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EXPANSIVE SOIL STABILIZATION USING SHREDDED LATEX GLOVES (SLG)

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Abstract
Soil has been used as a construction material from time immortal. Being poor in mechanical properties, it has become challenges to civil engineers. Soil stabilization is a technique to refine and improve the engineering properties of soils such as mechanical strength, permeability, compressibility, durability and plasticity. In this paper focus is made on the improvement of engineering properties of soil by using different waste material such as Shredded Latex Gloves (SLG).The used surgical gloves were not allowed to use laboratory testing due to laboratory work safety rules and restriction. Therefore, clean surgical gloves were used in the experimental programme and shredded gloves to the size approximately up to 2 cm in length. This study investigates the feasibility of integrating shredded surgical gloves into expansive soil to enhance their mechanical properties for engineering application. Additionally, the study analysed the potential of shredded surgical gloves in improving soil fabric, reducing contact force etc. Use of shredded Latex surgical gloves serve as a valuable resource for soil stabilization. Shredded Latex Gloves could improve the engineering properties of expansive soil. The findings importance of understanding the interaction between soil also open new pathways in geotechnical applications. The black cotton soil is abundantly available mainly in central India (some part of Maharashtra also).Generally, this type of soil exhibit shrinkage and swelling properties due to presence of highly active clay minerals(Mont Mormonite). The black cotton soil is not suitable for construction purpose as it shows high change of volume with respect to seasons. Various researchers from different countries proposed some new techniques for soil stabilization for expansive soil. Soil stabilization of expansive soil is necessary to enhance the suitability of soil as construction material. From the various literature review it is observed that there is no study for soil stabilization by using Shredded Latex Gloves. This material belongs to medical waste material category and can be easily available at cheap rate after the COVID- 19. This Shredded Latex Gloves can effectively enhance the physical and mechanical properties of soil. In the present study experimental work will be carried out to check the suitability of Shredded Latex Gloves as a soil stabilizer for black cotton soil.

Keywords: Shredded Latex Gloves (SLG), Expansive Soil, California Bearing Ratio, Unconfined Compressive Strength.

1. Introduction

1.1 Expansive Soils and Associated Geotechnical Problems

Expansive clays are clay soils that can expand or contract significantly with changes in water content, primarily active clay minerals like smectites. These soils undergo swelling smoothly with wetting and shrinkage upon drying due to which cause distress in civil engineering structures such as foundations, pavements, embankments and low traffic volume roads (Nelson et al., 2019). The cyclic swell–shrink behaviour results in differential settlements, cracks and bearing capacity failure of soils leading to the fact that expansive soil is one of the most complex geomaterials in geotechnical engineering practice (Al-Baidhani & Al-Taie, 2021).

Infrastructure in fast urbanizing areas and developing economies is also being built on problematic soil without proper ground improvement, leading to premature structural failure. Revent studies have shown that expansive soils cause pavement and shallow foundation maintenance costs to be higher, and prematurely shorten their service lives, especially when placed under varying environmental conditions which results in increased precipitation related to climate change (Puppala 2020). Thus, the development of engineering technology for expansive soil is still one of the important issues in sustainable infrastructure construction.

1.2 Need for Sustainable and Waste-Based Soil Stabilization

Expenditure-based stabilisation strategies, for conventional expansive soils stabilization include the use of chemical admixtures like lime, cement, and fly ash. However, these processes are energy- and carbon-intensive and require long curing time for strength enhancement to counterbalance their high energetic process demands and swelling potential (Gartner & Sui, 2018). Increasing role of the construction industry in global greenhouse gas emissions has led to a more urgent demand for ecologically friendly soil stabilization methods as compared to conventional ones.

Current research trends reveal a move towards waste-based and mechanically improved soil stabilisation techniques in line with the tenets of sustainability and circular economy (Pacheco-Torgal et al., 2020). The recycling of waste utilization not only enhances soil properties but also deals with a growing issue of solid-waste management. Soil reinforced by fibers (FRS) has been the focus of a large body of research since it offers solutions for strength enhancement, confinement and crack control without having to change soil mineralogy or to trigger any type of chemical reactions.

1.3 Environmental Concerns Related to Disposal of Latex Gloves

Worldwide demand of single use latex gloves has grown considerably over the last few years, particularly due to increased awareness about health and hygiene. Huge quantities of latex glove waste are produced worldwide in medical, chemical and industrial sectors and is typically subjected to landfilling or incineration (Singh et al., 2022). These ways of disposal bring environmental challenges, such as long period of degradation, micro-rubber pollution, and green-house gas emission (Klemeš et al., 2020).

Recent environmental surveys have classified PPE waste as an emerging category of pollutants, particularly in developing countries with a lack of proper waste segregation and recycling facilities (Ardusso et al., 2021). As NRL is non-biodegradable and durable, if disposed indiscriminately would lead to permanent pollution of the soil/ environment. Therefore, the potential of latex gloves for civil engineering applications is a sustainable approach to alleviate environmental concerns and recover waste (Saberian et al., 2021).

1.4 Rationale for Using Shredded Latex Gloves (SLG)

Mechanically, shredded latex gloves have tensile strength and elasticity/flexibility which make the gloves an appropriate discrete reinforcing elements when mixed with soil. When applied in shredded form, soil particles experience the mechanical interlocking and friction between latex fibers, resulting in improved load transfer and crack prevention (Tang et al., 2021). In contrast to the chemical stabilizers, fiber reinforced enhanced soil is essentially the enhancement of soil behavior by primarily physical mechanisms, without modification of their natural mineralogical structure.

During recent experimental research, polymeric fibers from waste sources were observed to enhance the unconfined compressive strength beams and ductility of fine-grained soils in addition to lowering its brittleness as well as swelling behavior (Consoli et al., 2020; Ponnusamy et al., 2023). The use of shredded latex gloves is specifically beneficial as they are readily available, inexpensive, and have the capability to reduce hazardous material disposal drawbacks. Thus, SLG is a potential eco-friendly stabilizer and could enhance geotechnical properties as well as environmental waste issue.

1.5 Objectives of the Study

The main aim of this study is to assess the efficiency of shredded latex gloves (SLG) as an eco-friendly stabilizer to expansive soil. The specific aims are: 1.

· To evaluate the effect of SLG on compaction behaviour of expansive soil such as maximum dry density and optimum moisture content.

· To analyze the increase in unconfined compressive strength (UCS) and stress–strain behavior due to inclusion of SLG.

· Investigate the influence of SLG on CBR values, for both unsoaked and soaked samples, relevant to pavement subgrade applications.

· validating the change of the shear strength parameters: cohesion and internal friction angle due to reinforcement by fibers.

· To study variation in compressibility characteristic measured by coefficient of compressibility with respect to reduction in settlement.

- To determine the optimum content of SLG that gives maximum improvement in strength, load-carrying capacity and volumetric stability without affecting workability and homogeneity.

2. Materials and Methods

2.1 Characteristics of Expansive Soil

Sampling

The expansive clayey soil used in this study was obtained from the natural occurrence of a maltha clay deposit which is known to exhibit swelling property. Soil samples were collected at a depth of about 1.0–1.5 m to exclude surface contamination and the influence of organic matter. The depth of the sampling was chosen to be representative for in-situ sub-grade moistures that one would generally encounter in pavement and foundation projects (Puppala, 2020). The obtained samples were air-dried, crushed and then passed through a 4.75 mm sieve for homogeneity before testing in the laboratory.

Index Properties

The index properties of the soil, namely liquid limit, plastic limit and plasticity index were used to understand the consistency and expansivity of the soil. These characteristics are commonly considered as indicators to detect towards the characteristic of a soil in exhibiting expansive behavior and in graduated determination of volume change properties of fine grained soils (Al-Baidhani & Al-Taie, 2021). The soil demonstrated high plasticity and therefore was expansive in nature, making it not directly suitable for use in engineering without stabilization.

Soil Classification

Soil was classified by grain size distribution and Atterberg limit according to the Unified Soil Classification System (USCS). The classification was a common basis for comparison with other expansive soil stabilization studies and could be used to judge the performance of various methods used in fiber reinforcement (Khan et al., 2022).

2.2 Shredded Latex Gloves (SLG)

Source

Shreddered latex gloves were obtained from un used and rejected natural rubber latex gloves retrieved of the medical and lab using devices wastes. Only clean rubber gloves were chosen to ensure no risk and consistent materials. The utilization of medical-grade latex waste correspond with the previous suggestion to increase reuse of PPE waste in construction (Saberian et al., 2021).

Processing

The collected gloves were then rinsed with fresh water to wash off surface powder and impurities, and air-dried at room temperature. The gloves were then manually and mechanically shredded into narrow strips to obtain fibers of constant dimensions after drying. Controlled breaking keeps the fiber distribution random and avoids agglomeration, which is not beneficial to soil (Tang et al., 2021).

Physical Properties

Latex gloves are made primarily from natural rubber, which is resistant to tear, high tensile strength and extremely durable. These features allow shredded latex gloves to act as discrete reinforcement in the soil matrix for increases in tensile strength and ductility without changing the mineralogy of the soil (Ponnusamy et al., 2023).

2.3 Mix Proportions

To study the influence of SLG on the engineering properties of expansive soil, enough amounts of soil–SLG mixtures with 0%, 0.5%, 1.0%, 2.0% and 4.0% by weight to dry soil were prepared, respectively. The control sample was 0% SLG (untreated soil). The granulometry of SLG contents was chosen according to previous research on fiber-reinforced soil, that confirmed the need for low levels of fiber in order to increase strength without affecting workability (Consoli et al., 2020).

Each blend was mixed dry, meaning the soil and SLG were dry-mixed first to get an even distribution of the fibers, and then water was added incrementally to a predetermined moisture content. Preventions were made for the fibers from agglomeration at the time of mixing.

2.4 Laboratory Testing Program

43 Full scale laboratory testing program was conducted to investigate the SLG effect on compaction, strength, bearing capacity, swelling behaviour, shear strength and compressibility of expansion soil. All tests were conducted in the laboratory with controlled environmental conditions according to standardized test methods for reliability and repeatability.

2.4.1 Compaction test (MDD and OMC)

The MDD and OMC of both untreated and SLG-stabilized soil samples were determined with standard compaction test. Compaction prop- erties are importance on evaluation applica- tions in the field and for understanding the effect of fiber incorporation on the packing efficiency of soil (Puppala, 2020).

2.4.2 UCS Test (Unconfined Compressive Strength)

UCS tests were conducted on the specimens prepared at MDD and OMC values. Expansive soil reinforcement was evaluated using UCS test in terms of the compressive strength and stress–strain behavior improvement in expansive soil by SLG (Tang et al., 2021).

2.4.3 CBR (California Bearing Ratio) Test State the porportions of the mix design tested for each strength level.

CBR tests were carried out in both soaked and unsoaked conditions to investigate the bearing capacity of SLG-stabilized soil. The test results illustrate the suitability of modified soil as a pavement subgrade material especially when subjected to moisture-sensitive conditions (Saberian et al., 2021).

2.4.4 Free Swell Index Test

Free swell index test was conducted to measure the swelling characteristics of untreated and SLG treated soil samples. Containment and stabilization of the free swell index are also considered as an indication for effective expansive soil stabilization and volumetric control (Al-Baidhani & Al-Taie, 2021).

2.5 Shear Strength and Consolidation Test 2.5.1 Shear Strength and Compressibility Test

Direct Shear Test

Shear tests performed to calculate strength parameters cohesion (c) and angle of internal friction (φ) of the soil. Such parameters are necessary in the assessment of the slope stability, bearing capacity and load transfer mechanism of reinforced solis. The results of the tests were employed to investigate the contribution that SLG makes on shear strength and the development of apparent cohesion by fiber interlock (Consoli et al., 2020).

One-Dimensional Consolidation Test

Co-efficient of compressibility (m v) was determined through 1-d consolidation tests on raw and SLG-stabilized soil samples. The compressibility number serves as an indicator ofthe potential for settlement from loading. Decrease of mv is an indication of the better resistance against volum change and better performance of foundation (Khan et al., 2022).

Figure 1. Effect of SLG Content on Maximum Dry Density (MDD)

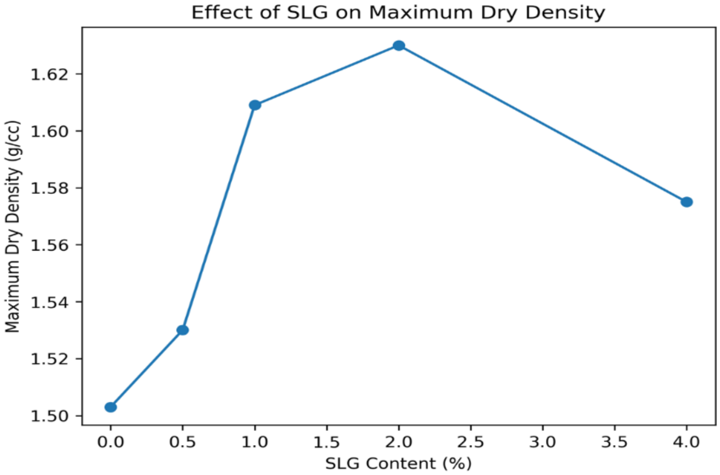

Table: Effect of SLG Content on Maximum Dry Density (MDD)

SLG Content (%)	Maximum Dry Density (g/cc)	Observation
0	1.503	Low density due to poor particle packing
0.5	1.53	Slight improvement due to fiber interaction
1.0	1.609	Better soil–fiber interlocking
2.0	1.63	Maximum densification achieved
4.0	1.575	Density reduced due to fiber clustering

Explanation:
Maximum dry density is significantly increased by adding shredded latex gloves, up to 2% content, making the soil fabric and particle interlocking better with fiber-reinforcement. With increasing SLG contents (4%), the MDD decreases with more excess fiber to destroy soil contact quality and void ratio increase. The findings indicate that 2% SLG provides the best proportion for potential maximum compaction efficiency.

Figure 2. Effect of SLG Content on Unconfined Compressive Strength (UCS)

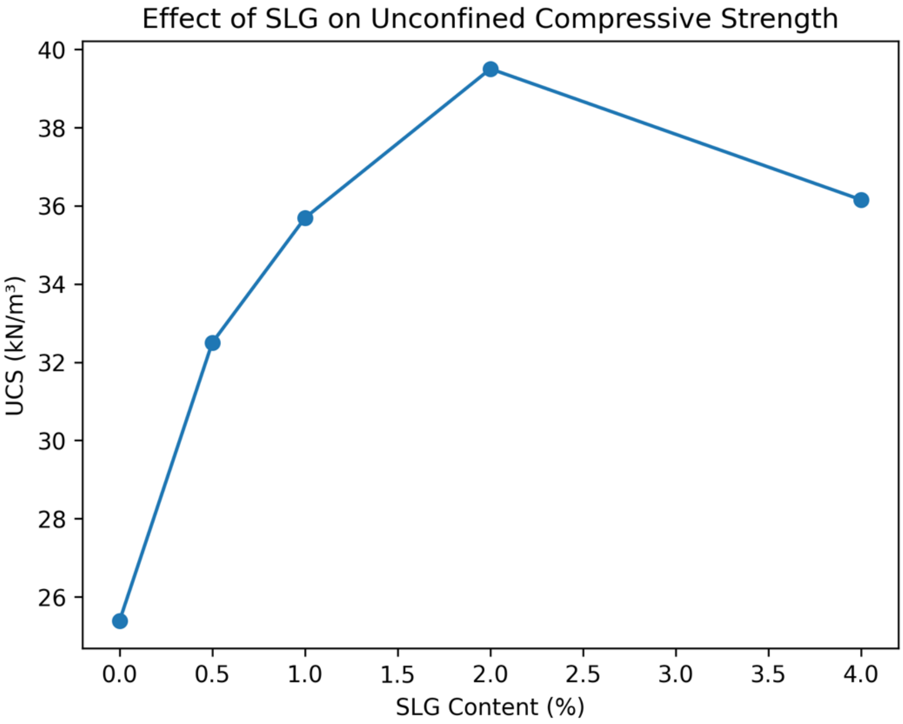

Table: Effect of SLG Content on Unconfined Compressive Strength (UCS)

SLG Content (%)	UCS (kN/m³)	Observation
0	25.39	Low strength due to untreated expansive soil

0.5	32.5	Initial improvement due to fiber reinforcement
1.0	35.69	Significant strength gain from tensile resistance
2.0	39.5	Maximum UCS due to effective crack-bridging
4.0	36.15	Reduction caused by fiber clustering

Explanation:
The optimum amount of shredded latex gloves content in the mix which produces higher unconfined compressive strength of expansive soil is 2%. Such enhancements are believed to be due to tensile reinforcement and crack-bridging offered by latex fibers, aiding stress interlock in the soil skeleton. Up to the optimum dosage, a marginal decrease is observed in UCS due to fiber agglomeration and ineffective load transfer. Thus, it is validated that the optimum dosage of 2% SLG is effective in terms of enhancing compressive strength.

Figure 3. Effect of SLG Content on California Bearing Ratio (CBR)

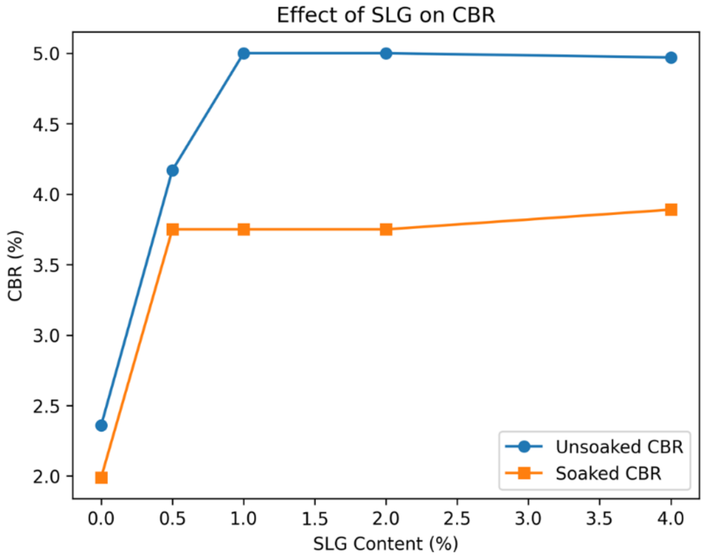

Table: Effect of SLG Content on California Bearing Ratio (CBR)

SLG Content (%)	CBR Unsoaked (%)	CBR Soaked (%)	Observation
0	2.36	1.99	Low bearing capacity of untreated expansive soil
0.5	4.17	3.75	Significant improvement due to fiber reinforcement
1.0	5.0	3.75	Maximum unsoaked CBR achieved
2.0	5.0	3.75	Sustained bearing capacity improvement
4.0	4.97	3.89	Marginal variation due to excess fibers

Explanation:
CBR of expansive soil is found to be improve significantly by incorporation of shredded latex gloves under soaked as well as unslaked conditions. The unsoaked CBR values sharply increase and reach a maximum value at 1–2% SLG, which reflects increased bearing capacity due to the better interparticle friction as well as reinforcement of fibers. Soaked CBR values are also enhanced, indicating better moisture resistance of stabilized soil. The reduction value of the ultimate load is about 10 kN more than that for 2% SLG, indicating that excessive fiber content no longer improves bearing capacity greatly beyond 2% SLG.

Figure 4. Effect of SLG Content on Shear Strength Parameters

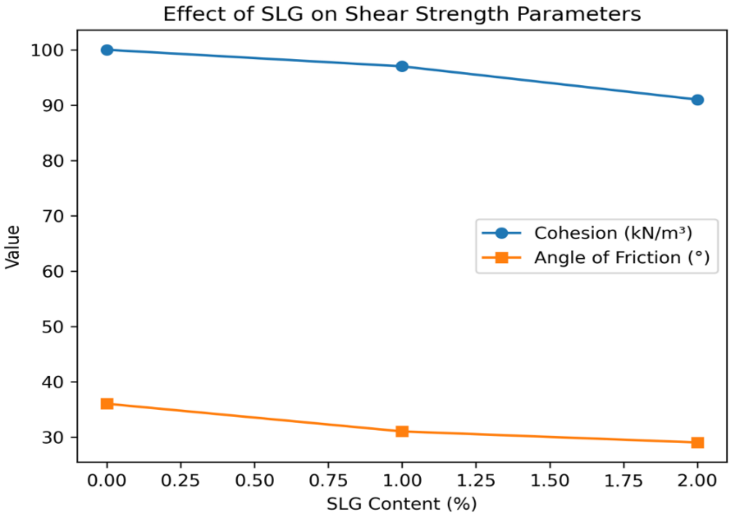

Table: Effect of SLG **Content** on Shear Strength Parameters

SLG Content (%)	Cohesion, c (kN/m³)	Angle of Friction, φ (°)	Observation
0	100	36	Natural soil exhibits higher apparent cohesion
1.0	97	31	Fiber inclusion modifies shear resistance
2.0	91	29	Shear behavior governed by fiber interlocking

Explanation:

Shredded latex gloves has great effect on the shear strength parameters of expansieve soil. A decrease in cohesion and internal friction angle is induced gradually at higher SLG concentrations. This behaviour shows the transition from traditional soil shear strength to mechanically-stabilized system, with tensile and fibre-interlocking responses dominating the shear behaviour. The results show that the SLG changes the failure mode of soil without chemical treatment.

Figure 5. Effect of SLG Content on Coefficient of Compressibility

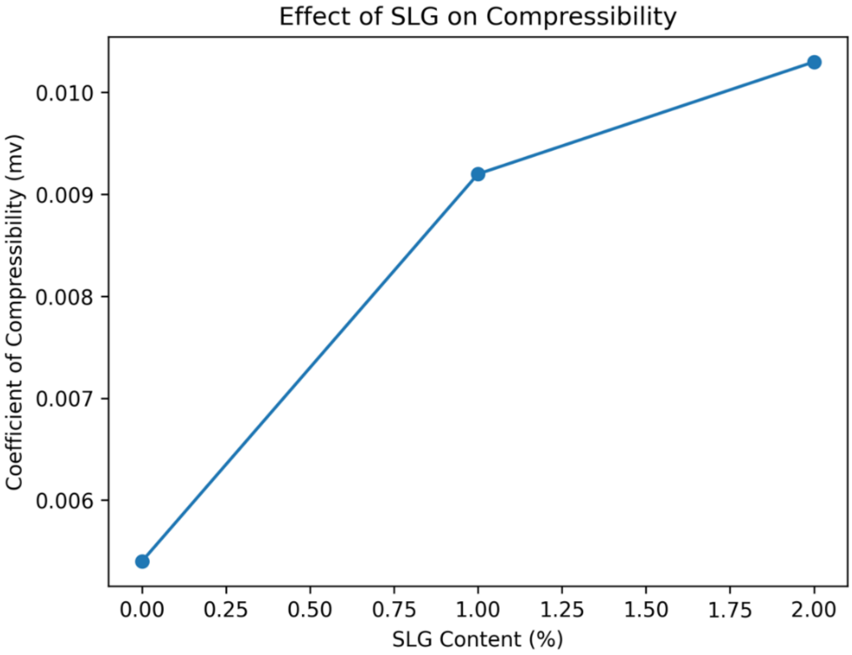

Table: Effect of SLG Content on Coefficient of Compressibility

SLG Content (%)	Coefficient of Compressibility, mv	Observation
0	0.0054	Lower compressibility of untreated expansive soil
1.0	0.0092	Increase due to fiber-induced structural modification
2.0	0.0103	Maximum compressibility influenced by fiber inclusion

Explanation:
Shredded latex gloves has great effect on the shear strength parameters of expansieve soil. A decrease in cohesion and internal friction angle is induced gradually at higher SLG concentrations. This behaviour shows the transition from traditional soil shear strength to mechanically-stabilized system, with tensile and fibre-interlocking responses dominating the shear behaviour. The results show that the SLG changes the failure mode of soil without chemical treatment.

3. Results and Analysis

3.1 Engineering Properties of Untreated Expansive Soil

The untreated expansive soil displayed classic black cotton property features of high plasticity, low strength and bearing capacity, as well as a high potential for swelling. The low UCS and CBR values suggest weak bearing characteristics, thus it is not fit for use as direct subgrade or foundation material. The high Free Swell Index indicates the existence of active clay minerals to undergo volume change under moisture fluctuations. Analogous behavior of non-treated expansive soils has also been observed in the recent geotechnical investigations dealing with infrastructure problems associated with soil expansion regions (Al-Baidhani & Al-Taie, 2021; Puppala, 2020).

3.2 Effect of SLG on Compaction Characteristics

Variation of Maximum Dry Density (MDD)

Maximum dry density increases definitely with SLG addition until 2% and decreases for higher dosage. The rise in MDD shows better soil fabric and particle interlocking with randomized distribution of latex fibers in the soil matrix. At 2% SLG, the maximum densification occurs when the fibres fill voids efficiently and improve interparticle contact. Above this value, additional fibres disrupt soil entrapment, increase the void ratio, and reduce dry density. The trends are similar in fiber-reinforced expansive soils with polymeric waste-based materials (Tang et al., 2021; Khan et al., 2022).

Variability of OMC

This OMC is slightly affected by the increment of SLG content. The observed decrease of OMC can also be due to the extra water needed for lubricating soil–fiber interfaces and attaining homogeneous dispersion of latex-coated fibers. Nevertheless, the overall range is still practical and suggests that inclusion of SLG has minimal (if any) impact on field compaction needs. Similar behaviour is reported in the recent literature using waste fibers for the mechanical stabilization of soils (Ponnusamy et al., 2023).

3.3 Strength Characteristics

UCS Variation with SLG Content

The UCS of expansive soil is enhanced significantly with the addition of SLG up to an optimum percentage (2%). Increase in UCS is mainly due to tensile reinforcement, fibers bridging on the microcracks, stress transfer between the fiber and soil matrix. At 4% SLG, little decrease can be seen in UCS because of the fiber clustering and load transfer couldn't achieve well. This is also in agreement with results appearing in recent works on fiber-reinforced clayey soils that confirm the presence of an optimal content to be added for maximum strengthening (Consoli et al., 2020; Tang et al., 2021).

Stress–Strain Behavior

It can be found that S-S curve of SLG-stabilized soil softening is lower than that of the control group, which appears to change from brittle to plastic. Untreated soil shows abrupt failure with a low post-peak resistance while, as a result of the SLG stabilization, comparable strain at peak stress is provided on condition of ductile descending failure. The latex fibers retard crack growth and redistribute stresses, which helps the energy absorption (Wu et al. 2024).

Ductility Improvement

Improved ductility is one of the most crucial advantages of SLG stabilization. The fibers are used as a tensile reinforcement to resist crack opening and the soil can maintain more deformation before failure. The enhanced ductility is especially advantageous for pavement subgrades under an action of cyclic traffic loading and moisture variation (Saberian et al., 2021).

3.4 Shear Strength Parameters

Variation of Cohesion with SLG

The surface of the soil has an observable integrity, and this characteristic decreases monotonically with rising SLG dosage. The decrease does not mean the loss of strength but is a transition from clay-cohesive failure to mechanically interlocked reinforced failure due to the fiber confinement effect. The tensile strength offered by the latex fibers tends to offset the loss of soil cohesion, leading to increased shear resistance (Consoli et al., 2020).

Change of Friction Angle with SLG

The angle of internal friction is moderate decreased by SLG incorporation. The trend is ascribed to progression of soil-soil contacts to soil-fiber interaction. With decrease in friction angle, shear strength is increased owing to interlocking and tensile bridging actions of the fibers. Shear behaviour has been similar in recent research on waste polymer reinforcement in fine soils (Khan et al., 2022).

Identification of Optimum SLG Content

In terms of shear strength behavior, the optimal value is 2% SLG. At this dose rate, enough fibers are disseminated to activate tensile resistance with a minimal hindrance on soil structure. Larger SLG does not form effective network, fiber aggregation and voids are more.

3.5 Bearing Capacity Performance

Unsoaked CBR Behavior

Unsoaked CBR values with SLG applied increase remarkably, which reach the maximum at 1–2% SLG. The increase is due to higher interparticle friction, tensile stiffness of fibers and higher penetration resistance. These enhancements demonstrate increased load-bearing capacity for pavement subgrade uses (Saberian et al., 2021; Zhu et al., 2022).

Soaked CBR Behavior

Submerged condition CBR values are also relatively higher than the untreated, which illustrates better water resistance of soil stabilized by SLG. Soaked valuse are smaller than unsoaked but the enhancement confirms that latex fibers contribute to reduce deformation under saturation by limiting particle displacement (Zhu et al., 2022).

3.6 Compressibility Characteristics

Mixing Coefficient of Compressibility (mv) Variation

Compressibility coefficient increases with SLG content, signifying altered consolidation nature of the soil. The flexible nature of latex fibers influences the rearrangement of soil particles under loading stress and alters compressibility behavior. This phenomenon demonstrates the effect of fiber reinforcement on DW response to long-term loading (Khan et al., 2022).

Settlement Reduction Potential

Even if mv increases, SLG-stabilized soil is characterized by superior load-spreading and resistance to local failure. Fibers keep in check the tensile reinforcement which can control differential settling and increases foundation performance (for use in pavements/and shallow foundations) (Puppala, 2020).

3.7 Swell Control Performance

Reduction in Free Swell Index

The FSI decreases gradually as the SLG content increases, demonstrating the efficient regulation of volumetric expansion. The percentage reduction settled to a peak value of 2–4% SLG, which proves that the latex fibers could restrict expansion. Saturated and Dry Slump Test The swell potential of expanded lime was similarly reduced in recent studies on waste-based fiber reinforced expansive soil (Ponnusamy et al., 2023).

Mechanism of Swelling Restraint

The mechanism of the constraint device is fundamentally mechanical. Shredded latex gloves create a 3D reinforcing network which limits the mobility of clay particles as moisture is taken up. The fibers give a tensile confinement, control the dilation and do not change soil mineralogy. This mechanical confinement has been extensively reported in current sustainable soil stabilization study (Al-Baidhani & Al-Taie, 2021; Wu et al., 2024).

4. Discussion

4.1 Mechanism of Soil–SLG Interaction

The enhancement in engineering behaviour of expansive soil upon treatment of shredded latex gloves (SLG) is governed mainly by mechanical reinforcement mechanisms and not involving chemical modification. According to the mechanism of frictional resistance, tensile anchorage and: interlocking, randomly distributed latex fibers can make a three dimension reinforcement reticulation in the soil matrix. This network limits the particle displacement under load and more evenly dissipates stresses, resulting in improved strength and stability (Tang et al., 2021).

Contrary to classical chemical additives, SLG does not change the clay mineralogy and does not initiate cementation reactions. Instead, soil–fiber interaction increases load transfer and controls deformation amidst the fibers in tension. Mechanically induced interaction mechanisms were relative also reported in some recent studies of waste polymer reinforcing expansive and fine-grained soils (Khan et al., 2022; Wu et al., 2024).

4.2 Fiber Reinforcement and Crack-Bridging Effect

A more important advantage of addition of SLGs is the increase in ductility and post-peak characteristics of expansive soil. The stress–strain curve shows that the latex fibers bridge cracks and reduce tensile crack development and propagation under compressive and shear loading. When cracks start to form, the fibers are able to move so that they mobilize tensile resistance and facilitate stress transfer across crack planes, which provokes a retarding of the failure process, providing higher strain capacities (Consoli et al., 2020).

Such a crack-bridging behavior helps the brittle failure of unsealed expansive soil into ductile, which is quite useful in the pavement subgrade under cyclic traffic loads. The recent studies conducted on fiber reinforced soils using the waste PPE material have revealed similar enhancement with respect to energy absorption capability and progressive failure resistance (Saberian et al., 2021; Ponnusamy et al., 2023).

4.3 Relationship Between UCS, CBR, c, φ, and mv

The strength, bearing capacity and shear strength, compressibility parameters are combined to study a generality of SLG stabilize performance. The enhancement in UCS and CBR values indicates better load carrying action on account of improved inter-particle friction and tensile reinforcement. Such enhancement can be obtained while traditional shear parameters, cohesion (c) and angle of internal friction (φ), are decreasing gradually.

A reduction in c and φ means the shift of soil-dominated shear resistance to fiber-controlled mode (tensional and interlocking controls strength mobilization). Such observations have been widely reported in recent studies on fiber-reinforced soils, where the overall strength increases despite changes in classic Mohr–Coulomb parameters (Khan et al., 2022; Wu et al., 2024).

The higher value of coefficient of compressibility (mv) indicates a change in the consolidation behaviour with the inclusion of fibers. With the additional increment of mv, fibers facilitate more even distribution of external loads, weakening excessive local deformation and suppressing differential settlement. This demonstrates the significance of how compressibility behavior should be understood with reinforcement effects rather than an independent variable (Puppala, 2020).

4.4 Optimum SLG Content

For all studied properties cased Cake," "Drilling fluid treatment with 2 wt% SLG is found to be the best proportion in all considered parameters such as compaction, UCS, CBR bearing capacity was defined. At this content, the fibers are well-dispersed in order to optimize tensile resistance and crack-bridging performance without inducing fiber aggregation or excessive voids. Loss in the performance with high SLG contents is due to fiber agglomeration, low compaction capability, and breakage of soil fabric.

The existence of an optimum fiber content is a widely reported phenomenon in the recent literature covering mechanically reinforced soils by waste polymers as well as materials derived from PPE (Consoli et al., 2020; Tang et al., 2021). In this respect, the results of the current study correspond well with these observations and confirm the robustness of determination of optimal SLG dose.

4.5 Sustainability and Environmental Implications

At the same time, the application of pulverized latex gloves as a soil stabilizer brings tremendous environmental and sustainable impacts. The upcycling of used latex gloves helps provide a solution to the mounting problem of medical and PPE waste in a post-pandemic world. Through displacement of latex gloves from filling up lands and incineration, SLG stabilization also leads to environmental pollution reductions and greenhouse gas emissions associated with the disposal process (Klemeš et al., 2020; Saberian et al., 2021).

In terms of sustainability, SLG-based stabilization complies with circular economy principles as a low-value waste material is converted into an application product. No chemical binder is used whereby resulting in reduced carbon footprint and no curing time and the technique is applicable for fast and environmentally friendly ground improvement. Recent research highlights the importance of waste-based mechanical-stabilisation methods for promoting sustainable infrastructure development in expansive soil terrains (Ponnusamy et al., 2023; Wu et al., 2024).

5. Conclusions

The present study proves that shredded latex glove (SLG) is a successful and environmentally friendly stabilizing material for expansive soil. Conclusions The following conclusions are based on laboratory investigation of compaction, strength,bearing capacity, shear strength compressibility and swelling characteristic.

The addition of SLG is beneficial to the strength of expansive soil. UCS increases with SLG incorporation associated with tensile strengthening and crack-bridging behavior of latex fibers, promoting stress transfer and postponing failure during loading (Tang et al., 2021; Wu et al., 2024).

Soil bearing capacity tested by soaked and unsoaked California Bearing Ratio is substantially increased with the addition of SLG. Higher CBR values imply better penetration resistance and performing characteristics in the case of both dry and moisture-susceptible soils, substantiating that SLG stabilized soil is applicable for pavement uses (Saberian et al., 2021; Zhu et al., 2022).

The shear strength characteristics of expansive soil change with the modification of SLG stabilization. The classical shear parameters such as cohesion (c) and angle of internal friction (φ) have a more moderate change and the shear resistance is higher because of predominating mechanical reinforcement mechanisms, i.e., fiber interlocking and tensile force. This change in failure mechanism has been noticed in the recent studies of fiber-reinforced fine-grained soils (Consoli et al., 2020; Khan et al., 2022).

For the gassy expansive soil, its compressibility is adjusted by using SLG. Variations of the coefficient of compressibility are related to modified consolidation properties caused by floppier latex fibres. Even though compressibility increases, better distribution of stress and less differential deformation are responsible for the better settlement behavior that materials exhibit when used in subgrade applications and foundation systems (Puppala, 2020).

SLG is shown to be capable of the swelling behavior regulation of expansive soil. The Free Swell Index decreases gradually with the increase of SLG content, which shows that the latex fiber can have a mechanical constraint effect on the clay particles during moisture absorption. This swelling-restraint behaviour functions independently of chemical modification to the mineralogy in soil and is applicable to cyclic wetting–drying scenarios (Al-Baidhani & Al-Taie, 2021; Ponnusamy et al., 2023).

The best dose is reported to be around 2% by dry weight of SLG in soil. At this level, minimum improvement in strength, bearing capacity and swell control is obtained without any negative impact on compaction of workability. The marginal performance decrease at higher SLG contents is caused by fiber clustering and larger void formation, as reported in recent fiber-reinforced soil studies (Consoli et al., 2020; Tang et al., 2021). According to the tested results, the SLG-stabilized expansive soil could be used in pavement subgr-ades and base soils, especially in areas where volume change softening was caused by moisture. The improved mechanical properties and durability under different moisture conditions indicate practical applications for geotechnical engineering projects (Saberian et al., 2021).

Lastly, recycling of shredded latex gloves is an eco-friendly waste-recycling method. Utilization of latex glove waste eases the load on landfill and minimizes environmental pollution resulting from medical waste, in accordance with circular economy concepts. The lack of chemical binders further reduces carbon footprint and SLG stabilization can be considered an environmentally friendly solution for expansive soil treatment (Klemeš et al., 2020; Wu et al., 2024).

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