

## Part 3

# COMBATING RILLS AND GULLY EROSION



- **Cut slopes tend to exhibit more cohesion near their crown, if capped by a residual soil horizon. **Rill erosion** is most problematic in low cohesion materials, like silts, sands, granule gravels, and dispersive clays.**





- Once a **rill** is established, it may soon form a deeply incised erosion gully, like that shown here. These can be very difficult to mitigate, requiring a lot of hand work.





- Many people don't believe in drainage benches; especially if it hasn't rained recently. This shows what can happen on a 3:1 fill slope.





- **This shows a new v-ditch at the foot of a 3:1 fill slope with silt fences; which was completely filled by raveling debris.**



- **Drainage terraces are intended to curtail surficial raveling and gully erosion of both cut and fill slopes, which can be severe prior to establishment of vegetation on such slopes.**





- **Staked hay bales are often employed as temporary erosion control weirs, to catch suspended sediment and retard velocity of runoff on steep, exposed slopes**





- **Polyethylene sheeting is often used to cover slopes, after they have failed. Impermeable membranes restrict direct infiltration, but seldom prevent actual landslippage, which is exacerbated by shallow groundwater flow**





- **Batter boards** have been employed on steep slopes with mixed results. They are intended to provide temporary support until woody vegetation can take root



- Paving blocks and other precast interlocking systems like that pictured above can serve as useful facing elements restricting further slope raveling, but their success is dependent on **adequate subdrainage** being provided.





- **A wide array of precast masonry paving blocks are available for facing slopes.**
- **Some systems offer interconnecting blocks, and most allow free drainage through some system of macro voids**

## Part 4

# MECHANICALLY STABILIZED EMBANKMENTS (MSE's)





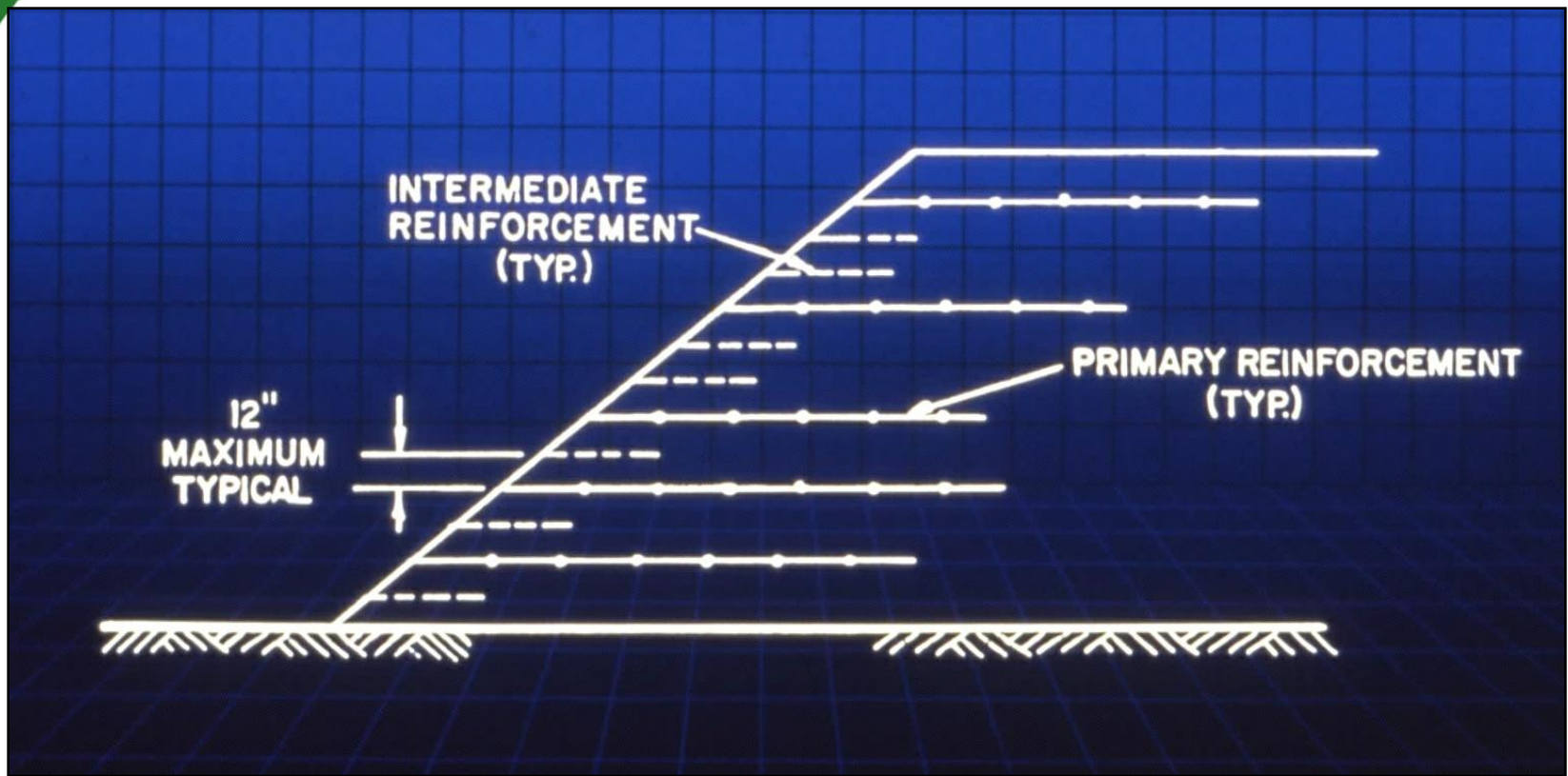
- Geogrid-wrapped hay bales can be used as temporary facing elements for **mechanically-stabilized embankments**. These materials do not corrode, so are more “**environmentally friendly**”





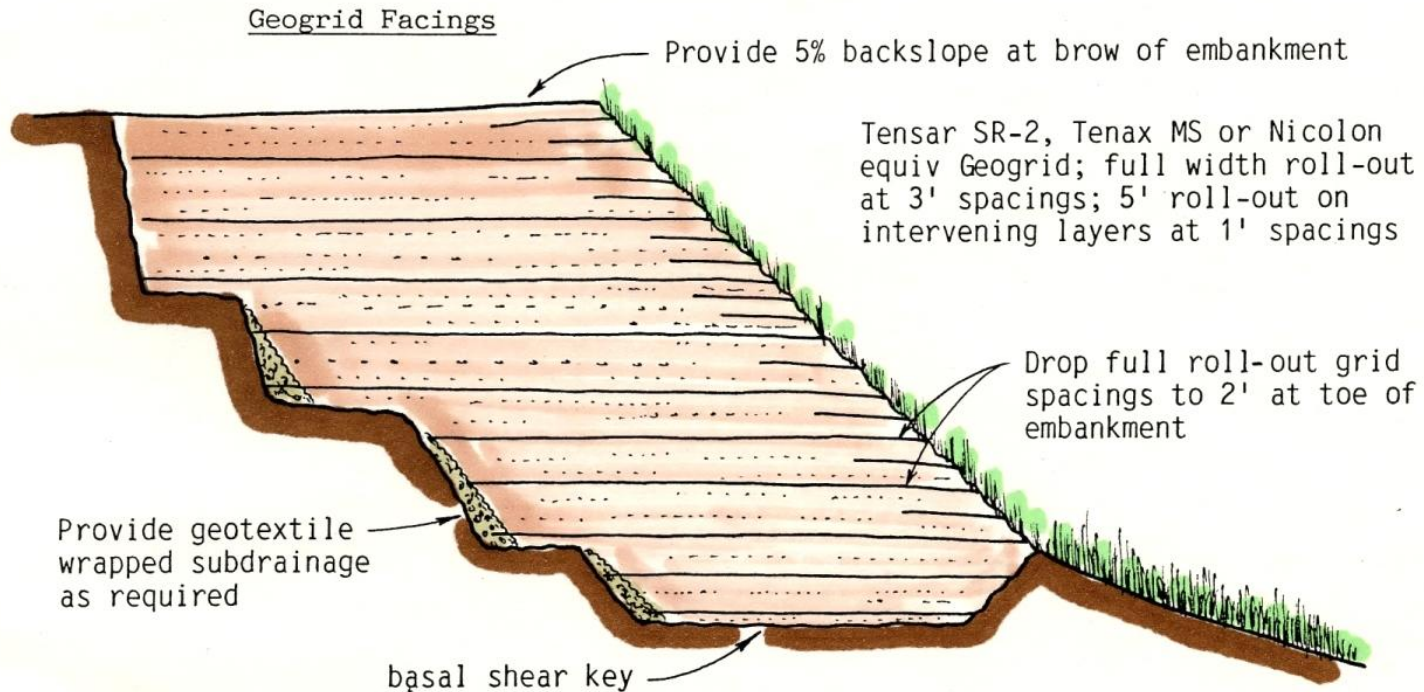
- **This shows geogrid wraps around hay bales as facing elements for a ‘shoefly,’ or temporary highway alignment, while the main alignment is being re-constructed.**





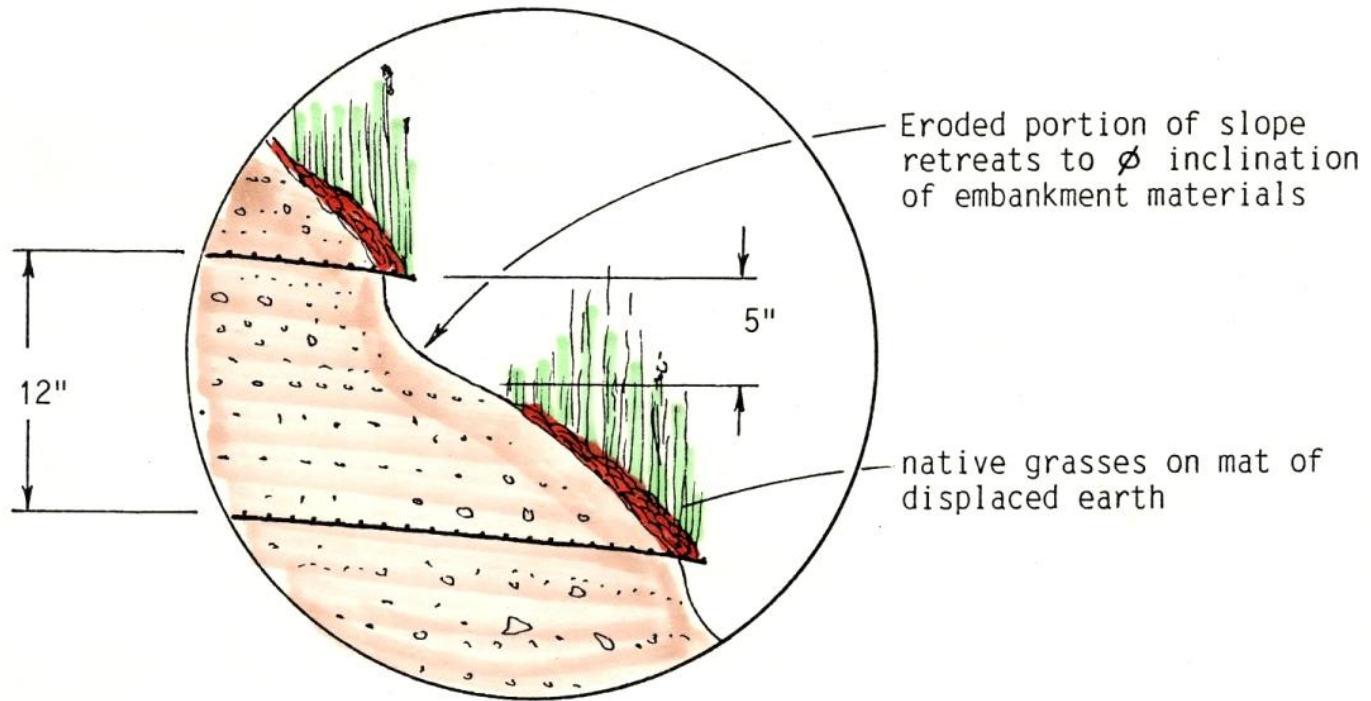
- Short strips, or “**false layers**” of geotextiles can be incorporated between reinforcement layers of mechanically stabilized embankments (MSE) to restrict slope raveling and erosion

## Erosion Control with Geosynthetics



- **Section through a MSE embankment with a 1:1 (45 degree) finish face inclination. The embankment utilized false layers every 12 inches, extending just 5 feet into the slope**





Detail view of the erosion which can be expected to occur between Geogrid layers. The effective slope height is reduced to 12" by embedment of the Geogrid.

- **Detail of geotextile “false layers”, placed every 12 inches to retard rill erosion**



- **Construction of 45 degree sidehill embankment for a road in steep terrain. Both false and full-depth geotextile mats were incorporated into the embankment, spaced every 12 inches**





- **Same slope after hydroseeding and sprouting with a mix of wild mustard and other grasses.**





- **Same project, as viewed 20 years later, in 2007. During this interim the slope had suffered a brush fire and the road's right slope shoulder exhibits some tension cracks, likely due to the expansive soils.**





- **Example of a 45 degree fill face supporting a parking lot adjacent to a line of mature trees. The embankment was constructed using false layers of geotextiles spaced 12 inches apart**



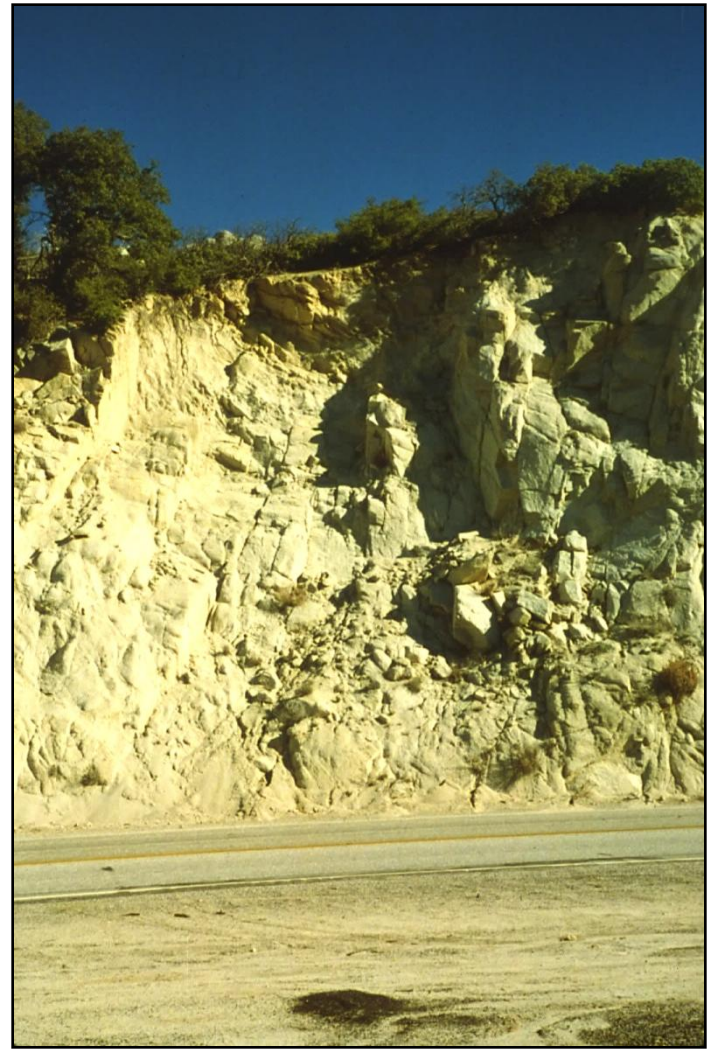


- **Same 45 degree fill slope after hydroseeding and sprouting of fescue grass mix. All runoff from above was directed away from the slope face**



## Part 5

# SOIL FIBER REINFORCEMENT



- **The most difficult raveling problems usually occur on cuts in weathered rock, like those depicted here.**



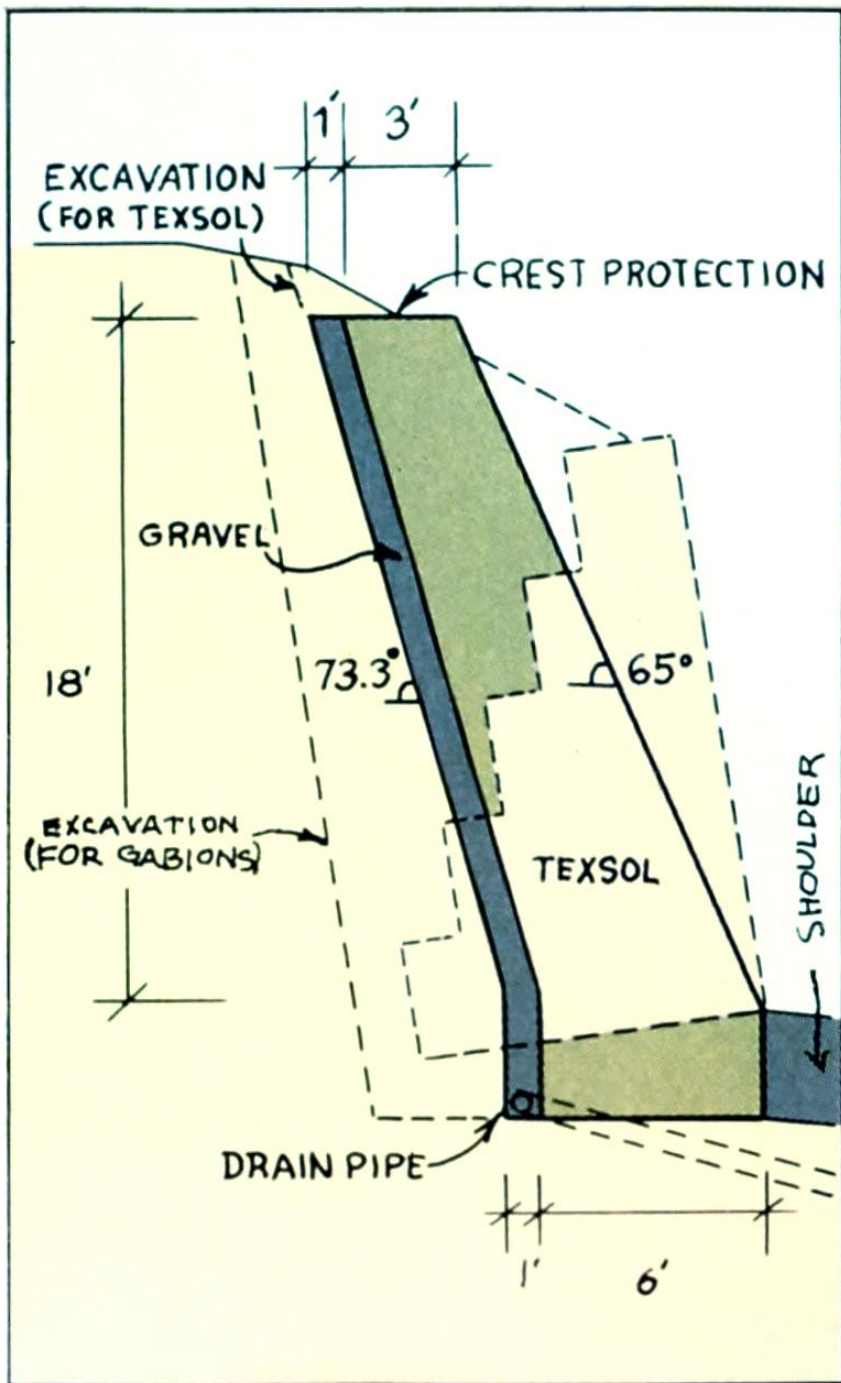


- **Soil Fiber Reinforcement**
- **Fiberglass threads, termed “roving”, can be used to reinforce cohesionless soils, like this cylinder of sand**
- **The volume of fiberglass fibers is between 0.10 and 0.20% of the weight of the soil mixture by weight**



- **The sand and fiber mixture can be sprayed onto a problem slope like shotcrete, creating a free-draining gravity retention structure. The roving is typically applied at a nominal rate of 20 m/sec.**





- Typical section through a Texsol soil fiber reinforced retention structure.
- Note blanket drain at back of structure
- Designed as a gravity retaining wall
- Embedded roving increases soil cohesion between 100 and 300 KN/m<sup>2</sup>

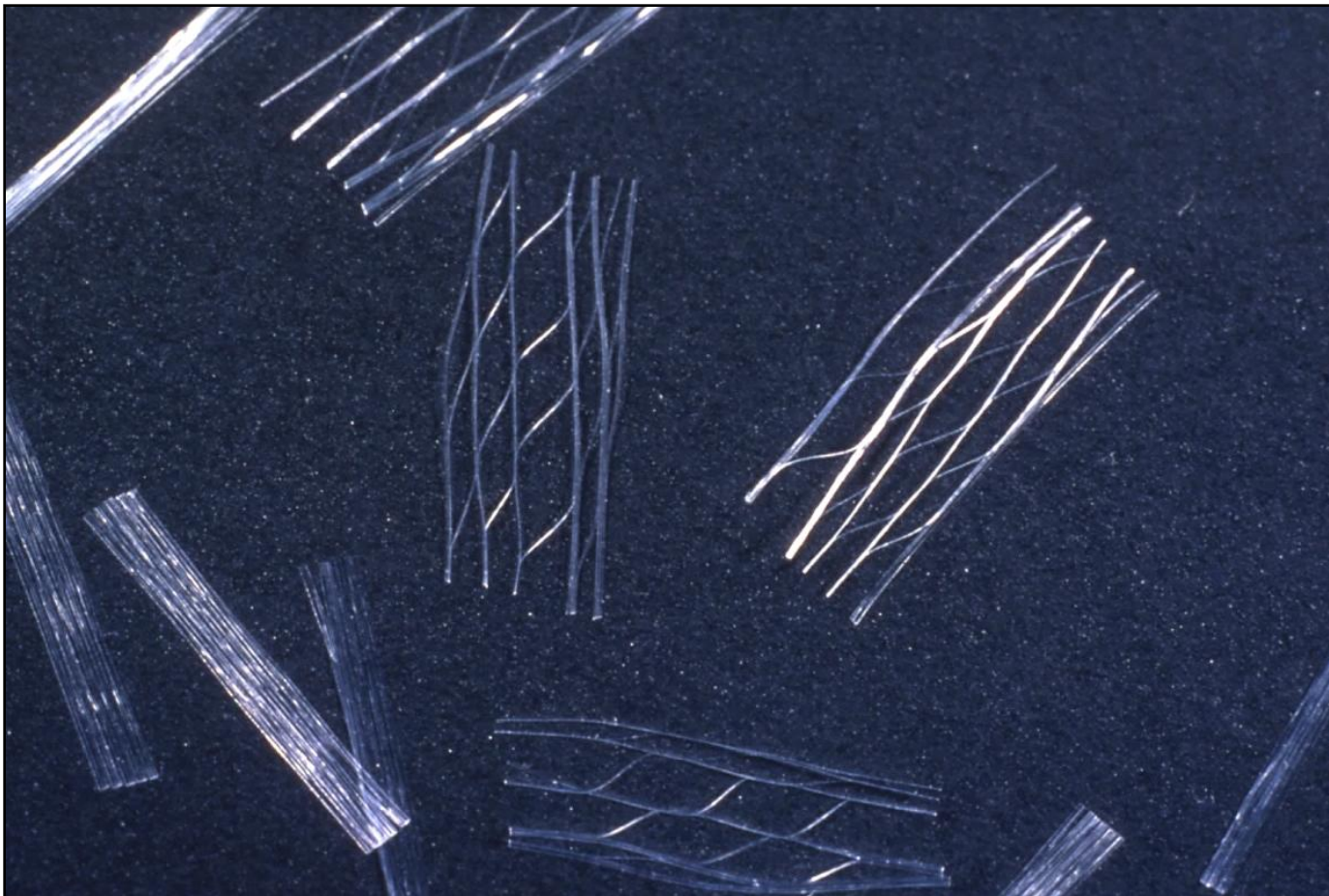


- **Texsol fiber reinforced soil retaining wall shortly after construction, along existing mountain highway in Europe**





- **Fiber reinforced soil wall after grass cover has germinated. The fiberglass roving is an effective tackifiber, promoting seed adhesion and root penetration**



- **Geofibers© are expandable polypropylene strands that are mixed with soils to increase their shear strength. Typical mixtures vary between 0.1 and 0.4% by weight.**





- **Geofibers can be mixed with subgrade soils, as shown above. Their inclusion raises the maximum density about 5% and reduces the optimum moisture content of the compacted soil mixture about 5% as well.**



- **Geofibers are compacted into the soil using kneading compaction for cohesive soils and vibratory rollers for granular mixtures**





- **Erosion gullies** are a common problem on unprotected slopes, especially in low cohesion materials, like sand, dispersive clays, and soils containing gypsum
- **Effective repairs** can be made with **Geofibers**





- **Test block using Geofiber-reinforced soil mixture sprayed onto the eroded cut slope, infilling the erosion gullies**





- Backhoe cutting inspection trench into the treated slope a year or so later, after **vegetation** had taken hold. **Revegetation** is increasingly valued for aesthetic reasons.

## Part 6

# BIOTECHNICAL SLOPE PROTECTION





- **Vegetation** plays a crucial role in soil conservation and erosion control



**Hydroseeding** using fescue and wildflower mixes are commonly applied to graded slopes for “**erosion control**”.

The effectiveness of grass seeding depends on the maturity, depth and density of the root mat before heavy precipitation impacts the slope.

**Watering** may be required prior to onset of the rainy season







- **Biotechnical slope protection** emanated from the humid climates of western Europe, where it has been employed for hundreds of years. This view shows a fill embankment above Berkeley in 1934, before it was planted.



- Growth of **willow wattles** planted on Grizzly Peak fill slope during summer of 1935. The wattles were not irrigated during 7 months of dry weather, so losses were significant.





- **Willow wattles** planted along contours of fill slope depicted above, as viewed in 1937, two years later. Similar schemes were successfully employed along the Angeles Crest Highway (State Route 2) in southern California during this same period (1937-40).





- **Bamboo fascines** are used extensively to protect cut slopes in Asia, such as this example in Taiwan. In Europe fascines are usually made of creek willow chutes.



## TURF REINFORCEMENT

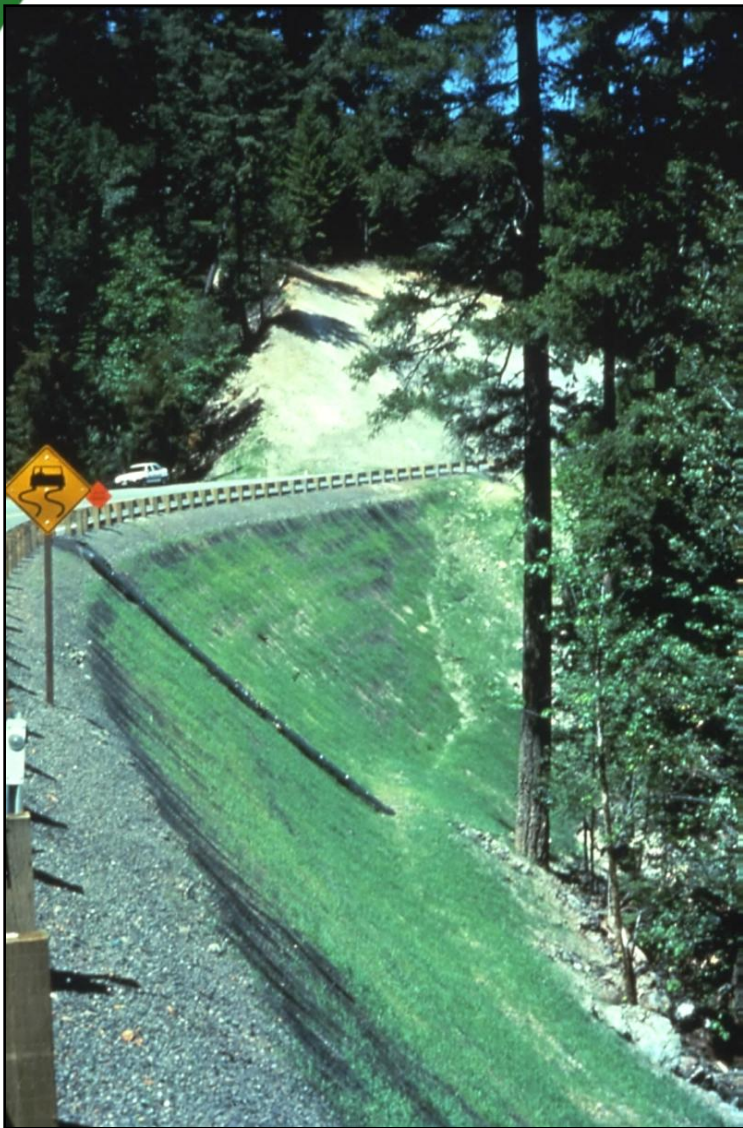


● Reinforced Rhizome Layer



**Turf reinforcement mats** provide an excellent anchor for grass and can resist rill erosion on very steep slopes





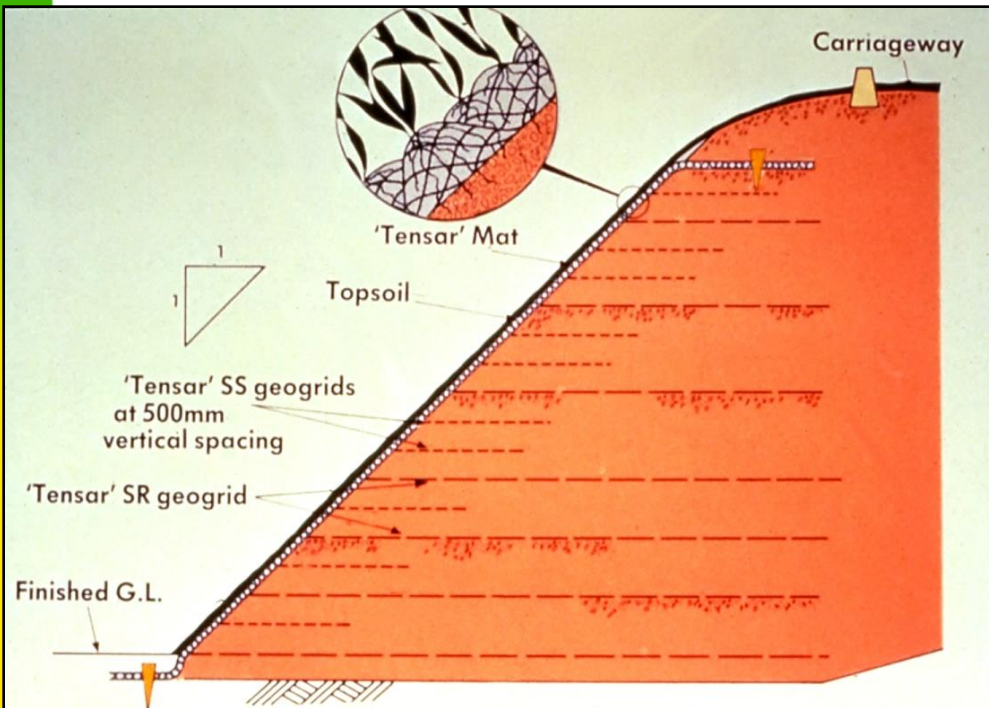
**Turf reinforcement mats** are being employed to stabilize slopes and ephemeral channels, as shown in these examples.





**Turf reinforcement mats** have been successfully applied to slopes as steep as 45 degrees in humid areas.

Sometimes this surface treatment can be combined with “deeper” stabilization techniques like **Soilnails**.

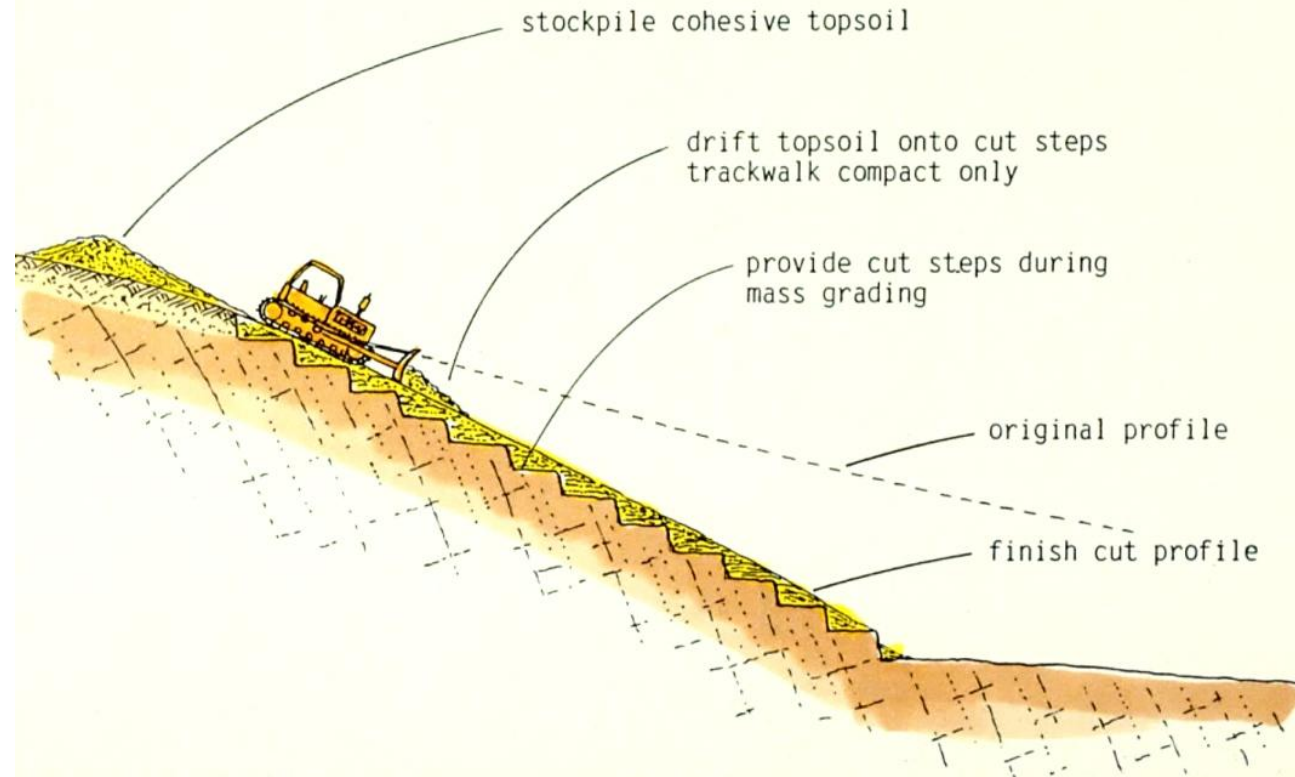




- **Cut slopes comprised of granular or blocky material may appear “raw” and unsightly; presenting a real challenge to effectively mitigate erosion or improve viewing aesthetics**



## Stepped Cut with Soil Fill and Planting

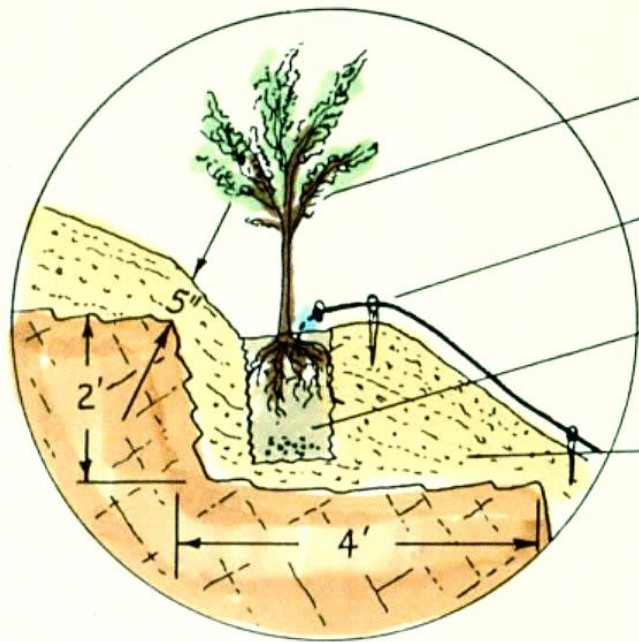


- **Bedrock cuts** in granular materials can be graded as stepped cuts, then backfilled with cohesive soil to provide a planting base with decreased susceptibility to rill erosion



- **Example of cut steps that have been infilled with cohesive topsoil to promote re-vegetation. The section has been exposed by a temporary haul road cut**





provide desired vegetation; 10 gal woody veg typ.

provide drip irrigation; 1 gpm emitters typ  
timers run 2X/day 5 min ea typ

auger 12"-dia hole, min 18" deep; provide  
slow releasing fertilizer/nutrients

cohesive topsoil backfill; trackwalk no  
greater than 7.5 psi track pressure

- **Soil filled steps allow planting of brush and woody vegetation on top of the bedrock cut. Small pipes may be used to convey drip irrigation water down to the root tips, so they are pulled down, into the underlying soil or rock, where water can be infused from joints.**



- Selected planting of **woody vegetation**, using 10 gallon tree cans set in power augured holes with slow releasing nitrogen fertilizer. Taken in 1983 shortly after grading.





- **Same slope as viewed 6 years later, in 1989. The survival rates and trunk diameters are tied to the severity of jointing and available water in the underlying bedrock**





- **Same slope as seen in 2001, 18 years after planting. The near continuous shade canopy has promoted growth of the undersized trees as well.**





- **Biotechnical methods** are limited in their ability forestall slope instability insofar as their depth and density of rooting, as depicted in this landslide scarp.

# About the Presenter



■ J. David Rogers, Ph.D., P.E., P.G. holds the Karl F. Hasselmann Chair in Geological Engineering at the Missouri University of Science & Technology. He can be contacted at [rogersda@mst.edu](mailto:rogersda@mst.edu)

- Professor Rogers served as Chair of the Building Codes Committee of the Association of Environmental & Engineering Geologists between 1990-97 and was AEG representative to the International Conference of Building Officials (ICBO) while the 1991, 1994 and 1997 UBC's and 2000 IBC were developed.
- Since 1984 he has taught short courses on grading and excavation codes for ICBO, the University of Wisconsin, University of California, the Association of Bay Area Governments and the City of Los Angeles.