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# Environment Friendly Soil Stabilization Using Lignin Biopolymer

*Dr. S. Syed Enayathali [1], V. Nachiappan[2]*
*[1] Assistant Professor - Department of Civil Engineering, Anna University Tiruchirappalli (BIT Campus), India.*
*[2] PG - Department of Civil Engineering, Anna University Tiruchirappalli (BIT Campus), India.*
***Emails:*** *enayathali2013@gmail.com[1], sirchabasan@gmail.com[2]*

## Abstract
*The using of lignin biopolymer for soil stabilization offers a sustainable solution that promotes environmental protection and conservation while meeting the engineering and agricultural wishes for soil control. the usage of lignin biopolymer for soil stabilization is an incredible environmentally friendly method. Lignin, a complicated natural polymer found in plant mobile partitions, has diverse packages because of its potential to bind soil debris together and enhance soil systems like Biodegradability, Soil Erosion, development of Soil houses, reduction of Chemical utilization, Waste usage, Compatibility with natural farming.*

***Keywords**: Atternbeg Limit; Biopolymers; Lignin; Soil Stabilization;*

## 1. Introduction
The pursuit of innovation in soil stabilization continues unabated, with ongoing research aimed at refining techniques and exploring new avenues. A notable example is the investigation into lignin-stabilized soil, as evidenced by laboratory studies. Such endeavours not only contribute to the advancement of soil stabilization practices but also underscore the importance of sustainable and resilient infrastructure development in the face of evolving challenges. Beyond the realm of civil engineering, soil stabilization serves broader societal objectives. By improving the natural terrain for motorway construction, it facilitates economic development and connectivity, essential for sustained growth. Moreover, in times of emergencies, such as military operations or natural disasters, soil stabilization plays a pivotal role in rapidly rendering terrain usable, thereby aiding relief efforts and ensuring swift access to affected areas. The Various methods to stabilize the soil like Mechanical Stabilization, Chemical Stabilization, Bituminous Stabilization, Electro-Chemical Stabilization, Vegetation stabilization.

### 1.1.Role in Soil Stabilization

i. Researchers have made substantial efforts to utilize Lignosulphonate (LS) as an expansive soil stabilizer [1].
ii. LS is a natural polymer derived from lignin.
iii. It physically binds soil particles together and has minor chemical effects.
iv. Individual soil particles can become coated in a thin adhesive-like film, effectively cementing them together
v. **Consistency:** LS impacts the consistency of the soil [2].
vi. **Swelling-Shrinkage Behaviour:** It helps control soil expansion and contraction.
vii. **Strength Characteristics:** LS contributes to soil strength.
viii. **Permeability:** It affects the flow of water through the soil.

### 1.2.Applications in Soil Stabilization

i. **Dust Control:** Sodium lignosulfonate can be applied to unpaved roads, construction sites, and other areas to control dust emissions. When sprayed onto the soil surface, it forms a thin film that binds soil particles together, reducing dust generation from vehicle traffic, wind erosion, and other source [3].
ii. **Soil Conditioning:** Sodium lignosulfonate can be used to improve the workability and compaction of soils in construction projects.

When mixed with soil, it acts as a soil conditioner, enhancing soil plasticity and reducing the amount of water needed for compaction. This helps achieve the desired soil density and stability more efficiently [4].

iii. **Erosion Control:** Sodium lignosulfonate can help prevent soil erosion by stabilizing soil aggregates and enhancing soil structure. When applied to erodible slopes, embankments, or disturbed soils, it binds soil particles together, reducing surface runoff and soil loss caused by rainfall and surface water flow [5].

iv. **Vegetation Establishment:** Sodium lignosulfonate can be used as a mulching agent to promote vegetation establishment on bare soils. When applied as a soil amendment or mixed with hydro seeding slurries, it helps retain moisture, improve seed germination, and protect seedlings from environmental stresses, thus enhancing vegetation cover and soil stability over time [6].

v. **Compatibility with Other Additives:** Sodium lignosulfonate can be combined with other soil stabilizers, such as polymers, enzymes, or biopolymers, to enhance their effectiveness or tailor their properties for specific soil stabilization applications. Its compatibility with a wide range of soil types and additives makes it a versatile option for soil stabilization projects. Site Details is shown in Table 1.

### 1.3.Site Information

**Table 1 Site Details**

| | | |
|---|---|---|
| Location | : | Kalla kudi, Tiruchirappalli |
| retrieval Site | : | Kalla kudi Tollgate |
| Latitude | : | 10°59’53” N |
| Longitude | : | 78°57’49” E |
| State | : | Tamil Nadu |
| Sample retrieval Depth | : | 90-100cm |


**Figure 1 Site Location**

## 2. Methodology

### 2.1.Materials and Specifications

#### 2.1.1. Biopolymers

Biopolymers are a class of polymers that are produced by living organisms or derived from renewable natural sources such as plants, animals, and microorganisms. Unlike synthetic polymers derived from petrochemicals, biopolymers are considered more environmentally friendly because they are biodegradable and often have lower carbon footprints. Site Location is shown in Figure 1.

i. **Polynucleotides:** These are long polymers of nucleotides. The most well-known examples are RNA and DNA, which play crucial roles in genetic information storage and transfer [7].
ii. **Polypeptides:** Polypeptides include proteins and shorter polymers of amino acids. Proteins are essential for various biological functions, such as enzymes, structural components (like collagen and actin), and blood clotting (like fibrin).
iii. **Polysaccharides:** These are linear or branched chains of sugar carbohydrates. Examples of polysaccharides include:
iv. **Starch:** A storage form of energy in plants.
v. **Cellulose:** A major component of plant cell walls.
vi. **Alginate:** Found in brown algae and used in various applications [8].

#### 2.1.2. Lignin

Lignin is a complex organic polymer found in the cell walls of plants, particularly in wood and bark. It is one of the most abundant organic polymers on Earth, second only to cellulose. Lignin plays a crucial role in providing structural support to plants and conducting water and nutrients through the plant tissues. It is responsible for the rigidity and strength of wood and is a major component of plant biomass [9].

**Here are Some Key Aspects About Lignin:**

Chemical Structure: Lignin is a heterogeneous polymer composed of phenyl propane units, primarily coniferyl alcohol, sinapyl alcohol, and p- coumaryl alcohol, linked together through various chemical bonds. The exact composition and structure of lignin vary among plant species and cell types [10].

**Extraction and Utilization:** Lignin can be extracted from plant biomass through various processes, such as pulping in the paper industry or biomass pre-treatment in biofuel production. Once extracted, lignin has potential applications as a renewable feedstock for the production of chemicals, materials, and fuels.

**Environmental Impact:** Lignin is highly resistant to degradation by microorganisms, which contributes to its role in carbon sequestration and the formation of soil organic matter. However, lignin degradation is also important in carbon cycling and nutrient recycling in ecosystems.

**Challenges and Opportunities:** Despite its abundance and potential, lignin utilization faces challenges related to its heterogeneity, complex structure, and variability in properties. Research efforts are focused on developing efficient processes for lignin extraction, depolymerisation, and conversion into high-value products, as well as understanding its role in plant biology and ecosystem dynamics.

In conclusion, lignin is a versatile and abundant biopolymer with significant potential for various industrial and environmental applications. Its unique properties and complex structure make it a valuable resource for sustainable bio refinery processes and the development of renewable products and materials. Continued research and innovation are essential to fully unlock the potential of lignin and realize its benefits in a bio-based economy [11].

### 2.1.3. Sodium Lignosulfonate

Sodium lignosulfonate (Figure 2), also known as sodium lignin sulfonate or lignosulfonic acid sodium salt, is a water-soluble lignin derivative obtained during the sulfite pulping process in the paper industry. It is a by-product of wood pulp production and is widely used in various industrial applications due to its unique properties. While sodium lignosulfonate is primarily utilized as a dispersing agent, binder, and additive in concrete, ceramics, and other industries. [12]

**Figure 2 Sodium Lignosulphonate**

### 2.1.4. Reaction Time and Method

The reaction time for lignosulfonate to react with soil can vary depending on the specific conditions and the desired outcomes. Studies have shown that lignosulfonate treatment can have significant effects on soil properties, such as reducing negative surface charge, enhancing soil strength, and improving stability. The duration of the reaction can range from 1 hour to 72 hours, depending on factors like temperature, pressure, pH value, and the specific type of lignosulfonate used. Typically, the reaction time falls within this range to allow the lignosulfonate to effectively interact with the soil and bring about the desired improvements in soil properties [13].

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### 2.1.5. Tests and IS Codes

**Table 2 IS Code**

| S.No | Test | IS-Code |
|---|---|---|
| 1. | Grain Size Analysis | IS 2720 (Part 4): 1985 |
| 2. | Hydrometer | IS-3104:1965 |
| 3. | Atternbeg Limits | IS 2720-5 (1985) |
| 4. | Heavy compaction tes | IS 2720-1980 (Part VIII) |
| 5. | CBR | IS: 2720 (Part 16): 1987 |
| 6. | UCS | IS 2720-10 (1991 |
| 7. | Free Swell Index | IS 2720 – Part -40-1970 |

## 3. Result and Discussion

### 3.1.Soil Propertied

**Table 3 Soil Properties**

| SOIL PROPERTY | OBTAINED VALUE |
|---|---|
| Specific gravity | 2.67 |
| UCS Strength (kg/cm²) | 0.634 kg/cm² |
| Liquid limit (IS 2720 part 5) | 33% |
| Plastic limit (IS 2720 part 5) | 20.66% |
| Plasticity index (IS 2720 part 5) | 12.34% |
| Shrinkage limit (IS 2720 part 5) | 19.06% |
| Optimum moisture content (IS 2720 part 7) | 24.50% |
| Maximum dry density (IS 2720 part 7) | 1.65 g/cc |
| **Percentage of sand (IS 2720 part 4)** | **7.20%** |
| **IS classification** | **CL** |

### 3.2.Atternbeg Limits

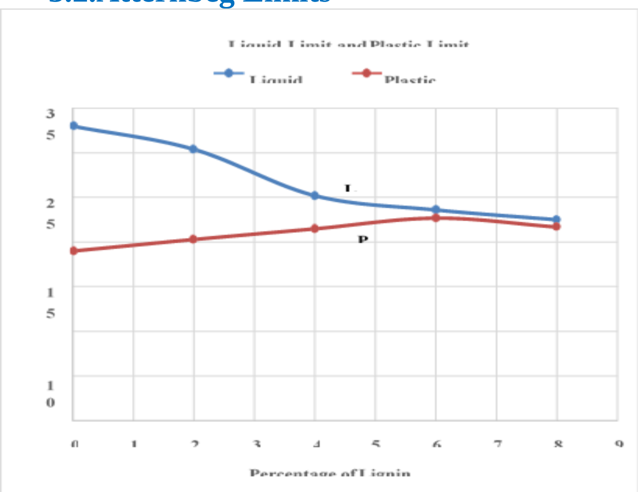

**Figure 3 Plot between Percentage of Lignin and Plastic Limit, Liquid Limit**

**Table 4 Atternbeg Limits**

| Percentage of Lignin | LL | PL |
|---|---|---|
| 0 | 33 | 19 |
| 2 | 30.4 | 20.3 |
| 4 | 25.2 | 21.5 |
| 6 | 23.6 | 22.7 |
| 8 | 22.5 | 21.7 |

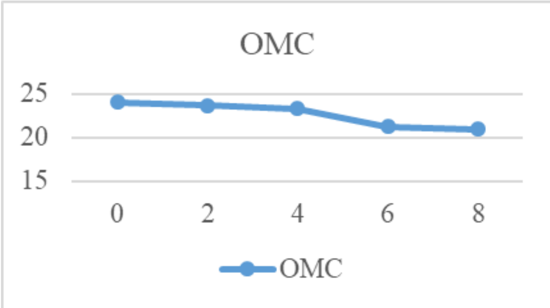


**Figure 4 Plot between Percentage of Lignin and Optimum Moisture Content**

As the percentage of lignin increases, a discernible shift in soil behaviour occurs: the liquid limit decreases while the plastic limit increases, ultimately leading to a significant reduction in soil plasticity. This phenomenon results in a soil that is nearly non-plastic, with the plastic index also decreasing proportionally. Such observations highlight the transformative impact of lignin on soil properties, offering insights into its potential as a stabilizing agent. By mitigating soil plasticity, lignin presents an opportunity to enhance soil stability and engineering performance, particularly in applications where high plasticity soils pose challenges [14].

### 3.3.Optimum Moisture Content and Maximum Dry Density

**Table 5 Maximum Dry Density and Optimum Moisture Content**

| Percentage of Lignin | MDD | OMC |
|---|---|---|
| 0 | 1.64 | 24.1 |
| 2 | 1.665 | 23.7 |
| 4 | 1.76 | 23.35 |
| 6 | 1.71 | 21.3 |
| 8 | 1.69 | 21 |

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One notable finding is the relationship between lignin percentage and Maximum Dry Density (MDD). It has been observed that as the percentage of lignin increases, MDD initially experiences a steady rise, reaching a peak at around 4%, before gradually decreasing thereafter.

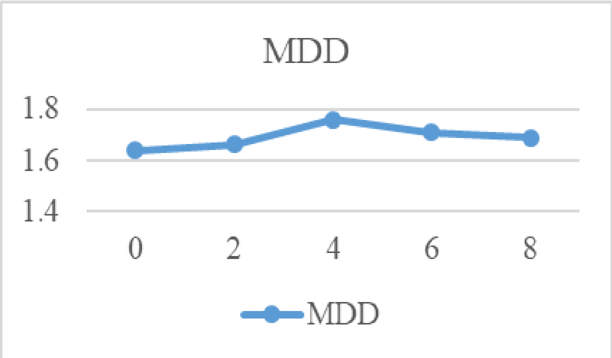


**Figure 5 Plot between Percentage of Lignin and Maximum Dry Density**

### 3.4.Unconfined Compressive Strength

It has been observed that as the percentage of lignin increases, there is a notable enhancement in shear strength, peaking at around 4% lignin content, beyond which a decline ensues. For instance, at the critical threshold of 4% lignin content, the shear strength undergoes a substantial increase, rising from an initial value of 30.16 kPa to 70.52 kPa. This significant improvement underscores the efficacy of lignin as a stabilizing agent in enhancing soil mechanical properties. Moreover, the temporal evolution of shear strength following lignin stabilization is a subject of interest. By plotting the variations in strength over 7, 14, and 28-day intervals, researchers can discern trends in the long-term effectiveness of lignin stabilization. Such analyses provide valuable insights into the durability and sustainability of lignin-treated soils, informing optimal stabilization practices for diverse engineering applications. These findings underscore the multifaceted nature of soil-lignin interactions and highlight the potential of lignin as a promising additive for soil stabilization endeavours. Further research into the underlying mechanisms driving these observations holds promise for refining soil stabilization techniques and advancing sustainable infrastructure development practices. (Refer Tables 2 to 6)

**Table 6 Shear Strength**

| % of Lignin | 7 Days | 14 days | 28 Days |
|---|---|---|---|
| 0 | 30. 16 | 30. 16 | 30. 16 |
| 2 | 36.2395 | 44.4034 | 47.53 |
| 4 | 44.286 | 63.2552 | 70.52 |
| 6 | 41.864 | 57.5808 | 63.6 |
| 8 | 42.039 | 57.9908 | 64.1 |

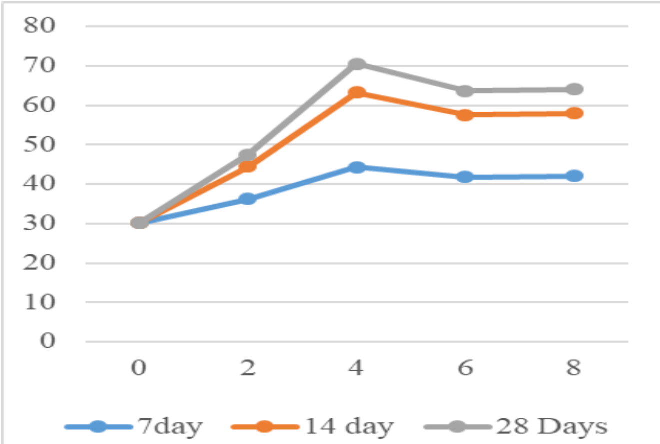


**Figure 6 Plot between Percentage of Lignin and Unconfined Shear Strength**

## Conclusion

Results are shown in Figures 3 to 6. The tests are conducted and the potential of lignin biopolymer utilization as an alternative soil's stabilizers to conventional materials and the effects of lignin concentration, curing time and specimen moisture were determined [15]. The unconfined compressive strength and direct shear test were carried out as a mechanical characterization and moisture retention were used for physical evaluation. The result show that incorporation of lignin to a clayey soil could enhance the antiparticle cohesion and therefore entries the mechanical properties of the matrices. However, this mechanism is affected by two major factors of moisture content and curing durations. The soil specimen which is subjected to wet conditions (OMC, water content and saturated states), lignin acta as a cohesive agent to enhance the bond of soil particles at early ages, while it loses its efficiency due to the hydro degradability overtime. The mechanical properties such as the Atternbeg limits of the clay with lignin resulted in a moderate decrease in the LL and PI, but the PL remains relatively constant. Therefore, the PI is essentially the reflection f the LL. lignin stabilized expansive oil showed the increased sensitivity of dry density to the variation of moisture content. The stabilization effect of the lignin on the expansive soil was measured using the swelling index, which is a reasonable indicator of the degree of swelling or shrinkage when moisture content of the stabilized expansive soil fluctuates. the swelling index CS is the clays soil, decreased with an increase in lignin content, which may improve the strength and performance of the soil by reducing expansion or shrinkage in the soil. The study shows that satisfactory level of stabilization of expansive soil could be achieved by adding 4% lignin content.

## References

[1]. Gupta, A., Choudhary, Awdhesh K., Choudhary, Anil K., 2021. Experimental Investigation of Silty Soil Treated with Sodium Lignosulfonate, in: Patel, S., Solanki, C.H., Reddy, K.R., Shukla, S.K. (Eds.), Proceedings of the Indian Geotechnical Conference 2019. Springer, Singapore, pp. 825–833.

[2]. Ilman, B., Balkis, A.P., 2023. Review on Biopolymer Binders as Renewable, Sustainable Stabilizers for Soils. Int. J. of Geosynth. and Ground Eng. 9, 49.

[3]. Investigation of soil stabilization using biopolymers - ProQuest

[4]. Latifi, N., Horpibulsuk, S., Meehan, C.L., Abd Majid, M.Z., Tahir, M.M., Mohamad, E.T., 2017. Improvement of Problematic Soils with Biopolymer—An Environmentally Friendly Soil Stabilizer. Journal of Materials in Civil Engineering 29, 04016204.

[5]. Vijayan, G., Sasikumar, A., 2019. Stabilisation of Clayey Soil by using Lignosulfonate 06.

[6]. Yang, D., Qiu, X., Zhou, M., Lou, H., 2007. Properties of sodium lignosulfonate as dispersant of coal water slurry. Energy Conversion and Management 48,2433–2438.

[7]. Zhang, T., Yang, Y.-L., Liu, S.-Y., 2020. Application of biomass by- product lignin stabilized soils as sustainable Geomaterials: A review. Science of The Total Environment 728, 138830.

[8]. Xin, H.; Wei, M.; Li, G.-Y.; Mu, Y.-H.; Zhou, Z.-W.; Fei, W. Influence of lignosulfonate on mechanical properties of Lanzhou loess., Rock Soil Mech. 2017.

[9]. ASTM D2487-17; Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). ASTM International: West Conshohocken, PA, USA, 2017.

[10]. Chang, I.; Im, J.; Cho, G.-C. Geotechnical engineering behaviours of gallant gum biopolymer treated sand. Can. Geotech. J. 2016, 53, 1658–1670

[11]. Pouyan Bagheri., et.al., Mitigation of soil erosion and enhancement of slop stability., Poly, 16091300, MDPI 2024.

[12]. Ayeldeen, M: Ngam, A: EI – Sawwaf, M.,et.al., Enhancing Mechanical Behaviour of collapsible soil using two biopymers J.Rock Mech. Geotech ng. 2017.

[13]. ASTM D422-63; Standard Test Method for Particle-Size Analysis of Soils. ASTM International: West Conshohocken, PA, USA, 2017.

[14]. Zhang, T.; Cai, G.; Liu, S. Assessment of mechanical properties in recycled lignin-stabilized silty soil as base fill material. J. Clean. Prod. 2018.

[15]. Latifi, N.; Horpibulsuk, S.; Meehan, C.L.; Majid, M.Z.A.; Tahir, M.M.; Mohamad, E.T. Improvement of problematic soils with biopolymer—An environmentally friendly soil stabilizer. J. Mater. Civ. Eng. 2017, 29,04016204.