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Effect Of Calcium Oxide And Aluminium Oxide On The Durability Of Quarry Dust Stabilized Soft Clayey Soil

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Abstract: ***The use of quarry dust was found to be effective to increase the strength of soft clayey soil. The durability of quarry dust stabilized soil is very less due to lack of bonding between soil and quarry dust. It is essential to satisfy the durability conditions for long term use of stabilized soil as subgrades especially in regions wet and dry climatic conditions prevail. This study investigated the use of Calcium Oxide and Aluminium Oxide to enhance the durability of soft clayey soil subgrade stabilized with quarry dust. It also focuses on the effect of Calcium oxide on durability of soft clayey soil treated and not treated with Quarry dust.***

Keywords: Drying-wetting cycle test, Soft clayey soil, Unconfined compressive strength.

I. INTRODUCTION

Construction on soft ground area is a great challenge in the field of geotechnical engineering. Many engineering problems in the form of slope instability, bearing capacity failure or excessive settlement could occur either during or after the construction phase due to low shear strength and high compressibility of this soil [1]. Soft soil with high percentage of clay content have very strength.

In order to increase consistency(firmness) of soft cohesive clayey soil addition of cohesionless materials was found to be effective [2]. Very fine quarry dust (particle size less than 425micron) cannot be used for other purposes such as concrete works and as it is cheap and cohesionless it can be used for stabilization of soft soil.

Due to the lack of bonding between soil and quarry dust particle the stabilized mix will not be durable under series of drying and wetting cycles. Calcium Oxide (cao) was found to be effective to improve the strength of soft soil [3].

The present study includes the effect of cao in treated and untreated with Quarry dust in order to compare the increase in durability and the effect of Aluminium oxide (Al_2O_3) on quarry dust stabilized soil treated with cao.

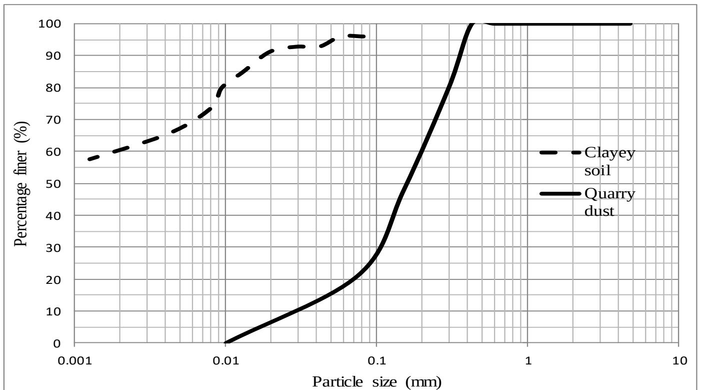
II. Materials Used

2.1 Three Different Materials Were Used In This Research: Clayey Soil, Quarry Dust, Calcium Oxide And Aluminium Oxide Clayey Soil

The soil used for work was collected from Thonnakkal, Thiruvananthapuram, Kerala, India. The properties of soil were tested and tabulated in Table 1. Based on Indian Standard Classification System (ISCS), the soil is classified as Clay of low compressibility (CL). Unconfined compression test was conducted to confirm the soil is soft. The grain size distribution of clay was found out using hydrometer analysis (IS: 2720 (Part 4)- 1983) is shown in Fig. 1.

Table 1. Properties of Clayey Soil

Soil Properties	Values Obtained
Specific gravity	2.53
Liquid limit (%)	33
Plastic limit (%)	20.2
Shrinkage limit (%)	18.3



Plasticity Index (%)	12.9
IS Classification	CL
OMC (%)	24.5
Percentage of clay (%)	60
Percentage of silt (%)	36
Percentage of sand (%)	4
UCS (kPa)	28.7

2.2 Quarry Dust

The quarry dust used in the study was collected from a local stone crushing site in pallichal, Thiruvananthapuram, Kerala, India. The collected quarry dust was first dried and screened over sieve size 4.75mm to remove any impurities. Then it was sieved through sieve size 425 micron to obtain fine quarry dust particles. The properties of fine quarry dust were tested and tabulated in Table 2. The grain size distribution of quarry dust was found out by sieve analysis (IS: 2720 (Part 4)- 1983) is shown also in Fig. 1.

Table 2. Properties of Quarry Dust

Soil Properties	Values Obtained
Specific gravity	2.7
Effective Size D10(mm)	0.03
D60(mm)	0.2
D30(mm)	0.1
Co-efficient of curvature, C_C	1.67
Uniformity Co-efficient, C_u	6.67
% fines below 0.425mm	100
Angle of internal friction (Φ)	47^0
Cohesion, c (kPa)	0

Fig. 1. Grain size distribution curves for clayey soil and Quarry dust

2.3 Calcium Oxide and Aluminium Oxide

Laboratory reagent grade Calcium Oxide (cao) and Aluminium Oxide (Al_2O_3) was used as the binding agent. Distilled water was used in preparing the test specimens and for curing.

III. Method Of Study

3.2 Tests Conducted

Following tests were conducted.

a) Standard proctor test (IS: 2720 (Part 7)-1983)
b) Unconfined compression test
(IS: 2720 (Part 10) -1983)
c) Drying wetting cycle test
(ASTM D4843 - 88(2016))

3.3 Methodology

Mix Design

For Mix 1: Standard Procter compaction tests were conducted on clayey soil to determine the optimal moisture content. Then cylindrical specimens with 7.5cm height and 3.8cm diameter of clayey soil were prepared based on their respective optimal moisture content and dry density for unconfined compression test.

For Mix 2: Standard Procter compaction tests were conducted to determine the optimal moisture content and maximum dry density for soil mixed with different contents Quarry dust. Cylindrical specimens of stabilized soil were prepared based on their respective optimal moisture content and dry density. Unconfined compression test was conducted on each specimen. The specimen with maximum UCS value was selected as Mix 2.

For Mix 3: Standard Procter compaction tests were conducted to determine the optimal moisture content and maximum dry density for clayey soil mixed with different contents cao. Cylindrical specimens of clay-cao mix were prepared based on their respective optimal moisture content and dry density. It was allowed to cure for 14 days. Unconfined compression test was conducted on each specimen. The specimen with maximum UCS value was selected as Mix 2.

For Mix 4: Standard Procter compaction tests were conducted to determine the optimal moisture content and maximum dry density for soil-quarry dust mix (Mix 2) mixed with different percentages cao. Cylindrical specimens of clay-quarry dust-cao mix were prepared based on their respective optimal moisture content and dry density. It was allowed to cure for 14 days. Unconfined compression test was conducted on each specimen. The specimen with maximum UCS value was selected as Mix 4.

For Mix 5: Mix 4 was mixed with an excess amount of cao and small amount of Al_2O_3 and standard Procter compaction tests were conducted to determine the optimal moisture content and maximum dry density. Then cylindrical specimens were prepared based on their respective optimal moisture content and dry density for unconfined compression test.

Drying – Wetting Cycle Test

Cylindrical specimens were prepared using each mix (Prepare at least 8 specimens from one mix). Specimens were allowed to cure for 14 days.

When the curing was finished, the specimens were taken out to perform the dying-wetting cycling tests [4],[5]. In the drying process, each specimen was wrapped with plastic film and placed in an oven with temperature at 60 ± 1°C for 23 h.

In the subsequent wetting process, the specimen was taken out from the oven and placed on a porous stone in an immersion chamber for 1 hour. After this, distilled water was continuously added to immerse the specimen and maintained for 23 h. Finally, the specimen was taken out of the chamber followed by 1 h equilibrium. After this conduct Unconfined compression tests on one specimen of each mix. Then the procedures mentioned above were repeated for 1, 3, 5, and 7 cycles.

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IV. Results And Discussions

4.2 Unconfined Compression Test Results For Mix Design

UCS Of Clayey Soil

UCS of clayey soil specimen was found as 28.7kpa. As it is between 25kpa and 50kpa the soil is soft and stabilization is essential.

Ucs Of Clayey Soil Treated With Quarry Dust

The UCS values of Clayey soil treated with different percentage of quarry dust is given in Table 3. And the variation of UCS is given in Fig. 2.

Table 3. Unconfined Compressive Strength of Clay-Quarry Dust Mixes

Soil mix	**UCS, q_u (kpa)**
Clayey soil	28.7
Clayey soil + 10% Quarry dust	78.3
Clayey soil + 20% Quarry dust	101.5
Clayey soil + 30% Quarry dust	119.2
Clayey soil + 40% Quarry dust	150
Clayey soil + 50% Quarry dust	90.5

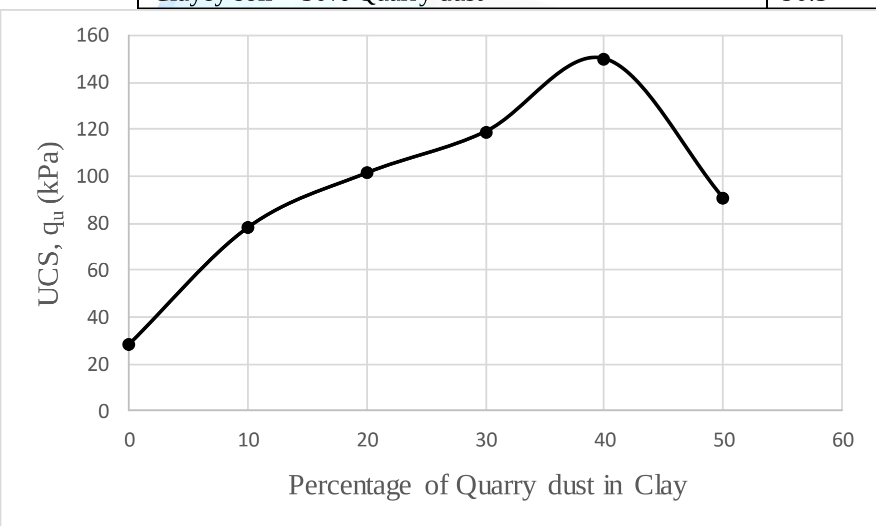

Fig. 2. Variation in Unconfined compressive strength with varying percentages of quarry dust in clayey soil

Addition of quarry dust in clay increases UCS of mix up to a certain limit due to filling of voids in dust by clay. But after a certain limit the clay content in that mix became insufficient to fill voids and UCS starts decreasing due to increase in void ratio.

Mix with Clayey soil + 40% quarry dust was selected as Mix 2 as it gives maximum UCS.

Ucs of clayey soil and quarry dust stabilized clayey soil treated with cao

The ucs values of clayey soil and quarry dust stabilized clayey soil with different percentages of cao (after 14 days curing) is given in table 4. And the variation of ucs is given in fig. 3.

When cao reacts with clayey soil and water pozzolanic reaction will occur and ucs will increase. The formation of gelatinous material due to pozzolanic reaction is more in quarry dust stabilized soil due to the high amount of silica content.

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Table 4. Unconfined compressive strength of clayey soil and quarry dust stabilized clayey soil treated with cao

Percentage of cao added (% by dry weight of soil)	**UCS, q_u (kpa)**	
	In clayey soil	***In Clayey soil +40% Quarry dust***
0	28.7	150.1
1	50.5	165.4
2	150.5	228.5
3	240.5	340.1
4	267	272
5	200.5	217.65

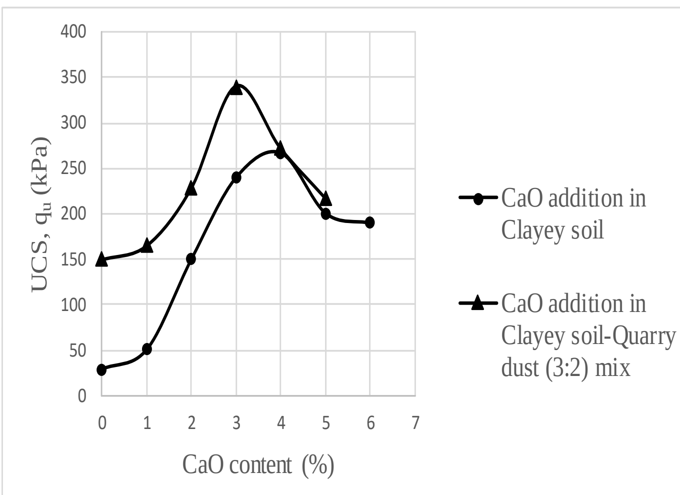

Fig. 3. Variation in Unconfined compressive strength with varying percentages of cao in clayey soil and quarry dust stabilized clayey soil

Mix with Clayey soil + 4% cao was selected as Mix 3 and Mix with Clayey soil + 40% quarry dust + 3% cao was selected as Mix 4.

Ucs of quarry dust stabilized clayey soil treated with excess cao and al_2o_3

In order to find the effect of aluminium oxide (al_2o_3) on quarry dust stabilized soil 1% al_2o_3 and excess 3% cao is added to mix 4 to prepare mix 5. The ucs was found to be higher because of c_3a formation by the reaction of al_2o_3 with excess lime.

Table 5. Shows the initial ucs at the failure of prepared mixes

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Table 5. Mix design summary

Mix	Composition	Ucs, qu (kpa)
Mix 1	Clayey soil	28.7
Mix 2	Clayey soil+ 40% quarry dust	150.1
Mix 3	Clayey soil+ 4% cao	267
Mix 4	Clayey soil+ 40% quarry dust + 3% cao	340.1
Mix 5	Clayey soil+ 40% quarry dust + 6% cao + 1% al_2o_3	390.8

4.3 Drying-Wetting Cycle Test Results For Checking Durability

Drying-wetting cycle tests were conducted as per astm d4843 - 88(2016) on each mix. The results are tabulated in table 6. And shown in fig. 4.

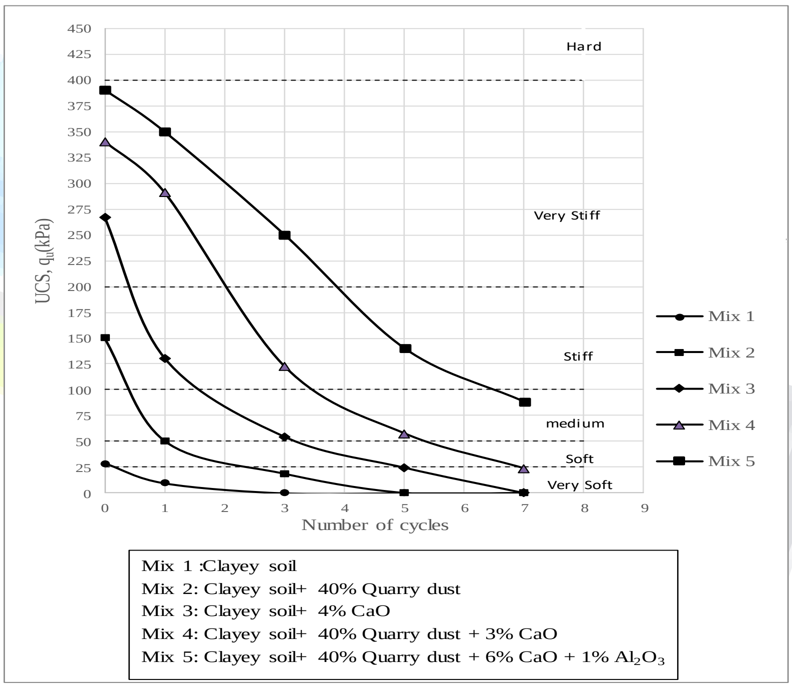

Fig. 4. Effect of drying-wetting cycle on UCS of mixes

Table 6. Results of Drying-Wetting Cycle Test

Mix	**UCS, qu (kpa)**				
	Number of cycles				
	0	1	3	5	7
Mix 1	28.7	9.6	0	0	0
Mix 2	150.2	50.5	18.6	0	0
Mix 3	267	130.6	54.5	24.6	0
Mix 4	340.1	290.7	122.4	57.5	23.6
Mix 5	390.8	350.2	250.5	140.6	88.8

The consistency of Mix 5 remains in medium even after 7 cycles of drying and wetting. So that Quarry dust stabilized soil treated with 6% cao and 1% Al_2O_3 can be used as durable material for subgrade.

V. Conclusions

- Addition of quarry dust shows a substantial increase in unconfined compressive strength of soft clayey soil.
- The UCS of Clay-quarry dust mix will become zero after 5 cycles of drying and wetting which is an indication of low durability.
- Durability of Clay-cao mix is also low.
- Clay-quarry dust-cao mix shows comparatively greater durability than Clay-cao mix. Because Clay-quarry dust-cao mix shows a strength value even after the 7^{th} cycle of drying and wetting.
- Due to the formation of gelatinous materials quarry dust stabilized soil treated with 6% cao and 1% Al_2O_3 shows high durability. It shows a higher value of UCS even after the 7^{th} cycle of drying and wetting.

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