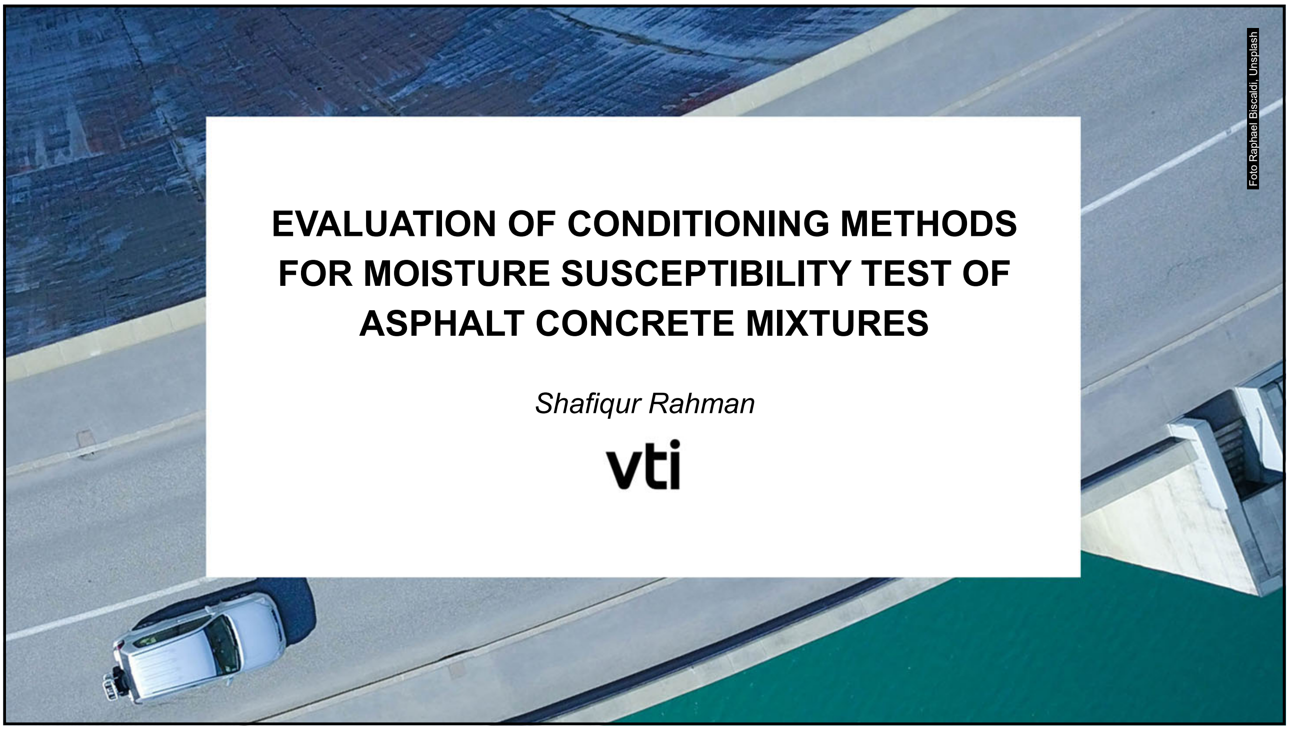

EVALUATION OF CONDITIONING METHODS FOR MOISTURE SUSCEPTIBILITY TEST OF ASPHALT CONCRETE MIXTURES

Shafiqur Rahman

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1

Moisture Damage in Pavements

- Moisture damage is a major concern for asphalt concrete (AC) pavements
- Moisture in all physical states (liquid, vapor and frozen) contributes to various forms of damages such as:
  - Stripping
  - Raveling
  - Rutting
  - Cracking

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2

Short-term moisture damage:

- Mechanical damage
- Pumping action
- Cyclic pore pressure generation
- Erosion
- Accelerates long-term damage

Long-term moisture damage:

- Moisture diffusion
- Molecular process
- Binder’s physio-chemical properties change
- Cohesive strength reduces
- Adhesive bond weakens
- Results in stripping/raveling

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Moisture conditioning approaches

For design and maintenance of pavements, it is essential to evaluate the asphalt concrete (AC) mixtures with respect to moisture damage susceptibility.

Two commonly used laboratory methods in Europe/Sweden:

- **EN 12697-12:2018 *Determination of the water sensitivity of bituminous specimens***
- **TDOK 2017:0650 *Bestämning av vattenkänslighet genom pressdragprovning***

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4

Moisture conditioning approaches

Drawbacks:

- Disregards the pumping action (short-term moisture processes)
- Do not correlate well with field performance
- Variable (lack of tight control on the water saturation)
- Long testing time (> 24 hours)

To overcome some of the drawbacks, the moisture induced sensitivity test (MIST) was developed.

The MIST conditioning method was the focus of this study.

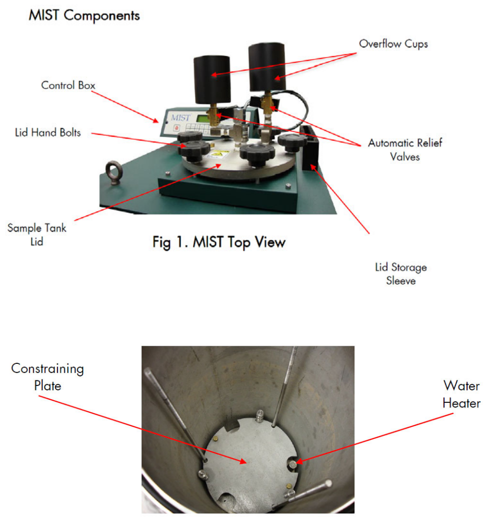
5

MIST (Moisture Induced Sensitivity Test)

- Accelerated moisture conditioning method for AC mixes
- Applies cyclic pore pressure
- Attempts to simulate the pumping action of water (stripping mechanisms) due to traffic loading
- The long-term damage is simulated by the elevated conditioning temperature
- Relatively shorter conditioning time (< 24 hours)
- Can be conducted on compacted laboratory and field samples.
- Adjustable temperature, pressure and number of cycles
- Automated and sensors monitored

6

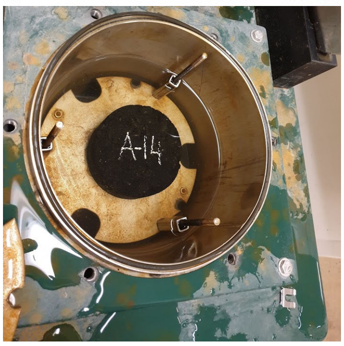
MIST (Moisture Induced Sensitivity Test)



- Conditioning inside a cylindrical sample chamber (3 levels for up to 3 samples)
- The device includes a hydraulic pump and piston mechanism
- Cyclically adds and relieves pressure inside the sample chamber (through a bladder inside the sample tank).

7

MIST (Moisture Induced Sensitivity Test)



- The test involves placing a sample inside the sample chamber, filling the chamber with water, closing the sample chamber lid and starting the test.
- The machine automatically heats up the water/sample and start cycling (to desired temperature and pressure).
- The entire cyclic conditioning process takes approximately 3 – 8 hours.

8

MIST (Moisture Induced Sensitivity Test)

Specifications	
Temparature range	40°C to 60°C
Maximum pressure	517 kPa
Frequency of cyclic pressure	0.5 Hz
Number of cycles	1 to 50 000
Sample height	25 mm to 150 mm
Sample diameter	100 mm to 150 mm
Maximum number of samples	3

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9

MIST standard

ASTM D7870/D7870M -13

Moisture Conditioning Compacted Asphalt Mixture Specimens by Using Hydrostatic Pore Pressure

Sample size, mm (dia. x height)	150x100 or 100x63
Pressure	40 psi (275.79 kPa)
Temparature	60°C (>PG60)
	50°C (<PG60 or WMA)
Number of cycles	3500
Recommended air void	6.5 to 7.5% or optimum (±0.5%)

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10

MIST standard

- No European standard
- Different researchers have used different temperatures and cycles
- Different mixes require different temperatures and cycles

Conditioned specimens can be tested for changes in properties such as bulk specific gravity, ratio of stiffness modulus, indirect tensile strength ratio (ITSR), flow number and visual changes.

InstroTek acceptance criteria: ITSR > 80%

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11

BVFF Project at VTI

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Objectives

- To evaluate and compare MIST, EN 12697-12:2018 and TDOK 2017:0650
- Preliminary study to standardize MIST in future
- Additionally, five AC mixes were compared for moisture sensitivity

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12

BVFF Project at VTI

The following five conditioning approaches were evaluated:

- MIST (0.28 MPa pore pressure, 40° C temperature)
  - 3500 cycles (3 specimens)
  - 7000 cycles (3 specimens)
  - 12000 cycles (3 specimens)
- TDOK 2017:0650: Five AC specimens submerged in 40° C water for 164 hours
- EN 12697-12: Three AC specimens submerged in 40° C water for 72 hours

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13

BVFF Project at VTI

The following mechanical properties of the AC mixes were evaluated and compared:

- Stiffness modulus: before and after conditioning
- Indirect tensile strength ratio (ITSR): ratio of the indirect tensile strength (ITS) of the conditioned specimen (wet state) to that of reference specimens (five specimens in dry state)

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14

BVFF Project at VTI

The following lab prepared specimens were tested

Designation	Mix type	Maximum aggregate size (mm)	Bitumen content (%)	Binder PEN grade	Air voids (%)	Other information
Mix A	ABT11(wearing course)	11	6	70/100	5.0	
Mix B	ABT11(wearing course)	11	6	70/100	8.0	
Mix C	ABT11(wearing course)	11	6	70/100	5.0	Mix A with cut surfaces
Mix D	ABT11(wearing course)	11	6	70/100	8.0	Mix B with added amines for improved water resistance
Mix E	AG16 (base course)	16	4.8	100/150	6.0	

15

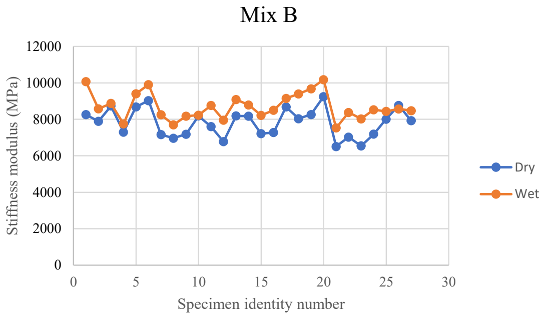
Project at VTI

Steps

1. Initial dry stiffness (28 specimens)
2. Initial wet stiffness (after submerging in water) (28 specimens)
3. Grouping of specimens for different types of conditioning (22 specimens)
4. Reference indirect tensile strength (ITS)
5. MIST conditioning (3500 cycles) → stiffness modulus → ITSR
6. MIST conditioning (7000 cycles) → stiffness modulus → ITSR
7. MIST conditioning (12000 cycles) → stiffness modulus → ITSR
8. EN conditioning → stiffness modulus → ITSR
9. TDOK conditioning → stiffness modulus → ITSR

16

Results: Initial stiffness moduli: dry versus wet

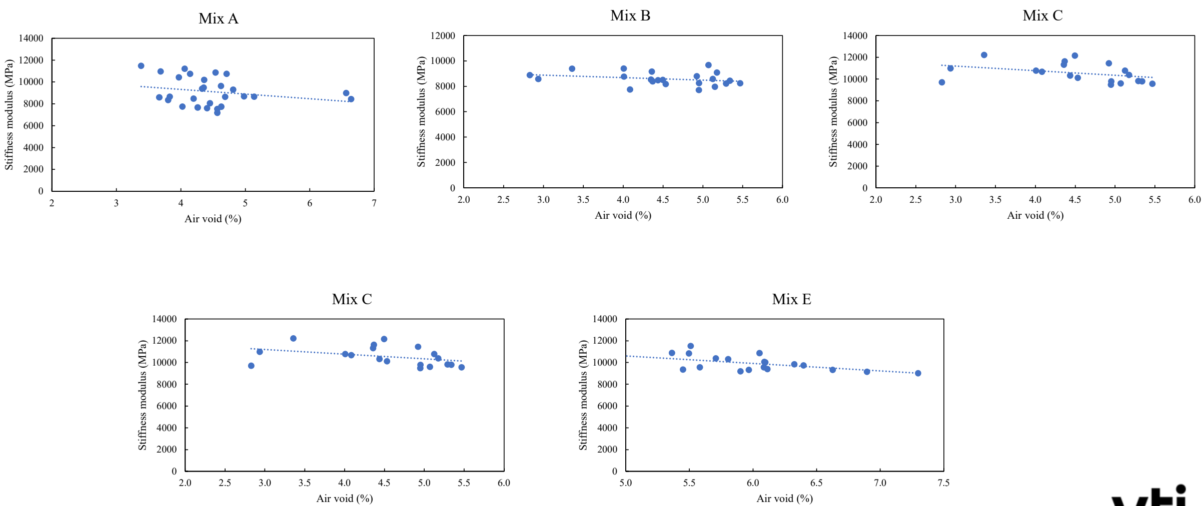


Stiffness modulus test

AC mixture	Average stiffness modulus (MPa)		Difference in stiffness (%)
	Dry	Wet	
Mix A	8628	10105	17.9
Mix B	7812	8692	11.3

17

Results: Stiffness modulus versus air voids plots for the different AC mixes



Results: Example of grouping

Group	Test type	Required numbers of samples	Sample identity	Thickness (mm)	Diameter (mm)	Stiffness modulus (MPa)	Air void (%)	Mean values: Stiffness modulus (MPa)	Mean values: Air void (%)
1	Reference ITS	5	d4	50.3	100.0	9213	5.5	8557	6.6
			d5	50.2	100.2	7953	-		
			d11	49.8	100.3	8005	7.3		
			d14	50.1	99.9	8015	7.3		
			d25	50.2	99.9	9597	6.2		
2	MIST 3500	3	d6	49.9	100.0	8048	6.7	8791	6.5
			d9	50.2	100.0	9196	6.0		
			d24	50.1	99.8	9129	6.8		
3	MIST 7000	3	d13	50.2	100.0	8082	7.4	8420	7.5
			d20	50.3	99.8	8051	7.6		
			d27	50.2	100.0	9126	7.4		
4	MIST 12000	3	d2	50.5	100.0	8090	7.2	8639	6.7
			d16	50.2	100.1	8731	7.2		
			d17	50.1	99.9	9095	5.8		
5	EN	3	d15	50.2	100.0	8123	7.4	8449	7.2
			d18	50.1	99.9	8698	6.7		
			d22	50.3	99.9	8526	7.5		
6	TDOK	5	d7	50.1	100.1	8237	6.9	8481	6.9
			d8	50.3	100.0	8948	6.4		
			d10	50.0	100.0	8591	6.8		
			d19	50.2	99.9	8196	7.5		
			d23	50.0	100.0	8433	6.9		

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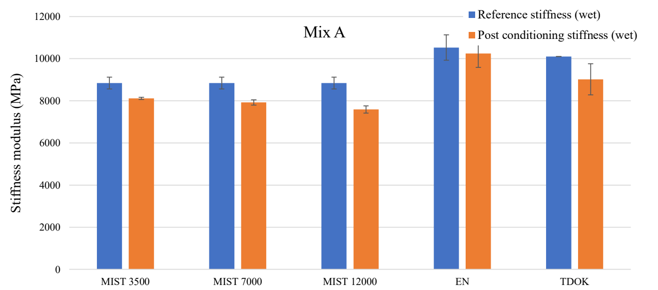
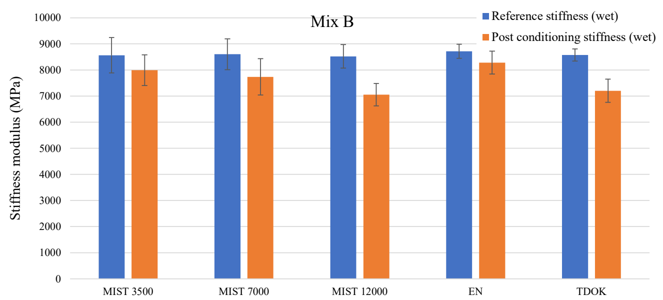
19

Results: Impact of conditioning methods on stiffness moduli





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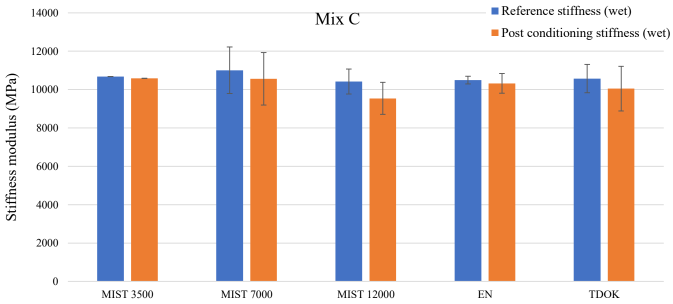
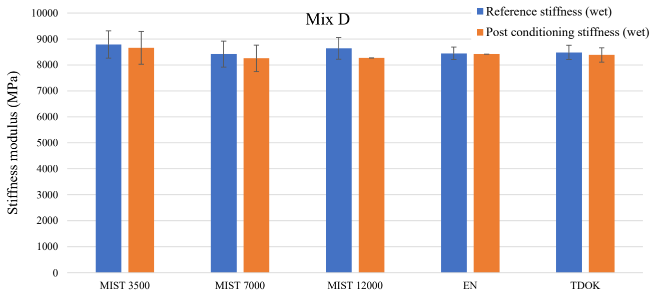
20

Results: Impact of conditioning methods on stiffness moduli





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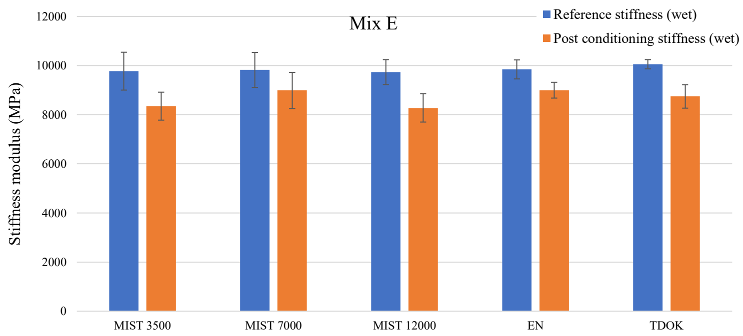
21

Results: Impact of conditioning methods on stiffness moduli



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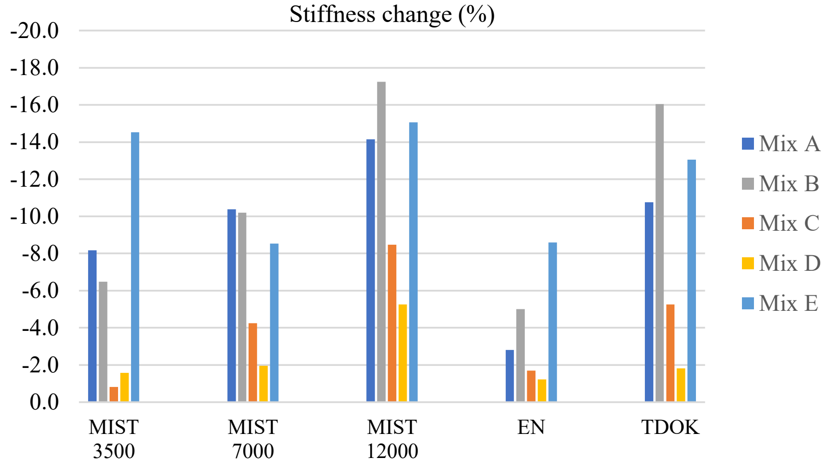
22

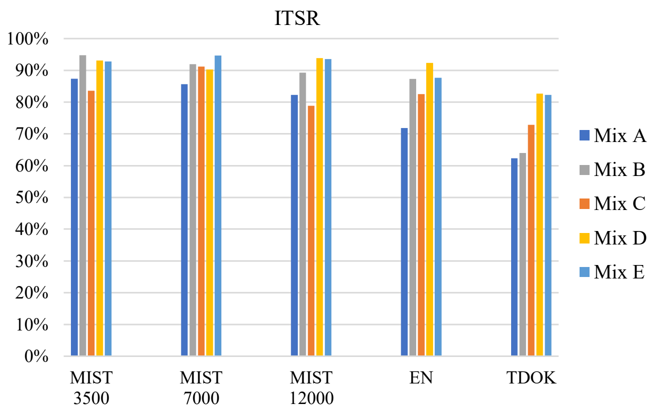
Results: Impact of conditioning methods on stiffness moduli



* -ve values means reduction in stiffness

23

Results: Impact of conditioning methods on ITSR



24

Summary of Findings

- MIST is a fast and convenient approach.
- MIST is more realistic since it simulates short-term mechanical damage (pore water pressure) in addition to long-term damage (elevated temperature).

(Some researchers suggest applying MIST conditioning after EN or TDOK conditioning)

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25

Summary of Findings

- Stiffness modulus in wet state can be significantly higher compared to dry state.
- Comparison should be made in identical states (preferably in wet condition: more convenient, reduced healing)
- MIST 12000 and TDOK showed the strongest impact. MIST requires much shorter time.
- No significant difference between the impact of MIST 3500 and MIST7000. EN method also showed similar effect.

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26

Summary of Findings

- MIST appears to impact more on stiffness properties compared to ITS.
- Both EN and TDOK methods seem to affect more on the ITS.
- Air voids and surface cutting showed some impact on moisture susceptibility.
- Amine additive significantly improved moisture resistance
- The AC base layer (different from the other mix types) was more affected by the moisture conditioning.

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27

Future work

- MIST should be standardized
- Settings should be specified for different mix types and intended applications
- Should correlate well with field performance
- Acceptability criteria should be established for intended applications, traffic, climate and design life.
- Future studies should involve more mix types

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28

Future work

- Current study focused on number of pore pressure cycles only
- Future studies should also involve pressure and temperature adjustments
- All settings should be practically based on calculated tire pressure, design ESALs and climatic conditions.
- Field studies should be conducted to validate correlations
- Predictive models should be developed

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29

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30