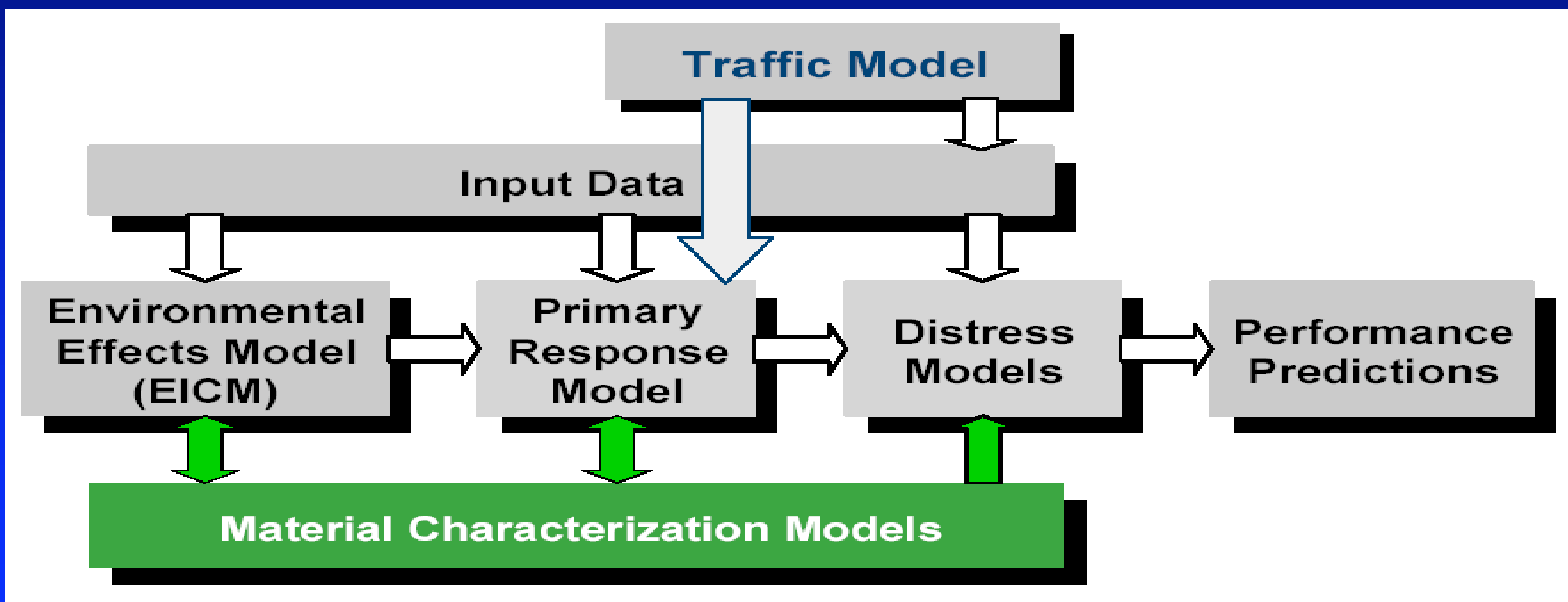
Geosynthetic Subsurface Drainage Systems For Pavements

Foundation Performance Association

January 10, 2007

CONVENTIONAL FLEXIBLE PAVEMENTS

MECHANISTIC-EMPIRICAL FRAMEWORK THE 2002 PAVEMENT DESIGN GUIDE.



Related References

- FHWA, 1992, Demonstration project 87: "Drainable pavement systems", Participant Notebook, FHWA-SA-92-008.
- US Army Corps of Engineers, 1992, "Engineering and design drainage layers for pavements", Engineer Technical Letter, 1110-3-435, Department of Army.
- Cedergren, 1987, "Drainage of highway and airfield pavements", R. E. Krieger publishing Co, FL
- Christopher and McGuffey, 1997, NCHRP Synthesis of highway practice 239, "Pavement subsurface drainage systems", Transportation Research Board.
- Christopher, Hayden, and Zhao, 1999, "Roadway Base and Subgrade Geocomposite Drainage Layers, " ASTM STP 1390, American Society for Testing and Materials, June
- Christopher and Zhao, 2001, "Design manual for roadway geocomposite underdrain systems", Tenax Corporation.

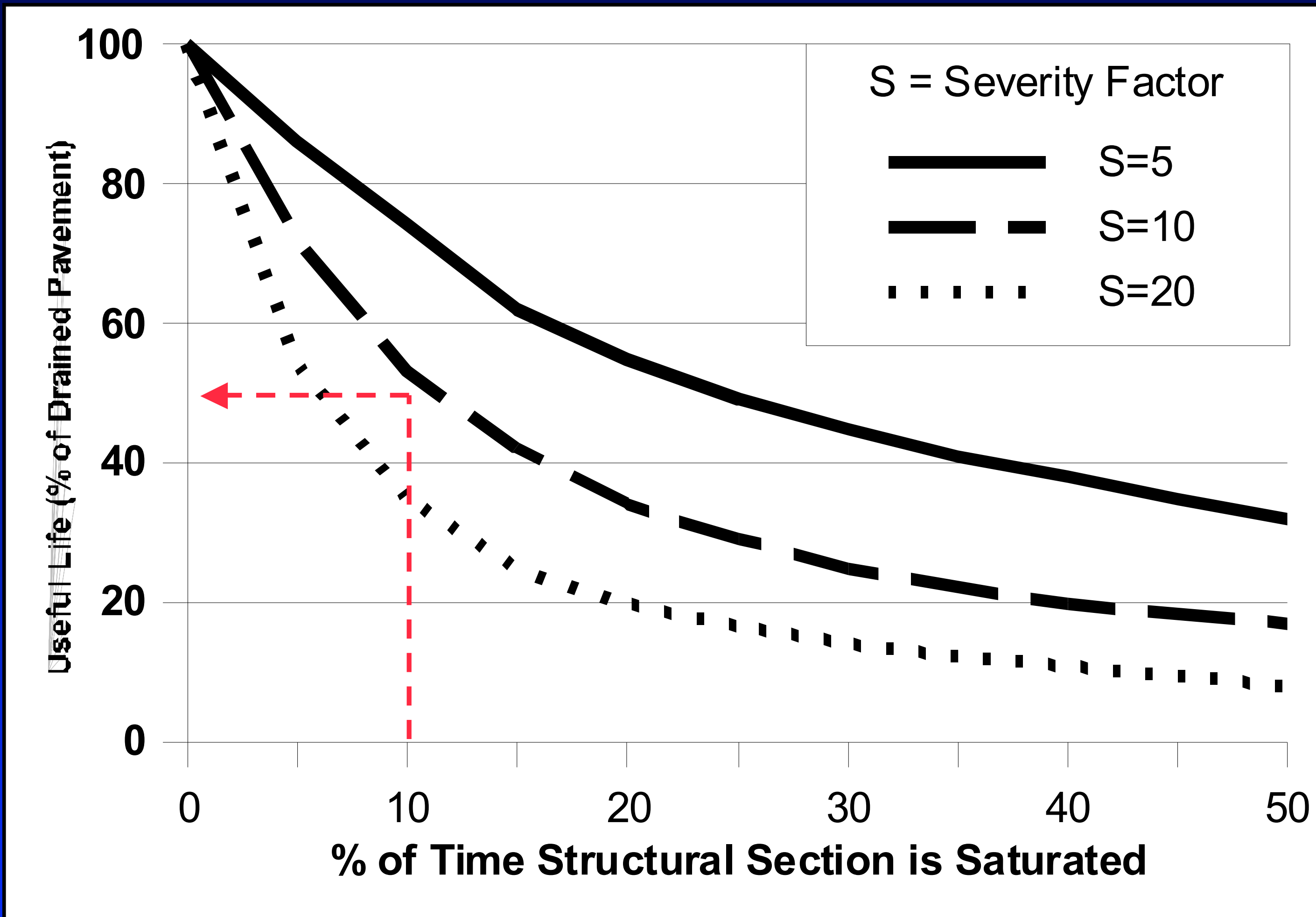
Water in the Pavement Structure → **Primary Cause of Distress**

- INDEX (County Road)
1421

Water in Pavement Systems

AASHTO (1993) reports:

- Water in the asphalt surface
  - Moisture damage, modulus reduction and loss of tensile strength
  - Saturation reduces dry modulus of the asphalt ∃ 30 %
- Moisture in unbound aggregate base and subbase
  - Loss of stiffness ∃ 50 %
- Water in asphalt-treated base
  - Modulus reduction of up to 30 percent
  - Increase erosion susceptibility of cement or lime treated bases
- Saturated fine grained roadbed soil
  - Modulus reductions ∃ 50 %

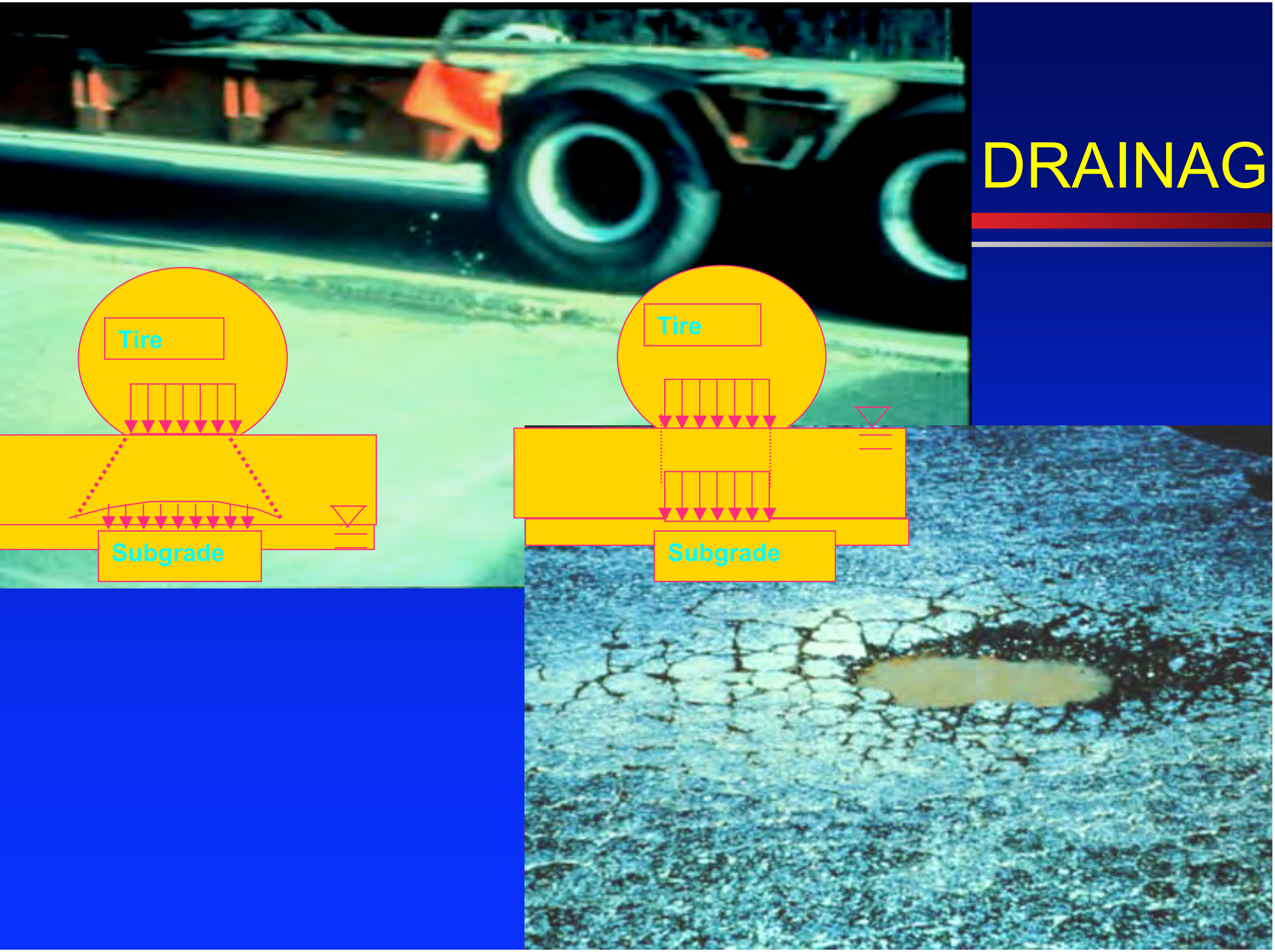


Severity fa
measures
the relative
damage
between w
and dry pe

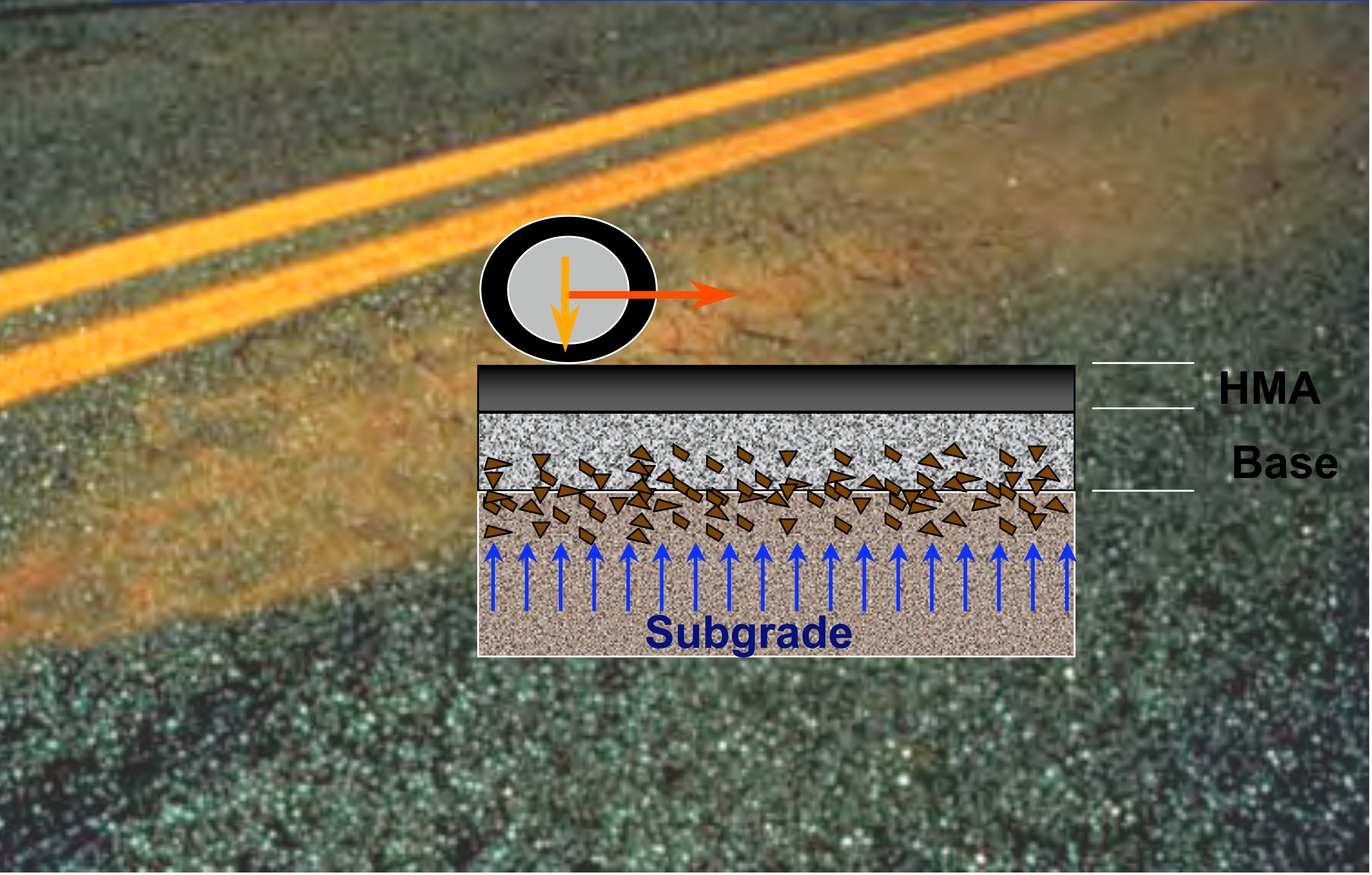
For a pavement section with a moderate severity factor of 10, if 10% of time the pavement is approaching saturation, the pavement service life could be reduced by half.

Ref. Cedergren, H.R. 1987, Drainage of highway and airfield pavements, Robert E Krieger Publishing C

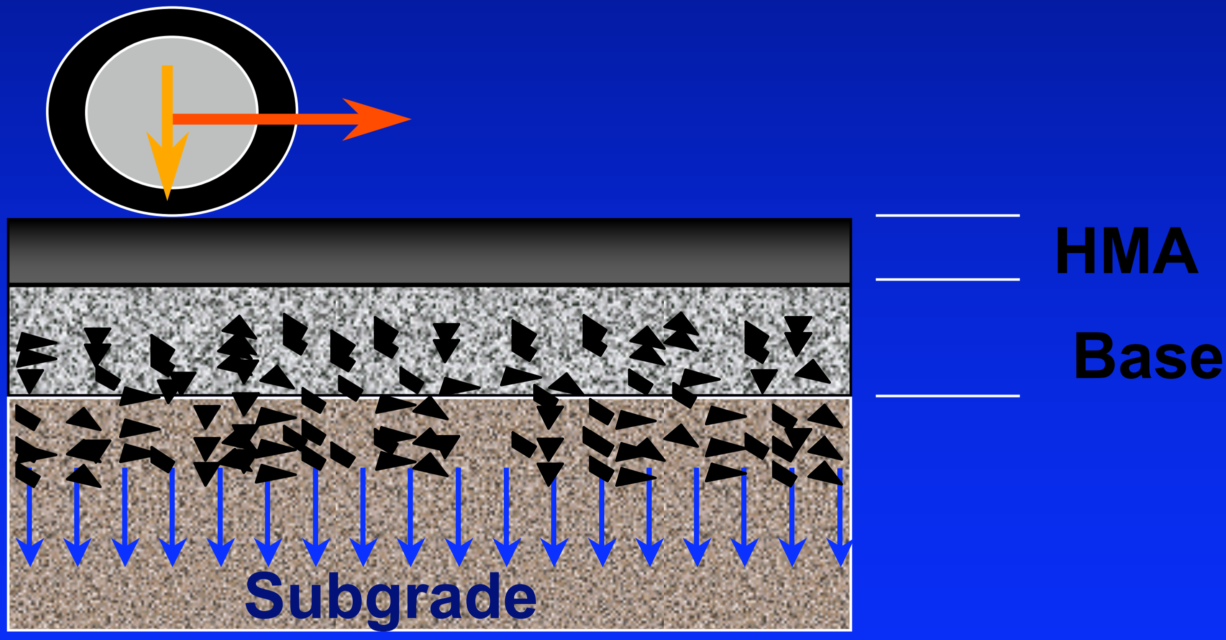
DRAINAG



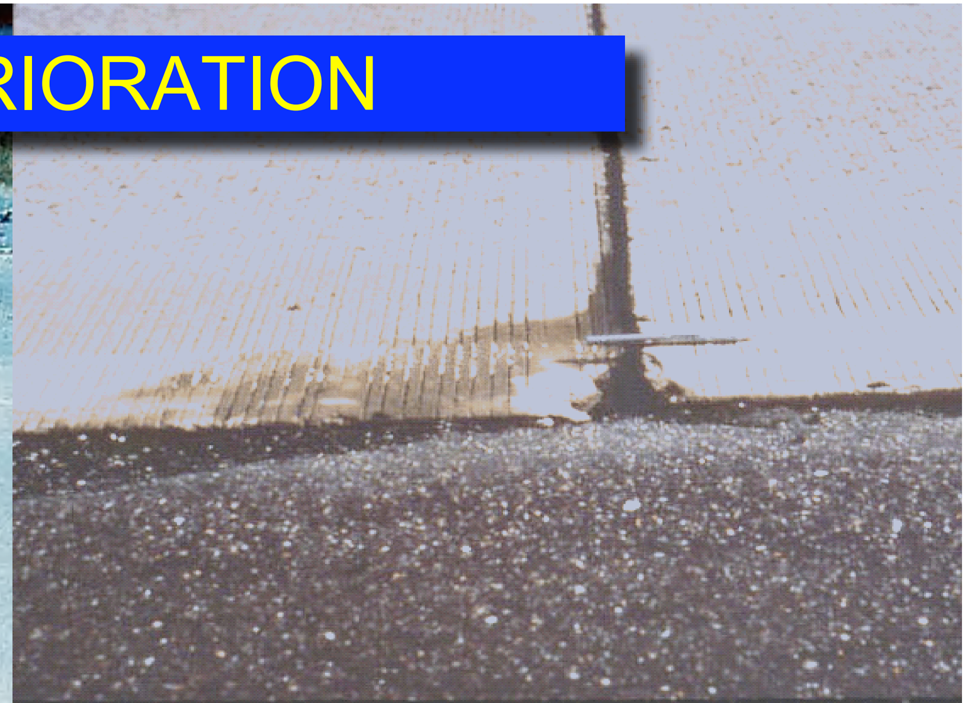
CONTAMINATION/ PUMPING

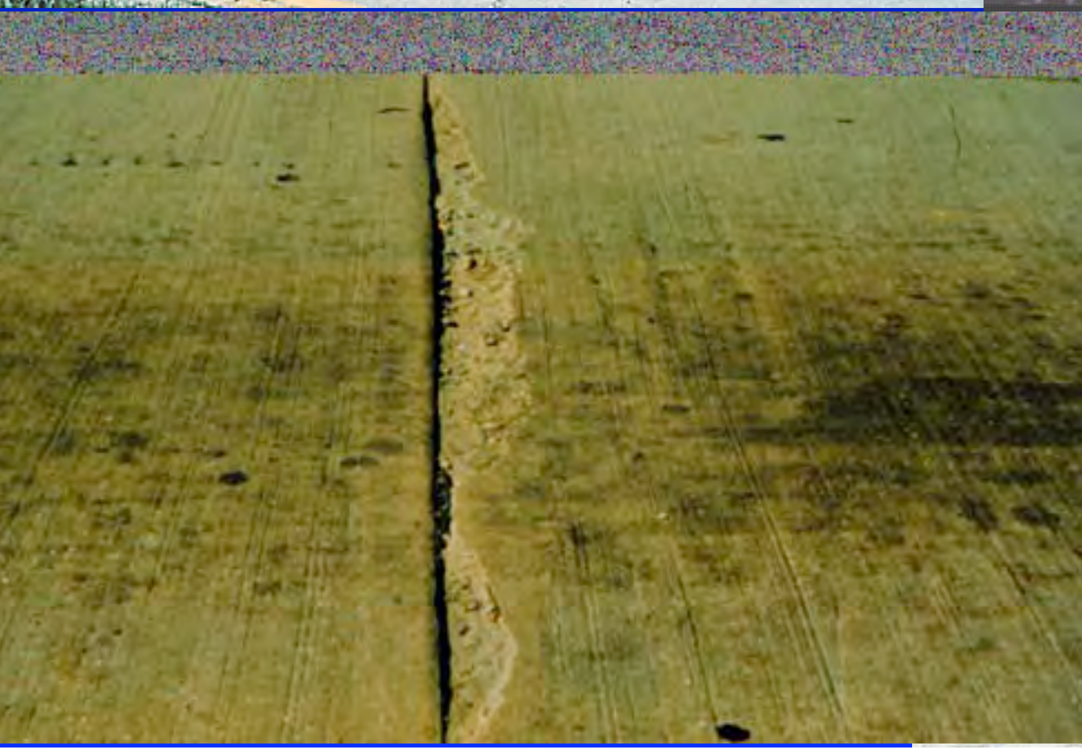


AGGREGATE PENETRATION



JOINT DETERIORATION



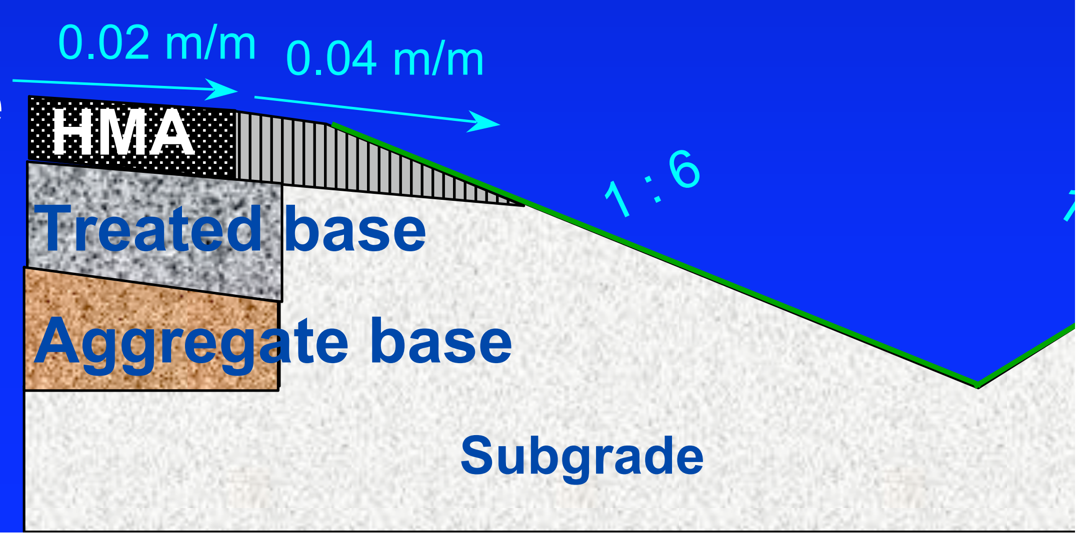


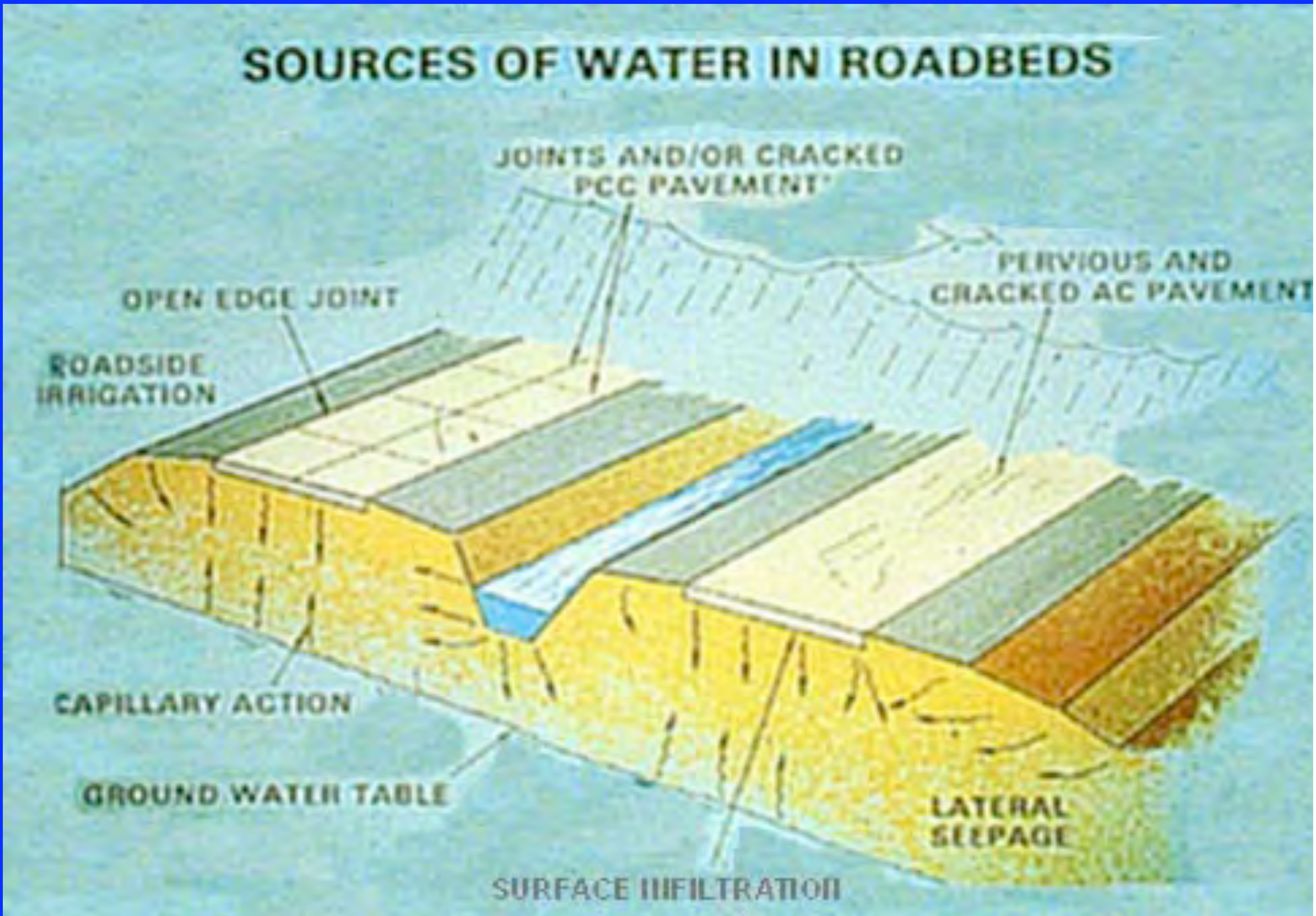
Water in Pavements Summary

- Stripping in HMA
- Loss of Subgrade Support
- Reduction of Granular Layer Stiffness
- Erosion of Cement-Treated Base Layers
- Reduction in the Pavement Service Life If Base Is Saturated for Sometime
- Debond between Layers

HOW TO ADDRESS THE PROBLEM?

- Pavement geometry (slopes and ditches)
- Crack sealing
- Treated Layer
- Thicker Layers
- Full Width
- Subsurface Drainage



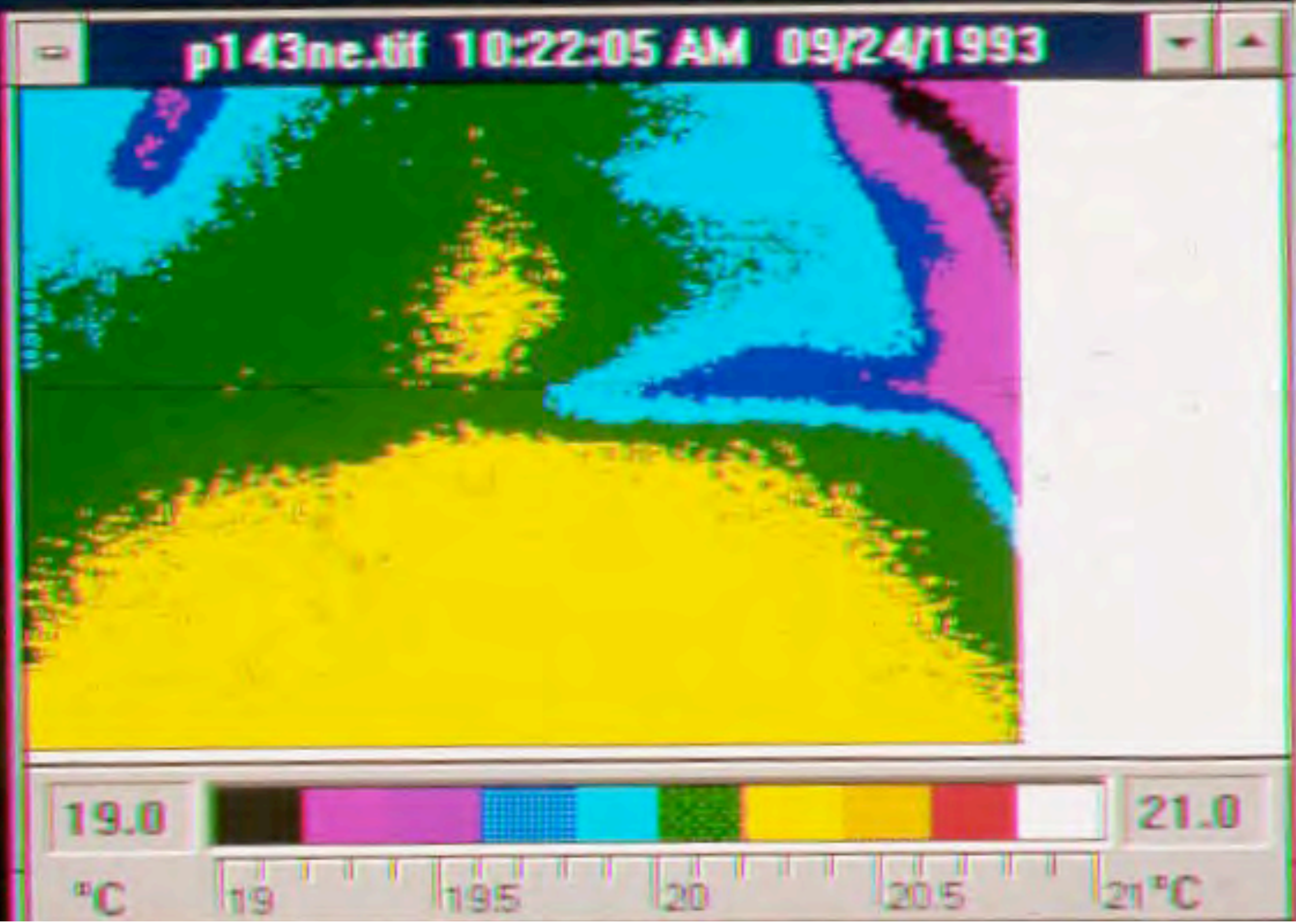

SOURCES OF WATER IN ROADBEDS
JOINTS AND/OR CRACKED PCC PAVEMENT
PERVIOUS AND CRACKED AC PAVEMENT
OPEN EDGE JOINT
ROADSIDE IRRIGATION
CAPILLARY ACTION
GROUND WATER TABLE
LATERAL SEEPAGE
SURFACE INFILTRATION

Precipitation Runoff Into Surfac
Cracks In PCC

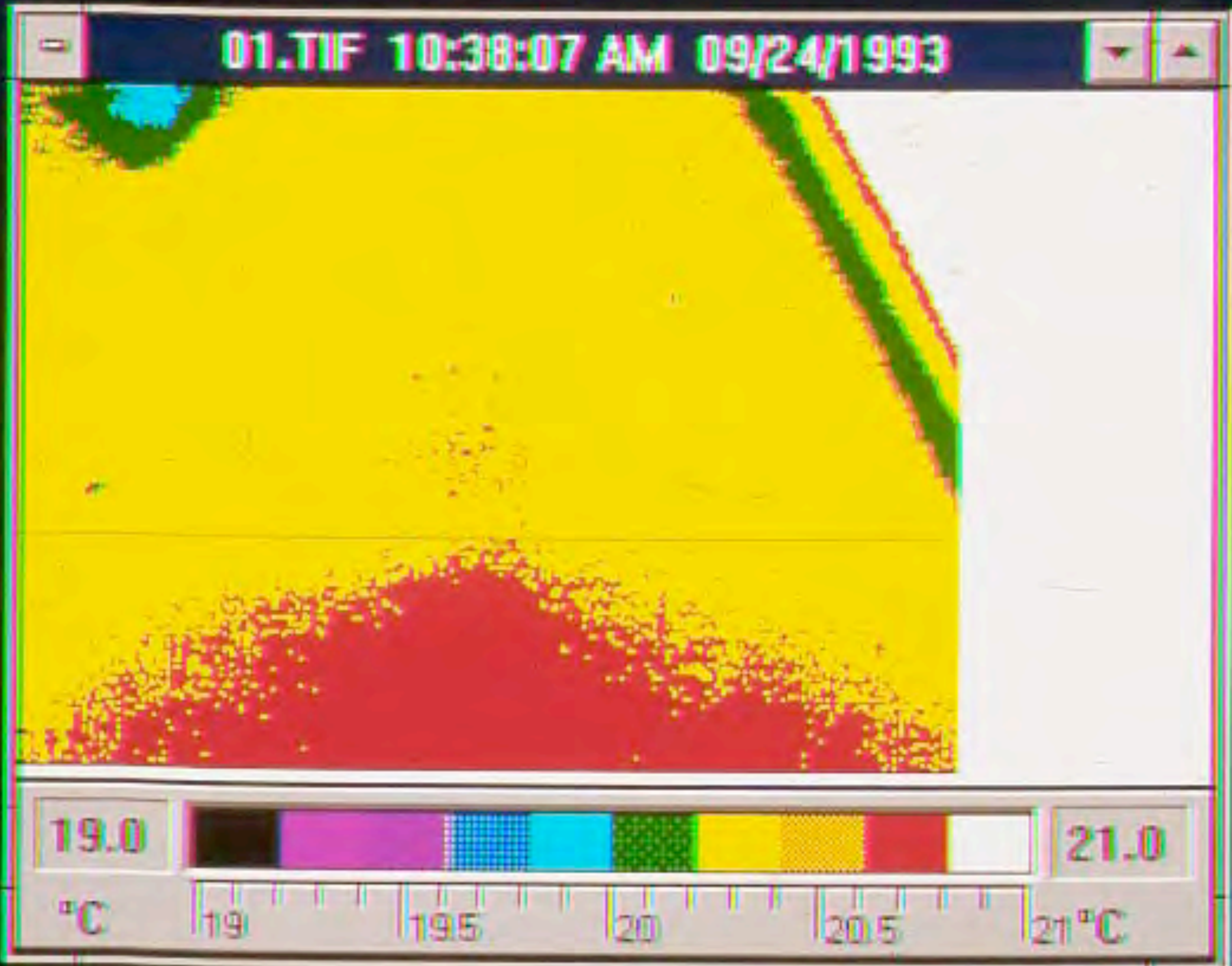
(2 in./Hour Event)

Crack Width (in.)	Pavement Slope (%)	Percent Of Run entering crack (
0.035	2.50	76
0.050	2.50	89
0.125	2.50	97

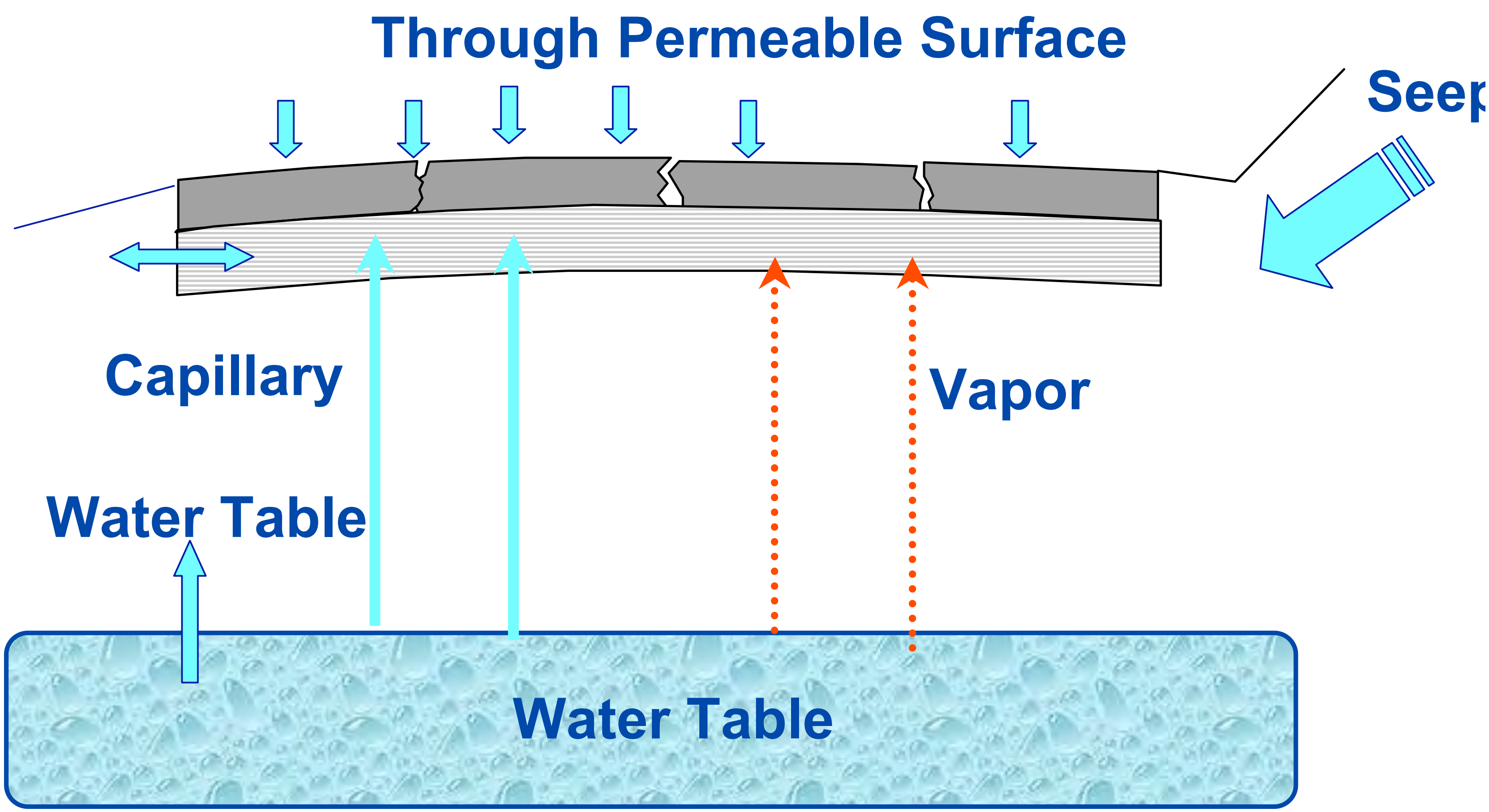
INFRARED SCAN OF PCC PAVEMENT WITHOUT EDGE DRAINS



INFRARED SCAN OF PCC PAVEMENT WITH EDGE DRAINS



Capillary Rise



Three important components for a good pavement design

Drainage

Drainage

Drainage

AASHTO Drainage Definitions

Quality of Drainage	Water Removed Within*
Excellent	2 Hours
Good	1 Day
Fair	1 Week
Poor	1 Month
Very Poor	Water will not Drain

*Based on time to drain

AASHTO Guide for Design of Pavement Structur

Design for Drainage

(AASHTO, 1993 Design Method)

Structural Number (SN) for a pavement section is:

$$SN = a_1*d_1 + a_2*d_2*m_2 + a_3*d_3*m_3$$

- a_1 a_2 a_3 = layer coefficients for AC, BC and Sub base laye
- d_1, d_2, d_3 = their thickness
- m_2, m_3 = drainage coefficients for the base and sub base la
- $\log_{10}W_{18} = (Z_R)(S_0) + (9.36)(\log_{10}(SN+1) - 0.20 + \log_{10}[\Delta PSI/($

  $1.5)]/[0.40 + (1.094/(SN+1)^{5.19})] + (2.32)(\log_{10}M_R) - 8$

Recommended Drainage Coefficient, m_i, fo
Flexible Pavements

Quality of Drainage	Percent of Time Pavement Structure is Exposed Moisture Levels Approaching Saturation			
	Less Than 1%	1-5%	5-15%	Great Than 2
Excellent	1.40-1.35	1.35-1.30	1.30-1.20	1.20
Good	1.35-1.25	1.25-1.15	1.15-1.00	1.00
Fair	1.25-1.15	1.15-1.05	1.00-0.80	0.80
Poor	1.15-1.05	1.05-0.80	0.80-0.60	0.60
Very Poor	1.05-0.95	0.95-0.75	0.75-0.40	0.40

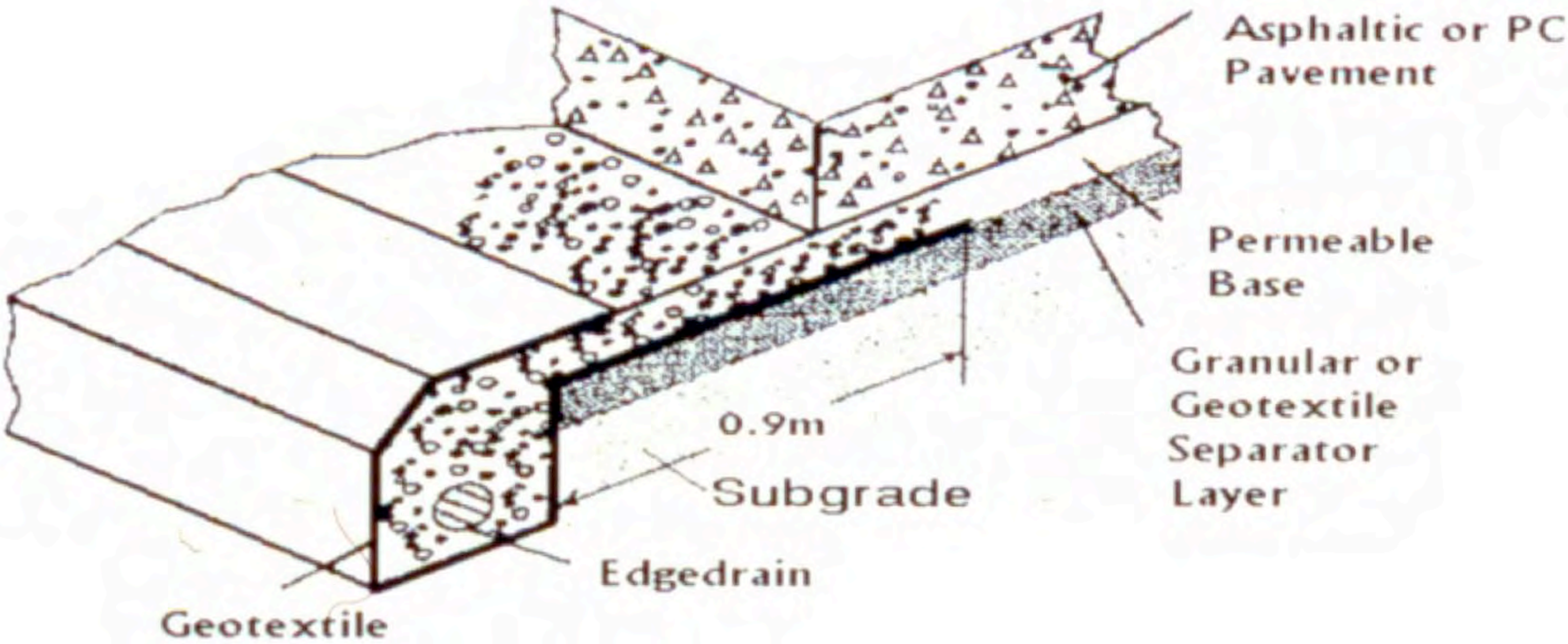
AASHTO Guide for Design of Pavement Structur

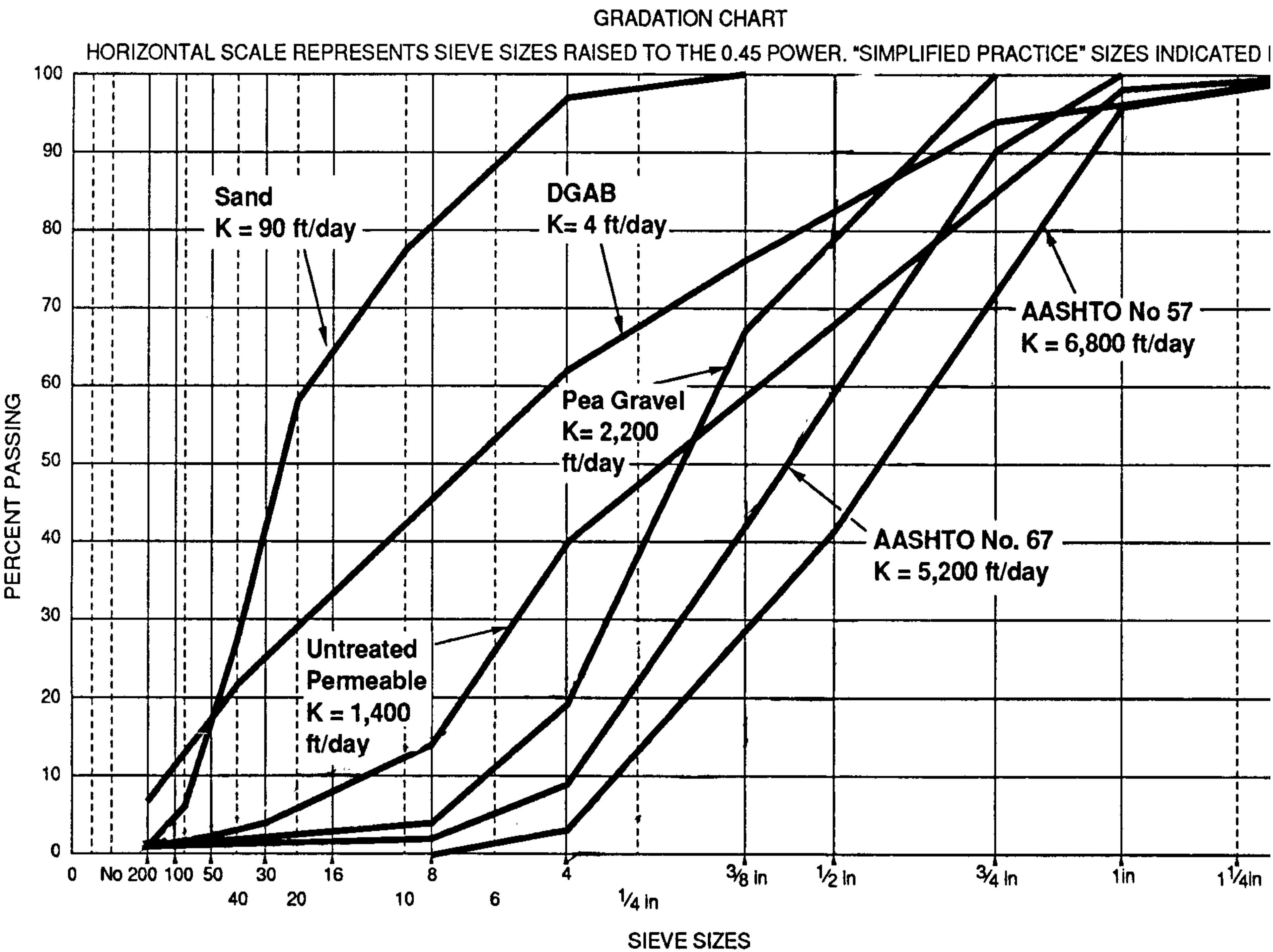
Time to drain

- For two lane road - Lane width = 24 ft, Slope = 0.01

Base	k	time to drain	Quality
OGB	1000 ft/day	2 hrs to drain	Excelle
DGAB	1 ft/day	1 week	Fair
DGAB w/ fines	0.1 ft/day	1 month	Poor
Reality	no drains	does not drain	Very P

Pavement Drainage




GRADATION CHART
HORIZONTAL SCALE REPRESENTS SIEVE SIZES RAISED TO THE 0.45 POWER. "SIMPLIFIED PRACTICE" SIZES INDICATED I
PERCENT PASSING
0
10
20
30
40
50
60
70
80
90
100
Sand
K = 90 ft/day
DGAB
K= 4 ft/day
Pea Gravel
K= 2,200
ft/day
Untreated
Permeable
K = 1,400
ft/day
AASHTO No 57
K = 6,800 ft/day
AASHTO No. 67
K = 5,200 ft/day
0
No 200
100
50
40
30
20
16
10
8
6
4
1/4 in
3/8 in
1/2 in
3/4 in
1in
1 1/4in
SIEVE SIZES




SUBSURFACE DRAINAGE

OGDL → EDGE DRAIN

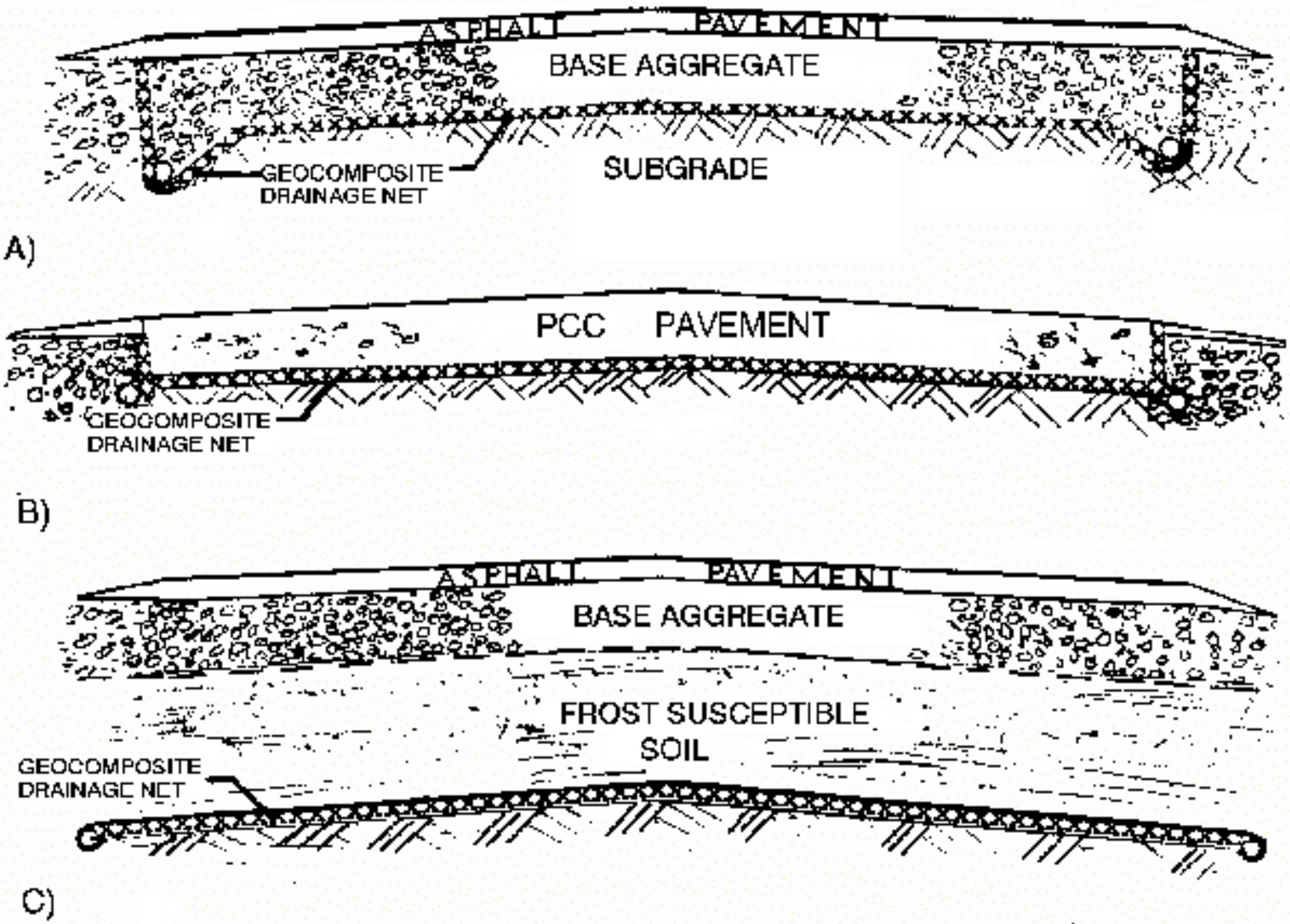
Crushed Ou

Clogged Outlet

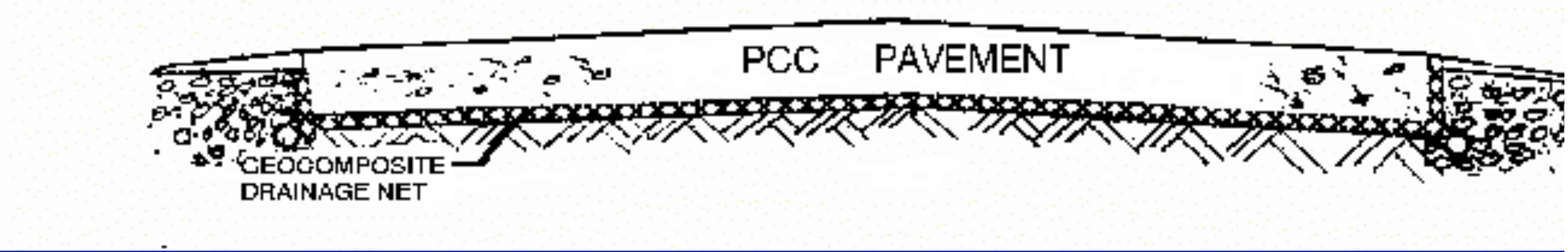

DRAIN
OUTLET

Geocomposite Drainage Layers

Uses of Horizontal Geocomposite Drainage Layers



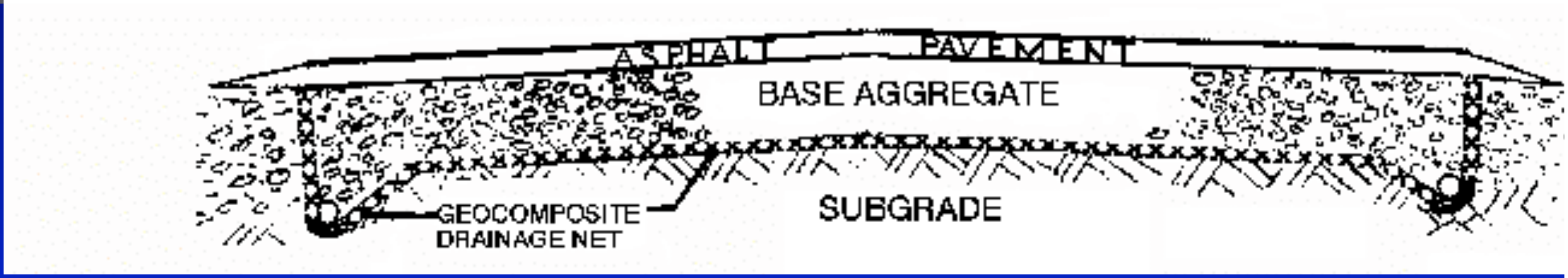
Geocomposite Drainage Layer Solutions - Replace OGAB



Drainage

- For Rigid Pavements
  - Improved Design
  - > Cd
- For Flexible Pavements
  - Improved design life

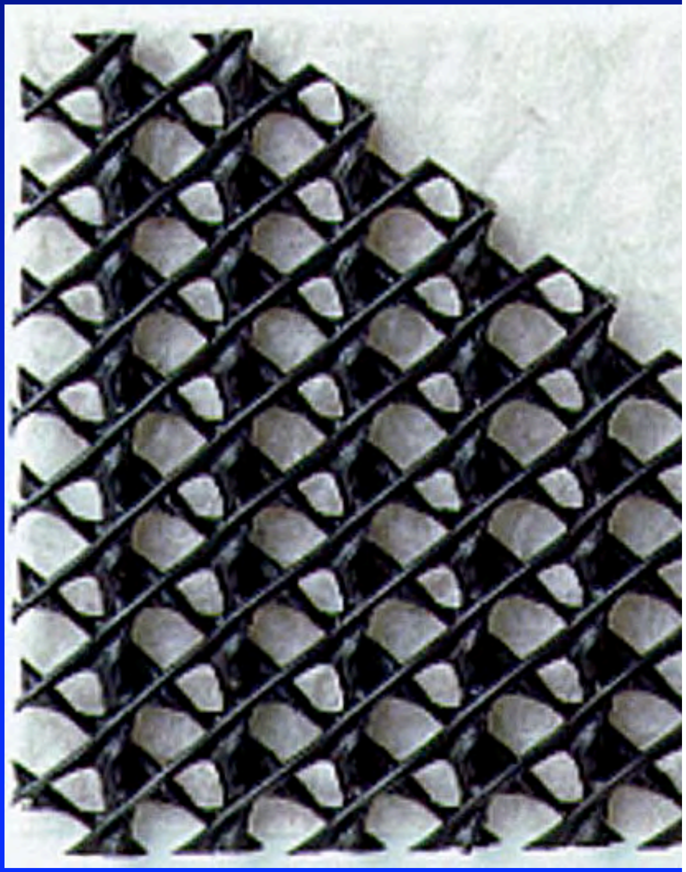
Geocomposite Drainage Layer Solutions - Improve Performance of DGAB



- Drainage -
  - Improved Pavement Design
  - > m or C_d
  - > SN
- Separation
  - Improved long term performance
- Stabilization
  - Improved construction
- Reinforcement
  - Improved Support - LCR

Geocomposite Drain Requirements

- Sufficient stiffness to support traffic without significant deformation under dynamic loading
- Inflow capacity > infiltration from adjacent layers
- Sufficient transmissivity to rapidly drain the pavement section and prevent saturation of the base
- Sufficient air voids within geo-composite to provide a capillary break



Drainage Geocomposite - Important Properties

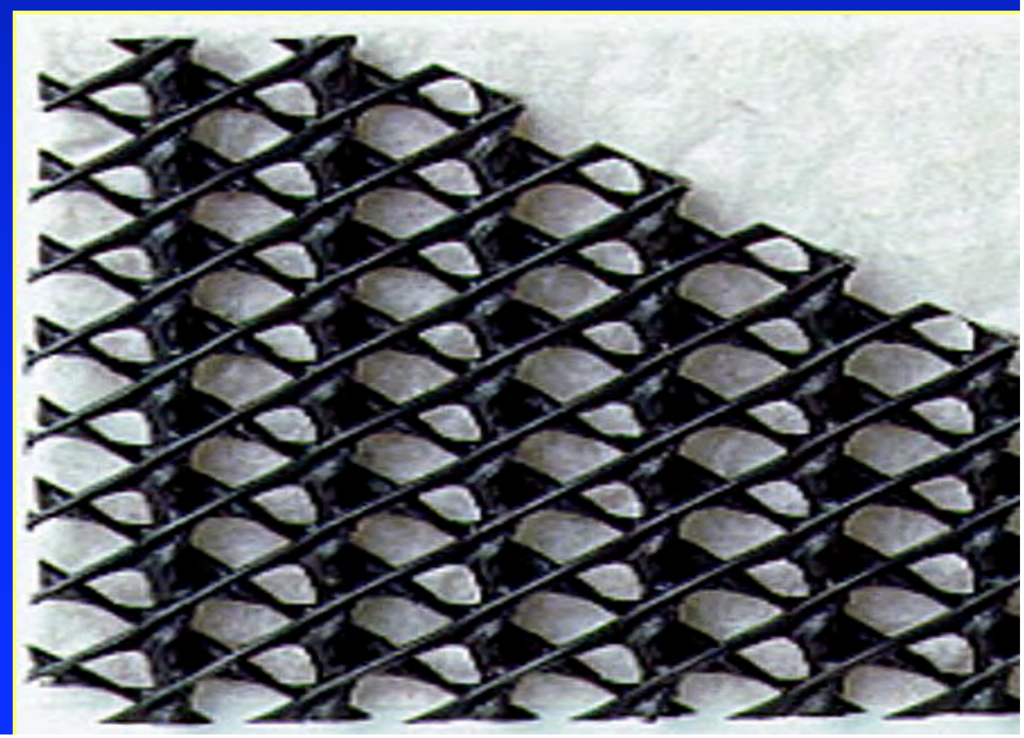
- Transmissivity = 4500 ft^2/day (0.005 m^2/sec)
  - Estimated Discharge: 30 ft^3/day /ft
- Creep Resistance under high Loads
- Long-term Resistance to Compression
- Stability Traffic Loads = Univ. of Illinois Study
- Effective Porosity = 0.7
- Geotextile Filtration Requirements

Tri-Planar Important Properties (Cont.)

- Transmissivity = 4500 ft^2/day (0.005 m^2/sec):
  - Transmissivity of 4in-OGDL (k =1000–3000 ft/day) = 3 1000 ft^3/day/ft
    - **OGDL flow rate @2% = 6–20 ft^3/day/ft**
  - Transmissivity of tri-planar = 1500 ft^3/day/ft @15ksf (considering an equivalency factor between tri-planar a soil drains)
    - **Tri-planar flow rate @2% = 30 ft^3/day/ft**

Tri-Planar Drainage System

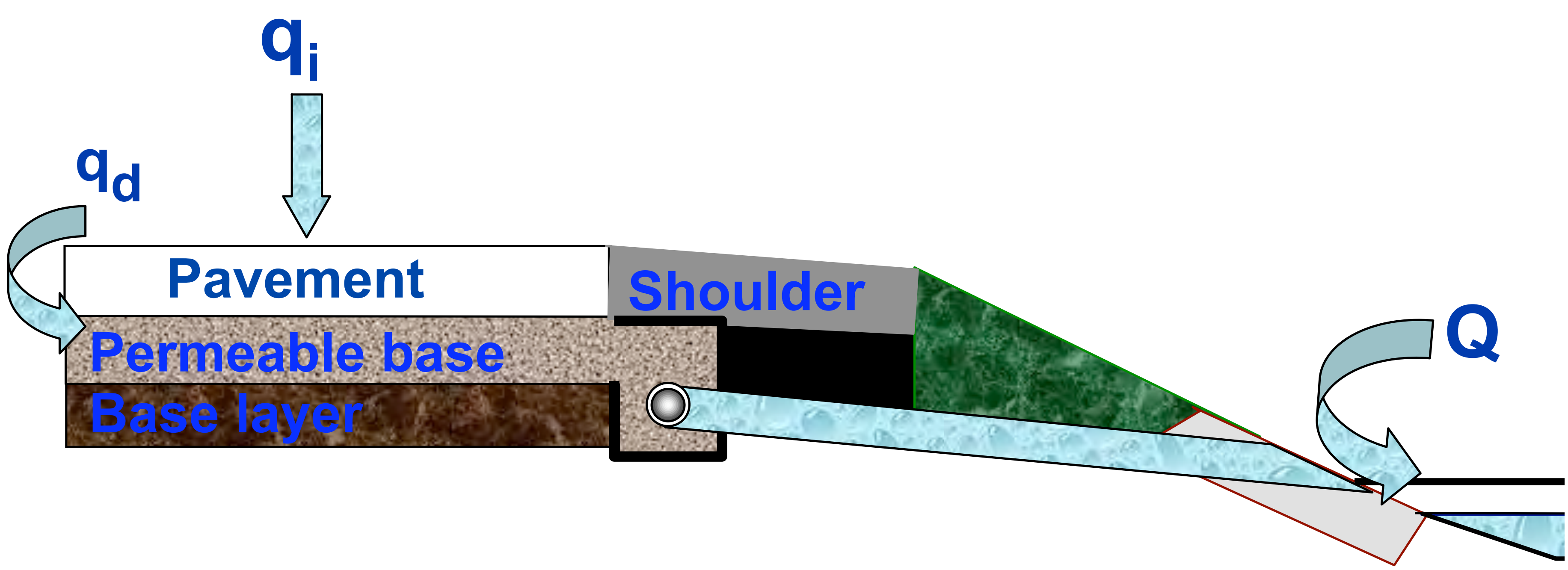
- Replaces OGDL
- Provides Excellent Drainage Capability
- Capillary Break
- May Provide Strain Energy Absorption Capabilities



Time-to-Drain Design Assumptions

- During a rainfall event water infiltrates into the permeable base until it is saturated
- Excess rainwater runs off to a side ditch
- Time required to drain certain amount of water from the drainage layer after a rain event

Time-to-Drain



AASHTO Drainage Definitions
(For Pavements - 50% time to drain)

Quality of Drainage	Water Removed Within
Excellent	2 Hours
Good	1 Day
Fair	1 Week
Poor	1 Month
Very Poor	Water will not Drain

- For Interstate highways: 50% drained in 2 hrs
- If heavy traffic, in 1 hr

AASHTO Guide for Design of Pavement Structur

RoaDrain Time to Drain

- Case 1 - Beneath Pavement
  - Time to Drain < 2 min
- Case 2 - Beneath Subbase
  - for 12 in subbase with k = 1 ft/day
  - Time to drain ~ 1 hours
- Case 3 - Base drainage alone
  - Time to drain ~ 840 hours

Potential Cost Benefit

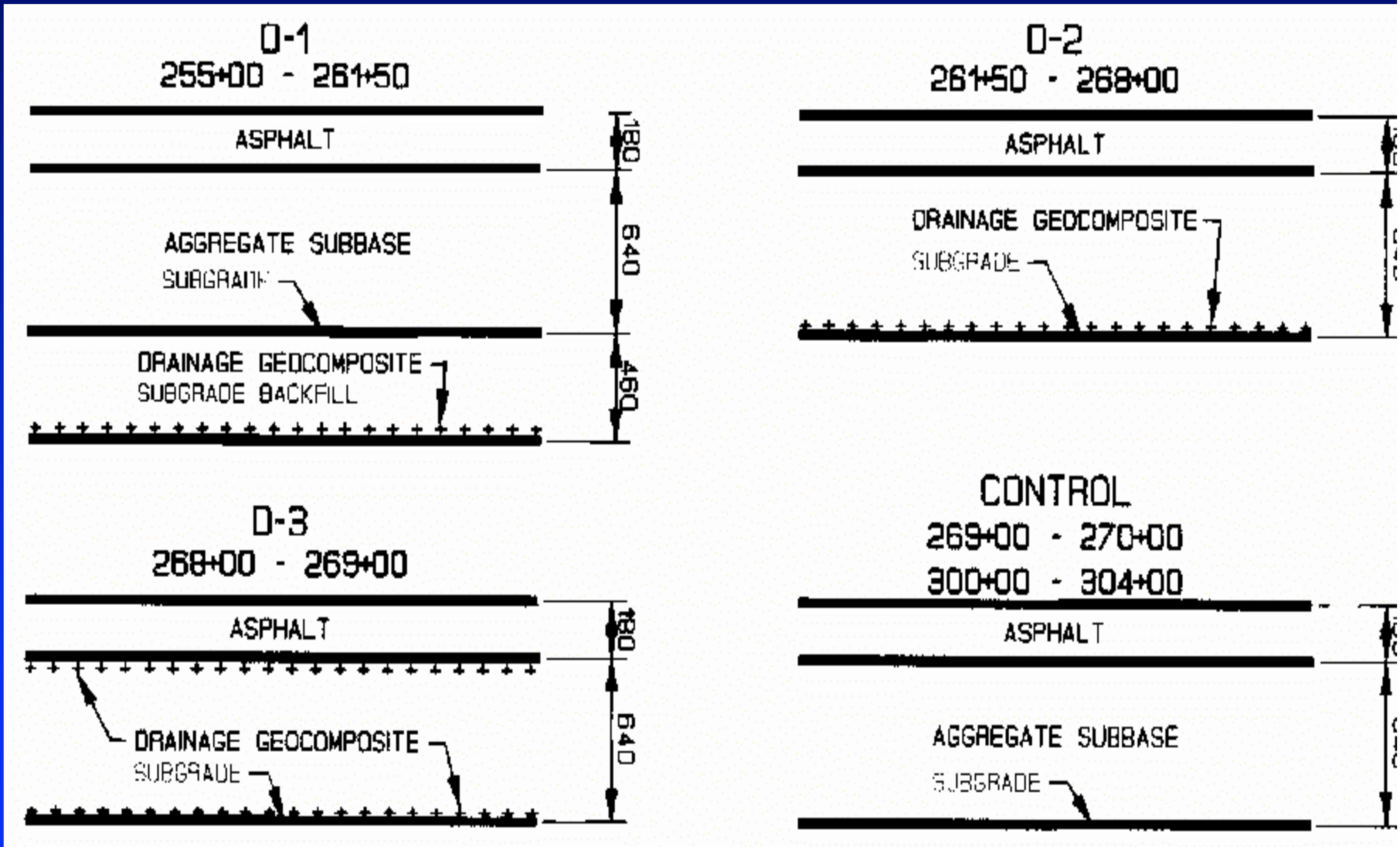
Quality of Drainage	m	Structural Number (maintaining section)	Reduction in Base (maintaining SN = 4.3 and HMA thickness and)	Reduction in Asphalt (maintaining SN = 4.3 and base thickness)	Estimated Performan Period (maintainin section)*
Excellent	**1.3**	**4.93**	**- 3.5 in.**	**-1.43 in.**	**38 yrs**
Good (Standard)	**1.0**	**4.3**	**0**	**0**	**20 yrs**
Poor (Actual)	**0.7**	**3.67**	**+6.5 in.**	**+1.43 in.**	**8 yrs**
Total savings	**-**	**-**	**10 in.**	**2.86 in.**	**??????**

* Based on 20 -year performance period and a 3 percent growth

Some Case Studies

Maine DOT -
Frankfort to Winterport Highway

Drainage Test Sections



Construction Details

Geocomposite Placement

- Installing the Roadrain
- Plastic ties to secure conne between rolls

Construction Details

Collection Pipe Inlet/Outlet System

Underneath HMA

Important Parameters

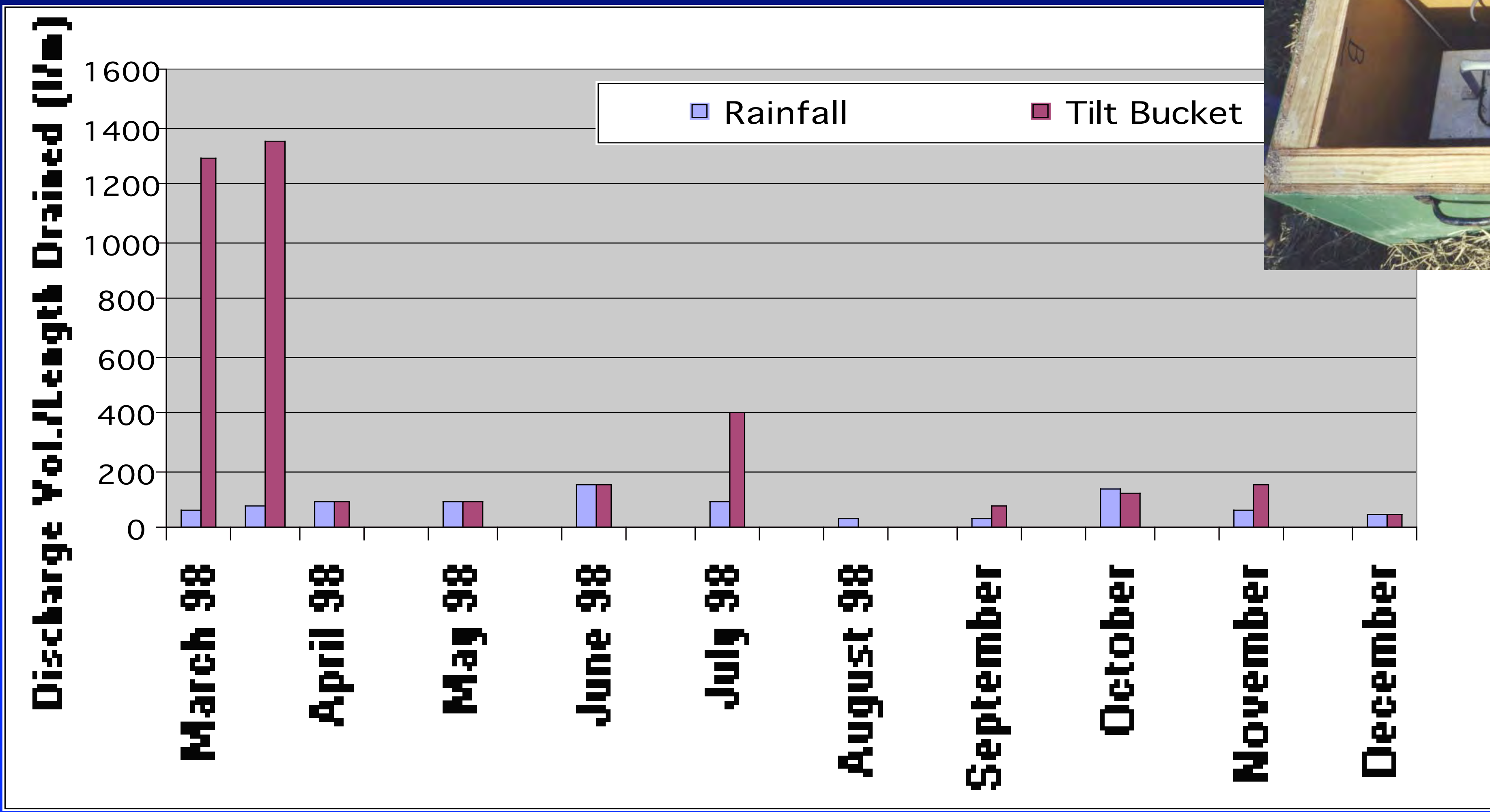
- Flow
  - through pavement and base
  - at outlets (time to drain)
- Pore pressure
  - base, sub base & subgrade
  - positive & negative
- Moisture content
- Long-term support
  - pavement, base and su base
- Road surface movement
- Water level
- Temperature with depth
- Weather
  - rainfall & temperature
  - atmospheric pressure

Drainage Discharge

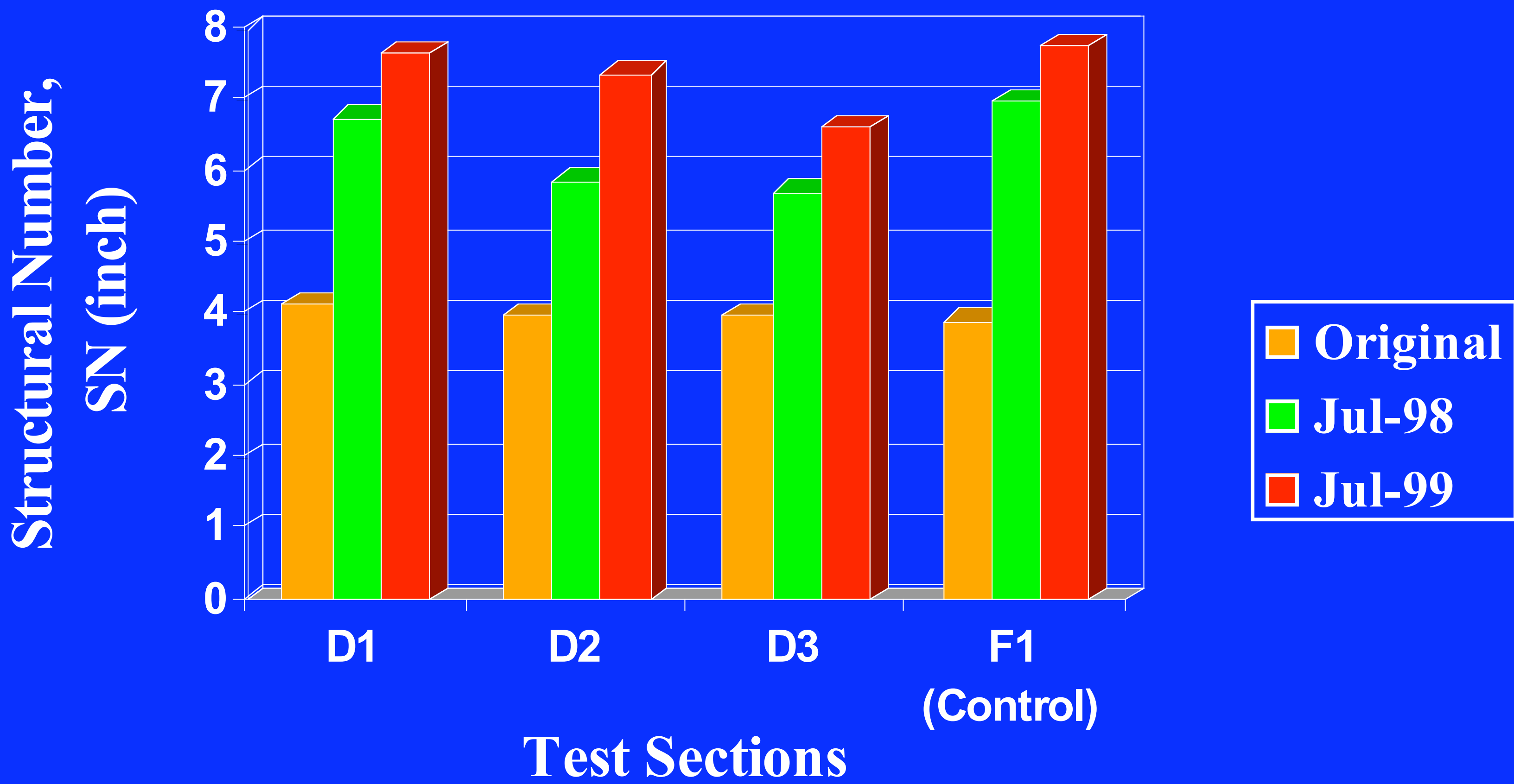
Discharge Volumes from Monitored Outlets Per Length of Drained Section

Monitoring Period	Discharge Volumes Per Length of Drained Section (L/m)						
	Outlet A D-1	Outlet B D-1	Outlet C D-1	Outlet D D-2	Outlet E D-3	Outlet F D-3	Monthly Totals
March 98	-	77	1094	118	0	0	1289
April 98	-	0	0	91	0	0	91
May 98	-	0	0	94	0	0	94
June 98	0	4	63	73	6	0	146
July 98	2	0	339	56	0	0	397
August 98	0	0	7	0	0	0	7
September 98	0	0	80	0	0	0	80
October 98	0	0	22	79	17	0	118
November 98	0	0	51	102	0	0	133
December 98	0	0	18	21	0	0	39
January 99	0	0	0	0	0	0	0
February 99	0	0	1	0	0	0	1
March 99	0	16	843	464	41	0	1364
Totals	2	97	2518	1098	64	0	3779

Monthly Discharge Volumes
(Per Length of Drain and Rainfall)

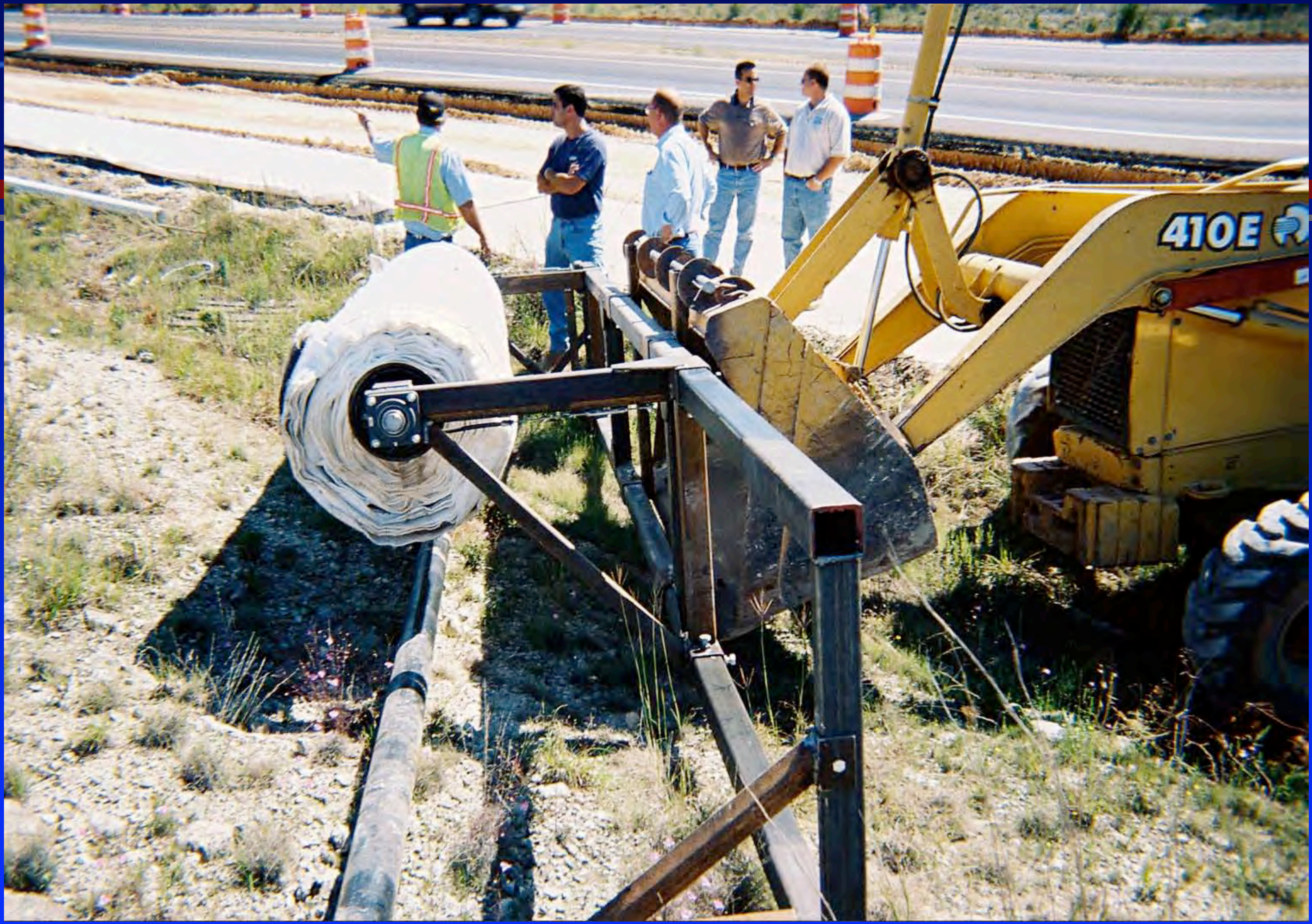


Falling Weight Deflectometer (FWD) Results (Drainage Sections), Maine DOT



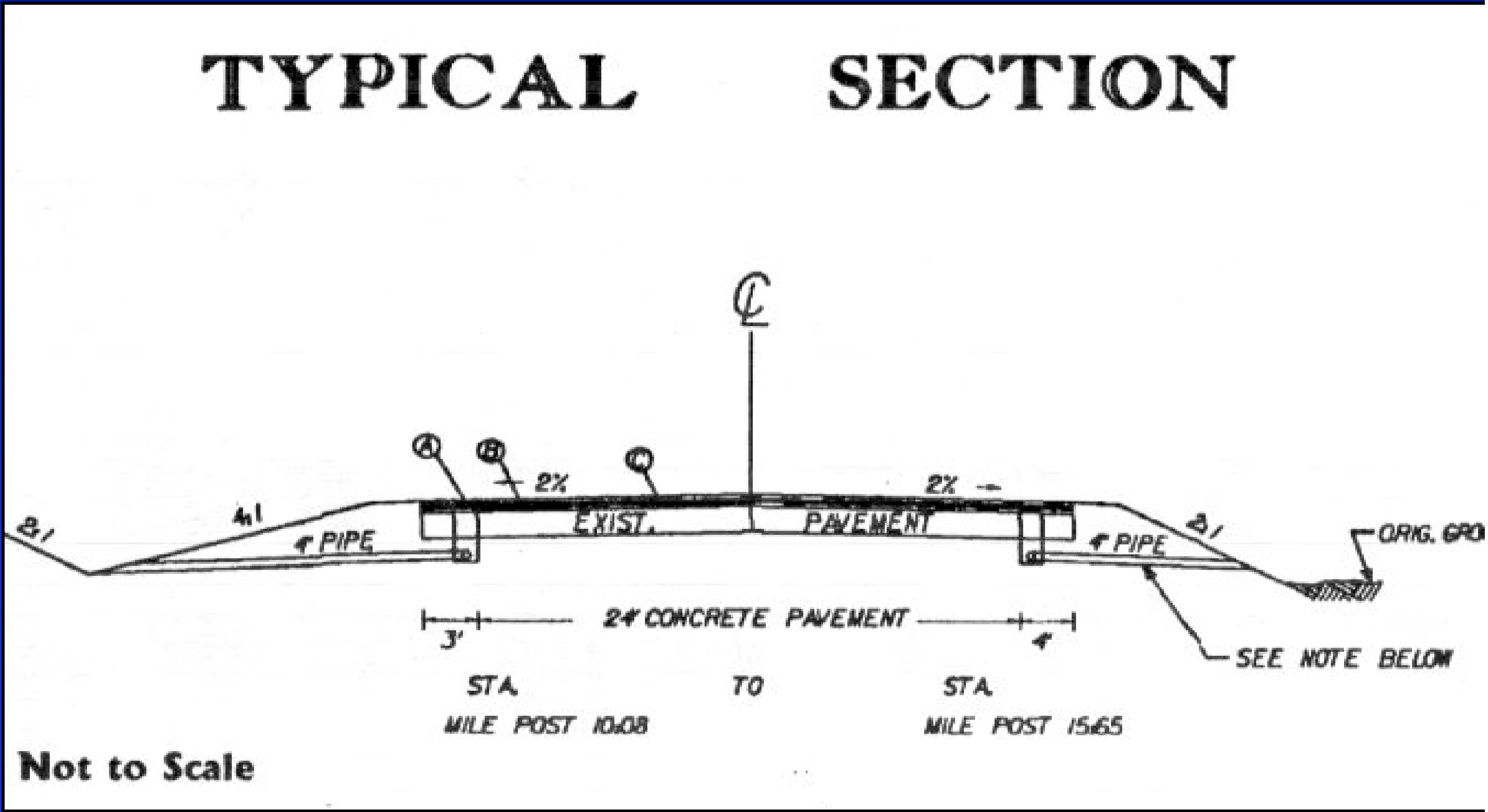
Maine DOT
Post-Installatio

Southwest Parkway
Austin, TX


410E


Galion
CAUTION
FREIGHTLINER
OF
AUSTIN

VADOT-Route 58 Rehabilitation Proje



Route 58 Rehabilitation Project

- 2-lane in each direction
- 24ft wide (3ft inner and 4ft outer shoulders)
- 2% surface slope (CL center line)
- 9in reinforced jointed concrete (spaced @ 61.5ft)
- 6in cement treated subgrade
- 9in HMA overlay (3 layers):
  - 1in SM, 2in IM, and 5.5in BM
- Geocomposite installed in the passing lane
- The project has edgedrain

Tack coat applied and geocomposite placement

Figure 2

Figure 5

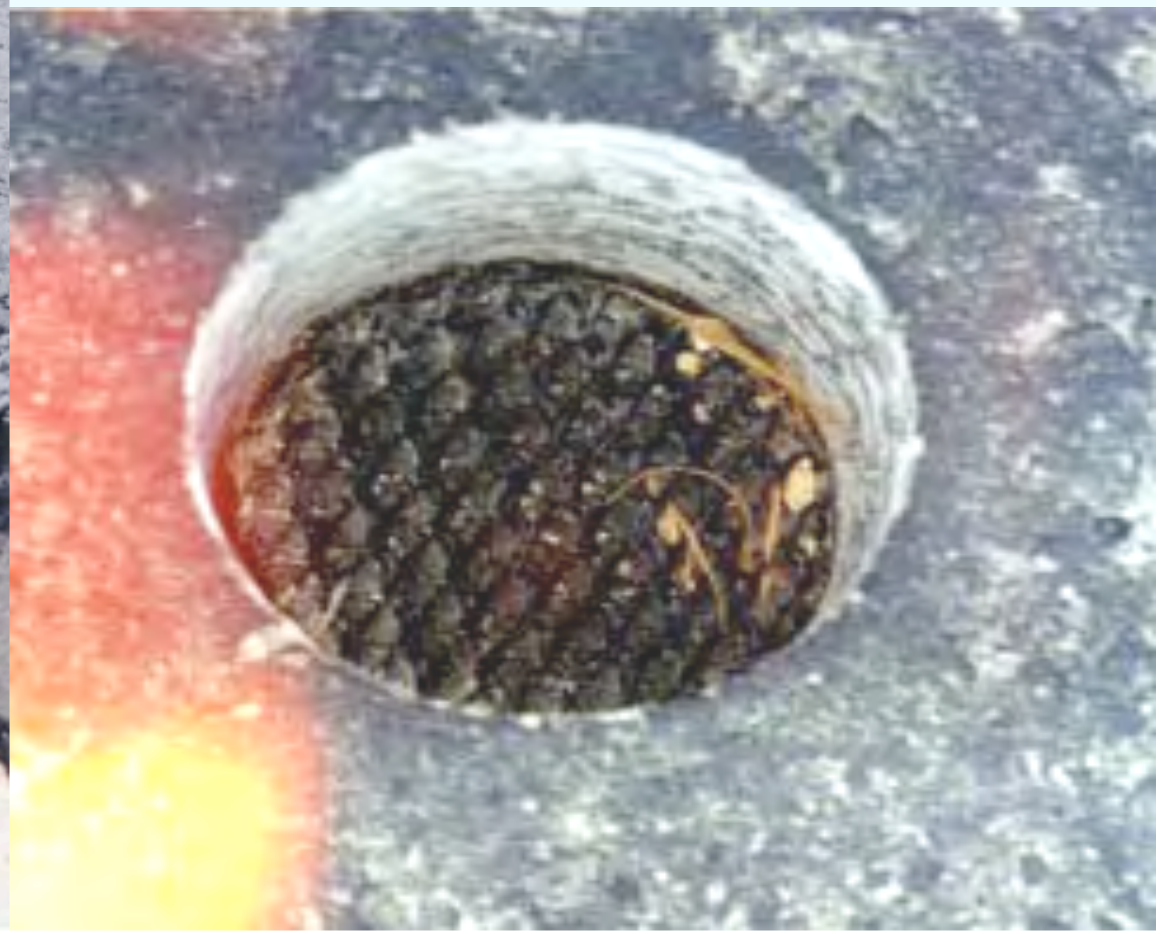
Traffic over the geocomposite panel

Asphalt placement over the geocomposite

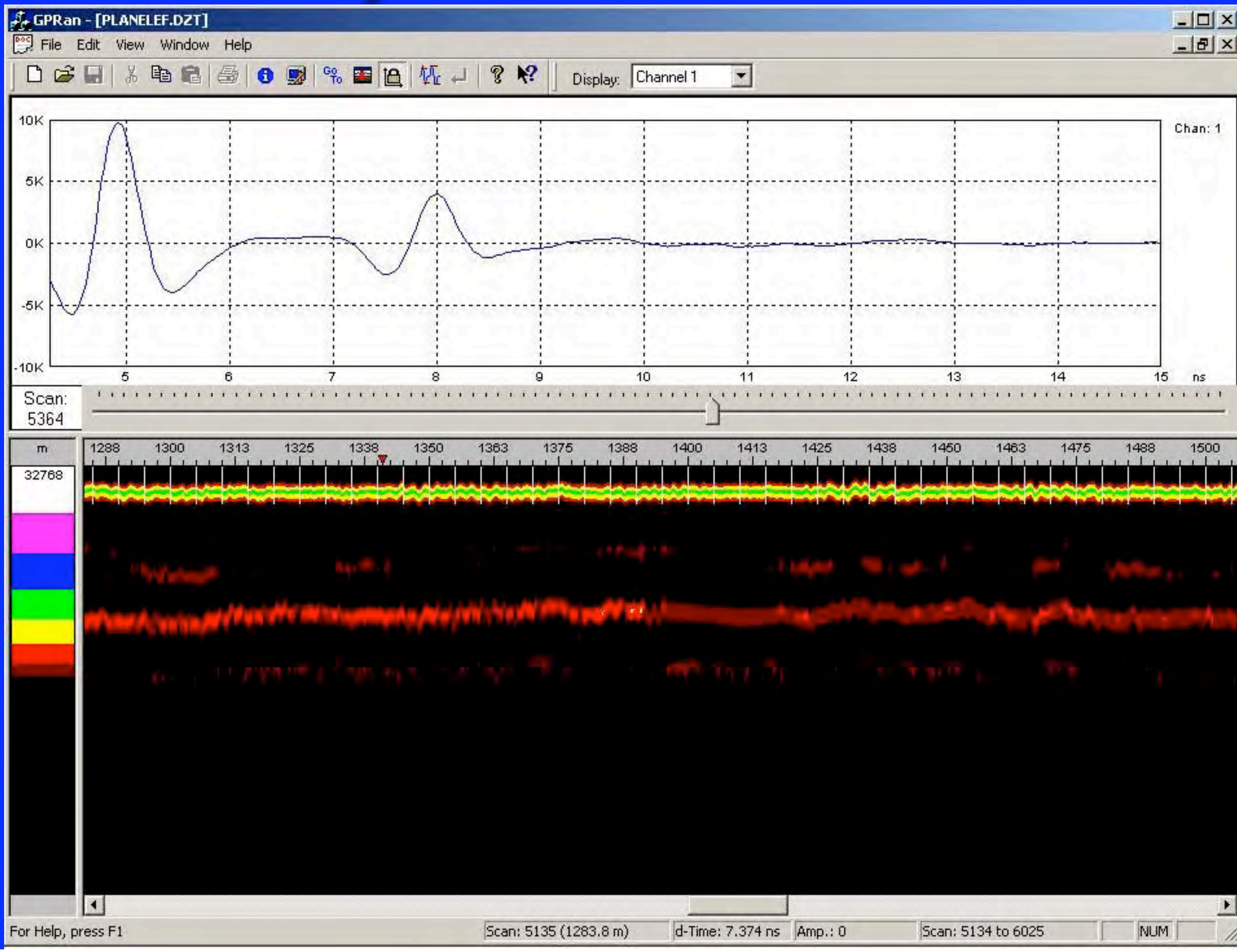
Figure 9

Figure 11

HMA over Geocomposite



GPR Survey



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File Edit View Window Help
Display: Channel 1
Chan: 1
10K
5K
0K
-5K
-10K
5 6 7 8 9 10 11 12 13 14 15 ns
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m
32768
1288 1300 1313 1325 1338 1350 1363 1375 1388 1400 1413 1425 1438 1450 1463 1475 1488 1500
For Help, press F1
Scan: 5135 (1283.8 m)
d-Time: 7.374 ns
Amp.: 0
Scan: 5134 to 6025
NUM

Missouri DOT
Route 63- Ashland MO

Concrete Joint Repair

*With **JointDrain***

Failed Joints on Route 63- Ashland, MO
MO DOT Project

Cutting out a 25’ section of concrete between 2 failed concrete joints

Clearing debris to prepare subgrade

Compacting subgrade in preparation for the installation of JointDrain

A drainage trench must be dug at the edge of the road to collect moisture that drains through the JointDrain.

Drilling dowel holes at the edge of each concrete "cut"

Applying epoxy into dowel holes before placement of dowel rods

Placement of dowel rods

Rolling out material to cut a 12’x24’ JointDrain panel. Rolls come in 6.7’ and 12’ widths and lengths of 200 ft.

Placement of 1st panel of JointDrain. The panel is installed under the dowel bars with the main drainage path going towar the drainage trench.

Placement of 2nd panel of JointDrain. Please note that geotextile is shingled from 1 panel to the other where the panels meet. This keeps drainage course free from concrete debris.

A Perforated PVC Pipe is placed as a drainage outlet at the end of the 25’ section.

After last panel of JointDrain is placed, metal mesh is placed. Metal mesh is rested on dow bars, and on top of JointDrain panel.

Ready-mix concrete is poured directly on JointDrain panels.

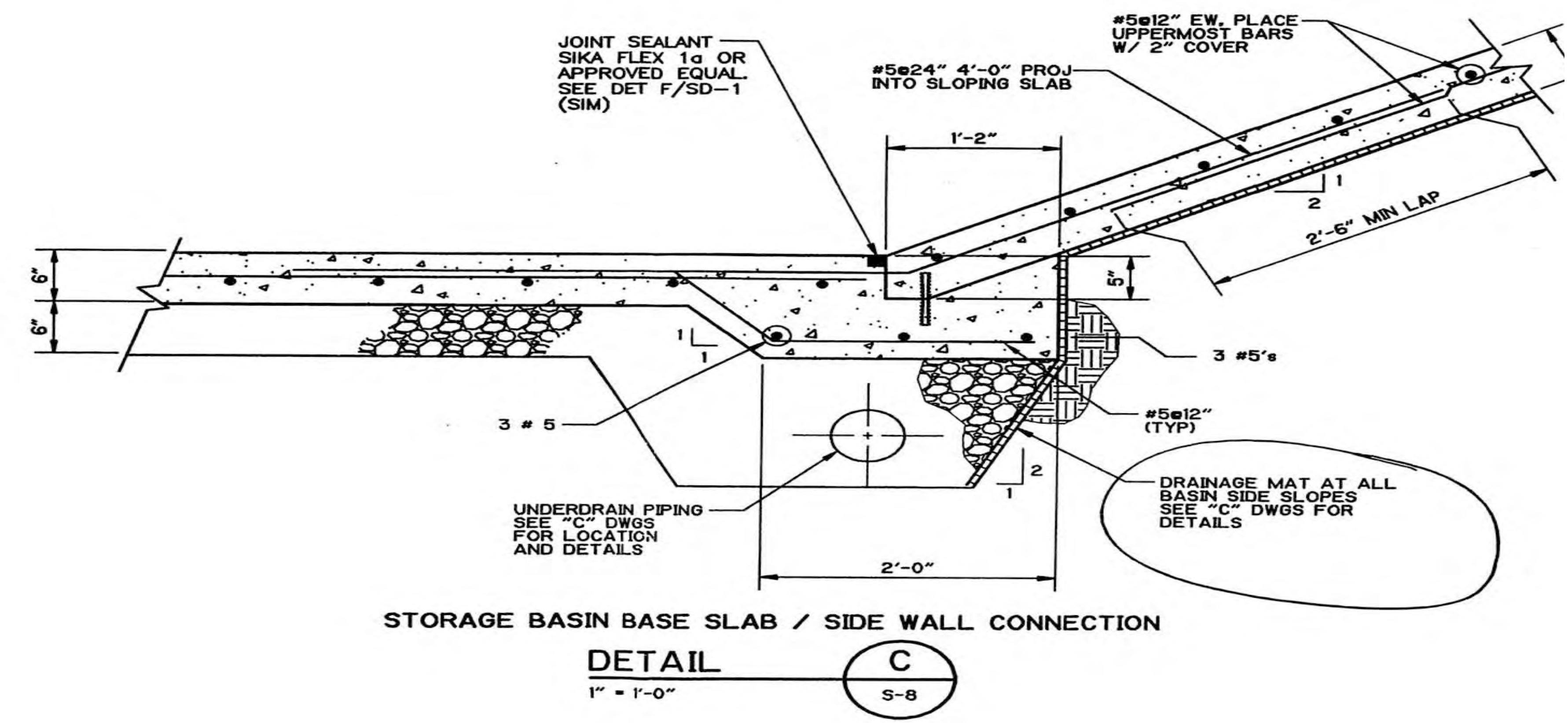
Screed is used to smooth and fla the poured concrete.

After a couple of passes of the screed, the concrete is ready for finishing touches.

As a final step, the concrete is brushed for a finished look.

The final poured concrete that poured on top of JointDrain order to repair 2 faulty concr joints.

Equalization Basin Detail



Pouring of Concrete on Geocomposite

Conclusions

- The RoaDrain geocomposite drainage layer is an effective alternative for pavement drainage.

- Calculations based on time-to drain approach indic
  - adequate infiltration rates to handle significant storm ev
  - < 10 min. to drain the geocomposite layer.
  - < 2 hours hours to drain the road even when placed bene moderately permeable dense graded aggregate base.
  - i.e. excellent drainage based on AASHTO 1998 criteria.

QUESTIONS ?