Key Findings from NAPTF Testing of Unbonded PCC Overlays

IPRF Innovative Pavement Research Foundation

Federal Aviation Administration

Project 04-02: Improved Overlay Design Parameters for Concrete Airfield Pavements
—The Baseline Experiment

Project 06-03: Evaluation of Design Parameters for Rigid Overlays
—SCI Validation Study

Key Project Team Members

QES: Dennis Morian, Joe Reiter, Suri Sadasivam

Penn State: Shelley Stoffels, Lin Yeh, Vishal Singh

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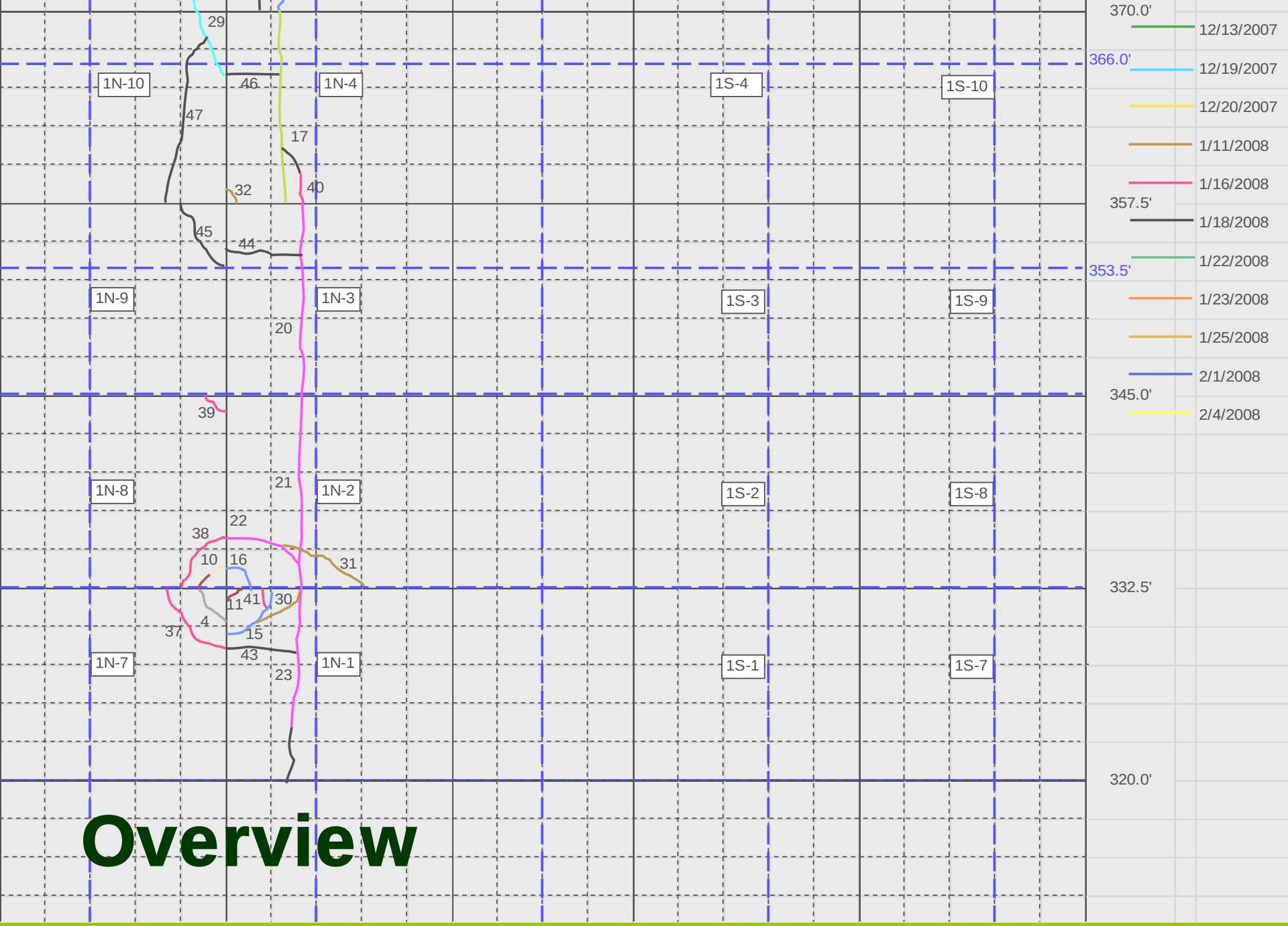
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357.5'
353.5'
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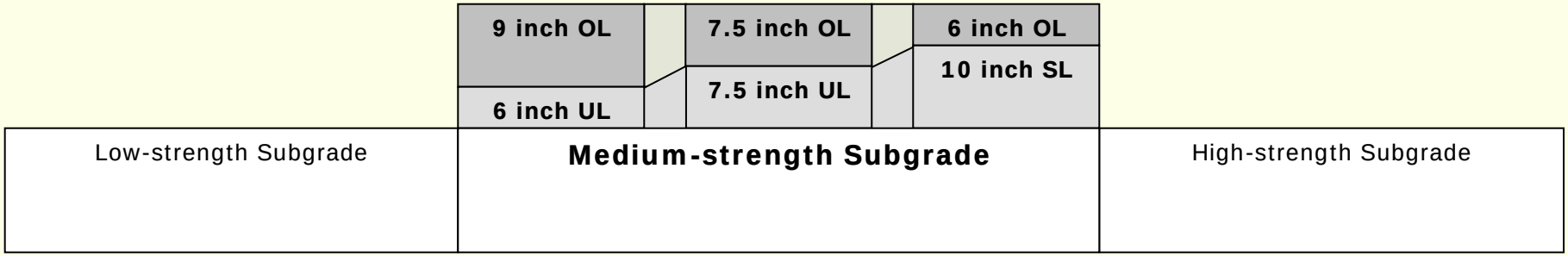
332.5'
320.0'
12/13/2007
12/19/2007
12/20/2007
1/11/2008
1/16/2008
1/18/2008
1/22/2008
1/23/2008
1/25/2008
2/1/2008
2/4/2008
1N-10
1N-4
1S-4
1S-10
1N-9
1N-3
1S-3
1S-9
1N-8
1N-2
1S-2
1S-8
1N-7
1N-1
1S-1
1S-7
29
46
47
17
32
40
45
44
20
39
21
22
38
10
16
31
11
41
30
4
37
15
43
23

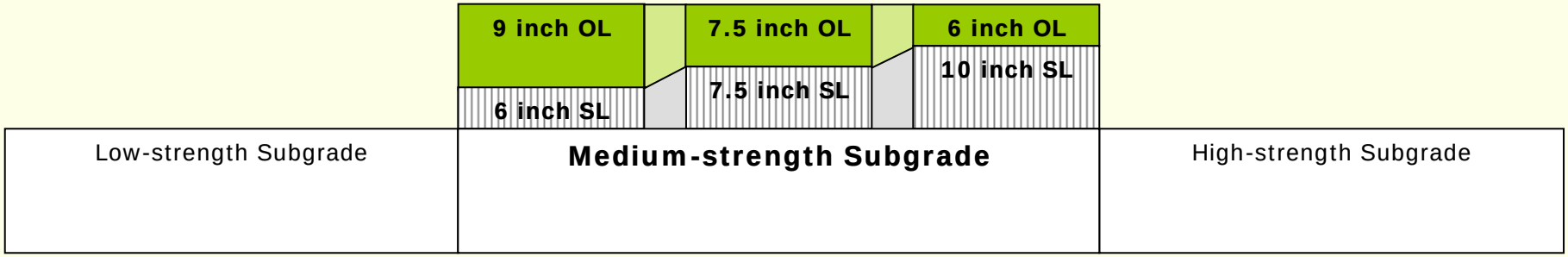
Overview

Full-Scale Testing at the NAPTF

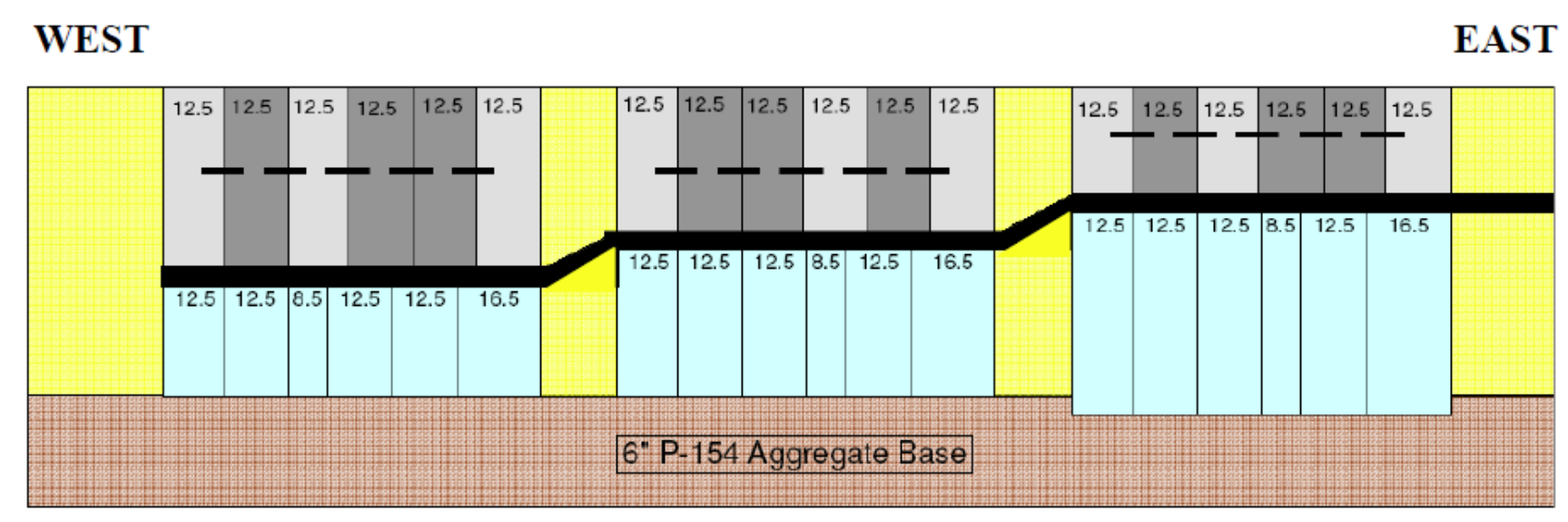
Baseline Experiment—2006

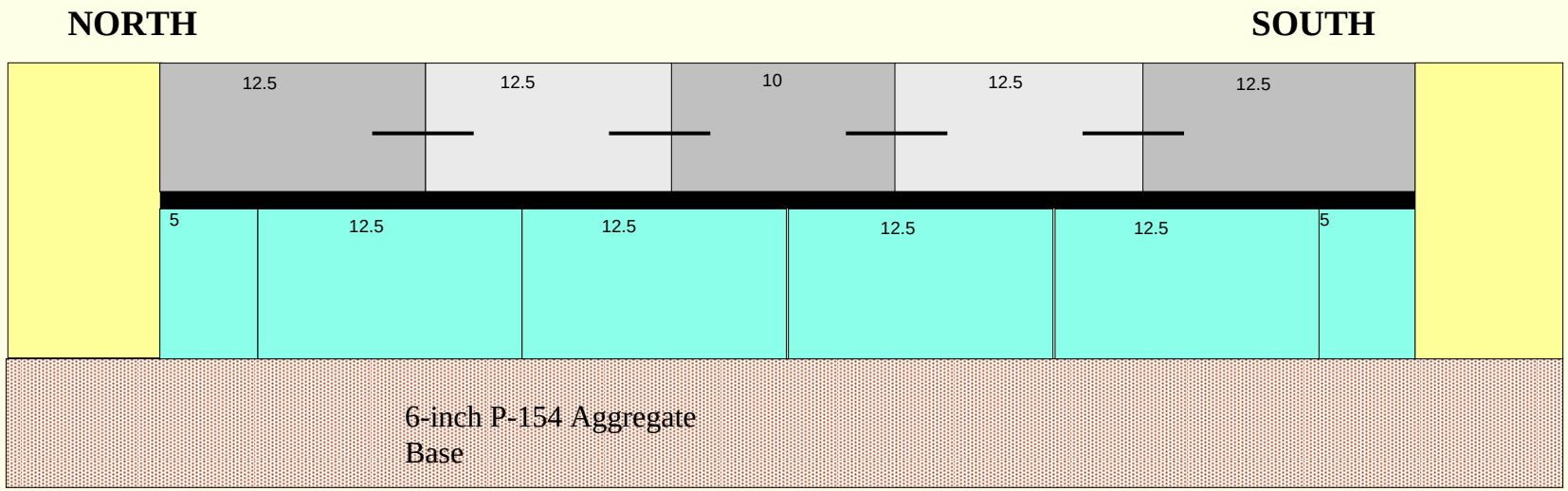


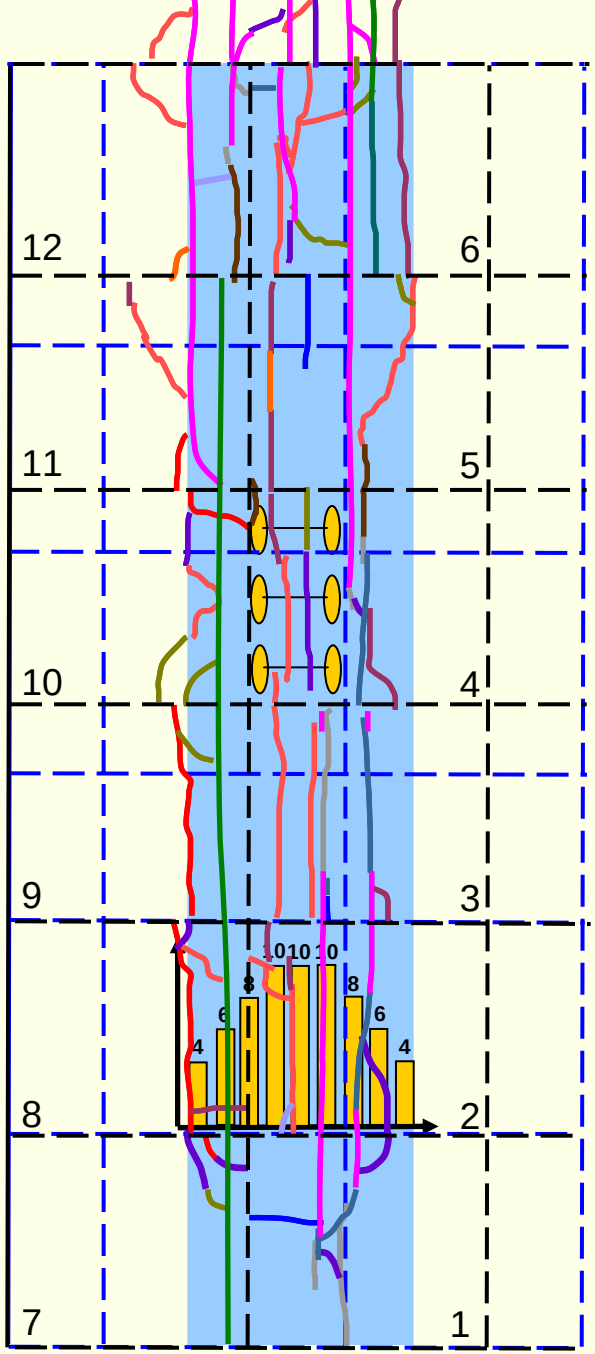
SCI Validation Study—2007/2008



Longitudinal and Transverse Cross-Sections





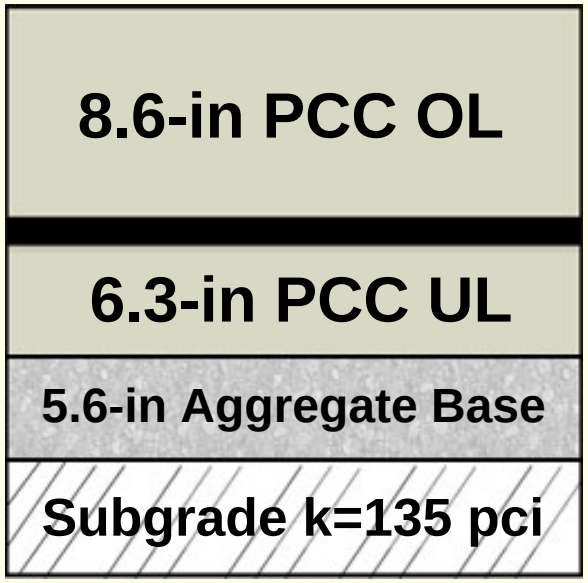


-30 -25 -17.5 -12.5 -5 0

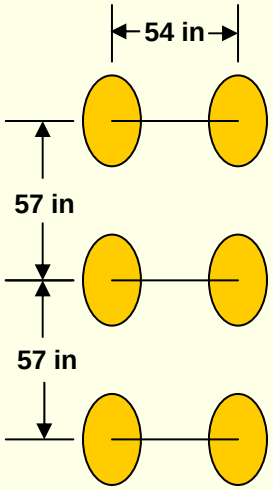
Test Item N1

UL SCI = 100

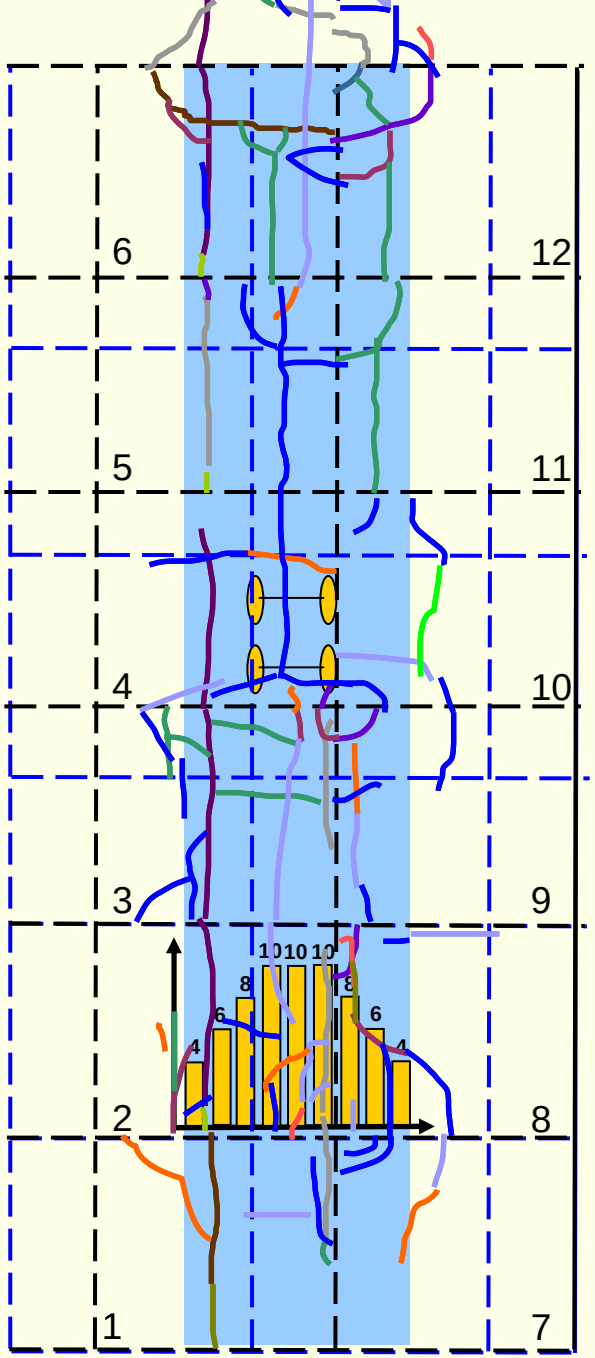
Date	Passes	SCI
08/01/06	2046	100
08/03/06	2574	80
08/04/06	2574	73
08/10/06	2772	73
08/11/06	3234	68
08/24/06	3234	63
08/28/06	3234	57
09/13/06	3234	46
09/14/06	3744	39
09/19/06	4552	31
09/22/06	5146	24
09/29/06	5146	19
10/02/06	5146	16
10/03/06	5146	14



Triple Dual Tandem



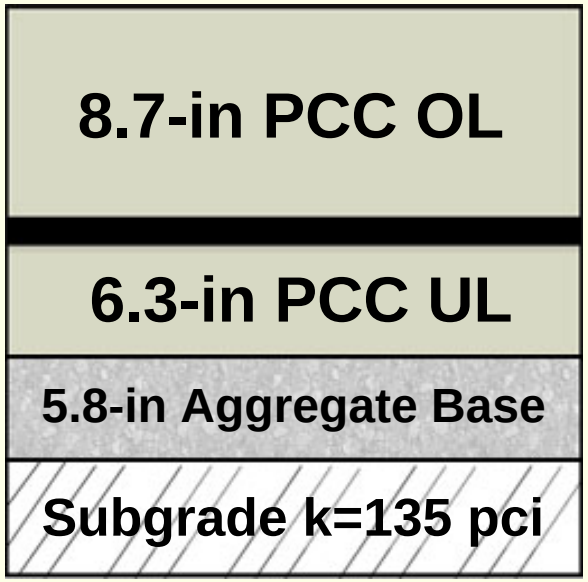
50,000 lbs/wheel
230 psi tire pressure



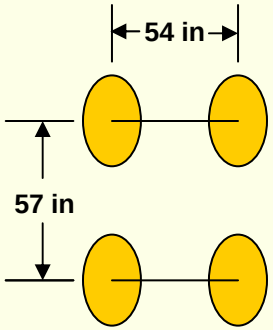
Test Item S1

UL SCI = 100

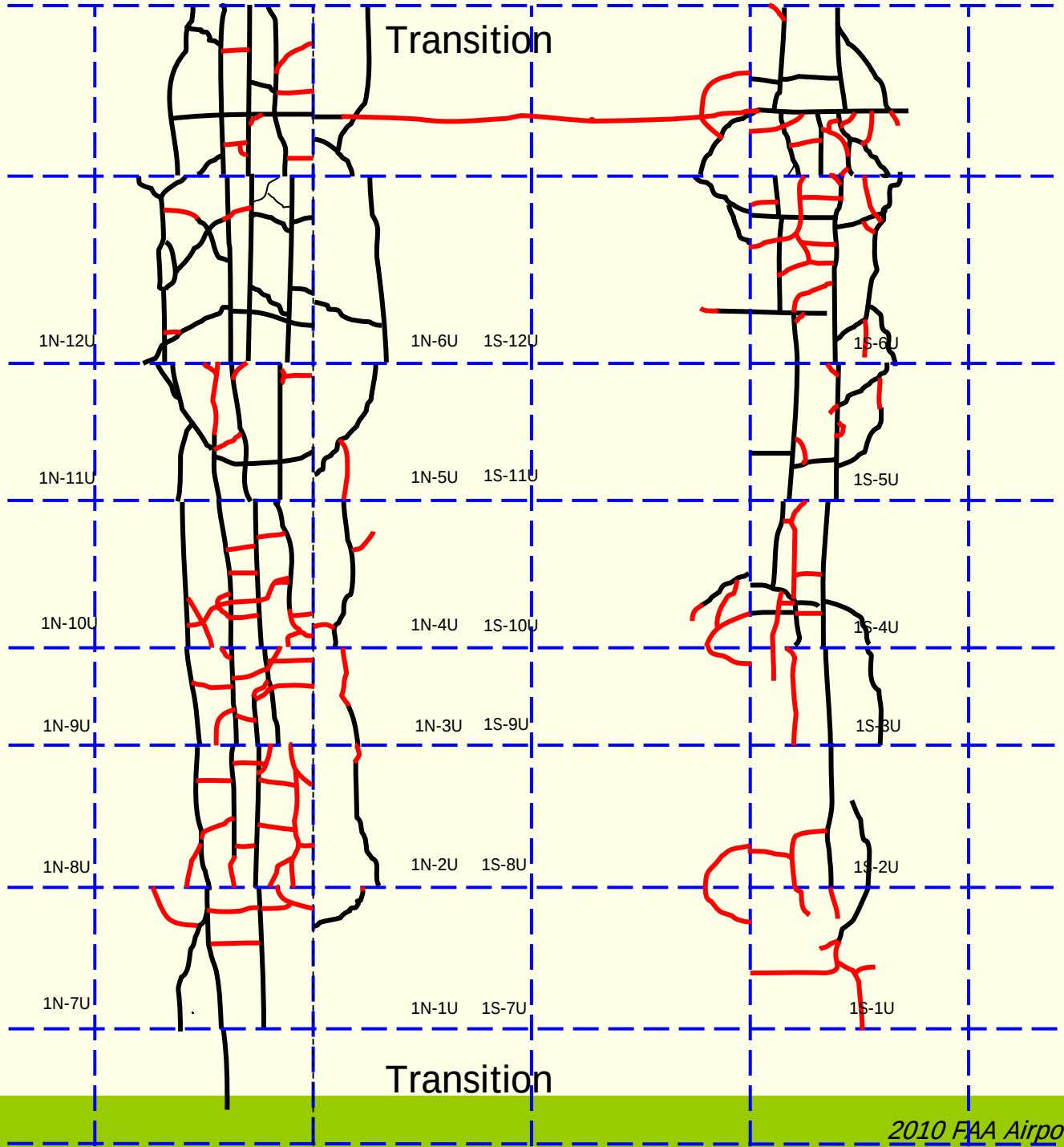
Date	Passes	SCI
08/04/06	3168	93
08/08/06	3432	85
08/09/06	3894	78
08/10/06	4356	76
08/11/06	4818	67
09/13/06	5016	54
09/14/06	5526	51
09/19/06	8116	50
09/22/06	8116	46
09/26/06	9370	32
09/29/06	11020	22
10/02/06	11614	16
10/03/06	12142	7
10/31/06	12142	7



Dual Tandem



50,000 lbs/wheel
230 psi tire pressure

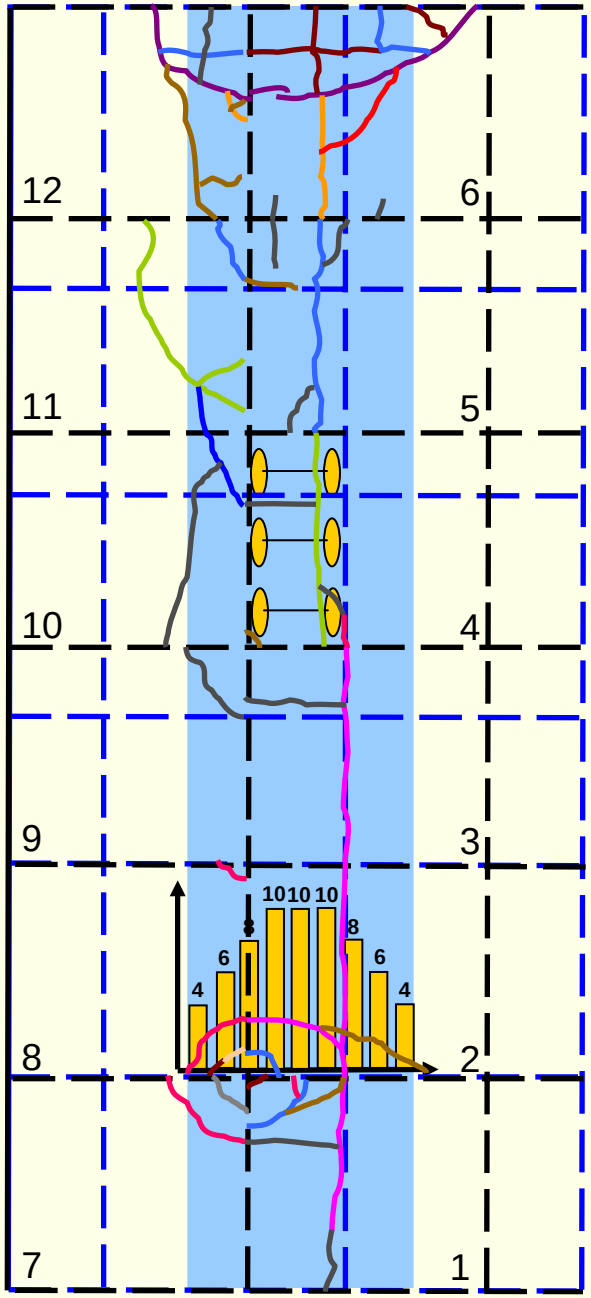


12/18/06

02/20/07

Underlay Cracking

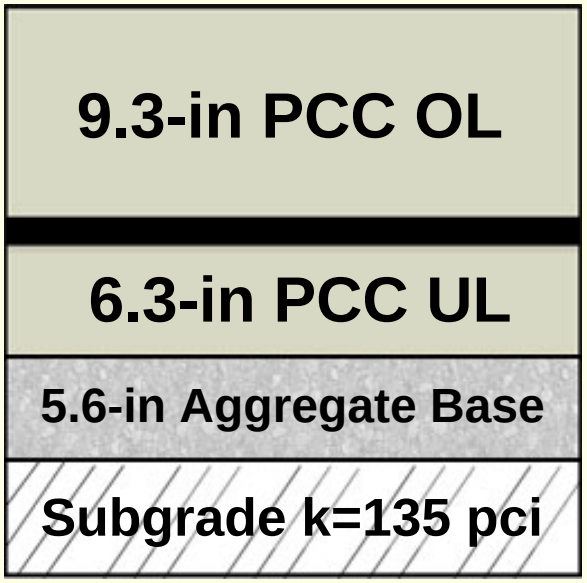
Test Items N1 and S1



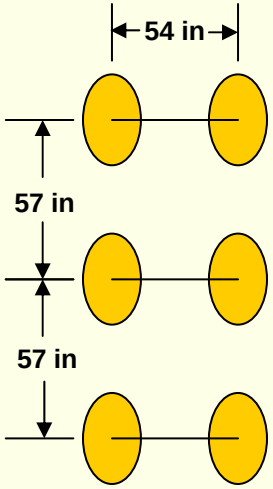
Test Item N1

Date	Passes	SCI
11/14/07	3696	88
11/19/07	4422	83
11/21/07	4950	77
12/03/07	7194	68
12/05/07	7986	55
12/07/07	8712	51
12/10/07	9108	48
12/11/07	9504	42
12/19/07	11286	27
01/11/08	13398	26
01/16/08	14850	24
01/18/08	15510	12

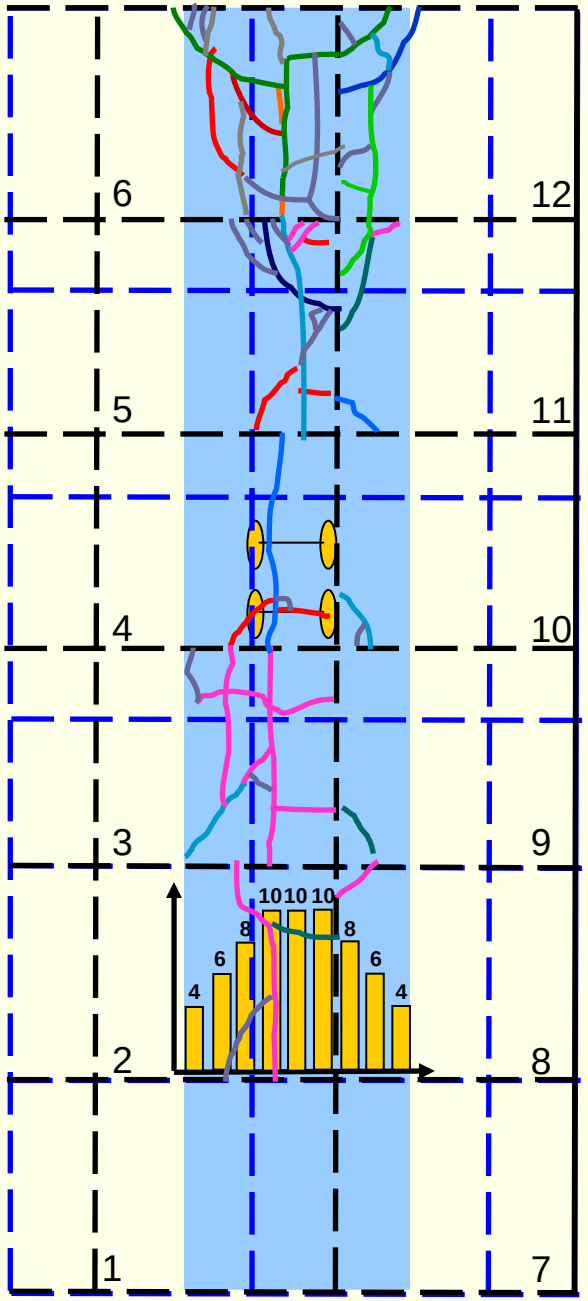
Underlay	SCI
Beginning	25



Triple Dual Tandem



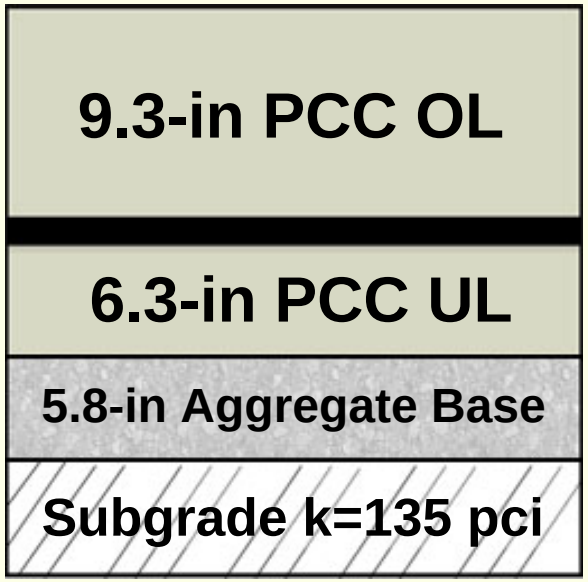
42.5k lbs/wheel
230 psi tire pressure



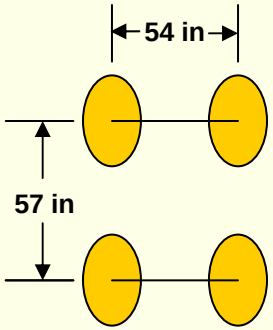
Test Item S1

Date	Passes	SCI
12/13/07	9966	88
01/16/08	14850	80
01/23/08	16316	80
02/01/08	19008	70
02/04/08	19602	63
02/25/08	20328	58
03/05/08	24684	52
03/11/08	27126	46
03/20/08	30096	31
03/21/08	30756	29
03/24/08	31350	23
03/26/08	32604	20
04/02/08	33264	18

Underlay	SCI
Beginning	23



Dual Tandem



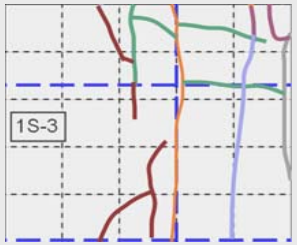
42.5k lbs/wheel
230 psi tire pressure

Final Loading Status

Test Item	Baseline Passes, k	Baseline SCI	SCI Val. Passes, k	SCI Val. SCI
North 1	5,100	5	15,500	12
North 2	5,100	24	35,300	29
North 3	5,100	21	35,300	27
South 1	12,100	5	33,300	18
South 2	16,400	11	42,800	66
South 3	12,100	23	35,300	39

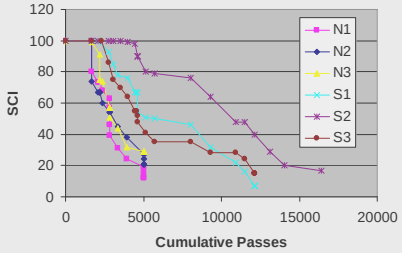
50,000-lb wheel load **42,500-lb wheel load**

SCI

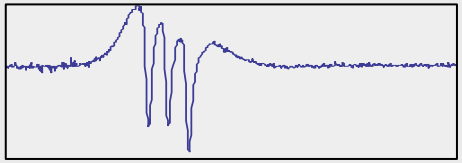


Gears

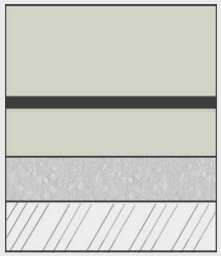
Performance



Measured Responses



Layer Interactions

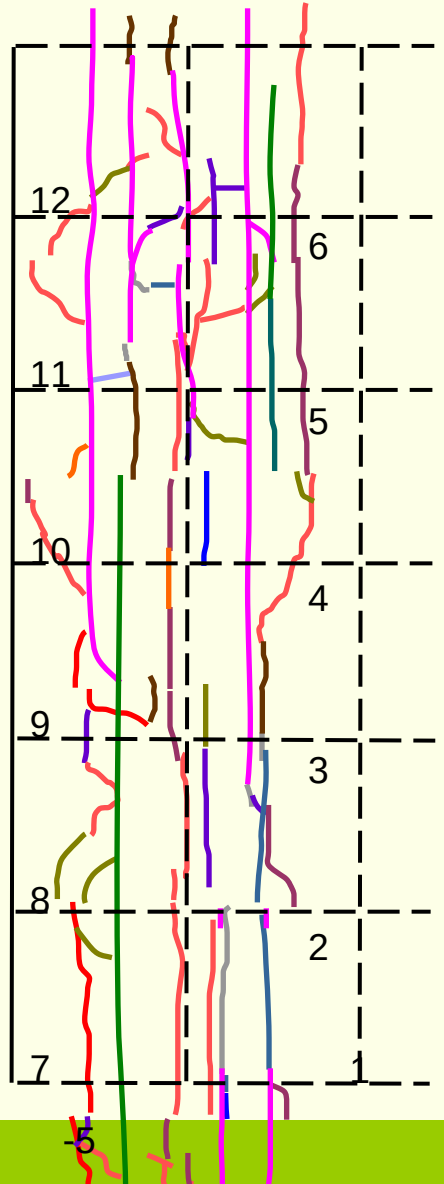


Summary of Goals and Findings

Overall Goals from the Roadmap

A. Refine the relationship between underlying pavement effective modulus and SCI.
B. Improve understanding of how underlay condition affects overlay performance.
C. Improve understanding of the interaction between the pavement layers.
D. Quantify differences in responses and resulting impacts on failure criteria between dual tandem and triple dual tandem gears.
E. Verify whether measured responses match predicted responses from current models and design methods.

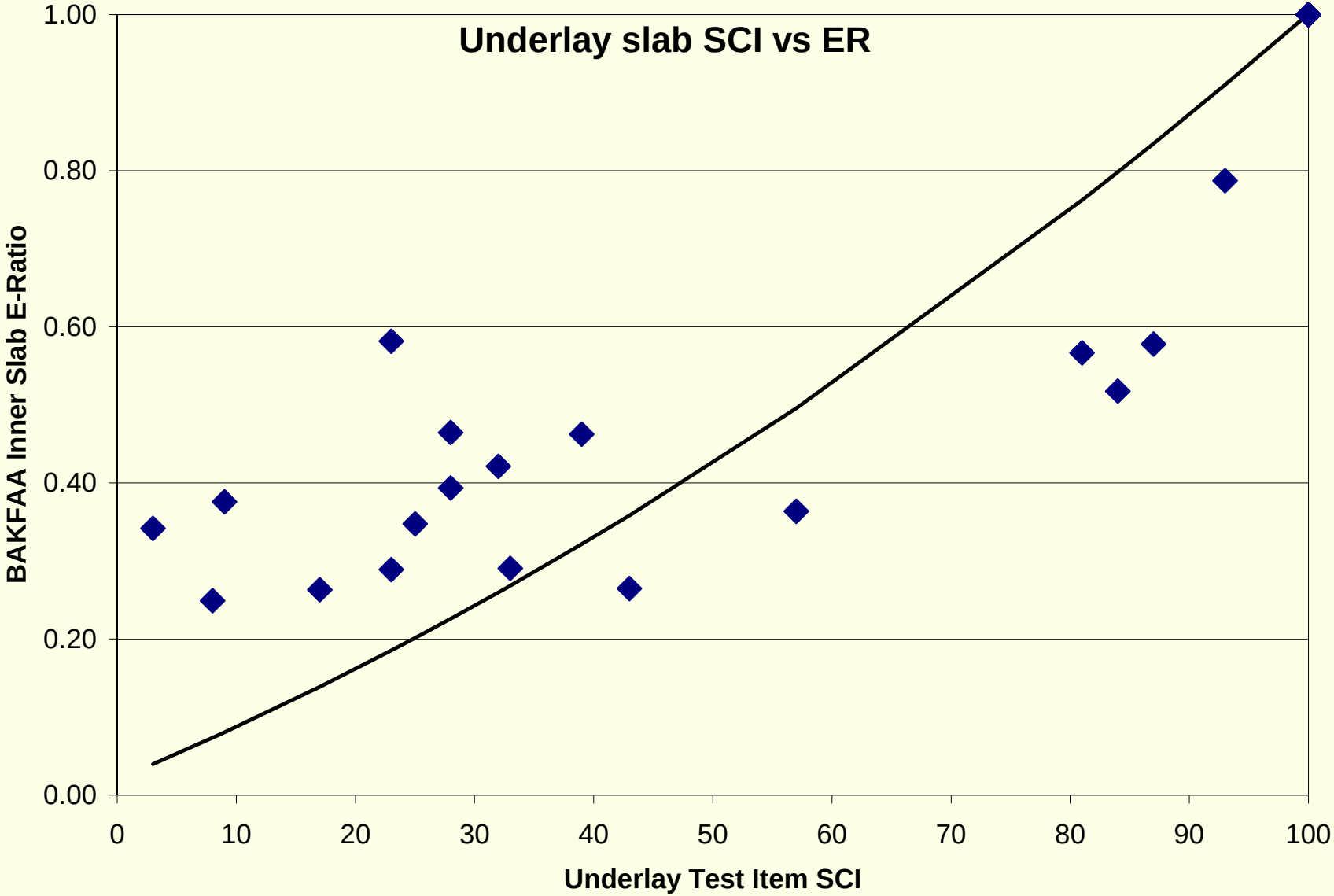
A. Refine the relationship between underlying pavement effective modulus and SCI.

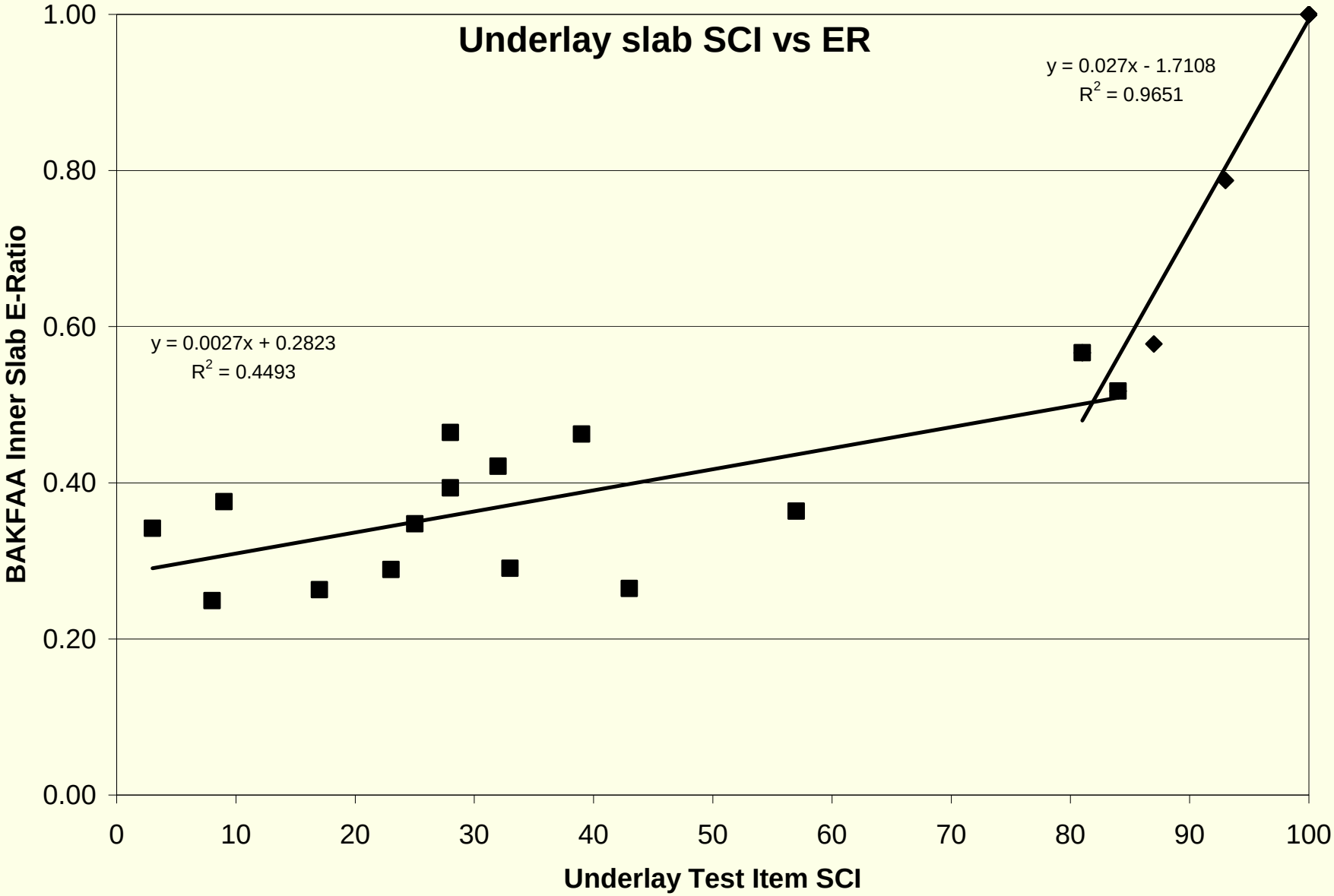


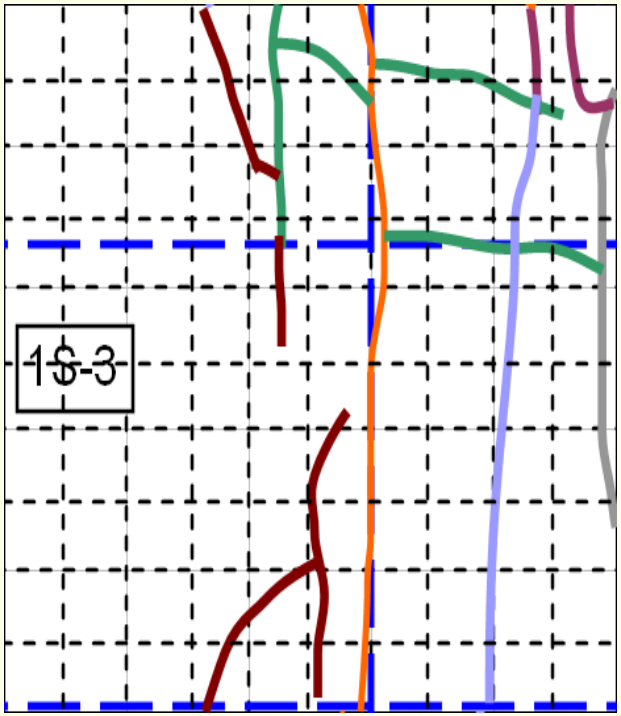
SCI was calculated according to ASTM D 5340 "*Standard Test Method for Airport Pavement Condition Index Survey.*" The SCI value of a test item represents the crack types, crack density and crack severity that are distributed in the 12 slabs within a test item.

Underlay SCI Investigation

Comparison to Rollings Relationship



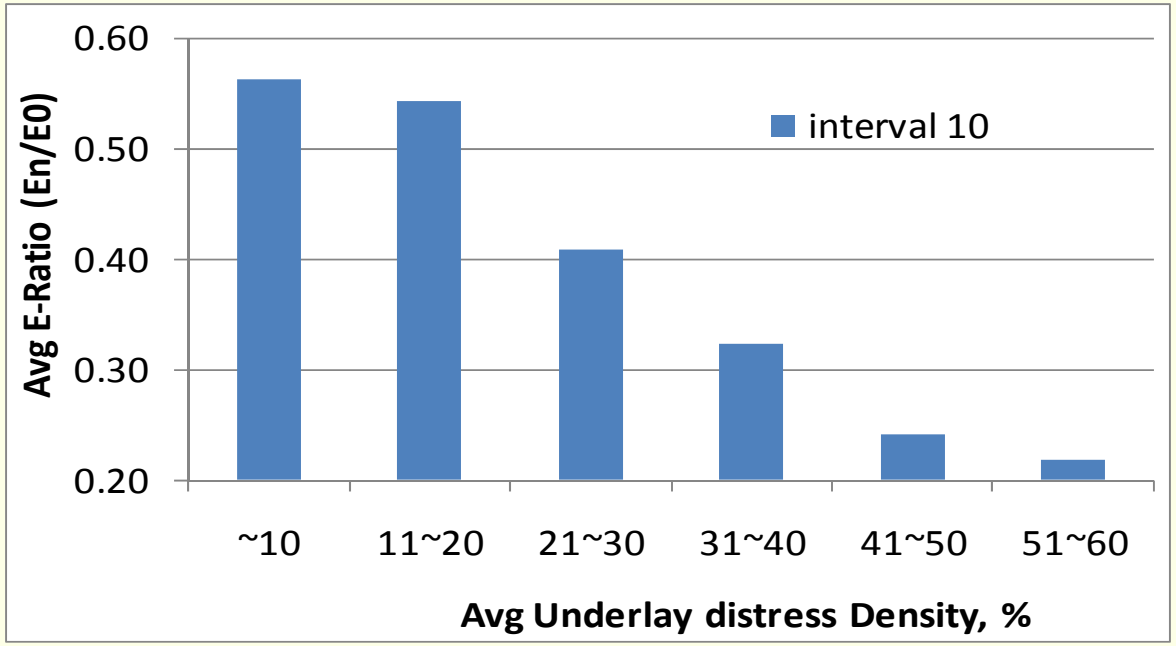

Underlay slab SCI vs ER
y = 0.027x - 1.7108
R2 = 0.9651
y = 0.0027x + 0.2823
R2 = 0.4493
BAKFAA Inner Slab E-Ratio
Underlay Test Item SCI
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100



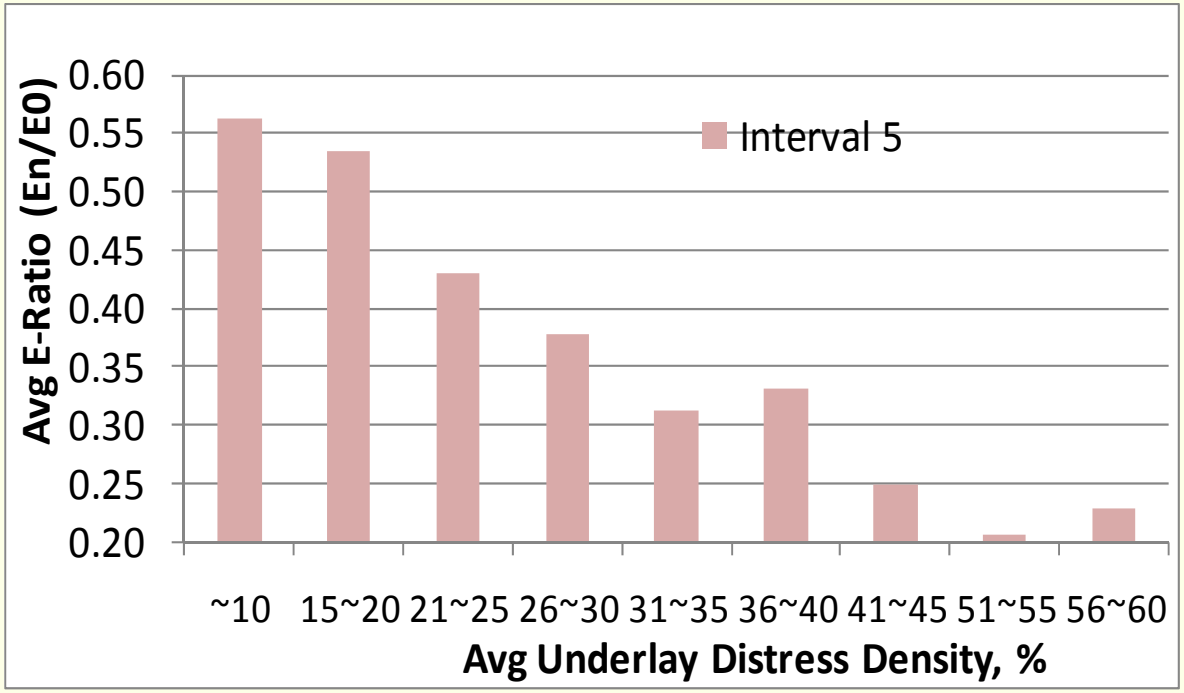
10 X 10 grids in 12.5 ft X 12.5 ft slab

10 X 10 grids is selected

Date	Crack Density	total crack length, ft	# of pieces
8/8/2006	11/100 = 11%	12.5	2
8/10/2006	18/100 = 18%	19.9	3
9/22/2006	21/100 = 21%	24.1	4
9/26/2006	30/100 = 30%	34.7	6
9/29/2006	35/100 = 35%	48	9
10/2/2006	43/100 = 43%	58.8	11



Relationship between Underlay E-Ratio and Distress Density within intervals

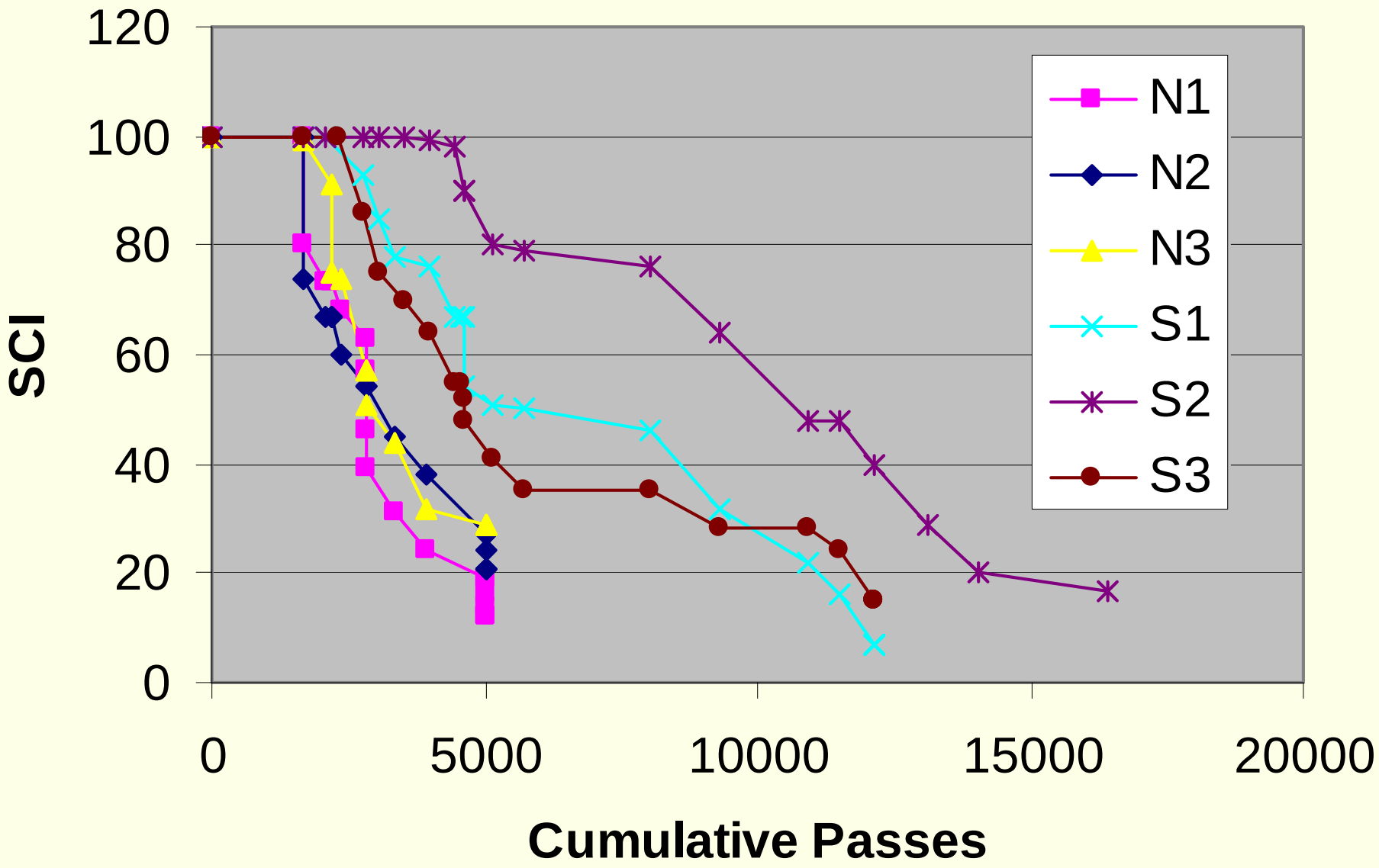


- Finding: Rollings equation using SCI provides a reasonable fit to BAKFAA moduli from HWD testing for the underlay.
- Recommendation: Continue use of the Rollings equation, with some modification.

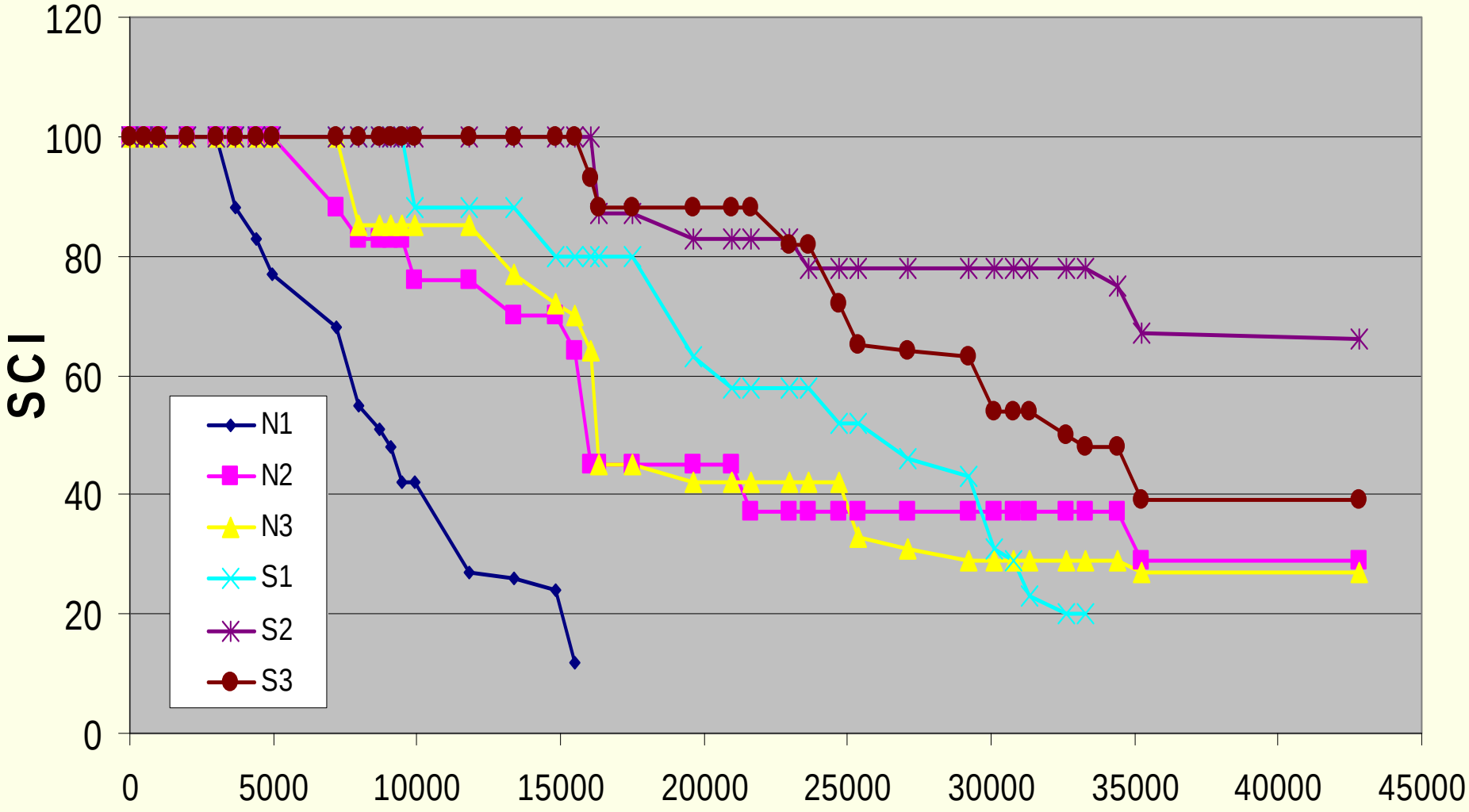
B. Improve understanding of how underlay condition affects overlay performance.

Test Item	Baseline Passes, k	Baseline SCI	SCI Val. Passes, k	SCI Val. SCI
North 1	5,100	5	15,500	12
North 2	5,100	24	35,300	29
North 3	5,100	21	35,300	27
South 1	12,100	5	33,300	18
South 2	16,400	11	42,800	66
South 3	12,100	23	35,300	39

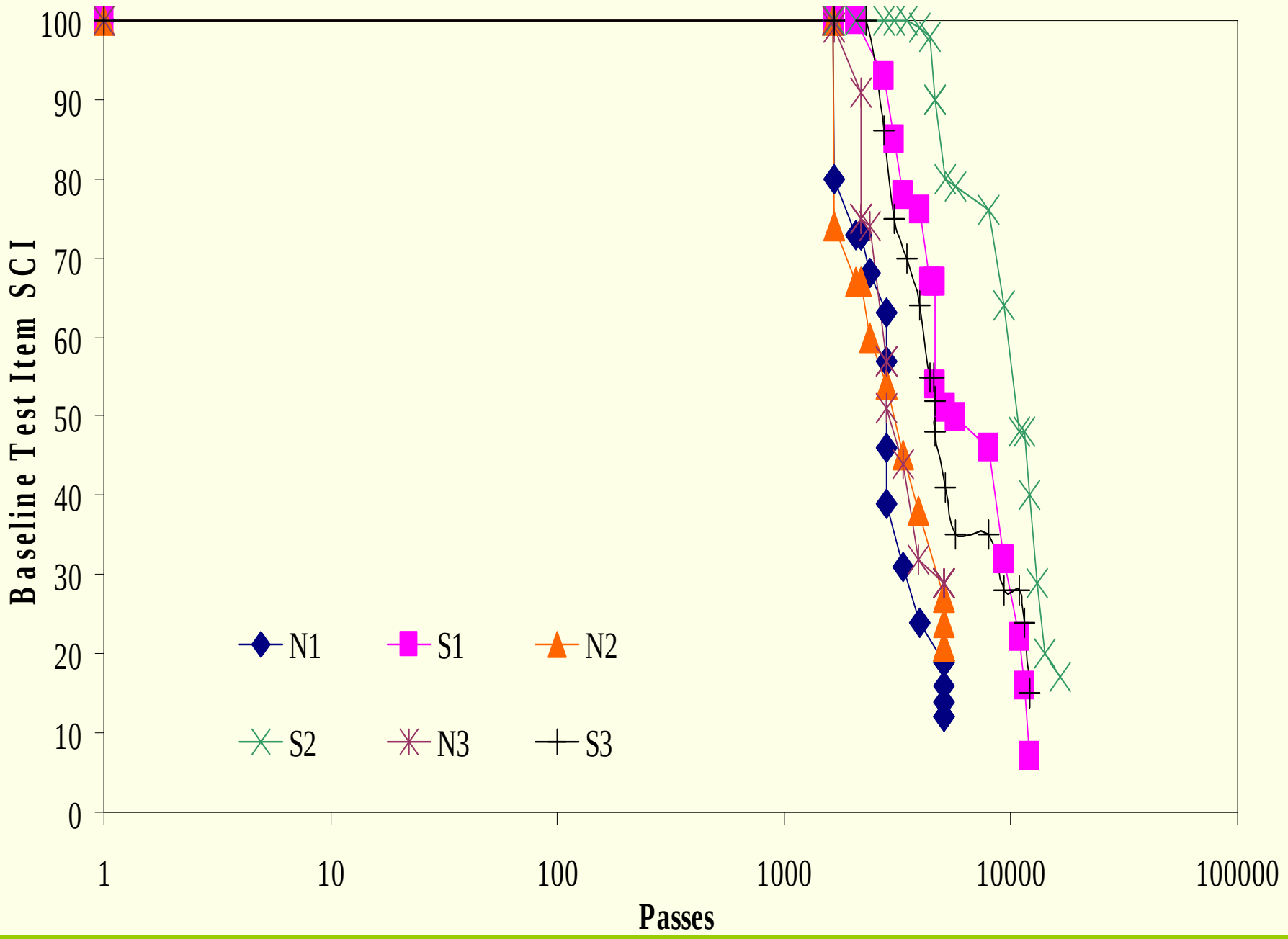
50,000-lb wheel load **42,500-lb wheel load**

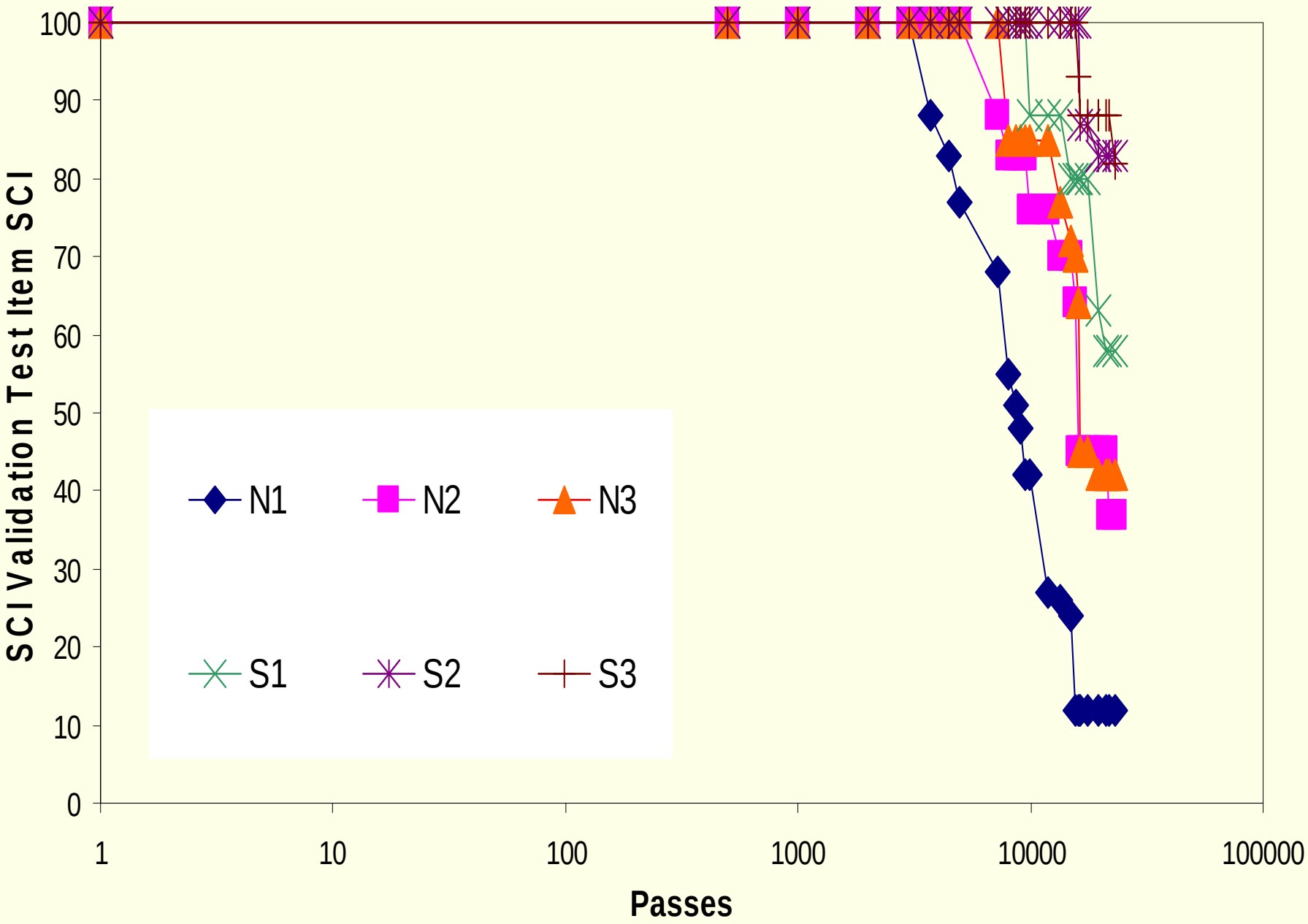

120
100
80
60
40
20
0
SCI
0
5000
10000
15000
20000
Cumulative Passes
N1
N2
N3
S1
S2
S3

Baseline



SCI Validation


Baseline Test Item SCI
100
90
80
70
60
50
40
30
20
10
0
1
10
100
1000
10000
100000
Passes
N1
S1
N2
S2
N3
S3


SCI Validation Test Item SCI
100
90
80
70
60
50
40
30
20
10
0
1
10
100
1000
10000
100000
Passes
N1
N2
N3
S1
S2
S3

Baseline Experiment: Approximate Passes to SCI Values

SCI	Passes					
	N1 9”/6”	S1 9”/6”	N2 7.5”/7.5”	S2 7.5”/7.5”	N3 6”/10”	S3 6”/10”
80	2456	3762	2456	5524	2574	3300
60	3234	5016	3234	9370	3234	4580
40	3742	8743	4088	12142	4440	5524

SCI Validation Study: Approximate Passes to SCI Values

SCI	Passes					
	N1 9”/6”	S1 9”/6”	N2 7.5”/7.5”	S2 7.5”/7.5”	N3 6”/10”	S3 6”/10”
80	5000	15000	10000	23000	12500	24000
60	7500	20000	15000	>42000	16000	30000
40	10000	30000	21000	???	25000	35000

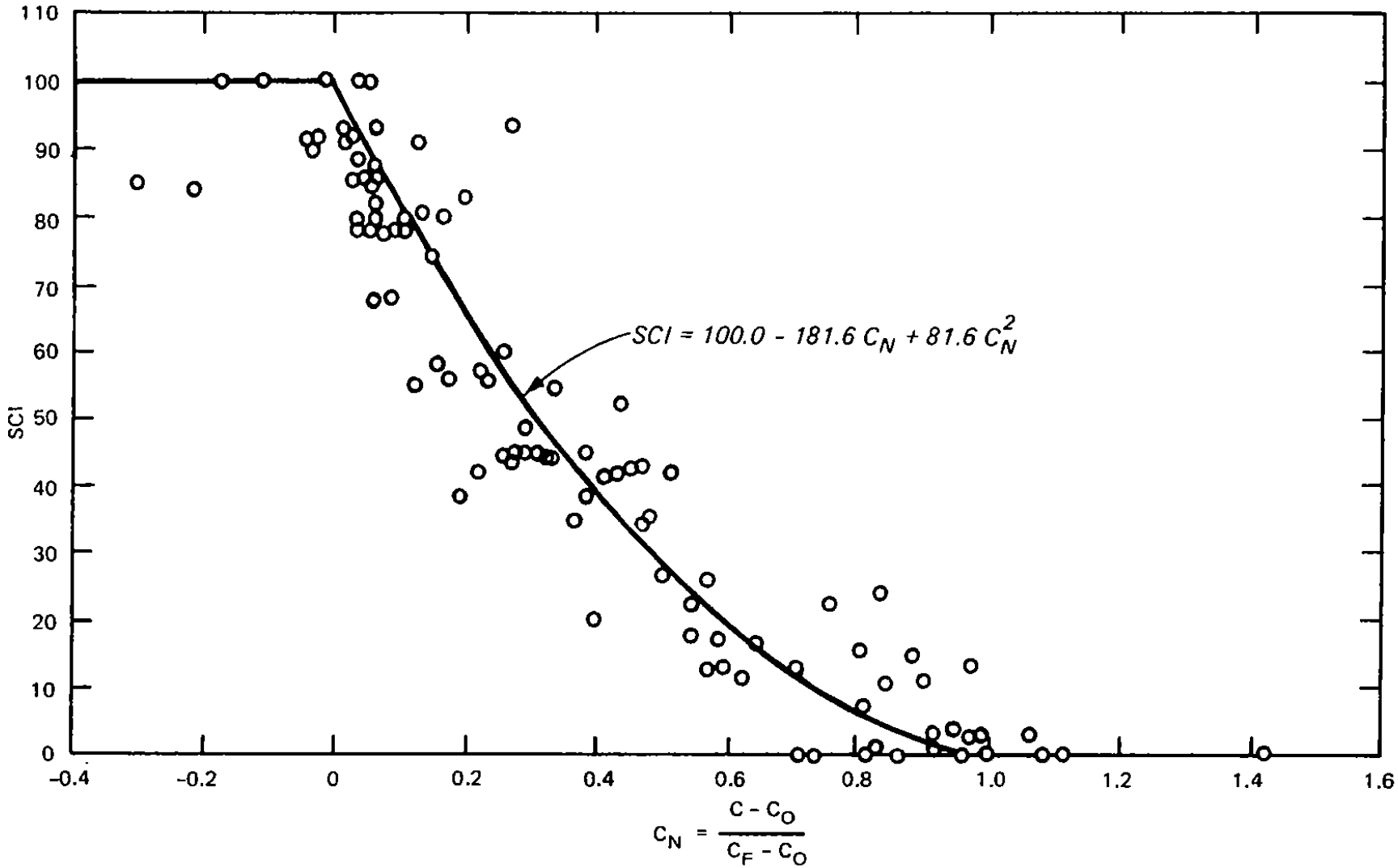
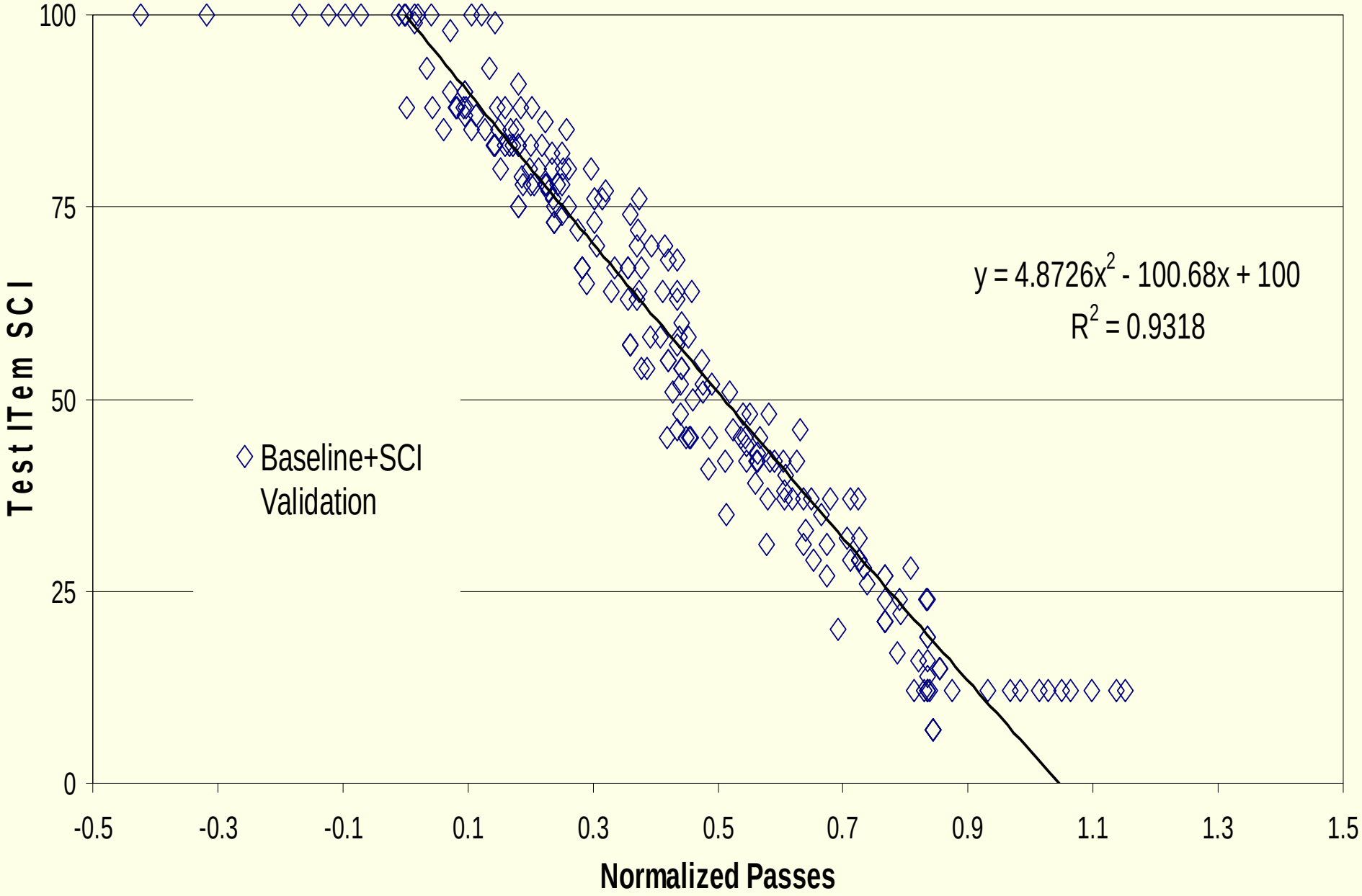


Figure 13. SCI C_N relationship

(Rollings, 1988)


100
75
50
25
0
Test ITem SCI
-0.5
-0.3
-0.1
0.1
0.3
0.5
0.7
0.9
1.1
1.3
1.5
Normalized Passes
Baseline+SCI Validation
y = 4.8726x2 - 100.68x + 100
R2 = 0.9318

C. Improve understanding of the interaction between the pavement layers.

Terminal SCIs and Passes

Test Item	Baseline OL	Baseline UL	SCI OL	SCI UL
N1	14 (5146)	32	12 (15,510)	25 - 3
N2	21 (5146)	57	29 (35,260)	43 - 17
N3	29 (5146)	87	27 (35,260)	84 -26
S1	7 (12,142)	39	18 (33,264)	23 - 6
S2	17 (16,567)	33	66 (42,834)	26 - 9
S3	15 (12,142)	92	39 (35,250)	81 - 23

Terminal SCIs and Passes

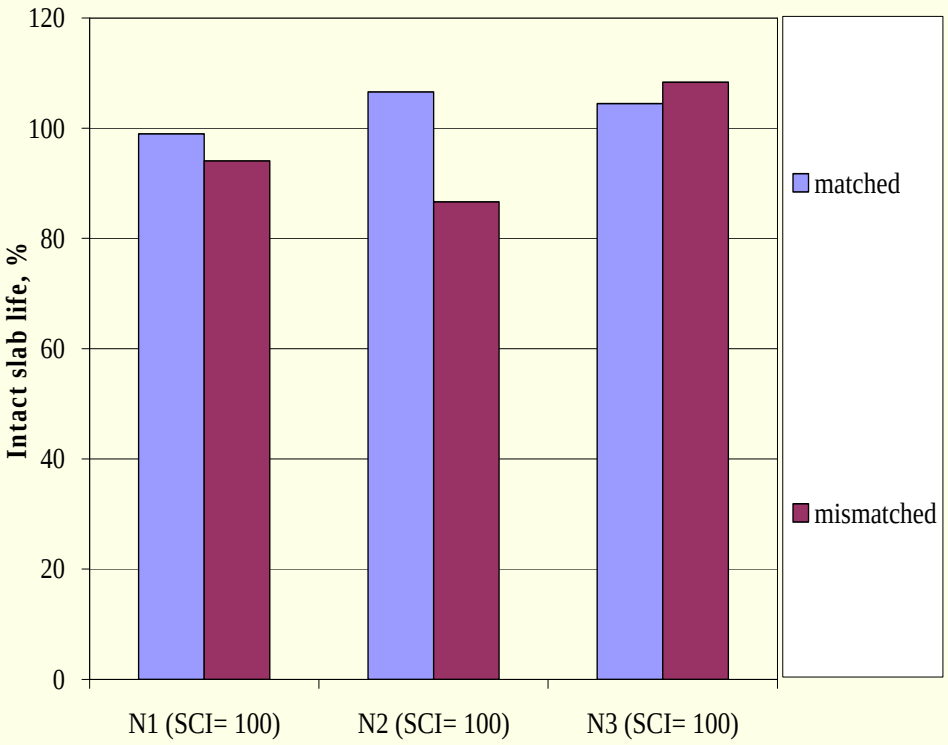
Test Item	Baseline OL	Baseline UL	SCI OL	SCI UL
N1	14 (5146)	32	12 (15,510)	25 - 3
N2	21 (5146)	57	29 (35,260)	43 - 17
N3	29 (5146)	87	27 (35,260)	84 -26
S1	7 (12,142)	39	18 (33,264)	23 - 6
S2	17 (16,567)	33	66 (42,834)	26 - 9
S3	15 (12,142)	92	39 (35,250)	81 - 23

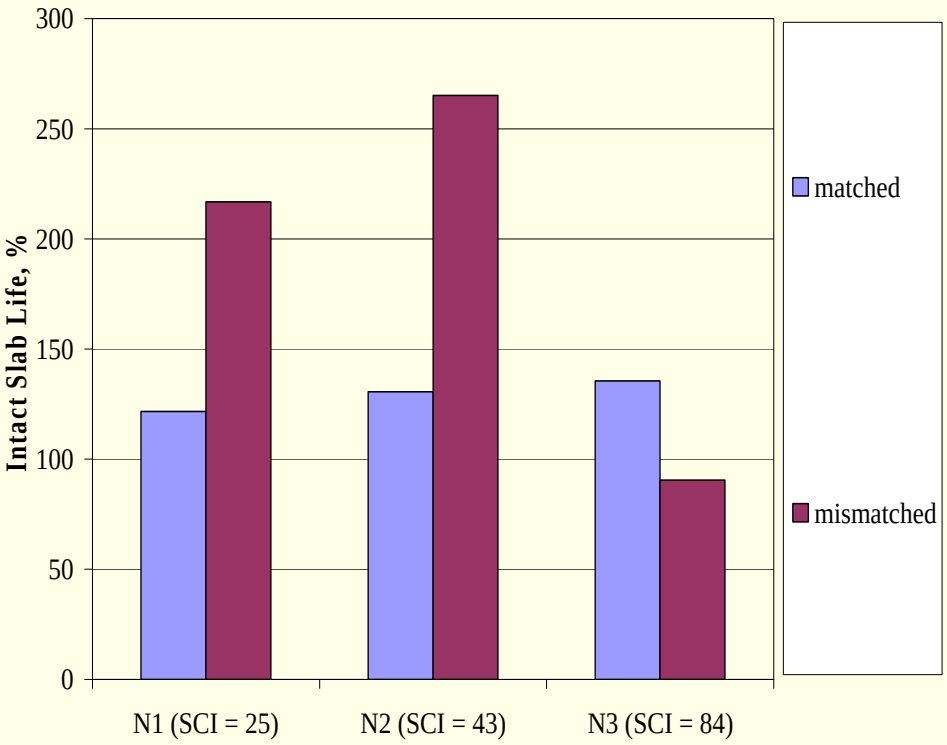
Matched and Mismatched Transverse Joints

- Examined on the basis of:
  - Overall performance
  - Intact slab life
  - Load transfer efficiency
  - Deflection basin area

- Although matched and mismatched transverse joints exhibited slightly different mechanical behavior for the unbonded overlay, the passes prior to the first crack or to failure are affected more by other structure parameters such as D0, E*h ratio and LTE.

Intact Slab Life – Number of passes prior to the first crack of a slab normalized to number of passes prior to SCI = 80 of the test item





- Recommendation: From this experiment, there was no evidence to indicate that joints should not be mismatched if there is a reason to do so. Other factors should govern this decision.

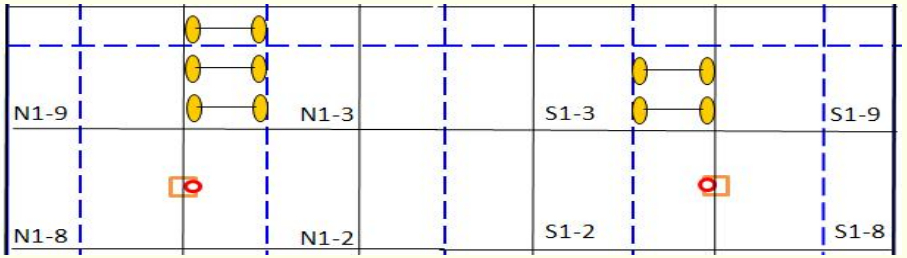
D. Quantify differences in responses and resulting impacts on failure criteria between dual tandem and triple dual tandem gears.

Passes to SCI Levels

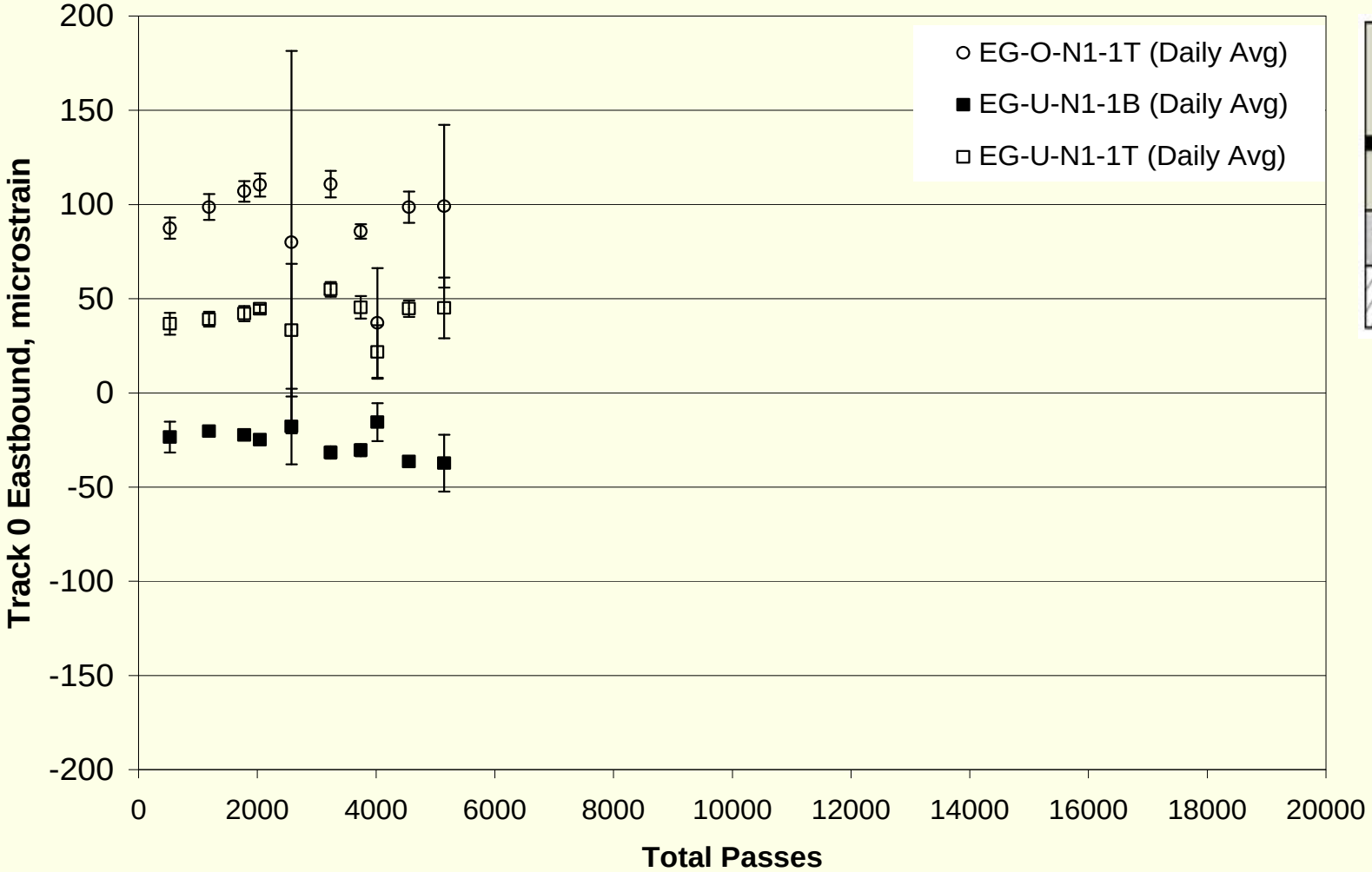
Baseline						
SCI	**N1 (Pass)**	**S1 (Pass)**	**N2 (Pass)**	**S2 (Pass)**	**N3 (Pass)**	**S3 (Pass)**
80	2456	3668	2361	5524	2574	3344
60	3234	5016	3234	9783	3234	4561
40	3669	8653	3989	12142	4441	5582
20	5146	11218	5146	14056	6204	11849
SCI Validation						
80	4686	14850	9674	23364	12804	23839
60	7681	20434	15510	55757	16097	29524
40	10155	29453	21401		24831	31431

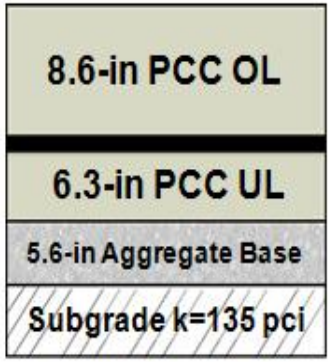
Ratios of Passes on South to North Test Items

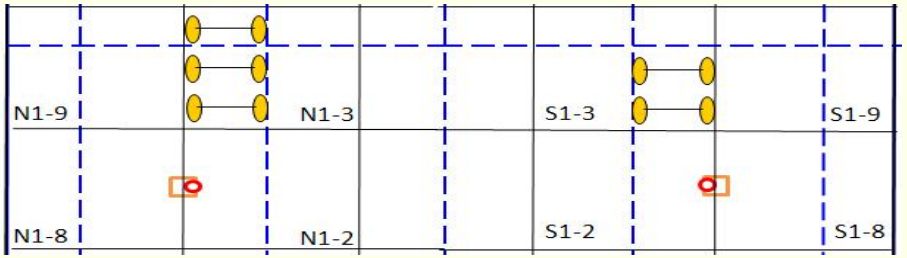
Baseline			
SCI	**Section 1 Pass Ratio**	**Section 2 Pass Ratio**	**Section 3 Pass Ratio**
80	1.5	2.3	1.3
60	1.6	3.0	1.4
40	2.4	3.0	1.3
20	2.2	2.7	1.9
SCI Validation			
80	3.2	2.4	1.9
60	2.7	3.6	1.8
40	2.9	-	1.3



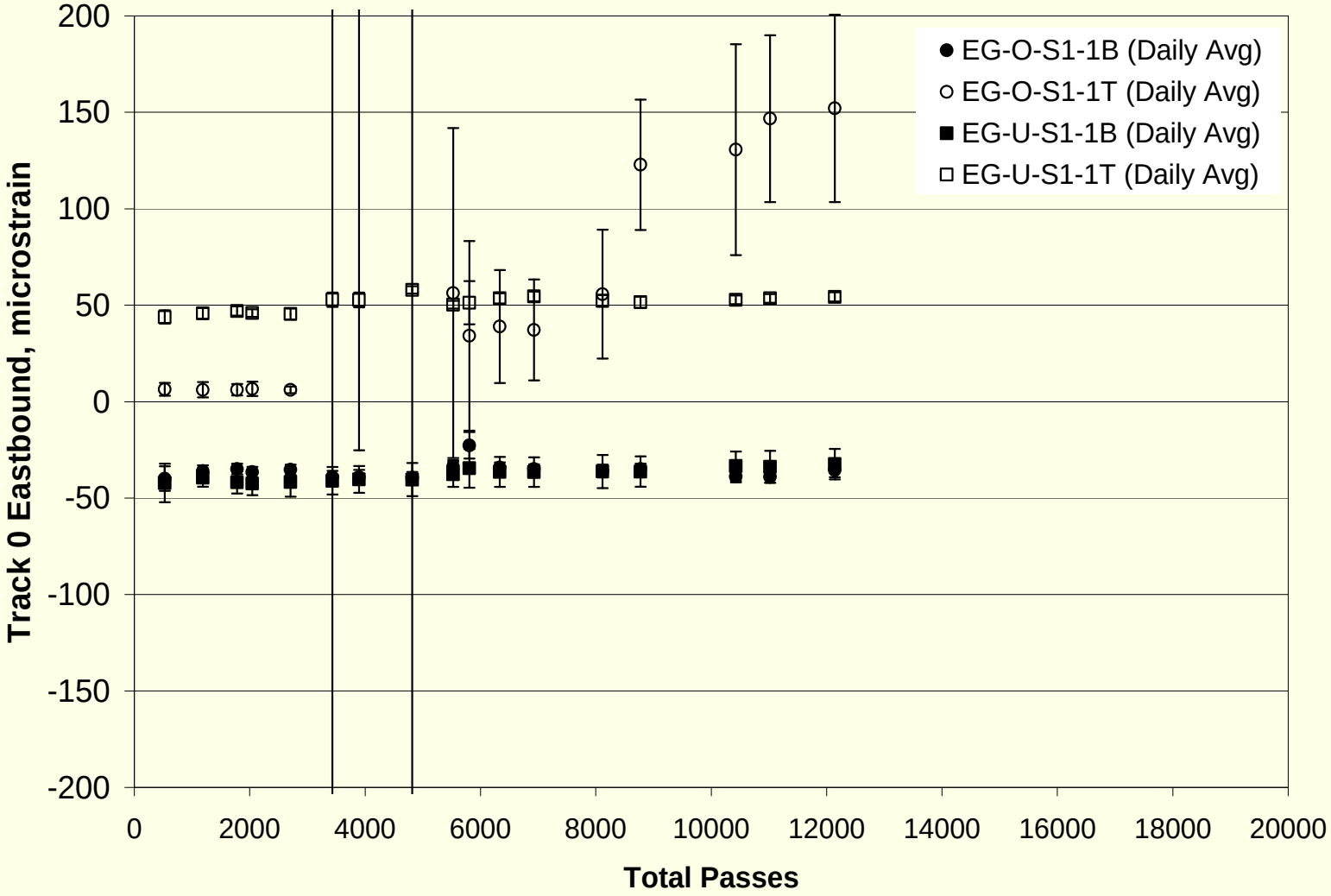
Baseline
Test Item N1

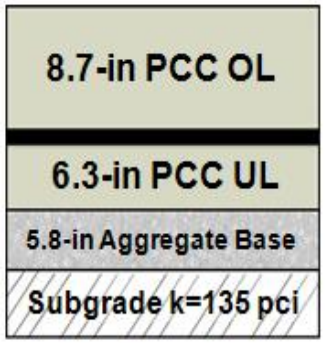


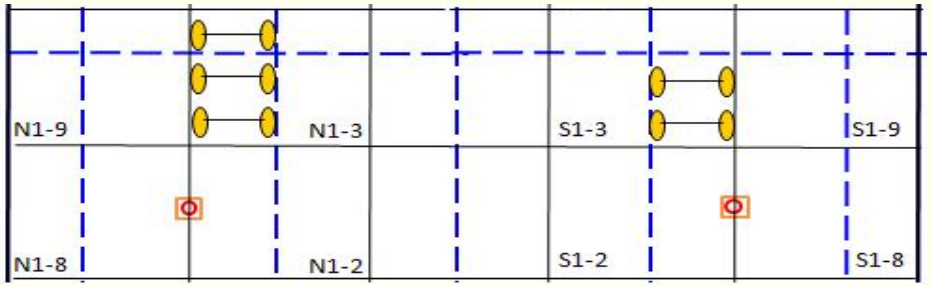




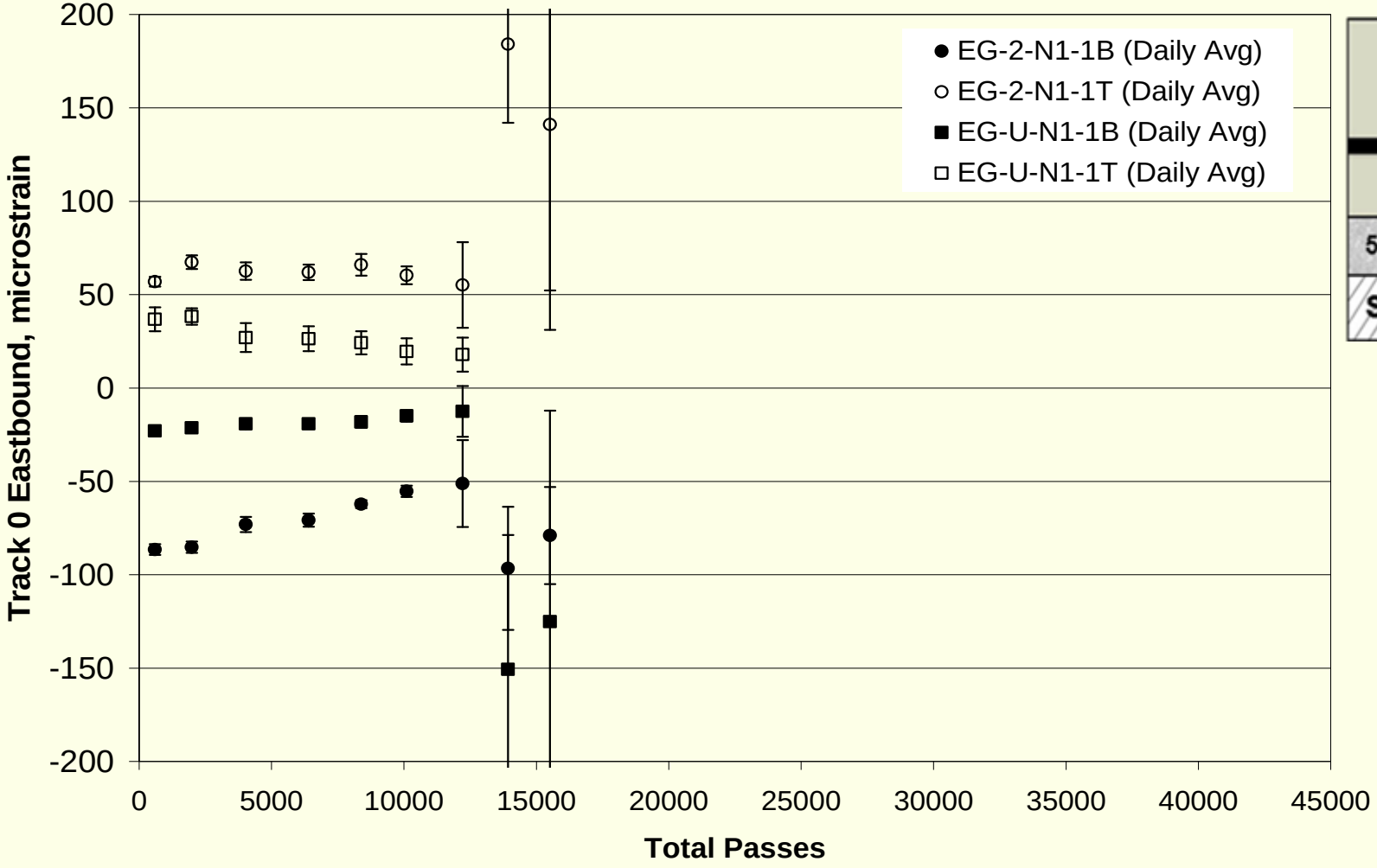
Baseline
Test Item S1

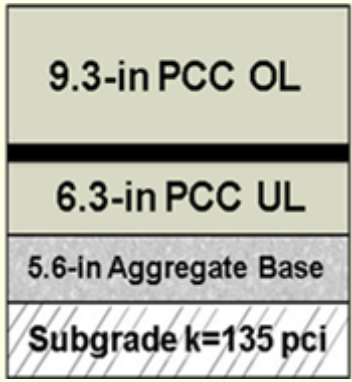


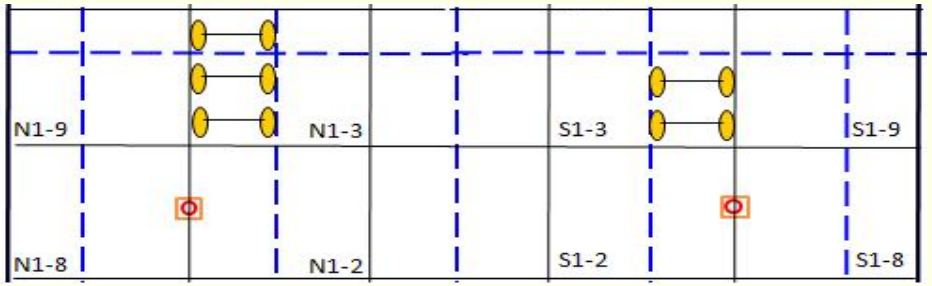




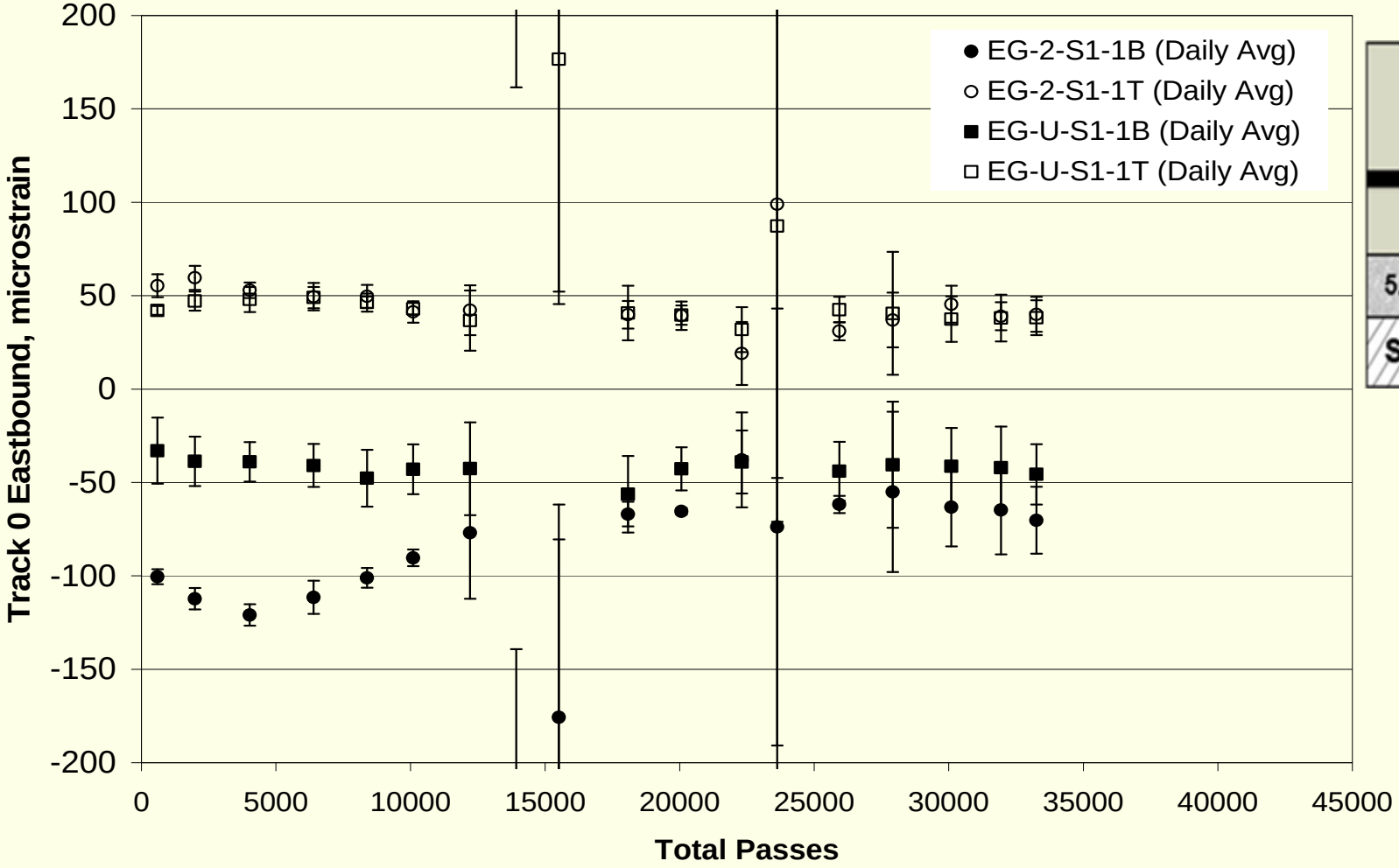
SCI Validation
Test Item N1

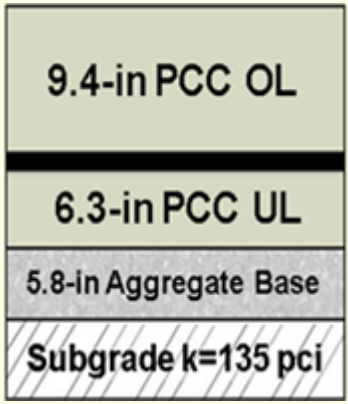






SCI Validation
Test Item S1





E. Verify whether measured responses match predicted responses from current models and design methods.

BASELINE EXPERIMENT
FAARFIELD 1.304 ANALYSIS SUMMARY
WITH MR = 550 psi

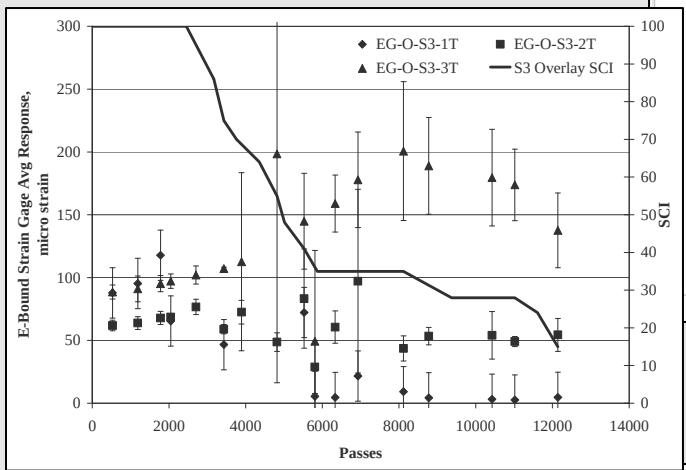
TEST ITEMS	N1	S1	N2	S2	N3	S3
STRUCTURAL CROSS-SECTIONS	8.6-in OL 6.3-in UL 5.6-in Agg	8.7-in OL 6.3-in UL 5.8-in Agg	7.4-in OL 7.4-in UL 5.5-in Agg	7.3-in OL 7.7-in UL 5.7-in Agg	5.6-in OL 9.8-in UL 4.7-in Agg	5.7-in OL 9.8-in UL 4.8-in Agg
INITIAL UNDERLAY SCI	100	100	100	100	100	100
MATERIAL INFORMATION	E_{pcc} = 4M psi, MR = 550 psi, k_{sub} = 135 pci, %CDFU = 0%					
LOADING CONFIGURATION	Dual Spacing: 54 in., Tandem Spacing: 57 in. Wheel Load: 50,000 lb., Tire Pressure: 230 psi					
	Triple	Twin	Triple	Twin	Triple	Twin
PREDICTED STRESSES (psi)						
OVERLAY	688	665	747	724	807	795
UNDERLAY	402	383	364	362	318	308

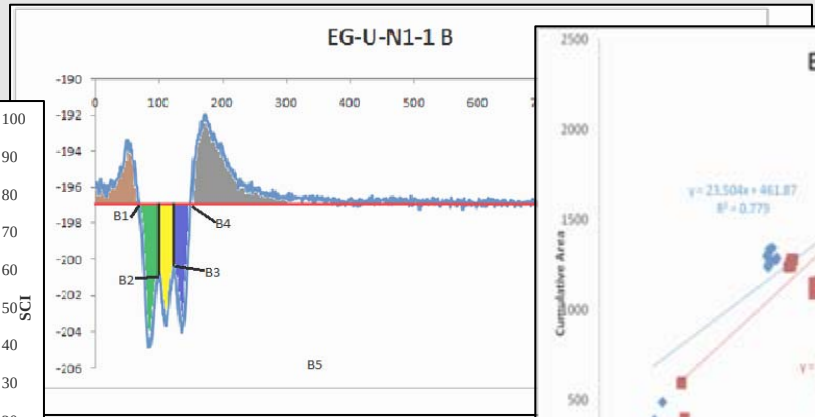
SCI VALIDATION STUDY
FAARFIELD 1.304 ANALYSIS SUMMARY
WITH MR = 550 psi

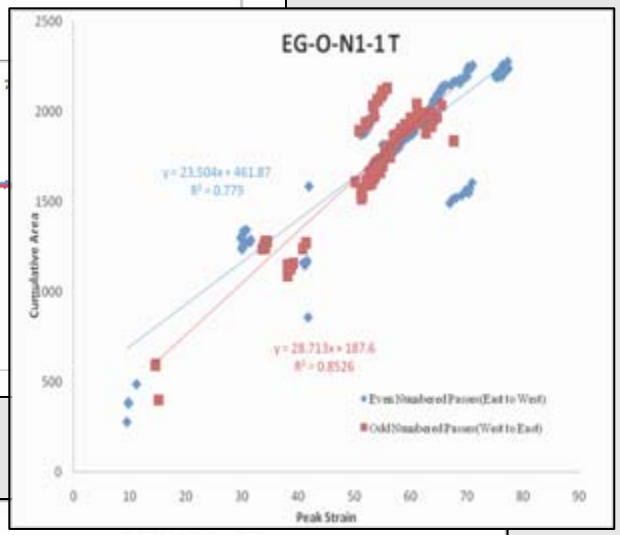
TEST ITEMS	N1	S1	N2	S2	N3	S3
STRUCTURAL CROSS-SECTIONS	9.3-in OL 6.3-in UL 5.6-in Agg	9.4-in OL 6.3-in UL 5.8-in Agg	8.2-in OL 7.4-in UL 5.5-in Agg	8.2- in.OL 7.4-in UL 5.7-in Agg	6.5-in OL 9.8-in UL 4.7-in Agg	6.5- in.OL 9.8-in. UL 4.8-in Agg
INITIAL UNDERLAY SCI	25	23	43	28	84	81
MATERIAL INFORMATION	E_{pcc} = 4M psi, MR = 550 psi, k_{sub} = 135 pci, %CDFU = 100%					
LOADING CONFIGURATION	Dual Spacing: 54 in., Tandem Spacing: 57 in. Wheel Load: 42,500 lb., Tire Pressure: 230 psi					
	Triple	Twin	Triple	Twin	Triple	Twin
PREDICTED STRESSES (psi)						
OVERLAY	626	607	647	670	618	595
UNDERLAY	70	62	166	105	274	280

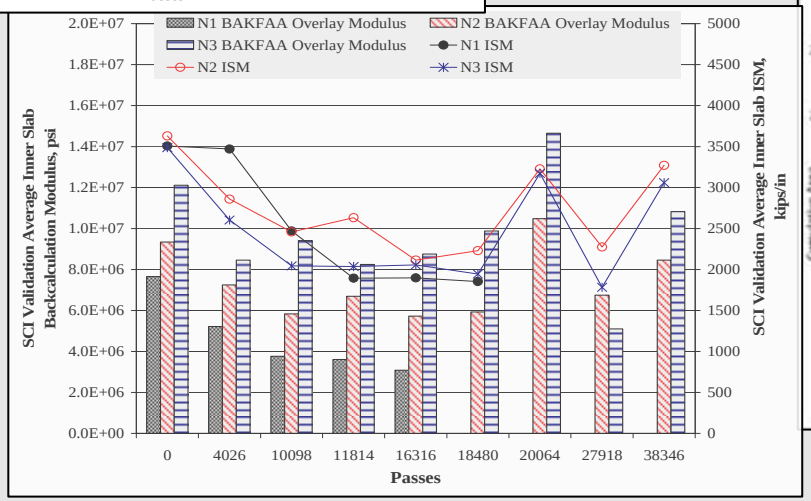
Performance Predictions

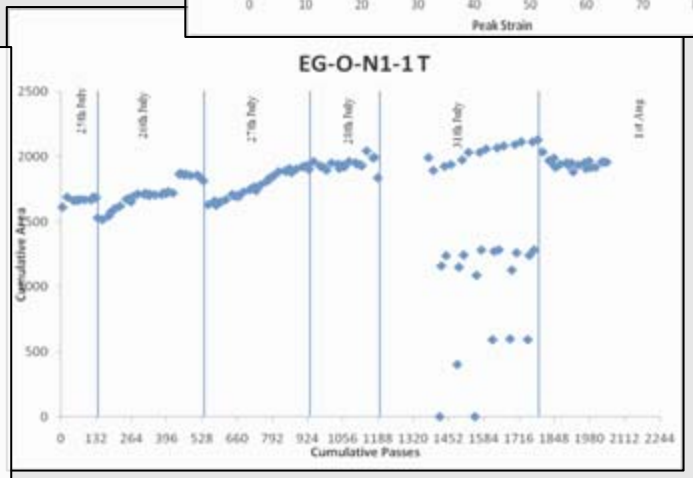
- Comparative deterioration of underlying pavement and overlay
- Comparative deterioration of structural cross-sections
  - Thick overlay over thin underlying pavement
  - Thin overlay over thick underlying pavement
  - Approximate equal thicknesses of overlay and underlying pavement
- Impact of underlay SCI on overlay deterioration











Data for Ongoing and Future Analysis