Performance Prediction Models

PROJECT HWY-30604 DT

September 6, 2007

Fugro Consultants, Inc.

Applied Research Associates, Inc.

Presentation Outline

1. Introduction & Overview of Project
2. Ancillary Studies
3. Determination of MEPDG Inputs
4. Database
5. Verification & Calibration of MEPDG for Use in Montana
6. Summary & Concluding Comments

Objective

- To calibrate & streamline a design procedure based on HMA distress prediction models using mechanistic-empirical principles in Montana
- To verify and calibrate the distress prediction models or transfer functions included in the MEPDG for use in Montana

Project Team

- Harold L. Von Quintus, PE
- Brian Killingsworth, PE
- Amy Simpson, PhD, PE
- Weng-On Tam, PhD, PE
- Dragos Andrei, PhD, PE
- Matthew Witczak, PhD
- Mark Hallenbeck, PhD
- James Moulthrop, PE

Phases for MEPDG Implementation

Phase I - Planning

Phase II – Initial Data Collection & Analyses

Phase III – Annual Data Collection, Analyses, & Calibration

Road Map for Implementation

Phase I

1. Distress Prediction Models.
2. Typical Design Features, Materials, Construction Procedures
3. Experimental Design Factorial
4. Monitoring & Test Plans

Phase II

5. Initial Data Collection & QC
6. Data Analysis & Calibration

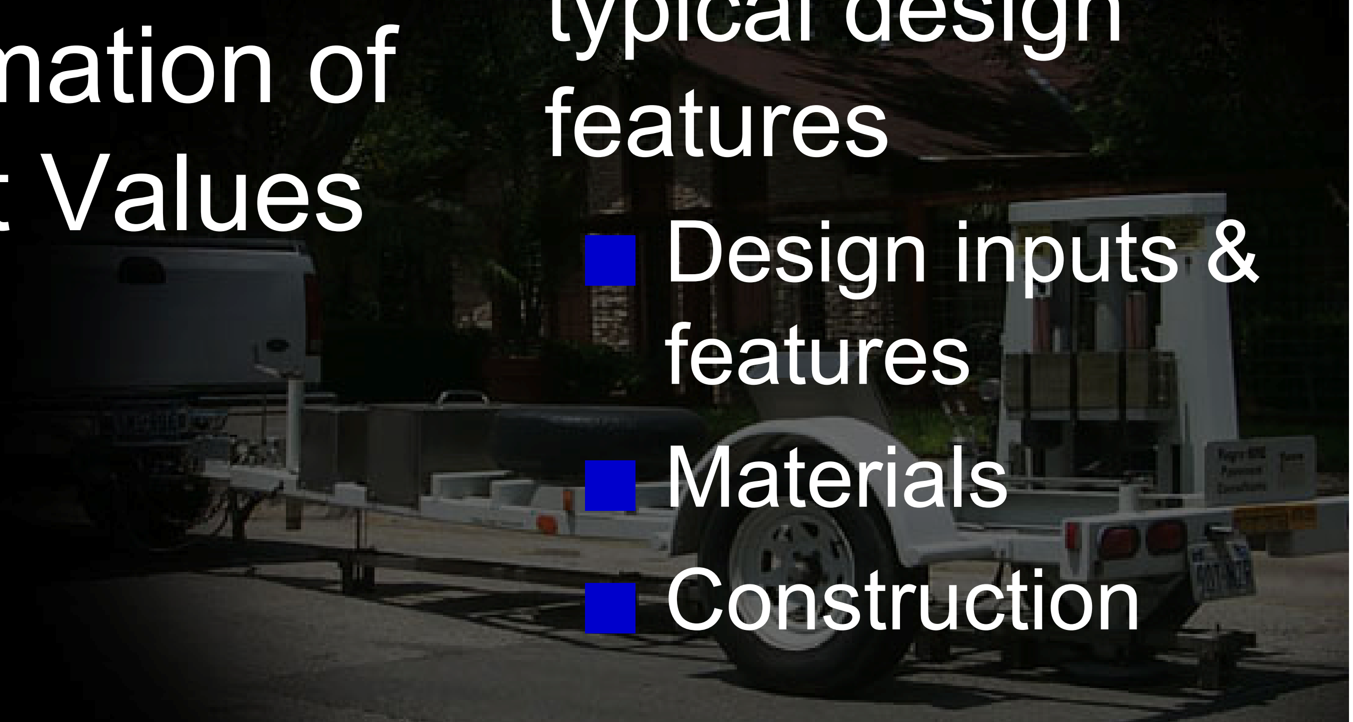
Phase III

5. Annual Data Collection
7. Data QC & Updates to Calibration Function

Dual Purpose Experimental Factorial

1. Local Calibration
2. Confirmation of Default Values

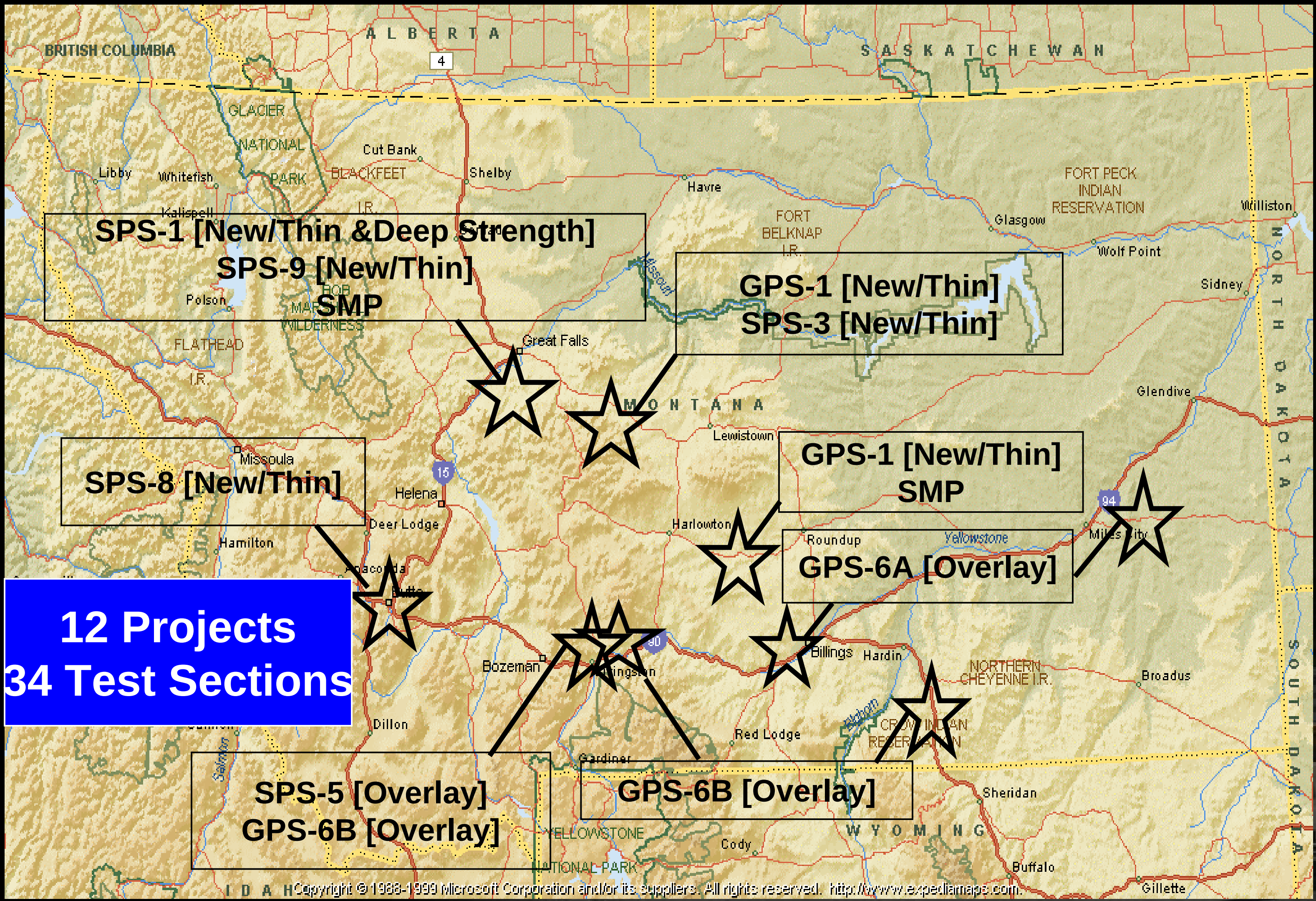
- Identify test sections to cover typical design features
  - Design inputs & features
  - Materials
  - Construction



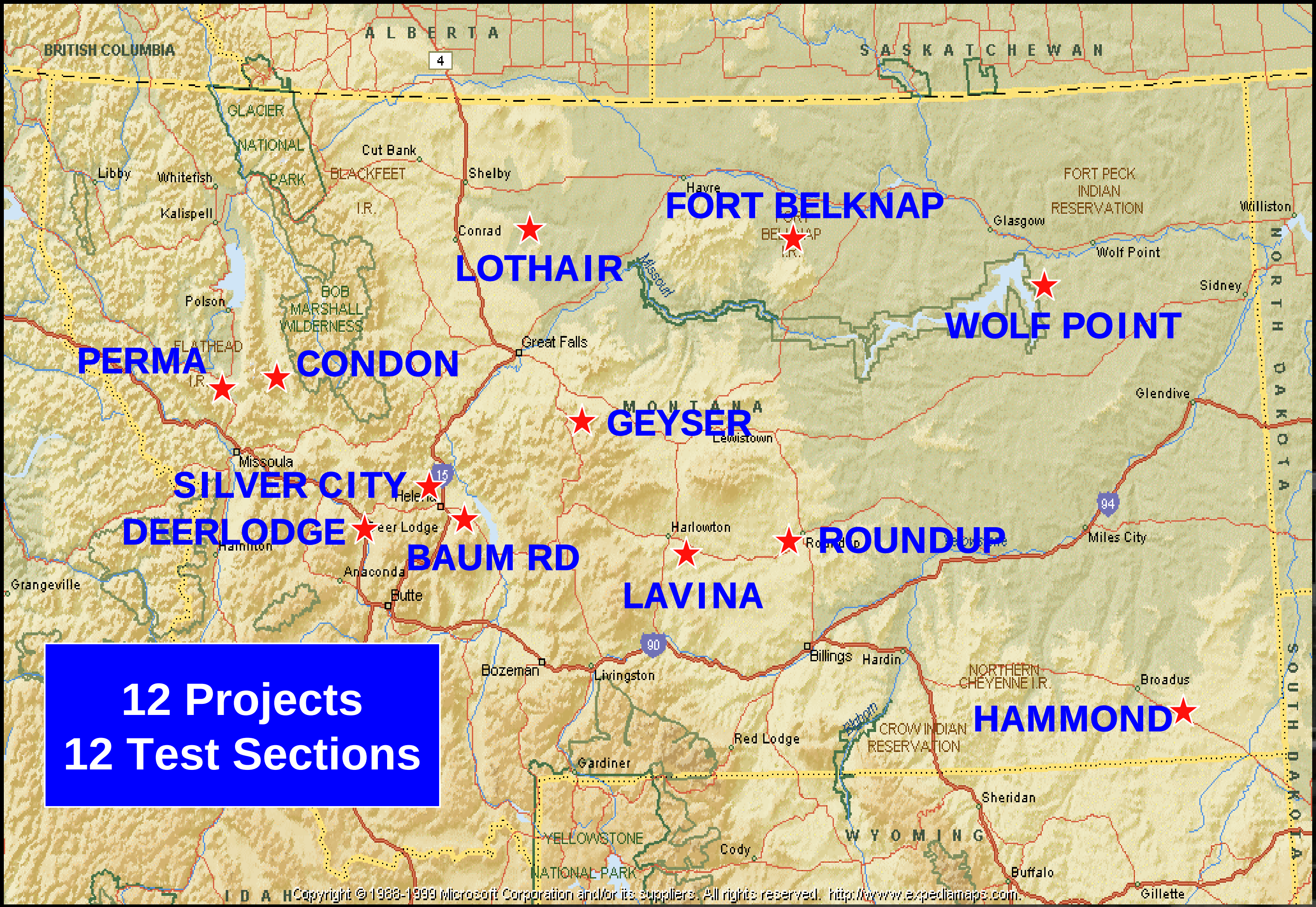
Experimental Factorial

<table>
<tr><th colspan="2">Climate/Region</th><th colspan="3">Western</th><th colspan="3">Eastern</th></tr>
<tr><th colspan="2">Mix Designation</th><th>B</th><th>D</th><th>SP</th><th>B</th><th>D</th><th>SP</th></tr>
<tr><td rowspan="3">Conventional HMA Pavement</td><td>Type A Base</td><td rowspan="2">1</td><td rowspan="2">2</td><td rowspan="2">3</td><td rowspan="2">4</td><td rowspan="2">5</td><td rowspan="2">6</td></tr>
<tr><td>Type B Base</td></tr>
<tr><td>ATPB (SPS-1)</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td></tr>
<tr><td colspan="2">Deep-Strength Pavement</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td></tr>
<tr><td colspan="2">Semi-Rigid Pavement</td><td rowspan="2">19</td><td rowspan="2">20</td><td rowspan="2">21</td><td rowspan="2">22</td><td rowspan="2">23</td><td rowspan="2">24</td></tr>
<tr><td rowspan="2">Reconstruct.; In-Place Recycle</td><td>Semi-Rigid</td></tr>
<tr><td>Granular</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td></tr>
<tr><td rowspan="3">HMA Overlay</td><td>HMA</td><td rowspan="2">37</td><td rowspan="2">38</td><td rowspan="2">39</td><td rowspan="2">40</td><td rowspan="2">41</td><td rowspan="2">42</td></tr>
<tr><td>Mill-Overlay</td></tr>
<tr><td>Semi-Rigid</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td></tr>
</table>

Test Sections: LTPP – Montana



Test Sections: Non-LTPP – Montana



Test Sections:
LTPP – Surrounding States

State, Experiment (No. of Sites)

- ID, GPS-1 (7), GPS-6 (1)
- ND, GPS-2 (1)
- SD, SPS-8 (2)
- WY, GPS-1 (1), GPS-2 (6), GPS-6 (3)
- AB, SPS-5 (9), GPS-1 (3), GPS-2 (1) SPS-9 (3)
- SK, GPS-1 (1), GPS-6 (6)

33 Projects
44 Test Sections

Total Projects

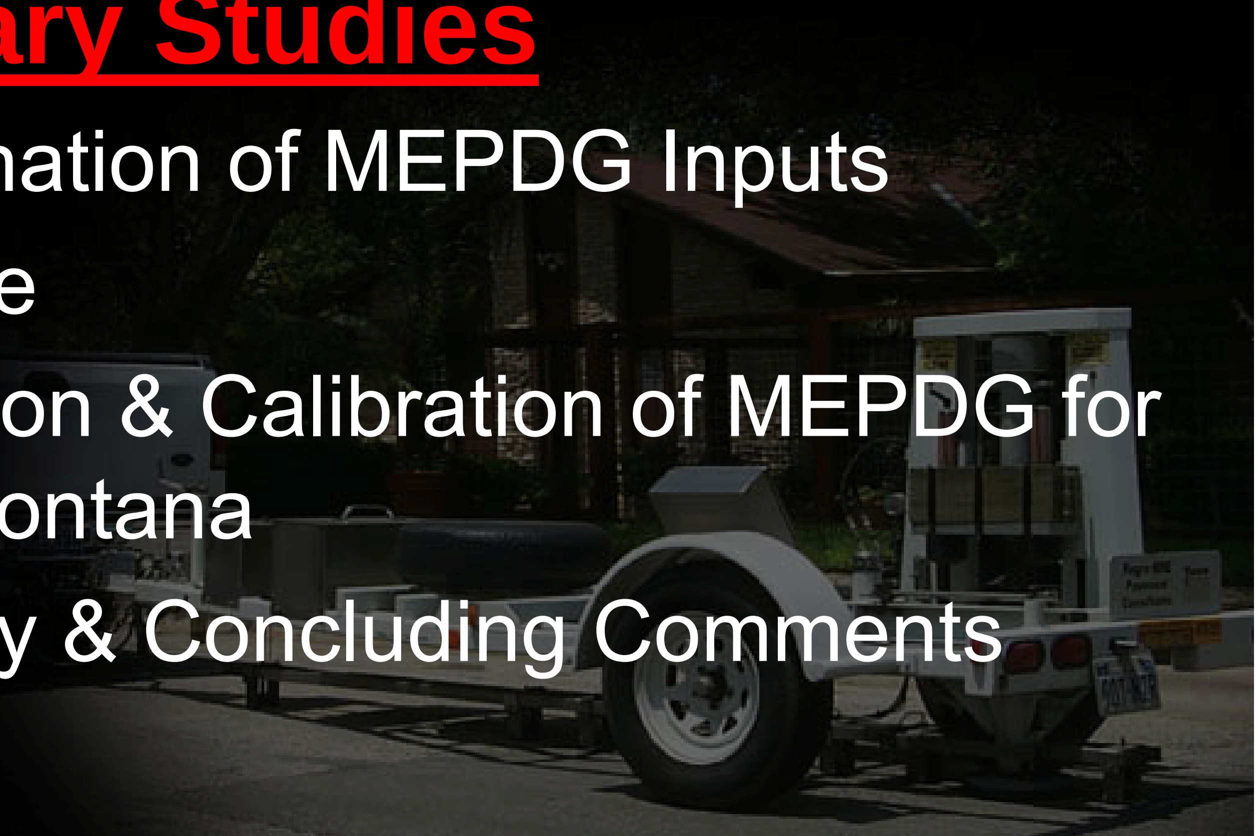
- Total Number of Projects and Test Sections available:
  - 57 Projects
  - 90 Test Sections
- Total Number of Projects and Test Sections Used in the Study:
  - 40 Projects
  - 52 Test Sections

Lab & Field Investigations: Non-LTPP Sites

- ☑ **Materials Recovery & Laboratory Testing**
  - HMA
  - CTB
  - Unbound Materials & Soils
- ☑ **FWD Testing**
- ☑ **Traffic from MDT Database**
- ☑ **Profile**
- ☑ **Distress Surveys**

Presentation Outline

1. Introduction & Overview of Project
2. **Ancillary Studies**
3. Determination of MEPDG Inputs
4. Database
5. Verification & Calibration of MEPDG for use in Montana
6. Summary & Concluding Comments



Ancillary Studies

- Test sections located in Montana versus those located in adjacent States:
  - Performance comparisons
  - HMA volumetric properties
  - Traffic volumes
- Distribution of Weather Stations
- Deflection basin comparisons between LTPP FWD and Montana's FWD
- Profile comparisons between LTPP profilometer & Montana's profilometer

Performance Comparisons: Montana Vs. Adjacent States

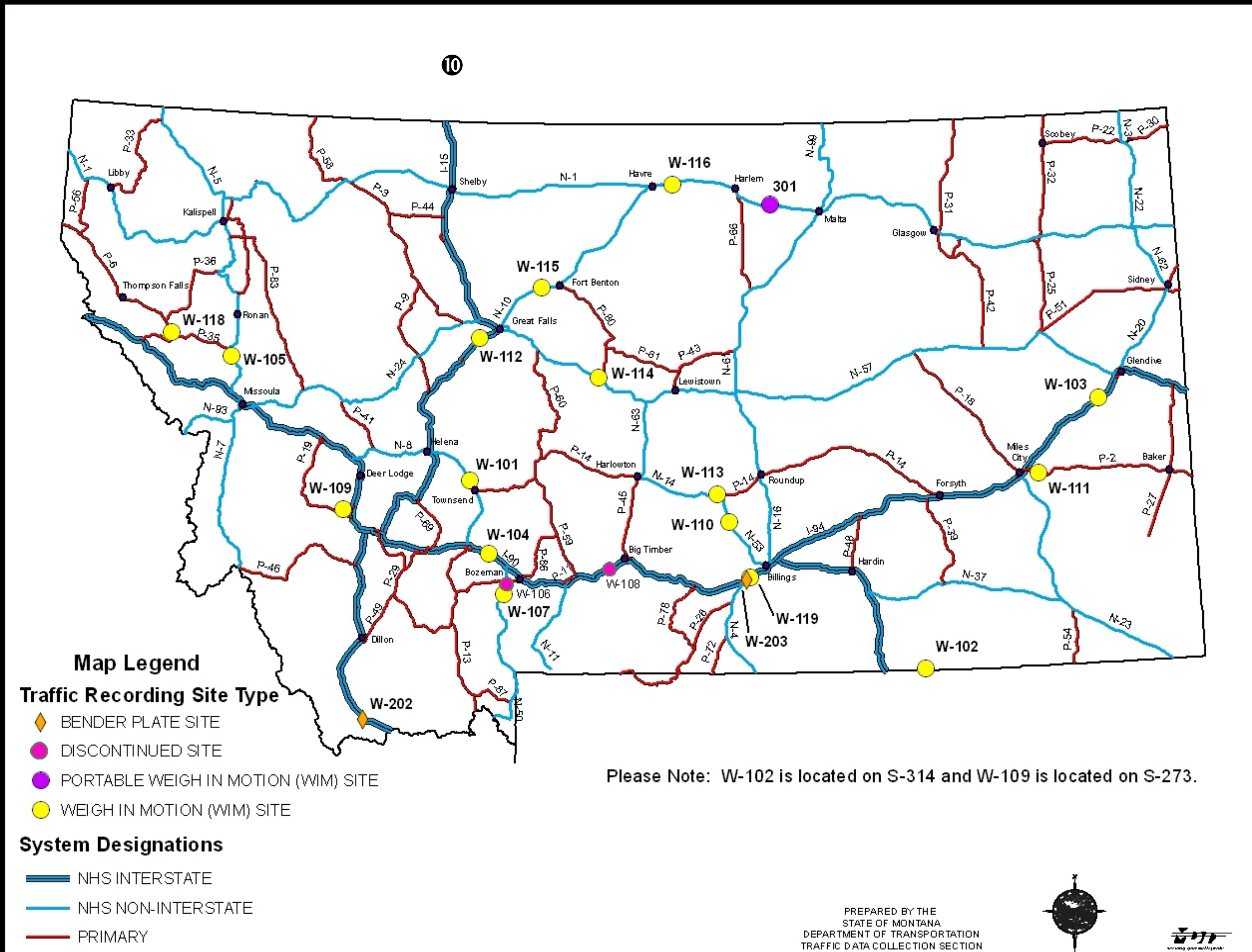
Distress, Average	Montana Sections	Adjacent State
Rutting, in.	0.29	0.50
Transverse Cracking, ft./mi.	479	2026
Semi-Rigid; Fatigue Cracking	None	55%
Longitudinal Cracking, ft./mi.	965	1576
Raveling	None	30%

Result: Systematic difference in performance between Montana sections & those in adjacent States

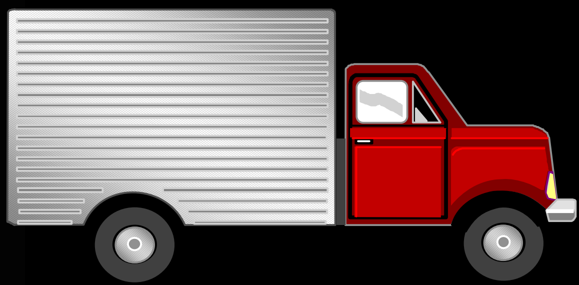
HMA Volumetric Properties: Montana Vs. Adjacent States

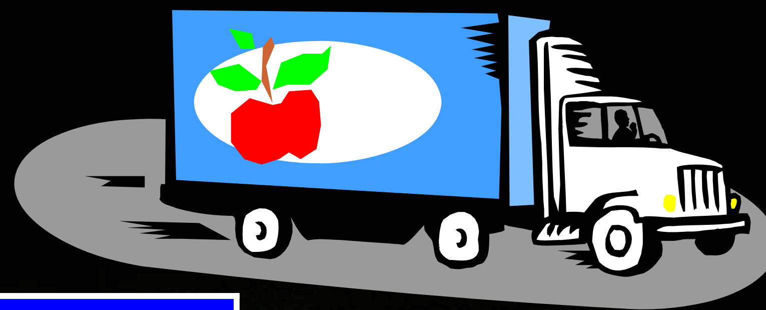
- Air voids of the HMA mixtures were generally lower from the cores recovered from the Montana sections than from the test sections located in adjacent States
- No significant systematic difference in total asphalt content by weight.
- Effects of Pavement Preservation Activities?

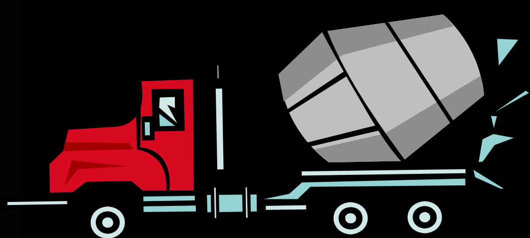
Traffic WIM Sites



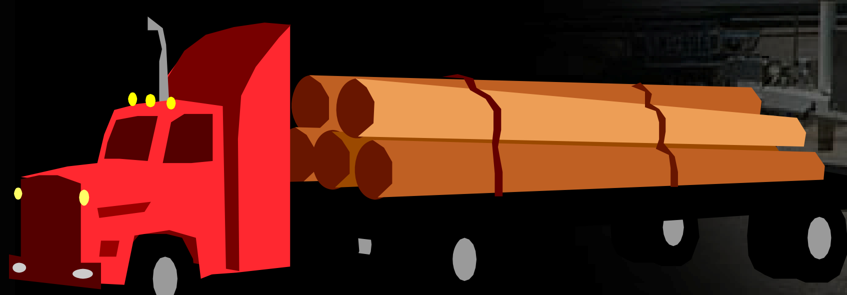
Traffic



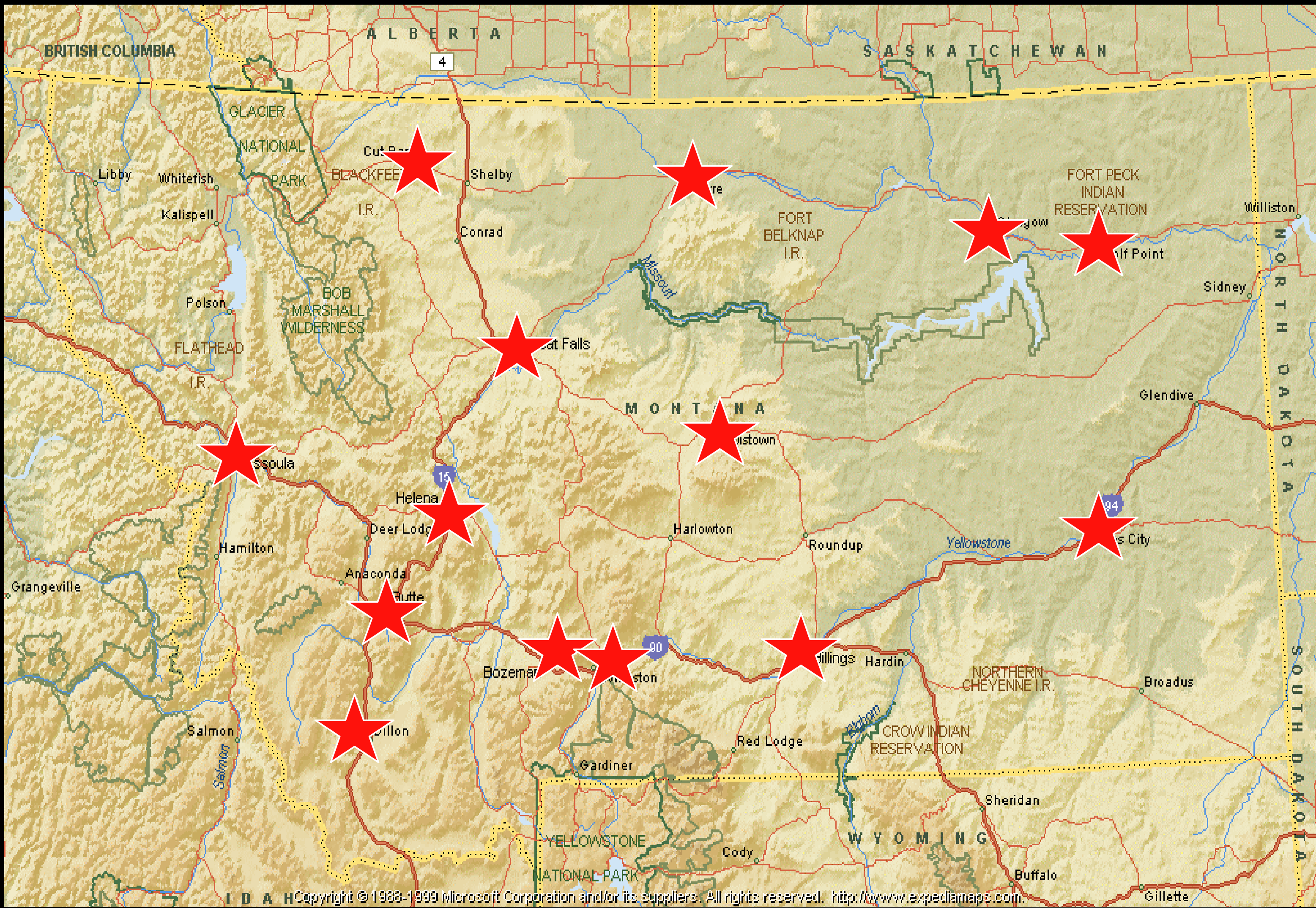




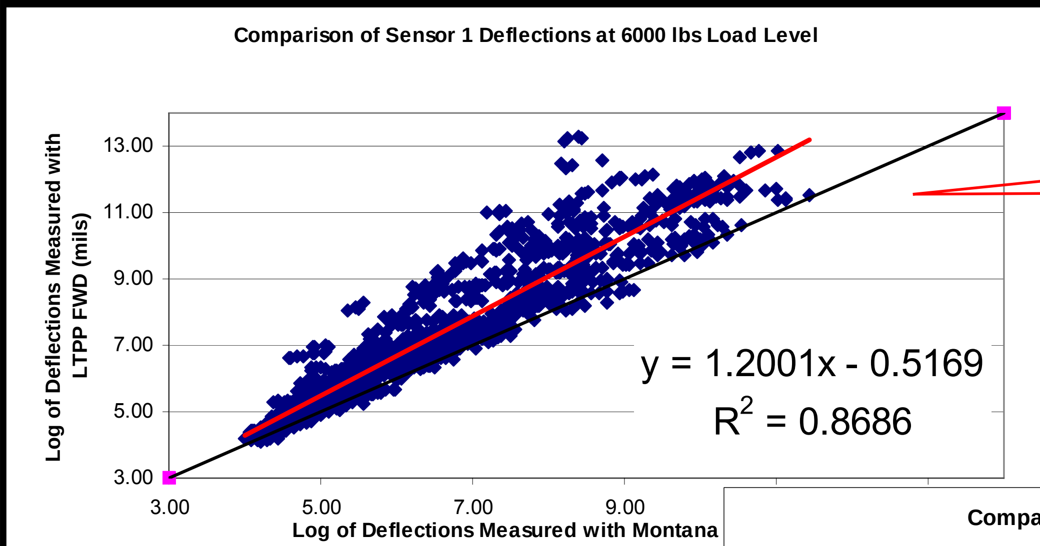
No significant systematic difference in truck volumes and distributions between Montana & adjacent States



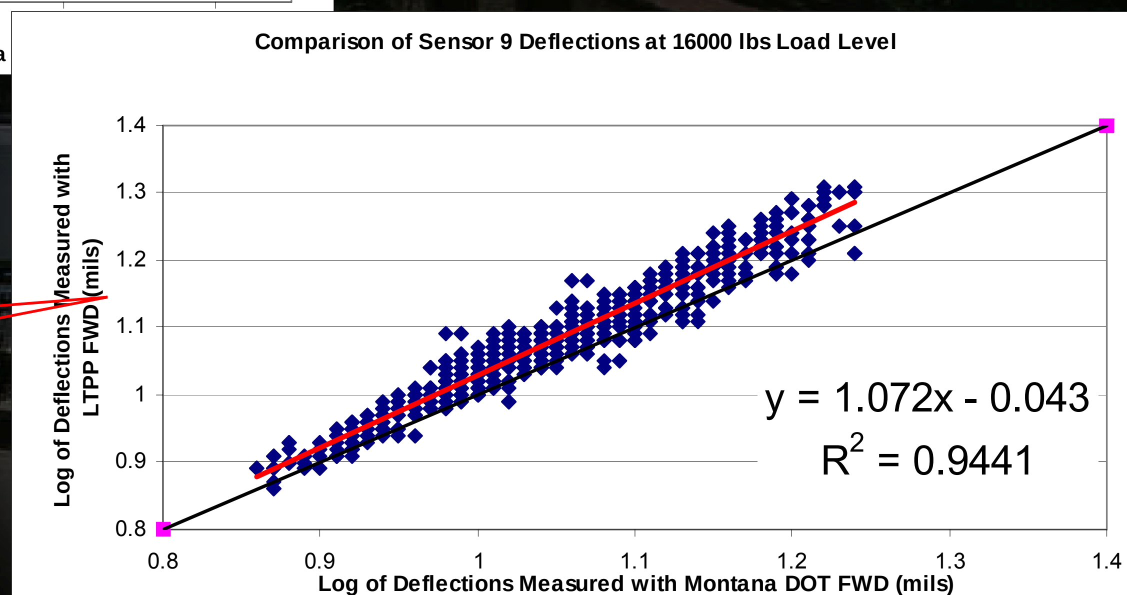
Weather Stations



FWD Comparison Study: Deflections

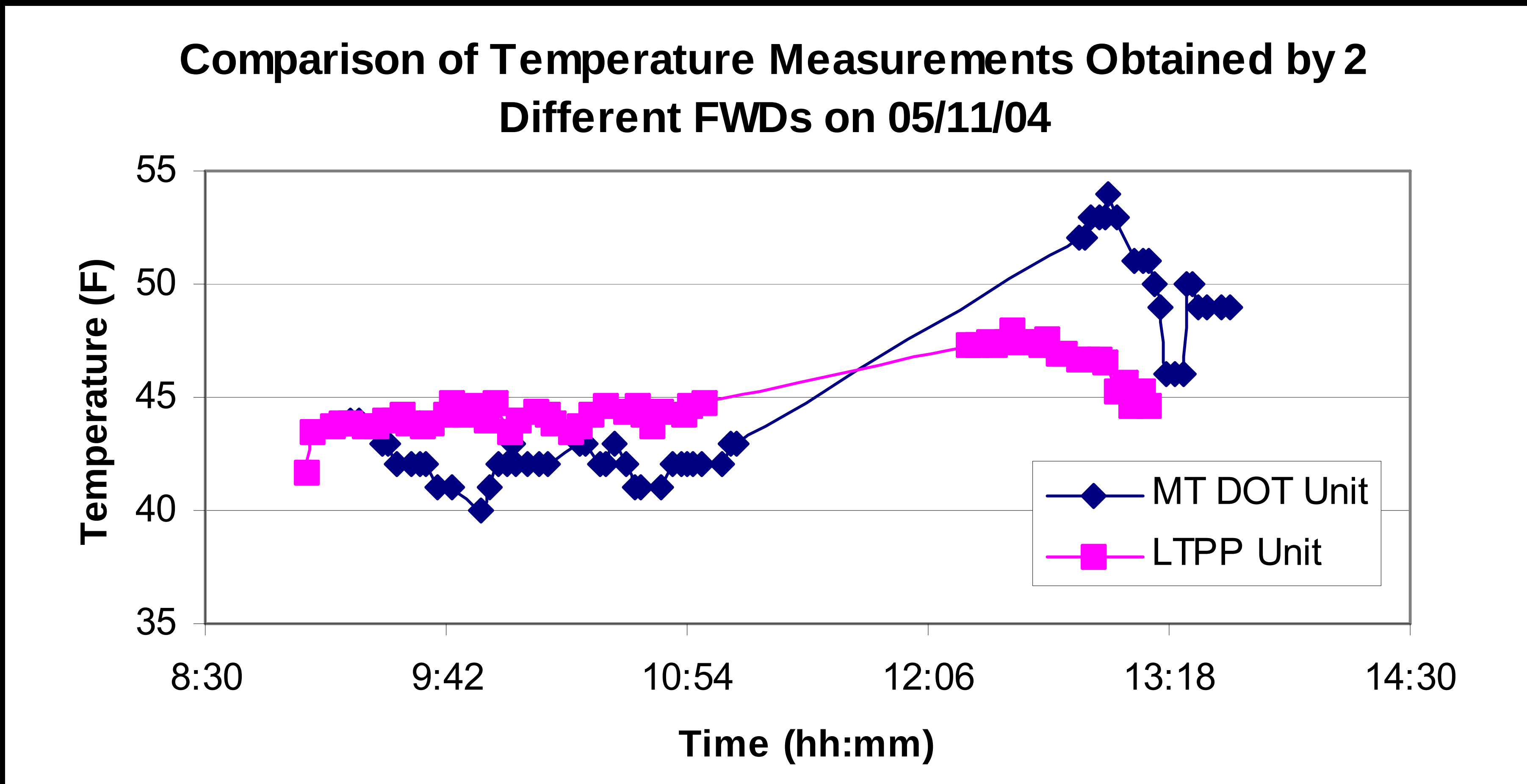


Sensor #1

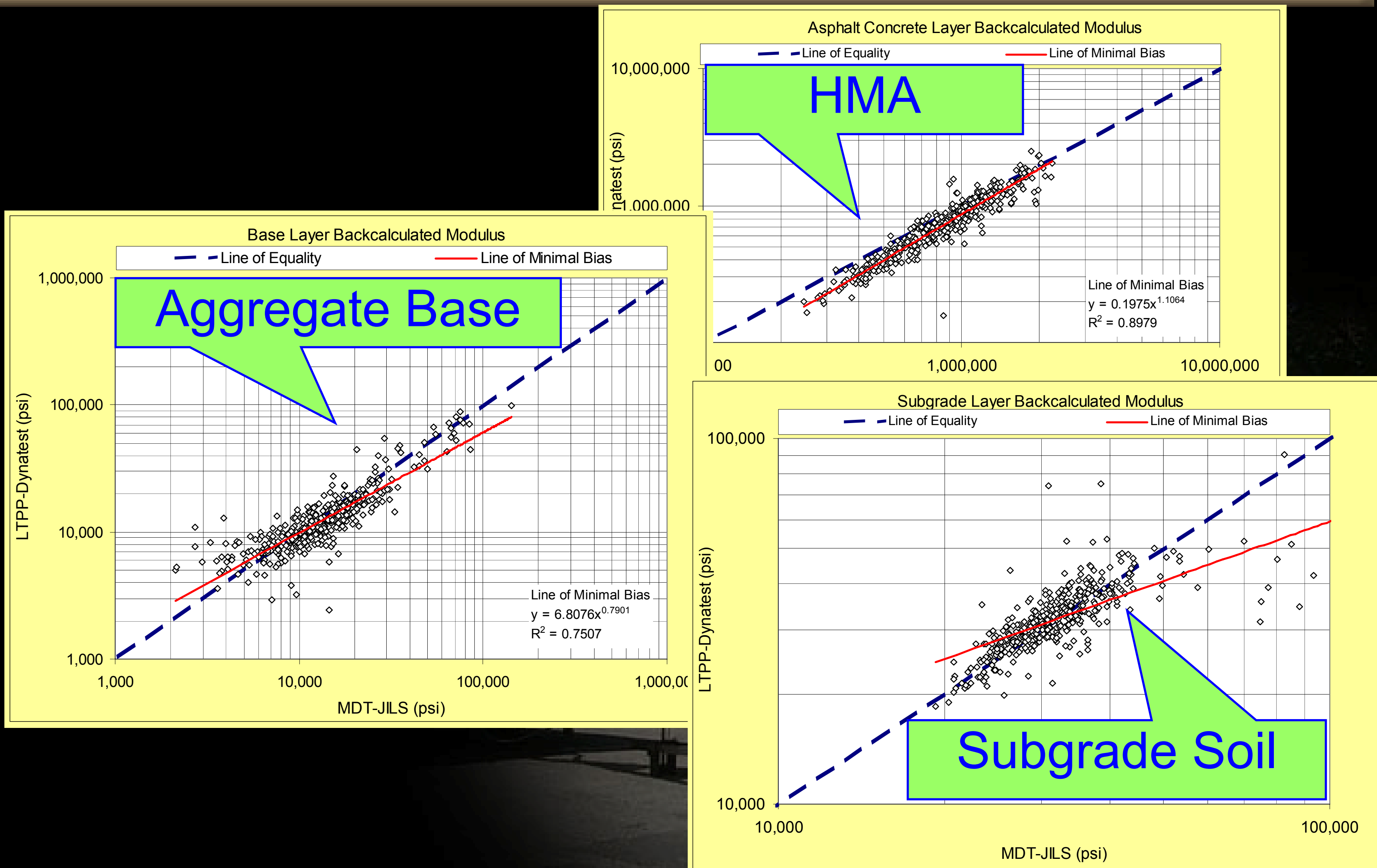


Sensor #9

FWD Comparison Study: Temperature Readings



FWD Comparison Study: Modulus



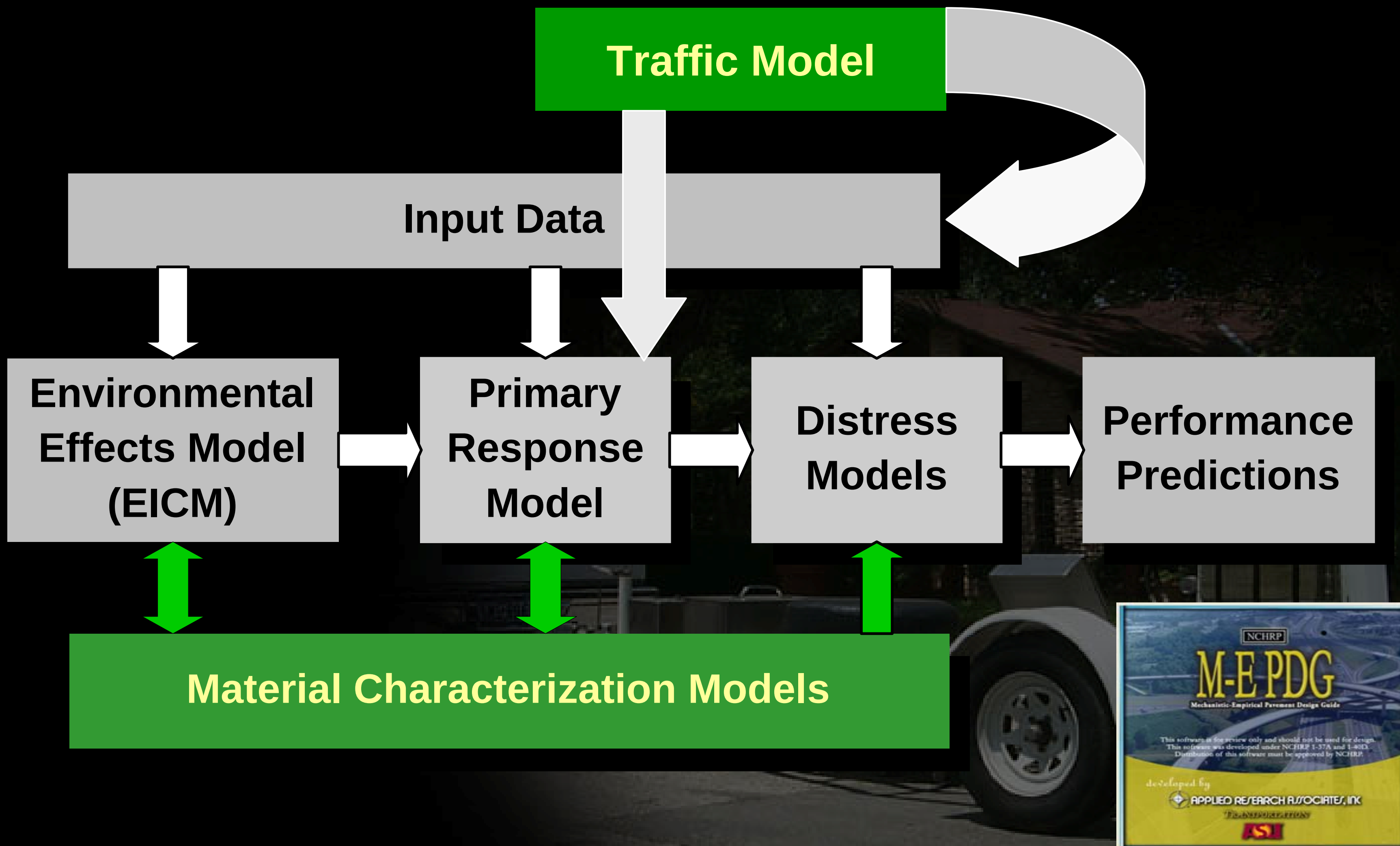
FWD Comparison Study: Results

- The LTPP equipment consistently measured higher deflections when compared to the MDT equipment.
- The difference between the two devices decreased further from the loading plate.
- Back-calculated elastic layer modulus values:
  - Subgrade and aggregate base layers – no significant difference.
  - HMA layers – elastic modulus values from LTPP measured basins are consistently lower than those from the Montana measured basins.

Presentation Outline

1. Introduction & Overview of Project
2. **Determination of MEPDG Inputs**
3. Database
4. Verification & Calibration of MEPDG for Use in Montana
5. Summary & Concluding Comments

MEPDG Design Process



Traffic: Volume Distribution Factors

Roadway Description	Applicable TTC Group
Interstate Highways & Primary Arterials, Heavier Volume Roadways	TTC-11
Primary & Secondary Arterials, Moderate Volume Roadways	TTC-5
Secondary Arterials, Lower Volume Roadways	TTC-8
Local Routes with Low Truck Volumes	TTC-15

Traffic: Seasonal Distribution Factors

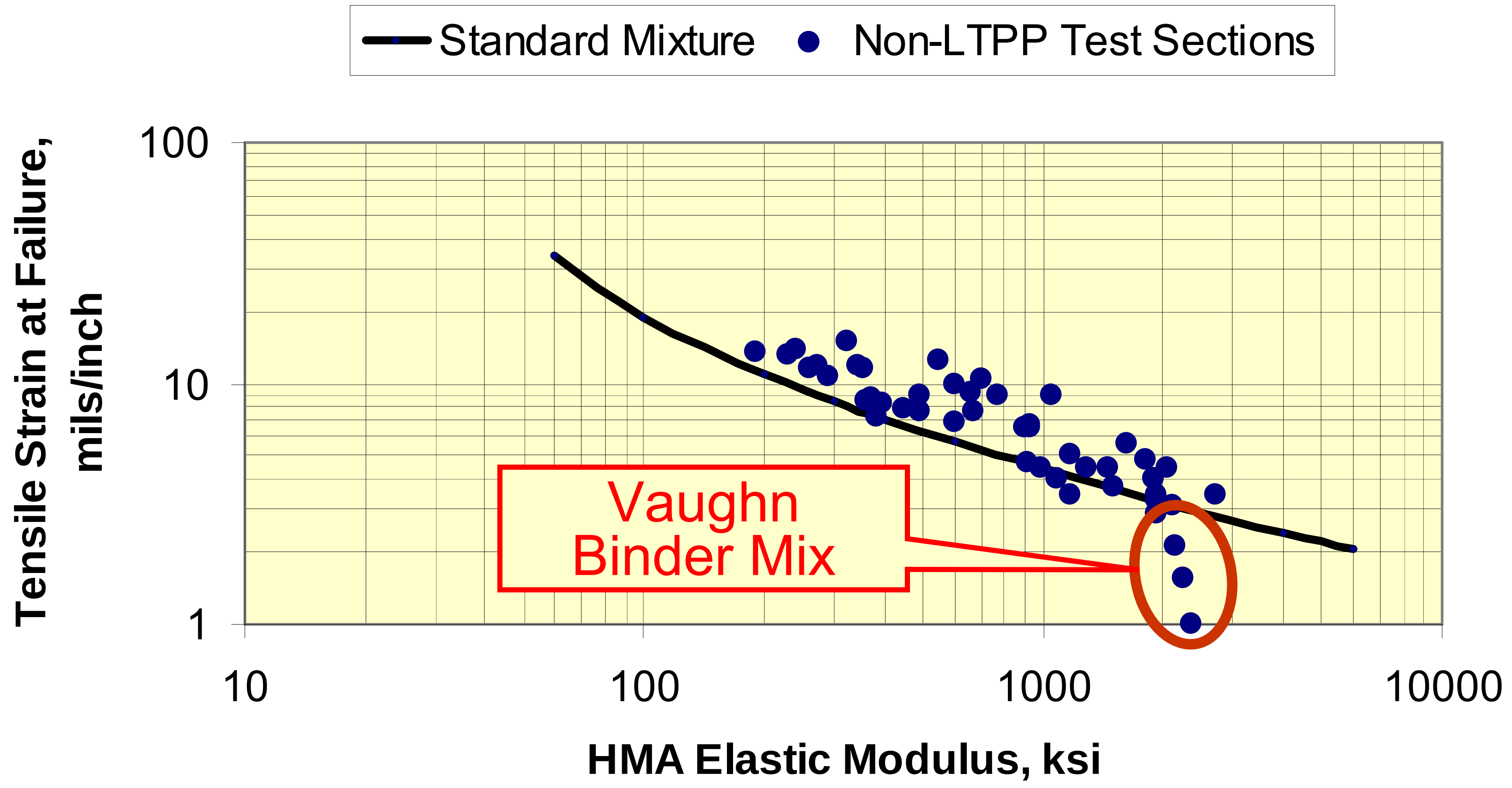
Month	Single Units	Combination Trucks	Multi-Trailer Trucks
Jan.	0.84	0.91	0.99
Feb.	0.79	0.92	0.89
Mar.	0.76	0.94	0.88
April	0.86	0.99	0.99
May	1.10	1.06	1.03
June	1.30	1.09	0.96
July	1.43	1.02	0.92
Aug.	1.39	1.06	1.11
Sept.	1.14	1.00	1.09
Oct.	1.06	1.15	1.12
Nov.	0.87	1.00	1.00
Dec.	0.76	0.84	0.87

Traffic: Axle Load Distribution Factors

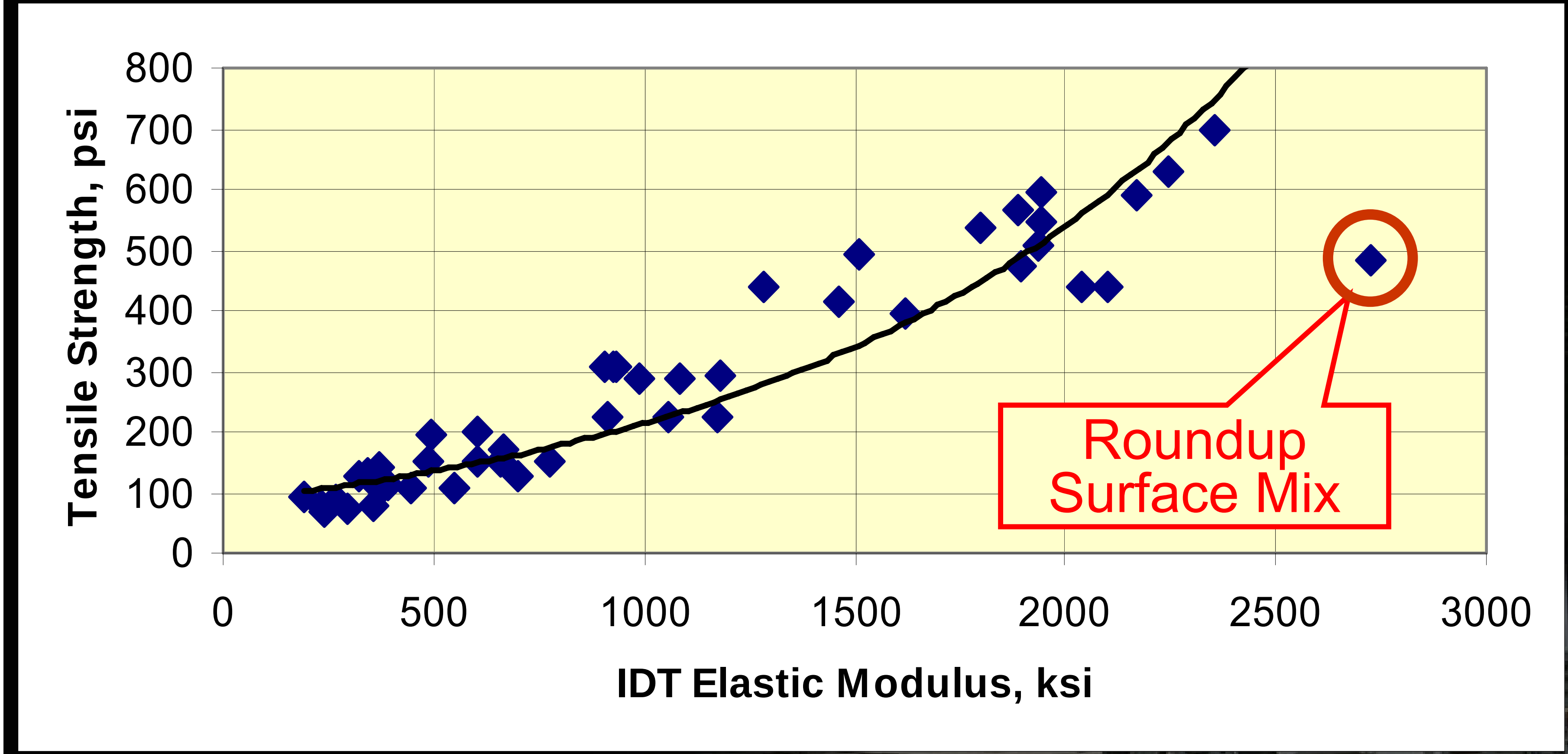
1. Primarily Loaded Trucks
2. Bimodal Loaded Condition – Heavy Distribution
3. Bimodal Loaded Condition – Even Distribution
4. Lightly Loaded Trucks

MEPDG defaults used because of drifts noted in 2000-2001 data

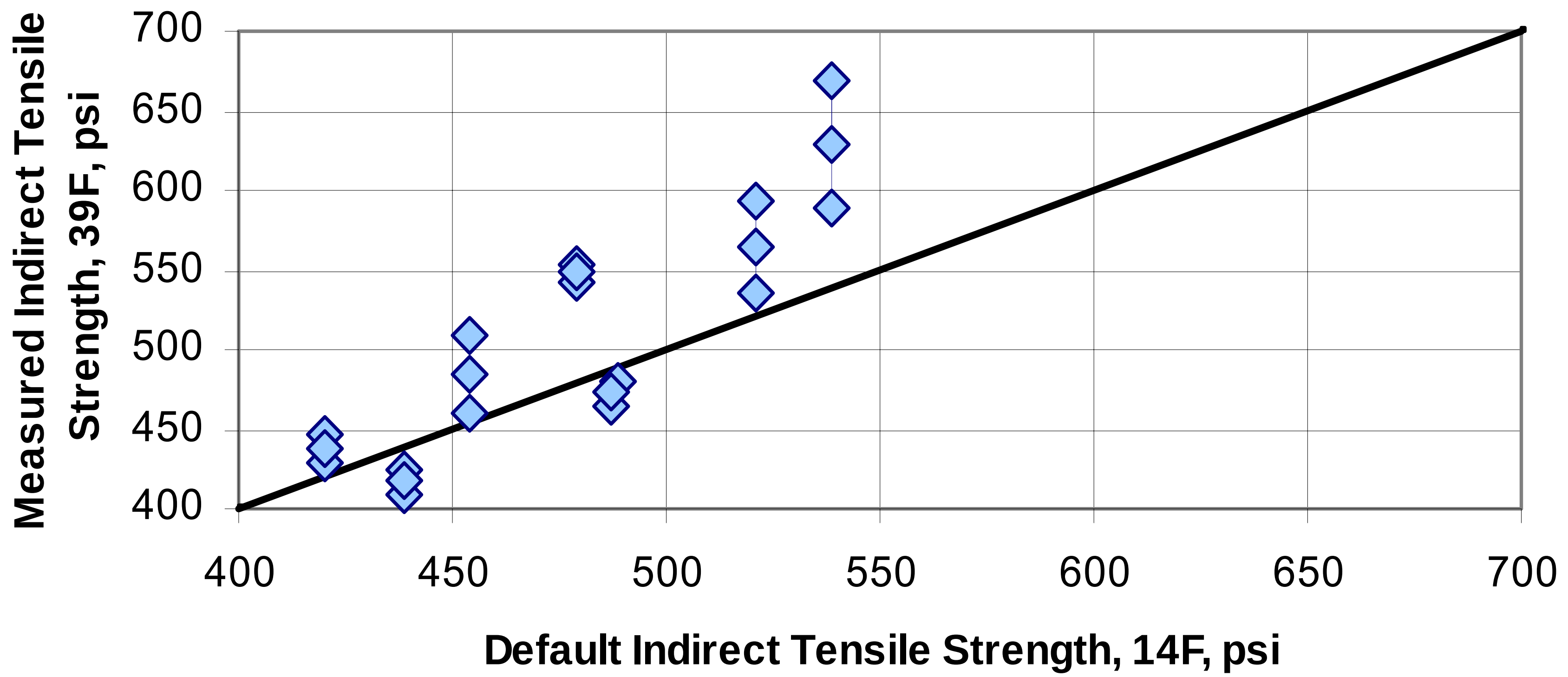
HMA Characterization



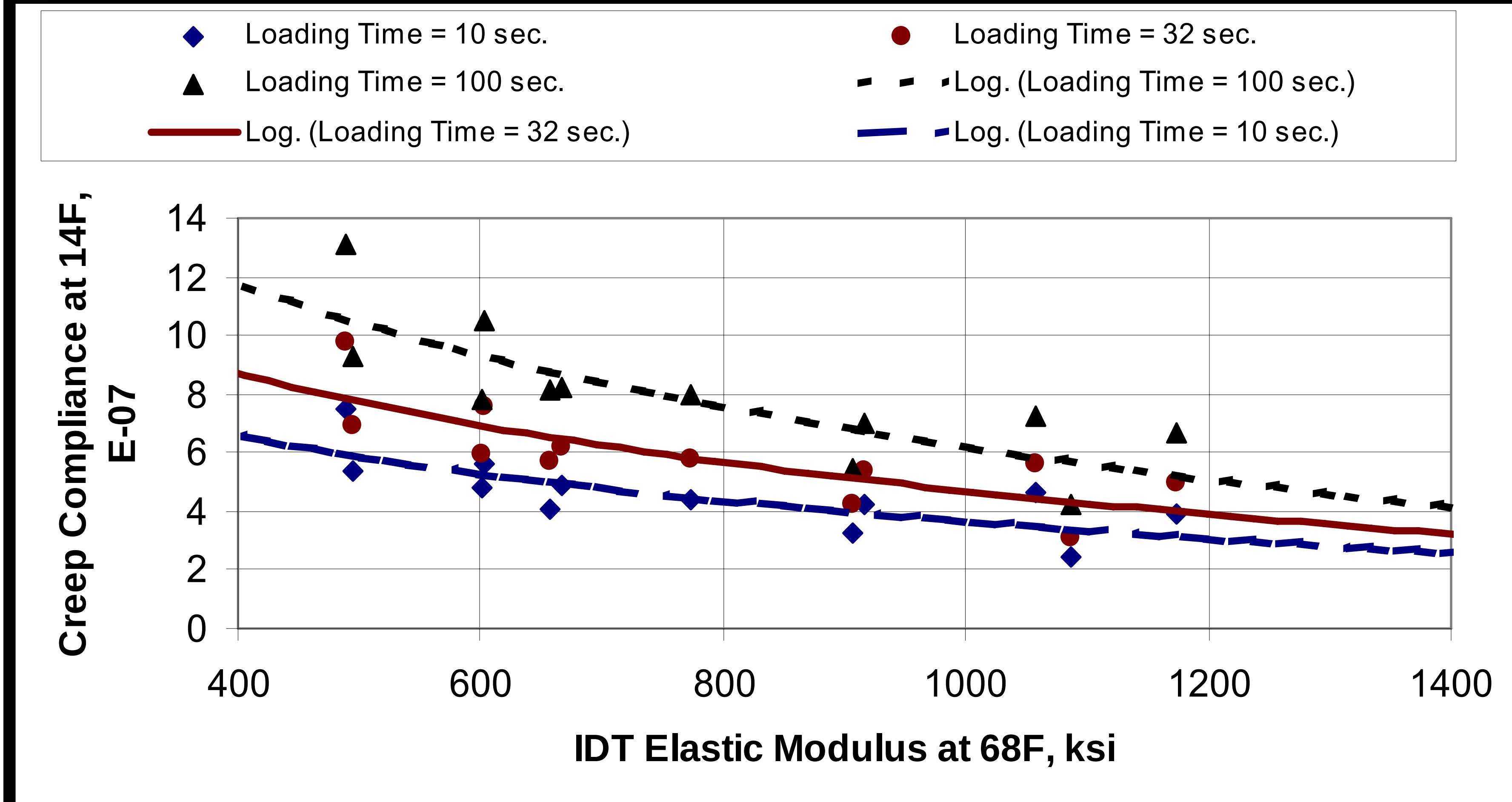
HMA Characterization



IDT Strength

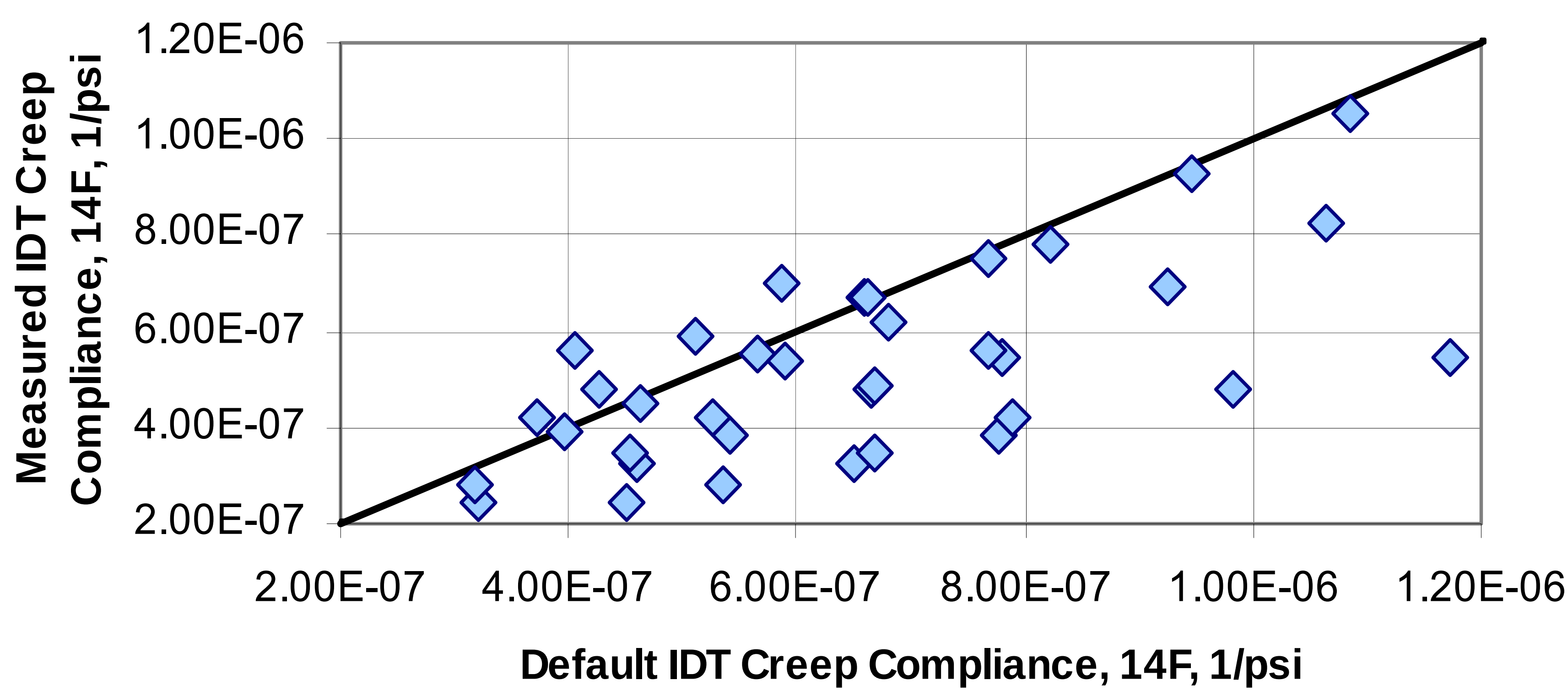


IDT Creep Compliance

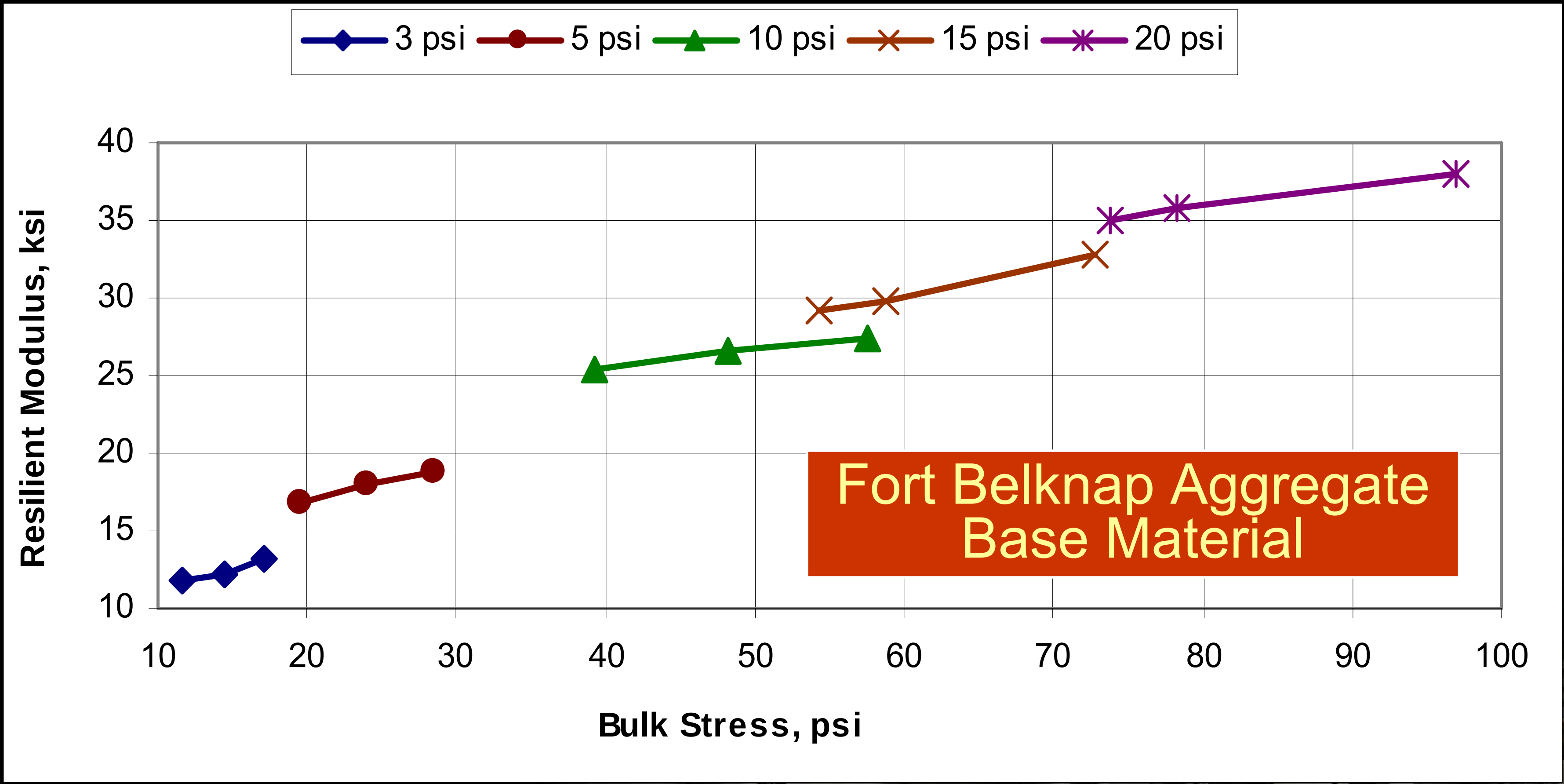


Default values versus laboratory measured values

IDT Creep Compliance

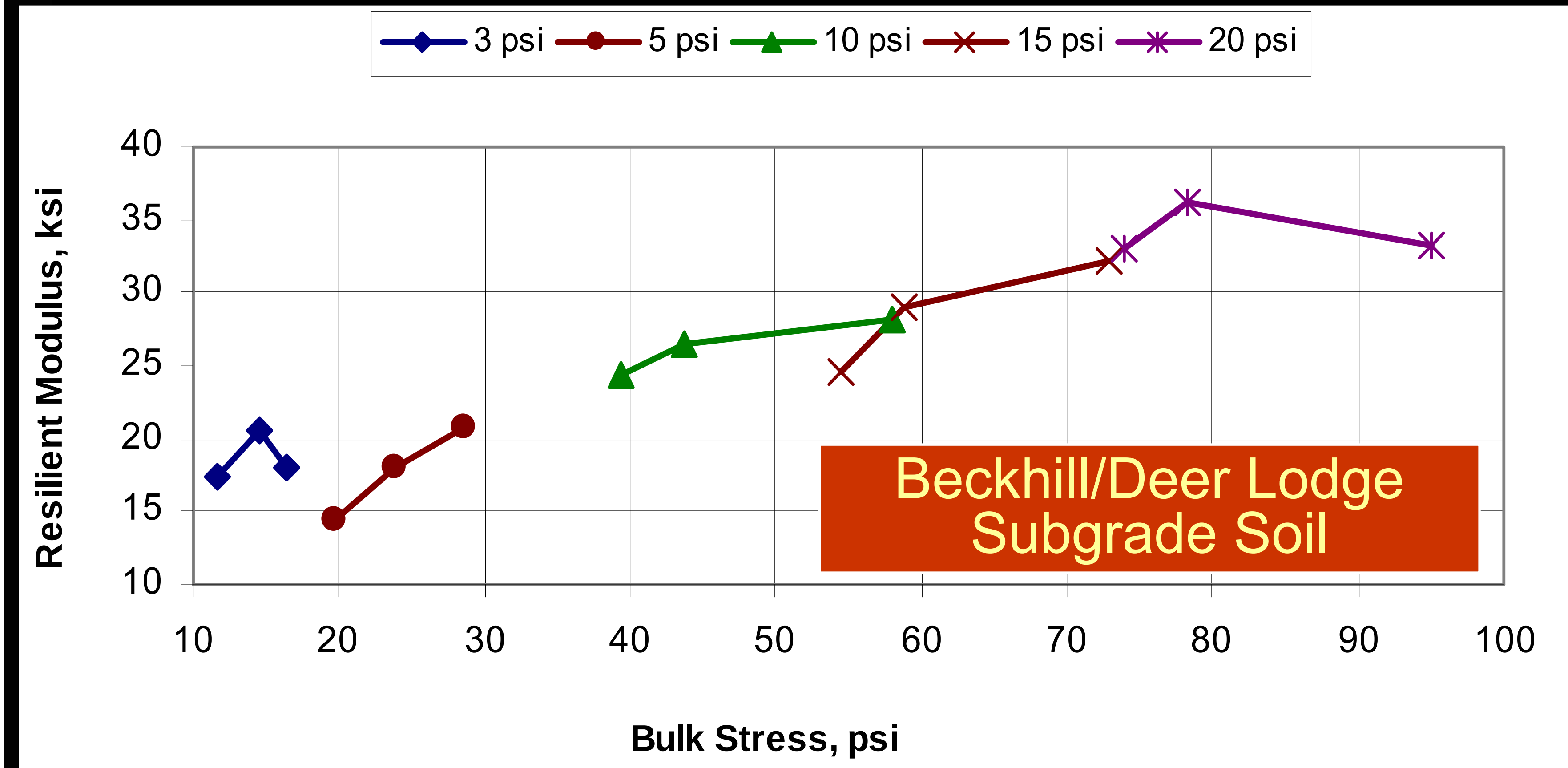


Resilient Modulus of Unbound Materials & Soils



Default values versus laboratory measured values

Resilient Modulus of Unbound Materials & Soils

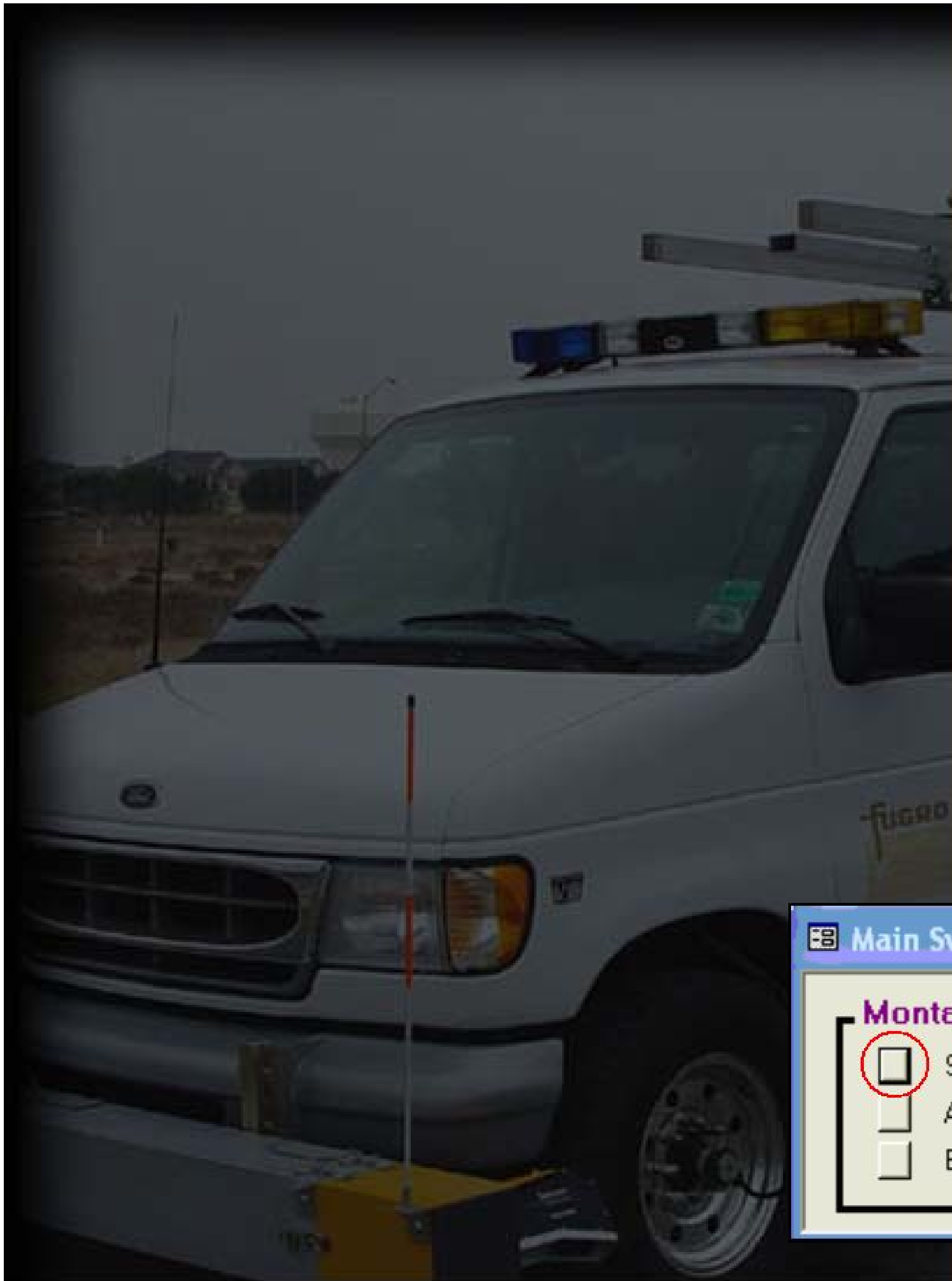


Conversion Factors for Backcalculated Modulus Values

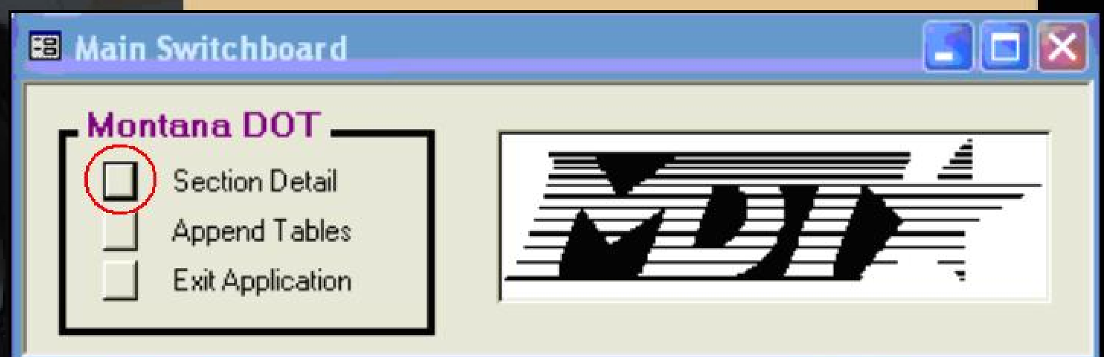
Layer & Material Type	Layer Description	Adjustment Factor
Subgrade Soil/Foundation	Soil Under a CAM without granular base	1.00
	Soil under a CAM with a granular base	0.50
	Soil under flexible pavement with a granular base	0.50
Aggregate Base Layers	Granular base under a CAM layer	0.75
	Granular base under an HMA surface or base	0.60
CAM Layers	Cement treated aggregate	1.50
HMA Layers	Temperature = 41F	0.90
	Temperature = 77F	0.60
	Temperature = 104F	0.50

Presentation Outline

1. Introduction & Overview of Project
2. Determination of MEPDG Inputs
3. **<u>Database</u>**
4. Verification & Calibration of MEPDG for Use in Montana
5. Summary & Concluding Comments



Database


Main Switchboard
Montana DOT
Section Detail
Append Tables
Exit Application

Calibration/Validation Database

- Incorporates pavement related data from 93 LTPP sections (MT, adjacent States, and Provinces)
- 13 Non-LTPP sections
- Database is relational-linked

Pavement Data Includes

- Section identification and layer data
- Pavement materials data
- Traffic data
- Performance data

Section Information

- Contains details regarding test sections such as:
  - Location
  - Lanes (number, width, etc.)
  - Construction dates
  - Construction events (including maintenance or rehabilitation)

Pavement Materials Data

- Includes test information for:
  - HMA materials (aggregate, binder)
  - Unbound materials (base, subbase, and subgrade)
  - Depth to water table

Pavement Performance Data

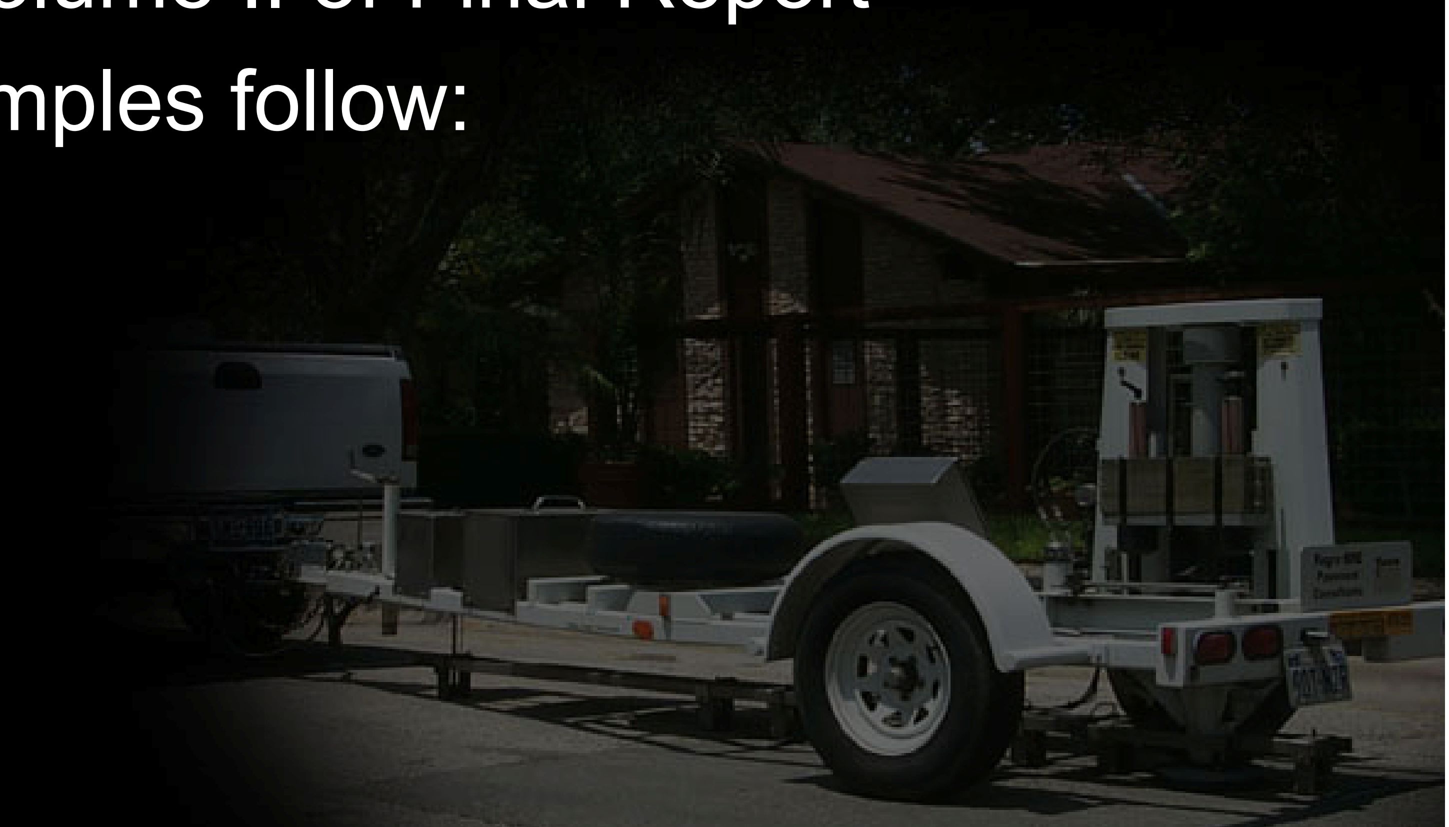
- Deflection
  - Raw deflection data
  - Backcalculated layer moduli
- Longitudinal profile data
- Distress data (cracking)
- Rutting data

Traffic Data

- Equivalent Single Axle Loading (ESAL)
- Axle load spectra (Automated Vehicle Classification and Weigh-in-Motion)

Table Structure/ Database Schema

- Details contained in Appendix B and D of Volume II of Final Report
- Examples follow:



Section Information

SECTION

PK	ID
U1	STATE_CODE
U1	SHRP_ID
	HIGHWAY
	DIRECTION_OF_TRAVEL
	TOT_LANES
	LANE_NUMBER
	FUNC_CLASS
	TRAFFIC_OPEN_DATE
	COUNTY
	LATITUDE
	LONGITUDE
	ELEVATION
	LOCATION_INFO
	LANE_WIDTH
	SHOULDER_TYPE
	SHOULDER_WIDTH
	ACCESS_CONTROL
	MEDIAN
	DESCRIPTION

SECTION_EVENTS

PK	ID
FK1,I1,U1	idSECTION
U1	CONSTRUCTION_NO
	EXP_NO
	TERMINAL_SI
	STRUCTURAL_NO
	PAVE_TYPE
	RIGID_DEPTH_ESAL
	CN_ASSIGN_DATE
	CN_CHANGE_REASON
	DATE_EARTHWORK

Profile

MON_PROFILE_MASTER	
PK	ID
U1 FK1,I1,U1	PROFILE_DATE idSECTION

MON_PROFILE_RAW	
PK	ID
FK1,I1,I2 I2	idMON_PROFILE_MASTER RUN_NUMBER FILTER_WAVELENGTH SURFACE_CONDITION TEMPERATURE CLOUD_CONDITIONS AVERAGE_SPEED IRI_LEFT_WHEEL_PATH IRI_RIGHT_WHEEL_PATH IRI_AVERAGE PROFILE_MANUFACTURER PROFILE_MODEL_NUMBER SENSOR_TYPE

MON_PROFILE	
PK	ID
FK1,I1	idMON_PROFILE_MASTER AVG_IRI_LEFT_WHEEL_PATH STD_IRI_LEFT_WHEEL_PATH MIN_IRI_LEFT_WHEEL_PATH MAX_IRI_LEFT_WHEEL_PATH AVG_IRI_RIGHT_WHEEL_PATH STD_IRI_RIGHT_WHEEL_PATH MIN_IRI_RIGHT_WHEEL_PATH MAX_IRI_RIGHT_WHEEL_PATH AVG_IRI_AVERAGE STD_IRI_AVERAGE MIN_IRI_AVERAGE MAX_IRI_AVERAGE

Traffic

TRF_MONITOR_MASTER	
PK	ID
FK1,I1	idSECTION
	DATE_YEAR
	ATR_VOLUME_DAYS
	AVC_VOLUME_DAYS
	AVC_CLASS_DAYS
	WIM_CLASS_DAYS
	WIM_W4_DAYS
	AADT_RDWAY
	TRUCK_VOLUME_EST
	AADT_PCT_NON_LTPP_DIRECTION
	AADT_PCT_LTPP_DIRECTION
	AADT_PCT_LTPP_LANE
	TRUCK_PCT_LTPP_LANE
	VEHICLES_CLASSIFIED
	VEHICLES_WEIGHED
	ESAL_VEHICLE_DATA_MEAN
	ANNUAL_ESAL_DATA

TRF_ESAL_MASTER	
PK	ID
FK1,I1	idSECTION
	DATE_YEAR
	AADT_ALL_VEHIC
	AADT_TRUCK_COMBO
	ANL_KESAL_TOT_LTPP_LN_YR
	METHOD_EST

TRF_VEHICLE_DISTRIB	
I2	ID
FK1,I3,I1	idTRF_MONITOR_MASTER
	VEHICLE_TYPE
	VOLUME_EST
	VEHICLES_CLASSIFIED
	VEHICLES_WEIGHED
	ESAL_VEHICLE_DATA_MEAN

TRF_AXLE_DISTRIB_WEIGHT	
PK	ID
FK1,I1,U1	idTRF_MONITOR_MASTER
U1	DATE_MONTH
	idKEYCODES_AxleGroup
	WEIGHT_RANGE_LOW
	WEIGHT_RANGE_HIGH
	NUMBER_OF_AXLES

TRF_AXLE_SUMMARY	
U1	ID
FK1,I1	idTRF_MONITOR_MASTER
	idKEYCODES_AxleGroup
	ANNUAL_AXLE_NUMBER_EST
	ANNUAL_AXLE_NUMBER_ACT
	ANNUAL_VEHICL_NUMBER_ACT

Rutting

MON_RUT_MASTER	
PK	ID
FK1,I1	idSECTION TEST_DATE STATION WIRELINE_RUT_LEFT_WHEELPATH WIRELINE_RUT_RIGHT_WHEELPATH HMA_RUT_LWP HMA_RUT_RWP BASE_RUT_LWP BASE_RUT_RWP SUBGRADE_RUT_LWP SUBGRADE_RUT_RWP

MON_RUT_RAW	
PK	ID
FK1,I1	idMON_RUT_MASTER STATION DEPTH

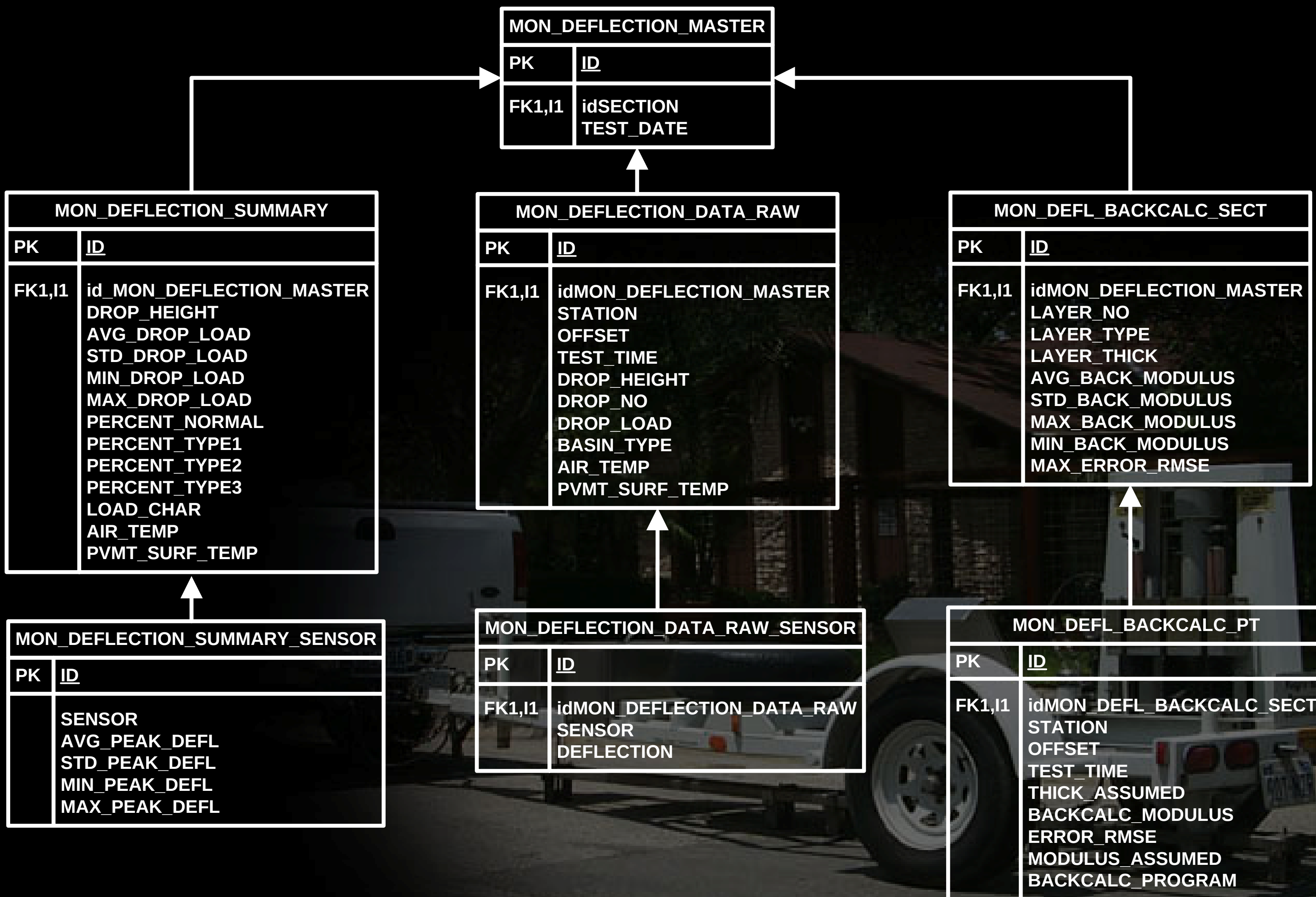
MON_RUT_RAW_DISTANCE	
PK	ID
FK1,I1	idMON_RUT_RAW DISTANCE DEPTH_RUT

Distress

MON_DISTRESS_MASTER	
PK	ID
FK1,I1	idSECTION
	SURVEY_DATE
	PERCENT_FATIGUE
	CRACK_ORIGIN
	THERMAL_CRACK
	AVG_WIRELINE_RUT_DEPTH
	STD_WIRELINE_RUT_DEPTH
	STUDDED_TIRE_WEAR
	OTHER

MON_DISTRESS_RAW	
PK	ID
FK1,I1	idMON_DISTRESS_MASTER
	idKEYCODES_Distress
	idKEYCODES_Severity
	Value
I2	Number
	idKEYCODES_Unit
	idKEYCODES_Wheelpath
	idKEYCODES_Sealed
	idKEYCODES_Reflective

Deflection



MON_DEFLECTION_MASTER
PK ID
FK1,I1 idSECTION
TEST_DATE
MON_DEFLECTION_SUMMARY
PK ID
FK1,I1 id_MON_DEFLECTION_MASTER
DROP_HEIGHT
AVG_DROP_LOAD
STD_DROP_LOAD
MIN_DROP_LOAD
MAX_DROP_LOAD
PERCENT_NORMAL
PERCENT_TYPE1
PERCENT_TYPE2
PERCENT_TYPE3
LOAD_CHAR
AIR_TEMP
PVMT_SURF_TEMP
MON_DEFLECTION_DATA_RAW
PK ID
FK1,I1 idMON_DEFLECTION_MASTER
STATION
OFFSET
TEST_TIME
DROP_HEIGHT
DROP_NO
DROP_LOAD
BASIN_TYPE
AIR_TEMP
PVMT_SURF_TEMP
MON_DEFL_BACKCALC_SECT
PK ID
FK1,I1 idMON_DEFLECTION_MASTER
LAYER_NO
LAYER_TYPE
LAYER_THICK
AVG_BACK_MODULUS
STD_BACK_MODULUS
MAX_BACK_MODULUS
MIN_BACK_MODULUS
MAX_ERROR_RMSE
MON_DEFLECTION_SUMMARY_SENSOR
PK ID
SENSOR
AVG_PEAK_DEFL
STD_PEAK_DEFL
MIN_PEAK_DEFL
MAX_PEAK_DEFL
MON_DEFLECTION_DATA_RAW_SENSOR
PK ID
FK1,I1 idMON_DEFLECTION_DATA_RAW
SENSOR
DEFLECTION
MON_DEFL_BACKCALC_PT
PK ID
FK1,I1 idMON_DEFL_BACKCALC_SECT
STATION
OFFSET
TEST_TIME
THICK_ASSUMED
BACKCALC_MODULUS
ERROR_RMSE
MODULUS_ASSUMED
BACKCALC_PROGRAM

Populating the Database-LTPP Data

1. Use the current LTPP data release to update the database with the latest information for LTPP sections
2. A set of queries has been created to add new data and delete existing data for LTPP sections (detailed instructions are provided in Volume II of the Final Report)

Populating the Database- LTPP Data

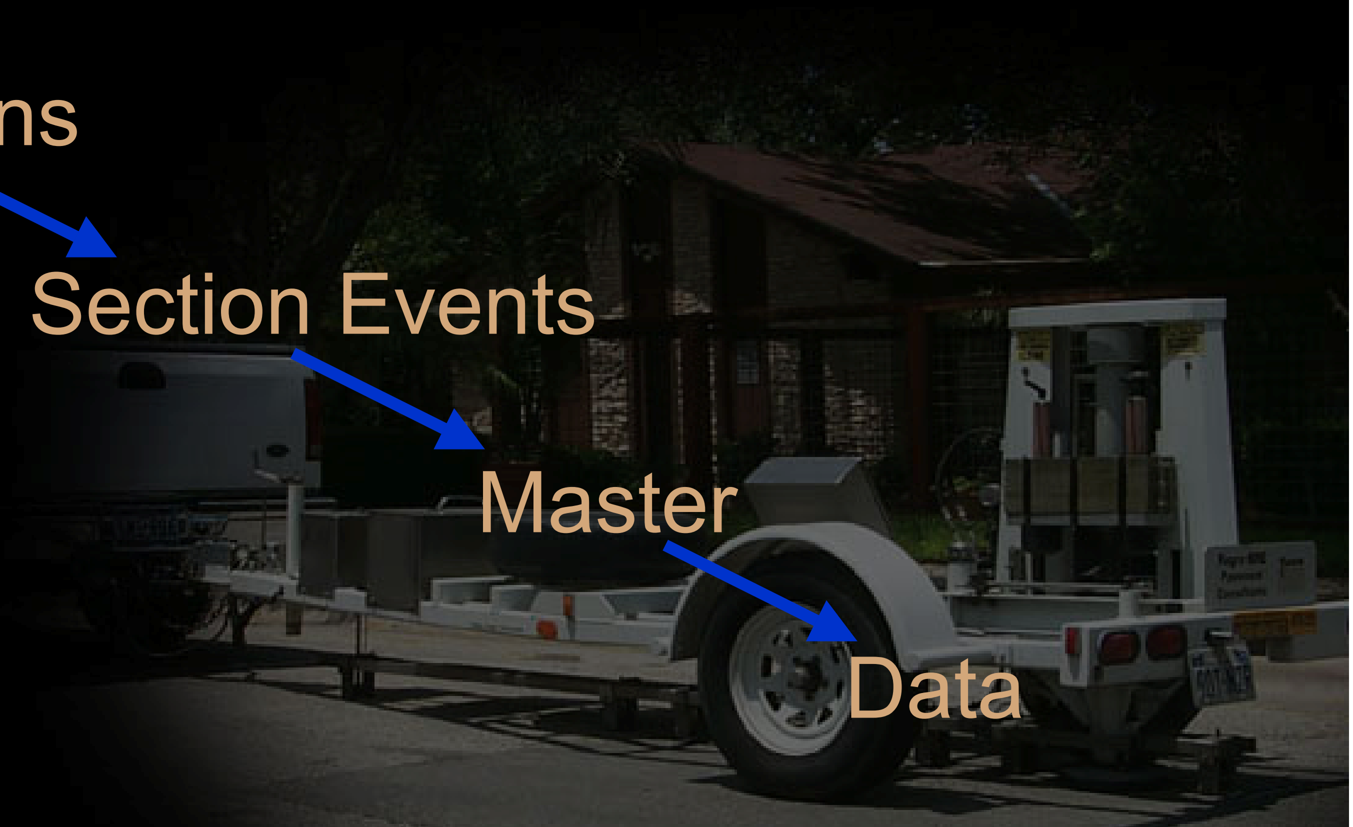
3. Store the LTPP data tables from the new release and re-establish links to these tables with the MDT calibration/ validation database
4. Use queries to delete old data and update the MDT calibration/validation database with the latest data in the most recent LTPP data release

Populating the Database-Non-LTPP Data

- Accomplished manually using forms and tables
- Detailed instructions in Volume II of Final Report

Populating the Database- Non-LTPP Data

- Populate the data tables in the following order:



Sections

Section Events

Master

Data

Presentation Outline

1. Introduction & Overview of Project
2. Determination of MEPDG Inputs
3. Database
4. **Verification & Calibration of MEPDG for Use in Montana**
5. Summary & Concluding Comments

Calibration of Distress Transfer Functions

Pavement Response

- Stresses
- Strains
- Deflections

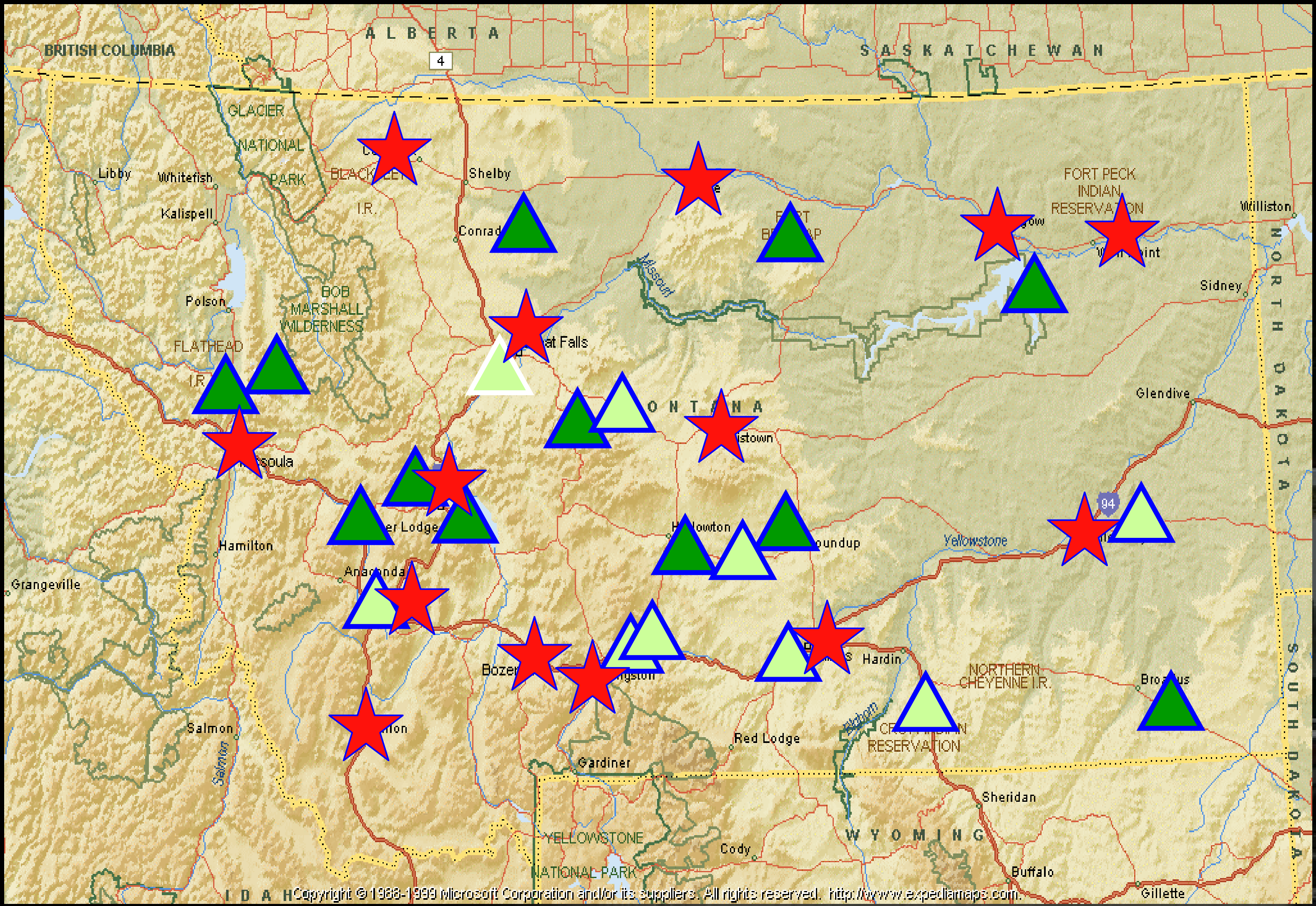
TRANSFER FUNCTION

Calibration is a key

Distress

- Fatigue Cracks
- Rut Depths
- Transverse Cracks

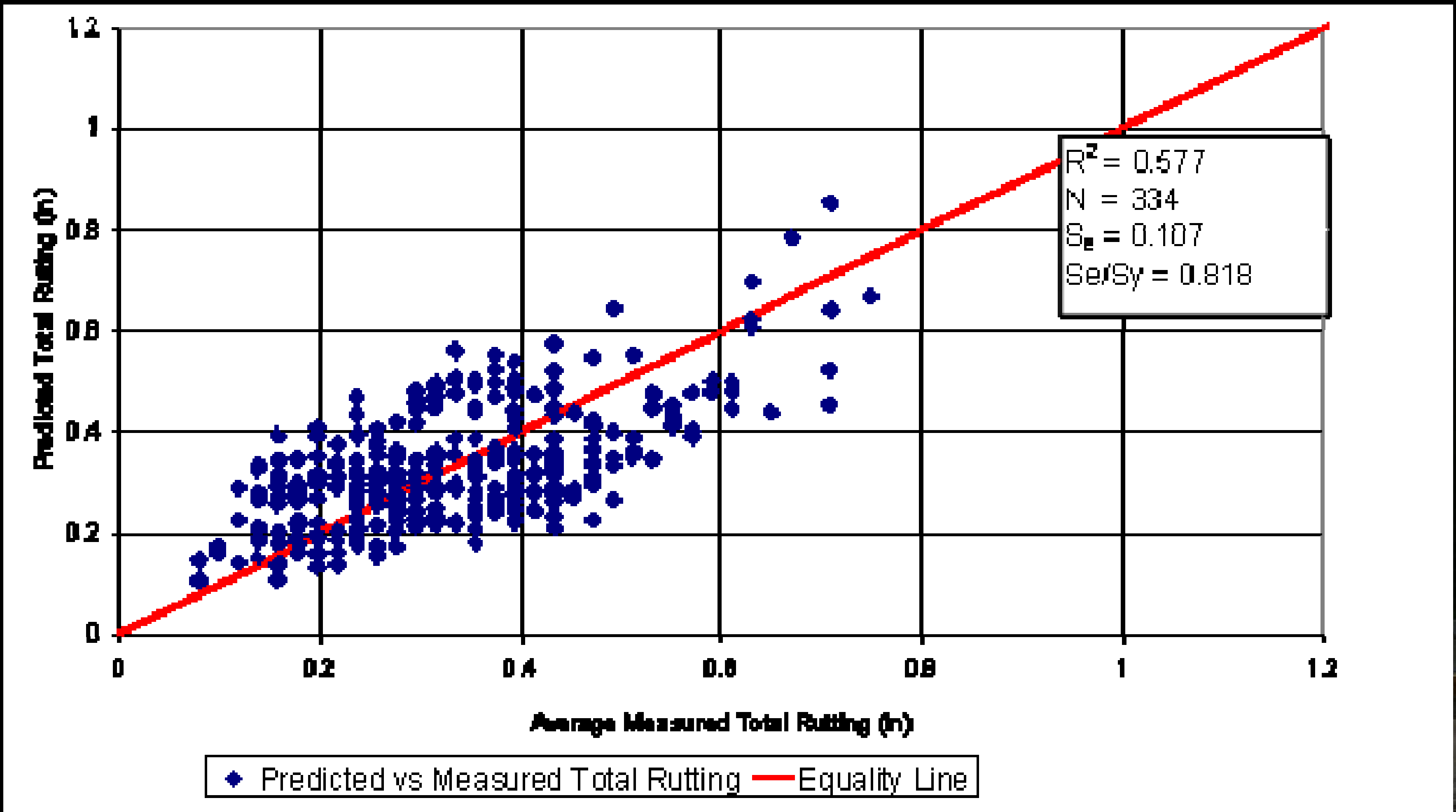
Test Sections
Weather Stations



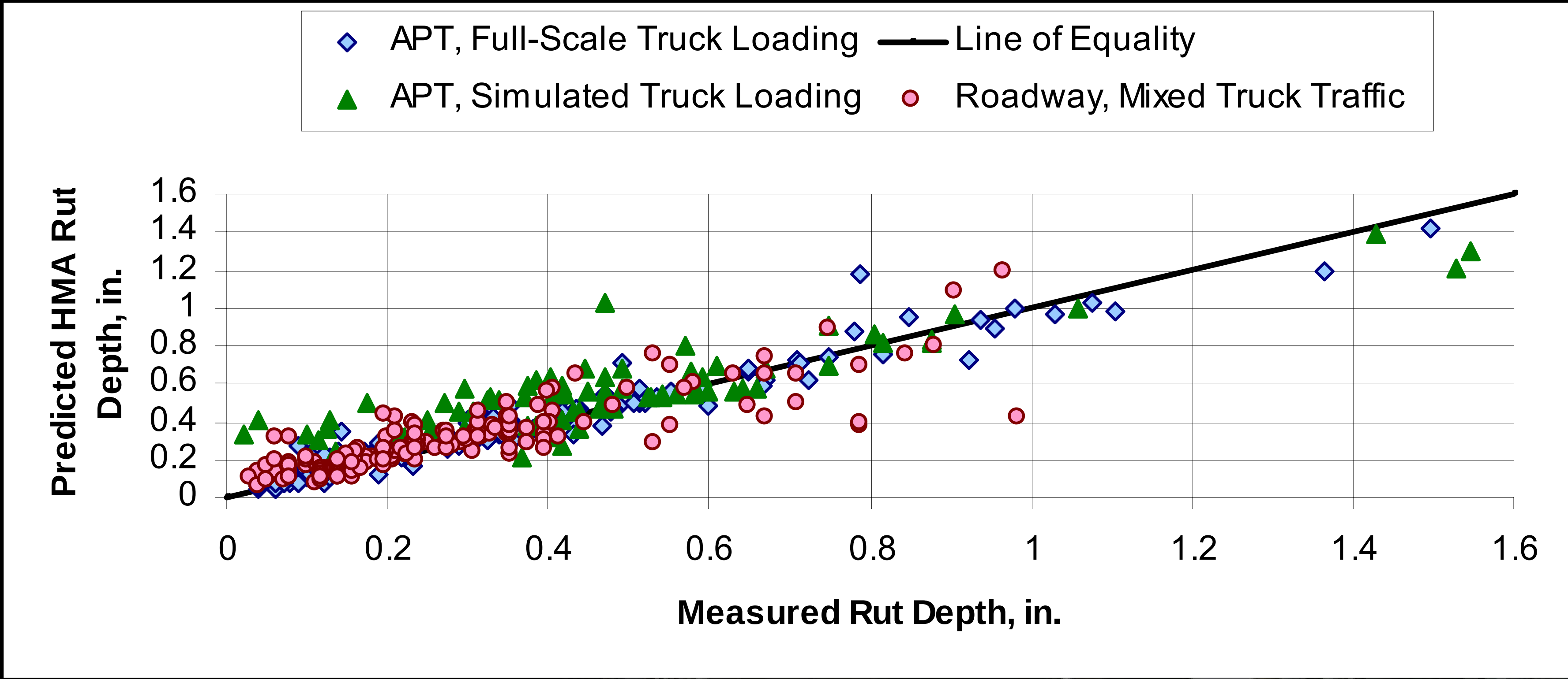
Rut Depth Prediction Model

- Unbound Layers
- HMA Layers

Total Rutting: NCHRP 1-40D



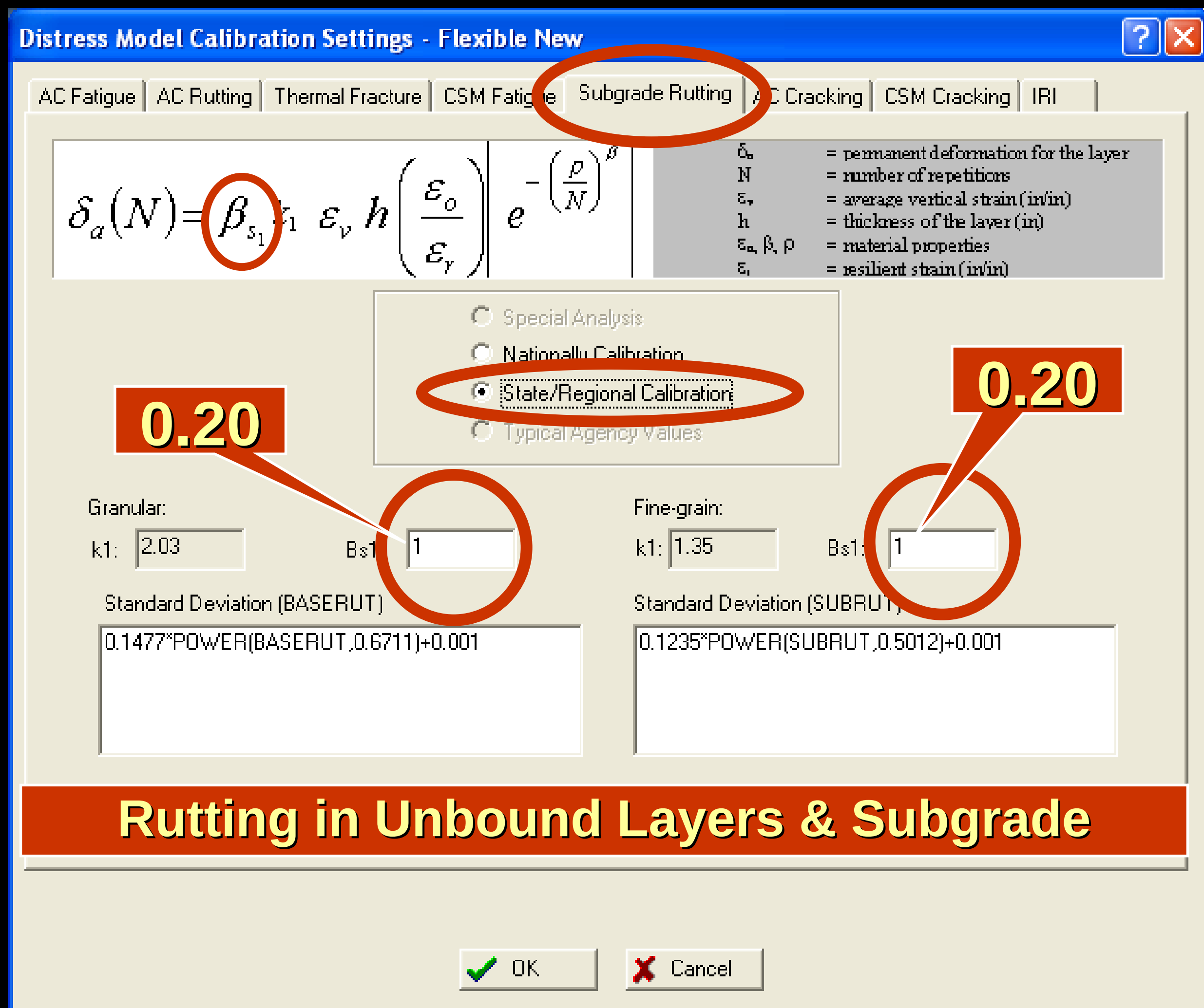
HMA Rutting: NCHRP 1-40B



# of Points	Bias	RMSE	S_e/S_y	R^2
418	0.0303	0.1170	0.439	0.837

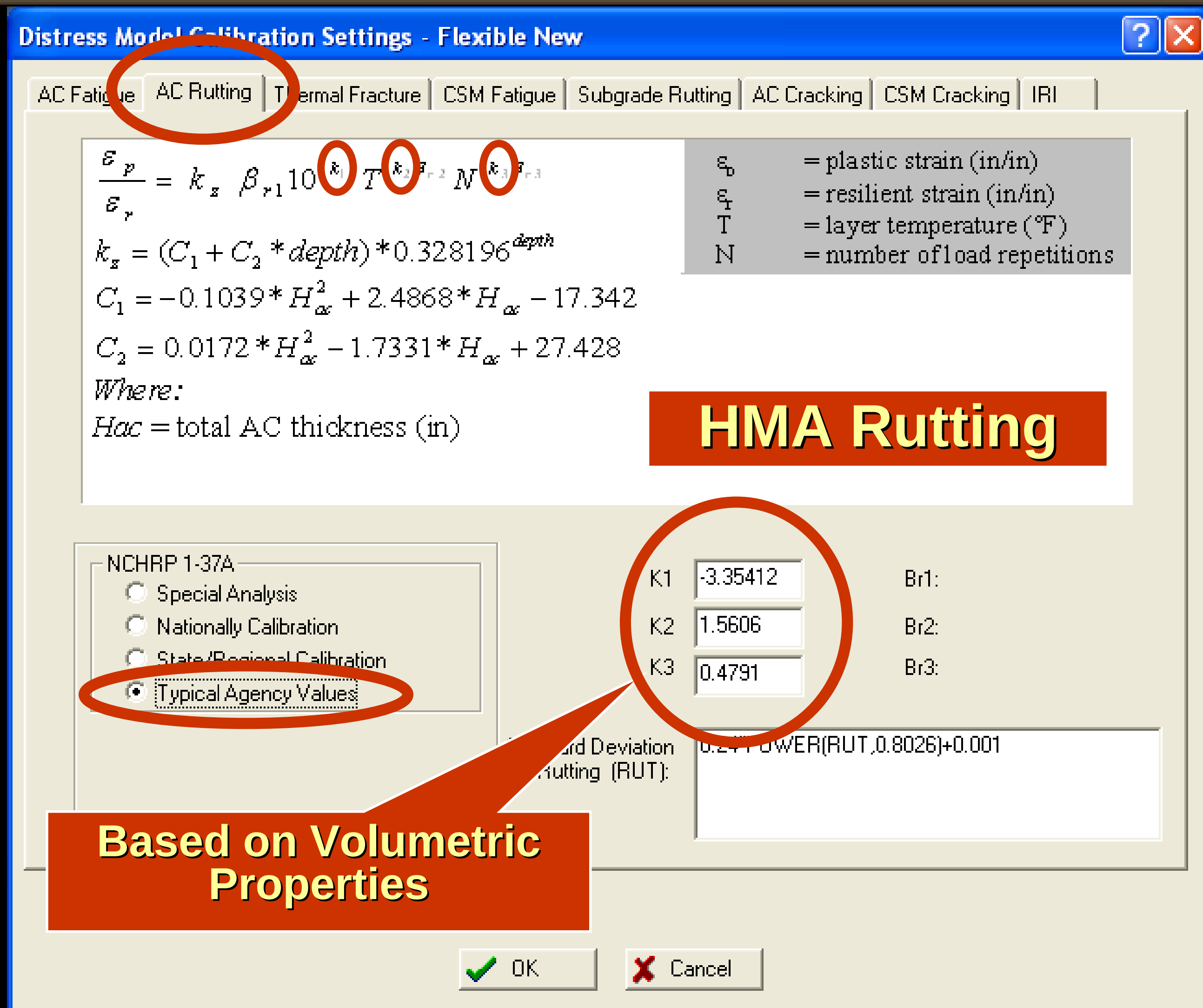
Tools Menu,Drop-Down Box

Rutting, Unbound Layers



$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_o}{\varepsilon_r}\right) e^{-\left(\frac{\rho}{N}\right)^{\beta}}$$

HMA Rutting



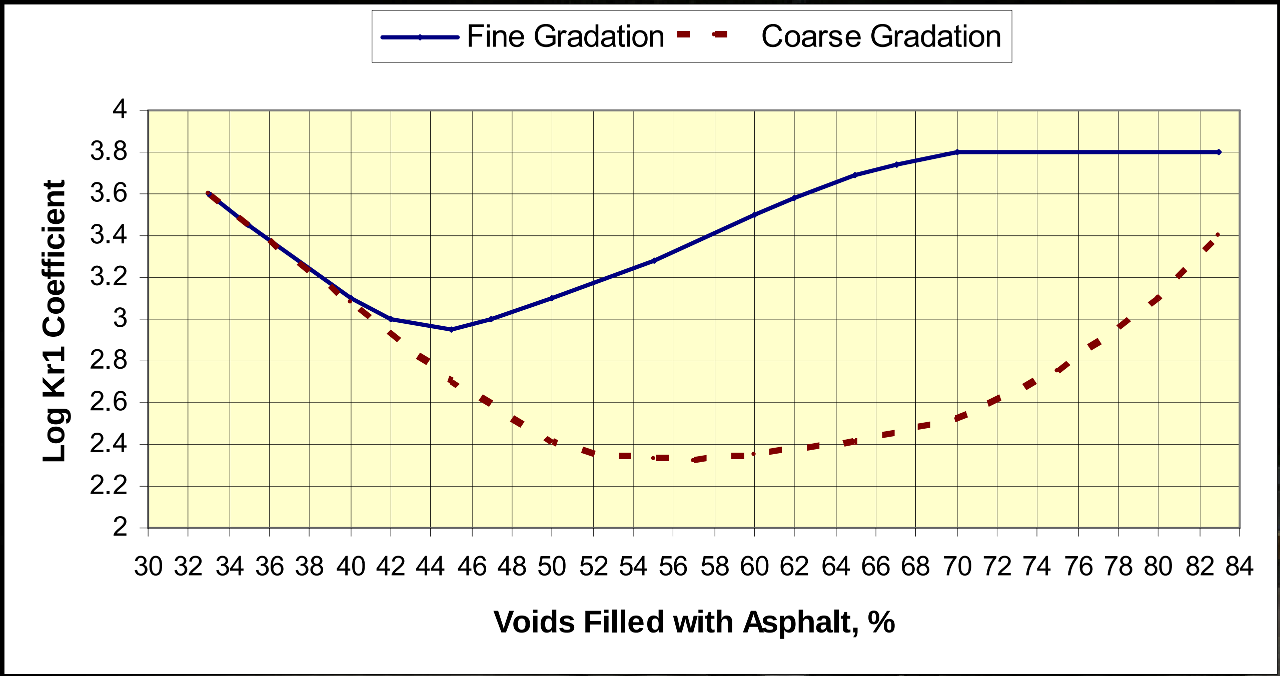
Distress Model Calibration Settings - Flexible New
AC Fatigue
AC Rutting
Thermal Fracture
CSM Fatigue
Subgrade Rutting
AC Cracking
CSM Cracking
IRI
$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$
$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$
$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$
$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$
Where:
Hac = total AC thickness (in)
ε_p = plastic strain (in/in)
ε_r = resilient strain (in/in)
T = layer temperature (°F)
N = number of load repetitions
HMA Rutting
NCHRP 1-37A
Special Analysis
Nationally Calibration
State/Regional Calibration
Typical Agency Values
K1 -3.35412
K2 1.5606
K3 0.4791
Br1:
Br2:
Br3:
Standard Deviation Rutting (RUT):
0.24*POWER(RUT,0.8026)+0.001
Based on Volumetric Properties
OK
Cancel

Calibration Refinement

Determine the k_{r1} coefficient

$$k_{r1} = Log\left[0.0015093\left(K_{r1}\right)\left(V_a\right)^{0.5213}\left(V_{be}\right)^{1.0057}\right] - 3.4488$$

V_a= Air Voids, %
V_{be}= Effective asphalt content by volume, %



Calibration Refinement

Determine the k_{r2}, temperature exponent

$$k_{r2} = 1.5606\left(\frac{V_a}{V_{a(Design)}}\right)^{0.25}\left(\frac{P_b}{P_{b(Design)}}\right)^{1.25}\left(F_{Index}\right)\left(C_{Index}\right)$$

$V_{a(Design)}$	= Design air void level to determine asphalt content, %
P_b	= Asphalt content by weight, %
$P_{b(Design)}$	= Design asphalt content by weight, %
F_{Index}	= Fine aggregate angularity index
C_{Index}	= Coarse aggregate angularity index

Calibration Refinement

F_{Index}		
Gradation; Restricted Zone	Fine Aggregate Angularity	
	<45	>45
Dense, External	1.00	0.90
Dense, Through	1.05	1.00

C_{Index}					
Gradation	Percent Crushed with Two Faces				
	0	25	50	75	100
Well-Graded	1.1	1.05	1.0	1.0	0.9
Gap-Graded	1.2	1.1	1.05	1.0	0.9

Calibration Refinement

Determine the k_{r3}, number of load applications exponent

$$k_{r3} = 0.4791\left(K_{r3}\right)\left(\frac{P_b}{P_{b(Design)}}\right)$$

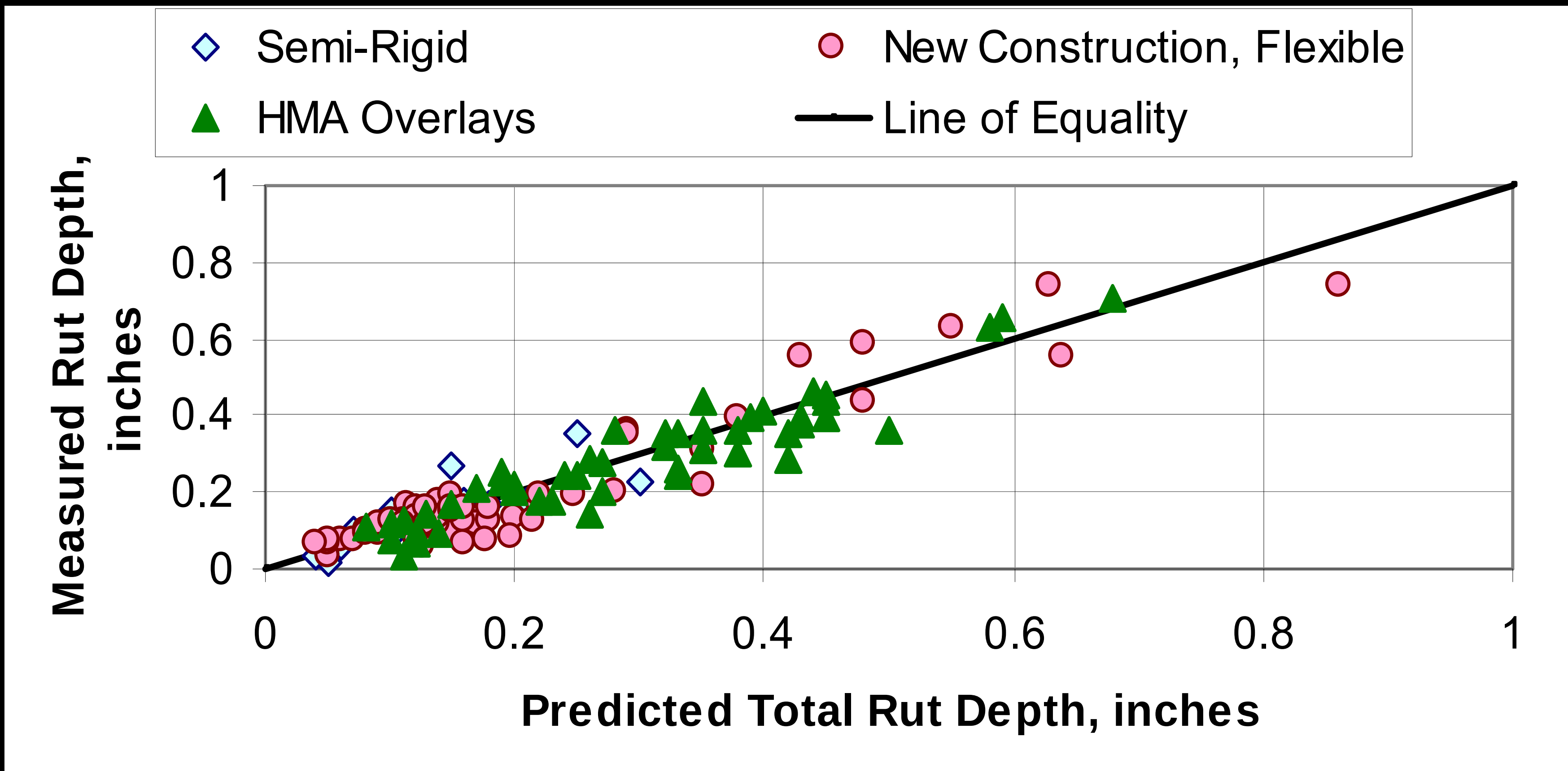
Gradation	G-Index	K_{r3}
Fine-Graded	<20	0.40
Coarse-Graded	20 to 40	0.70
Coarse-Graded	>40	0.80

Gradation Index

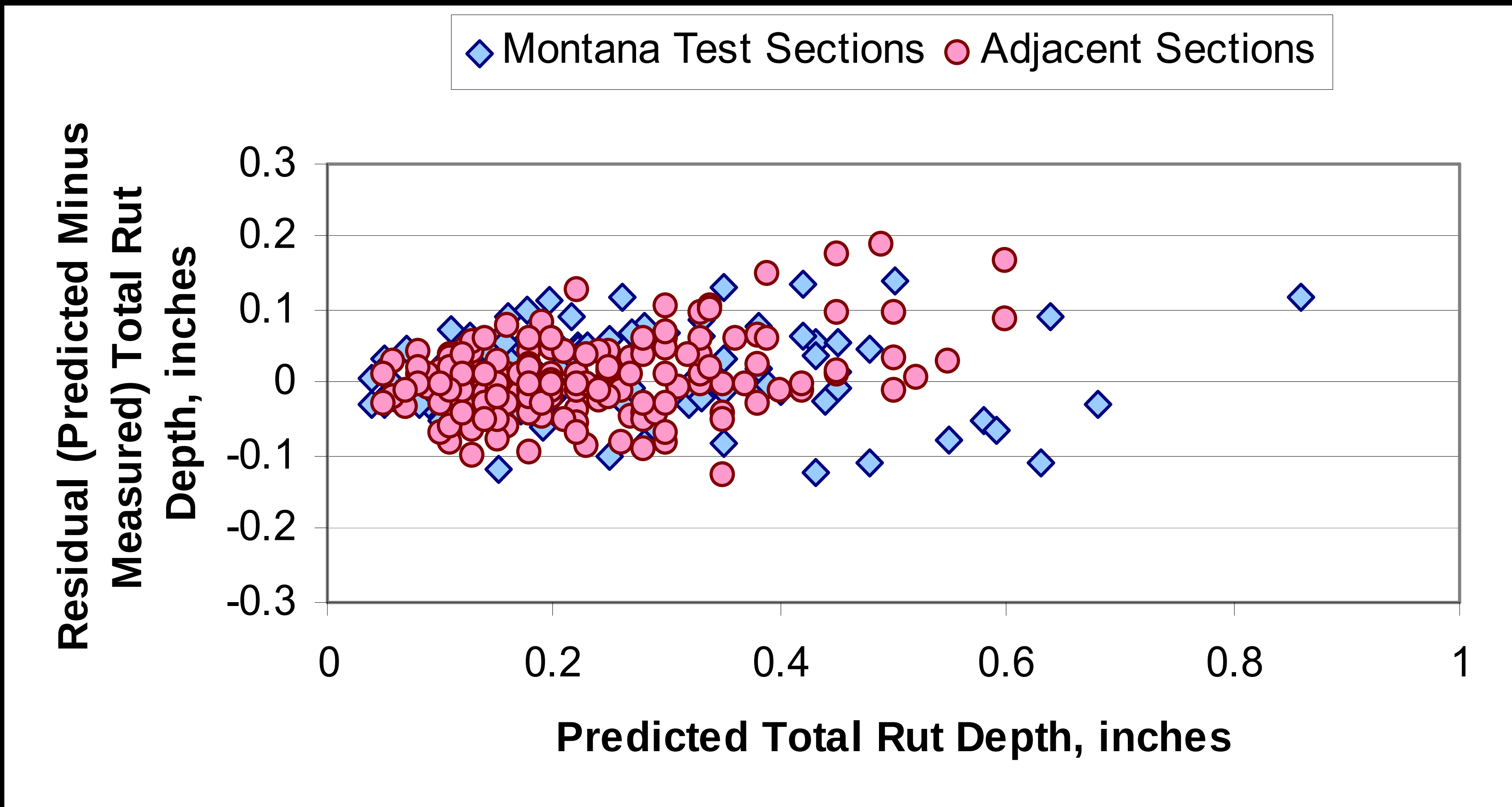
$$GI = \sum_{i=\#3/8}^{\#50} \left| P_i - P_{i(0.45)} \right|$$

GI	= Gradation Index
P_i	= Percent passing sieve size i, %
$P_{i(0.45)}$	= Percent passing sieve size i for the FHWA 0.45 maximum density line

Total Rutting



Total Rutting



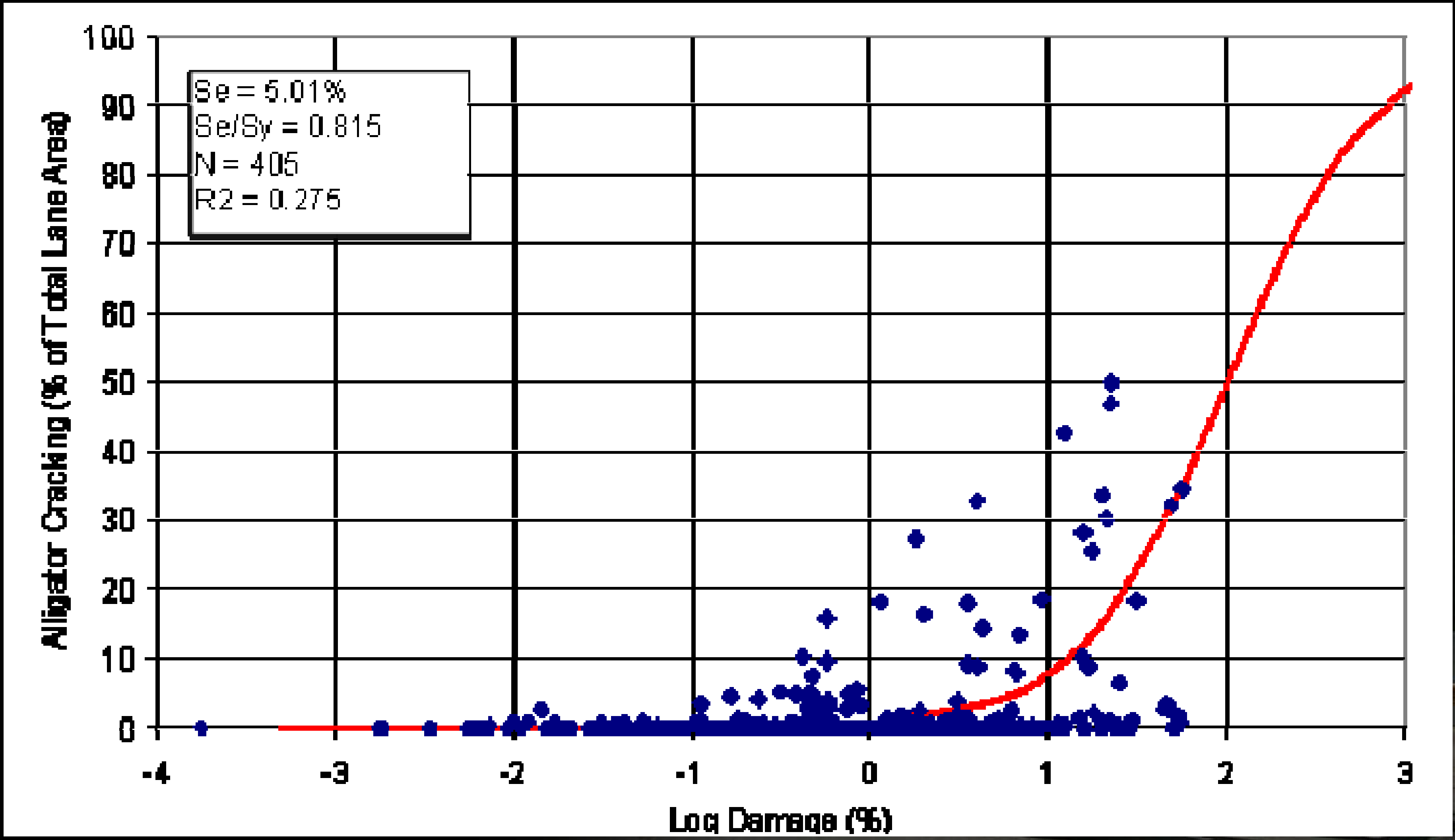
MDT Calibration Project: Total Rutting

Type of Pavement		No. of Points	Bias, in.	Standard Error, in.	RMSE, in.	S_e/S_y
MT Sites	New Construction, Flexible Pavts	67	0.0069	0.0536	0.1098	0.342
	Semi-Rigid Pavts	18	-0.0103	0.0457	0.0789	0.662
	HMA Overlays of Flexible Pavts	50	0.0126	0.0520	0.0937	0.359
All Sites	New Construction, Flexible Pavts	72	0.0108	0.0539	0.0988	0.418
	Semi-Rigid Pavts	32	-0.0023	0.0472	0.0833	0.384
	HMA Overlays, All Type Pavts	75	0.0058	0.0494	0.0941	0.4927

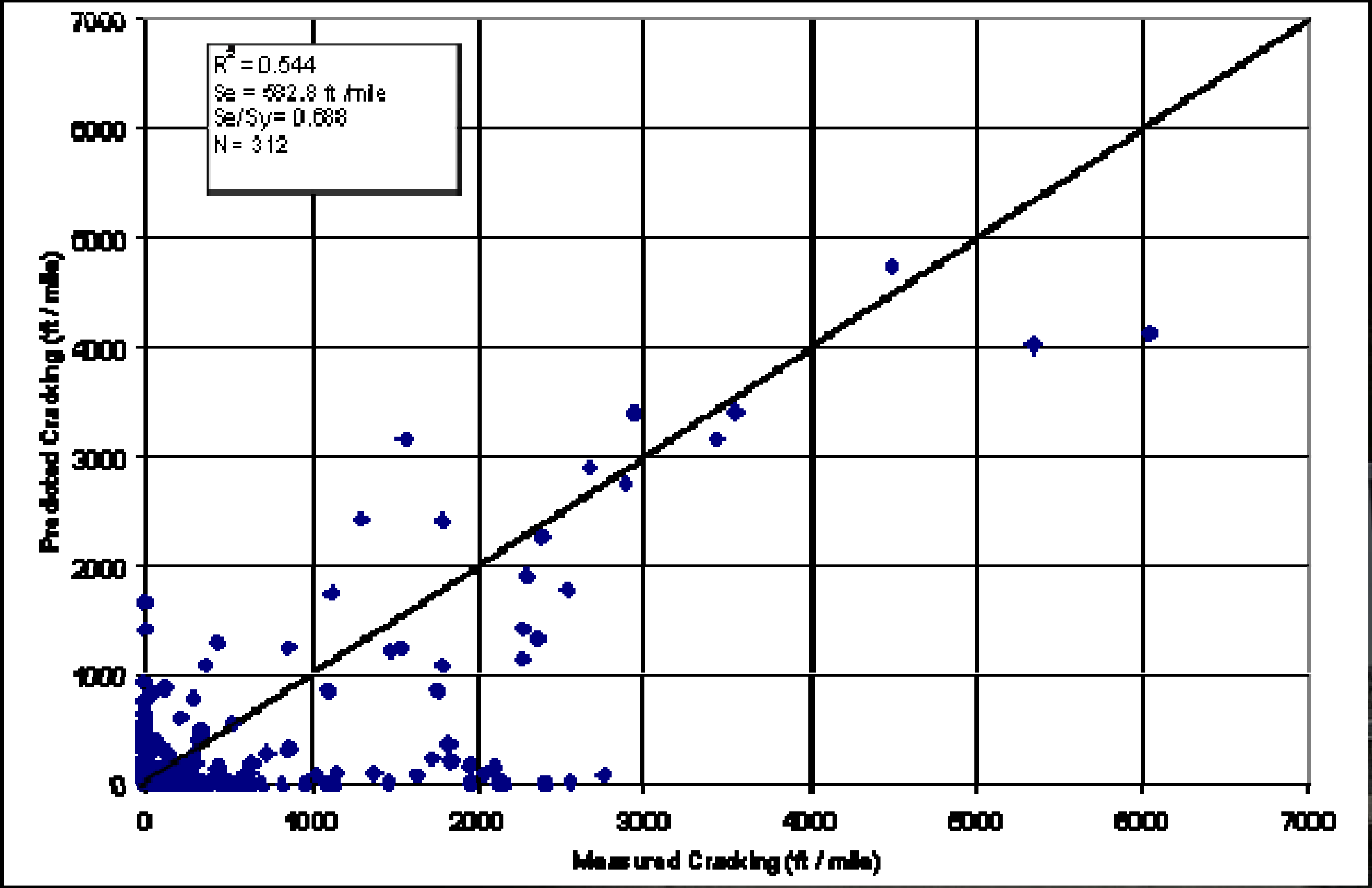
Load Related Cracking Model

- Surface Initiated Cracks - LCWP
- Bottom Initiated Cracks – Area Cracking

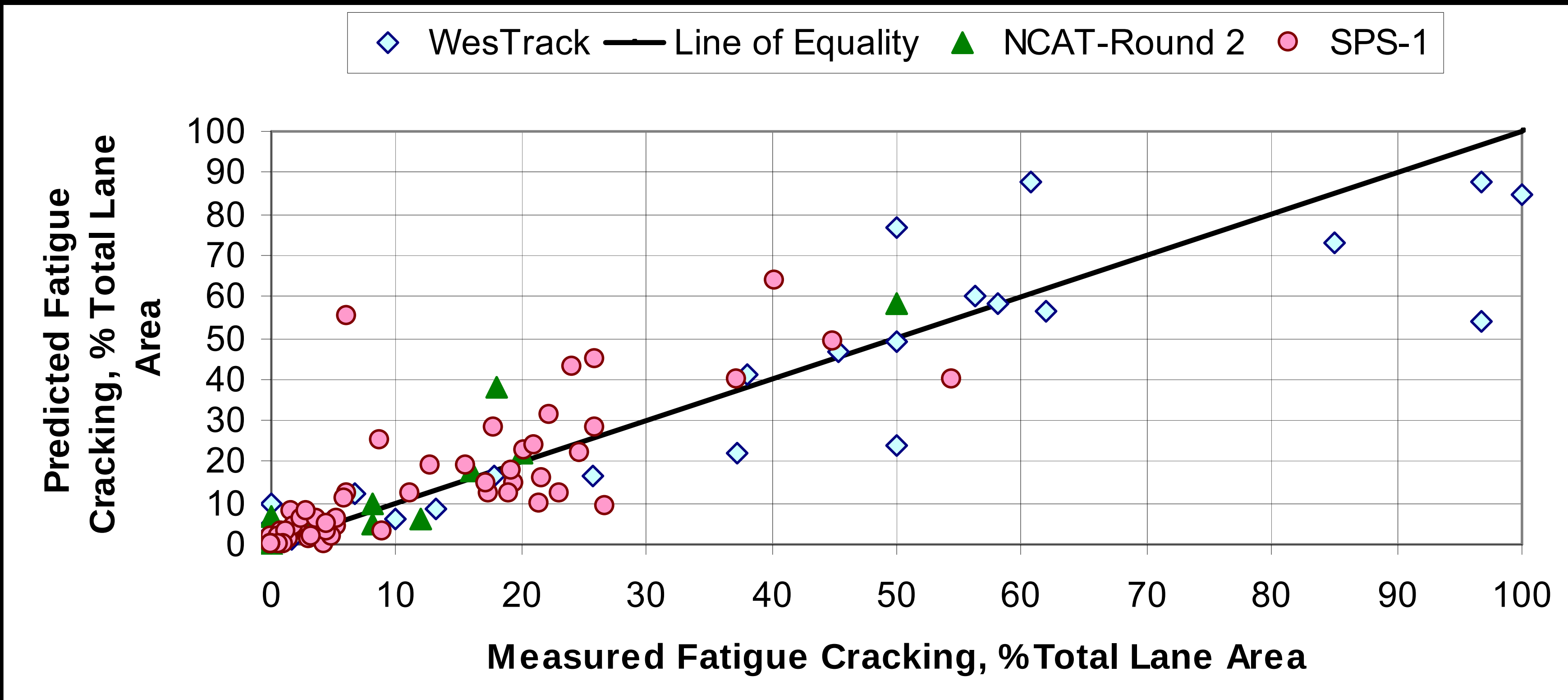
Alligator Cracking – HMA: NCHRP 1-40D



Longitudinal Cracking – HMA: NCHRP 1-40D

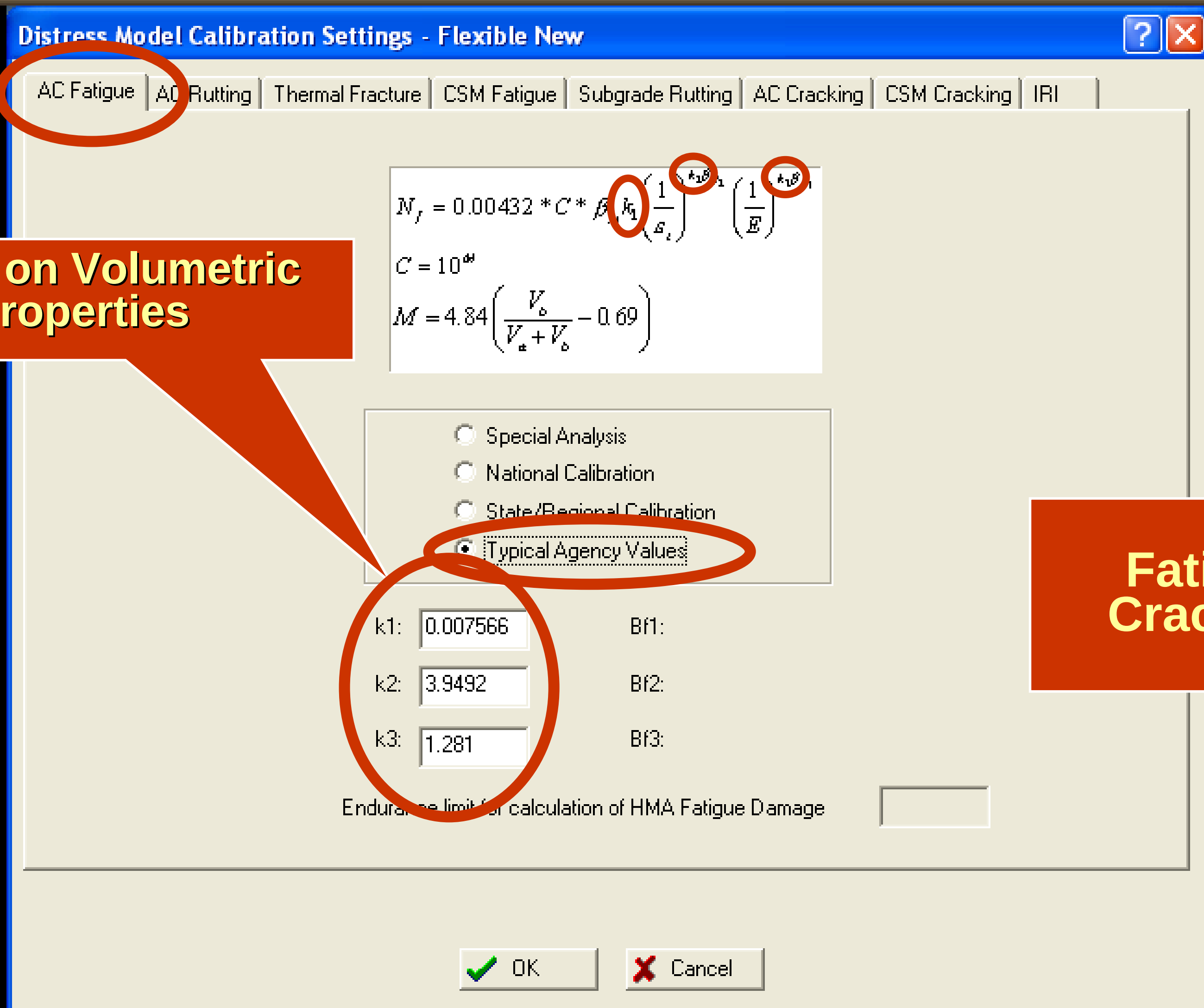


Alligator Cracking – HMA: NCHRP 1-40B



Bias	RMSE	S_e/S_y	R^2
-0.616	7.84	0.409	0.841

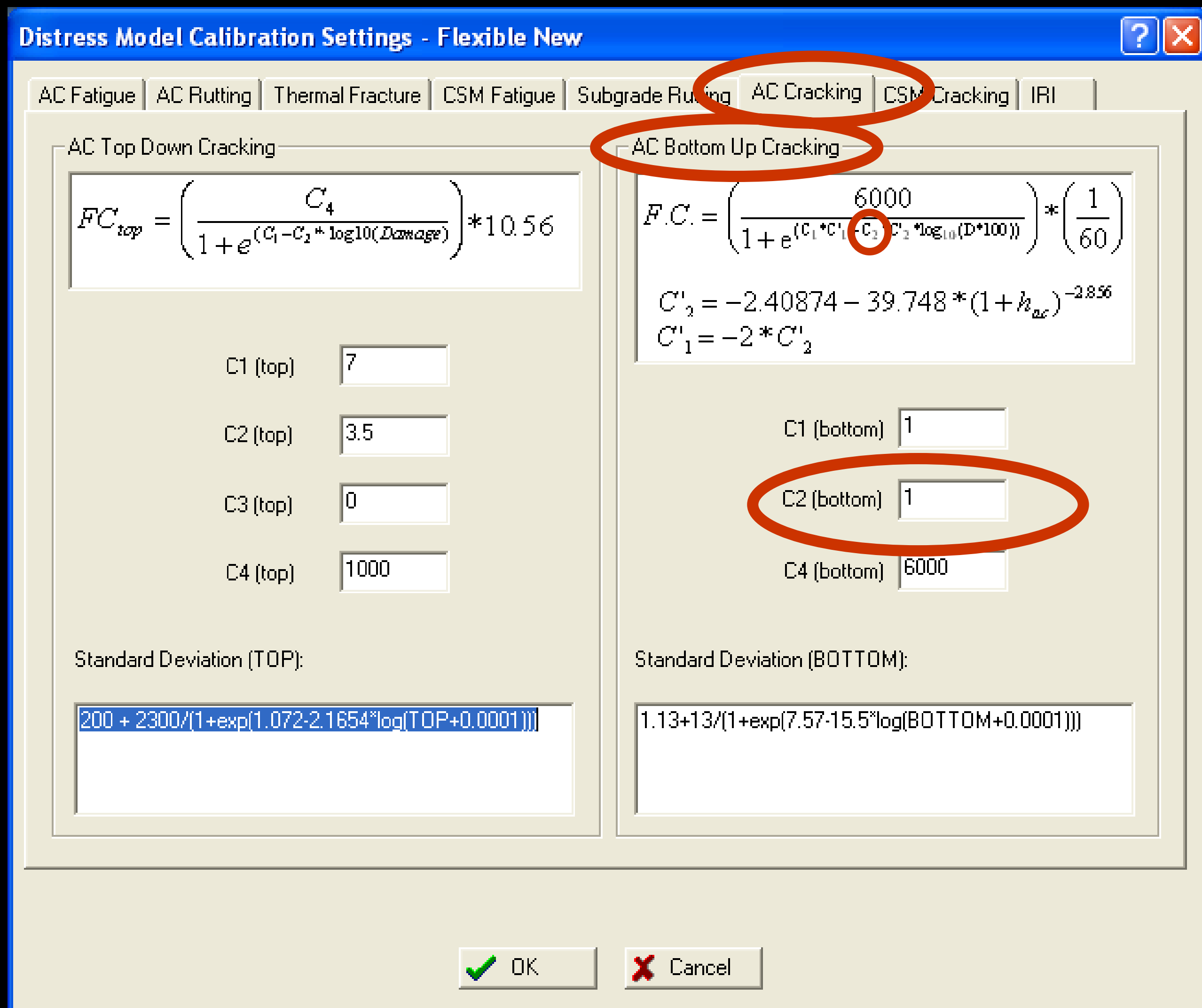
Fatigue Cracking



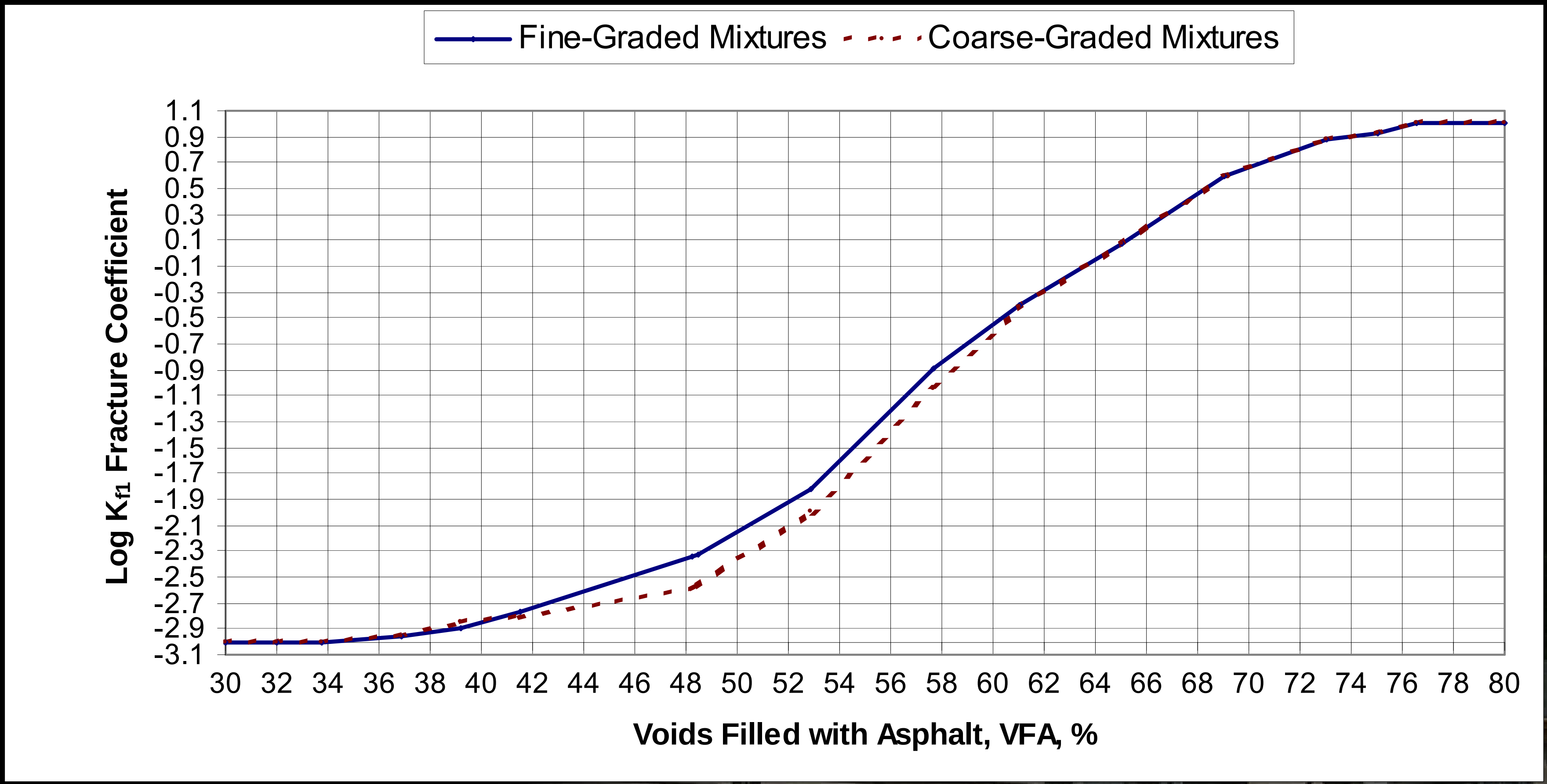
Based on Volumetric Properties

Fatigue Cracking

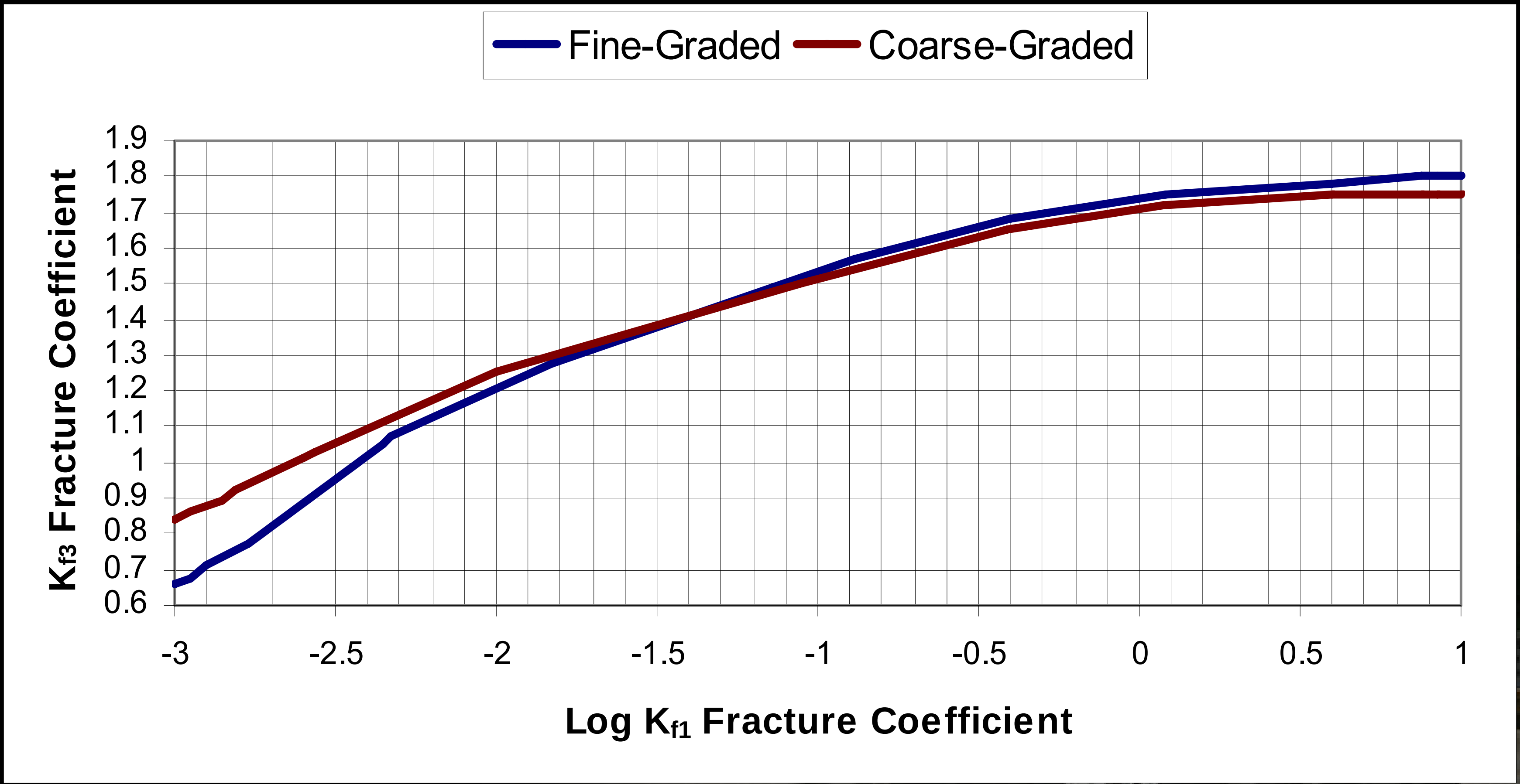
Fatigue Cracking



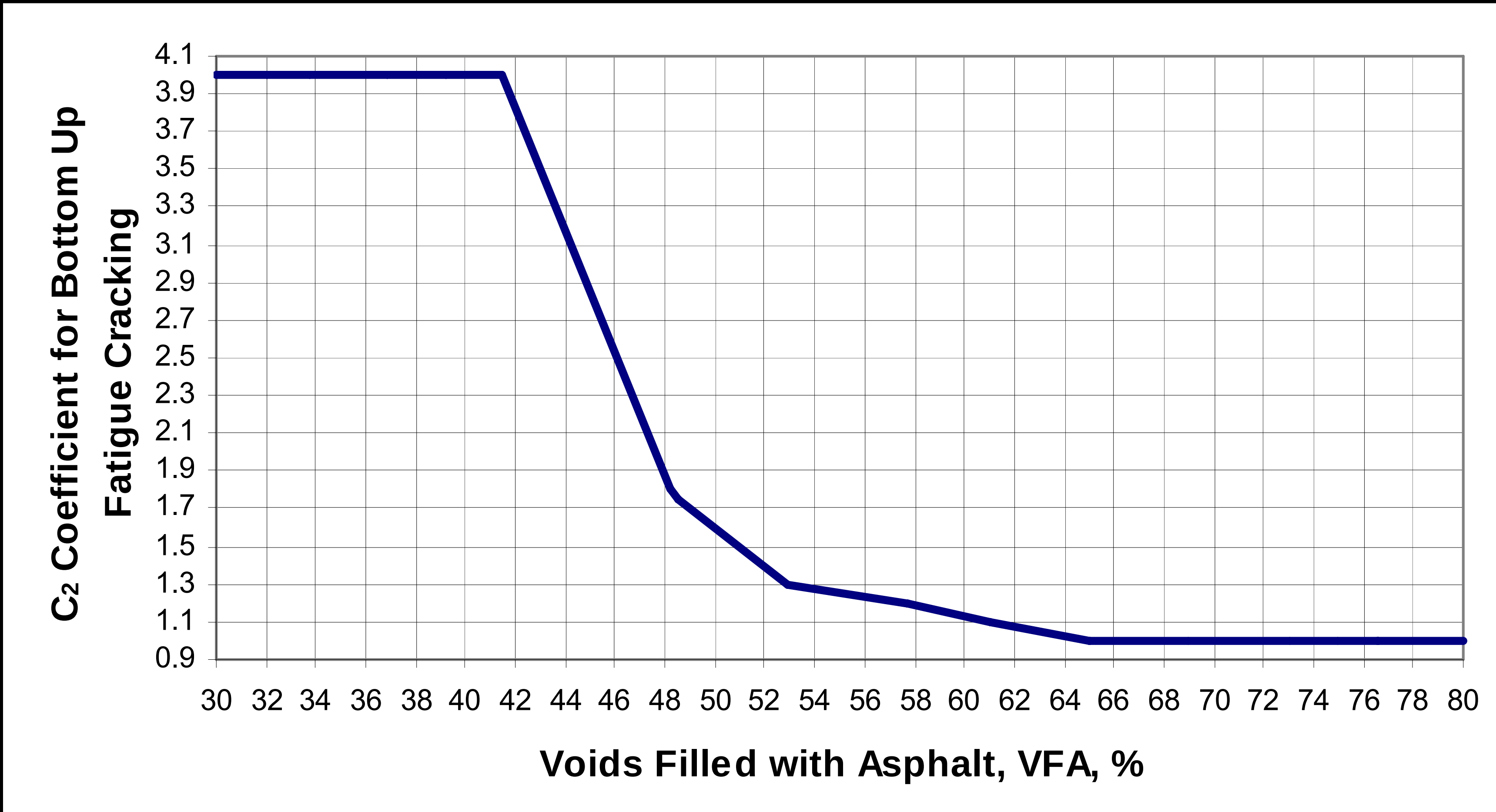
Fatigue Cracking – Mix Calibration Adjustment



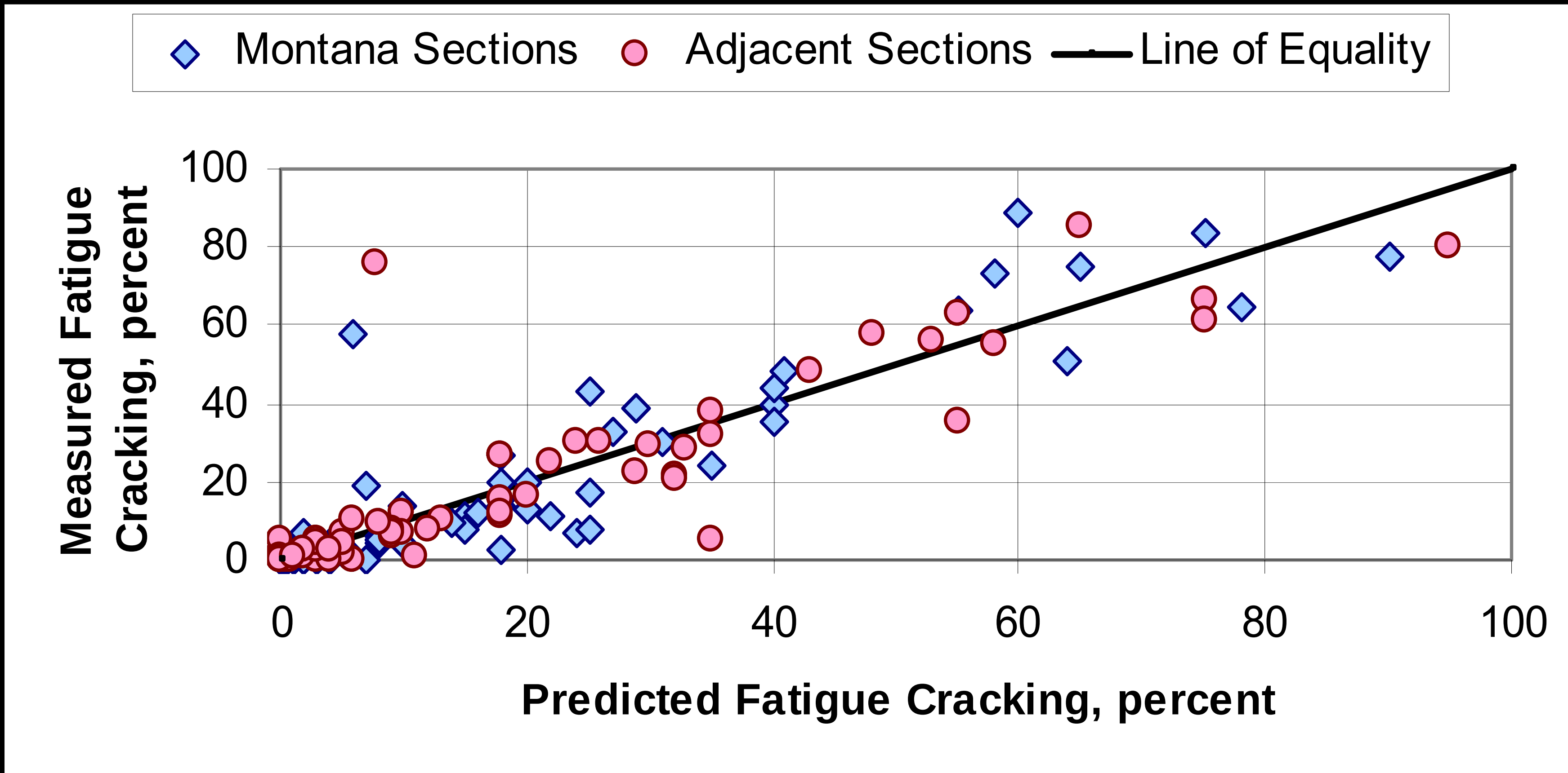
Fatigue Cracking – Mix Calibration Adjustment



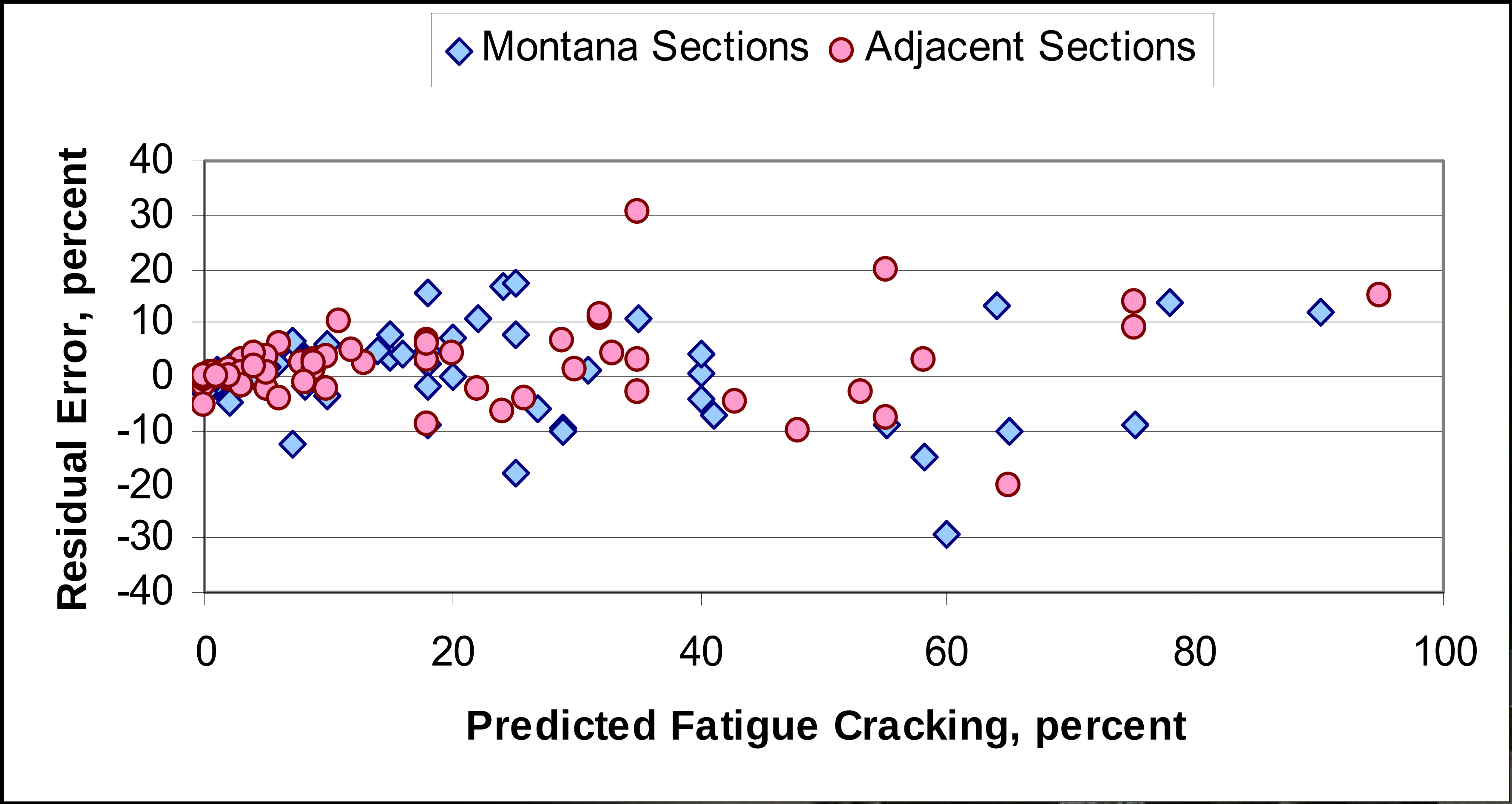
Fatigue Cracking – Calibration Refinement Adjustments



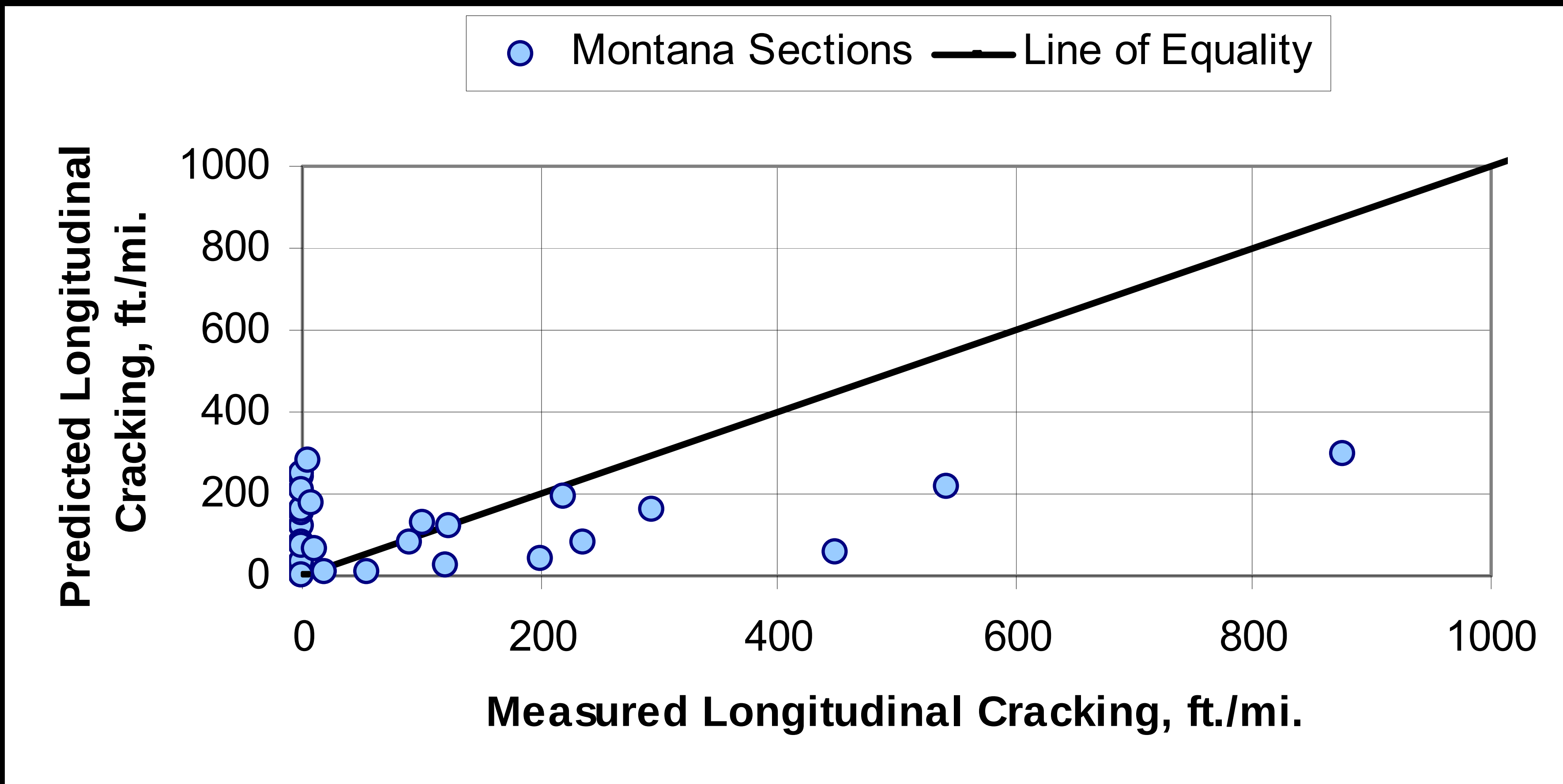
Fatigue Cracking



Fatigue Cracking



Longitudinal Cracking



Fatigue Cracking, Semi-Rigid

Distress Model Calibration Settings - Flexible New

AC Fatigue | AC Rutting | Thermal Fracture | CSM Fatigue | Subgrade Rutting | AC Cracking | CSM Cracking | IRI

$$N_f = 10^{\left(\frac{k_1\beta_{c1} - \left(\frac{\sigma_s}{M_r}\right)}{k_2\beta_{c2}}\right)}$$

N_f = number of repetitions to fatigue cracking
σ_s = Tensile stress (psi)
M_r = modulus of rupture (psi)

- Special Analysis
- National Calibration
- State/Regional Calibration
- Typical Agency Values

k1: 1
k2: 1

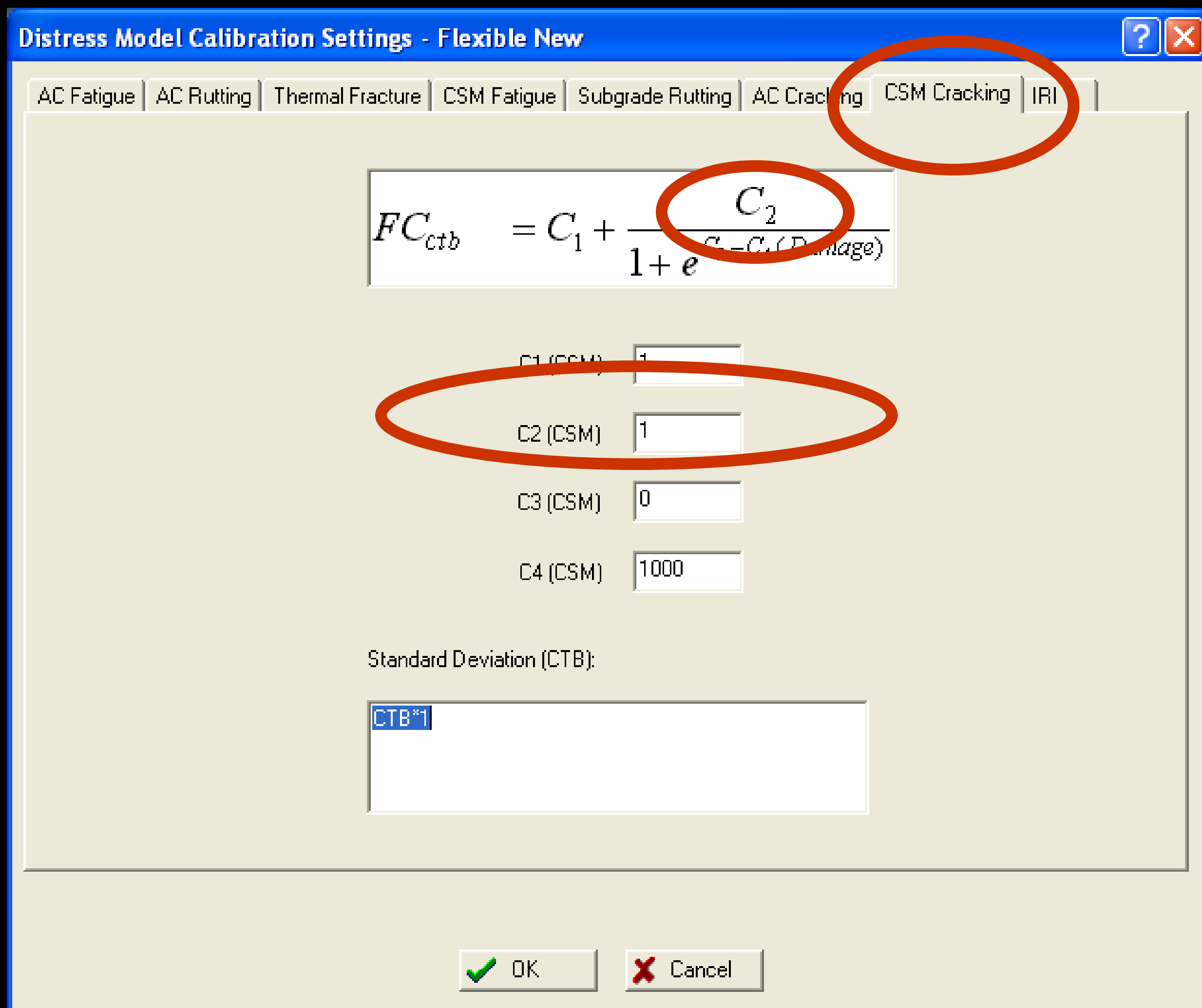
Bc1: 1
Bc2: 1

Factor Dependent on CAM Strength

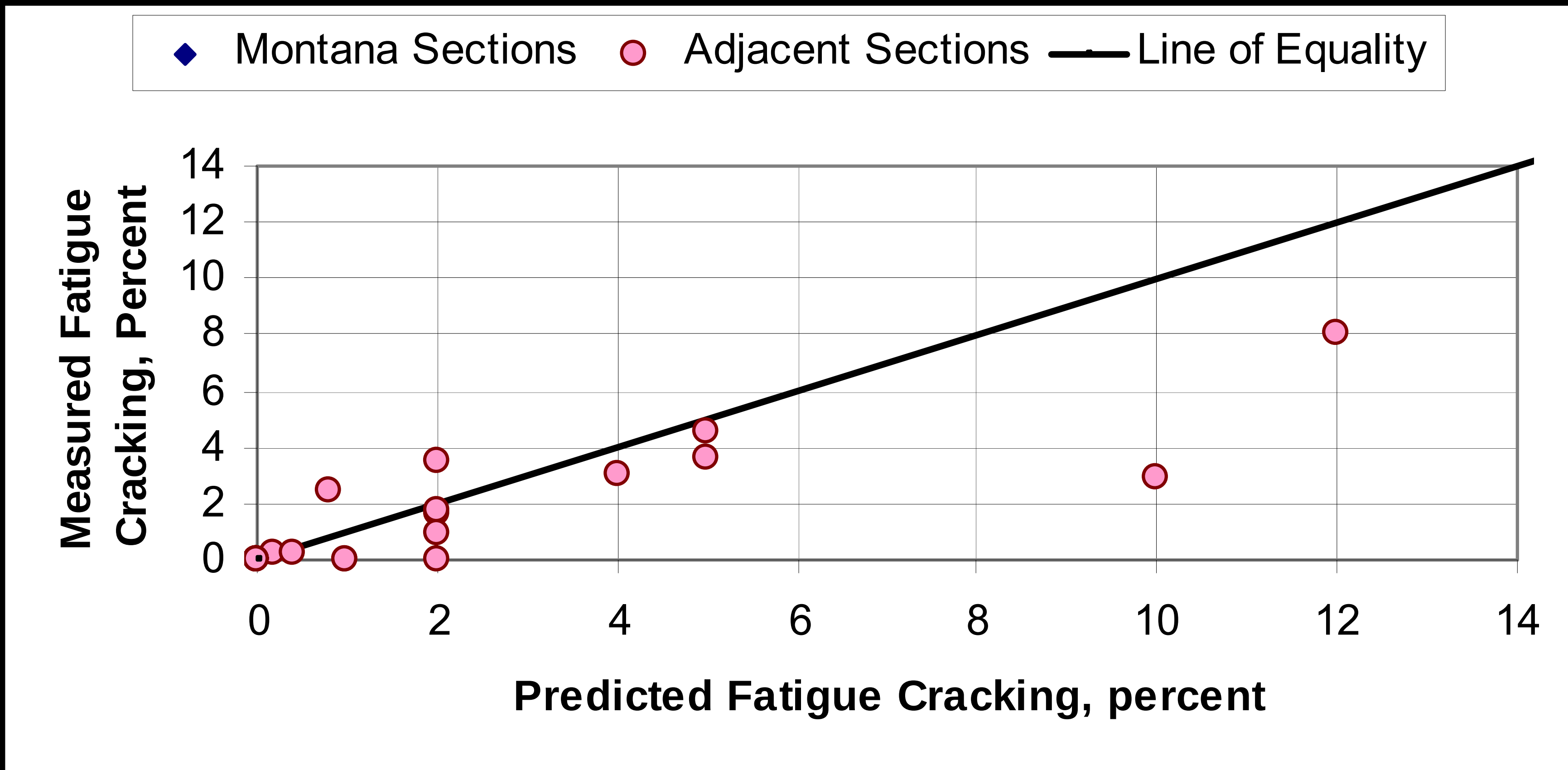
Fatigue Cracking of Semi-Rigid Pavements

OK
Cancel

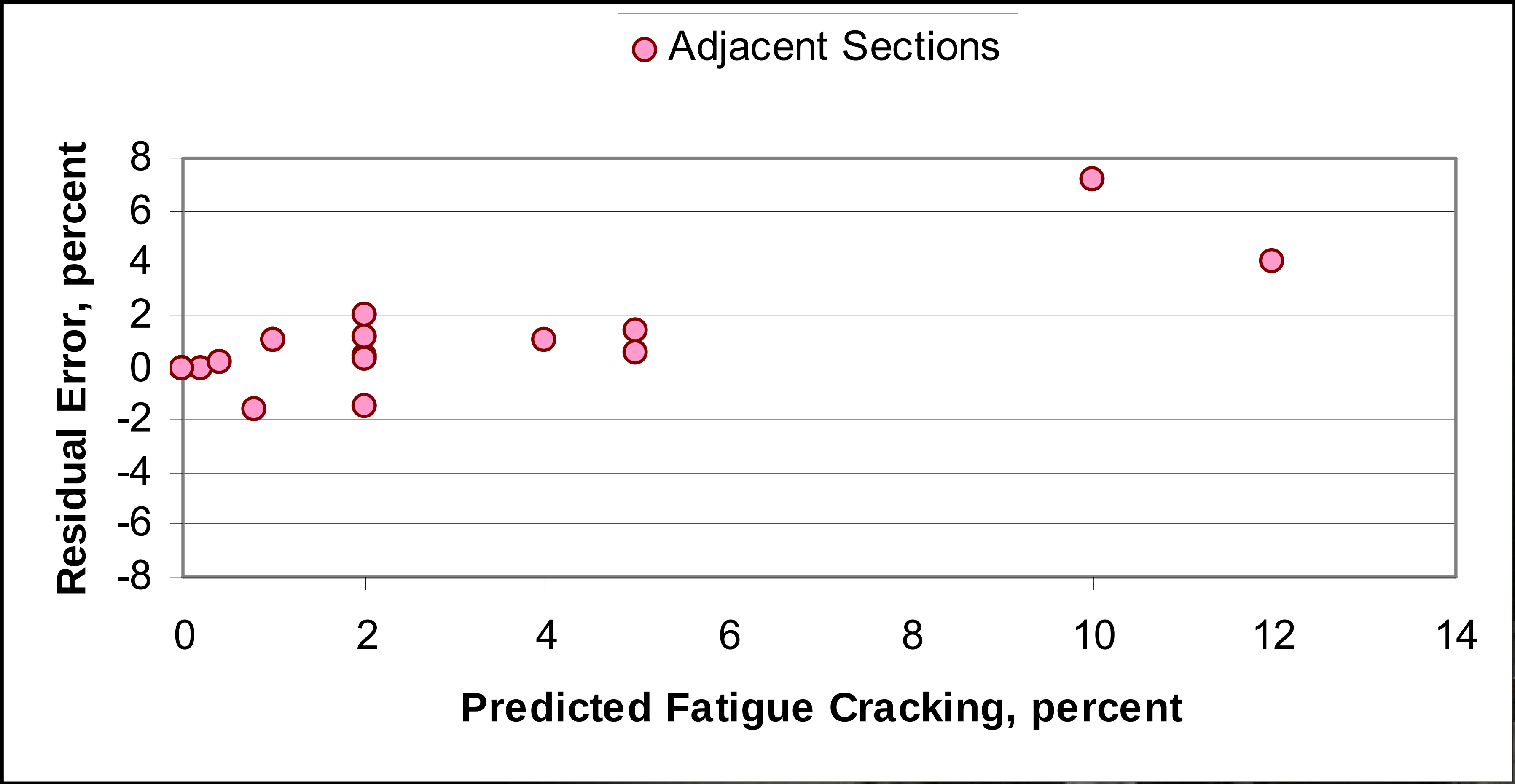
Semi-Rigid Pavements



Fatigue Cracking of Semi-Rigid



Fatigue Cracking: Semi-Rigid

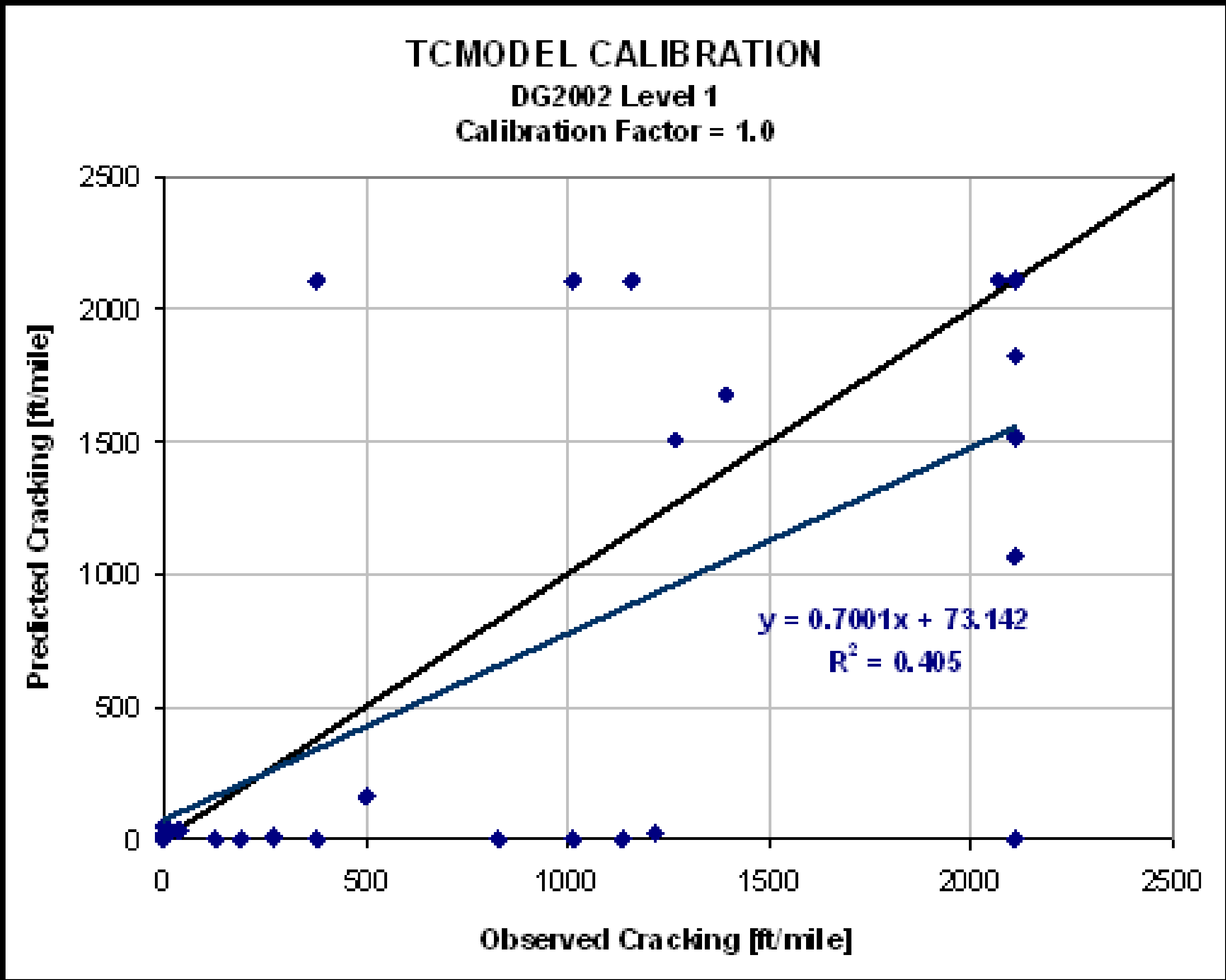


MDT Calibration Project – Alligator Cracking

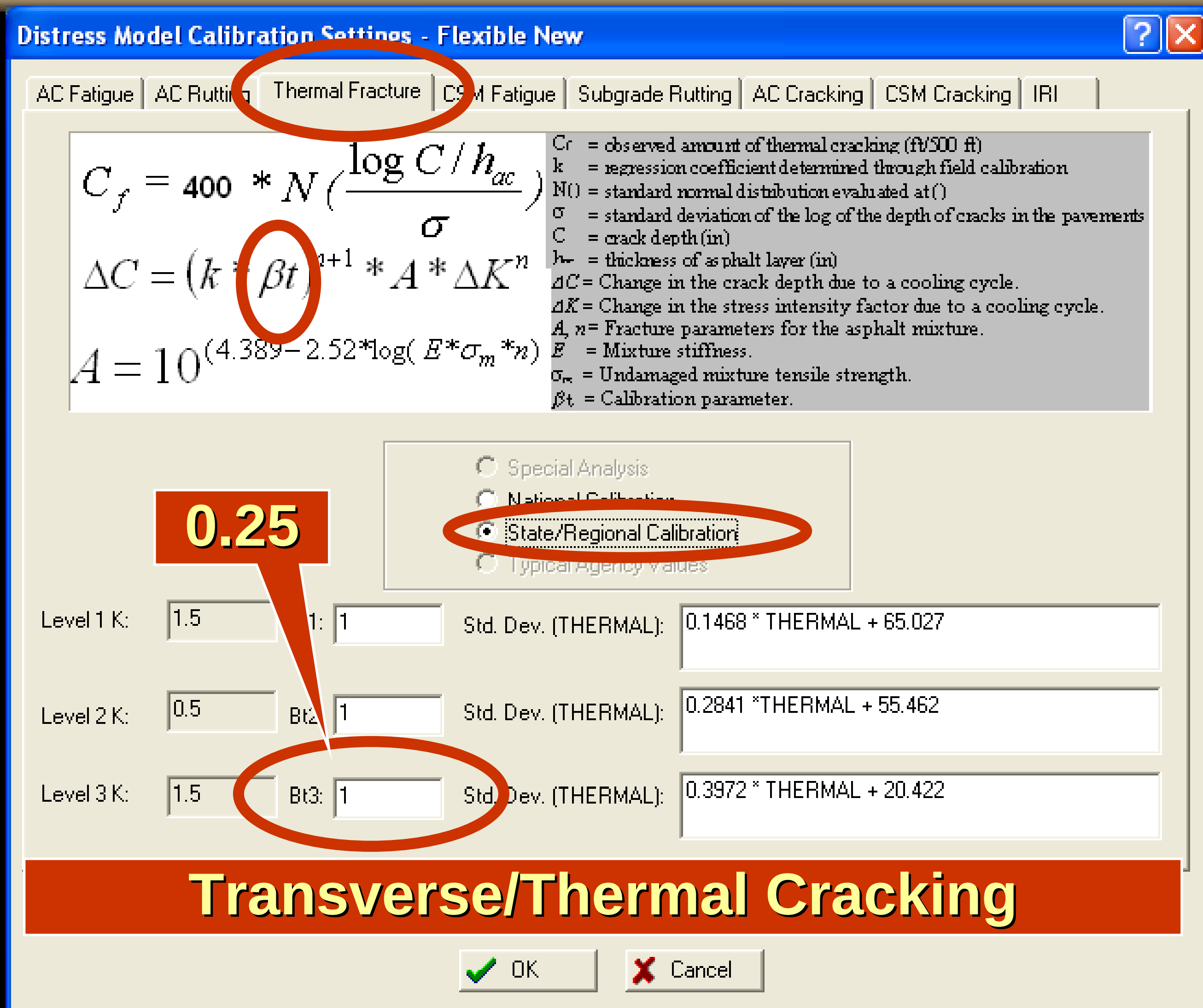
Type of Pavement		No. of Points	Bias in.	Standard Error, in.	RMSE in.	S_e/S_y
Montana Sites	New Construction; Flexible Pavts.	58	1.11	2.34	5.11	0.401
	Semi-Rigid	No alligator cracking measured!				
	HMA Overlays of Flexible Pavts.	50	-0.02	8.17	14.30	0.318
All Sites Combined	New Construction; Flexible Pavts.	76	0.15	2.45	4.67	0.315
	Semi-Rigid Pavts.	51	0.51	1.51	2.86	0.532
	HMA Overlays, All Type Pavts.	70	0.67	7.670	13.94	0.318

Transverse Cracking Prediction Model

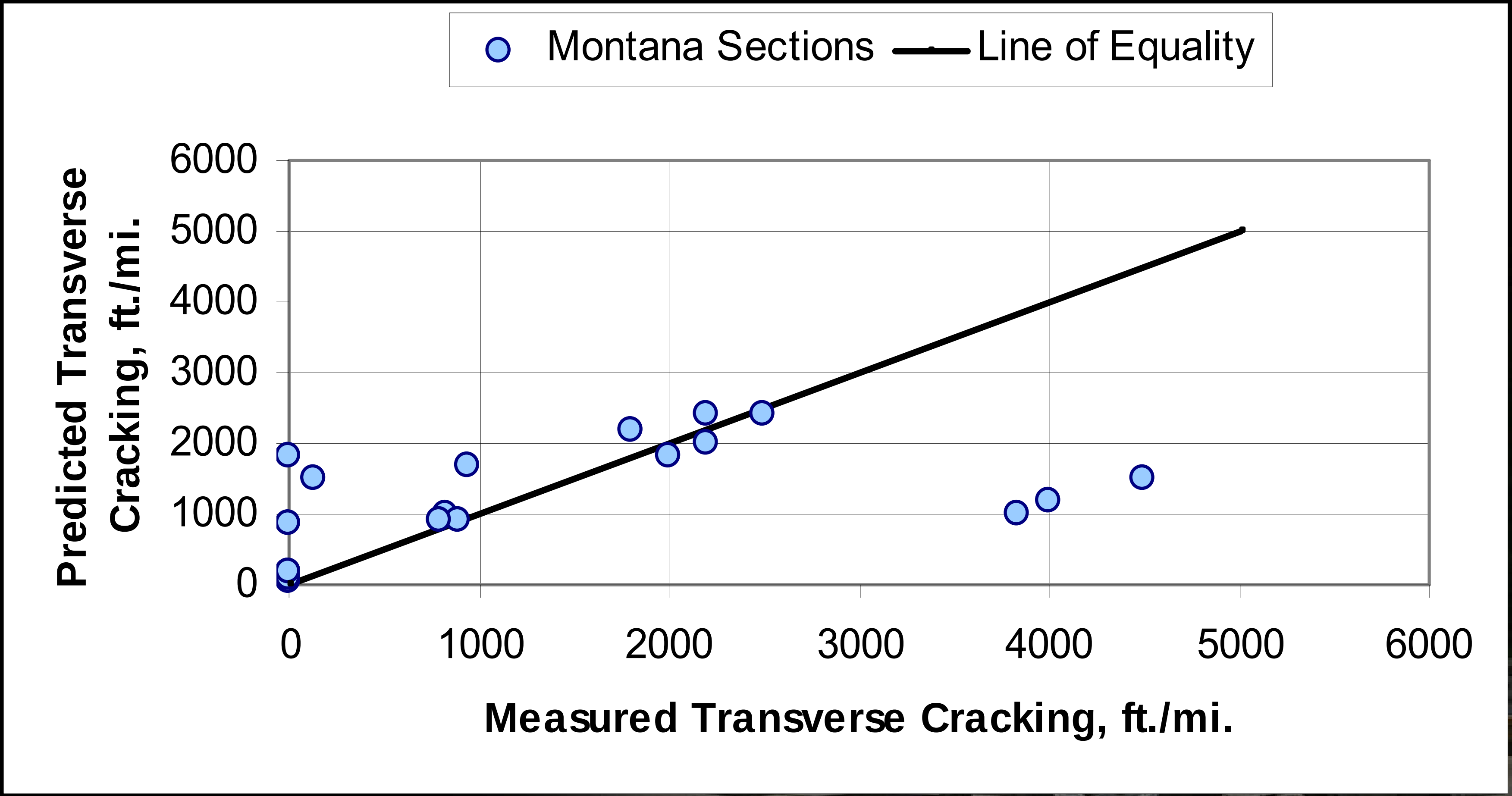
Transverse Cracking – HMA: NCHRP 1-40D



Transverse/Thermal Cracking

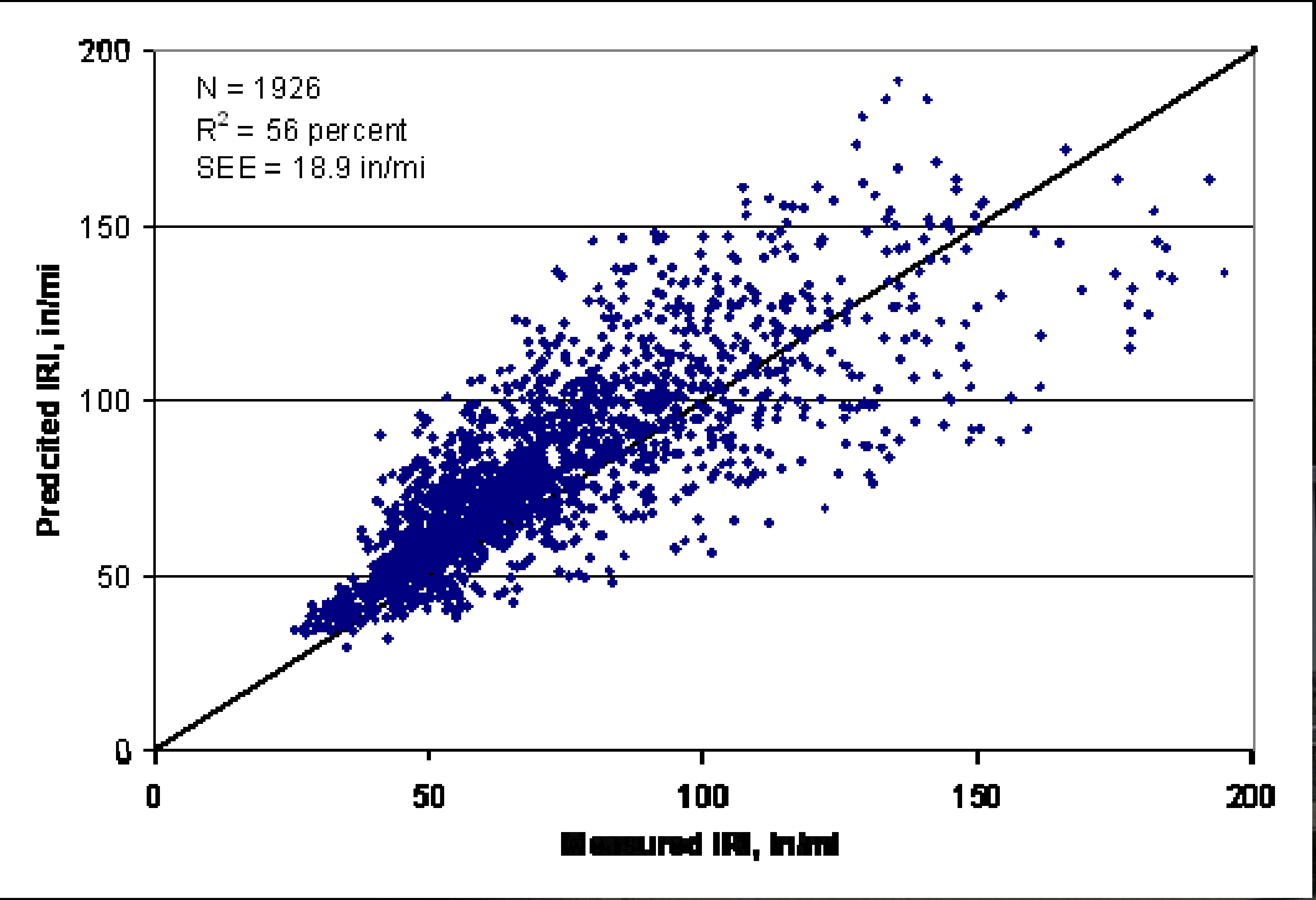


Transverse Cracking

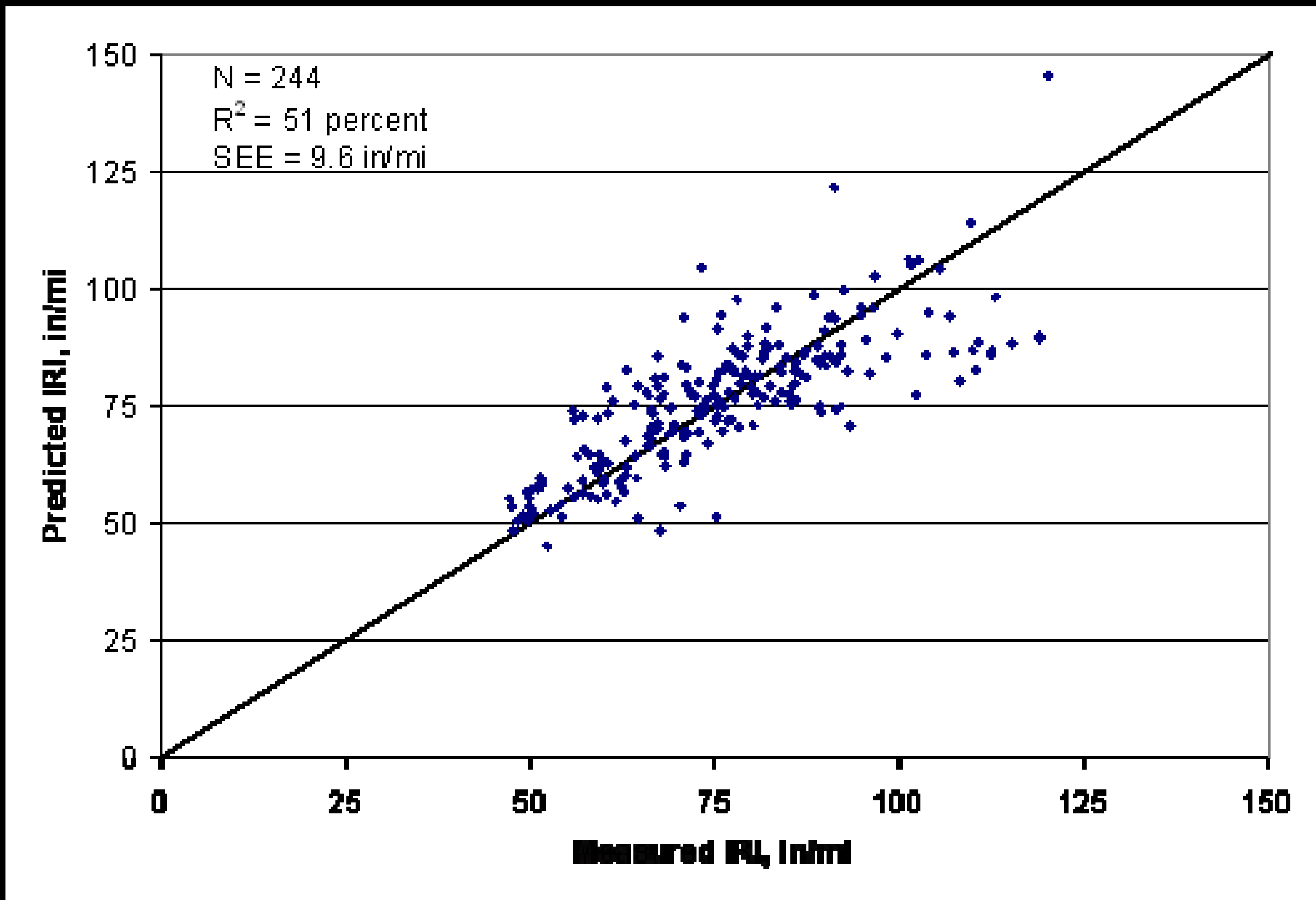


IRI / Smoothness Prediction Model

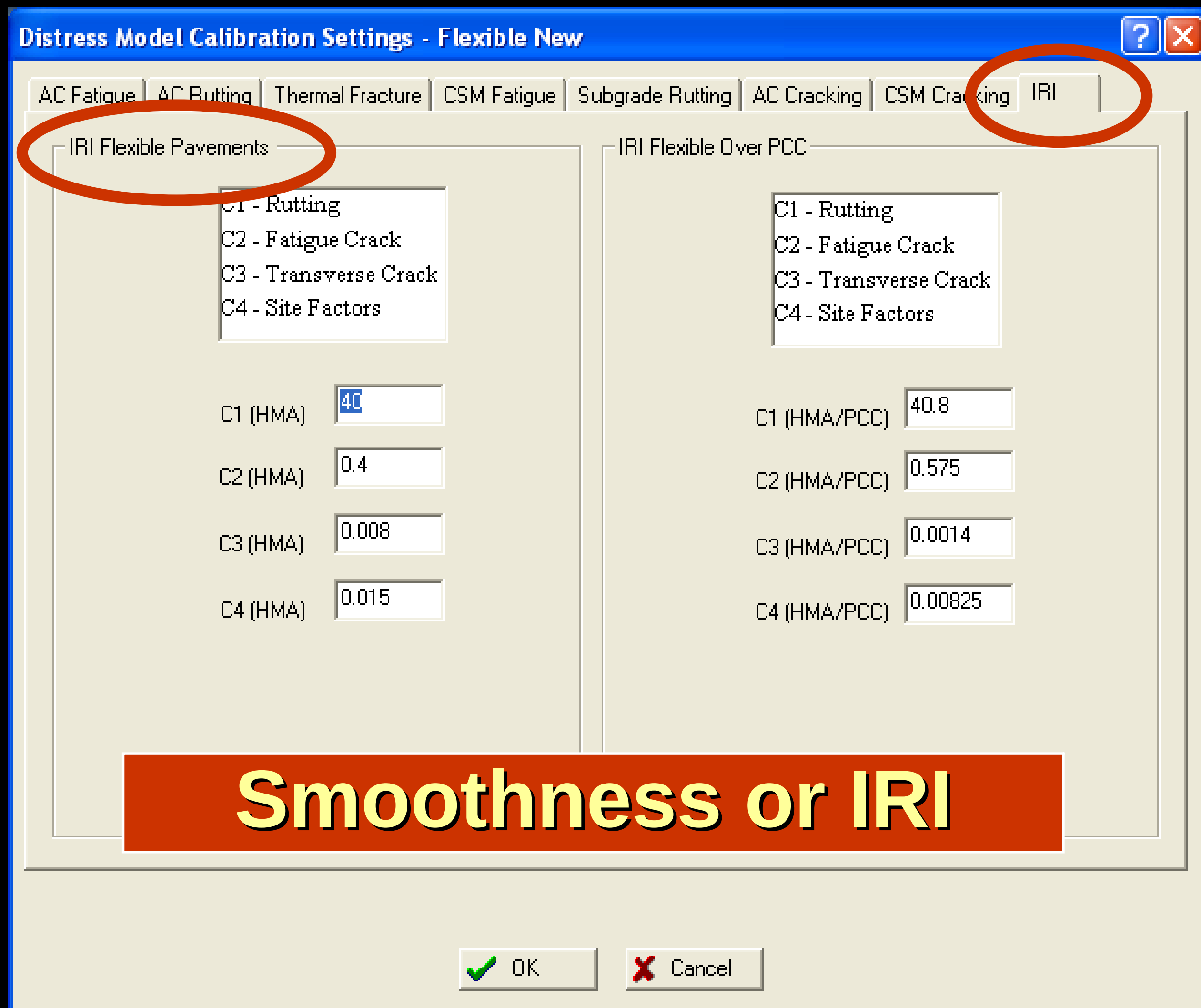
IRI / Smoothness – HMA / HMA



IRI / Smoothness – HMA / PCC

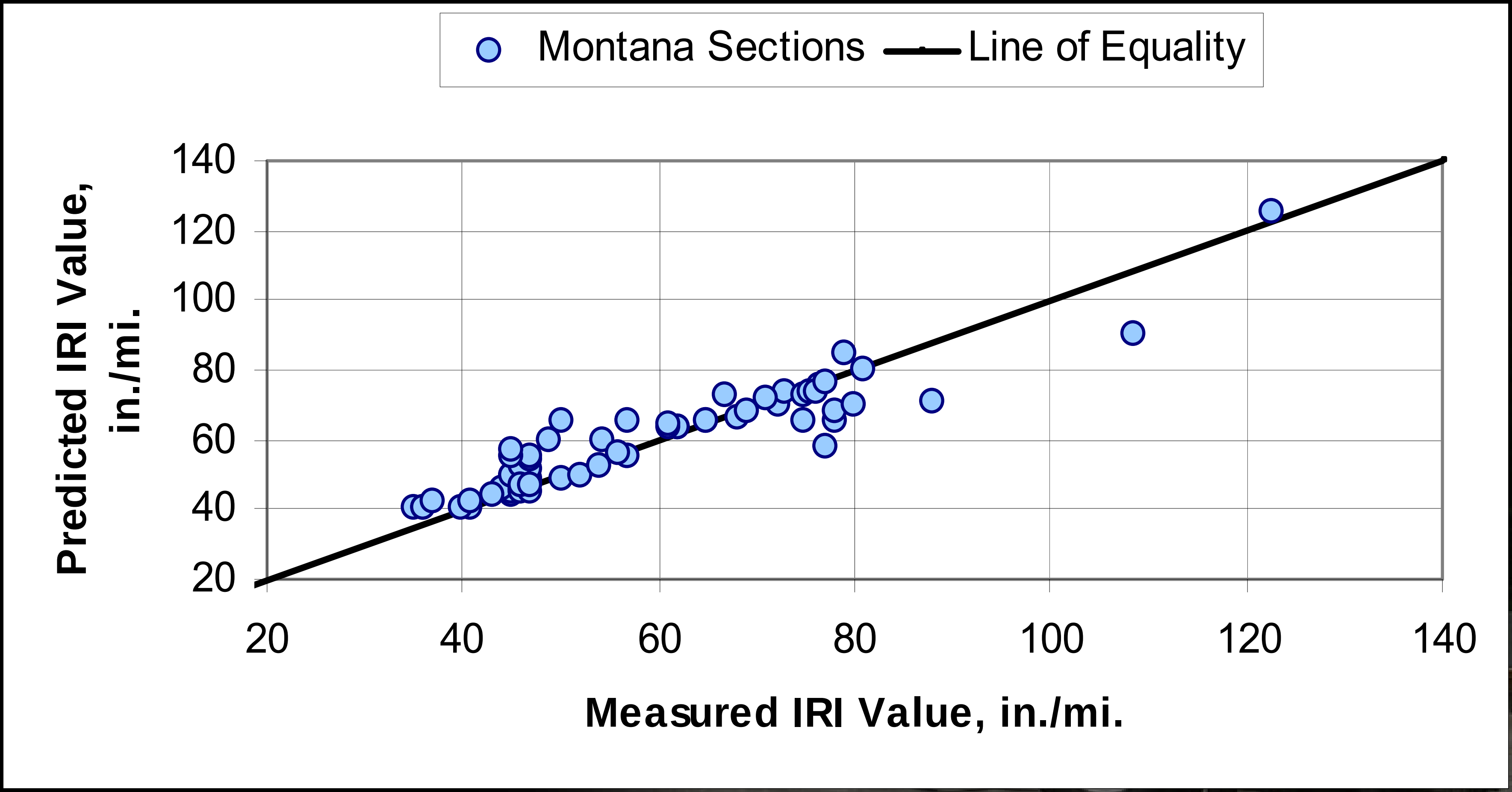


Smoothness/IRI



Smoothness or IRI

IRI



Montana Sections
Line of Equality
Predicted IRI Value, in./mi.
140
120
100
80
60
40
20
20
40
60
80
100
120
140
Measured IRI Value, in./mi.

Presentation Outline

1. Introduction & Overview of Project
2. Determination of MEPDG Inputs
3. Database
4. Verification & Calibration of MEPDG for Use in Montana
5. **Summary & Concluding Comments**

Conclusions & Recommendations

Inputs for MEPDG:

- ☑HMA and other materials characterization
- ☑Traffic characterization
- ☑Climate

Conclusions & Recommendations

Performance Prediction Models:

- ☑ Rutting
- ☑ Fatigue Cracking
  - ☑ Alligator, area cracking
  - ☒ Longitudinal cracking
  - ☐ Fatigue, semi-rigid layers
- ☑ Thermal/transverse cracking
- ☑ Smoothness or IRI

Suggested Improvements

Material Properties & Characterization

- Polymer modified binders
- Fatigue properties of semi-rigid layers
- Full-depth reclamation layer properties

Performance Prediction Models

- Load related longitudinal cracking
- Rutting in unbound aggregate layers and soils of pavements with thin surface layers

Topics to be Quantified (not included within scope of work)

1. Benefit & effect of pavement preservation activities on reducing distress & extending a roadway's serviceable life.
2. Benefit of increased density: comparison of roadways with lower and higher air voids.
3. Determine reason for differences between LTPP & MDT FWDs.
4. Continue to measure IDT strength, modulus, strain at failure, & creep compliance on some mixes for use with the MEPDG.
5. Wear from use of studded tires believed to be minor on non-LTPP & other segments of roadways included within study.

Questions?

THANK YOU