Extended Testing Conditions for the Evaluation of Water Sensitivity of HMA Mixes

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ISAP TC on Constitutive Modelling

2016 Yearly Meeting

Washington DC

Sunday 10th January 2016

Water sensitivity

- Damage to pavements due to water
- Always been difficult to develop tests and methods that truly capture performance
  - Current method such as AASHTO T283 and T324 are based upon implementation of tests that have been shown to relate to performance
- Do we have the correct conditions in these test methods?
  - Presentation considers some review of older information and new data generated looking at longer conditioning times

Water damage

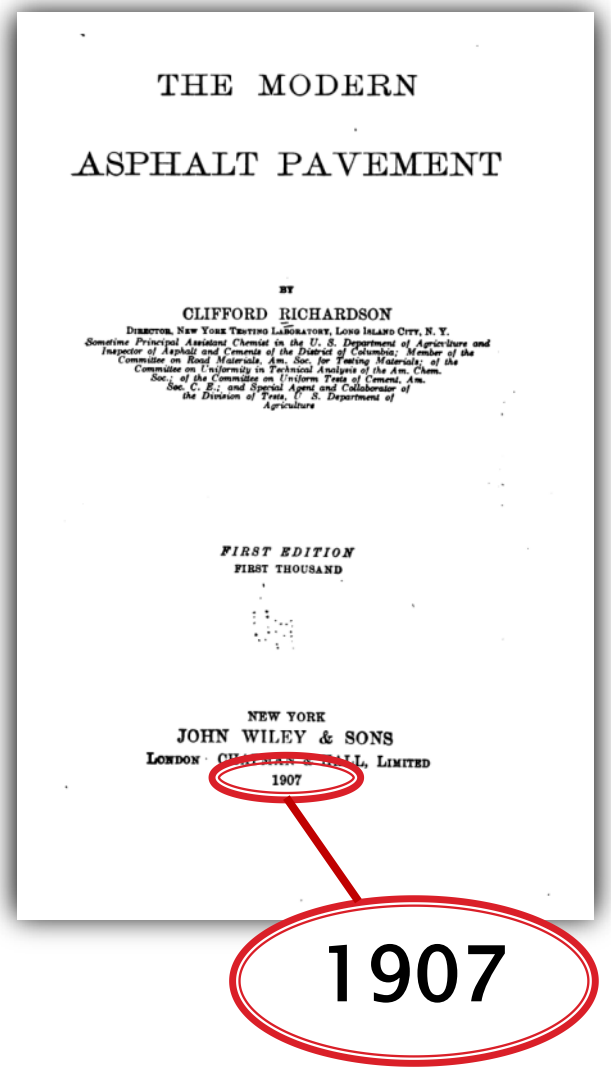
- A personal story for me!
- In the 1970s – working in East Anglia, UK – with silica gravel aggregates – adhesion was a problem!
- Materials would "sweat" with certain conditions and produce pools of asphalt on top of the trucks
- Specifications typically required hydrated lime or Portland cement as additive for performance

← From recent TRB Publication (Huber)

Typical gravel deposit in Norfolk (October 1982) →

Some early thoughts

- **"The Modern Asphalt Pavement"** -- on Water Action
  - "It is always advisable where a pavement shows signs of disintegrating to examine into the cause in a most careful manner and not pass snap judgment"
  - "I have heard men with considerable experience, commenting on a bad place in a pavement that they had not carefully examined, remark, '*They used bad oil or asphalt in that piece of work.*'"

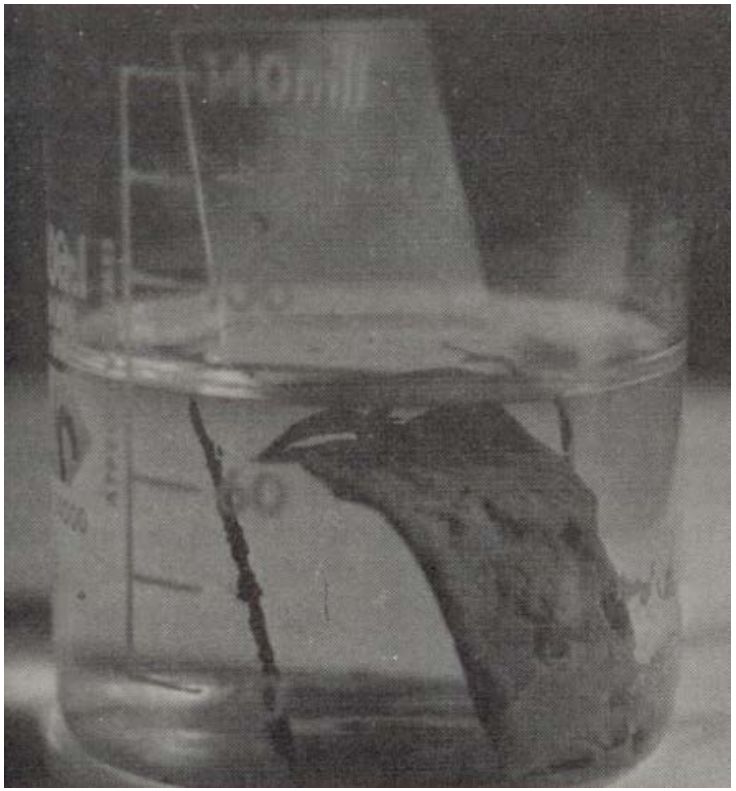


Concepts to explore !

- Emulsification
- Debonding
- Traffic stresses
- Time and temperature

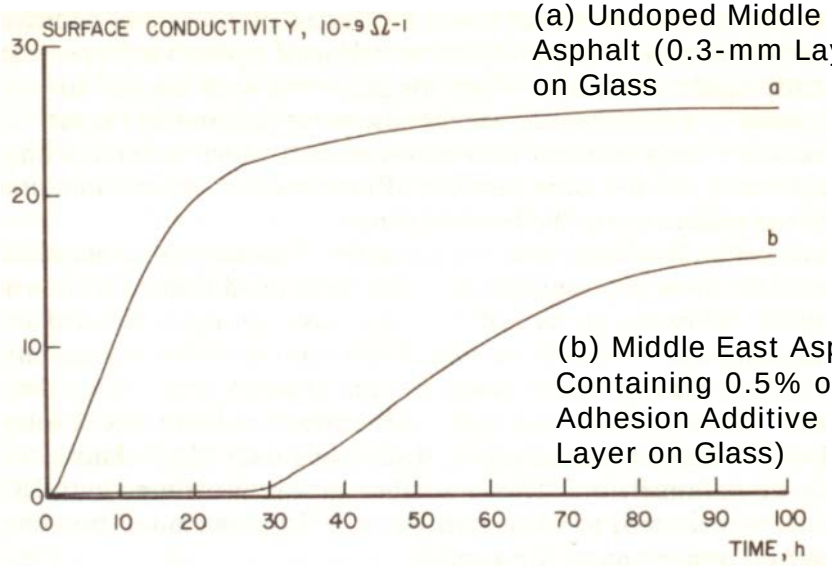
Emulsification

- Water emulsification into binder film – for example, Fromm 1974 AAPT
  - Surface tension breaks films away from glass slides
  - Some adhesion agents made emulsification worst!
  - No additives stopped breaks in films
  - Tests 10 to 24 days



Debonding

- In Scott's 1978 AAPT paper he considered the "asphalt disbonding" …
  - "When an adhesion additive is included, the most common effect is delay in tine before initial surface conductivity rise."
  - Several hours to several weeks
  - "delay but not prevent"



Change in Electrical Surface Conductivity with Time of Exposure to Water Vapor (Scott AAPT 1978 – page 35)

Test - As water enters the asphalt/glass interface the conductivity rises, 15C. After a short time the asphalt film can be peeled away leaving a hydrophilic surface.

Traffic Stress and IWTT

- IWTT tests date from the early 1930s.
  - 1933 – AAPT (p. 61)
    - … "by flooding the track with water, we can cause disintegration after a few hundred cycles"
  - 1939 paper – Implemented in test laboratory in New Jersey, USA.
- Showed relationships between adhesively and life on test track
- Tests conducted to 40,000 passes (approx. <u>84 hours or 3 ½ days</u>)

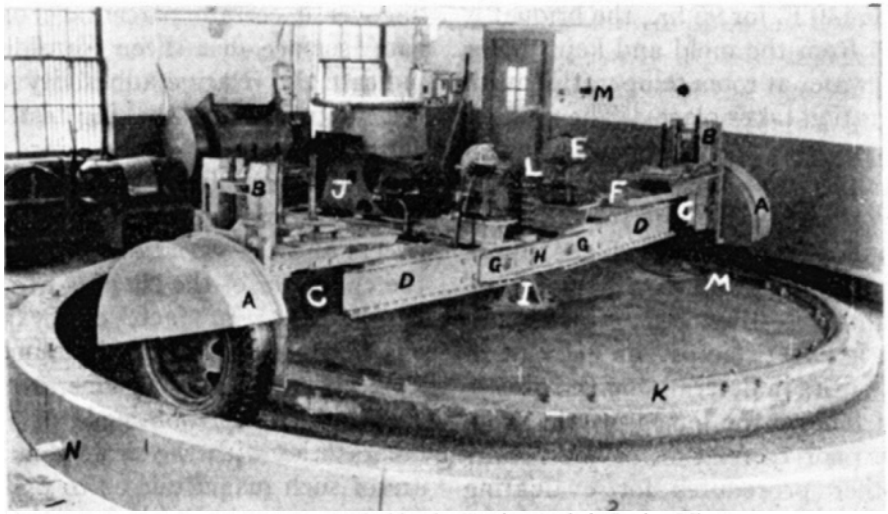
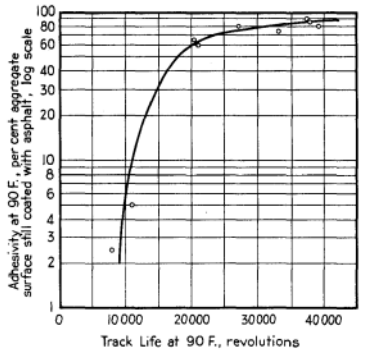


FIG. 1.—Circular Track Machine for Testing Asphalt Paving Mixtures.

A Wheel assembly.
B Height adjustment for *A*.
C Beams which are reciprocated telescopically inside.
D The main beams.
E The motors and gear reducers for reciprocating beam *C*.
F The stops and switches which control and reverse the travel of *C*.
G Heavy pins permitting vertical motion in the beams while attached to *H*, the rigid T member which is rotated around, *I*, the fixed pivot.
J The motor drive for rotating the equipment.
K Steel track on which the driving wheel runs.
L Commutator arrangement for electrical connections.
M Electrical revolutions counter.
N Drains for removing water from track.

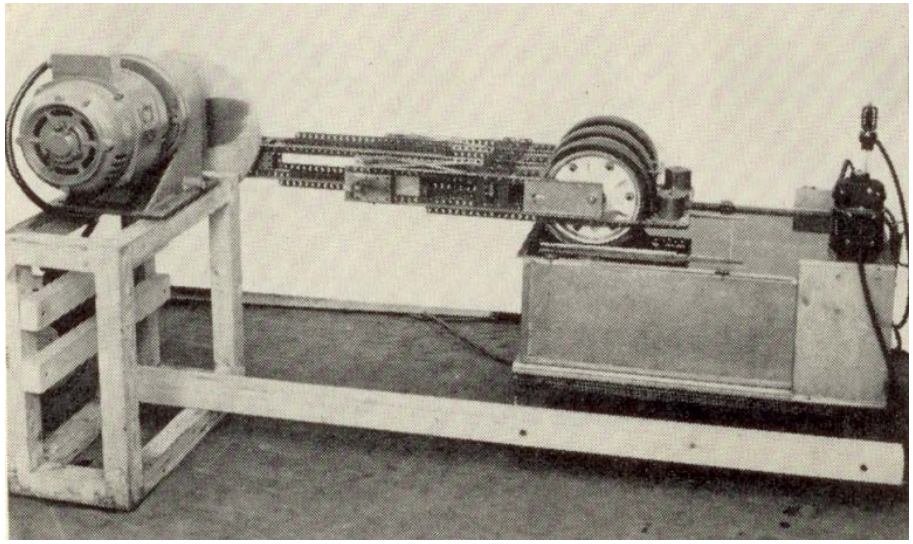
Lab versus IWTT performance from 1939 →

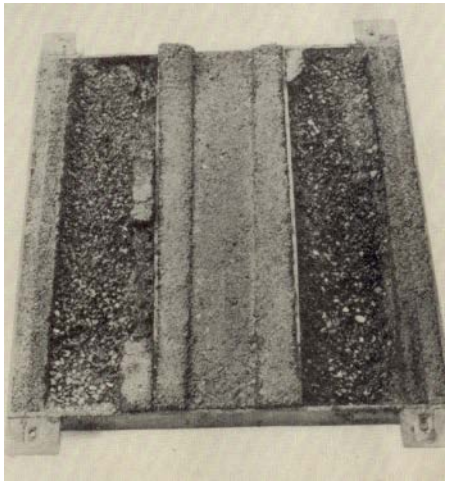


Holmes. A., "Evaluating the Adhesive Properties of Asphalt," ASTM, 1939, 39, 1140. (Standard Oil – Elizabeth, NJ)

Traffic stresses

- 1953 – Lee noted "Investigations have shown that traffic, as well as water, is an operative factor in producing adhesion breakdown."
- Device dates from around 1941 (Mack, SCI)



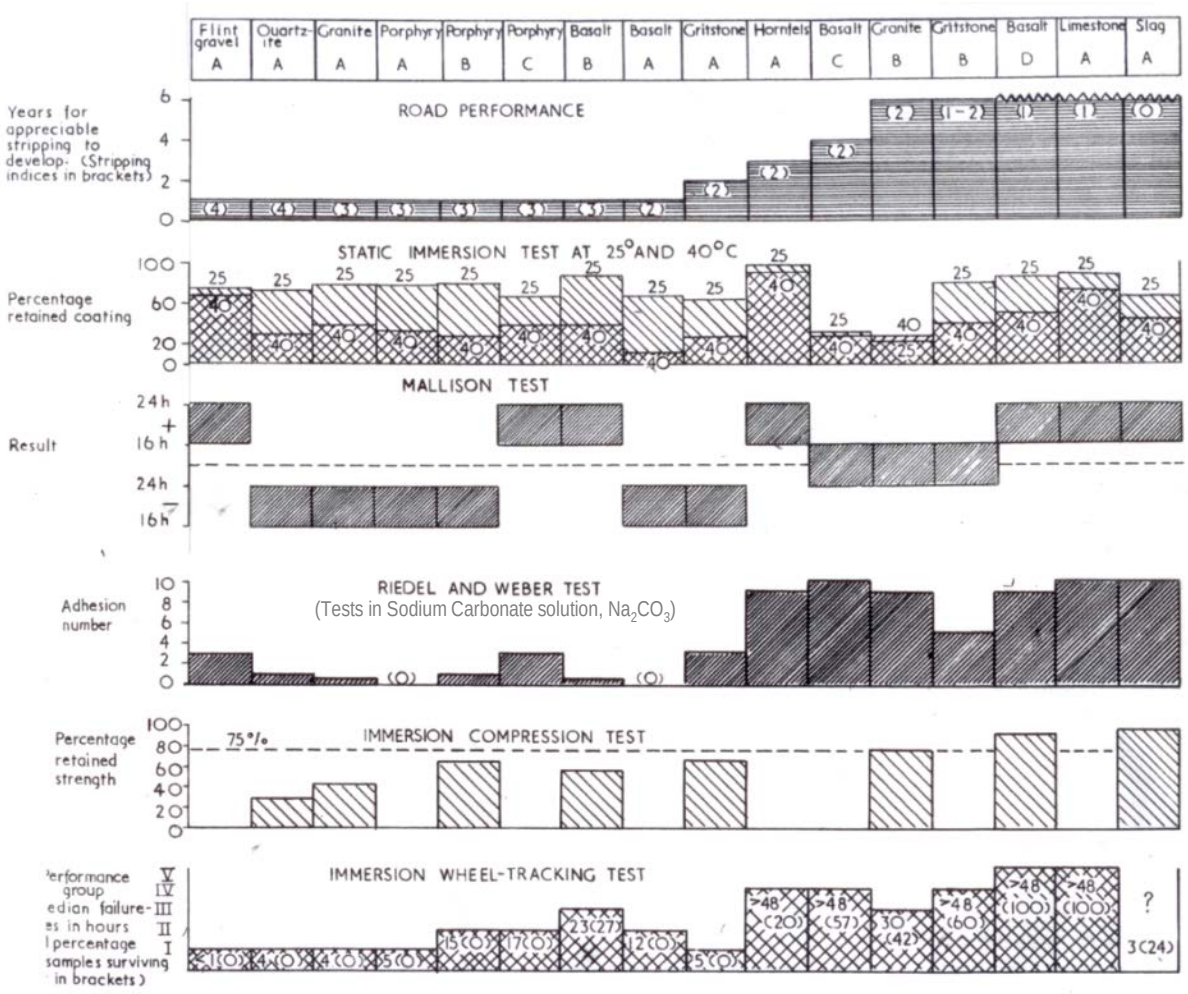


Wheel tracking testing apparatus and sample after submission to wheel tracking test

Lee, A.R., "Recent Developments in Asphalt Technology," Lecture held before the Vereniging voor Bitumineuze Werken V.B.W. in Hotel Witte Brug, Scheveningen, Holland, 29th April 1953.

IWTT

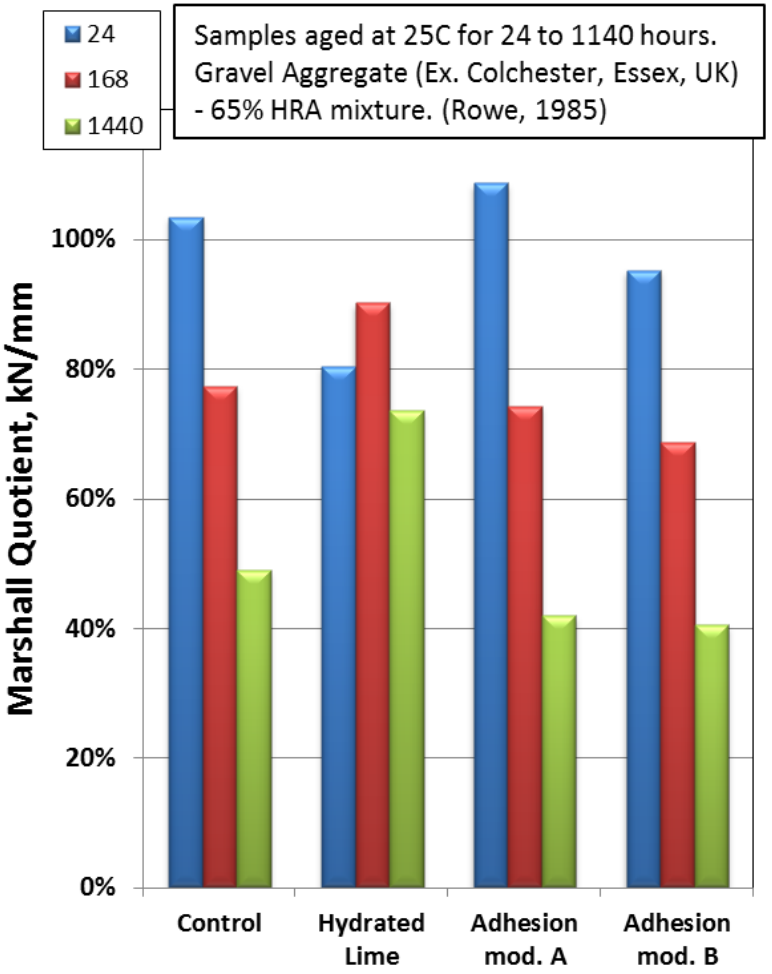
- 1964 – The best correlation with road performance of the aggregates in bitumen-macadam was given by the "Immersion Wheel-tracking Test"
- Tests conducted to >48 hours at 40°C



Mathews, D.H., Colwill, D.M. and Yuce, R., "Adhesion Tests for Bituminous Mixtures," (Laboratory Note No. LN/698/DHM.DMC.RY. November, 1964. RB. 448.) Paper presented before the Society of Chemical Industry, Road and Building Materials Group, 19th November, 1964.

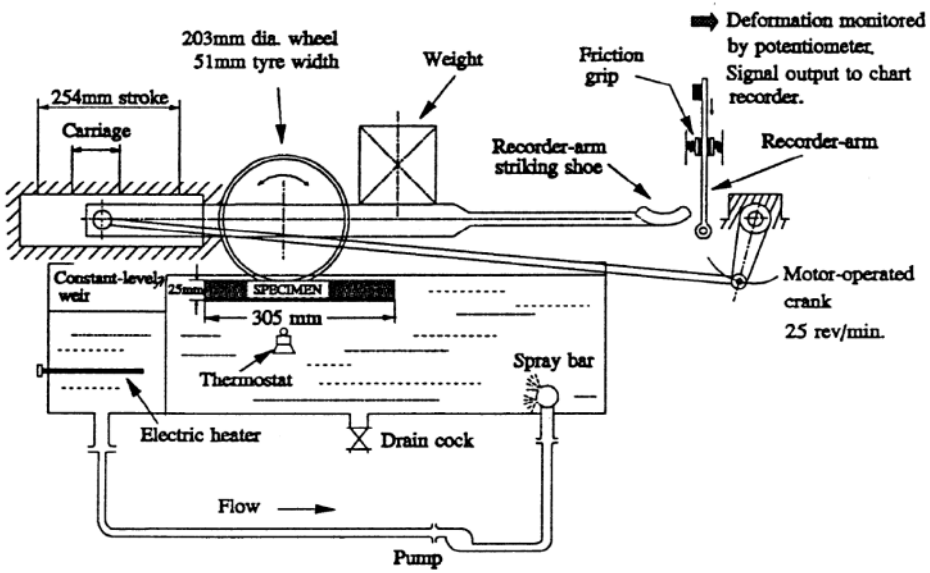
Time and temperature

- Early tests considered longer time and some varying temperatures
- Applied in evaluation of additives (1980s)
  - Extended water saturation tests showed large differences in performance
    - Longest tests – 2 months



The SHRP study

- IWTT used in SHRP – "There exists almost perfect agreement between the A-002A predictions and the SWK/UN results."
  - This procedure was modified from the earlier IWTT method to include for longer soak time based upon earlier work with extended saturation conducted by Rowe (1985)
- Soak for 144 hours (at 60°C) with a 24 hour freeze cycle
- Test conducted at 40°C
- Tests terminated at 7-days (168 hours) if no failure recorded



Schematic of Immersion Wheel Tracking Device, "Bituminous Materials in Road Construction, HMSO 1962"

Terrel, R.L., Scholz, T.V., Al-Joaib, A. and Al-Swailmi, S., "Validaation of Binder Properties used to Predict Water Sensitivity of Asphalt Mixtures," Proceedings AAPT, 1993.

Historical perspective

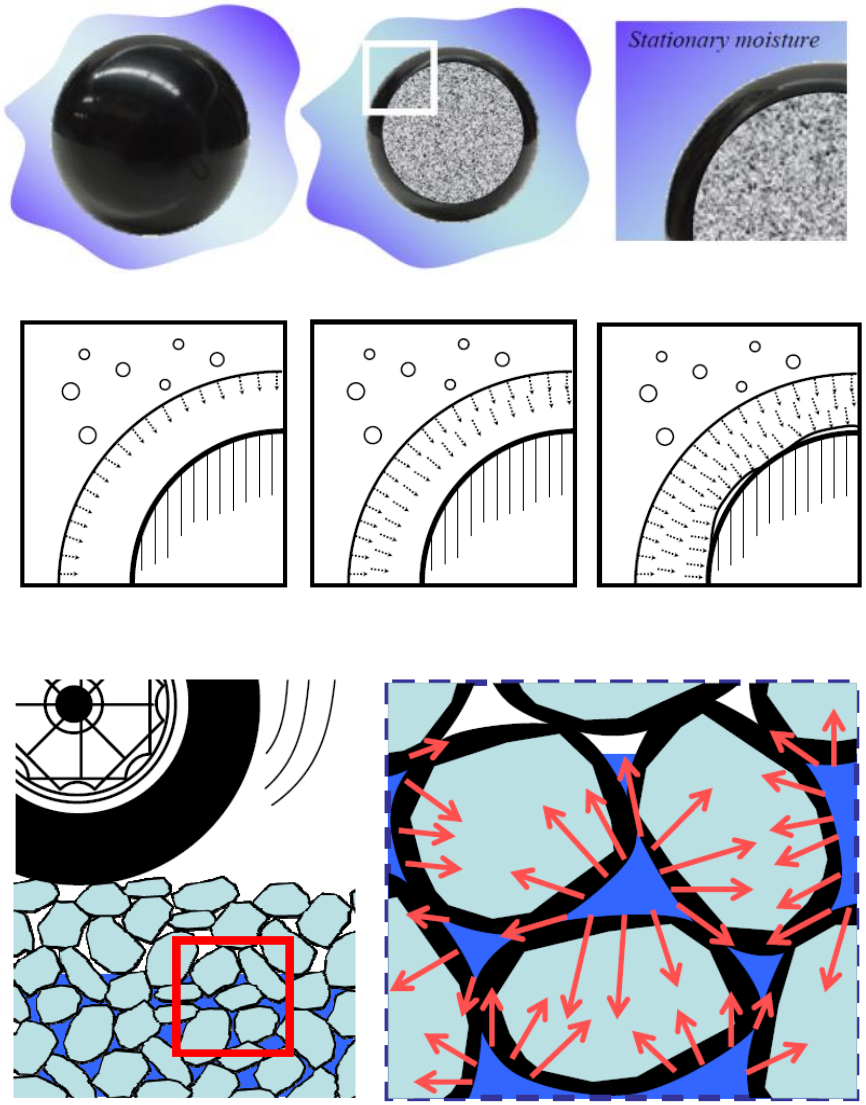
- Tests that rank mixtures well involve
  - Long times of saturation
    and/or
  - Conditioning at elevated temperatures
- But ….
  - AASHTO T283
    - 24 hours @ 60C, optional freeze-thaw, 2 hours @ 25C – then test
  - AASHTO T324
    - Placed in device at test temperature for ½ hour. Stop test at 20,000 cycles (approx. 6.7hrs.)
- Previous information on longer times/conditioning/temperatures will not be captured by current test procedures
  - Test procedures typically designed for easy laboratory operation!

Failures due to water damage

- Still occurring and are a important consideration
  - On some roads – I have shoveled base materials – so badly stripped!
  - How to we develop better methods?

Mechanism

- Water penetrates film
- Films swells, detaches (adhesion)
- Mechanical effects – pore pressures result in breaking of film (cohesion ?)
- Removal of binder by washing/pumping action



(figures from Kringos, 2007)

Hamburg Wheel Tracking Test (HWTT)

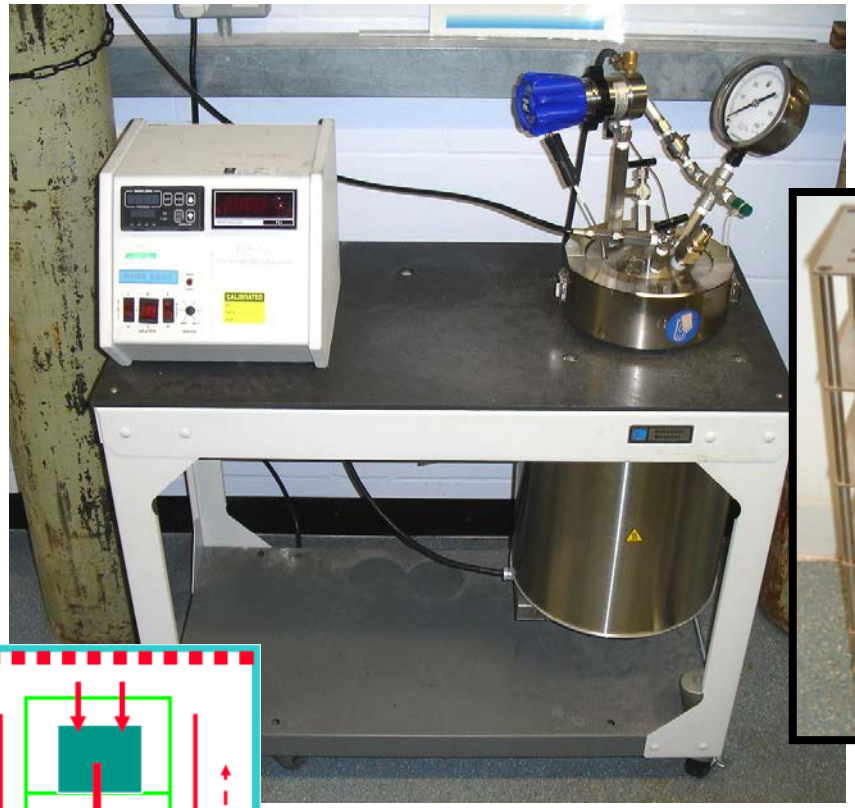
- Developed in the 1970's by Esso A.G. of Hamburg, Germany.
  - It was based on the TRL wheel tracker
  - Test generally not run with extended conditioning times!

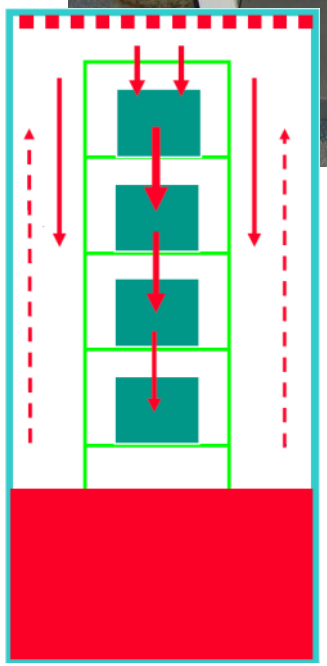
New approaches

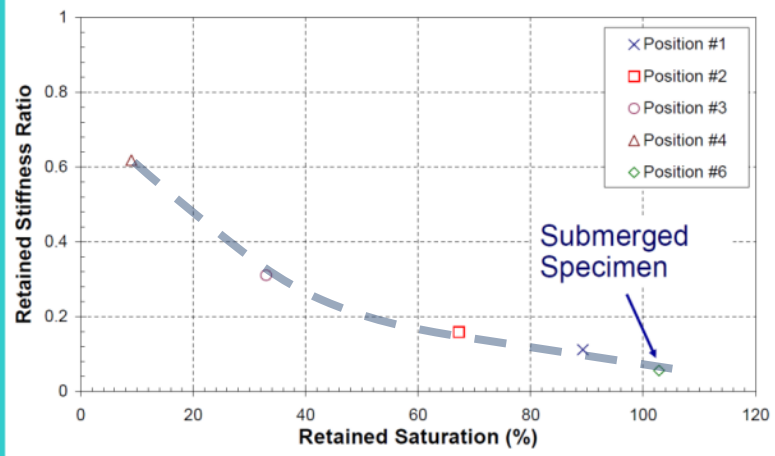
- SATS
  - Saturation Ageing Tensile Stiffness
  - Specimens aged and saturated at different levels in a pressurized chamber with water/moisture
    - Tested after removal from device
  - Total procedure – around 5-days
- MIST
  - Specimens subjected to cyclic loading
  - Pre or post conditioning can be done
  - Tests for absorbed water
    - Other tests performed on specimen after removal from device

SATS

- Specimens loaded at different levels
- Water at bottom with one specimen submerged
  - 85°C, 2.1MPa, 65hrs
  - Approx. 5 days method
- Water evaporates and condensates on top and then drips down
  - Produces different saturation levels in specimens (say 10 to 90%)
- Advantage – multiple saturation levels/ conditions
- Disadvantage – no cyclic stresses



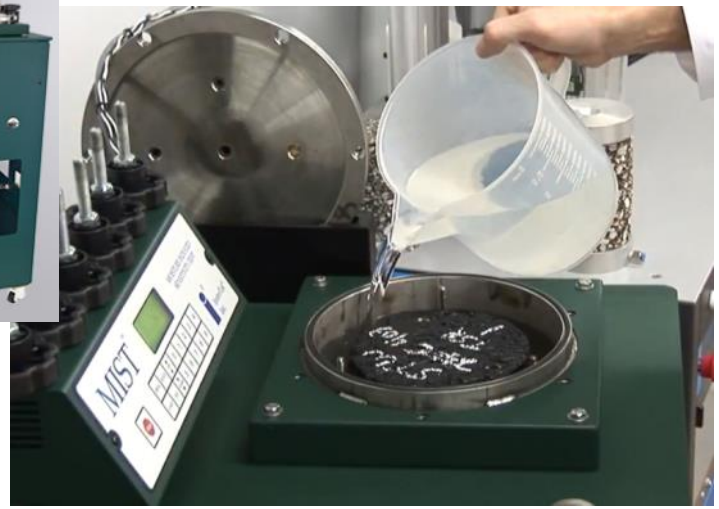




Airey et al., AAPT 2005

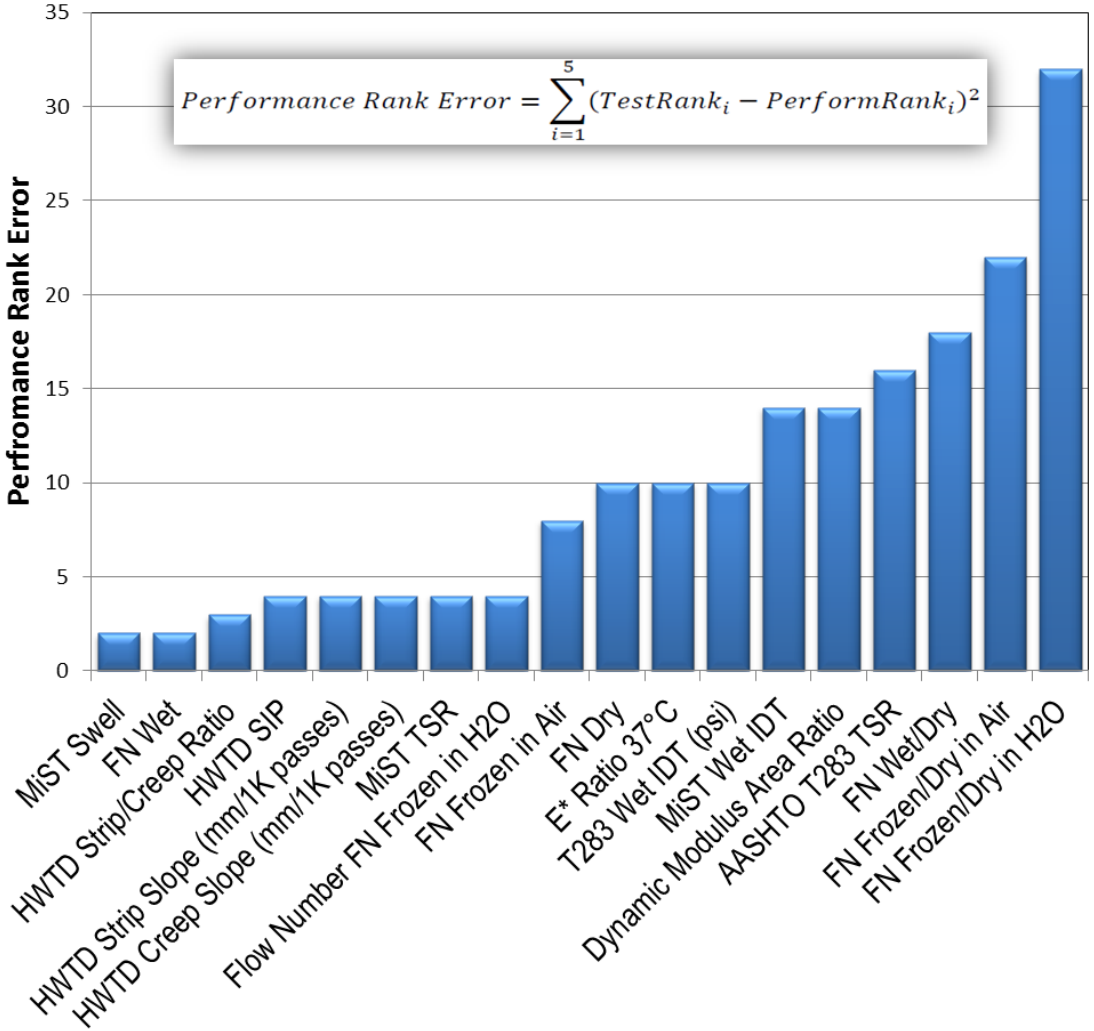
MIST™

- Moisture Induced Sensitivity Test
  - Conditions the test specimen
  - Specimen placed in chamber which is filled with water
  - Pressure is cycled 3500 times to a predetermined level (40 psi)
  - Finally the specimens are placed in a water bath at 20°C for 2-hours before testing for Indirect Tensile Strength
- Advantage – cyclic stress, mimics pumping/ traffic stresses
- Disadvantage – produces specimens at a single condition/ saturation level



How does MIST compare?

- Schram and Williams 2012 published performance ranking
  - 16 mixes/sites, 5 test types, 11 test conditions evaluated
  - #1 MIST Swell & Flow Number
  - Swell is a function of saturation of binder film



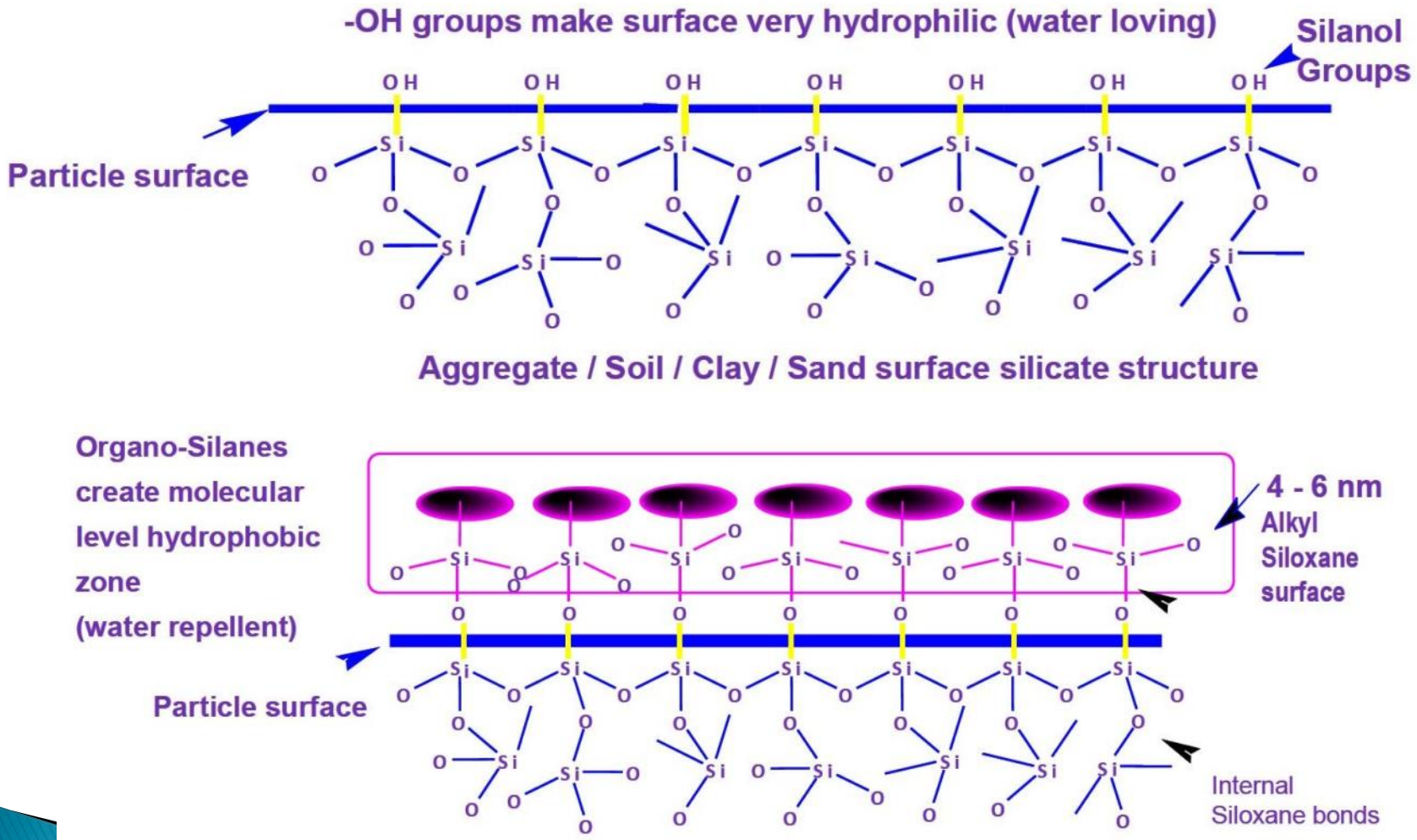
Why MIST?

- Both procedures interesting
  - SATS generates different saturation levels!
  - Does MIST provide a similar experience
    - Try MIST at different conditions ……
  - MIST performed at different temperature
    - Has advantage that damage should be quicker since stress pulse applied
  - Used with
    - 20-hr post-soak
    - 20hr pre-soak
    - Multiple temperatures, cycles and stress levels

Performance tests

- Consider need to run longer performance tests
- **Tests conducted with two types of materials**
  - Amine type modification (A)
  - Organo Silanes (Z)
  - Controls
- Study performed to evaluate assess how Organo Silanes perform compared to other modification systems
- Will show
  - Previous standard test results
  - MIST testing with extended temperatures
  - Others comments on testing

Organo Silanes



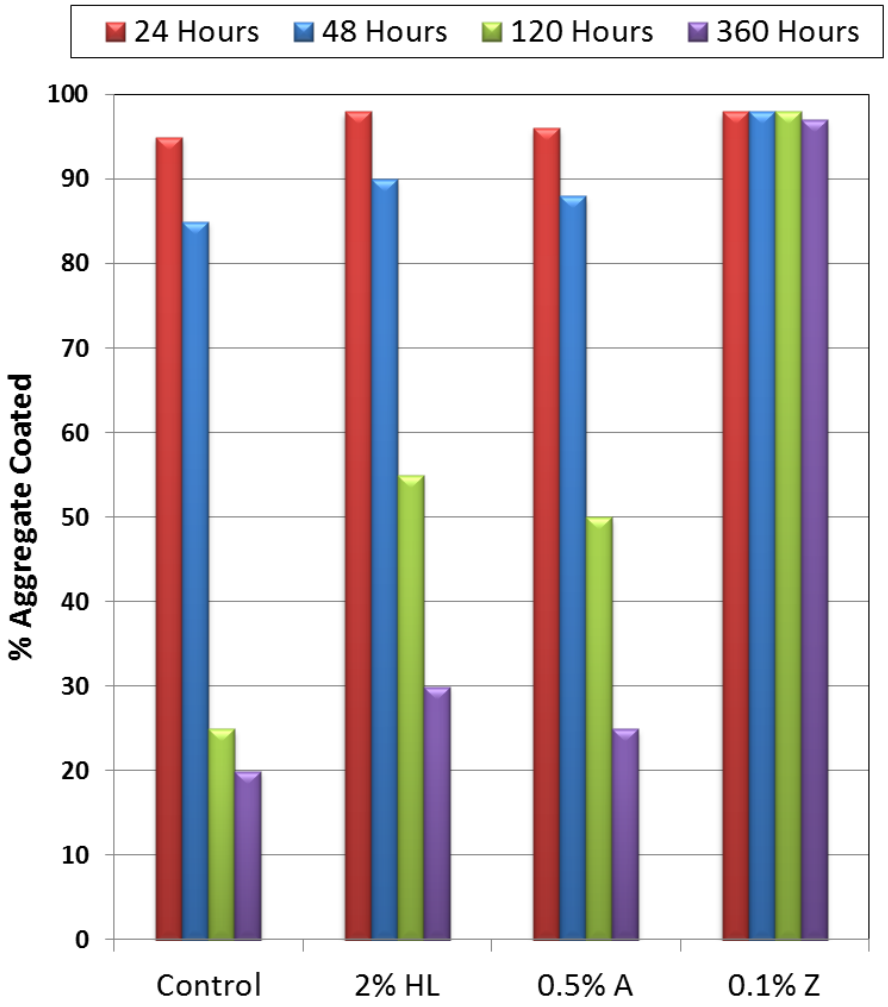
Previous test data

- Examples
  - AASTHO T182
    - Standard Method of Test for Coating and Stripping of Bitumen-Aggregate Mixtures – Static Immersion Test
  - AASHTO T283
    - Standard Method of Test for Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage – Tensile Strength Ratio
  - ASTM D3625
    - Standard Practice for Effect of Water on Bituminous-Coated Aggregate Using Boiling Water

      - Tests with Gravel and Basalt aggregates

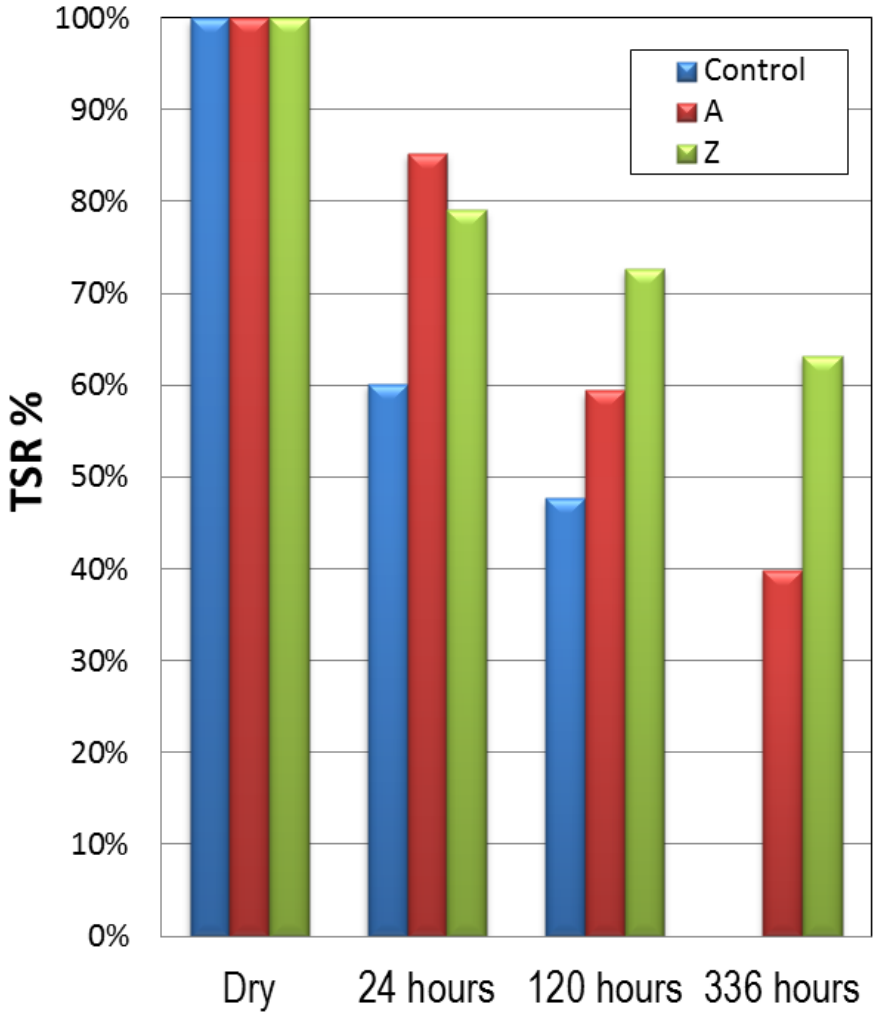
AASHTO T182 at 60°C

- Static Immersion Test
- Basalt Aggregate DBM
  - 45% 20mm, 10% 10mm, 45% 6mm/dust
  - Asphalt AC-20
- Normal standard <85% coating considered as failure



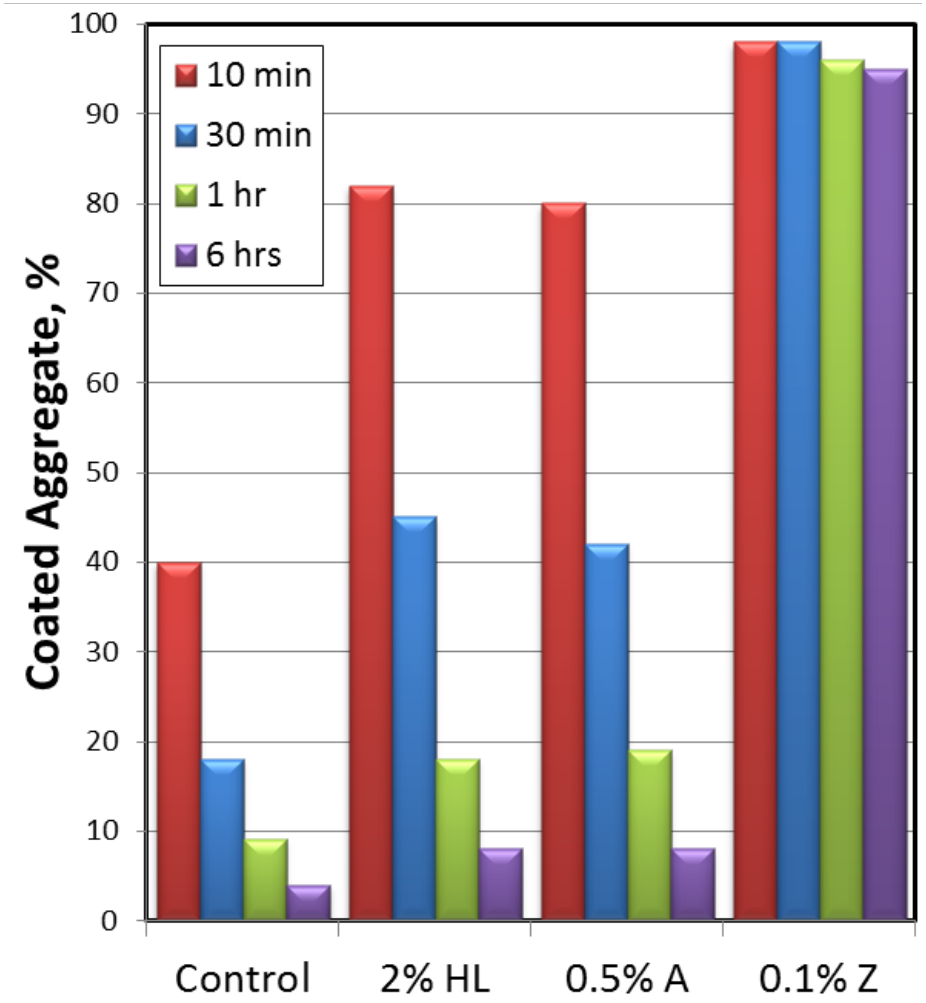
AASHTO T283

- Extended aging with extra data sets
- Extended aging
  - 120 hours (5-days)
  - 336 hours (14-days)



ASTM D3625

- Boiling test
- Basalt Aggregate DBM
  - 45% 20mm, 10% 10mm, 45% 6mm/dust
  - Asphalt AC-20
- Extended boil times
  - Normal test =10 mins



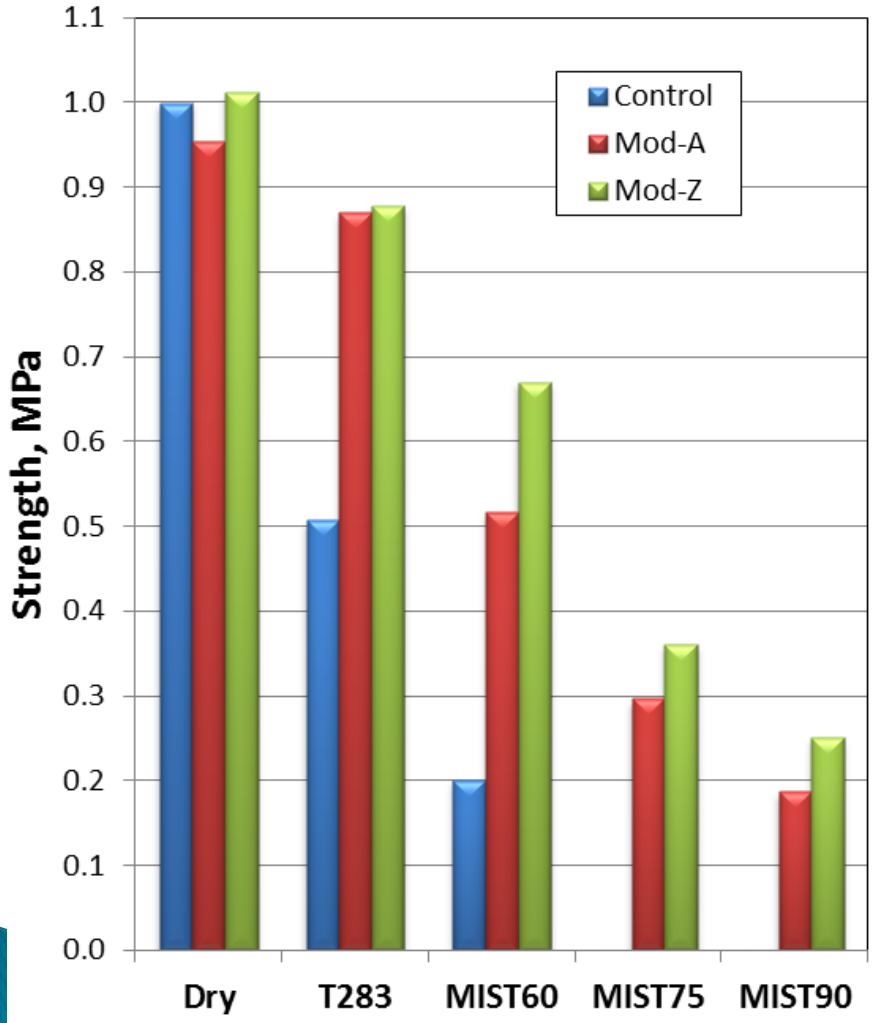
Testing – 2015

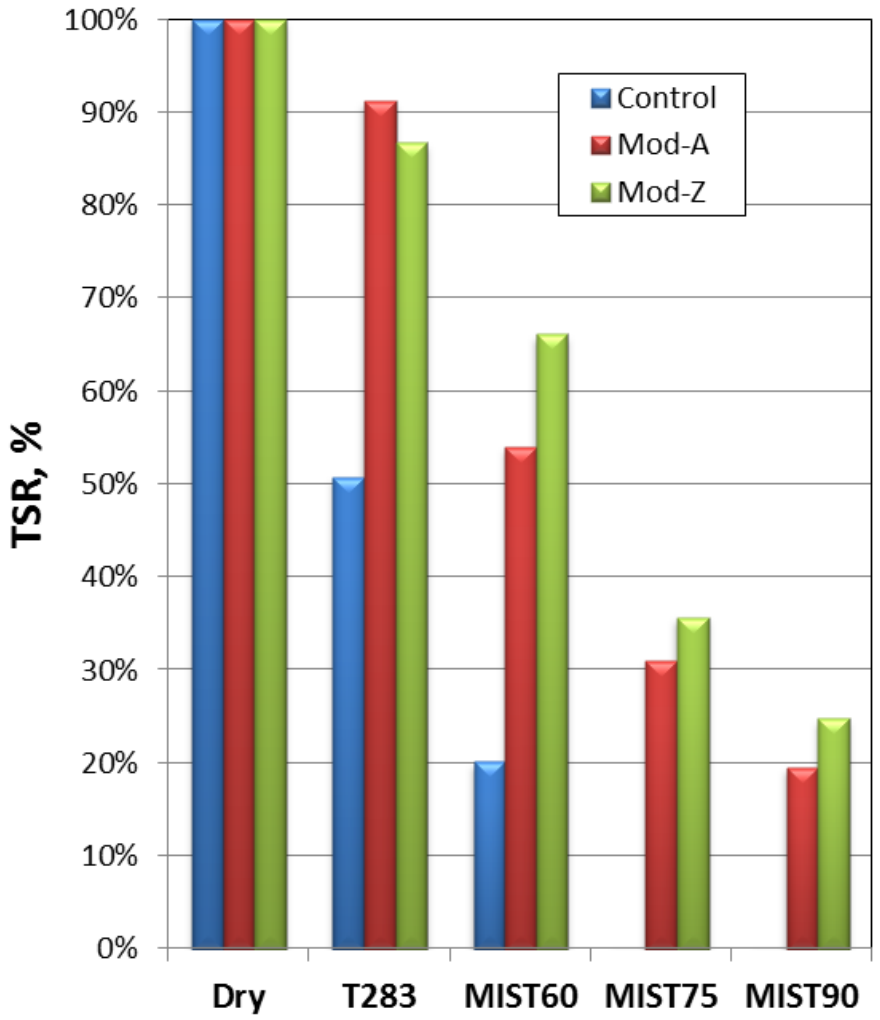
- NCDOT Superpave S9.5B with PG 64-22 asphalt binder
- Aggregates chosen for this experiment were a mix of granite materials with a history of moisture sensitivity problems
  - Hanson Crabtree Quarry (67%)
  - Wake Forest Quarry (33%)
- Specimens made at a target void content of 7%

Results: Post-Soak

- Some swells not measured with product A at highest temperature due to condition of sample
- Control did not survive higher two temperatures
- Photographs – showed visual condition
  - Control looks more brown!

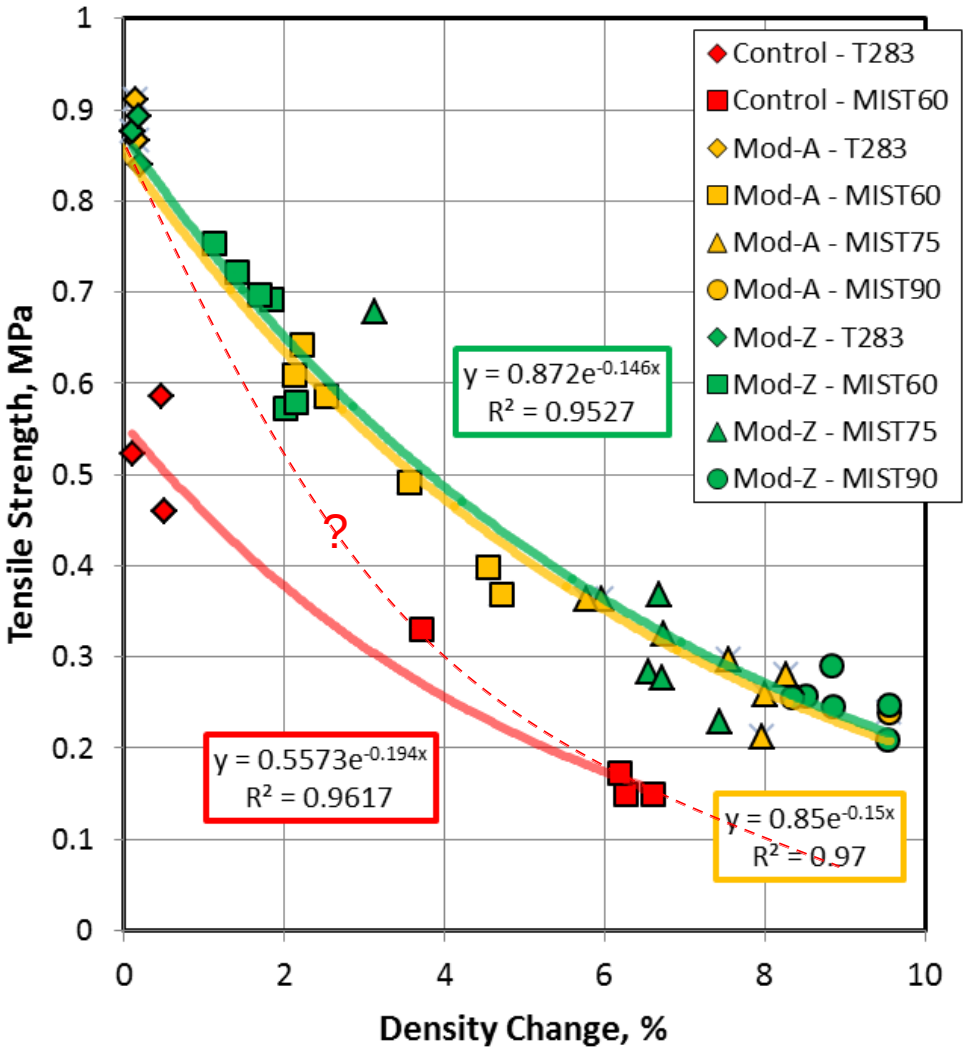
Results – Strength and TSR%





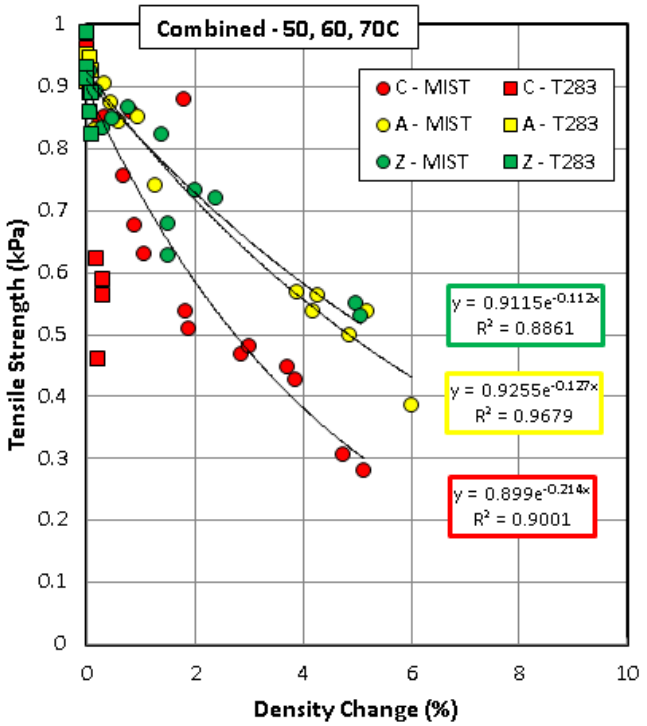
Change in density

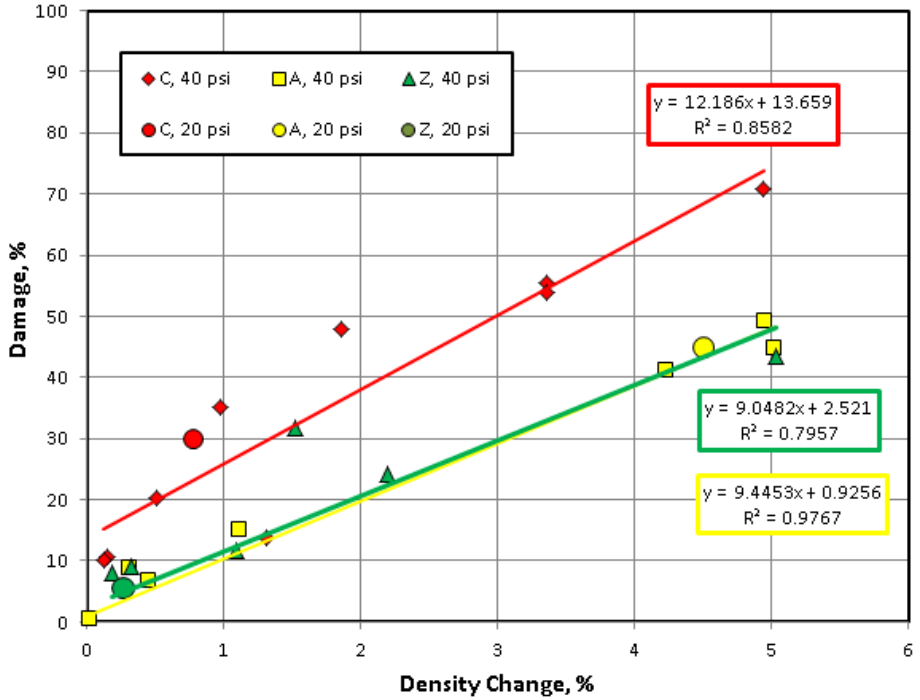
- Density change reflects water absorbed into specimen and swelling
  - Significant difference between control and treated mixes
  - Difference between modifiers is marginal in this study
  - If density is key indicator – then very different tensile strengths



Results: Pre-Soak

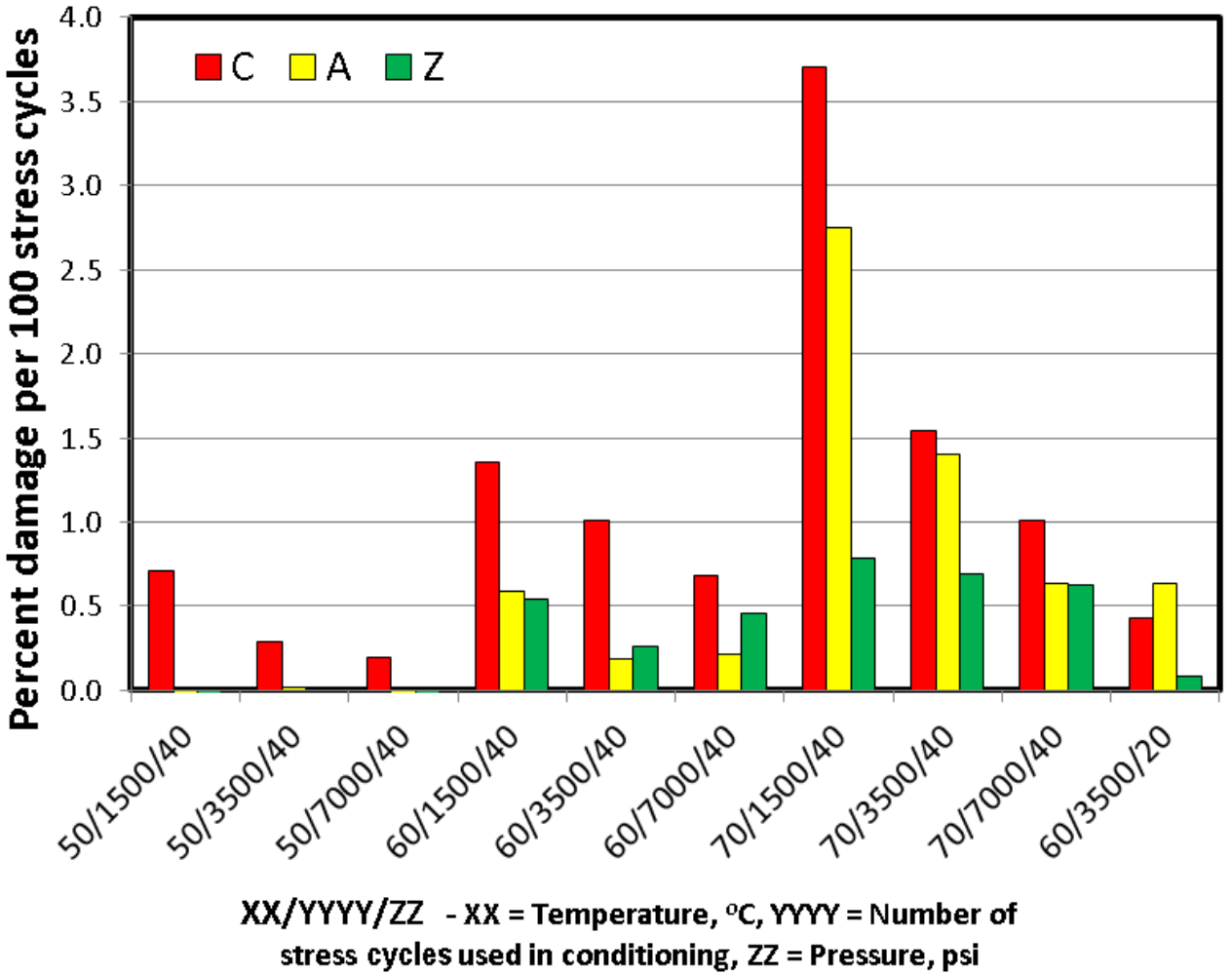
- T283 shows different behavior
- All trends show similar initial strengths
- Results from different pressures appears consistent with other data





Rate of damage

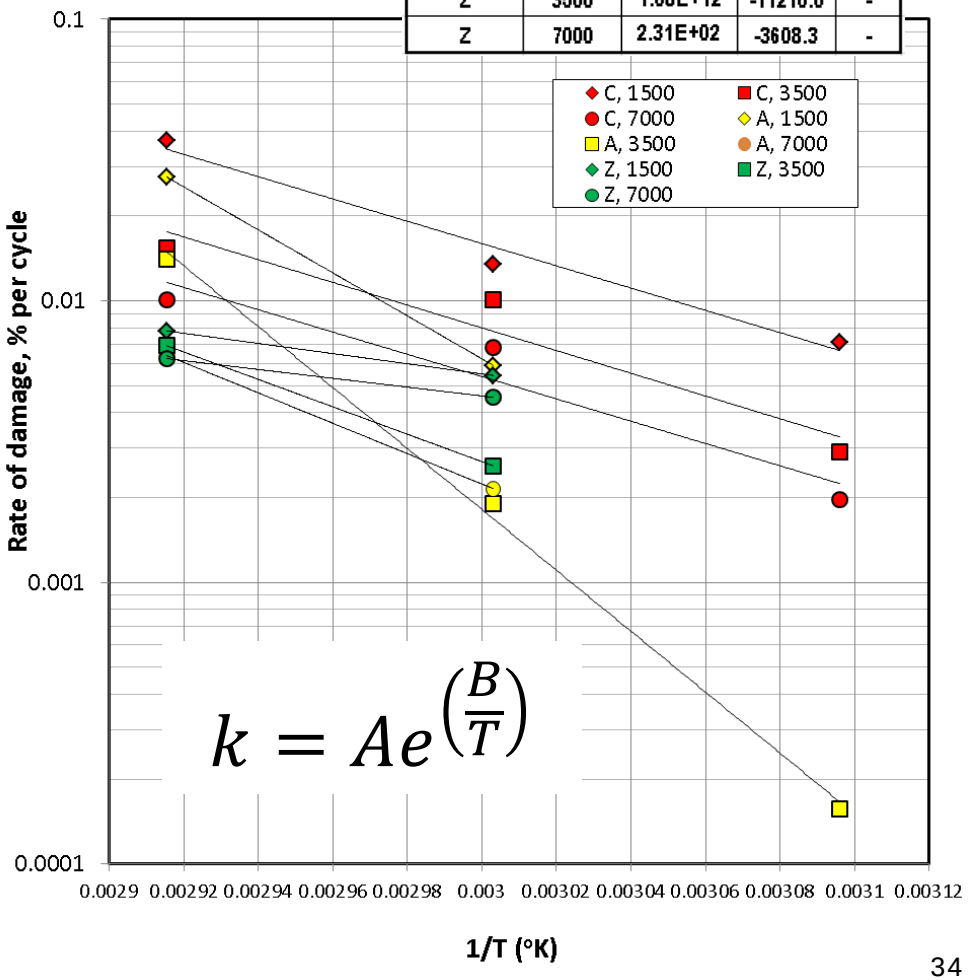
- Rate of damage is faster in earlier part of MIST cyclic loading
- Damage rate slowest with Z type modification



Interaction of rate and temperature

- The rate of damage (for a given test duration) is related to the temperature in an Arrhenius manner
  - $k =$ rate
  - A & B constants
  - $T =$ temperature
- More data needed to expand this data set!

Material	Cycles	A	B	r^2
C	1500	1.19E+10	-9110.9	0.98
C	3500	1.03E+10	-9293.5	0.93
C	7000	4.06E+09	-9116.8	0.93
A	1500	4.89E+20	-17573.0	-
A	3500	5.20E+29	-24912.0	1.00
A	7000	3.53E+13	-12433.0	-
Z	1500	1.41E+03	-4152.2	-
Z	3500	1.08E+12	-11210.0	-
Z	7000	2.31E+02	-3608.3	-



Summary

- Saturation, density changed – reflects performance in both SATS and MIST methods
- MIST method can be used at different temperatures to produce variable saturation levels
- Strength and TSR related strongly to saturation level
- MIST produces significant damage with a relatively short conditioning time
- Loading time and temperature effects related in Arrhenius manner
- Post conditioning gives more logical curves
- Density Change a good factor for normalization
- Additional work could be conducted looking at pressure effects

Acknowledgements

- Norma Hair, ASTM
  - For help with some of the old references used
- Trimat Materials Testing
  - Laboratory testing
- Ali Regimand, Instrotek
  - Provision of the MIST device
- Zydex Industries
  - Funding for this study


Thankyou for your attention!
Comments or Questions?