Pavement Underdrain to Achieve Longer Life Pavement Structure

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Sources of Moisture

Through permeable surface

From edge

Capillary action

Vapor movements

Seepage from high ground

Rising water table

Water table
Surface Infiltration

- **Major source of moisture into pavement**
- **Typical values of infiltration ratios for older pavements**
  - HMA pavement: 33 to 50 percent
  - PCC pavement: 50 to 67 percent
Moisture-Related Damage

- Moisture-related damage falls into three categories
  - Weakening of pavement layers
  - Degradation of pavement material (stripping and erosion of HMA, erosion of other materials, D-cracking of PCC)
  - Loss of bond between layers (pavement stripping)
- All three types of damage can occur simultaneously
Moisture-Related Damage

- More damage when pavement is saturated (e.g., rainy seasons and spring thaw)
- More damage when weakened pavement is subjected to heavy axle loads
Variation of Resilient Modulus with Moisture Content

Resilient Modulus MR, ksi

% Saturation, S

100% AASHTO - T99

95% AASHTO - T99
Moisture-Related Distresses PCC

- Pumping
- Faulting
- Corner cracking
- Transverse cracking
- D-cracking
- Alkali-silica reaction
Pumping
Faulting
Corner break

Punch-out
D-cracking
Moisture-Related Distresses - HMA

- Rutting of unbound layers and subgrade
- Potholes
- Alligator/ fatigue crack deterioration
- Pumping of fines
- Stripping of asphalt
Rutting
Alligator (fatigue) cracking
Pumping
High-severity pothole
AC stripping and erosion
Approaches to Addressing Excess Moisture

- Prevent moisture from entering the pavement
  - Pavement geometry (slopes and ditches)
  - Crack sealing/resealing (HMA)
  - Joint and crack sealing/resealing (PCC)
Crowned Cross Slopes

- 3.7 m (12 ft)
- 1.9 m (6 ft)
- 18.5 m (60 ft)

Layers:
- PCC slab
- Treated base
- Aggregate base
- Subgrade

Shoulder:
- 2%
- 4%

Grading:
- 1:6
- 7:4
Approaches to Addressing Excess Moisture

- Use non-erodible base materials
  - Granular pavement base (open graded)
  - Cement-treated base (CTB), open graded
  - AC-treated base (ATB) with adequate asphalt binder fortified with anti-stripping agents (INDOT specified PG 76-22)
Approaches to Addressing Excess Moisture

- **Other design features that reduce PCC pavement moisture damage**
  - Dowels
  - Tied shoulders
  - Widened lanes
  - Thick granular base (with granular subbase for underdrain)
Approaches to Addressing Excess Moisture

- Quickly remove infiltrated moisture by incorporating drainage systems in pavements
- INDOT Permeable base permeability
  - Granular open graded +/- 8,000 ft/day
  - Stabilized open graded +/- 3,000 ft/day
- FHWA recommendations
  - Time-to-drain of less than 2 hours
    - Permeability values in excess of 300 m/day (1000 ft/day).
Approaches to Addressing Excess Moisture

- Combination of approaches can be used for pavements under heavy traffic
  - Minimize infiltration of moisture
    - Pavement preservations
  - Use non-erodible base materials
    - Granular base (stabilized and non-stabilized)
  - Use design features that reduce moisture damage
    - Provide dowel, ditches, etc.
  - Provide subsurface drainage
Permeable Base

Thick granular/ stabilized open graded permeable base
Permeable Base

- Open-graded drainage layer
- Can be treated or untreated
- Could be daylighted or edgedrained

Cement -treated permeable base
JPCP cross section

9” – 15” JPCP

3” Open graded stone

6” - 12” Dense graded stone

14” Soil treatment

Soil subgrade
HMA pavement cross section

1.5” Surface
2.5” Intermediate
3”+ Dense graded base
3” Open graded base
3” Dense graded base
14” Soil treatment
Soil subgrade
Separator Layer

- A dense-graded aggregate layer or a geotextile layer with low permeability (suitable permeitivity)
- Used along with a permeable base
- Maintains separation between the subgrade and the permeable base
- Deflects surface infiltration towards the edgedrains
Pipe Edgedrains

- Perforated metallic or plastic pipes
- Run along the pavement length
- Interceptor water exiting the pavement

Longitudinal pipe edgedrain
Prefabricated Geocomposite Edge drains

- **PGED**
  - Also called “panel” or “fin” drains
  - Rigid plastic core wrapped with a geotextile
  - Lower hydraulic capacity than a pipe
  - Used in limited retrofit applications
Outlet Pipes

- Short metallic or plastic pipes connected to the edgedrains
  - New project 6” pipe, retrofit is 4” pipe
- Perpendicular to the roadway
- Spaced at regular intervals
  - INDOT is <400 feet, typically 300 feet
- Carry water from edgedrains to the side ditches/storm drains
Side Ditches/ Storm Drains

- Carry water from the outlet pipes and surface runoff away from the pavement
- Should have adequate depth
- In urban locations storm drains are used instead of side ditches to collect water
Types of Subsurface Drainage Systems
Typical Drainage Systems

- **Permeable base system**
  - Permeable base
  - Separator layer
  - Longitudinal edgedrains or daylighting
  - Outlet pipes and ditch or storm drain
Permeable Base System with Edgedrains

- Pavement
- Permeable base
- Shoulder
- Separator layer
- Longitudinal pipe edgedrain
- Rigid outlet pipe
- 150 mm (6 in) outflow
- Ditch
Daylighted Permeable Base

- Pavement
- Shoulder
- Embankment
- Permeable base
- Separator layer
- Subgrade
- Fabric separator
- Ditch
Other Types of Subsurface Drainage Systems

- Longitudinal edgedrain systems with
  - Erodible or non-erodible base
  - Pipe drains or geocomposite drains
  - Outlet pipes and ditch/storm drain

- Non-erodible base with porous concrete shoulder (for PCC pavements)

- Daylighted dense-graded bases (DGAB)
Example Section with Geocomposite Edgedrains

AC/PCC pavement
Aggregate base
Subbase/Subgrade
Sand Backfill

Shoulder
Geocomposite drain

25 mm (1 in)
100 mm (4 in)
Non-erodible Base with Porous Concrete Shoulder

- **PCC pavement**
- **Nonerodible base**
- **Separator layer**
- **Porous concrete**
- **AC Shoulder**
- **Slotted pipe**
- **Geotextile**
Structural Benefits of the Drainage Systems
Subgrade Resilience Modulus

SR-67: A-4 or A-7-6
(Lime Modified Subgrade)

US-231: A-4
(Lime Modified Subgrade)

SR-545: A-4 or A-6

SR-42: A-4 or A-6
Modulus of Subgrade Reaction (k)

SR-61: A-4 or A-6
US-6: A-3 or A-2-4
I-164: A-4 or A-6
US-30: A-6
SR-51: A-3
HMA Equivalent Thickness
PCC Equivalent Thickness

- Drained
- Undrained

Equivalent Thickness

- I-184
- US-30
- US-8
- SR-51
- SR-61
Common Mistakes in Pavement Underdrain
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Summary

- Surface infiltration represents a major source of moisture in the pavement
- Moisture can be detrimental to pavement performance
- Drainage systems should be designed to remove moisture from pavement before damage occurs
Summary

- Pavement drainage system provides significant structural benefits to the pavement structure
- Subsurface drainage is a viable option to address moisture problems
- Various subsurface drainage alternatives exist
QUESTIONS???