Reutilization of Stone Industry Waste Materials for Stabilization of Expansive Soil

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Abstract

Expensive soil shrink and swell during the wet and dry seasons which causes the differential settlement and lead to failure of different engineering structures. This study depicts the experimental investigation of the impact of stone dust as an admixture on the geotechnical characteristics of expansive soils. Moreover, this study explore to utilize the stone dust waste for strengthening the soil and making the environment pollution-free. The percentages of stone dust employed in the studies were 0%, 7%, 14%, 21%, and 28% by dry weight of soil, which substantially reduced the soil's swelling potential up to 0.3%. The results show significant improvements in the desirable geotechnical characteristics of the expansive soil. The optimal quantity of stone dust was concluded to be 28% based on the findings for treating the weaker expansive soil.

Keywords: Expensive soil, Soil Stabilization, Stone dust utilization, Maximum dry density, unconfined compressive Strength, shear strength, California bearing ratio, swell potential

Introduction

The enlargement of both urbanization and industrialization leads to more structural development as well as roads infrastructure and eventually they demand good soil conditions to be used as the strong foundations, but expansive soils are more problematic for construction purposes and are generally available in some countries around the globe [1]. Every year, expensive soil degradation causes more financial loss than floods, hurricanes, tornadoes, and earthquakes. [2]. According to the American Society of Civil Engineers, about 25% of homes suffer from expensive soil-related damage[3, 4]. Expensive soil typically shows its properties, including unforeseen expansion and contraction, extended water retention, low permeability rates, poor load transmission mechanism, and high compression [5].The expansive soils undergo a transformation from soft to hard state throughout the monsoon season. This characteristic of expansive soil creates significant difficulties while laying roadways. So there is utmost need to enhanced the engineering characteristics of expansive soils [6]. Traditional remedial ways to treat such type of soil were to replace the available weaker expansive soil but this solution create additional complication because of high costs and may cause environmental degradation [7]. Another possible solution to the problem is to treat the soil with certain stabilizer which leads to a reduction in soil compressibility and enhancement in its shear strength which in turn play an important role in improving soil bearing capacity, slope stability, and earth retaining structure like coffer dams and retaining walls etc.[8].

Soil stabilization states to the exercise of modifying a natural soil's structure, by physical and/or chemical alteration techniques, such that it is able to achieve definite engineering requirements [9]. In the present era, waste material is given preference in the stabilization of soil. This is due to the production of excessive waste materials like stone dust which not only affects health but also creates the pollution problems in the environment. This environmentally friendly has technique drawn the attention of researchers, to utilized ecologically safe and long-lasting stabilizers for expansive soil improvement [5]. A great extent of problems can be reduced by using stone dust waste materials for the stabilization of expansive soil. Stone dust is a waste product generated by the stone pulverizing industry, and each crusher unit is assessed to produce 15- 20% of stone dust [10]. It acts as a mechanical stabilizer, has high shear strength, and improves the geotechnical characteristics of soil when properly proportioned. Due to the angular form of stone dust particles, they have a high interlocking strength with soil, which not only increases soil density and compaction properties but also decreases the plasticity of extremely plastic soils[11]. Additionally, stone dust is pozzolanic in nature and includes coarse particles not seen in other admixtures such as fly ash. Numerous research studies were carried out for soil stabilization, the results show the significant positive impact of waste on soil properties [9]. Since, we are in the contemporary industrial age, with the fast development in the industrial zone, we must look for new additive materials, including modern wastes that will enhance our wellbeing while simultaneously causing negative consequences such as health issues and pollution. As a result, the usage of stone dust is critical for both health and stability [12].

Black cotton soil is an expensive kind of soil with increased shrinkage and swelling characteristics, making it unsuitable for subgrade and foundation use. As a result, bagasse ash and coir fiber are used to enhance the characteristics[13]. Research work has conducted experiments to determine the impact of crusher dust lime on the compaction characteristics of expansive soil. They have replaced expansive soil up to 70% (in increments of 10%), i.e. 10%, 20%, 30%, 40%, 50%, 60%, 70%, and quarry dust is added to soil samples to determine the characteristics of mixtures. They found that when crusher dust is put to expanding soil liquid limit, the plastic limit drops[14]. The researchers investigated "The impact of fly ash and lime fly ash on the properties of expansive soil," and discovered that when fly ash is applied to expansive soil, the plasticity index and California bearing ratio values arise[15]. A study was conducted to determine the impact of the addition of 20 percent stone dust on the engineering characteristics of expansive soils. It was discovered that the CBR and MDD values of expansive soils improved by 35 percent and 5 percent each respectively, while the Atterberg limits and optimum moisture content declined, allowing the soil to be used as a subgrade[16]. The impact of

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quarry dust concentration on the swelling properties of quarry dust black cotton soil mixes was studied in this study. A decrease in the free swell strain has been seen when quarry dust is added to black clay, as shown in this experiment. Quarry dust was utilized to reduce free swell strain, which was reduced from 45 percent to 16 percent when 50 percent of the quarry dust was added[17]. The study was carried out on pavement failure due to hydraulically bound materials. Quarry dust was introduced to tackle the failure. The problems faced were compressive strength, durability, shrinkage, etc. At commencement, experiments were conducted on soft soil to determine its characteristics. Then, quarry dust was substituted and fresh samples with QD attributes were tested. The results show that the addition of QD enhances the shrinkage limits, compressive strength, and durability [18].

Considering the toxic nature of expansive soil, geotechnical researchers are always on the lookout for novel and creative solutions to mitigate its undesirable characteristics via the use of soil stabilizing techniques[19]. Researchers objective in stabilizing expansive soil using different stabilizers is to preserve the volume change and flexibility or workability characteristics while significantly increasing the strength attributes[7]. Additionally, these stabilizers are expected to not only effectively reduce the volumetric strain associated with expanding soils, but also to address problems such as strength and cost. Moreover, the recommended stabilizers should be formulated in an environmentally friendly manner[20]. Therefore, this experimental research investigates the possible use of stone dust as an environmentally acceptable material for the enhancement of the geotechnical characteristics of expansive soil. The primary objective of this study is to ascertain the effect of stone dust on a material's liquid limit, maximum dry density, swelling resistance, California bearing ratio, shear strength and unconfined compression strength. Furthermore, the optimum quantity of stone dust is recommended based on the geotechnical characteristics of the expansive soil.

MATERIALS AND EXPERIMENTAL METHODS

Materials

The soil used in this investigation is obtained from the University of Lahore, Islamabad ground area where excavation has been carried out for the development purpose. And the stone dust utilized was obtained from crushing facilities located in Taxila's Margalla highlands Pakistan. 0% to 28 % doses of stone dust were added to analyze the impact on geotechnical characteristics of expansive soil. The soil properties are shown **Error! Reference source not found.**.

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S.no	Test names	Standards	Obtained values
1	Liquid limit (L.L)	ASTM D 4318	40%
2	Plastic limit (P.L)	ASTM D4318	15.18%
3	Plasticity index (P.I)	ASTM D4318	24.82
4	Moisture content (%)	ASTM D 2216	15.18
5	Specify gravity	ASTM D854	2.68
7	Optimum moisture content (%)	ASTM D698	14.50
8	Maximum dry density (g/cm3)	ASTM D698	1.914

Soil Classification

The soil classification is carried out as per AASHTO classification standard protocols. As per the AASHTO soil classification requirements sieve analysis was also carried and the result is shown in Figure 1.

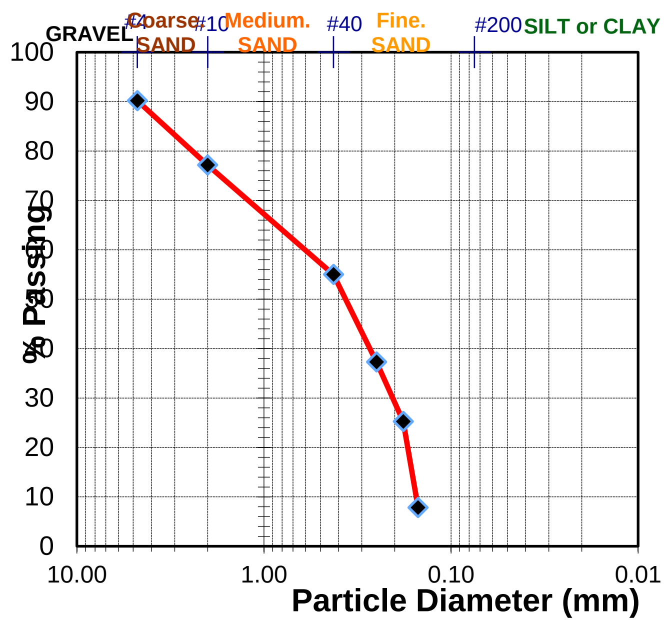

Figure 1 Gradation curve of collected soil

The AASHTO soil classification standard protocols was used for **Error! Reference source not found.**, the soil is A6 type which is clayey in nature.

Sample Preparation for Geo-Technical Investigation of Soil

Different samples of soil were prepared for both control and stabilized specimens according to the AASHTO standard guidelines. Different percentages were kept during the sampling 8%, 12%, 16% and 20%. Initially without admixture the soil was tested at these moisture percentages for maximum dry density. Like in the same way the maximum dry density test is carried out for 7%, 14%, 21% and 28% admixture replacement respectively. Similarly samples for CBR test and percentage of swell is prepared as per the AASHTO T193-2007.

Experimental Testing for Geo-Technical Investigation of Soil

Different experimental tests were conducted on the all samples prepared according to the ASTM/AASHTO standards. At very first stage Atterberg's limit were determined for soil classification, followed by maximum dry density, CBR, swelling percentage, shear box and unconfined soil strength for soil geo-technical investigation.

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Results and Discussion

Atterberg's Limit

Atterberg's limit result of the soil specimens were presented in Figure 2, with replacement of different percentages of stone dust. It can be seen that the liquid limit of the soil specimen decreases significantly by increasing the proportion of stone dust. It is derived that the flow properties of the soil sample are progressively improved with addition of stone dust. Minimum value of liquid limit was observed at 28% of stone dust. This reduction in the liquid limit is because of the improvement in the soil texture and structure characteristics that leading to a cementing effect. Moreover it was revealed that plasticity index decreased gradually in a comparable manner. This reduction in flow characteristics of soil due to addition of stone dust lead to prevent failure patterns in road building over expansive subgrade soils.

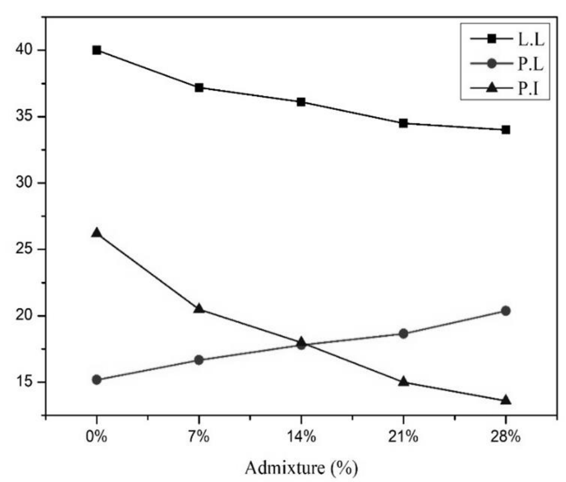

Figure 2 Stone dust effect on Atterbergs limit of A6 soil

Maximum Dry Density (MDD)

Maximum dry density values against different admixture (stone dust) percentages were shown in Figure 3. The analysis of the results shows that percentage of stone dust in the soil is directly proportional to the value of maximum dry density. The maximum dry density of soil is significantly increased with addition of stone dust. The maximum value was obtained at 28% replacement of admixture. This increase is because of appropriate soil particle rearrangement and the addition of non-plastic material, which enhances the binding capacity.

California Bearing Ratio

The variation of CBR values with the increment of stone dust percentages are presented in Figure 4. The result shows that CBR value rises as the amount of stone dust increased. It is worth mentioning that beyond the 28% dosage of admixture the curve shows slight reduction in the rate of CBR value. This clearly indicate the optimum limit of stone dust dosage i.e., 28% which is feasible and cost-effective. The rise in the CBR value of soil caused by the addition of stone dust in comparison to the original soil is due to an increase in density of soil mass with greater strength.

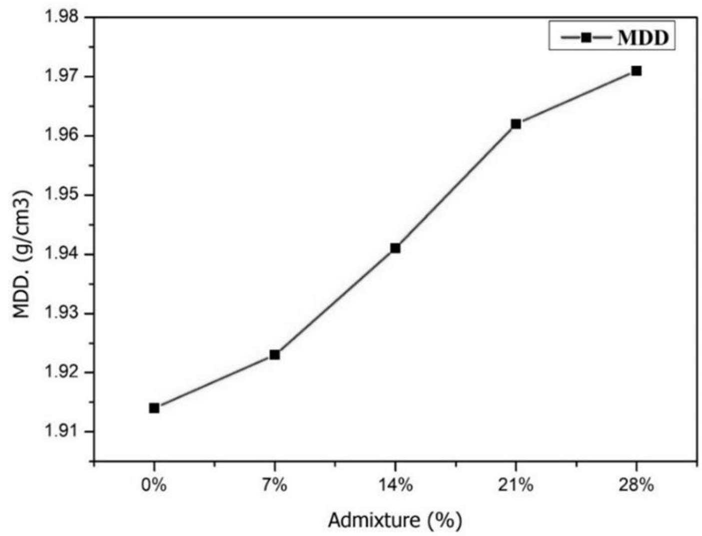

Figure 3 Stone dust effect on maximum dry density of A6 soil

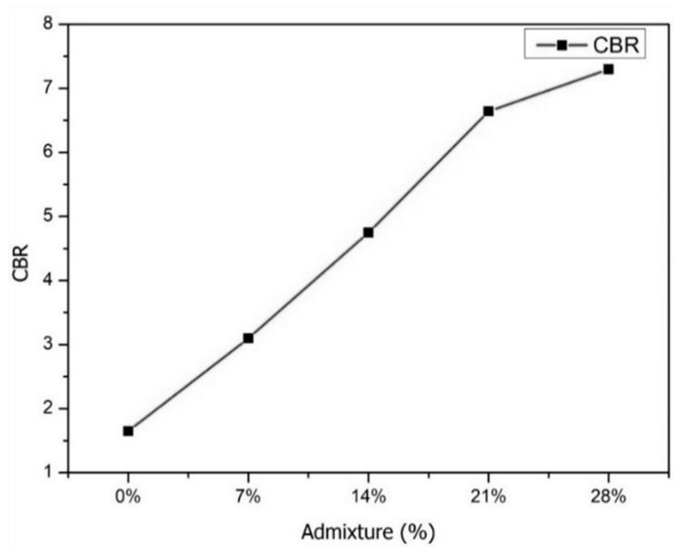

Figure 4 Stone Dust effect on California Bearing Ratio (CBR) of A6 soil

Swelling Index (SI)

Swelling index (SI) values variation with different percentages of admixture are presented in **Figure 5**. According to the results SI values of the expansive soil have reduced as the proportion of stone dust content has increased. With addition of stone dust as a stabilizer it remarkably reduced the swelling and shrinking of the expansive soil. It is further added that the recommended value of 0.3% swell is achieved at 21% of admixture with 65 blows. Beyond this percentage the swell index is further reduced, it is recommended that 21% dosage is an optimum value of soil stabilization against swelling.

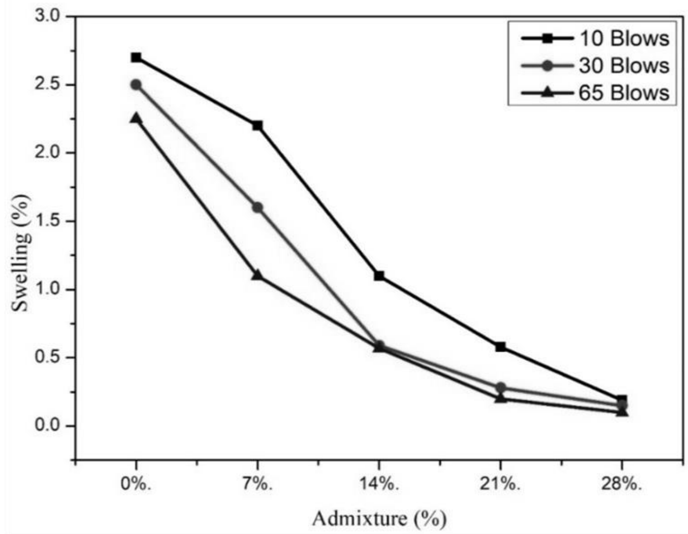

Figure 5 Stone Dust effect on Swelling of A6 soil

Shear Strength

Effect of stone dust on shear strength parameters C and Φ are shown in **Figure 6** and **Figure 7** respectively. The results indicate that the cohesion of the soil was first reduced, because initially the lack of courser particles and bonding were the problem, but it subsequently increased with increase of stone dust percentage beyond 14%. Furthermore, the angle of internal friction fluctuation was observed in an expensive soil with stone dust %. The Angle of Internal Friction of soil increases as the amount of stone dust added increases. When the percentage addition of stone dust reaches 28 %, the Angle of Internal Friction increases to 27^o from 18^o, and then decreases. When stone dust is added at a proportion of 28 %, the greatest increase in Angle of Internal Friction is 75%, compared to the Angle of Internal Friction of virgin expanding soil.

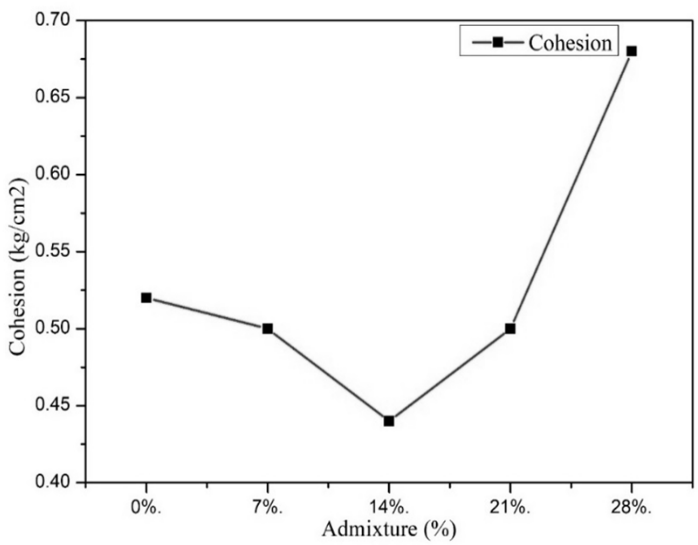

Figure 6 Stone dust effect on cohesion of A6 soil

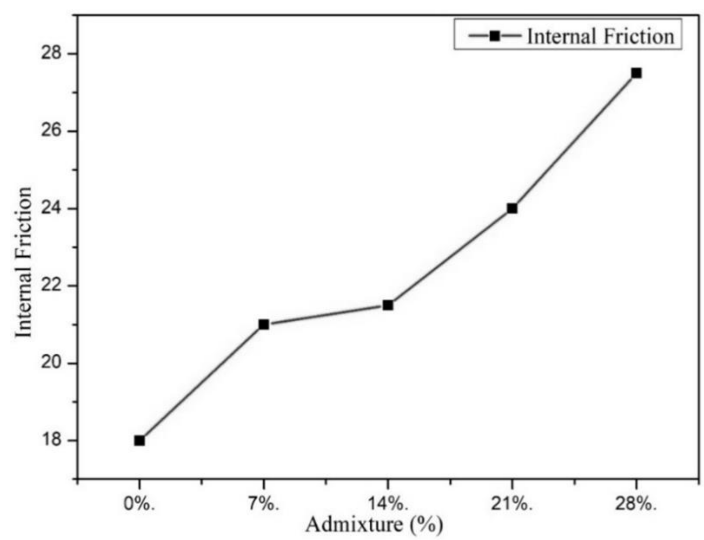

Figure 7 Stone dust effect on internal friction of soil

2.1. *Unconfined Compressive Strength (UCS)*

The results of the unconfined compressive strength test are shown in Figure 8. It is apparent from the results that the UCS value of the tested soil was raised to a value of 5.25 kg/cm^2 by the addition of 14% stone dust to the soil. Further UCS value dropped as the percentage of stone dust increased beyond 14 percent.

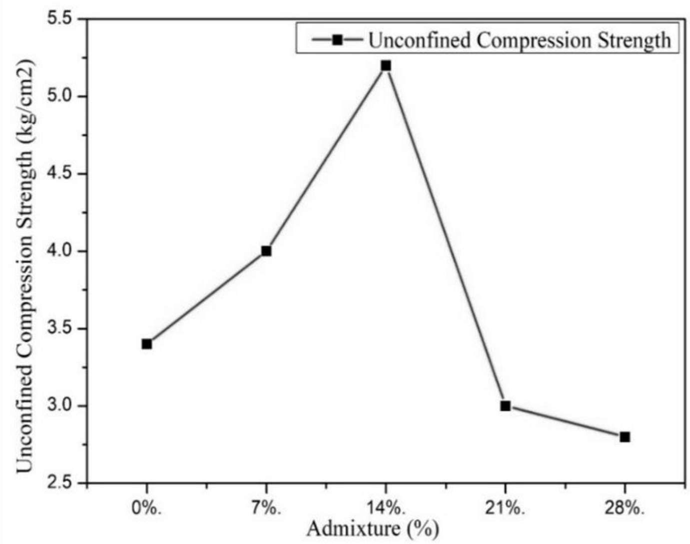

Figure 8 Stone dust effect on unconfined compression strength of A6 soil

Conclusions

Based on the findings of this research it is concluded that while increasing the quantity of stone dust it raised plastic limit, maximum dry density and California bearing ratio of the expansive soil. At the same time, it decreases the liquid limit, plasticity index, swelling potential, and optimum moisture content. Furthermore, the swelling percentage decreased to the recommended value of 0.3% with the addition of 21% stone dust. Initially, the soil cohesion is reduced by the addition of stone waste, but it is increased by incorporating a 28% dosage of the admixture. A very slight rise in the angle of internal friction of soil is observed but the addition of stone dust increased the UCS value obtained at 14% dosage which further declines by adding more admixtures. Based on the overall result investigation it is concluded that 28% of stone dust is recommended as an admixture that significantly enhanced the geotechnical properties of expensive soils. Beyond this limit the stone dust adversely affects the expansive soil properties and make the soil stabilization uneconomical. Moreover, up to 28% it is quit economical because of the availability of stone dust and its environmental implication because stone dust is a waste product and we have to utilize this with a constructive manner.

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