Effect of Granite Sand and Calcium Lignosulphonate on Shrinkage Characteristic of Clay

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ABSTRACT: Clay soils that undergo significant volume change due to seasonal moisture variations cause severe damage to the superstructure. The shrink-swell potential is quantified by relying on either shrinkage characteristics or by measuring the swelling characteristics. This study explains the shrinkage behaviour of clay soil stabilized with Granite Sand (GS) and Calcium Lignosulphonate (CLS). CLS is used as a binder for clay-GS mix. The dosages of GS and CLS (by weight of soil dry mass) were maintained at 30% - 50% and 0.5% - 2% respectively. With the increase in dosage of GS, the shrinkage limit increased by 88.46% at 50% dosage. This is attributed to the replacement of a fine fraction of the soil with GS. In similar lines, the addition of CLS increased the shrinkage limit to the maximum of 123% at 2% CLS dosage. This is attributed to the formation of a flocculated structure. In addition to this, the clay is blended with both GS and CLS in the combination of each of the dosages to know the response of shrinkage characteristics which will enhance its potential applicability for targeted civil engineering applications.

Keywords: Calcium Lignosulphonate, Clay, Granite Sand, Shrinkage.

1. Introduction

Clays are inherent materials that are predominantly composed fine grained minerals which are responsible for the volume change when subjected to water and are site specific. These clays exhibit poor performance in terms of shear strength, compressibility, shrinkage and swelling [13, 20]. Addressing to these challenges, the geotechnical engineers have come up with several solutions that enhance the performance poor soils. Chemical stabilization is one of the ground improvement techniques which is pronouncing rapidly for its superior outcomes. Additives like cement [23], lime [12], Magnesium chloride [34], phospho-gypsum [35], Phosphoric acid [20] etc., are used to improve the properties of weak soils. Despite their workability, they are limited by a high pH of groundwater, expansion in production as per requirement, economic issues, and environmental issues like CO_2 emissions [20]. These issues led to the exploration of sustainable alternatives having lower greenhouse gas emissions like biopolymers for expansive clay [9], Lignosulphonates for erodible soil [32], Calcium carbide residue for clays [20], Fly ash and slag for recycled demolition aggregates [4]. These studies showed that the type of soil, dosage, chemical chain formed affect the competence and outcome of the process for respective problems.

Volumetric shrinkage is the parameter that affect the soil and structure upon drying and affects the performance of clay soil under atmospheric conditions [31]. This parameter is assessed by shrinkage limit. Some of the works related are, Sivapullaiah et al.,[28] worked on lime stabilization of clays where the optimum content of lime required for clay is 6%. The shrinkage limit of kaolinite and montmorillonite increased with lime up to some extent irrespective of clay mineral. Azzam [7] worked on the polymer to create nanocomposites in the soil to improve the shrinkage property of that soil. The range of polymer dosage is 0-15%. He observed that increased polymer content reduced the volumetric strain of the dry pat. Vydehi et al.,[33] worked on the shrinkage of the biopolymer treated soil and concluded that biopolymer treatment on low plastic clay leads to curling and desiccation cracking. An investigation is done on a thin layer of clay that is subjected to shrink and examined the occurrence of desiccation cracking which is followed by vertical subsidence. This work also examined the crack length, crack propagation and crack intersections formed on the dry clay pat [31]. A swell-shrink study is done on compacted expansive clay stabilized with lime. The lime dosage ranges from 0-4%. It is concluded that the samples prepared at OMC and less than OLC (Optimum Lime Content) show less swelling pressure with an increase in lime content [3]. Though, many stabilizers are existing to address the volumetric shrinkage and cracking, the works are still limited to the dosage of the additive and its occurrence. This led to the exploration of better additives to overcome the limitations. The current study focuses on stabilization of clay against shrinkage by using Granite Sand (GS) and Calcium Lignosulphonate (CLS).

GS is a waste by-product obtained from the aggregate crushing industry. It is considered for consumption because it has a similar mineral composition to sand and is regarded as an industry by-product formed during the crushing process, which increased the utilization possibilities [6,18]. Ogbonnaya and Illoabachie [25] used granite dust to stabilize Abakaliki clays and observed an improvement in the index and engineering properties. Kufre Etim et al.,[19] used micro sized granite dust particles to stabilize a disturbed laterite soil added with cement. They observed an increase in California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) at 6% cement and 8% Quarry dust. A Study was made on stabilizing Black cotton soil with quarry dust by different compactive efforts to know the effect on compaction attributes and CBR [24]. Mudgal et al.,[22] studied the binary effect of lime and stone dust on the engineering properties of Black cotton soil. Chetia and Sridharan [11] reviewed on the effect of quarry dust on different properties of different soils.

Lignosulphonates are obtained from the wood and paper industry after sulphite pulping of the soft wood. The type of Lignosulphonate is obtained from the extraction process of the complex polymer [26,6]. It is a nontoxic admixture that stabilizes cohesive and cohesionless soils. Since, the quantity to be used is very less, the effect of leaching on groundwater chemistry is very less or negligible [32]. Alazigha et al.,[1] stated that 2% addition of CLS is required to decrease the swell potential of the remolded expansive soil. Silty sand and dispersive clay were treated with 0 to 0.6% CLS dosages where the residual strength of silty sand is increased with an increase in dosage of CLS [10]. An expansive soil in China is stabilized using CLS to improve its durability property [14].

The significance of using these stabilizers is their enormous availability at low cost with zero carbon footprint. The authors tried to improve the locally available clay with different dosages of GS and CLS. Many studies are conducted on the effective use of GS alone, CLS alone, or in combination with GS and other additives to treat various types of soil, but no comparisons have been made with an inert material (GS) and a non-traditional additive (CLS) individually on clay and the combination. This work unveils the effect of GS, CLS, and GS-CLS at different dosages of each on shrinkage of clay soil.

2. Materials

2.1 Clay

The soil is collected from the Hanamkonda region of Telangana State. It is a remoulded soil collected at 3ft depth from the ground level. The soil is tested for index and engineering properties. Table 1 shows the characterization of clay.

Table 1. Physico-Chemical and Index properties of clay

Properties	Results
Color	Greyish black
Specific gravity	2.6
W_l (%)	45
W_p (%)	22
I_p (%)	22
W_s (%)	13
Fines (%)	59
IS Classification	CI
Differential free swell (%)	33
pH	7.7

(Notation: W_l : Liquid Limit, W_P : Plastic Limit and I_P :Plasticity Index)

2.2 GS

It is collected from Rampur village in Telangana. The collected GS is tested for its characterization according IS codal provisions. This typical GS bears the properties shown in Table 2.

Table 2. Physical, Chemical and Index properties of GS

Properties	Results
Color	Grey
Specific gravity	2.72
Sand fraction (%)	90
Coarse sand (%)	19
Medium sand (%)	32
Fine sand (%)	39
Mean particle size (μ)	600

IS classification	SP
pH	7.36

2.3 CLS

CLS is a fine powder which exhibits hydrophilic phenomenon. Table 3 shows the typical characteristics of CLS.

Table 3. Physical and Chemical properties of CLS

Properties	Results
Color	Yellow brown
Molar mass	528.61g/mole
pH	4.3
Solubility	Soluble in water

2. Sample Preparation

Studies were conducted by varying GS content in the range of 30% ,40% and 50% dosages at a defined volume. Each sample is denoted as 7C3G (70%Clay and 30%GS),6C4G (60%Clay and 40%GS), and 5C5G (50%Clay and 50%GS). The selected dosages are according to Soosan et al.,[29]. The CLS dosages are 0.5%, 1%, 1.5% and 2% dry weight of clay-GS mix. Studies from Chen et al.,[10], Alazigha et al.,[1] Alazigha et al.,[2] the maximum dosage of CLS required to stabilize the soil is 6%. As the selected soil is performing moderated compressibility, the range of dosages is restricted to 2%. The W_l , W_p and I_p are determined according to IS 2720 part 5 1985[16] for each dosage of GS and CLS individually. During the sample preparation of CLS-clay soil and GS-CLS-clay, the required quantity of CLS is initially mixed with measured water content and mixed constantly till it attains a lump free solution. This solution is added to the clay alone and clay-GS blended soil and mixed meticulously to attain a homogeneous mix. This mixture is left for a maturing period of 6hrs. The samples are tested after that effective period [7].

3.1 Shrinkage Limit

As per IS 2720 part 6 1972 [15], volumetric shrinkage test was performed on the GS, CLS, and GD-CLS treated soil by measuring water equal to or greater than the liquid limit of the mix. A small shrinkage dish with a diameter of 45mm is used to evaluate the shrinkage of the soil. To allow the soil to shrink freely, the walls of the shrinkage dish are coated with thin layer of grease. The homogeneous mix is placed in dish by tapping mould to release the air voids. The sample is exposed to air for 6 hours to shrink naturally and then it is oven dried for a period of 24h

3. Results and Discussions

4.1 Effect of GS and CLS on Liquid Limit and Plastic Limit

With an increase in dosage of GS, W_l, W_p and I_p of clay-GS mix is decreased. From Figure 1, it is evident that a significant reduction in W_l and W_p at 30% GS is observed i.e., 20.69% and 41.1% respectively. Since GS is an inert material, adding GS to plastic soils reduces the plasticity index by filling the voids in the clay soil.

From Figure 2, the W_l and W_p of Clay - CLS is improved with an increase in dosage of CLS. This is due to the transformation of stabilized clay particles from discrete state to non-discrete and change in particle size distribution [2].

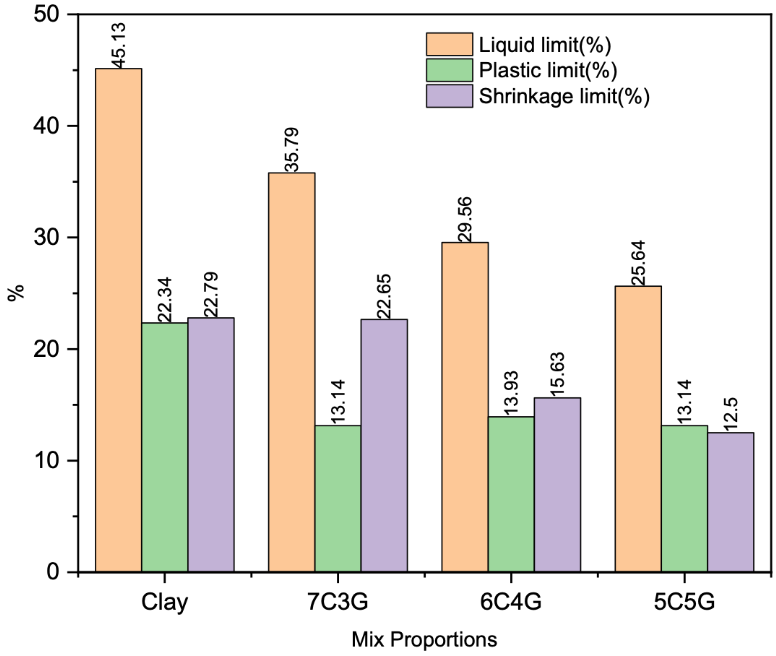

Fig.1. Effect of GS on Liquid Limit, Plastic and Shrinkage limit of clay

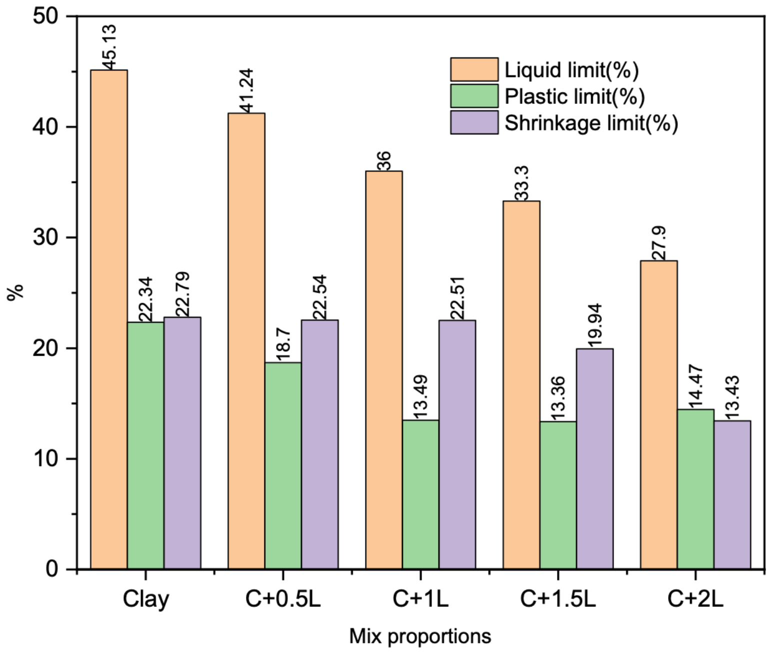

Fig.2. Effect of CLS on Liquid Limit, Plastic and Shrinkage limit of clay

(Notation: C+0.5L: Clay and 0.5%CLS; C+1L: Clay and 1%CLS; C+1.5L: Clay and 1.5%CLS; C+2L: Clay and 2%CLS)

4.2 Effect of GS, CLS and GS-CLS on Shrinkage Limit of Clay

From table 4, the shrinkage limit of the clay is increased with an increase in dosage of GS and CLS individually. The improvement in shrinkage with addition of GS is due to the breakage of particle-water-particle bond which is explained in figure 3. An increase in shrinkage limit with the addition of CLS is due to the formation of flocs at the CLS-soil interface and hence a decrease in diffused double layer [7]. From Table 5, the combined effect of GS and CLS on the clay decreased the shrinkage limit till the addition of 1.5% CLS and then it is increased up to 2% CLS. This behavior is observed at 30% GS and 40% GS (i.e., 7C3G and 6C4G). This is due to the presence of CLS which makes the matrix finer [24]. From 1.5 - 2% CLS, the soil matrix undergoes a strong peripheral bonding and hence increase in shrinkage limit [2]. For 50%GS (5C5G), the shrinkage limit of the soil is increased till 1.5%CLS which is due to increase in silt fraction than the sand content and clay content [26]. It is then reduced up to 2% CLS due to the increase in repulsive forces with the excess CLS [30]. Besides this, addition of CLS to clay-GS mix, cover the cracks that are formed due to reduction in cohesion with increase in dosage of GS which is explained in figure 4.

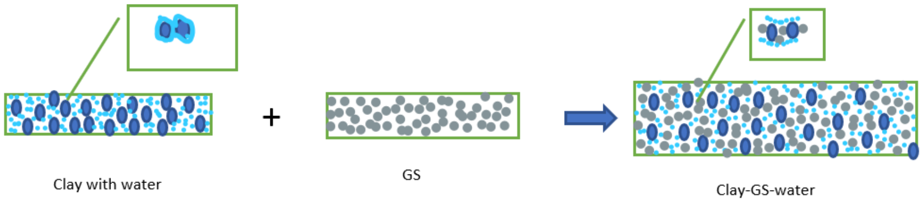

Fig.3. Mechanism behind the increase in shrinkage limit in the presence of GS

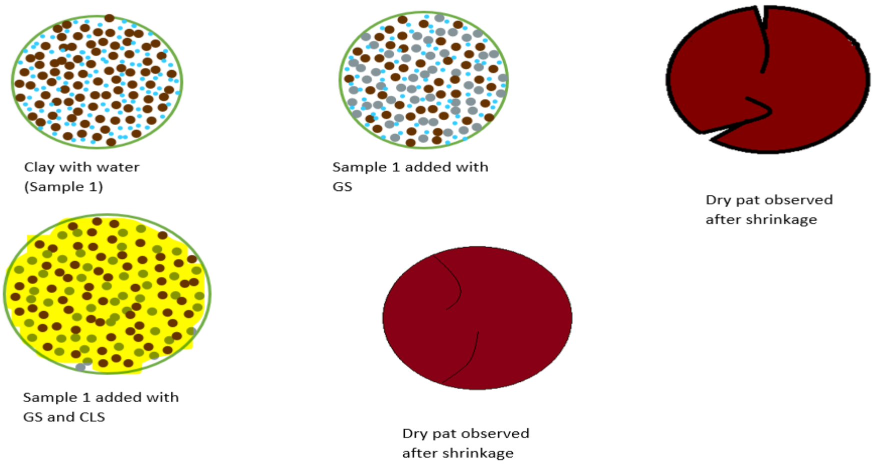

Fig.4. Effect of CLS on crack formed out of drying shrinkage of clay-GS mix

Table 4. Variation in shrinkage limit with addition of GS and CLS individually

Soil	Shrinkage limit (%)
Clay	13
7C3G	13.2
6C4G	21.92
5C5G	24.5
C+0.5L	19.3
C+1L	20
C+1.5L	27
C+2L	29

Table 5. Response of shrinkage limit Clay mixed with GS and CLS

Dosage	Shrinkage limit (%)		
CLS	7C3G	6C4G	5C5G
0.5L	24.35	17.42	8.89
1L	17.61	9.37	17.15
1.5L	11.9	4.69	23.07
2L	16	15.1	20.32

4. Practical Importance of the Study

CLS and GS are the two sustainable materials emerging across the world. GS is highly contributed as filler, subgrades and backfills (Amulya et al.,[5]) whereas Lignosulphonate contributes as erosion resistant material (Vinod et al.,[31]), strength and ductility improving material, waterproofing material, viscosity reducing material (Alazigha et al.,[1]).

In the current study, the shrinkage behavior of clay mixed with GS, CLS, and both GS and CLS is determined which is different from the existing behavior of clay as explained above. Though the shrinkage limit of clay increased in the presence of GS and CLS, the binary blended clay yielded a peculiar response which also influences the engineering properties. This might occur due to the less reactivity of GS with CLS. The blend of GS and CLS improves shrinkage limit which nullify the crack formation that might occur due to heavy loads and seasonal variations.The scope of the work contains the assessment of shrinkage of clay blended with CLS alone and both GS and CLS at different curing periods for medium to high expansive soils.

5. Conclusions

The study is carried out on clay to improve the shrinkage of clay by blending GS and CLS in the dosages of 30%, 40%, and 50% and 0.5%, 1%, 1.5%, and 2% respectively. The following are the outcomes listed out of their individual and binary action on clay.

1. The studied soil is suitable for basic and primary field applications as W_l , W_p and I_p is decreased with an increase in dosage of GS and CLS alone.

2. The Shrinkage limit of the clay is increased with an increase in the content of GS and CLS alone. However, a significant improvement is observed in the case of 6C4G and C+1.5L respectively. The addition of GS cuts the electron affinity of clay but reduces cohesion. The addition of CLS agglomerates the particles and prevents crack formation in soil. Hence, either of the stabilizers are considered for soil modification against plasticity.

3. With the addition of GS and CLS to the clay, the response of shrinkage limit is irregular in pattern however at an initial dosage of CLS for each of the GS mix yield a high value of shrinkage limit. Besides this, the shrinkage of the blended clay decreased with an increase in dosage of GS.30% GS

with 0.5% CLS yielded a higher improvement i.e., 24.35%. High plastic soils require high amount of GS to improve but lacks in cohesion. The presence of CLS in addition to GS aids in using a lesser quantity of GS and improves cohesion.

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