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Study on Geotechnical Properties of Expansive Soil Treated with Quarry Dust and Sodium Hydroxide

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Abstract: ***Expansive soils have problems to civil engineers in general and to geotechnical engineers in particular because of alternate swell and shrinkage, distress is caused to the foundations of structures laid on such soils. Stabilization of the expansive soil is studied by using quarry dust and Sodium Hydroxide. This paper includes the evaluation of soil properties like compaction and California Bearing Ratio (CBR) tests by blending different percentages of quarry dust and sodium Hydroxide with a view to determine the effect on strength characteristics and optimum percentages.. From the experimental results, it has been observed that various properties of soil added with these stabilizers at certain percentage show remarkable positive changes as compared to the expansive soil. The value of compaction parameters has increased enabling increase California Bearing Ratio in soaked conditions which indicates that improved in strength. From these results, it was found that optimum quarry dust 20% and Sodium Hydroxide 5% combination gives the maximum increment in the CBR value compared with all the other combinations.***

Keywords: Expansive Soil, Quarry Dust, *Sodium Hydroxide*, Compaction, *California Bearing Ratio*

1. Introduction

Civil and environmental engineering includes the analysis, design, construction and maintenance of structures and systems. All are built on, in, or with soil or rock. The properties and behavior of these materials have major influences on the success, economy, and safety of the work. Geo-engineers play a vital role in these projects and are also concerned with virtually all aspects of environmental control, including waste disposal. Many researchers are doing extensive studies on waste materials and research projects concerning the feasibility and environmental suitability. Soil stabilization is the alteration of one or more soil properties, by mechanical or chemical means, to create an improved soil material possessing the desired engineering properties. Effect of waste Ceramic Dust and Quarry Dust on expansive soil by performing the various testes such as liquid limit, plastic limit, CBR test, compaction test &UCS test with addition of different percentages of these wastes. These wastes increases the strength of soil & CBR value of soil up to 100-150% and also help to attain the Maximum Dry Density of soil and decreasing the Optimum Moisture Content. By this study it is also help to solve the disposal problem of these wastes which is also create hazards problem in environment [1]. Laboratory test on selected soil sample to study the effect of tiles waste and sodium hydroxide on the soil, the addition of tiles waste and NaOH decreases the liquid limit and plastic limit of the soil up to 35% and it increases beyond this limit. The addition of tile waste and sodium hydroxide changes the soil group from CI to ML according to IS 1498- 1970. MDD increase with increase in 1% of tile waste and NaOH. The shear stress increases by addition of tiles waste and NaOH. Up to 35% of tile waste and 7.5% of NaOH and tend to decrease beyond this limit. The CBR value increase with increase in addition of tile waste and NaOH[2]. Experimental study on black cotton soils blended with Quarry Dust and Lime with different percentages on the geotechnical properties. Results showed that Specific gravity of Black Cotton Soil decreased with the addition of Quarry Dust and Lime, this reduction of specific gravity value may be due to the reduction of plasticity character of Black Cotton Soil. Maximum Dry Density (MDD) is observed at soil sample 3 for addition of Quarry Dust and Lime. Further addition of it, MDD value decreased. The strength of Black Cotton Soil increasing with the addition up to soil sample 4 and further decreased. From the test it is concluded that the strength characteristics of Black Cotton Soil are optimum at Soil sample 4 (8% lime + 20% quarry dust) [3]. Conducted experimental study on utlisation of waste Rubber Tyre and Quarry Dust, the results showed that significantly improved the properties of expansive soil, CBR value of soil shows good improvement by the addition of Crumb Rubber and Quarry Dust, significant increase in unconfined compressive strength and other parameters related to the soil. Their use in soil sub-grade will result in the increase in the bearing strength of soil which intern will reduce the design thickness of pavement; therefore it will prove economical for the road construction. Furthermore, there will be the proper disposal of waste tyres and Quarry Dust thereby reducing the air and soil pollution. Transportation cost can also be reduced as we need not to borrow the improved soil from far places. Thus, reducing the transportation cost as well[4].It is observed that the specific gravity of black cotton soil increased with the addition of Quarry Dust and Granite Waste, this increment of specific gravity value may be due to the addition of plasticity character of black cotton soil, Liquid Limit decreased from 21% to 17%, Unconfined Compressive Strength improved by adding 20% Quarry Dust and Granite Waste. Addition of

different ratio of Quarry Dust and Granite Waste to the Black Cotton Soil gets stabilized, thus the Maximum Dry Density increases and Optimum Moisture Content goes on decreases. Coefficient of Curvature and Coefficient of Uniformity goes on increasing on addition of Granite Waste and Quarry Dust [5]. Different concentrations of NaOH percentage by weight of water is reacts with present minerals (Kaolinite and Montominerllite) with in ions (Na+ & OH-) react with different concentration for changes in engineering properties. The OMC is decrease and MDD increase, as well as at 16% NaOH concentration shown 17.10% OMC given stable condition for OMC and MDD both properties of soil. At 0 to 16% NaOH concentration with the unconfined compressive strength of soil is decrease and at reaches at zero, it's say that strength does not exist in black cotton soil and change in sand properties. NaOH concentration at 2% given the better result of unconfined compressive strength of soil comparison to normal soil [6]. Experimental study conducted on different samples and concluded that expansive behaviour of Black Cotton Soil can be effectively reduced with addition of industrial waste material like quarry dust and the engineering properties of Black Cotton Soil are improved. The Differential Free Swell values are reduced from 58% to10%, Optimum Moisture Content of black cotton soil has decreased from 21.1% to 12.6% and Maximum Dry Density has increased from 1.6g/cc to 1.76 g/cc with increase in the percentage of Quarry Dust, significant improvement in the Soaked CBR values with the addition of Quarry Dust and addition of 40% of Quarry Dust into Black Cotton Soil increases the CBR values from 1.75 % to 7.05% [7]. Series of laboratory tests to study the effects of quarry dust on the expansive soil and from results, Liquid Limit, Plastic Limit and Plasticity Index are on decreasing with addition of quarry dust in different percentages, Maximum Dry Density (MDD) is increasing and Optimum Moisture Content (OMC) is decreasing with increase in percentage of Quarry Dust and Unconfined Compressive Strength (UCS) is increasing with increase in percentage of Quarry Dust [8]. Various experiments on expansive soil blending with different % of quarry dust and from the results Differential Free Swell values goes on decreasing with the increase in percentage of Quarry Dust to the expansive soil from 100% to 83% at 10% of quarry dust, soaked CBR goes on increasing from 1.2% to 6.7% at 10% addition of Quarry Dust to the expansive soil. The shear strength parameters such as cohesion goes on decreasing from 16 kN/m^2 to 4 kN/m^2 and angle of internal friction goes on increasing from 190 to 290 with the addition of 10% Quarry Dust to the expansive soil. 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 up to 10% beyond not much effective [9].Experimental study on effect of Quarry dust addition on conventional soil reveals that the addition of the Quarry Dust to the soil reduces the clay content and thus increases in the percentage of coarser particles, reduces the Liquid limit by 26.86% and Plasticity Index by 28.48% of unmodified soil. Optimum Moisture Content of soil is decreased by 36.71%, with increase in Percentages of Quarry Dust. Maximum Dry Density of soil is increased by 5.88% by addition of (40%) Quarry Dust. It is also identified that addition of (40%) Quarry Dust yield high CBR value [10]. The present paper discusses the properties of selected expansive soil and quarry dust, Sodium Hydroxide mixed with different proportions and evaluated Index properties, Compaction properties and California Bearing Ratio (CBR) Test are considered in this investigation. From the results maximum increase in strength at 20% quarry dust and 5% Sodium Hydroxide compared to other combinations

2. Materials Used

The following materials are used in this study.

2.1 Expansive Soil

The Expansive Soil used in this investigation was brought from Tummalapalli village, Allavaram Mandal East Godavari District of Andhra Pradesh State, India. Index and Engineering properties of Expansive soil were determined as per IS codes and are presented in Table-1.

Figure 1: Expansive Soil

Table 1: Physical Properties of Expansive Soil

Property	Symbol	Value
Liquid Limit (%)	W_L	87
Plastic Limit (%)	W_P	37.5
Plasticity Index (%)	I_P	49.5
Gravel (%)		0.0
Sand (%)		5.0
Silt (%)		12.0
Clay (%)		83.0
Soil Classification	--	CH
Specific Gravity	G	2.65
Differential Free Swell (%)	FS	130
Optimum Moisture Content (%)	OMC	27.99
Maximum Dry Density (g/cc)	MDD	1.443
CBR(%)	--	1.23
Natural Moisture Content (%)	w	11

2.2 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 soil were determined as per IS codes and are presented in Table-2.

Figure 2: Quarry Dust

Table 2: Physical Properties of Quarry Dust

Property	Value
Index properties	
Liquid Limit (%)	Nil
Plastic Limit (%)	NP
Plasticity Index	NP
Specific Gravity	2.53
Grain(Particle) size Distribution	
Coefficient of Uniformity(Cu)	18.59
Coefficient of Curvature(Cc)	3.95
Engineering Properties	
Optimum Moisture Content (%)	12.19
Maximum Dry Density(kN/m^3)	15.58
California Bearing Ratio	7.0

2.3 Sodium Hydroxide (NaOH)

Sodium hydroxide is highly caustic base alkali, which decomposes protinns at ordinary ambient temperature and may cause severe chemical burns. It is highly soluble in water and readily absorbs moisture and carbon dioxide from the air The influence of NaOH concentration in the range of 4M to 18M was systematically studies.

Figure 3: Sodium Hydroxide

3. Laboratory Experimentation

The overall testing program is conducted in two phases. In first phase, expansive soil was blending with different percentages of Quarry Dust (QD), i.e. 10%, 15%, 20% and 25% by weight was used for conducting various tests in the laboratory with a view to determine the optimum percentage of Quarry Dust . The optimum percentage of Quarry Dust content is obtained from the results of compaction and soaked CBR tests. In second phase, expansive soil with optimum percentage of quarry dust as base sample blended with Sodium Hydroxide with 0 %, 3%, 4 %, 5% and 6 % weight was used for preparing different samples for compaction and soaked CBR test. All the tests are conducted as per Indian Standard Codes for finding optimum percentage of quarry dust and Sodium Hydroxide material and the effect on strength characteristics of expansive soil.

3.1 Index Properties

Liquid Limit, Plastic Limit of all the samples tried in this investigation were determined by following Standard procedures as per IS: 2720 (Part-5)-1985 and IS: 2720 (Part-6)-1972.

3.2 Compaction Characteristics

The Compaction Characteristics of untreated and treated Expansive soil with various percentages of Quarry dust and Sodium Hydroxide were determined in the laboratory by following standard test procedure of IS heavy compaction test as per IS 2720 part-VIII.

3.3 California Bearing Ratio (CBR) Test

CBR test was carried out on prepared soil samples of Untreated Expansive soil and treated Expansive soil with various percentages of Quarry dust and Sodium Hydroxide under soaked condition as per recommendations in IS :2720 part XVI-1987 as shown in the Fig.4

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Figure 4: California Bearing Ratio Test Apparatus

4. Results and Discussions

Various tests were conducted in the laboratory as per IS Code provisions and the test results are furnished below with a view to determine the optimum percentages and the effect on strength characteristics.

4.1 Effect of Quarry Dust and Sodium Hydroxide on Index Properties

Liquid limit and plastic limit values were reduced from 87% to 61% and 37.5% to 28.2% with blending of different percentages of quarry dust varying from 0 % to 25% blending in expansive soil respectively as shown in the

Fig.5.Considering 20% quarry dust with expansive soil as base soil mix adding different percentages of sodium hydroxide (NaOH) 0%, 3%, 4%, 5% and 6% respectively , liquid limit and plastic limit values varies from 65% to 48% and plastic limit values are reduced from 30.9 to 20.05 as shown in the Fig.6

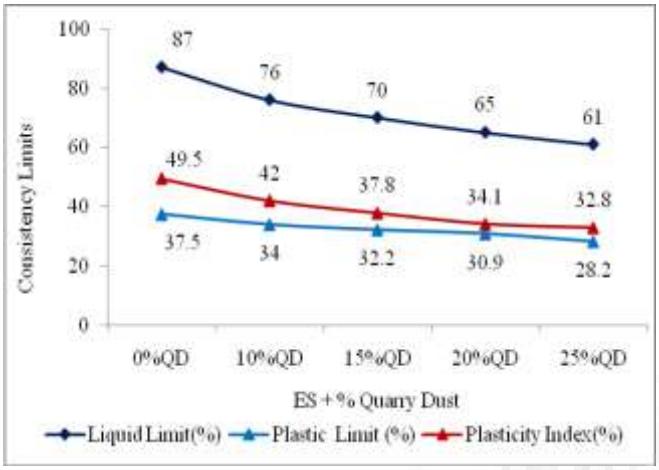

Figure 5: Variation of Consistency Limits Values of Expansive Soil Treated with Different % of Quarry Dust

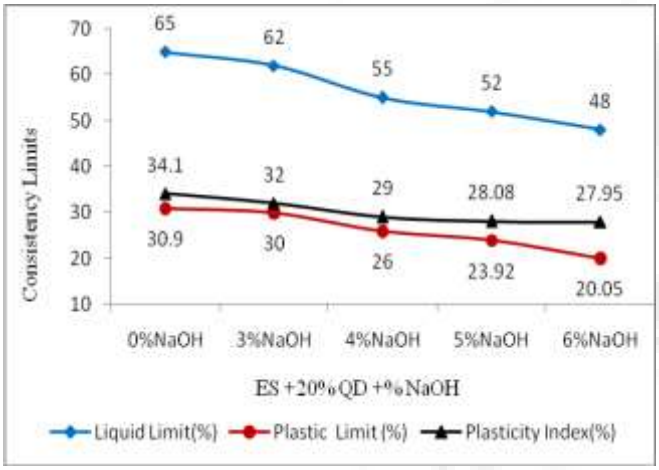

Figure 6: Variation of Consistency Limits Values of Expansive Soil Treated with Optimum % of Quarry Dust (20%) Treated with Different % of Sodium Hydroxide (NaOH).

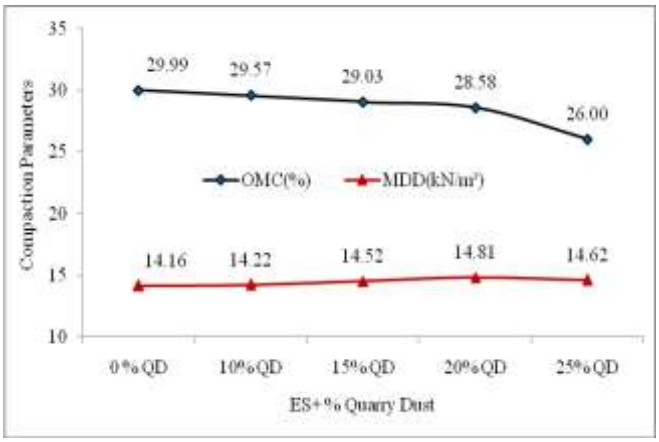

Figure 7: Variation of Compaction Parameters of Expansive Soil Treated with Different % of Quarry Dust

4.2 Effect of Quarry Dust and Sodium Hydroxide on Compaction Properties

All the Samples are tested as per IS: 2720 (Part VIII) and graphs drawn between water content and dry density for each percentage and determined the OMC & MDD. The results of different combinations of Quarry Dust and Sodium Hydroxide (NaOH) are presented in the Figs. 7 & 8. From the compaction test results the Maximum Dry Density values are increased from 14.16 kN/m^3,14.22 kN/m^3,14.52 kN/m^3,14.81 kN/m^3 and 14.62 kN/m^3 and the Optimum Moisture Content values are decreasing from 29.99%, 29.57%, 29.03%, 28.58 % and 26 % respectively when the expansive soil is mixed with 0 %, 10 %,15% ,20% and 25 % of quarry dust as shown in the Fig.7. From the above results at 20% of quarry dust blending sample attained maximum dry density as compared to other combinations.OMC values are decreasing from 27.99%, 27.34%, 25.25%, 24.02% and 23.07% ;and MDD values are varies 14.81 kN/m^3 ,14.96 kN/m^3 ,15.30 kN/m^3 ,16.19 kN/m^3 and 15.70 kN/m^3 respectively when Sodium Hydroxide (NaOH) adding with 0%,3%,4%,5% and 6% respectively in the stabilized expansive soil with 20% quarry dust as shown in the Fig.8.From the above results dry density at 5% addition of Sodium Hydroxide (NaOH) when compared to other samples tried in this investigation.

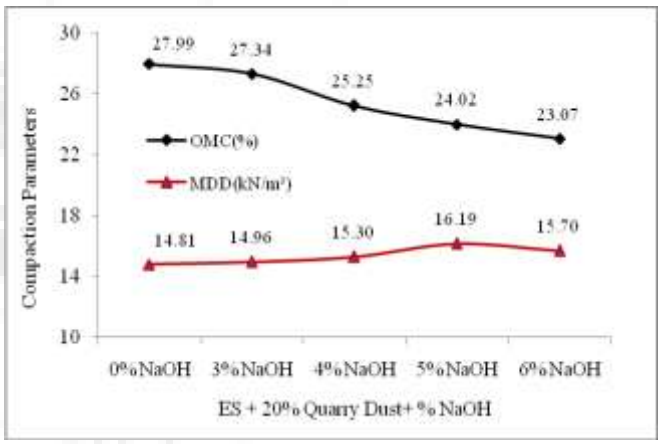

Figure 8: Variation of Compaction Parameters of Expansive Soil Treated with Optimum % of Quarry Dust (20%) Treated with Different % Sodium Hydroxide (NaOH).

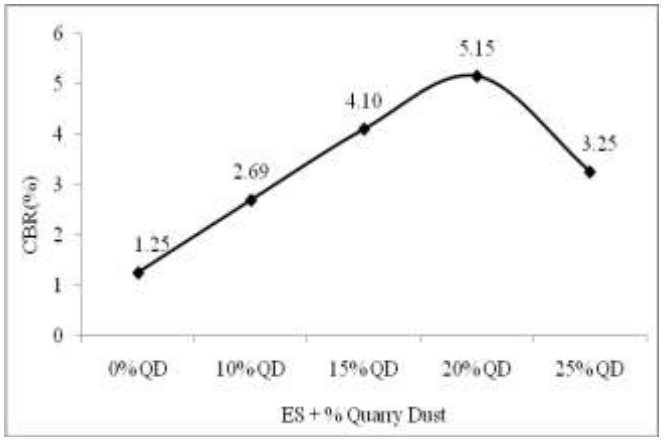

Figure 9: Variation of Soaked CBR Values of Expansive Soil Treated with Different % of Quarry Dust

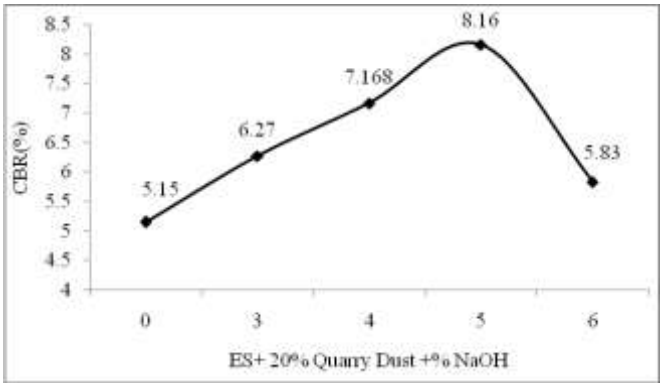

Figure 10: Variation of Soaked CBR Values of Expansive Soil Treated with Optimum % of Quarry Dust (20%) Treated with Different % of Sodium Hydroxide (NaOH).

4.3 Effect of Quarry Dust and Sodium Hydroxide on Soaked CBR

CBR tests were conducted for expansive soil material mixed with different percentages of quarry dust and the results were presented in the Fig. 9. It is observed from that expansive soil mixed with different percentages of quarry dust soaked CBR values are 1.25 %, 2.69 %, 4.10 %, 5.15 % and 3.25 % for 0 %, 10 %, 15 %, 20 % and 25 % of adding quarry dust and found that 20% quarry dust has obtained maximum CBR value as compared to other samples tried in this investigation as shown in the Fig.9. Soaked CBR values are varied from 5.15%, 6.27%, 7.168%, 8.16% and 5.83% respectively when Sodium Hydroxide adding with %, 3%, 4%, 5% and 6% in the stabilized expansive soil with 20% optimum quarry dust as shown in the Fig.10.From the above results maximum soaked CBR attained at 5% addition of Sodium Hydroxide (NaOH) when compared to other samples tried in this investigation.

5. Conclusions

The following conclusions were drawn based on the laboratory studies carried out on this study.

Liquid limit of the expansive soil decreases from 87 % to 61 % and the plastic limit from 37.5% to 28.2% by adding with the addition of quarry dust from 0% to 25% and 65% to 48% of liquid limit, 30.9 % to 20.05 % of plastic limit decreases by adding 0% to 6% sodium hydroxide which shows increase in particle size and decrease in cohesion of soil.

The Maximum Dry Density (MDD) 14.81kN/m^3 attained at 20% blending of Quarry Dust and 16.19 kN/m^3 for 5% Sodium Hydroxide where as Optimum Moisture Content (OMC) is decreasing with increase in percentages.

The soaked CBR value of the expansive soil treated quarry dust increases from 1.25 % to 5.15 % which is 3.2 times greater than that of expansive soil at 20% quarry dust and beyond decreased.

The soaked CBR value of the expansive soil treated with optimum quarry dust and different percentage of sodium hydroxide increases from 1.25 % to 8.16 % which is 7.2 times greater than that of untreated expansive soil at 5% sodium hydroxide and beyond decreased.

Hence, from the laboratory results, the optimum percentages of Quarry Dust as 20% and Sodium Hydroxide 5% shows maximum increase in strength properties as compared to other samples.

Both Quarry dust and Sodium Hydroxide which will improve the dry density and soaked CBR values blending with different percentages in expansive soil will change the soil structure and improve the geotechnical properties .Hence, the use of quarry dust and Sodium Hydroxide in geotechnical applications is economically beneficial and environmentally advantageous and substantial save in cost of construction.

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