Mitigating Moisture-Related Road Problems with Wicking Geotextile

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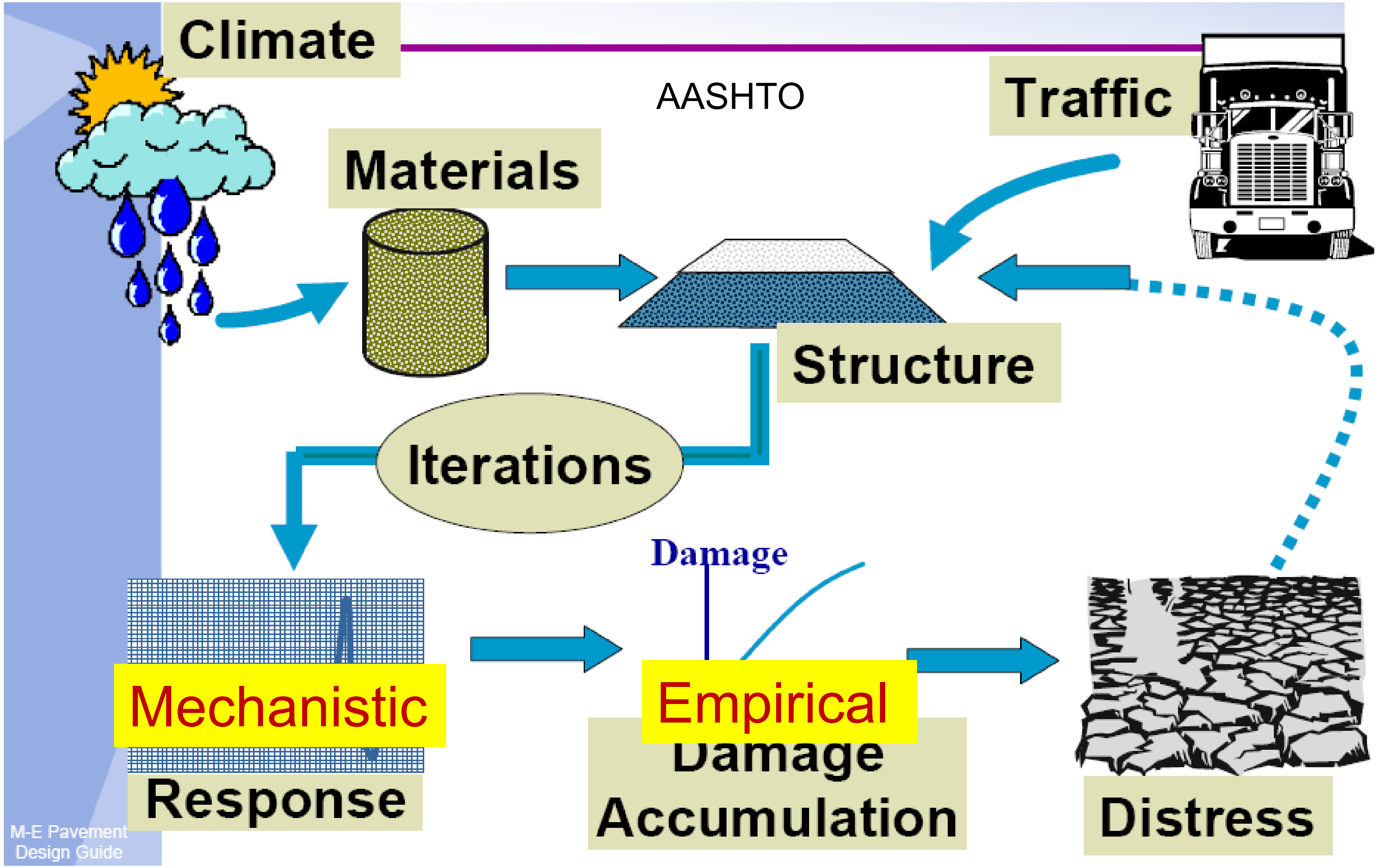
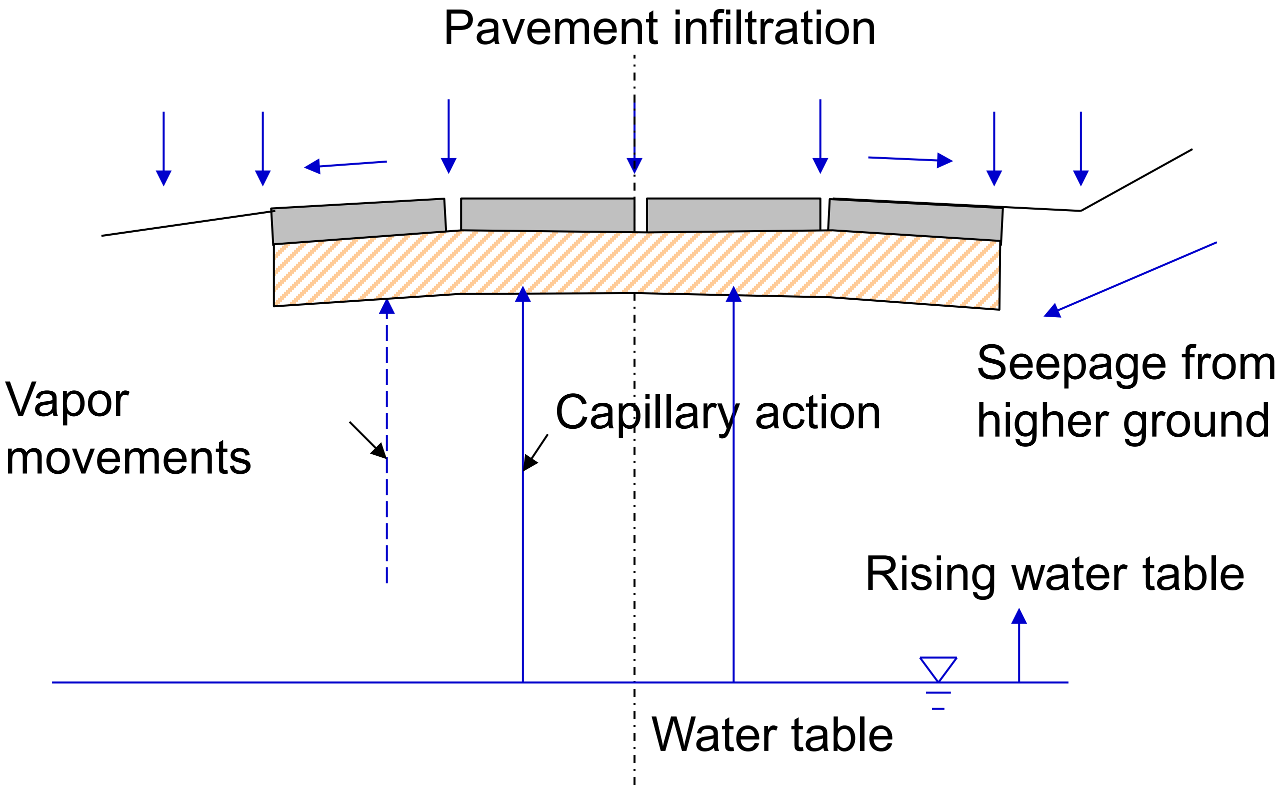
Outline of Presentation

- Introduction
- Mechanisms and Benefits
- Laboratory Tests and Results
- Case Studies
- Concluding Remarks

Mechanistic-Empirical (M-E) Pavement Design

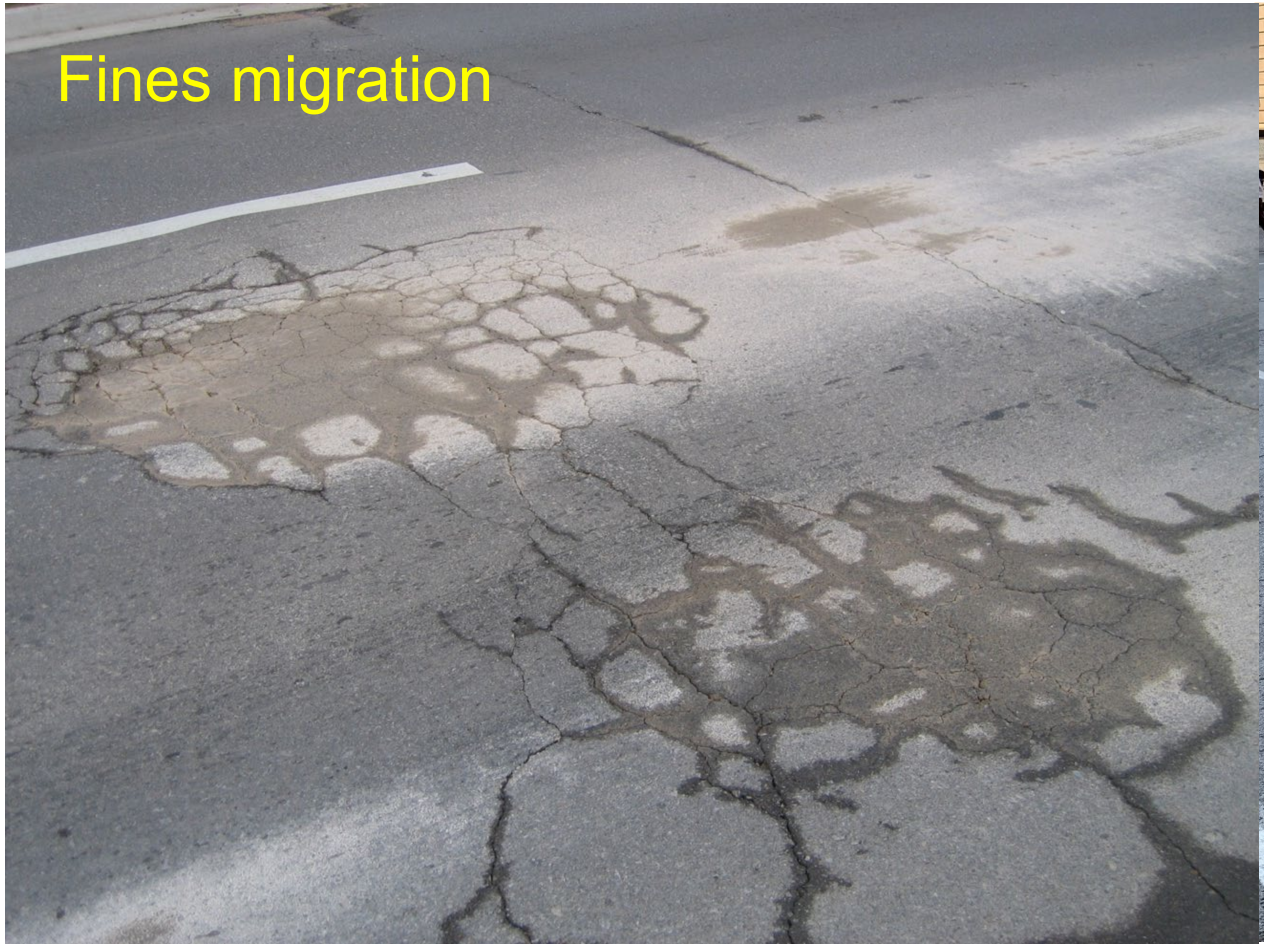


Source and Effect of Water



- Reduction of soil strength and stiffness
- Erosion of concrete pavement
- Soil expansion
- Migration of fines
- Freeze-thaw

Moisture-related Pavement Distresses



Lawrence, Kansas, USA

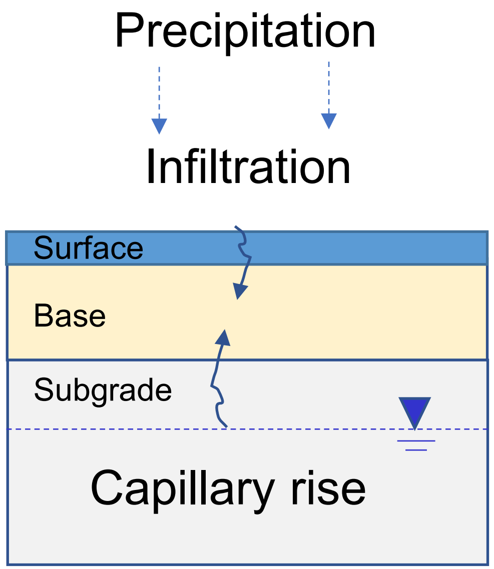
Montreal, Canada, 9/15/2024

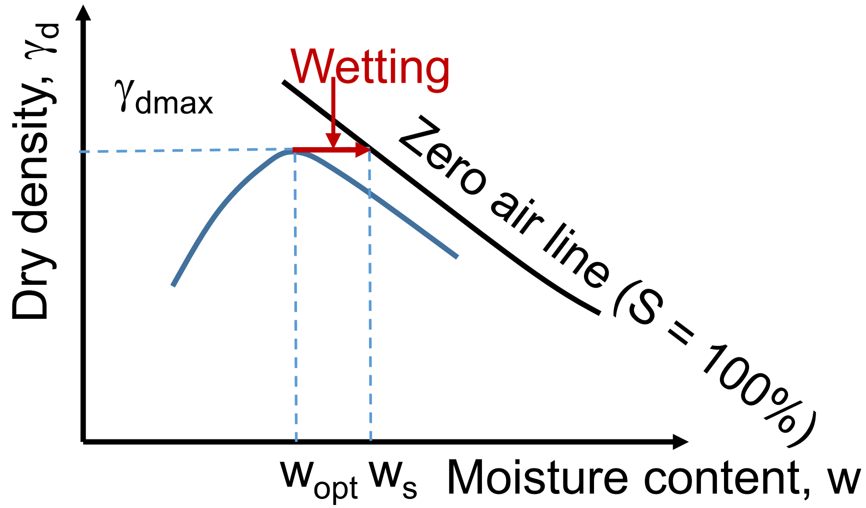
Moisture-related Pavement Distresses

Credit: City of Edmonton, Canada

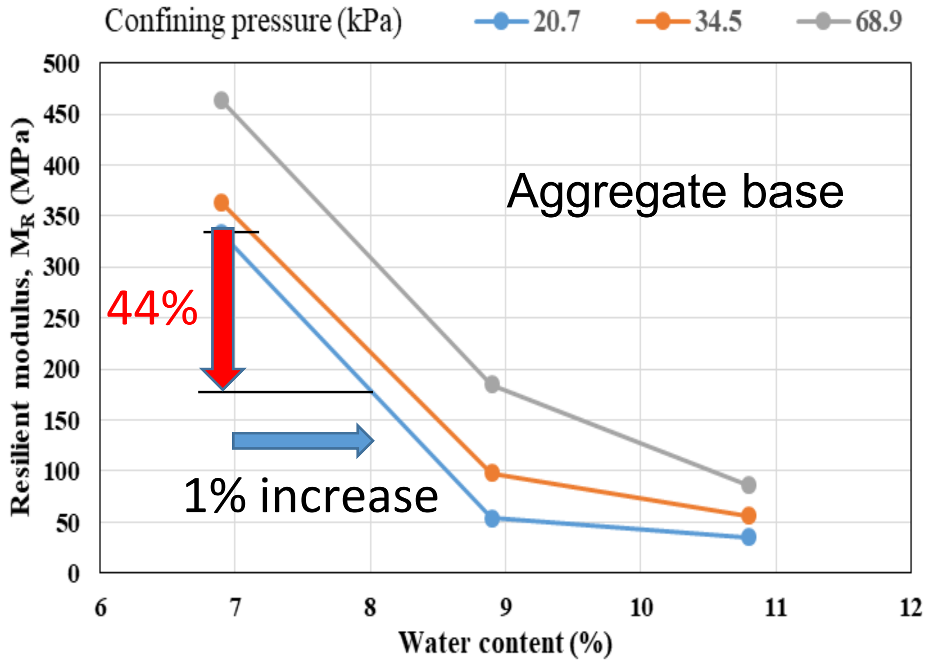
Failed after one freeze-thaw cycle due to high groundwater table

Behavior of Compacted Soil



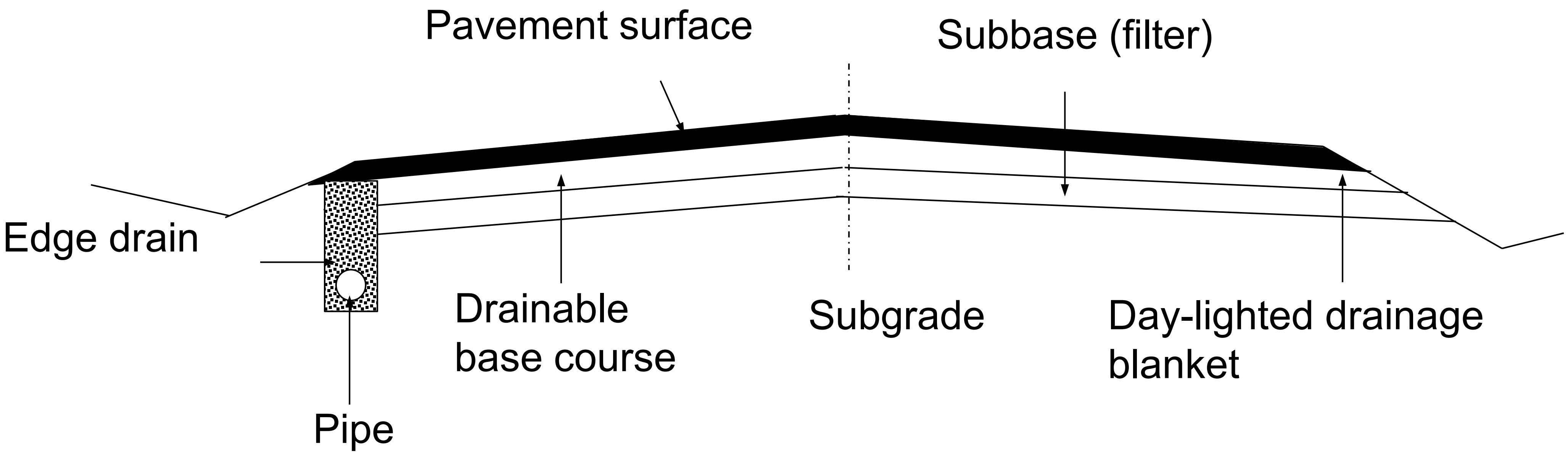


Degree of saturation, $S = w/w_s$
Typically, S = 80 to 90% at w_{opt}



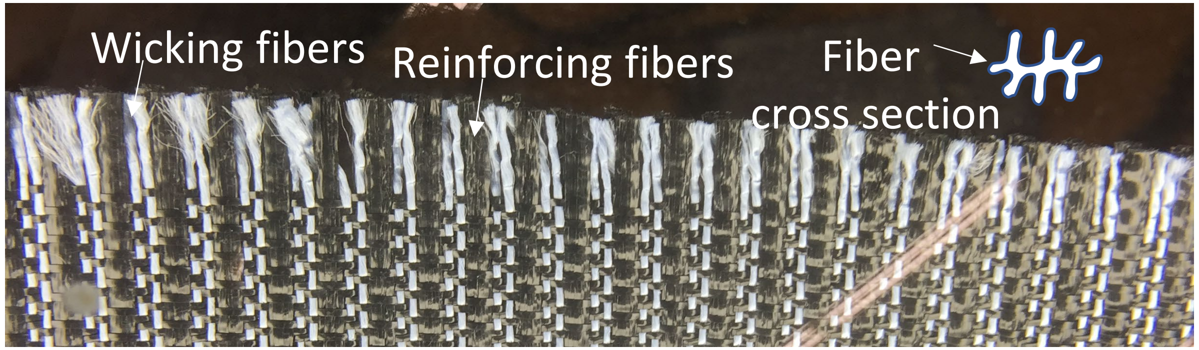
Plotted from Lin et al. (2019)

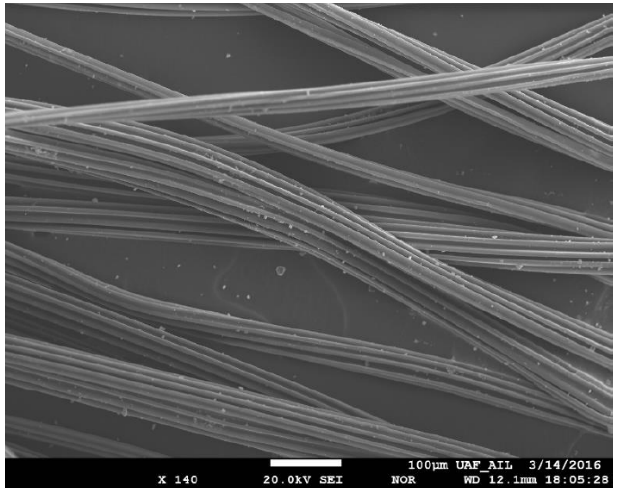
Road Drainage and Problems

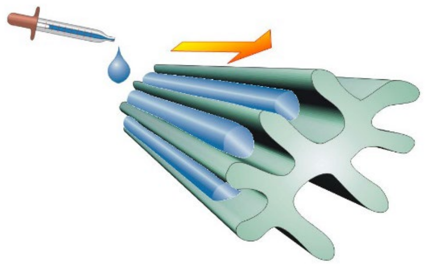


1. Conventional approach: use drainage materials (aggregate, sand layers, or geotextile), only reducing moisture content to a field capacity condition
2. Road condition: often unsaturated and subjected to capillary rise

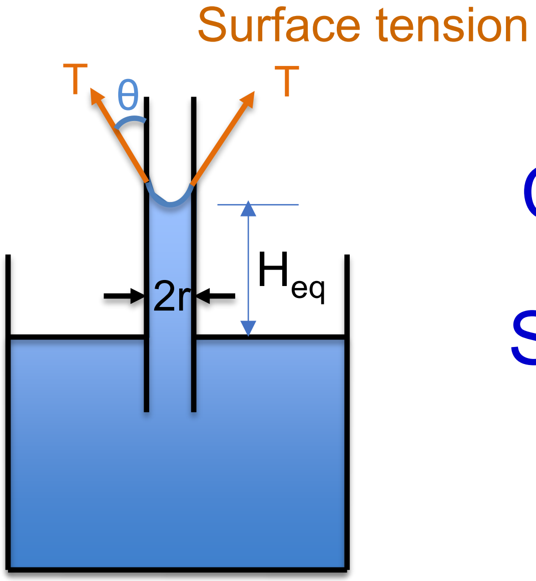
Wicking Geotextile







Deep-grooved fiber
Groove diameter: 30-50 μm
Groove spacing: 5-12 μm



Capillary rise height

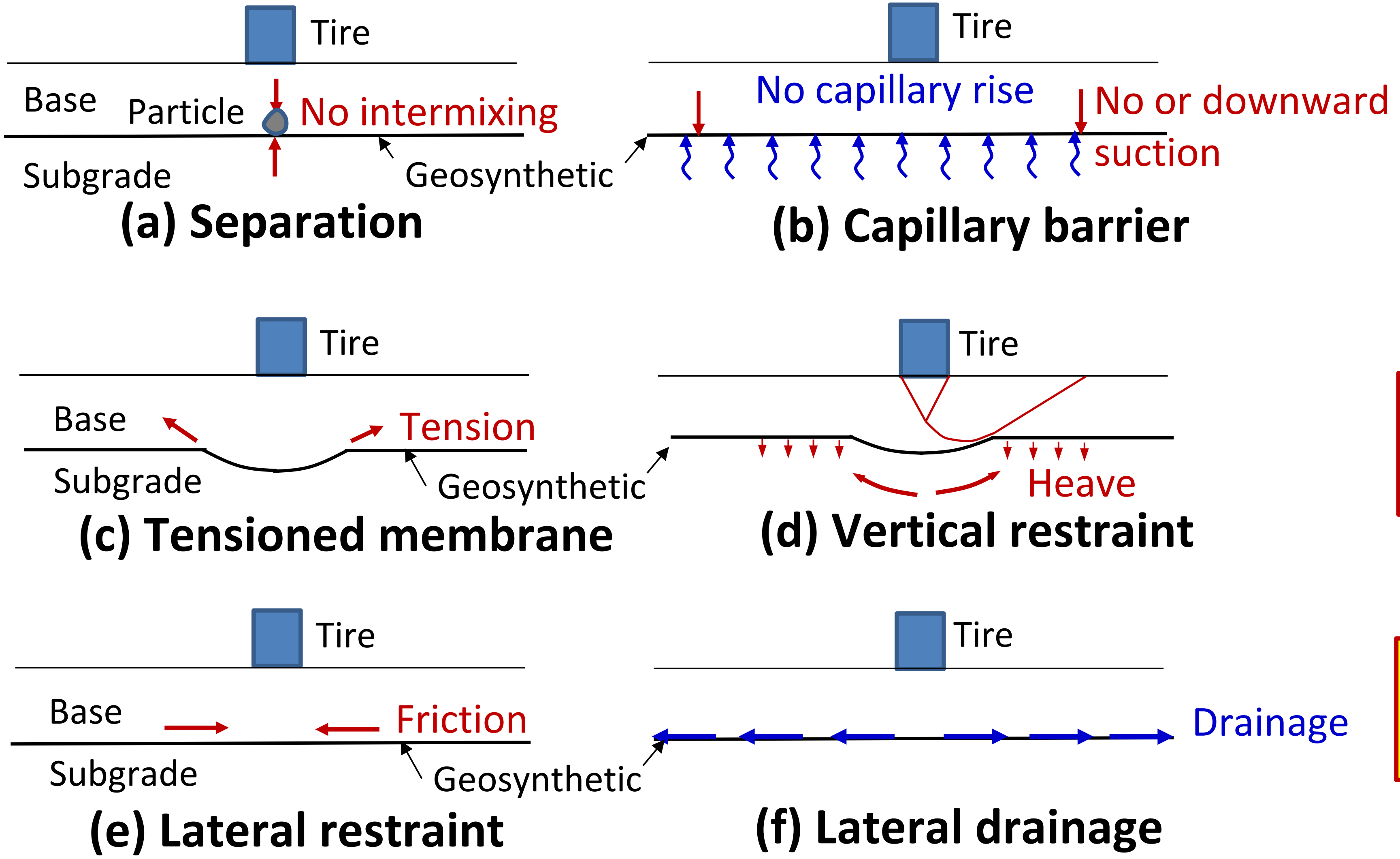
$$H_{eq} = \frac{2T\cos\theta}{\gamma r}$$

Suction

$$u_f = H_{eq}\gamma = \frac{2T\cos\theta}{r}$$

T = liquid surface tension; θ= contact angle;
γ= unit weight of liquid; r = capillary radius

Mechanisms & Benefits of Geosynthetics in Roads



(a) Separation

(b) Capillary barrier

(c) Tensioned membrane

(d) Vertical restraint

(e) Lateral restraint

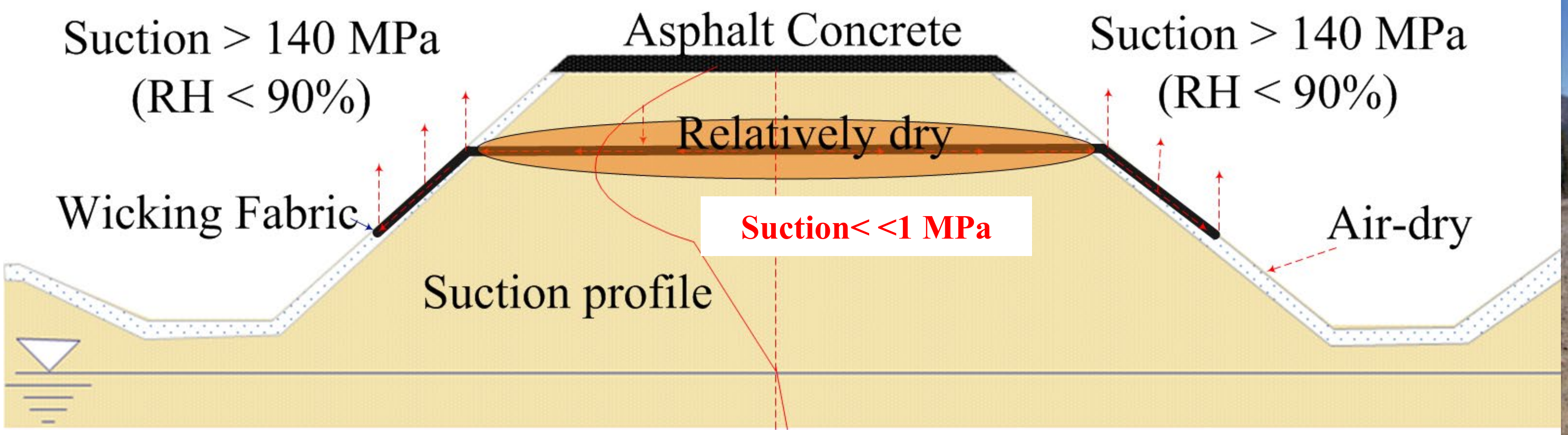
(f) Lateral drainage

Maintain strength & modulus of base course

Increase strength of subgrade & base course

Increase strength & modulus of base course

Wicking Geotextile to Remove Water in Pavement Structure



Courtesy of J. Lostumbo

Suction in air

$$u_a = -\frac{RT\rho_w}{M_w}\ln(RH)$$

(Fredlund and Rahardjo 1993)

R = universal gas constant (8.31432 J moL^{-1} K^{-1}), T = absolute temperature,
ρ_w = density of water as a function of temperature,
M_w = molecular mass of water vapor, and
RH = relative humidity.

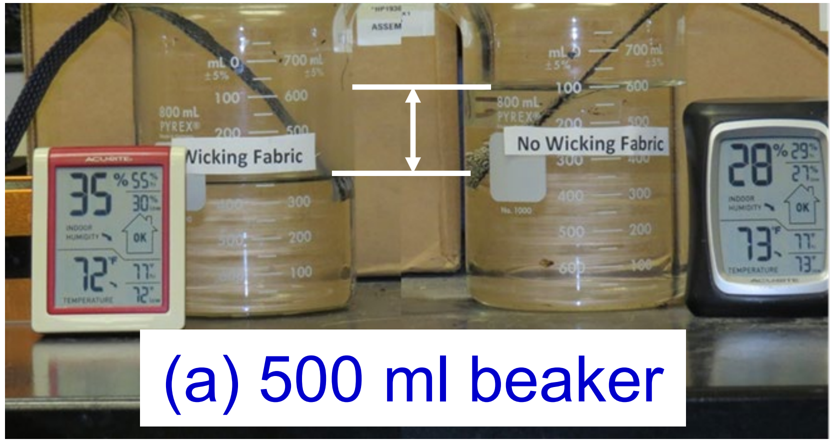
$$u_a > u_f > u_s$$

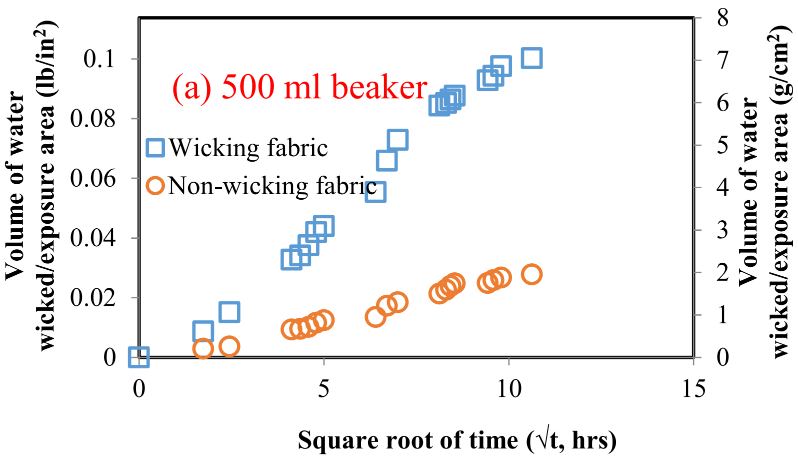
Air Fibers Soil

Zhang et al. (2014)

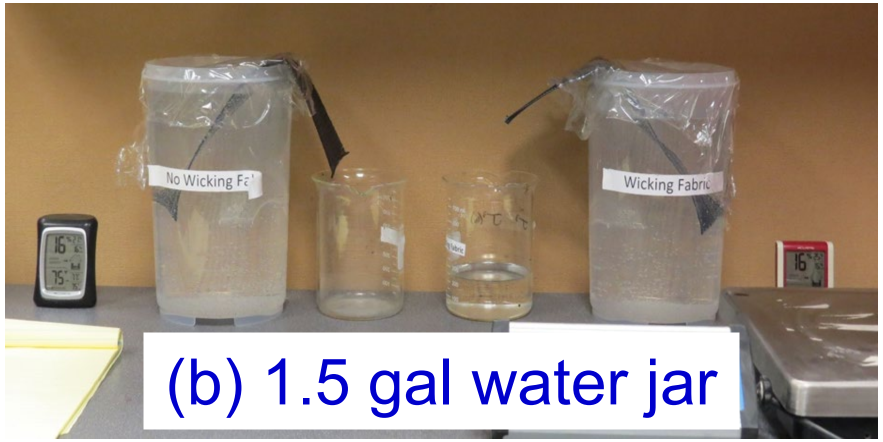
Wicking vs. Non-wicking Geotextile

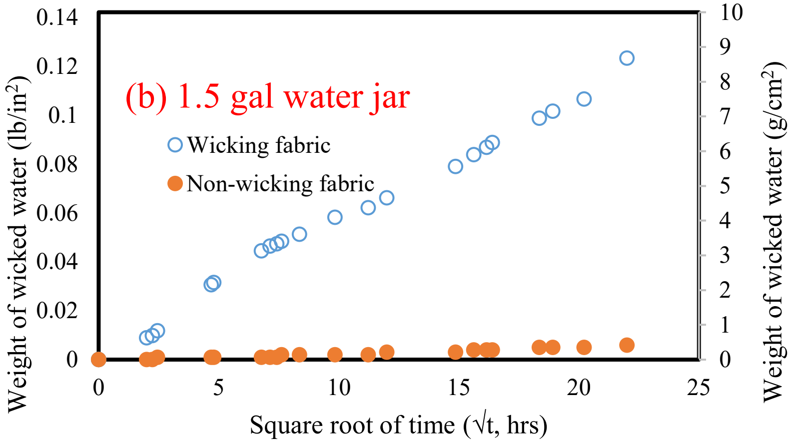
Top open





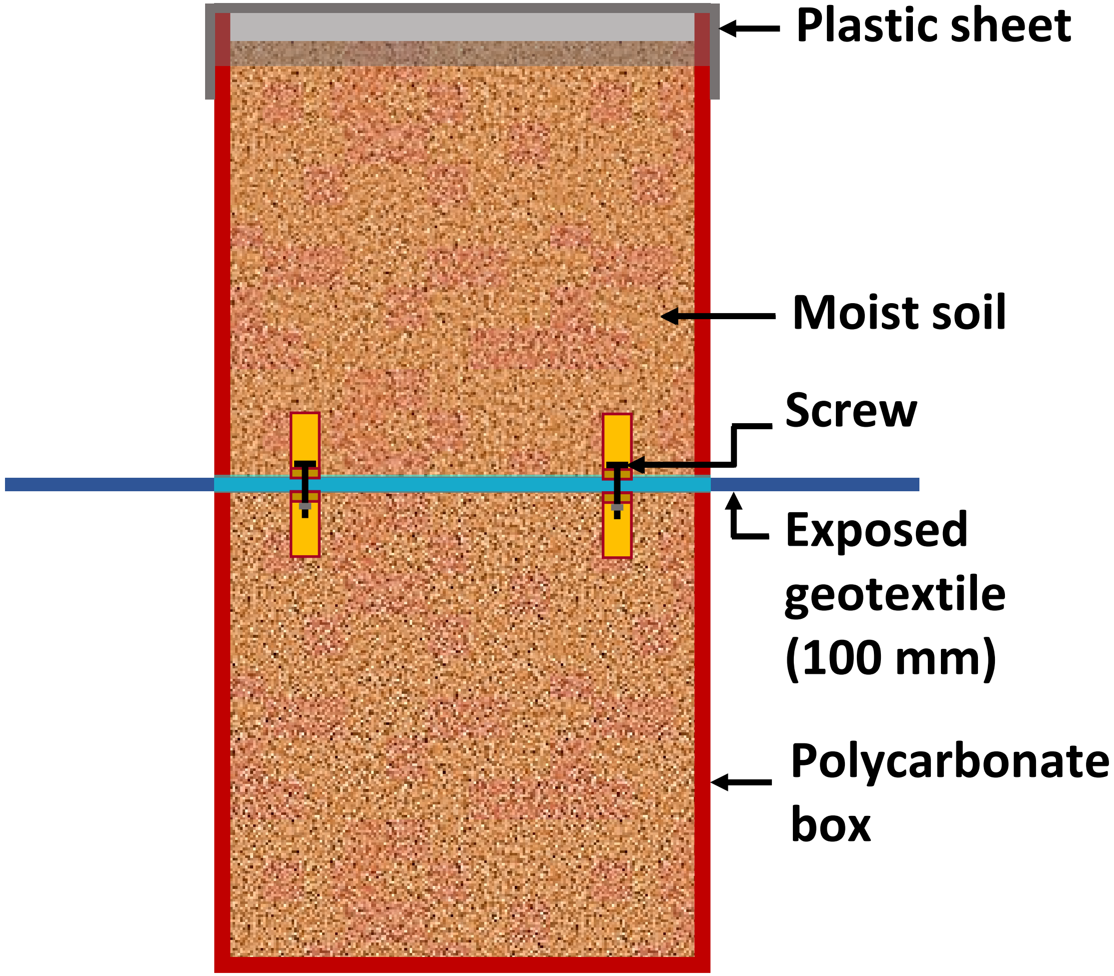
Top covered



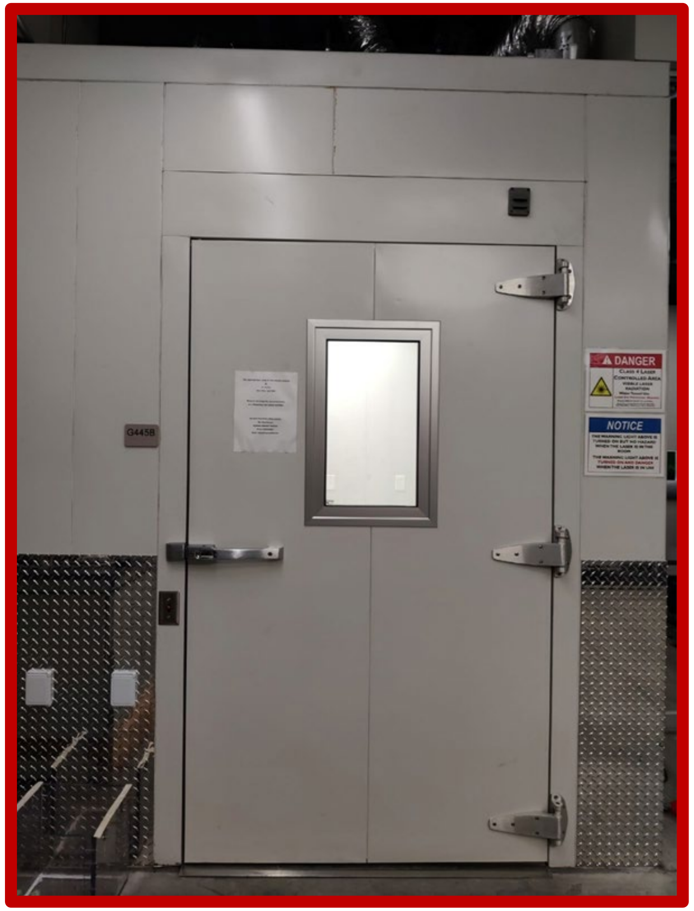


Almost no water was wicked out by the non-wicking geotextile !!

Moisture Reduction Tests



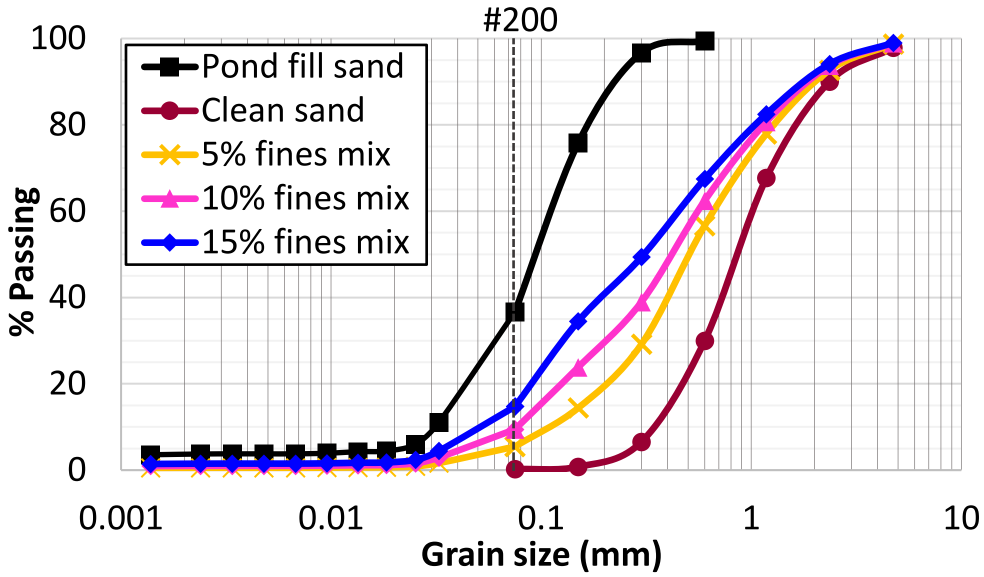
300 x 300 x 600 mm high



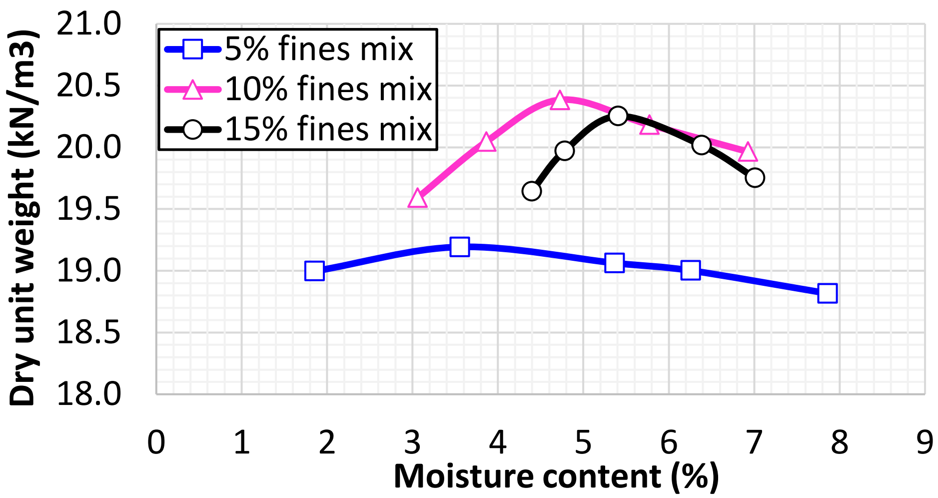
Controlled Room
T ~10°C, RH ~50%

Fines Effect

Pond fill sand collected



Particle size distribution



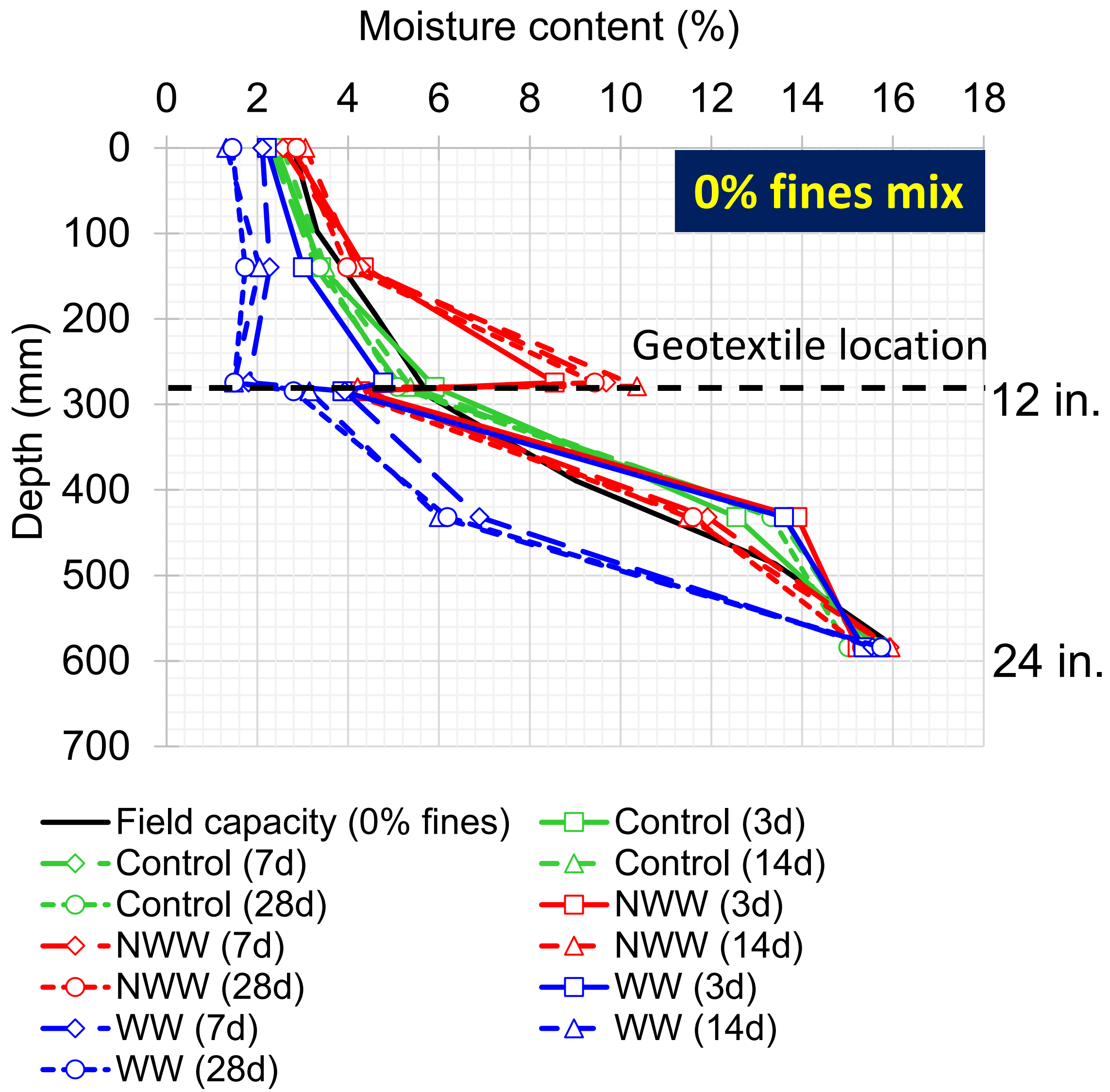
Standard Proctor compaction

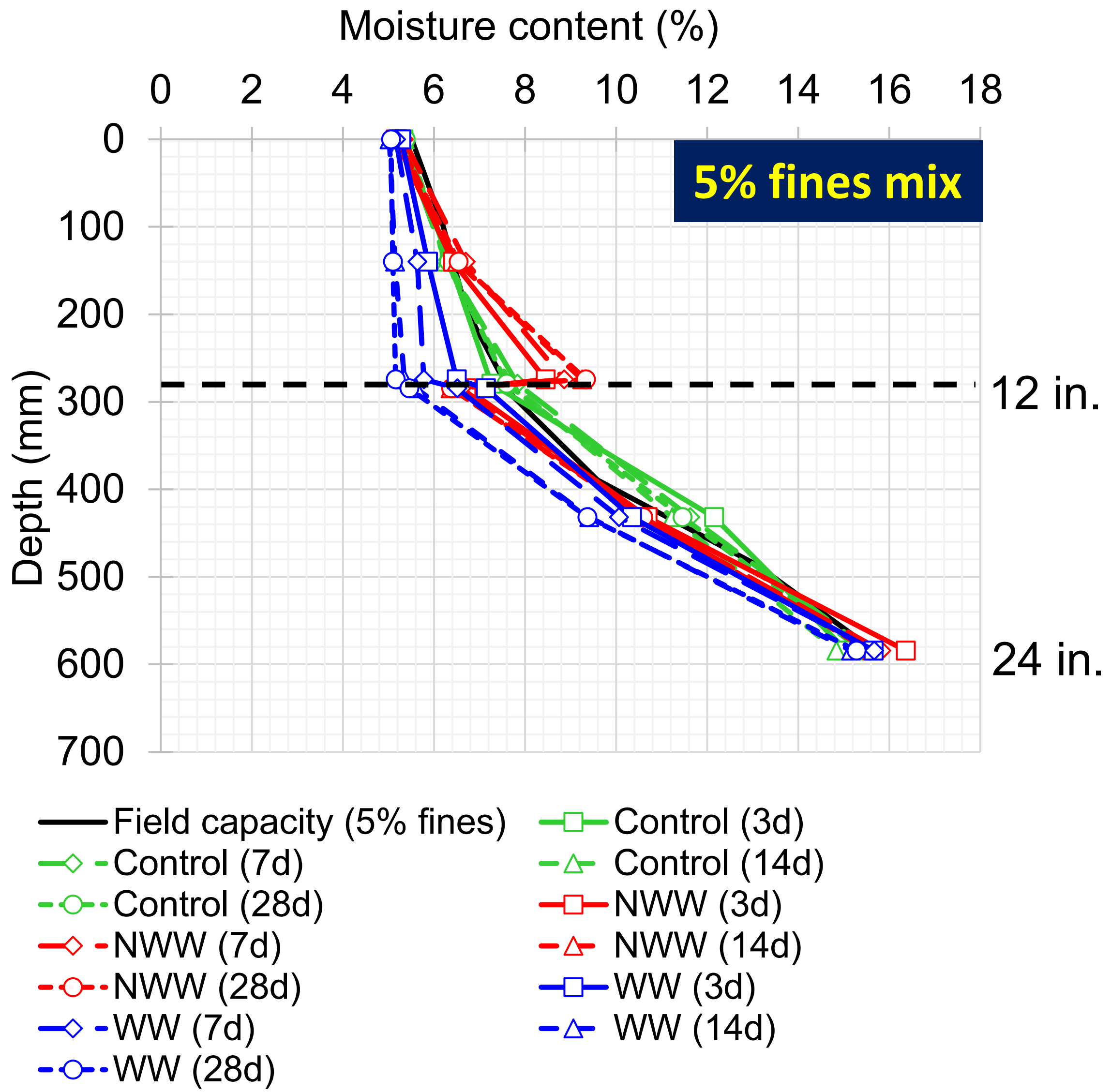
Clean sand (0% fines):

$\gamma_{d,max}$ (kN/m^3) = 18.85

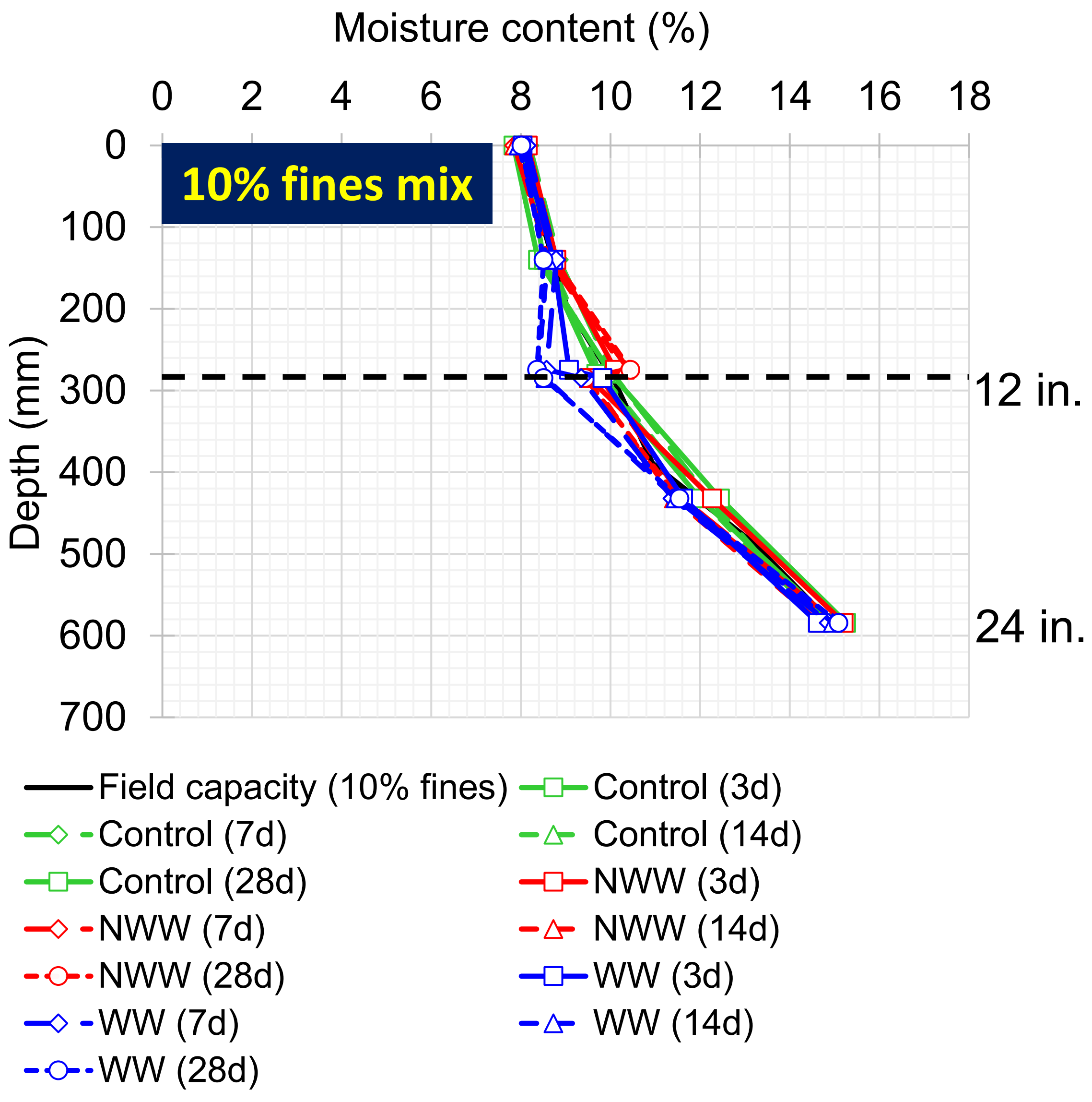
$\gamma_{d,min}$ (kN/m^3) = 16.02

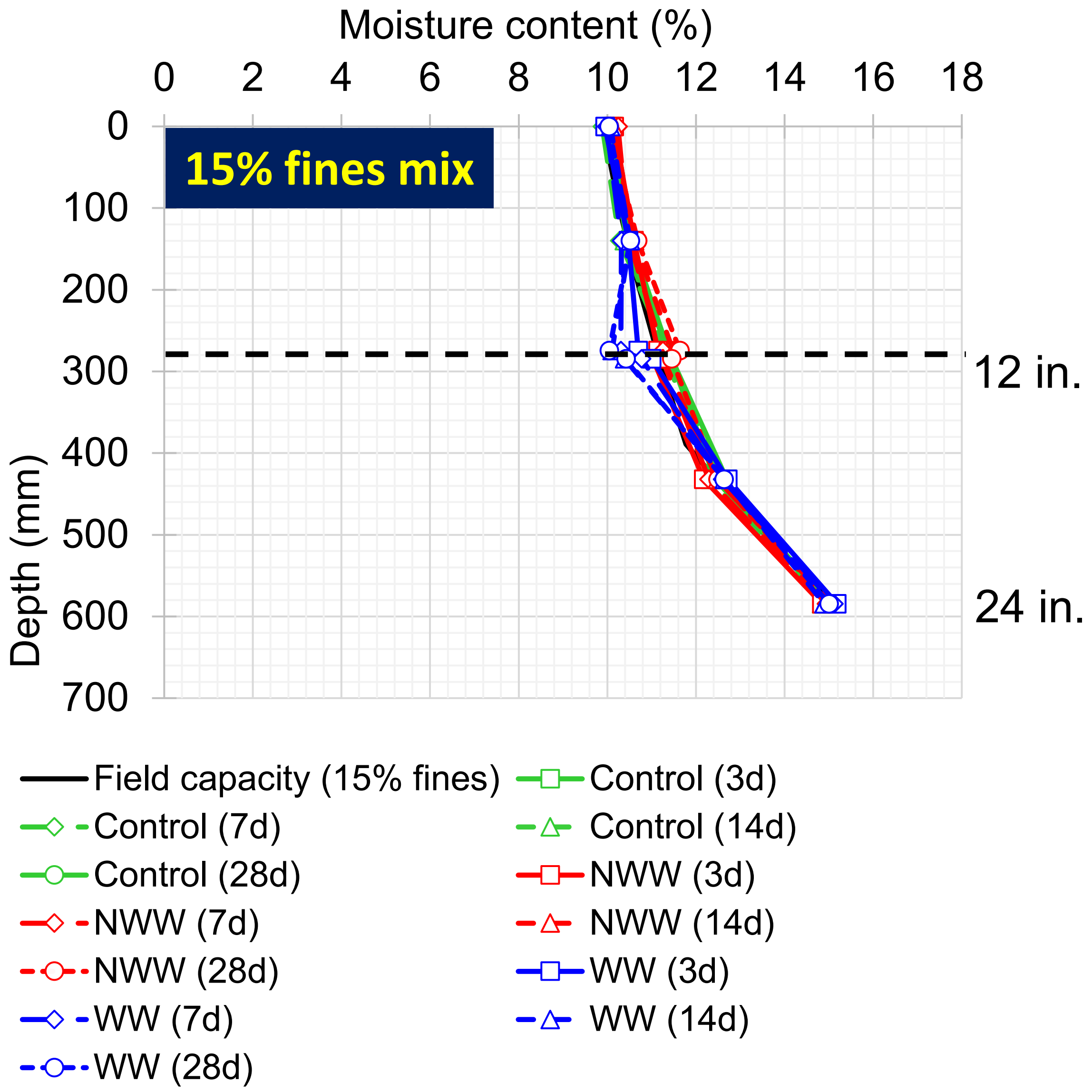
Moisture Reduction Test Results



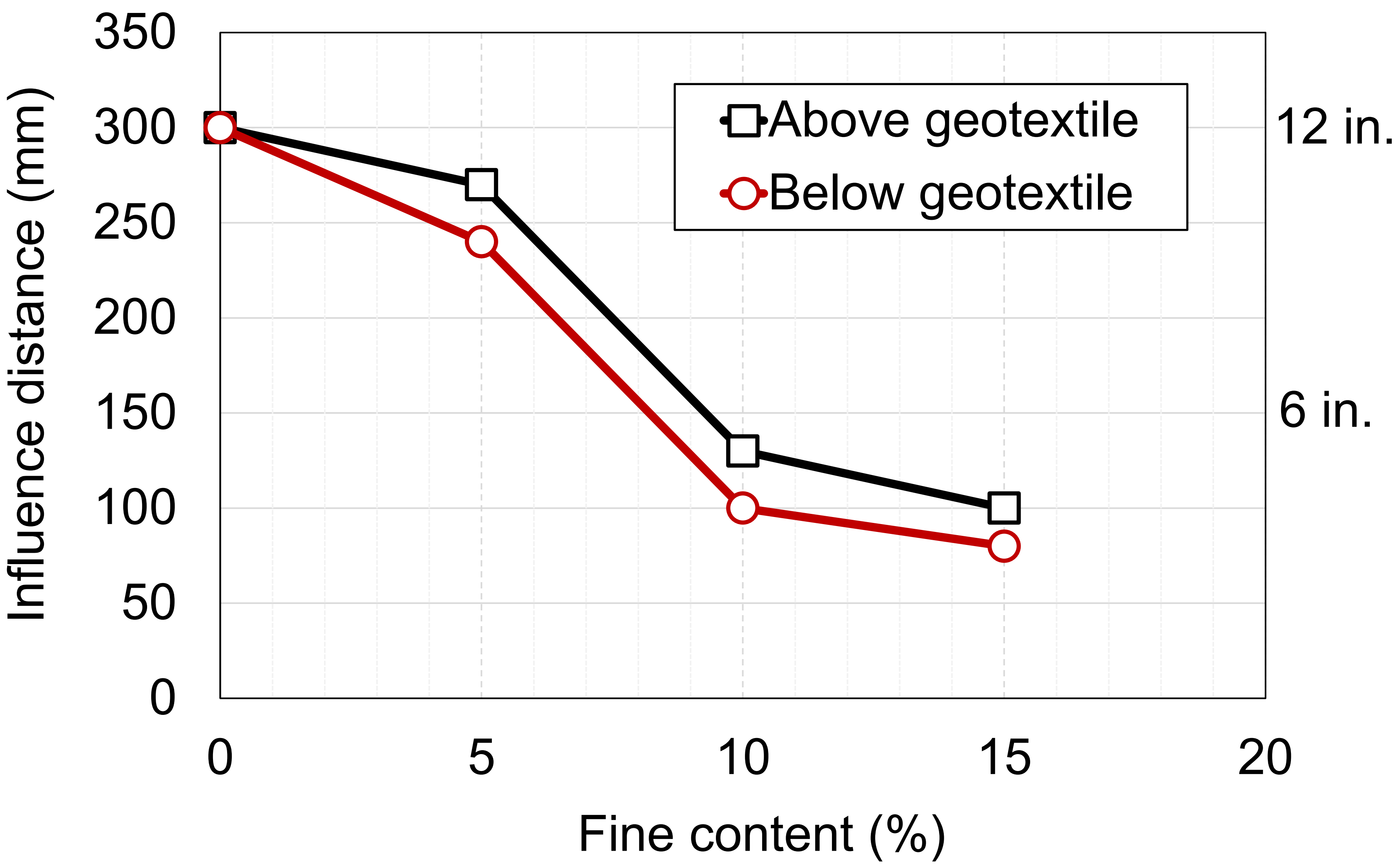


Moisture Reduction Test Results

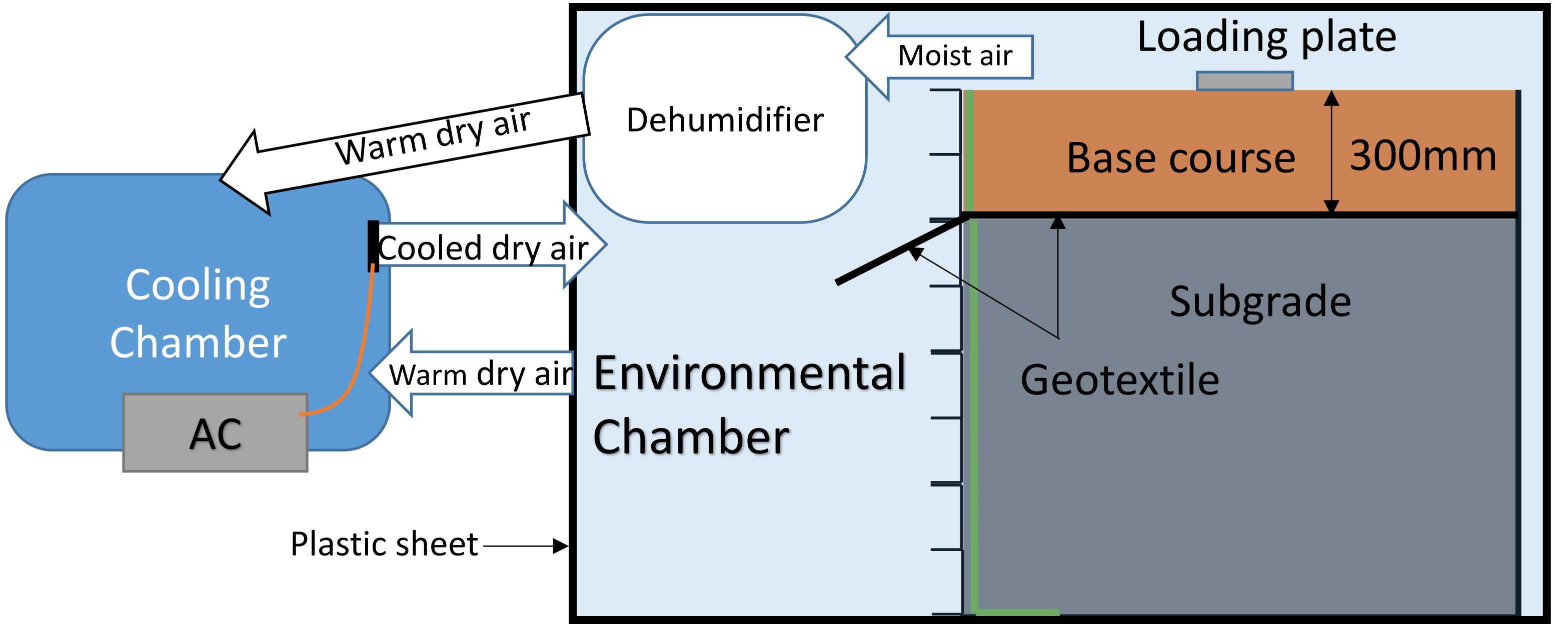


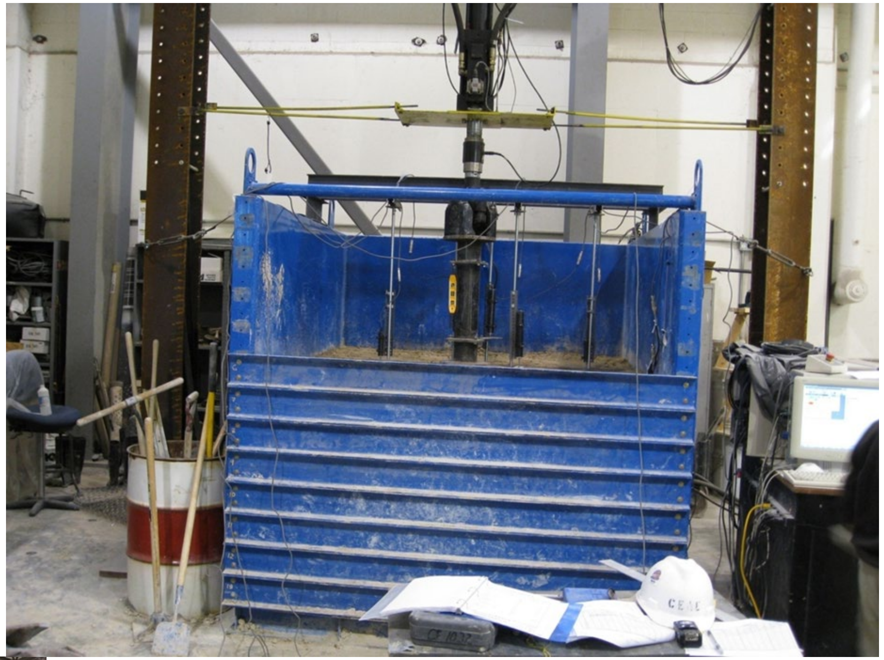


Influence Distance of Wicking Geotextile



Large Box Tests

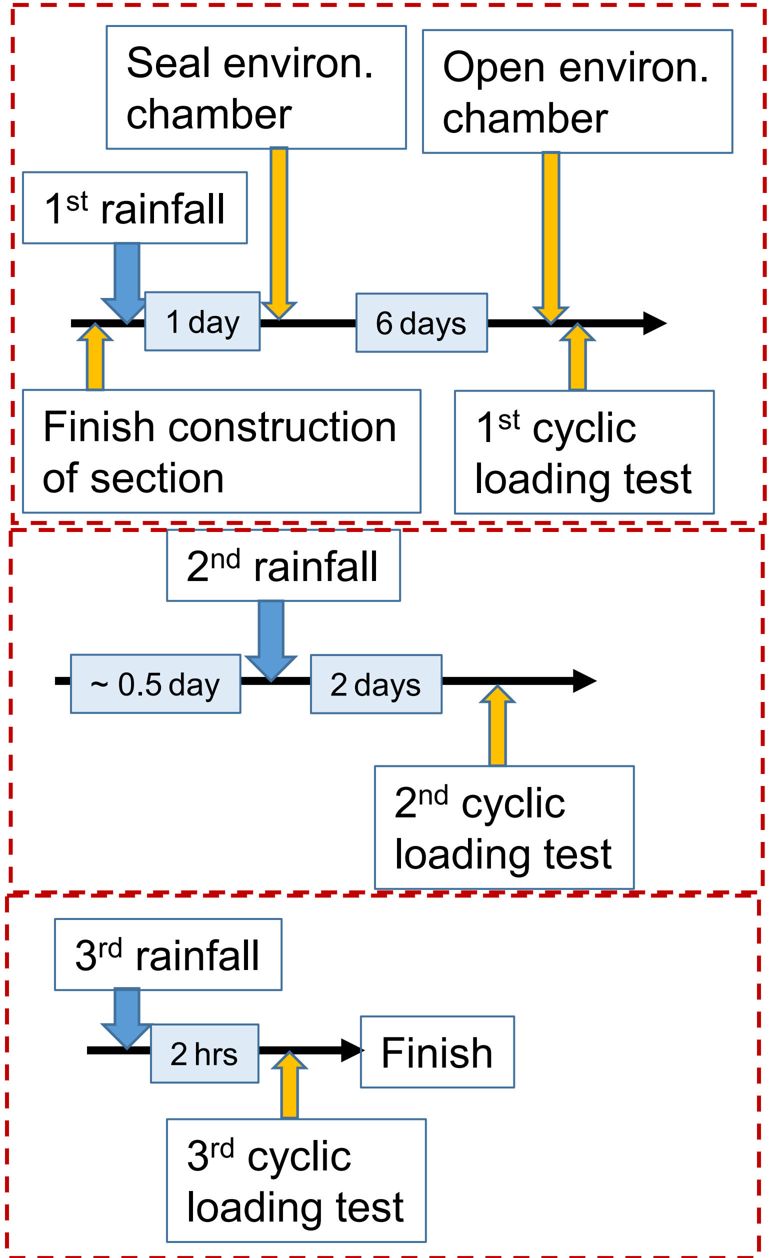




Test No.	Subgrade CBR	Geosynthetic
1	3.3%	N/A
2	2.9%	Non-wicking woven geotextile
3	3.1%	Wicking geotextile
4	4.7%	N/A
5	4.8%	Non-wicking woven geotextile
6	5.0%	Wicking geotextile

Guo, J., Han, J., Zhang, X., and Li, Z. (2021). "Experimental evaluation of wicking geotextile-stabilized aggregate bases over subgrade under rainfall simulation and cyclic loading." Geotextiles and Geomembranes, 49, 1550-1564.

Test Procedure and Results

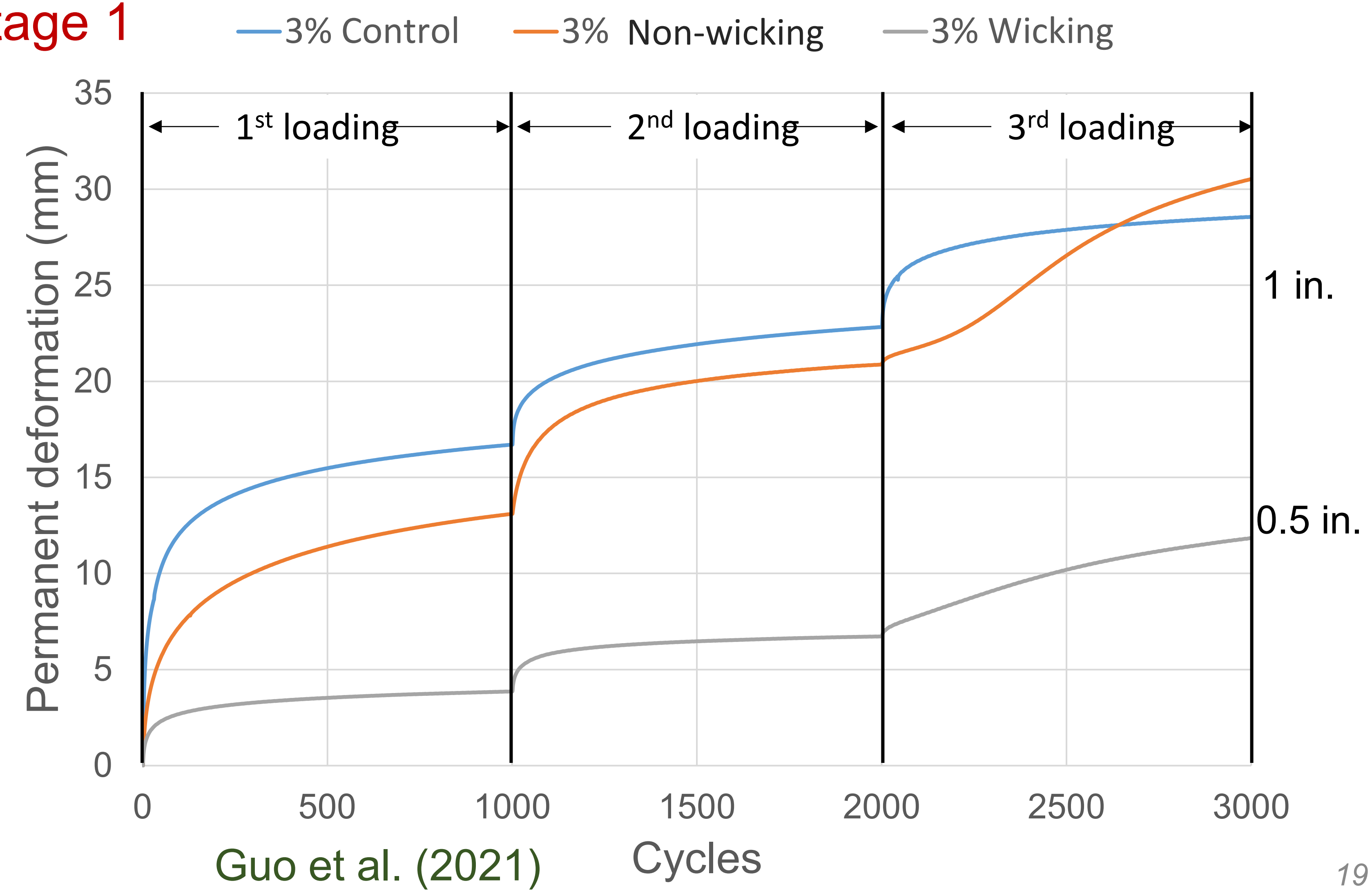


Stage 1

2

3

1000 cycles of plate loading test at p = 140 kPa (20 psi)

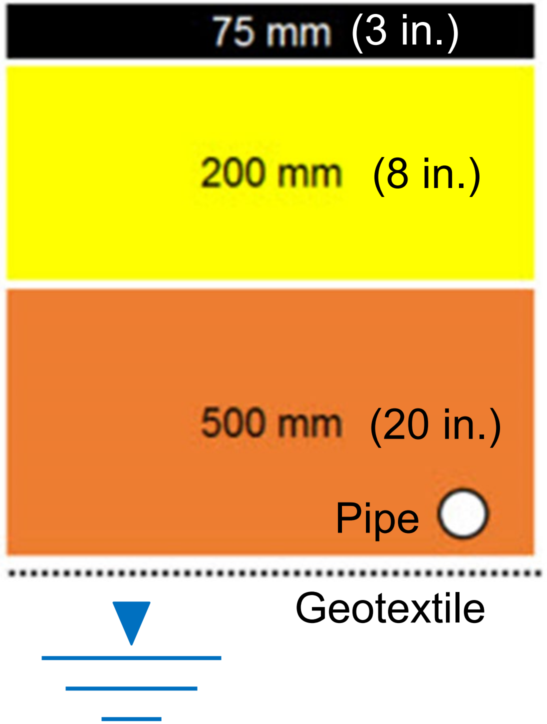


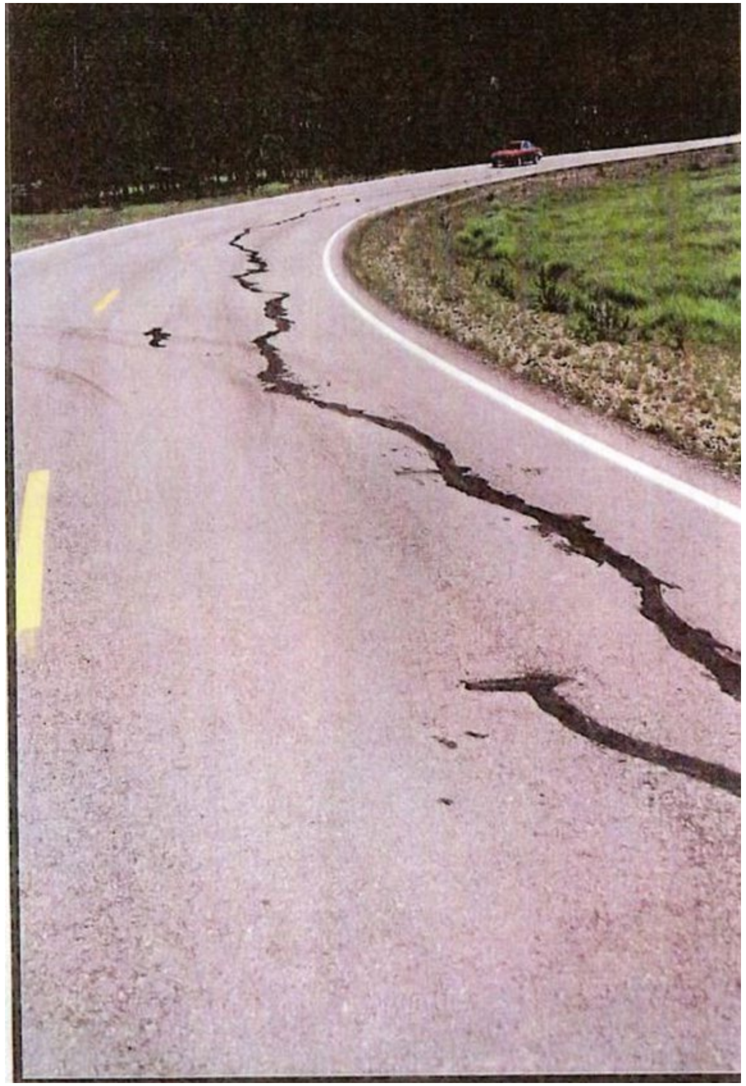
Guo et al. (2021)

Frost Heave Prevention

Pioneer Scenic Byway in Montana, USA

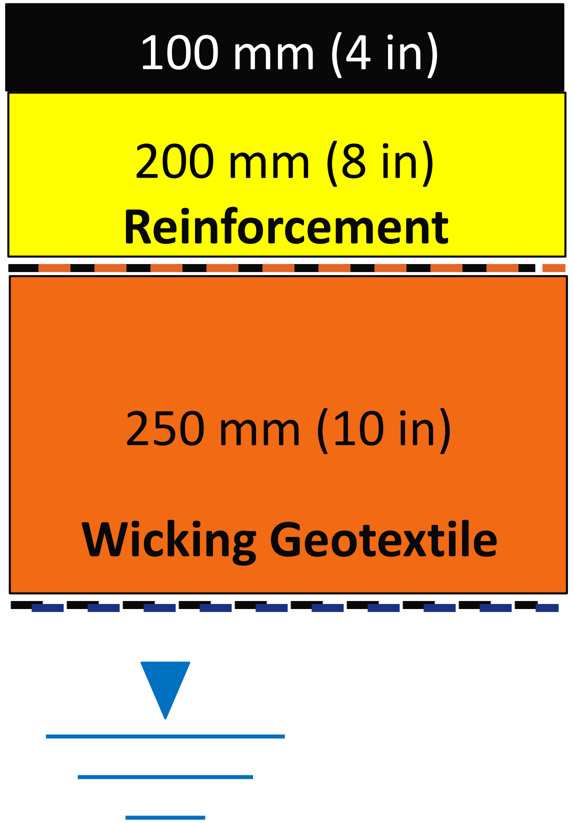
Previous treatment





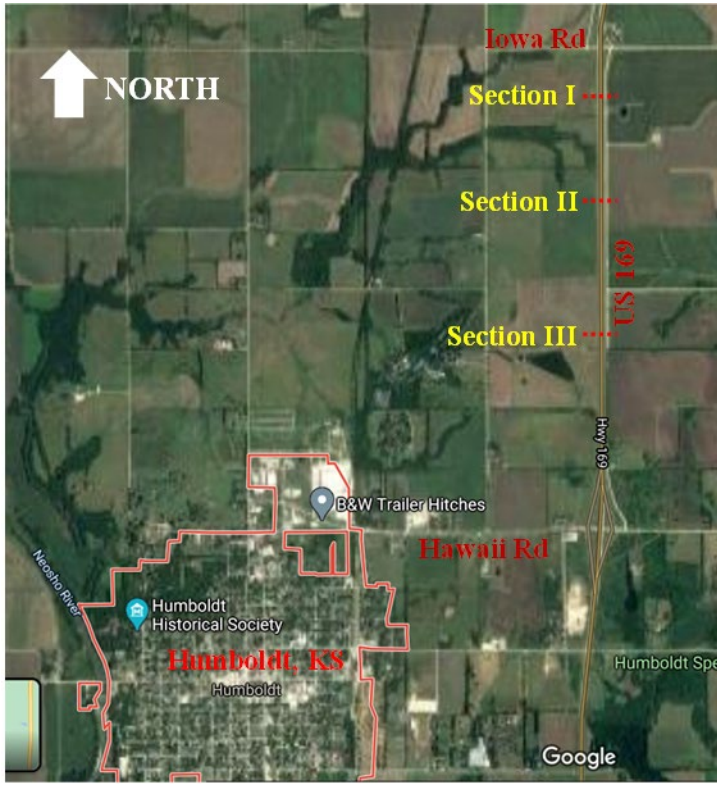
Courtesy of
J. Lostumbo

New Treatment with Wicking Geotextile



Courtesy of
J. Lostumbo

Mitigating High Groundwater Table and Freeze-thaw Problems for Concrete Pavement



US169 in Iola, Kansas , USA

Pavement Condition before Reconstruction

Most frequent level of faulting

Fault Score per segment

Avg. no. of distressed joints per location

YEAR	LANE	RIDE			RIGID DISTRESS									
		IRI in/mi	Mays in/mi	PL	F	FS	J0	J1	J2	J3	J4	F1	F2	F3
2014	0	55	39	1	0.6	6.3	0.5	-	-	-	-	6.1	-	-
2015	0	68	50	1	-	-	-	-	-	-	-	-	-	-
2016	0	82	61	1	1.0	24.6	0.6	-	-	-	-	21.6	1.3	0.1
2017	0	88	68	1	1.3	34.1	1.8	0.3	0.1	-	-	26.6	3.0	0.4
2018	0	119	9	2	1.6	46.9	-	-	0.1	-	1.1	35.4	4.3	0.8

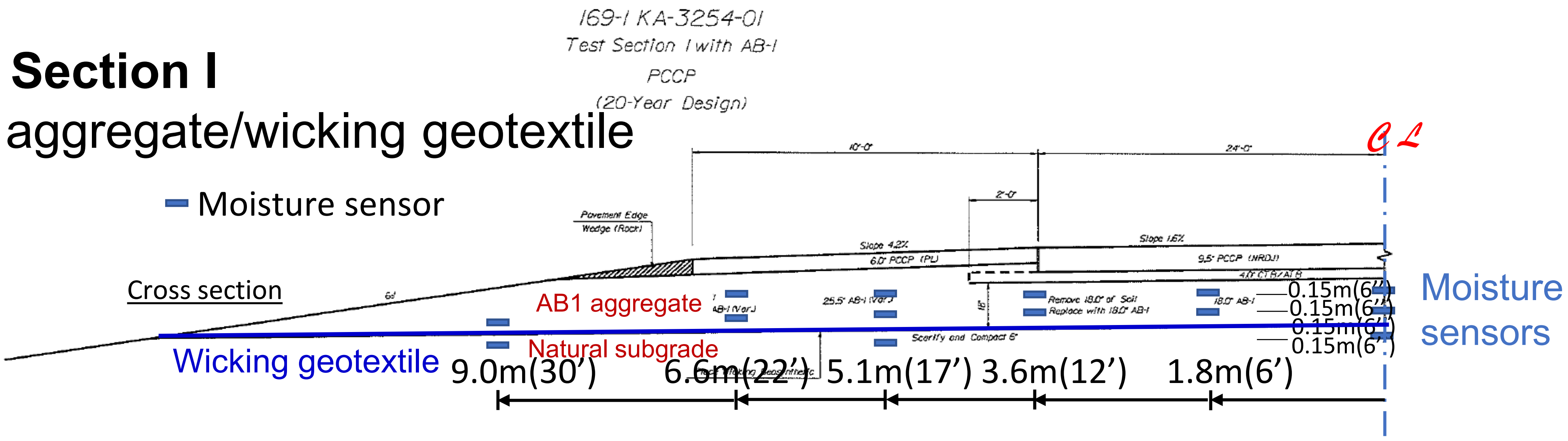
International Roughness Index

Performance Level

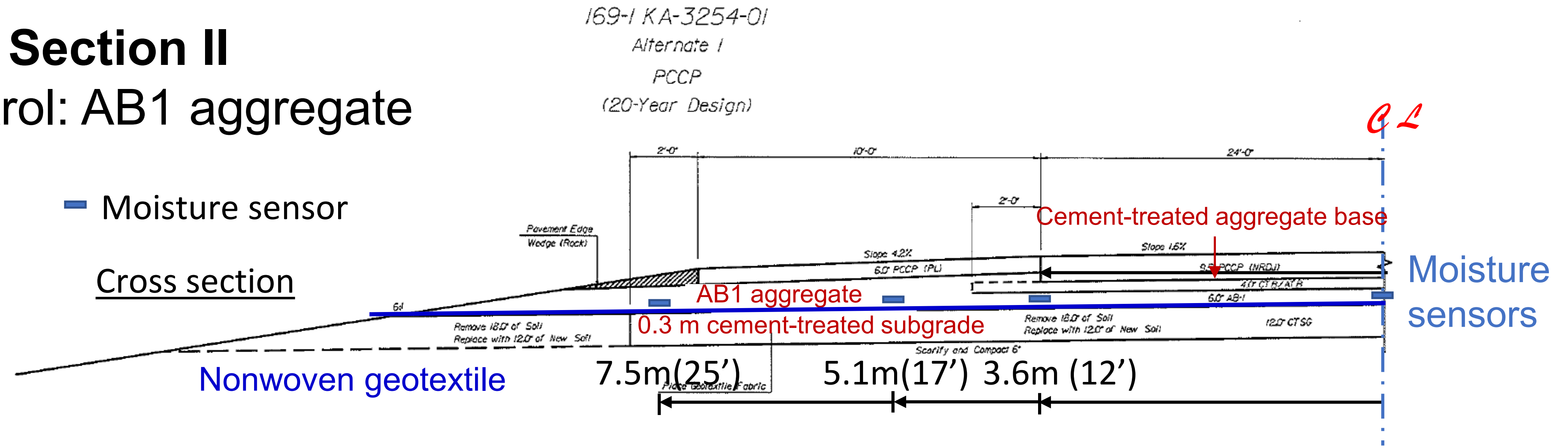
Liu, H., Han, J., Al-Naddaf, M., Parsons, R.L., and Kakrasul, J.I. (2022). "Field monitoring of wicking geotextile to reduce soil moisture under a concrete pavement subjected to precipitations and temperature variations." Geotextiles and Geomembranes, 50(5), 1004-1019.

Instrumented Test Sections with Moisture Sensors

Test Section I
AB1 aggregate/wicking geotextile



Test Section II
Control: AB1 aggregate

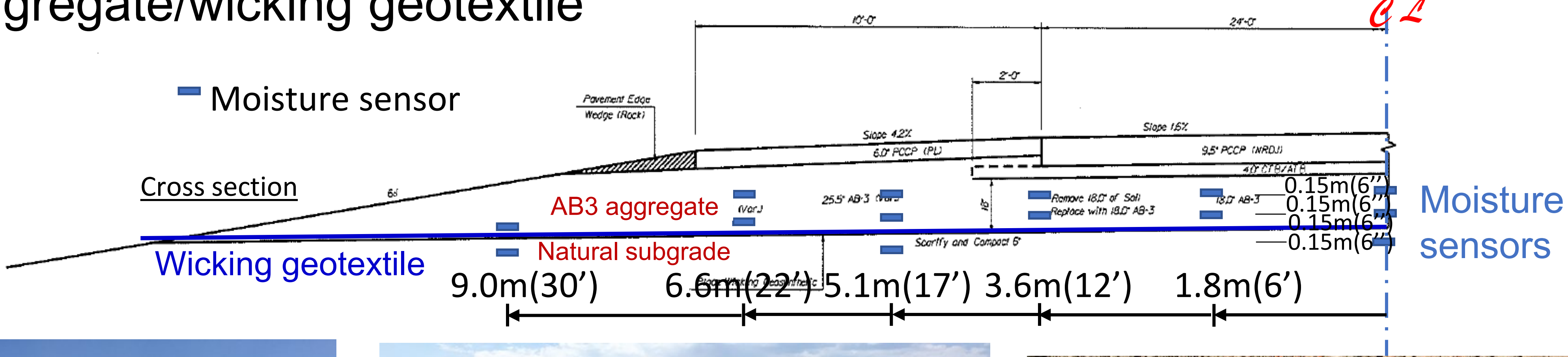


Instrumented Test Sections with Moisture Sensors

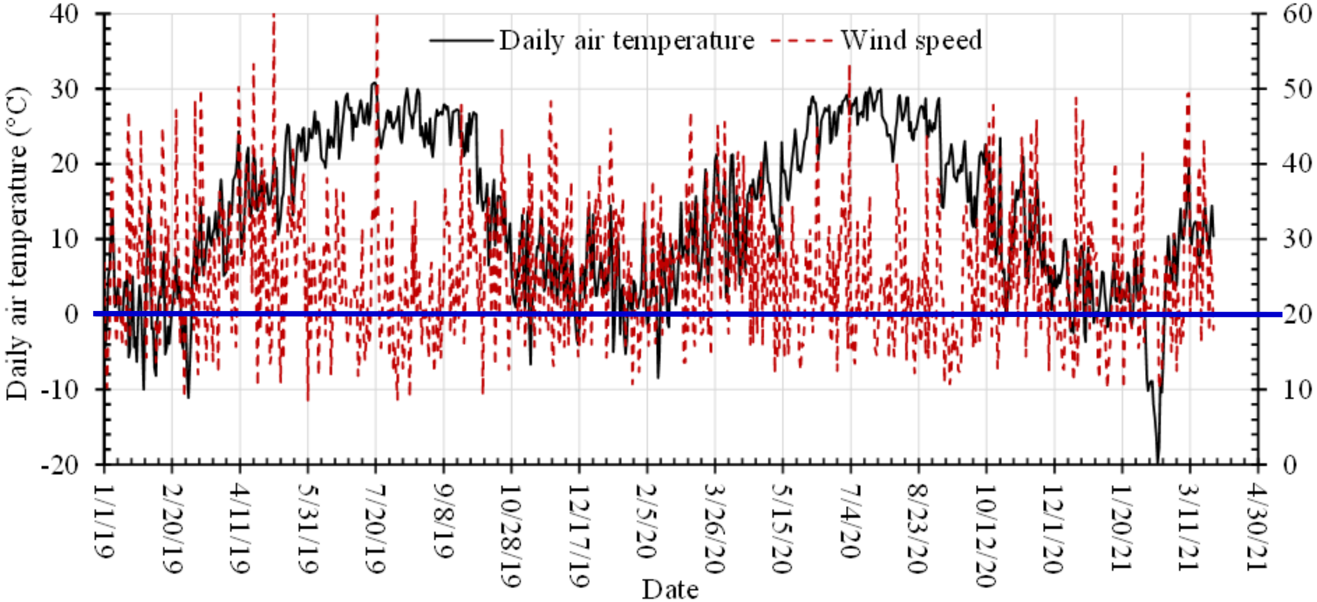
I69-I KA-3254-01
Test Section I with AB-3
PCCP
(20-Year Design)

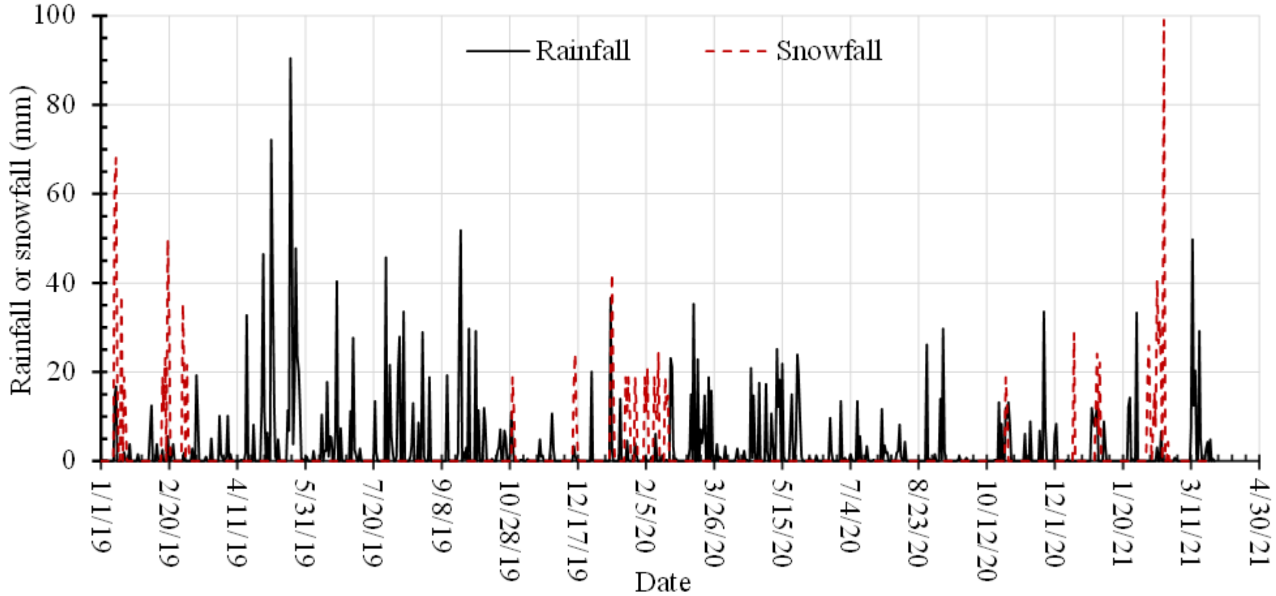
Test Section III

AB3 aggregate/wicking geotextile

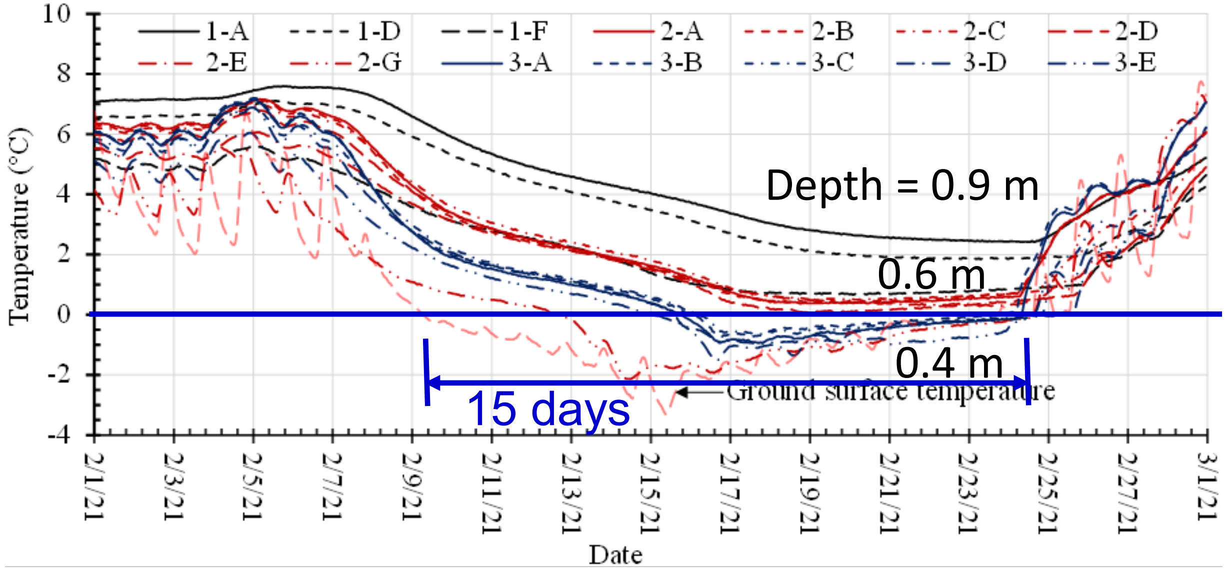


Climatic Condition





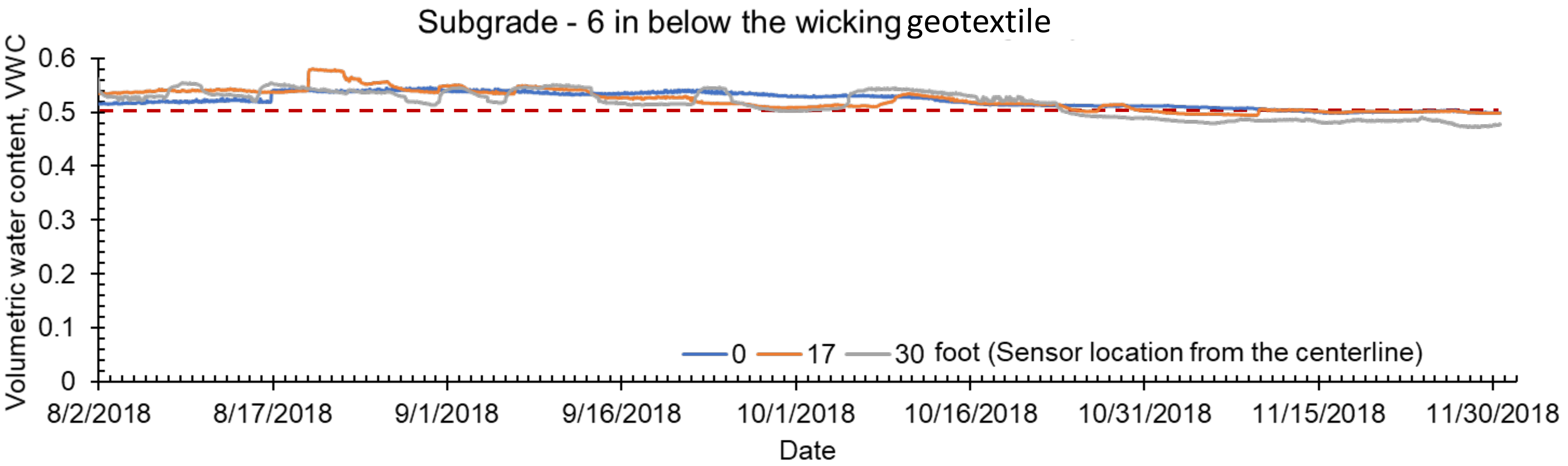
Test Section III
AB3 aggregate/wicking geotextile

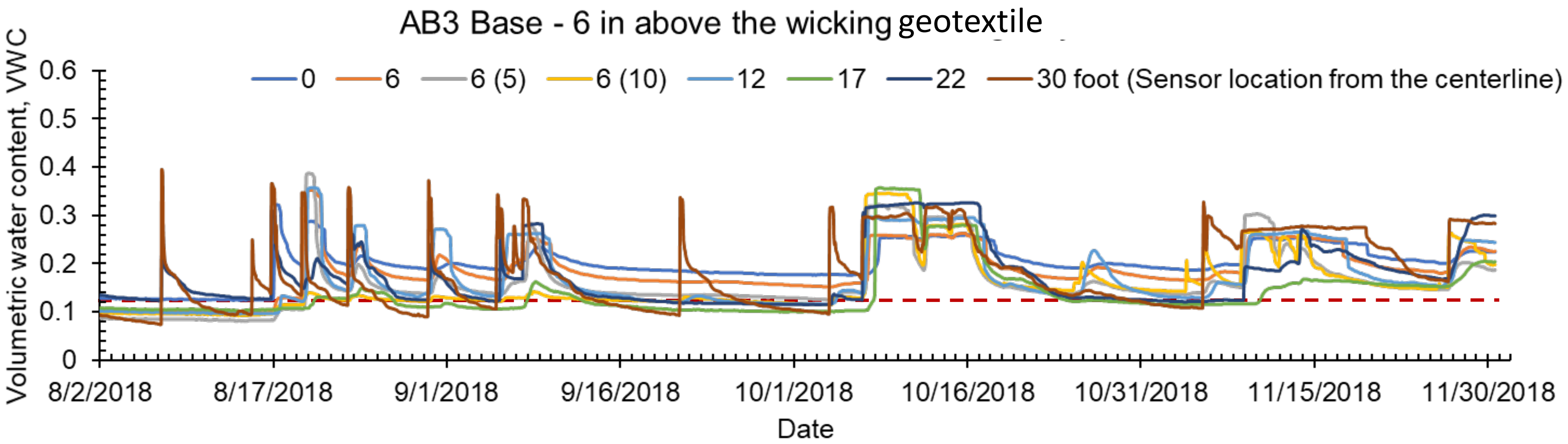


Frozen depth = 0.6 m (24 in)

Field Monitoring Results

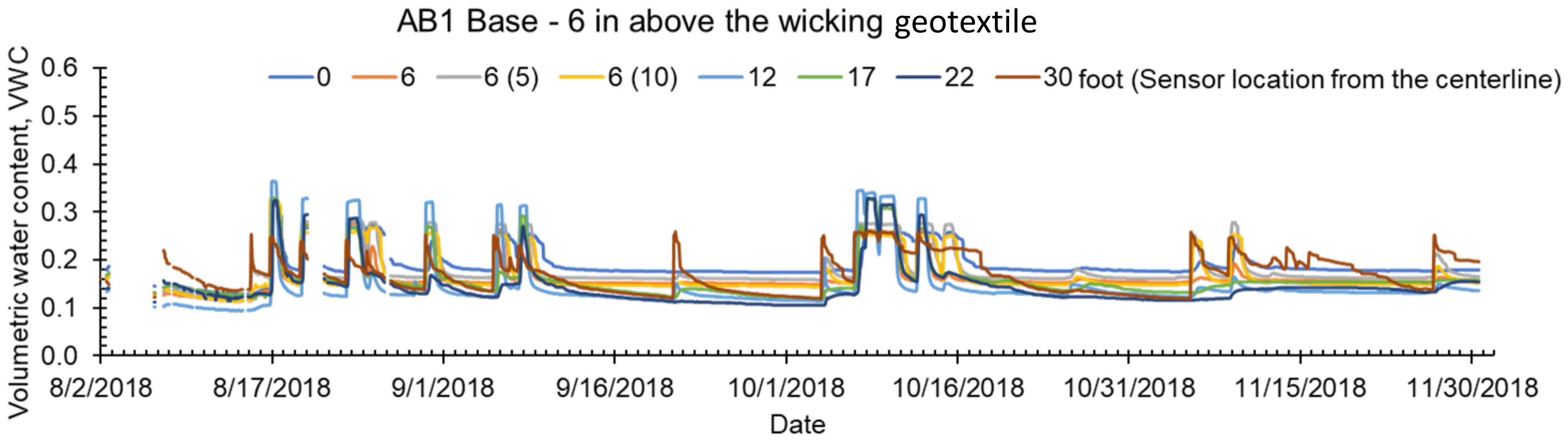
Test Section III: AB3 aggregate/wicking geotextile

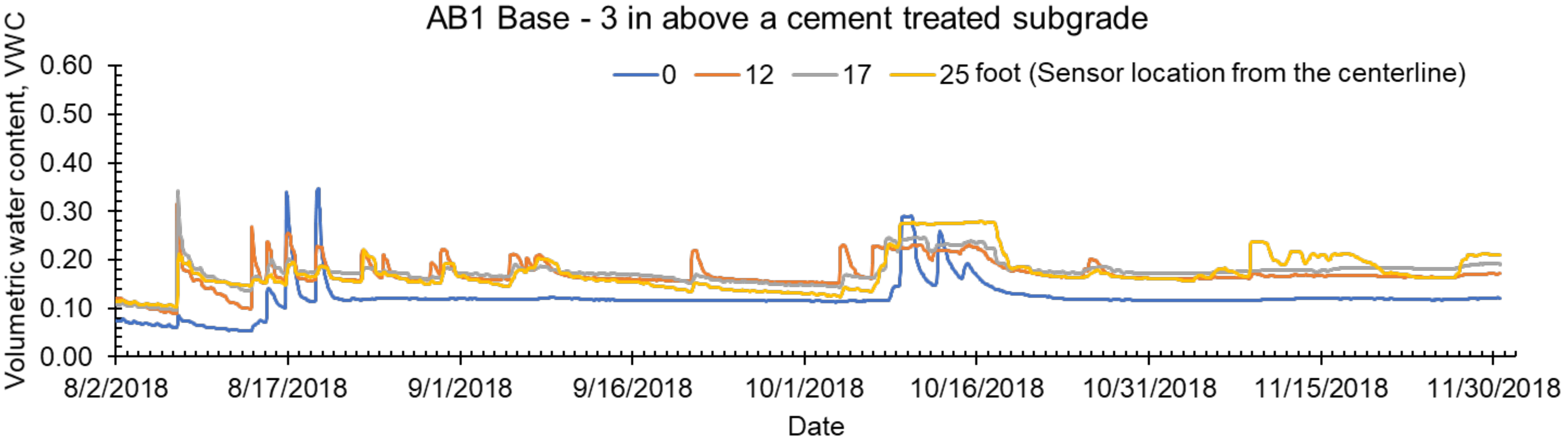




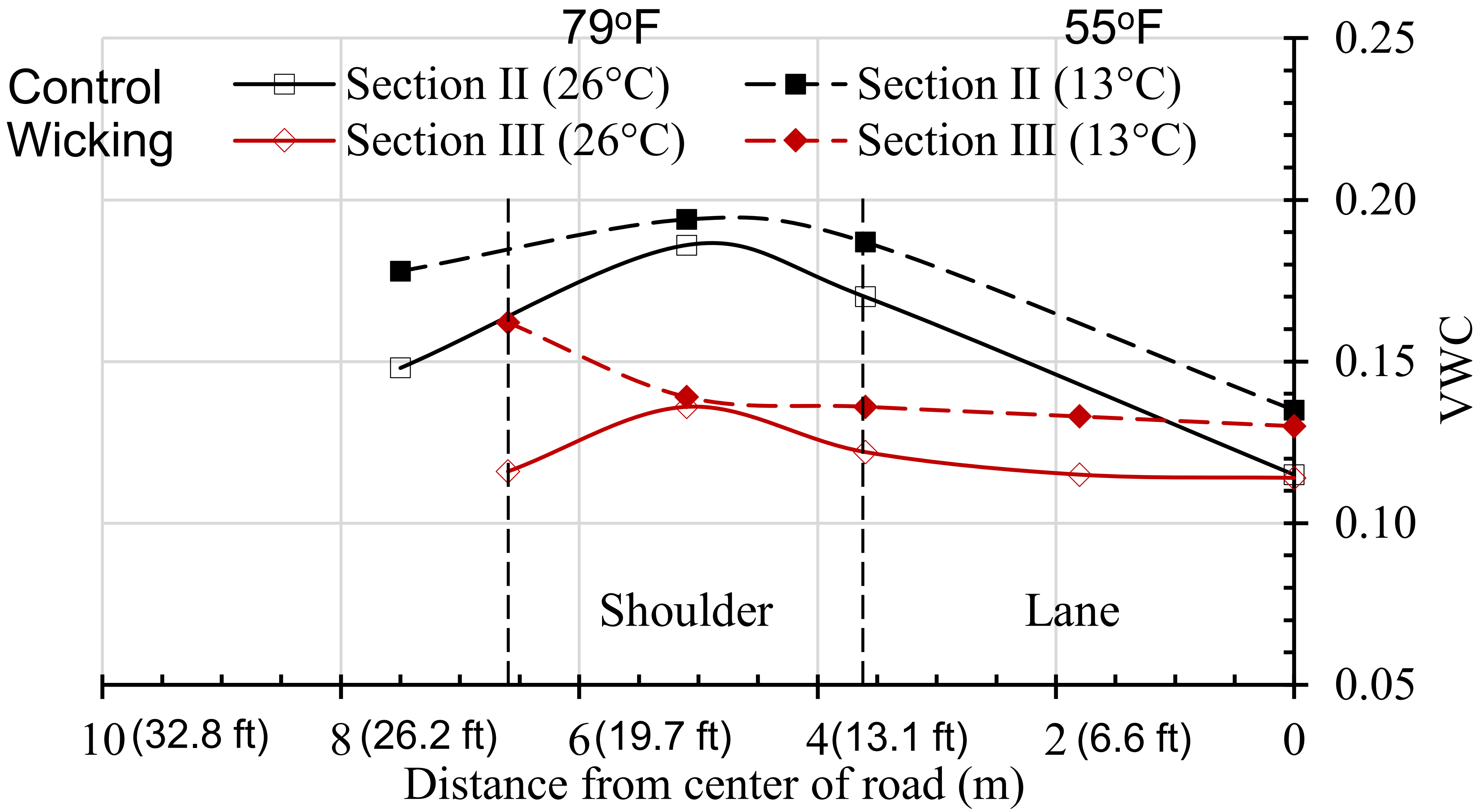
Field Monitoring Results

Test Sections I & II: AB1 aggregate/wicking geotextile & Control





Field Monitoring Results



Both evaporation and drainage reduce moisture content.

Field Monitoring Results

Section 1: wicking geotextile

Section 2: no wicking geotextile

Section 3: wicking geotextile

Concluding Remarks

- Wicking geotextile could remove water from soil under a field capacity (unsaturated).
- Wicking geotextile was more effective in reducing water content with time than non-wicking geotextile.
- The ability of wicking water from soil by the wicking geotextile depended on temperature, relative humidity, fines content, and distance to the wicking geotextile.
- The wicking geotextile significantly reduced permanent deformations of test sections under cyclic loading.
- Field studies confirmed the effectiveness of wicking geotextile in removing moisture and mitigating moisture-related road problems.

Thanks!

Questions?