IOWA STATE UNIVERSITY
Institute for Transportation

Biofuel Co-Product Uses for Pavement Geo-Materials Stabilization

tech transfer summary

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RESEARCH PROJECT TITLE
Biofuel Co-Product Uses for Pavement Geo-Materials Stabilization

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The mission of the Institute for Transportation (InTrans) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, reliability, and sustainability while improving the learning environment of students, faculty, and staff in transportation-related fields.

Lignin-containing co-products of biofuel production can help stabilize pavement bases and subgrades and can potentially make biorefineries economical while establishing sustainable road infrstructures.

Objectives

- Evaluate the ability of biofuel co-product (BCP) to function as an effective soil stabilizing agent.
- Investigate the effect of BCP on the engineering properties of soil-BCP mixtures for Iowa conditions.

Problem Statement

Using biomass as a sustainable, renewable energy source can be part of a solution for reducing dependence on fossil fuel–based energy and mitigating global warming, and both the production and use of biofuels made from biomass have increased. Biofuel production creates not only biofuel or ethanol, but also co-products containing lignin, modified lignin, and lignin derivatives.

The use of these co-products to help stabilize pavement soils and other geo-materials has been studied over the past decades. However, most lignin-related soil stabilization studies have investigated sulfite lignins (lignosulfonates) derived from the paper industry, while the lignins obtained from biofuel or ethanol production are sulfur-free.

The use of lignin-based BCPs in pavement geo-materials stabilization need to be investigated, as it is hypothesized that stronger geo-materials stabilization may be achieved and may reduce the amount of geo-materials needed to stabilize soils. Newer uses of biomass-derived lignin could also provide additional revenue streams for bio-based products and the bioenergy industry.

Lignin is a co-product of biofuel production, which uses plant materials with a high concentration of cellulose.

Research Description

Soils Samples

Natural soils were collected from a new road construction site for US 20 in Calhoun County, Iowa. The samples were identified as A-6(8) in the AASHTO classification system, CL (sandy lean clay) in the USCS system, or Class 10 in the Iowa Department of Transportation system.

Two types of BCPs containing lignin were used as additives:

- A liquid type BCP with relatively high lignin content (co-product A)
- A powder-type BCP with relatively low lignin content (co-product B)

These BCP-treated samples were compared to untreated and traditional stabilizer-treated (fly ash) soil samples. Various additive combinations (co-product A + fly ash, co-products A + B, etc.) were also evaluated.

Laboratory tests evaluated the samples' strength performance and moisture susceptibility.

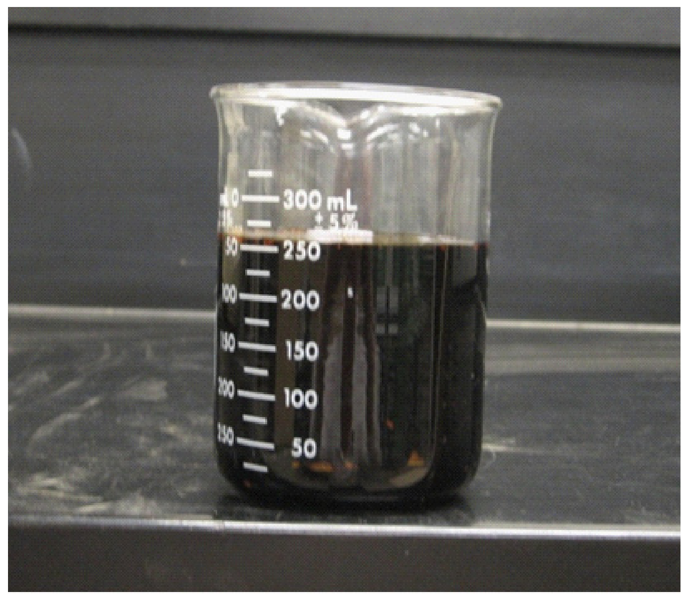
Strength Testing

Strength performance was evaluated using an unconfined compression strength (UCS) test, and engineering properties were evaluated using Atterberg limits and standard Proctor compaction tests. Additive contents, moisture contents, and curing periods were incorporated as variables into the strength property test factorial.

Moisture Susceptibility Testing

Moisture susceptibility was evaluated through UCS tests after "dry" and "wet" conditioning procedures as well as through visual observations of soaked specimens (so-called soaking tests). The UCS tests were conducted on both dry and wet specimens to evaluate the strength loss due to moisture intrusion. Each specimen was also fully soaked in water over a period of time to examine whether specimens would fail due to moisture effects and how long they could withstand moisture damage.

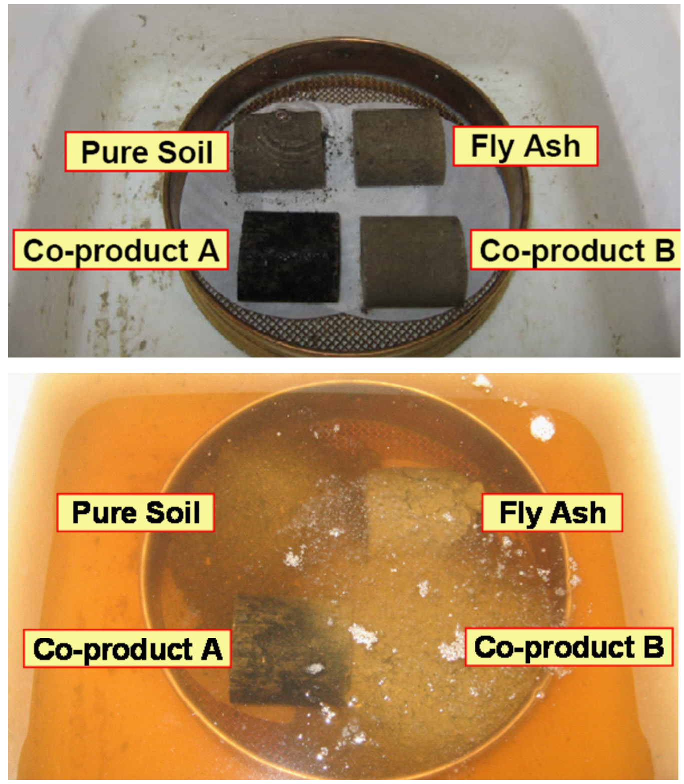
Natural soils were collected from a new road construction site in Calhoun County, Iowa.



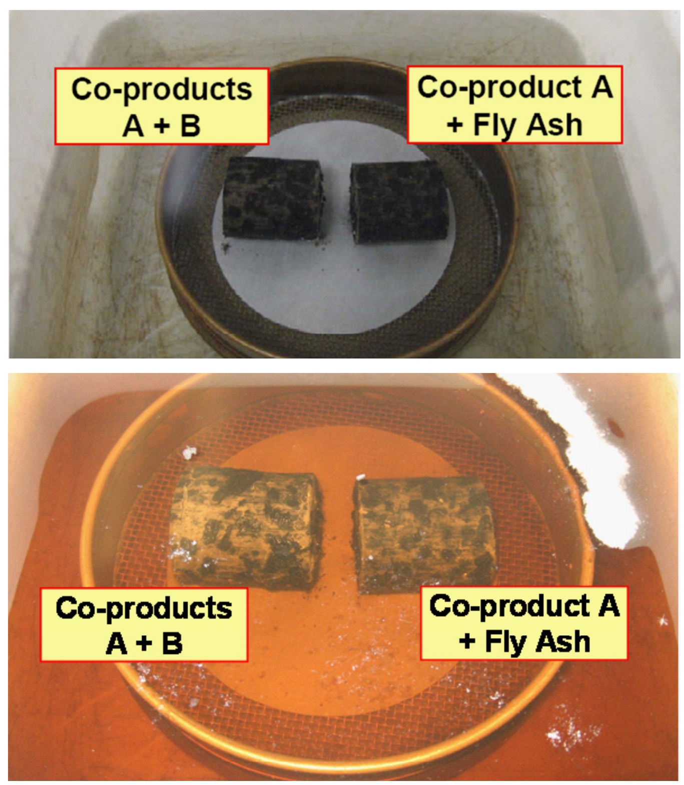
Liquid type biofuel co-product A (above) and powder type co-product B (below)

Key Findings

- The investigated biofuel co-products are promising materials for improving the strength of Iowa Class 10 soils classified as CL or A-6(8).
- Biofuel co-products containing sulfur-free lignin provide excellent moisture degradation resistance for Iowa Class 10 soils classified as CL or A-6(8).
- Co-product A was more effective than other additives in improving strength under dry conditions, while co-product B was more effective in improving strength under wet conditions.
- The UCS results for the co-products–treated soil samples increased with an increased co-products content. A high increase in UCS occurred in all cases where the sample included 12% of co-product A.
- Co-product A, having a greater lignin content than co-product B, provides more effective moisture resistance than co-product B or fly ash.
- Under drier-than-optimum conditions, the additive combinations of 10% co-product A + 2% fly ash and 10% co-product A + 2% co-product B provided strength comparable to that of fly ash treatment.
- Under wetter-than-optimum conditions, the additive combination of co-product A + fly ash possessed strengths similar to those of fly ash treatment alone.
- Curing periods have more influence on strength gain for soils treated with co-product A than soils treated with co-product B.
- Additive combinations of 10% co-product A + 2% fly ash and 10% co-product A + 2% co-product B provide moisture resistance comparable to that of co-product A.



Soil+additive, pure soil, and fly ash-treated samples at moisture susceptibility test setup (top) and after seven days (bottom)



Additive combination samples at moisture susceptibility test setup (top) and after seven days (bottom)

Implementation Benefits

Using BCPs as soil stabilization material appears to be one of the many viable ways to improve the profitability of bio-based products and the bioenergy industry. Because more biofuel co-product is disposed than utilized, using biofuel co-products more productively can have considerable benefits for sustainable development.

The BCPs used in this experiment demonstrated excellent potential for stabilizing low-quality materials for use in low- and high-volume roads. These co-products could be used to stabilize existing subgrade materials to provide a stable working platform and to improve the strength of undesirable soil materials so that they can be used as the load-bearing layer within a pavement system.

From an economic perspective, the transition from fossil fuel–based energy to renewable energy could result in decreased production and higher costs of fly ash, which is a byproduct in coal-fired power plants. However, this change could also result in increased production and lower costs of biofuel co-products to make these products comparable to traditional soil stabilizers. While fly ash has the potential to leach heavy metals that contaminate the soil, biofuel co-products could be used without adversely impacting the environment because the feedstock used for biofuel and its co-products is natural, biodegradable biomass.

Recommendations

Further research is needed to evaluate the freeze-thaw durability and characterize the resilient modulus of BCP-treated soils. Considering the wide range of pavement-related applications in which modified lignins have already been used, such as concrete admixtures, dust suppressants, and potentially pavement base layer treatment agents and joint and crack sealants, the use of lignin-containing BCPs in these applications should be investigated.

These innovative uses for BCPs in pavement-related applications could not only provide additional revenue streams to improve the economics of biorefineries, but also serve to establish green road infrastructures.