Usage of Quarry Dust and Lime as a stabilization agent for Fine grained soils

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Abstract— *From recent past, a great amount of attention has been given to the use of alternative materials, which provide higher engineering quality than conventionally used materials as well as the financial affordability. Engineers have been facing a challenging task of improving the qualities of fine grained soil by using different materials. Clay soils have been found to be having better plastic properties because increased moisture results in a lower shear strength, compressive strength and volume changes. Soils of this nature can be tackled effectively using soil stabilization. This research was done to determine whether quarry dust (QD) with the combination of lime (L) can be used as stabilizing agents for fine grained soils. In this study, different mixture proportions of quarry dust and lime were used to improve the soil. Then the properties of soils including liquid limit (LL), plastic limit (PL), maximum dry density (MDD) and optimum moisture content (OMC) were determined and compared to another soil based on the laboratory observations. It was found that 13% of lime and 27% of quarry dust as the optimum mixture. From the cost comparison, it was found that soil stabilization method is more economical than the conventional excavation and backfilling method.*

Keywords— **Lime, Quarry dust, Stabilization**

I. Introduction

Stabilization is achieved by various methods which change the properties of a soil to improve its engineering performance. Stabilization techniques are used for numerous engineering applications such as construction of roads, embankments, foundations and runways. The main objectives of stabilization are to increase the stability or strength of the soil and reduce the construction cost by making maximum utilization of locally available materials.

From a civil engineer's point of view, soil is defined as sediments or other accumulation of mineral particles created by the physical or chemical disintegration of rocks. Natural soil is usually a variable, porous, complex, non homogeneous material. The condition of the existing soil directly affects the construction being put up on it. In some scenarios the existing soil condition is incapable of meeting the requirements of the construction. When the requirements of the project are not met at specific region of the soil, the engineer is forced to decide whether to proceed with the available soil and limit the plan to meet the standards forced by its current quality, to remove the soil and replace it or to modify the current soil to meet the requirements of the project. The final choice, the alteration of the properties to meet project requirements is called as "soil stabilization". The following objectives are expected from this research:

- To study the fine grained soil and behaviour of quarry dust and lime as stabilizing agents.
- To determine index properties of untreated and treated soil with four different quarry dust and lime contents.
- To determine the MDD and OMC of the fine grained soil using different quarry dust and lime contents.
- To study the improvement of compaction in fine grained soil using the process of lime-quarry dust stabilization.

One of the most common techniques used all around the world to improve the geotechnical characteristics of soil in civil engineering projects is Compaction. Proper compaction is required for tasks like backfilling. Compaction increases soil density or unit weight and reduces the air volume. Assuring the proposed design specifications of compacted fills is one of the major concerns of geotechnical engineers. Characteristics of engineering importance like strength, stiffness, resistance to shrinkage and imperviousness of the soil will increase due to the increased soil density by compaction. At the point of the optimum moisture content, the highest density for a specified compaction can be achieved.

Soil improvement is done worldwide by using additives to stabilize the soil. The properties of the soil are improved through physical and chemical changes. The strategy of improvement can only be arrived at after conducting a deep study about the behaviour of the fine soil.

Lime and quarry dust were used to find out the effect on the properties of fine grained soil in this study. Any improvement regarding compaction properties of the soil due to the addition of lime and quarry dust will help to find a solution materials like quarry dust and also it can be utilized as a proper stabilizing agent.

II. LITERATURE REVIEW

Sherwood (1993) found that by adding lime into the soil, the consistency can be changed significantly. When a soil with a moisture content of 35% and plastic limit of 25% was treated by adding 2% of lime into it, the plastic limit of the treated soil has increased to the value of 40% and the moisture content decreased 5% below the value of plastic limit.

According to the study of Mallela et al. (2004), they have revealed that a clay soil exhibits various reactions with lime in the presence of water. Cation exchange, flocculation-agglomeration, carbonation and pozzolanic reaction were the reactions which occurred. The reactions such as cation exchange and flocculation-agglomeration caused modifications in strength, soil consistency and workability of the soils. The initiation of these reactions occurred soon after mixing.

O'Connell and Cook (2008) determined that the strength gain in lime stabilization in first seven days was achieved very rapidly but not as fast as in cement. After that the increment of strength gain slowly reduced with time. The strength of lime stabilized soil depends on factors such as curing time and temperature.

Priyankara and Wijesooriya (2008), found that a mixture of quarry dust and cement produce better improvement of properties in weak soils. Quarry dust is only one type of the various types of quarry wastes. It is approximately 25% of the output of each crusher unit.

Kumar and Biradar (2014) studied the feasibility of stabilizing soft sub-grade by using quarry dust. Optimum moisture content was reduced by 36.71% with the addition of quarry dust. The peak values for California Bearing Ratio (CBR) and maximum dry density was found at 40% of quarry dust and there was an increment of 5.88% at 40% of quarry dust.

Jose, et al. (2014) studied the effect of using egg shell powder (ESP) and quarry dust to improve clayey soil. Soil properties were checked by conducting several tests with different mixture proportions of egg shell powder and quarry dust. ESP was used as an alternative to lime because it is rich in lime, calcium and protein. It was found that Optimum Moisture Content increases and maximum dry density decreases with the increase in percentage of ESP. The shear strength improved with increase in percentage of ESP and became constant after 20%. Shear strength and friction angle increased with varying percentages of QD, while ESP was held at the optimum percentage. Finally, they decided 20% ESP and 30% QD as optimum mixture percentages for soil stabilization.

Al-Joulani (2012) studied the effect of stone powder and lime on shear strength, compaction and CBR properties of fine grained soils. In this study, compaction, direct shear and CBR tests were conducted to find out the basic properties. Stone powder and lime were both added at percentages of 10%, 20% and 30% by weight of the soil and blended with the value obtained for optimum moisture content from the compaction test. A slight decrease in maximum dry density and optimum moisture content were identified when 30% stone powder was added. However, 19% decrease in maximum dry density and 13.5% decrease in optimum moisture content were obtained by addition of 30% lime.

Sabat (2012) studied the effect of lime on some geotechnical properties such as atterberg's limit, compaction, shear strength and durability of an expansive soil stabilized with optimum percentage of quarry dust. The optimum quarry dust percentage was taken as 40%. The lime percentage from 2% to 7% was varied with increments of 1%. It was found that addition of QD decreases the Liquid Limit, Plastic Limit, Plasticity Index (PI) and increases the shrinkage limit of the expansive soil. It was observed that any increment in lime percentage decreases the LL, PI and increases the shrinkage limit and PL in expansive soil - quarry dust mixtures. A reduction in OMC and increment in MDD was found with the addition of QD. When lime content was increased in expansive soil quarry dust mixtures, it causes an increase in OMC and decrease in MDD. Even though the MDD decreased it was greater than the MDD of the natural soil with 5% of lime. It was found that more durable mixes of soil quarry dust can be achieved by adding lime.

Deepiya, et al. (2004) investigated about the effect of utilizing quarry dust and lime for stabilization of clay soils. The range used was 8% - 38% of quarry dust and constant lime content of 2%. It was found that the maximum strength was obtained by the soil with 38% of quarry dust and 2% of lime. In this study, variation of lime percentage was not considered.

III. MATERIALS AND METHODS

A. Materials Used

• Fine grained soil

Fine grained soil samples from two different sites were collected and used for this study. First soil sample (sample 1) used in this study was collected from a site at Makumbura, Kottawa, Sri Lanka. Another soil sample (sample 8) was collected from Homagama, Sri Lanka. The samples were thoroughly oven dried (105°C) and stored in sacks at room temperature. Both soils were sieved through 600μm before use in order to remove coarser particles and lumps. The soils were tested for liquid limit, plastic limit, optimum moisture content and maximum dry density. For the soil samples, the general properties obtained are tabulated in Table 1.

Table 1. General soil properties of soil samples 1 and 8

Property	Sample 1	Sample 8
Type	CL	SM
Liquid limit (%)	28.15	19.65
Plastic limit (%)	18.75	17.14
Plasticity Index (%)	9.4	2.51
Optimum moisture content (%)	24.23	17.02
Maximum dry density (kg/m^3)	1642.5	1769.6

• Lime

Lime was purchased from local market. Quick lime (CaO) was the type of lime that was used in this study. The lime was sieved through 425μm before use in order to take uniform size and powder type material for mix easily.

• Quarry dust

The quarry dust used was collected from a crusher near Rathnapura, Sri Lanka. The quarry dust was sieved through 1.18mm sieve before use to mix with lime and soil easily.

B. Test Methods

In order to accomplish the objectives of this study, following soil tests were conducted.

- Particle size distribution test
- Atterberg limits using Casagrande method
- Standard proctor compaction test

This study was carried out in three phases. In the first phase, soil classification was done for sample 1 and 8 by using particle size distribution test (sieve analysis) and Atterberg limit test. Soil was classified according to the Unified Soil Classification System (USCS). Atterberg limit tests were conducted for sample 1 for various lime and quarry dust mixtures in order to determine the behaviour of lime and quarry dust on consistency of the soil. Lime was added 3% by weight initially and with a 5% increment for next mixtures. The variation of lime percentages were 3%, 8%, 13% and 18%. Quarry dust was added 37% by weight initially and with a 5% reduction for next mixtures. The variation of Quarry dust percentages were 37%, 32%, 27% and 22%.

In the second phase, standard proctor tests were conducted for sample 1 and 8. Initially, standard proctor compaction tests were conducted for sample 1 according to the above given mixtures. Then same mixtures were used to conduct the standard proctor test for sample 8. The comparison results obtained for sample 1 and 8 were used to determine the optimum mixture of lime and quarry dust. Another set of standard proctor tests were carried out to check the behaviour of quarry dust around the optimum percentage for lime for stabilization.

In the third phase, a cost comparison was done for conventional excavation and backfilling and soil stabilization by using optimum lime and quarry dust mixture.

IV. RESULTS AND DISCUSSION

A. Particle Size Distribution

Particle size distribution curves for sample 1 and Sample 8 are shown in figure 1 and figure 2.

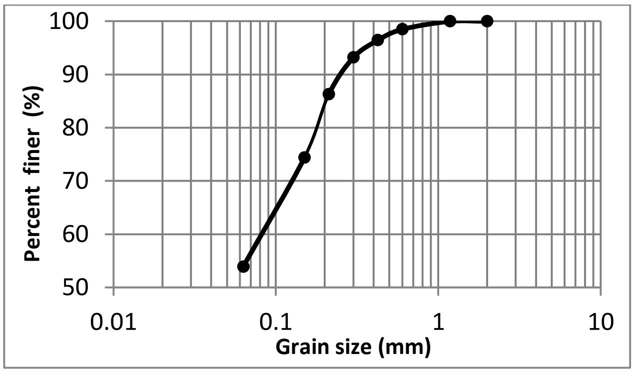

Figure 1. Particle size distribution curve for sample 1

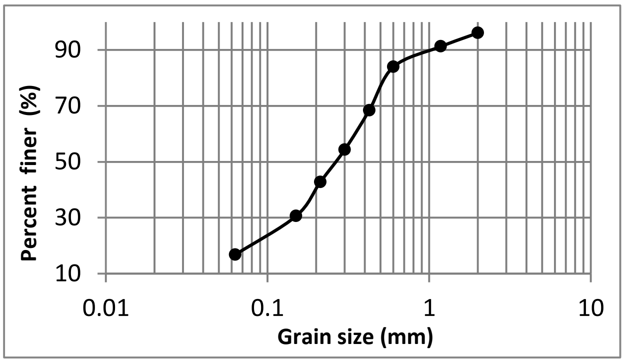

Figure 2. Particle size distribution curve for sample 8

B. Atterberg's Limits

This study mainly focuses on the fine grained soils. Because of that main consideration was given to the silty clay sample (sample 1). Table 2 shows the influence of lime and quarry dust mixture on the consistency limits of silty clay soil.

Table 2. Consistency limits of sample 1 for different mixtures of lime and quarry dust

%L + %QD	LL	PL	PI
0 + 0	28.1	18.75	9.4
3 + 37	27.2	21.73	5.47
8 + 32	26.1	20.88	5.22
13 + 27	25.4	20.59	4.81
18 + 22	27.5	24.32	3.18

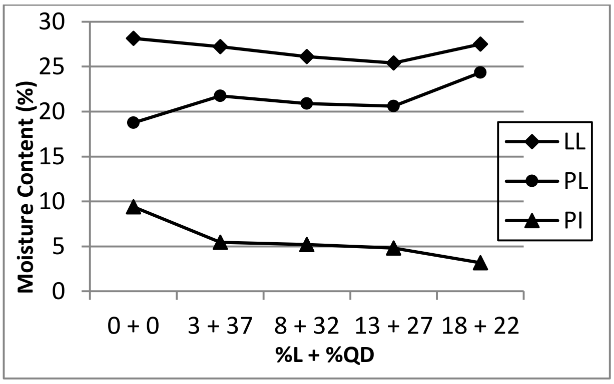

Figure 3. Variation of consistency limits of silty clay soil sample

The variation of consistency limits of silty clay soil sample is shown in figure 3. It can be seen that liquid limit decreased slightly (initially) from 28.1% to 25.4% with natural soil sample to sample having a mixture of 13% lime and 27% quarry dust. Then liquid limit increased to 27.5% in the final mixture (18% lime + 22% quarry dust). But liquid limit of final sample is still having a lower liquid limit than the natural untreated silty clay soil sample.

The plastic limit increased slightly from 18.75% to 21.73% and remained relatively constant for next two mixtures (8% L + 32% QD, 13% L + 27%QD). In the last mixture, liquid limit increased by nearly 4%. Consequently, the plasticity index decreased from a value of 9.4% to 3.18%. It can be seen that plasticity index is gradually decreasing for various mixtures with comparing to the untreated silty clay soil sample.

C. Standard Proctor Compaction Test

The OMC and MDD for different mixtures are shown in table 3 for silty clay sample. It can be seen that the optimum moisture content keeps reducing from sample 2 to sample 4. An increment of 1.83% can be seen in sample 5 with comparing to sample 4. The variations of OMC with different mixtures are shown in figure 4. It can be seen that the maximum dry density is increased from sample 2 to sample 4. A reduction of 75.66 kg/m^3 can be identified in sample 5 with comparing to sample 4. The variations of MDD with different mixtures are shown in figure 5.

Table 3. MDD and OMC values of different mixtures of lime and quarry dust for silty clay

Sample No.	%L + %QD	OMC (%)	MDD (kg/m^3)
2	3%L + 37%QD	20.92	1685.04
3	8%L + 32%QD	16.73	1772.31
4	13%L + 27%QD	15.42	1784.4
5	18%L + 22%QD	17.25	1708.74

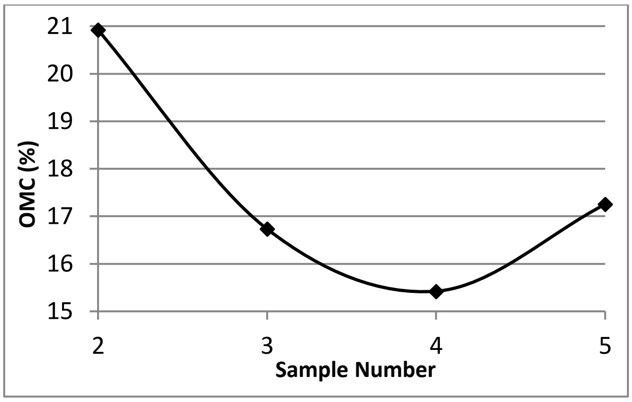

Figure 4. Variation of mixture proportions and OMC for silty clay

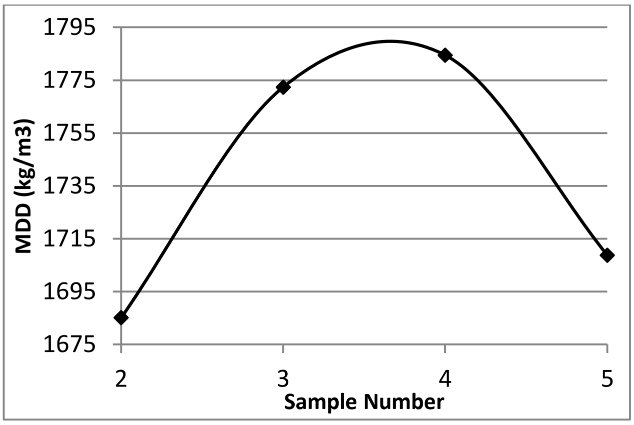

Figure 5. Variation of mixture proportions and MDD for silty clay

The sample 4 (13%L + 27%QD) has the highest value for MDD and the lowest value for OMC. It can be identified as the optimum mixture for silty clay soil. Another soil sample (sample 8) was used to verify the same mixture proportions produce the optimum values for other soils. Only mixture proportions around the peak values of MDD and OMC were taken into consideration due to time restrictions. Because of this 3%L + 37%QD was not considered for standard proctor test in sample B.

The OMC and MDD for different mixtures are shown in table 4 for silty sand sample.

Table 4. OMC and MDD for different mixtures for silty sand

Sample No.	%L + %QD	OMC (%)	MDD (kg/m^3)
9	8%L + 32%QD	16.49	1848.66
10	13%L + 27%QD	13.76	1853.1
11	18%L + 22%QD	16.29	1793.22

The variations of OMC with different mixtures are shown in figure 6. The minimum OMC and maximum MDD can be seen in the sample having 13% lime and 27% quarry dust. The variations of MDD with different mixtures are shown in figure 7.

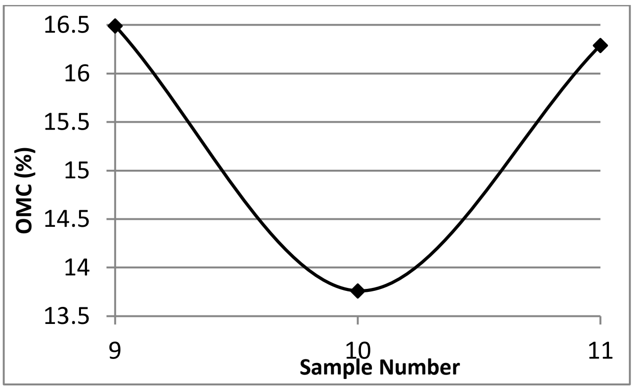

Figure 6. Variation of mixture proportions and OMC for silty sand

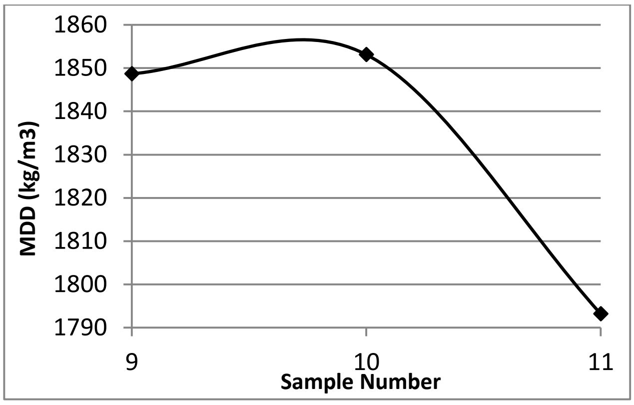

Figure 7. Variation of mixture proportions and MDD for silty sand

From the both soil types, the mixture having 13%L + 27%QD is selected as the optimum mixture. From all these tests, 11% - 13% lime and 27% - 29% quarry dust were determined as the optimum percentage ranges.

The effect of quarry dust was determined by keeping constant lime content of 13%. The mixtures used are shown in table 5.

Table 5. OMC and MDD for constant lime of 13%

Sample No.	Reference No.	%L + %QD	OMC (%)	MDD (kg/m^3)
6	1	13%L + 22%QD	19.08	1758.29
4	2	13%L + 27%QD	15.42	1784.4
7	3	13%L + 32%QD	14.70	1798.23

The OMC is keep reducing from 19.08% to 14.7% while MDD is increasing from 1758.29 kg/m^3 to 1798.23 kg/m^3. The OMC (%) was reducing with the increment of quarry dust. Figure 8 shows the variation of OMC with constant lime and increasing quarry dust percentage The MDD was increasing with the increment of quarry dust. Figure 9 shows the variation of MDD with increasing quarry dust percentage.

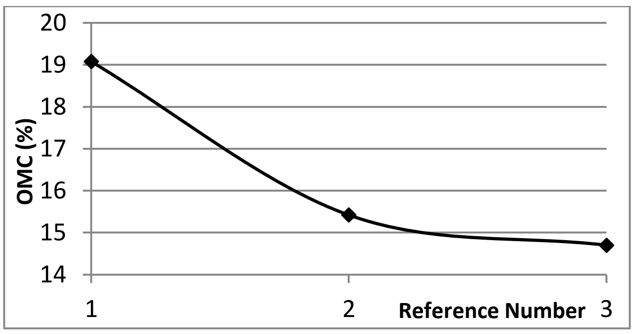

Figure 8. Variation of OMC with increasing quarry dust percentage

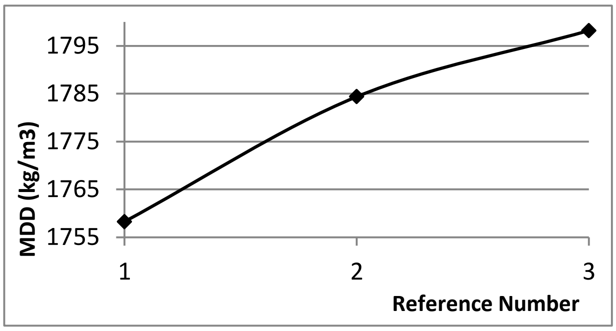

Figure 9. Variation of MDD with increasing quarry dust percentage

From the cost analysis between conventional excavation and backfilling method and soil stabilization method, It was determined that 12.5% cost can be saved by using soil stabilization method. Cost for 1m^3 of soil for both methods are given in Table 6.

Table 6. Comparison of costs of conventional method and soil stabilization method by using lime and quarry dust

	Conventional method	Soil stabilization method (13% L + 27% QD)
Cost in Rs. (1m^3 of soil)	6840.00	5983.72
Cost saving (%)	-	**12.5%**

V. Conclusions

From the analysis, it can be seen that 13% of lime and 27% of quarry dust gives considerable improvement in maximum dry density and optimum moisture content of silty clay soil. The optimum percentage ranges are determined as 11% - 13% of lime and 27% -29% of quarry dust.

Maximum dry density increases and optimum moisture content decreases considerably with addition of optimum percentages of lime and quarry dust. The improvement in maximum dry density is 8.6% compared to the natural untreated silty clay soil. The reduction in optimum moisture content is found as 36.4% with comparing to the non-treated silty clay soil.

Addition of various percentages of quarry dust while keeping lime constant at optimum percentage (13%) improves the maximum dry density and reduces the optimum moisture content.

From the Atterberg limit test, it is obtained that 9.8% reduction in liquid limit and 48.8% reduction in plasticity index. Plasticity limit is increased by 9.8% as well.

From the cost analysis between conventional excavation and backfilling method and soil stabilization method, It was determined that 12.5% cost can be saved by using soil stabilization method.

In the light of above observations, we can conclude that lime along with QD used in combination with clay possessed certain properties which enables it to be used economically for improvement of fine grained soil.

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Abbreviations

L	lime
QD	quarry dust
ESP	egg shell powder
OMC	optimum moisture content
MDD	maximum dry density
CBR	california bearing ratio
USCS	unified soil classification system
LL	liquid limit
PL	plastic limit
PI	plasticity index

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