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Effect of Stone Dust on Geotechnical Parameter of Fine Grained Soil

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Abstract

Large volume of Construction activities in building, road, Concrete work has resulted in increase in use of Crushed Stone. To account for this, large number of Crusher plants are installed all over the country. Stone Dust is formed as a by-product in process of Crushing, Screening and Stock Piling during Crushing Operation. It is a waste product and leads to pollution and problem of stock piling in crushing plant. To address this issue Stone Dust is used in this Study. Sample was collected from problematic site and modification of soil is carried out by addition of stone dust in the range of 0 to 50% by the percentage increase of 10%, 20%, 30%, 40% and 50%. The effect of Stone Dust on Liquid Limit, Plastic Limit, Plasticity Index, Optimum Moisture Content, Maximum Dry Density and Unconfined Compressive Strength (UCS) value is considered. Liquid limit, Plastic Limit and Plasticity Index of original sample 83.32%, 37.93% and 45% were reduced to 60.77%, 29.55% and 31% respectively. The OMC and MDD values of original sample was 50.2% and 1099.16 Kg/m^3 which transformed to 37.97% and 1268.29Kg/m^3 at 50% stone dust content. Also with addition of stone dust the Unconfined Compressive Strength of Soil sample increased as anticipated.

Keywords

Stone Dust, Liquid Limit, Plastic Limit, UCS

1. Introduction

Rapid Industrialization and Urbanization has resulted in increase in Volume of Construction Activities. The limitation of Area expansion, poor Soil Properties, Geological hurdles creates limitation in Expansion of Construction activities. Soil may be problematic containing soft Clays, waterlogged land, expansive soil, and loamy soil. The existing site conditions may not be favorable for bearing up loads coming in them. Variation of moisture content leads to variation of strength resulting in settlement problem in foundation. In order to overcome this, either Stabilization or replacement is mandatory. In here we are dealing about mechanical stabilization of Problematic soil by use of Stone Dust. Property of Clayey soil is suitable for mechanical stabilization. So clayey soil was chosen, and geotechnical properties were evaluated varying the Stone Dust Content. The study conducted on soft soil reveals that the strength and stiffness of soil changes with cementation changes [1].

The variability of properties of soil from place to place is drastic. In addition, the strength of Clayey soil changes with variation of moisture content and leads to settlement problems. If the Soil Forming Foundation layer and Subgrade is soft and sensitive to moisture Variation, the successive loading of overlying layer can cause structural hazards in Superstructure. So clayey soil are posing serious risk to the structures being built. Soft clay and dredged marine clays are difficult to work with as construction materials. This is due to the clay's high water content, high compressibility, and limited permeability, which causes ground and structural instability. [2] Problem of heave, Rutting failure, allegator cracking are very common in road construction due to poor subgrade quality. Whenever soil available for subgrade, foundation layera are not suitable to build superstructure above them stabilization of soil becomes mandatory to have the desired properties required. The major goal is to minimize building costs by enhancing the characteristics of the clayey soil by adding local waste stone dust, which is easily and inexpensively accessible from a crusher. The major soil deposits in valley are lacustrine deposits (kalimati clay) and fluvio deltaic deposit [3]. This shows the formation of valley soil is suceptible to failure and pose serious geotechnical hazard to structure. This depicts the significane of the study.

The primary objective of this study is to improve the geotechnical parameter of problematic soil. For this, Study the effect of stone dust on liquid limit, plastic limit and plasticity index of soil. Study of these parameter shows the fineness of soil and its capacity to undergo plastic deformation. It also gives good indication of compressibility, swelling and Shrinkage. Study the effect of stone dust on compaction characteristics of soil. It shows the maximum density that can be achieved in field at certain moisture content. Study the effect of stone dust on Strength Characteristics of soil.

2. Literature Review

Soil is complex in nature as well as critical element influencing the success of any construction project. Any Soil for bearing load from structure should be stable, should not undergo volumetric changes due to moisture variation, have permanency of strength and should be easily compacted with least possible energy. Though soft and organic soil do not fulfill almost all of these requirements, but it can be treated to modify its property to address the issue.

Soil stabilization is the process of changing or preserving one or more soil qualities in order to enhance a soil's engineering features and performance. Preparing soils of desired gradation by blending or mixing different additives that modifies texture, gradation or plasticity are some example of the process. The fundamental goal of foundation soil stabilization is to minimize permeability and compressibility while also increasing shear strength and bearing capacity. Commonly used stabilization technique are mechanical stabilization and Chemical stabilization which is briefly explained below:

2.1 Mechanical stabilization

The application of mechanical energy to densify soil is known as mechanical stabilization or compaction. Densification happens when air is sucked out of soil holes while the water content remains relatively constant. It is achieved by combining or blending soils of two or more gradations to produce a material that meets the specified requirements. This procedure entails combining materials with different properties, each with individually unacceptable properties, to create a material with the required properties (typically particle size distribution and/or plasticity), resulting in a material with enhanced properties that overcomes the source material's limitations. If the soil is subjected to severe moisture variations, the approach may not be effective. In this study we will be dealing about mechanical stabilization. Stabilization of waste stone dust are mainly due to their lime (CaO) content. The main reaction involved in stone dust application are: cation exchange, flocculation and pozzolanic reaction.

2.1.1 Cation Exchange

The excess of ions of opposite charge (to that of the surface) in the diffuse double layer over those of similar charge is referred to as exchangeable ions. By changing the chemical composition of the equilibrium electrolyte solution, these ions can be replaced by a group of other ions with the same total charge [4]. Clay particles with a negative charge absorb cations of a certain sort and quantity. The ease with which cations can be replaced or exchanged is determined by numerous parameters, the most important of which is the cation's valency. Cations with a higher valence can easily replace cations with a lower valence. Being all other circumstances equal, divalent cations are held more firmly than monovalent cations. This also holds true for Divalent and trivalnet cations i.e trivalent are held more tightly than divalent cation. [5].

2.1.2 Flocculation

Flocculation is primarily caused due to cation exchange reactions. Due to which reduction in number of clay size material occurs resulting in decrease in soil surface area. This leads to reduction in Plasticity. [6]. The swelling of soil can be reduced accountably by changing the texture of soil.

2.1.3 Pozzolanic reaction

For enhancement of various index and engineering properties of soil, time-dependent pozzolanic reactions play a major role [7]. Calcium silicate hydrate(CSH) and Calcium Aluminate hydrate(CAH) are formed out of pozzolanic constituents.

Ca^{2+} +2$(OH)^-$ +SiO_2 (Clay Silica) = CSH

Ca^{2+} + 2$(OH)^-$ +Al_2O_3 (Clay Alumina) = CAH

Coating of clay surface by calcium silicate gel resulting in binding up of clay particle together. Then crystallization of gel occures forming an interlocking structure. this results in increase of strength of soil.

2.2 Chemical stabilization

The treatment process which Involves the application of chemical to modify the soil characteristics is coined as chemical stabilization. It increases the bearing capacity of the soil , increases the strength and stiffness through cementation [8] . Chemical stabilization has high range of applicability. It is used to make the soil less permeable, when and where necessary.Reduce the moisture content in case of excess, enhance the shrinkage and swelling behaviour, enhance the bearing capacity and improve the compatibility of clay. dry out soil where moisture content is high, reduce the swelling and shrinkage, enhance the bearing capacity and improve the compatibility of clay. Commonly used stabilizing agents are Lime, Cement, and combination of these in different proportion.

Selection of particular stabilizing technique is influenced by various parameters. Soil characteristics, the need and purpose of stabilization, the desired strength and durability after stabilization are some of the parameters highly influencing the stabilization technique. The cost and environmental criteria should also be considered wisely.

Experiments on effect of Crusher dust Lime and quarry dust on properties of Expansive soil was carried out. They have replaced expansive soil upto 70% (with increment of 10%) i.e. 10%, 20%, 30%, 40%, 50%, 60%, 70% and quarry dust is added to soil samples for finding the properties of mixes. Based on the results they have observed that when crusher dust added to expansive soil liquid limit, plastic limit decreases. For experimental work they have collected expansive soil and stone dust from Bhubaneshwar [9].

The investigation into the effects of stone dust on the geotechnical qualities of poor soil came to a conclusion that addition of Stone Dust resulted in reduction of LL, PL, PI and OMC and increase of MDD (maximum dry density) and CBR (California Bearing Ratio) value [10]. The use of Stone Dust to improve the properties of Expansive Soil was studied. Two different sample of expansive soil and Stone Dust were collected and mixed in increment of 10% of Stone Dust content. The experiment led to the conclusion that Stone Dust can be employed as an embankment as well as a backfill material for the sub-base lower layer due to it's high specific gravity and soaked CBR value [11]. Konganti et. al. [12] carried out experimentation on strength behaviour of expansive soil using Quarry Dust and concluded in reduction of the expansive behavior of the Black Cotton soil, Decrease in OMC and increase in MDD and CBR value. Soosan et. al. [13] studied the use of quarry dust in embankment and pavement constructions. In the work they have found that the quarry dust has high shear strength and high specific gravity, soaked CBR value for standard compaction and modified compaction efforts are found to be around 23% and 49% respectively. The effects of stone dust and fly ash (equal proportions) on the swelling and strength characteristics of an expansive soil waas investigated. The combination in different proportion resulted in the greatest increase in strength characteristics when compared to either fly ash or stone dust applied separately [14].Gupta et al. conducted research on the stabilization of black cotton soil using crusher dust, and discovered that the optimum amount of crusher dust was 40%. [15]

3. Materials and methodology

The materials used in the study were Collected from Kupandol area. Stone Dust was Collected from Commercial outlet at Jorpati. Atterberg Limit test, Compaction test and Unconfined Compressive Strength test were performed. Properties of Soil Sample and Stone Dust are presented below in tabular form:

Table 1: Geotechnical Properties of Soil Sample

SN	Properties of Soil	Values
1	Specific Gravity	2.57
2	Liquid Limit	83.32%
3	Plastic Limit	37.93%
4	Plasticity Index	45
5	Optimum moisture content	50.2%
6	Maximum dry density (Kg/m^3)	1099.16
7	Unconfined compressive strength kpa	140.9

All tests were performed according to IS standard. Specific Gravity was obtained using pycnometer. Liquid Limit was determined by using Casagrande Apparatus. Compaction Characteristics based on Standard proctor test. UCS was performed based on constant strain principle at strain rate of 1.25mm/min. For UCS test, remolded samples were prepared at OMC using Harvard Miniature Compaction Apparatus. Classification of soil was done based on

Unified soil Classification system (USCS). All the parameter that was determined for natural soil was also determined for mixed soil. Sample was air dried in laboratory for about 1.5 months until the reduction in moisture was insignificant. Stone dust was dried at 60degree Celsius temperature in oven. Then soil sample was modified with 10%, 20%, 30%, 40% and 50% Stone Dust content. The samples were dry mixed. Then all index properties and Engineering properties with and without modification was observed and compared.

4. Results and Discussion

4.1 Variation of LL, PL and PI with stone dust Content

With addition of Stone dust, the Liquid limit, Plastic Limit and Plasticity Index was reduced. The Problematic soil has been modified by addition of stone dust collected from nearby quarry in the range of 10% to 50% of original soil. The liquid limits, plastic limit, plasticity index of original soil without modification are 83%, 38% and 45% respectively. After modification with 10%, 20%, 30%, 40% and 50% of stone dust, the liquid limit of modified soils is found to be 80.75%, 77.04%, 72.49%, 67.00% and 60.77% respectively, the Plastic limit are found to be 37.93% 37.01%, 35.02%, 32.69%, 31.02% and 29.55% respectively and Plasticity index is found to be 45%, 44%, 42%, 40%, 36% and 31% respectively. The reason behind the reduction in value of Liquid limit of soil may be due to addition of non-Plastic material. Stone dust has subsequently low liquid limit than soil sample. So, their addition results in reduction of liquid limit. Same reasoning is applicable to Plastic Limit. The amount of expansive clay present in soil mainly imparts the plasticity in soil. The clay mineral with bonded crystal structure has negative charge.

Table 2: Variation of LL,PL and PI with Stone Dust Content

SD%	Liquid Limit%	Plastic Limit%	PI
0%	83.32	37.93	45
10%	80.75	37.01	44
20%	77.04	35.02	42
30%	72.49	32.69	40
40%	67.04	31.02	36
50%	60.77	29.55	31

Cations and water molecules are attracted to its negatively charged surfaces in order neutralize the charge deficiency, forming a diffuse double layer. The thicker the double layer, the more plastic the soil. when stone dust is added, cation exchange takes place on clay surface. This results in shrinkage of diffuse double layer reducing the Plasticity Index. The trend of reduction is presented graphically in section below:

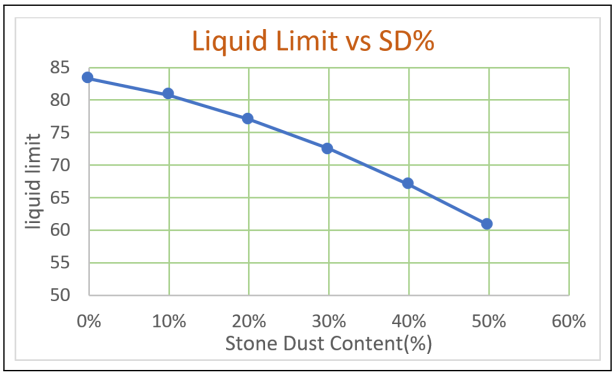

Figure 1: Variation of LL with stone dust content.

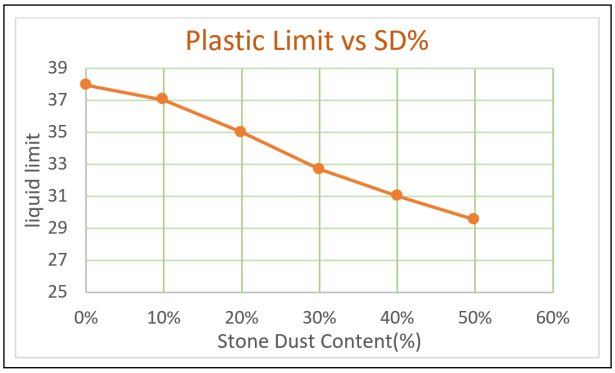

Figure 2: Variation of PL with stone dust content.

4.2 Variation of Compaction Characteristics

The Optimum Moisture Content and Maximum Dry Density are two properties that is counted as compaction behavior of soil. The magnitude of maximum Dry Density and Optimum Moisture Content primarily depends upon the type of soil and amount of Compactive effort applied. Usually with increase in Compactive effort the maximum dry density increases and optimum moisture content decreases. In our soil, With addition of stone Dust the Optimum moisture content reduced upto 40% Stone dust Content and increased for 50% Stone Dust. The Maximum Dry Density showed the opposite trend, it increased up to 40% stone Dust Content and decreased for 50% Stone Dust. OMC and MDD value for Original Sample were 50.2% and 1099.16 Kg/m^3.

With 10%, 20%, 30%, 40% and 50% addition of Stone Dust, OMC value changed to 41.88%, 40.01%, 37.50%, 35.59% and 37.97% respectively and MDD value changed to 1199.12Kg/m^3, 1225.32Kg/m^3, 1247.60Kg/m^3, 1288.43Kg/m^3 and 1268.29Kg/m^3, respectively. The Curve shows a shift from right to left for OMC. The probable reason for increase in maximum dry density of soil by addition of stone dust is due to proper rearrangement of soil particles and addition of non-plastic material which improves the binding capacity.

Table 3: Variation of OMC and MDD with Stone Dust Content

SD%	OMC%	MDD Kg/m^3
0%	50.2	1099.16
10%	41.88	1199.12
20%	40.01	1225.32
30%	37.5	1247.60
40%	35.59	1288.43
50%	37.97	1268.29

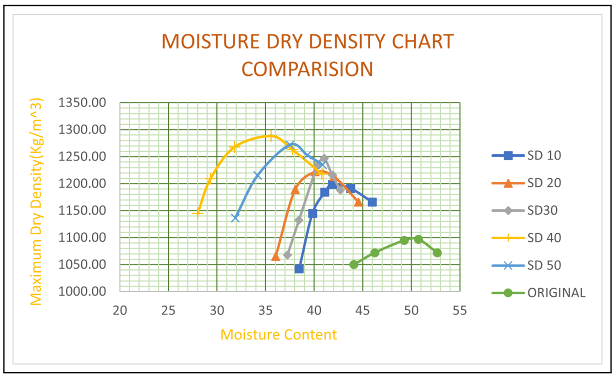

Figure 3: Moisture Dry Density comparision with stone dust content.

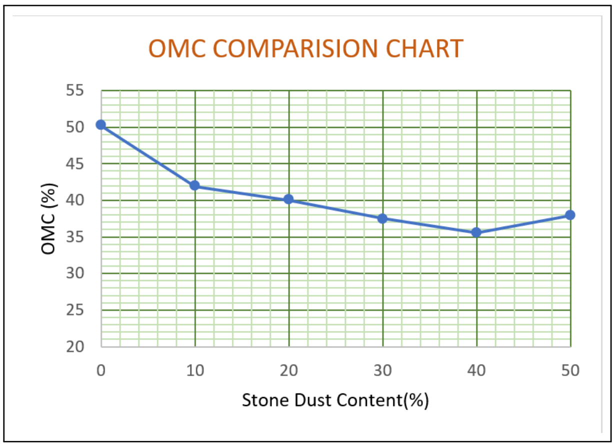

Figure 4: Variation of OMC with stone dust content.

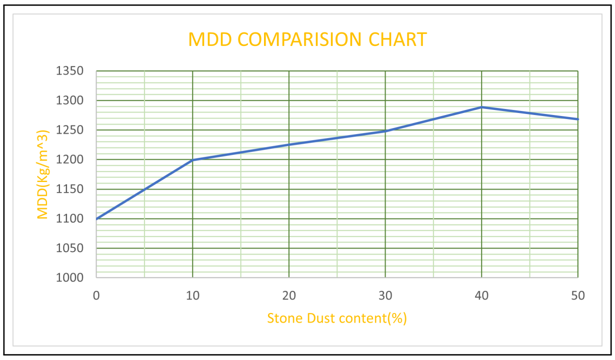

Figure 5: Variation of MDD with stone dust content.

4.3 Variation of Strength Characteristics

Unconfined Compressive Strength test was performed to find the strength parameter. Unconfined compressive strength of each sample is determined with the help of Stress-Strain curve. UCS value of original sample was 140.9 KPa. With addition of Stone dust, UCS value of soil increased up to 40% of Stone Dust content and decreased for 50% stone dust content. For 10%, 20%, 30%, 40% and 50% addition of Stone Dust UCS value reported were 167.30KPa, 199.46KPa, 226.76KPa, 254.17KPa and 234.77KPa. With addition of Stone Dust, the Cohesion of soil decreases and angle of internal friction increases. (sabat et al). The stress-strain plot for different percentage of stone dust shows that with increase in percentage of stone dust the mode of failure shifts from ductile to brittle. The percentage strain for ultimate shear strenth for lower percentage of stone dust is more as compared to that for higher percentage of stone dust. The increase in value of Unconfined compressive strength is due to cation exchange, floculation and pozzolanic reaction.

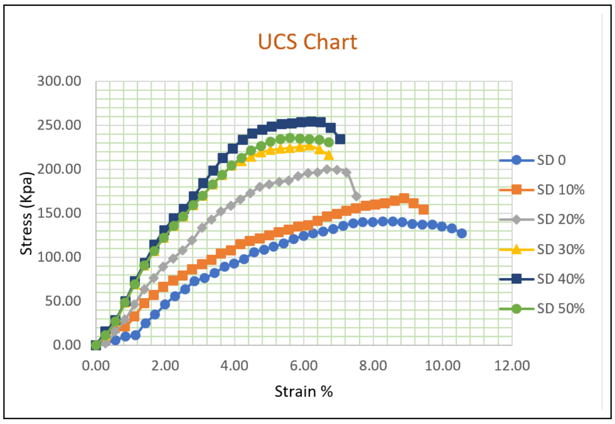

Figure 6: Stress-Strain Curve for different stone dust content.

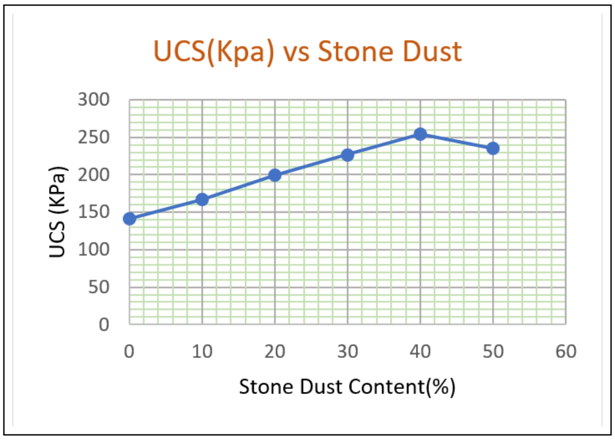

Figure 7: Variation of UCS with stone dust content.

5. Conclusion and Recommendations

As the percentage of stone dust is increased, the liquid limit reduces at faster rate and plastic limit to slower rate resulting in decrease in Plasticity index i.e., there is decrease in plasticity index (PI) with increase in Stone dust content. Addition of Stone Dust resulted in increase of Maximum Dry density and reduction of Optimum Moisture Content up to 40% stone Dust content and for 50% Stone dust content reversal of MDD and OMC result. The Unconfined Compressive Strength of the stone dust mixed soil increased up to 40% Stone dust content and reduced for 50% stone dust content. This may be due to reduction in cohesion and increase in angle of internal friction resulting from addition of stone dust.

Study of changes in CBR value of subgrade with addition of Stone Dust is recommended. UCS does not account for the effect of confining pressure encountered in field. The influence of confining pressure on the strength of a stone dust treated soil with triaxial test is suggested. Study of change in permeability of the soil on addition of stone dust is recommended.

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