Biogeotechnical Solutions for Mitigation of Fugitive Dust and Erosion Contol

by

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What is Biogeotechnical Engineering?

Emerging sub-discipline in geotechnical engineering, including:

Bio-mediated processes: Managed and controlled through biological activity (living organisms)

Bio-inspired processes: Biological principles employed to develop new, abiotic solutions (no living organisms)

Example: Carbonate Precipitation

:

MICP: Microbially induced carbonate precipitation

- A bio-mediated process

EICP: Enzyme induced carbonate precipitation

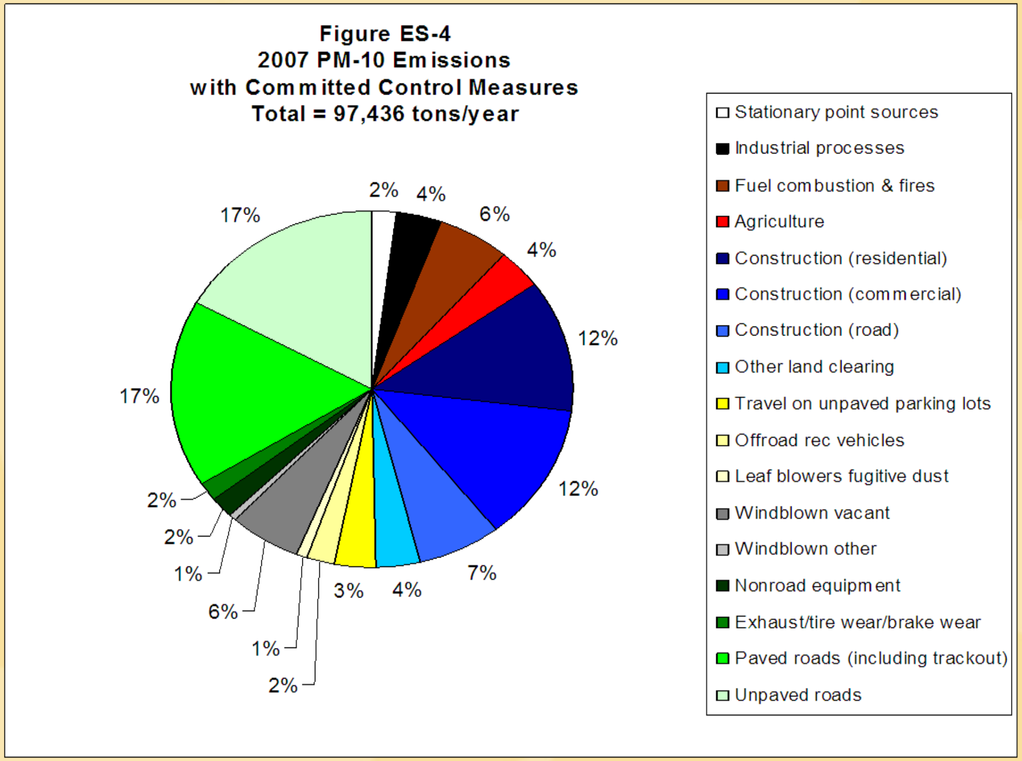
- A bio-inspired process

Wind Erosion (Fugitive Dust)

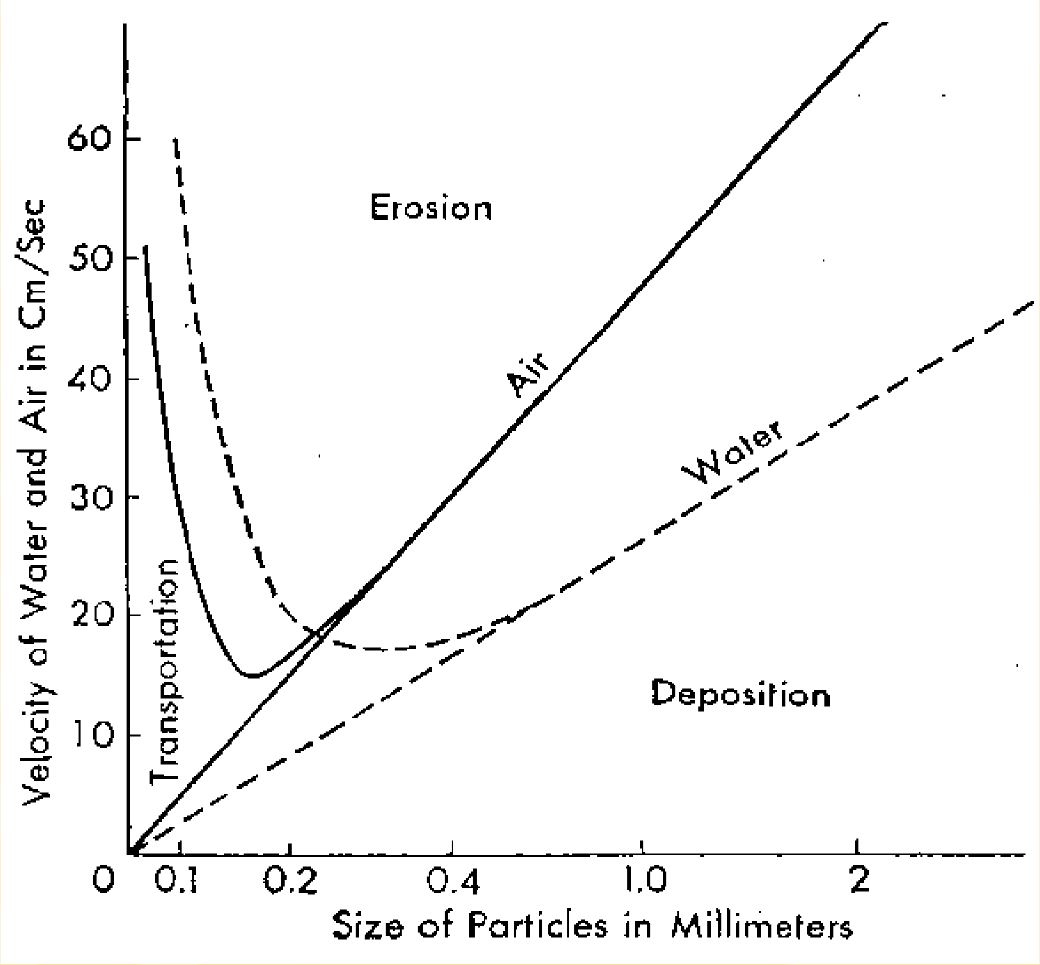
Phoenix: Air-quality non-attainment zone

- Due to wind-blown soil (not vehicles or industry)
- Serious health problem
- Potential loss of highway funds ($8 billion)
- $5.3 Million in penalties issued in 2007
- Plagues many other areas

Fugitive Dust Emission Sources



Erosion Susceptibility



Source: Garrels, 1951

Traditional Dust Control

Water, salt solutions

Biogeotechnical dust control

Advantages:

- “One and done” (but for how long?)

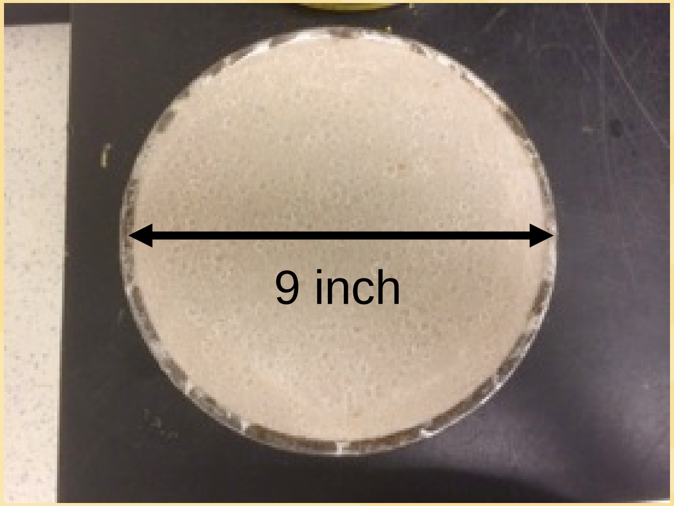
Disavantages

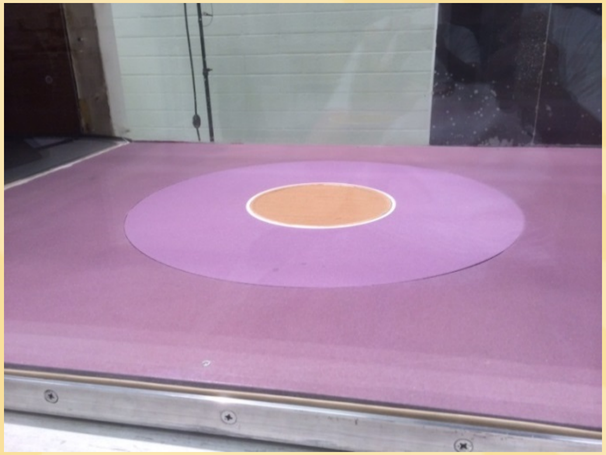
- Cost
- Environmental impact

Biogeotechnical Options

- Biopolymers
  - Kavazanjian et al. (2009): Xanthan gum
  - Chen et al. (2014): Xanthan gum, guar gum
- Carbonate precipitation via ureolysis
  - Bang et al. (2011): MICP and EICP
  - Hamdan (2014): EICP

ASU/NASA Planetary Wind Tunnel





Soils Tested

- Arizona silty sand
  - Well graded, $d_{50} \approx 0.2$ mm, 30% < #200
- Ottawa F-60 sand
  - Poorly graded, $d_{50} \approx 0.15$ mm, 0% < #200
- Mine tailings
  - Well graded, $d_{50} \approx 0.22$ mm, 10% < #200

Biopolymers/Biofilms

Biopolymers:

- Polymer Biomolecules
- Covalently bonded monomers
- Polynucleotides, polypeptides, polysaccharides

Biofilms :

- *Aggregate* of microorganisms within a biopolymer matrix
- Adhered to each other and/or to a surface.

Biopolymers/Biofilms (2)

Biofilm growth:

- A bio-mediated processes

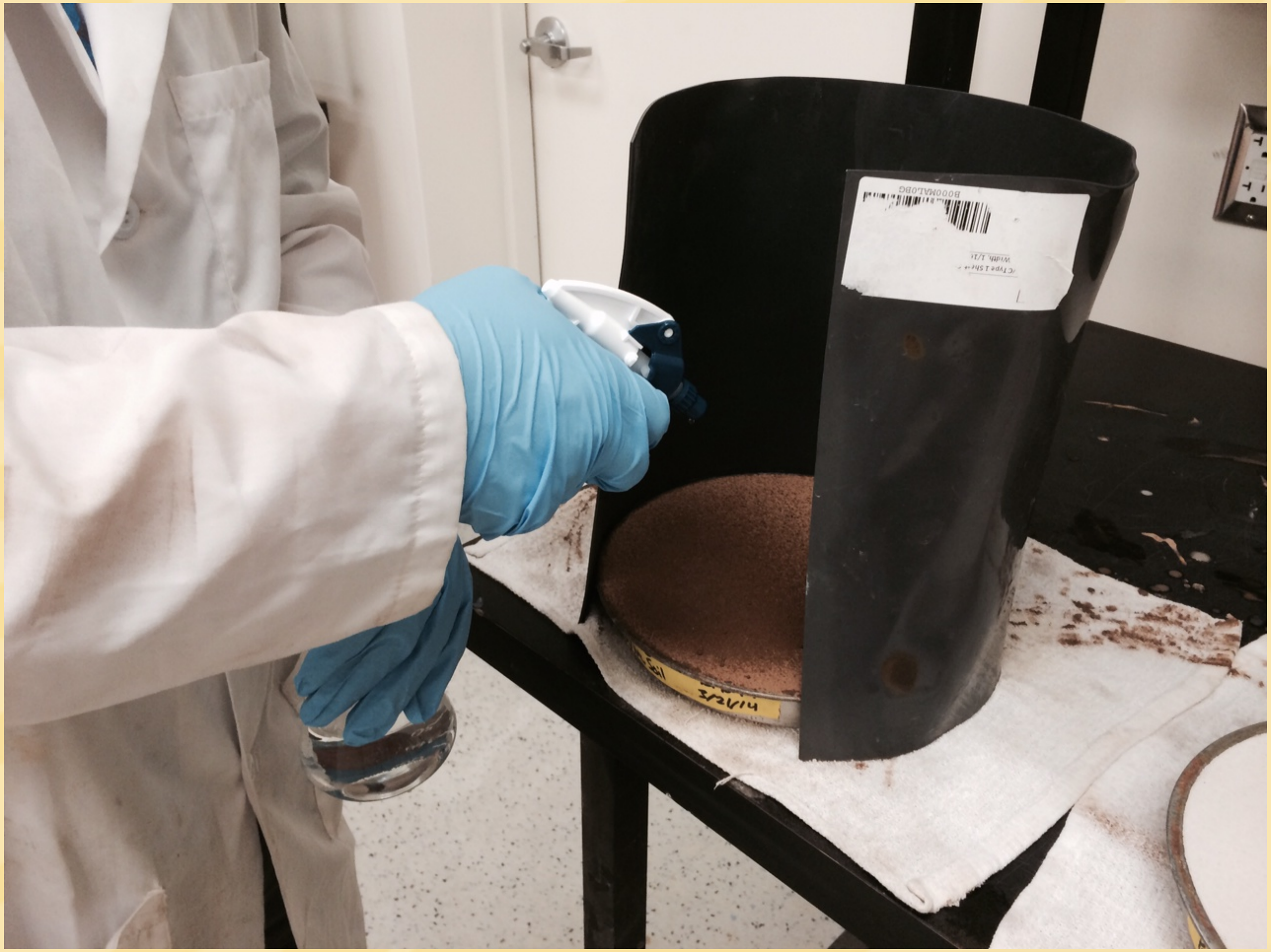
Biopolymer spray or mix and compact:

- Bio-inspired application

Candidate Biopolymers

Selection Criteria	Xantahn	Guar	Chitosn	PGA	PHB
Water soluble	x	x		x	
Readily available	x	x	x		
Extensive literature on properties	x	x	x	x	x
Price per gram (compared to other biopolymers)	x	x	x		
Ease of application (no special equipment needed)	x	x	x		

Spray Application

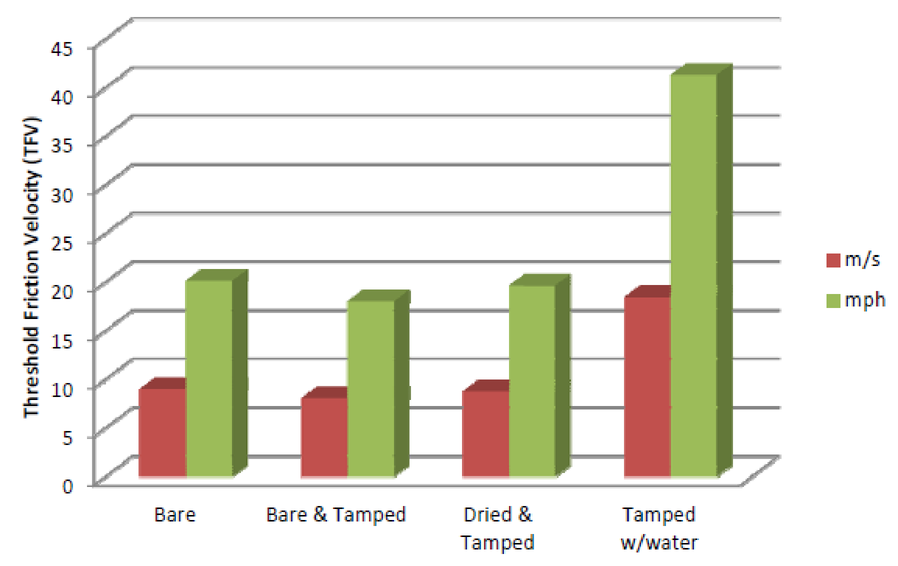


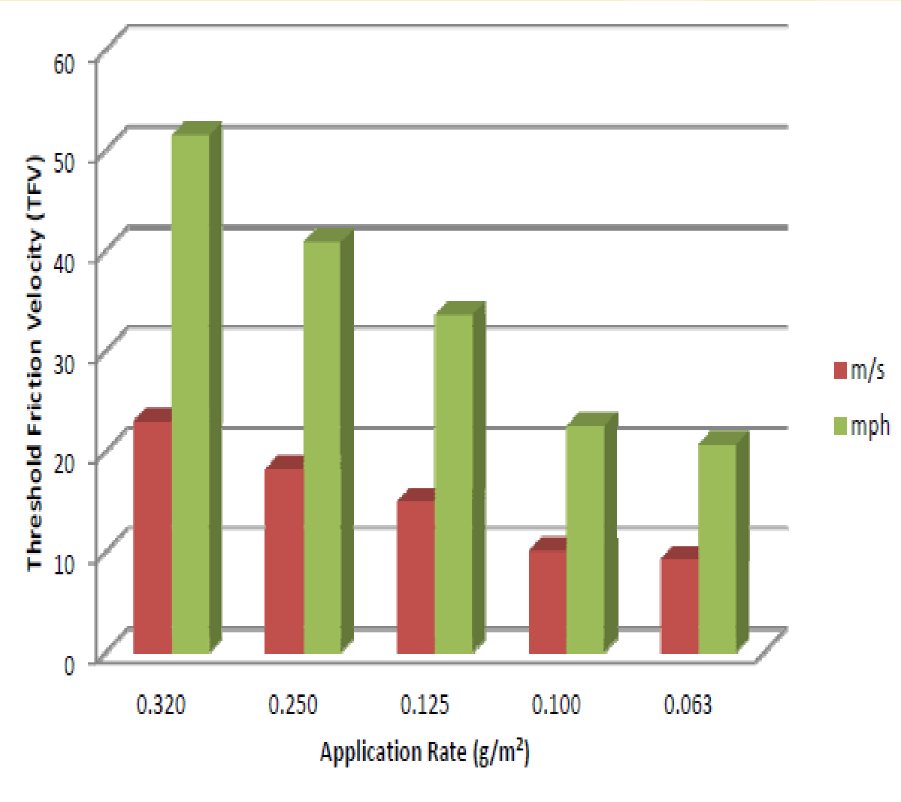
Biopolymer Erosion Control

ASU/NASA Planetary Wind Tunnel Testing

Xanthan Gum Treated Samples

Untreated Samples

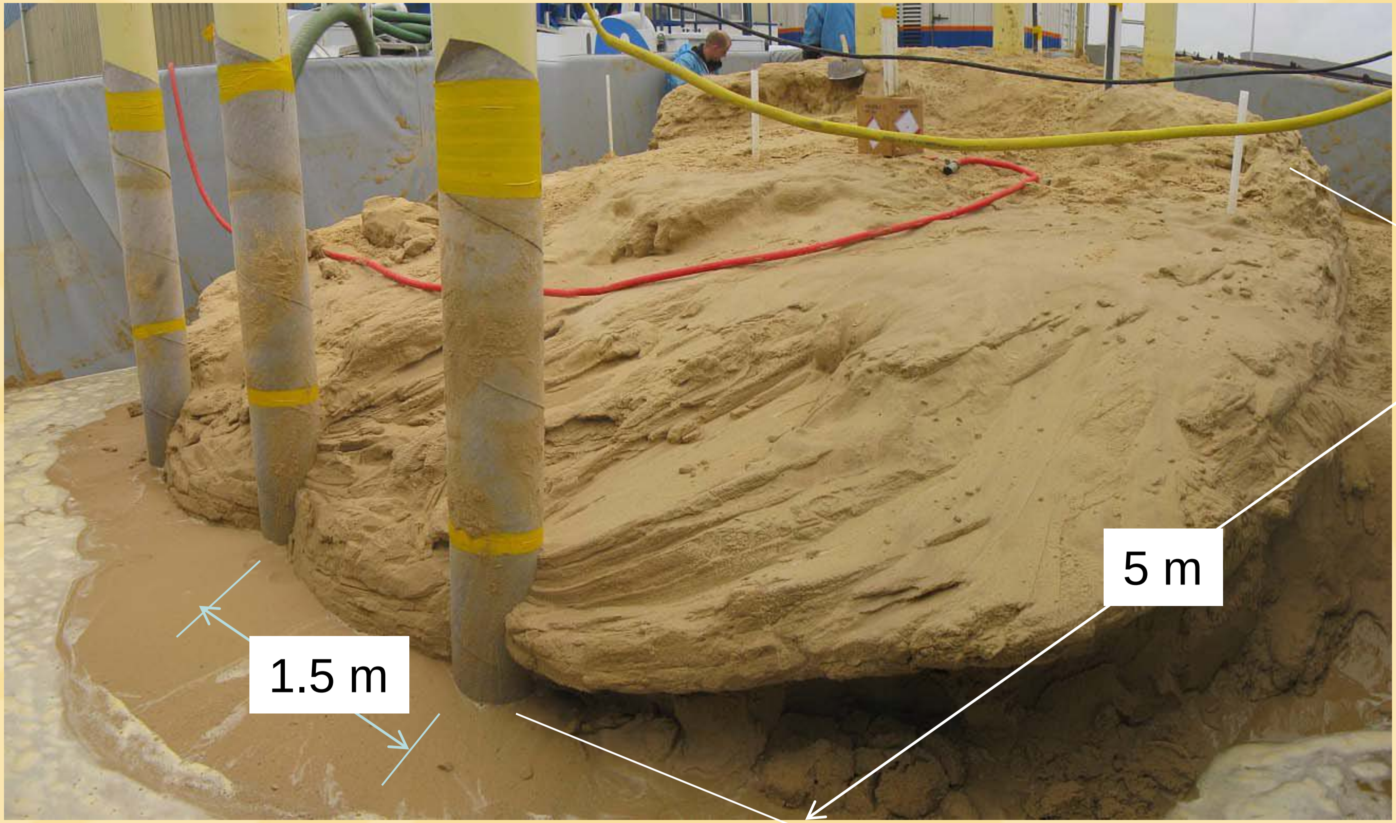




Carbonate Precipitation

- Several mechanisms
  - Ureolysis (hydrolysis of urea) most studied
- Enzyme urease catalyzes the reaction
  - $Urea_{(aq)}$ speciates into CO_3^-, $2NH_4^+$
  - $CaCO_3$ precipitates in the presence of Ca^{2+}, alkaline pH

TU Delft MICP Tank Test (van Paassen et al.)



EICP

Ureolysis w/ agricultural urease

- Common in beans, melons, squash
- Jack bean (*C. ensiformis*) most studied

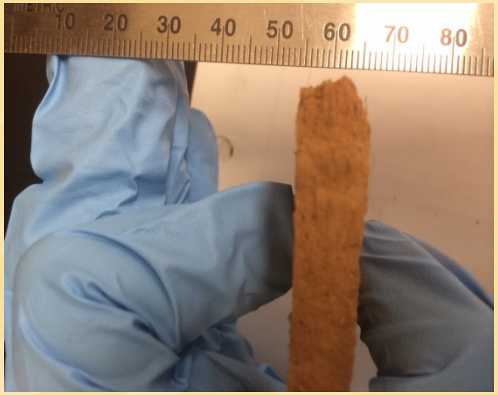
EICP Columns (ASU)

100-mm dia. lab columns

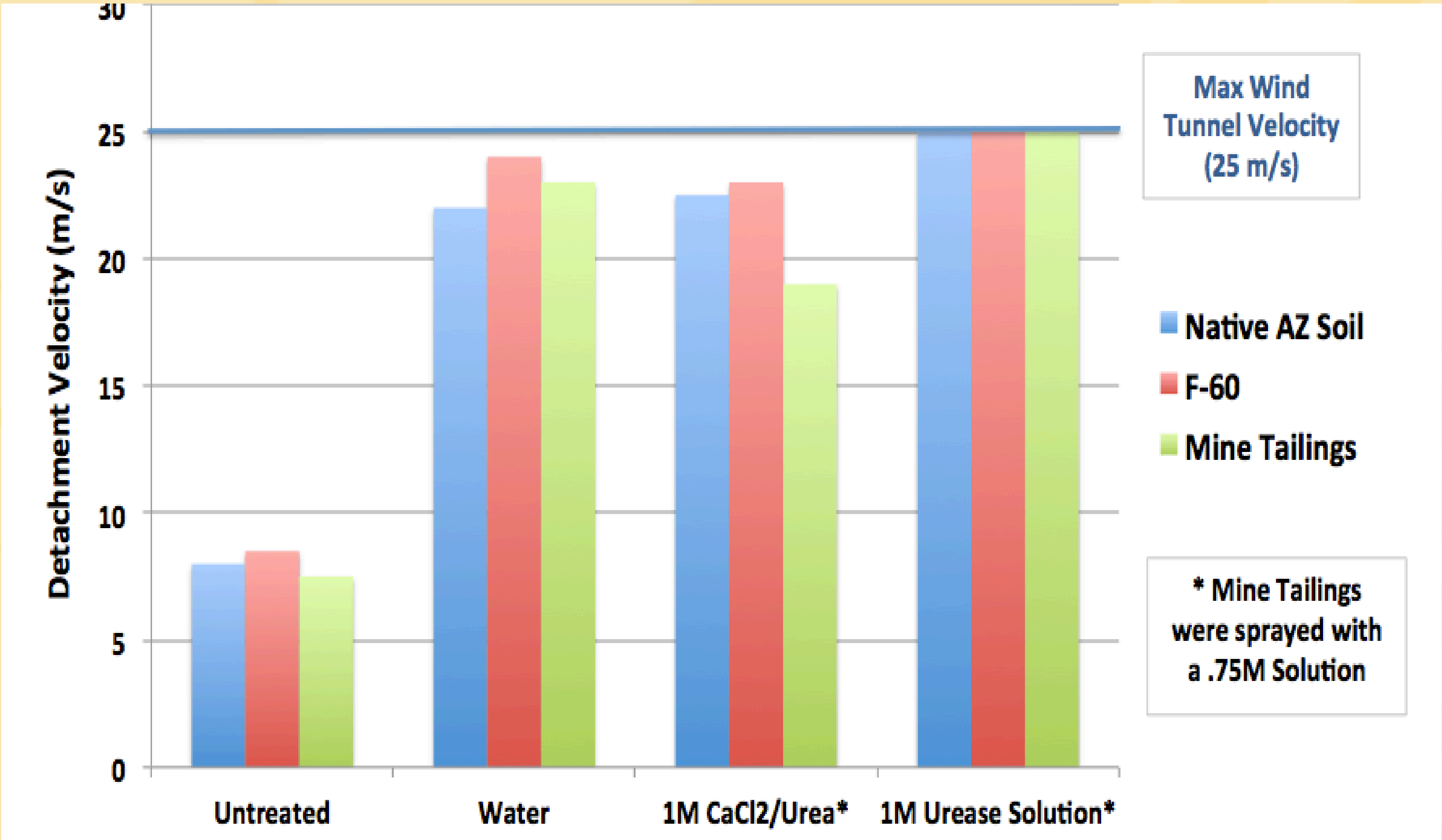
275-mm diameter, 19 liter bucket test
w/ 50-mm diameter perforated pipe

EICP or Dust control

- Two-part mixture
  - Part 1: Urea and $CaCl_2$ in solution
  - Part 2: Urease in solution
- Applied simultaneously (by spraying)
  - Forms a cemented crust



EICP Treated Samples



Surface Water Erosion Resistance

Control, no $CaCO_3$

$CaCO_3$ crust

Collected water runoff
Control (left), $CaCO_3$ (right)

Enhanced Erosion Resitance

Mix and compact cementation with soil

- Resistance to surface water
- Stabilize low volume roads

Other Biogeotechnical Applications

- Soil and groundwater remediation
- Soil improvement
- Liquefaction mitigation
- Surface and subsurface barriers
- Sequestration of contaminants
- Alternative to Portland cement
- Corosion control

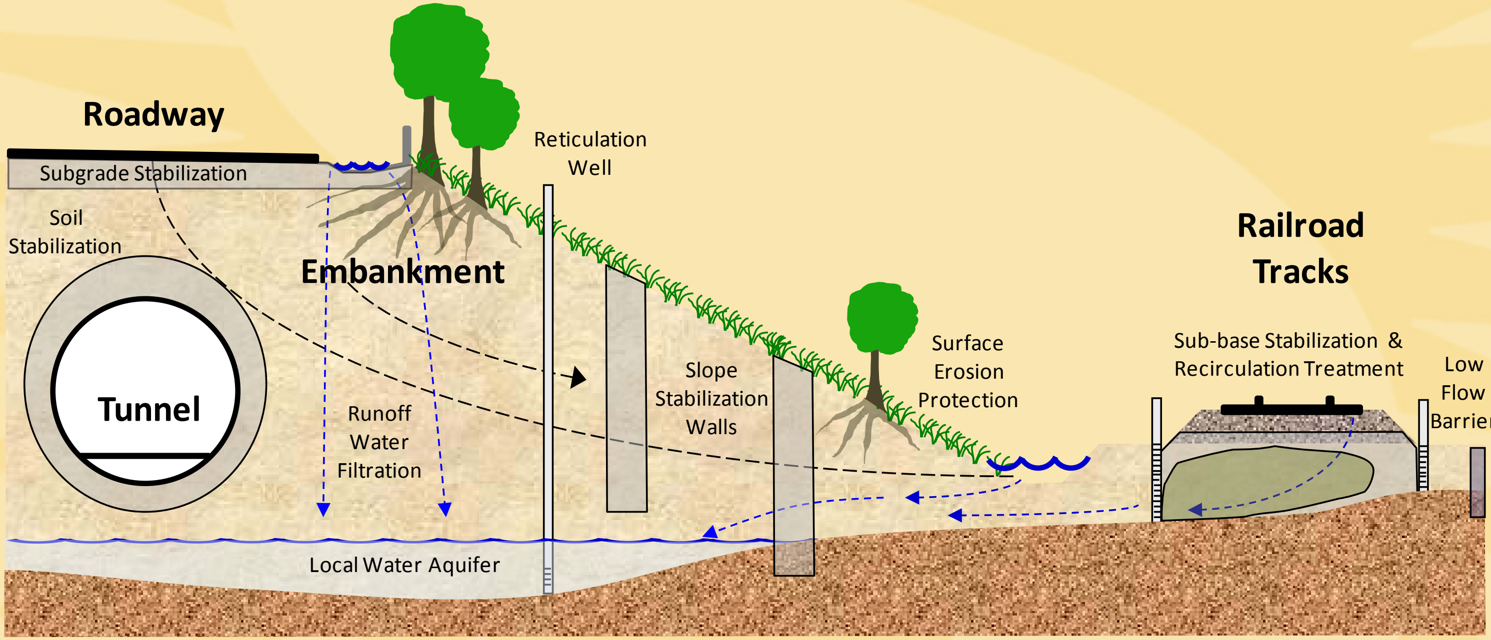
Issues to Consider

- Cost
- Permanence/reversability
  - Reversability may be beneficial in some applications
- Energy consumption
- Environmental impacts
- Unanticipated side effects

Conclusion

Fugitive dust contol: One of many potential biogeotechnical applications

Many more waiting to be discovered



DeJong et al. (2011)

Thank You for your attention

Any Questions ????