IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 6 Ver. V (Nov. - Dec. 2015), PP 104-110
www.iosrjournals.org

Study on Geotechnical Properties of Stabilized Expansive Soil-Quarry Dust Mixes

H.Venkateswarlu[1], Dr DSV Prasad[2], Dr.GVR Prasada Raju[3]
[1]*(M. Tech. Student, Dept of civil Engineering, BVC Engg College/ JNTU Kakinada, Andhra Pradesh, India)*
[2]*(Principal& HOD of Dept of civil Engineering, BVC Engg College/ JNTU Kakinada, Andhra Pradesh, India)*
[3]*(Professor, Dept of civil Engineering, Registrar, JNT University Kakinada, Andhra Pradesh, India)*

Abstract: *The population growth, industrialization, consumerism and technological development have led to uncontrollable accumulation of waste. Proper waste disposal is of great importance in both rural and urban areas. This study discussed the suitability of waste material that is quarry dust for stabilization of expansive soil. Quarry dust is mixed with expansive soil sample in different proportions and their influence on geotechnical properties of expansive soil were studied. In this paper, the test results such as shear strength parameters, soaked CBR and differential free swell obtained on expansive clays mixed with different proportions of Quarry dust are presented. Also the performance of quarry dust treated expansive soil is discussed on the basis of cyclic plate load test criteria. From the results, it is observed that at optimum percentage, i.e., 10% quarry dust, there is a marked improvement in the strength of soil.*

Keywords: *Expansive soil, Quarry dust, Shear strength parameters, Soaked CBR, Cyclic plate load test, Deformations.*

I. Introduction

The availability of buildable land is decreasing day by day in India due to population growth, rapid industrialization and scarcity of land with good natural bearing capacity. This leads to construction of buildings on poor soils which eventually lead to structural foundation failures. The expansive soils are the one which are more problematic for construction and are predominantly available in majority places in Andhra Pradesh. These soils undergo swelling and shrinkage as the moisture content changes in it. Due to high swelling and shrinkage, these soils pose lot of problems to the structures founded on them. For a safe construction, it is necessary to improve the quality of ground by adopting some suitable ground improvement techniques. Many innovative foundation techniques have been devised as a solution to the problem of expansive soils. The selection of any one of the technique is to be done after detailed comparison of all techniques and adopting a well suited technique for the particular system. Lime and Cement are commonly used as stabilizers for altering the properties of expansive soils. From the recent studies, it is observed that solid waste materials such as Quarry dust and flyash are used for this intended purpose with or without lime or cement.

Quarry dust is a waste material produced from aggregate crushing industries. 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, these can be disposed in a proper and safe manner. Also to ensure a more economically viable disposal, these are blended with other construction materials like clayey soil then it can be used best for various construction purposes like sub grade, foundation base and embankments. Quarry dust exhibits high shear strength which is highly beneficial for its use as a geotechnical material **Soosan et al., (2001a)**. It has a good permeability and variation in water content does not seriously affect its desirable properties.

II. Review Of Literature

Various researchers have been done research on Quarry dust for stabilization of Expansive soils, like

Naman Agarwal (2015) carried out tests such as compaction, specific gravity and CBR in the laboratory on expansive clays with different proportions of stone dust by dry weight of soil and from the test results, addition of stone dust to BC soil decreases its OMC and increases MDD, CBR value increased nearly by 50% by adding 30% stone dust and is found to be optimum. **Akanbi and Job (2014)** done research on suitability of stabilized black cotton soils with cement and quarry dust for road subbase and foundations by mixing with 0-6% cement and 0-20% quarry dust by weight of dry soil. The laboratory tests like California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS) and compaction and from the test results, there is an improvement in the Atterberg's limit of the soil, decrease in the plasticity index (PI), liquid limit (LL), plastic limit (PL) and an increase in maximum dry density (MDD) with increase in quarry dust content in all cement proportions used and as compared with the values obtained from the natural soil. It was also observed that as QD increased the UCS and CBR values of the stabilized black cotton soil increased with compactive effort. The peak UCS value of 1880kN/m^2 was obtained for soil stabilized with 6% cement and 20% QD contents and 186% for CBR. The economic analysis from this research reveals that stabilized black cotton soil with 6% cement and 20% QD results in savings of approximately 20% cost compared with the only cement stabilized soil. **Arun Kumar, Kiran B. Biradar (2013)** studied the effect of quarry dust mixed in different % of expansive soil. Atterberg's limits and compaction and CBR tests were carried out on both unmodified and modified soil. From the experimental results, addition of the Quarry dust to the soil reduces the clay content and thus increases the percentage of coarser particles, reduces the Liquid limit by 26.86% and plasticity index by 28.48% of unmodified soil and OMC of soil is decreased by 36.71%, Maximum dry density of soil is increased by 5.88% by addition of (40%) Quarry dust and it is also identified that addition of (40%) Quarry dust yields high CBR value. **Sridharan et al., (2006)** studies the effect of shear strength on soil-quarry dust mixtures. The results showed that the quarry dust proved to be a promising substitute for sand and can be used to improve the engineering properties of soils. The dry density increased with the addition of quarry dust and decrease in the optimum moisture content. **Sridharan et al., (2005),** studied the effect of quarry dust on geotechnical properties of soil used in highway construction and concluded that the CBR value steadily increased with increase in percentage of quarry dust and the improvement in CBR value can be contributed to the significant improvement in angle of shearing resistance. Higher CBR values of soil-quarry dust mixes enhance their potential for use as a subbase for flexible pavement. Quarry dusts are considered as one of the well accepted as well as cost effective ground improvement technique for weak soil deposits. They provide the primary function of reinforcement and drainage, and thus improve the strength and deformation characteristics of weak soil deposits.

In the present work, an attempt was made by using Quarry dust (stone dust) as stabilization material in expansive soil. In this investigation different laboratory experiments like differential free swell, Shear strength parameters, soaked CBR and cyclic load tests conducted on stabilized expansive soil with different percentages of quarry with a view to find the optimum percentage of Quarry dust. Also presented cyclic load test results conducted on model flexible pavement systems to know the performance of stabilized expansive soil with different percentages of (0%, 5%, 10% and 15%) Quarry dust.

III. Materials Used

3.1 Black Cotton Soil

The soil used in this project is a black cotton soil collected from Tummalapalli village, near Amalapuram in East Godavari District of Andhra Pradesh State in India. The black cotton soil was collected by method of disturbed sampling after removing the top soil at 150mm depth and transported to the laboratory. The soil was air dried and sieved with is sieve 4.75mm as required for laboratory test shown in fig.3.1. The index and engineering properties of the black cotton soil were determined as per IS codes and are presented in table-3.1.

3.2 Quarry Dust

Quarry Dust for this study was collected from Rajahmundry, East Godavari District of Andhra Pradesh, India. The Index and Engineering properties of the Quarry dust were determined as per IS codes and are presented in Table.3.2. The Quarry dust was air dried and sieved with IS sieve 4.75mm as required for laboratory test shown in Fig.3.2.

Fig.3.1: Expansive Soil

Fig.3.2: Quarry Dust

Table: 3.1Properties of Expansive soil

Laboratory Test	Symbol	Results	Relevant IS Codes
Atterberg's limits			
Liquid Limit	W_L	89%	IS 2720 Part V
Plastic Limit	W_P	41.26%	IS 2720 Part V
Plasticity Index	PI	47.73%	IS 2720 Part V
Specific Gravity	G	2.70	IS 2720 Part III
Grain Size Analysis			
Coefficient Of Uniformity	Cu	7.77	IS 2720 Part IV
Coefficient Of Curvature	Cc	2.05	IS 2720 Part IV
Compaction Parameters			
Optimum Moisture Content	OMC	28.5%	IS 2720 Part VIII
Maximum Dry Density	MDD	18kN/m^3	IS 2720 Part VIII
California Bearing Ratio(Un Soaked)	CBR	3.00	IS 2720 Part XVI
California Bearing Ratio(Soaked)	CBR	1.20	IS 2720 Part XVI
Shear Strength Parameters			
Cohesion	C	16kN/m^2	IS: 2720 Part-13-1986
Angle Of Shearing Resistance	Ǿ	19^0	IS: 2720 (Part-10)-1991
Unconfined Compressive Strength	UCS	53.46kN/m^2	IS 2720 Part X
Differential Free Swell	DFS	100	IS 2720 Part XI

Table: 3.2Properties of Quarry Dust

Laboratory Test	Symbol	Result	Relevant IS Code
Atterberg's Limits			
Liquid Limit	W_L	NA	IS 2720 Part V
Plastic Limit	W_P	NA	IS 2720 Part V
Specific Gravity	G	2.52	IS 2720 Part III
Compaction Parameters			
Optimum Moisture Content	OMC	12.16%	IS 2720 Part VIII
Maximum Dry Density	MDD	15.56 kN/m^3	IS 2720 Part VIII
California Bearing Ratio (unsoaked)	CBR	7	IS 2720 Part XVI
Grain Size Analysis			
Coefficient of Uniformity	Cu	9	IS 2720 Part IV
Coefficient Of Curvature	Cc	2.45	IS 2720 Part IV

IV. Experimental Investigation

In Order to determine the effect of Quarry dust on strength behavior, different percentages of Quarry dust were mixed in expansive soil upto a maximum of 15% at an increment of 5%. In total, four mixes were prepared. Differential free swell test, California Bearing Ratio test under soaked condition and direct shear test were conducted on these mixes as per Indian Standard Codes for finding optimum percentage of Quarry dust material. This investigation is further carried out by constructing laboratory model flexible pavements for Expansive soil and stabilized expansive soil with different percentages of Quarry dust. Cyclic plate load tests were carried out on the pavement system to find out load bearing (carrying) capacity.

4.1 Differential Free Swell Test:

Standard procedures recommended in the respective I.S. Codes of practice [IS: 2720 (Part-4)-1965], were followed while finding the Differential free swell of the samples in this investigation.

4.2 Direct Shear Test:

The direct shear test were conducted in the laboratory as per IS Code (IS: 2720 (Part-13)-1986) as shown in Fig. 4.1. The required percentage of quarry dust by dry unit weight of soil was mixed uniformly with the soil. The soil was compacted to maximum dry density (MDD) of untreated soil. The specimens were tested in a 6 cm × 6 cm square box at different normal stresses (N/mm^2) for each percentage of quarry dust with expansive soil and sheared at a rate of 1.25 mm/min.

4.3 California Bearing Ratio (CBR) Test:

In present investigation CBR test was carried out on prepared soil samples of Untreated Expansive soil and treated Expansive soil with various percentages of Quarry dust under soaked condition as per recommendations in IS 2720 part XVI-1987 as shown in the fig.4.2.

Fig.4.1: Direct Shear Test Apparatus

Fig.4.2: California Bearing Ratio Test Apparatus

4.4 Cyclic Load Tests on Laboratory Model Flexible Pavements:

Cyclic plate load tests were conducted on prepared model flexible pavement systems with untreated and treated expansive soil with different percentages of quarry dust in a mild steel tank and details of preparation of model tank as described below:

The expansive soil used in this study was brought from Tummalapalli village was allowed to dry and then pulverized to small pieces with wooden rammers and sieved through 4.75mm sieve. Then it was compacted to 2.0 cm thickness in 15 layers to a total thickness of 30 cm to its optimum moisture content and maximum dry density in mild steel test tank of diameter 60 cm as shown in Fig.4.3.

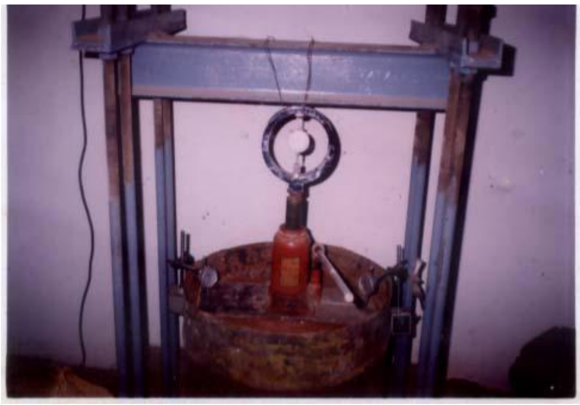

Fig.4.3: Experimental Set Up For Cyclic Plate Load Test

The loading was done through a circular metal plate of 10 cm diameter laid on flexible pavement system. The steel tank was placed on the pedestal of the compression testing machine. Five ton capacity proving ring was connected to the loading frame and the extension rod welded to the circular plate was brought in contact with proving ring. Two dial gauges of least count 0.01 mm were placed on the metal flats welded to the vertical rod to measure the vertical displacements of the loading plate. The load is applied in increments corresponding to tyre pressures of 300, 350,400,450,500,550 and 600kPa and each pressure increment was applied cyclically until there was insignificant increase in the settlement of the plate between successive cycles. The testing was further continued till the occurrences of failure to record the ultimate loads. All these tests were conducted at OMC and MDD.

V. Results And Discussions

5.1 Differential Free Swell Test:

The differential free swell tests were conducted as per IS: 2720 (Part-4)-1965 in the laboratory for all the Expansive soil samples treated with different percentages of quarry dust. The differential free swell of expansive soil was found to be decreased from 100 to 72 with the addition of quarry dust shown in Fig.5.1

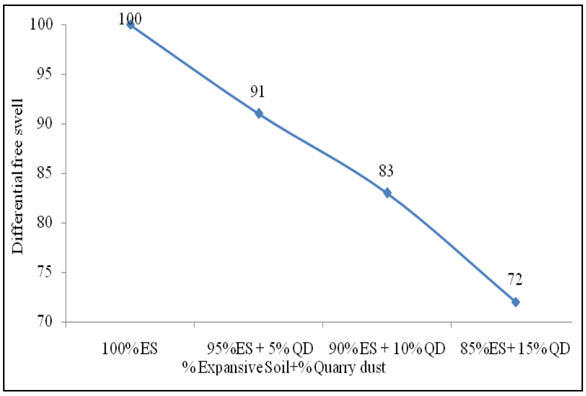

Fig.5.1: Variation of Differential Free Swell for Expansive Soil Treated with Different Percentages of Quarry Dust

5.2 California Bearing Ratio (CBR) Test Results:

The CBR test were conducted in the laboratory for all the expansive soil samples treated with different percentages of Quarry Dust as per I.S.Code (IS: 2720(part-16)-1979).The results of soaked CBR tests on expansive soil treated with increase in percentage of quarry dust, soaked CBR values of Expansive soil goes on increasing from 1.2 to 6.7 respectively up to the addition of optimum percentage of quarry dust i.e., 10% and the results are presented in below Fig.5.2.

5.3 Direct Shear Test Results:

The direct shear test were conducted as per IS: 2720 (part XIII, 1986) in the laboratory for Expansive soil sample treated with different percentages of quarry dust. The cohesion of expansive soil was found to be decreased from 16kN/m^2 to 1kN/m^2 with the addition of quarry dust and Angle of internal friction of expansive soil was found to be Increased from 19^0 to 30^0 with the addition of quarry dust, results are furnished in Fig.5.3.

5.4 Cyclic Plate Load Test Results:

Cyclic load test were carried out for untreated and treated expansive soil with different percentages of Quarry dust (5%, 10% and 15%) at different pressure increments. The cyclic pressure-deformation curves for untreated and treated expansive soil on model Flexible Pavement System laid at OMC are plotted and presented below. It can be observed that the load carrying capacity has increased for expansive soil treated with 10% of quarry dust when compared to other percentages of quarry dust. A model graph of Cyclic Load Test Result of Pressure Vs Deformation for Expansive soil presented below in fig 5.4. The total and elastic deformation values obtained for different pavement systems on different subgrades are deduced from the cyclic Pressure-deformation curves and are shown in Figs.5.5and 5.6

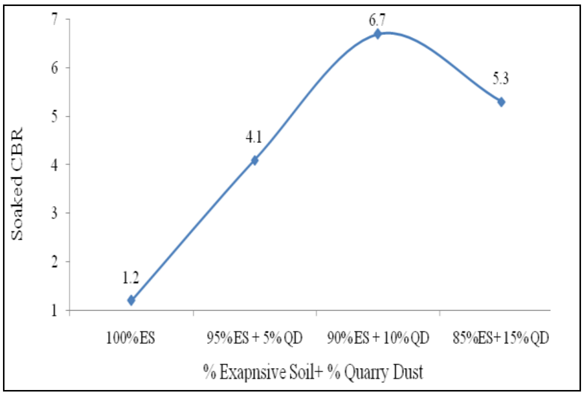

Fig.5.2Variation of Soaked CBR values for Expansive Soil Treated with Different Percentages of Quarry Dust

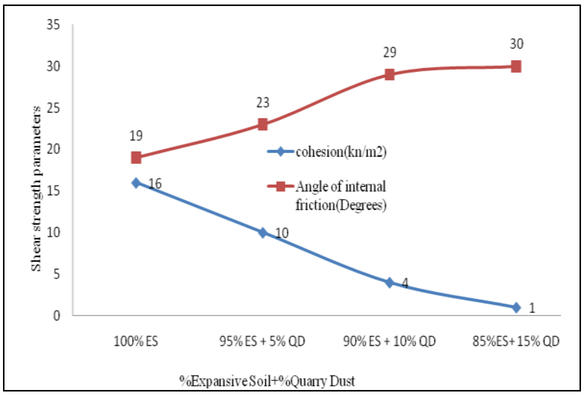

Fig.5.3.Variation of Shear Strength Parameters for Expansive Soil Treated With Different Percentages of Quarry Dust

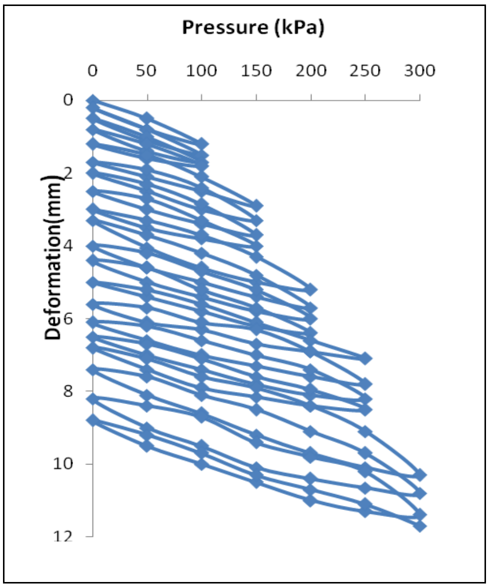

Fig.5.4: Cyclic Load Test Result of Pressure Vs Deformation for Expansive soil

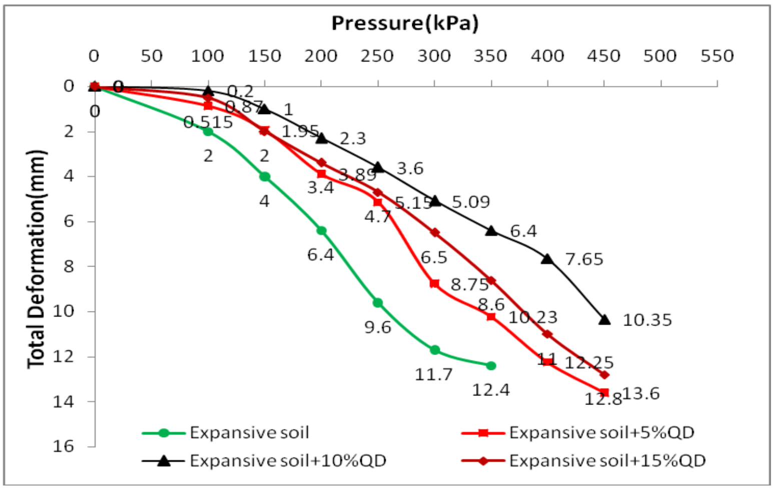

Fig.5.5: Pressure Vs Total Deformation Curves For Untreated and Treated Expansive Soil with Different % of Quarry Dust

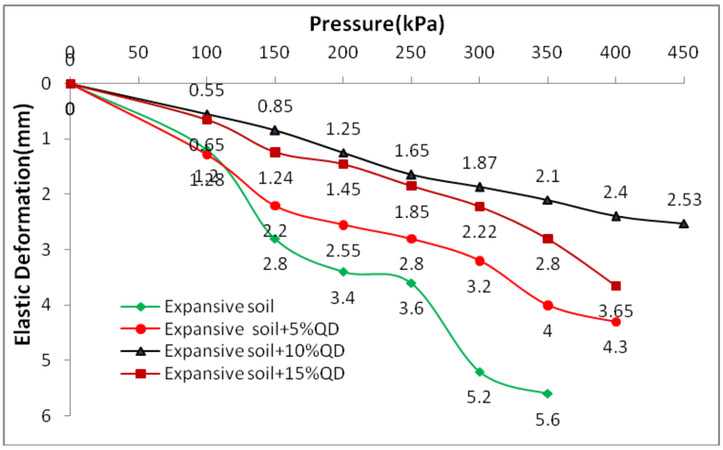

Fig.5.6: Pressure Vs Elastic Deformation Curves For Untreated and Treated Expansive Soil with Different % of Quarry Dust

The total and elastic deformations corresponding to optimum moisture content at a load of 350 kPa are equal to **12.4** mm, 5.6 mm for untreated expansive soil; 8.6 mm, 4.0 mm for treated expansive soil with 5% quarry dust, 6.4 mm, 2.1 mm for treated expansive soil with 10% quarry dust, 8.75 mm, 2.8 mm and treated expansive soil with 15% quarry dust respectively. It is observed from the figs.5.5&5.6. That the total and elastic deformations are decreased by 30.64 , 28.57%; 48.38%, 62.5 % and 29.43%, 50 % for treated expansive soil with 5%, 10% and 15% quarry dust respectively. From the above deformations load carrying capacity increased for 10% quarry dust treated expansive soil when compared to other treated samples. Hence 10% of quarry dust is the optimum percentage.

VI. Conclusions

1.Differential Free Swell values of Expansive soil goes on decreasing with the increase in percentage of Quarry Dust to the expansive soil from 100% to 83% at 10% of quarry dust.

2.The soaked CBR goes on increasing from 1.2 to 6.7 at 10% addition of of Quarry Dust to the expansive soil.

3.The shear strength parameters such as cohesion goes on decreasing from 16 kN/m^2 to4 kN/m^{2}and angle of internal friction goes on increasing from 19^0 to29^0 with the addition of 10% quarry dust to the expansive soil.

4.From the cyclic load test results it was observed that,load carrying capacity of expansive soil goes on increasing by the addition of quarry dust upto 10% beyond not much effective.

5.The total and elastic deformations are decreased by 30.64 , 28.57%; 48.38%, 62.5 % and 29.43%, 50 % for treated expansive soil with 5% quarry dust, treated expansive soil with 10% quarry dust and treated expansive soil with 15% quarry dust respectively.

6.From the above experimental analysis addition of 10% quarry dust to expansive soil is the optimum percentage.

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