Evaluation of Full Depth Reclamation (FDR) for Suburban Local Roads Using Mechanical Testing and Pavement Design Predictions

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Introduction

- FDR currently lacks:
  - mechanics-based testing procedures
  - performance based specifications
- In this task, four FDR materials were subjected to lab testing to determine:
  - Material properties
  - Potential performance in FDR process
- Material properties were then entered into MnPAVE simulation software to assess pavement life
- Preliminary LCCA was also performed

Lab Testing--Materials

Material Type	Sample ID	Additive	Mix Procedure
Field mixed	FL	3.6% emulsion	field mixed, lab compacted
Lab mixed	LL	3.6% emulsion	lab mixed, lab compacted
Cement Additive	LLC	3.6% emulsion and 1% Portland cement	lab mixed, lab compacted
GNP additive	GNP	3.6% emulsion/ graphene blend	lab mixed, lab compacted

Dry FDR material collected from TH-5 in Carver County, MN was used in all four material types

Lab Testing--Sample Prep

- Heat reclaimed material to 40°C
- Mix with water, emulsion and additive
- Place 4.75 kg of mixture in the compaction mold with diameter of 150 mm
- Compact mixture using 40 gyrations
- Cure at room temperature for at least ten days
- Cut each core into two 38 mm thick samples
- Use epoxy to fasten buttons onto samples for extensometers

Lab Testing--Tests Performed

- Indirect Tensile (IDT) Creep Stiffness
  - Following AASHTO Designation T322-07
- IDT Strength
  - Following AASHTO Designation T322-07
- Dynamic Modulus (|E*|) in IDT Mode
  - Following Kim, Y., Seo, Y., King, M., & Momen, M. (2004). Dynamic Modulus Testing of Asphalt Concrete in Indirect Tension Mode. *Transportation Research Record*, No. 1891, 163-173

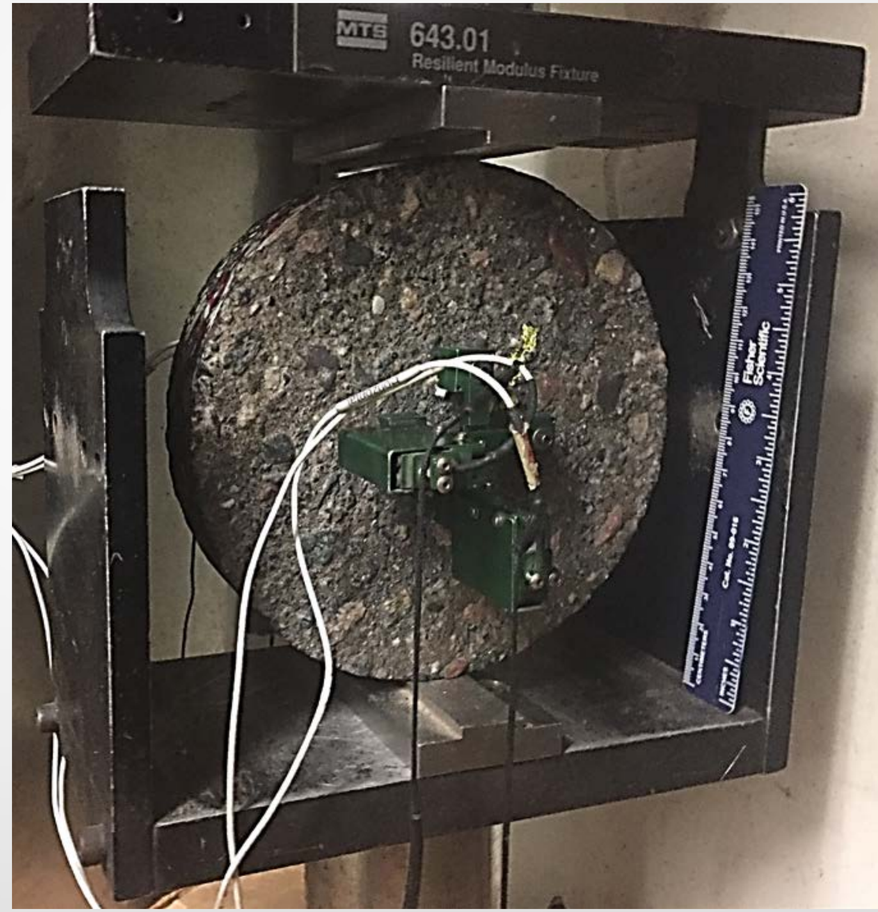
Lab Testing--IDT Creep Stiffness and Tensile Strength

Creep Stiffness
- Loaded diametrically
- Constant load of 0.8 kN/sec
- Samples were tested at -12°C, 0°C, and 12°C

Tensile Strength
- Constant vertical deformation rate
- Increased load to failure

Lab Testing--Dynamic Modulus

Traditional Mode

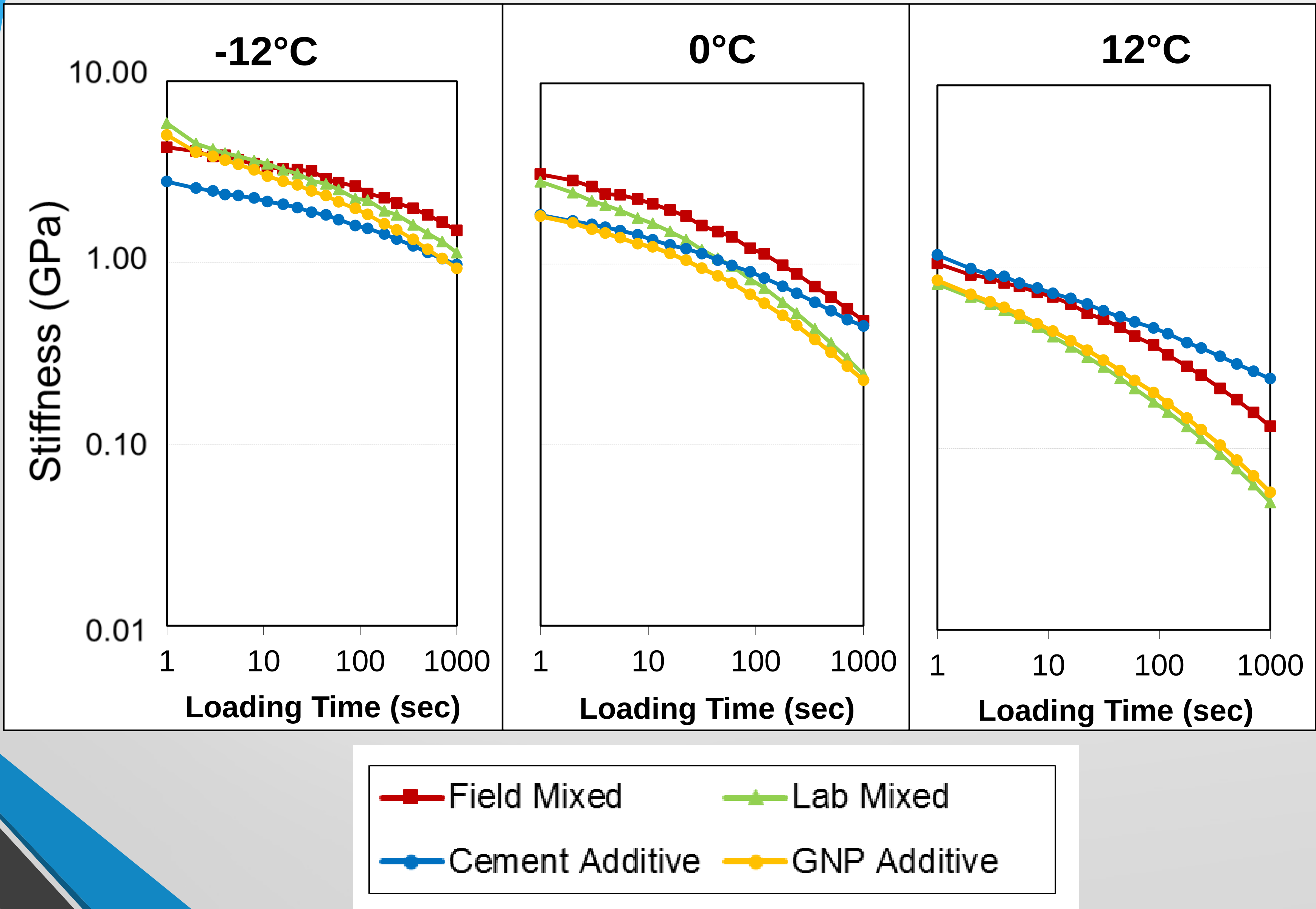


IDT Mode

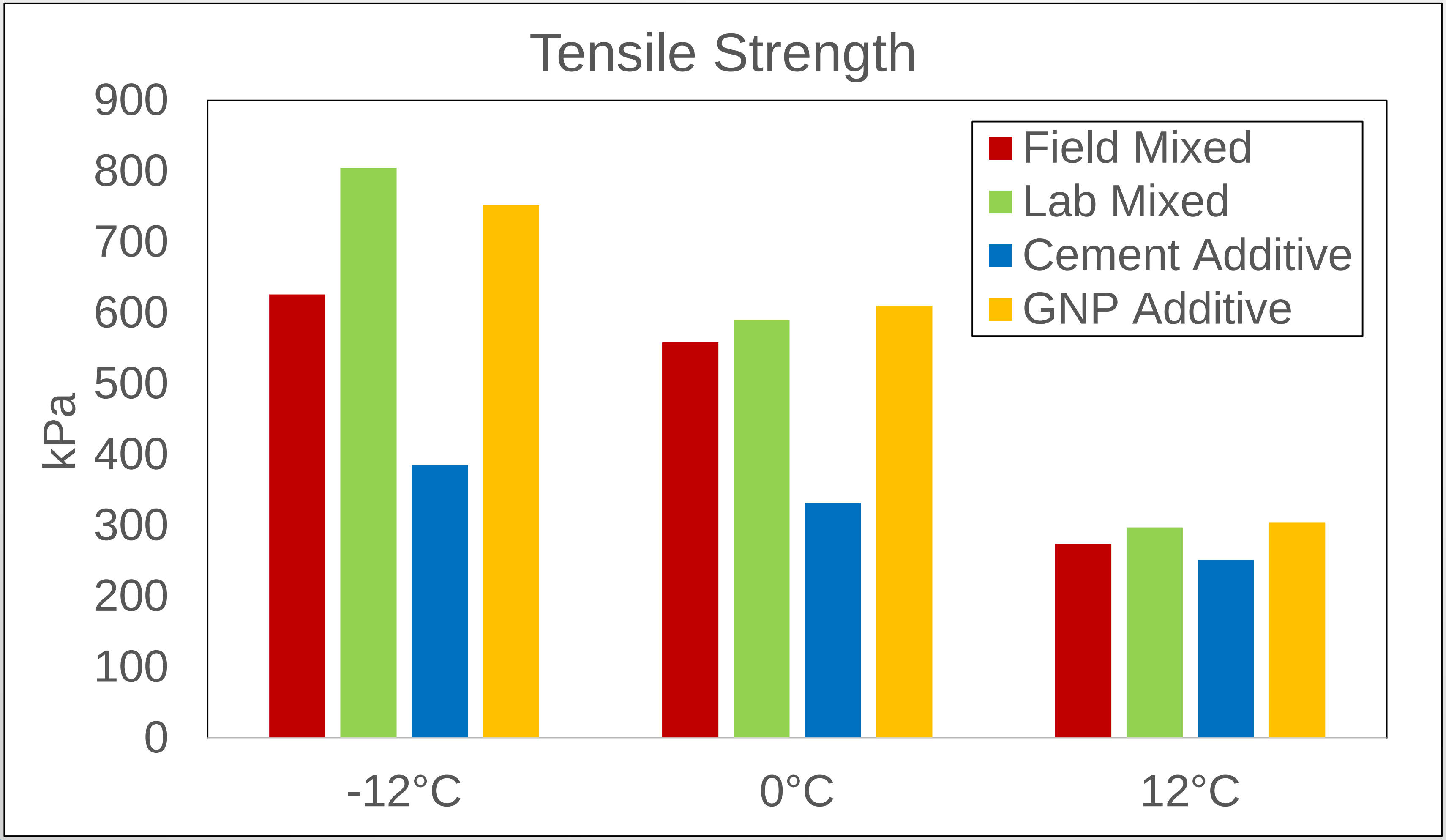
Lab Testing--Dynamic Modulus

- Frequency sweeps at eight frequencies ranging from 25 Hz to 0.01 Hz
- Performed at 3 temperatures: -12°C, 0°C, and 12°C.
- |E*| were calculated for each of the 24 temperature and frequency combinations
- Average |E*| values were calculated from three replicates, which were used to construct master curves for all four materials

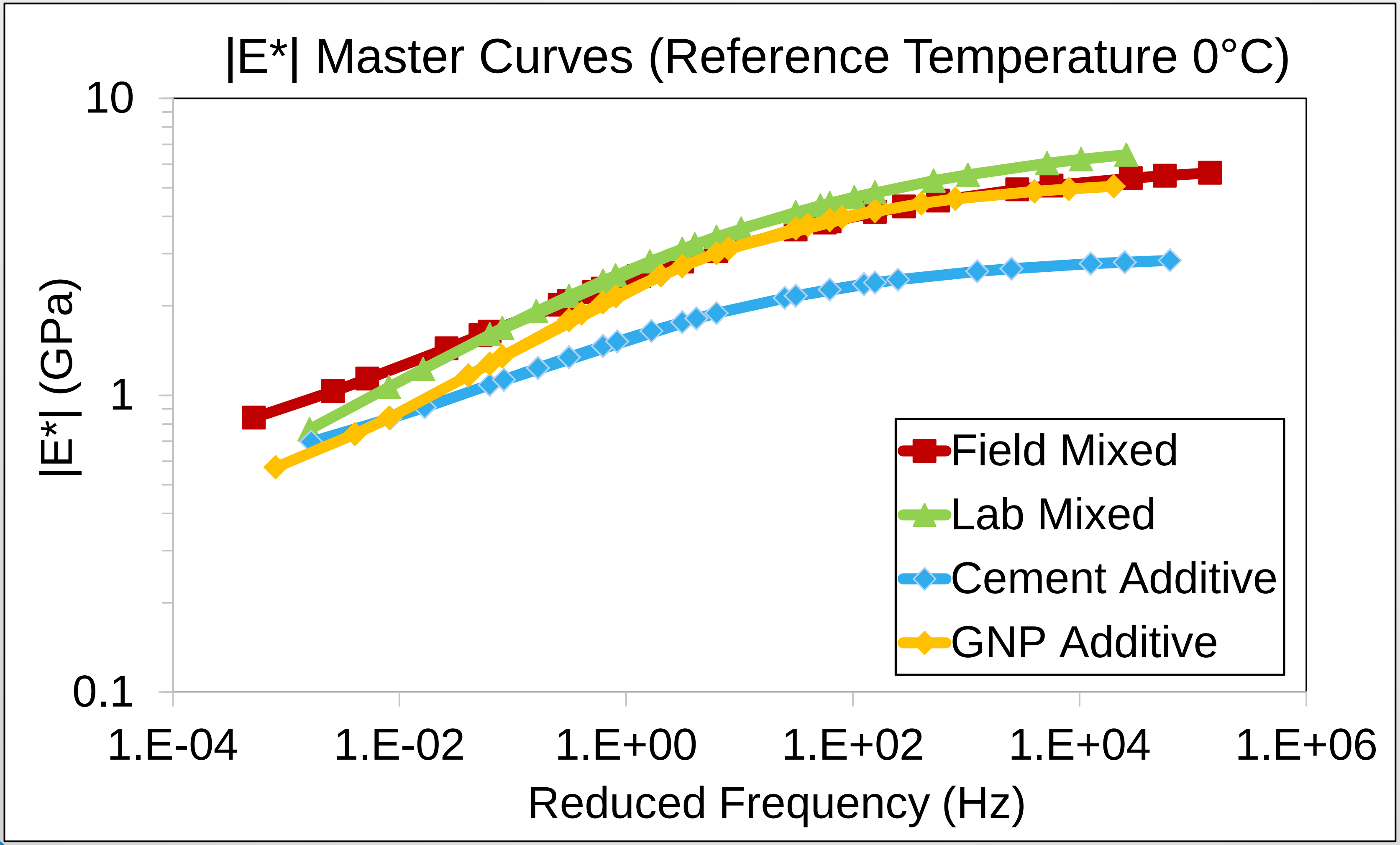
Results--Creep Stiffness



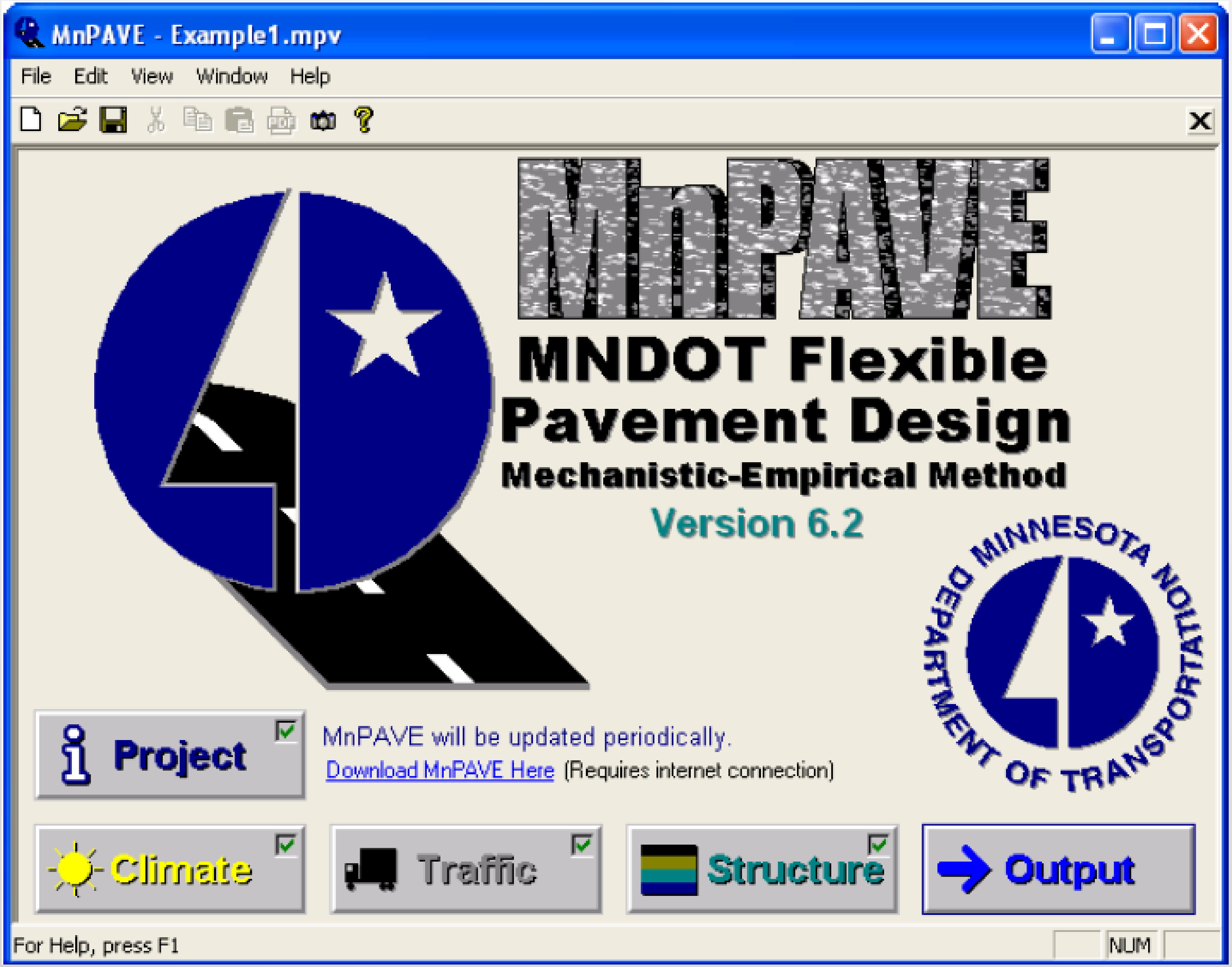
Results--Tensile Strength



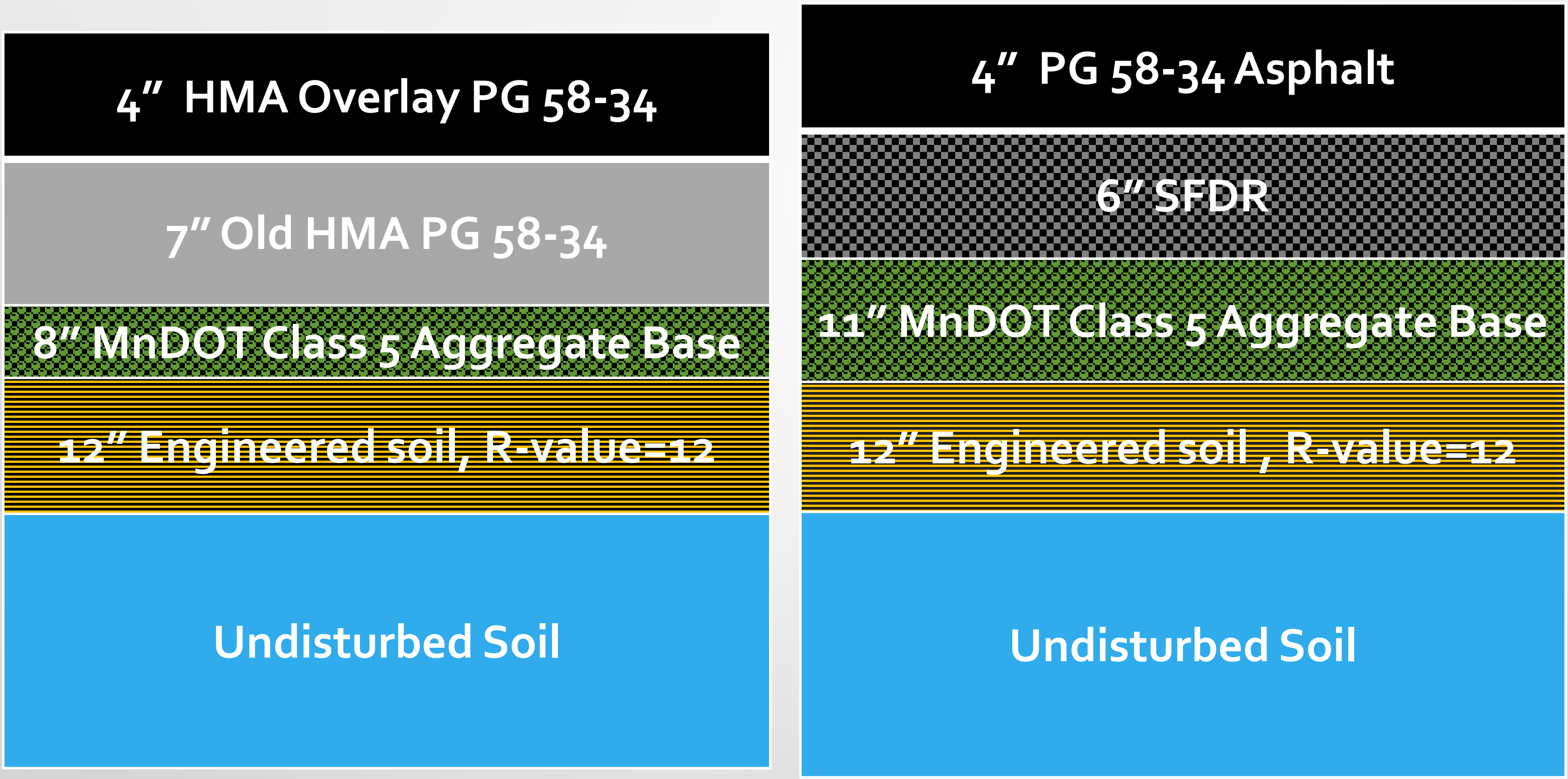
Results--Dynamic Modulus



MnPAVE Analysis



MnPAVE Analysis—Input



Control pavement structure-Mill and Overlay

FDR pavement structure

MnPAVE Analysis--Input

	Fall	Winter	Early Spring	Late Spring	Summer
Temperature (°F)	48	24	39	59	84
Days	92	90	14	56	113

|E*|	Fall	Winter	Early Spring	Late Spring	Summer
	(ksi)	(ksi)	(ksi)	(ksi)	(ksi)
Field Mixed	303	240	417	196	88
Lab Mixed	351	288	457	241	172
Cement Additive	194	158	256	133	74
GNP Additive	287	220	403	175	70

Traffic was input as 1.995 million lifetime ESALs with a 1.82% simple annual growth rate for a 20 year design period.

MnPAVE Analysis--Results

Material Type	Fatigue Design Life (years)	Rutting Design Life (years)	Quick Reliability Fatigue (%)	Quick Reliability Rutting (%)	Monte Carlo Fatigue Reliability (%)	Monte Carlo Rutting Reliability (%)
Control	>50	18	100	82	99.3	86.8
Field Mixed	>50	32	100	95	100	98.9
Lab Mixed	>50	38	100	97	100	99.7
Cement Additive	>50	29	100	95	100	98
GNP Additive	>50	29	100	95	100	97.6

- Rutting design life is based on a half inch limit.
- The design life calculation is limited to a maximum of 50 years.
- The reliability level is the probability that the pavement will survive (for example, have less than a half inch of rutting)

Cost Estimate-Initial Costs

Mill and Overlay	Depth (in)	Width (ft)	Quantity (mile)	Unit	Unit Price	Cost (mile)
MILL BITUMINOUS SURFACE (2.0")	2	40	23466.7	SY	$1.01	$23,679
TYPE SP 12.5 WEARING COURSE MIXTURE	2	24	1591.0	TON	$56.99	$90,678
TYPE SP 12.5 WEARING COURSE MIXTURE	1.5	40	1988.8	TON	$56.99	$113,348
AGGREGATE SURFACING CLASS 1	2	3	178.2	TON	$25.00	$4,455

FDR-stabilized with emulsion	Depth (in)	Width (ft)	Quantity (mile)	Unit	Unit Price	Cost (mile)
MILL BITUMINOUS SURFACE (2.0")	2	40	23466.7	SY	$1.01	$23,679
Stabilized Full Depth Reclamation (SFDR)	8	24	112640.0	SY-in	$0.88	$98,851
TYPE SP 12.5 NON WEARING COURSE MIXTURE	2	24	1591.0	TON	$53.92	$85,784
ULTRATHIN BONDED WEARING COURSE	5/8	24	14080.0	SY	$6.05	$85,157
TYPE SP 12.5 WEARING COURSE MIXTURE	2	16	1060.7	TON	$63.65	$67,510
AGGREGATE SURFACING CLASS 1	2	3	178.2	TON	$25.00	$4,455

Rehabilitation Method	Initial Costs
Mill and Overlay	$232,161
FDR with emulsion	$365,438
FDR with Cement Additive	$368,524
FDR with GNP Additive	$399,890

Cost Estimate--Maintenance Schedule

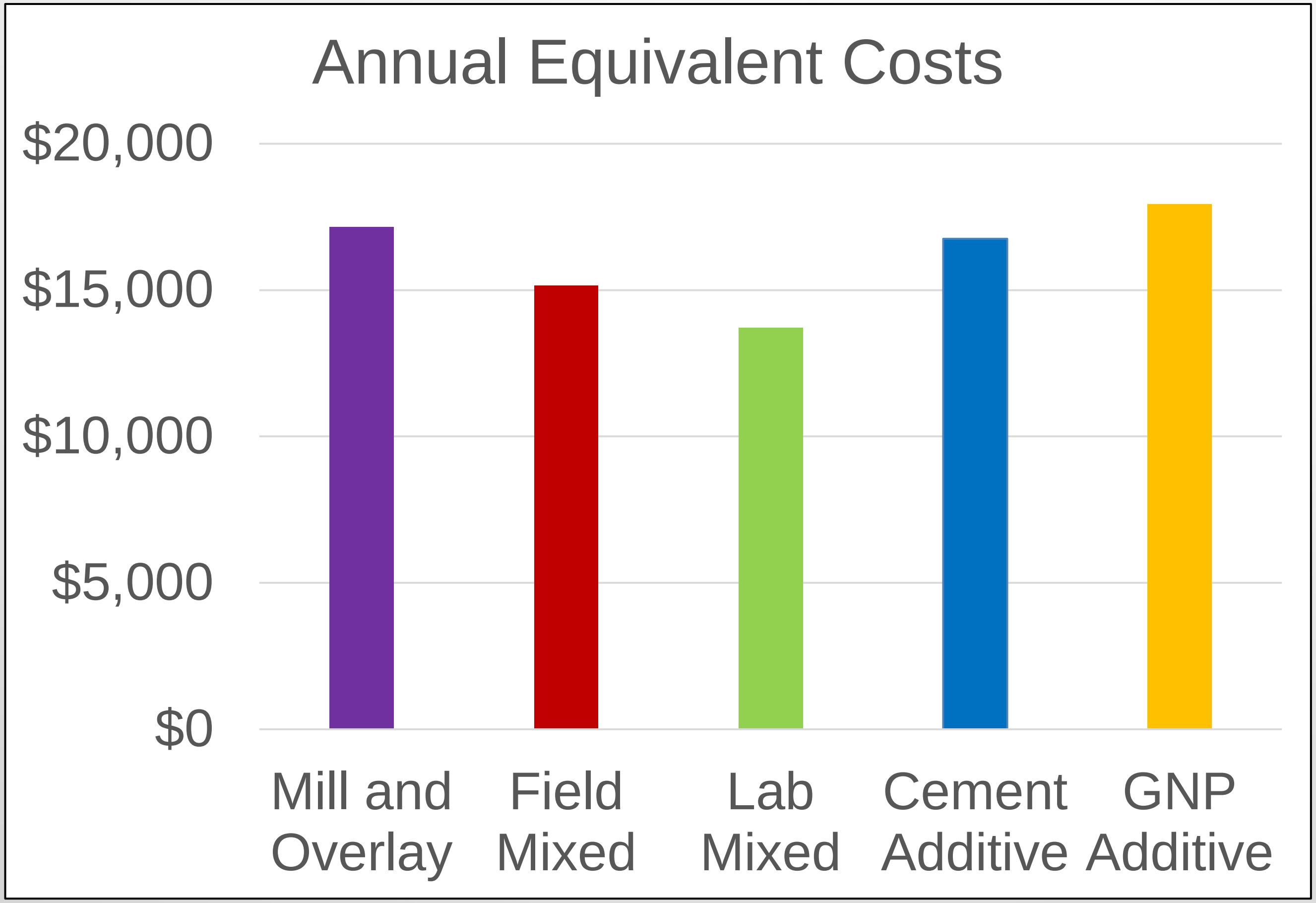
Year	Activity	Cost	Year	Activity	Cost
0	Mill and Overlay	$232,161	21		
1			22		
2			23		
3	Crack Treatment	$2,534	24	Seal	$11,520
4			25		
5			26		
6			27		
7	Seal	$11,520	28		
8			29		
9			30		
10			31		
11			32		
12			33	ML Overlay 4"	$259,860
13			34		
14			35	Remaining Life	-$225,212
15					
16					
17	ML Overlay 3.5"	$233,196			
18					
19					
20	Crack Treatment	$2,534			

Mill and Overlay

Year	Activity	Cost	Year	Activity	Cost
0	6" FDR	$365,438	21		
1			22		
2			23		
3			24	Seal	$11,520
4			25		
5			26		
6			27		
7			28		
8			29		
9			30		
10			31		
11			32	ML Overlay 4"	$259,860
12			33		
13			34		
14			35	Remaining Life	-$246,630
15					
16					
17					
18					
19					
20	Crack Treatment	$2,534			

FDR with emulsion

Cost Estimate-Annual Equivalent Costs



Conclusions

- Preliminary results indicate that these materials used in the FDR process represent viable solutions for extending the life of pavement structures.
- For a 35-year analysis, the FDR alternative provides a more effective way of rehabilitating pavement than a traditional mill and overlay
- If this analysis included user costs, the FDR scenario would be even more attractive since the mill and overlay needs to be rehabilitated after 18 years.