Proposed Small Specimen Standards

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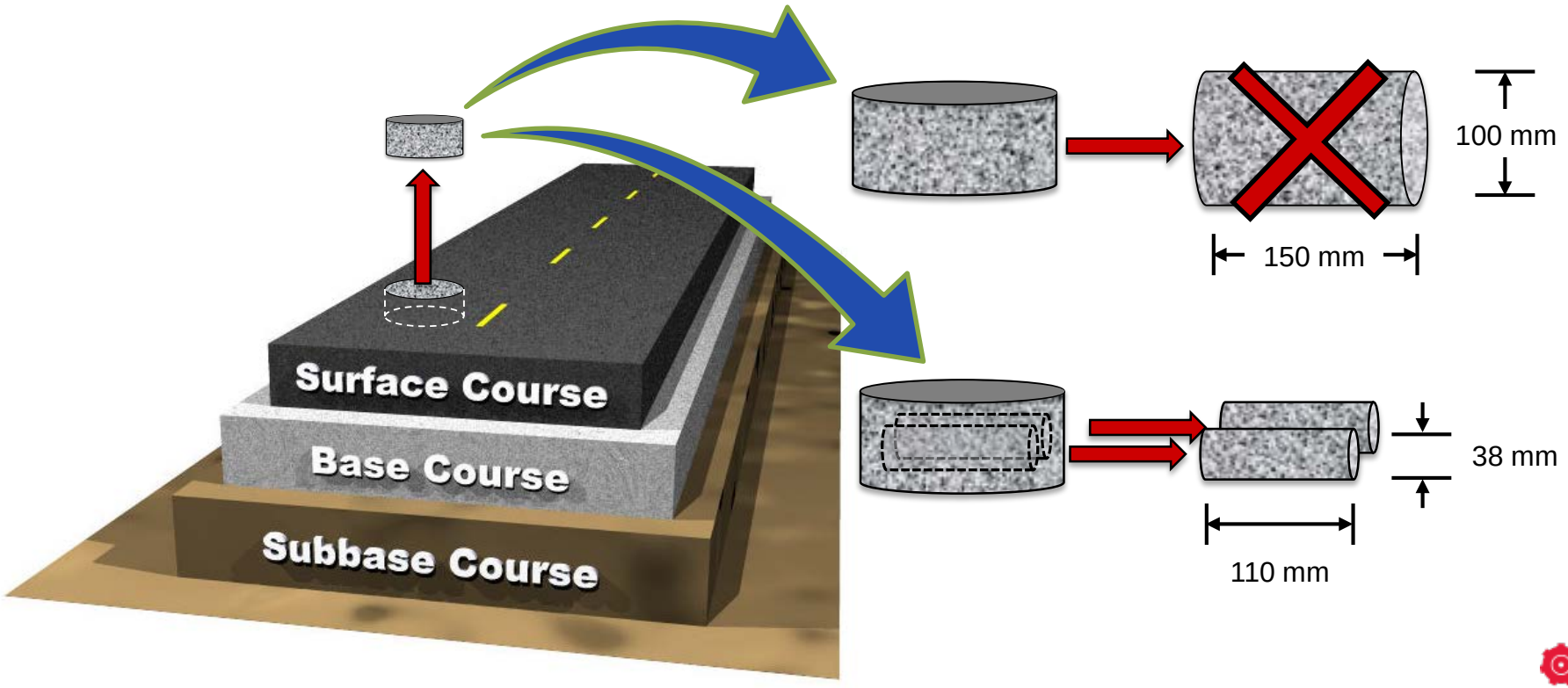
Outline

- Introduction
- Review of NCHRP IDEA Project N-181
- Proposed AASHTO Standards

Introduction

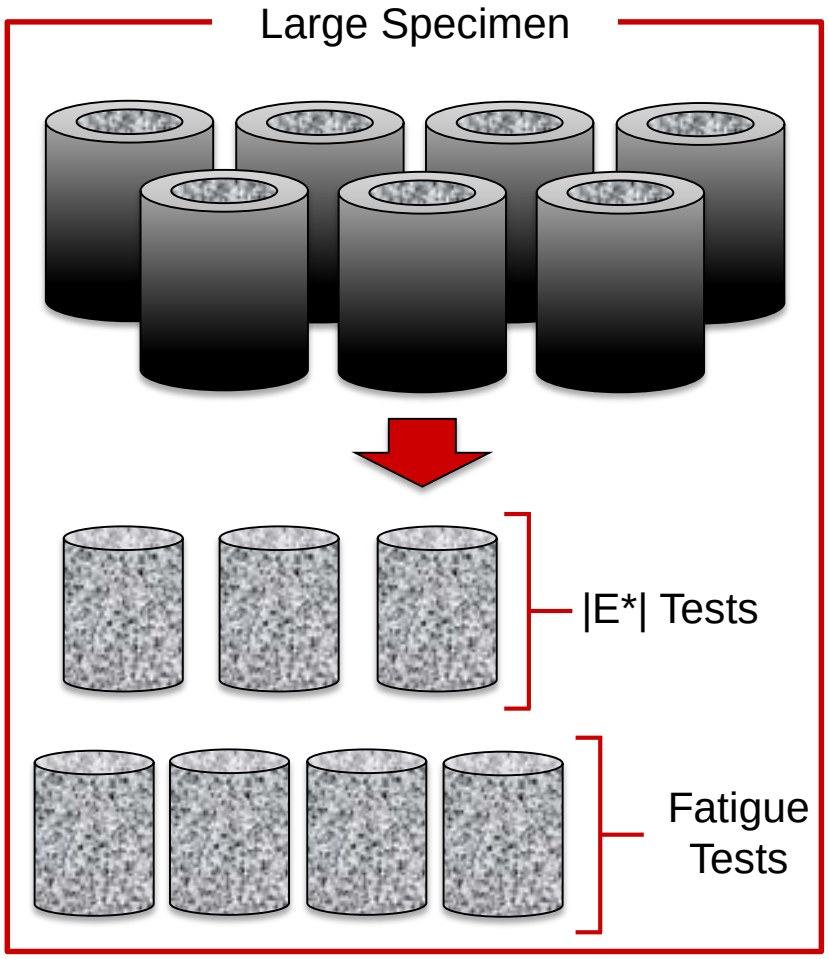
Small Specimen Geometries

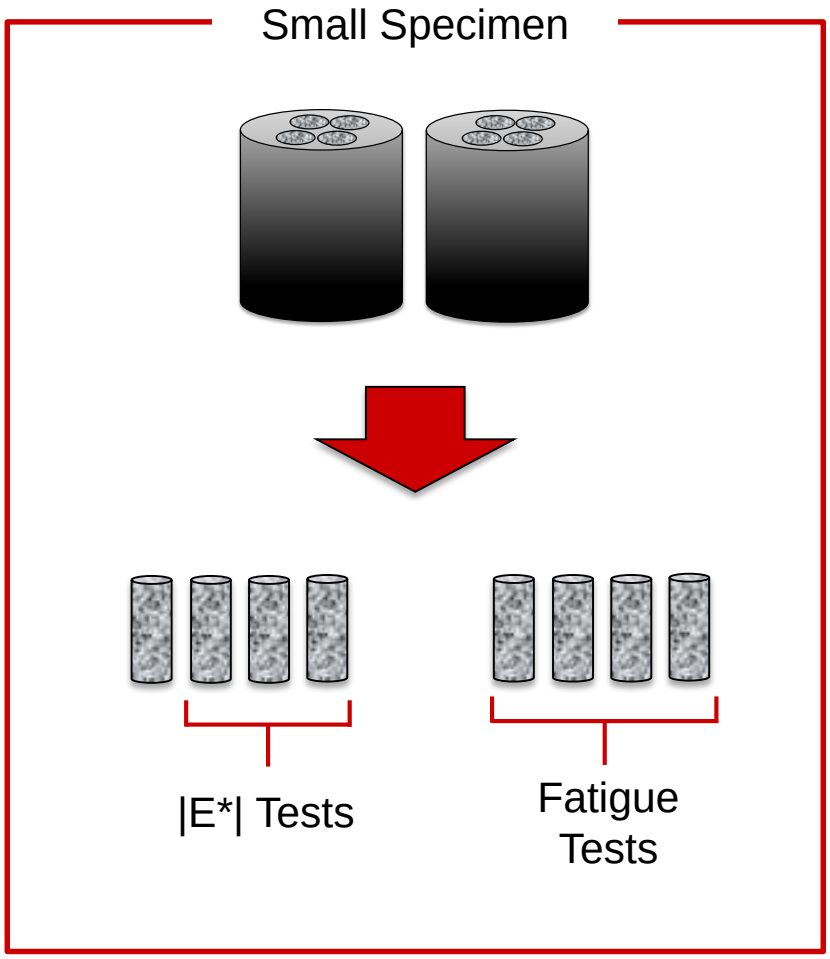
- Proposed to enable field core testing (Kutay et al. 2009, Park and Kim 2013, Li and Gibson 2013, and Bowers et al. 2015)



Introduction

Small Specimen Geometries





NCHRP IDEA Project N-181

- Objectives
  - Evaluate the effects of specimen geometry on AMPT dynamic modulus and cyclic fatigue tests using mixtures with various NMAS values
  - Optimize the laboratory fabrication of small specimens extracted from gyratory-compacted samples

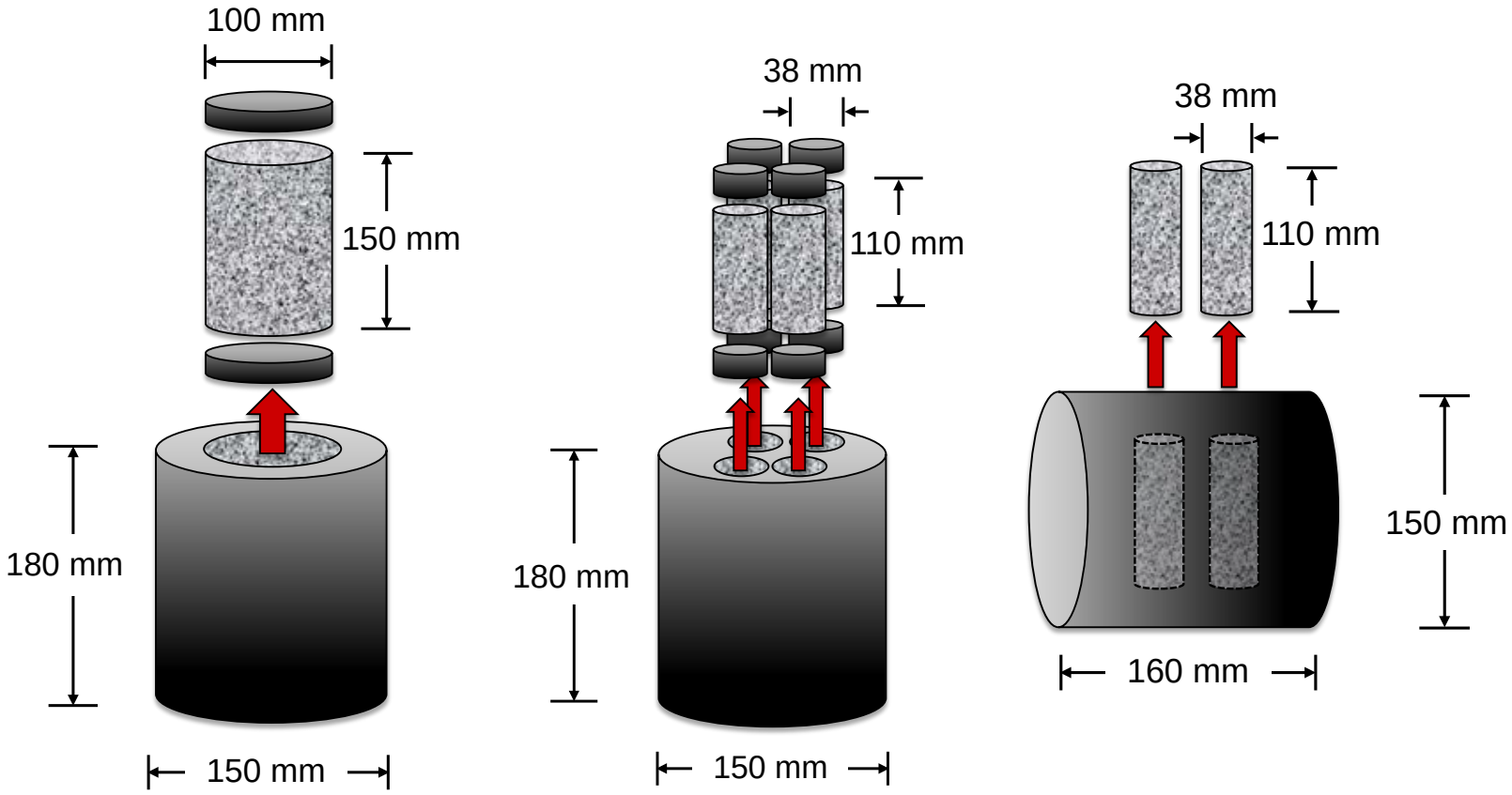
Materials Evaluated

- Plant-produced loose mixtures

Mixture Type	NMAS (mm)	Asphalt Binder	RAP Content (%)
RSF9.5A	9.5	PG 64-22	30
RS9.5D	9.5	PG 76-22	20
SM12.5A	12.5	PG 64-22	30
RI19.0B	19.0	PG 64-22	20
RI19.0B(2)	19.0	PG 64-22	34
RB25.0B	25.0	PG 64-22	30

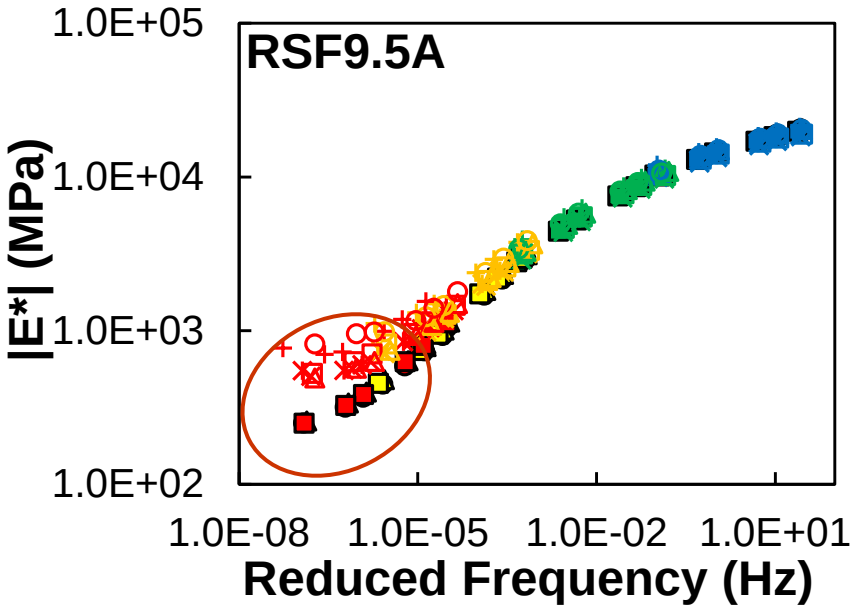
Experimental Efforts

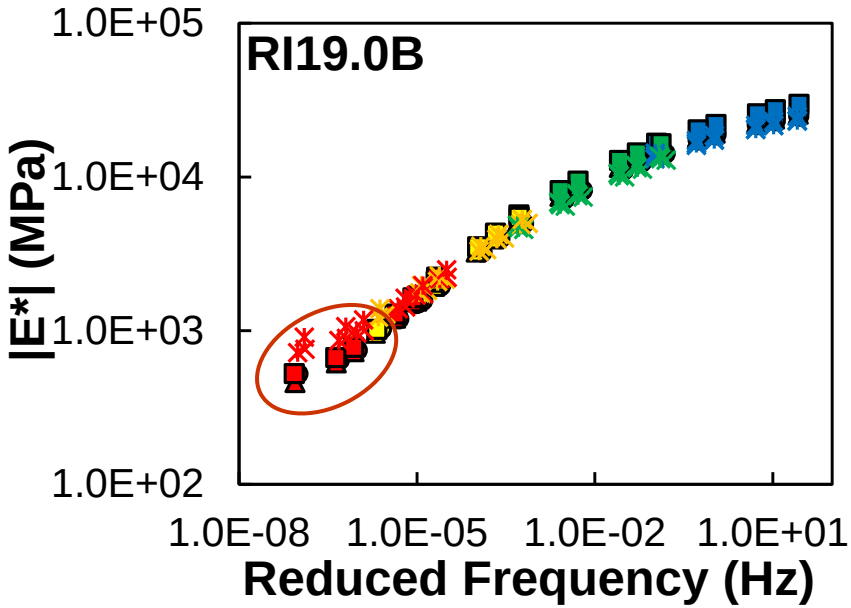
Specimen Fabrication



Results

Specimen Geometry Effects





Solid: large specimen
Line: small cylindrical specimen
Empty: small prismatic specimen

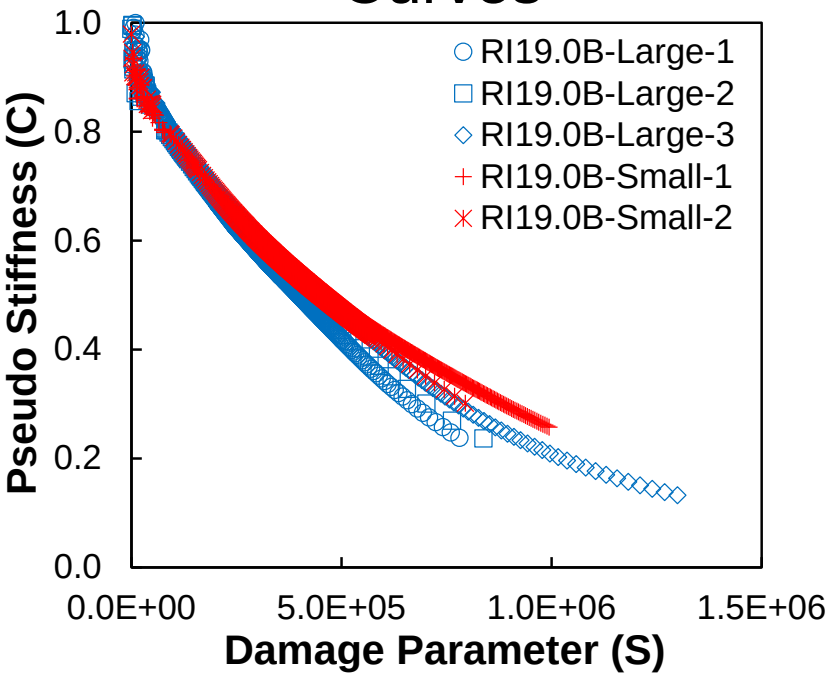
Blue: 4°C test temperature
Green: 20°C test temperature

Yellow: 40°C test temperature
Red: 54°C test temperature

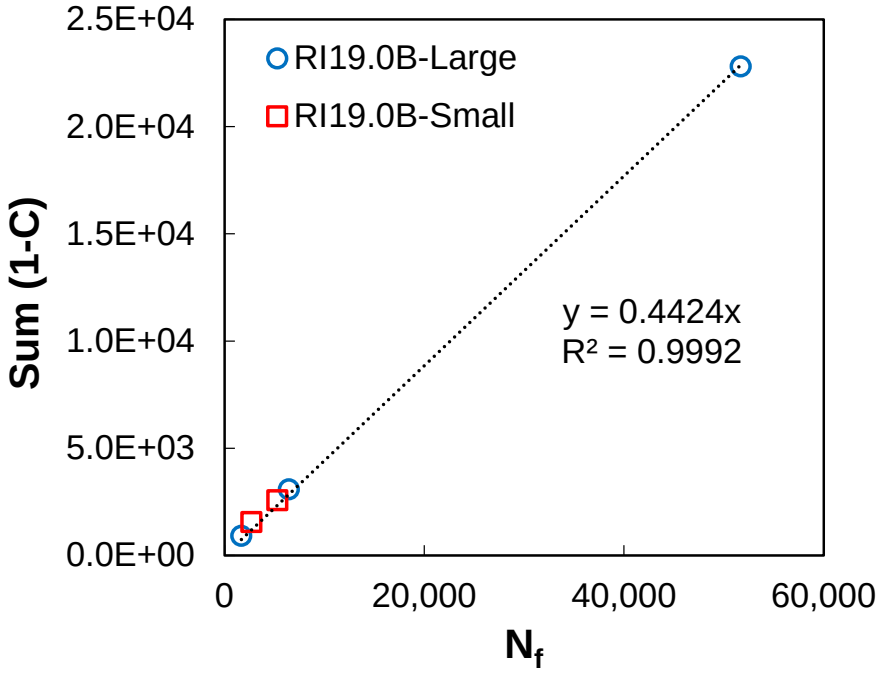
Results

Specimen Geometry Effects - RI19.0B

Damage Characteristic Curves

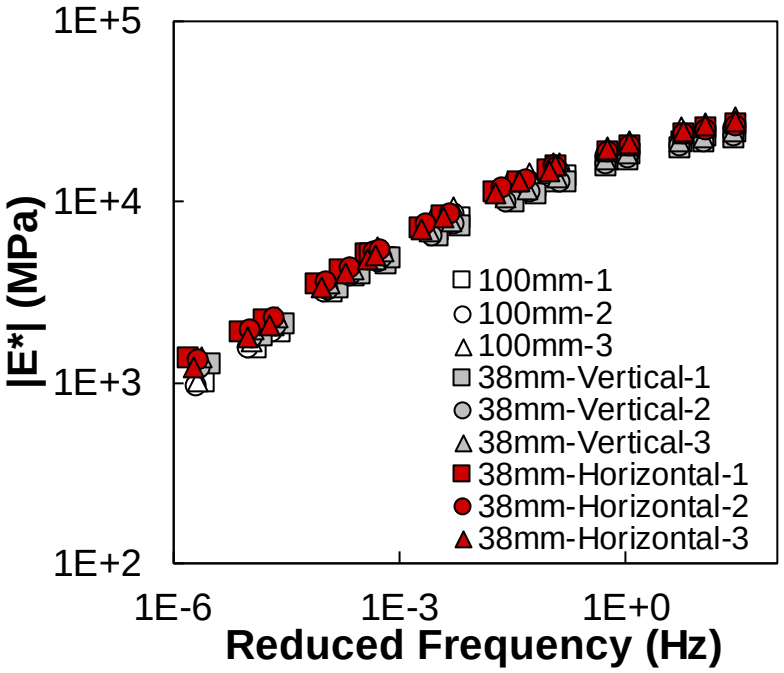


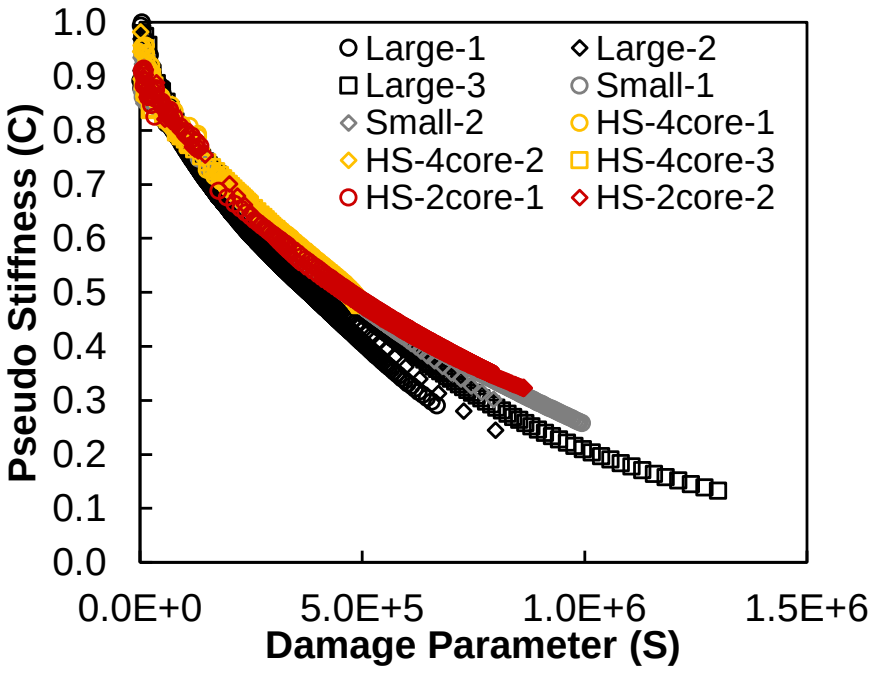
Failure Criterion



Results

Effect of Coring Direction - RI19.0B





- Horizontally-extracted specimens subjected to fatigue testing experienced end failure

NCHRP IDEA Project N-181 Findings

- Small specimen testing provides equivalent dynamic modulus results to large specimens at low and intermediate temperatures
  - Do not recommend testing above 40ºC
- Small specimen testing provides equivalent cyclic fatigue test results to large specimen testing
- Anisotropy in gyratory-compacted samples does not affect dynamic modulus or cyclic fatigue test results
- Horizontal coring in laboratory specimen fabrication should be avoided because it leads to end failure in cyclic fatigue tests
- The recommended procedure for laboratory fabrication of small specimens is the vertical coring of four specimens from the inner 100-mm diameter of gyratory-compacted samples

Proposed AASHTO Standards

Overview

- Fabrication
  - Follows AASHTO R 83
  - Covers laboratory specimen fabrication and the extraction of small specimens from field cores
- AMPT Dynamic Modulus Testing
  - Follows AASHTO T 378
- AMPT Cyclic Fatigue Testing
  - Follows AASHTO TP 107

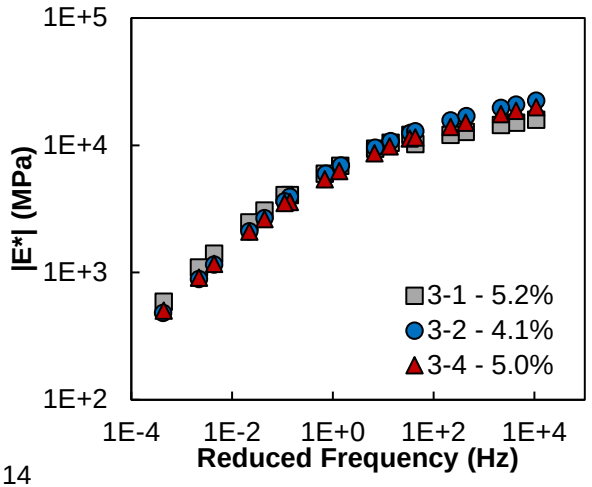
Improvements to Proposed Standards

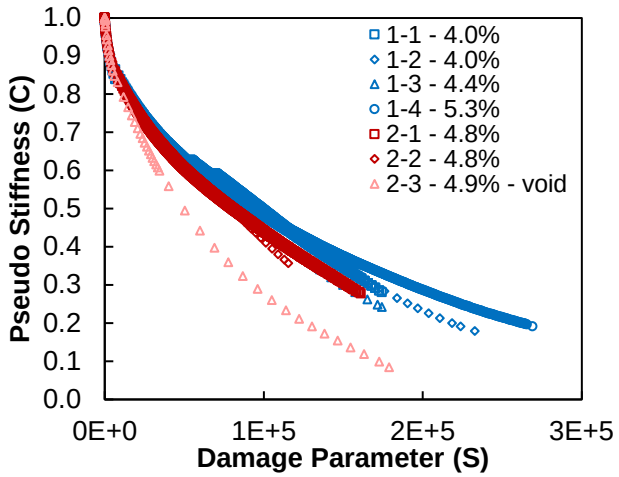
- Revised standard scope
- Revised procedures for selecting dynamic modulus and cyclic fatigue testing temperatures
- Improved temperature conditioning guidance for cyclic fatigue testing
- Improved strain selection procedure for cyclic fatigue testing

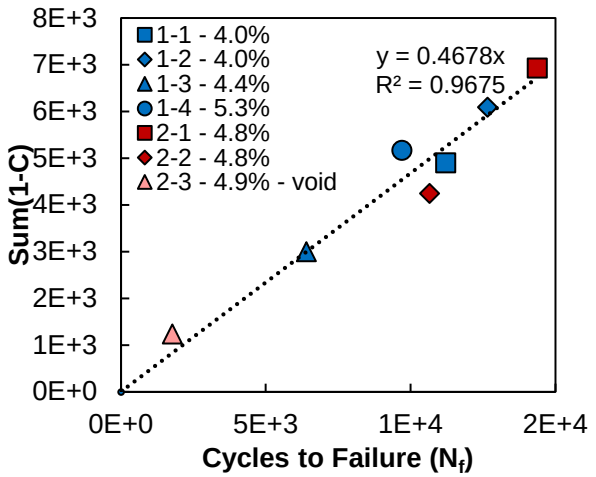
Standard Scope

- Standards applicable to dense-graded mixtures with NMAS up to 19.0 mm
  - Currently evaluating the applicability of the small specimen standards to 25-mm NMAS mixture under FHWA Contract No. DTFH6117C00037

25-mm Mixture Results from NCHRP IDEA N-181







Dynamic Modulus Testing Temperature Selection

- Revised to limit maximum testing temperature to 40ºC
- Removed 0.01 Hz at highest test temperature
  - Previously referred to AASHTO R 84 for test temperature and frequency selection

PG 58-XX and Softer		PG 64-XX and Stiffer	
Temperature °C	Loading Frequencies, Hz	Temperature °C	Loading Frequencies, Hz
4	10, 1, 0.1	4	10, 1, 0.1
20	10, 1, 0.1	20	10, 1, 0.1
35	10, 1, 0.1	40	10, 1, 0.1

Cyclic Fatigue Testing Temperature Selection

- Testing temperature selected based on the specified PG of the binder used

PG Low Temperature, °C	Test Temperature, °C PG High Temperature, °C						
	46	52	58	64	70	76	82
-10	15	18	21	21	21	21	21
-16	12	15	18	21	21	21	21
-22	9	12	15	18	21	21	21
-28	9	9	12	15	18	21	21
-34	9	9	9	12	15	18	21
-40	9	9	9	9	12	15	18
-46	9	9	9	9	9	12	15

- For binders graded with an “H”, “V”, or “E” designation by AASHTO M332, use one PG high temperature grade higher than specified
- For mixtures with recycled material and the use of softer PG binders than originally specified, use originally specified grade

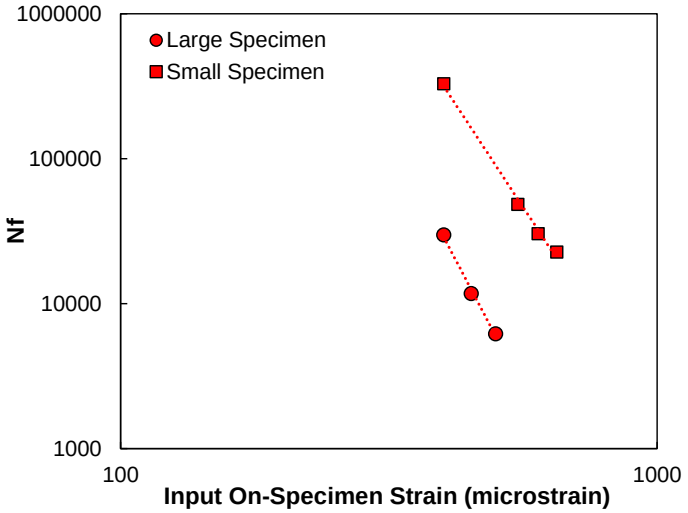
Temperature Conditioning Times

|ΔT| (°C)	AMPT Condition	AMPT Conditioning Time (hours) Test Setup Time (min) after External Conditioning			
		2.5	5	10	20
15	1.50	*	*	1.00	1.25
14	1.50	*	*	1.00	1.25
13	1.50	*	*	1.00	1.25
12	1.25	*	*	1.00	1.25
11	1.25	*	*	1.00	1.25
10	1.25	*	*	1.00	1.25
9	1.25	*	0.75	1.00	1.00
8	1.25	*	0.75	1.00	1.00
7	1.25	*	0.75	1.00	1.00
6	1.25	*	0.75	1.00	1.00
5	1.00	*	0.75	0.75	1.00
4	1.00	0.50	0.75	0.75	1.00
3	1.00	0.50	0.50	0.75	0.75
2	1.00	0.25	0.50	0.75	0.75
1	0.75	0.25	0.25	0.50	0.50

*The return to test temperature could not be achieved in this amount of time.

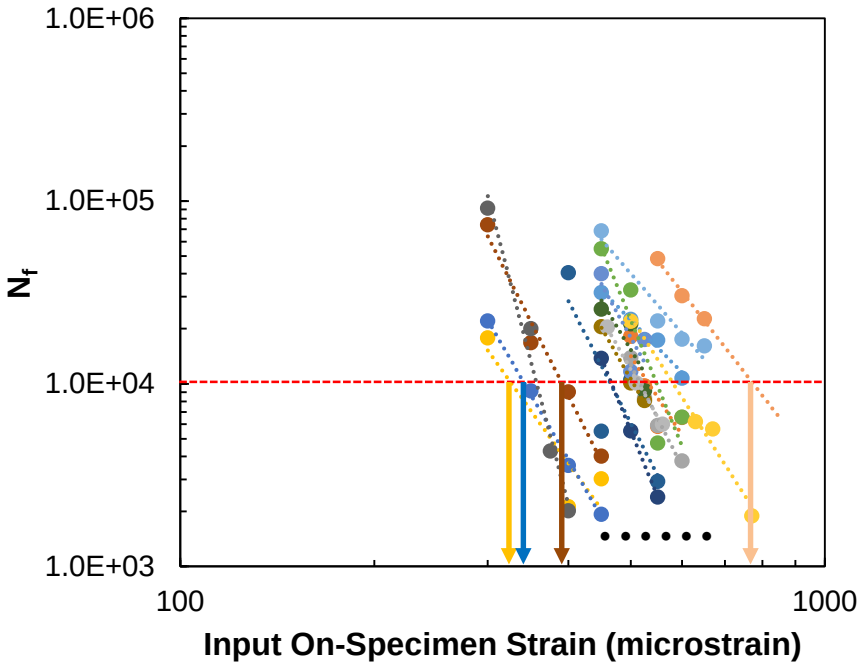
TP 107 Strain Selection Guide

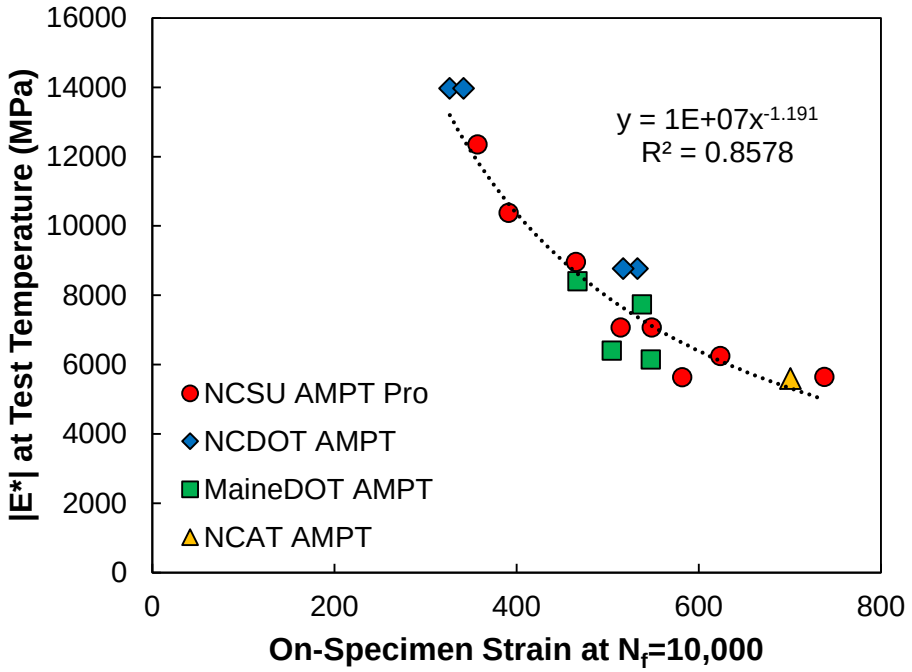
Programmed Actuator Microstrain	If $\lvert E^* \rvert_{fingerprint}$ is > 8,800 MPa, select 300 µstrain as the first specimen's strain				If 8,800 > $\lvert E^* \rvert_{fingerprint}$ > 4,400 MPa, select 500 µstrain as the first specimen's strain					If $\lvert E^* \rvert_{fingerprint}$ is <4,400 MPa, select 800 µstrain as the first specimen's strain			
200	62,514	129,033	258,702	503,812									
250	4,220	10,969	27,219	64,485	145,856	314,972							
300	**467**	**1,464**	**4,324**	**12,022**	31,468	77,539	179,856						
350	72	267	913	2,905	8,605	23,704	60,744	144,799					
400			237	849	2,798	8,491	23,721	61,010	144,466				
450				287	1,039	3,433	10,350	28,465	71,421	163,488			
500					**428**	**1,527**	**4,929**	**14,392**	**38,032**	90,944			
550						734	2,519	7,766	21,507	53,501	119,549		
600							1,365	4,422	12,781	32,962	75,847	155,720	
650							777	2,634	7,919	21,111	49,906	104,615	
700								1,630	5,084	13,975	33,872	72,385	136,383
750								1,043	3,365	9,518	23,613	51,374	98,022
800								687	2,287	**6,646**	**16,849**	**37,278**	**71,969**
850									1,592	4,742	12,271	27,581	53,840
900									1,131	3,450	9,101	20,761	40,952
950									818	2,553	6,859	15,869	31,613
1,000										1,919	5,246	12,298	24,730
1,050										1,463	4,064	9,650	19,579
1,100										1,129	3,187	7,658	15,670
1,150										881	2,526	6,140	12,667
1,200											2,022	4,970	10,332
1,250											1,633	4,057	8,498
1,300											1,330	3,339	7,043
1,350											1,092	2,768	5,879
1,400											903	2,310	4,940
1,450											752	1,940	4,176
1,500												1,640	3,550
1,550												1,393	3,035
1,600												1,190	2,607
1,650												1,021	2,250
1,700												880	1,950
1,750												762	1,697
1,800													1,483
1,850													1,301



Development of Small Specimen Strain Selection Procedure

- 4 testing machines (NCSU, NCDOT, MEDOT, NCAT)





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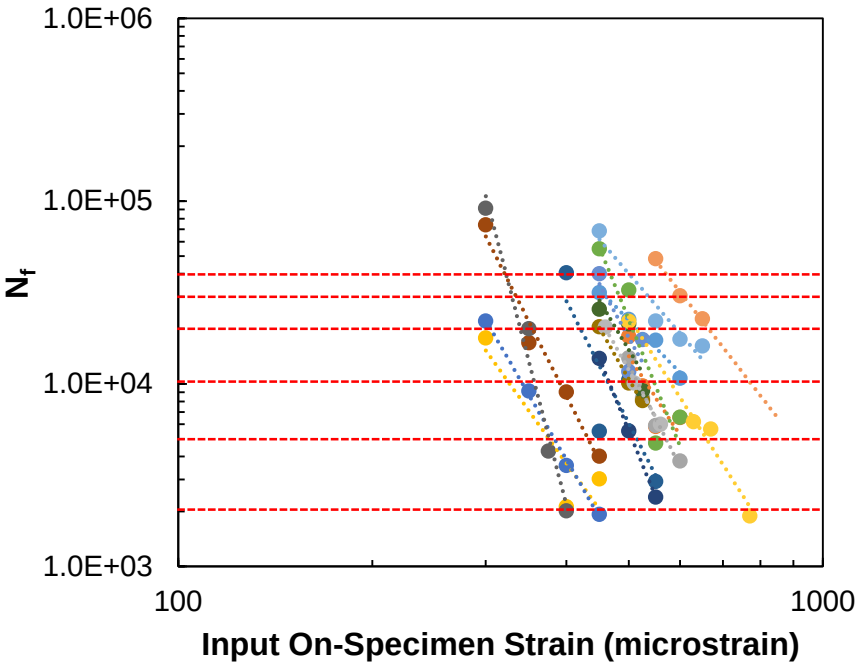
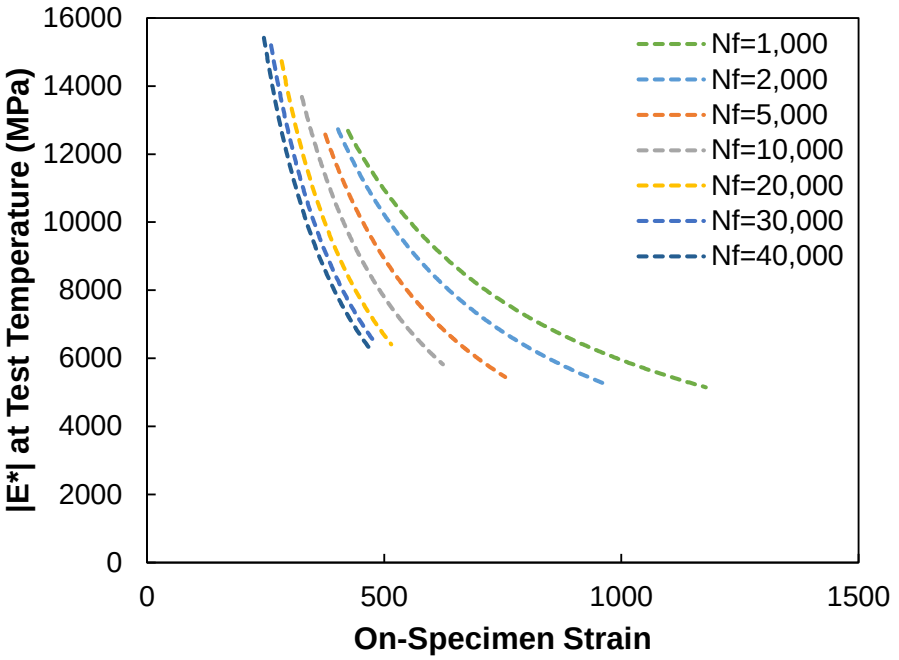
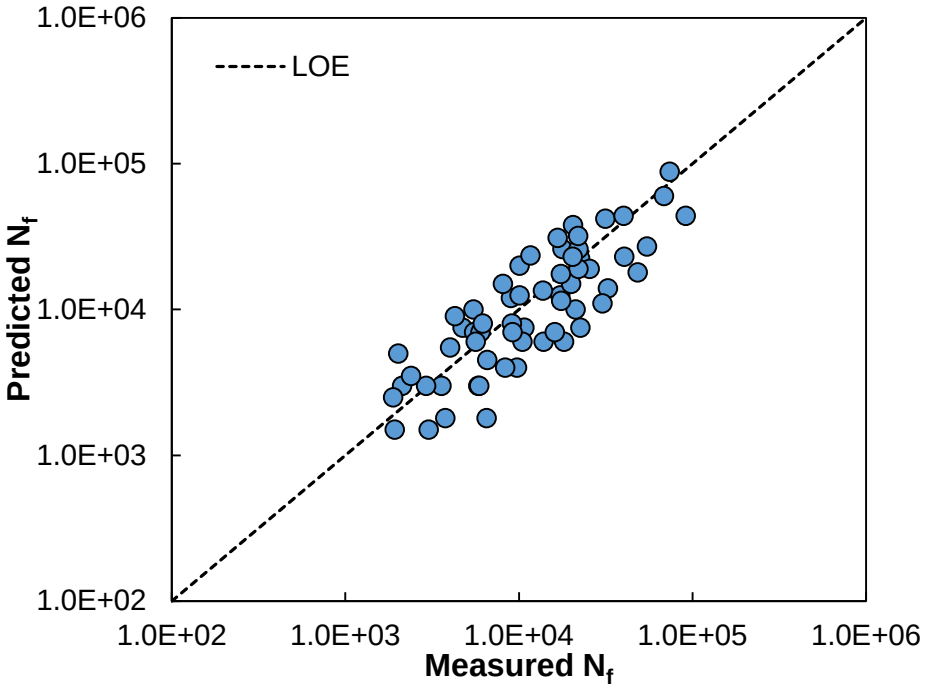
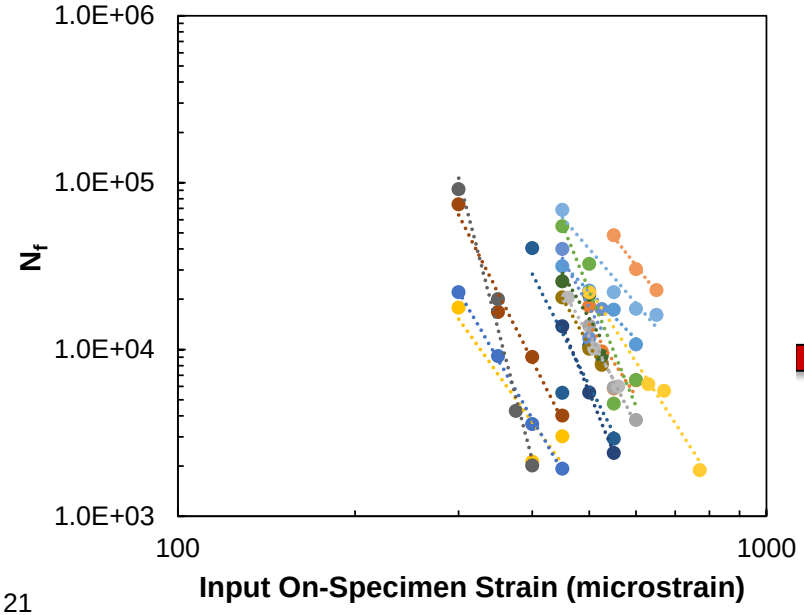




Evaluation of the Predictive Equation

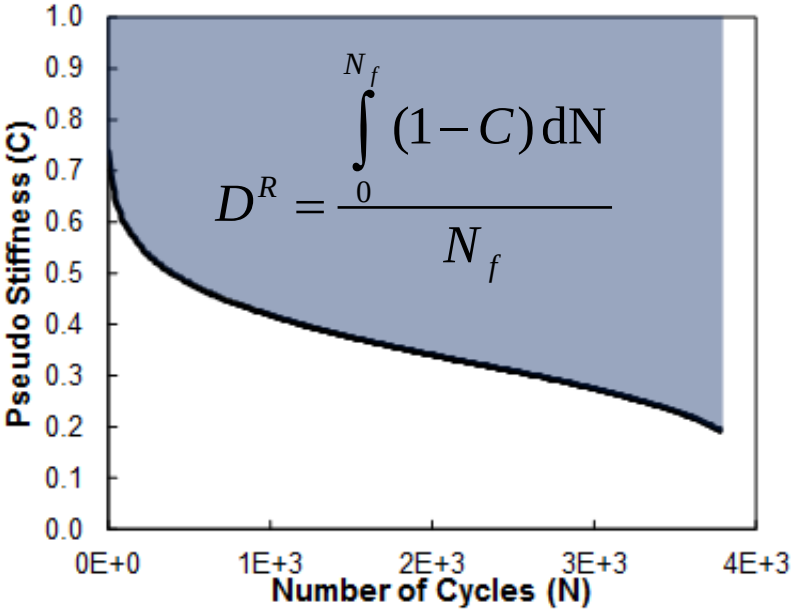
$$\varepsilon_{Input} = a_1 N_f^{a_2} \left|E^*\right|^{b_2 \ln(a_1 N_f^{a_2}) + b_2}$$

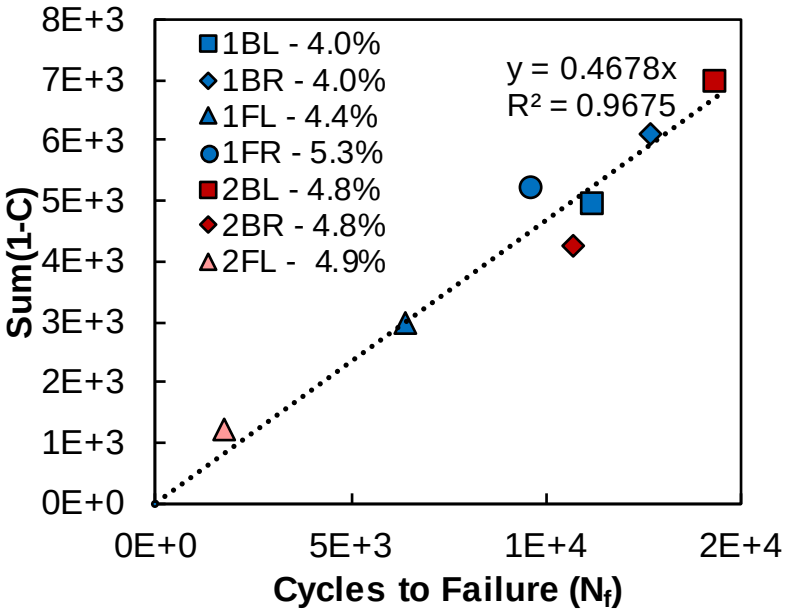




New Failure Criterion

- D^R is equal to the average reduction in pseudo stiffness (i.e., C) up to failure
  - Does not require a broad range in N_f values
  - Strain selection procedure targets N_f range of 5,000 to 40,000

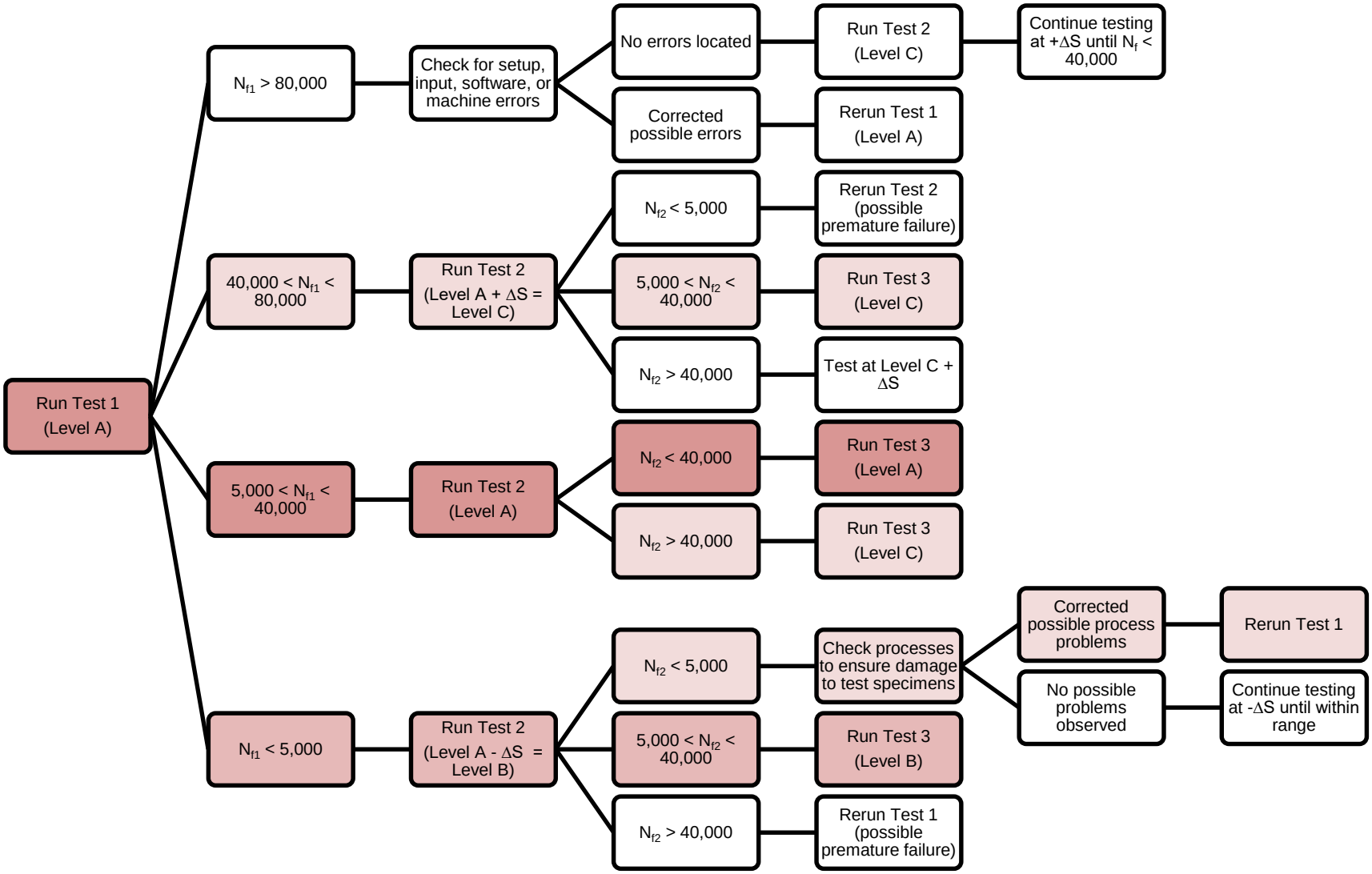




Strain Selection Table

|E*| (MPa)	Target On-Specimen Strain Levels (microstrain)			ΔS
	Level A	Level B	Level C	
2500	1030	890	1170	140
3000	920	800	1040	120
3500	830	730	930	100
4000	760	670	850	90
4500	710	620	790	80
5000	660	580	740	80
5500	620	550	690	70
6000	590	520	650	60
6500	560	500	620	60
7000	530	470	590	60
7500	510	450	560	50
8000	490	440	540	50
8500	470	420	520	50
9000	450	410	500	50
9500	440	390	480	40
10000	420	380	460	40

|E*| (MPa)	Target On-Specimen Strain Levels (microstrain)			ΔS
	Level A	Level B	Level C	
10500	410	370	450	40
11000	400	360	440	40
11500	390	350	430	40
14500	330	300	360	30
15000	330	300	360	30
15500	320	290	350	30
16000	310	290	340	30
16500	310	280	340	30
17000	300	280	330	30
17500	290	270	310	20
18000	290	270	310	20
18500	280	260	300	20
19000	280	260	300	20
19500	280	250	300	20
20000	270	250	290	20


Run Test 1 (Level A)
N_{f1} > 80,000
Check for setup, input, software, or machine errors
No errors located
Run Test 2 (Level C)
Continue testing at +ΔS until N_f < 40,000
Corrected possible errors
Rerun Test 1 (Level A)
40,000 < N_{f1} < 80,000
Run Test 2 (Level A + ΔS = Level C)
N_{f2} < 5,000
Rerun Test 2 (possible premature failure)
5,000 < N_{f2} < 40,000
Run Test 3 (Level C)
N_{f2} > 40,000
Test at Level C + ΔS
5,000 < N_{f1} < 40,000
Run Test 2 (Level A)
N_{f2} < 40,000
Run Test 3 (Level A)
N_{f2} > 40,000
Run Test 3 (Level C)
N_{f1} < 5,000
Run Test 2 (Level A - ΔS = Level B)
N_{f2} < 5,000
Check processes to ensure damage to test specimens
Corrected possible process problems
Rerun Test 1
No possible problems observed
Continue testing at -ΔS until within range
5,000 < N_{f2} < 40,000
Run Test 3 (Level B)
N_{f2} > 40,000
Rerun Test 1 (possible premature failure)

Summary

- The scope of the small specimen standards has been revised to include dense-graded mixtures with NMAS up to 19.0 mm
- The revised dynamic modulus test temperatures do not exceed 40ºC due to concerns with higher testing temperatures
- The revised cyclic fatigue test temperature procedure is based on the specified binder PG (AASHTO M 320 or M 332)
- A calibrated heat diffusion model was used to develop improved guidance for temperature conditioning times in cyclic fatigue tests
- A small specimen strain selection guide was developed for cyclic fatigue testing

Questions?