IOWA STATE UNIVERSITY

Department of Civil, Construction & Environmental Engineering

Author: Bo Yang

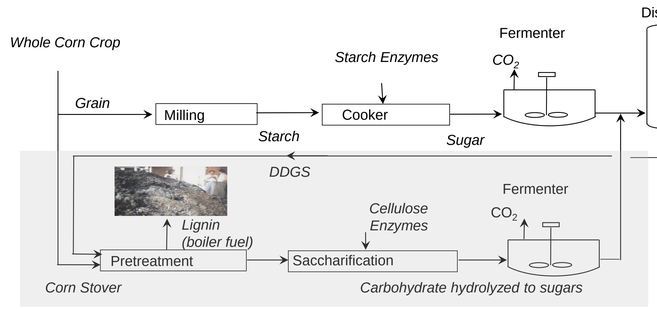
Co-Authors: Halil Ceylan, Kasthurirangan Gopalakrishnan, and Sunghwan Kim

Major Professor: Dr. Halil Ceylan

Strengthening of Pavement Subgrade Soil Using Biofuel Co-products

Motivations

- **Sulfur-free lignin has been more available as a co-product of the increasing biofuel or ethanol productions**
- **As a renewable and economic resource, lignin has been given more attention to use in highway geomaterials stabilization**



(Photo Courtesy: Prof. R. Brown, Iowa State University)

(Photo Courtesy: EnviroTech Services Inc)

Objectives

- **To investigate the strength improvements of Iowa soils treated with two different biofuel co-products (BCPs) containing lignin for pavement geo-materials stabilization**
- **Two types of BCPs investigated in this study are**
  - **A liquid type with higher lignin content (co-product A)**
  - **A powder type with lower lignin content (co-product B)**

Experimental Materials

- **Soil: Iowa loess**

Property	Loess Soil
Classification	
AASHTO (group index)	A-4(2)
USCS group symbol	CL-ML
USCS group name	Sandy Silty with clay
Grain size distribution	
Gravel (> 4.75 mm), %	0.1
Sand (0.075–4.75 mm), %	37.2
Silt and clay (< 0.075mm), %	62.7
Atterberg limits	
Liquid limit (LL) , %	29.1
Plasticity limit (PL), %	22.9
Plasticity index (PI), %	6.2
Standard Proctor test	
Optimum moisture content (OMC), %	18.2
Maximum dry unit weight ($g_{d\,max}$), kg/m^3(pcf)	1,631 (101.8)

- **Additives**

Biofuel Co-product A (higher lignin content)

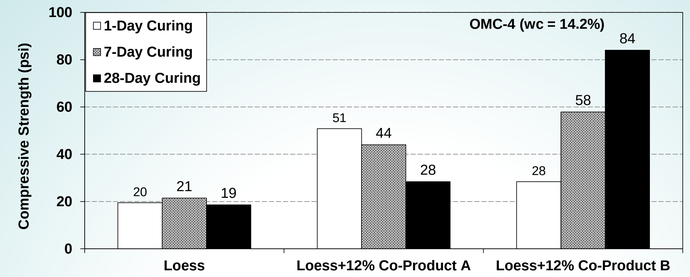
Biofuel Co-product B (lower lignin content)

Experimental Plan

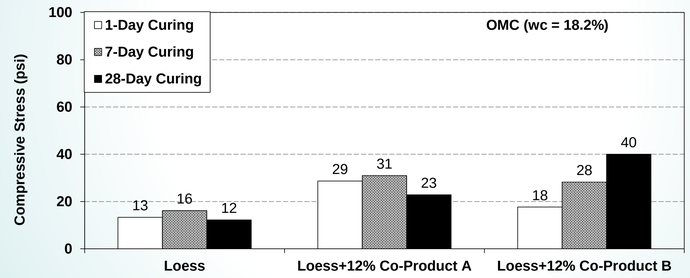
- **Sample categorization: (1) untreated soil samples (control), (2) soil samples treated with the BCP A, (3) soil samples treated with the BCP B**
- **Sample geometry: 2 in. diameter by 2 in. height.**
- **Additive content: 12% by dry soil weight for treated sample and no additive for untreated sample**
- **Moisture content: OMC-4%, OMC and OMC+4%.**
- **Curing period: 1-day, 7-day, 28-day air dry curing (wrap is required to avoid moisture loss)**
- **Sample repetition: three (in total 81 samples)**

Unconfined Compressive Strength (UCS) Test Results

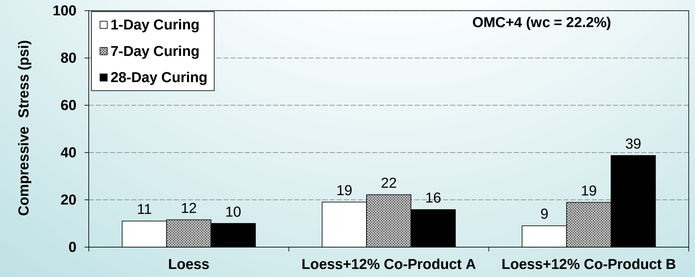
Compressive strength results under OMC-4 (wc=14.2%):



Compressive strength results under OMC (wc=18.2%):



Compressive strength results under OMC+4 (wc=22.2%):



Preliminary Findings

- **Both BCPs can improve soil strength of Iowa loess soil**
- **BCP A performs better under short term curing condition but BCP B performs better under long term curing condition**
- **Higher moisture content in soils reduces strength capacity of all sample tested**

Acknowledgements: The authors gratefully acknowledge the Iowa Department of Transportation (IA DOT), Iowa Highway Research Boards (IHRB), and Iowa State University (ISU) for supporting this study.
The authors are also grateful to ISU Bioeconomy Institute and Grain Processing Corporation (GPC) of Muscatine for supplying the experimental biofuel co-product materials.