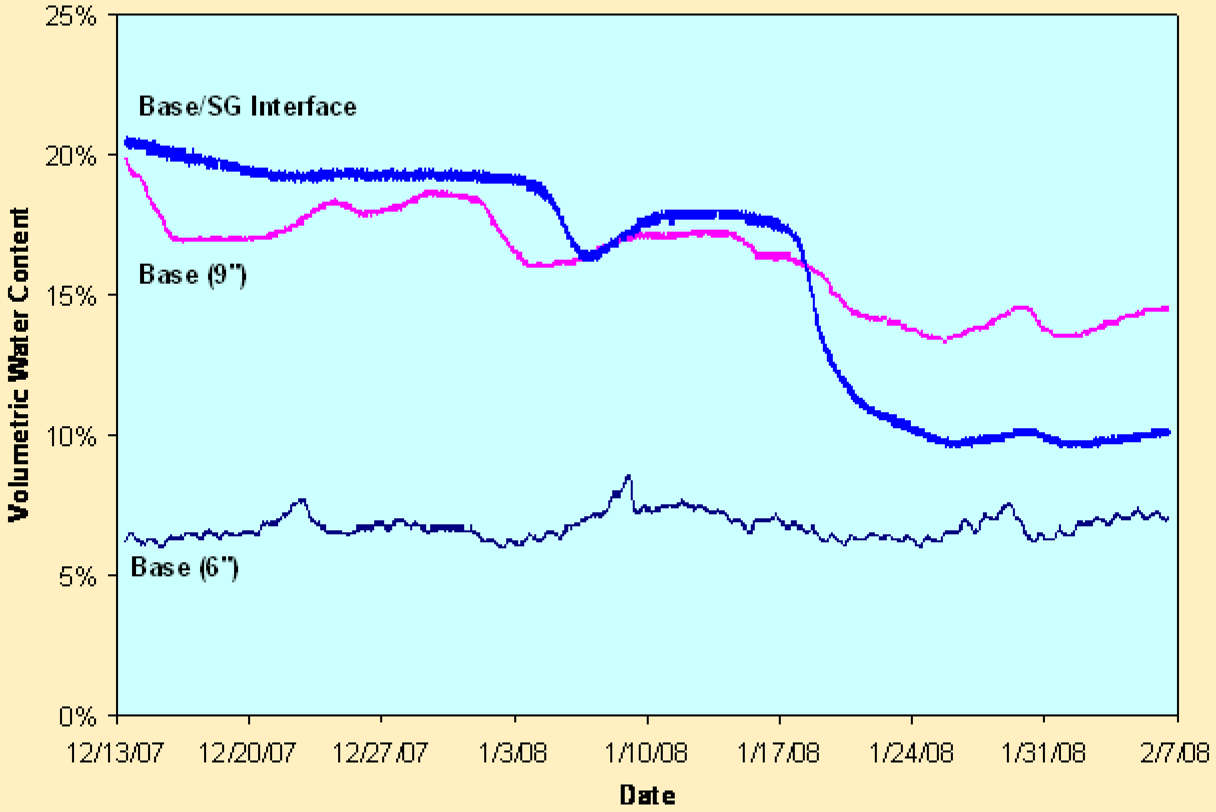
Instrumentation

- Temperature



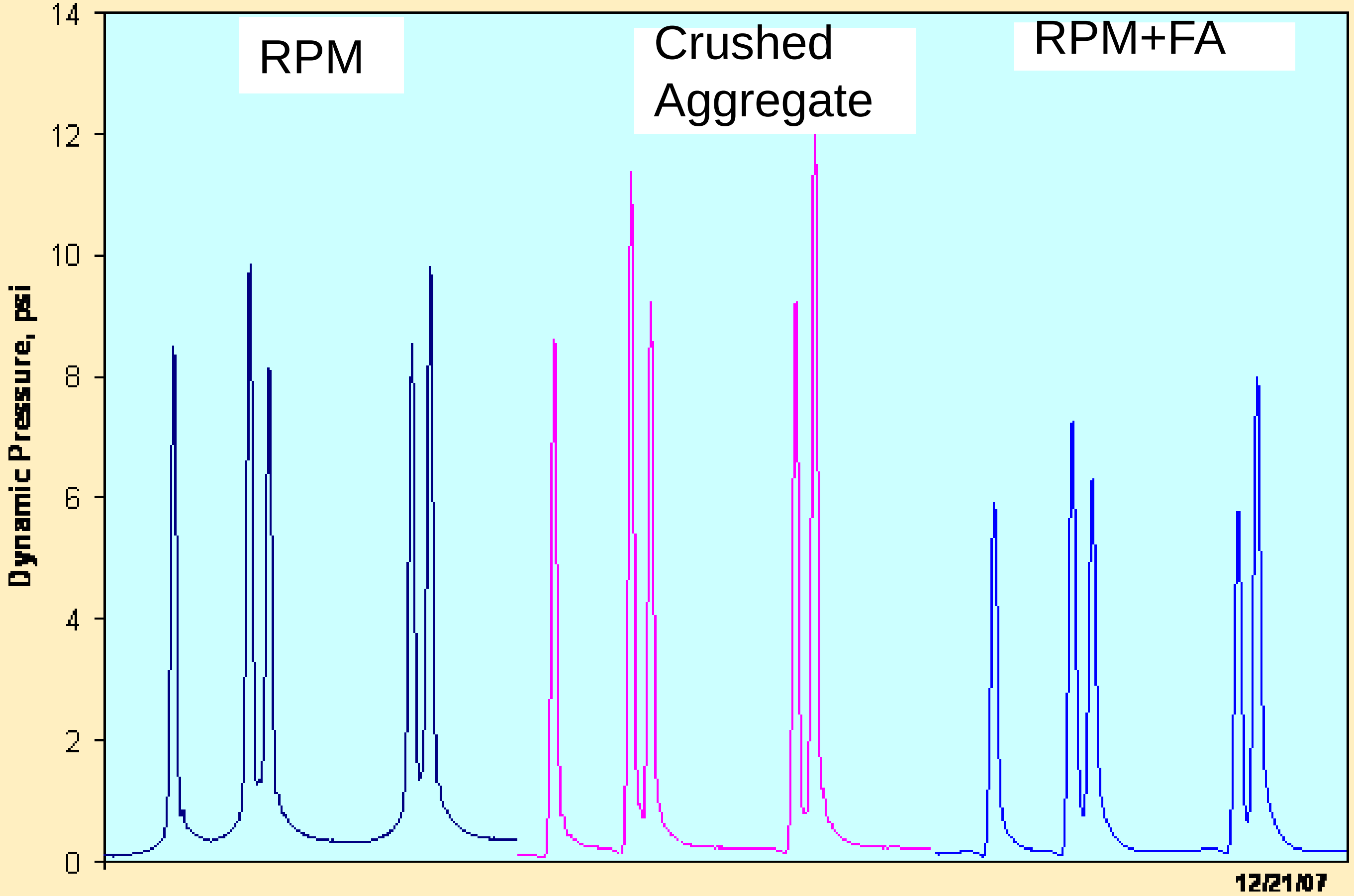
Instrumentation

- Moisture Content



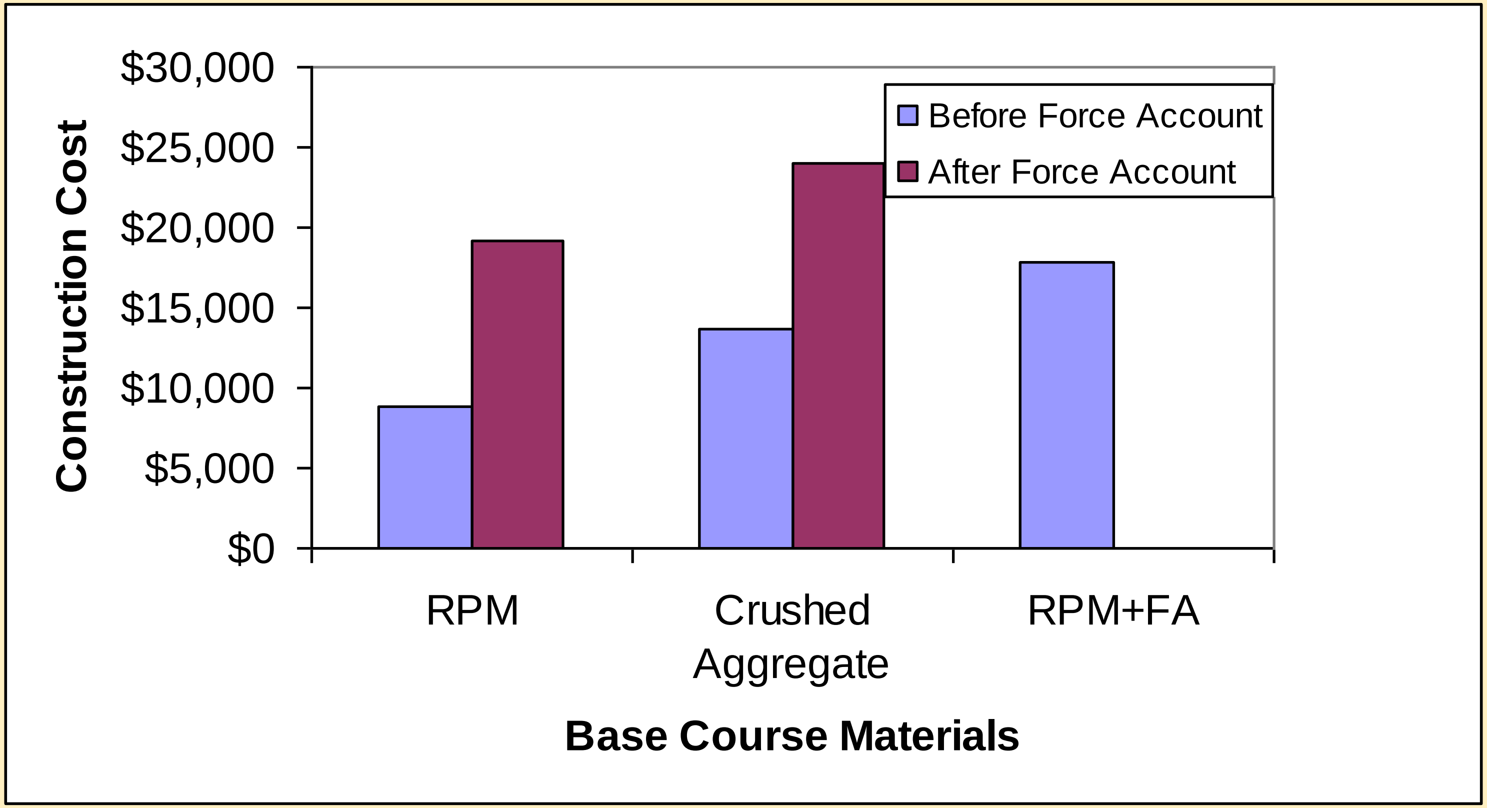
Instrumentation

- Stress at the bottom of base



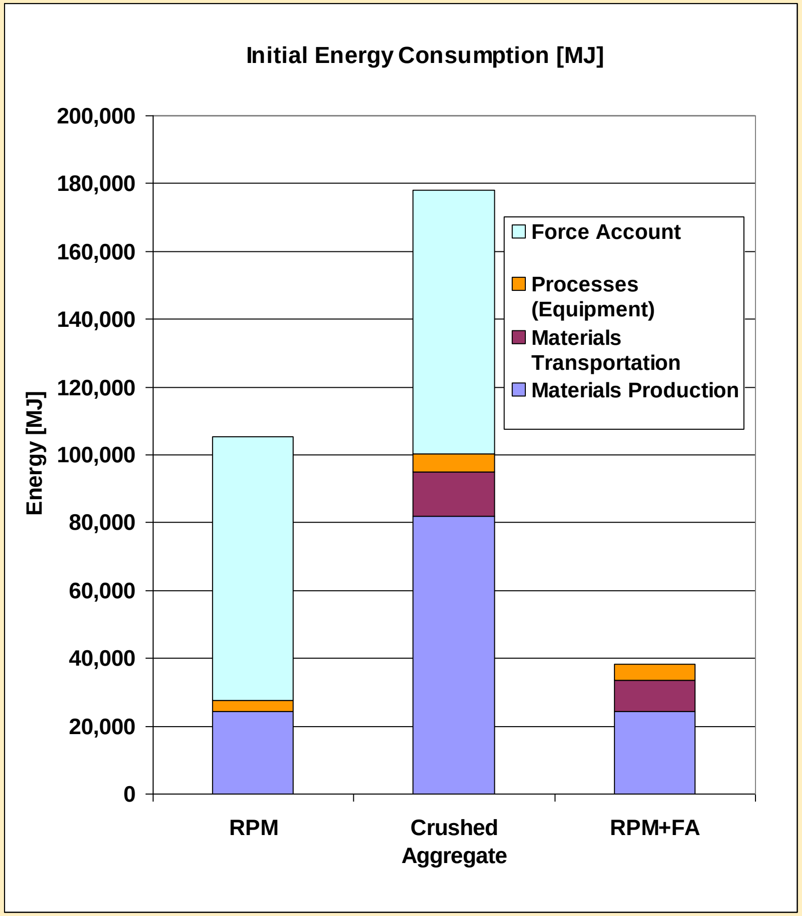
Construction Costs

- Initial Construction Cost of Base Courses



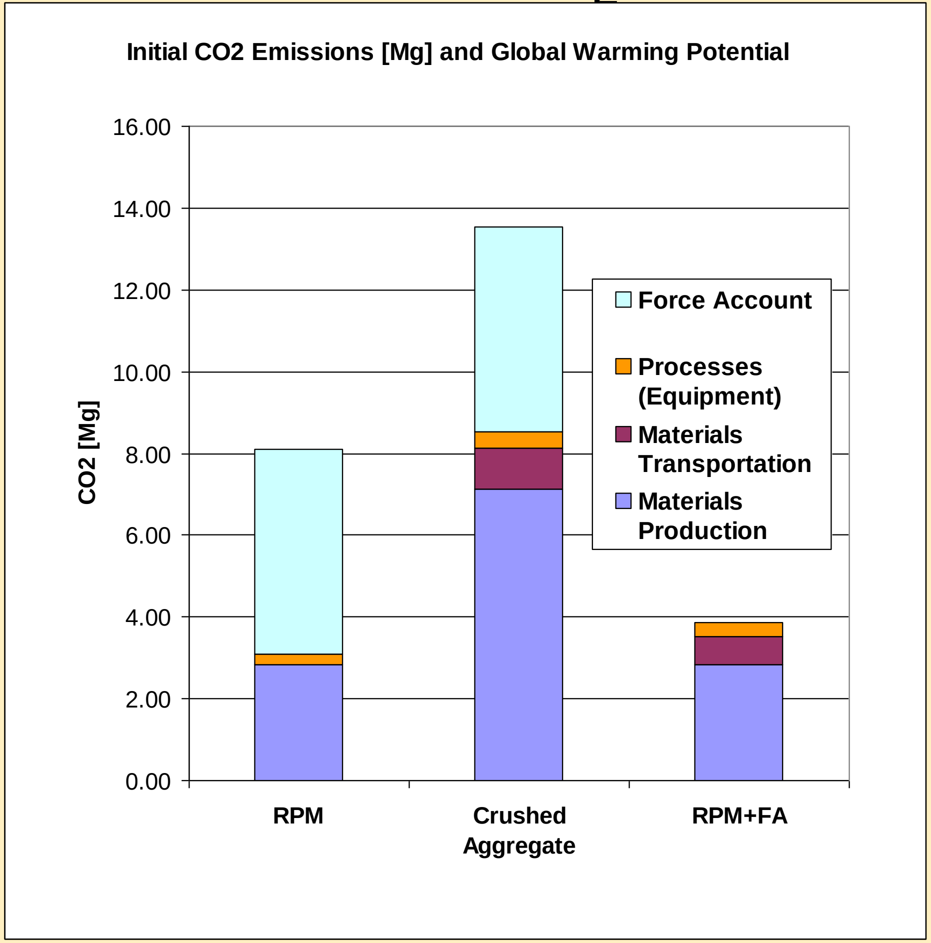
Energy Consumption

- Comparison of Initial Energy Consumption



Greenhouse Gas Emission

- Comparison of Initial CO_2 Emission



Leachate Collection

Leachate Samples

Rotator

Inductively Coupled Plasma (ICP)

Leaching Results

- Leaching Results

Standards		Boron	Mangane	Cadmium	Chromiu	Molybde	Arsenic
WI NR 140.10 Groundwater -		960	50 (Pub. V	5	100	40	10
Preventative Action Limit		190	25 (Pub. V	0.5	10	8	1
MN-Health Risk Limits (µg/L=ppb) (updated as of July, 2007))		600	100 (due t	4	100	None	None
Minnesota Drinking Water MCL		None	None	5	100	None	10
USEPA MCL (µg/L=ppb)		None	None	5	100	None	10
MNRd-77, RPM	TOTAL MINERALS				HEAVY METALS		
Sample	Date	B	Mn	Cd	Cr	Mo	As
		ppb	ppb	ppb	ppb	ppb	ppb
MNRd-77	09/11/07	31.55	246.06	<4	1.3	<4	<30
MNRd-77	10/08/07	37.05	4.29	<4	7.18	423.635	91.065
MNRd-77	12/07/07	<20	773.54	<4	8.67	4.14	<30
MNRd-78, CA	TOTAL MINERALS				HEAVY METALS		
Sample	Date	B	Mn	Cd	Cr	Mo	As
		ppb	ppb	ppb	ppb	ppb	ppb
MNRd-78	09/11/07	38.55	0.39	<4	<1	8.955	<30
MNRd-78	10/08/07	78.55	<1.00	<4	2.44	44.495	<30
MNRd-78	12/07/07	67.1	21.7	<4	3.03	<4	52.87
MNRd-79, RPM+FA	TOTAL MINERALS				HEAVY METALS		
Sample	Date	B	Mn	Cd	Cr	Mo	As
		ppb	ppb	ppb	ppb	ppb	ppb
MNRd-79	9/11/07	1301.55	29.73	7.69	119.18	18175.71	<30
MNRd-79	10/8/07	1470.55	18.85	<4	43.31	1576.41	107.455
MNRd-79	12/07/07	684.1	1.7	<4	18.40308	310.81	<30

Leaching Results

- Leaching Results

Standards		Arsenic	Selenium	Vanadiur	Silver	Antimony	Thallium	Nitrate	Sulfate
WI NR 140.10 Groundwater -		10	50	30	50	6	2	10000	250000 (P
Preventative Action Limit		1	10	6	10	1.2	0.4	2000	125000 (P
MN-Health Risk Limits (µg/L=ppb) (updated as of July, 2007))		None	30	50	30	6	0.6	10000	None
Minnesota Drinking Water MCL		10	50	None	None	6	2	10000	None
USEPA MCL (µg/L=ppb)		10	50	None	None	6	2	10000	None
MNRd-77, RPM	AL MINERAVY META			ICP-OES ELEMENTS				N CHROMATOGRAP	
Sample	Date	As	Se	V	Ag	Sb	Tl	NO3	SO4
		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
MNRd-77	09/11/07	<30	<30	<3	25.1	1051	136.4	<10	128450
MNRd-77	10/08/07	91.065	<30	<3	<1	51.9	85.2	520	86210
MNRd-77	12/07/07	<30	<30	<3	<0.0	7.6	<0.0	890	119840
MNRd-78, CA	AL MINERAVY META			ICP-OES ELEMENTS				N CHROMATOGRAP	
Sample	Date	As	Se	V	Ag	Sb	Tl	NO3	SO4
		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
MNRd-78	09/11/07	<30	<30	<3	24.1	27.2	92.5	15460	113520
MNRd-78	10/08/07	<30	<30	<3	0.8	21	85.1	4300	34080
MNRd-78	12/07/07	52.87	<30	<3	<0.0	<0.0	32.7	15430	109260
MNRd-79, RPM+FA	AL MINERAVY META			ICP-OES ELEMENTS				N CHROMATOGRAP	
Sample	Date	As	Se	V	Ag	Sb	Tl	NO3	SO4
		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
MNRd-79	9/11/07	<30	392.84	75.65	2.8	95.2	216	<10	4268650
MNRd-79	10/8/07	107.455	<30	103.65	8.9	24.1	27.2	2610	1987680
MNRd-79	12/07/07	<30	<30	95.80	<0.0	<0.0	<0.0	1270	4166950

Column Leaching Test

Column Leaching Test

Column Leaching Test

Phase II Study Findings

- Field and lab tests confirmed that high carbon fly ash significantly increased the modulus of RPM
- Field and lab tests confirmed untreated RPM has higher modulus than crushed aggregate
- These observed pattern are supported by the various tests utilized, although there are quantitative differences between different tests
- Instrumentation results indicates that adding fly ash reduces the stress level on the top of subgrade, which could reduce the rutting in subgrade

Phase II Study Findings

- Using high carbon fly ash improved the bearing capacity of base course for construction
- In this field demonstration, using high carbon fly ash saved initial construction costs
- Leaching water contains heavy metals from all three different base course materials, including natural granite
- The leaching levels reduces as time passes
- High carbon fly ash section has lowest initial energy consumption and greenhouse gas emission

Further Study

- Continuously environmental monitoring
- Performance testing and monitoring
- Life cycle cost analysis
- Life cycle energy consumption
- Life cycle emission

Thank You