STRUCTURAL PAVEMENT DESIGN

Using Recycled In-place Pavement Layers
TxDOT Perspective

Outline

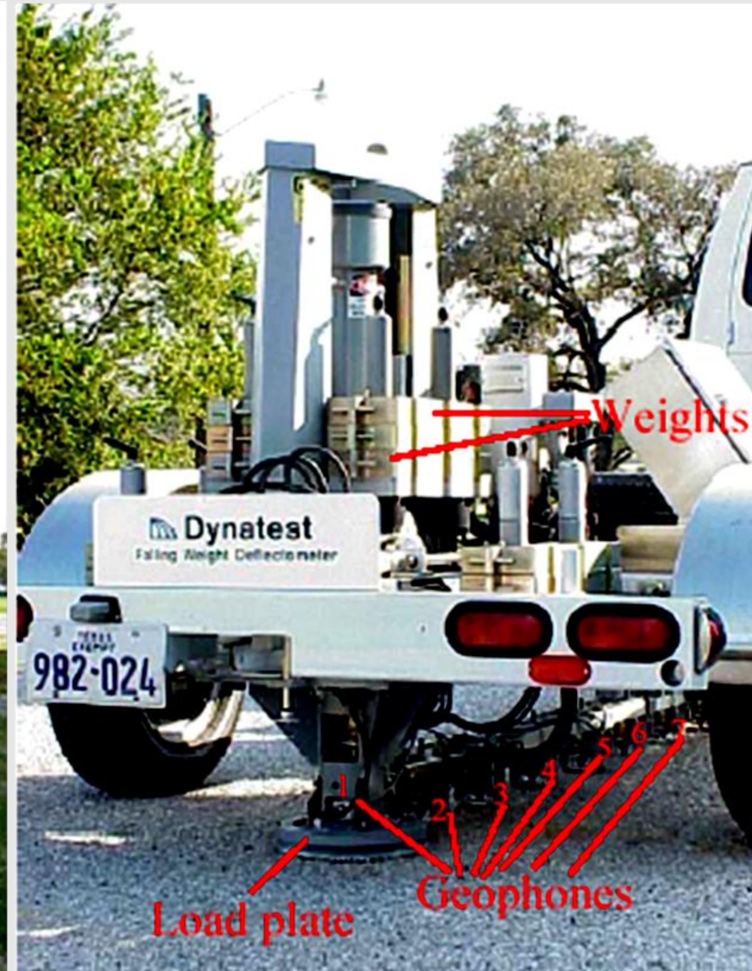
Basic Design Concepts - 1

- TxDOT uses a rudimentary mechanistic-empirical design procedure where materials are characterized by their modulus and Poisson's ratio at a design temperature of 77F.
  - Current version of design software is FPS 21
  - Traffic Loading in terms of cumulative 18-kip ESALs
  - No environmental inputs
  - Performance equation tied to deterioration in SI, initial deflection index and cumulative traffic loading.

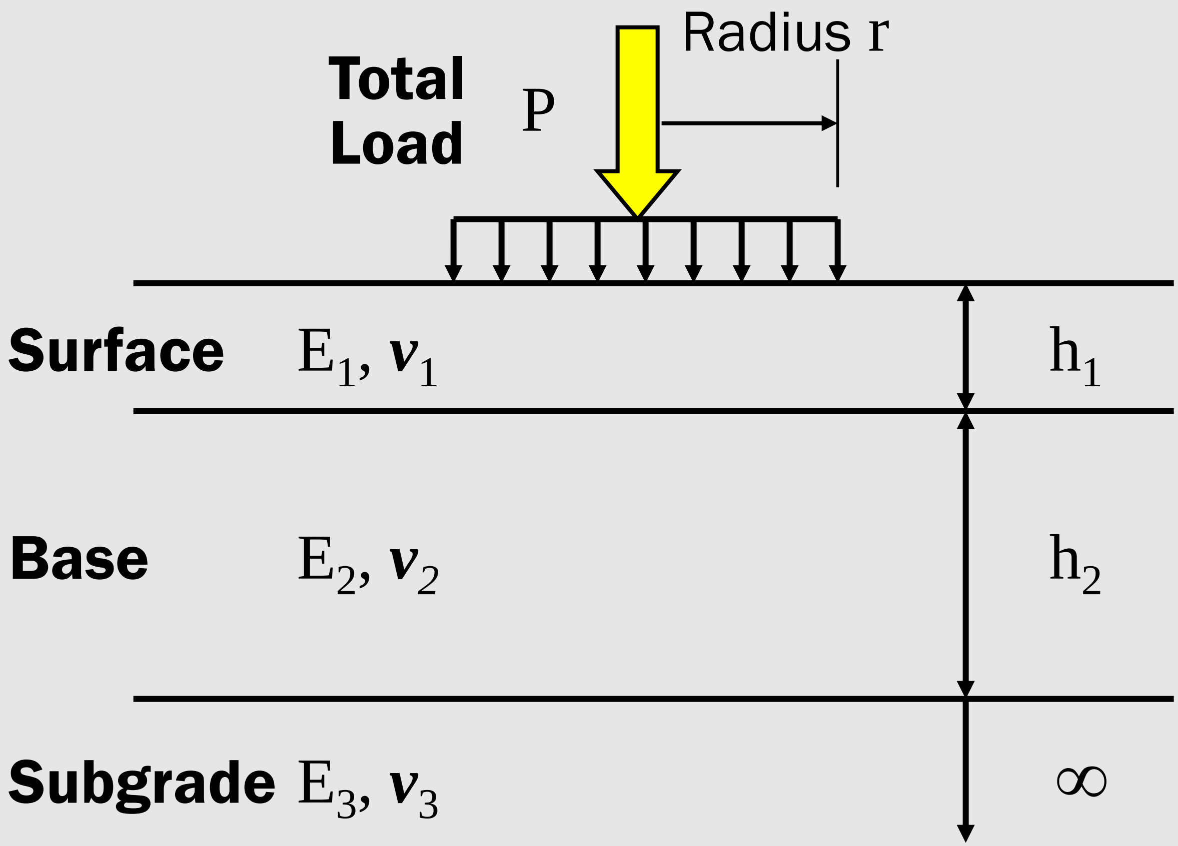
Basic Design Concepts - 2

- The layer modulus is preferably acquired by back-calculation using measured deflections.
  - 9,000-lb dynamic load is imparted to the pavement surface to simulate truck wheel load (one-half of a standard 18kip axle)
  - MODULUS 6.1 is used to perform back-calculation
  - Average pavement layer thicknesses must be measured/assumed.

The Falling Weight Deflectometer (FWD)



Pavement Modeling (Elastic Layer Theory)



Evaluate Existing Material Properties

- Other Non-destructive tests
  - GPR
  - DCP
- Field Samples:
  - Coring
  - Auguring/Spot Milling
  - Lab Tests (AC content, gradations, stabilization series, mix design)

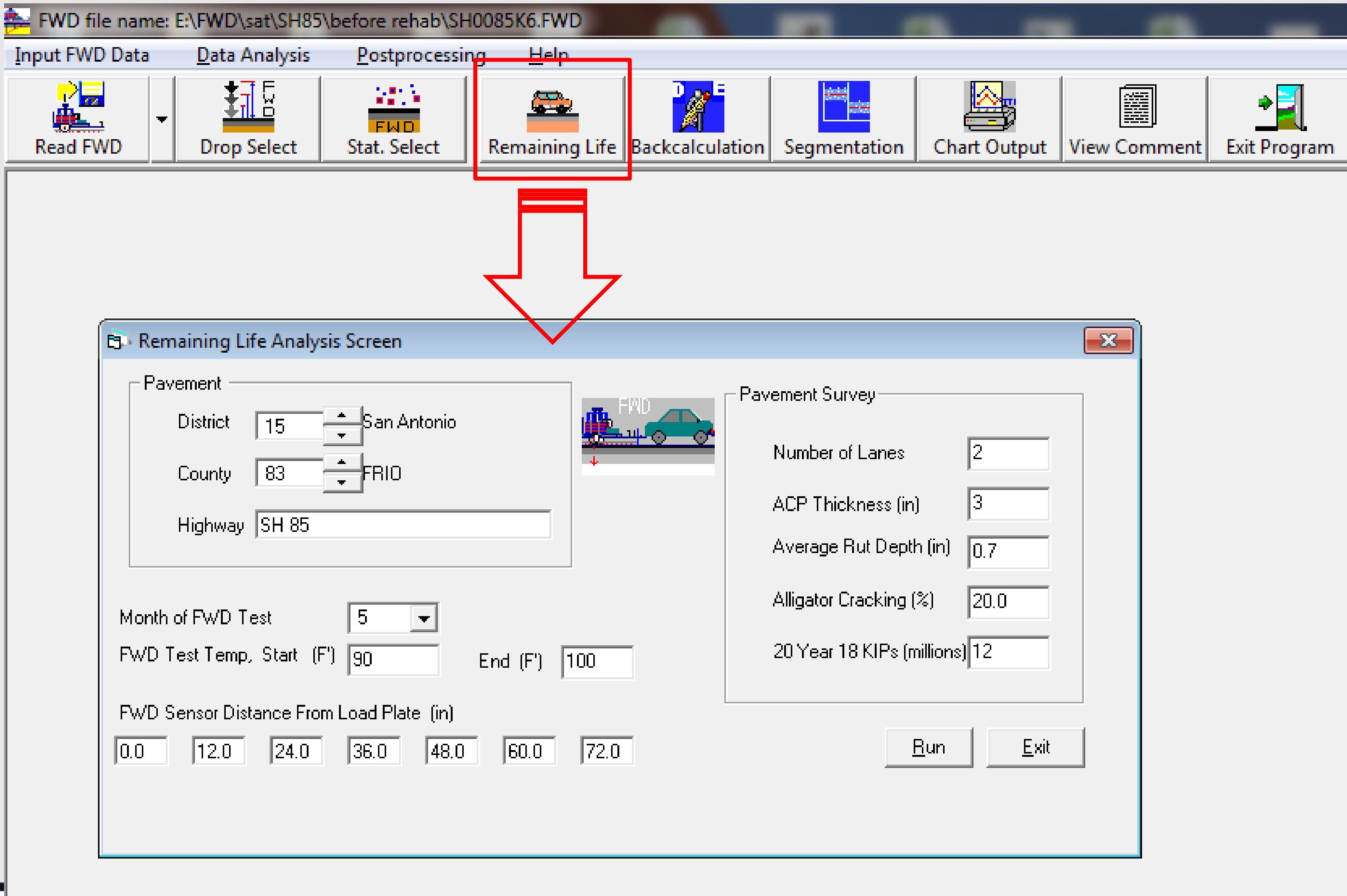
MODULUS 6.1 Structural Evaluation of Existing Pavement

MODULUS

Windows 7 or Above

Version 6.1.0

MODULUS Remaining Life



Remaining Life Utility

- Use non-backcalculated indices to:
  - Make rough estimates of remaining life in terms of fatigue cracking and full-depth rutting
    - Need estimate of current distress
    - 20-year cumulative ESALs
  - Locate problematic layers
- A screening tool to determine level of rehabilitative effort

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****
* R E L A P S *
****

TTI FLEXIBLE PAVEMENT DEFLECTION BASIN ANALYSIS PROGRAM

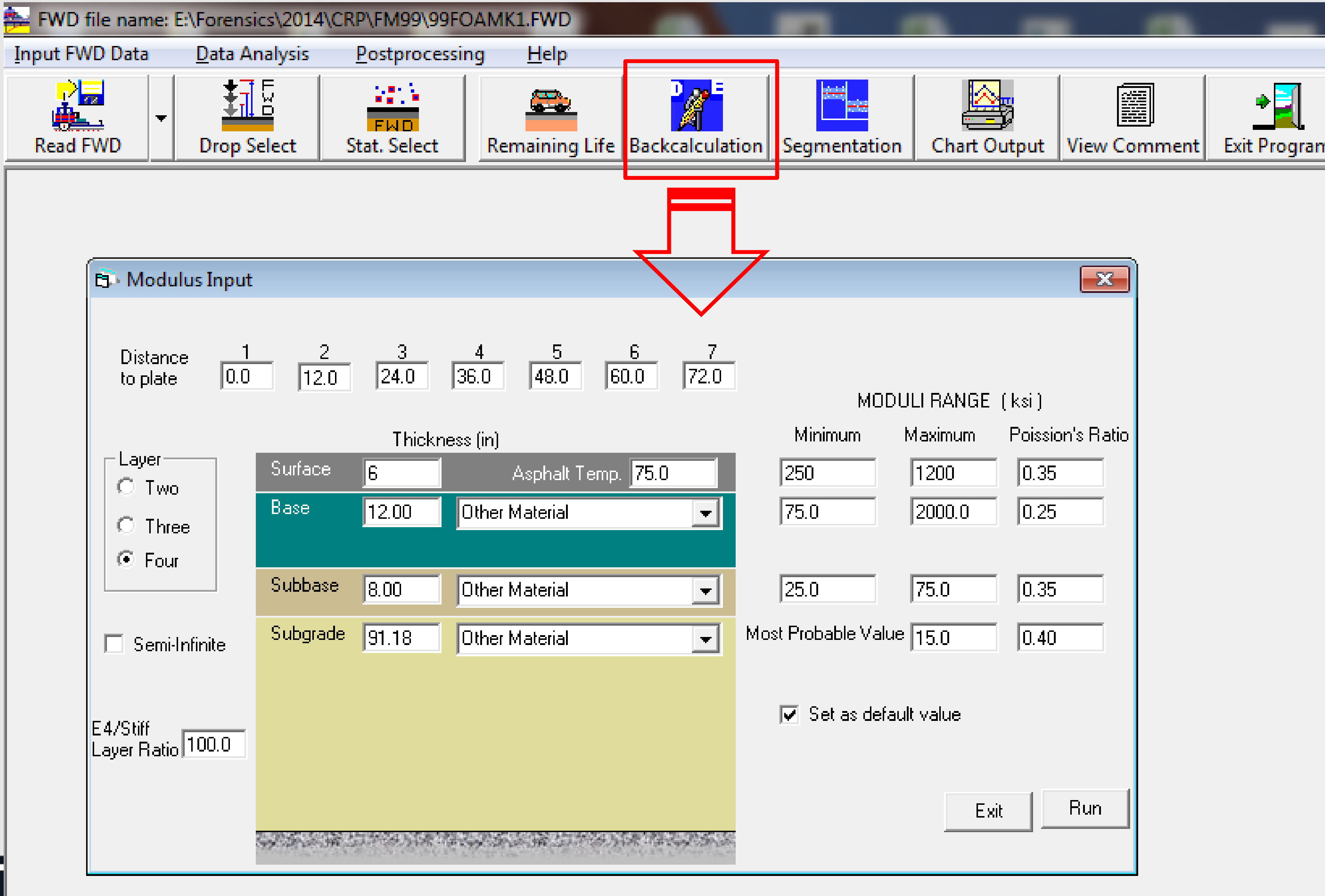
FWD TESTED FILE NAME : E:\FWD\sat\SH85\before

DISTRICT	: 15--San Antonio	ASPH. THICKNESS	: 3.00
COUNTY	: 7--ATASCOSA	MONTH TESTED	: MAY
HIGHWAY	: SH	DESIGN LOAD (lbs)	: 9000
TEMPERATURE ("F) start:	96.3 knd: 100.0	20 year 18 KIP(m)	: 12.00
AVERAGE RUT DEPTH(in)	: 0.7	LANES	: 2
ALLIGATOR CRACKING	: 20.0 %	SENSORS:	0 12 24 36 48 60 72

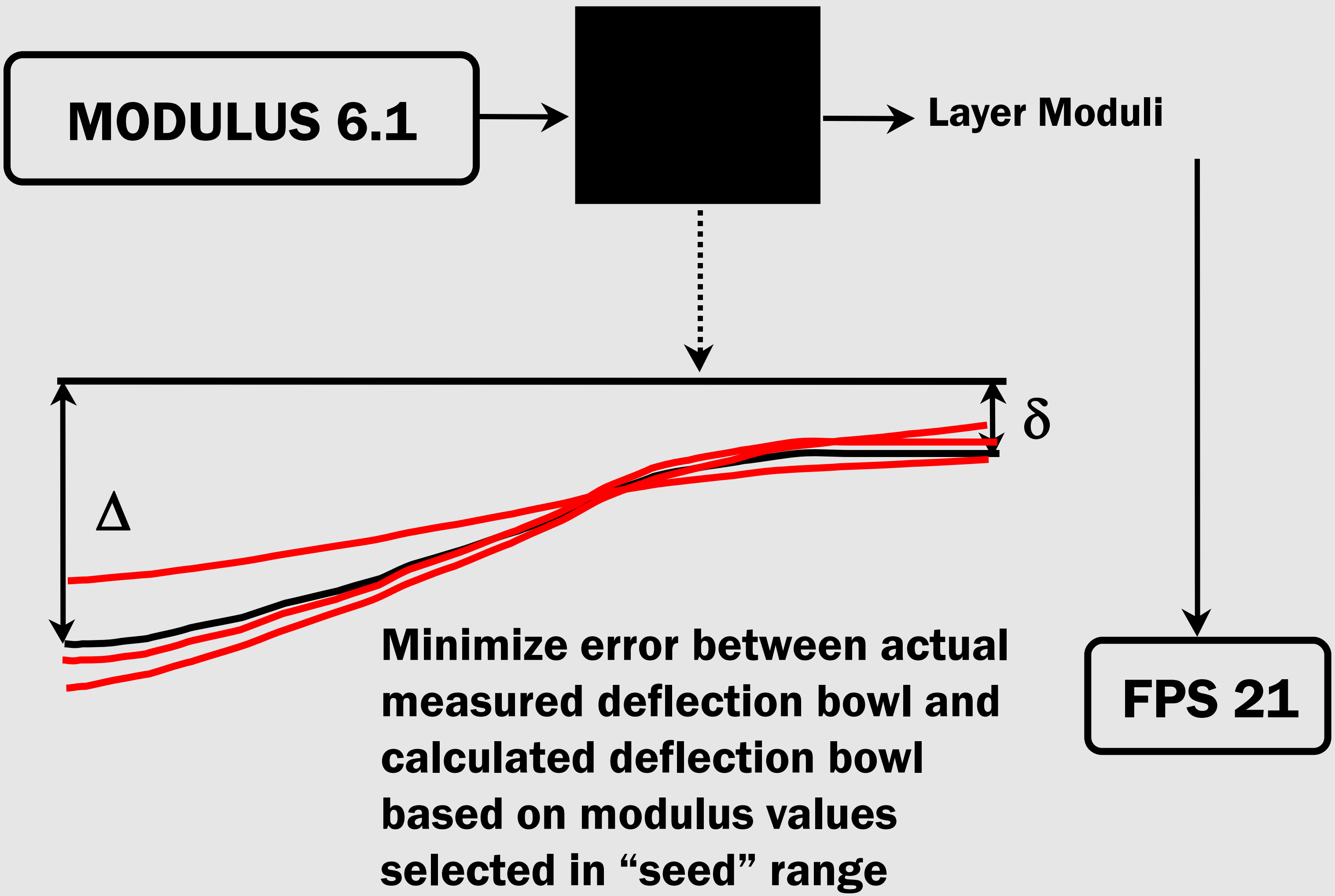
STATION	** NORMALIZED DEFLECTION (mils) ** R1	R2	R3	R4	R7	ASPH TEMP DEF F	DESIGN SCI MILS	LAYER STRENGTHS UPR	LWR	SGR	REMAINING LIFE (yrs) RUT	CRK
3.101	53.38	24.66	9.01	4.75	1.80	96.3	22.00	VP	VP	PR	0-2	0-2
3.200	55.17	28.53	10.34	5.70	2.04	96.5	19.86	PR	VP	PR	0-2	0-2
3.300	57.84	30.14	12.02	6.31	2.20	96.7	20.56	VP	VP	VP	0-2	0-2
3.400	77.57	36.92	12.75	6.36	2.02	96.9	30.75	VP	VP	PR	0-2	0-2
3.500	28.70	12.71	4.94	2.28	1.03	97.1	12.23	MD	MD	GD	0-2	0-2
3.601	18.25	9.65	4.49	2.48	1.13	97.3	6.31	GD	GD	GD	0-2	2-5
3.701	58.13	28.73	11.88	6.09	2.72	97.5	21.89	VP	VP	VP	0-2	0-2
3.819	65.55	30.81	13.61	7.39	2.69	97.6	26.12	VP	VP	VP	0-2	0-2
3.901	61.31	31.70	13.63	7.80	3.04	97.8	21.70	VP	VP	VP	0-2	0-2
4.000	52.19	26.68	12.31	7.09	2.62	98.0	18.71	PR	VP	VP	0-2	0-2
4.100	41.24	25.34	13.19	7.85	2.86	98.2	10.81	MD	VP	VP	0-2	0-2
4.200	66.25	35.34	14.00	7.01	2.43	98.4	22.26	VP	VP	VP	0-2	0-2
4.300	59.86	30.93	12.83	7.00	2.80	98.6	20.99	VP	VP	VP	0-2	0-2
4.402	42.75	21.89	9.93	5.28	1.96	98.8	15.14	PR	VP	PR	0-2	0-2
4.500	74.47	28.63	9.05	4.60	1.85	99.0	35.04	VP	VP	PR	0-2	0-2
4.600	45.98	20.72	6.16	3.25	1.47	99.2	18.80	PR	VP	MD	0-2	0-2
4.700	23.80	10.44	3.43	1.82	0.85	99.4	9.96	GD	MD	VG	0-2	0-2
4.805	48.71	23.47	9.72	5.36	2.07	99.6	18.42	PR	VP	PR	0-2	0-2
4.900	47.29	23.56	9.28	4.79	1.77	99.8	17.12	PR	VP	MD	0-2	0-2
5.024	34.50	13.55	4.95	2.86	1.06	100.0	15.80	PR	MD	GD	0-2	0-2
MEAN:	50.65	24.72	9.88	5.30	2.02		19.22	PR	VP	PR		
STD DEV:	15.89	7.92	3.42	1.91	0.66		6.78					
COF VAR:	31.36	32.05	34.65	36.05	32.86		35.25					

* 0~2:Failed 2~5:Problem 5~10:OK for Now 10+:Good

MODULUS Backcalculation



Backcalculation Process



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TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.1)

District:
County :
Highway/Road: 16149 fm0099

	Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
Pavement:	6.00	250,000	1,200,000	H1: v = 0.35
Base:	12.00	75,000	2,000,000	H2: v = 0.25
Subbase:	8.00	25,000	75,000	H3: v = 0.35
Subgrade:	91.18(by DB)	15,000		H4: v = 0.40

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
506.000	10,000	24.89	11.27	6.08	4.04	2.94	2.37	2.11	250.0	75.0	25.0	7.6	20.71	192.8	*
600.000	10,625	11.11	8.30	5.91	4.36	3.06	2.42	1.78	744.6	75.0	46.6	8.6	1.72	125.8	*
701.000	10,811	10.00	7.57	5.68	4.34	3.29	2.56	1.96	850.5	97.6	75.0	7.8	0.69	117.2	*
801.000	10,504	8.71	7.16	5.43	4.19	3.30	2.64	2.14	1200.0	139.4	50.0	7.5	1.90	169.5	*
903.000	10,384	10.81	8.15	5.63	4.35	3.46	2.46	2.03	709.3	75.0	75.0	7.6	1.90	95.9	*
1003.000	10,866	9.07	6.83	5.13	3.95	3.12	2.51	2.07	744.3	146.7	75.0	8.4	1.90	205.3	*
1104.000	10,745	9.51	7.49	5.77	4.37	3.31	2.54	2.02	1153.5	110.0	45.4	8.0	0.74	150.3	
1206.000	10,734	8.30	6.95	5.50	4.27	3.28	2.50	1.89	1200.0	129.6	71.0	7.6	1.73	109.6	*
1310.000	10,877	6.76	5.94	4.49	3.87	2.98	2.36	1.77	1200.0	362.0	31.4	8.4	2.44	87.7	*
1404.000	10,471	9.28	6.93	5.43	4.07	3.06	2.38	2.20	650.2	167.9	36.3	8.7	1.38	180.5	
1504.000	10,570	8.02	6.71	5.28	3.99	3.16	2.37	1.52	1200.0	144.9	64.8	7.9	1.92	79.6	*
1602.000	10,460	11.52	7.43	4.66	3.07	2.15	1.69	1.23	337.7	75.0	42.2	13.1	4.21	124.7	*
1724.000	10,263	12.43	6.91	4.48	2.87	1.95	1.43	1.17	250.0	75.0	35.1	14.8	3.32	109.1	*
1816.000	10,581	5.50	4.86	3.89	3.10	2.42	1.90	1.53	1200.0	508.5	25.0	10.2	2.44	136.5	*
1923.000	10,669	6.03	5.13	3.91	2.95	2.07	1.58	1.15	1200.0	211.9	41.1	13.3	3.91	111.5	*
2014.000	10,526	7.07	4.84	3.72	2.79	1.98	1.46	1.20	436.7	317.6	28.1	14.8	0.90	107.2	
2101.000	10,723	8.04	5.58	3.88	2.74	1.98	1.43	1.07	783.8	100.4	75.0	14.3	0.64	101.1	*
2202.000	10,230	11.36	6.08	4.01	2.70	1.87	1.35	0.98	250.0	75.0	75.0	15.0	2.17	99.9	*
2302.000	10,811	6.79	5.03	3.85	2.89	2.17	1.68	1.28	1011.6	185.1	75.0	12.4	1.14	106.3	*
2402.000	10,800	7.41	5.37	4.02	2.91	2.14	1.72	1.25	903.4	145.5	75.0	12.5	2.26	178.5	*
2573.000	10,745	5.45	4.03	3.12	2.40	1.77	1.43	0.99	988.7	313.0	75.0	15.0	1.56	154.8	*
2700.000	10,450	9.23	7.19	5.48	4.16	3.15	2.39	1.85	925.4	136.6	33.5	8.5	0.68	124.8	
2801.000	10,329	7.63	5.29	3.73	2.66	1.82	1.30	1.08	654.3	152.2	28.4	16.0	0.79	96.6	
2952.000	10,592	8.09	6.30	4.42	3.16	2.29	1.76	1.40	1200.0	99.5	44.2	12.1	2.27	142.9	*
3099.000	9,803	6.59	4.90	3.55	2.54	1.85	1.36	1.06	1195.9	121.2	56.4	14.0	0.86	108.5	
3252.000	9,858	6.37	5.00	3.76	2.75	1.94	1.44	0.95	1200.0	182.9	25.0	13.7	1.44	79.5	*
3401.000	9,650	13.82	8.06	4.52	2.73	1.78	1.32	1.03	250.0	75.0	25.0	13.6	9.97	91.4	*
Mean:		9.25	6.49	4.64	3.42	2.53	1.94	1.51	840.4	159.2	50.2	11.2	2.80	117.2	
Std. Dev:		3.80	1.52	0.87	0.71	0.61	0.50	0.43	353.1	104.3	20.0	3.0	4.02	29.2	
Var Coeff(%):		41.03	23.45	18.66	20.72	24.28	25.58	28.82	42.0	65.5	39.8	27.3	143.61	24.9	

Backcalculation Limitations

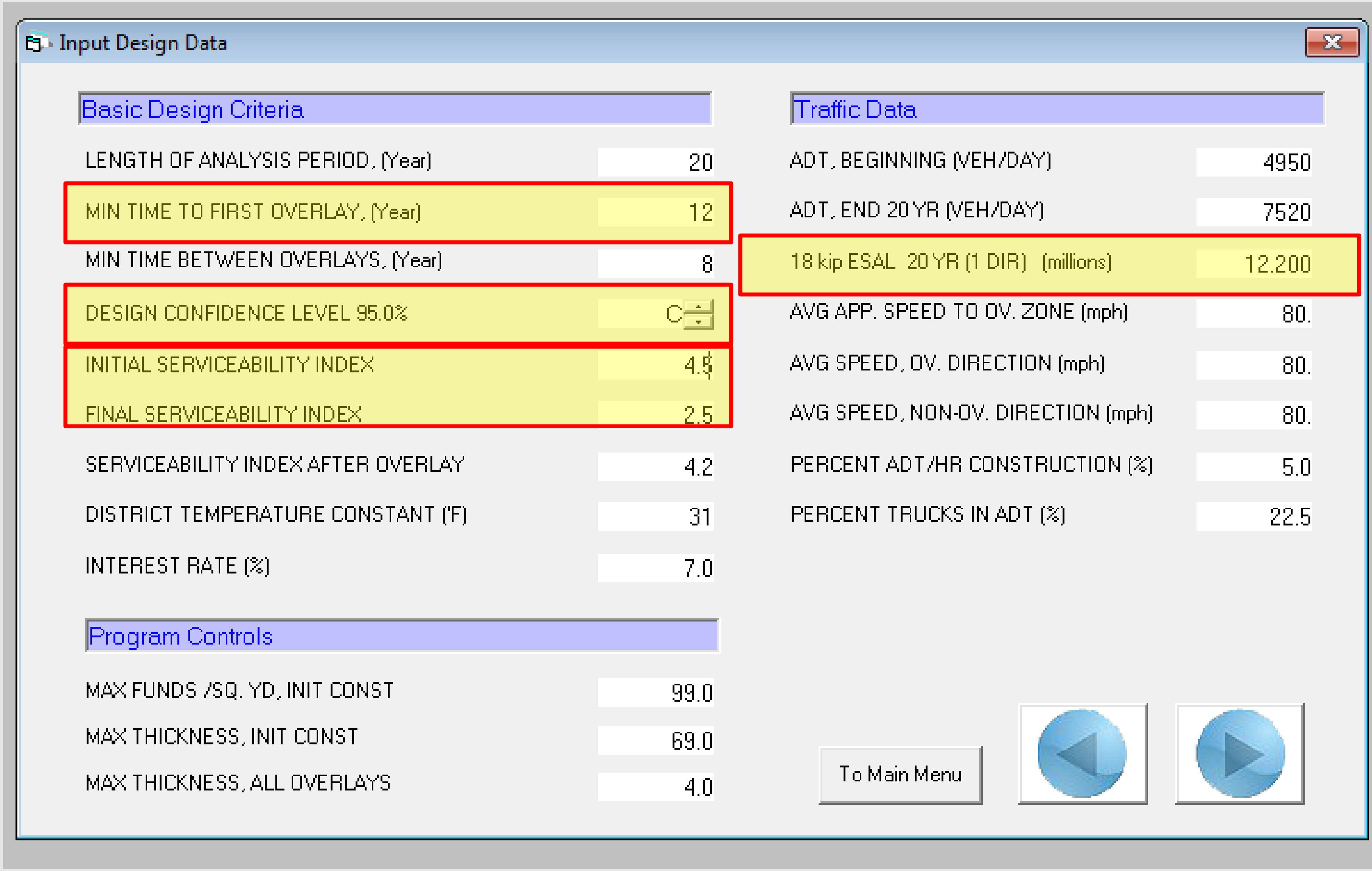
- Layer Thickness at least 3.0-in
- 4-layer maximum limitation
  - Mathematical process: results may not always reflect reality
  - 4-layer solutions are often unreliable (high variability)
- Can not differentiate between similar layers adjacent/bonded together
  - Layer consolidation to determine "composite" modulus

Pavement Design Using FPS 21

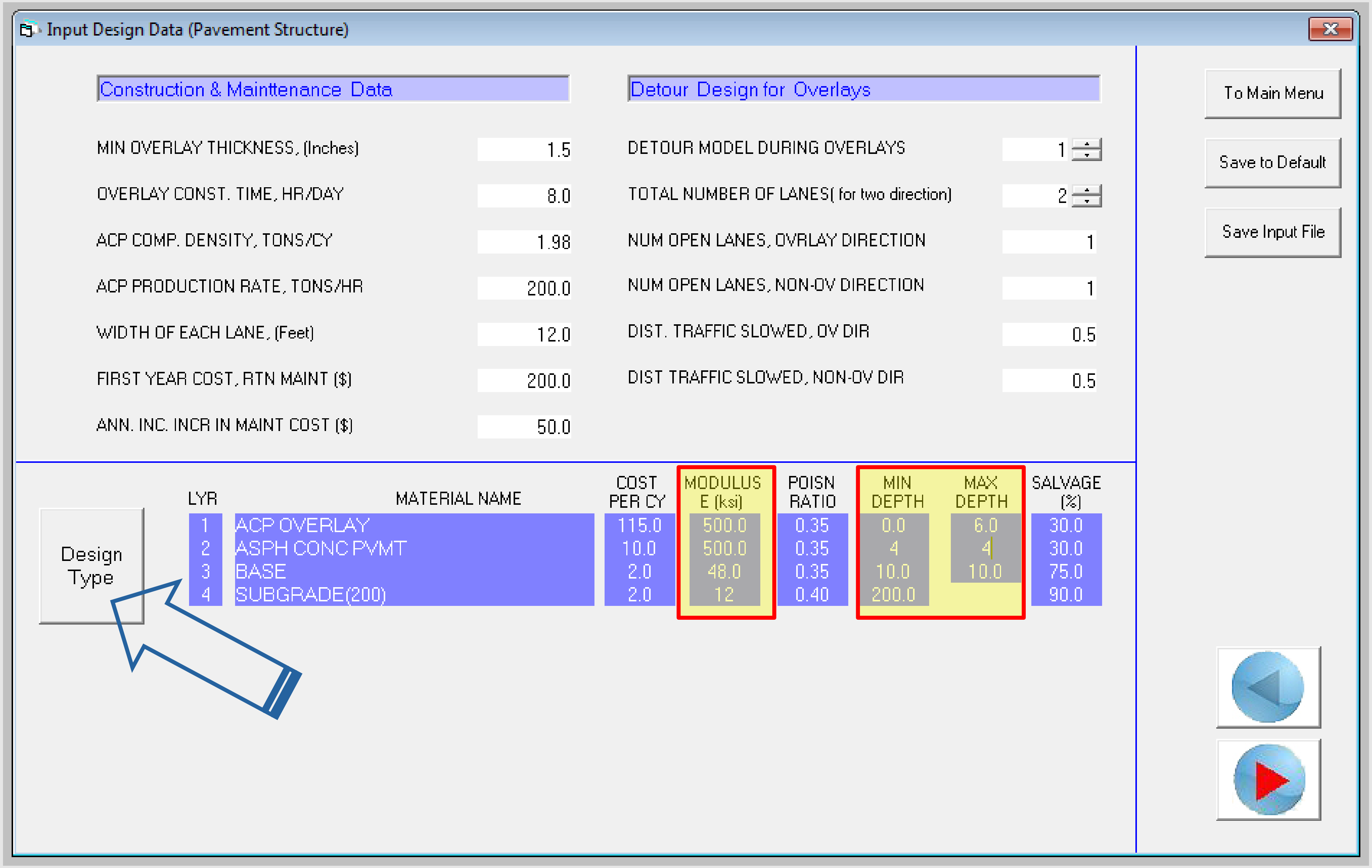
FPS 21 Inputs Affecting Thickness Requirements

- Length of Performance Period
  - Typically use staged construction
- Confidence/Reliability Level
- Change in Serviceability Index
- Cumulative Traffic Loading
- Layer Modulus/Allowable Thickness

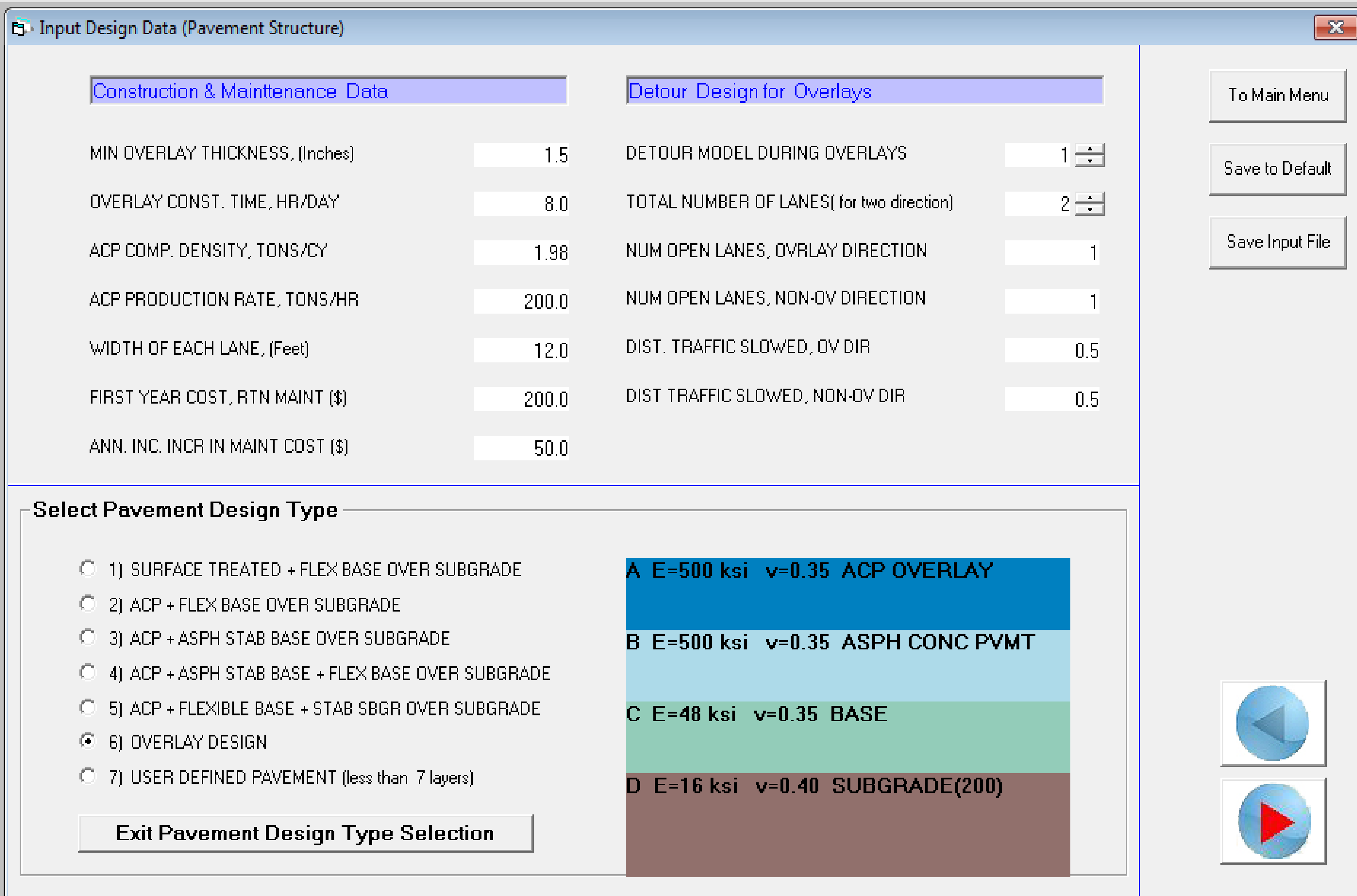
FPS 21 Design Parameters That Affect Thickness



FPS 21 Materials Table and Design Type Selection



FPS 21 Design Types



FPS 21 Post Design Checks

- Modified Texas Triaxial Check
  - Evaluate subgrade shear failure under single heavy wheel load
  - Design parameters are:
    - ATHWLD
    - Subgrade Texas Triaxial Class
- ME Checks for Full-depth Rutting and Fatigue Cracking
  - Various models, but all are very rudimentary
    - Linear Elastic Layer Theory
    - Not material specific
  - All based on # passes 18-kip axle load

The Modified Texas Triaxial Check

Texas Triaxial Design Check for Pavement - 1

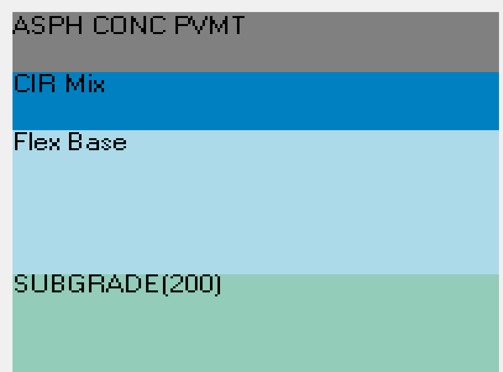
The Heaviest Wheel Loads Daily (ATHWLD)	12000.	(lb)		Triaxial Thickness Required (inches)	25.50
Percentage of Tandem Axles	50.	(%)		The FPS Design Thickness (inches)	18.00
Modified Cohesiometer Value (Cm)	800.	Reference		Allowable Reduction (inches)	8.39
				Modified Triaxial Thickness (inches)	17.11

Input Subgrade Texas Triaxial Class (TTC) 5.42

Design OK !

- Option 1: Input TTC based on TEX-117-E
- (selected) Option 2: Enter soil PI to estimateTTC 27
- Option 3: Select TTC based on predominate soil type

Thick. (in)	Modulus(ksi)	v	Material Name
4.00	500.0	0.35	ASPH CONC PVMT
4.00	160.0	0.35	CIR Mix
10.00	45.0	0.30	Flex Base
120.00	12.0	0.40	SUBGRADE(200)



Print

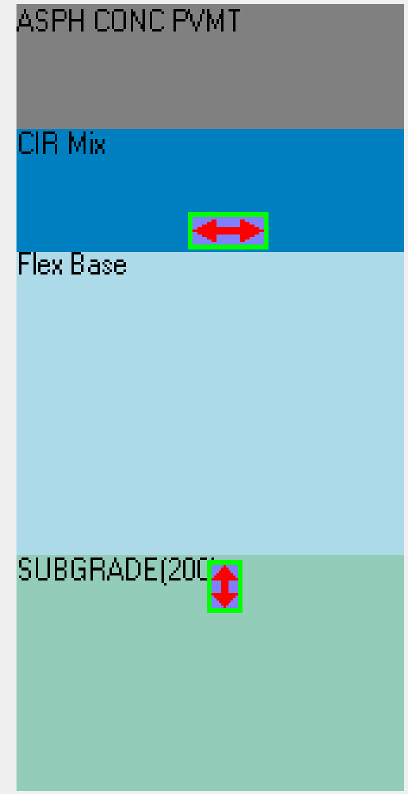
Exit

FPS 21 ME Checks

Mechanistic Design Check for Pavement - 1

Thick. (in)	Modulus(ksi)	v	Material Name
4.00	500.0	0.35	ASPH CONC PVMT
4.00	160.0	0.35	CIR Mix
10.00	45.0	0.30	Flex Base
120.00	12.0	0.40	SUBGRADE(200)

Vary Thickness: 0.50



f1	7.96E-02
f2	3.291
f3	.854
f4	1.37E-09
f5	4.477

Analysis Mode: (•) Design ( ) User Define

$$N_f = f_1(\varepsilon_t)^{-f_2}(E_1)^{-f_3}$$

$$N_d = f_4(\varepsilon_v)^{-f_5}$$

Run

Exit

FPS 21 Design of Pavements Incorporating HIR

- The HIR process would typically be considered a "Pavement Preservation" technique –
  - Not a candidate for "structural design process"
  - However, typical design philosophy should still be used to determine whether the structure has adequate remaining life to consider PP viability.
    - Remaining Life Good or Very Good
    - Uniformity/composition of surface material
  - Use "Structural Overlay" design (Type 6) option and assign a design modulus to HIR layer (500 ksi unless better information available)

FPS Design of Pavements Incorporating CIR

- Design Modulus?
  - Limited experience with product in Texas
  - One job from the early 90's on US 62 (Lubbock District) showed that a temperature corrected (77F) modulus was on the order of 150ksi
  - Uniformity/composition of bituminous material
- Use either a Type 4 Design format:
  - ACP surface/ST
  - CIR layer
  - Flex Base
  - Subgrade
- . . . or Type 7 (User Defined) format.

FPS 21 User Defined Design Format

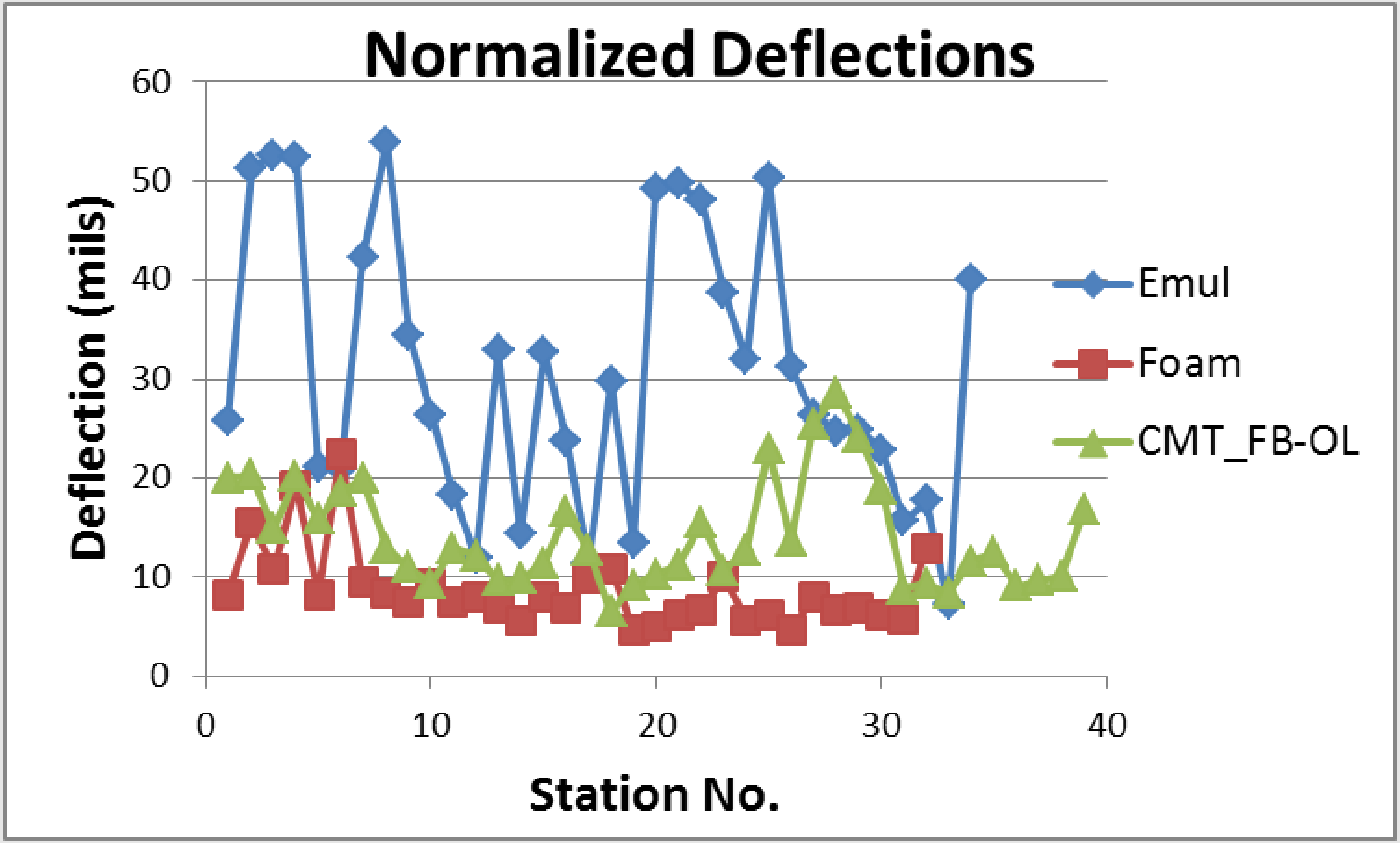
User Define Pavement

No	Material Type	2004 Specificati	Design Modulus	Poisson' Ratio	Layer Type
1	SURFACE TREATMENT	Item 316, 318	200 ksi	0.35	AC Layer
2	DENSE-GRADED HMA Thin	Item 340, 341	500 ksi	0.35	AC Layer
3	DENSE-GRADED HMA Thick	Item 340, 341	650 ksi	0.35	AC Layer
4	PFC	Item 342	300 ksi	0.30	AC Layer
5	PERFORMANCE MIX 3/4SF	Item 344	650 ~ 950 ksi	0.35	AC Layer
6	PERFORMANCE MIX 1in SF	Item 344	650 ~ 950 ksi	0.35	AC Layer
7	STONE-MATRIX ASPHALT	Item 346	650 ~ 850 ksi	0.35	AC Layer
8	LIMEROCK ASPH PVMT	Item 330	200 ~ 350 ksi	0.35	AC Layer
9	HOT-MIX COLD-LAID ACP	Item 334	300 ~ 400 ksi	0.35	AC Layer
10	RICH BOTTOM LAYER	Item 344	400 ~ 600 ksi	0.35	AC Layer
11	FA or LFA STABILIZED	Item 265	50 ~ 150 ksi	0.35	Base Layer
12	ASPHALT TREATED BASE	Item 292	250 ~ 400 ksi	0.35	Base Layer
13	EMULS ASPH TRT BASE	Item 314	50 ~ 100 ksi	0.35	Base Layer
14	FLEXIBLE BASE	Item 247	40 ~ 70 ksi	0.35	Base Layer
15	LIME STABILIZED BASE	Item 260, 263	60 ~ 75 ksi	0.30 ~ 0.35	Base Layer
16	CEMENT STABILIZED BASE	Item 275, 276	80 ~ 150 ksi	0.20 ~ 0.30	Base Layer
17	FA OR LIME-FLY ASH STAB	Item 265	30 ~ 45 ksi	0.30	SubBase Layer
18	LIME(CEMENT) STAB SUBG	Item 260, 275	30 ~ 45 ksi	0.30	SubBase Layer
19	EMULS ASPH TREAT SUBG	Item 314	30 ~ 45 ksi	0.35	SubBase Layer
20	SUBGRADE		16 ksi	0.40 ~ 0.45	Sub-Grade Layer

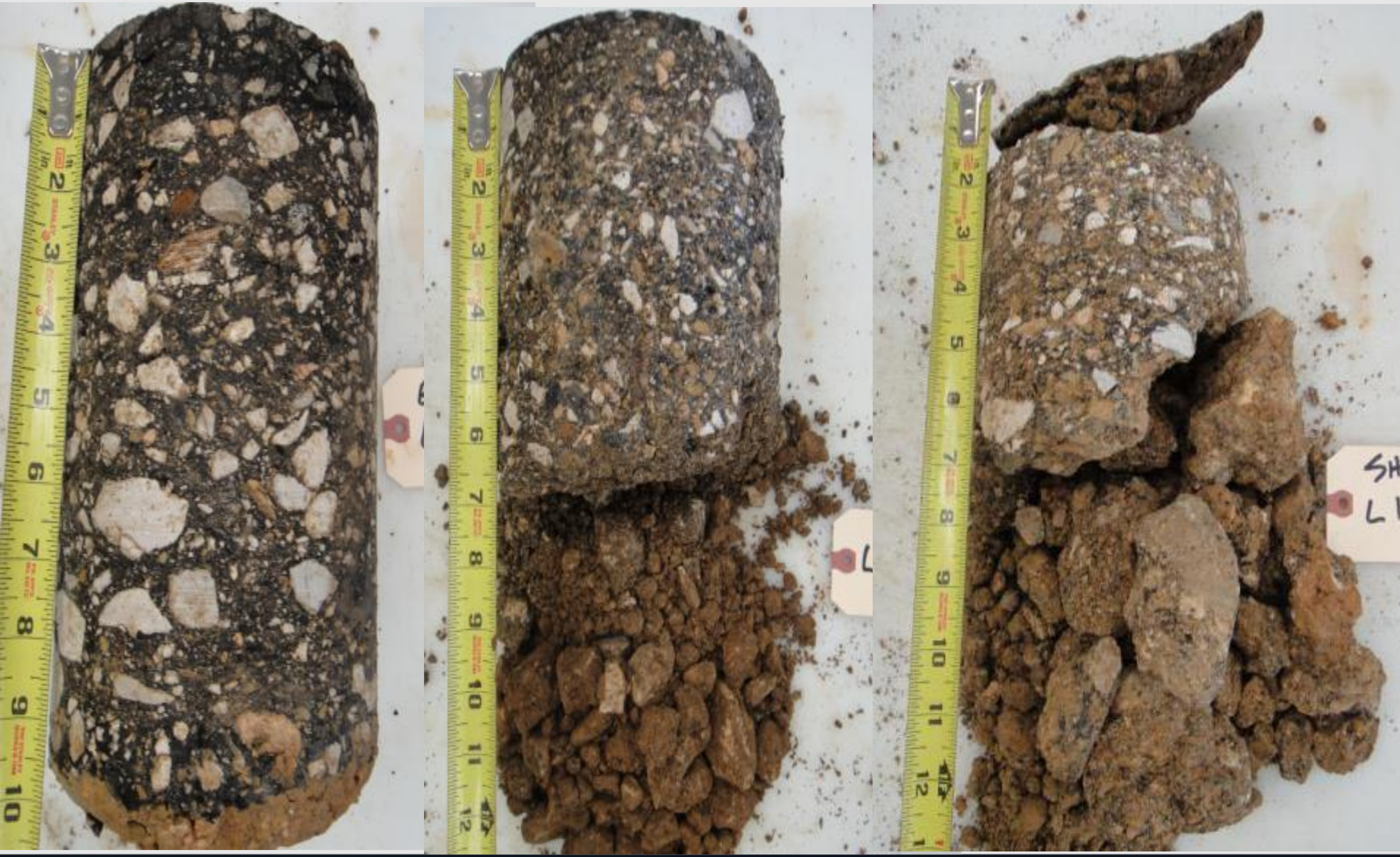
FPS Design of Pavements Incorporating FDR

- Design Modulus?
  - Experience shows highly variable, depending on:
    - Parent material & uniformity
    - Stabilizing Agent
    - Environment
    - Sophistication of Reclaimers
- Use either a Type 3 Design Format
  - ACP surface
  - Reclaimed/Stab. Base
  - Subgrade
- . . . or Type 7 (User Defined), if 4 or more layers involved.

End Product In-place Variability



Stabilization Variability



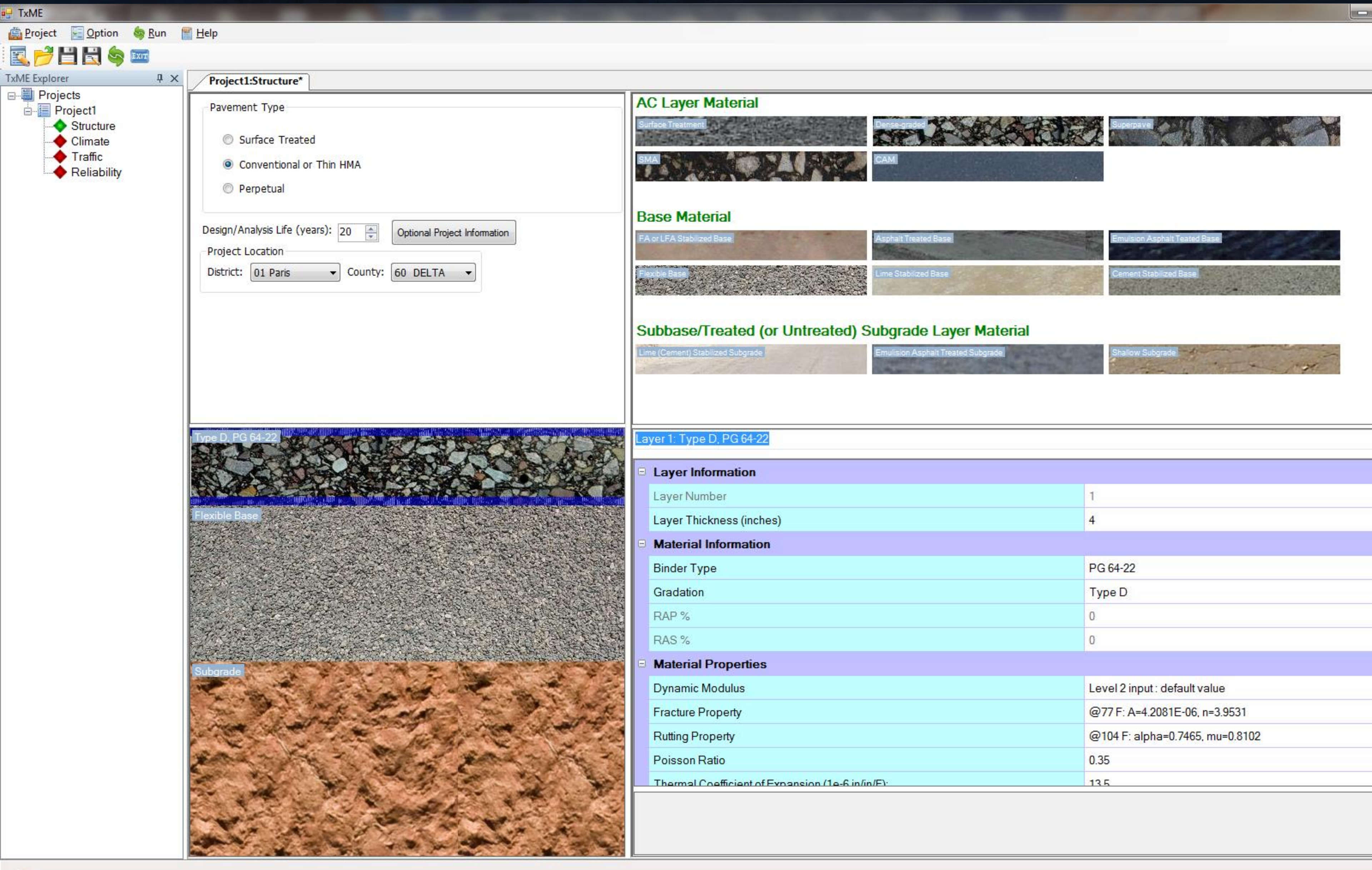
Reclaimers

High Efficiency Reclaimer – Emulsion or Foam

Issues and Gaps in Knowledge

- Better assessment of candidate jobs
- Better uniformity of construction
- Urgent need to move to a more mechanistic design procedure.
  - Need better materials characterization
  - Need to incorporate climate effects
  - Need to account for traffic loading in terms of load spectra
- TxDOT not likely to adopt AASHTO Pavement ME
  - 2006/2007 TxDOT Research Study
- TxDOT Research Program evaluating TxME
  - Hope to have limited implementation project approved in FY 15

TxME


TxME
Project
Option
Run
Help
TxME Explorer
Projects
Project1
Structure
Climate
Traffic
Reliability
Project1:Structure*
Pavement Type
Surface Treated
Conventional or Thin HMA
Perpetual
Design/Analysis Life (years): 20
Optional Project Information
Project Location
District: 01 Paris
County: 60 DELTA
AC Layer Material
Surface Treatment
Dense-graded
Superpave
SMA
CAM
Base Material
FA or LFA Stabilized Base
Asphalt Treated Base
Emulsion Asphalt Treated Base
Flexible Base
Lime Stabilized Base
Cement Stabilized Base
Subbase/Treated (or Untreated) Subgrade Layer Material
Lime (Cement) Stabilized Subgrade
Emulsion Asphalt Treated Subgrade
Shallow Subgrade
Type D, PG 64-22
Flexible Base
Subgrade
Layer 1: Type D, PG 64-22
Layer Information
Layer Number 1
Layer Thickness (inches) 4
Material Information
Binder Type PG 64-22
Gradation Type D
RAP % 0
RAS % 0
Material Properties
Dynamic Modulus Level 2 input : default value
Fracture Property @77 F: A=4.2081E-06, n=3.9531
Rutting Property @104 F: alpha=0.7465, mu=0.8102
Poisson Ratio 0.35

Questions?