Proceedings of 8th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2020 Month: June Volume: 8

Effect of Rice Husk Ash and Brick Burnt Dust on Engineering Properties of Cohesive Soil of Suryabinayak, Bhaktapur District

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Abstract

There have been many innovative upgrading methods and techniques including chemical stabilization in practice for improving the engineering properties of problematic clay soil because of their swelling and shrinkage properties when it comes in contact with water. Due to this property of clay, the load bearing capacity of soil and other engineering properties are very poor. This study presents the effect of Burnt Brick Dust (BBD) and Rice Husk Ash (RHA) on engineering properties of an cohesive soil. Atterberg's limit test (Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI), Shrinkage Limit(SL)), Free Swell Index (FSI) and modified compaction test were determined at varying percentages of RHA and BBD. The practices have been performed on four proportions 4%, 6%, 8% and 10% soil. The virgin soil was fallen under A-7-6 classification using AASHTO (American Association of State Highway and Transportation Officials) and CL (Lean Clay) according to USCS (Unified Soil Classification System). The research result showed considerable reduction in swelling of soil. With increasing amount of stabilizer swell decreases. Maximum decrement in swelling has been noted in 10% of replacement of soil by BBD as compared to RHA. For increasing content of stabilizing agent BBD and RHA, LL and PL were also increasing and decreasing in PI. SL decreased with increasing percentage of BBD whereas SL increased with addition of RHA. Maximum decrement in shrinkage has been noted in 10% replacement of soil by BBD. There was a significant improvement in Maximum Dry Density (MDD) achieved while at lower percentages Optimum Moisture Content (OMC).

Keywords

Cohesive soil, Chemical Stabilization, RHA, BBD, Engineering Properties

1. Introduction

Partially saturated clayey soils having high plasticity are very sensitive to variations in water content and show excessive volume changes. Such soils, when they increase in volume because of an increase in their water contents, are classified as expansive soils. The swelling potential depends on the type of clay mineral, crystal lattice structure, cation exchange capacity, ability of water absorption, density and water content [1].

Most of soil deposit in Kathmandu valley are sand, silt and clay with organic content [2]. Cohesive soil can be termed as clay or silty clay, and it contains very fine particles lesser than 0.075 mm [3] which can hold water to increase volume of soil particle. It can also release moisture content to decrease volume of the soil. This type of soil is the common name for a number of fine-grained, earthy materials that become plastic when wet. Chemically, clays are hydrous aluminium silicates, usually containing minor amounts of impurities such as potassium, sodium, calcium, magnesium, or iron. The soils under study is major deposit in Bhaktapur district, having high clayey and silt content of very soft to soft consistency on the basis of several soil test report collected from G.S. Soil and Materials Engineeers Pvt. Ltd., Gairigaun, Kathmandu. Clay minerals typically form over long periods of time as a result of the gradual chemical weathering of rocks, usually silicate-bearing, by low concentrations of carbonic acid and other diluted solvents. These solvents, usually acidic, migrate through the weathering rock after leaching through upper weathered layers. In addition to the weathering process, some clay minerals are formed through hydrothermal activity. Clay can be identified by their very fine grain size of less than 0.002 mm, and have different properties depending on which particular clay minerals they contain.

High water content, high compressibility and low workability of these soils often caused difficulties in the civil engineering construction projects. The soil used for construction pavement or sub-base should have some specification of geotechnical properties for obtaining required strength against tensile stresses and strain variety [4].

In this research, waste material BBD and RHA have been used for improvement of the engineering properties of soil such as load-bearing capacity, settlement problem, shear strength, etc. The main purpose of this research is to improve the strength of the soil and to reduce the construction cost by making the best use of nearly available cheap materials. RHA is the most cost-effective agricultural waste produced from burning rice husk which is locally available materials act as a binding agent like cement which increases some geotechnical properties as well as stabilization of soil as an alternative option of cement and lime [4]. Rice husk ash has high quantity of silica with small quantities of oxide [5] having high specific surface that is very suitable for activating the reaction of soil and act as a binding material like cement.

Brick Dust is the component of burnt brick and the waste powder obtained from burning of the brick in the brick kiln. Since the year 2000, the amount of brick kilns in the Valley has increased by 200%. There are now roughly 500 brick kilns in operation during the dry season from December to May [6]. It has been used as soil stabilizer to improve the geotechnical engineering properties.

2. Materials and Method

2.1 Materials

2.1.1 Natural Soil

Dark Greyish and Blackish Silty Clayey soil was used in this study, collected from Suryabinayak Bhaktapur.The collected soil was hard and it was pulverized manually by hammer. Then the soils were screened through the sieve of 4.75mm apearture before preparing the specimens for testing. Table 1 shows some of the indices and engineering properties of the soil.

2.1.2 Rice Husk Ash (RHA)

RHA was collected from the locally available mill. RHA used in this investigation was passed through 425 micron sieve for convenient mixing with clay and compaction. The colour of RHA was whitish grey. As RHA particles have low specific gravity 2.17 and high external surface area, particles finer than 425 micron could result in nonuniform mixing. Hence, the RHA particle size was limited to 425 micron in the blends.

2.1.3 Brick Burnt Dust (BBD)

BBD was collected from the Bhaktapur Brick Kiln Industry near to the site. It was also passed through 425 micron sieve for the investigation for the uniform mixing with soil. The specific gravity of BBD is 2.29. The colour of BBD is yellowish brown.

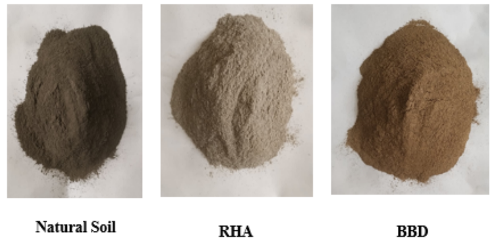

Figure 1: Samples

Table 1: Engineering properties of untreated soil

Engineering Properties	Soil
Specific gravity, G	2.67
Gravel size (%)	0
Sand size (%)	0
Silt size (%)	67.50
Clay size (%)	32.50
Liquid limit, LL (%)	44.631
Plastic limit, PL (%)	19.64
Plasticity index, PI (%)	24.99
Free swell index, FSI (%)	30
USCS classification	CL
AASHTO classification	A-7-6
Optimum moisture content, OMC (%)	28.83
Maximum dry density, MDD (KN/m3)	14.9

Table 2: Specific Gravity of Samples

Sample	Specific gravity, G
Untreated Soil	2.67
Rice Husk Ash	2.17
Burnt Brick Dust	2.29

Table 3: IS code for test specifications

Atterberg's limit	(IS: 2720 (Part V): 1985)
Free Swell	(IS: 2720 (Part 40):1977)
Modified Proctor Test	(IS:2720 (Part 7):1980)

2.2 Experiment Setup

In this study we are performing Atterberg's limits test, shrinkage test, free swell index, standard procter test for the determination of dry density and moisture content, unconfined compressive strength test on cohesive soil. The proportions of RHA and BBD for the tests were used in percentages as (0, 4, 6, 8 and 10) by dry weight of soil. The various tests are conducted as per IS code specifications which are shown in Table 3.

2.3 Preparation of testing Specimens

The collected soils, RHA and BBD contents were oven-dried at 105ºC overnight to remove moisture and repress microbial activity. Then the oven dried soil sample was mixed with different percentages of admixtures in a dry state.

2.4 Soil testing methods

2.4.1 Atterberg's Limit Test

LL and PL of the unblended cohesive clay were determined on oven-dried soil fraction passing 425 mm sieve. In the case of the blend samples, the cohesive clay was mixed by the pre-fixed amount of RHA and BBD, by dry weight of the soil, and then the tests on LL and PL were performed on the blends. LL of the soil samples were determined using conventional Casagrande's Method. The PL was determined by the conventional method of rolling the soil with fingers to form a thread of 3 mm diameter shown in figure 2, and Shrinkage limit by (Mercury Displacement Method). The samples for the determination of LL and PL were prepared under natural condition and additives mixed condition [7, 8].

Figure 2: Liquid Limit and Plastic Limit Test

2.4.2 Free Swell Index

Free swell index (FSI) was determined according to [9]. Oven-dried clay passing through 425 micron sieve was used for performing the FSI tests. The reference liquid used in the tests was kerosene. 10gm of oven-dried clay passing 425 micron sieve were poured into two 100 ml or 250 ml cylindrical jars containing kerosene and distilled water. The jars were made to stand for 24 h and then the volumes of the soil in the jars containing kerosene (V_k) and distilled water (V_d) were noted. Free swell index (FSI) is defined as the ratio of difference in volumes of soil in water and kerosene to the volume of soil in kerosene expressed as a percentage [10].

It is written as.

$$FSI = \frac{V_d - V_k}{V_k} x100 \tag{1}$$

In the case of FSI tests on cohesive clay blended with RHA and BBD, the oven-dry cohesive clay powder was replaced by the required amounts of RHA and BBD based on their dosages mentioned above, and FSI tests were performed on the blends as explained above.

2.4.3 Modified Proctor Test

Before conducting the compaction test, the non-treated and treated soils with stabilizers (4, 6, 8 and 10% RHA and BBD content) were mixed with water for about ten minutes by hand and kept this soil in an air tight container for about 18 to 20 hours. In the similar way, different amount of water contents were added to the different soil samples and mixing were done as described before to obtain the optimum moisture content and maximum dry density. A series of standard proctor tests on non-treated and stabilizer treated soils were conducted according to [11].

Modified Proctor Test **Determination of MDD & OMC**

Figure 3: Modified Proctor Test

2.4.4 X-Ray Powder Diffraction Test

Two grams each, of Oven dried fine powdered samples of untreated soil was provided to Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur for X –Ray diffraction analysis. The graph Obtained was analyzed using xpert highscore plus (software) to identify and quantify the minerals it contained.

3. Results and Discussion

3.1 Atterberg's limit

The index properties of soil is obtained from Atterberg's limit test results and free swell index test. The Atterberg's limits are a basic measure of the nature of a fine-grained soil. The test result of Atterberg's limit with RHA and BBD content is discussed below.

3.1.1 Liquid Limit

Figure 5 and 6 shows the variation of LL, PL and PI with RHA and BBD content respectively. The liquid limit of natural soil sample was found to be 44.63% and it increased from 44.63 to 50.88% when RHA content increased from 0 to 10%, indicating a increament of 14%. This improvement attributed that more water is required for the RHA treated soil to make it fluid because of the pozzalonic characteristics of RHA. Pozzolanic definition by ASTM C618 is 'a siliceous or siliceous and aluminous material which, in itself, possesses little or no cementitious value but which will, in finely divided form in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties'. Similarly, the LL increased to 51.84% with adding BBD content increased from 0 to 10%, indicates there is increament of 16.16%. In case of increasing LL using BBD is due to its pozzolanic properties [12].

3.1.2 Plastic Limit

For plastic limit that the value of plastic limit increases with the increases of RHA and BBD due to the pozzolanic characteristics. Pozzolanic materials has high silica content and porous structure [13]. This increase of plastic limit implies that RHA and BBD treated soil required more water to change plastic state to semisolid state. Plastic limit was found to be 19.64% on natural soil and it was also increased to 34.11% and 35.63% with increasing RHA and BBD content.

During the thread-rolling test for plastic limit the soil is subjected to a complicated stress path and critical straight line, as discussed by [14], as shown in Figure below. Where, q is deviatoric stress, p' is mean effective stress, u is pore pressure; soil suction and is negative, M is slope of critical straight line, c_u is undrained shear strength.

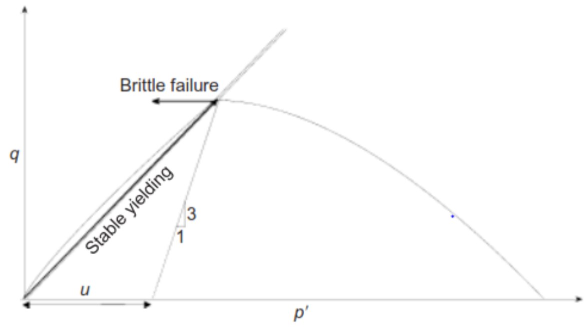

Figure 4: Stress path during plastic limit test

$$p' = \frac{\sigma_v}{3} - u \tag{2}$$

$$q = \sigma_v = Mp' \tag{3}$$

$$c_u = \frac{q}{2} \tag{4}$$

It can hence be shown that

$$2c_u = M(\frac{2}{3}c_u - u) \tag{5}$$

$$c_u = (\frac{3M}{6-2M})(-u) \tag{6}$$

The shear strength of the soil therefore increases linearly with increasing pore suction. The maximum pore suction that can be achieved without desaturation of the soil is limited by the lower of the air-entry value of the soil and the cavitation tension that can be sustained by the pore water [15].

3.1.3 Plasticity Index

The Value of plasticity index of soil sample was found to be 24.99% at zero percent added of RHA and BBD. The PI was decreased with increasing additives contents on soil. The reduction value at 10% of RHA content was 16.77% and similarly of BBD content was found to be 16.21%. There is no any huge changes in Atterberg's limit test result due to both additive contents.

3.1.4 Shrinkage Limit

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The variation of shrinkage limit is shown in Figure 7 and 8. Due to the replacement of the soil with the RHA particle which is inert and forms a rigid skeleton which resist towards the shrinkage. It is illustrated that as the addition of RHA the value of shrinkage limit increases. It is clear from that result that the RHA treated soil absorb more water to change semisolid state to solid state [4]. As shown in Figure 8, the value of SL decreasing as increasing BBD content. The value of SL was found to be 14.06 at 10% of BBD content. There was decrement of SL by 39.81%. This is because BBD treated soil absorb less water to change semisolid state to solid state due to the formation of free silt and coarser material than RHA.

3.2 Free Swell Index

The variation of free swell index with increasing RHA and BBD content is shown in Figure 9. The free swell index gradually decreased from 30% to 2.77% for up to 10% RHA content. Similarly, adding BBD upto 20% FSI decreased from 30% to 0% at 10% BBD content. So it is clear from the above discussion that swelling of soil as well as the possibility of crack formation on foundation can be minimized with the addition of RHA and BBD. The test result of various percentage content of RHA and BBD is shown in Table 6.

Table 4: Test result of Atterberg's limit with RHA content

RHA (%)	0	4	6	8	10
(LL),%	44.63	46.27	47.41	48.61	50.88
(PL),%	19.64	22.31	26.63	29.08	34.11
(PI),%	24.99	23.97	20.78	19.53	16.77

Table 5: Test result of Atterberg's limit with BBD content

BBD (%)	0	4	6	8	10
(LL),%	44.63	47.81	48.68	50.17	51.84
(PL),%	19.64	24.67	28.50	33.98	35.63
(PI),%	24.99	23.14	20.18	16.19	16.21

Table 6: FSI in various percentage of RHA and BBD

(%)	0	4	6	8	10
(FSI)RHA,%	30	27.27	19.36	9.09	2.77
(FSI)BBD,%	30	12.45	9.86	3.21	0

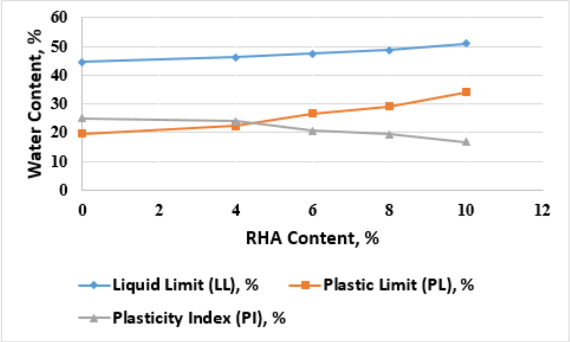

Figure 5: Variation of LL,PL,PI with RHA content

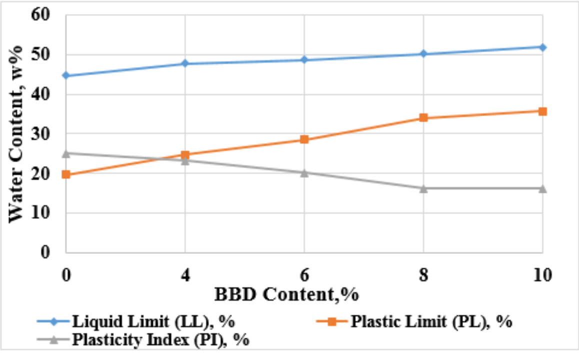

Figure 6: Variation of LL,PL,PI with BBD content

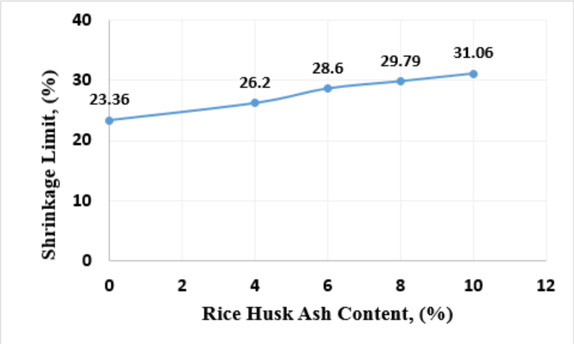

Figure 7: Variation of SL with RHA content

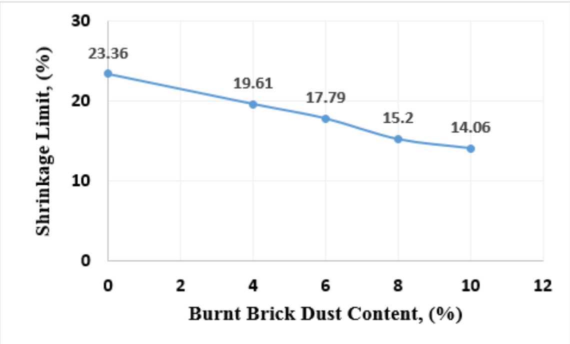

Figure 8: Variation of SL with BBD content

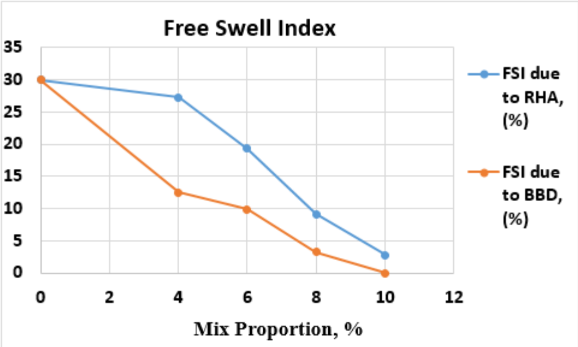

Figure 9: FSI chart for mix proportions soil and RHA,BBD

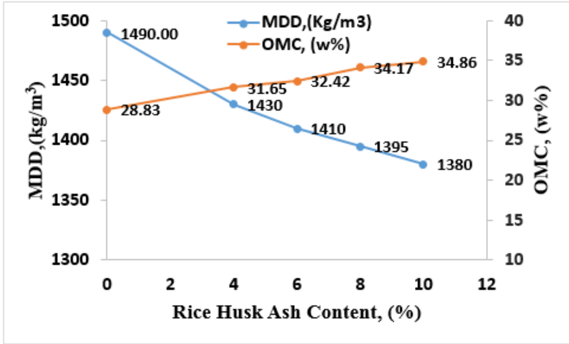

Figure 10: Variation of MDD and OMC with Rice Husk Ash content.

3.3 Compaction Characteristics

The variation of optimum moisture content and maximum dry density of RHA treated and untreated soil is shown in Figure 10. This figure represents the maximum dry density of soil decreases gradually with an increase of RHA content. This is due to comparatively low specific gravity value 2.17 of RHA than that of replaced soil 2.67 and the initial simultaneous flocculation and agglomeration of clay particles caused by cation exchange may be the another cause. On the other hand, the optimum moisture content of soil increases with an increase RHA, because RHA are finer than the soil. The more fines the more surface area, so more water was required to provide well lubrication. The RHA content also decrease the quantity of free silt and clay fraction, forming coarser materials, which occupy larger spaces for retaining water. The increase of water content was also attributed by the pozzolanic reaction of RHA with the soil. The variation of MDD and OMC of Soil with different percentages of Brick Burnt Dust is given in Figure 11.It was found that the OMC of Soil first increased by increasing the percentage of BBD to 6% and MDD decreased. The OMC of soil is increased from 28.83% to 31.12% and MDD decreased from 1490 kg/m^3 to 1430 kg/m^3 by increasing the percentages of BBD from 0% to 6%. As further increasing the percentages of BBD maximum dry density increased to 1590 kg/m^3 and result in decreasing OMC.The reason behind decreasing the OMC of on increasing BBD is the formation of an amount of free silt, clay fraction and coarser material due to which surface area increased hence less water required [16]. MDD drop on adding RHA occurs due to the reason that the void spaces between the clay soil particles are occupied by the RHA which has low specific gravity and hence is a low-density material decreasing the dry density [16]. Similarly, the BBD has high specific gravity as compared to RHA. Hence MDD of soil increased.

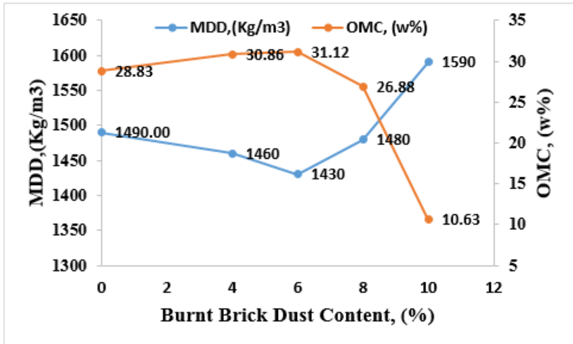

Figure 11: Variation of MDD and OMC with Burnt Brick Dust content.

3.4 Minerals Identification and Quantification

Based on the detail mineralogical identification and Quantification in Figure 12 and 13, it shows Quartz content is more in virgin soil.

4. Conclusion

In this study the effect of RHA and BBD on the engineering properties of cohesive soil are investigated and it can be concluded that there is an improvement of all the engineering properties of RHA and BBD treated soil.

1. The value of liquid limit and plastic limit increased with increasing the percentages of RHA and BBD where as the value of Plasticity Index decreased. LL and PL implies with the measurement of soil strengths. As slope stability is a strength-based phenomenon, it would seem rational to assume that soil at the liquid limit exhibits a fixed soil strength [17]. As increasing PL, shear strength of soil also increased. Hence, using RHA and BBD as soil

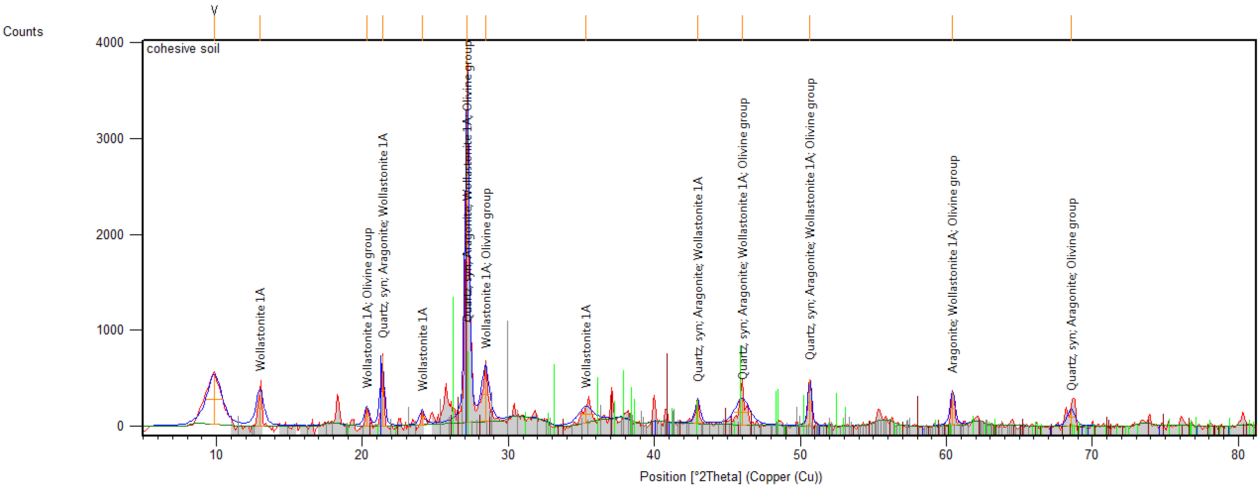

Figure 12: Mineral Identification

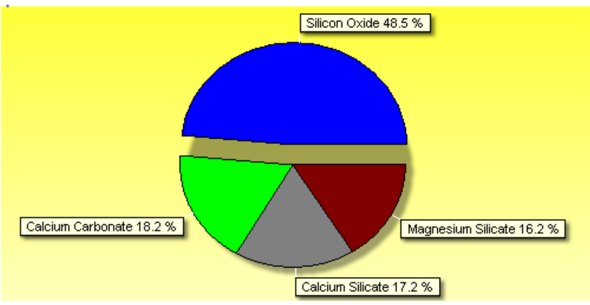

Figure 13: Mineral Quantification

stabilizer there is improvement on the soil shear strength.

2. Increasing the amount of RHA and BBD cause a increase and decrease in shrinkage limit respectively. The shrinkage factor helps in the design problems of structure made up of this soil or resting on such soil. It helps in assessing the suitability of soil as a construction material in foundations, roads, embankments, and dams.

3. The free swell index decreased with increase of RHA and BBD content which reduced the possibility of crack formation on the surface of foundation.

4. The maximum dry density of soil decreased with the addition of RHA because of the lower specific gravity of RHA. The value of optimum moisture content of RHA treated soil increased because of the pozzalonic action of RHA and soil, which needs more water. This shows that the soil can be made lighter which leads to decrease in dry density and increase in moisture content and reduced compressibility due to addition of RHA with the soil.

5. The maximum dry density of soil first decreased with increasing percentage of BBD from 0% to 6% and then increased in MDD from 6% to 10%, while OMC first increased from 0% to 6% and then decreased. This implies that improvement on soil bearing capacity with increasing BDD.

6. Minerals present on soil was identified and quantified using Xpert Highscore Plus software and found quartz is major mineral content on untreated soil.

   Addition of these two soil stabilizers with soil, resulting the improvement in engineering properties of the untreated soil at the micro-structural level, can pave the way for better utilization of these waste materials.

Acknowledgments

The authors are grateful to IOE, Department of Applied Sciences and Chemical Engineering, Pulchowk Campus. Special thanks to Society for Engineering Research and Design and G.S. Lab for their kind support and regards to Mr. Prakash Dulal, Ms. Neeru KC and Mr. Siddi Bhakta Maharjan.

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