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Effectiveness of Stone Dust as an Expansive Soil Stabilizer

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Abstract- This paper mainly deals with the laboratory investigation of waste stone dust to improve problematic expansive soils that shrink and swell during wet and dry season. The expansive soils result in shrink /swell and differential settlement of structures. Soil survey conducted in Sudan reveals the fact that almost one third of Sudan's 2,600,000 km^2 area is occupied with the expansive soil[1]. Usage of certain kind of admixtures on expansive soil looks prepossessing on the works where other improvement techniques become extensive and therefore are expensive too. So, to maintain a balance in between the source budget and project efficiency and ultimately to avoid problem of disposing available soil, and borrowing the soil, betterment in problematic soil through admixtures looks appealing. Therefore, an experimental examination was conducted on the soil by blending the soil with SD (Stone Dust) to study impact of stone dust on soil properties. The percentage of stone residue was taken within range of 5% to 20% of the total soil sample in tests. The primary arrangement of tests incorporates specific gravity, liquid limit, plastic limit, CBR, Optimum moisture content and maximum dry density were performed on soil and same tests were directed in the second arrangement on the soil sample blended with stone dust. Laboratory examinations states that soil swell potential was diminished to 4.4% from 8.4% at 12% SD and soil transformed to non-expansiveness from medium expansiveness similarly plastic index and liquid limit values were found to be gradually decreasing from 20.1% to 8.4% and 40.7% to 31.9% respectively at 0% to 18% SD, moreover the values of OMC reduced from 12.4% to 6.2% and MDD improved from 1.84 (g/cm3) to 2.16 (g/cm3) at 0% to 20% SD, likewise the void ratio and porosity improved from 0.632 to 0.637 and 38.74% 38.89% respectively at 0% to 18% SD.

Keywords- Soil Stabilization, Expansive Soil, Stone Dust.

1. INTRODUCTION

The growth of urbanization and industrialization leads to more structural development and roads infrastructure and ultimately they demand for good soil conditions to be used as the strong foundations, but expansive soils are more problematic for construction purposes and are generally available to a large extent in various regions of the world, including Argentina, Zimbabwe, China, Mexico Cuba, Ethiopia, India, Iran, Japan, Morocco, Spain, United States of America, Ghana, Myanmar, Australia, Oman, Saudi Arabia, South Africa, Sudan, Turkey, Canada, Venezuela, Israel and Brazil**.**[2] Traditional ways to deal with such type of soil were to replace the available problematic soil, that appeared to be more complicated because of high costs as well as due to the environmental reasons. In Sudan damage due to expansive soil exceeds $6,000,000 (that is almost 8,000,000 Sudanese pounds) annually[1]. Expansive soil absorbs moisture from surroundings and the backfill soil oversaturates that causes the shrinkage and swelling phenomenon in soil due to which it exerts elevated pressure on the walls of foundations and cracks are produced in the walls and ultimately differential settlement of structure takes place and finally the failures occurs. Expansive soil occurs in such areas where annual evapotranspiration and evaporation is more than precipitation and geotechnical reports by various agencies state that expansive soil occurs in Dera Ismail Khan, Khairpur (Sind) and Chakwal [3] while current investigations is upon Chakri soil. The ground improvement results in reduction in soil compressibility and enhancement in its shear strength which in turns play an important role in improving soil bearing capacity, slope stability and earth retaining structure like coffer dams and retaining walls etc. [2] Methods primarily opted for ground improvement include Biological, Physical and Chemical which improve the soil engineering properties. Biological soil stabilization is done by planting and it is suitable for the soil that is exposed to wind and water. Chemical stabilization is done in a way that the chemicals are mixed in water and sprinkled over the problematic soil to increase compaction and to act like binders. Physical stabilization includes drainage and compaction. A few other mechanical ways to improve poor soils are pre wetting, soil replacement water content control, imposing surcharge and other natural or man-made fiber additions like jute and geotextiles[4]. Solid waste Stone Dust is easily accessible in Pakistan from Sargodha, Margalla, Barnalla and Mangla crushers. SD utilized in current investigation is the solid waste of stone crushing industry of Margalla, and was taken in laboratory testing by dry weight of soil from 0% to 20%, and blended into the soil to inspect the impact of blending on various geotechnical properties of soil like OMC, Plastic Limit, MDD, Liquid Limit, Specific Gravity and CBR properties of soil. In the past researches although the trends obtained from different researchers are somehow similar to this investigation but optimum values are different because of difference in geotechnical properties of locally available soil of different areas. This shows that there is a need of increasing data bank by using problematic soils present in different parts of the world to understand the possible variations in optimum ranges.

2. LITERATURE REVIEW

The improvement of soil by addition of different admixtures has been carried out by different researchers. But less statistics have been published on the geotechnical properties of soil that is reinforced by Waste Stone Dust (WSP). [4] Conducted the standard compaction test, Atterberg's limit tests and California bearing ratio test by adding with the blend of stone dust and lime in percentage of 6% and 1%, respectively in the soil sample and study revealed the fact that CBR value of soil was improved up to 26%. Moreover, Stone dust addition to week soil increases the shrinkage limit, angle of internal friction, maximum dry density and decreases the Atterberg limits, soil cohesion and optimum moisture content.[5] Performed various tests including compaction test, plasticity test and strength tests by adding different percentages of stone powder on the soil that was basically gravelly in nature and he came to know that by mixing soil with stone dust, CBR value was increased and plasticity was decreased and soil was able to meet the specifications of morth as sub base material only by addition of stone dust up to 25-35%. [6] carried out the tests like liquid limit, plastic limit, unconfined compressive test, California bearing ratio, and standard compaction test on soil by blending lime and waste stone powder mix as an admixture and found remarkable results. For CBR test 1% lime plus 6% stone powder and for UCS 7% lime and 6% stone powder have shown distinctive effect on strength properties. [7] Introduced the experimental test results of the examination of impact of fly ash and stone dust blending in various percentages and by the addition of 20%-30% of admixture, controlled the swell index of expansive soil and marked improvements in various properties of soil, and inferred that blend of stone dust and fly ash is more efficient than fly ash and stone dust alone in soil reinforcement. [8] Led arrangement of tests and inferred that increase in proportion of quarry dust diminishes Optimum moisture content (OMC),Atterberg's limit values and cohesion while improves the properties like Angle of internal friction and Maximum dry density of shrink/swell soil.[9] Performed various tests to examine impact of quarry dust gathered from Madepalli, India, on mud compaction properties and replaced the soil with quarry dust in extents of 10,20,30,40 and 50%and inferred that solitary 30% of quarry dust utilized as an admixture in soil is adequate to improve its properties and to make it suitable for development.[10] Shear quality test, consistency test and compaction tests were performed on gravelly soil by addition of stone residue in the scope of (20%-30%) and it uncovered the fact that maximum dry density increased from (3%-7%) and California Bearing Ratio value improved from (16%-52%) and soil meet the (MoRTH) specifications. The addition of 20% stone dust in expansive soil uncovered the way that MDD and CBR value improved by 5% and 35% respectively, whereas optimum moisture content (OMC) and Atterberg limit values were diminished that made the soil suitable for the subgrade. Previous researchers have selected locally available problematic soils of their region. Although their trends are somehow similar but optimum values are different. This shows that there is a need of increasing data bank by using problematic soils present in different parts of the world to understand the possible variations in optimum ranges.

3. RESEARCH METHODOLOGY

3.1. *Material Collection*

3.1.1 Expansive Soil

Black cotton soil, shrink/swell soil or Expansive soil is present in abundance in Pakistan. The primary reason of its occurrence is the chemical decomposition of rocks, for example, Basalt and by phenomenon of igneous rocks erosion. These type of soils are rich in Iron, Magnesia, Alumina and Lime while suffering in the Phosphorous, organic contents and Nitrogen [7]. The soil for this study is collected from Chakri, Rawalpindi, Pakistan. The soil is expansive having good shear strength in dry form but becomes very soft, weak and swells when comes in contact in water and drastically decreases when comes in contact with moisture content. Untreated soil properties are listed in table-1.

Table -1 Properties of Soil without adding Admixture

Sr. No	Test Names	Standard	Value Obtained
1	Liquid Limit	ASTM D 4318	40.7%
2	Plastic Limit	ASTM D4318	20.7%
3	Plastic Index	ASTM D4318	20.1%
4	Grain Size Analysis	ASTM D-6913	96% fines
5	Moisture Content (%)	ASTM D 2216	22.17
6	Specific Gravity	ASTM D854	2.695
7	Optimum Moisture Content (%)	ASTM D698	12.4
8	Maximum Dry Density (g/cm3)	ASTM D698	1.84
9	Swelling Potential	ASTM D 1883	8.4%
10	Void Ratio	$e = (G.\rho_w/\rho_d) - 1$	0.632
11	Porosity	$n = (e / (1+e)) * 100$	38.74%

3.1.2 Stone Dust

Stone dust is a waste material produced in stone pulverizing industry, and each crushing unit is evaluated to deliver 15-20% of stone dust.[11] It is the mechanical stabilizer and has high shear strength and enhances geotechnical properties of soil when mixed with it in suitable proportions. It stabilizes the problematic soils by improving its compaction characteristics and reducing the plasticity. Stone dust particles have angular shape therefore have good interlocking strength with soil and not only improves soil density but also reduces plasticity of highly plastic soils. [11]Moreover, stone dust possesses pozzolanic nature and contains coarse particles that is not observed in other admixtures like fly ash. The Stone dust used in current study was collected from the crushing plants working on Margalla hills, Taxila. The stone dust is taken by the dry weight of soil from 0% to 20%, and blended with soil to examine effect of mixing on properties of soil.

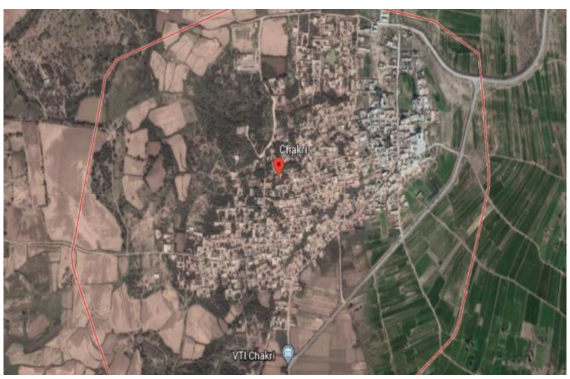

Figure 1-Chakri Soil Extraction Site

Figure 2-Margalla Quarry site

3.2. EXPERIMENTAL WORK

3.2.1. Sample Preparation

For mechanical soil stabilization, sample was set up in such a way that stone dust and soil were in dry state at mixing time, so, expansive soil sample and stone dust were placed into oven at 105 °C for 24 hrs. before mixing soil with the stabilizer. Stone dust was used in percentages of 5%, 12% and 18% of the dry mass of the soil sample to observe the soil behavior at even smaller percentages of SD to bring more efficiency in improvement as well as taking considerations of economicity. In this way, samples were prepared for the soil stabilization.

3.2.2. Experimental Program

Preliminary tests, for example, soil gradation, liquid limit, plastic limit and specific gravity were performed followed by compaction test to acquire maximum dry density (MDD), OMC and finally strength tests like California Bearing Ratio and Direct Shear test were performed under soaked conditions. The same series of tests was repeated for soil mixed with different percentages of stone dust. Results of the soil testing before adding admixture are given in Table-1.

Table-2 Sieve Analysis Results

Sieve #	4	10	20	40	60	100	200	
Diameter (mm)	4.75	2.00	0.85	0.425	0.25	0.15	0.075	Pan
Soil Retained (g)	0.40	3.90	1.30	0.00	1.90	0.60	0.40	191.5
Soil Retained (%)	0	2	1	0.00	1	0.3	0.2	96
Cumulative Passing (%)100	100	98	97	97	96	96.0	96.0	0

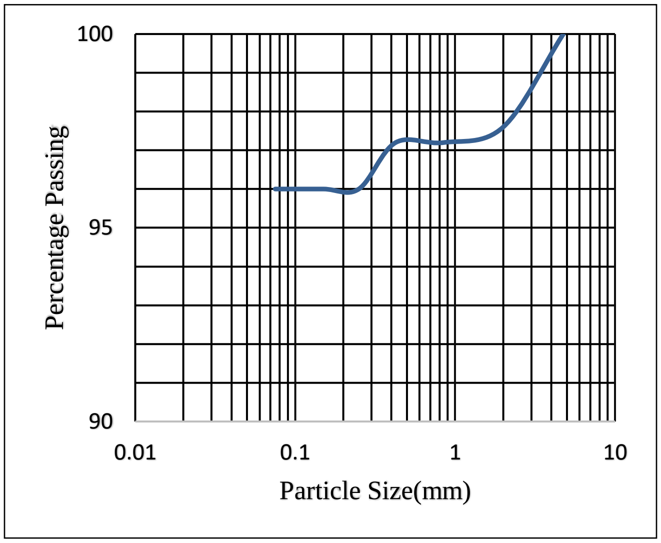

Figure-3 Soil Graduation Curve

3.3. *Soil classification:*

After performing the tests on soil, the soil is classified as CL (Lean Clay) according to USCS (Unified soil classification system) as shown in Table 3 and A-7-6 (clayey soil) according to AASHTO as shown in Table 4.

Table-3 Soil Classification according to USCS

Percentage Passing from Sieve #200	96% which is >50% Then Fine grain soil
Liquid Limit	40.7%
Plastic Limit	20.7%
PI= L.L-P. L	40.7- 20.7=20.1 %
P_{200}>50%---Fine grain Soil ~ P.I>7----Clay ~ L. L<50%	
Then Group of Soil	CL (Highly Plastic Clay)

Table-4 Soil Classification according to AASHTO

Percentage Passing from Sieve #200	96% which is >36%
Liquid Limit	40.7%
Plastic Limit	20.7%
PI = L.L-P. L	40.7-20.7 = 20.1 %
Then, Group of Soil	A-7-6 (clayey soil)

According to criteria defined by [12], soil used for this study is categorized as medium expansive.

4. RESULTS AND DISCUSSION

4.1. Effect of Stone Dust on Specific Gravity G_s

The untreated soil specific gravity was found to improve from 2.695 to 2.702 with increase in percentage of the stone dust (Fig-4).

4.2. Effect of Stone Dust on Void Ratio (e)

The void ratio of untreated soil sample was found to improve from 0.632 to 0.637 with increase in percentage of stone dust (Fig-5).

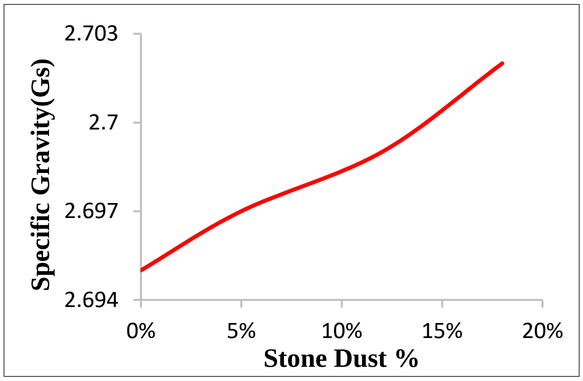

Figure 4-Effect of Stone Dust on Specific Gravity

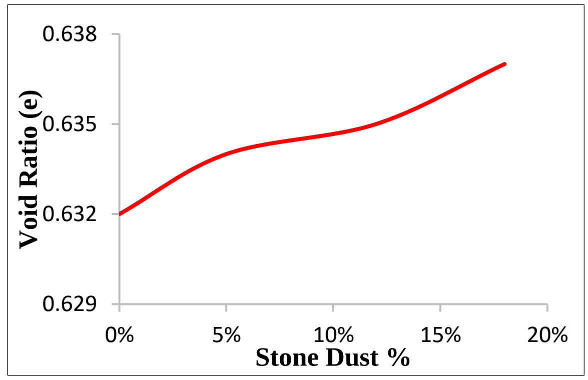

Figure 5-Effect of Stone Dust on Void Ratio

4.3. Effect of Stone Dust on Porosity (n)

Porosity of expansive soil was improved from 38.74% to 38.89% with increment in percentage of stone dust in (Fig-6).

4.4. Effect of Stone Dust on Liquid Limit (L.L)

Liquid limit estimation of expansive soil was found to diminish from 40.7% to 31.9% with increment in Stone Dust content (Fig-7).

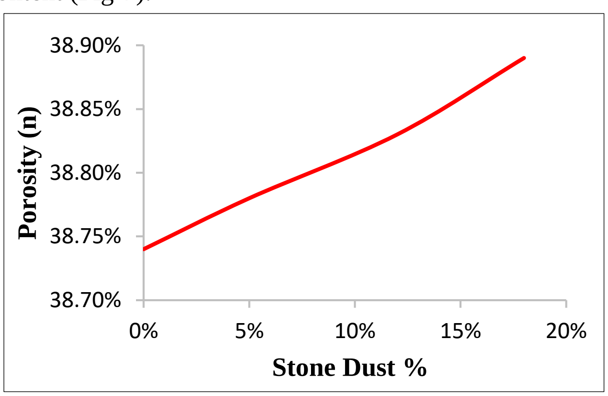

Figure 6-Effect of Stone Dust on Porosity

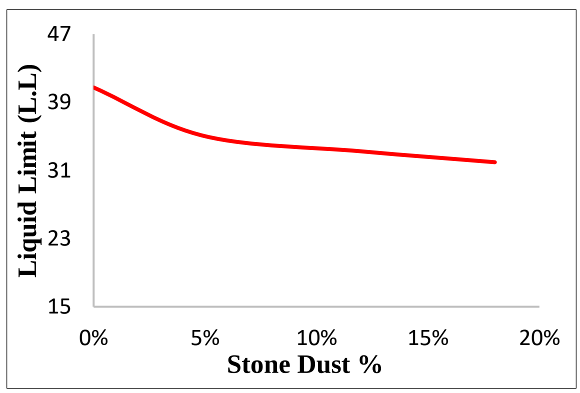

Figure 7-Effect of stone dust on liquid limit

4.5 Effect of Stone Dust on Plastic Limit (P.L)

The Plastic limit estimation of expansive soil was found to increase from 20.67% to 25% with increment in the percentage of Stone Dust. (Fig-8).

4.6 Effect of Stone Dust on Plastic Index (P.I)

The Plastic Index estimation of expansive soil was found to decrease from 20.064% to 8.4% with increment in percentage of Stone Dust (Fig-9).

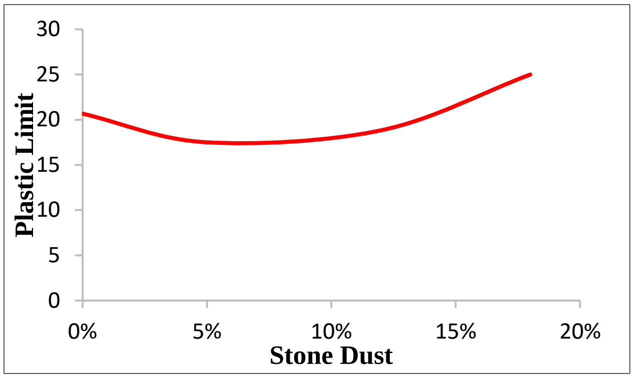

Figure 8-Effect of stone dust on plastic limit

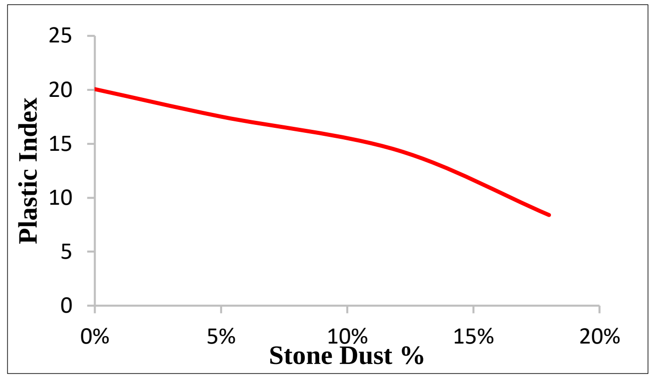

Figure 9-Effect of stone dust on plastic index

Table-5 Properties of Soil at different Admixture Percentages

S. No	Property	Value at 5%SD	Value at 12%SD	Value at 18%SD
1	Specific Gravity	2.697	2.699	2.702
2	Liquid Limit	35.1%	33.2%	31.9%
3	Plastic Limit	17.5%	18.8%	25%
4	Plasticity Index	17.52%	14.4%	8.4%
5	Void Ratio(e)	0.634	0.635	0.637
6	Porosity (n) (%)	38.78%	38.83%	38.89%

Table-6 Swelling of Soil treated with SD

S. No	Property	Value at 0%SD	Value at 5%SD	Value at 12%SD
1	Swelling (%)	8.4	6.56	4.43

Table-7 OMC and MDD of Soil treated with SD

S. No	Property	Value at 0%SD	Value at 10%SD	Value at 15%SD	Value at 20%SD
1	OMC (%)	12.4	11.76	9.16	6.2
2	MDD (g/cm3)	1.84	1.96	2.06	2.16

4.7. Effect of Stone Dust on OMC and MDD:

The MDD estimation of shrink/swell soil was found to be increasing from 1.84 (g/cm3) to 2.161 (g/cm3) with increment of Stone Dust. On the other hand, OMC of soil diminishes to 6.2% from 12.4% with increment in amount of Stone Dust. (Fig-10-12).

4.8. Effect of Stone Dust on CBR:

(Fig-13) shows that soaked CBR value of soil blended with different percentages of stone dust has decreasing pattern. The swelling of expansive soil decreases to 4.43% from 8.4% with increase in percentage of Stone Dust.

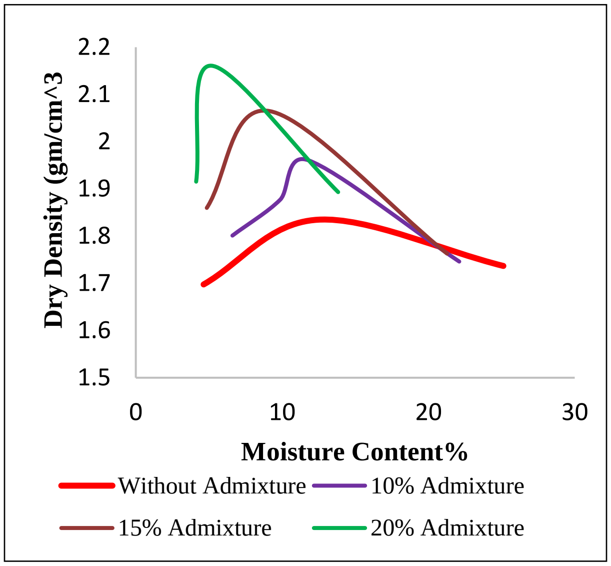

Figure 10-Compaction curve at variable SD percentage

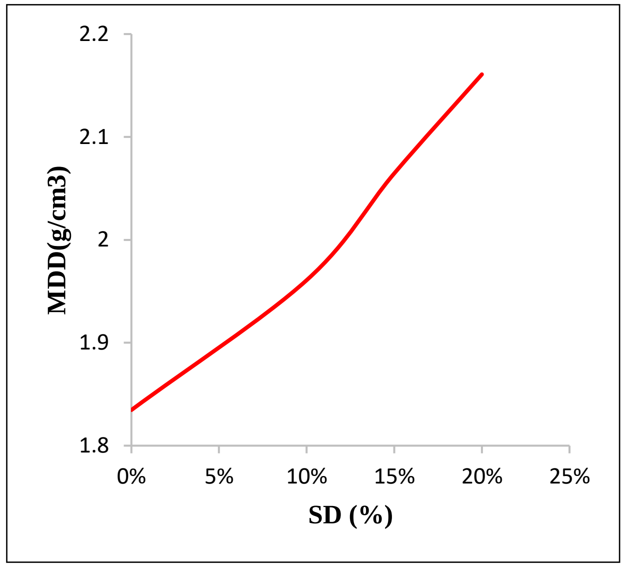

Figure 11-Effect of Stone Dust on Maximum Dry Density

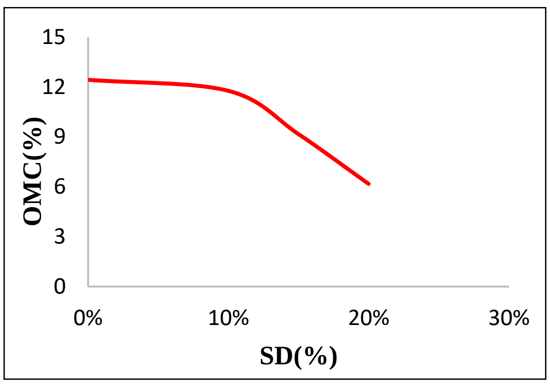

Figure 12-Effect of Stone Dust on optimum moisture content

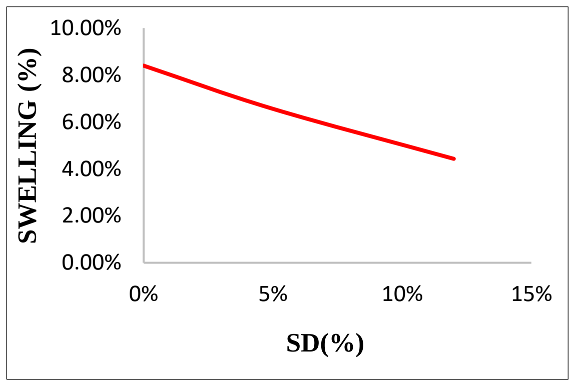

Figure 13-Effect of stone dust on soil swelling

So, it is clear from above experimental results that by increasing the amount of stone dust the value of specific gravity, plastic limit, void ratio, porosity and Maximum Dry density was increased and the properties like liquid limit, plasticity index, swelling potential and optimum moisture content were decreased as shown in Table (5-7). The soil swell potential reduced to 4.4% at 18% SD that lies in acceptable range and similar improvement was made when [9] used the quarry dust in range of 10,20,30,40 and 50% and concluded that only 30% was enough to improve soil properties. The reason why stone dust improves soil properties is that it possesses pozzolanic nature and contains coarse particles that improves compaction characteristics and reduces the plasticity. Moreover, it has good interlocking strength with soil because of its angular shape.

Research application in the construction industry is that the places like Dera Ismail Khan, Khairpur (Sind),Chakwal, Chakri and many more that are suffering from the problem of expansive soil can use the waste stone powder in improving the soil geotechnical properties instead of using the expansive material like cement and moreover they can get rid of fatigue of borrowing and disposing available soil.

Research significance is to provide guidelines and proper recommendations to be followed by locals during preconstruction period to avoid any post construction settlement problems in structures.

5. CONCLUSION

1. From the laboratory test results it is observed that initially the soil was medium expansive in nature but later at optimum percentage of 12% SD soil was transformed in to non-expansiveness.

2. The grain size analysis of soil clearly shows that the soil contains maximum quantity of fines almost 96% and initially the high value of plasticity index was observed that showed that the soil was highly plastic and cohesive in nature but later at optimum percentage of 18% SD plasticity of soil was reduced.
3. Optimum Moisture Content was found out to be decreasing gradually with increase in percentage of stone dust and reduced to 6.2% at 20% SD content which was beneficial in diminishing the amount of water required during compaction, and MDD was found to be gradually increasing from 1.84 to 2.16 and there was no optimum value but gradual increase in density with increase in SD.
4. The investigations uncover the fact that the liquid limit and plasticity index of the soil were reduced from 40.7% to 31.9% and 20.1% to 8.4% respectively and the plastic limit and specific gravity were improved from 20.7% to 25% and 2.695 to 2.702 at the optimum percentage of SD. So, SD can be considered best and economical soil reinforcing agent.

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