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Quarry Dust as an Auxiliary Additive to Lime Stabilized Expansive Soil in Subbase

S. Srikanth Reddy, A.C.S.V. Prasad

Abstract*: Various researchers tried stabilizing expansive soil with different materials viz. lime, cement, fly ash etc., for the last few decades to improve various properties of soil. Of these, lime stabilization is the best stabilization technique for expansive soil. Lime stabilization of expansive soils involves various physico-chemical reactions which results in reduction of plasticity of the soil. However, the cost of lime stabilizer, in present days, has increased resulting in surge of project cost which led to need for alternative and cost effective waste materials. Quarry dust, one among the alternative materials, is a waste material produced at rock crushing plants. The objective of the study is to investigate the utilization of quarry dust as a suitable proportioning additive to lime stabilized expansive soil for making the resulting mix a cost cutting and effective subbase material. Expansive soil which is procured from the local area, is found to be high plastic in nature. In addition, upon testing, it is found unsuitable for use as subbase material based on CBR value as per MORTH. The soil is then stabilized with lime to make it non-plastic. Then the quarry dust (QD) is proportioned with lime stabilized expansive soil (LS) to obtain optimum mixture that yields a better CBR value. The mix proportions of 60%LS+40%QD, 40%LS+60%QD, and 20%LS+80%QD under study resulted in increase in the CBR value by about 18.3, 21.6, and 24.7 times in comparison with expansive soil. Thus, it is promising to use the quarry dust as suitable additive to lime stabilized expansive soil for using the mix as subbase material in flexible pavements.

***Index Terms*: Quarry dust, Expansive soil, Proportioning, Soaked CBR.**

I. INTRODUCTION

Expansive soils are the soils known for their extreme swelling and shrinkage behaviour, because of the presence of mineral montmorillonite. These soils swell, when they imbibe water and are shrunk, when they lose water. In addition, in the presence of water they lose their strength. Often roads constructed on these expansive soils are susceptible to huge deformations. Hence there is a need for improvement of in-situ expansive soils to make them suitable for use in pavements as subbase material. Stabilization, one best known technique from past few decades, helps in improvement of behaviour of expansive soils. Stabilization of expansive soils using lime, cement, fly ash, rice husk ash, brick powder etc., are successfully attempted by various researchers [1]-[7]. Of these various stabilizations, lime stabilization is the best technique to treat expansive soils. Addition of lime to expansive soils results in short-term and long-term reactions. Short-term reactions of lime stabilization involves processes of hydration and flocculation and long-term reactions involve processes of cementation and carbonation of soil particles [8]. The objective of addition of lime to expansive soil in the present study is to allow only for short term reactions namely, hydration and flocculation. Hydration, which involves reaction of Calcium Oxide, CaO (also known as Quick lime) with water, results in formation Calcium Hydroxide, $Ca(OH)_2$. Flocculation stage involves exchange of calcium ions with sodium and other cations adsorbed to clay minerals resulting in the deterioration of whole clay mineral structure without the formation of substantial new crystalline phases [9]. This stage also makes the particles of expansive soil non-plastic. In recent days, the cost of lime is increasing and relying only on lime for stabilization in turn increases the cost of project. As lime stabilization makes the expansive soil non-plastic, adding other cost effective suitable material not only reduces the cost but may also result in best suitable material for use in subbase of pavements.Quarry dust is one such material, produced during crushing of rocks at rock crushing plants to produce coarse aggregate and is available at cheaper costs. It is a granular material containing majorly of sand sized angular particles. The amount of quarry dust generated is about 20 to 30 percent of rock crushed depending on type of rock [10]-[11]. At present, quarry dust is being used as an admixture to lateritic soils [10], as filler in basement of buildings, and as an alternative fine aggregate in concrete making [12]. Also, potential use of highest quantities of quarry dust is identified by researchers in cement treated subbase and flowable fill [13]. In present days, rock flour is also being used as frictional fill reinforced soil structures [11]. Recent studies showed the use of quarry dust for stabilizing expansive soils [14]. But, merely using quarry dust alone for stabilization doesn't result in effective mixing of both the materials because of high plastic nature of expansive. Stabilization of expansive soil by lime reduces the plasticity characteristics and mixing the lime stabilized expansive soil with rock flour will result in effective mixing. Also, it results in reduction of cost and utilization of quarry dust, a waste material, in an effective manner. Hence in the present study lime stabilized expansive soil is mixed in different proportions with quarry dust to obtain a stable and cost economic mix proportion suitable for use as subbase material in pavements.

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* Correspondence Author
S. Srikanth Reddy*, Assistant Professor, Department of Civil Engineering, S R K R Engineering College, Bhimavaram, India.
A.C.S.V. Prasad, Associate Professor, Department of Civil Engineering, S R K R Engineering College, Bhimavaram, India.

II. PROPERTIES OF MATERIALS USED IN THE STUDY

A. Expansive Soil

Expansive soil, procured from Bhimavaram of Andhra Pradesh, India, is tested in laboratory to assess its properties. The results obtained from the tests are presented in Table I.

Table I Properties of Expansive soil

Engineering Property	Value
Specific Gravity	2.67
Grain Size Analysis a) Gravel Size (%) b) Sand Size (%) c) Fines (%)	 0 3 97
Plasticity Characteristics a) Liquid Limit (%) b) Plastic Limit (%) c) Plasticity Index (%)	 69 32 37
IS Classification	CH
Differential Free Swell (DFS) Index (%)	110
Maximum Dry Density (g/cc) IS Light Compaction Optimum Moisture Content (%)	1.36 33
Soaked CBR (%)	1.17

It is evident from Table 1 that the soil used in the study has a DFS value greater than 100%. Hence it is having higher degree of expansion as per IS:1498-1970(R2007). Also the soaked CBR of the soil is 1.17%, which does not meet the standard for use as subbase material as per MORTH.

B. Quarry Dust

Quarry dust (QD) used in the study is procured from a local source. Various tests are carried out to determine the properties of quarry dust. The results so obtained from the tests are presented in Table II.

Table II Properties of Quarry Dust

Engineering Property	Value
Grain Size Analysis a) Gravel Size (%) b) Sand Size (%) c) Fines (%)	 3 74 23
Plasticity Characteristics	NP
IS classification	SM
Maximum Dry density(g/cc) IS Light Compaction Optimum Moisture Content (%)	1.98 13%
CBR (%)	33.33%

III. LIME STABILIZATION OF EXPANSIVE SOIL

Expansive soil with high degree of expansion, under study is mixed with lime in varying proportions of 2%, 4%, and 6%. The lime mixed soil is then cured, by sprinkling water, for a duration of 3 days. The lime-soil mixture is then oven-dried for 1 day after curing. The oven dried lime-soil mixture is then tested to determine its plasticity characteristics, compaction characteristics, differential free swell index, and CBR value and the details of the results are presented in Table III.

Table III Properties of lime stabilized soil

Engineering Property	2% LS	4% LS	6% LS
Plasticity Characteristics a) Liquid Limit (%) b) Plastic Limit (%) c) Plasticity index (%)	54 36 18	NP	NP
Differential Free Swell (DFS) Index (%)	90	40	30
Maximum Dry density (g/cc) IS Light Compaction Optimum Moisture Content (%)	1.40 28	1.51 25	1.44 31
CBR (%)	7.59	8.52	6.62

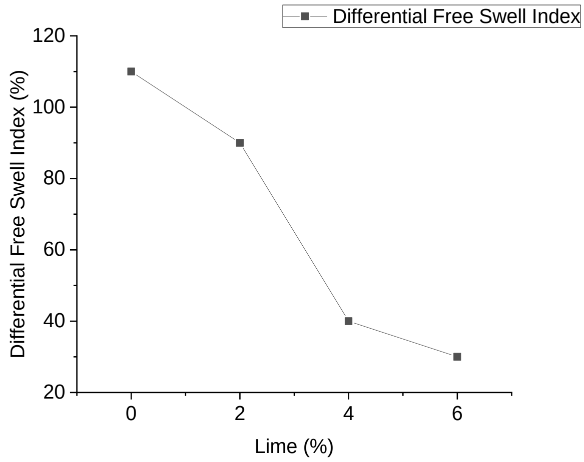

Figure 1. Variation of differential free swell index with varying content of lime

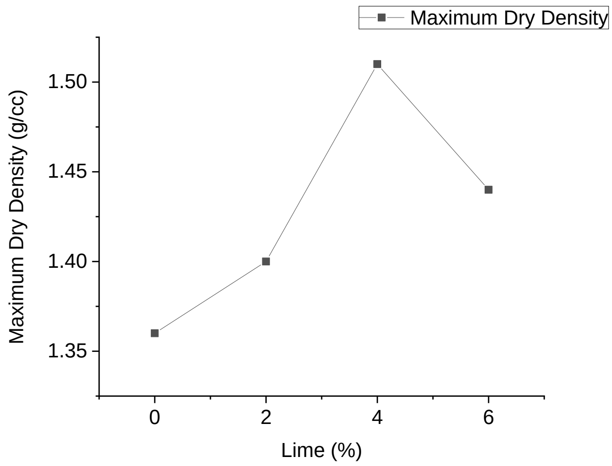

Figure 2. Variation of maximum dry density with varying content of lime

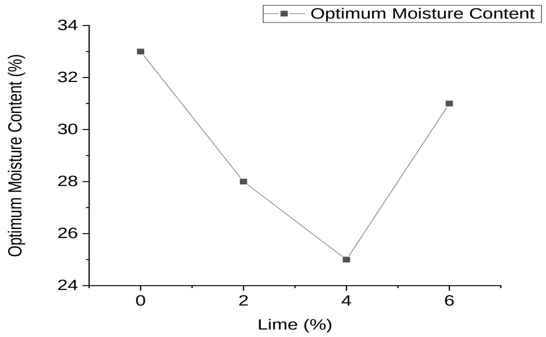

Figure 3. Variation of optimum moisture content with varying lime content

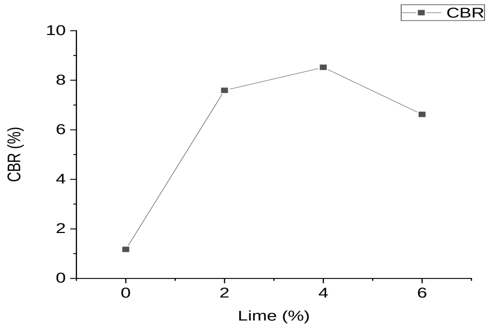

Figure 4. Variation of soaked CBR value with varying lime content

The plasticity characteristics of the expansive soil decreased with increased lime content from 0% to 2% and from 4% lime content the soil behaved as a non-plastic soil. From Fig 1., it is evident that as the lime content is increased, the differential free swell index of the expansive soil under study is reduced from 110% at 0% lime content to 30% at 6% lime content. The maximum dry density of lime-soil mixtures increased from 1.36 g/cc at 0% lime content to 1.51 g/cc at 4% lime content and thereafter it decreased to 1.44 g/cc at 6% lime content, as observed from Table III. In addition, it can be observed that the optimum moisture content of lime-soil mixture showed a decrease from 33% at 0% lime content to 25 % at 4% lime content and thereafter it increased to 31% at 6% lime content. Soaked CBR value, as observed from Fig 4, improved from a value of 1.17% at 0% lime content to a value of 8.52% at 4% lime content and then it reduced to a value of 6.62% at 6% lime content. From the compaction characteristics and CBR value of different lime-soil mixtures, the optimum content of lime to be added for expansive soil under study is identified to be 4%, as it accounted for orientation of particles to dense state and making the expansive soil non-plastic.

IV. PROPORTIONING OF LIME STABILIZED EXPANSIVE SOIL AND QUARRY DUST

The expansive soil stabilized with 4% lime is then mixed with quarry dust in various proportions namely, 80%LS+20%QD, 60%LS+40%QD, 40%LS+60%QD, and 20%LS+80%QD. These different mix proportions are tested in laboratory to determine compaction characteristics and soaked CBR value. The results of the tests are tabulated in Table IV.

Table IV Properties of quarry dust and lime stabilized soil

Engineering Property	80%LS+ 20%QD	60%LS+ 40%QD	40%LS+ 60%QD	20%LS+ 80%QD
Maximum Dry density (g/cc) (IS Light Compaction)	1.67	1.78	1.96	2.01
Optimum Moisture Content (%) (IS Light Compaction)	20	18	15	14
Soaked CBR (%)	13.75	21.42	25.34	28.91

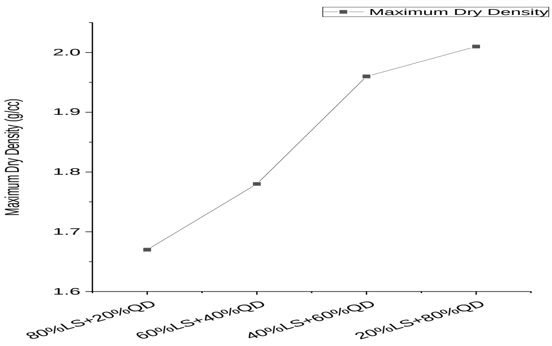

Figure 5 Variation of maximum dry density with varying proportions of LS and QD

Fig 5. shows the variation of maximum dry density for different mix proportions of LS and QD. The variation of optimum moisture content for different LS and QD mix proportions is graphically represented in Fig 6. The increase in soaked CBR value for different LS and QD mix proportions can be inferred from Fig 7.

V. DISCUSSION

With varying mix proportions of lime stabilized expansive soil and quarry dust, the maximum dry density and soaked CBR values of the LS and QD mix increased from 1.67 g/cc for 80%LS+20%QD to 2.01 g/cc for 20%LS+80%QD. This is attributed to quarry dust, having higher dry density, being used in the mix proportions.

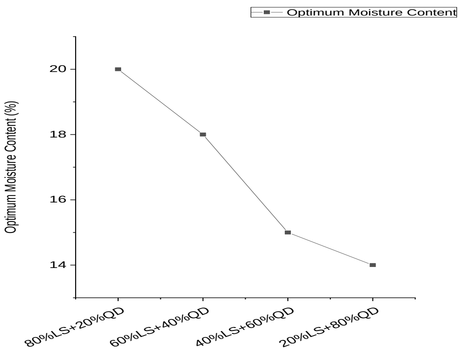

Figure 6 Variation of optimum moisture content with varying proportions of LS and QD

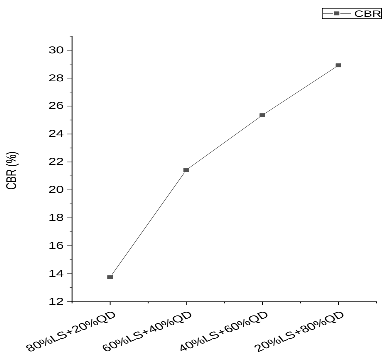

Figure 7 Variation of soaked CBR value with varying proportions of LS and QD

The optimum moisture content of lime stabilized expansive soil and quarry dust mix showed a decline in the value from 20% for 80%LS+20%QD to 14% for 20%LS+80%QD. This is due to lower optimum moisture content of quarry which is mixed in varying contents to different proportions of lime stabilized expansive soil.

Among the mix proportions of lime stabilized expansive soil and quarry dust tested in the study, mix proportions of 60%LS+40%QD, 40%LS+60%QD, and 20%LS+80%QD showed soaked CBR values of 21.42%, 25.34% and 28.91% respectively. These values satisfy the minimum required value of soaked CBR of 20% as per MORTH for subbase.

VI. CONCLUSION

The concept of mix proportions of lime stabilized expansive soil and quarry dust resulted in the following conclusions:

- Mixing lime stabilized soil and quarry dust resulted in improvement of maximum dry density and soaked CBR value and reduction in optimum moisture content values.
- Mix proportions of 60%LS+40%QD, 40%LS+60%QD, and 20%LS+80%QD resulted in increase of soaked CBR by about 18.3, 21.6, and 24.7 times the soaked CBR of expansive soil, thereby satisfying the minimum value required for use as subbase material.
- The different mix proportions of lime stabilized soil and quarry dust namely, 60%LS+40%QD, 40%LS+60%QD, and 20%LS+80%QD, can be selected depending upon the availability of quarry dust at the site and required soaked CBR value.

Hence, it is satisfactory to use quarry dust as an auxiliary additive to lime stabilized expansive soil for using the mix as subbase material for pavements in areas with its abundancy.

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AUTHORS PROFILE

S. Srikanth Reddy, M.E. (Soil Mechanics and Foundation Engineering), B.E. (Civil Engineering). He published 11 research papers in various international and national journals and conferences. He is active member of Indian Geotechnical Society.

Dr. A. C. S. V. Prasad M.Tech (Geotechnical Engineering and Ph.D in Civil Engineering. He published 20 research papers in various international and national journals and conferences. He is active member in Indian Geotechnical Society and Institute of Engineer's India.