Usage of Fly Ash, Quarry Dust and Lime for Upper Sub-Base Stabilization

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Abstract: *Soil stabilization refers to the process of changing soil properties to improve strength and durability. There are many techniques for soil stabilization including adding materials such as quarry dust, fly ash, slag cement and foundry sand to the soil (by products and natural materials). Stabilization is mainly used in construction industry for various purposes such as sub-base for road, earth filling, backfilling and etc. This research was done to determine whether wastes (by product) such as fly ash and quarry dust with the combination of lime can be used as stabilization agents for soft soils. In this investigation, different mixture proportions of above materials were used to improve the soil. Then the properties of soil including liquid limit (LL), plastic limit (PL), maximum dry density, and optimum moisture content were determined on laboratory observations. It was found that quarry dust-20%, Lime- 3.5% and Fly ash- 5% as the optimum mixture. California Bearing Ratio (CBR) test was conducted for the optimum mixture and observed behaviour of the CBR values.*

Keywords: *Quarry dust, Lime, Fly ash, stabilization, soft soils*

1. INTRODUCTION

Construction is necessary for the proper functioning and development of economic activities for any country. Making sub-base for road, earth filling and back filling are main processes in the construction industry. Soil stabilization is one of the methods of treating soft soils to make them fit for disposal of large quantities of industrial by products as fills on disposal sites adjacent to industries not only requires large space but also create a lot of geo-environment problems. Quarry dust and fly ash are waste material producing from aggregate crushing industries and making electricity power using coal. The quantities of these waste materials imposing hazardous effect on environment and public health. In order to eliminate the negative effect of these waste materials it can dispose proper and safe manner. It can be used for various construction purposes like sub grade, foundation base and embankments by blending with other construction materials like soft soils. Due to rapid industrialization there is scarcity of land having desirable soil bearing capacities. Soil stabilization is the technique which improves the properties of expansive soil to meet the engineering requirements.

Soil improvement is done worldwide by using additives. 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 soft soil. A sub base is specified as it is more relevant to stabilization than back filling and earth filling. Currently soft soil is using for these processes but to keep better compressive and shear strength with advanced bonding quality it is wise to use various additives with soft soil. Lime, Quarry dust and Fly ash were used to find out the effect on the properties of poorly graded sand in this study. Any improvement regarding compaction properties of the soil due to the addition of fly ash and quarry dust help find solution for waste materials. Also it can be utilized as proper stabilizing agents. Previous researches have conducted under stabilization behaviour of soft soil with quarry dust, fly ash and lime separately. But combination of these compounds together has not carried out so far with regard to this matter. This study can be used to understand the behaviour of this combination in construction field.

2. LITERATURE REVIEW

Prasad and Sharma (2014) evaluated that the effectiveness of clayey soil blended with sand and fly ash for soil stabilization by studying the sub-grade characteristics. The purpose of this work was to find a solution for proper disposal of fly ash and also to provide good sub-grade material for pavement construction. The results showed that substantial improvement in compaction and CBR of composite containing clay, sand and fly ash. The swelling of the clay also reduced after stabilization. The Maximum Dry Density (MDD) of clay-sand-fly ash mix decreased with the addition of fly ash and Optimum Moisture Content (OMC) was increased. Thus the stabilized soil can be used for construction of flexible pavements in low traffic areas.

Satyanarayana et al (2013) conducted plasticity, compaction and strength tests on gravel soil with various percentages of stone dust and found that by addition of stone dust plasticity characteristics were reduced and CBR of the mixes improved. Addition of 25-35% of stone dust made the gravel soil meet the specification of Ministry of Road Transport and Highways (MORTH) as sub-base material.

Ali and Koranne (2011) presented the results of an experimental programme undertaken to investigate the effect of stone dust and fly ash mixing in different percentages on expansive soil. It was observed that at optimum percentages, i.e., 20 to 30% of admixture, the swelling of expansive clay is almost controlled and there was a marked improvement in other properties of the soil as well. It was concluded by them that the combination of equal proportion of stone dust and fly ash was more effective than the added of stone dust/fly ash alone to the expansive soil in controlled the swelling nature.

Phanikumar and Sharma (2004) conducted an experimental programme in order to determine the effect of fly ash on engineering properties of expansive soils. In this study, fly ash used in a range of 0%- 20% from dry weight of the soil with an increment of 5%. It was found a reduction in both plasticity characteristics and Free Swell Index (FSI) when increasing the fly ash content. The results showed an increment in mean CBR value when using 5% and 10% lime but 15% lime showed a reduction in mean CBR value. From this study, it was found that the addition of 10% lime is the best way to stabilize the soil.

Erdal Cokca (2001) studied the effect of fly ash on expansive soil. The fly ash contents between 0% and 25% were used with expansive soil for this study. The specimens were cured for 7 days and 28 days after which they were subjected to Odometer free swell tests. At the end of this study, it was found that both high calcium and low calcium class C fly ashes can be used as stabilizing agents in order to improve expansive soils.

3. MATERIALS AND METHODS

3.1. Materials Used

3.1.1. Soil

The sample used in this study was collected from Hettipola, Wilgamuwa, and Matale. The sample was thoroughly oven dried (105°C) and stored in sacks at room temperature. The soil was tested for liquid limit, plastic limit, and optimum moisture content, maximum dry density and CBR values. The general properties obtained for the soil sample were tabulated in Table 1.

Table 1 General soil properties of soil sample

Property of Soil	Value
Index properties	
Liquid Limit (%)	30.6
Plastic Limit (%)	22.8
Plasticity Index (%)	7.8
Engineering properties	
Optimum Moisture Content (%)	12.5
Maximum Dry Density (g/cm^3)	1.893
California Bearing Ratio (soaked)	13

3.1.2. Lime (L)

Lime was purchased from the available local market. Quick lime (CaO) was the type of lime that used in this study.

3.1.3. Quarry Dust (QD)

The quarry dust used was collected from a construction site in General Sir John Kotelawala Defence University, Rathmalana, Sri Lanka.

3.1.4. Fly Ash (FA)

The fly ash used in this investigation was brought from Norochcholai power plant and Holcim factory, Galle, Sri Lanka.

3.2. Test Methods

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

- Particle size distribution test
- Atterberg limit test
- Standard proctor compaction test
- California bearing ratio test

Soil classification was done by using particle size distribution test (sieve analysis) and atterberg limit test. Soil was classified according to the Unified Soil Classification System (USCS). Soil mixed with quarry dust from 0% to 25% at an increment of 5%. Fly ash from 0%, 5% and 10% and lime mixed from 0% and from 1.5% to 4.5%. The proportions of QD, L & FA used for the experiments are shown in Table 2.

Table 2 Soil mix proportions

Soil Sample no.	QD (%)	L (%)	FA (%)
01	0	0	0
02	10	1.5	5
03	10	1.5	10
04	15	2.5	5
05	15	2.5	10
06	20	3.5	5
07	20	3.5	10
08	25	4.5	5
09	25	4.5	10

Standard proctor tests were conducted for soil samples according to the above given mixtures. And CBR test was conducted for the optimum mixture selected from the results of standard procter compaction test.

4. RESULTS AND DISCUSSION

4.1. Particle Size Distribution Test

Particle size distribution curve for the soil sample used in this study is shown in Figure 1.

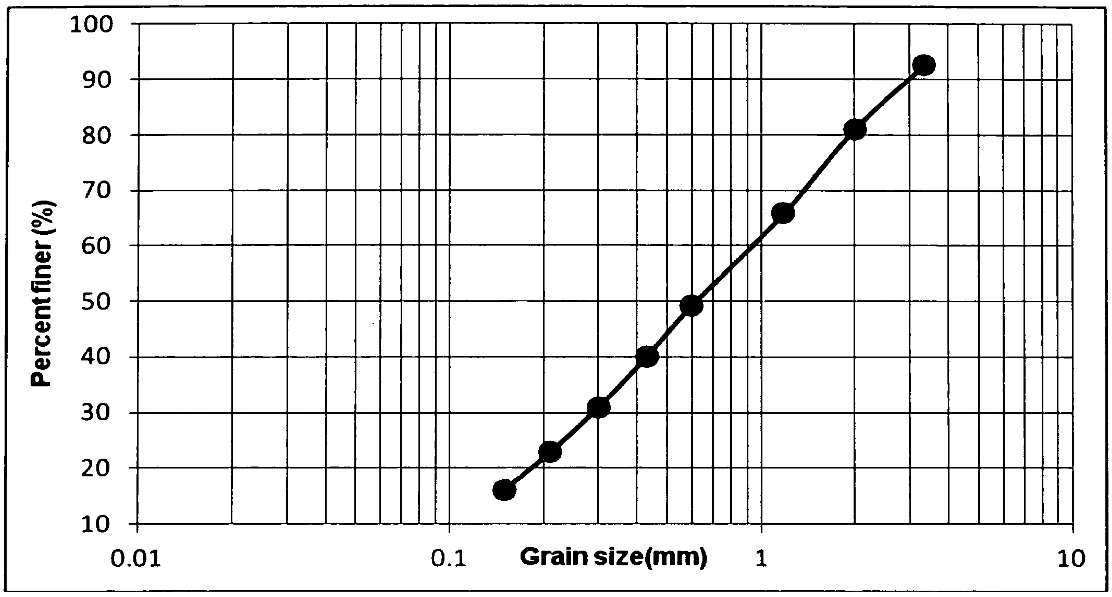

Figure1 Particle size distribution curve for soil sample

4.2. Plasticity Characteristics

The liquid limit and plasticity index (PI) of the conventional soil shows that the soil is a clay with intermediate plasticity (SP) as per the plasticity chart given in BS 1377 (part 4). The LL, PL and PI variations for various soil samples are shown in Figure 2.

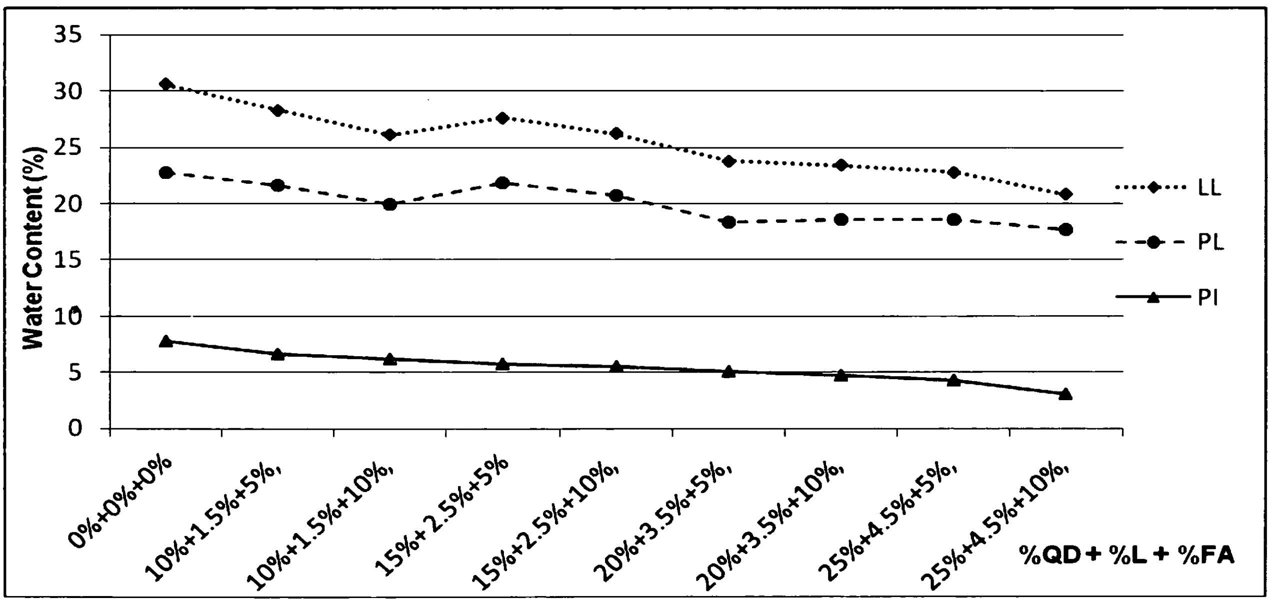

Figure 2 Plasticity Characteristics

The plasticity index is decreased from a value of 7.8% to 3.1%. It can be seen that plasticity index is gradually decreasing for various mixtures compared to the untreated soil sample.

4.3. Compaction Characteristics

The relationship between moisture content and dry density of a given soil is determined by standard proctor test as per BS 1377 (Part-4). The optimum moisture content and maximum dry density for different mixtures are shown in Table 3 for treated and untreated soil samples.

Table 3 OMC and MDD values of different soil mixtures

Sample no.	QD%+L%+FA%	MDD (g/cm^3)	OMC (%)
01	0% + 0% +0%	1.93	12.5
02	10%+1.5%+5%	2.00	11.8
03	10%+1.5%+10%	1.98	12.6
04	15%+2.5%+5%	2.00	11.7
05	15%+2.5%+10%	1.982	12.1
06	20%+3.5%+5%	2.035	11.2
07	20%+3.5%+10%	2.020	11.7
08	25%+4.5%+5%	2.018	11.5
09	25%+4.5%+10%	2.001	11.8

The minimum OMC is found in sample 06 and the value is 11.2%. A 10.4% reduction can be seen in sample 06 compared to untreated soil sample (sample 01). The variations of OMC with different mixtures are shown in Figure 3.

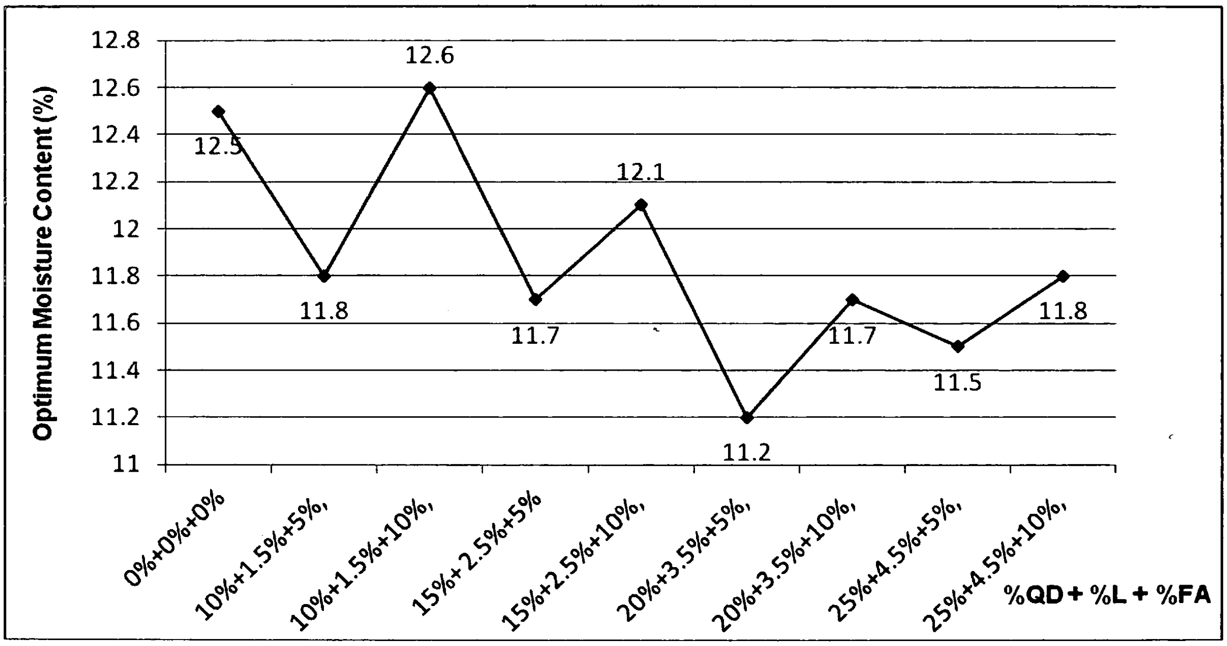

Figure 3 Variation of OMC with different soil mixtures

The maximum MDD is found in sample 06 and the value is 2.035 g/cm^3. A 5.44% increment can be seen in sample 06 compared to untreated soil sample (sample 01). The MDD value is increased due to the reduction of void percentage in the sample. The variations of MDD with different mixtures are shown in Figure 4.

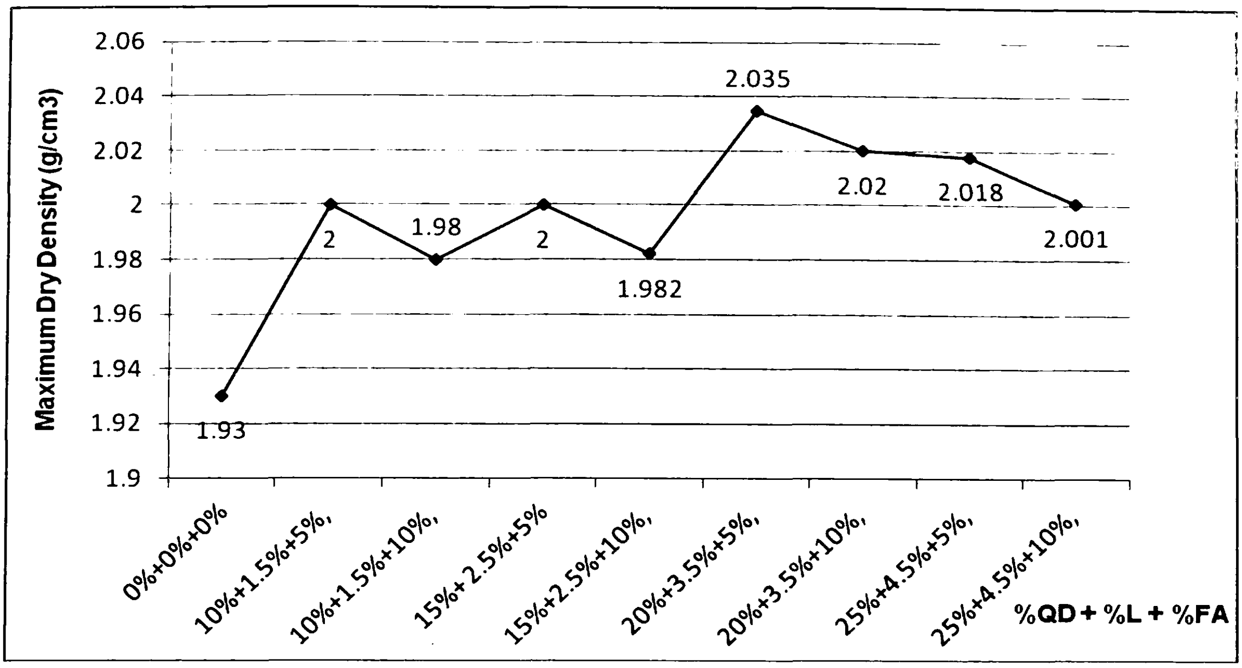

Figure 4 Variation of MDD with different soil mixtures

4.4. Comparison of California Bearing Ratio (CBR) Values

CBR test conducted for both the untreated soil sample (sample 01) and treated soil sample compacted to optimum moisture content obtained from the standard proctor test as per BS 1377 Part 4. The California Bearing Ratio values for sample 01 and sample 06 are shown in Table 4

Table 4 CBR test results

Sample no.	QD%+L%+FA%	CBR Value
01	0% +0% +0%	13
06	20%+3.5%+5%	194

It can be seen that the increment in CBR value from 13 to 194 in sample 01 and sample 06 respectively. From these values, the effect of percentage reduction in void ratio on CBR value in soil+ quarry dust- 20% + lime -3.5% + fly ash- 5% can be identified clearly.

5. CONCLUSION

The following conclusions can be drawn on the basis of the results and discussion made in this study.

The values of LL and PL are always lower than the LL and PL values in the untreated natural soil sample. Plasticity Index is reduced gradually with the addition of additives compared to the untreated soil sample.

It has been observed that the increment in fly ash content more than 5% reduce the compacting quality or the MDD value.

From the analysis, it is obtained that soil with 3.5% lime, 20% quarry dust and 5% fly ash gives considerable change in maximum dry density and optimum moisture content of the natural soil. The increment in MDD is found as 5.44% and the reduction in OMC is found as 10.4% compared to the natural soil.

The MDD and CBR values are greater than the value required for the upper sub base according to the ICTAD. It has been proven with laboratory experiments that the optimum mixture (20% QD+ 3.5% L+ 5% FA) is well suited for Upper Sub-base construction.

6. ACKNOWLEDGMENT

The first author wishes to acknowledge the contributions of technical officers and lab attendants of Soil Mechanics laboratory of General Sir John Kotelawala Defence University, Road Development Authority and Central Engineering Consultancy Bureau during the laboratory testing programme.

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