A New Test Method for Moisture Damage of Asphalt Mixtures

Haleh Azari, Ph.D.
AASHTO Advanced Pavement Research Laboratory (AAPRL)

89th Annual Meeting of the
North Eastern States Materials Engineers' Association
Portsmouth, NH
October 21 - 23, 2013

Reference Paper

"Improvement of the Test Method for Determining Moisture Damage Resistance"
(Haleh Azari and Alaeddin Mohseni)

RILEM Book series, Volume 8, 2013
Multi-Scale Modeling and Characterization of Infrastructure Materials
Proceedings of the International RILEM Symposium
Stockholm, June 2013

Background

- Moisture induced damage is a serious cause for diminishing the long-term performance of asphalt concrete
- Since late 1980's effort has been made to improve moisture susceptibility and to predict the behavior of the mixtures
- However, the results have not been universally successful
- AMRL conducted an ILS indicated high variability and erroneous results are still being reported (NCHRP Report 166, 2010)
- In a collaborative study with TU Delft, the causes of variability of the test were investigated (TRR 09-1530)

Problem Statements

Several Challenges were identified for AASHTO T283 Standard Test Method :

- long conditioning process/ total testing time
- high sample to sample variability
- components of moisture conditioning either too harsh, too long, not long enough, or not necessary
- ineffective sample shape/size for conditioning
- too severe mechanical test (strength test)

Objective

Recommend a testing protocol for moisture damage that has:

- improved variability
- effective conditioning method
- improved sample size/shape for enhanced conditioning
- More appropriate mechanical testing

Outline

- Tackle challenges of the AASHTO T 283 test
  - Investigate sample size and shape for improved moisture accessibility
  - Evaluate conditioning methods to improve effectiveness and to reduce conditioning time
  - Explore mechanical test to remove sample to sample variability
- Make recommendations towards improvement of moisture resistance test

Challenges with Sample Size

- Challenges:
  - Sample size should allow sufficient conditioning of the critical zones of the specimen
  - 150-mm diameter x 95-mm tall compacted cylinders are not uniformly conditioned
- Proposed Action:
  - Consider different sample shape/size that would allow better conditioning

Challenges with Existing Moisture Conditioning

- In the field, extent of heat and freezing in moisture damage is not clear
- Damage seems to happen during rainy season when temperature is rather mild
- 5 to 10 minutes suction at 27mm mercury is not enough to force moisture in micro pores of the specimens
- Non-uniform conditioning of the specimens (moisture might not be accessed to center of specimens)
- Conditioning process is too long

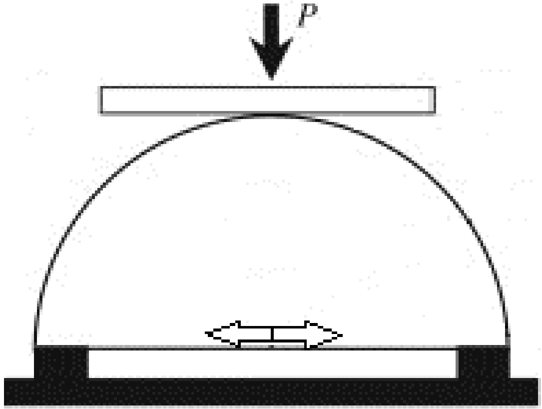
Possible Actions for Moisture Conditioning

- Make moisture available to the critical zone in the specimen
- Explore longer and higher level of vacuum
- Investigate loading saturated specimen as part of conditioning to create pore pressure
- Explore MIST device

Challenges with Existing Mechanical Test

- Challenges:
  - Tensile strength test method is too harsh
  - Produces high variable results
  - Includes sample to sample variability since strength test is conducted on separate sets of samples (wet and dry)

- Possible Actions:
  - Explore a mechanical test that is not failure based
  - Allows testing before and after conditioning to reduce variability
  - Parameter of the test should be sensitive to the damage caused by moisture
  - Load should be concentrated on the critical zone of the specimen



Additional Challenge with Existing Moisture Damage Test: Testing Specimens Wet

- Challenges:
  - AASHTO T283 does not require drying of conditioned specimens before testing
  - Wet samples show increased strength due to the pore pressure

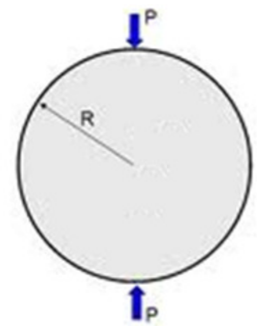
- Possible Action:
  - Dry the specimens before testing

Explored New Moisture Damage Test

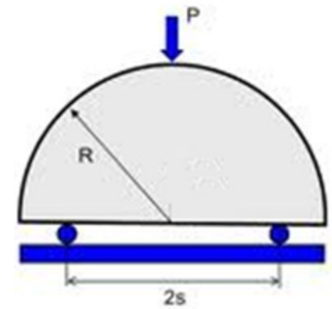
- Specimen geometry
- Specimen conditioning
- Mechanical test

Evaluated Specimen Shape/Size

- Indirect Tensile (IDT)
  - 100-mm diameter x 28-mm thick
  - 150-mm diameter x 38-mm thick
  - Tensile stress in the middle of the sample

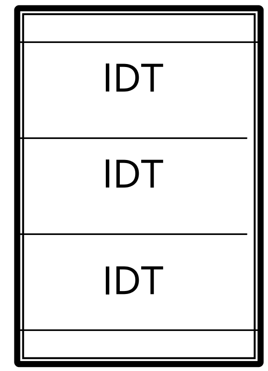


- Semi-circular Bend (SCB)
  - 150- mm diameter x 38-mm thick
  - Requires less load to produce tensile stress
  - Critical zone of the sample is exposed and can be better conditioned
  - Provides more replicates for testing

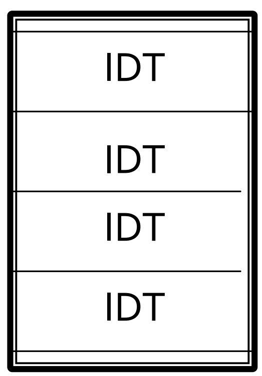


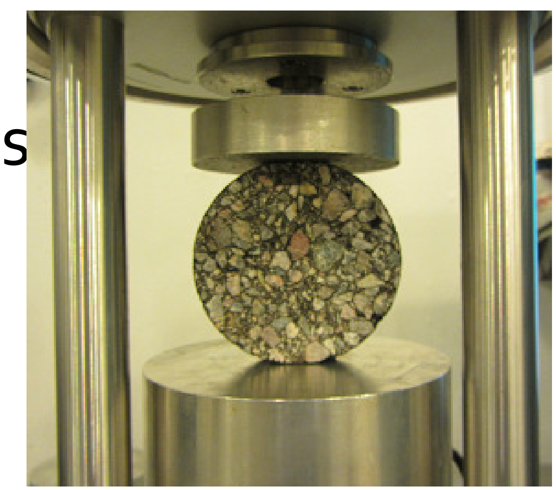
IDT Sample Preparation

- 150mm diam. x 175mm height
  - 25mm was cut from top and bottom
  - Three equal 38-mm thick disks



- 100mm diam. X 150mm height
  - Four equal 28-mm thick disk samples





SCB Sample Preparation and Testing

SCB	SCB
SCB	SCB
SCB	SCB

150mm diam. x 175mm height

- 25mm was cut from top and bottom
- Three equal 38-mm thick disks
- Disks are cut into semi-circular samples

Proposed Moisture Conditioning

- Longer and higher level of vacuum than T283 (e.g., 15 mm mercury for 1 hr)
- Mechanically loading saturated specimen to create pore pressure
- Dry specimens using CoreDry

Incremental Repeated Load Permanent Deformation (iRLPD)

- ***i*** – Testing several increments on the same sample
- **RL** – Loading rate similar to the field
  - (0.1 second load, 0.9 second unload)
- **PD** –Permanent deformation is measure of damage to the material

Proposed Provisional AASHTO Test Method - Oct. 2013

Proposed Standard Test Method for

PERMANENT DEFORMATION RESISTANCE OF ASPHALT MIXTURES USING INCREMENTAL REPEATED LOAD PERMANENT DEFORMATION (IRLPD) TEST

AASHTO Designation: TP XX-XX

1 SCOPE

1.1 This standard describes test method for measuring the resistance of asphalt mixtures to permanent deformation using Minimum Strain Rates from Incremental Repeated Load Permanent Deformation (IRLPD) Test conducted by means of Simple Performance Test (SPT) System. This practice is intended for dense- and gap- graded mixtures with nominal maximum aggregate sizes to 37.5 mm.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.*

2 REFERENCED DOCUMENTS

2.1 AASHTO Standards

- AASHTO TP 79-09, Standard Method of Test for Determining the Dynamic Modulus and Flow Number for Hot Mix Asphalt (HMA) Using the Asphalt Mixture Performance Tester (AMPT)
- NCHRP 9-29 PP 01, Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor
- AASHTO R30, Standard Practice for Mixture Conditioning of Hot Mix Asphalt (HMA)

1

1. Mohseni, A., Azari, H. "High-Temperature Characterization of Highly Modified Asphalt Binders and Mixtures", Submitted to TRB 2014.
2. Mohseni, A., Azari, H. "Intermediate-Temperature Characterization of Highly Modified Asphalt Binders and Mixtures", Submitted to AAPT 2014.
3. Haleh Azari and Alaeddin Mohseni, "Improvement of the Test Method for Determining Moisture Damage Resistance", RILEM Book series, Volume 8, 2013
4. Azari, H. and Mohseni, M., 2012, "*Incremental Repeated Load Permanent Deformation Testing of Asphalt Mixtures,"* TRB No. 12-4381
5. Azari, H. and Mohseni, A, 2013, "*Permanent Deformation Characterization of Asphalt Mixtures using Incremental Repeated Load Testing"*, TRB 2013
6. Azari, H. and Mohseni, A., 2013, "*Effect of Short-Term Conditioning and Long-Term Aging on Permanent Deformation Characteristics of Asphalt Mixtures"*, AAPT Journal, Volume 82
7. Azari, H., 2011, "Analysis of the Effect of Laboratory Short-Term Conditioning on Mechanical Properties of Asphalt Mixture," Report No. 11-1427, Transportation Research Board 90th Annual Meeting

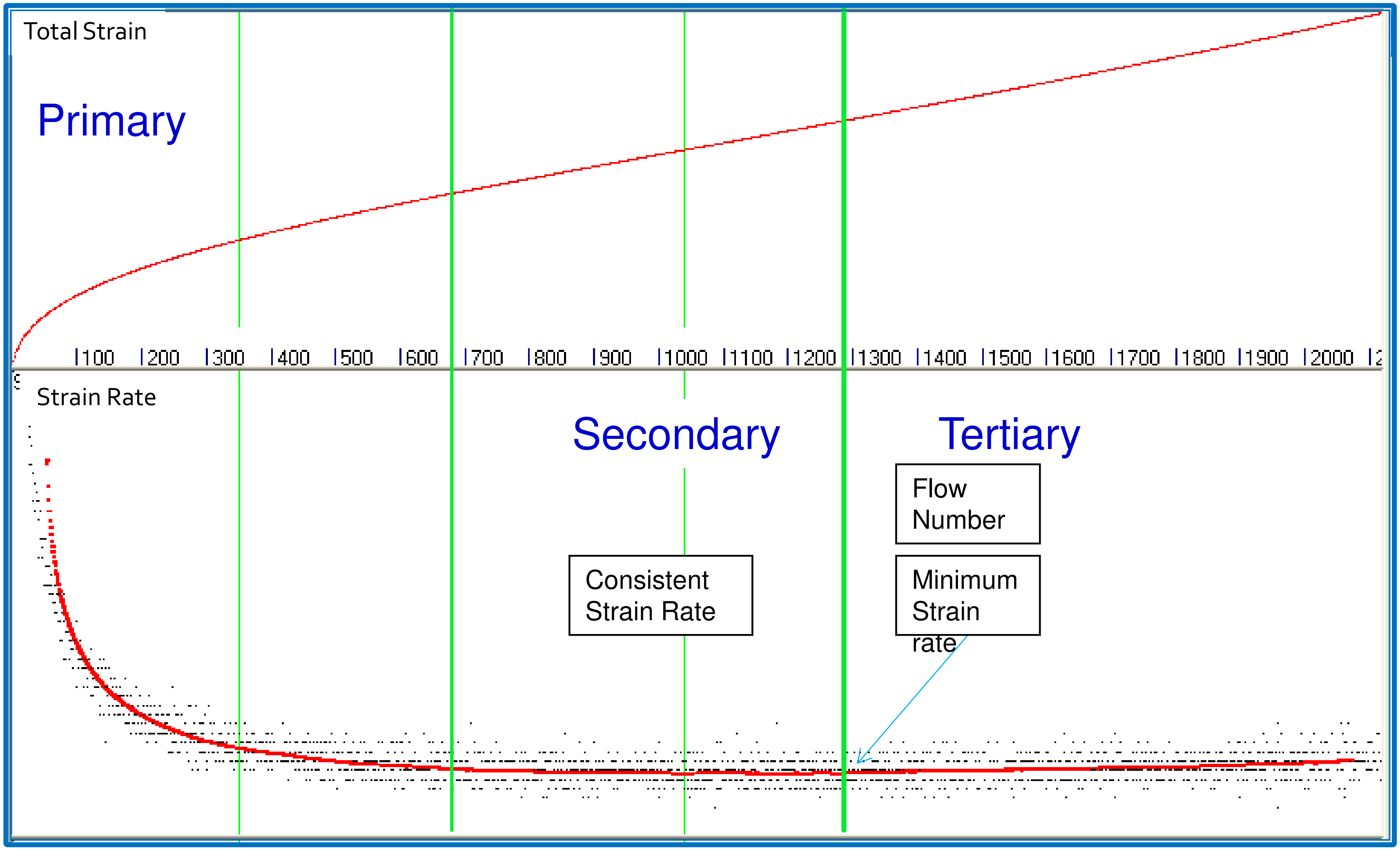
iRLPD Characteristics

- It's damaged-based vs. stiffness- or failure-based
  - Failure-based tests are too severe
  - Stiffness based tests do not engage the aggregate structure enough to show the effect of conditioning
- Level and duration of load is selected to cause incremental micro-damage to the material without causing it to fail
- Test will always be in the secondary stage; prior to reaching flow

iRLPD Testing Configuration

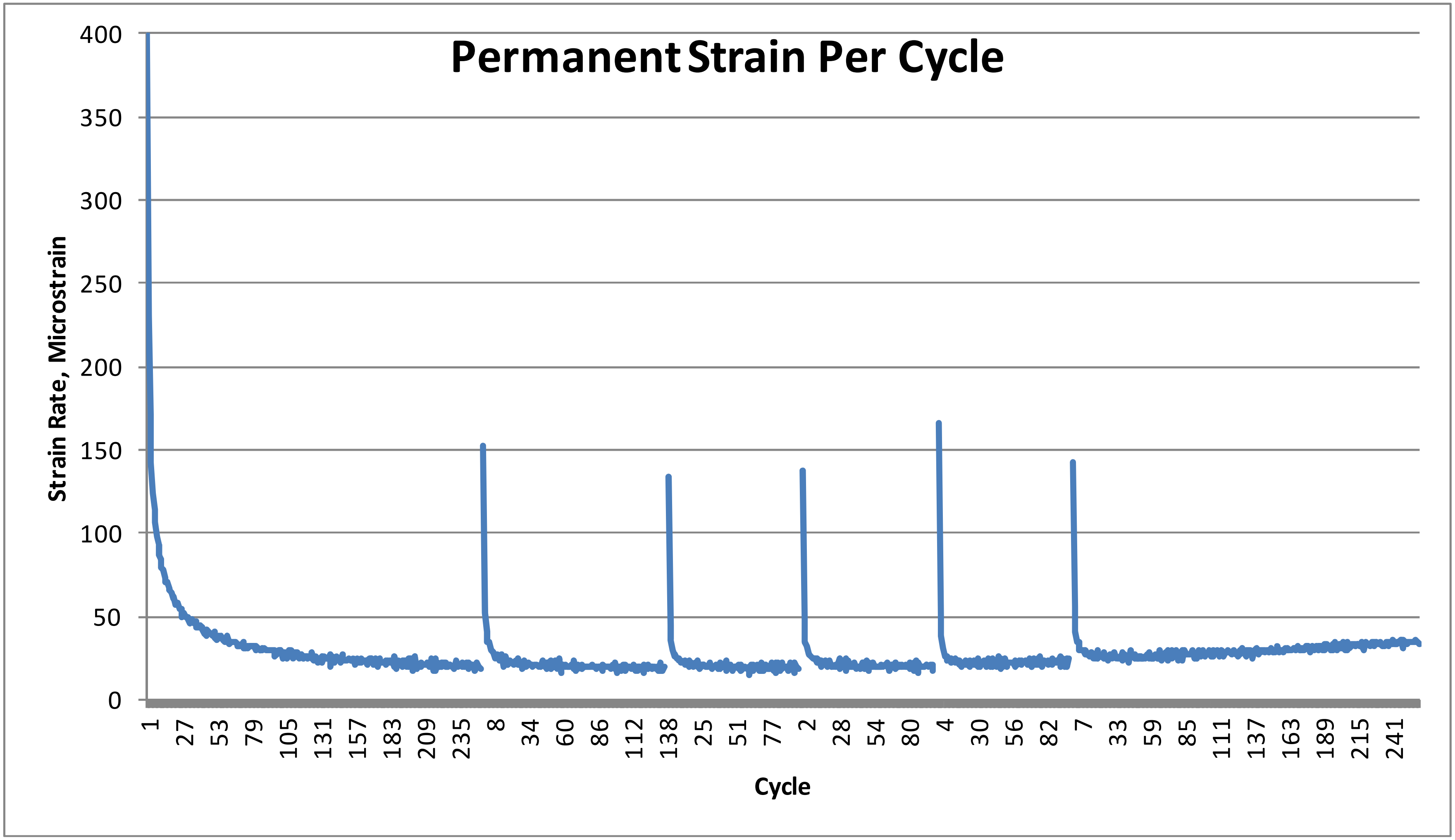
- Same loading configuration as Flow Number test (AASHTO TP 79)
  - 0.1 sec load followed by 0.9 sec unload
- Test is conducted in several increments, instead of one continuous loading till failure
- Test increments, each containing 300 cycles, are conducted before conditioning, as part of conditioning, and after conditioning on the same specimens
- 2 test increments with varying load before conditioning
- Each increment takes 5 min- total testing time 20 min.
- Test temperature 25°C

Output of Conventional Repeated Load Permanent Deformation Test



No. of Cycles

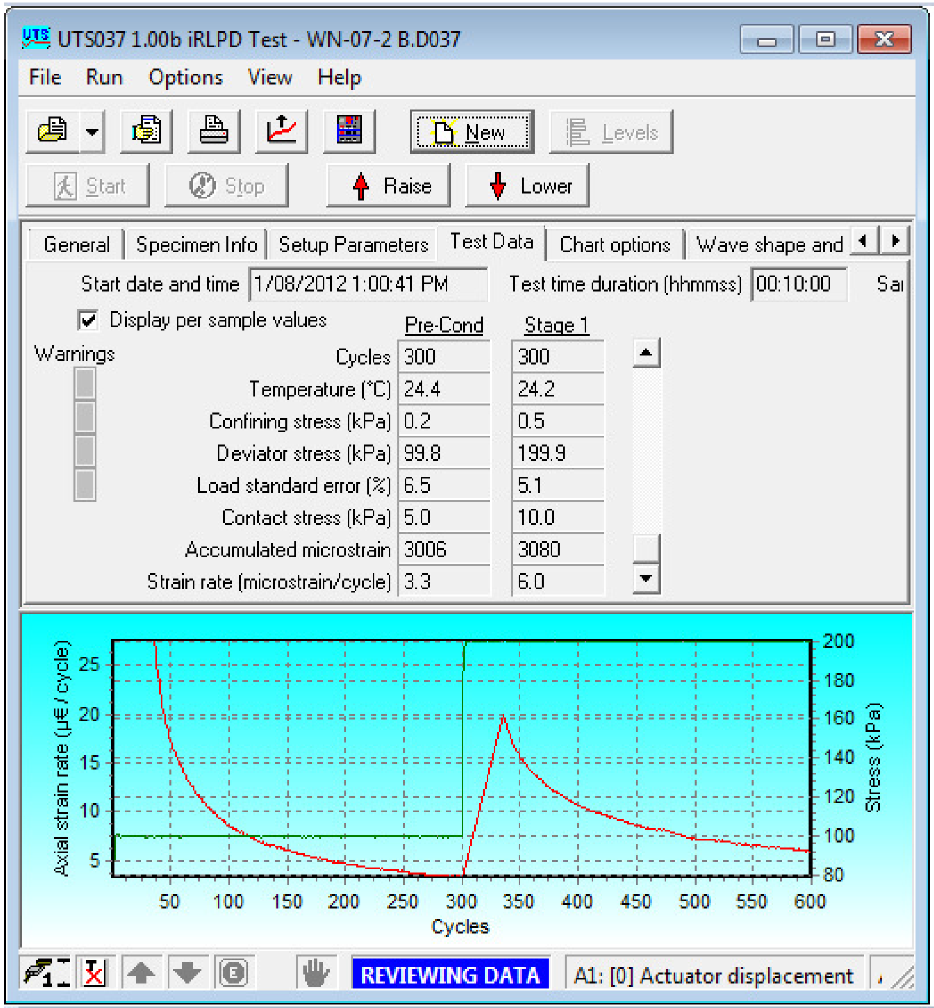
IRLPD Test, Effect of Repeating the Test at the Same Stress and Temperature

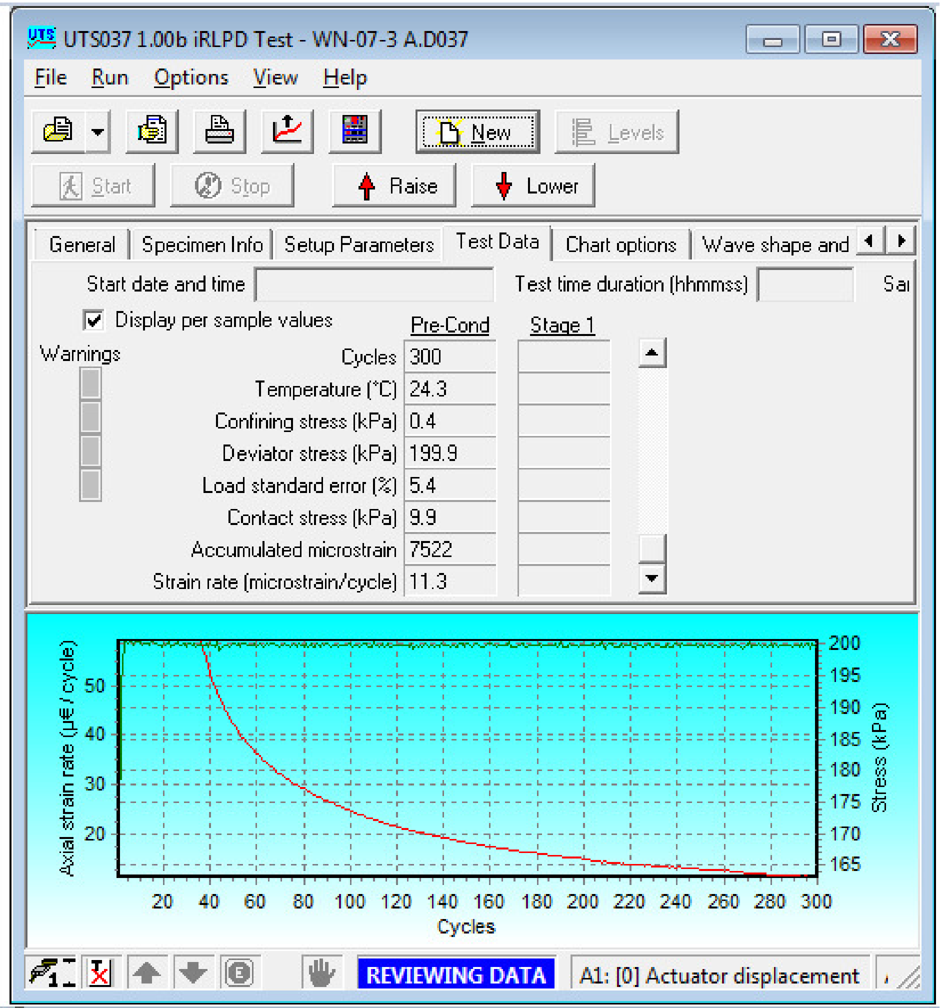


Loading Machine

AMPT servo-hydraulic loading machine

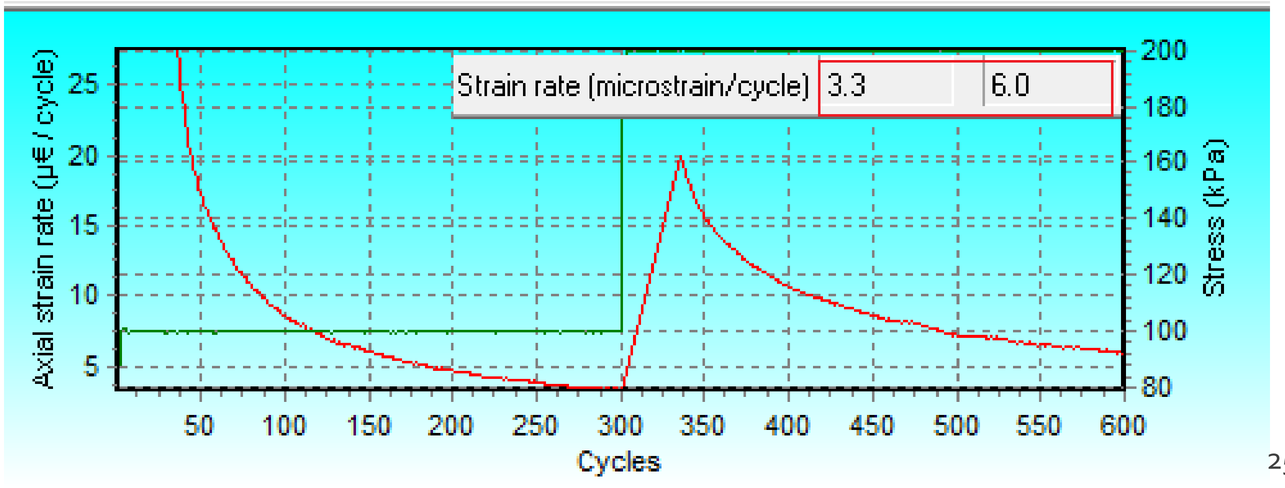
iRLPD Test Software





Test Parameter:
Minimum Strain Rate (MSR)

- MSR is used as the measure of damage
- MSR is the permanent strain due to the 300th cycle
- MSR of 5 to 10 microstrain should be achieved before conditioning
- Damage ratio is calculated as the ratio of MSR after conditioning to the MSR before conditioning
  - Ratio of 1 indicates no change in before and after MSR conditioning
  - Ratio >1 indicates increase in MSR after conditioning due to moisture damage

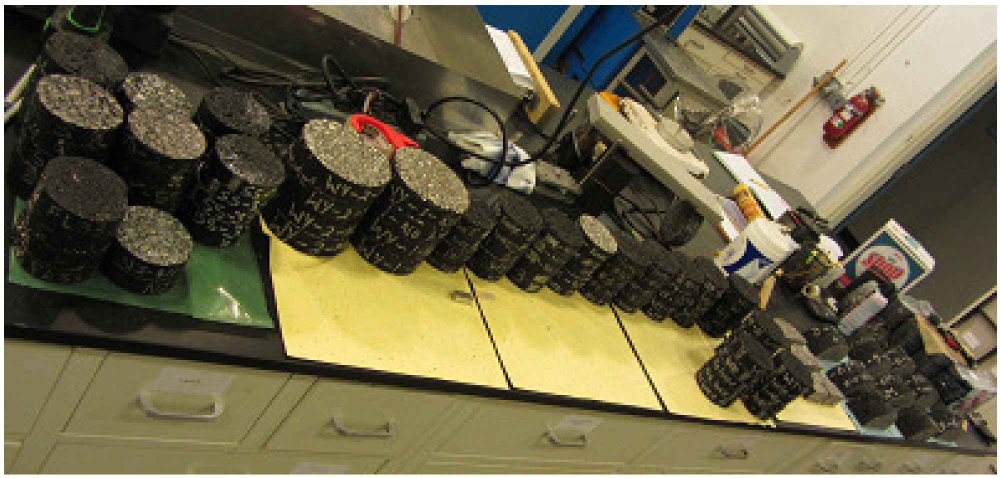


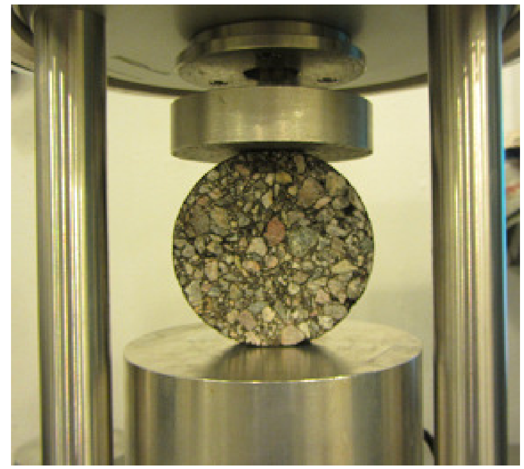
Experimental Testing and Results

Materials Selected

- Moisture susceptible mixture from Wyoming (WY-No Lime)
- Moisture resistance mixture by substituting filler with lime in Wyoming mixture (WY-Lime)
- Moisture resistance mixtures: limestone (LS) and sandstone (SS) from Maryland,
- Moisture resistance mixtures: Florida (FL) and New Jersey (NJ)

Prepared IDT and SCB Samples

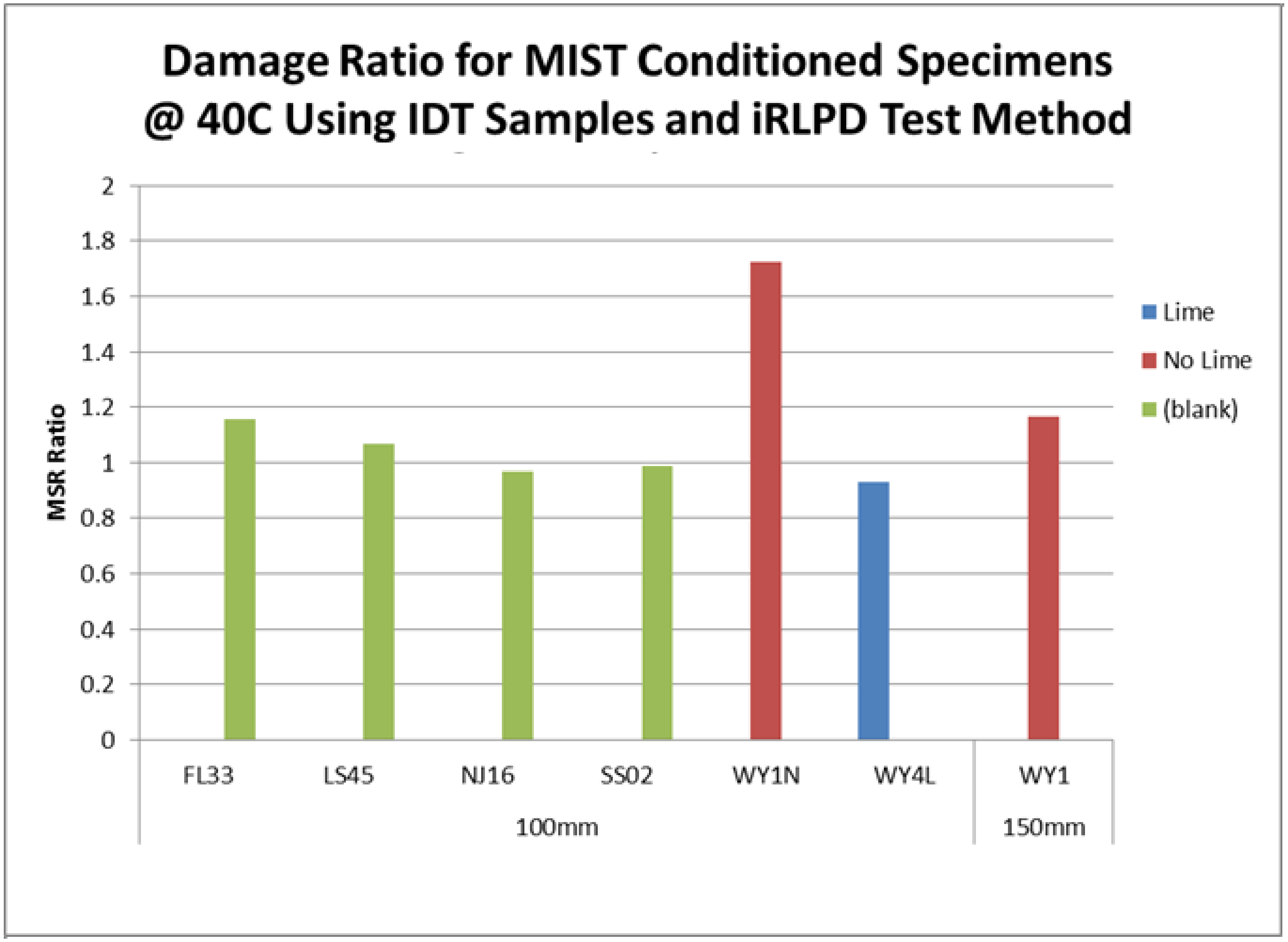


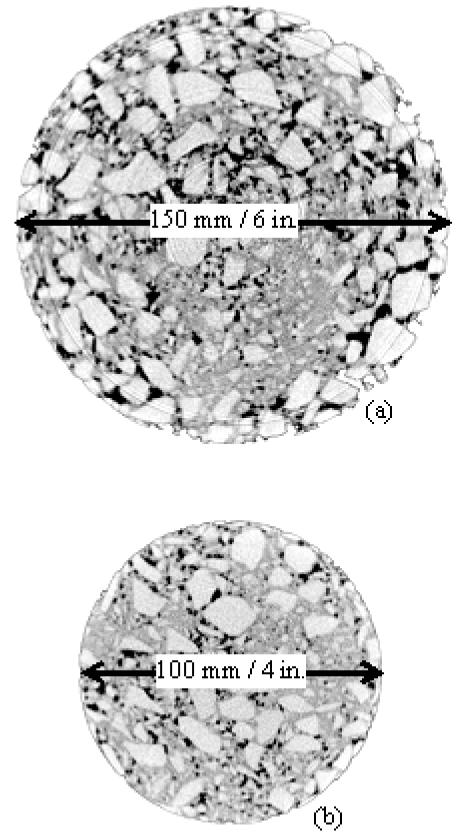


Examined Conditioning Types

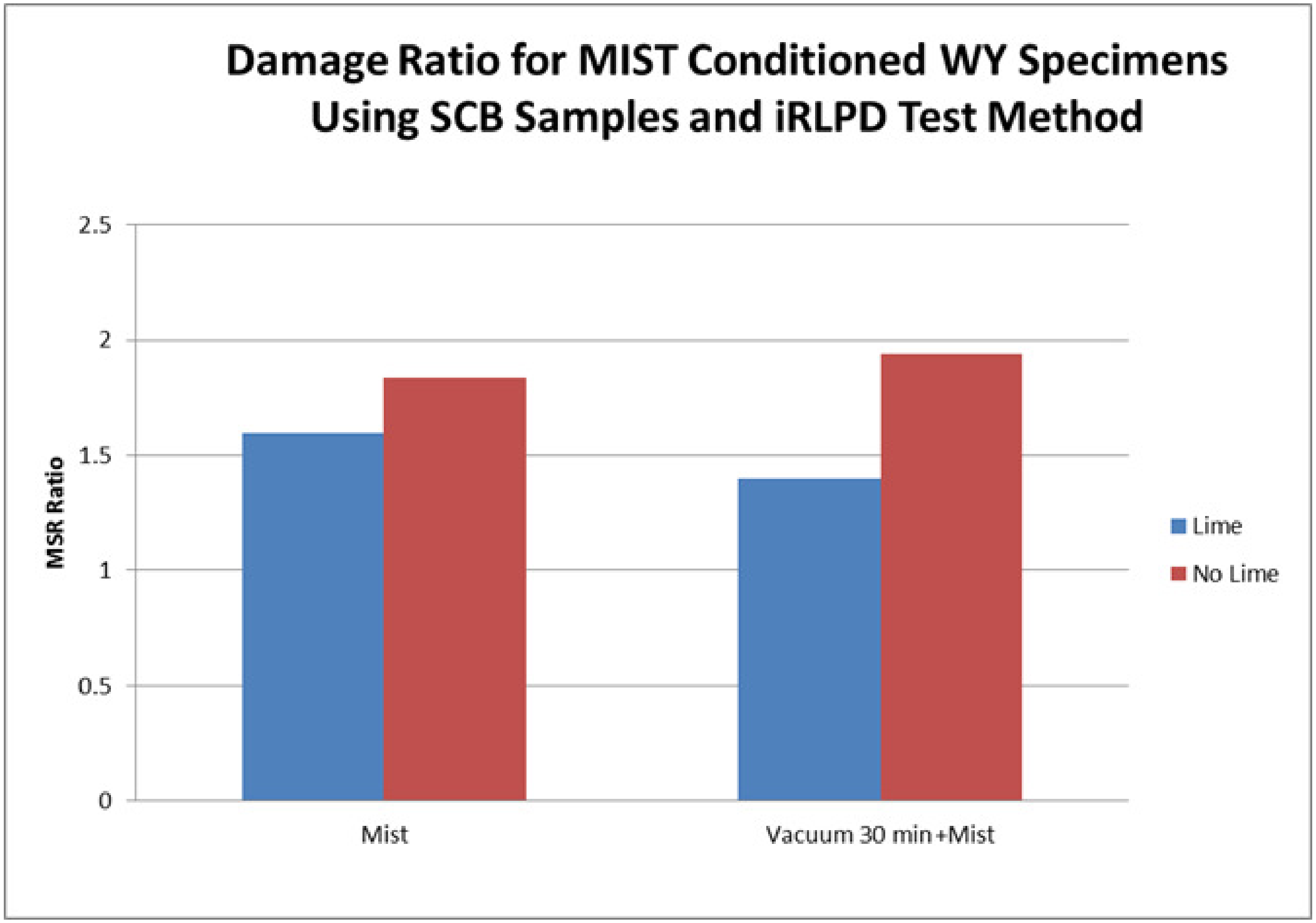
- Vacuum (at 15 mm Hg)
- Vacuum (at 15 mm Hg) + Wet loading (mechanical conditioning)
- Vacuum (at 15 mm Hg) + soaking
- AASHTO T283 (vacuum + freeze cycle + warm-water soaking)
- MIST (40°C, 40 psi, 3500 cycles) about 4 hours
- MIST + vacuum (at 15 mm Hg)
- Drying before mechanical test

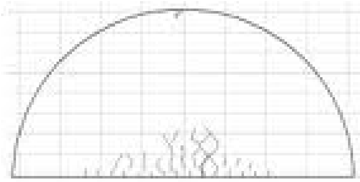
MIST Conditioned IDT Samples
(Effect of Material and Sample Size)

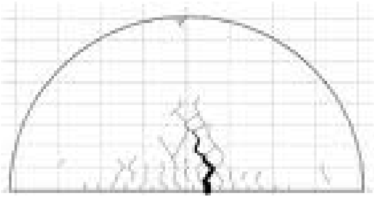




MIST Conditioned SCB Samples
(Effect of Vacuum)

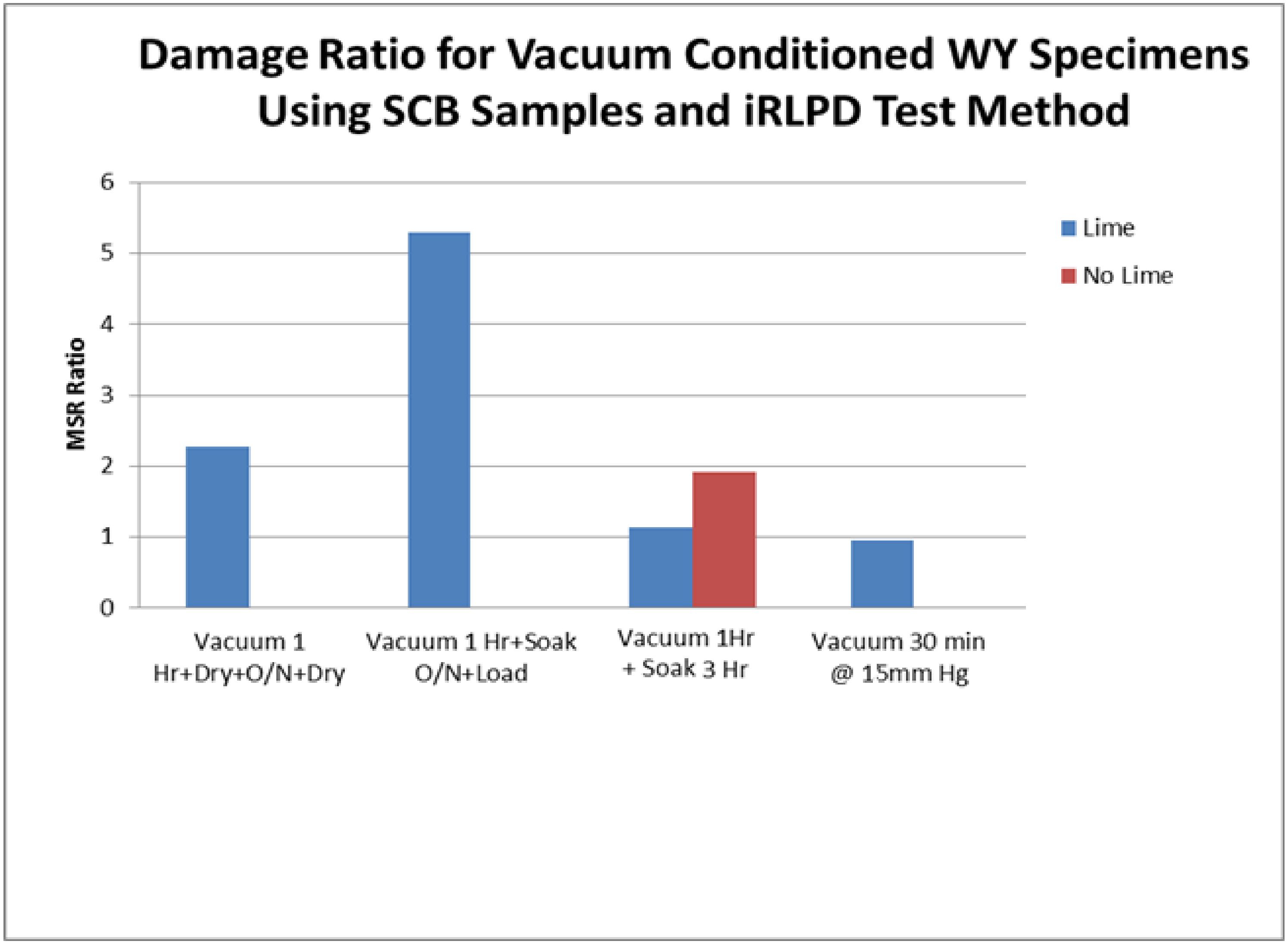


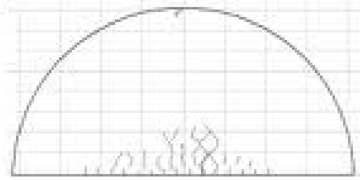


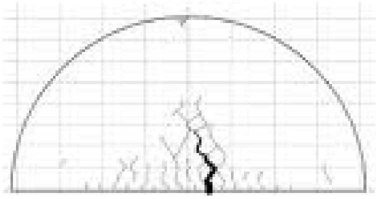


Vacuum Conditioned SCB Samples

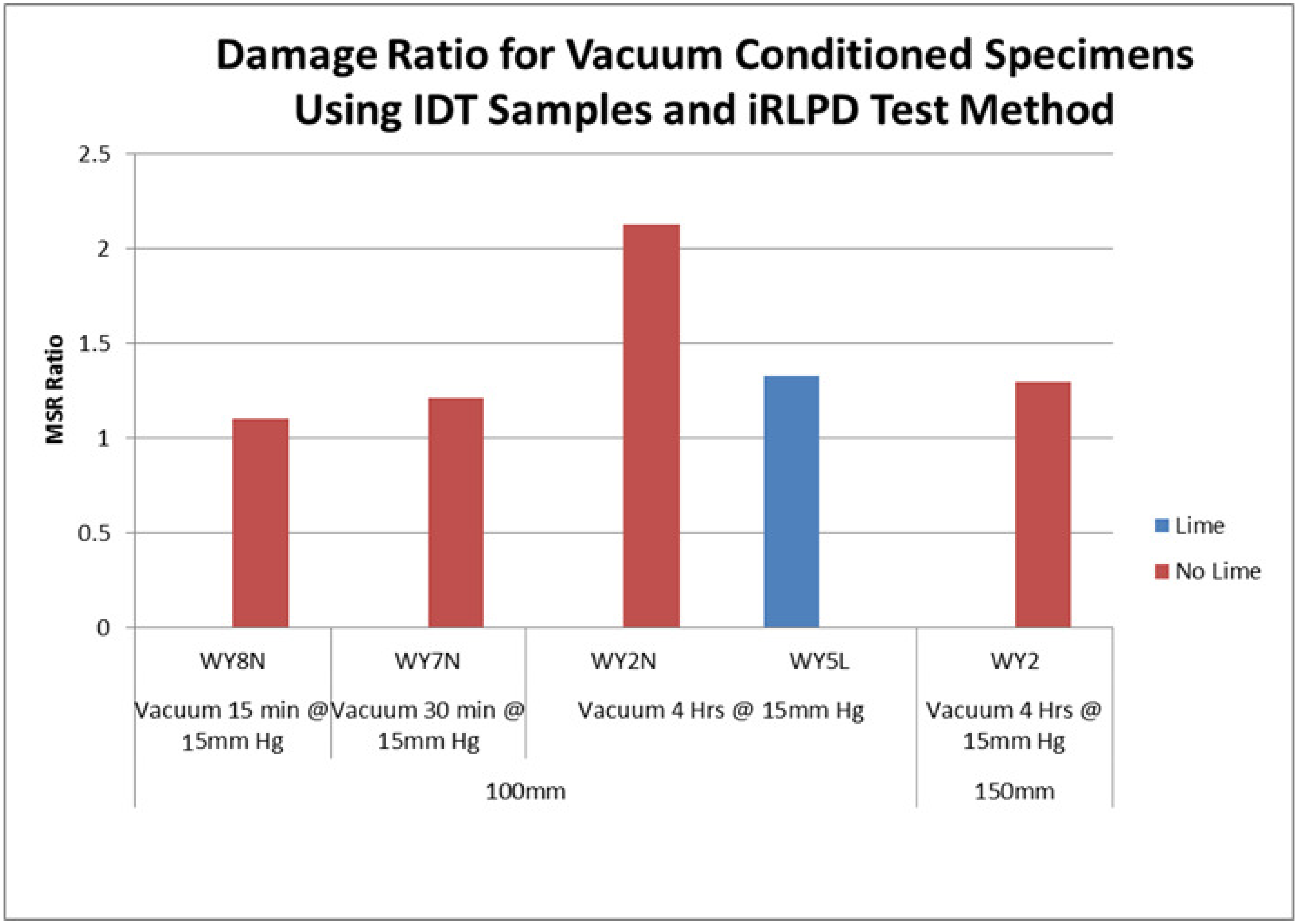
(Effect of load conditioning, soaking, vacuum duration)

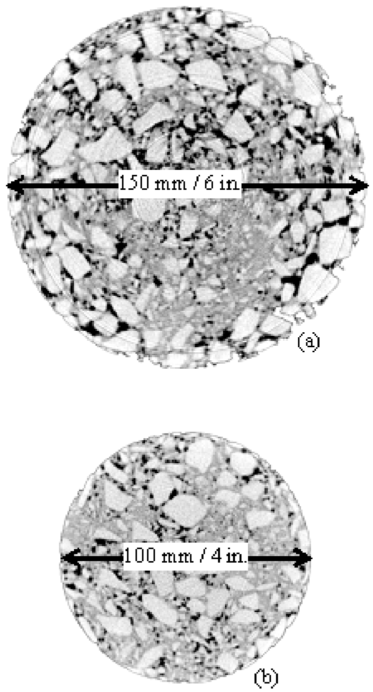




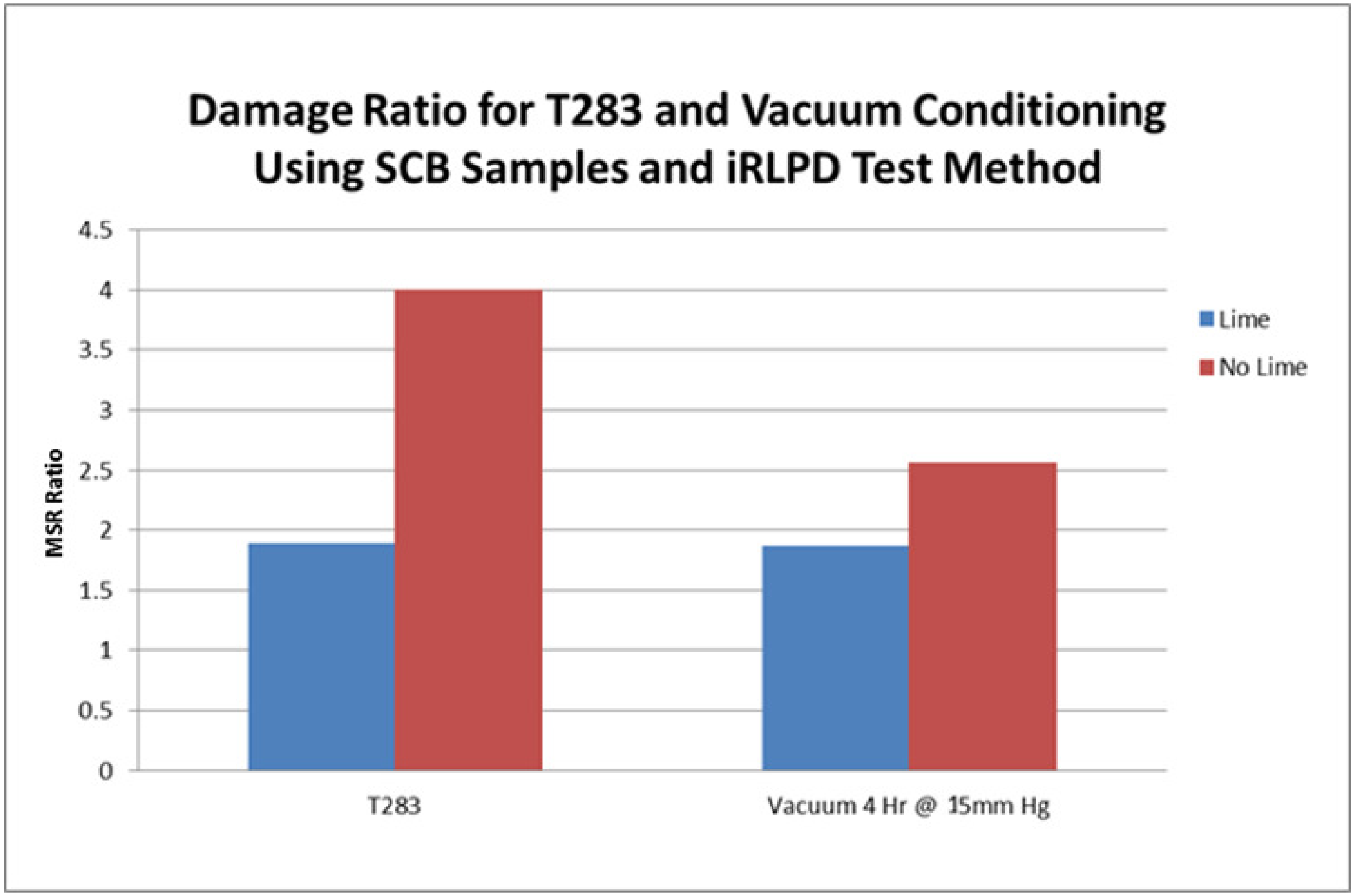


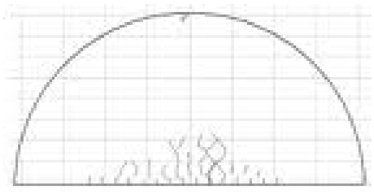
Vacuum Conditioned IDT Samples
(Effect of Vacuum Duration)

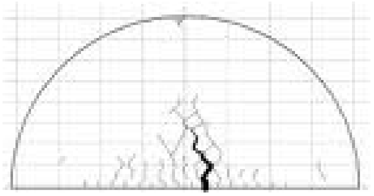




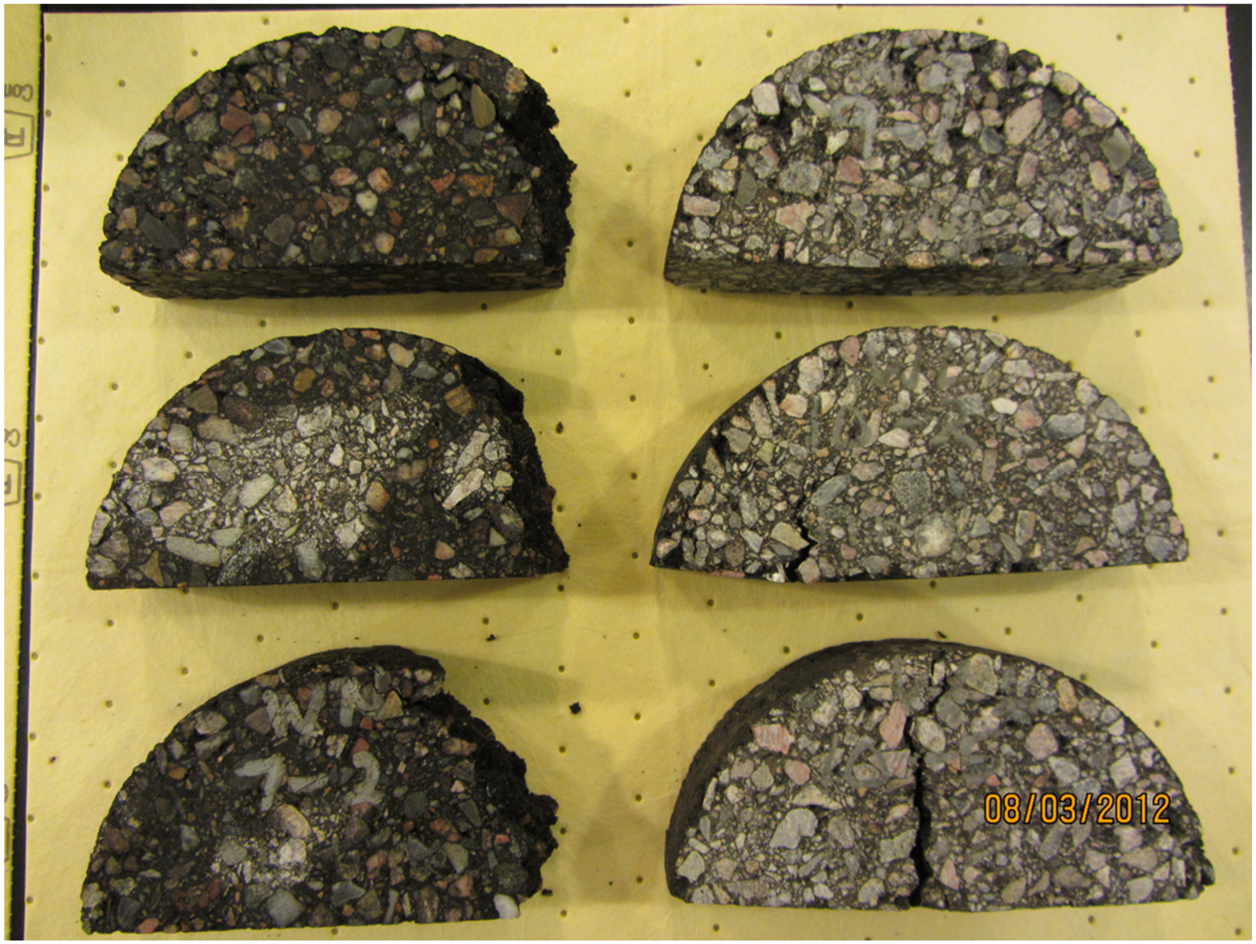
AASHTO T283 and Vacuum Conditioned SCB Samples



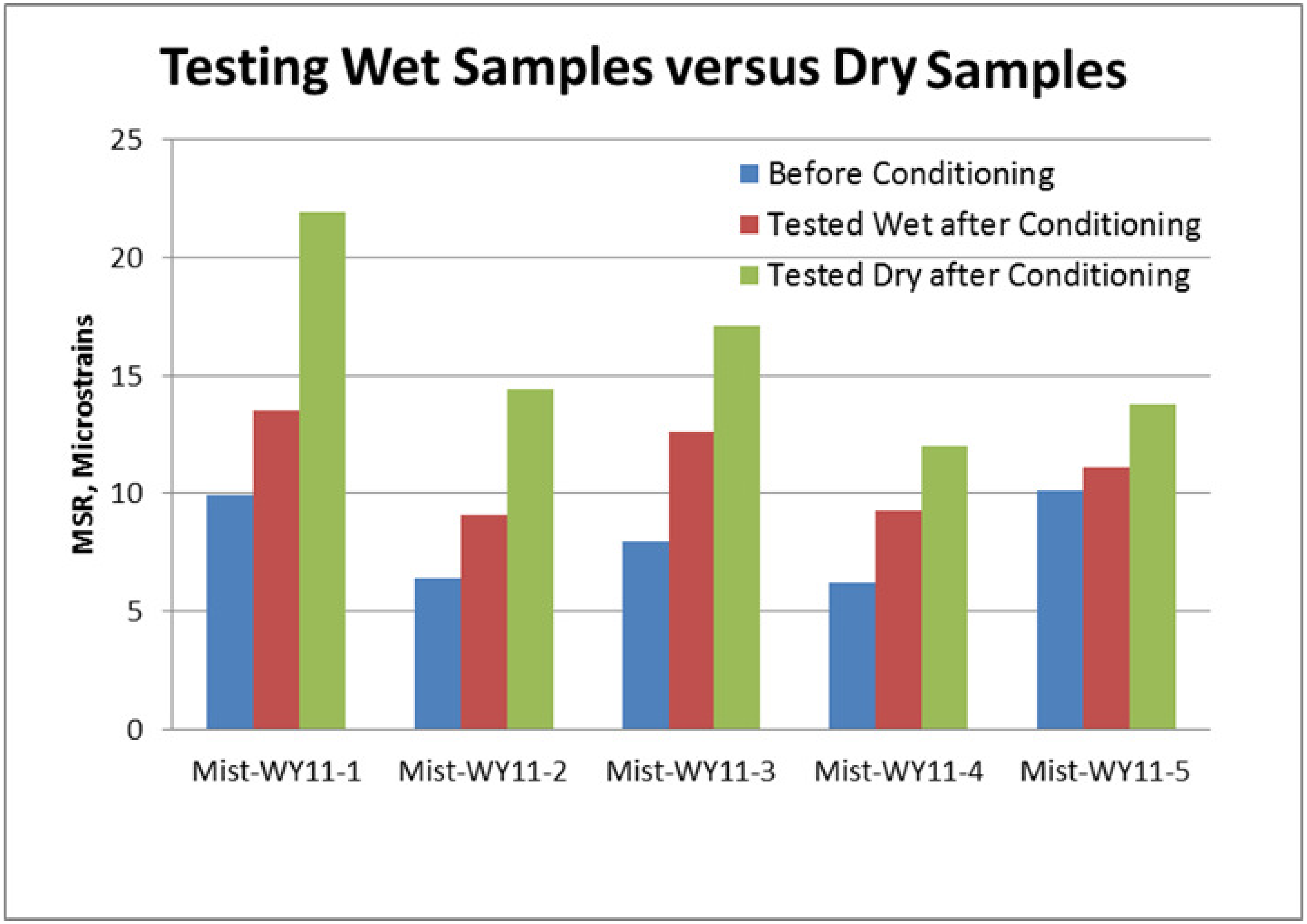


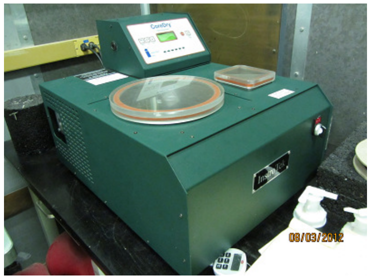


AASHTO T283 Conditioned Samples



Testing Wet Versus Testing Vacuum Dried



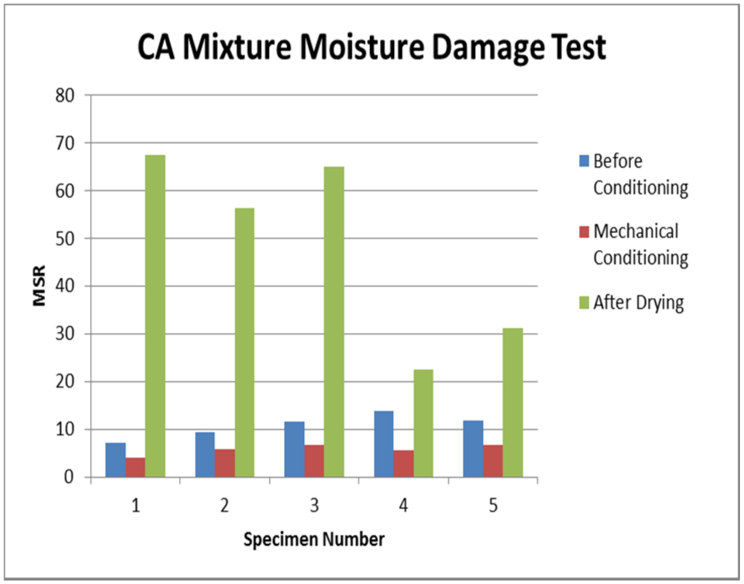


Summary of Proposed Test

- IDT testing in AMPT using iRLPD test at 25°C for 300 cycles of 0.1 second load, 0.9 second unload, load is increased until MSR of 5 to 10 was reached (typically requires 2 test increments)
- Moisture Conditioning: Samples are fully water saturated in vacuum for 1 hour
- Mechanical Conditioning: IDT testing on saturated specimens. The MSR radically drops due to pore pressure and at the same time moisture damage is induced in the mixture
- Specimens are dried
- Specimens are tested again after being dried and MSR is measured
- Total Conditioning and testing time: 1.5 hr

A Case Study, CA mixture

- Caltrans have had trouble characterizing their mixture for moisture resistance in laboratory
- Mixture has shown poor moisture resistance in the field while Hamburg results were borderline
- Using the proposed test the material was conditioned and tested
- Average MSR ratio of 5 indicated that material is moisture susceptible



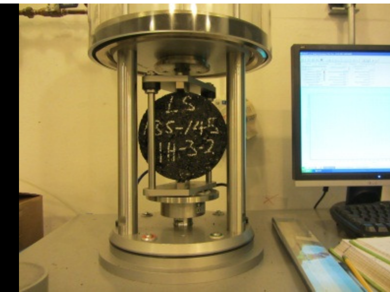
Conclusions

- Vacuum @ 15 mm Hg for 1 hr + one increment of wet loading causes moisture damage
- MIST causes equivalent moisture damage
- iRLPD allows testing the same specimens before, during, and after moisture conditioning
- iRLPD is very sensitive to material property and to moisture damage
- 100 mm x 28 mm IDT and 150-mm x 38-mm SCB samples allow more uniform conditioning

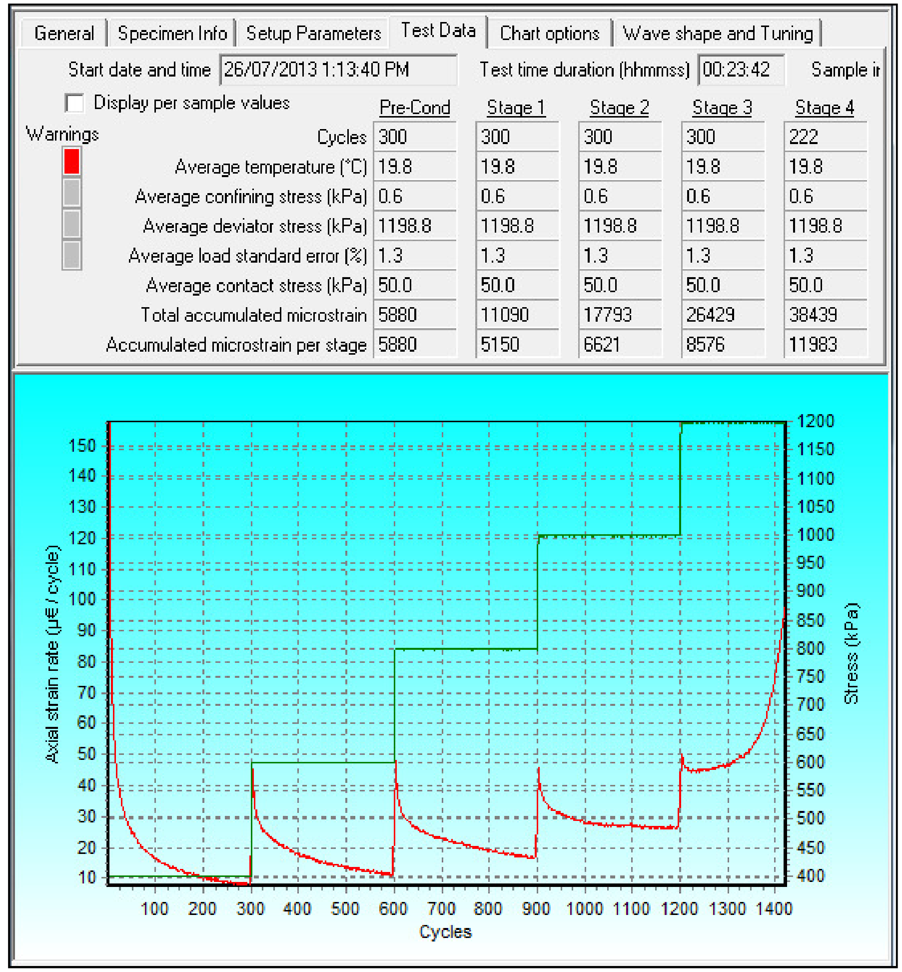
Proposed Pooled Fund Study

- A proposal for a pooled fund study was sent out through SOM list server Oct 2012
- 14 states indicated interest in the study
- Mixtures from different states will be characterized for moisture resistance using iRLPD, T283, and Hamburg
- Cost around 15 k to each state
- Looking for more state DOT participants
- Looking for a state or FHWA to lead the pooled fund

iRLPD Cracking Test



- Based on the iRLPD methodology, developed a test for fatigue resistance, particularly important for mixtures with RAP & RAS
  - AMPT
  - No LVDTs
  - 150-mm Dia. IDT
  - 38-mm Thick.
  - 300 Cycles/increment
  - Intermediate Temperature
  - Load Increments: 3, 5, 6, 7, 8 KN
  - MSR= Fatigue Damage
  - Traffic Prediction from MSR
  - Duration: 25 min., max



Thank you

Questions?

IDT Samples Tested

IDT Sample Diameter	Sample No	Conditioning Method							Grand Total
		Mist (40°C, 40psi)	Mist (40°C, 60psi)	Mist 40°c, 40 psi	Vacuum 1 Hr @ 15mm Hg	Vacuum 15 min @ 25mm Hg	Vacuum 30 min @ 15mm Hg	Vacuum 4 Hrs @ 15mm Hg	
100mm	FL33	5							5
	LS45	4							4
	NJ16	5							5
	SS02	5							5
	WY11L				5				5
	WY1N	4							4
	WY2N							5	5
	WY3N		5						5
	WY4L	4							4
	WY5L							5	5
	WY6L		5						5
	WY7N						5		5
	WY8N					4			4
150mm	WY1N			4					4
	WY2N							4	4
	Grand Total	27	10	4	5	4	5	14	69

SCB Samples Tested

Sample No.	Conditioning Method							Grand Total
	Mist	Vacuum 30 min @ 25mm Hg+Mist	T283	Vacuum 1 Hr+O/N+Dry	Vacuum 1Hr + Soak 3 Hr	Vacuum 30 min @ 25mm Hg	Vacuum 4 Hr @ 25mm Hg	
WL-09	2	1			2			**5**
WL-10	1	2	2		1			**6**
WN-07	1	1	2		2			**6**
WN-08	2	2	1		1			**6**
WN-09			1					**1**
Wy3	3						3	**6**
WY4				8				**8**
Wy5	2						2	**4**
WY6					4	2		**6**
Grand Total	**11**	**6**	**6**	**4**	**10**	**2**	**5**	**48**