SUSTAINABLE METHOD TO STABILIZE CLAYEY SOIL USING CHEMICAL REAGENTS

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Introduction:

- ✓ Louisiana soil mainly consists of silts and clays, making it a weak foundation for superstructures.
- ✓ Researchers and engineers are trying to utilize different techniques to improve the mechanical properties of the natural soils and make it suitable to carry superstructure loads.
- ✓ One of the effective ways to modify a soil layer is the chemical stabilization technique.
- ✓ Every soil needs to be studied to determine its best stabilization technique.
- ✓ Even several industrial projects are active in Southwest Louisiana; there is no documented study of the soil stabilization for this area.

Introduction:

- ✓ Selection of the best soil stabilization process depends on soil types, availability of the stabilizing reagent, economic justification, and efficiency of the stabilizing method.
- ✓ Improvement of the behavior of clays by utilization of emulsions and chemicals is called **soil stabilization**.
- ✓ The chemical reagents act as a binder in the soil and can aid in increasing the shear strength of the ground soil.
- ✓ **Hydrated Lime** and **Fly Ash** are utilized as chemical reagents to stabilize the soil.
- ✓ The outcome of a soil stabilization study is to find the **best recipe** to stabilize local soil.

Introduction:

"Chemical stabilization can aid in dust control on roads and highways, particularly unpaved roads, in water erosion control, and in fixation and leaching control of waste and recycled materials."

Distinguished Geotechnical Engineering Author Braja M. Das (2000)

- ✓ **Furthermore**, soil stabilization techniques have many other applications, including **road base and subbase construction**, **embankments**, **earth dams**, **levees projects**, **foundation**, and **runway construction**.

Literature Review

Lime and Fly Ash Stabilization

- ✓ Lime stabilization is a widely used methods of chemically altering weak soils into structurally rigorous construction foundations.
- ✓ Lime stabilization yields to a number of important engineering properties in soils including (Little et al., 2000):
  - ➢ improved strength;
  - ➢ improved resistance to fracture,
  - ➢ fatigue, and permanent deformation;
  - ➢ improved resilient properties;
  - ➢ reduced swelling; and
  - ➢ resistance to the damaging effects of moisture
- ✓ The pozzolanic reaction between lime and soil silica and soil alumina (released in the high-pH environment) is key to effective and durable stabilization in lime–soil mixtures (TRB Proceedings, 2000).

Literature Review

Mixture Design (from Little et al, 2000)

- ✓ Design of lime-stabilized mixtures is usually based on **laboratory analysis** of desired engineering properties.
- ✓ Laboratory testing procedures include determining **optimum lime/fly-ash** requirements and **moisture content**, preparing samples, and curing the samples under simulated field conditions.
- ✓ Pozzolanic reactions are slower than cement-hydration reactions and can result in construction and performance benefits, such as extended mixing times in heavy clays (more intimate mixing) and autogenous healing of moderately damaged layers, even after years of service.
- ✓ Protocols for lime/fly-ash and soil mixture design must address the impact of moisture on performance.

Lime Stabilization Construction

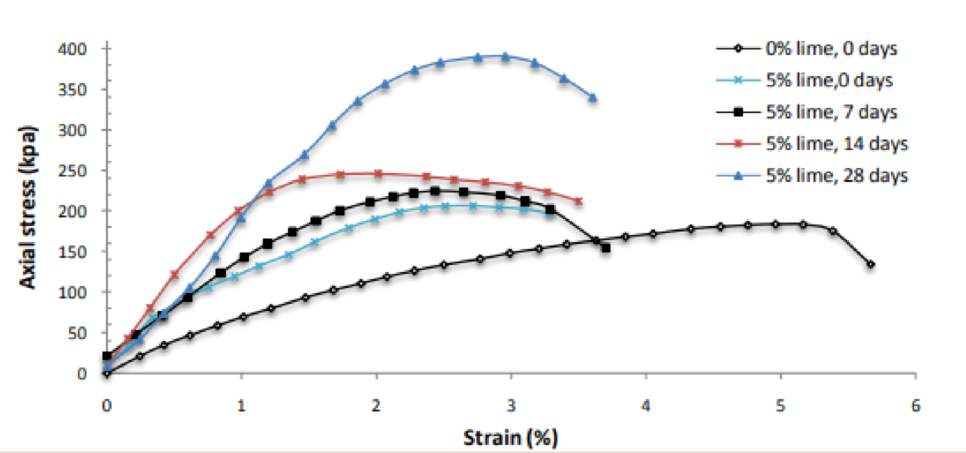
- ✓ Lime stabilization construction is relatively straightforward. In-place mixing (to the appropriate depth) is usually employed to add the proper amount of lime to a soil, mixed to an appropriate depth.
- ✓ Pulverization and mixing are used to combine the lime and soil thoroughly. For heavy clays, preliminary mixing may be followed by 24 to 48 hours (or more) of moist curing prior to final mixing.

Lime Stabilization Results

S. No	Soil and Lime	Maximum Dry Density	Optimum Moisture Content
1	Virgin Soil	1.87 g/cm^3	10%
2	Soil With 3 % Lime	1.78 g/cm^3	12.5%
3	Soil With 6 % Lime	1.711 g/cm^3	12.6%
4	Soil With 9 % Lime	1.714 g/cm^3	12.7%

S. No	Soil and Lime	Unconfined compressive strength
1	Virgin Soil	2.12 kg/cm^2
2	Soil With 3 % Lime	4.35 kg/cm^2
3	Soil With 6 % Lime	5.18 kg/cm^2
4	Soil With 9 % Lime	4.24 kg/cm^2

Results borrowed from Kaul and Sing (2012)



Wanatoswski and Mahmed (2013)

Chemical Stabilization to Mitigate Shallow Slides

- ✓ The types of shallow slides commonly occur in slopes constructed in **stiff** fissured, over-consolidated materials, as well as compacted slopes of **high plasticity clays** exposed to wetting and drying cycles.
- ✓ The **shrink/swell** characteristics of the high plasticity clays due to changes in moisture content can contribute to desiccation cracking of the materials during drought periods. This desiccation cracking can extend to considerable depths and create a possible conduit for surface water to deeper material depths during extensive rainfall periods.

Typical shallow slides in Dallas levees (photograph used with permission from Gamez and Stark *(2014)*

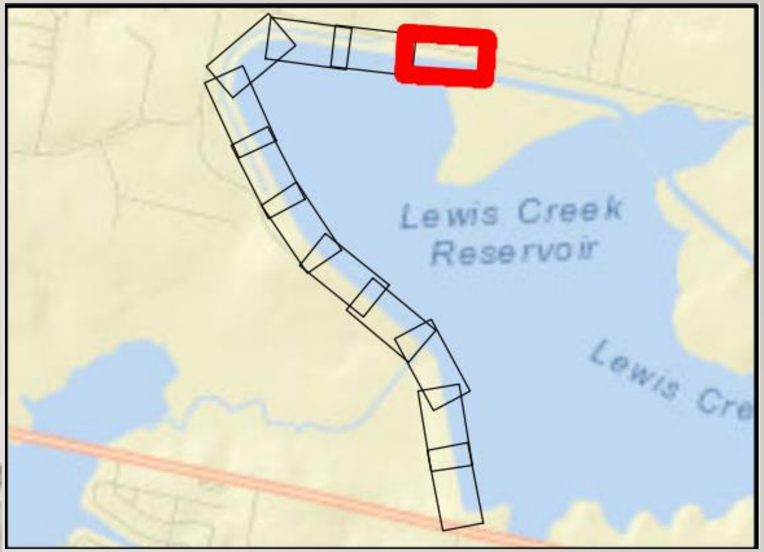
Chemical Stabilization to Mitigate Shallow Slides (A case study)

- The Lewis Creek Dam near Willis, Texas (Montgomery County) is an intermediate-size earthen embankment dam which impounds the Lewis Creek Reservoir. The reservoir provides cooling water for operations of the Entergy Lewis Creek Generating Facility. The storage capacity of the reservoir is approximately 16,000 acre-feet. The maximum structural height of the Lewis Creek Dam is approximately 55 feet. The downstream slope of the Lewis Creek Dam experienced some shallow slides, including soil slides in April and May 2015. These slides occurred after several years of drought conditions were followed by record rainfall.

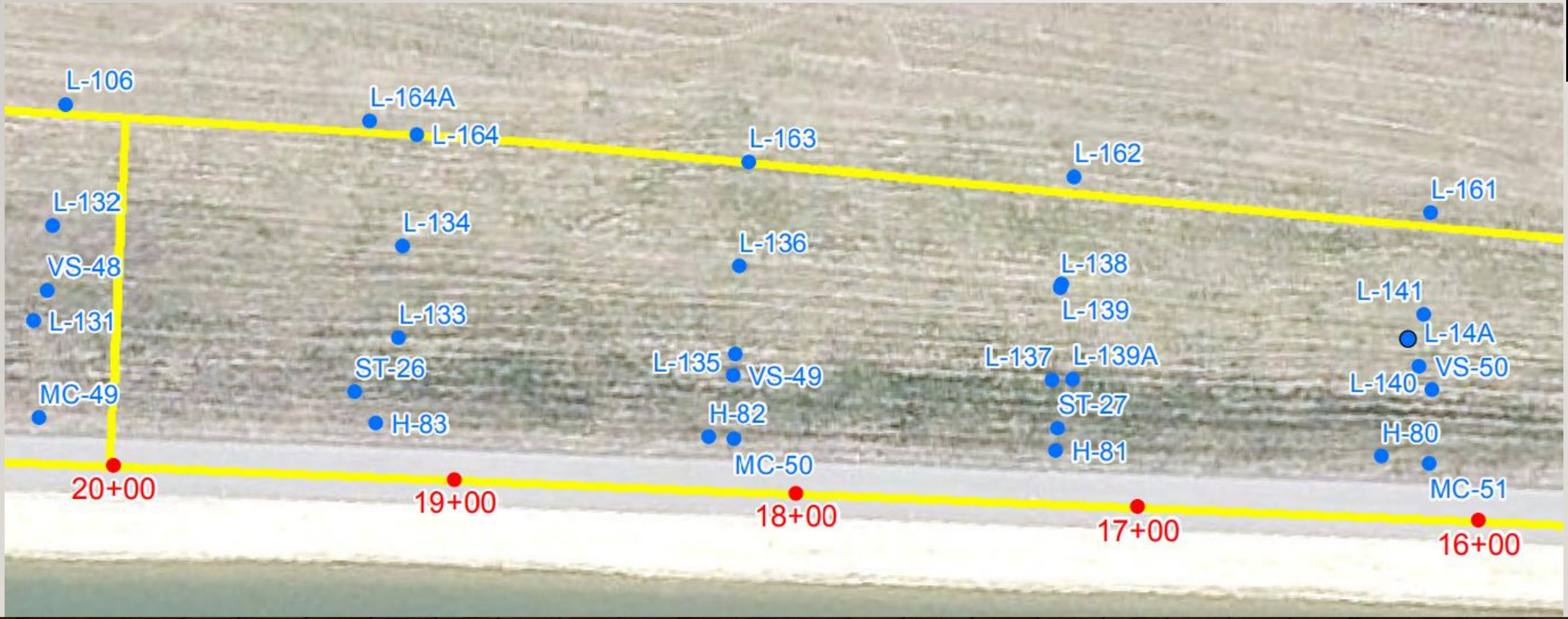
Lewis Creek reservoir, Montgomery, Texas
(photograph used from www.geoengineer.org)

Chemical Stabilization to Mitigate Shallow Slides (A case study)

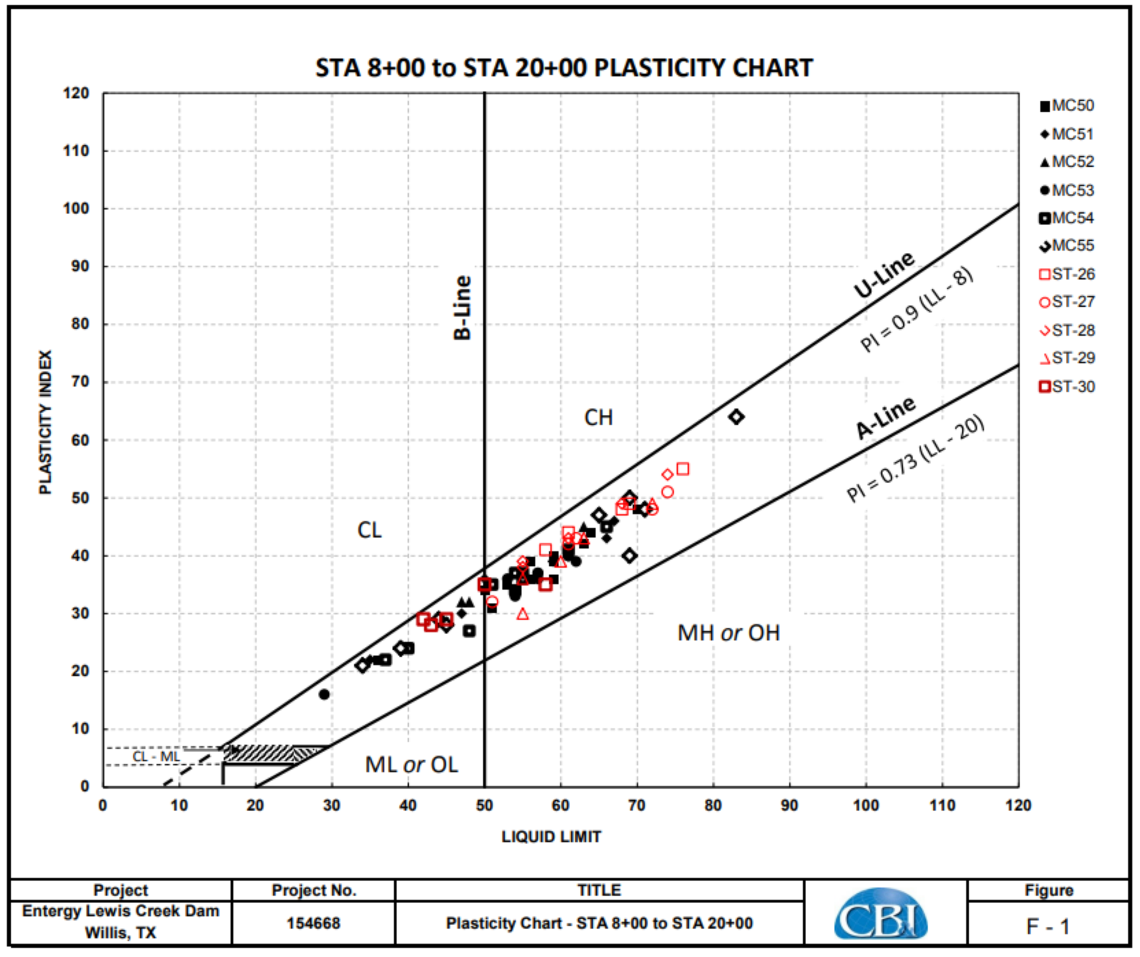
- The Lewis Creek Dam divided in 12 bay areas to study the slop soil.
- The soil investigation includes soil tests, bore logs, CPTs, Vane Shear Test etc.

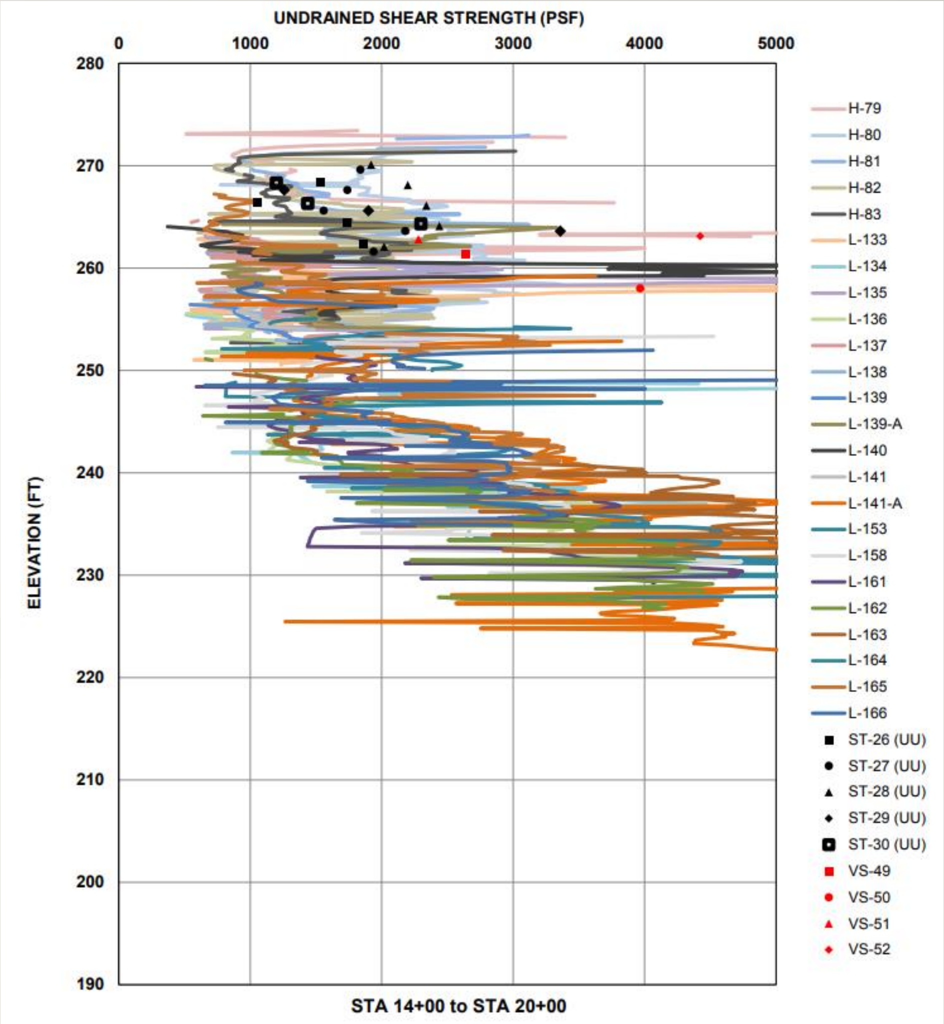


Lewis Creek reservoir, Montgomery, Texas (photograph used from CB&I Geotechnical Report)



Chemical Stabilization to Mitigate Shallow Slides (A case study)





A sample soil properties (from CB&I Geotechnical Report)

Chemical Stabilization to Mitigate Shallow Slides (A case study)

Hydrated Lime Dose (% of Dry Weight)	LL	PL	PI
0	58	16	42
6	54	35	19
8	53	36	17
10	53	36	17

A typical Lime Series Curve for Treating Soil (from CB&I Geotechnical Report)

Hydrated Lime Dose (% of Dry Weight)	pH
6	12.2
8	12.35
10	12.36

A typical Lime Series Curve 60/40 lime/FA Treatment (from CB&I Geotechnical Report)

Typical Mixture Before Compaction (from CB&I Geotechnical Report)

- Based on these results, two formulations were selected for durability and shrink-swell tests:
  - 8 % lime
  - 12% 70/30 Lime/Weathered Class C FA

Chemical Stabilization to Mitigate Shallow Slides (A case study)

Untreated sample

Lime treated

Lime + Flyash treated sample

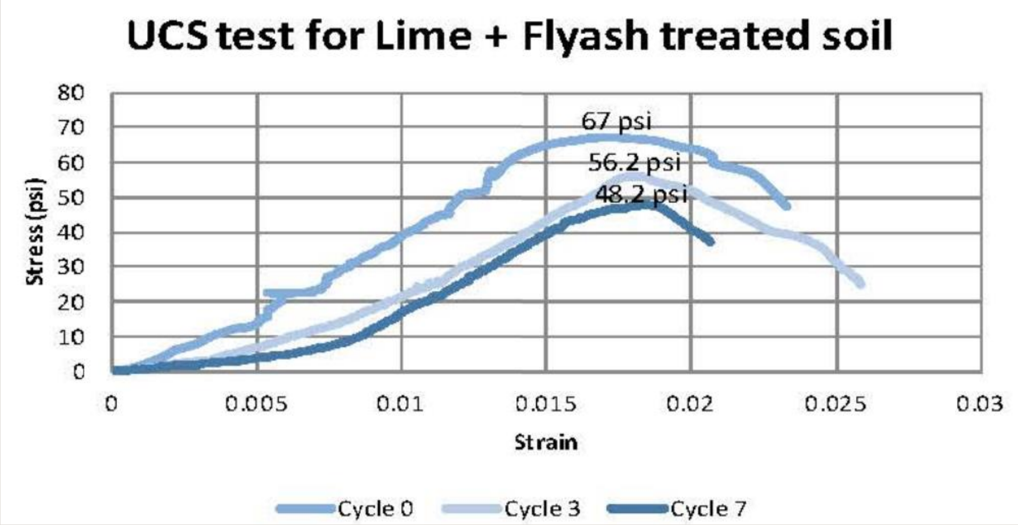
soil samples

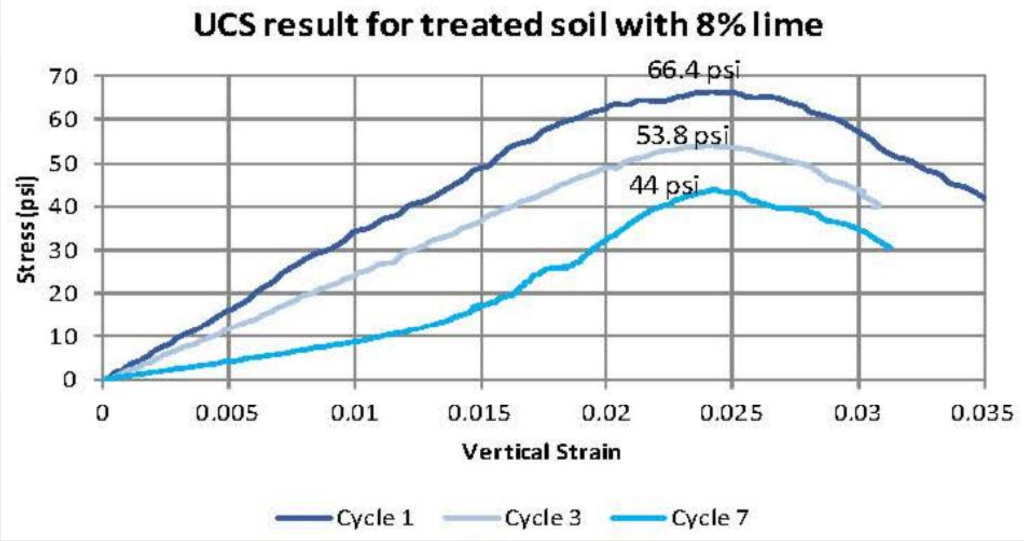
- Linear Shrinkage Bar Tests (TxDOT: Tex-107-E)) results are shown in Figure. The untreated soil volumetric shrinkage was very large at 47 percent. Treatment with 8% lime or 12% lime/FA reduced the shrinkage to 14 and 12 percent, respectively.

Soil Type	Lenth (in)			Average Length (in)	Height (in)			Average Height (in)	Width (in)			Average Width (in)	Average Volume (in^3)	Length strain (%)	Height strain (%)	Width strain (%)	Volumetric Shrinkage strain (%)
Untreated Soil	4.13	4.06	4.01	4.07	0.59	0.59	0.6	0.59	0.62	0.62	0.63	0.62	1.50	18.67	20.89	17.33	47.00
Lime Treated Soil	4.8	4.75	4.76	4.77	0.7	0.71	0.72	0.71	0.74	0.69	0.72	0.72	2.43	4.60	5.33	4.00	14.00
Lime + Fly Ash Treated Soil	4.78	4.81	4.83	4.81	0.71	0.72	0.73	0.72	0.74	0.69	0.73	0.72	2.48	3.87	4.27	4.00	12.00

Chemical Stabilization to Mitigate Shallow Slides (A case study)

- Durability Testing was conducted at UT-A. For the durability analysis (ASTM D 559-96) the UT-A results will be covered.
- UT-A used ASTM D 559-96 and AASHTO standardized procedure to prepare the formulations and cure them.





Future Research Proposal

- ✓ **Granted Proposal:**

CITGO PETROLEUM PROFESSORSHIP IN ENGINEERING #5 (2021). “Stabilization of Lake Charles Clayey soil using Fly-ash and lime.”

- ✓ **Submitted Proposal:**

Shearman Research Initiative Funds (SRIF) (2022). “Sustainable Method to Stabilize Southwest Louisiana Soil using Chemical Reagents.”

Thank You