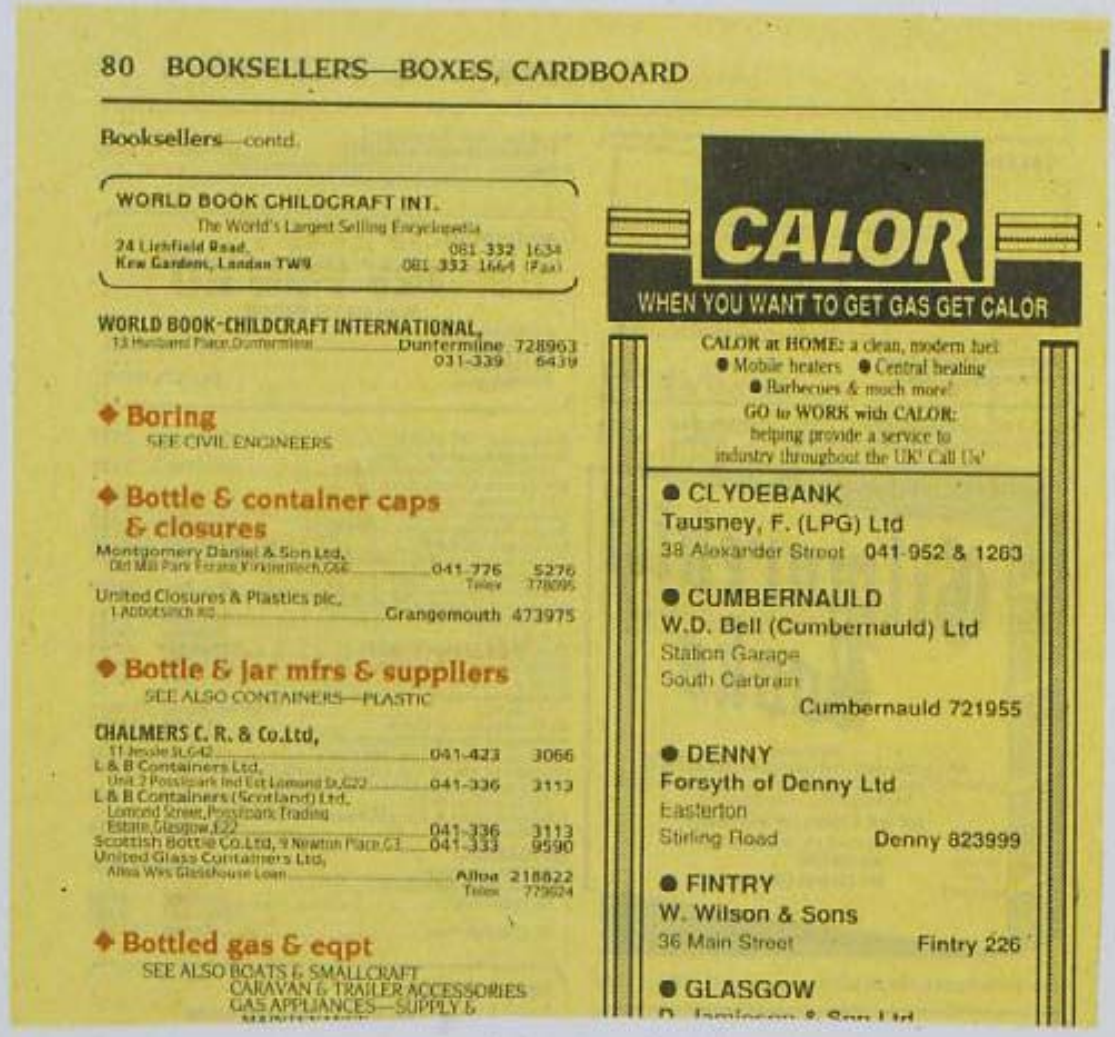
Geosynthetics in Transportation Engineering: New Solutions to Old Problems

Robert D. Holtz, PhD, PE
University of Washington, Seattle

***

Third G. A. Leonards Lecture
Purdue University
16 May 05

From the Glasgow telephone directory:



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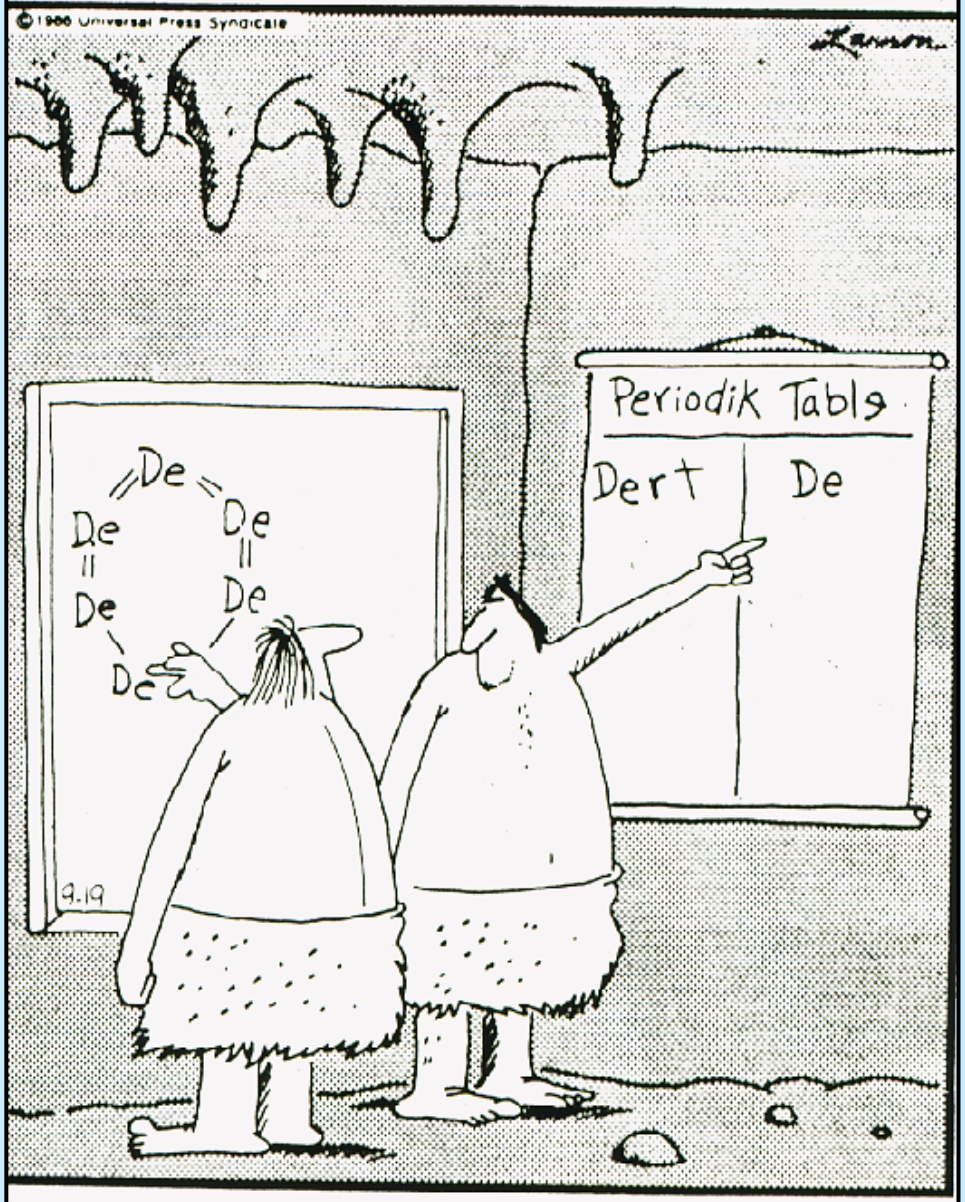
The Far Side

By GARY LARSON



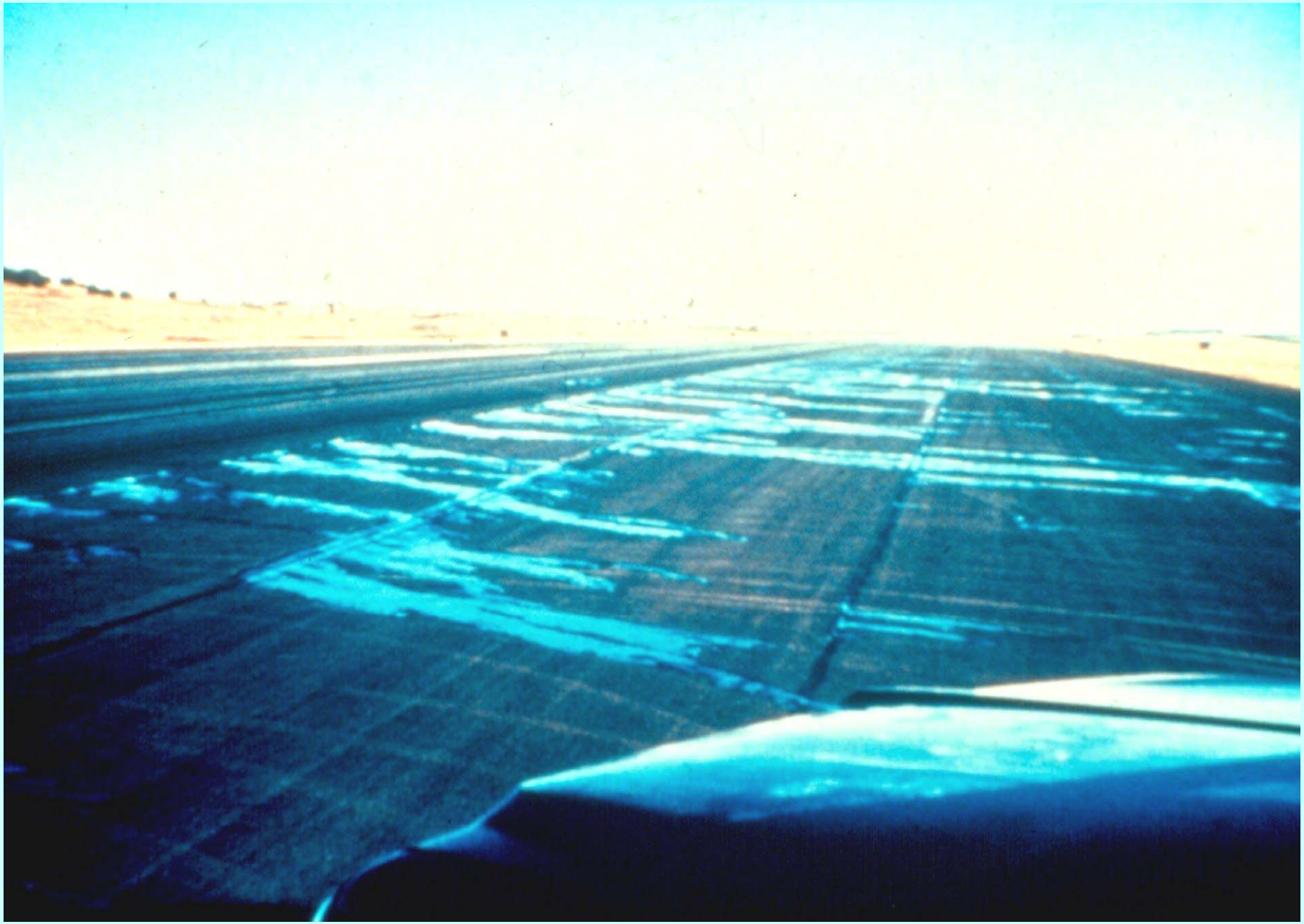
Early chemists describe the first dirt molecule

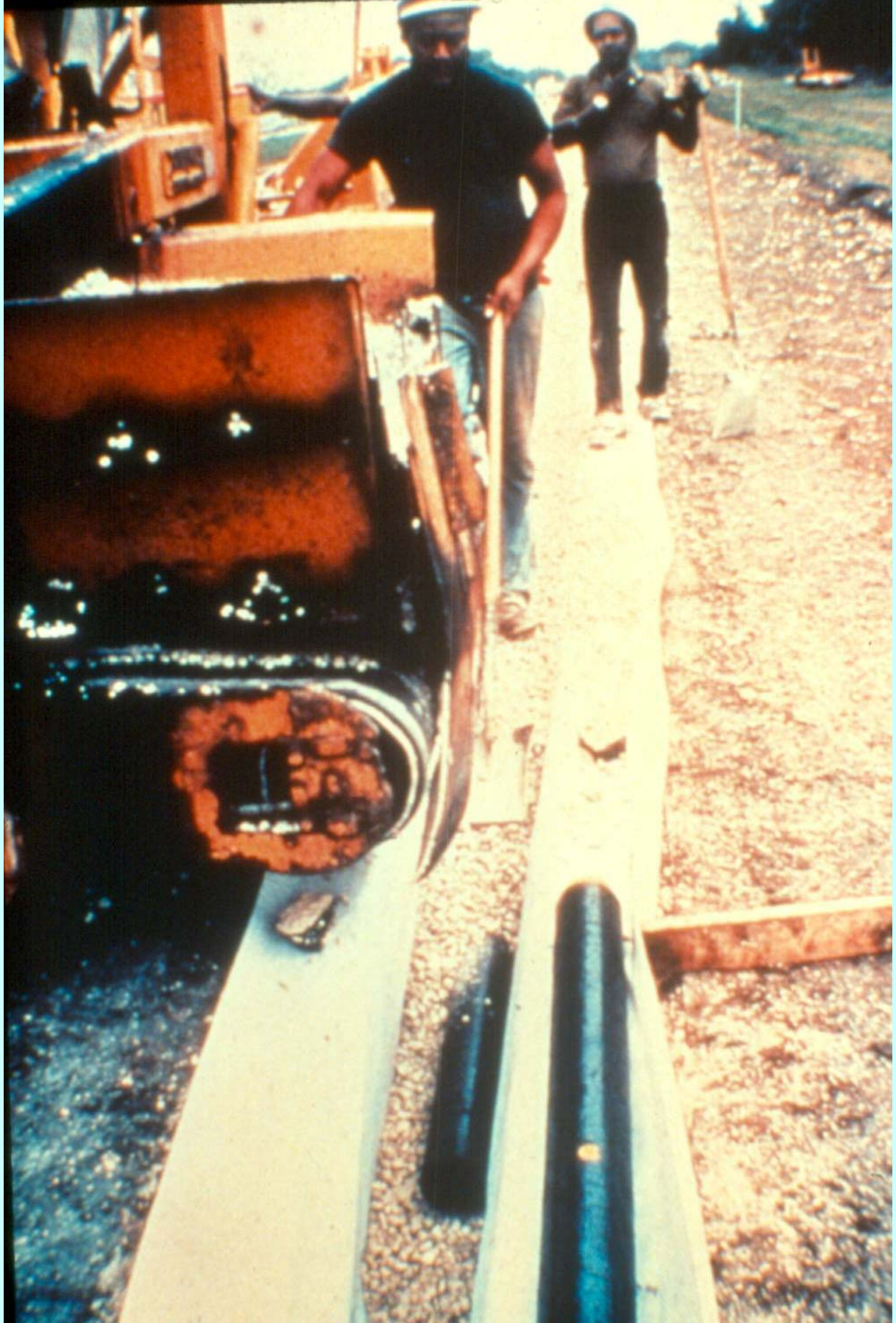
Geosynthetics in Transportation Engineering: New Solutions to Old Problems

Geotechnical problems in D C O M of transportation facilities:

- Drainage
- Erosion control
- Subgrade stabilization, etc.
- Embankment and slope instability
- Retaining structures and abutments

(*A few examples….*)






EDGE DRAINS


3 17 98


'02 5 26


02 5 28

Failure modes

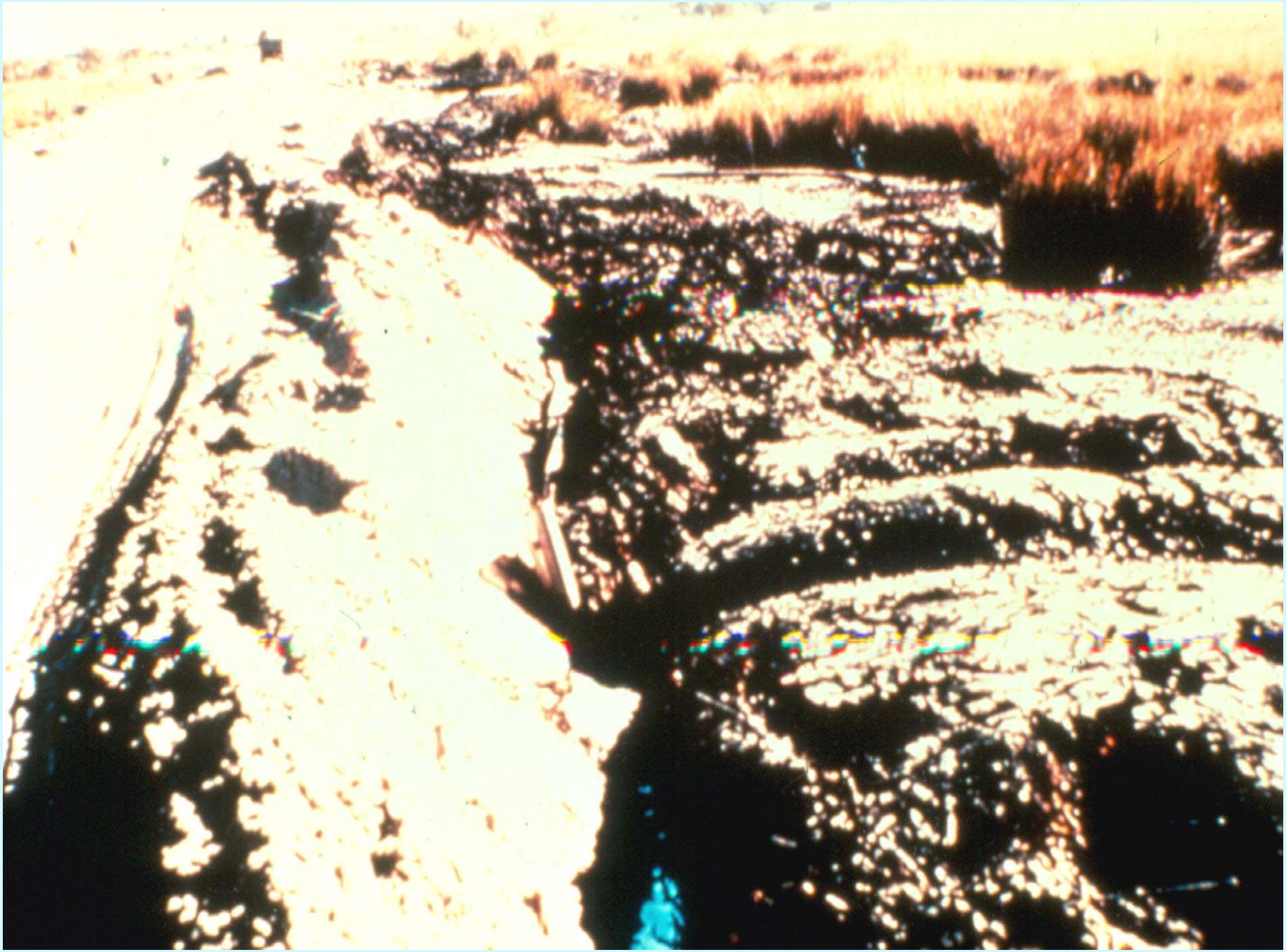
- **Structural**
- **Functional**

Causes

- **Excessive load (magnitude, cycles)**
- **Climate; environmental factors**
- **Poor drainage**
- **Improper construction**
- **Poor maintenance**

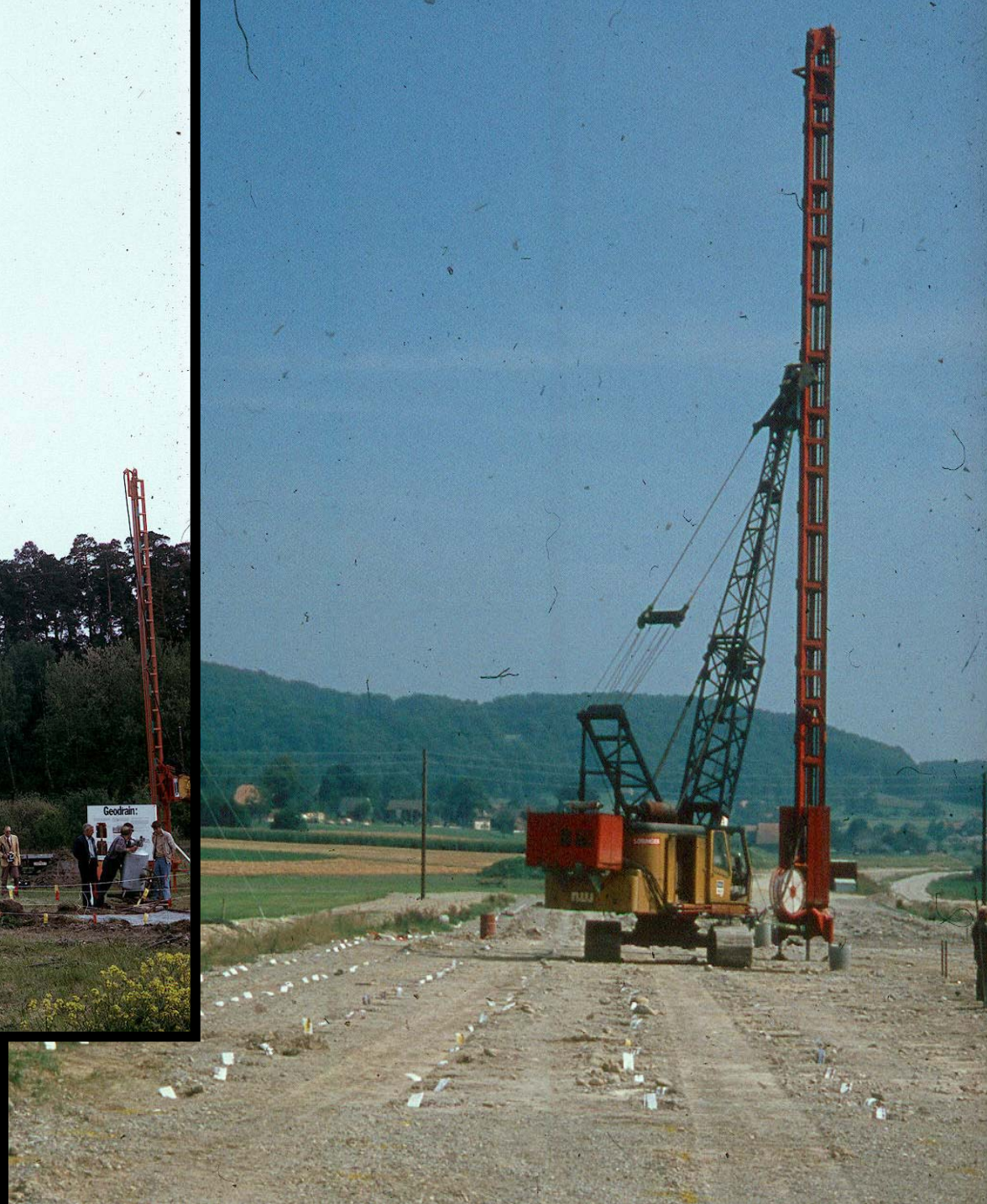

CITY


BECK
MUFFLER
SHOP

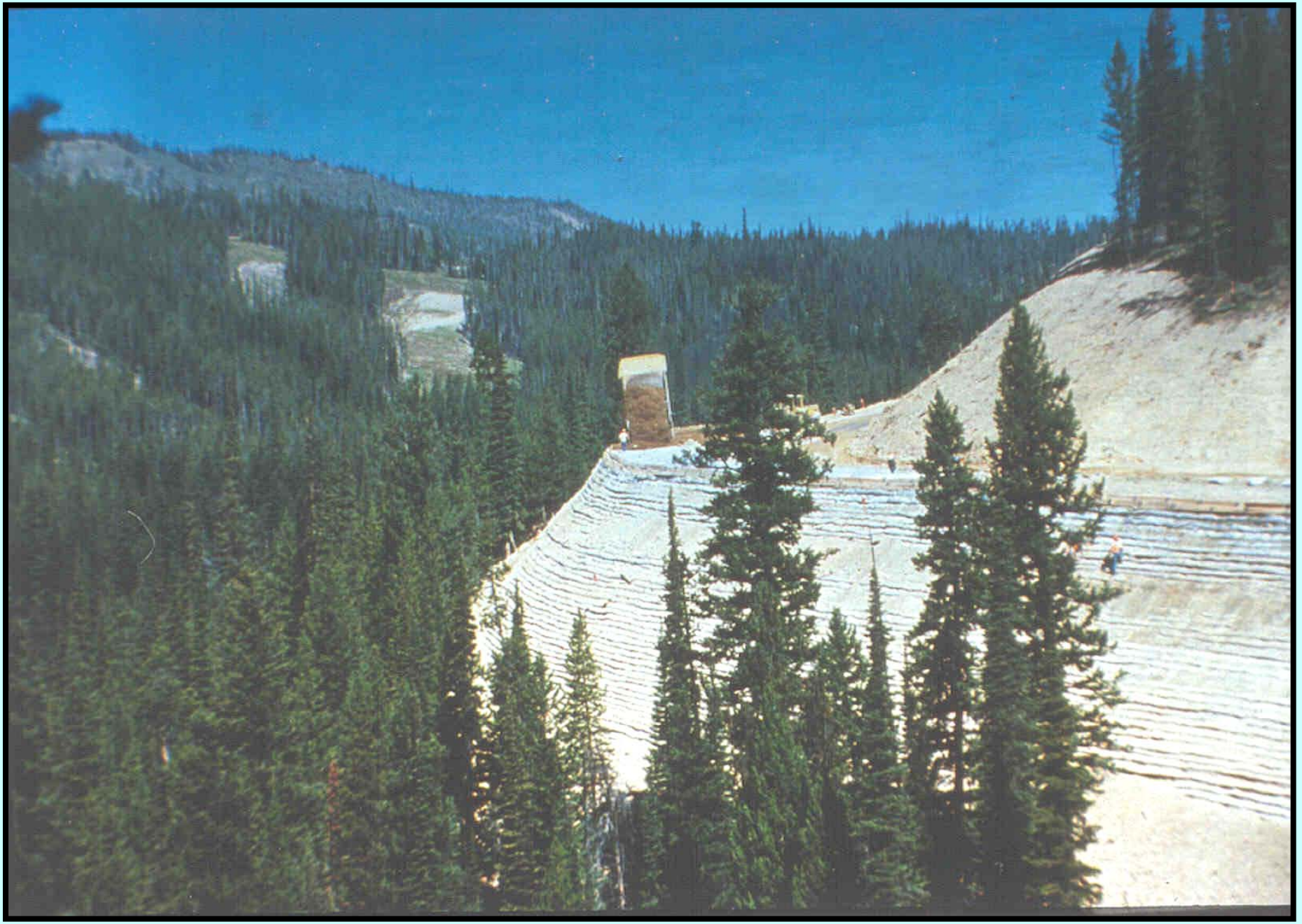



CASE
350B


BM-VOLVO
Geodrain:




TENSOL



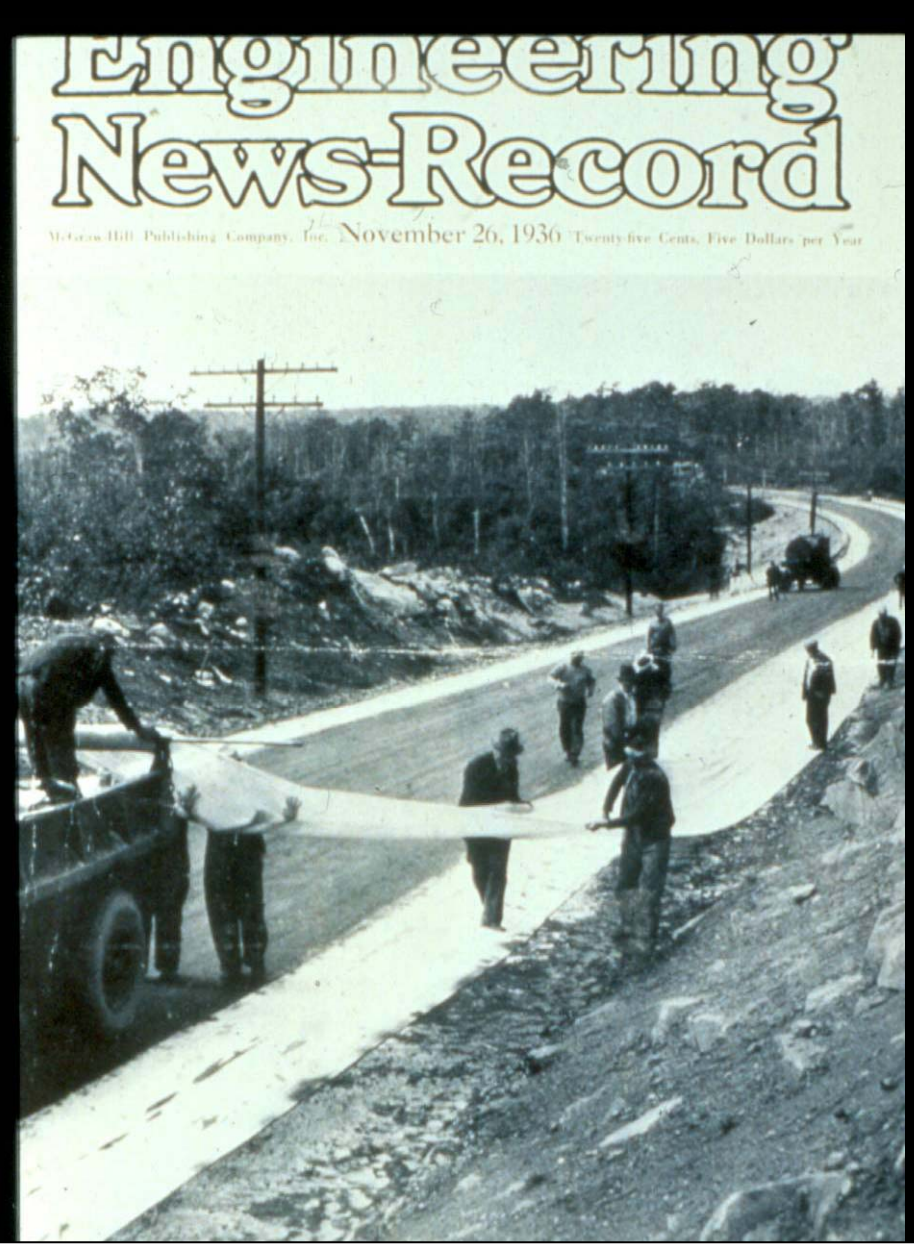
Founders Meadows Geosynthetic-reinforced Abutment (I-25, Exit 184)

DESIGN WITH GEOSYNTHETICS???

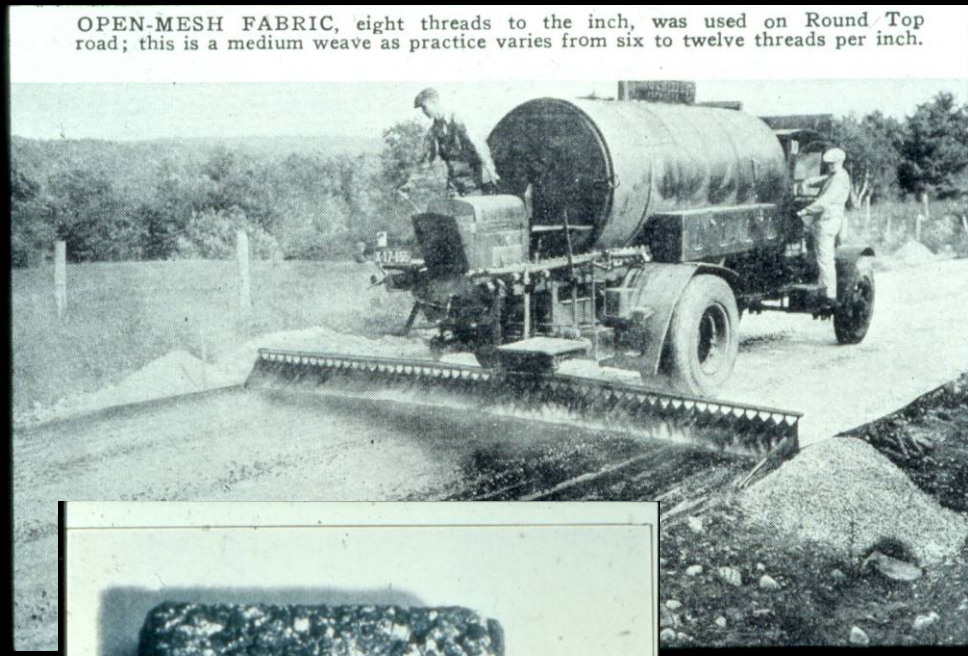
Geosynthetics in Roads and Highways

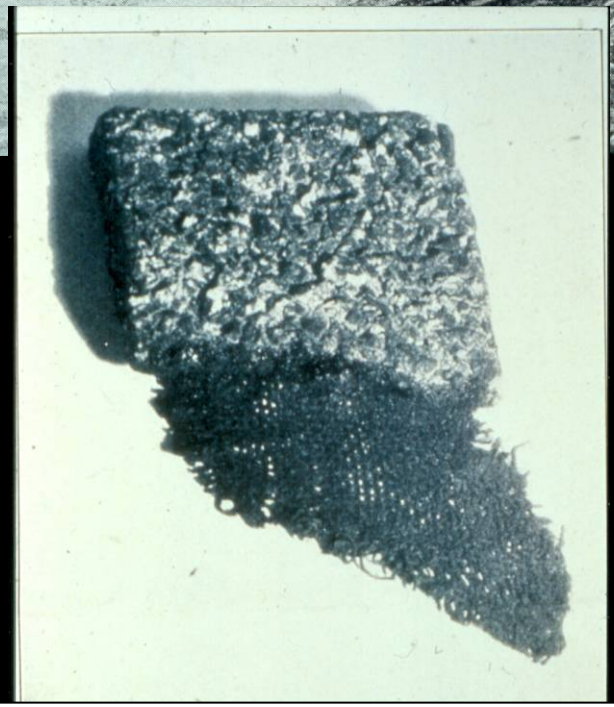
(outline)

- **Historical developments**
- **Subgrade conditions**
- **Functions and benefits**
- **Design procedures**
- **Materials properties and specifications**
- **Construction** *(….and, if time)*
- **Recent Research at UW**



Surfacing soft shoulders with cloth-reinforced asphalt in Rhode Island. The cotton strips are being laid out to the toe of the slope to prevent erosion.





Sample of surfacing taken up, June 18, 1935, on the first Cotton Road build in South Carolina in 1926, showing cotton membrane intact and unimpaired after being down nine years.


1


3


3


4

Use a geosynthetic when:

- ⬇ poor equipment mobility
- ⬇ aggregate contamination
- ⬇ subgrade pumping
- ⬇ subgrade bearing failure (ruts)

...occur during road construction.

Subgrade conditions for using geosynthetics:

- **Poor soils**
  - **(** *CL, CH, ML, MH, OL, OH, Pt* **)**
- **Low undrained shear strength**
- **(** τ_f *< 90kPa, CBR < 3,* M_r *< 30* **)**
- **High sensitivity**
- **High water table**

Function of geosynthetic

- **Separation**
- **Reinforcement**
- **Drainage**

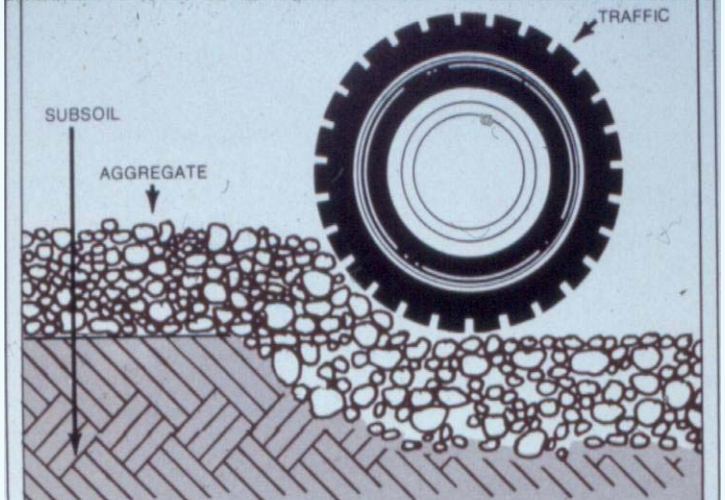


Figure 7. Typical temporary-road construction without Mirafi 140 fabric. The aggregate is compacted into the subsoil.

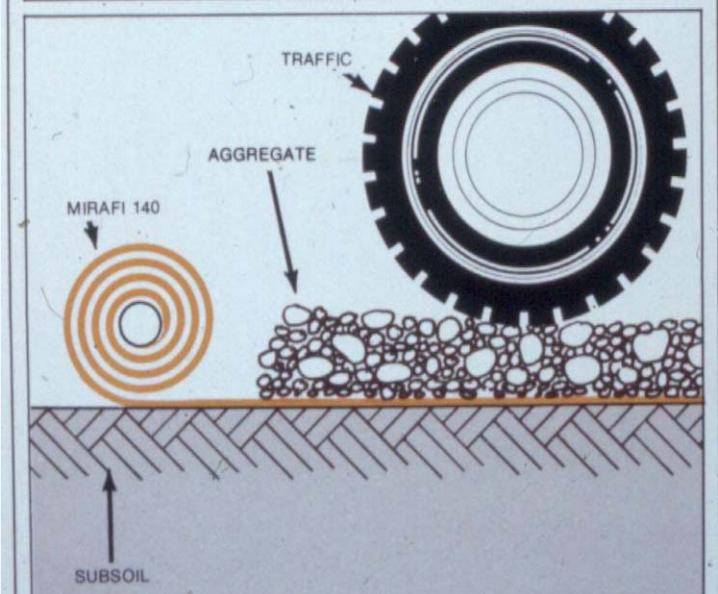


Figure 8. Typical temporary-road construction using Mirafi 140 fabric. The aggregate is separated from the subsoil by Mirafi 140 fabric.

***Possible reinforcement mechanisms*:**

1. **Lateral restraint**
2. **Increased bearing capacity**
3. **Membrane support**

Geotextile functions:

- **CBR = 2 - 3: Drainage, filtration**
- **CBR = 1 - 2: Separation (reinforcement?)**
- **CBR < 1: All functions**

Road design with geosynthetics:

1. Temporary roads
2. Permanent roads

1. TEMPORARY ROADS -- DESIGN APPROACHES

- **Separation**
- **Separation, filtration and some reinforcement**

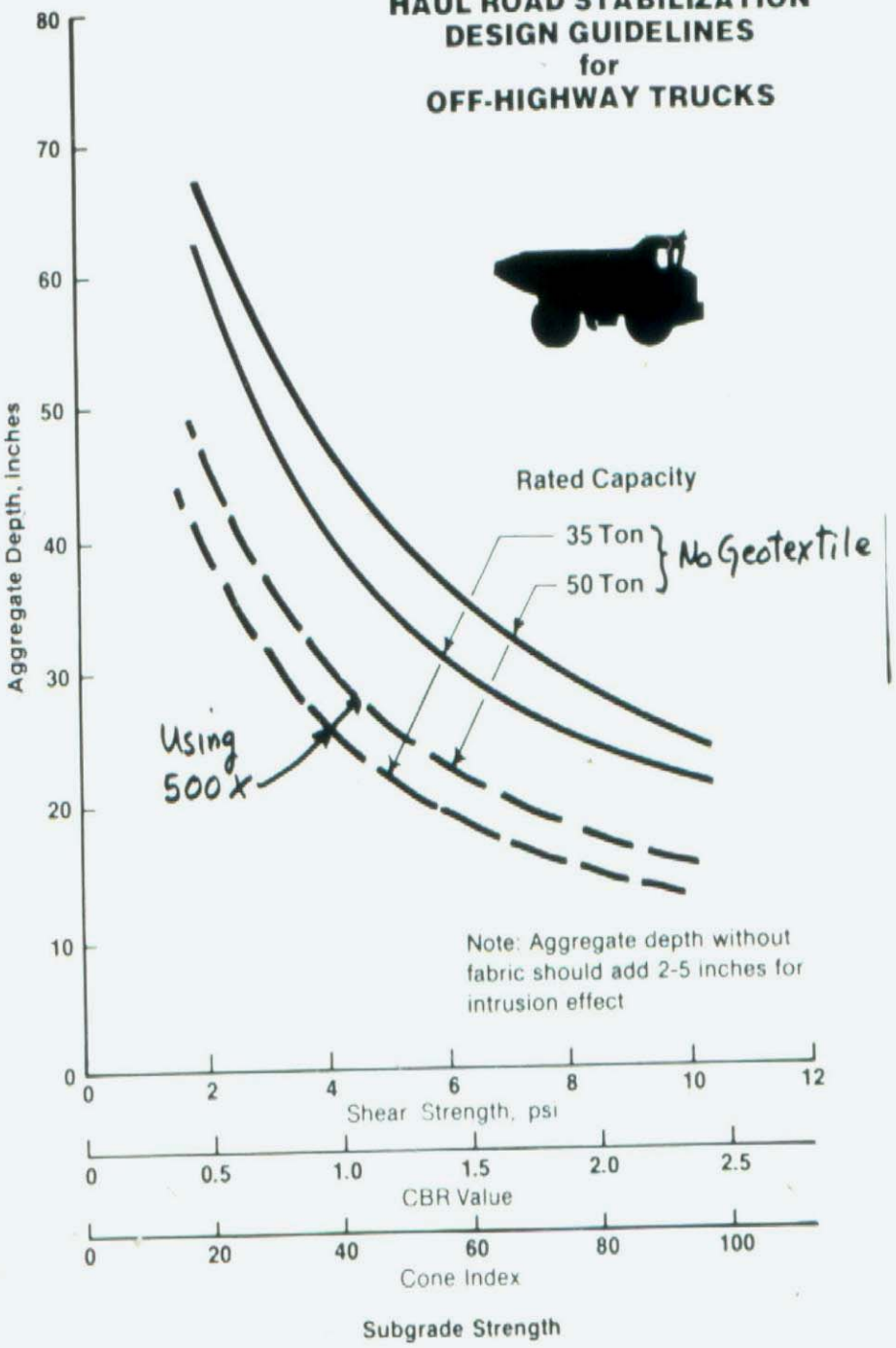
(*"Stabilization" – AASHTO 1997*)

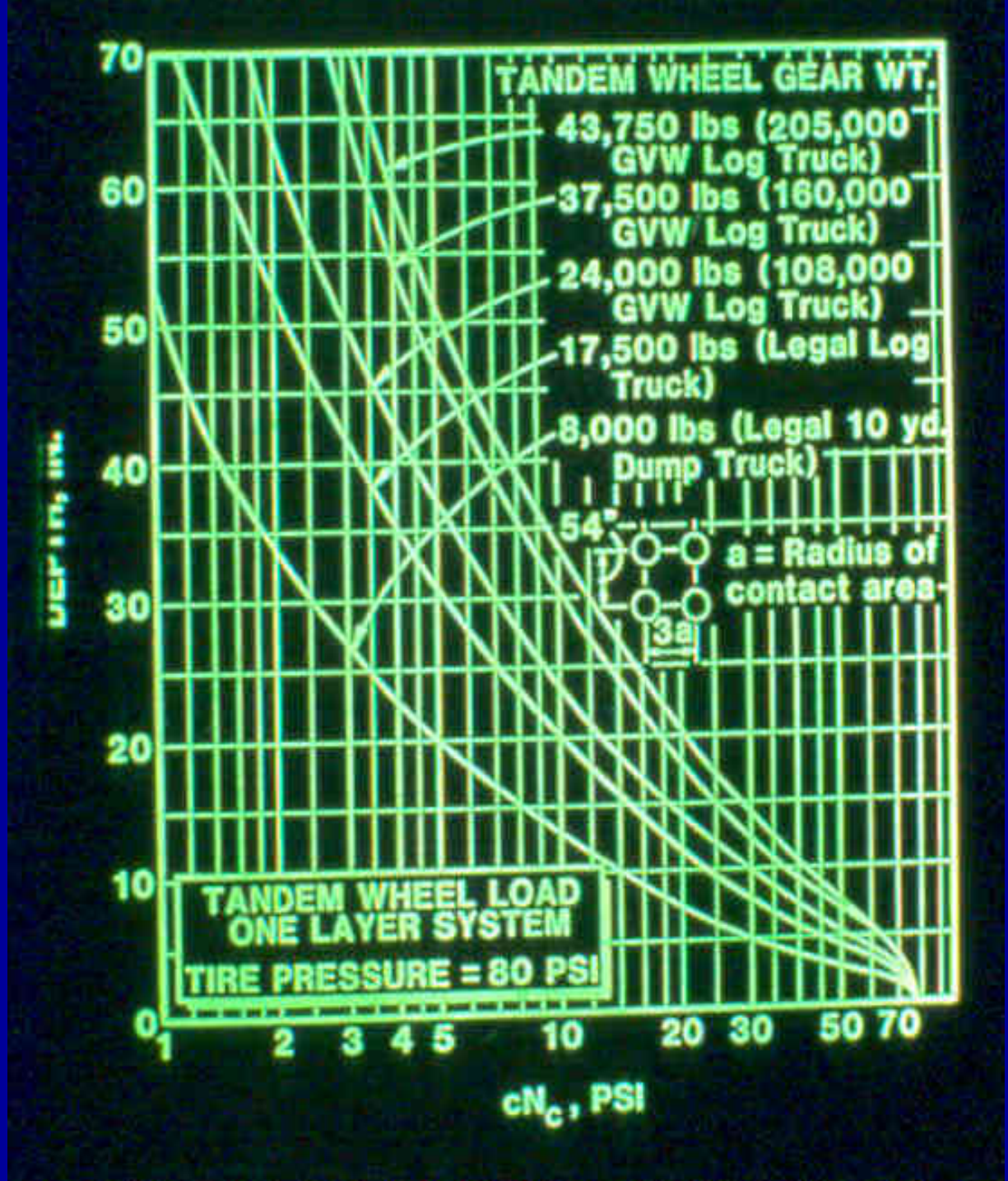
- **Don't forget drainage!**

Design procedures (stabilization)

- Bender & Barenberg (1978)
  Kenney & Barenberg (1980)
- Seward et al. (1977)
- Giroud & Noiray (1981)
- Haliburton & Baron (1983)
- Jewell et al. (1989; 1990; 1995)
- Giroud & Han (2004)

HAUL ROAD STABILIZATION DESIGN GUIDELINES for OFF-HIGHWAY TRUCKS




TANDEM WHEEL GEAR WT.
43,750 lbs (205,000 GVW Log Truck)
37,500 lbs (160,000 GVW Log Truck)
24,000 lbs (108,000 GVW Log Truck)
17,500 lbs (Legal Log Truck)
8,000 lbs (Legal 10 yd. Dump Truck)
54"
a = Radius of contact area
3a
TANDEM WHEEL LOAD
ONE LAYER SYSTEM
TIRE PRESSURE = 80 PSI
70
60
50
40
30
20
10
0
1
2
3
4
5
10
20
30
50
70
cNc, PSI

2. Design of

PERMANENT ROADS

Temporary road design procedures cannot be used for permanent roads*

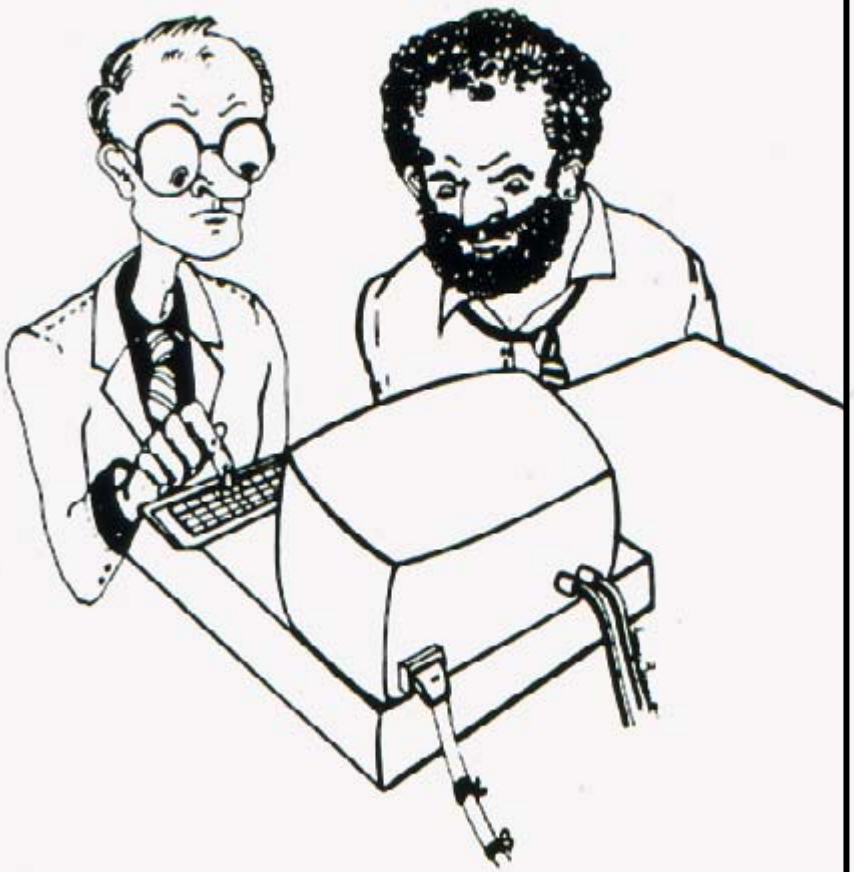
*except Christopher and Holtz (1991)

See also Holtz, Christopher, and Berg (1997)

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

Assumption: No structural support provided by the geotextile!

IF WE CAN INCORPORATE BOUNDARY ELEMENTS RATHER THAN SIMPLE FINITE ELEPHANTS, ENHANCE THE STATISTICAL EVALUATION OF PARAMETER GENERATION AND STICK WITH THE FUZZY SETS, I AM CONFIDENT THAT ACCURACY WILL BE INCREASED TO AT LEAST THE FOURTH DECIMAL



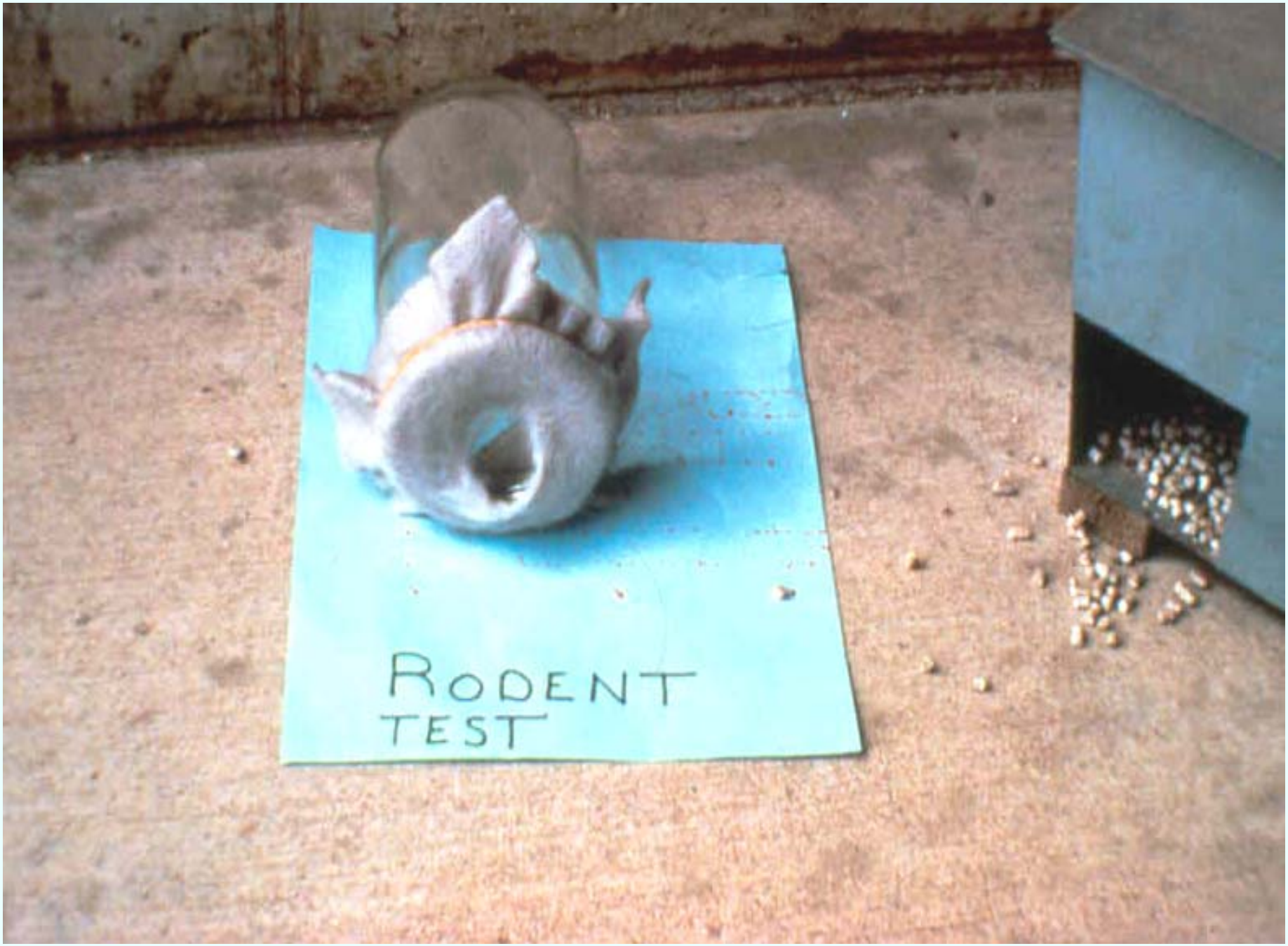
PUT ANOTHER SHOVEL IN PAT, IT'S FULL CORES THEY'RE WANTING

Properties Specifications:

Materials: AASHTO M288

Construction:

AASHTO-AGC-ARTBA Task Force 25

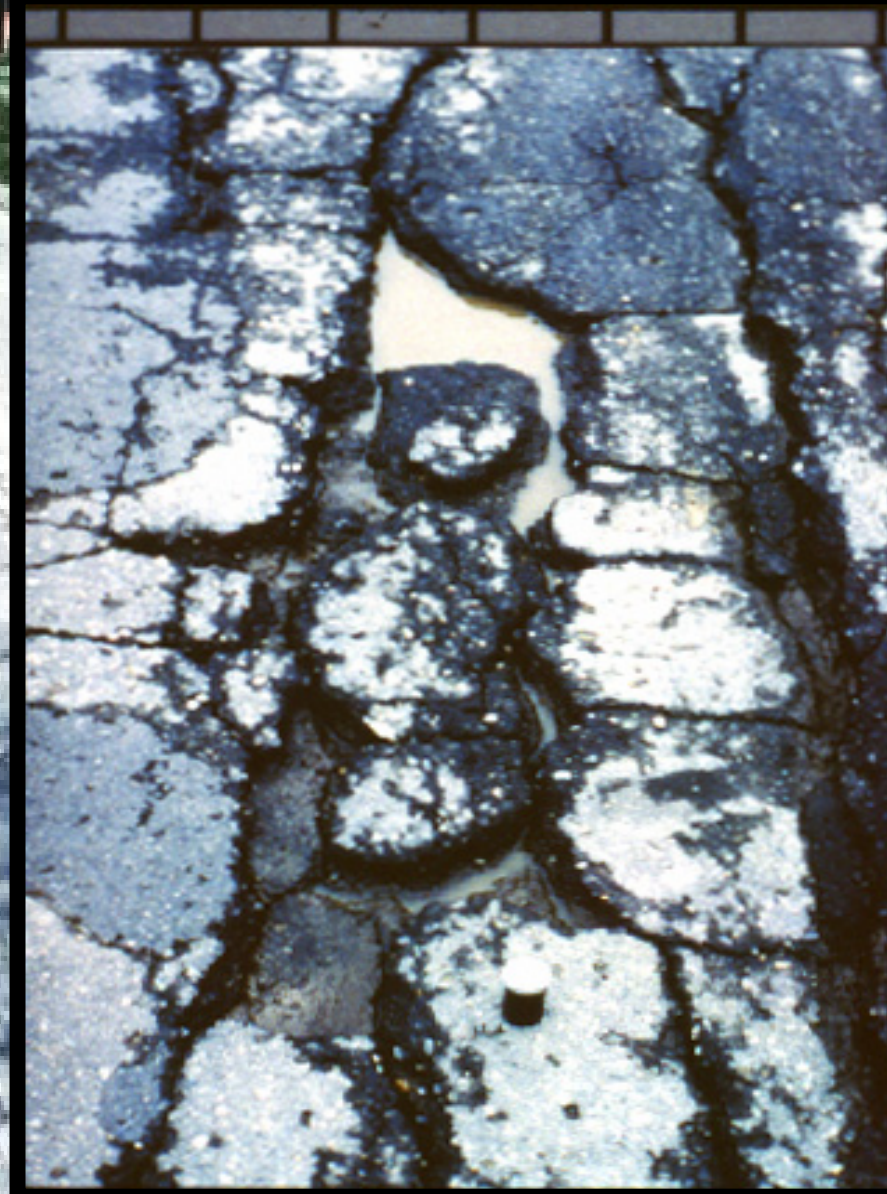

RODENT
TEST

Soil Properties-

As usual…

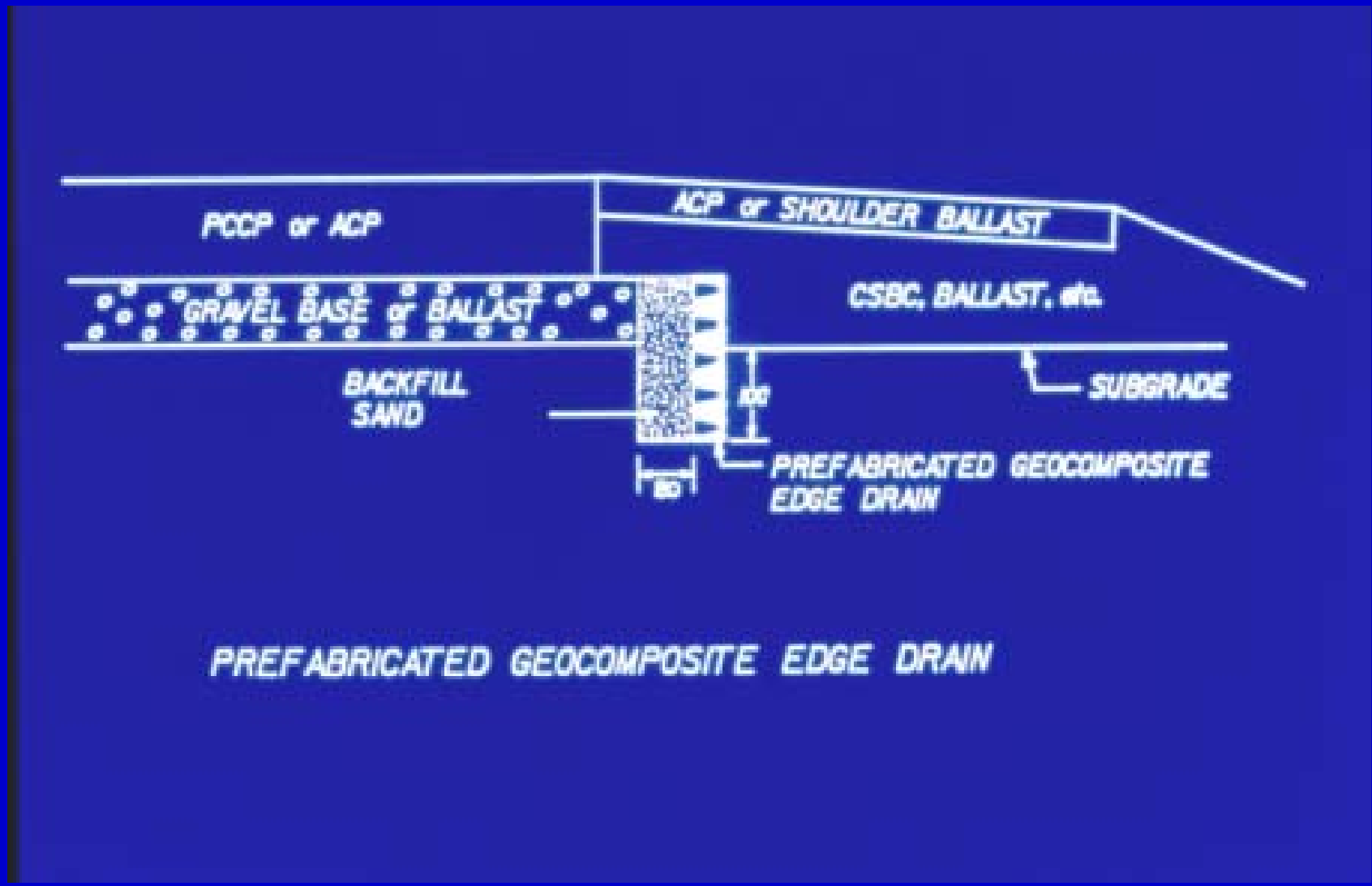
Problems in Pavement Structure Drainage

1. Well-graded and strong bases/subbases have low permeability
2. Open-graded materials have low structural strength



Most pavement structure drainage designs use underdrains adjacent to the pavement section.

GEOTEXTILE WRAPPED LONGITUDINAL EDGE DRAIN



PREFABRICATED GEOCOMPOSITE EDGE DRAIN

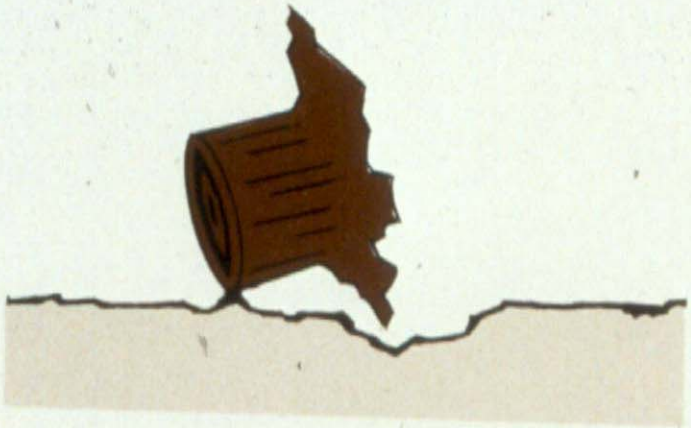

Edge Drains

Important geosynthetic design concept:

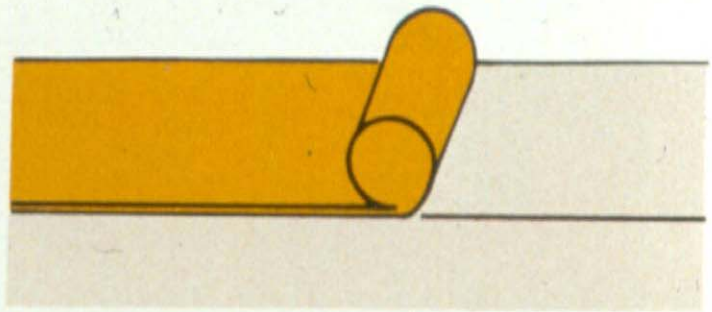
Geosynthetic cannot perform any function unless it survives all construction operations!

(Survivability)

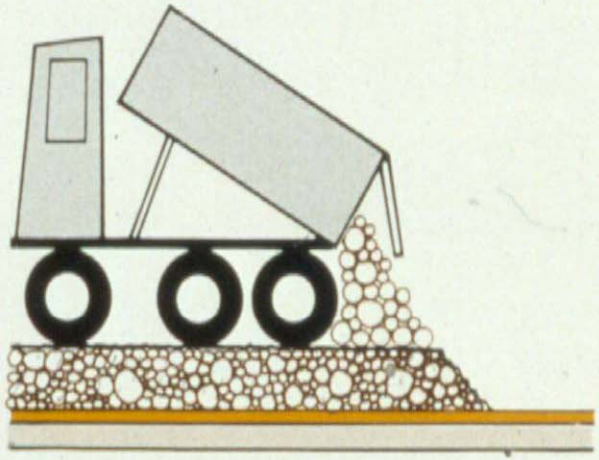
Construction Procedures



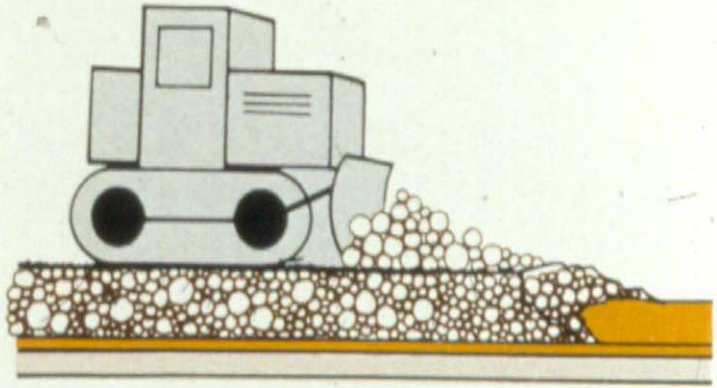
1 PREPARE THE GROUND
by removing stumps, large boulders, and other sharp objects.



2 UNROLL MIRAFI 140
directly over the ground to be stabilized. Two men can easily handle a roll. If more than one width is used, simply overlap about one meter.



3 BACK DUMP AGGREGATE
onto Mirafi 140. DO NOT DRIVE DIRECTLY ON THE FABRIC. Keep at least one foot of aggregate between truck tire and fabric.



4 SPREAD THE AGGREGATE
over Mirafi 140 to a depth of 12 to 18 inches depending on soil conditions.

5 COMPACT THE AGGREGATE
with vibratory compactor or dozer tracks.

RECENT RESEARCH

USING GEOSYNTHETICS* TO REDUCE FROST HEAVE

Karen S. Henry

*as capillary barriers

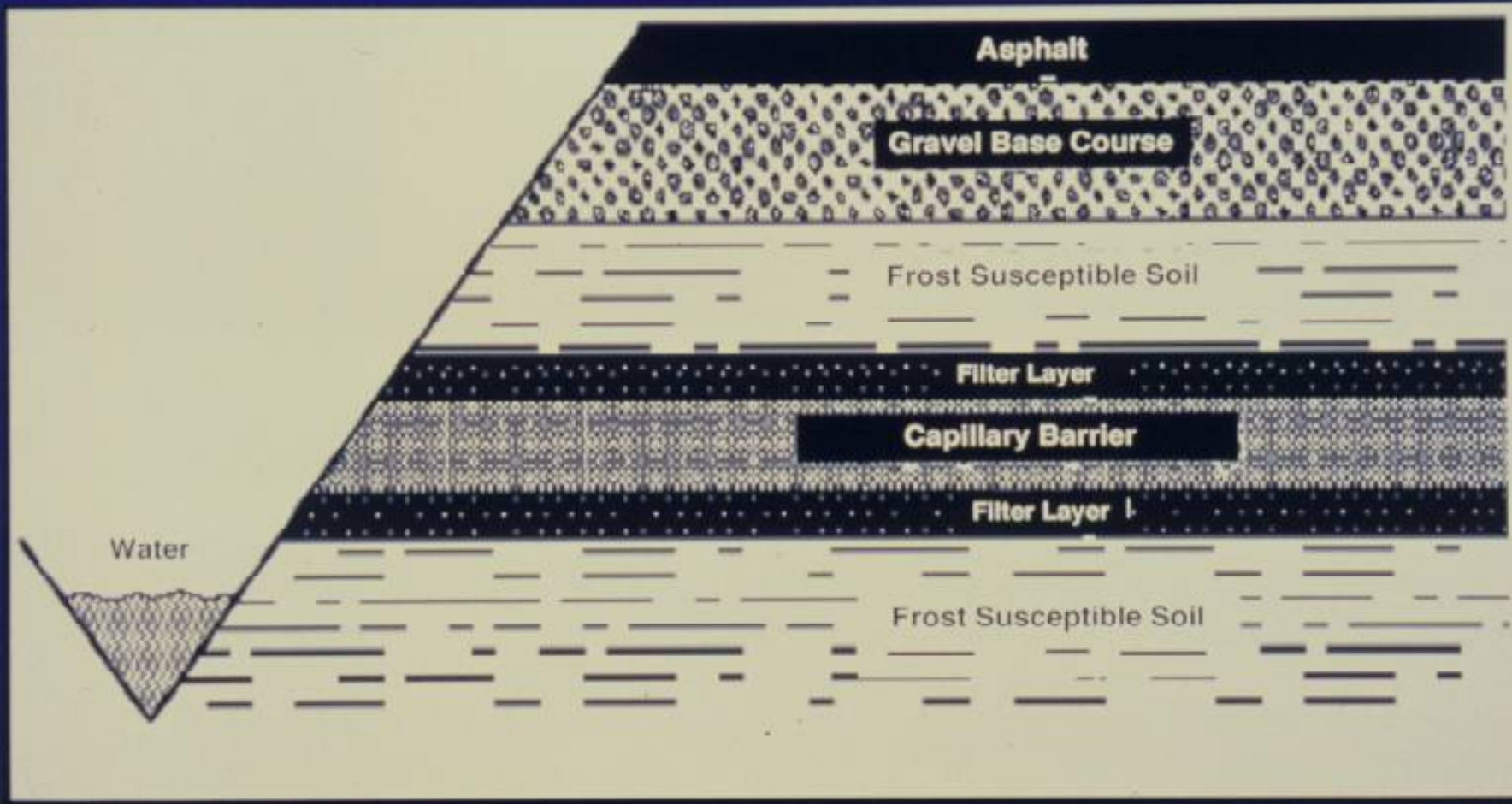
A1414-CGA-98-1404

Freezing and frost heave cause:

- significant damage
- maintenance $$$

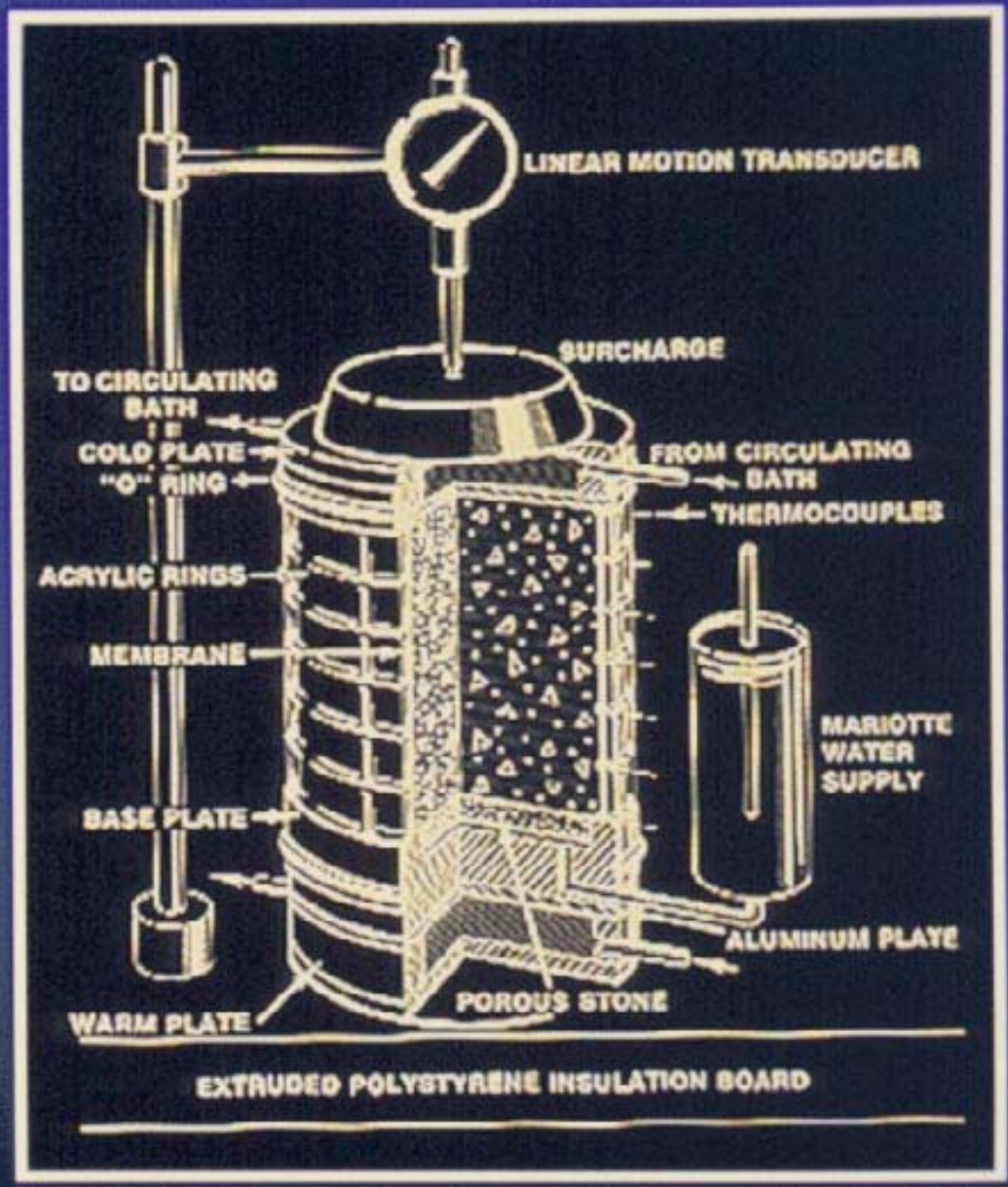
Frost Heave Requires:

1. Freezing temperatures
2. Frost-susceptible soil
3. Water supply

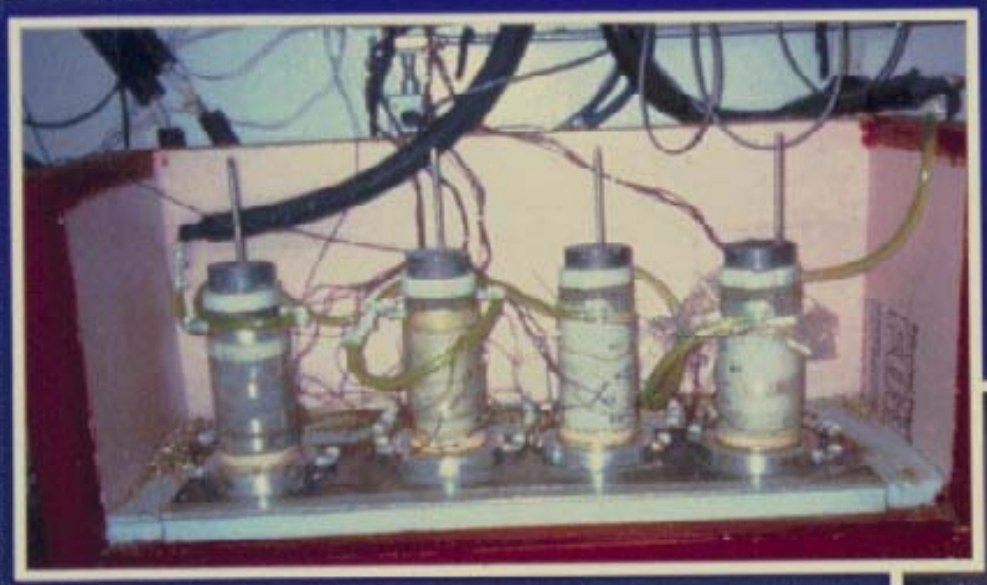

Asphalt
Gravel Base Course
Frost Susceptible Soil
Filter Layer
Capillary Barrier
Filter Layer
Water
Frost Susceptible Soil
A1414-CGA-98-1404

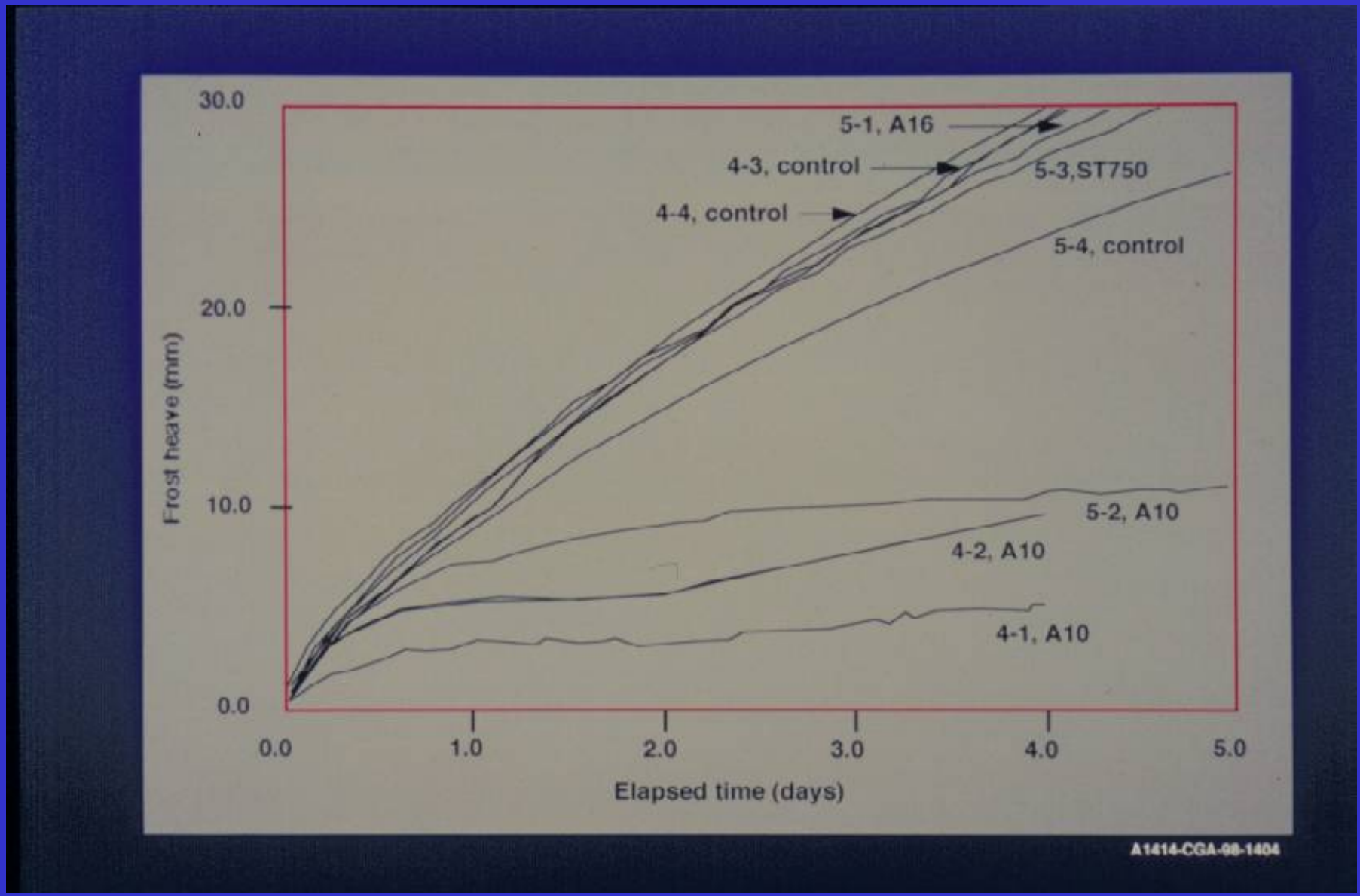
Freezing Tests

- 100 x 150 mm
- <25 mm water level
- Geosynthetic at 30 mm
- Bottom temp 0.7˚C
- Top temp
  - 1.5 (low)
  - 3.0 (high)



Freezing Tests




30.0
20.0
10.0
0.0
Frost heave (mm)
0.0
1.0
2.0
3.0
4.0
5.0
Elapsed time (days)
5-1, A16
4-3, control
4-4, control
5-3,ST750
5-4, control
5-2, A10
4-2, A10
4-1, A10
A1414-CGA-98-1404

Freezing Test Results

- Moist geotextiles did not reduce frost heave
- Moist geocomposites reduced frost heave when soil was < 75% saturated
- Above two results were not product dependent
- Results did not depend on freezing rate

Field Investigation to Evaluate the Long-Term Separation and Drainage Performance of Geotextile Separators

R.C. METCALFE
Woodward-Clyde Consultants

R.D. HOLTZ
University of Washington

T.M. ALLEN
Washington State Department of Transportation

February 1995

Washington State Department of Transportation
Woodward-Clyde
UNIVERSITY OF WASHINGTON

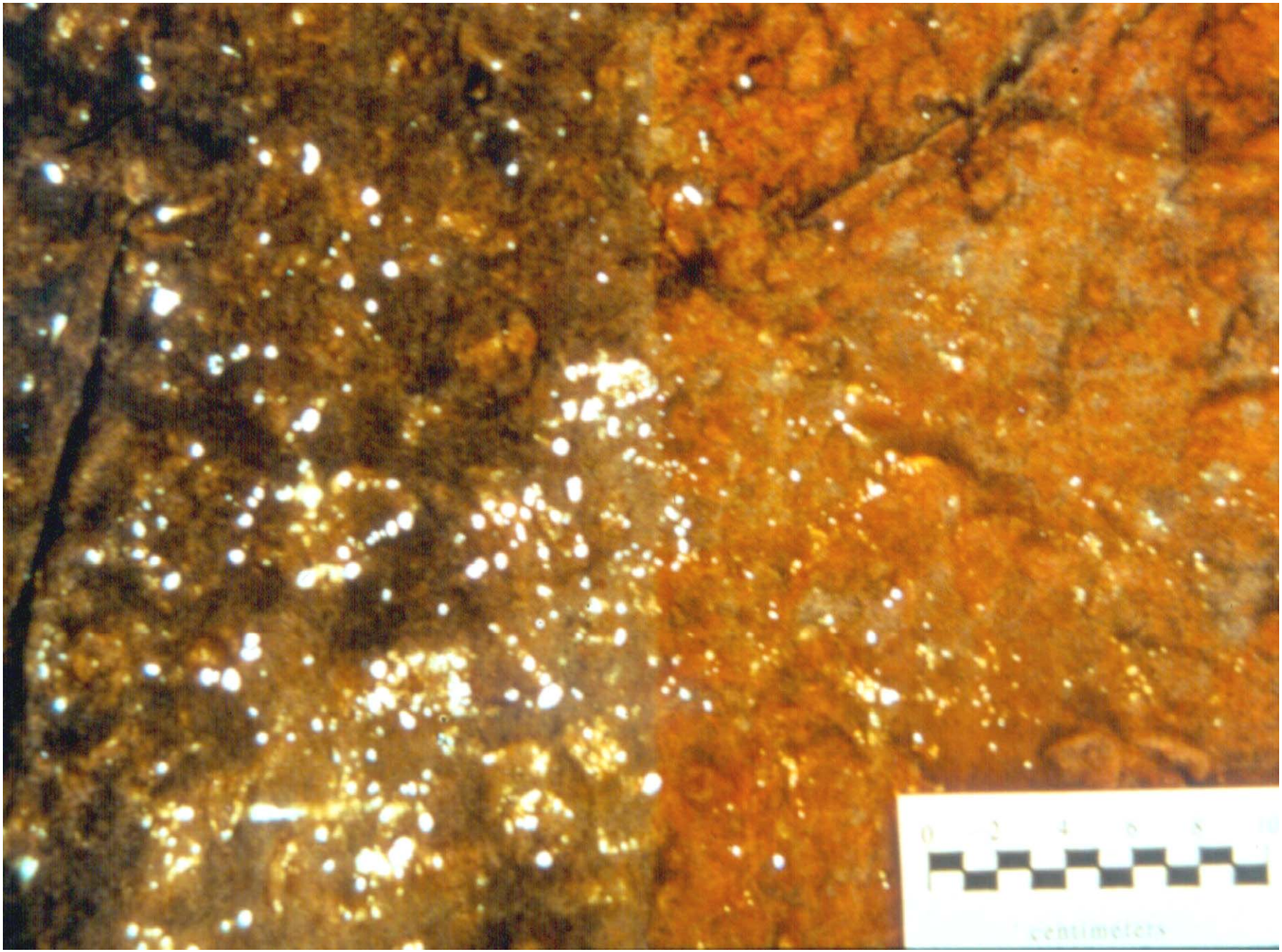
Objective:

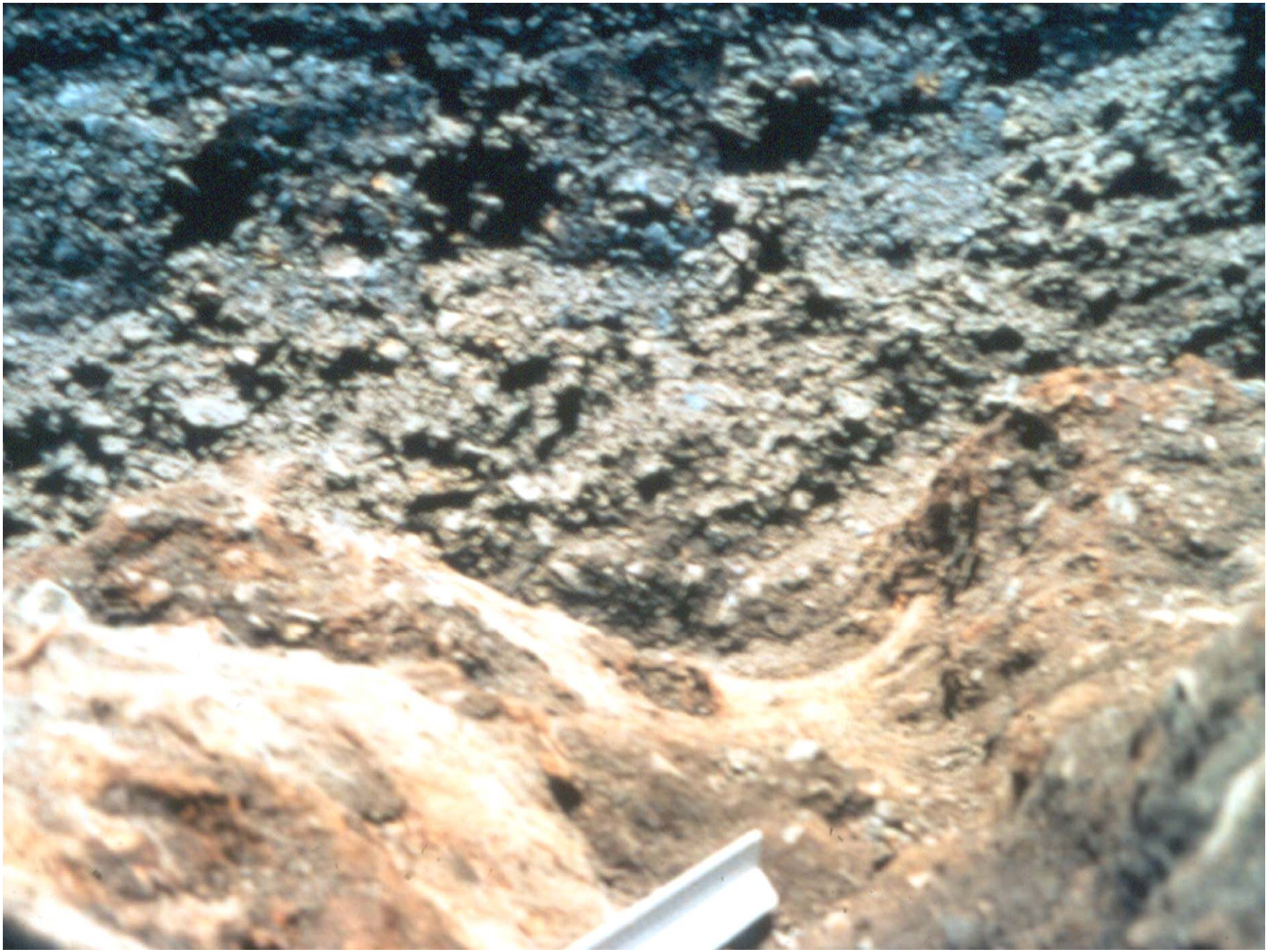
To evaluate the long-term separation and drainage performance of geotextile separators exhumed from paved roadways in Washington State.

Site Locations

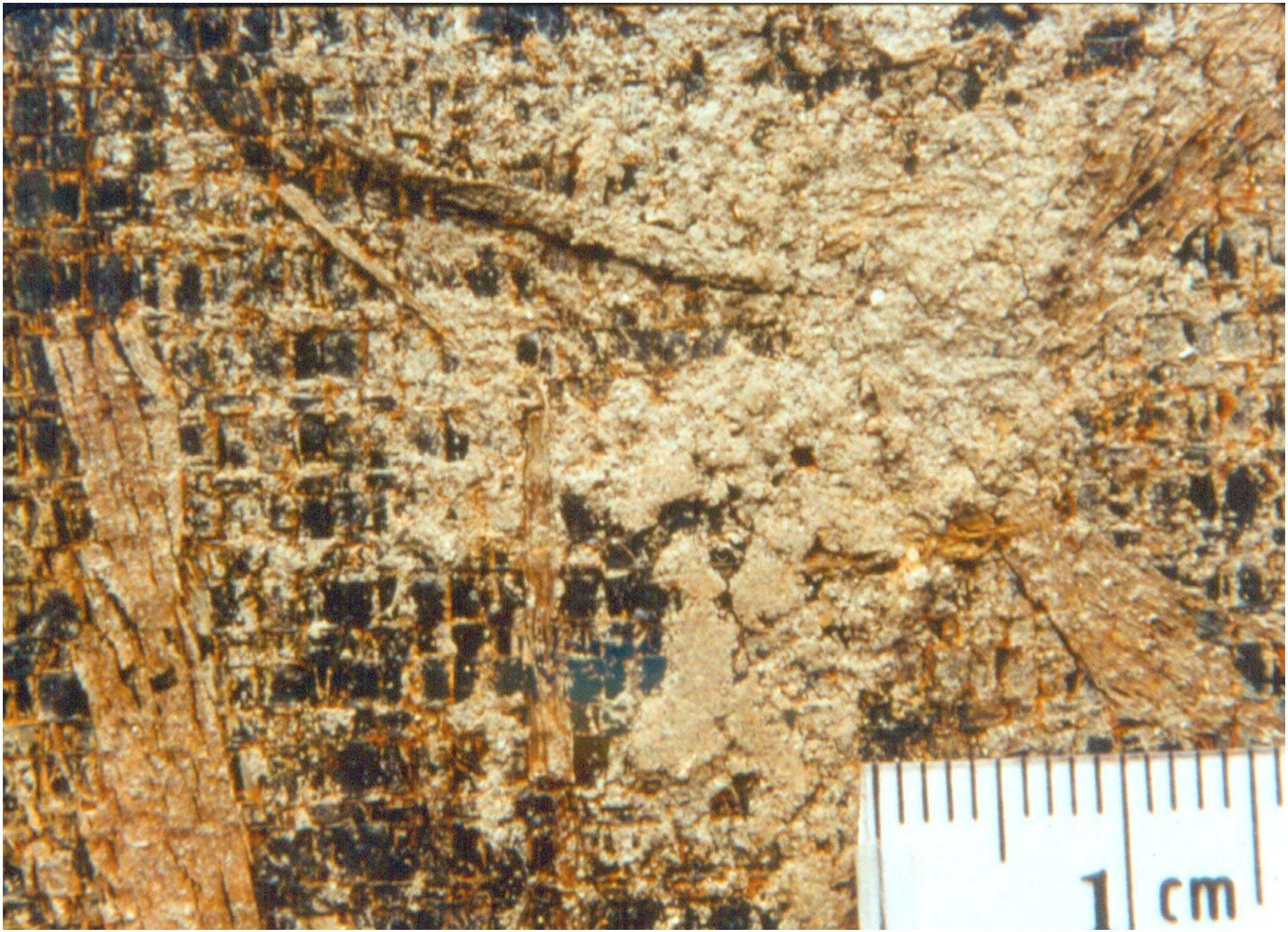
Recovered Geotextiles

- Woven slit-films (11)
  122 - 231 g/m^2 (3.6 - 6.8 oz/yd^2)
- Needle-punched nonwovens (8)
  143 - 270 g/m^2 (4.2 - 8 oz/yd^2)
- Heat-bonded nonwovens (3)
  118 - 140 g/m^2 (3.5 - 4 oz/yd^2)


0
2
4
6
8
10
centimeters




Columbia Heights
Road
Top Surface
Good Pavement Condition
centimeters


1 cm

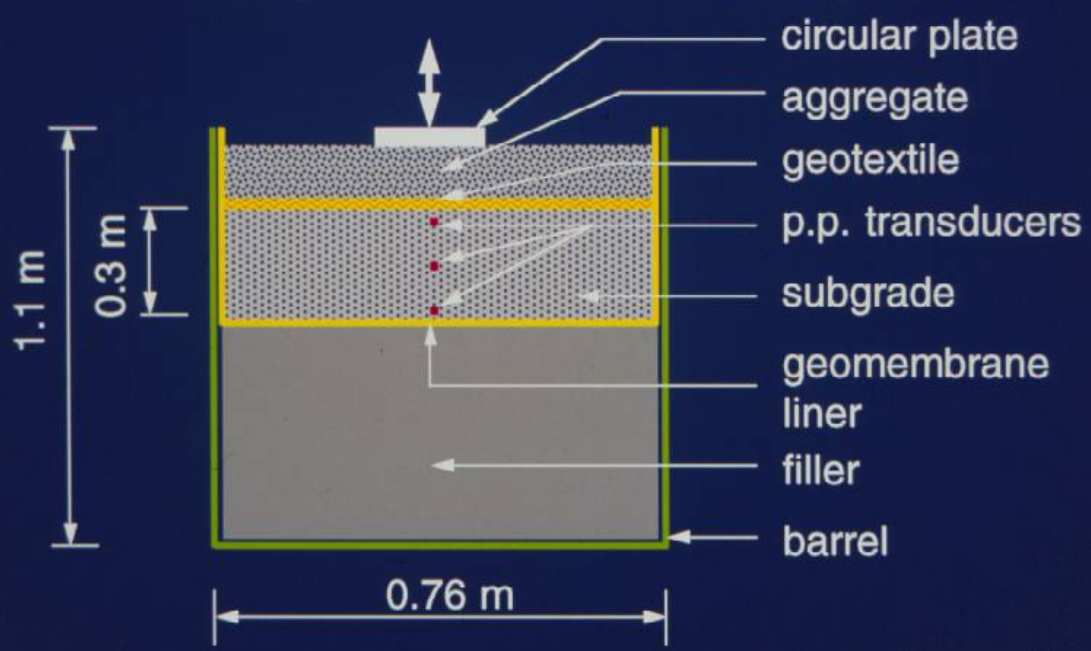
Conclusions

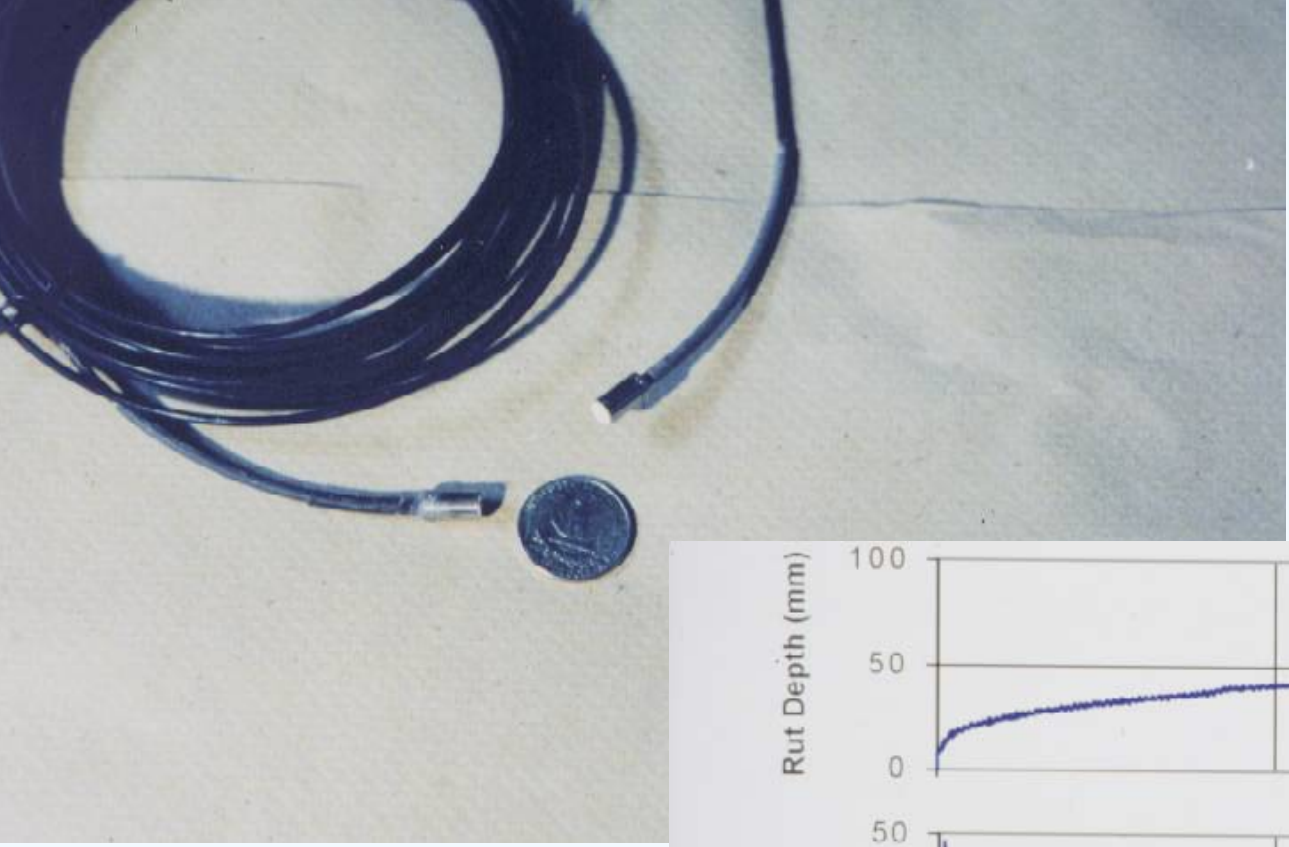
- All geotextiles performed well
- Woven slit-films susceptible to blinding, caking and iron deposits
- Needle-punched nonwovens had best overall performance; however, only slight differences between types
- No evidence of fines migration
- Geotextiles with larger AOS values may perform well
  - Task Force 25 and FHWA: too restrictive?
- Short-term more important than long-term performance

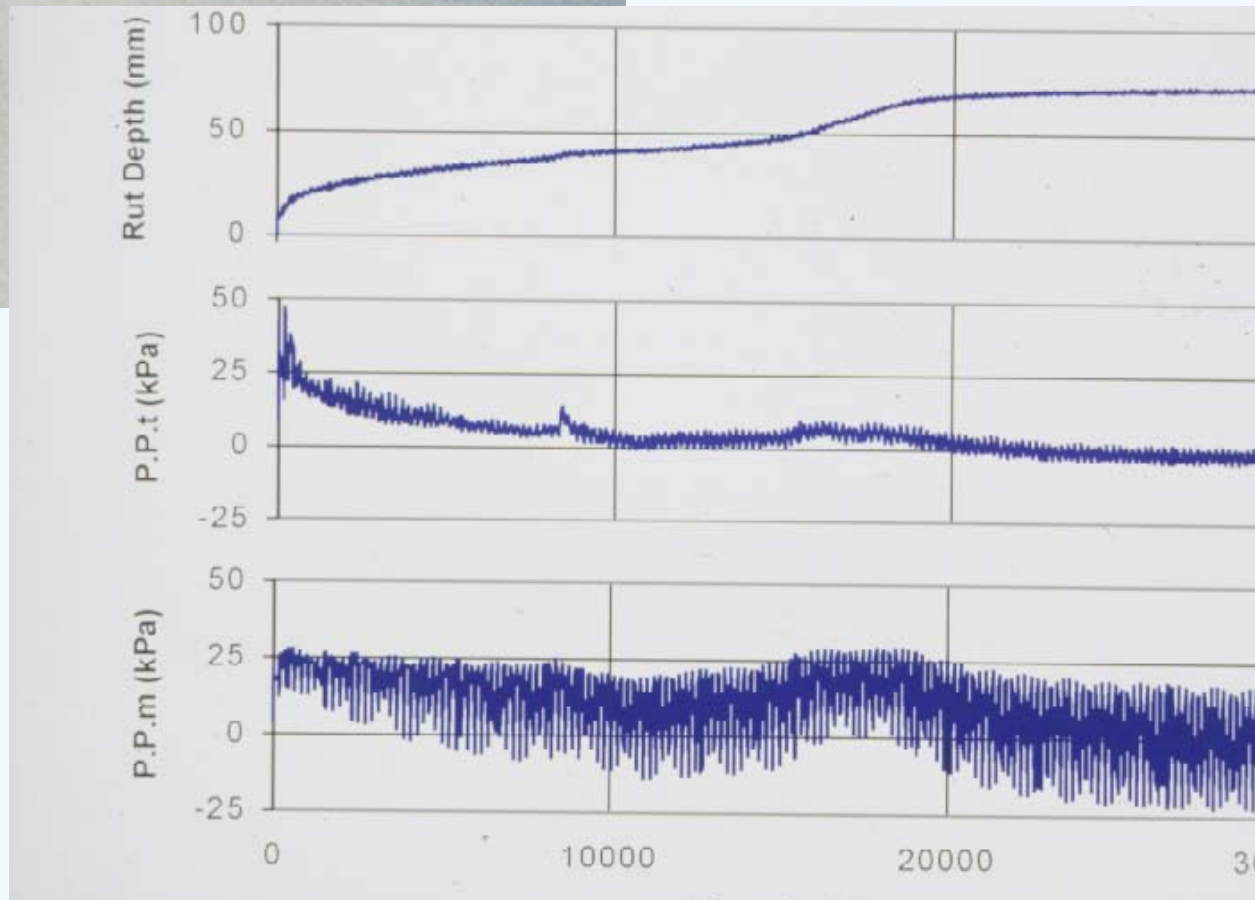
Performance of Geotextile Separators in Laboratory Model Tests

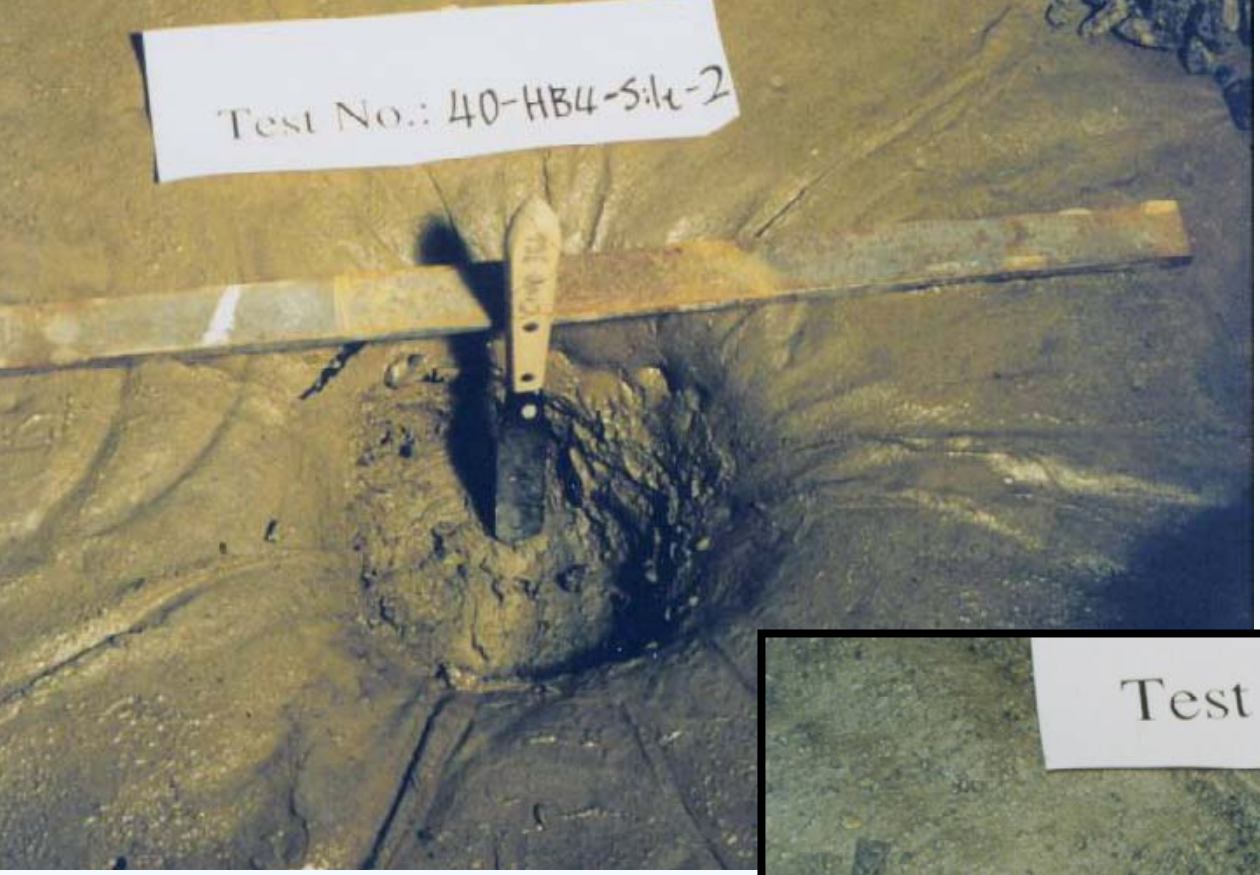
W.-S. Tsai and R.D. Holtz
University of Washington
USA

Experimental Setup






Rut Depth (mm)
100
50
0
P.P.t (kPa)
50
25
0
-25
P.P.m (kPa)
50
25
0
-25
0
10000
20000


Test No.: 40-HB4-Silt-2


Test No.: 40-HB4-Silt-2


40-HB4-Clay-2
8-30-94

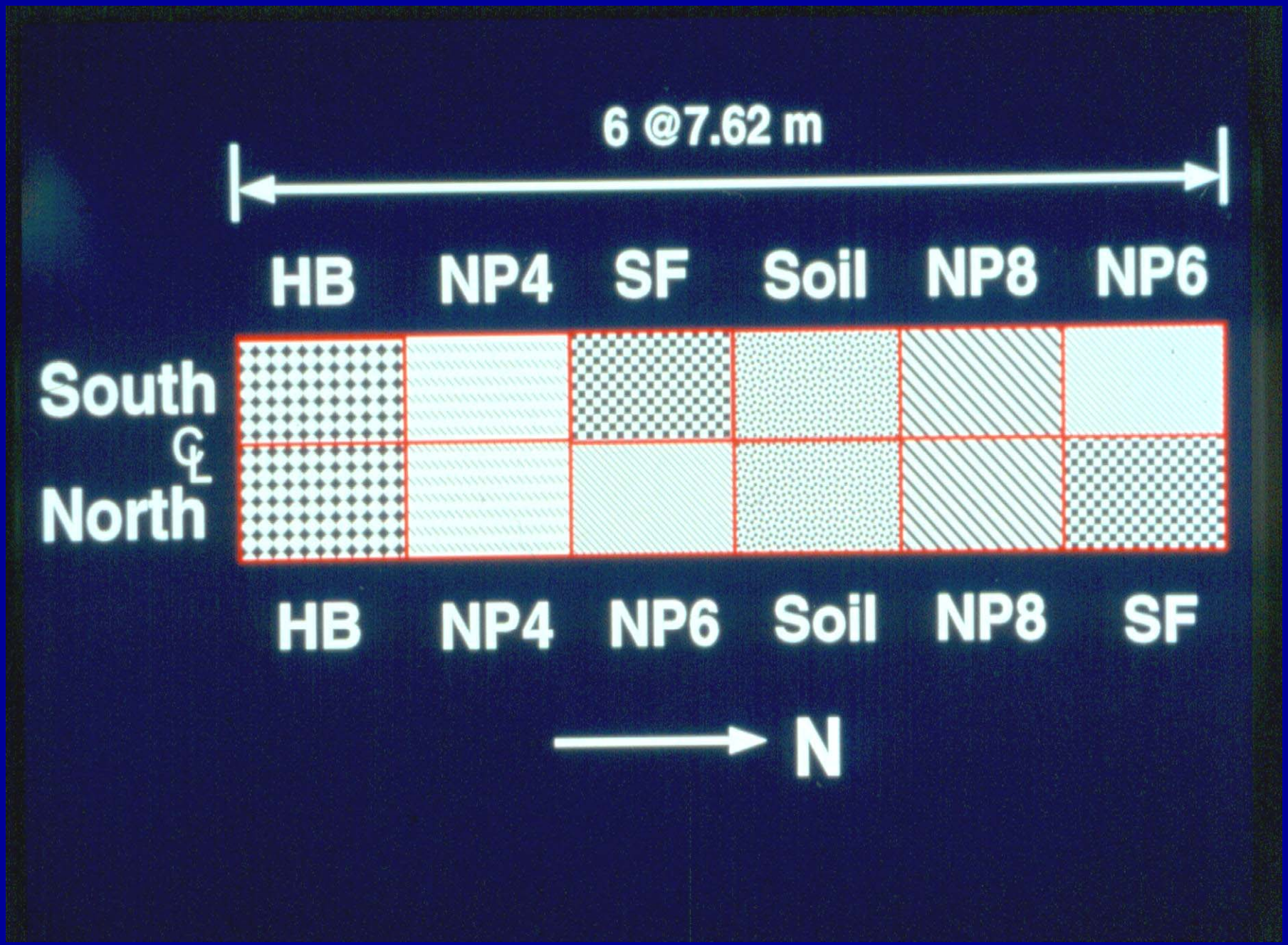
Evaluation of Geotextiles as Separators in a Full Scale Road Test

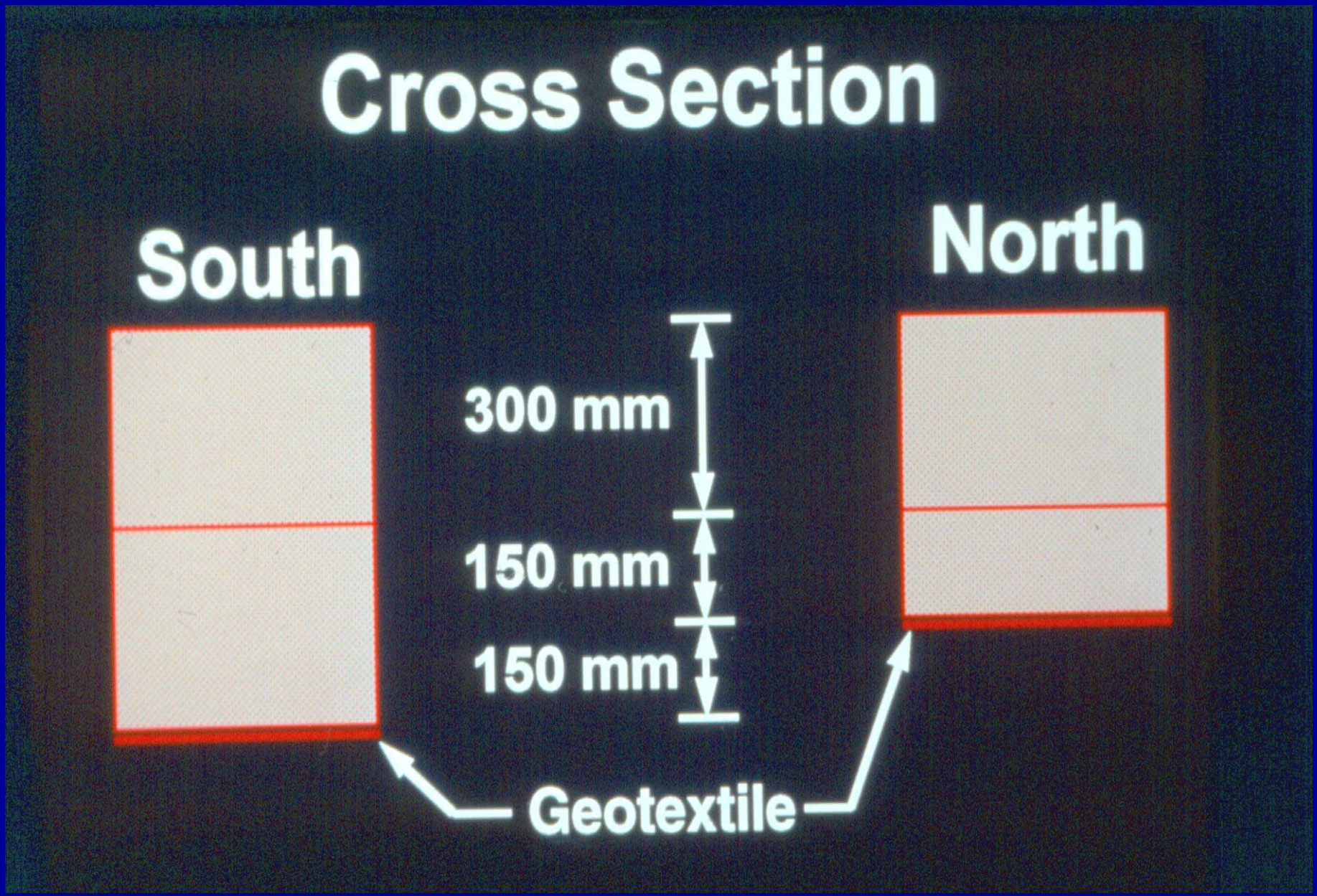
W.-S. Tsai, B.M. Savage, R.D. Holtz,
B.R. Christopher and T.M. Allen

Sponsored by WSDOT and Polyfelt


6 4 '91


6 4 '91


6 @7.62 m
HB
NP4
SF
Soil
NP8
NP6
South
℄
North
HB
NP4
NP6
Soil
NP8
SF
N


Cross Section
South
North
300 mm
150 mm
150 mm
Geotextile


LYNNWOOD, WA
206-743-9772


6 6 91


6 6 '91

Conclusions

- Prevent intermixing
- More uniform ruts
- NP8
  - best overall performance
  - enhanced drainage (?)
- SF
  - reduced subgrade strains
  - pumping (?)

Performance of Geotextile Separators: Bucoda Test Section--Phase II (1996)

P. Jason Black and R. D. Holtz

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NP4
NB

Conclusions:

- Geotextile separators effective in preserving integrity of pavements
- Heat-bondeds most susceptible to clogging
- Fines migration predicted OK by FHWA, but ?? by WSDOT and TF25
- More construction damage observed with thinner initial lift thickness
- TF25 survivability ≈ OK
- Subgrade sections with geotextiles consolidated more than control sections
- Long term performance of separators may not be critical

Long-Term Performance of Geotextile Separators: Bucoda Test Section--Phase III (2003-04)

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Long-Term Performance of Geotextile Separators: Bucoda Test Section--Phase III (2003-04)

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Scope of Research

- Field investigation
- Laboratory investigation
- Analysis of field and laboratory results
- Analysis of Falling Weight Deflectometer (FWD) data

Phase III Investigation

- Field investigation conducted during August 2003
- 12 years after construction
- Main objective: investigate influence of geotextiles on long-term performance of pavement section.

Field Investigation

- Excavation of 12 – 4’ x 6’ test pits
- Material sampling:
  - Base course at three levels
  - Subgrade
  - Geotextile
- In situ testing:
  - Shear strength – pocket penetrometer, torvane
  - Density – nuclear density gauge

Pavement Removal

Pavement Removal

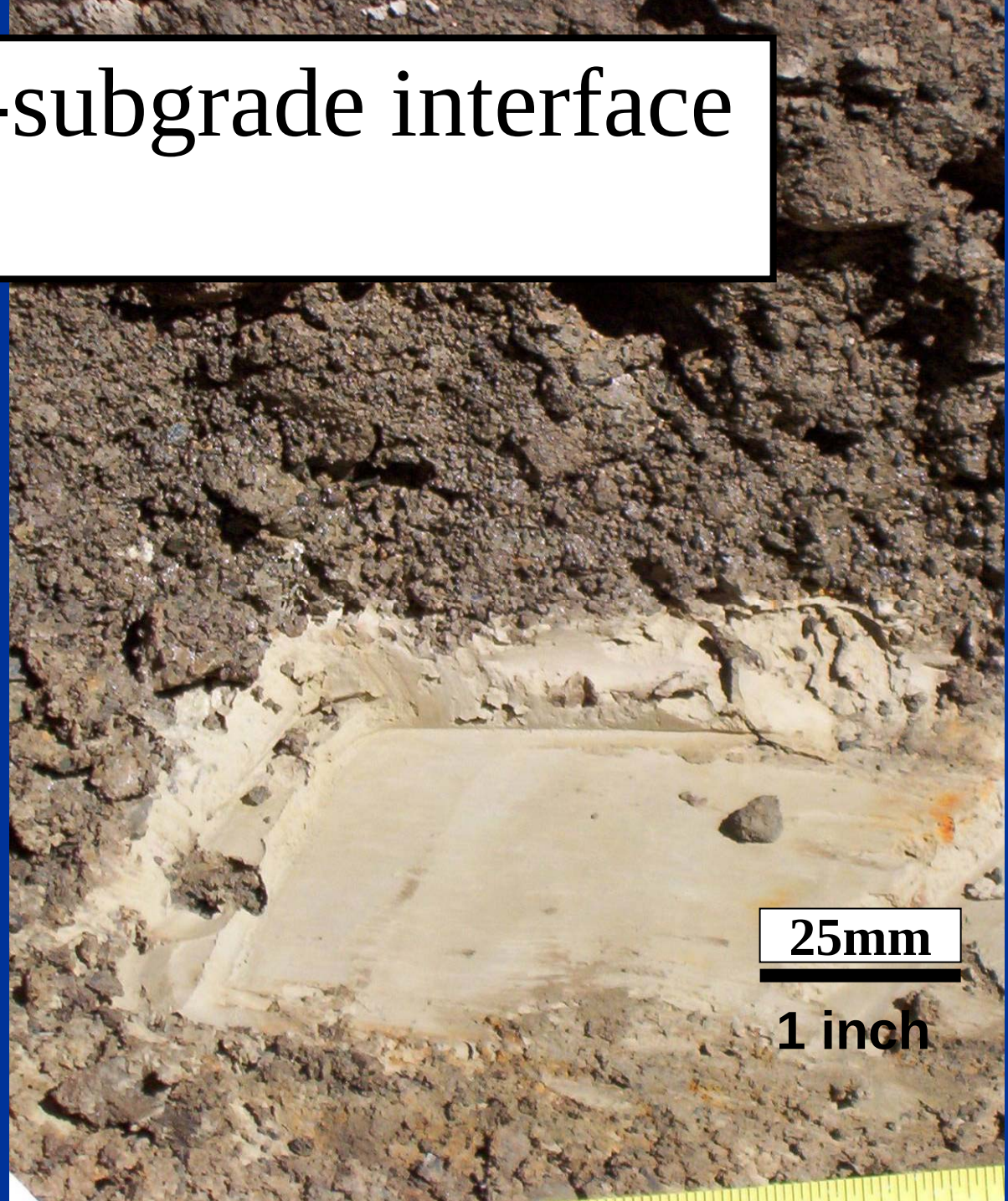
Base Course Removal

NP4-NB Rut

NP4-SB, Top and Bottom

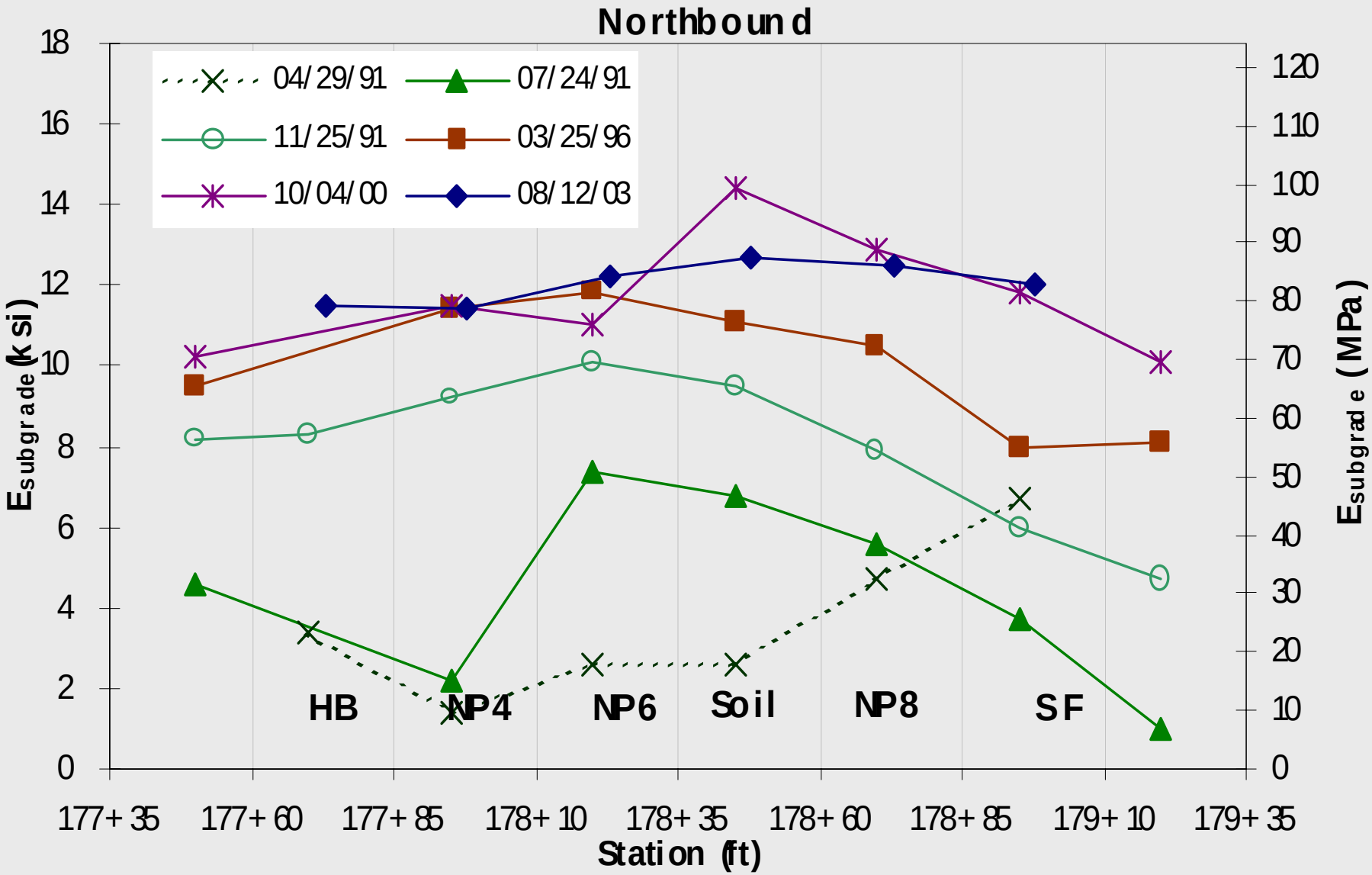
Soil-SB Test Pit

Base course-subgrade interface (SB–Soil)

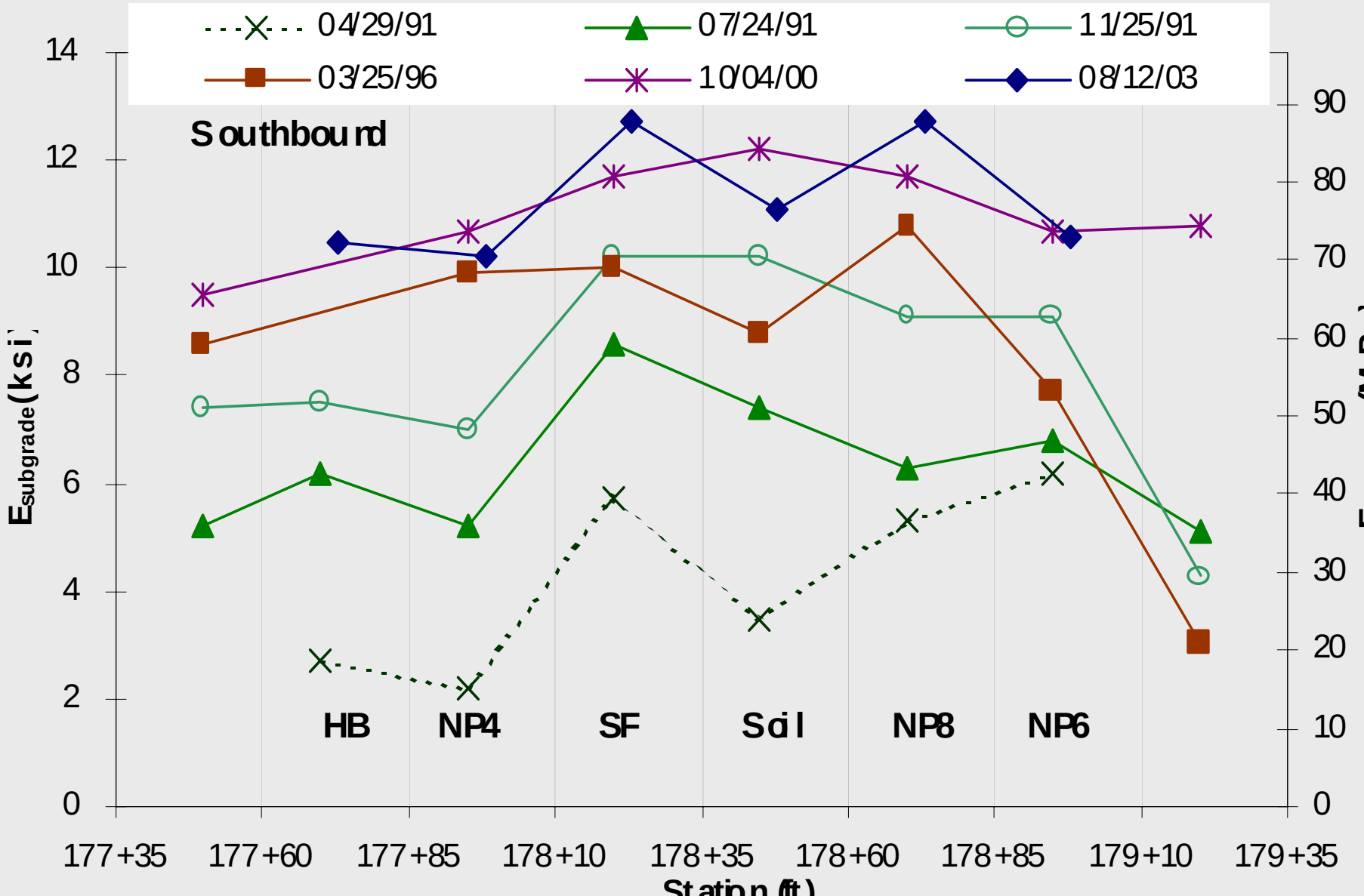


Trailer-Mounted FWD

FWD Results – subgrade moduli - NB



FWD Results – subgrade moduli - SB



Conclusions:

1. After 12 yr heavy traffic, test section still OK.
2. Consolidation + increase in subgrade modulus occurred within a few months after construction.
3. FWD useful for evaluating pavements with geotextiles.
4. IF the subgrade has moderate stiffness, thickness of stabilization aggregate may be reduced with a geotextile.
5. Lightweight geotextiles (<200 g/m^2) under moderate survivability conditions can perform as well as heavier geotextiles (for 12 yr….).
6. Current design methods for retention are OK -- but conservative.

- **Concluding remarks...**


UNIVERSITY OF WASHINGTON
LVX SIT
1861