Strength Behavior of Lateritic Soil Treated With Alccofine

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Abstract*: *One of the factors that affect the long term performance of a structure is the strength of the underlying soil strata. Presence of weak soil strata beneath the structure will affect the structural integrity. So, enhancing the engineering properties of the weak soil results in the betterment of bearing capacity of the soil. Nowadays, for improving the stability of the weak soil, various soil stabilization techniques are adopted. This paper presents an investigation of using alccofine as a soil stabilizing agent. Variation in shear strength parameters and compaction parameters of the soil is studied by adding different percentages of alccofine 1101 such as 1%, 2%, 3%, 4%, and 5%. Test results revealed that at the optimal rate of alccofine 1101, the shear strength characteristic is increased by 53.71% after a curing period of 3 days.

Keywords: Bearing Capacity, Alccofine, Shear Strength, Compaction.

I. INTRODUCTION

In border sense, soil stabilization is the modification of weak soil for its improved engineering performance. The term soil stabilization is used in connection with foundation construction, slope stability, and subgrade construction. It mainly aims at improving the bearing capacity of the soil and thereby increasing the soil resistance towards softening. Stabilization of weak soil leads to enhancement of shear strength, compressibility, and permeability, which in turn leads to the betterment of bearing capacity of the soil. Nowadays, several surfaces and sub-surface stabilization techniques are practiced in the field for the betterment of weak soils. Among them, a numerous amount of research works are going on physical stabilization of weak soils. Physical stabilization of the soil mainly deals with improvement of soil with the aid of binders. Conventionally used binders are lime, cement, bitumen, fly ash, ground granulated blast furnace slag, quarry dust, etc. When these binders are added to the weak soil at optimum percentages, these will react with the ions present in the soil, and as a result of this reaction, cementitious products will be formed, such as C-A-H and C-S-H. This leads to the enhanced shear strength of the soil.

Selecting a binder material for stabilization depends upon the type of soil to be stabilized, required strength of stabilized layer, quality of stabilized layer, the purpose for which stabilized soil is intended, cost aspects, environmental aspects durability of the stabilized layer. After stabilization, the soil should achieve improved characteristics such as improved volume stability, shear strength parameters, particle size distribution, and durability.

Alccofine is a chemical material having a particle size less than lime, cement, fly ash, etc. Due to its micro-fine particle size, its manufacturing is done in controlled conditions. It is usually used as a supplement to improve the performance of concrete in fresh and hardened states. Alccofine is primarily classified into two types, Alccofine 1103 and Alccofine 1203. Alccofine 1203 contains low calcium silicate and can be used as a replacement for silica fume, while Alccofine1101 contains high calcium silicate, which is mainly used for injection grout in underground tunnels, pre-packed injection, contact injection, water sealing, etc. [1].

Recently various studies were conducted to study the behavior of weak soil when stabilized with Alccofine 1203 along with some other binding material. The behavior of expansive soil, when a combination of 40% fly ash and an increasing amount of alccofine 1203 was stimulated in using MATLAB. As per the stimulated graphs, the Un-Confined Compression (UCC) strength of the soil increases from 30 kN/m^2 (40% FA and 0% Alccofine) to 35.5 kN/m^2 (40% FA and 10% Alccofine). Also, the soaked CBR value of the soil increased from 4% (40% FA and 0% Alccofine) to 8% (40% FA and 0% Alccofine) [2].

A combination of industrial waste such as silica fume and Alccofine 1203 has the potential to improve the strength properties of red soil. A combination of 20% silica fume and varying percentages of Alccofine 1203 (0% to 10%) shows that with the addition of Alccofine 1203 increases the California Bearing Ratio (CBR) and UCC values of red soil. A 70% increase in CBR value and 18% increase in the UCC value was observed when Alccofine 1203 percentage was increased to 10% [3]. A considerable amount of improvement in shear strength was found for expansive soil when marble dust and 5% alccofine is added. For subgrade stabilization of the expansive soil, a critical combination of 8% marble dust and 10% alccofine gives sufficient strength for subgrade [4]. Alccofine can be used as a supplementary agent while stabilizing expansive soil containing organic matter. An optimal dosage of 2.5% alccofine along with 15% cement kiln dust is giving adequate strength for the expansive soil [5]. For subgrade stabilization

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of highly plastic expansive soil, treatment with 30% pond ash and 3% alccofine 1203 results in 42% CBR value [6].

E.S. Nnochiri and O Anderinlewo suggested that laterite soil can be satisfactorily stabilized using banana leaf ash. Banana leaf ash was added to the soil at different percentages such as 2%, 4%, 6%, 8%, and 10%. Test results show that 4% of banana leaf ash can be considered as an optimum amount. At the optimal percentage, the shear strength characteristics were improved by 11.70% [7]. Segun N E and Oluyemisi E H studied the effects of coconut shell ash on lime stabilized the soil. Both the binders were added at varying percentages, 2%, 4%, 6%, 8%, 10%. At 6% of lime content, the optimum values of CBR and UCC were observed. AT 4% of coconut shell ash and 6% lime, CBR shows the optimum values. Similarly, at 6% coconut shell ash and 6% lime, UCC strength shows the optimum values [8].

From the studies of V Sharma and S G Upadhyay, an optimal percentage of 1.5% calcium chloride was sufficient for stabilizing laterite soil [9]. In-situ and laboratory tests on the effect of lime cement-treated laterite soil were studied by Y T Todingrara et al. shows that optimal combination of 12% lime and 5% cement can be used for subgrade stabilization [10]. Optimal mechanical behavior of laterite soil treated with calcinated paper sludge and cement is observed at 25:75 combination. Presence of calcium ions in the binder leads to improved CBR and UCC results [11]. K. J. Osinubi et al. studied the effect of using bagasse ash as binding material for weak laterite soils. CBR and UCC strength studies were focused on effect up to 12%. Test results indicate bagasse ash cannot be used as a stand-alone binder material it should be added along with cement or lime [12].

The stabilization capacity of cement and calcium carbide waste (CCW) were investigated by M. Joel and E. J. Edeh on Ikpayongo laterite soil. Laboratory investigation details show that a combination of 6 % cement plus 8 % calcium carbide waste is recommended for use as sub-base material in pavement work and a combination of 8 % cement plus 10 % calcium carbide waste is recommended for use as a base material in pavement work. Also, the plasticity index of Ikpayongo laterite decreased from 14 % to 5 %, when treated with 10 % cement plus 10 % calcium carbide waste [13]. Experimental studies conducted by O. Amu et al. revealed that sugarcane straw ash is an excellent soil stabilizer for lateritic soil. For the experimental purpose three different lateritic soil samples were collected and it was observed that Optimum moisture content increased from 19% to 20.5%, 13.3% to 15.7% and 11.7% to 17.0%, CBR increased from 6.31% to 23.3%, 6.24% to 14.88% and 6.24% to 24.88% and unconfined compression strength increased from 79.64kN/m^2 to 284.66kN/m^2, 204.86 kN/m^2 to 350.10kN/m^2 and 240.4 kN/m^2 to 564.6kN/m^2 in three samples respectively [14].

This study mainly aims to investigate the soil stabilization capacity of Alccofine 1101, i.e., whether Alccofine 1101 can be effectively used as a “stand-alone” binder for improving the shear strength of the weak soil.

II. MATERIALS USED

A. Soil Samples

Soil samples for the experimental study were collected from a damaged slope located in MBCCET, Peermade campus. In-situ core cutter method was adopted for collecting the samples and also to find out the in-situ density. Samples were procured from a depth of 30cm from the ground surface to avoid deteriorated topsoil and vegetation.

B. Alccofine

Alccofine for the experimental investigation was collected from Ambuja Cement Limited. Fig.1 shows Alccofine 1101, which was used for the experimental study as it contains high calcium silicate content. Table- I and Table- II shows the physical and chemical properties of Alccofine 1101 [1].

Table- I: Physical Properties of Alccofine 1101

Fineness (cm^2/g)	Specific Gravity	Bulk Density (kg/m^3)	Particle Size (μm)	
			D50	*D95*
6000	3.1	700-800	<9	6000

Table- II: Chemical Properties of Alccofine 1101

IR (max)	MgO (max)	SO3 (max)	LOI (max)	Cl- (max)
4%	6%	3%	5%	0.005%

Fig. 1. Alccofine 1101 used for the experimental study.

III. EXPERIMENTAL INVESTIGATION

For determining the optimal dosage of alccofine 1101 required for the slope or soil stabilization, different percentages of alccofine 1101 such as 1%, 2%, 3%, 4%, and 5% were added to the soil. For the determination of optimum compaction parameters, light compaction tests were conducted at varying percentages of alccofine from 1% to 5%. For defining the optimum shear strength parameters, direct shear tests were carried out at different proportions of alccofine varying from 1% to 5%. Table- III shows the different compositions of alccofine 1101 adopted for the experimental study.

Table- III: Different Compositions of Alccofine 1101 with Soil

Sl No.	Composition	Tests Conducted	
1	0% Alccofine 1101 + Soil	Light Compaction Test	Direct Shear Test
2	1% Alccofine 1101 + Soil	Light Compaction Test	Direct Shear Test
3	2% Alccofine 1101 + Soil	Light Compaction Test	Direct Shear Test
4	3% Alccofine 1101+ Soil	Light Compaction Test	Direct Shear Test
5	4% Alccofine 1101+ Soil	Light Compaction Test	Direct Shear Test
6	5% Alccofine 1101 + Soil	Light Compaction Test	Direct Shear Test

IV. RESULTS &DISCUSSIONS

A. Initial Test Results

A series of core cutter tests were conducted along the weak slope region in order to determine the in-situ density of the soil. Core cutter samples were collected at 1m intervals and the variation of in-situ density was represented in the Table-IV. From the in-situ core cutter test results it was concluded that the soil had an average density of around 1.30g/cm3, which makes it to fall into weak soil category.

Table- IV: In-Situ Field Density Details

Points Selected on the Weak Slope								
P1	P2	P3	P4	P5	P6	P7	P8	P9
In-Situ Density (g/cm3)								
1.34	1.36	1.29	1.31	1.32	1.34	1.39	1.45	1.38

For defining the basic properties of the soil samples collected, initial tests such as specific gravity, sieve analysis, permeability test, compaction test, and direct shear test were conducted as per the procedures specified in IS 2720. Table-V shows the results of various initial tests conducted on the soil samples (0% Alccofine 1101). From the sieve analysis data it was observed that the sand content was much more pronounced when compared with the gravel and fine content. As per IS soil classification, it was named as Lateritic Gravelly Sand.

Table- V: Details of Initial Test (0% Alccofine)

Sl No.	Description	Values	
1	Specific Gravity	2.65	
2	Permeability (cm/sec)	2.48×10^{-3}	
3	Max Dry Density (g/cm3) & OMC (%)	1.77 & 14.59	
4	Gravel (%)	6	Lateritic Gravelly Sand
	Sand (%)	95	
	Silt & Clay (%)	6	
5	Angle of Internal Friction (ϕ)	25.42^0	

B. Variation in Compaction Parameters

To modify the compaction properties of the weak soil, alccofine 1101 was added into the soil at different percentages such as 1%, 2%, 3%, 4%, and 5%. Table- VI represents the details of light compaction test conducted to identify the modified compaction parameters at different percentages of alccofine 1101. Fig. 2 and Fig. 3 represents the variation of compaction parameters at 1%, 2%, 3%, 4% and 5% Alccofine 1101 respectively.

Table- VI- MDD & OMC at Different Percentages of Alccofine 1101

Sl No.	Alccofine 1101 Percentage (%)	Maximum Dry Density (g/cm3)	Optimum Moisture Content (%)
1	0	1.77	14.59
2	1	1.80	15.17
3	2	1.81	16.06
4	3	1.83	16.43
5	4	1.77	16.87
6	5	1.70	17.21

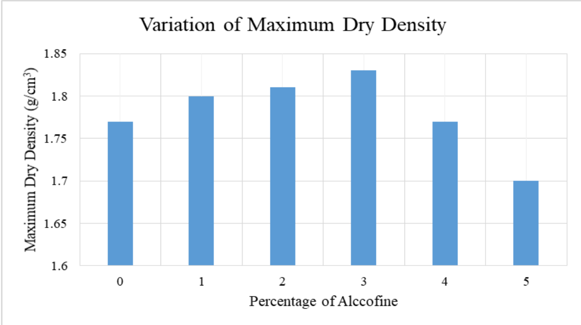

Fig. 2.Variation of Maximum Dry Density at different percentages of Alccofine 1101

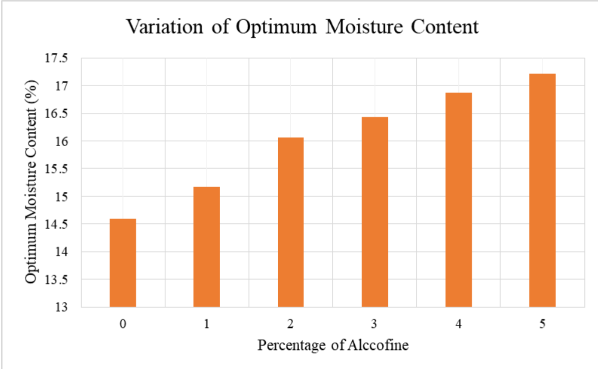

Fig. 3.Variation of optimum moisture content at different percentages of Alccofine 1101

From the test results represented in Table- VI, it is evident that the maximum dry density increases with the addition of different percentages of alccofine 1101 and attains an optimum value at 3% of alccofine 1101, afterward the optimum value, the maximum dry density starts decreasing. Also, an increase in the OMC was observed at various percentages of Alccofine 1101.

As shown in Fig. 2, the addition of Alccofine 1101 influences the soil-alccofine compatibility. The ultra-fine alccofine particles fill the void spaces in the soil, thereby increasing the dry density. Changes in maximum dry density are affected by the higher specific gravity of cement than sand, which in turn changes the grain-size distribution of the mixture [15]. When the soil-alccofine mixture is lubricated with the increase in the water content, the mixture will attain a densely packed condition. But beyond a particular water content, an additional amount of water will not cause a decrease in dry density. This is because, after the optimum, the extra water starts occupying the voids in the soil-alccofine mixture, thereby preventing the alccofine particles from moving into that space.

Fig. 3 illustrates that with the addition of Alccofine 1101 to the soil, the OMC starts increasing. Such an increase in OMC is mainly due to the ultra-fine nature of Alccofine 1101. Ultra fineness results in more surface area, so water required for the lubrication of the particles is more. Also, the increase in the water content was due to the pozzolanic reaction of Alccofine 1101 with the soil. Even though the lateritic soil used in this study contains more amount of sandy particles, a small fraction of silt and clay were also noted during sieve analysis. The addition of alccofine decreases the presence of silt and clay fraction by forming coarser materials, which occupy larger space for retaining water.

From Fig.2 and Fig.3, it was also noticed that, with the addition of Alccofine 1101 at different percentages, the variations in MDD, as well as OMC, were small. Such a slight difference in the MDD and OMC values were due to lack of curing period. If sufficient curing period were not provided, complete hydration process would not be completed. In this study, the curing period provided was around three days, so the rate of cementitious or pozzolanic reaction was less. Thus, the effect of a lower curing period will reflect in the compaction as well as the strength properties of the treated soil [16].

C. Variation in Angle of Internal Friction

To modify the shear strength parameters of the weak soil, alccofine 1101 was added into the soil at different percentages such as 1%, 2%, 3%, 4%, and 5%. The test was conduct after a curing period of 3 days. From the sieve analysis data, it was observed that the lateritic soil selected for modification contains sand particles as higher percentages. So direct shear test was proposed for defining the strength behavior of the weak soil at different percentages of Alccofine 1101. Table-VII represents the details of the direct shear test conducted to identify the modified shear strength parameter (Angle of Internal Friction) at different percentages of Alccofine 1101.

Table- VII: Angle of Internal Friction at Different Percentages of Alccofine 1101

Sl No.	Alccofine 1101 Percentage (%)	Angle of Internal Friction (^{0})
1	0	25.42
2	1	29.80
3	2	33.52
4	3	38.83
5	4	34.44
6	5	31.93

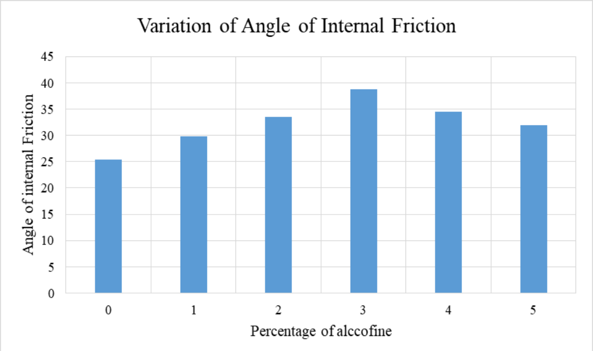

Fig. 4. Variation of angle of internal friction at different percentages of Alccofine 1101

Fig. 4. Illustrates the variation of angle of internal friction at different percentages of Alccofine 1101. Angle of internal friction values were increased from 25.42^0 (0% Alccofine) to 38.83^0 (3% Alccofine), afterward it decreases. So, optimum strength was observed when the weak soil is mixed with 3% Alccofine. A strength increment of 52.71% was noticed at optimum percent. The increased strength behavior is due to the formation of cementitious compounds formed in the soil matrix due to the addition of Alccofine 1101. Due to the reaction between the pozzolans, cementitious mixtures were created in the soil matrix, which results in agglomeration in large size particles, which in turn increases the shear strength of the soil matrix. But after the optimum percent of Alccofine 1101, the strength decreases, this is due to the excess presence of Alccofine 1101 introduced into the soil causing the formation of weak bonds between the soil and pozzolanic compounds formed. Also, such a satisfactory strength increment at 3% occurs due to lower curing period. If the curing period is increased or supplementary cementitious material is added, the strength behavior will be more pronounced [17].

V. CONCLUSION

Based on experimental studies conducted, it was revealed that an optimal dosage of 3% Alccofine1101 is efficient in stabilizing the weak lateritic sandy soil. Introduction of Alccofine1101 into weak lateritic soil turns up with a slight improvement in compaction parameters. Maximum Dry Density shows only a minimal increment of 2.5% at the optimum percentage of Alccofine1101. When compared with the ordinary soil (0% Alccofine1101), the addition of an optimal dose of Alccofine1101 (3%) shows a strength improvement of 52.71% after a curing period of 3 days. So, from the experimental investigations and literature studies, it was concluded that the introduction of Alccofine1101 into a weak lateritic soil turns up with satisfying strength improvement when compared alccofine 1203. Similar to stabilization using cement, Alccofine 1101 also develops sufficient CAH and CSH compounds, which increases the strength of the soil. This is mainly due to its ultra-fine particle size, which helps in filling the voids and thereby reacting with the ions in the soil to produce CAH and CSH compounds. The outstanding performance of Alccofine1101, as a stabilizing agent, will be possible if a minimal dosage of lime is also introduced in the soil.

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