Alternate Test Methods for Evaluating Moisture Sensitivity of Asphalt Mixtures

FHWA Mix ETG Meeting
April 27, 2016, Salt-Lake City Utah

Acknowledgement

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Disclaimer & Disclosure

The contents of this presentation reflects the views and opinions of the authors and not necessarily the views of the NC State University or the NC Department of Transportation.

The test methodologies and practices are under consideration for utility patents by the Office of Technology Transfer at the NC State University.

3 Part Presentation

1) Interpretation of subjective qualitative test(s) to objective quantification

2) Quantification of visual stripping in TSR test

3) A different method of using IR E* Ratio as opposed to tensile strength ratio (TSR)

AT-Index Test Method for Determining Compatibility Between Asphalt-Aggregate in Mixtures

Akhtar Tayebali (NCSU)

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Fractured TSR Specimens with TSR of 60. The Conditioned sample is on the right and the dry on the left.

- Examination of moisture sensitivity of aggregate–bitumen bonding strength using loose asphalt mixture and physico-chemical surface energy property tests

  Yawen Liu, Alex Apeagyei, Naveed Ahmad, James Grenfell and Gordon Airey

- Moisture susceptibility evaluation of asphalt mixes based on image analysis

  Soroosh Amelian, Sayyed Mahdi Abtahi, Sayyed Mahdi Hejazi

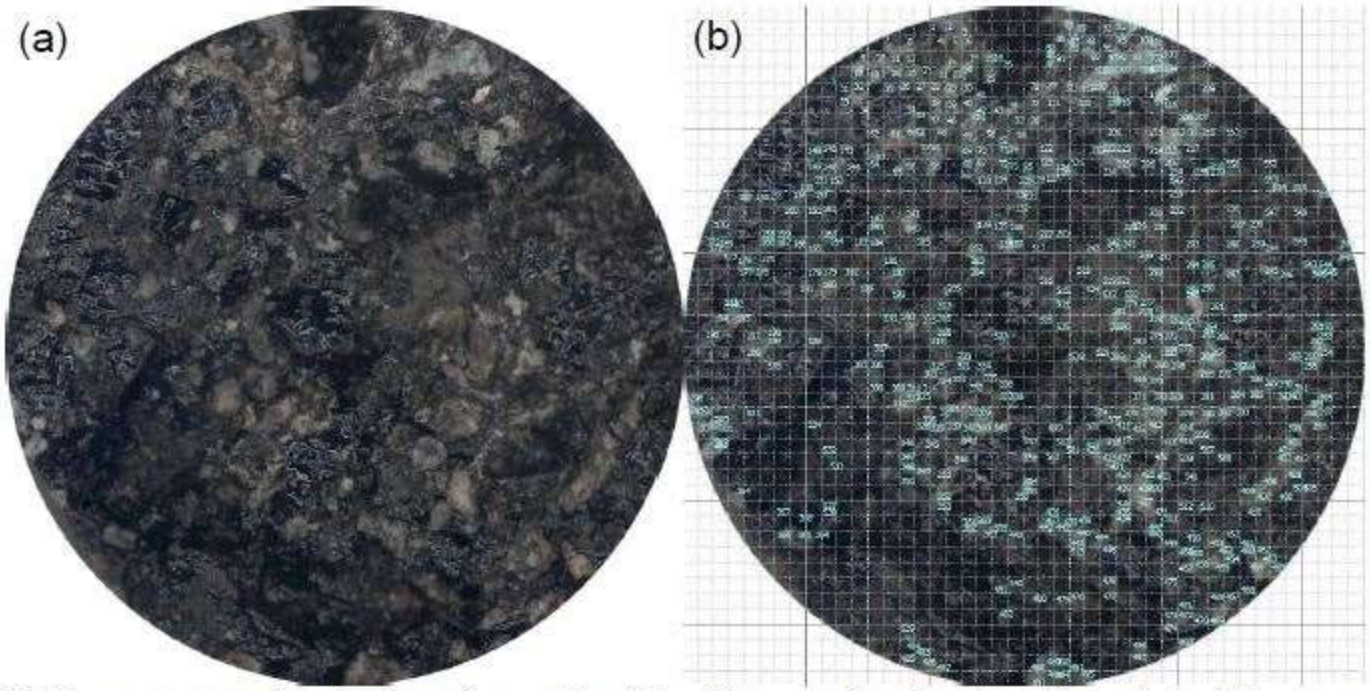


Figure 3.2 Percentage of stripping determined by fine mesh selection: (a) original image, (b) 44 x 44 fine mesh on original image (Lee et al. 2013)

Time Consuming

- Need to take picture
- Depends on quality of camera and scanner
- Have to establish grid pattern
- Dependent on the software, computer used
- Select gray scale
- Have to count the pixels on the graph

Loose Asphalt Mixtures

Colorimeter

Colorimeter

Can be used to measure the color index of the loose asphalt mix or fractured surface of asphalt concrete specimen from TSR test to measure the amount of stripping of asphalt from aggregate

Colorimeter

- Relatively inexpensive
- Easy to Use
- Repeatable and accurate measurements
- Per sample, testing time about 2 to 5 minutes

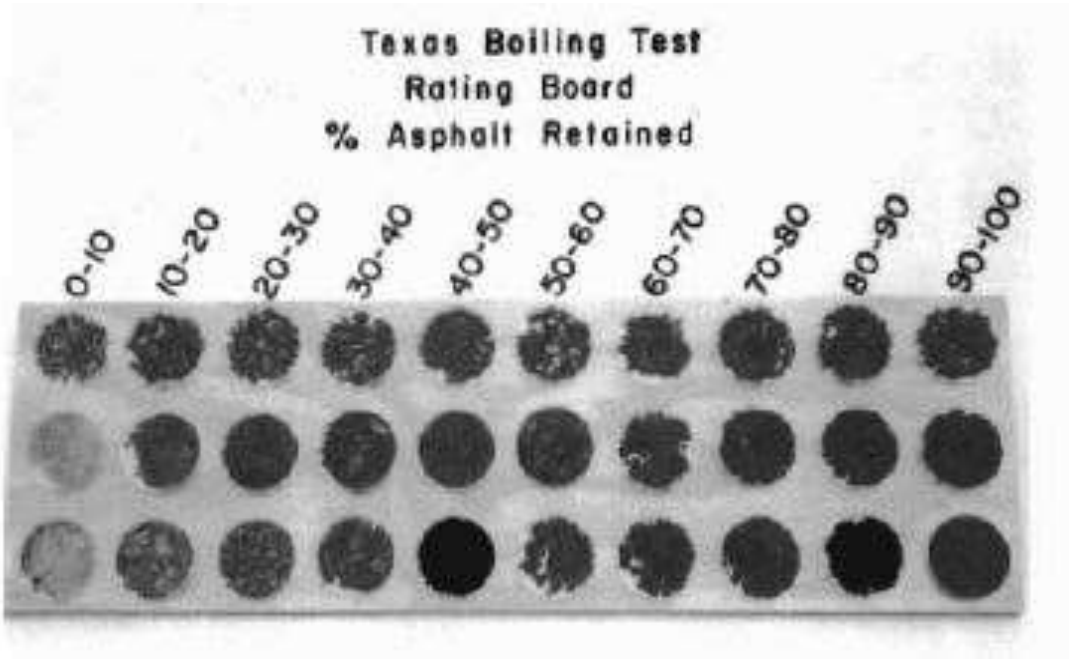
Colorimeter

- ASTM E284 color definition is used as a basis to measure the color index
- Measure value of L*, a* and b*
- L* determines light-dark index (gray scale)
- a* determines red-green index
- b* determines blue-yellow index

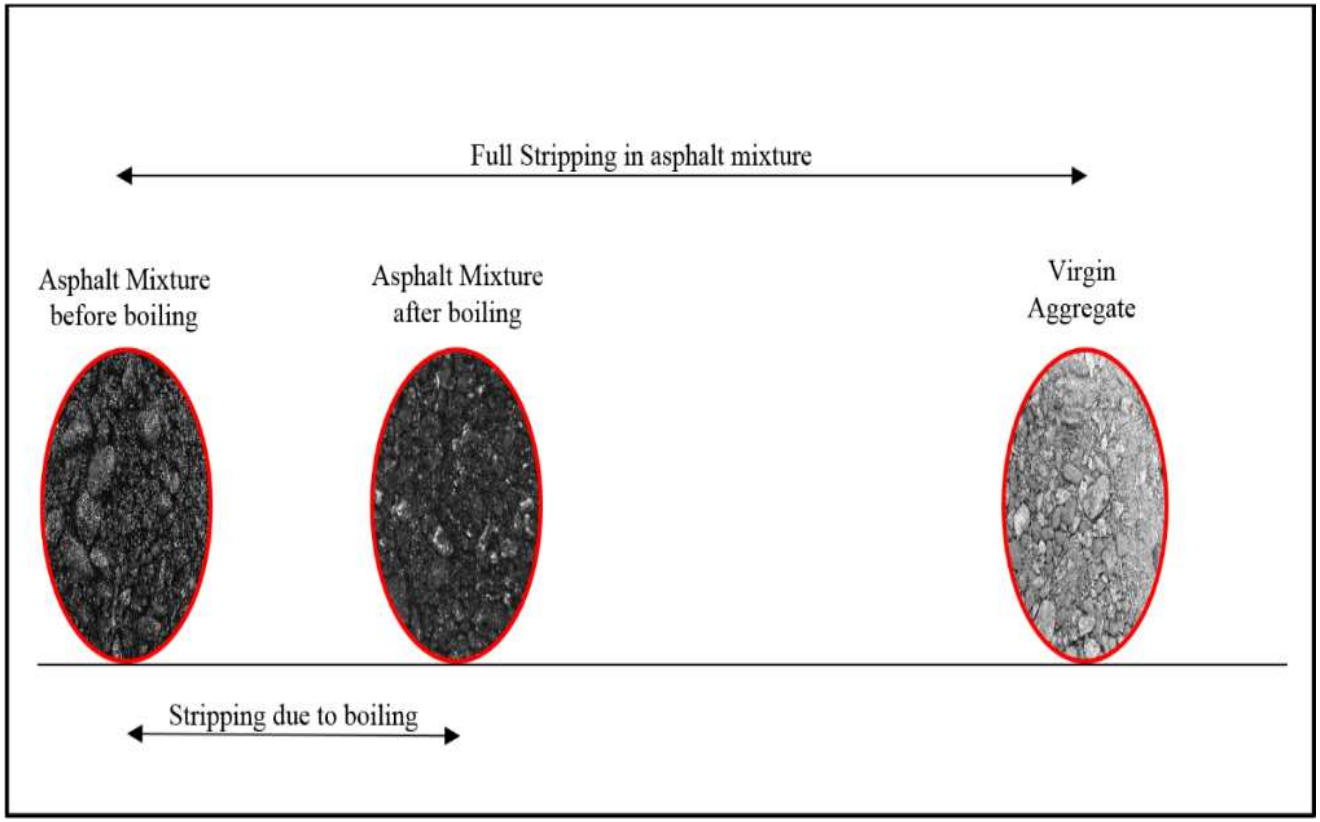
AT-Index Test Method Applications

- Several qualitative subjective methods exists for loose asphalt mixtures
- Example Boil Test ASTM D3625, Tex 530-C

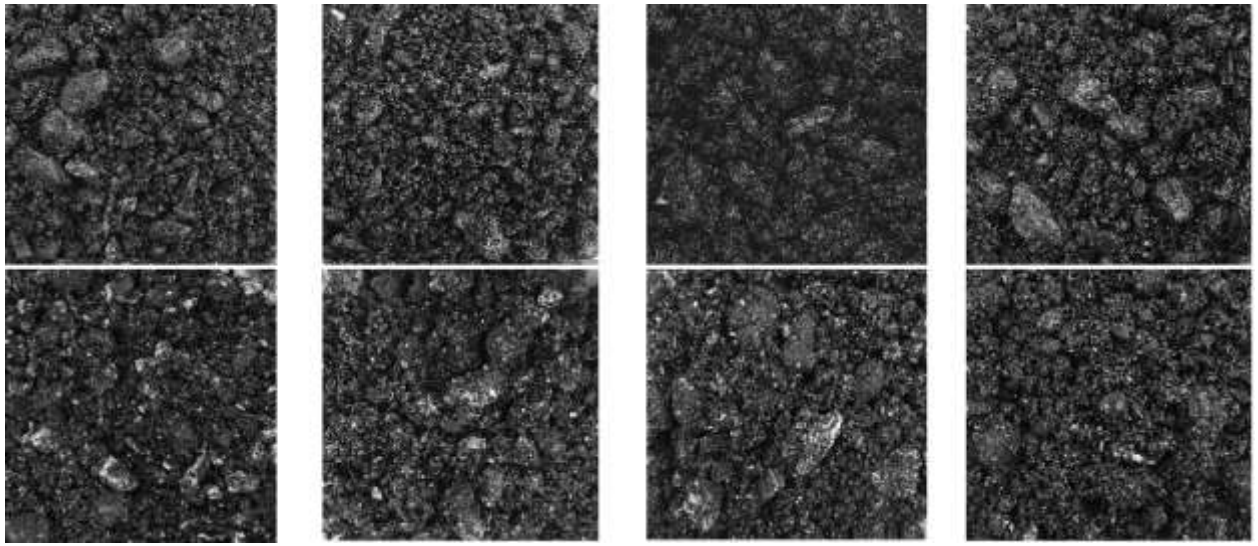
Texas Boil Test (Kennedy, et al. 1984)



AT-Index Test Concept

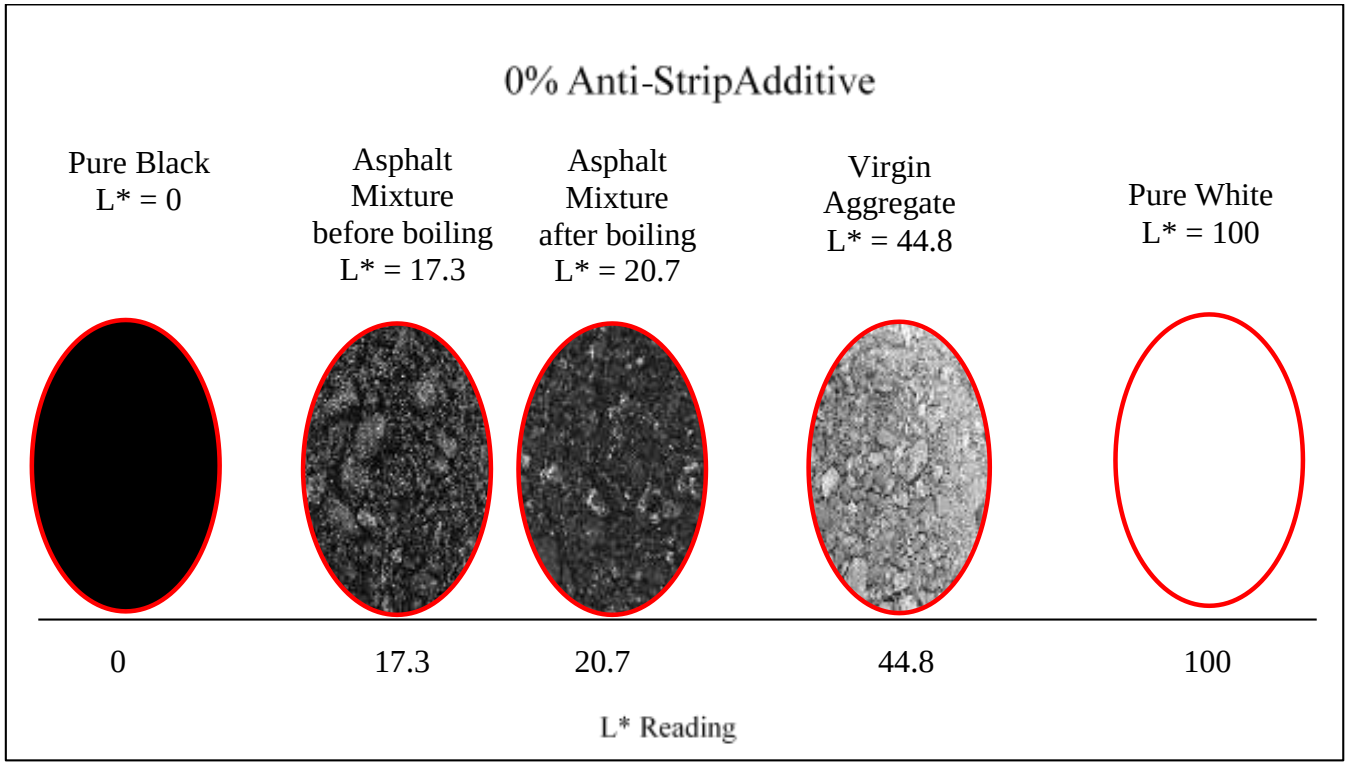


AT-Index Test Concept



Visual stripping due to Boil Test in asphalt mixtures with different additive content. The top pictures are of dry asphalt mixtures and the bottom ones are of boiled asphalt mixtures. (L to R): No anti-strip additive, 1.5% anti-strip additive, 2.5% anti-strip additive, 3.5% anti-strip additive

AT-Index Test Concept



AT-Index (Damage or loss of adhesion) calculation

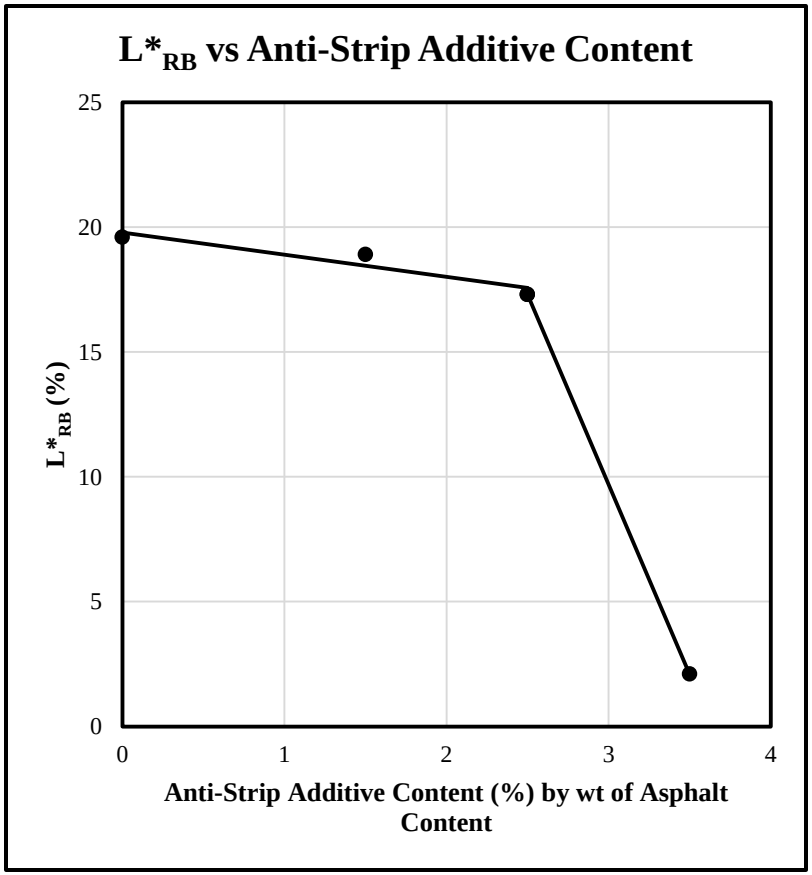
$$L^*_{RB} = \frac{(Boiled\ L^* - Dry\ L^*) * 100}{Dry\ L^*} \qquad (eq\ 1)$$

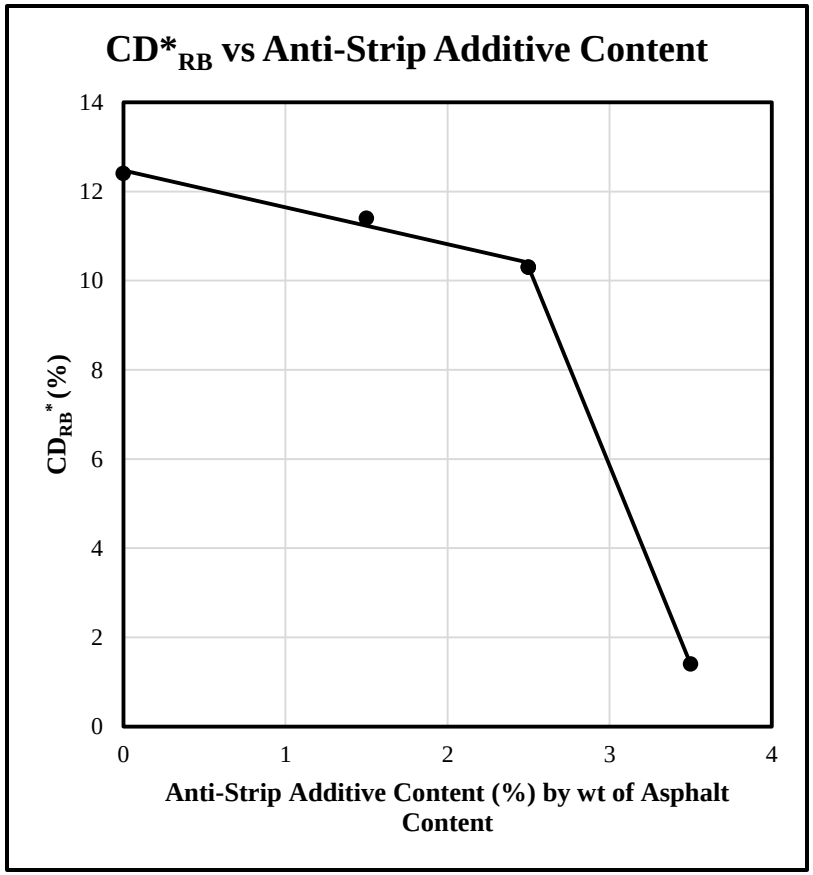
$$CD^*_{RB} = \frac{(Boiled\ L^* - Dry\ L^*) * 100}{Aggregate\ L^* - Dry\ L^*} \qquad (eq\ 2)$$

AT-Index (Damage Ratios Loss of Adhesion)

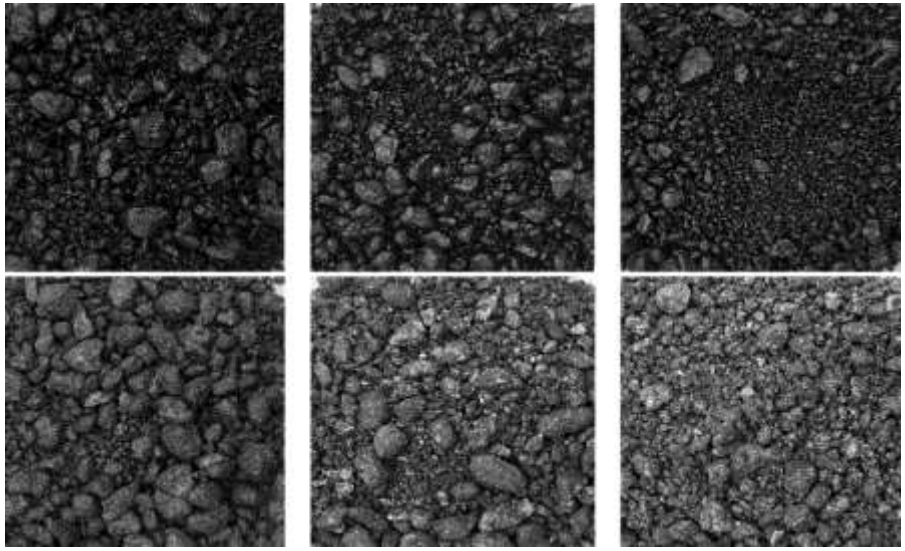
Additive Content	Dry L^*	Boiled L^*	L^*_{RB} (%)	CD^*_{RB} (%)
0	17.29	20.68	19.6	12.4
1.5	16.84	20.03	18.9	11.4
2.5	16.69	19.58	17.3	10.3
3.5	17.64	18.01	2.1	1.4
Virgin Aggregate	44.77	NA		

AT-Index effect of antistrip additive content



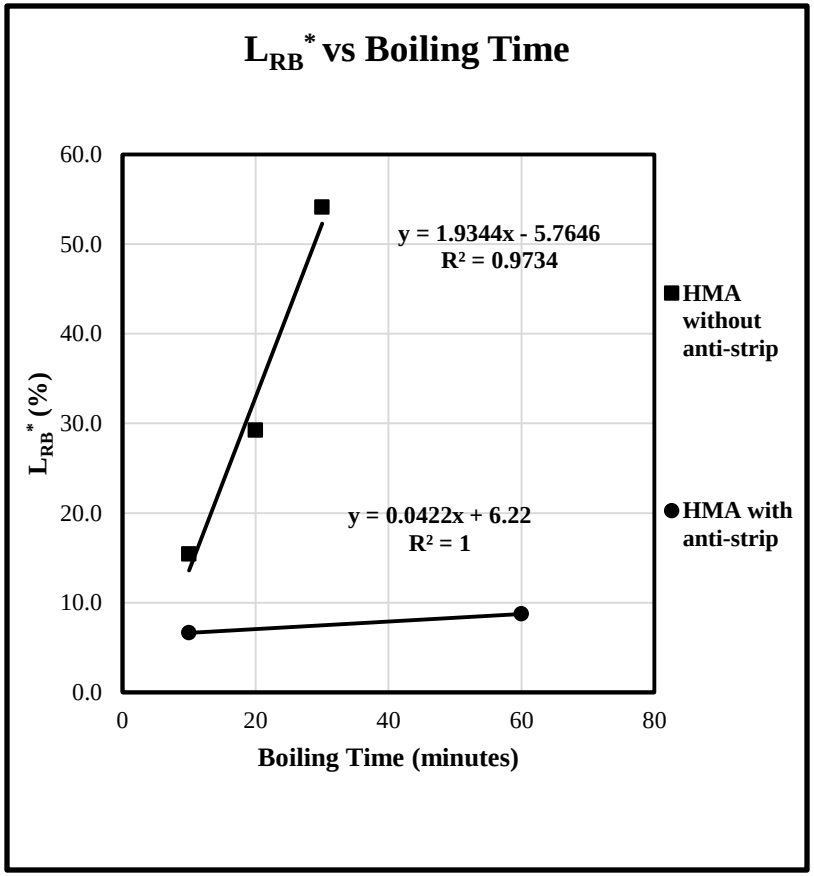


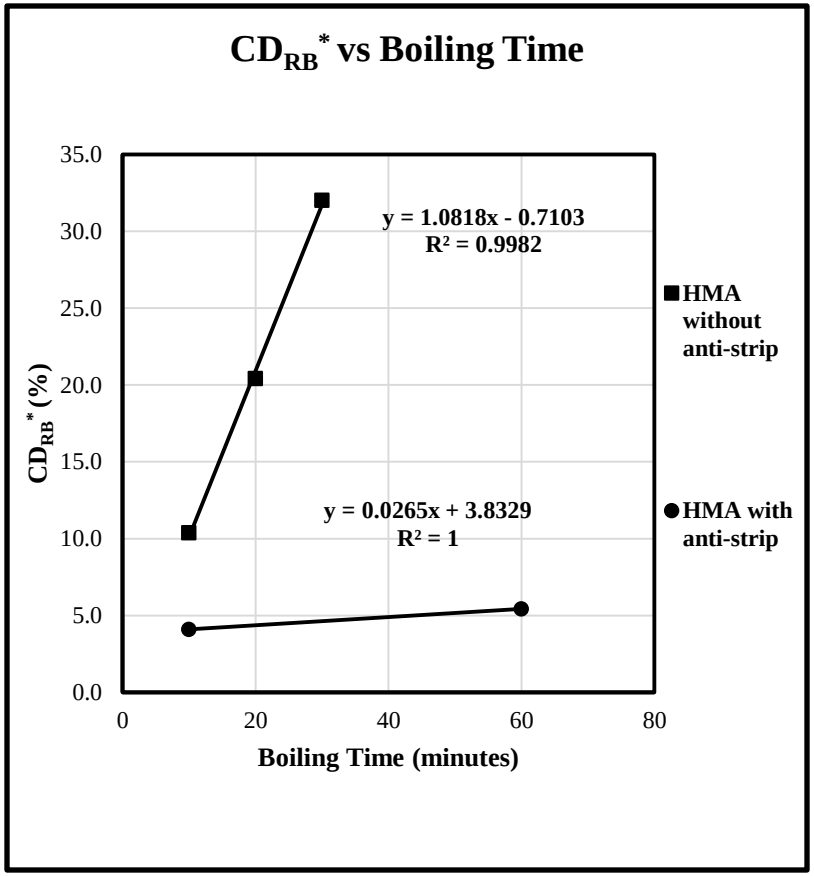
AT-Index effect of boiling time



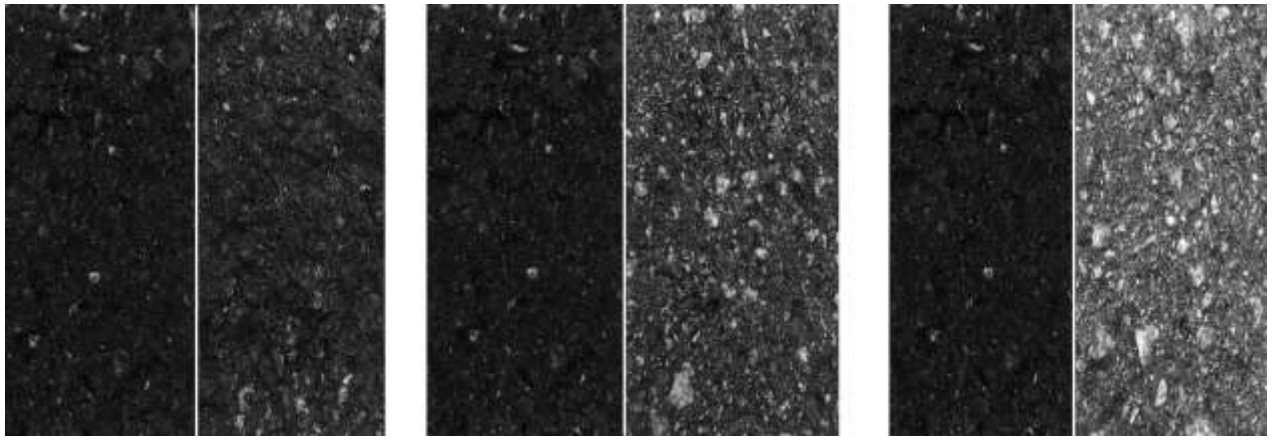
Visual stripping due to Boil Test for loose mixture without anti-strip additive for different boiling times. The top pictures are of dry asphalt mixtures and the bottom ones are of boiled asphalt mixtures. (L to R):10-minutes boiling, 20-minutes boiling, 30-minutes boiling.

AT-Index effect of boiling time



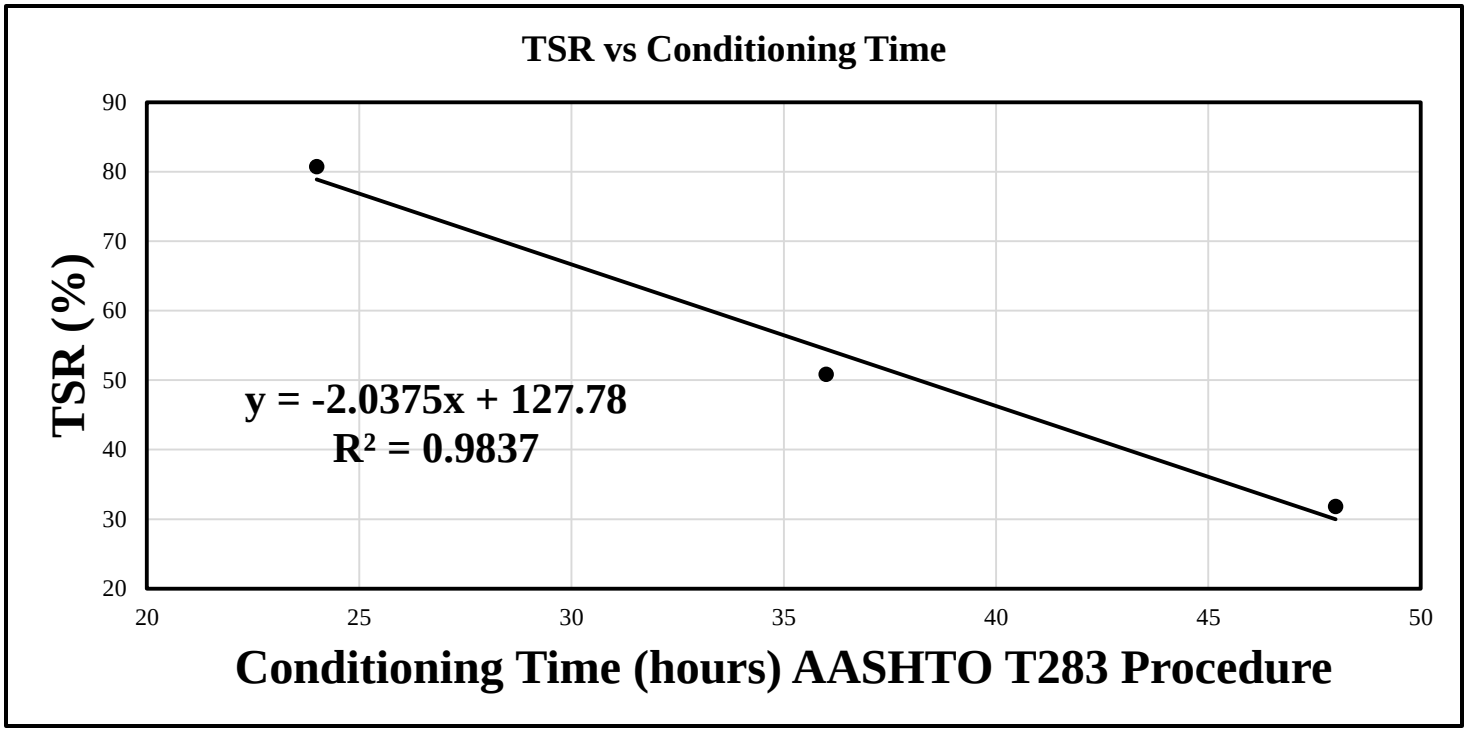


AT-Index application to TSR test

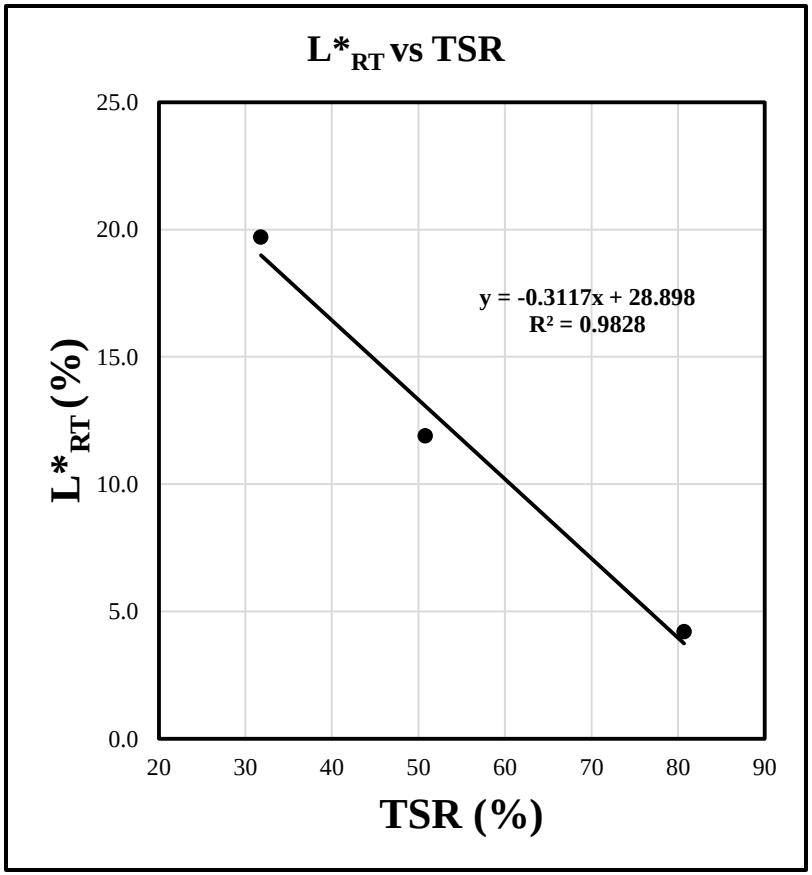


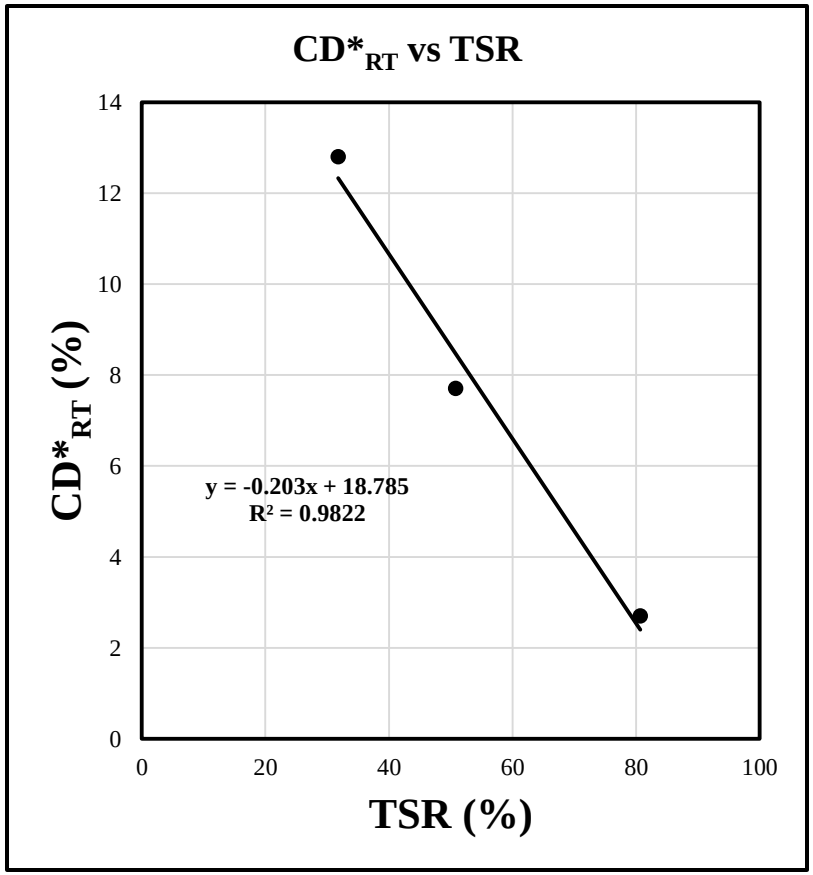
Visual stripping due to moisture conditioning using AASHTO T283 procedure for TSR Test for mixture without anti-strip additive with increase in conditioning times. The unconditioned mixture is on the left while the conditioned mixture is on the right. (L to R): 24-hour conditioning, 36-hour conditioning, 48-hour conditioning

AT-Index Application to TSR Test Results



AT-Index Application to TSR Test





Value of AT-Index Method

- Can be used as starting point in mix design to asses asphalt-aggregate compatibility with respect to moisture susceptibility – loss of adhesion
- Can be used to determine antistrip additive content (%)
- Can be used to compare effectiveness of different antistrip additives and even determine the most cost effective percentage and type of antistrip
- Can be used for quality control of plant mixtures to ensure proper adhesion throughout the production process

Quantification of visual stripping in TSR test

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NCDOT SAMPLES

Moisture Conditioning	ITS Values (kPa)	TSR (%)	L* Readings	L^*_{RT} Ratio
Dry Sample 1	1288.9	64.0	16.188	7.8%
Wet Sample 1	824.3		17.448	
Dry Sample 2	1342.5	78.7	16.767	4.4%
Wet Sample 2	1056.6		17.512	
Dry Sample 3	1401.3	88.7	16.89	2.1%
Wet Sample 3	1242.6		17.25	

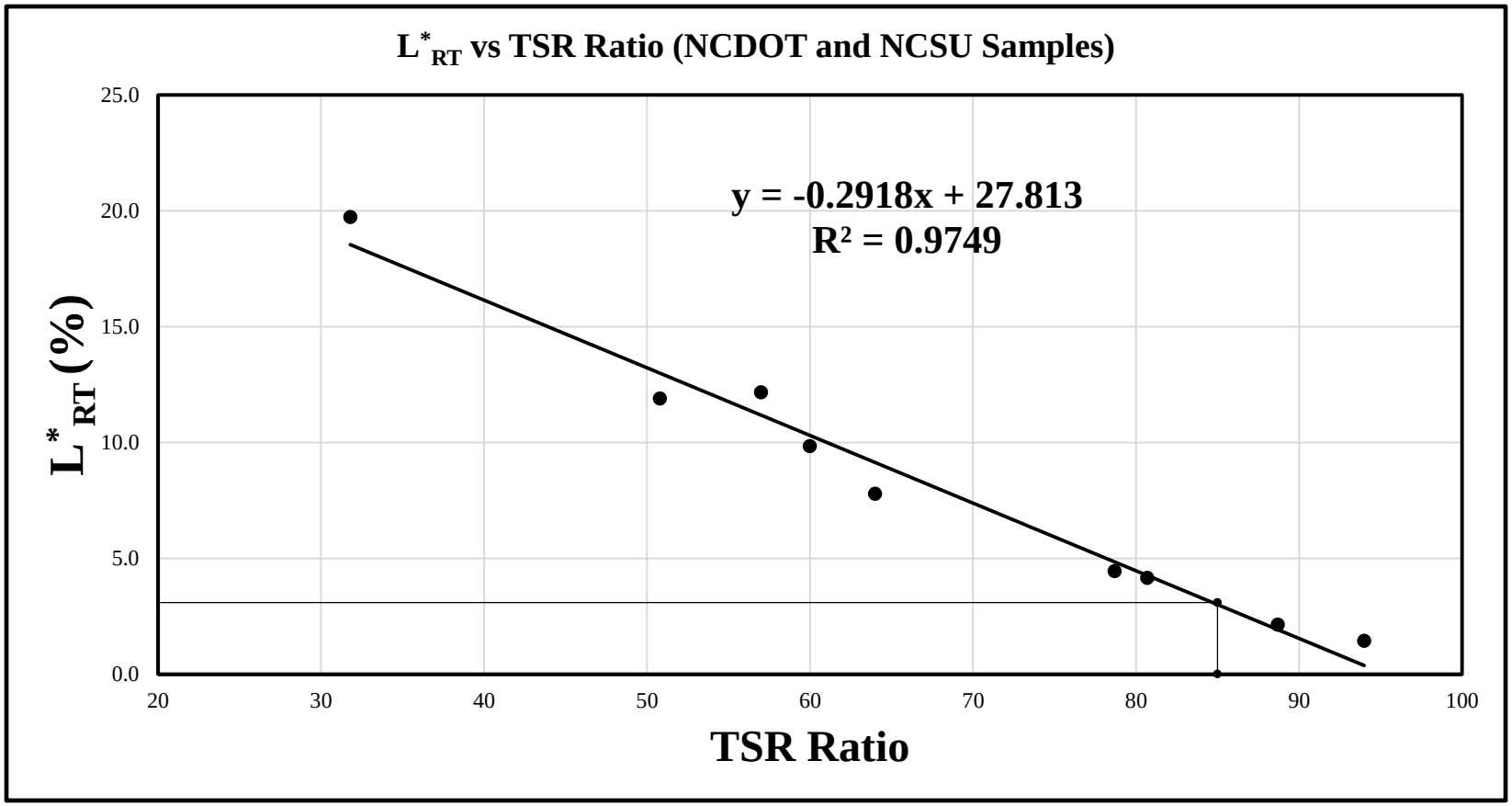
NCDOT SAMPLES

Moisture Conditioning	TSR (%)	L* Readings	L^*_{RT} Ratio
Dry Sample 1	57.0	15.917	12.2%
Wet Sample 1		17.853	
Dry Sample 2	60.0	16.57	9.8%
Wet Sample 2		18.2	

NCSU Laboratory Specimens

Moisture Cond.	Median ITS Values (kPa)	TSR (%)	L* Reading	L^*_{RT}	CD^*_{RT}
Dry	1247	94.0	19.343	1.4%	1.0%
Conditioned	1172		19.621		
Moisture Cond.	**Median ITS Values (kPa)**	**TSR (%)**	**L* Reading**	L^*_{RT}	CD^*_{RT}
Dry	947	-	18.247	-	-
24 hr	764	80.7	19.005	4.2%	2.7%
36 hr	481	50.8	20.417	11.9%	7.7%
48 hr	301	31.8	21.846	19.7%	12.8%

L^*_{RT} vs TSR Ratio (NCDOT and NCSU Samples)



- Equation (from the graph) to estimate TSR value from L* ratio

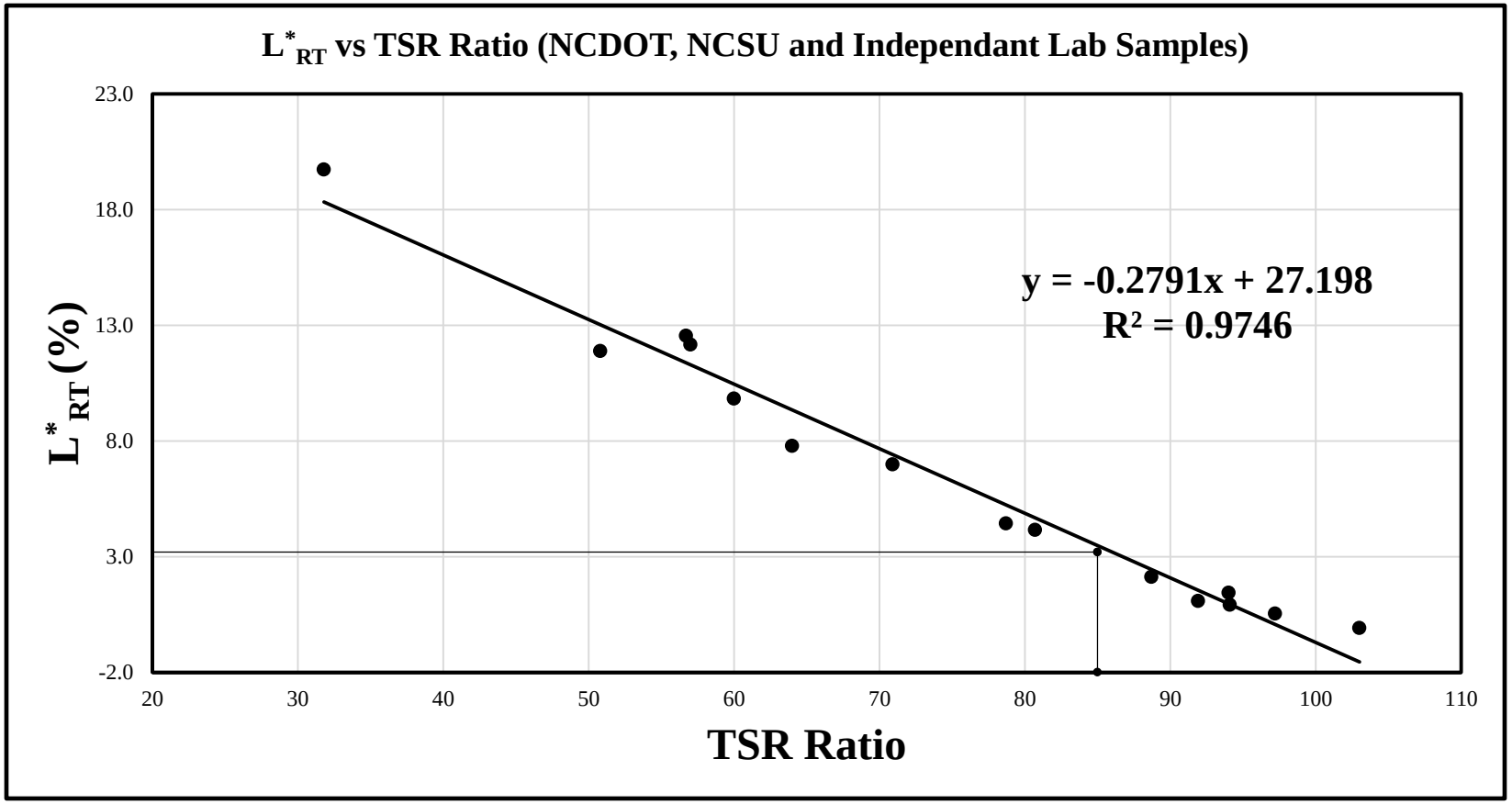
$$\textit{TSR ratio} = 94.609 - 3.341 \times (L^*_{RT})$$

- This equation was used to estimate the TSR value from L* ratio values for independent laboratory supplied specimens

Independent Lab Data

Moisture Conditioning	TSR (%)	L* Readings	L^*_{RT} Ratio	Estimated TSR (%)
Dry Sample 1	70.9	19.432	7.0%	71.2
Wet Sample 1		20.79		
Dry Sample 2	103	18.514	-0.1%	94.9
Wet Sample 2		18.50		
Dry Sample 3	91.9	19.38	1.1%	90.9
Wet Sample 3		19.591		
Dry Sample 4	94.1	19.097	0.9%	91.6
Wet Sample 4		19.274		
Dry Sample 5	97.2	19.121	0.5%	92.9
Wet Sample 5		19.224		
Dry Sample 6	56.7	20.554	12.5%	52.8
Wet Sample 6		23.132		

L^*_{RT} vs TSR Ratio (NCDOT, NCSU and Independent Lab Samples)



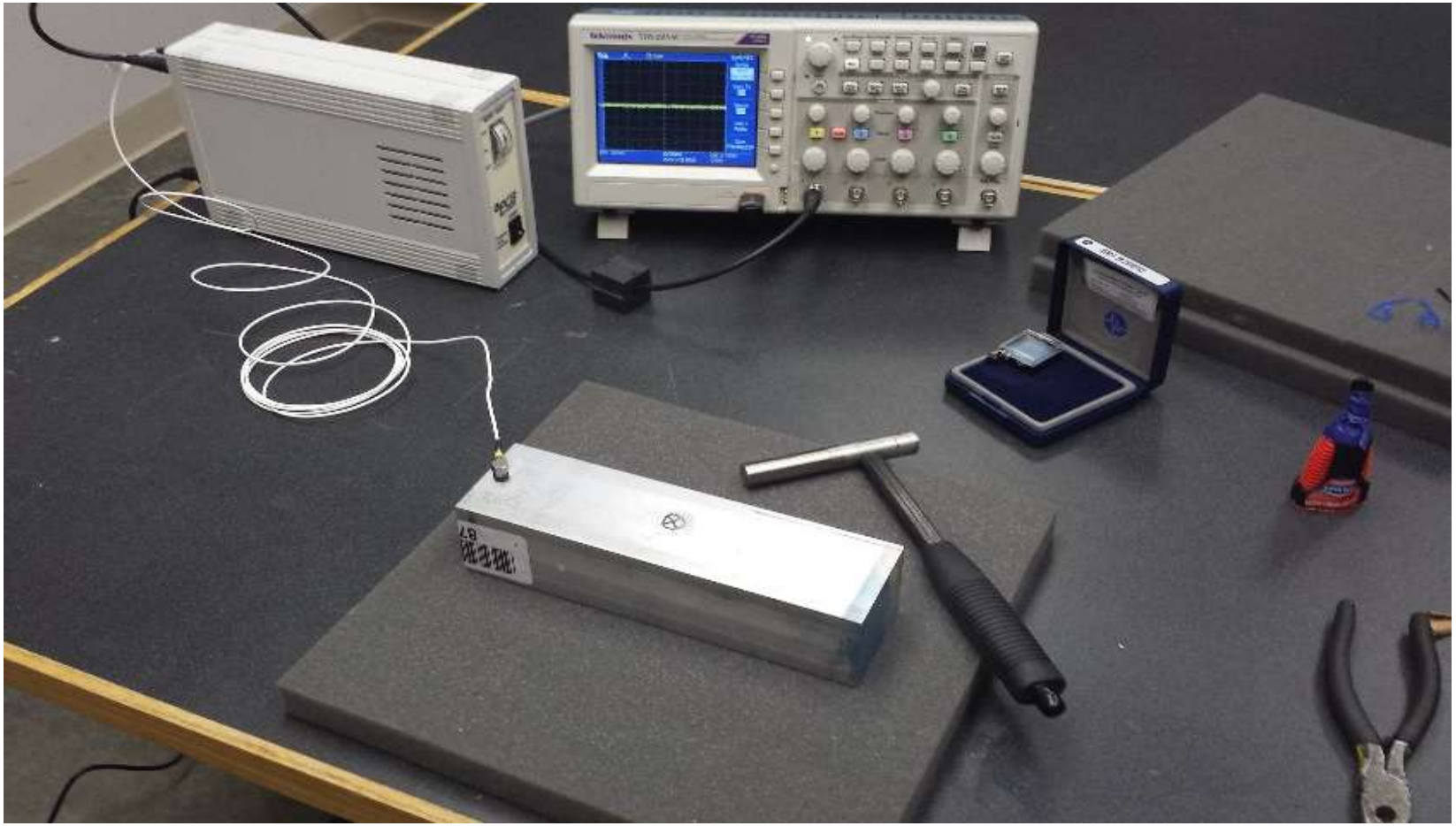
Final Equation

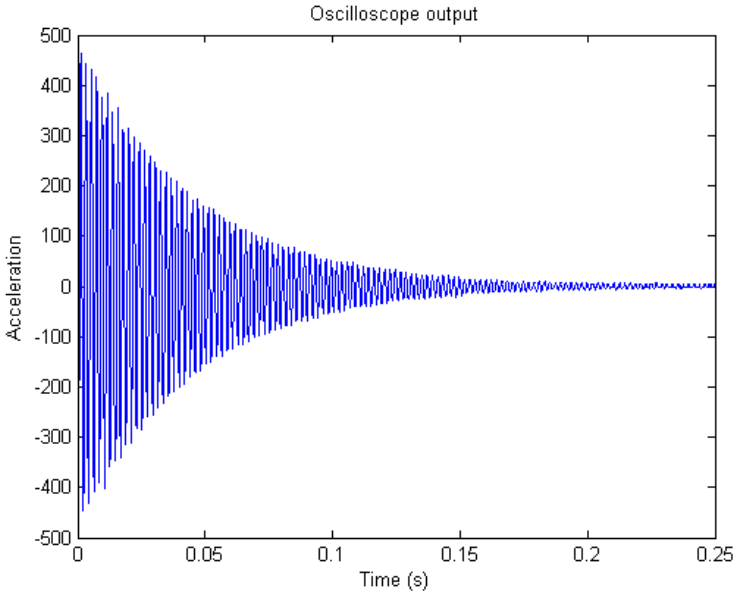
$$\text{TSR Value} = 96.888 - 3.4927 \times (L^*_{RT})$$

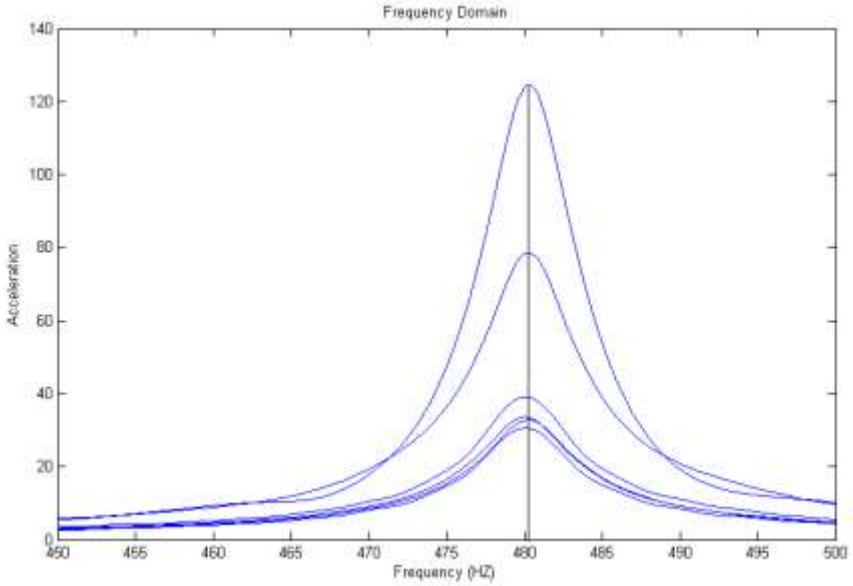
If the L^*_{RT} is known for a sample the TSR value can be estimated

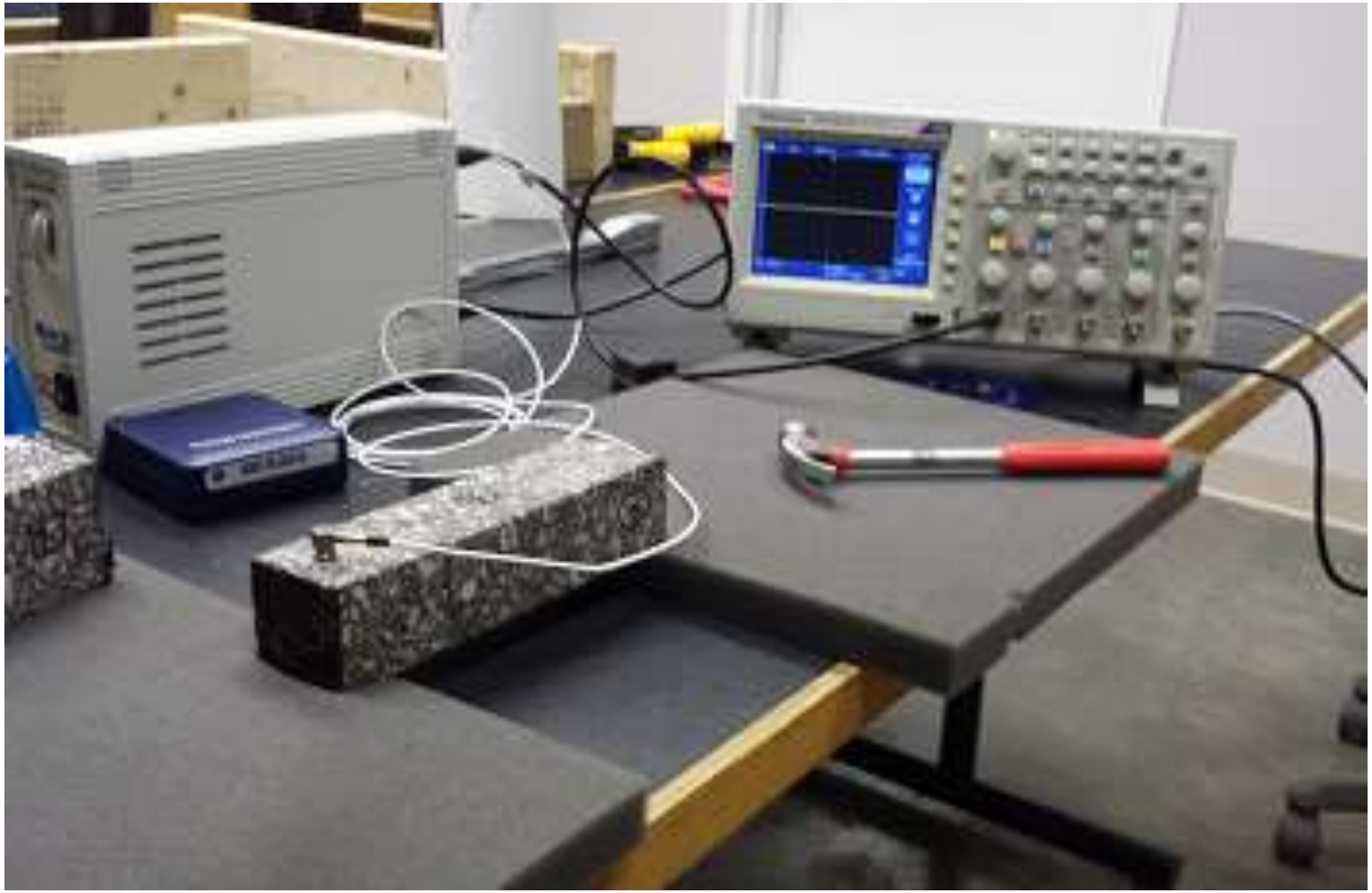
IR E* Ratio Versus TSR

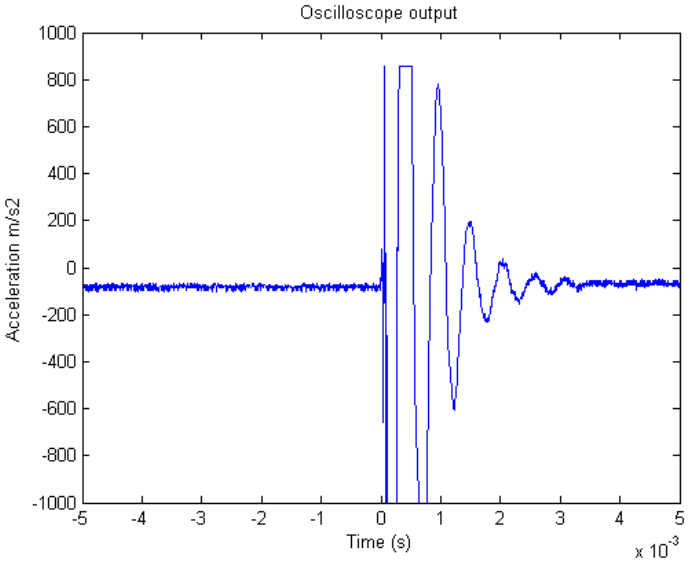
Impact Resonance Test

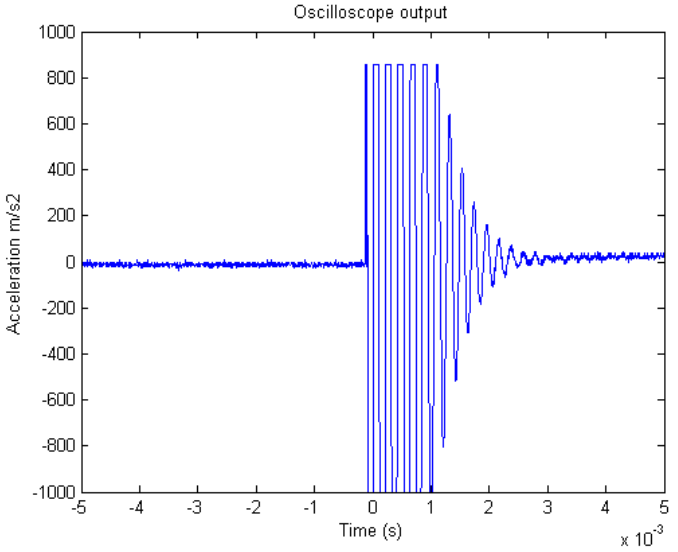


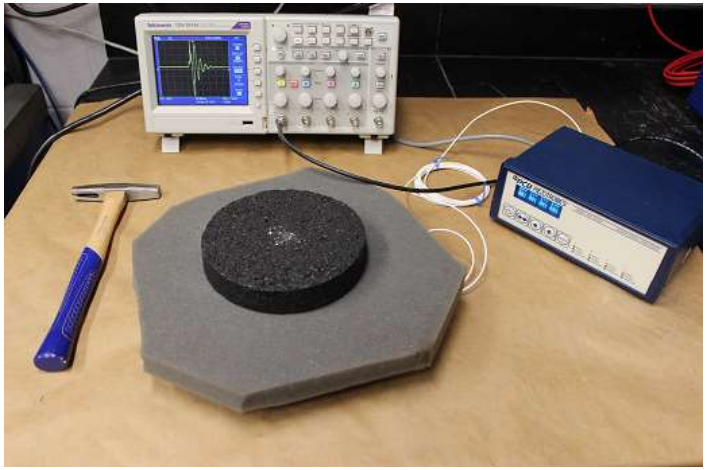

Oscilloscope output
Acceleration
Time (s)
500
400
300
200
100
0
-100
-200
-300
-400
-500
0
0.05
0.1
0.15
0.2
0.25


Frequency Domain
Acceleration
Frequency (HZ)
140
120
100
80
60
40
20
0
450
455
460
465
470
475
480
485
490
495
500

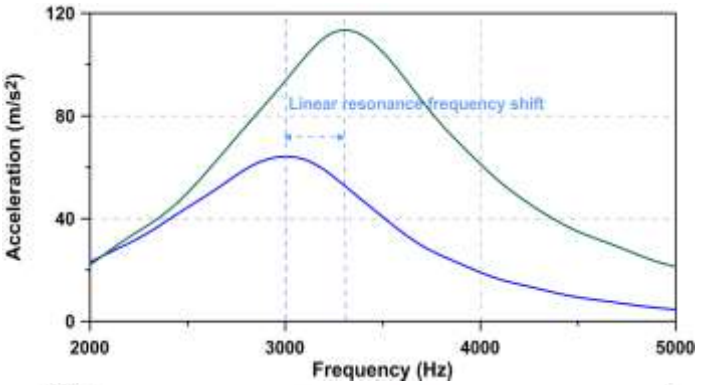


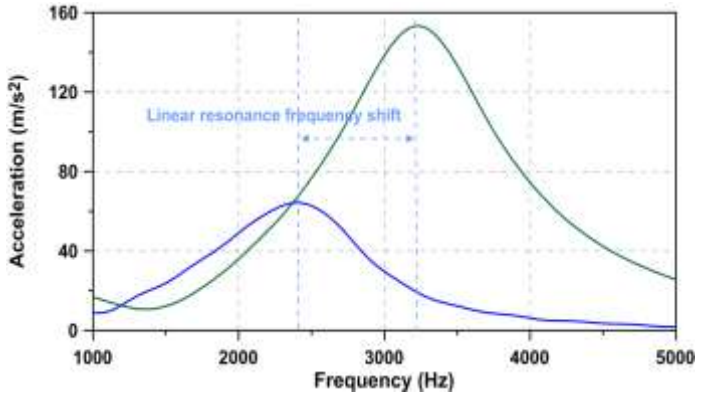


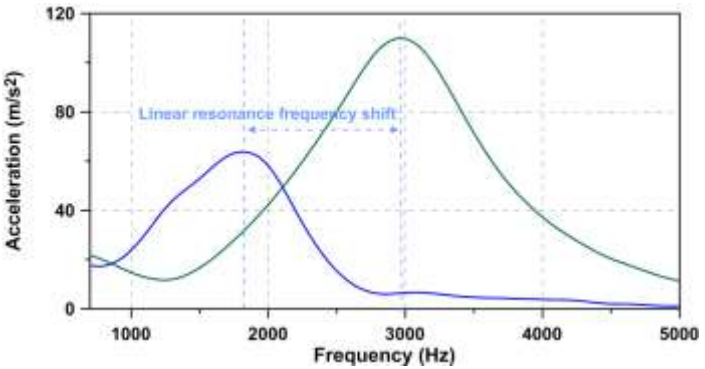


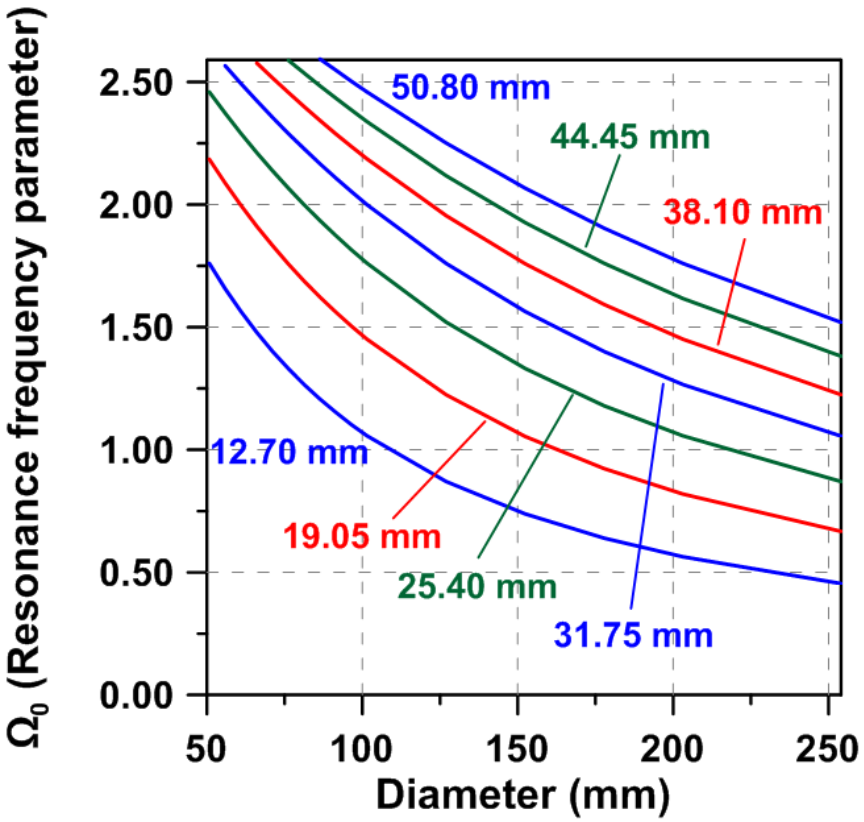


$$E_d = 2(1+\upsilon)\rho\left(\frac{\pi f d}{\Omega_0}\right)^2$$









$$E_d = 2(1+\upsilon)\rho\left(\frac{\pi f d}{\Omega_0}\right)^2$$

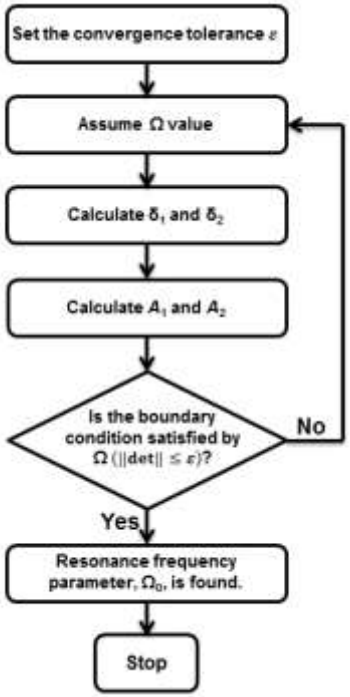
$$K\left(\psi' + \frac{\psi}{r} + \omega'' + \frac{\omega'}{r}\right) + \Omega^2\omega = 0$$

$$\frac{2}{1-\upsilon}\left(\psi'' + \frac{\psi'}{r} - \frac{\psi}{r^2}\right) - \frac{3K(\psi+\omega')}{h^2} + \Omega^2\psi = 0$$

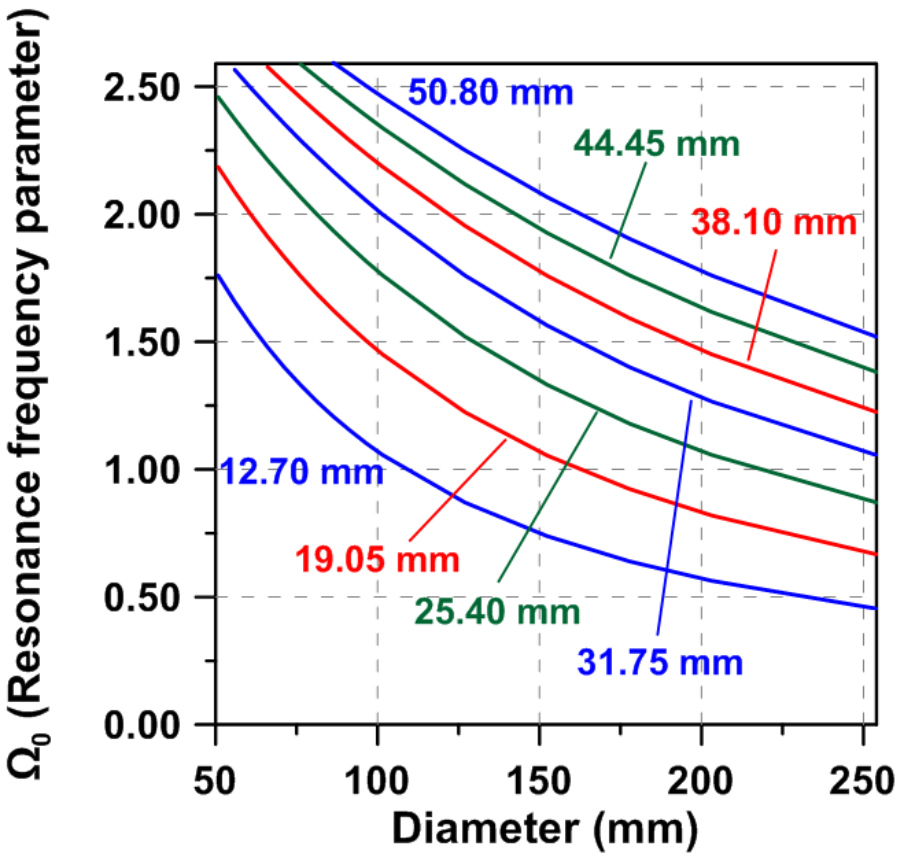
$$\delta^4 + a_1\delta^2 + a_2 = 0$$

$$a_1 = -\Omega^2\left(\frac{1}{K} + \frac{(1-\upsilon)}{2}\right)$$

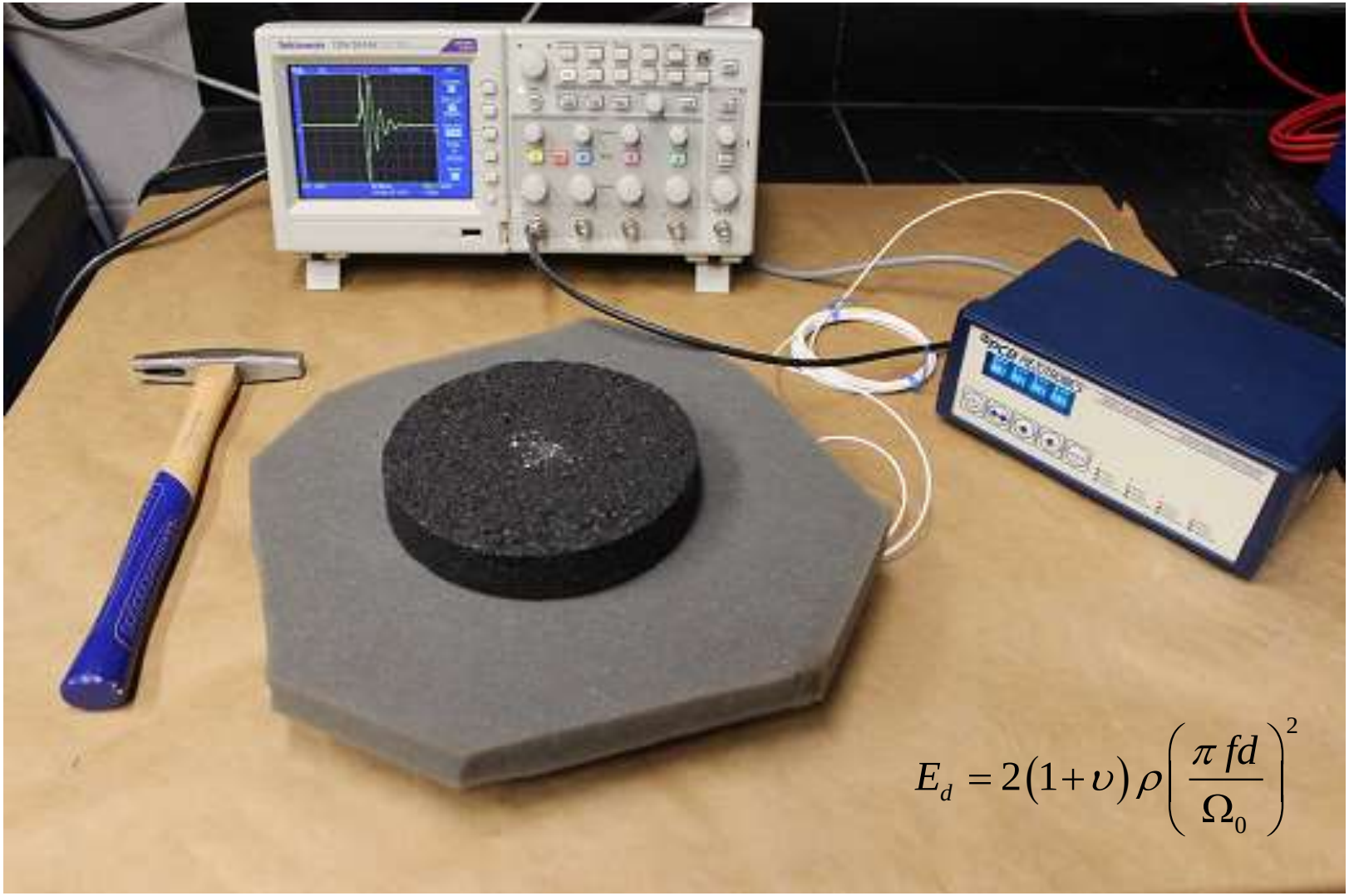
$$a_2 = \Omega^2\left(\frac{\Omega^2}{K} + \frac{3}{h^2}\right)\frac{1-\upsilon}{2}$$



$$\begin{bmatrix} K\delta & \Omega^2 - K\delta^2 \\ \delta^2 - \dfrac{2\delta^2}{(1-\upsilon)} - \dfrac{3K}{h^2} & \dfrac{3K\delta}{h^2} \end{bmatrix}\begin{bmatrix} 1 \\ A \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$



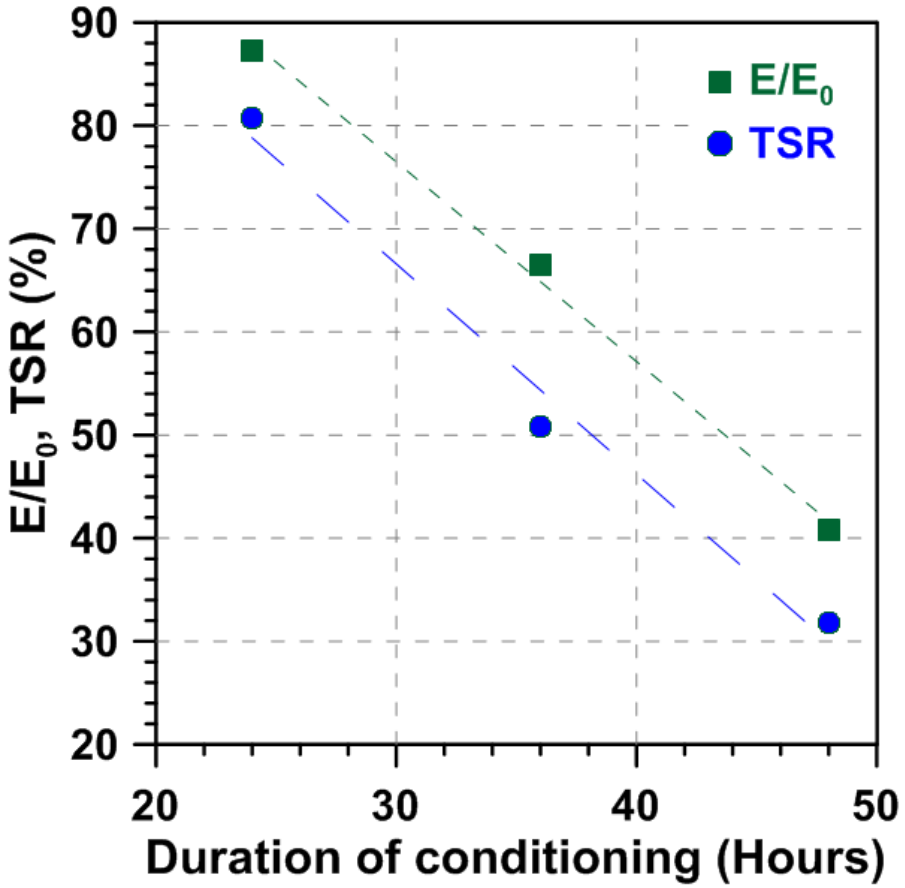
$$E_d = 2(1+\upsilon)\rho\left(\frac{\pi fd}{\Omega_0}\right)^2$$

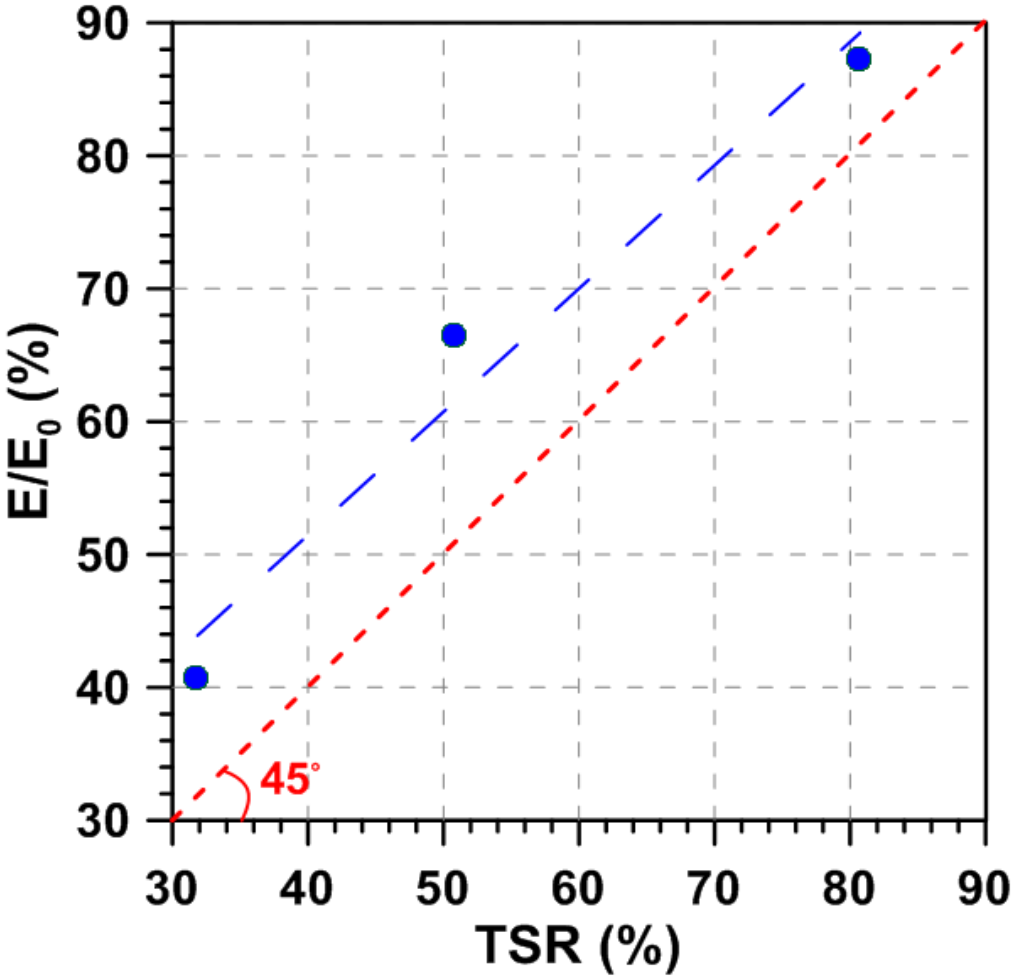


$$E_d = 2(1+\upsilon)\rho\left(\frac{\pi fd}{\Omega_0}\right)^2$$

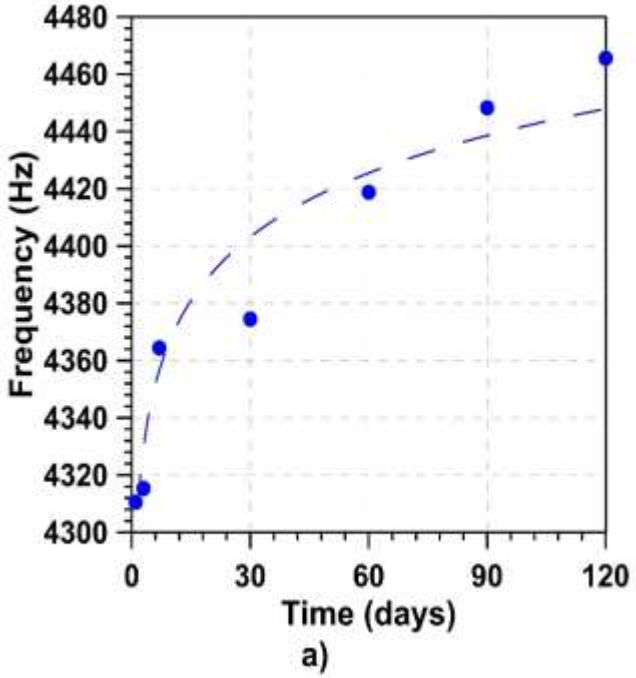
Impact Resonance vs TSR Test

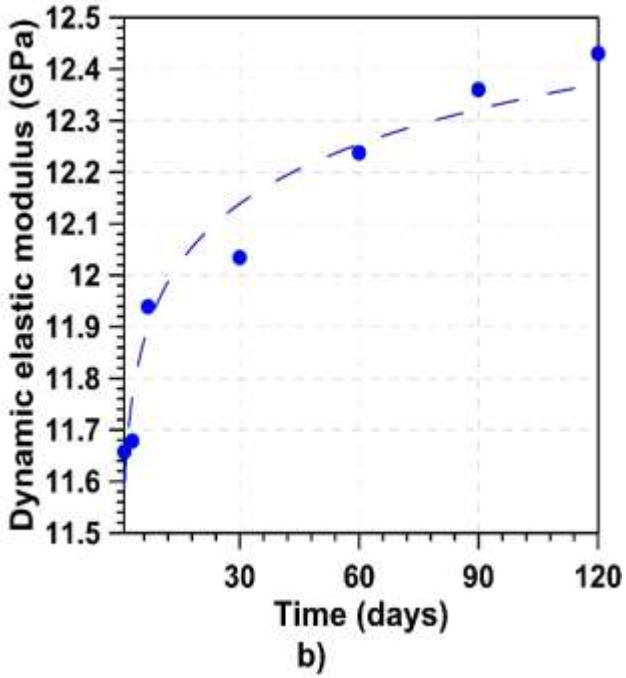
Effect of Conditioning Duration





Effect of Time Duration Before Testing





Thank You

Questions?