



Lecture 24

NPTEL Course

# GROUND IMPROVEMENT

USING GEOSYNTHETICS



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# Types, Functions and Applications

# Geosynthetics Terms

## Geosynthetics

### Permeable

### Nonpermeable

#### Geotextiles

#### Geogrids

#### Composites

#### Geomembranes waterproofing sheets

woven  
nonwoven  
knitted

woven  
knitted  
extruded+  
stretched  
welded

all  
combinations

Thermoplastic

Elastomeric

Bituminous

Geoclay liner

# Polymers

	Density (g/cm <sup>3</sup> )	Melting (°C)	Strain@uts (%)	creep
Polyolefines <b>PE,PP</b>	.90 to .95	110 to 170	>100	high
Polyester <b>PET</b>	1.38	>240	10 to 15	low

# Functions of Geosynthetics

- **Filtration**

- Allow the passage of fluids preventing the migration of soil particles (geotextiles, geocomposites)

- **Drainage**

- Transport of fluids  
geonets,  
geocomposites

# Functions of Geosynthetics

- **Separation**
  - Prevent the mixing of two different soils or materials using geotextiles, geocomposites
- **Protection**
  - Avoid damages to a structure, a material or another geosynthetic using nonwoven geotextiles, geonets, geocomposites

# Functions of Geosynthetics

- **Impermeabilization**
  - Fluid barrier using Geomembranes, geocomposites
- **Reinforcement of walls/steep slopes**
  - Provide tensile forces in the soil using geogrids, and geotextiles

# Functions of Geosynthetics

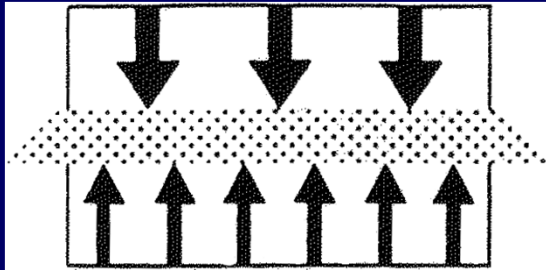
- **Reinforcement of soft soil**
- **Reinforcement of concrete, asphalt**
- Increase the bearing capacity using bidirectional geogrids, geotextiles, geocomposites
- Provide tensile and fatigue resistance bidirectional geogrids



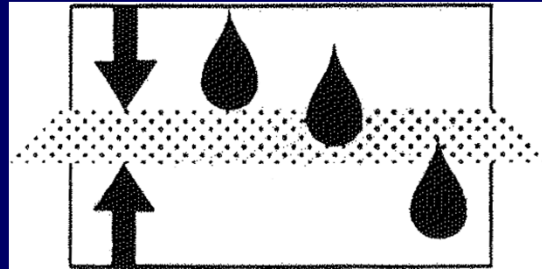
# Functions of Geosynthetics

- **Erosion control or surfacial stabilisation**
- Avoid the detachment and transport of soil particles by rain, runoff and wind; root anchorage using geomats, geocells, biomats, bionets
- **Confinement**
- Restrain the lateral movement of a soil mass  
geocells

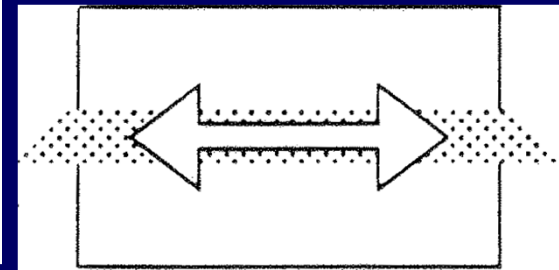
# Functions of Geosynthetics



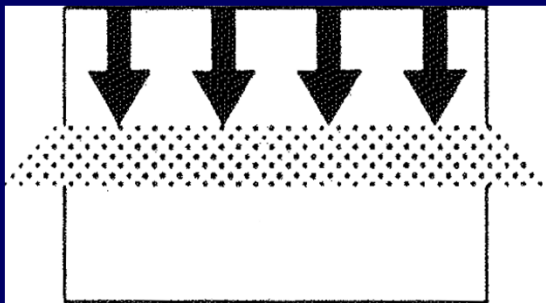
**Separation**



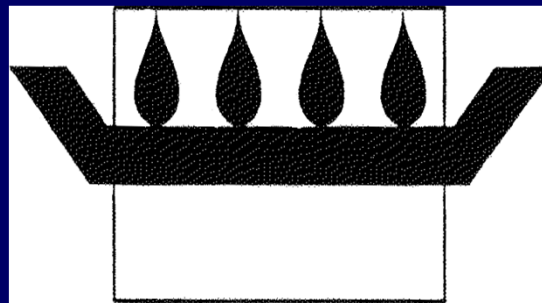
**Filtration**



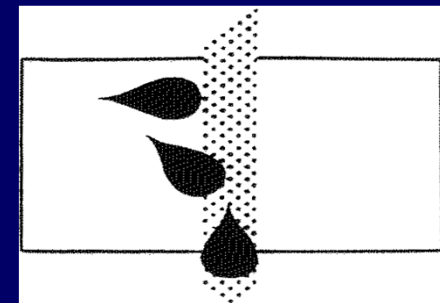
**Reinforcement**



**Protection**

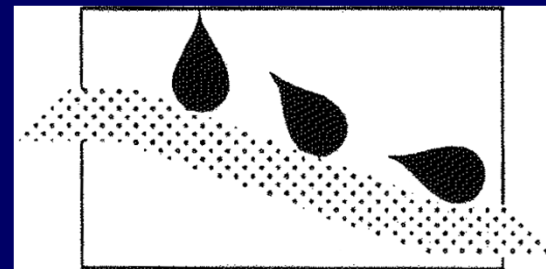


**Waterproofing**

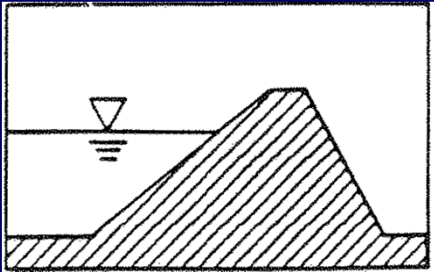


**Drainage**

**Erosioncontrol**



# Application of Geosynthetics



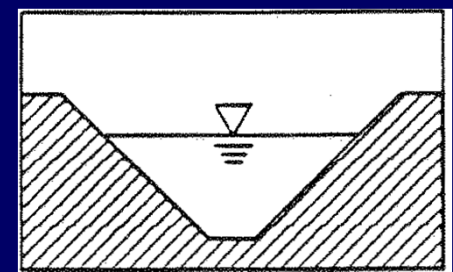
**Reservoirs, dams**



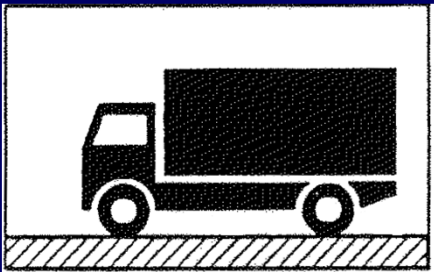
**Liquid waste**



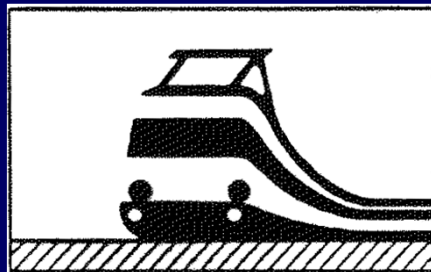
**Solid waste**



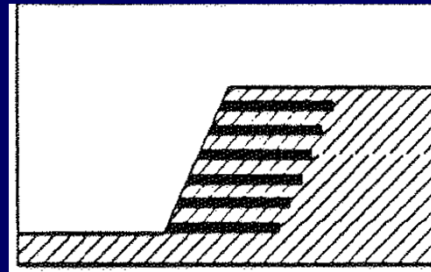
**Canals**



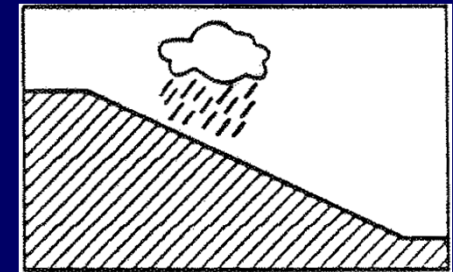
**Roads**



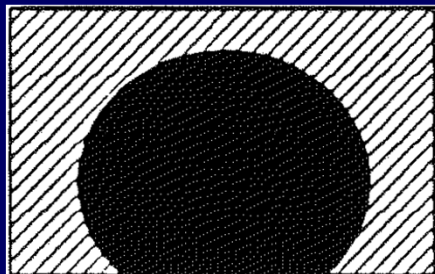
**Railroads**



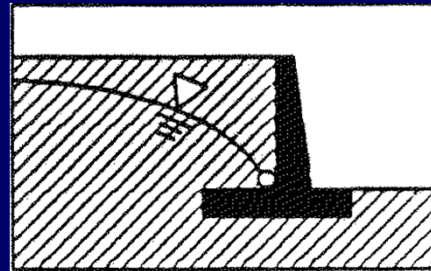
**Retaining walls**



**Erosion protection**

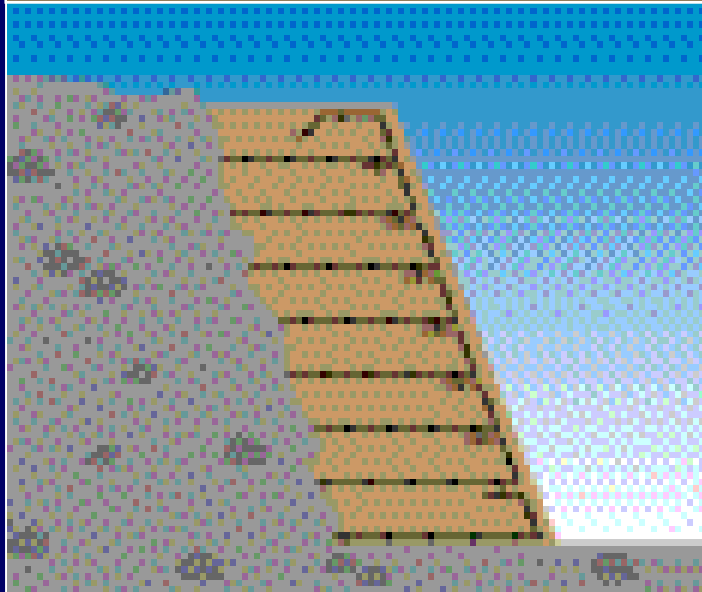
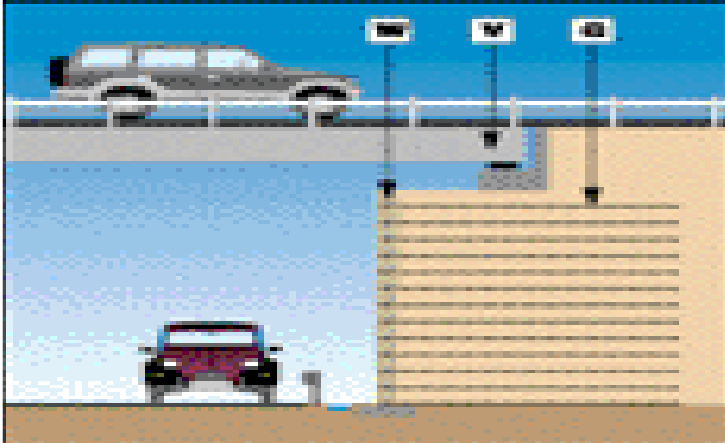
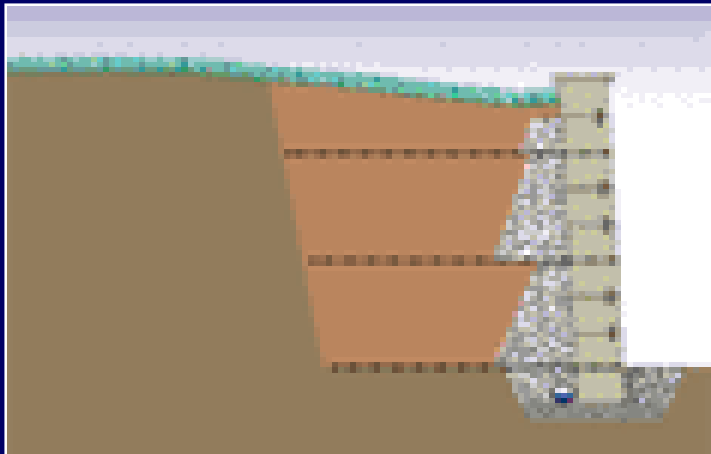


**Tunnels**

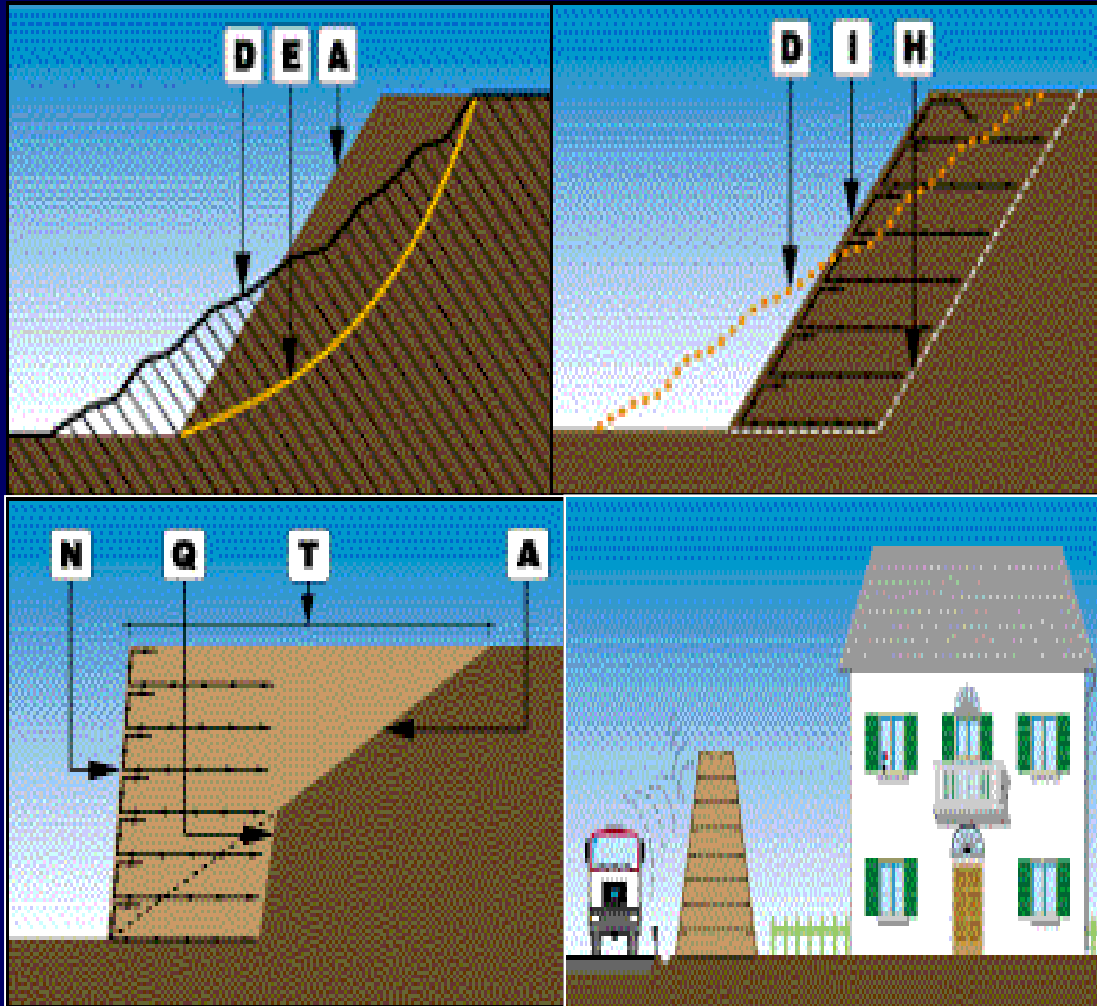


**Drainage systems**

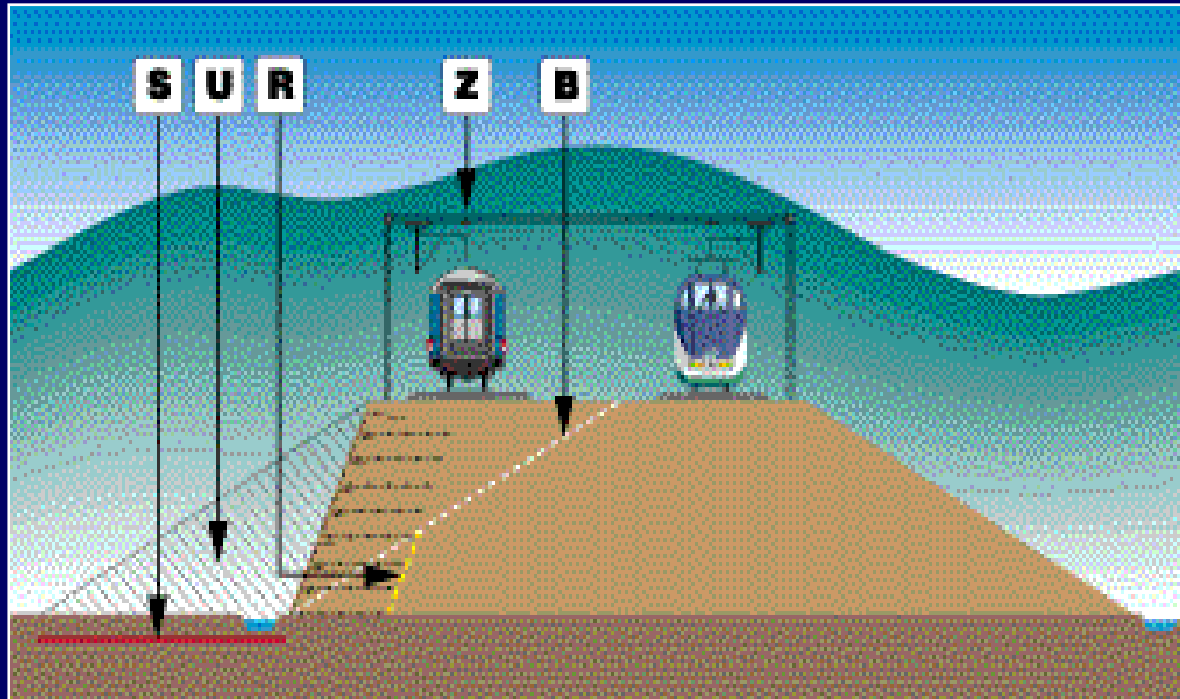
# Retaining Walls, Slopes



# Slope can be reinstated by reusing the same landslide soil



# Railway Embankment



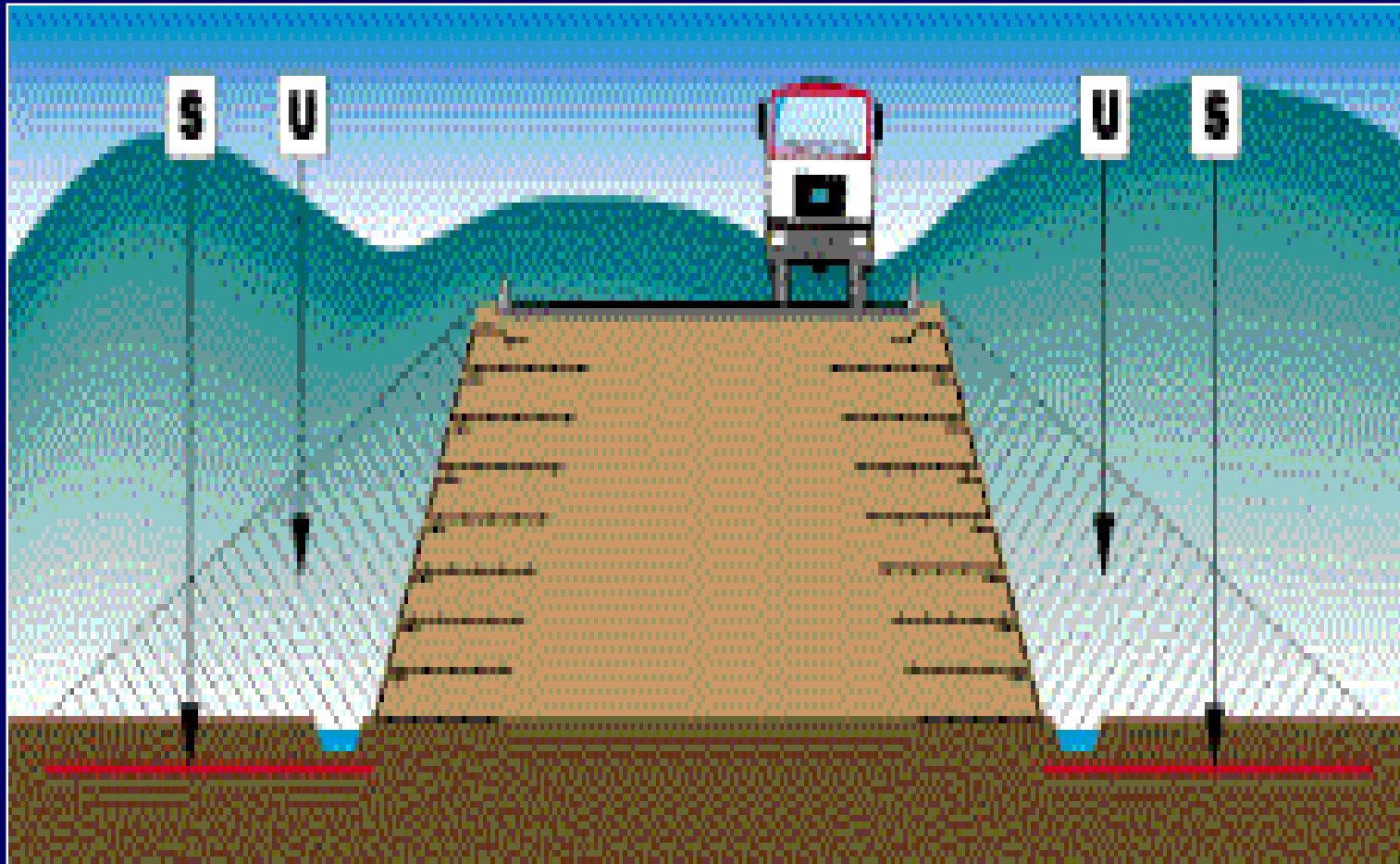
B - Original embankment profile

R - Cutting profile

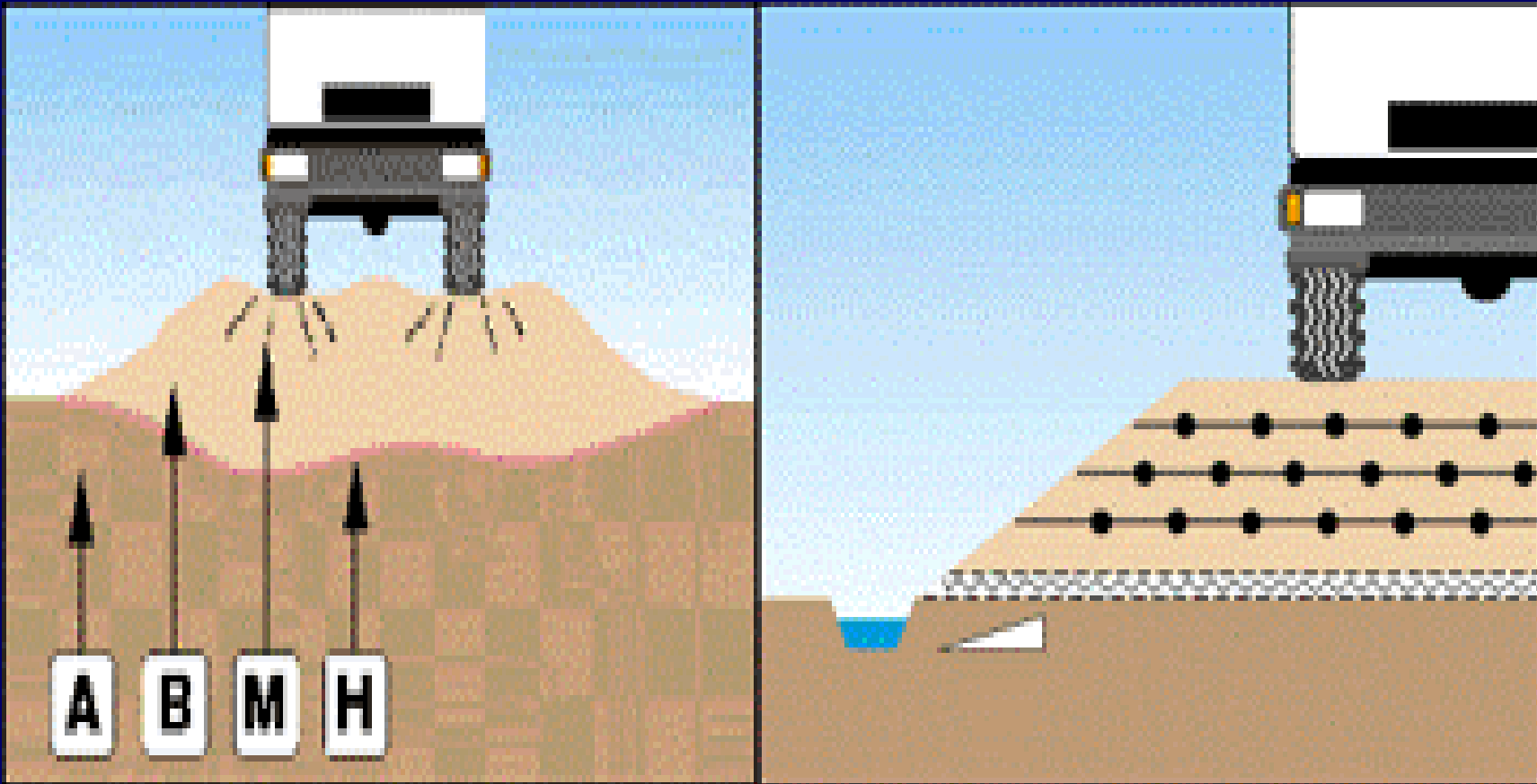
S - Saving of right of way

U - Fill soil saving, Z - New railway lane

# Highway Embankments



# Reinforced Pavements





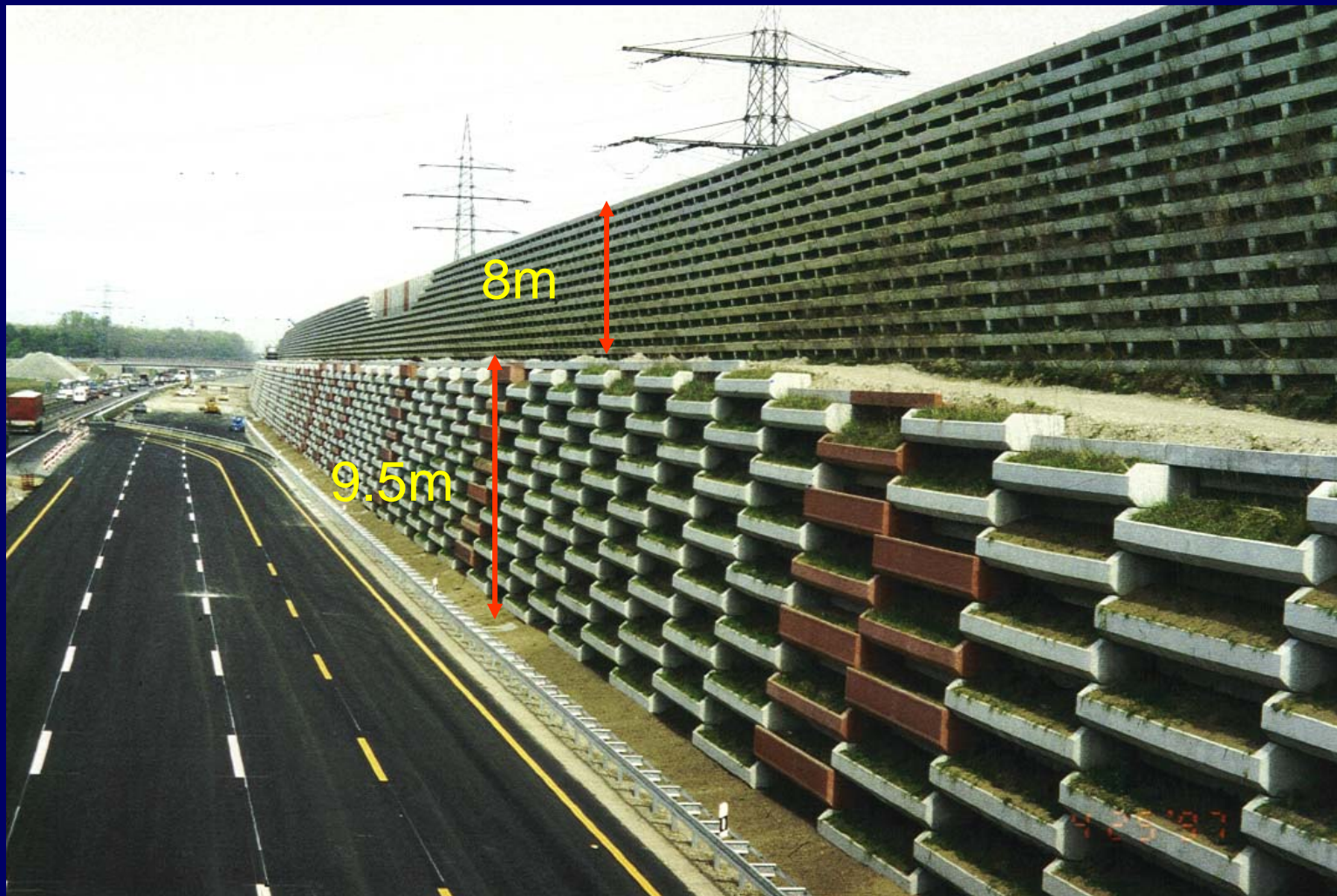
# Separation



# Separation + Reinforcement



# Reinforcement



# Reinforcement



# Reinforcement



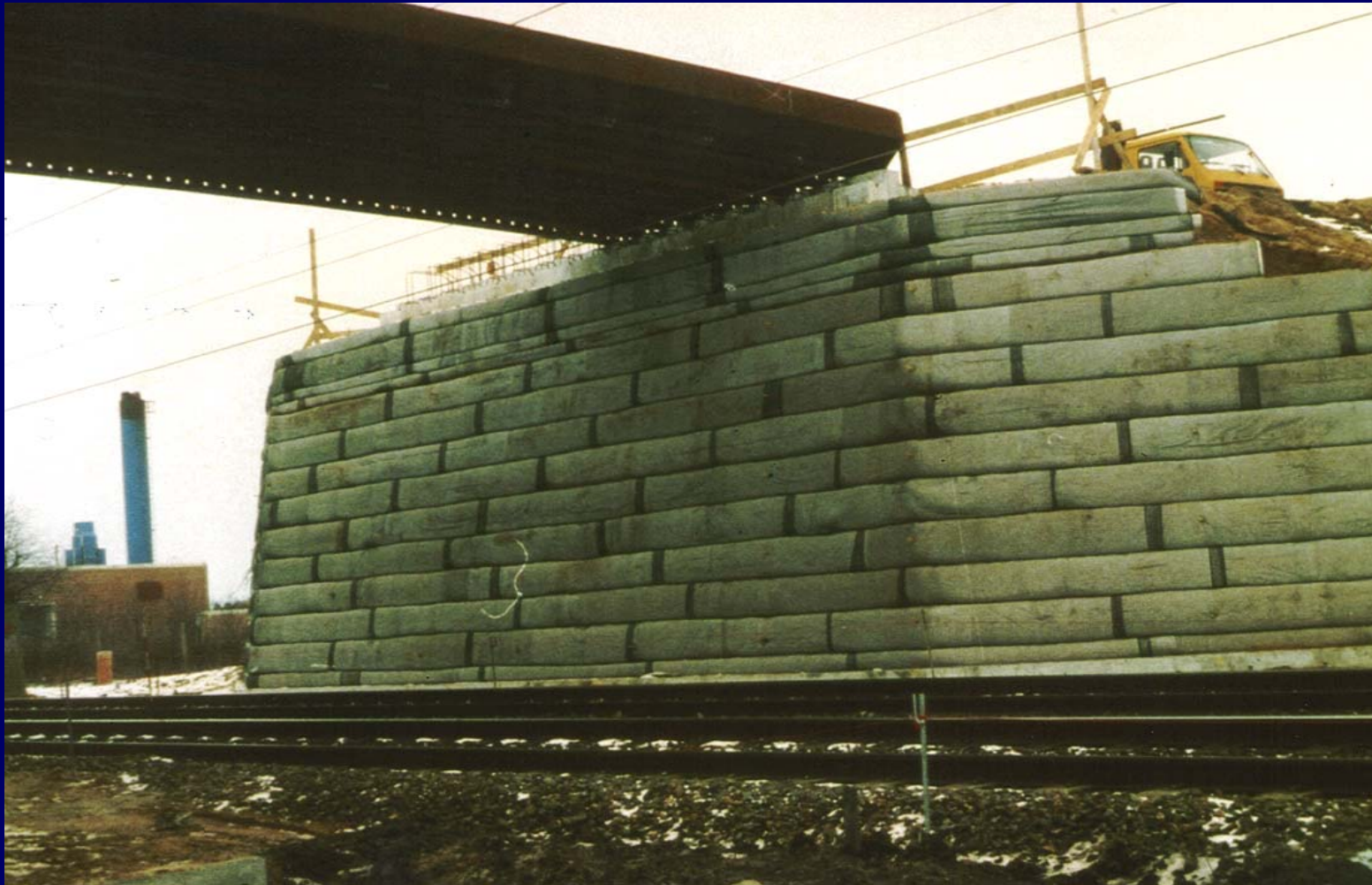
# Reinforcement



# Texsol

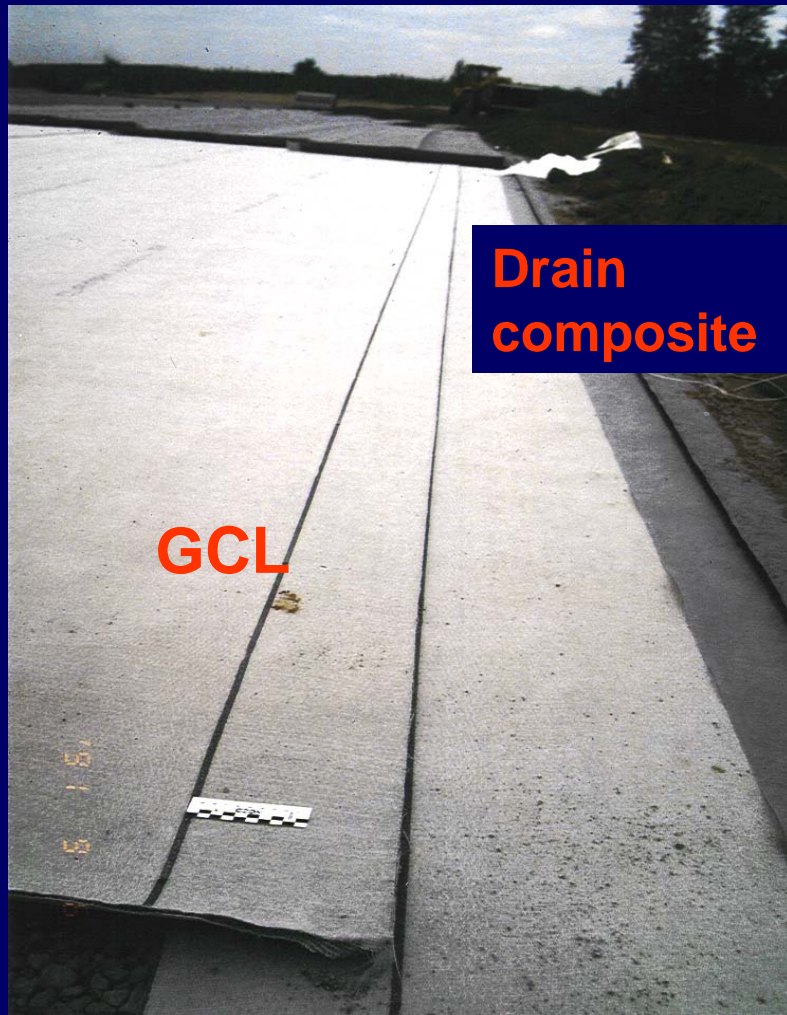


# Reinforcement





# Lining and Drainage



Capping of an  
old wastedump

# Erosion Control



# Hydraulic Engineering Applications

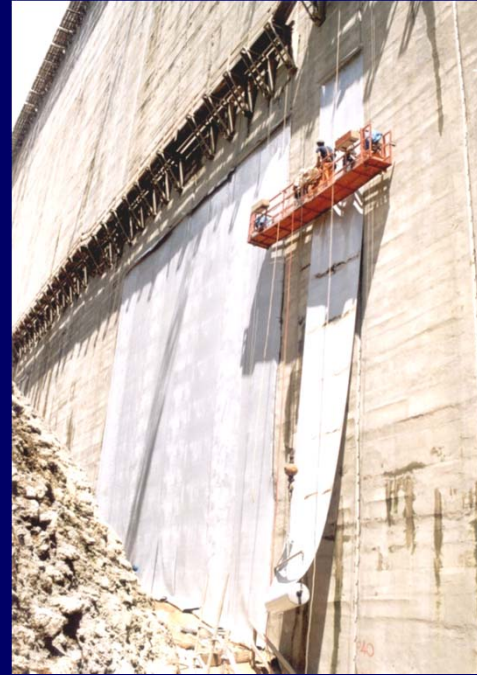
- Waterproofing of Dams
- Waterproofing of Canals
- Reservoir Liners/Floating Covers
- Tunnel Waterproofing & Rehabilitation
- Pipe Rehabilitation & Remediation

# Waterproofing of Dams

- masonry, concrete, earth and RCC dams
- GM is not a structural element, its waterproofing
- many dams over 50-years old often have leakage; sometimes excessive leakage
- methods are under rapid development mainly in European Alps and in China



(Concrete Dam Leaking!)



(Lining a  
Concrete Dam)



(Completed Concrete Dam Lining)



(Lined Earth Dam: Before Rip-Rap)

# Waterproofing of Canals

- conveyance of all liquids; however, water is the most common
- distances and quantities vary greatly
- fundamental issue is leakage (i.e., how much, if any, is allowable)
- some type of liner (GM or GCL) is necessary
- many federal agencies involved (BuRec, COE, DOA and NRCA)



(Lining a Canal: Before Soil Covering)



(GCL Lining of a Canal)



(GM Canal 18 years after GM Lined)



(Lining a "Live" Canal)

# Reservoir Liners/Floating Covers

- GM pond liners date back to 1930's
- used to contain all types of liquids
  - potable water
  - architectural ponds
  - shutdown water
  - gray water
  - industrial waters
  - process waste waters
  - sewage sludge
  - industrial sludge
  - agricultural wastes
  - hazardous liquids\*

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\*EPA estimates 206,000 in USA alone!



# Common Characteristics

- generally shallow liquid depths
- typically 2 to 7 m
- side slopes from 4(H)-to-1(V) to 1(H)-to-1(V), i.e.,  $\beta = 14^\circ$  to  $45^\circ$
- both exposed and covered
- exposed – GM durability issue
- covered – soil stability issue



(Lined Potable Water Reservoir)



(Floating GM Cover)



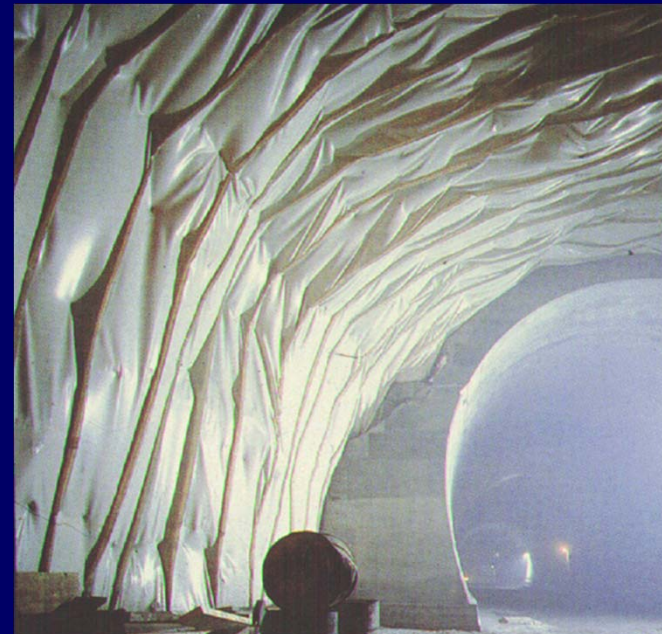
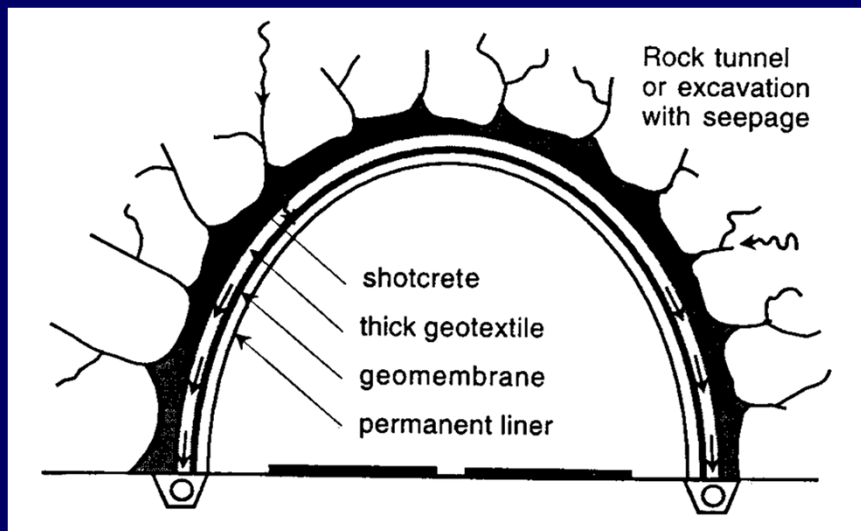
(Another Floating GM Cover)



(Huge GM Bag Transporting Potable Water)

# New Tunnel Waterproofing

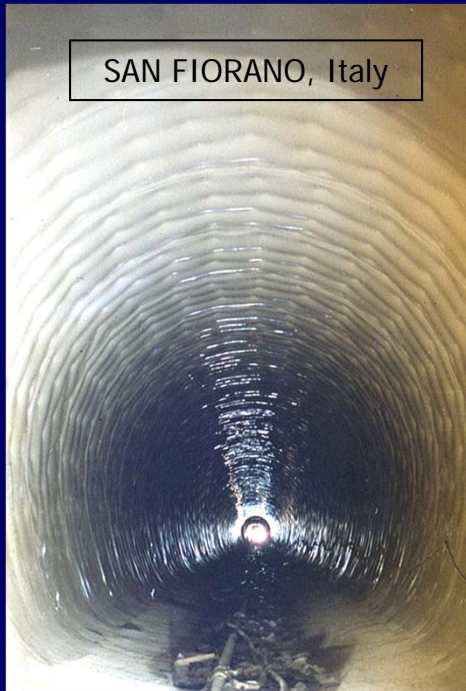
- many old tunnels without GMs are leaking
- white staining on surface is the “tell-tale”
- key is to use a GT and GM behind the permanent concrete surfacing
- in turn, this requires a GP drainage system



# Tunnel Rehabilitation

- concern is over excessive leakage
- leakage can lead to instability
- tunnels are essentially accessible pipes
- obviously, they are usually more critical
- water tunnels are the general target

SAN FIORANO, Italy

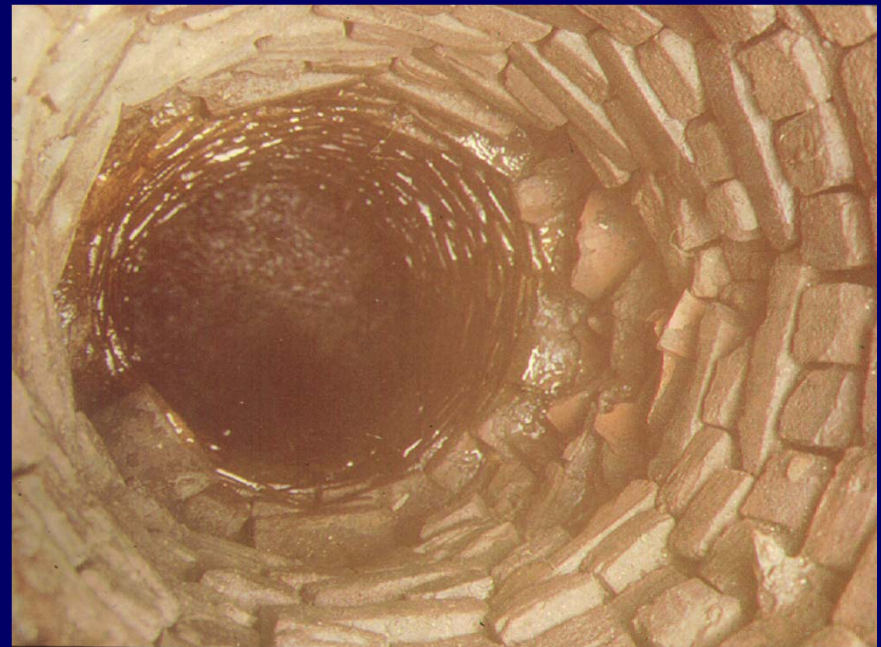


SPALOV TUNNEL, Czech Republic



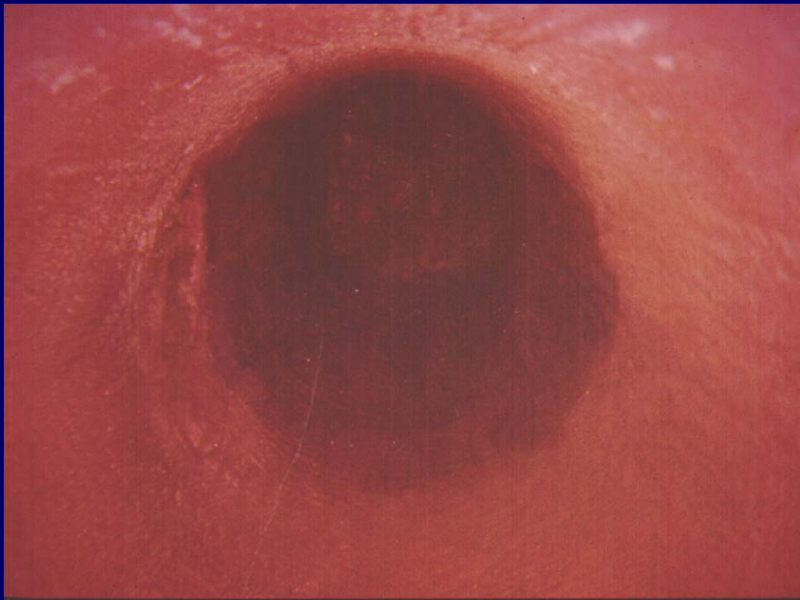
## Pipe Rehabilitation and Remediation

- focuses on old lifeline systems
- transmission lines (water, gas, oil)
- drainage (conduits, canals)
- sewers (sanitary and storm) ... see photos

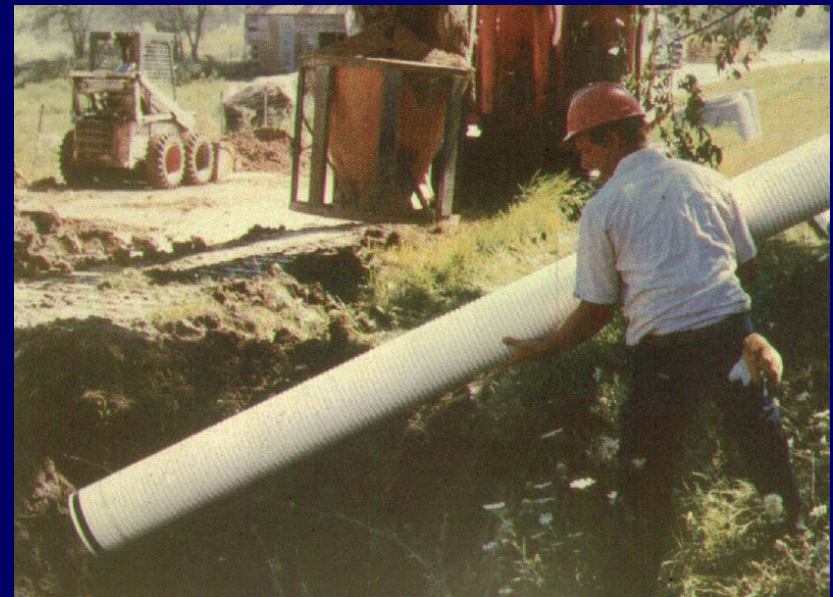


# Methods of Pipe Rehabilitation

- Coatings
- Slip Liners (Pipe-within-Pipe)
- Cured-in-Place Pipe
- Fold-and-Formed Pipe
- In-Situ Liners



(Epoxy Coated Pipe)



(Pipe-within-Pipe)

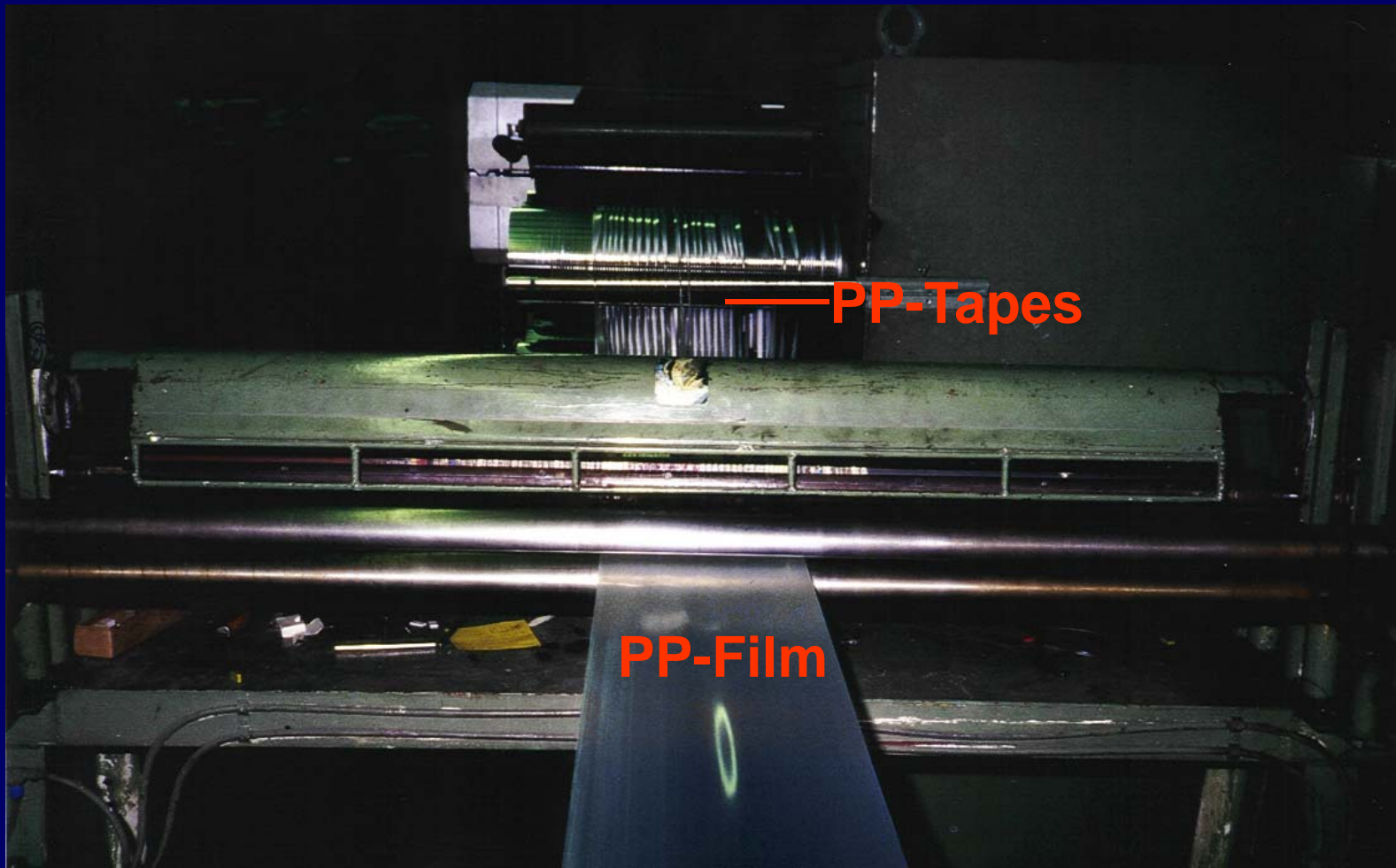
**FIBRES / TAPES**

# PP-Fibre Production





# PP-Tape Production

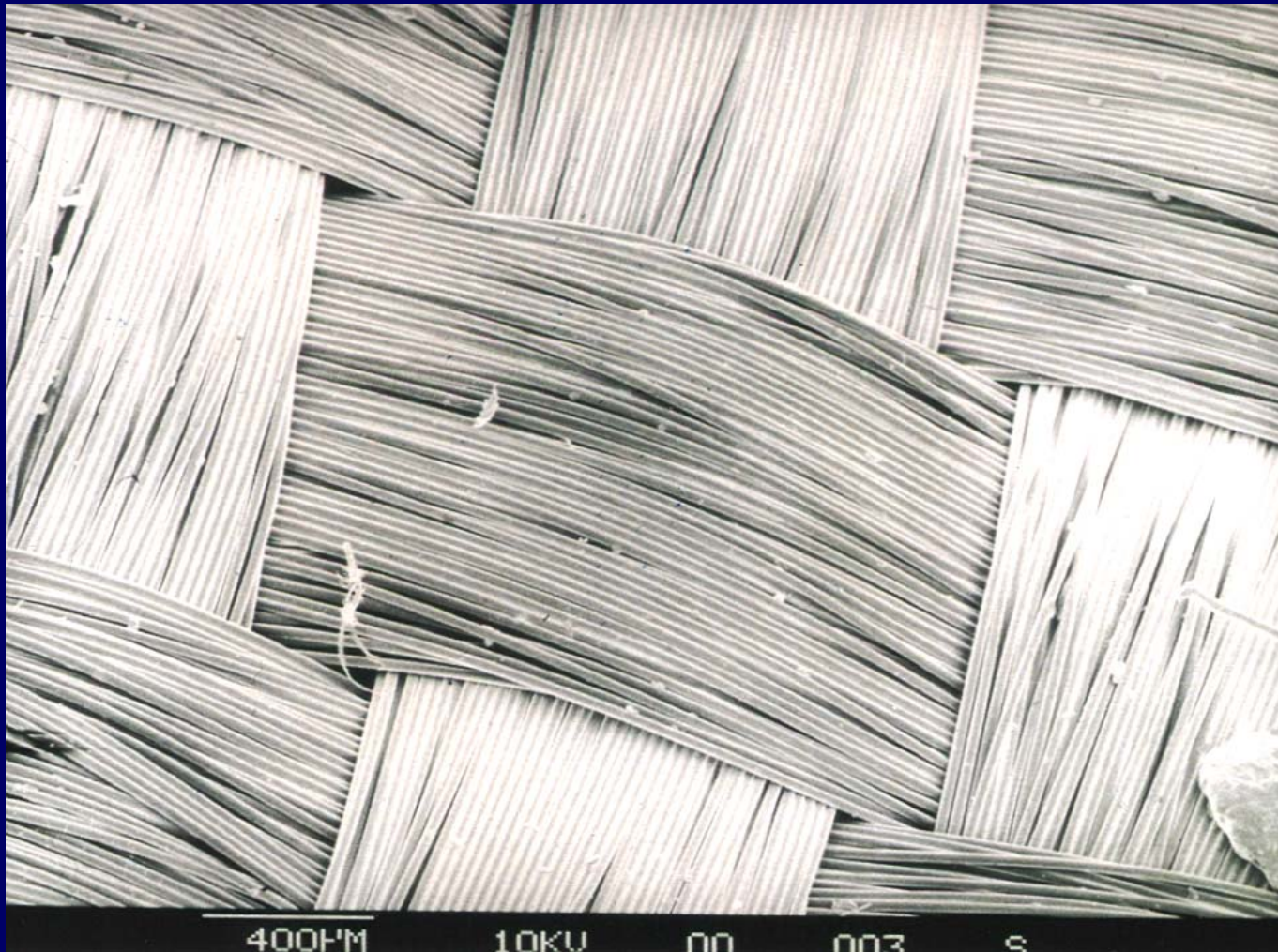


**WOVEN FABRIC**

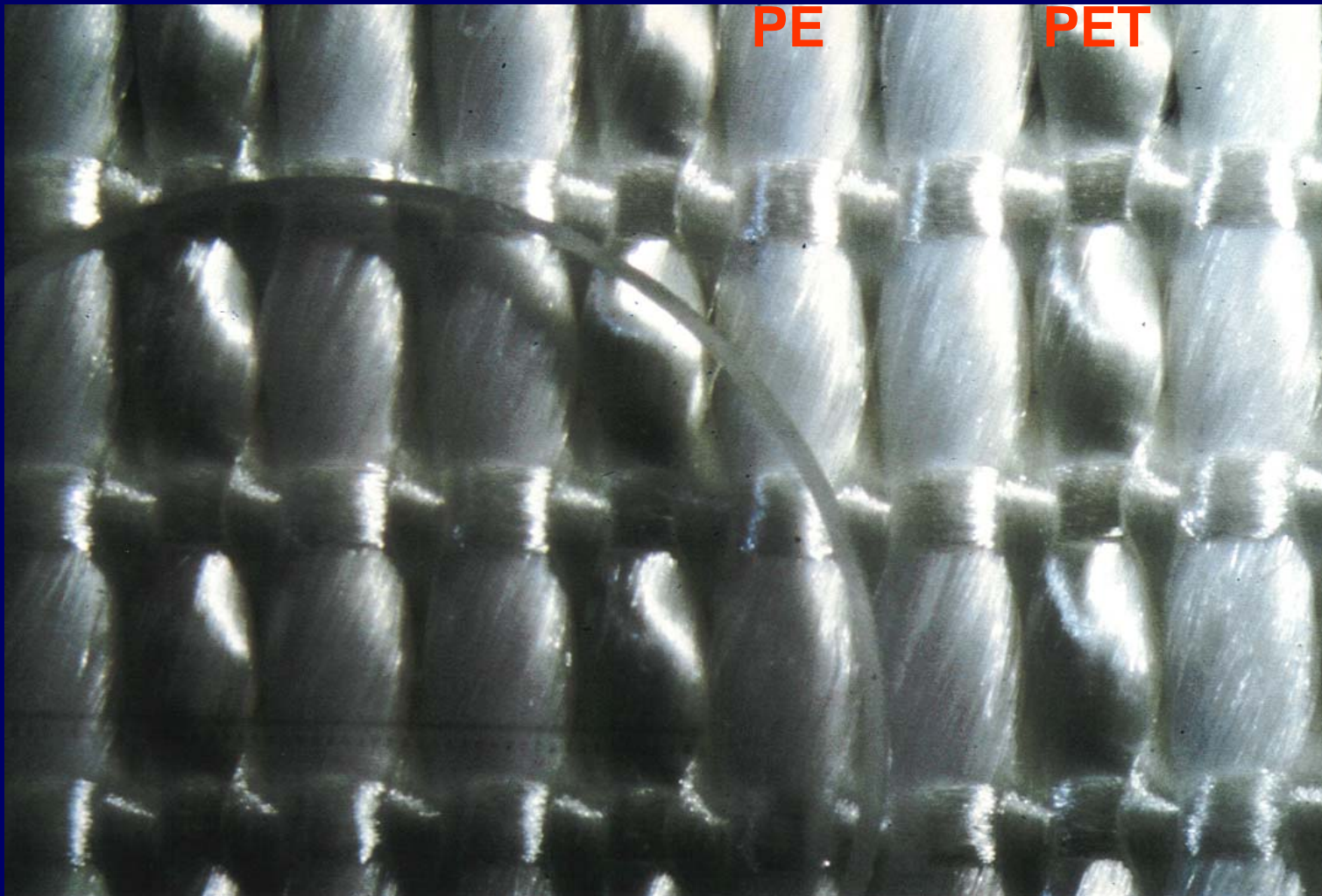
# Weaving Machine



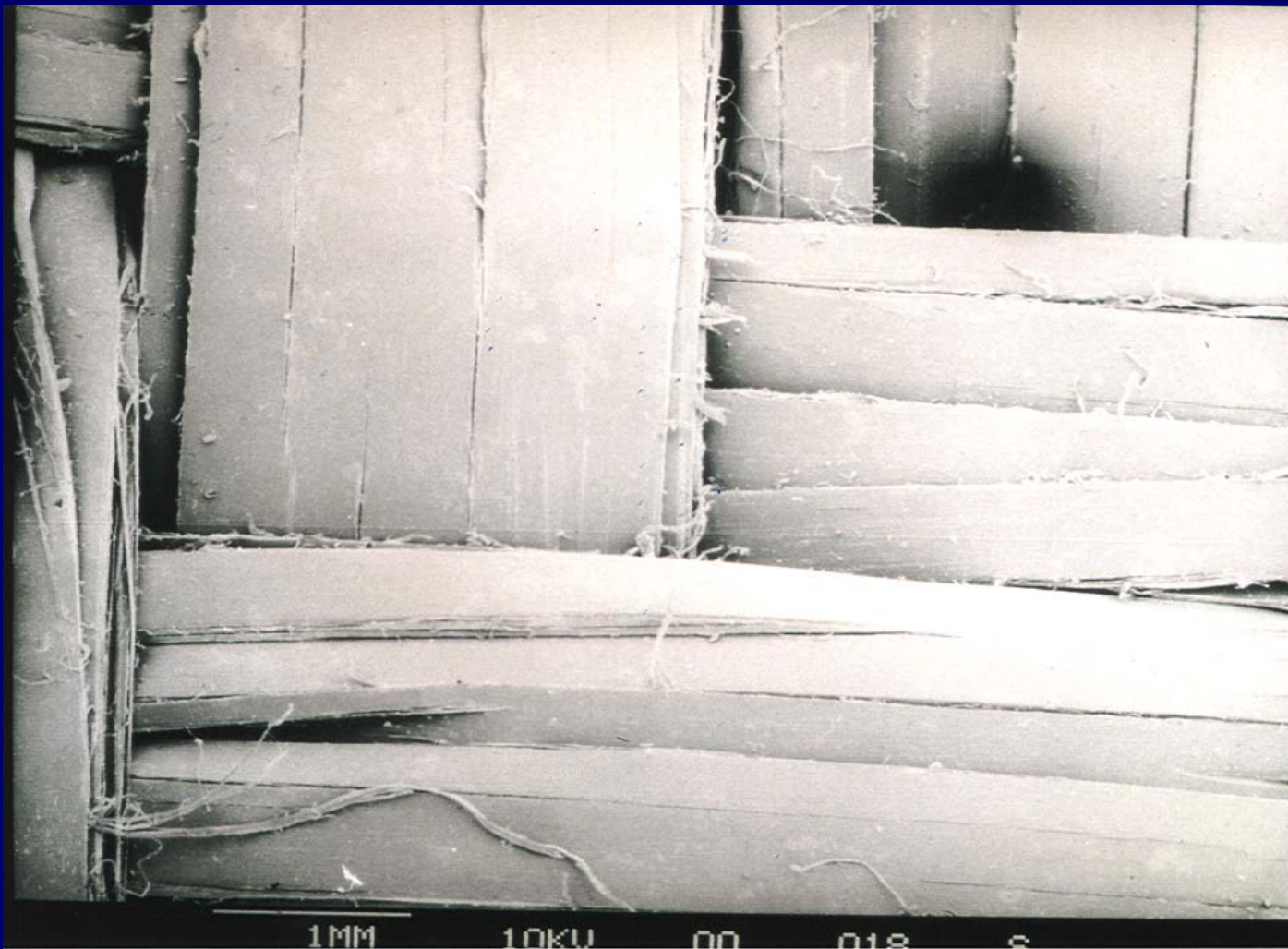
# PET Multifilament Woven Fabric



# PE/PET Woven Fabric



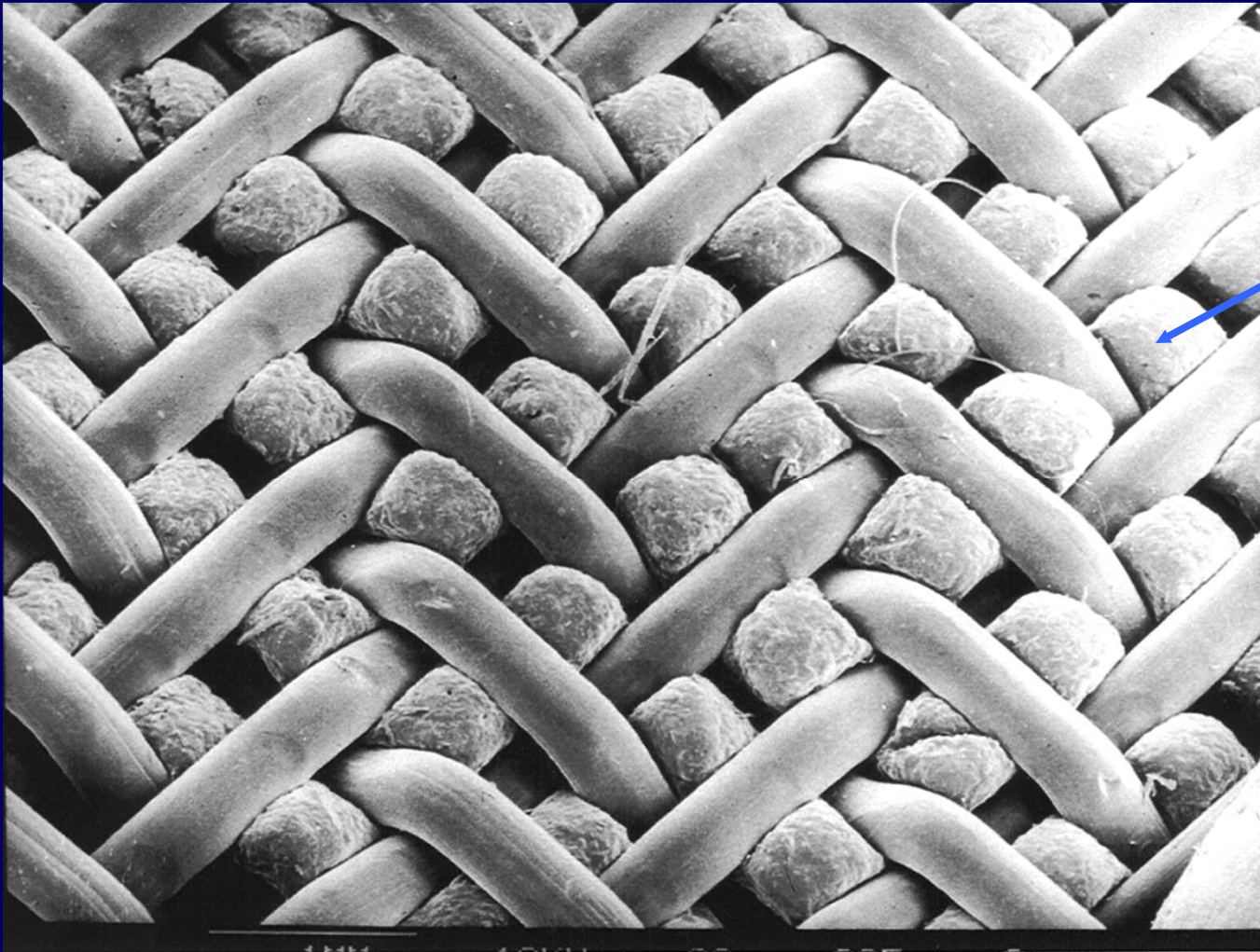
# PP-Tape Woven Fabric



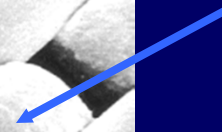
# PP-Tape Woven Fabric



# Monofil (wire) Woven Fabric



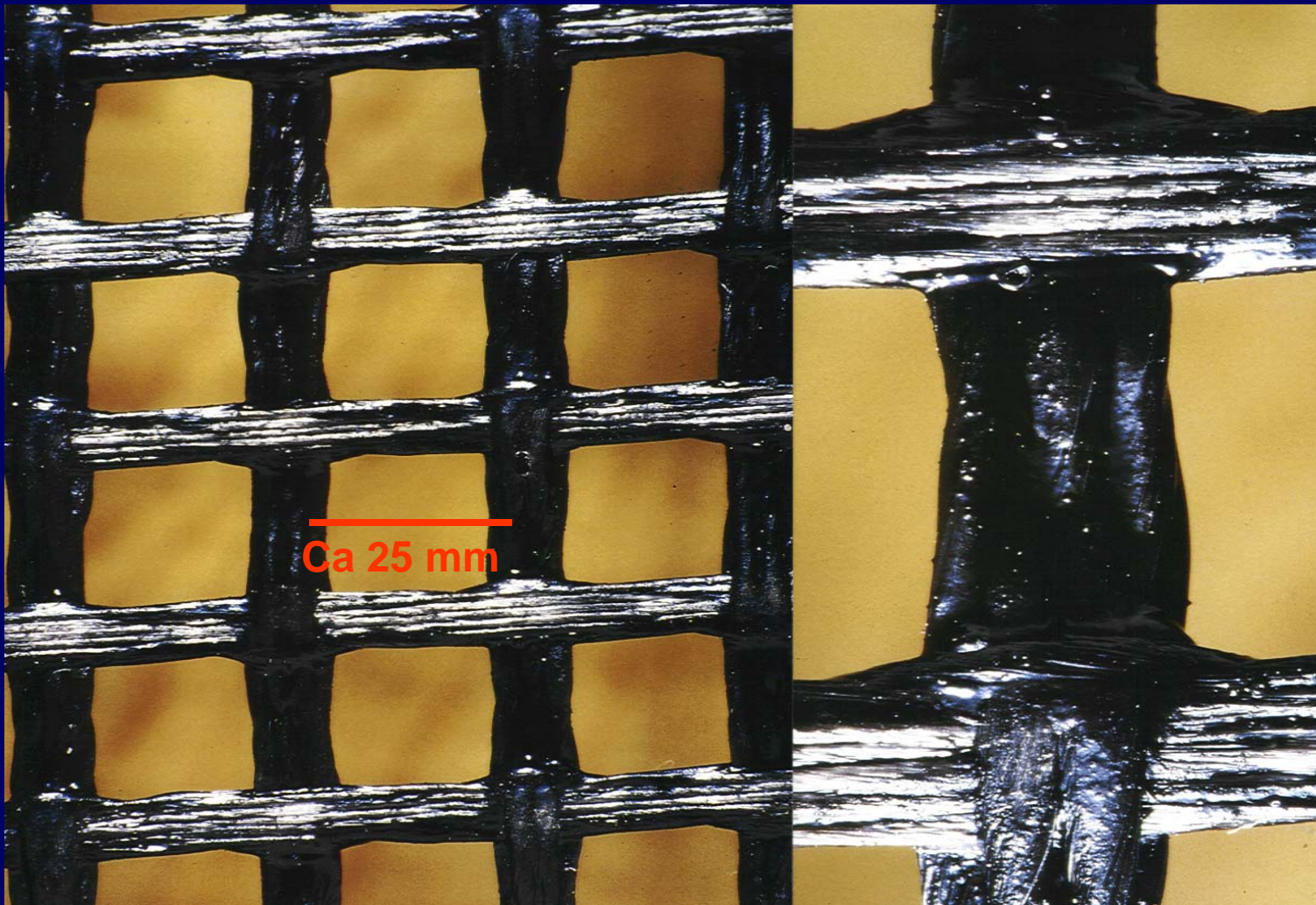
Fixing  
material





**GEOGRIDS**

# Coated PET-Geogrid



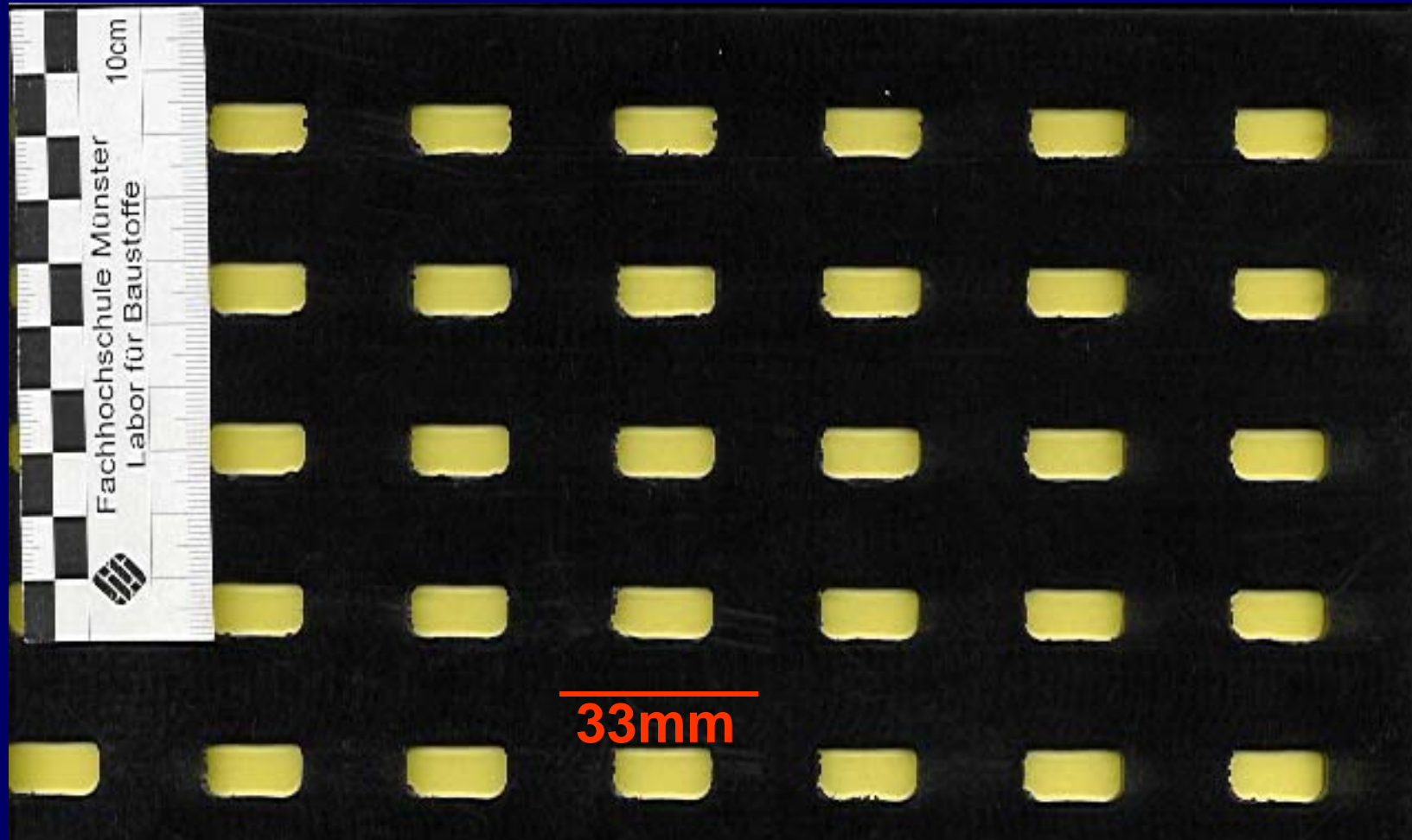
# Welded PET-Geogrids

Laserwelded

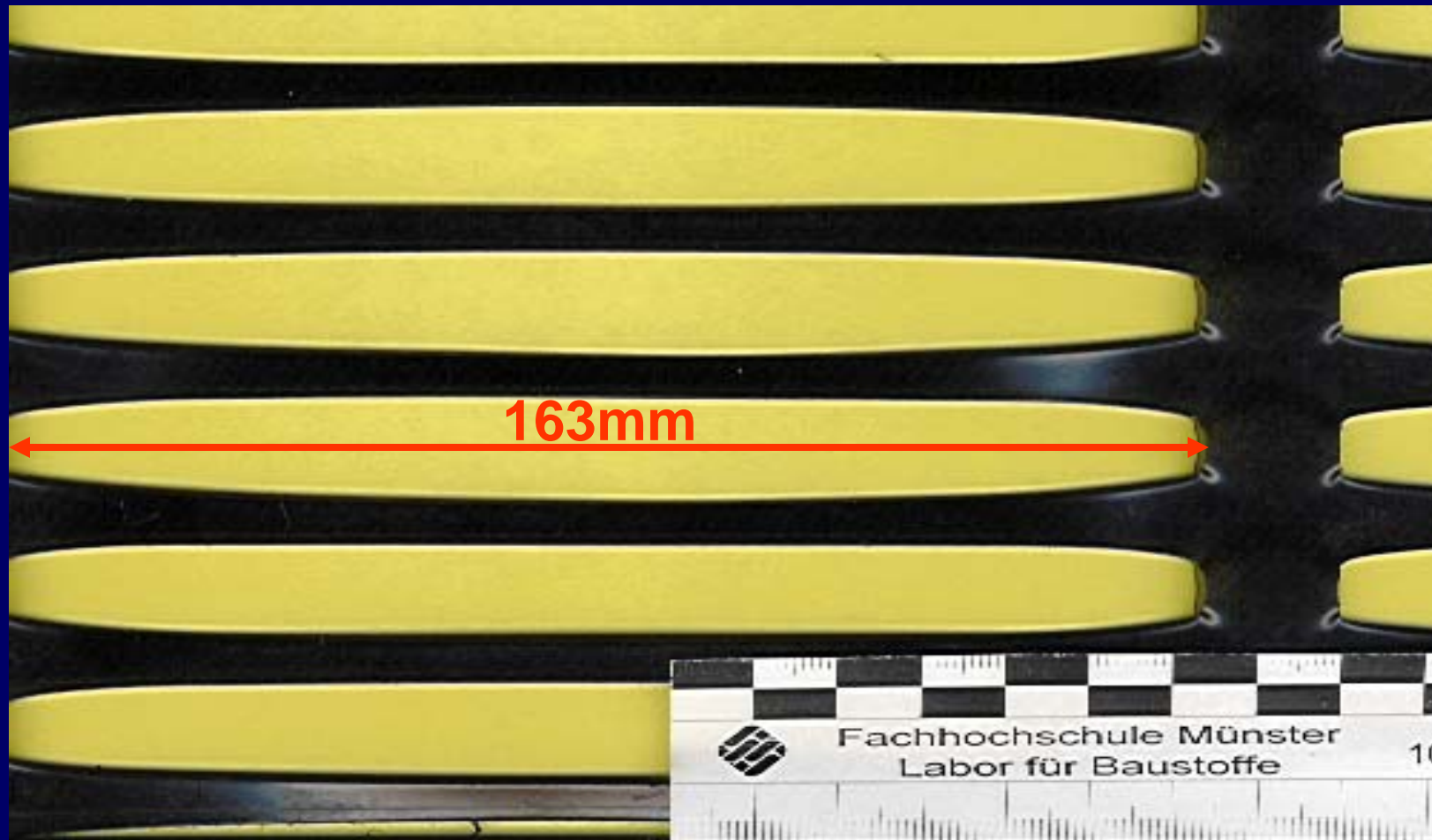


X-welded

# Punched Holes in a PE-liner



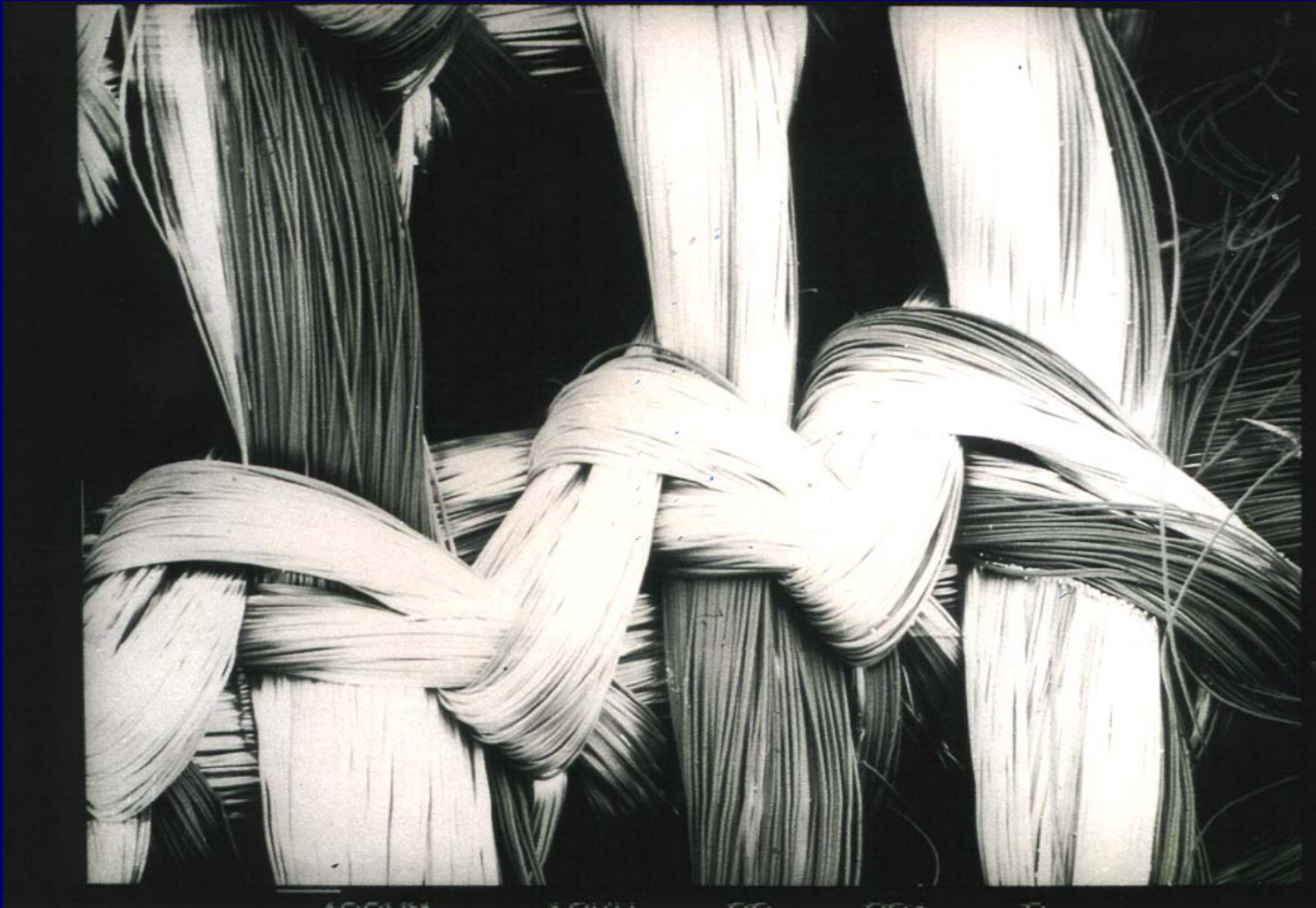
# Uniaxial Stretched PE-Geogrid



# Biaxial Stretched PP-Geogrid



# Knitted Structure



# Nonwoven Production

- Fibre composition
- Forming a fleece of oriented fibres
- Multiple layers of fleece for desired mua
- Bonding mechanically or thermally



# Bales of Staplefibres



# Staple Fibre Nonwoven



# Staple Fibre Nonwoven



# Nonwoven Fleece of oriented fibres



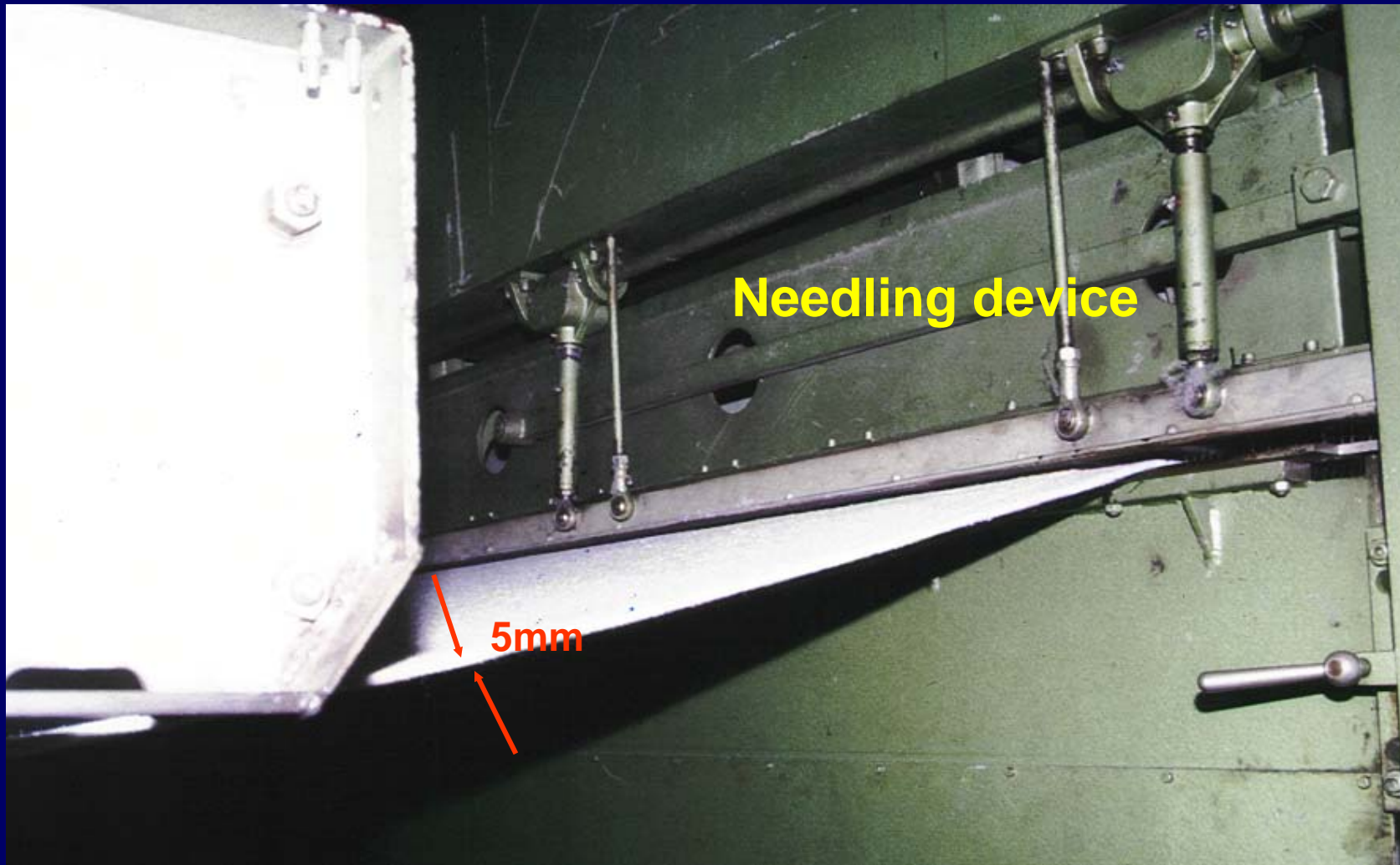
# Nonwoven Fleece of oriented fibres



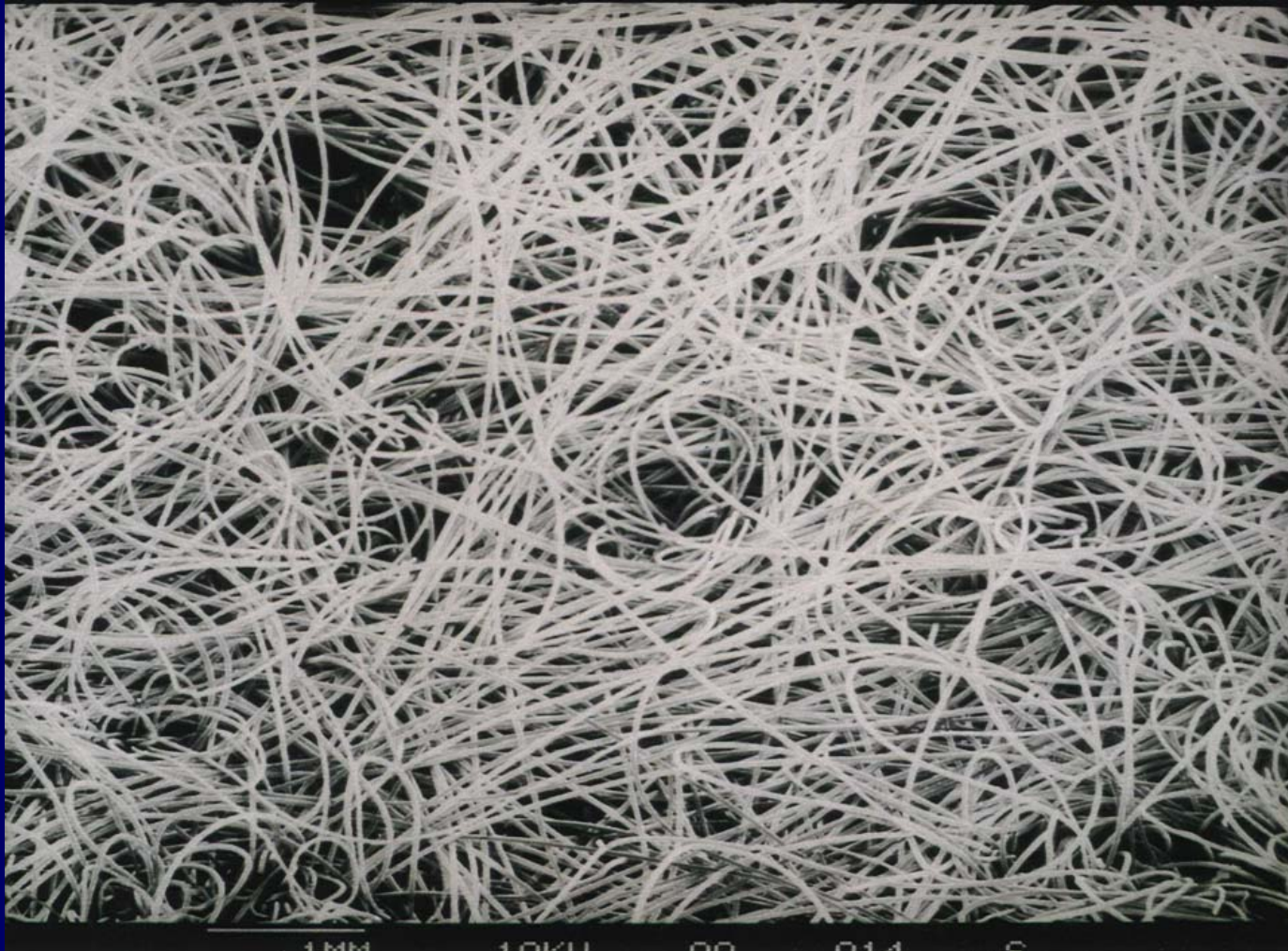
# Nonwoven Conveyor Crosslaying a Fleece



# Staple Fibre Nonwoven



# Nonwoven Needle Punched





# Nonwoven Heat Bonded

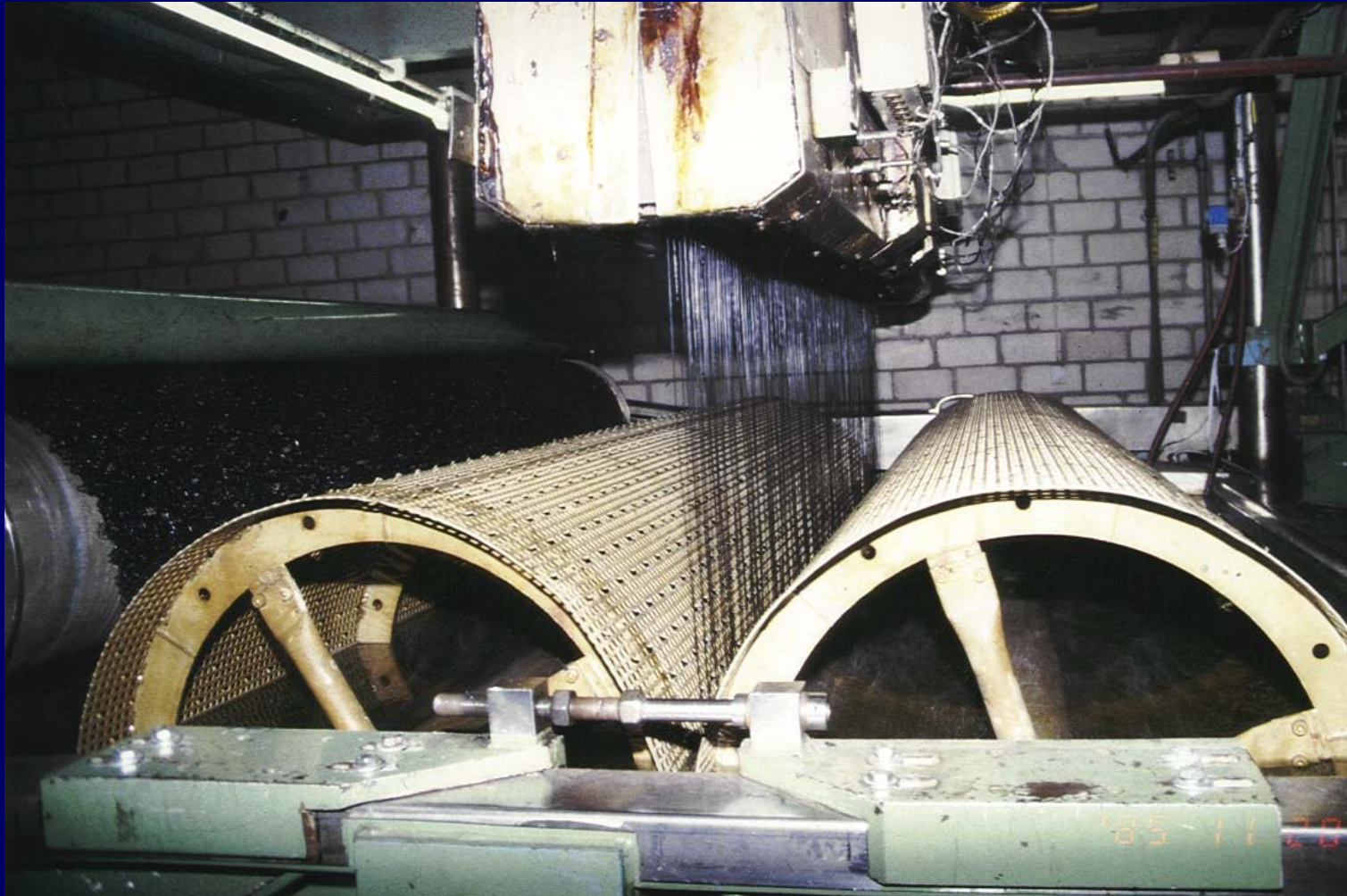


# Nonwoven Heat Bonded

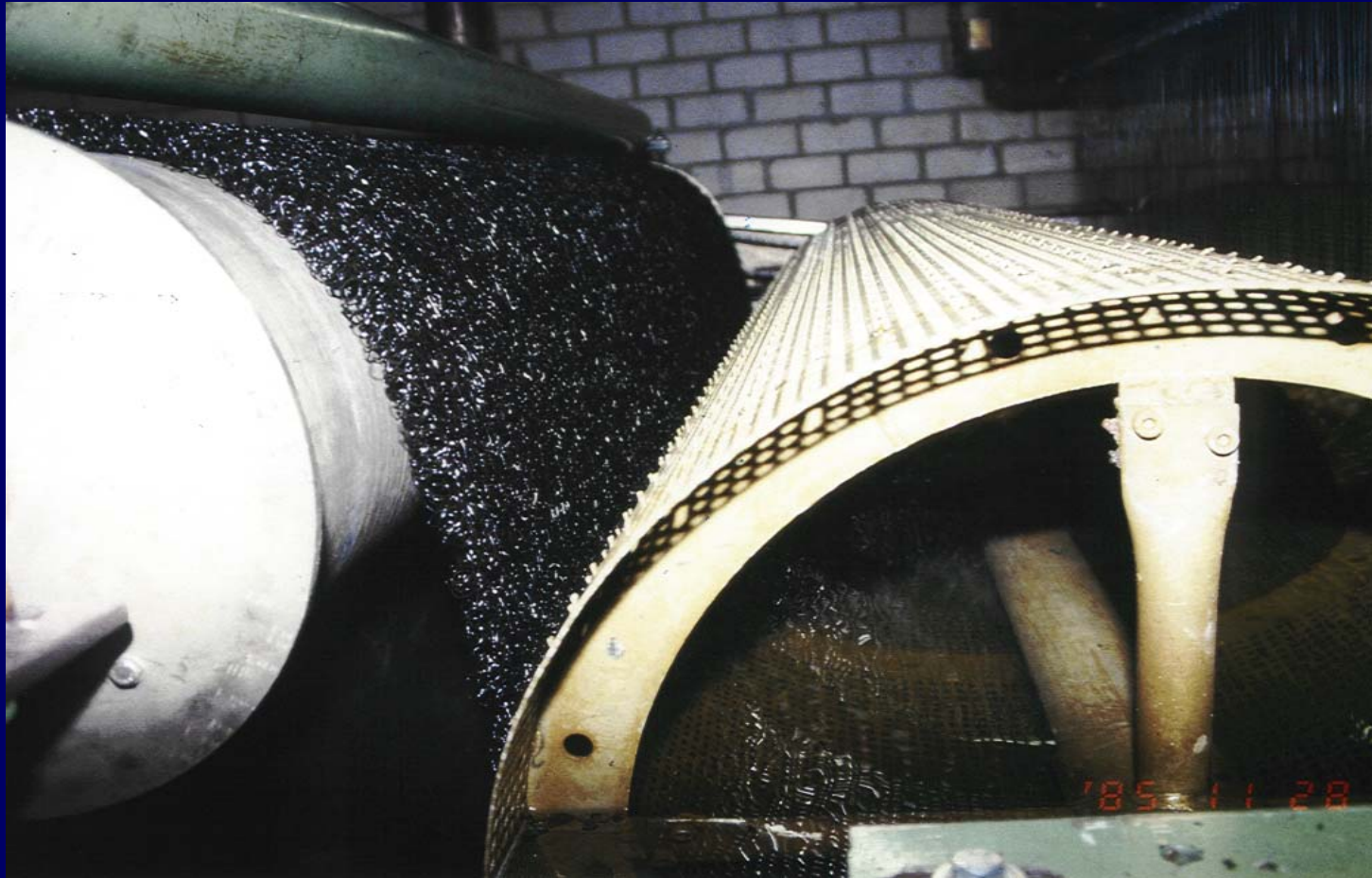


# EXTRUDED MATS

# Random Wire Draincore



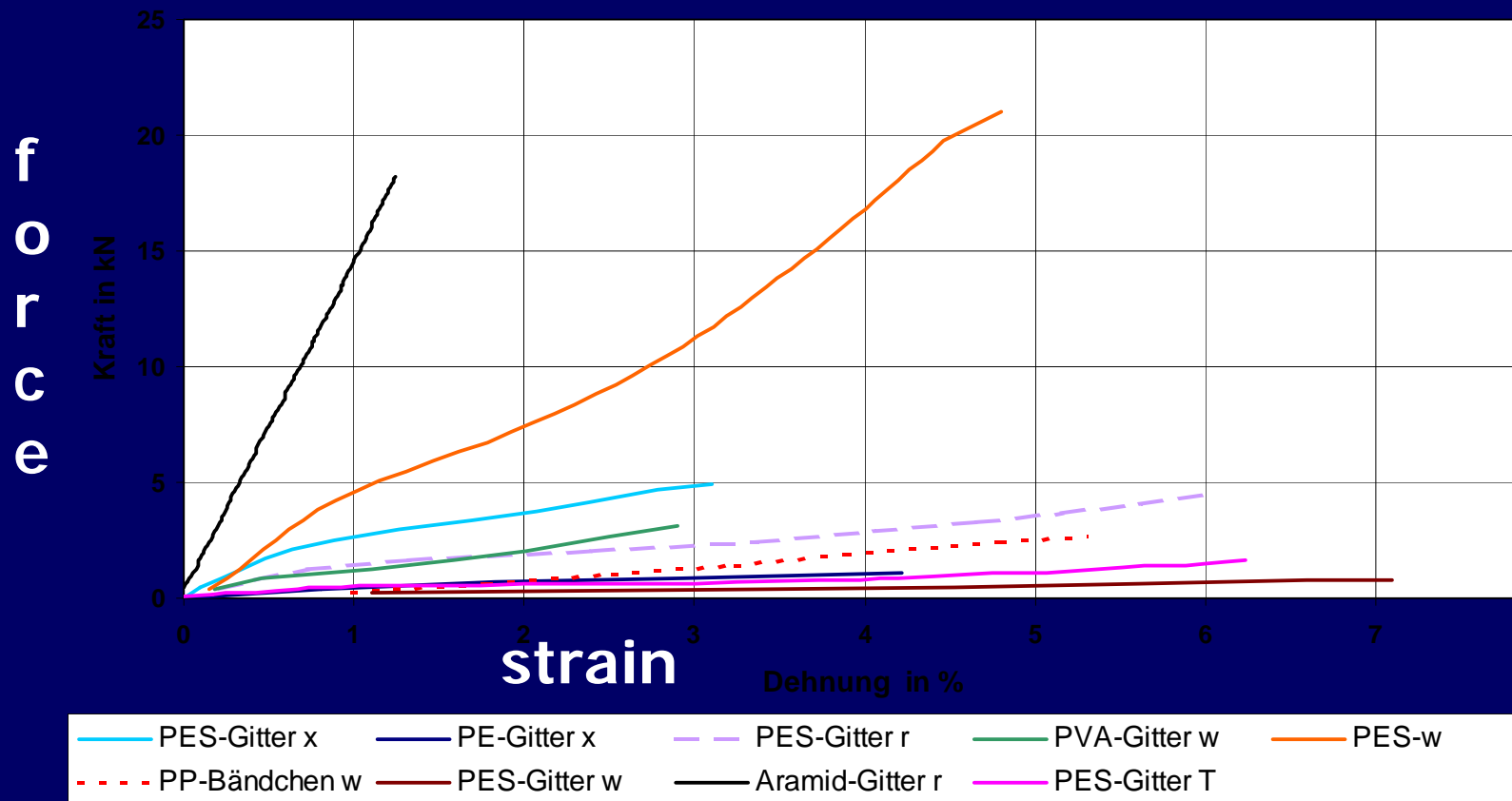
# Random Wire Draincore



# Characteristic Properties

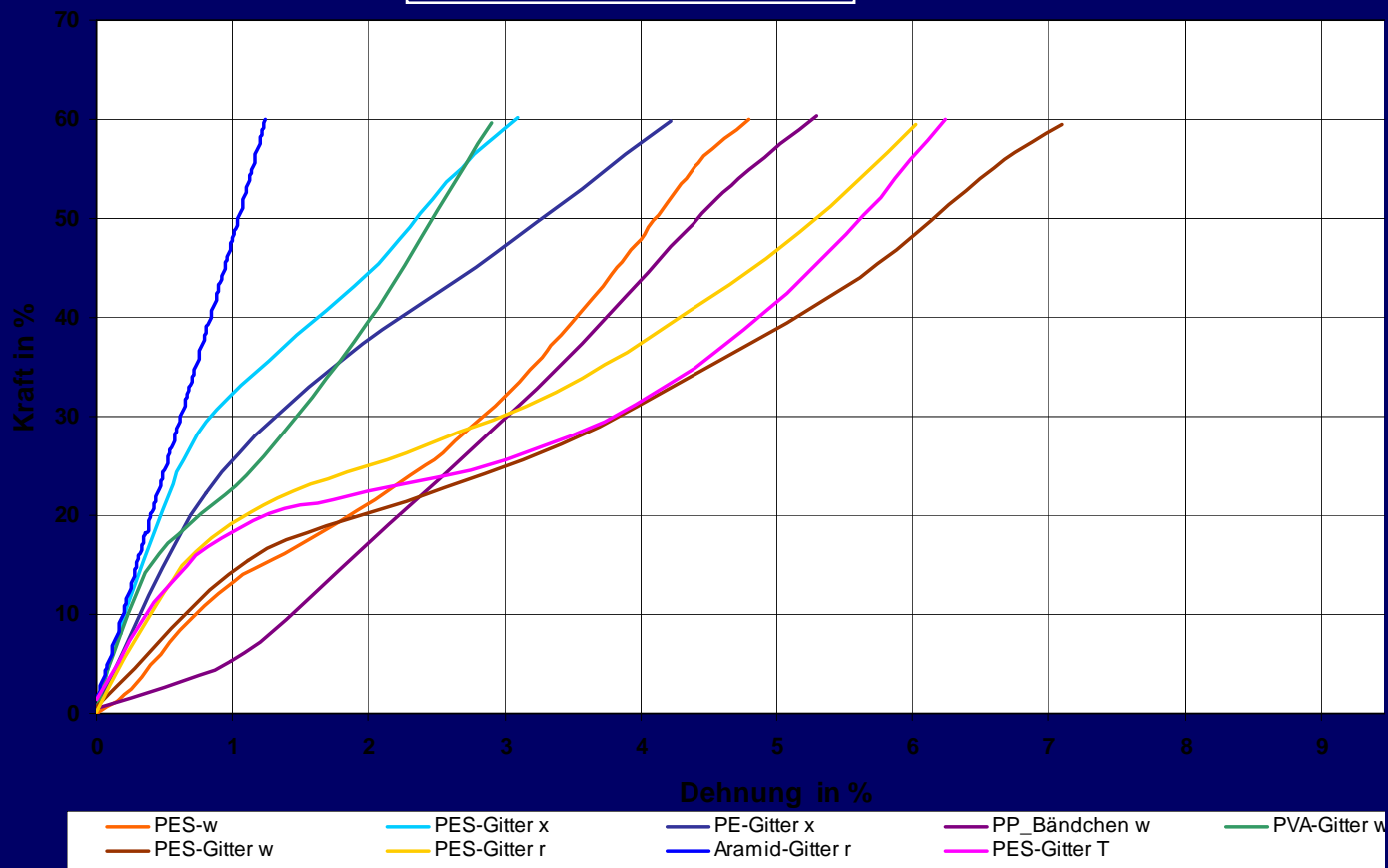
- Mechanical                      short/longterm
- Hydraulic                        short/longterm
- Durability
- Damage during installation

# Force/Strain Geosynthetics



# Force/Strain up to 60 % UTS

UTS = 100 %





# Concluding Remarks

- Organizations
- Publications
- Current Status
- Summary

# Web Sites of Geosynthetic Organizations

- Geosynthetic Institute (GSI)  
<<http://www.geosynthetic-institute.org>>
- International Geosynthetics Society (IGS)  
<<http://www.igs.rmc.ca>>
- Geosynthetics Materials Association (GMA)  
<<http://www.gmanow.com>>
- International Standards Organization (ISO)  
<<http://www.iso.ch/iso/en/ISOOnline.frontpage>>
- ASTM International  
<<http://www.astm.org>>

# Publications

- Journal of Geotextiles and Geomembranes - Prof. R. K. Rowe, Editor <[www.sciencedirect.com](http://www.sciencedirect.com)>
- Geosynthetics International Journal - Dr. Bathurst, Editor <http://www.icevirtuallibrary.com>
- GFR Magazine - <[www.ifai.com](http://www.ifai.com)>
- Designing With Geosynthetics - Prof. R. M. Koerner, Author <[www.geosynthetic-institute.org](http://www.geosynthetic-institute.org)>

# Comments on Current Status

## Transportation & Geotechnical Applications

- most mature of application areas
- focuses on GTs, GGs and GCs
- moving toward generic specifications

## Geoenvironmental Applications

- regulatory driven
- all GSs are involved with specs
- field performance is excellent

## Hydraulic Engineering Applications

- lagging behind other applications
- focuses on GMs and GCLs
- tremendous opportunities available

## Private Development Applications

- tremendous variety of applications
- all GSs are involved
- innovation and cost/benefit driven

# Summary

- Geosynthetics are bona fide engineering materials and must be treated as such
- Test methods and designs are available – challenge them accordingly
- Basic advantage of geosynthetics is quality control of factory manufactured products
- Products must be accompanied by rigorous CQC/CQA
- Field performance has been excellent
- Geosynthetics potential is awesome!

**THANK YOU**