Using Subsurface Drainage Systems for Building Long-Lasting Pavements

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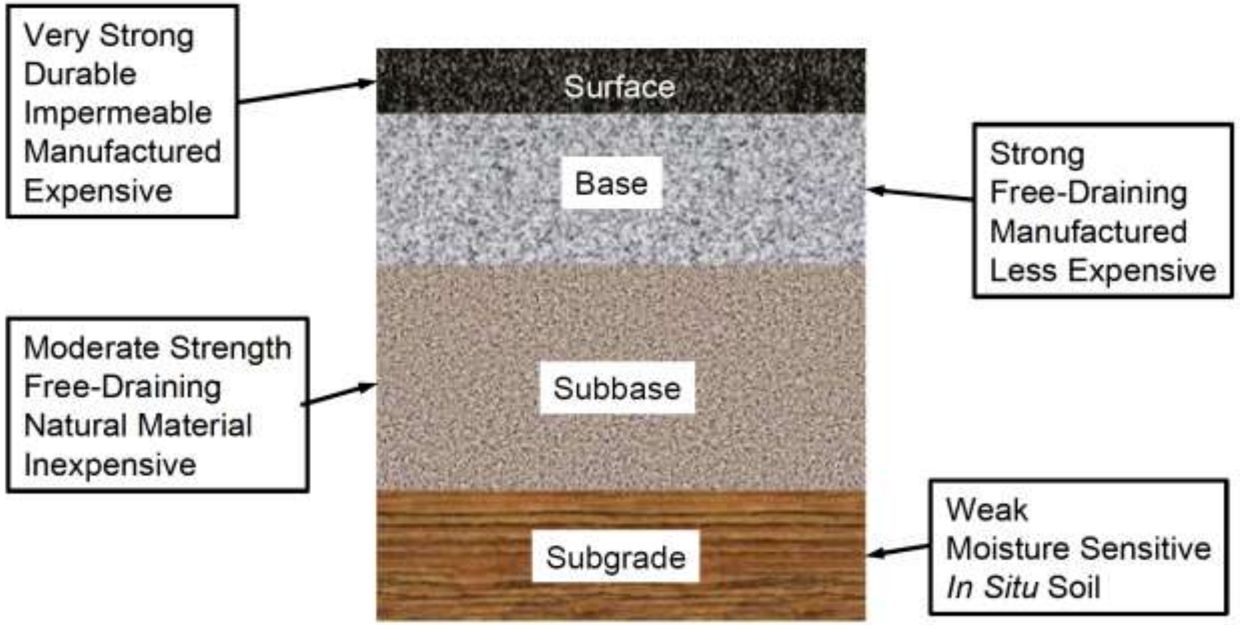
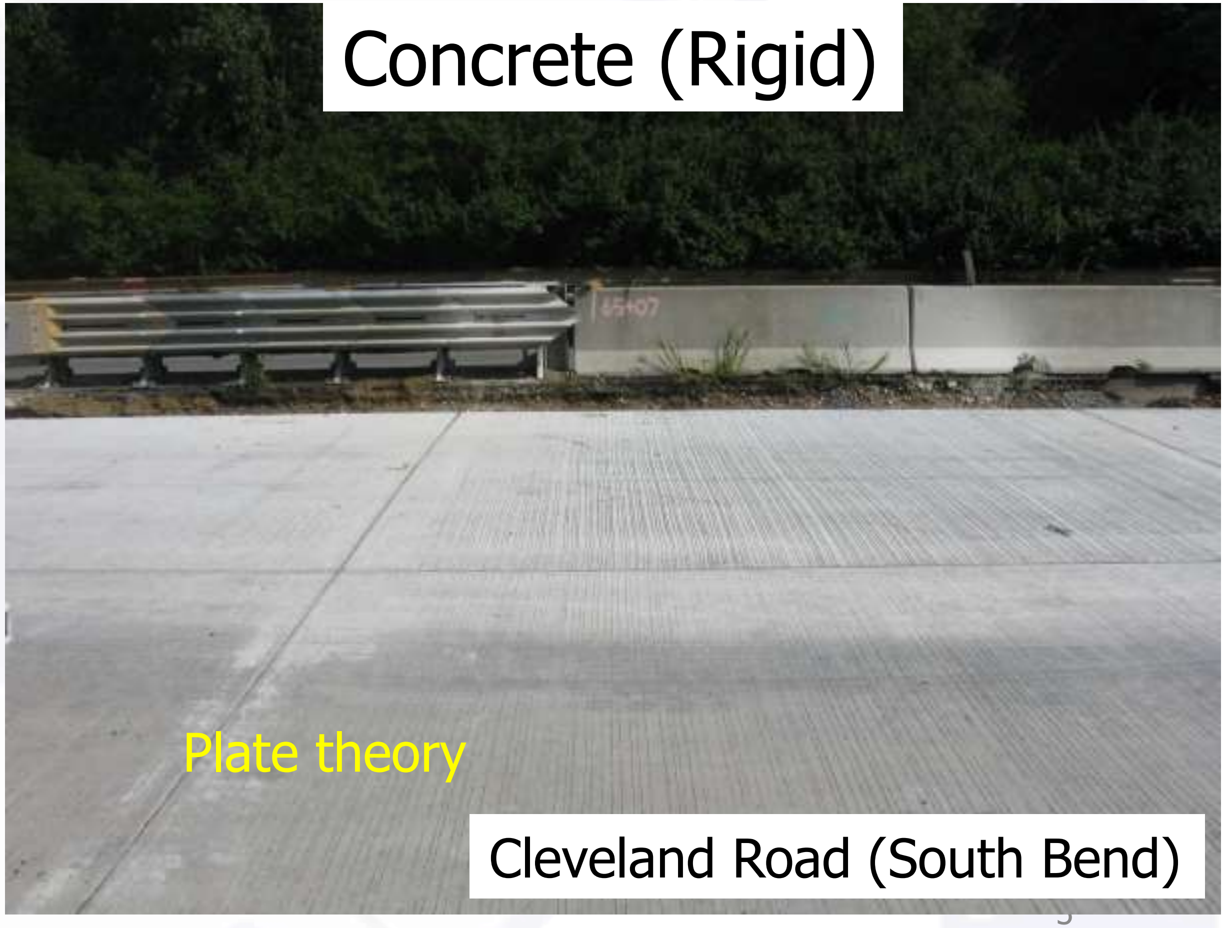


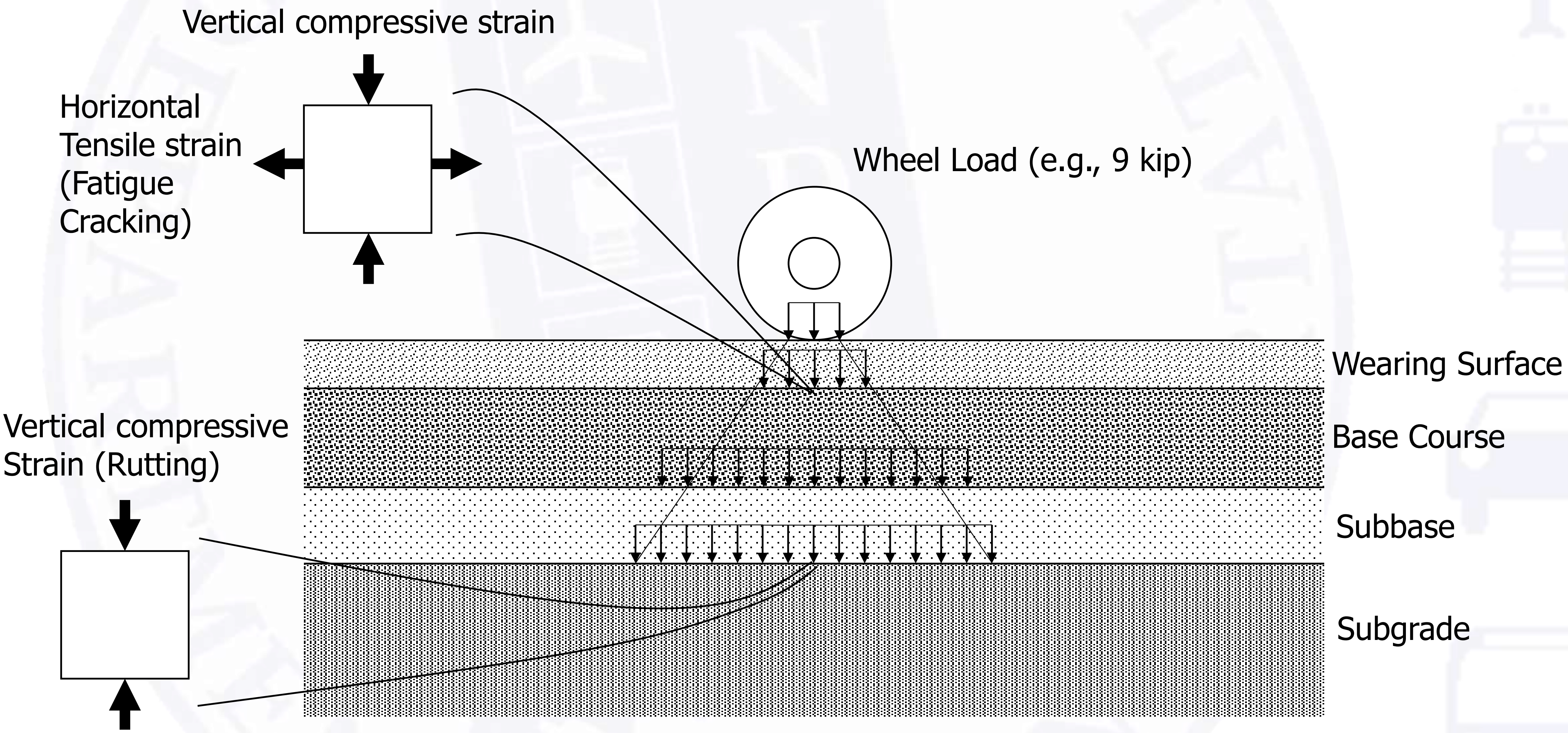
What are pavements? How do they work?

Pavements for Transportation Infrastructure

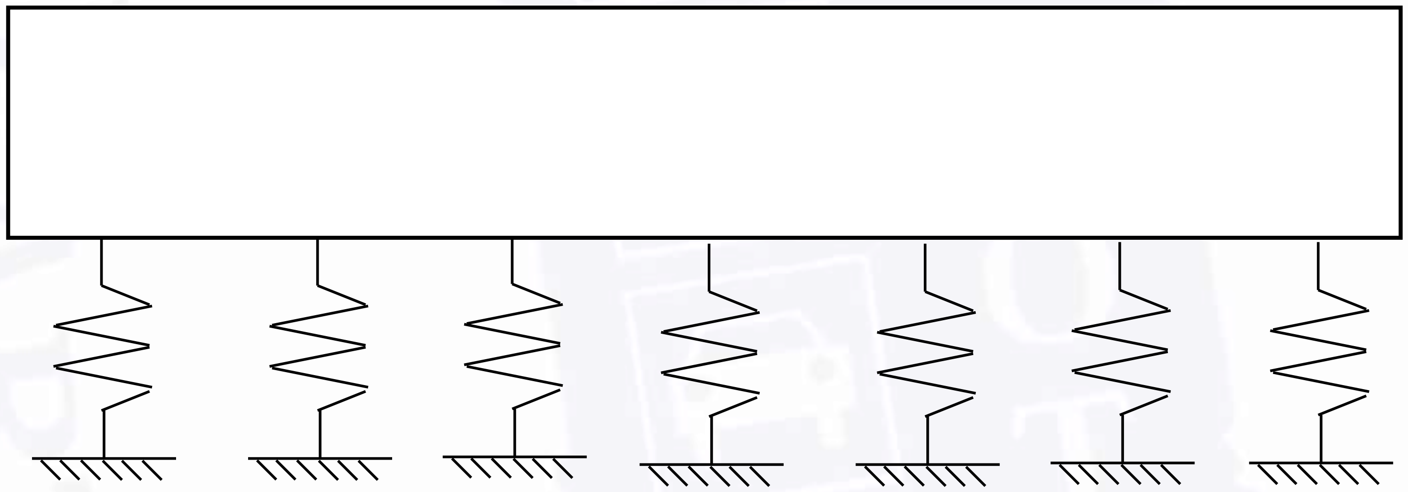
Pavements provide smooth surfaces for vehicles to safely travel during all climatic conditions (FHWA NHI-05-037)



Stresses and Strains in Asphalt Pavements



Stresses and Strains in Concrete Pavements



Concrete Pavement

Subgrade soil modeled as liquid foundation (series of springs)

$$\ell = \left[\frac{Eh^3}{12(1 - v^2)k}\right]^{0.25}$$

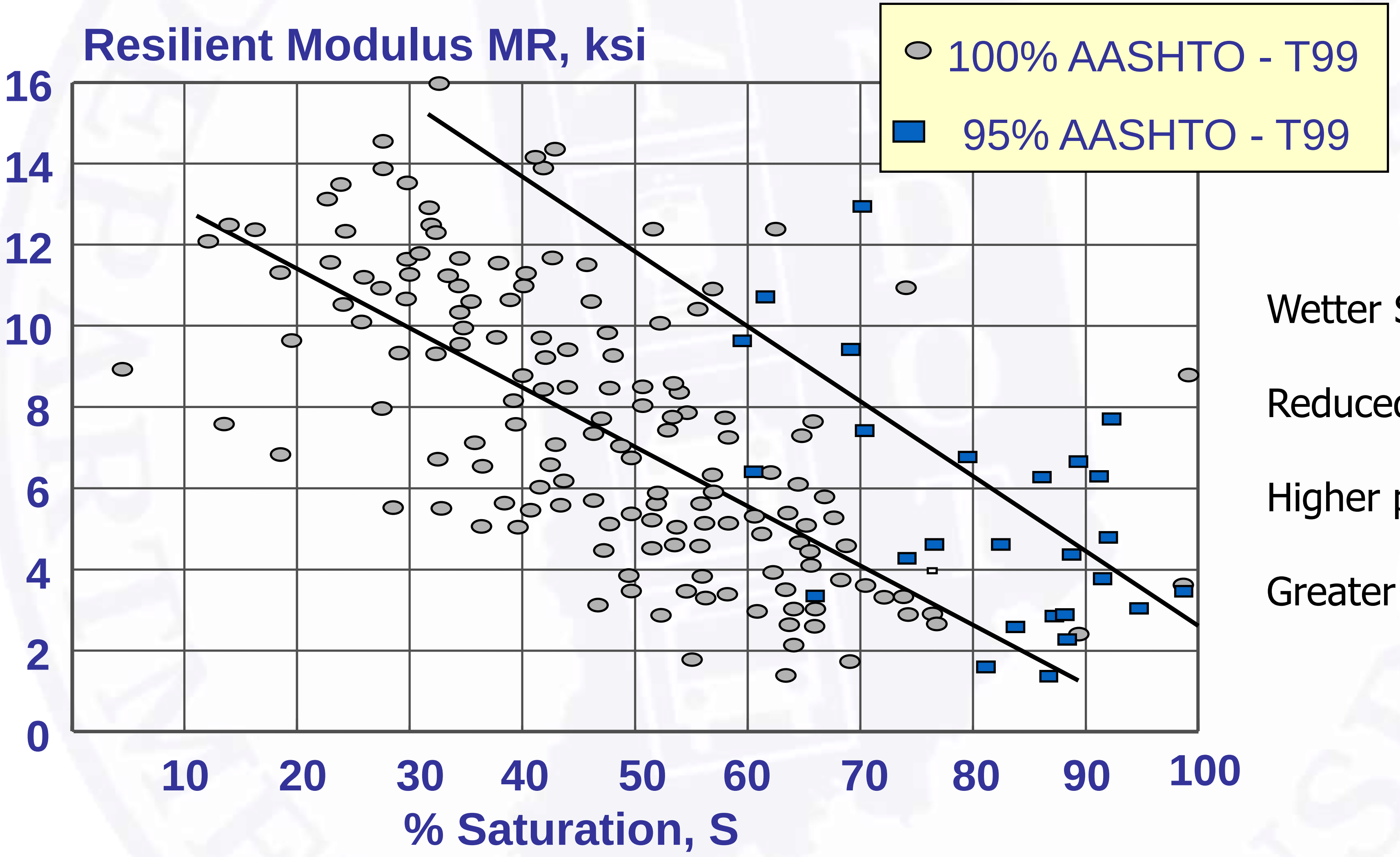
Radius of Relative Stiffness
(Used for calculating curling/warping stresses and stresses due to loading)

How does moisture affect pavement performance?

Categories of Moisture Related Damage

1. Weakening of pavement layers
2. Degradation of pavement material
    - Stripping and erosion of asphalt
    - Erosion of other materials
    - D-cracking of concrete
3. Loss of bond between layers

Weakening of Pavement Layers (e.g., Subgrade)



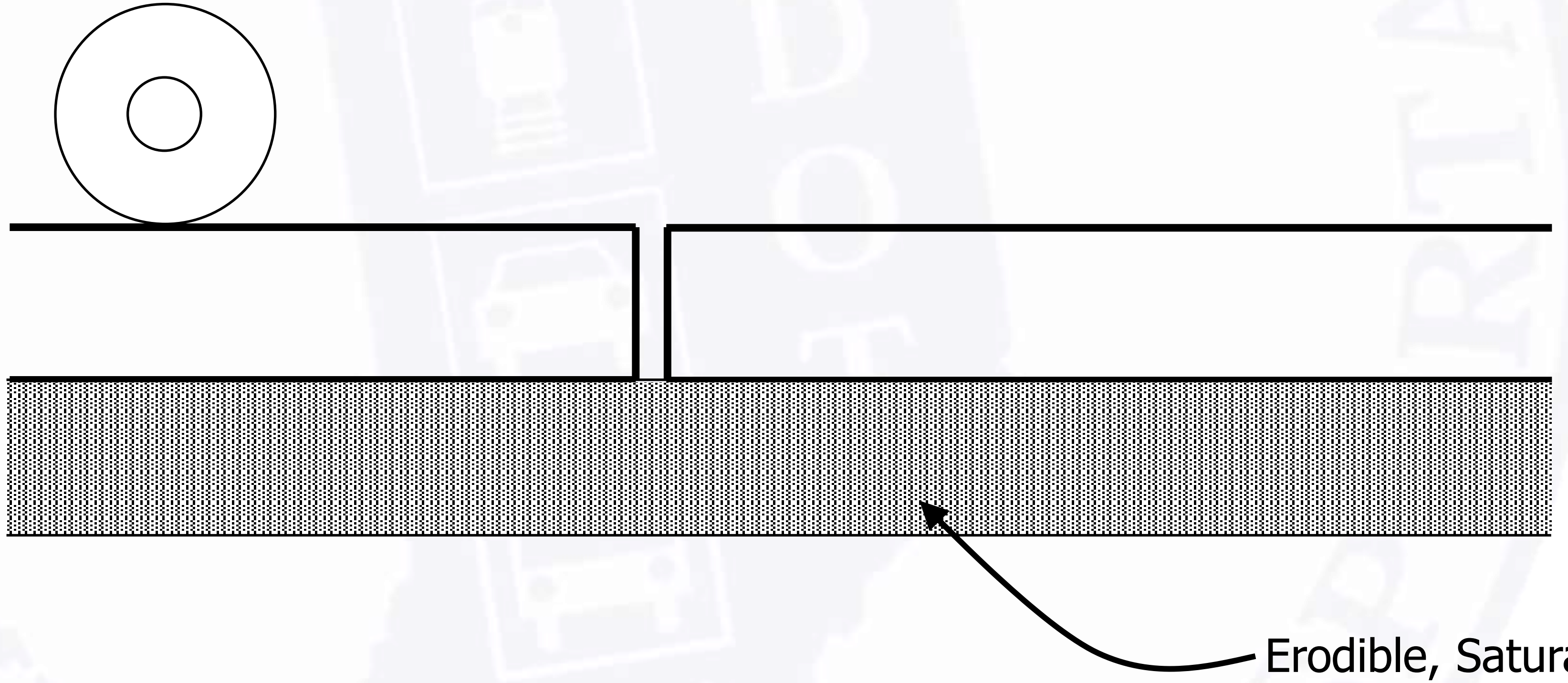
Wetter Soil ->

Reduced stiffness ->

Higher permanent deformations ->

Greater asphalt pavement rutting

Erosion of other materials (e.g., concrete pumping)



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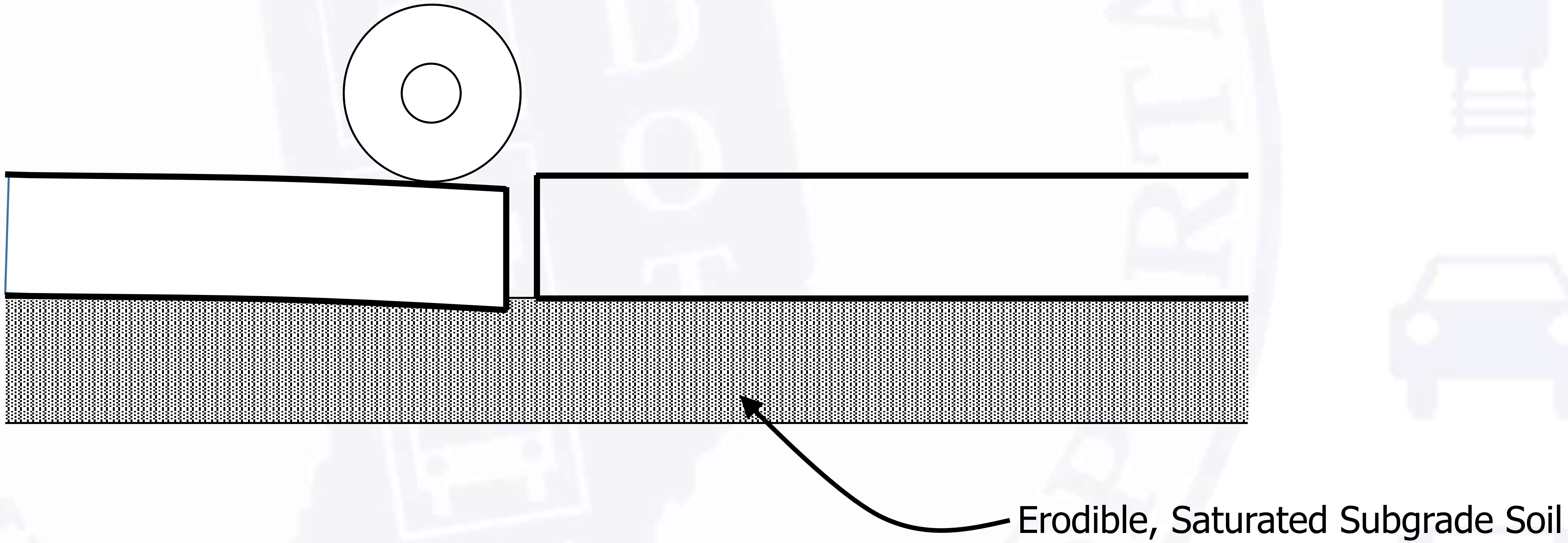

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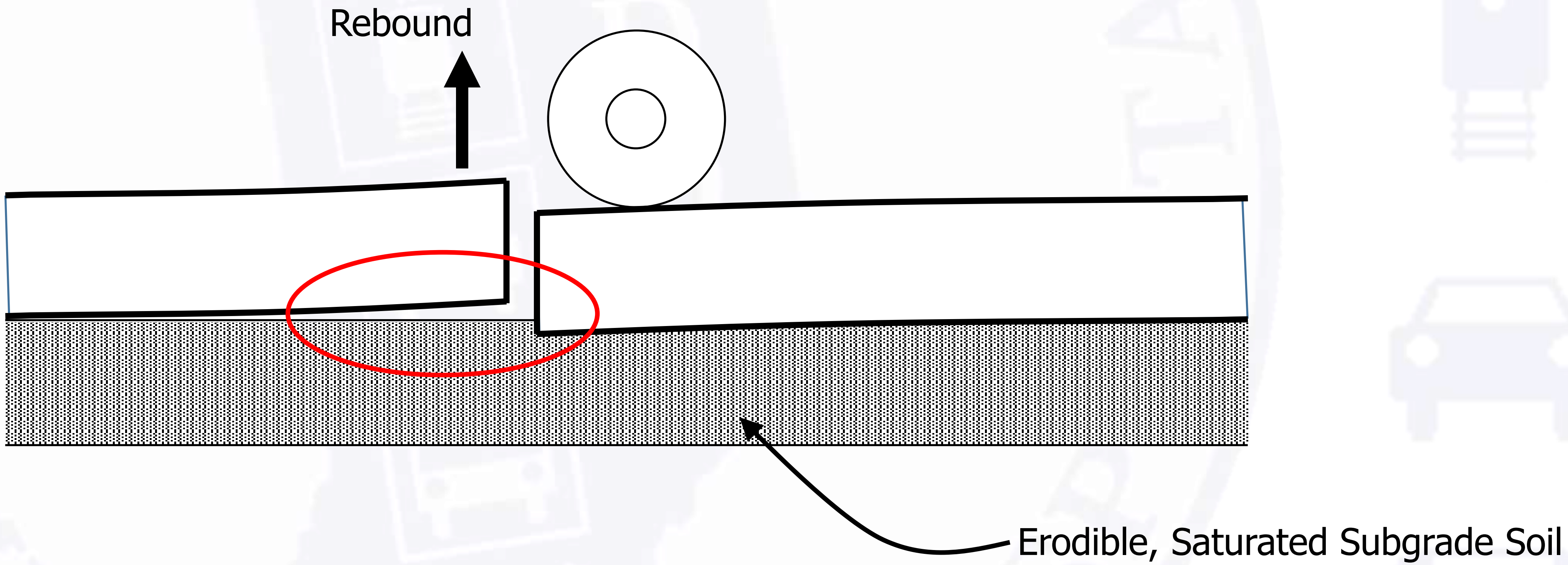

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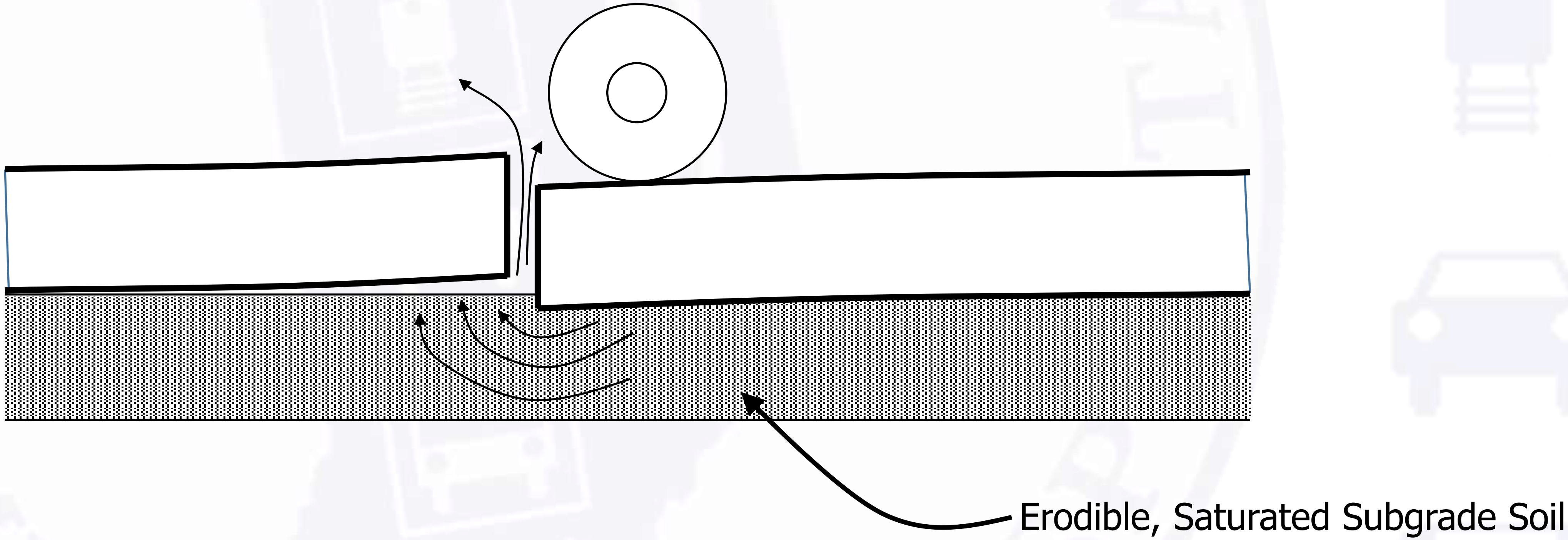

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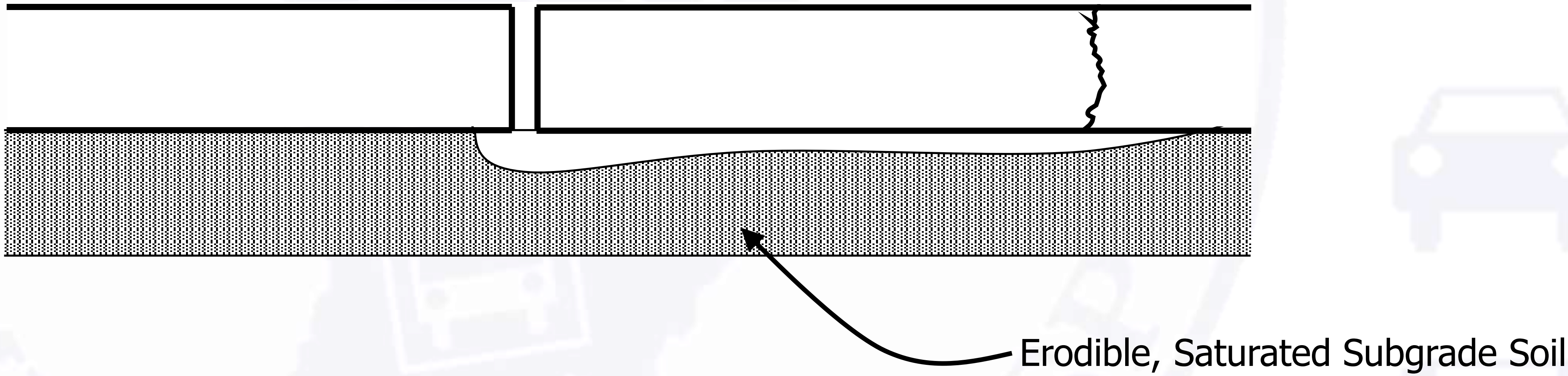

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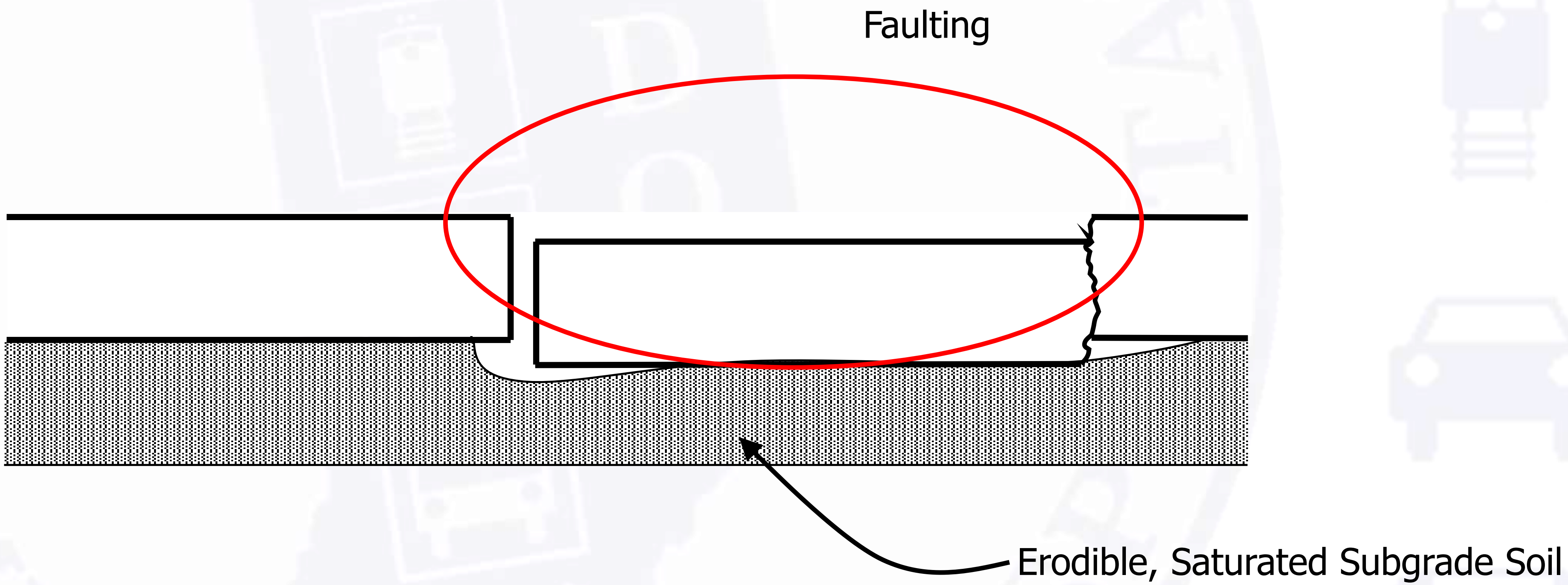
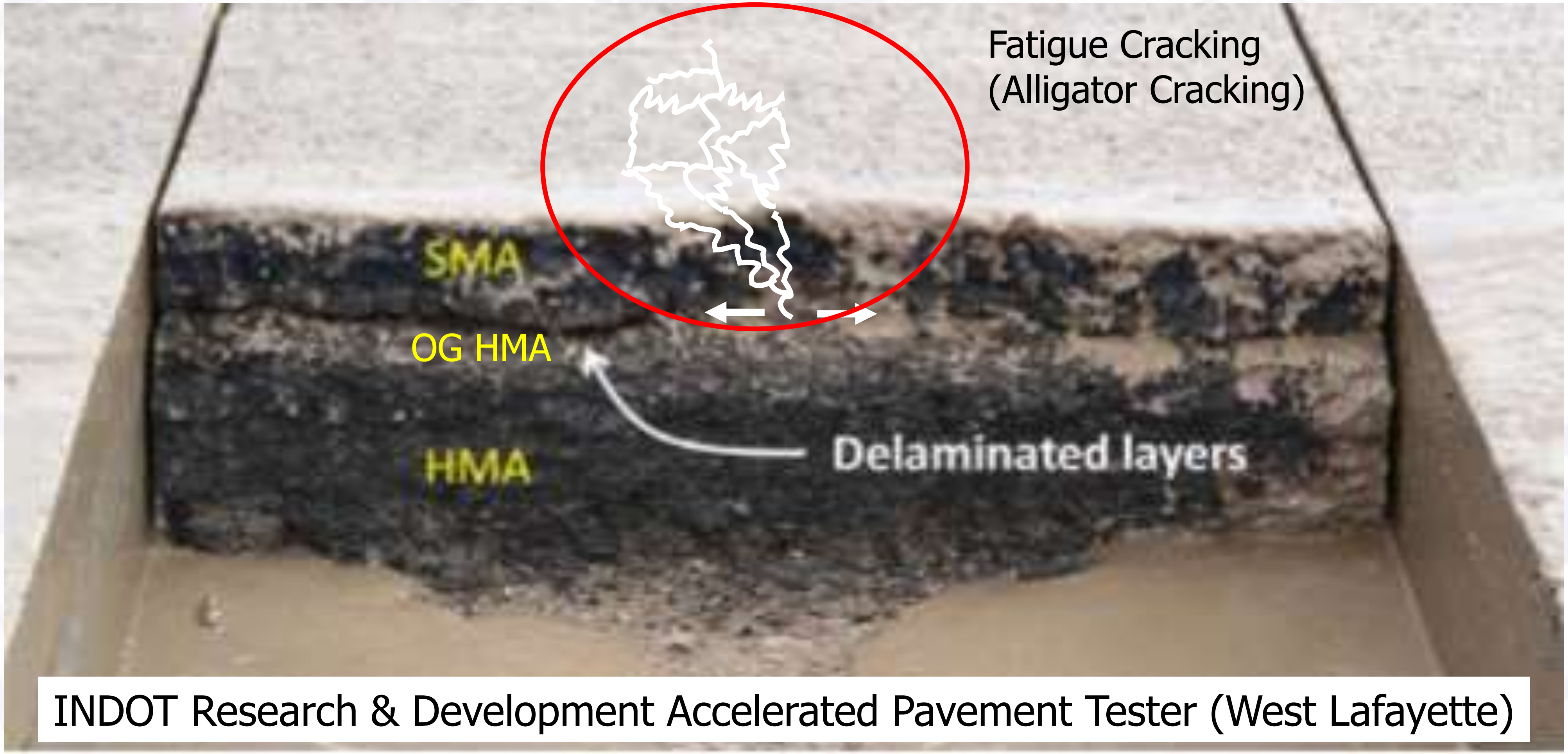
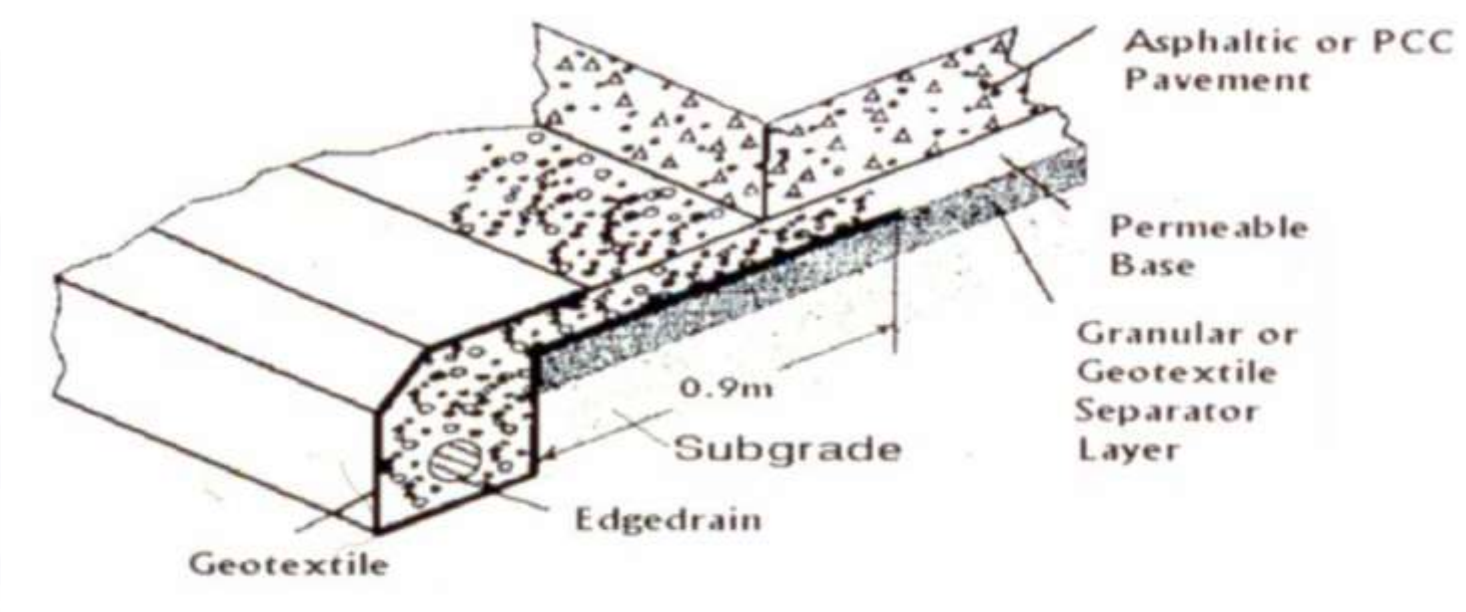


Loss of Bond Between Layers (e.g., asphalt delamination)



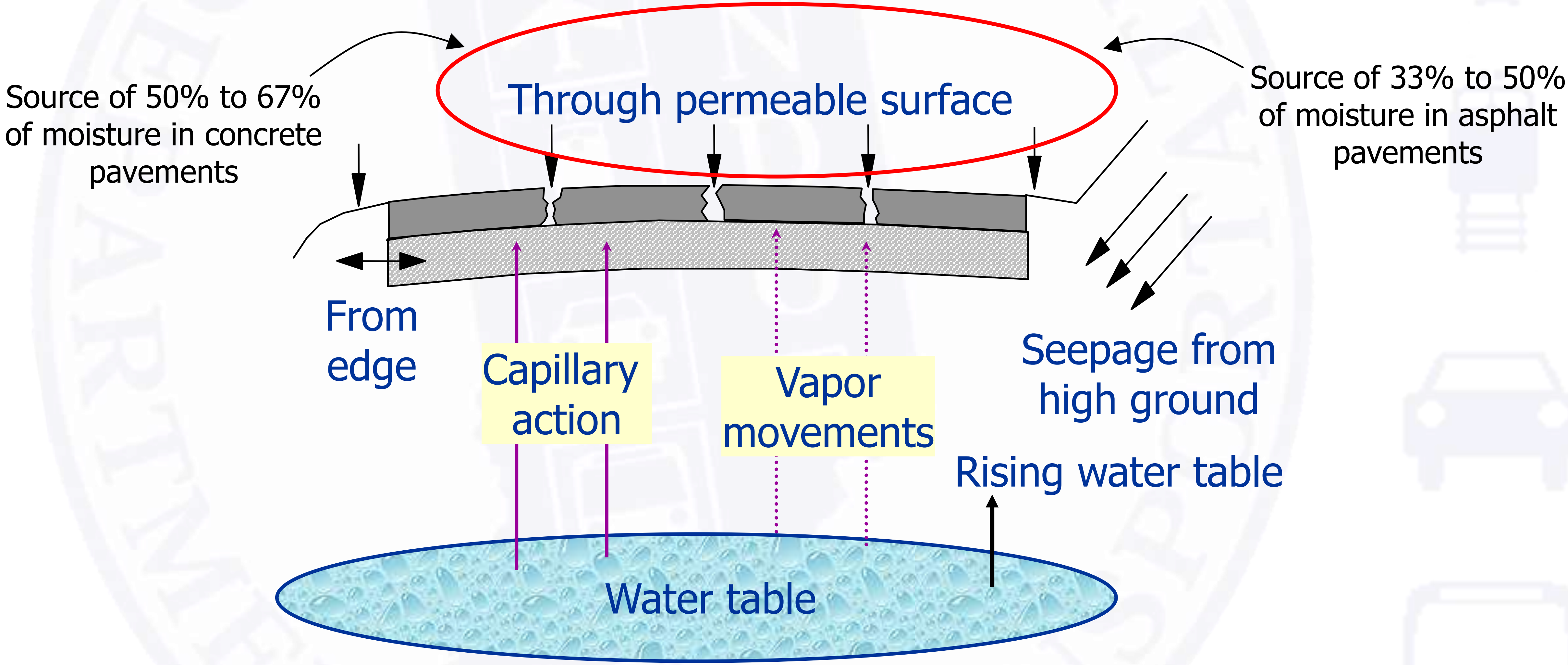
Categories of Moisture Related Damage

- All three types (weakening, degradation, loss of bond) can occur simultaneously
- More damage when pavement is saturated (e.g., rainy seasons and spring thaw)
- More damage when weakened pavement is subjected to heavy axle loads



How does moisture get into pavements?
How to get rid of it?

Sources of Moisture in Pavements

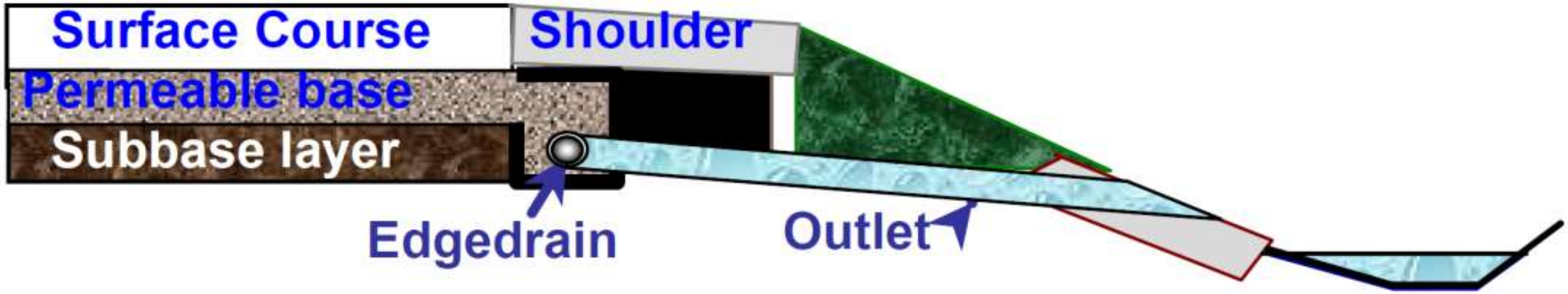


Factors Determining Subsurface Drainage Need

- Amount of free water that infiltrates into the pavement structure
  - Climate
  - Pavement type and condition
  - Surface drainage
- Potential for moisture-related damage to pavement
- Ability to design, construct, and maintain the drainage system
- Other general factors (e.g., topography)

Components of Pavement Subsurface Drainage

Typical Subsurface Drainage System



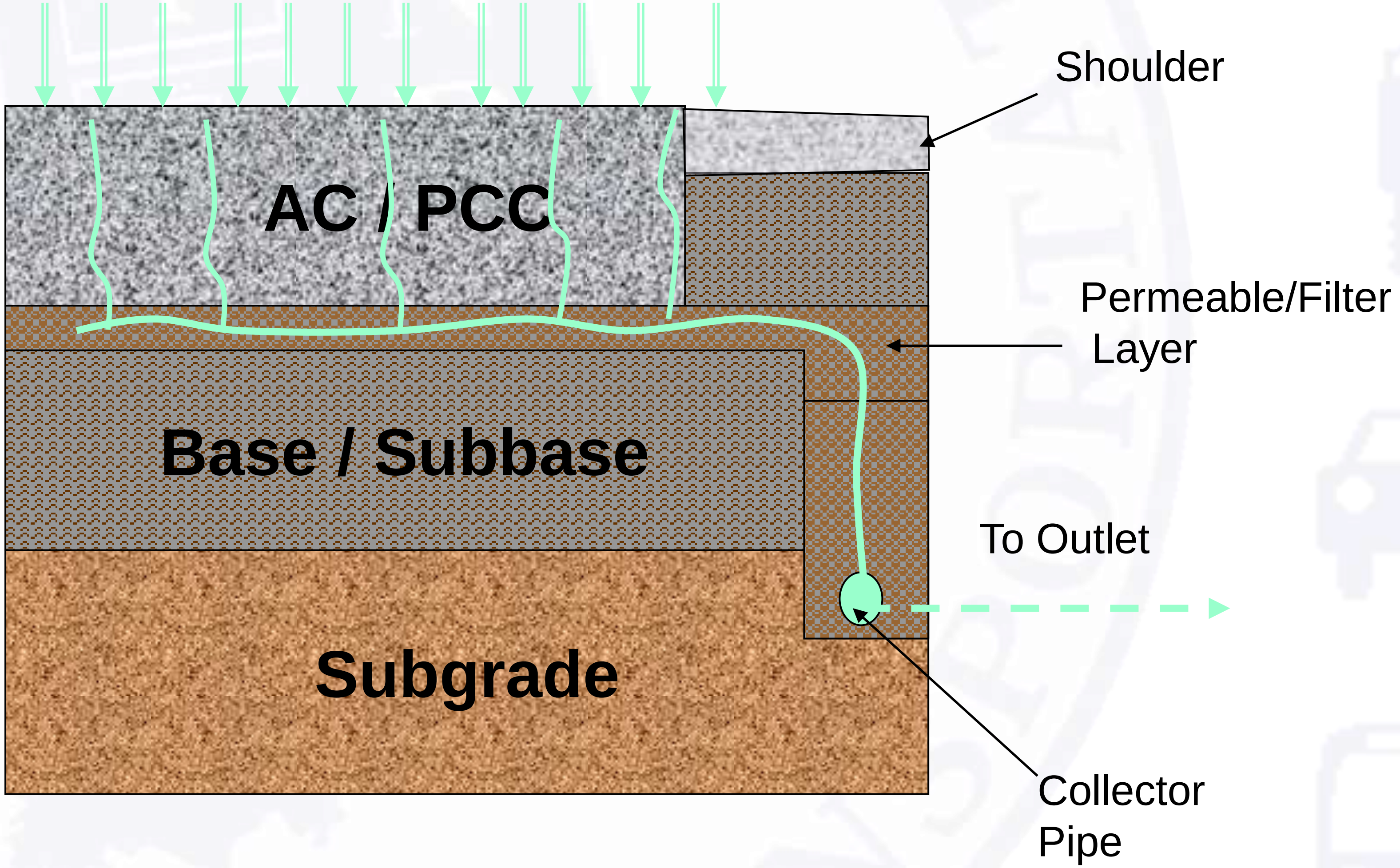
FHWA NHI-05-037
(Geotechnical Aspects of Pavements)

Permeable Base

- Remove infiltrated water from the pavement structure as quickly as possible
- Minimize the occurrence of moisture-related distress
- Maintain pavement stability

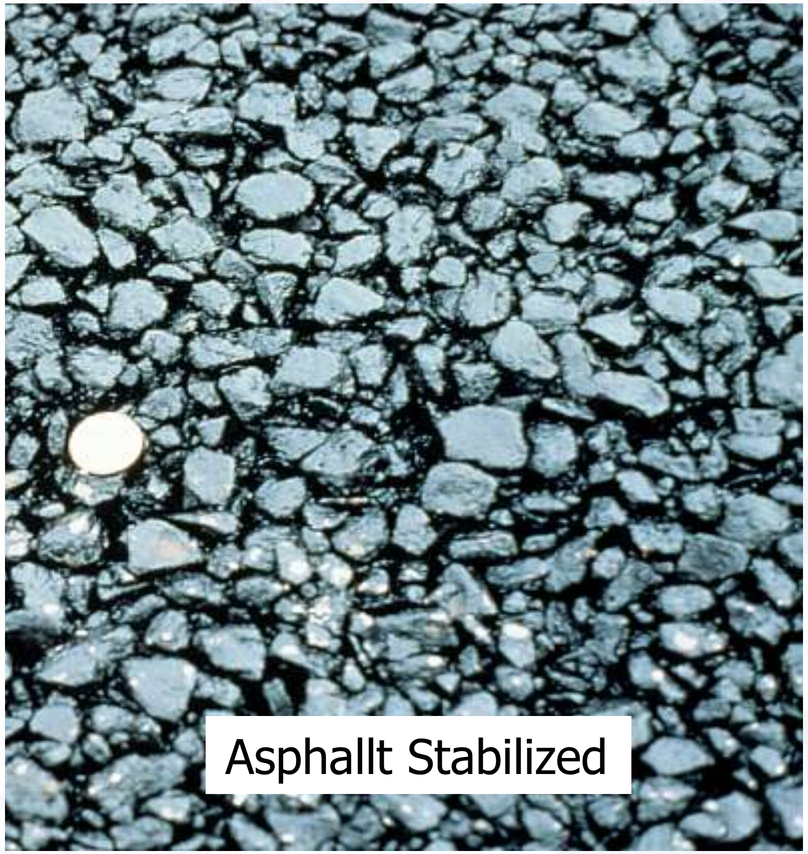
Functions of the Permeable Base Layer

1. Quickly remove infiltrated water
2. Minimize the occurrence of moisture-related distresses
3. Maintain pavement stability



Type of Permeable Bases

- Unstabilized permeable base
- Stabilized permeable base (cement or asphalt)



Common Permeable Base Gradations

Typical Unstabilized Permeable Base Gradations

State	Percent Passing Sieve Size										
	2 in	1 ½ in	1 in	¾ in	½ in	3/8 in	No. 4	No. 8	No. 16	No. 40	No. 5	No. 200
AASHTO #57		100	95-100		25-60		0-10	0-5				
AAHSTO #67			100	90-100		20-55	0-10	0-5				
Iowa			100					10-35			0-1	0-6
Minnesota			100	65-100		35-70	20-45			2-10		0-3
New Jersey		100	95-100		60-80		40-55	5-25	0-12		0-5	
Pennsylvania	100			52-100		33-65	8-40		0-12			0-5

Should provide permeabilities on the order of 1000 to 5000 ft/day

Note that unstabilized permeable bases tend to have more fines (passing No. 200 sieve)

Typical Asphalt Stabilized Permeable Base Gradations

State	Percent Passing Sieve Size					
	1 in	½ in	3/8 in	No. 4	No. 8	No. 200
California	100	90-100	20-45	0-10		0-2
Florida	100	90-100	20-45	0-10	0-5	0-2
Illinois	90-100	84-100	40-60	0-12		
Kansas	100	90-100	20-45	0-10	0-5	0-2
Ohio	95-100			25-60	0-10	
Texas	100	95-100	20-45	0-15	0-5	2-4
Wisconsin	95-100	80-95	25-50	35-60	20-45	3-10
Wyoming	90-100	20-50		20-50	10-30	0-4

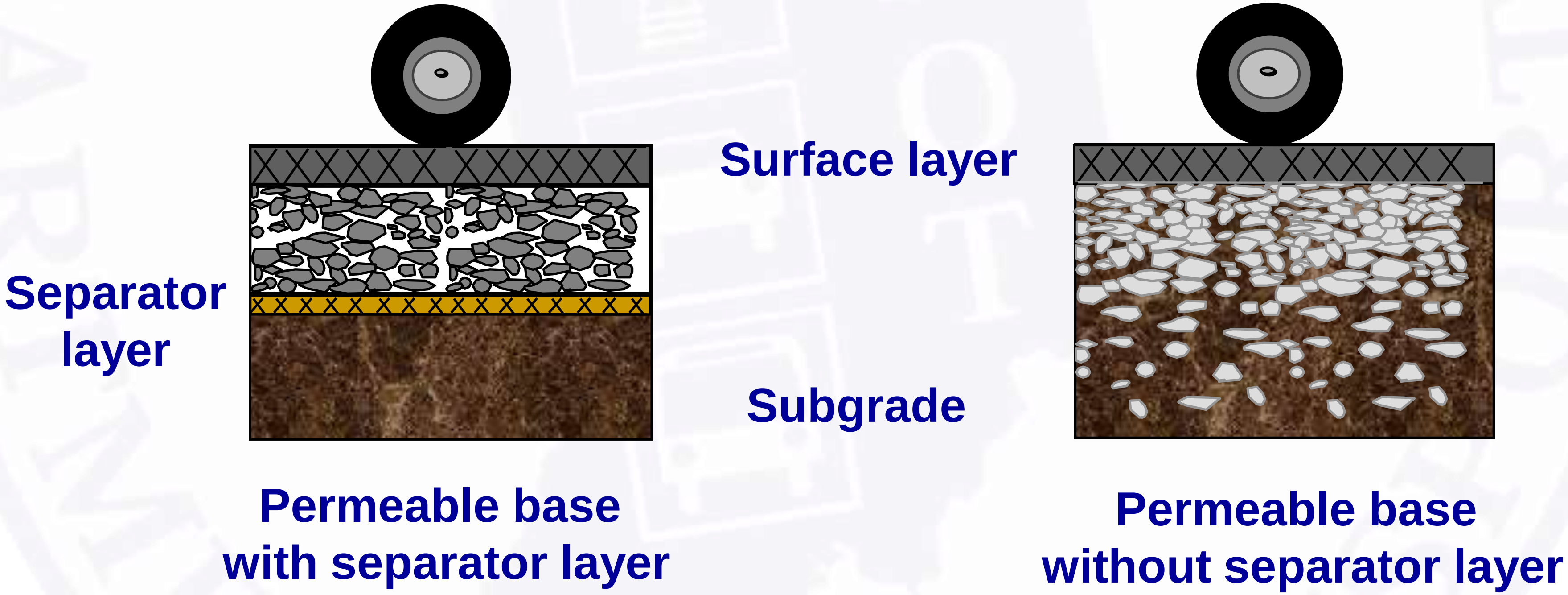
Typical Cement Stabilized Permeable Base Gradations

State	Percent Passing Sieve Size						
	1 ½ in	1 in	¾ in	½ in	3/8 in	No. 4	No. 8
California	100	88-100	X ± 15		X ± 15	0-16	0-6
Virginia		100		25-60		0-10	0-5
Wisconsin		100	90-100		20-55	0-10	0-5

FHWA-HI-99-028
(Pavement Subsurface Drainage Design)

Functions of the Separator Layer

- Keep subgrade soils from contaminating permeable base
- Provide stable working platform for construction
- Deflect infiltrated water into edge drains



Materials Used as Separator Layers

- Dense-graded aggregate (e.g., No. 53)
- Geotextiles (woven and non-woven)


No. 53 Aggregate (SR-46, Bloomington)


Woven Geotextile


Non-woven Geotextile

Factors to Consider in Selecting Separator Layer Type

- Effectiveness
- Cost
- Long-term performance
- Construction
- Nature of project or application
  - Highly Critical: Aggregate/geotextile combination
  - Moderately Critical: Aggregate separator layer
  - Least Critical: Geotextile or aggregate separator layer

Aggregate Separator Layer Gradation Requirements

- Percent fines (passing # 200 sieve) should be less than 12%
- Coefficient of uniformity (C_u) between 20 and 40

$$C_u = \frac{D_{60}}{D_{10}}$$

Table 4-5. Typical gradation requirements for separator layer.

Sieve Size	Percent Passing
$1\,^1/_2$ in	100
$^3/_4$ in	95 – 100
No. 4	50 – 80
No. 40	20 – 35
No. 200	5 – 12

Separator Layer Interface Requirements

With the Subgrade:

$$D_{15(Separator)} < 5\,D_{85(Subgrade)}$$

$$D_{50(Separator)} < 25\,D_{50(Subgrade)}$$

With the Permeable Aggregate Base:

$$D_{15(Permeable\ Base)} < 5\,D_{85(Separator)}$$

$$D_{50(Permeable\ Base)} < 25\,D_{50(Separator)}$$

INDIANA

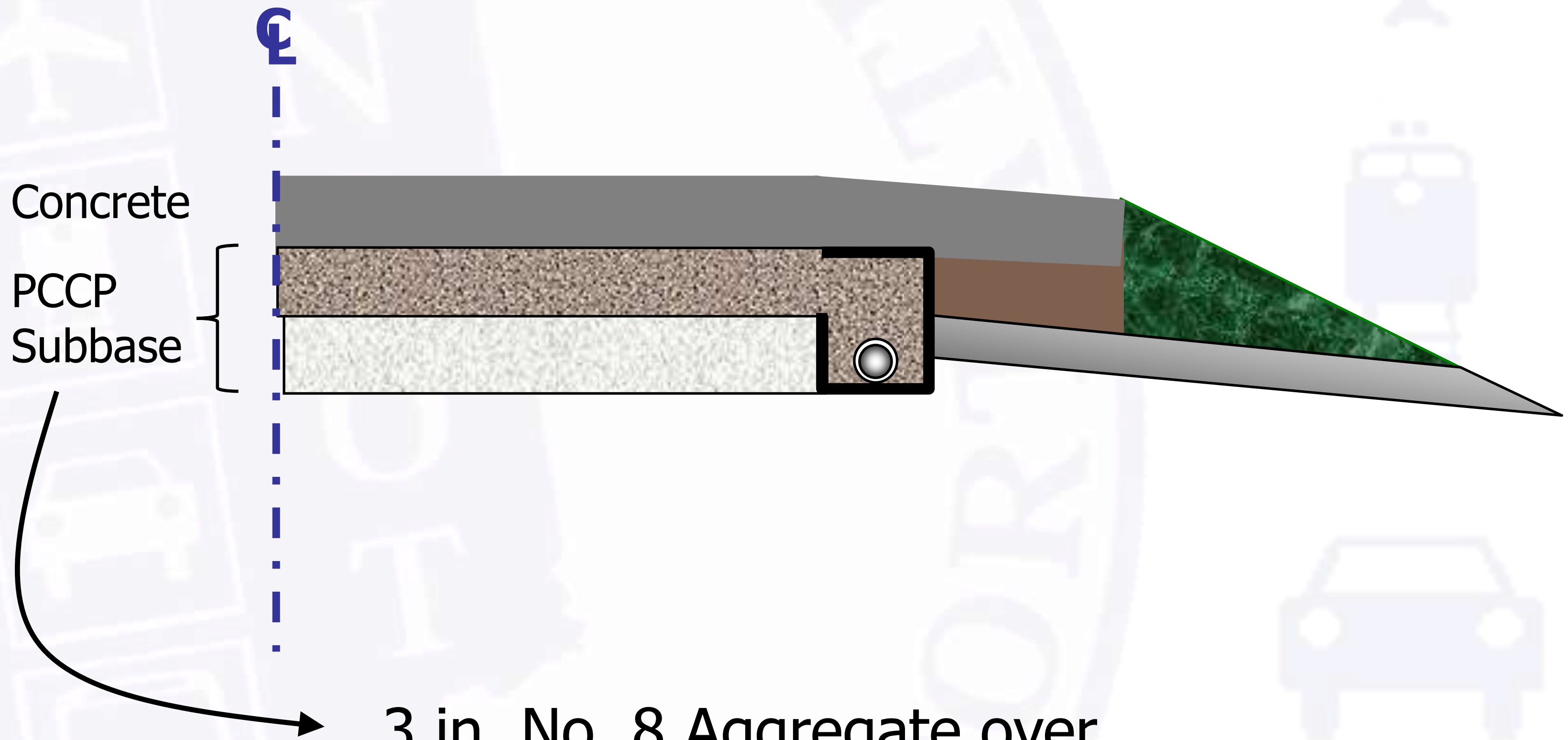
DEPARTMENT
OF
TRANSPORTATION

STANDARD
SPECIFICATIONS

What are INDOT’s current practices for subsurface drainage?

Typical INDOT Subsurface Drainage System for Concrete

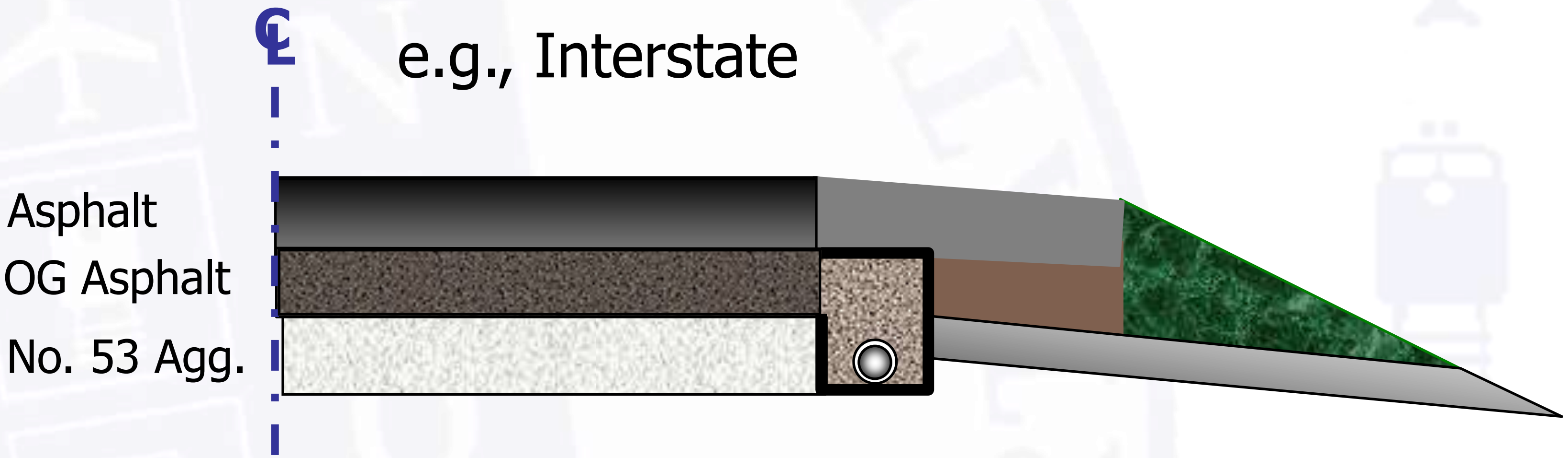
Sieve Sizes	8	53(1)
4 in. (100 mm)		
3 1/2 in. (90 mm)		
2 1/2 in. (63 mm)		
2 in. (50 mm)		
1 1/2 in. (37.5 mm)		100
1 in. (25 mm)	100	80 - 100
3/4 in. (19 mm)	75 - 95	70 - 90
1/2 in. (12.5 mm)	40 - 70	55 - 80
3/8 in. (9.5 mm)	20 - 50	
No. 4 (4.75 mm)	0 - 15	35 - 60
No. 8 (2.36 mm)	0 - 10	25 - 50
No. 16 (1.18 mm)		
No. 30 (600 µm)		12 - 30
No. 200 (75 µm)(2)		5.0 - 10.0(4)
Decant (PCC)(3)	0 - 1.5	
Decant (Non-PCC)	0 - 3.0	
Decant (SC)		

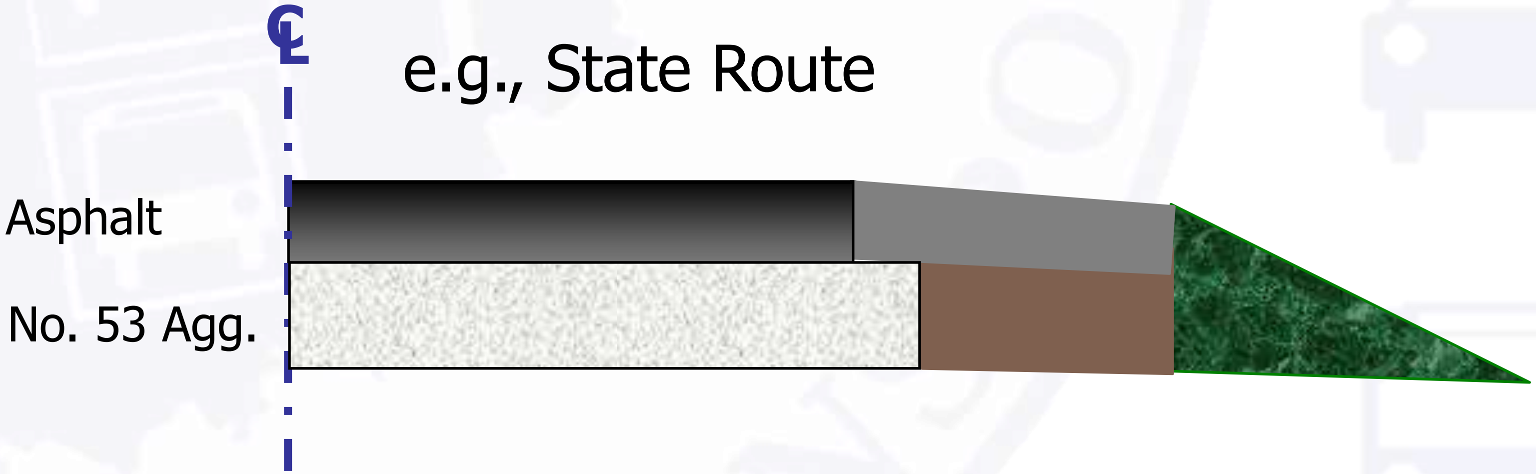


3 in. No. 8 Aggregate over
6 in. No. 53 Aggregate

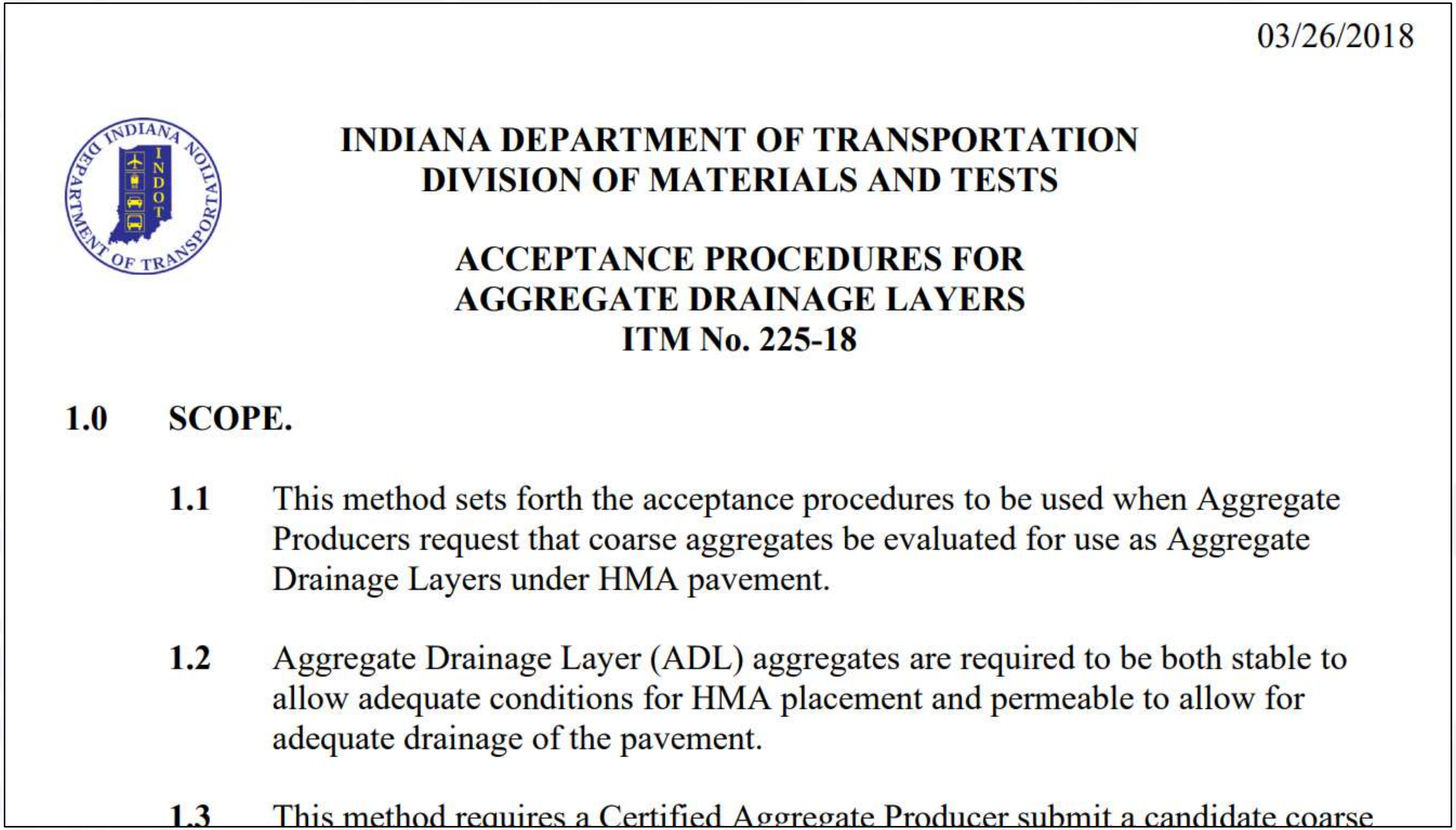
Typical INDOT Subsurface Drainage System for Asphalt

Sieve Sizes	53[1]
4 in. (100 mm)	
3 1/2 in. (90 mm)	
2 1/2 in. (63 mm)	
2 in. (50 mm)	
1 1/2 in. (37.5 mm)	100
1 in. (25 mm)	80 - 100
3/4 in. (19 mm)	70 - 90
1/2 in. (12.5 mm)	55 - 80
3/8 in. (9.5 mm)	
No. 4 (4.75 mm)	35 - 60
No. 8 (2.36 mm)	25 - 50
No. 16 (1.18 mm)	
No. 30 (600 μm)	12 - 30
No. 200 (75 μm)[2]	5.0 - 10.0[4]
Decant (PCC)[3]	
Decant (Non-PCC)	
Decant (SC)	





Aggregate drainage layer specifications



03/26/2018

INDIANA DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS

ACCEPTANCE PROCEDURES FOR
AGGREGATE DRAINAGE LAYERS
ITM No. 225-18

1.0 SCOPE.

1.1 This method sets forth the acceptance procedures to be used when Aggregate Producers request that coarse aggregates be evaluated for use as Aggregate Drainage Layers under HMA pavement.

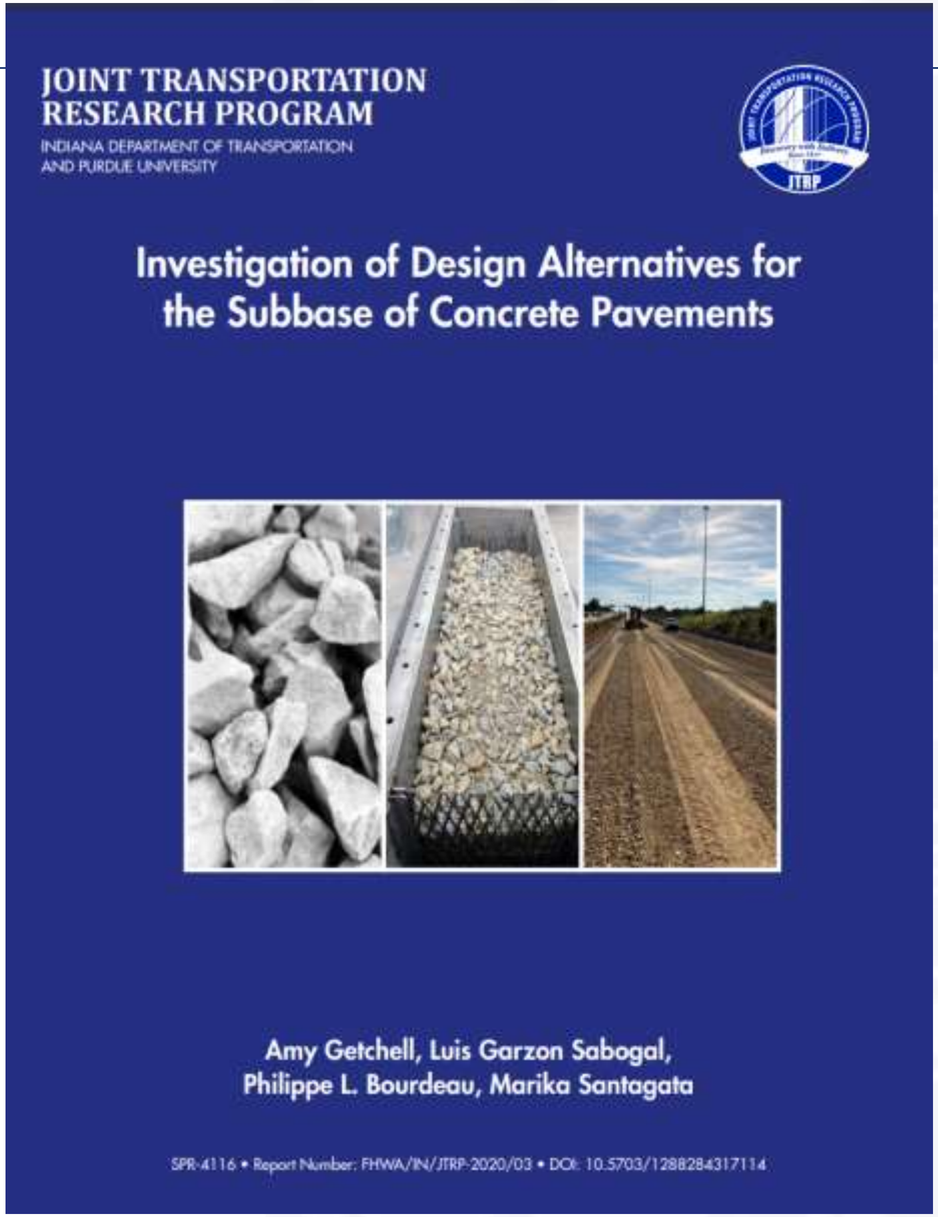
1.2 Aggregate Drainage Layer (ADL) aggregates are required to be both stable to allow adequate conditions for HMA placement and permeable to allow for adequate drainage of the pavement.

1.3 This method requires a Certified Aggregate Producer submit a candidate coarse

Acceptance Procedures for Aggregate Drainage Layers (ITM No. 225-18)

- Approving an Aggregate Drainage Layer Material
  - Permeability (AASHTO T 215) shall be a minimum 350 ft/day and a maximum 1000 ft/day
  - Resilient Modulus (AASHTO T 307) shall be a minimum 15,000 psi
  - Liquid limit (AASHTO T 89) shall be a maximum 25
  - Plasticity Index (AASHTO T 90) shall be a maximum 5
- If the material is approved, then its gradation is established as the target gradation for the approved material (in accordance with ITM 211)

What Research is INDOT sponsoring to improve pavement drainage practices?



JOINT TRANSPORTATION RESEARCH PROGRAM
INDIANA DEPARTMENT OF TRANSPORTATION AND PURDUE UNIVERSITY

Investigation of Design Alternatives for the Subbase of Concrete Pavements

Amy Getchell, Luis Garzon Sabogal, Philippe L. Bourdeau, Marika Santagata

SPR-4116 • Report Number: FHWA/IN/JTRP-2020/03 • DOI: 10.5703/1288284317114

Key Findings:

- Used horizontal permeameter to measure aggregate permeability
- No. 8 aggregate tends to have an unnecessarily high permeability (k > 10,000 ft/day)
- Aggregates for drainage layers are susceptible to segregation—need strict prescribed construction methods

SPR-4327: Development of Compaction Control Guidelines for Aggregate Drainage Layers and Evaluation of In Situ Permeability Testing Methods for Aggregates

Principal Investigators - Peter Becker (INDOT), Marika Santagata, Philippe Bourdeau

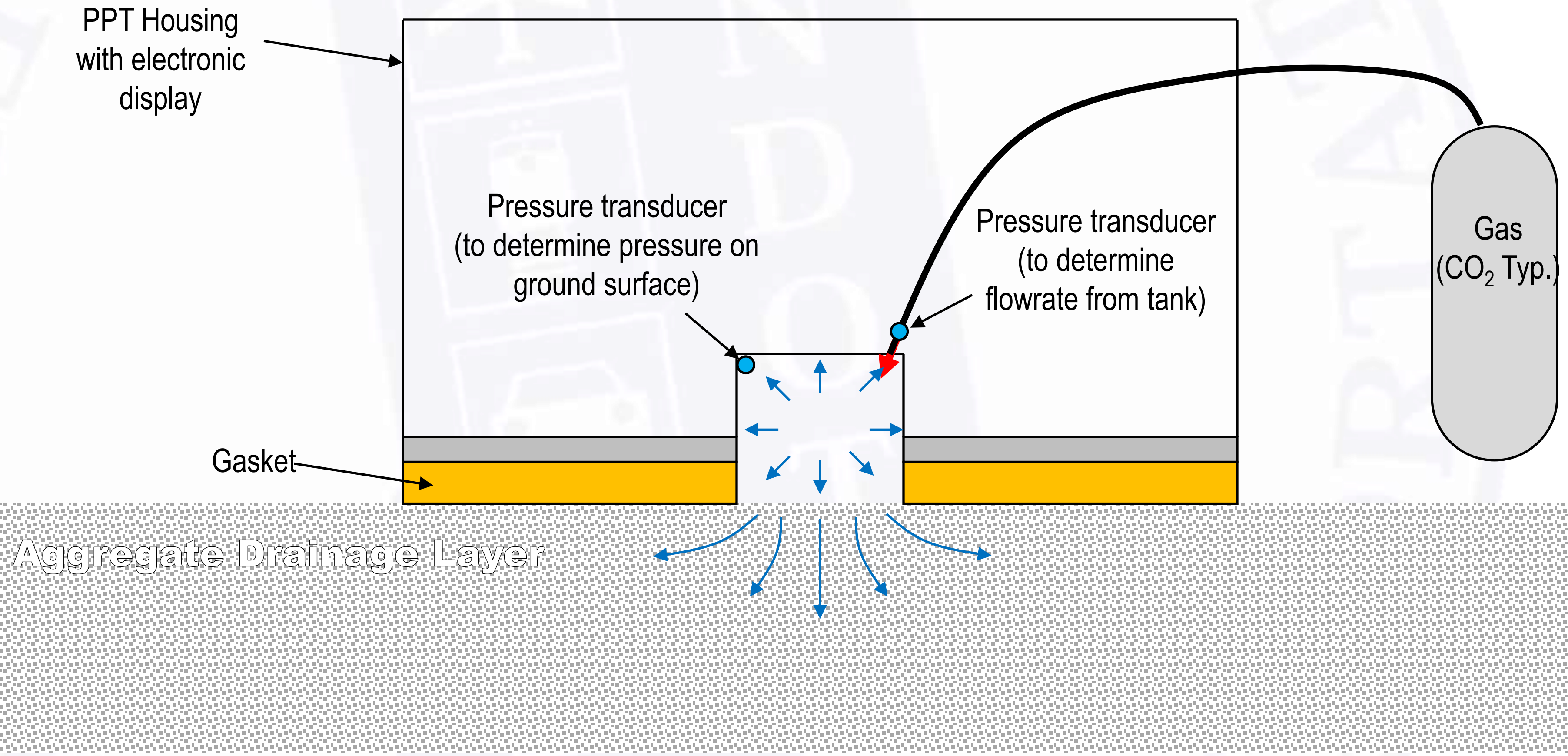
Start Date - 01/01/2019

Objective of this research is to improve the process for aggregate drainage layer construction within INDOT contracts. Results of the study will allow INDOT to move towards standardizing a performance based quality assurance approach for aggregate drainage layer construction.

Pavement Permeameter Test (PPT)

- Used for rapid determination of in situ saturated hydraulic conductivity (permeability) aggregate base and subbase layers
- Developed at Iowa State University
- Manufactured and distributed by Ingios Geotechnics

Permeability In Situ Testing (Performance Specifications)



The pressure within the PPT at the ground surface (relative to atmospheric pressure) for a particular flowrate is used to calculate in situ permeability

Summary

- Pavements (both asphalt and concrete) are highly susceptible to moisture-related damage
- Moisture will inevitably enter pavement structures so best practice is to quickly remove water using subsurface drainage systems
- Typical subsurface drainage systems include a permeable base layer, separator layer, longitudinal drain, and outlet pipe
- Permeable bases and separators are commonly composed of aggregates of varying gradations
- Although INDOT have typical subsurface drainage layouts, we are always looking to improve the current state of practice

Thank you for your attention!

Questions?

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