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RESEARCH ARTICLE OPEN ACCESS

Environment friendly soil stabilization using Lignin Biopolymer

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ABSTRACT:
Theusingofligninbiopolymerforsoilstabilizationoffersasustainablesolutionthatpromotes 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 environmentallyfriendlymethod.Lignin,acomplicatednaturalpolymerfoundinplantmobile partitions,hasdiversepackagesbecauseofitspotentialtobindsoildebristogetherandenhance 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;

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I. 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.

Rolein SoilStabilization

i. ResearchershavemadesubstantialeffortstoutilizeLignosulphonate(LS)asanexpansivesoil stabilizer.
ii. LSisanaturalpolymerderivedfromlignin.
iii. Itphysicallybinds soilparticlestogetherandhas minorchemical effects.
iv. Individualsoilparticlescanbecomecoatedinathinadhesive-likefilm,effectivelycementing them together
v. Consistency:LSimpactstheconsistencyofthesoil.
vi. Swelling-ShrinkageBehaviour: Ithelpscontrolsoilexpansionandcontraction.
vii. StrengthCharacteristics:LScontributestosoil strength.
viii. Permeability:It affectstheflowofwaterthroughthesoil.

Applicationsin SoilStabilization

i. **DustControl:**Sodiumlignosulfonatecanbeappliedtounpavedroads,constructionsites,and otherareas 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

ii. **Soil Conditioning:** Sodium lignosulfonate can be used to improve the workability and compactionofsoilsinconstructionprojects.Whenmixed withsoil,itactsasasoilconditioner, enhancingsoilplasticityandreducingtheamountofwater needed forcompaction.Thishelps achieve the desired soil density and stability more efficiently

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 disturbedsoils,itbindssoilparticlestogether,reducingsu

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rfacerunoffandsoillosscausedby rainfall and surface water flow

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 seedlingsfromenvironmentalstresses,thusenhancingvegetationcoverandsoilstabilityover time.

Figure1SiteLocation

Table 1 Site Details

II. Methodology

Materials and Specifications

Biopolymers

Biopolymers are a class of polymers that are produced by living organisms or derived from renewablenaturalsourcessuchasplants,animals,andmicroorganisms.Unlikesyntheticpolymers derived from petrochemicals, biopolymers are considered more environmentally friendly because they are biodegradable and often have lower carbon footprints.

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.

ii. **Polypeptides**:Polypeptidesincludeproteinsandshorterpolymersofaminoacids.Proteinsare essential for various biological functions, such as enzymes, structural components (like collagen and actin), and blood clotting (like fibrin).

v. **CompatibilitywithOtherAdditives:**Sodiumlignosulfonatecanbecombinedwithothersoil stabilizers,suchaspolymers,enzymes,orbiopolymers,toenhancetheireffectivenessortailor 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.

SiteInformation

Location	:	Kalla kudi, Tiruchirappalli
retrievalSite	:	Kallakudi Tollgate
Latitude	:	10°59’53”N
Longitude	:	78°57’49”E
State	:	TamilNadu
SampleretrievalDepth	:	90-100cm

iii. **Polysaccharides**:Thesearelinearorbranched chainsofsugarcarbohydrates.Examplesof polysaccharides include:

iv. **Starch**:Astorageformofenergyinplants.

v. **Cellulose**:Amajorcomponent ofplantcellwalls.

vi. **Alginate**:Found in brownalgaeand usedin variousapplications

Lignin

Ligninisacomplex organicpolymerfoundinthe cellwallsofplants,particularlyinwood 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. Herearesomekeyaspectsabout lignin:

i. **Chemical Structure**: Lignin is a heterogeneous polymer composed of phenyl propane units, primarilyconiferylalcohol,sinapylalcohol,andp-coumarylalcohol,linkedtogetherthrough various chemical bonds. The exact composition and structure of lignin vary among plant species and cell types.

ii. **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.

iii. **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.

iv. **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,ligninisaversatileandabundantbiopolymer withsignificantpotentialfor variousindustrialandenvironmentalapplications.Itsuniquepropertiesandcomplexstructure 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.

Sodium Lignosulfonate

Sodiumlignosulfonate,alsoknownassodiumligninsulfonateorlignosulfonicacidsodiumsalt, isawater-solubleligninderivativeobtainedduringthesulfitepulpingprocessinthepaperindustry. Itisaby-productofwoodpulpproductionandiswidelyusedinvariousindustrialapplicationsdue to its unique properties. While sodium lignosulfonate is primarily utilized as a dispersing agent, binder, and additive in concrete, ceramics, and other industries.

Figure2SodiumLignosulphonate

ReactionTimeand 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.

Testsand ISCodes

Table2 IS Code

S.No	Test	IS-Code
1.	GrainSizeAnalysis	IS2720(Part4):1985
2.	Hydrometer	IS-3104:1965
3.	AtternbegLimits	IS2720-5 (1985)
4.	Heavycompactiontest	IS2720-1980(PartVIII)
5.	CBR	IS:2720(Part16):1987
6.	UCS	IS2720-10(1991
7.	FreeSwellIndex	IS2720–Part-40-1970

III. Result and Discussion

Soil Propertie

Table 3 Soil Properties

SOILPROPERTY	OBTAINEDVALUE
Specificgravity	2.67
UCSStrength (kg/cm²)	0.634 kg/cm²
Liquidlimit(IS2720part5)	33%
Plasticlimit(IS2720part5)	20.66%
Plasticityindex(IS2720part5)	12.34%
Shrinkagelimit(IS2720part5)	19.06%
Optimummoisturecontent(IS2720part7)	24.50%
Maximumdrydensity(IS2720part 7)	1.65g/cc
Percentageofsand(IS2720part4)	**7.20%**
IS classification	**CL**

AtternbegLimits

Table4AtternbegLimits

PercentageofLignin	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

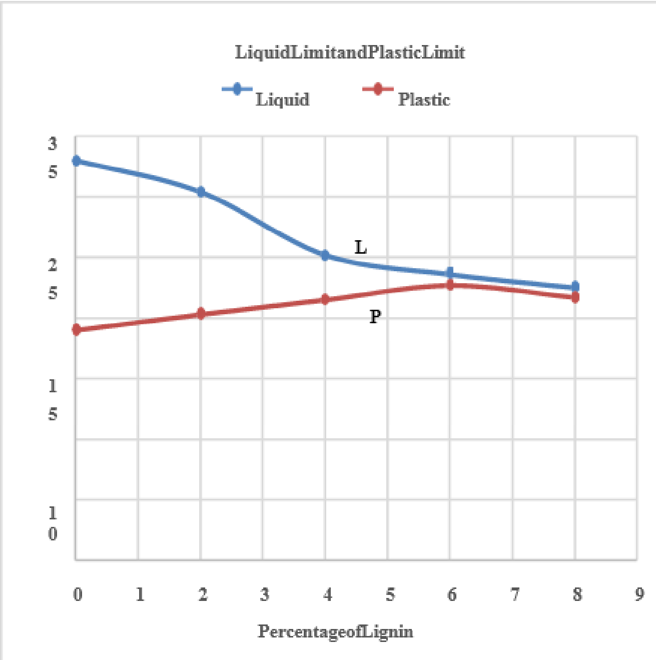


Figure 3Plot between percentage of LigninandPlasticLimit,LiquidLimit

Asthepercentageofligninincreases,adiscernibleshif tinsoilbehaviouroccurs:theliquidlimitdecreases while the plastic limit increases, ultimately leading to a significant reduction in soil plasticity. This phenomenonresultsinasoilthatisnearlynon-plastic,withtheplasticindexalsodecreasingproporti onally. 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.

OptimumMoistureContentandMaximumDryDensity

Table5MaximumDryDensityandOptimumMoistureContent

Percentageof 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

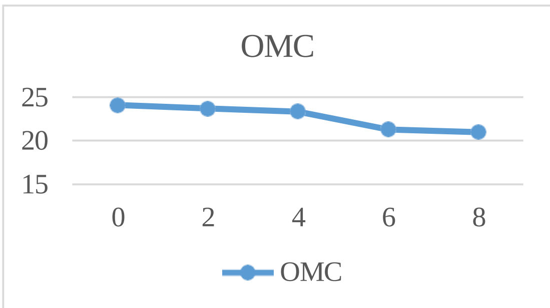
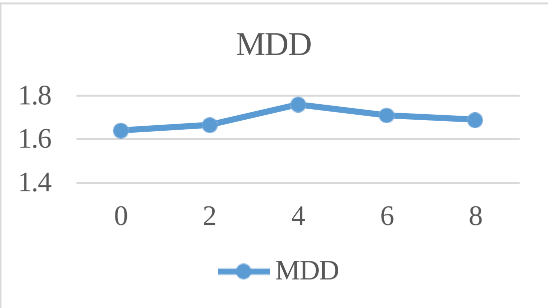


Figure 4Plot between percentage of ligninandOptimummoisturecontent

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.

Unconfined Compressive Strength

It hasbeen observed that asthe percentageof lignin increases,there isa notableenhancement 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 fromaninitialvalueof30.16kPato70.52kPa.Thissignificantimprovementunderscorestheefficacy 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 variationsinstrengthover7,14,and28-dayintervals,researcherscandiscerntrendsinthelong-term effectiveness of lignin stabilization. Such analyses provide valuable insights into the durability and sustainabilityoflignin-treatedsoils,informingoptimalstabilization practices fordiverseengineering 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.



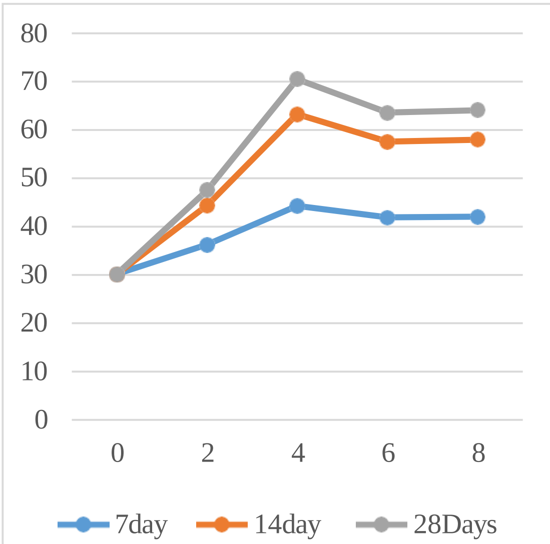


Figure5PlotbetweenPercentageof LigninandMaximumDryDensity

Figure 6Plot between Percentage of LigninandUnconfinedShearStrength

Table6ShearStrength

% of Lignin	7 Days	14 days	28Days
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

IV. Conclusion

Thetestsareconductedandthepotentialofligninbiopolymerutilizationasanalternative soil'sstabilizers to conventional materials and the effects of lignin concentration, curing time and specimen moisture were determined. The unconfined compressive strength and direct shear test were carried out as a mechanical characterization and moisture retention were used for physical evaluation.

Theresultshowthatincorporationoflignintoaclayeysoilcouldenhancetheantiparticle cohesionandthereforeentriesthemechanicalpropertiesofthematrices.However,thismechanism isaffectedbytwomajorfactorsofmoisturecontentandcuringdurations.Thesoilspecimenwhich issubjectedtowet conditions(OMC,watercontentandsaturated states),ligninactaas acohesive agent to enhance the bond of soil particles at early ages, while it loses its efficiency due to the hydro degradability overtime.

Themechanicalpropertiessuch as the Atternbeglimitsofthe claywithligninresulted 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 expansivesoilwasmeasuredusingtheswellingindex, whichisareasonableindicatorofthedegree 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.

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