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Swell Classification Analysis for Re-engineering Expansive Soil using Agricultural Waste Materials

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Abstract

Expansive Soils is the problem that does not only reach the required soil engineering properties but also its effect on the environment just because of the clay mineral constituents, that makes them display the swell classification. Looking for the best stabilizer to overcome problems in construction caused by weak soil is of significant interest. The objective of this study was to classify the effect of the properties of expansive soil through re-engineering using rice husk ash (RHA) and eggshell powder (ESP) as agricultural waste materials. The investigation provides on eleven (11) mix design with different percentage content of RHA, Chicken Egg Shell Powder (CESP) and Duck Egg Shell Powder (DESP) that has been tested. This paper thoroughly discussed their effectiveness for stabilizing expansive soils. Test for direct shear, Attenberg limit and Unconfined Compressive Strength (UCS) was conducted. Results revealed that adding of RHA along with CESP has considerably improved the unconfined compressive strength and shear strength of the soil performance. Moreover, the addition of RHA and CESP reduced the swell potential of the expansive clay soil.

Keywords: waste materials, swell classification, expansive soil, rice husk ash (RHA), eggshell powder (ESP)

1. INTRODUCTION

In the civil engineering field of specialization, various kinds of soils are being utilized; however, application in construction are suitable, by their natural form soil deposit. Whereas, without treatment, others are unsuitable, and become soil problems. Before they can undergo the applicable loads using upper structures, soils need to be dig and replaced on their properties should be modified. Expansive soils considered as typical problematic soils which are observed continuously worldwide, other than the arctic regions (Steinberg, 2000). Soil is the necessary foundation for any civil engineering structure. It is required to bear the loads founded on them without undergoing failure. In some places, the soil may be weak which cannot resist the loads that rested on them leading to the break-up of roadways, channel and reservoir linings, pavements, building foundations, water lines, irrigation systems, members for slab on grade and sewer lines (Gillesania, 2009).

One of the ancient technique is earth reinforcement and demonstrated in large amount in nature by the act of tree roots, animals, and birds. This technique has been utilized to process desire soil properties like permeability, compaction, shear strength, and bearing capacity. These fibers usually serve particles to lock together or materials and group the particles in a uniform analytic matrix (Prabakar and Sridhar, 2002). Natural fibers are the priorities obtained for soil improvement discover from trees. In geotechnical engineering applications, soil reinforcement has increased full acceptance because of the advantage of their economy, attainability, availability, secure handling, relative abundance, and they are environmentally friendly (Mattone, 2005; Li, 2009). Several works of literature reported improvement. This kind of soil has caused a significant amount of damage in the United States (Jones and Holtz, 1973), since its high susceptibility to volume change, sensitive to moisture content. The main result from fine-grained clay mineral content, volume change characteristics of expansive soils are thoroughly studied. Due to cost implication, geodetic engineers often prefer qualifying the properties of fine-grained soils in a site via stabilization in comparison with the soil replacement in practice (Buhler and Cerato, 2007; Hussey et al., 2010).

Some existing studies of expansive soil stabilization using rice husk ash (Rathan Raj R et al. 2016). Some other researchers made use of plastic and plastic bottles strips in stabilizing soil (Kumar et al., 2017). There were also studies using rice husk ash and fly ash combination mixed with the soil in various percentages with the dry weight of the soil (Brooks, 2009). Furthermore, studies were utilizing Eggshell powder and quarry dust in improving the clay soil properties (Geethu & Nimisha, 2016).

However, no study was found to use rice husk ash (RHA) and by adding eggshell powder (ESP) in stabilizing the soil. With this, the researchers decided to study on the effect from waste materials of rice husk ash (RHA) and eggshell powder (ESP) on the index and engineering properties for expansive soil reengineering using 4, 7, and 14 days cycle of curing.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Soil

The soil used in this study obtained from a road subgrade construction site Calbayog City, Province of Samar in the Philippines. A soil sample was in 1.5 m depths from the natural grid line that will use for the assessment.

2.1.2 Rice Husk Ash

Rice Husk was gotten from a local rice mill while the ash was obtained from the combusting Rice Husk under average pleasant temperature (open-air burning) until the husk turned to ash on a pure surface to avoid impurities.

2.1.3 Egg Shell Ash

Eggshell is the outermost part of the egg that serves to give protection to the component of the egg content from damage, either physically, chemically and microbiologically, the rest of the eggshell of chicks meant here is everything waste catalyze from industries that did not emerge from egg (sterile), and eggshells still contain the embryo dead. The pulverized egg shell collected from a local poultry farm, restaurants and eatery in the locality.

It continually dried at room temperature, and then, the soil was broken by a rubber hammer into small crumbs passing through 2.36 mm of ASTM C 136. The geotechnical properties of soil including particle size distribution, consistency limits and the specific gravity determined following ASTM D-4318-17el, Unconfined Compressive Strength (UCS) ASTM D 2166 and, the soil arranged as high plasticity clay (CH). The distribution curve of the soil through particle size was determine in accordance with wet sieving with the expansive soil index properties summarized in Table 1.

2.2 Methods

In soil mechanic, stabilization is one technique among various methods and procedures to improve the properties of the test soils (Onyelowe, 2017; Zhu et al., 2017; Srinivasan and Sivakumar, 2013; Onyelowe, 2017; Onleyowe and Maduabuchi, 2017; Onleyuwe et al., 2017; Onleyuwe and Okafor, 2012; BS 1924; Little et al., 2010). It is heavy duty to achieve stabilization in problematic soil like soft clay. These are because of the plasticity and the number of volume changes, due to precautionary measures that observed, erratic behavior, and optimum moisture content need to attain its ultimate dry density, because of their reaction on moisture to the materials is always uncertain. Through this process, compressing the porosity of treated soils, the ability gain and densification was achieved on the soil.

Table 1. Laboratory Result for the test conducted on Natural Soil

Test Conducted	Findings
Sieve Analysis	CH
Liquid Limit	68.81%
Plastic Limit	25.42%
Plasticity Index	43.39%
UCS (Unconfined Compressive Strength)	51.06 kPa
Direct Shear Test	139.09 kPa

3. RESULTS AND DISCUSSION

This paper analyzed the natural soil to determine its properties before it was treated then various mixtures designed to investigate if the properties of the soil improve after treating it with additives. Atterberg Limit test, Unconfined Compressive Strength test, and Direct Shear test performed on the various mixtures. The following results achieved from the experiments on specimen mixtures and natural soil.

Table 2. Liquid Limit, Plastic Limit and Plasticity Index of Soil added to waste materials

Quantity (%)	Liquid Limit (L.L)	Plastic limit (P.L)	Plasticity Index (P.I)
Rice Husk Ash (RHA)			
6 %	60.3 %	29.5 %	30.8 %
10 %	59.8 %	31 %	28.8 %
12 %	51.1 %	31.5 %	19.6 %
Egg Shell Powder			
Chicken	57.1 %	32 %	25.1 %
Duck	54.7 %	26.5 %	28.2 %

Table 2 shows RHA materials with a different value of percentage added to the soil. Its corresponding results of the liquid limit and plastic limit test and also its plasticity index manually tabulated with the increase in the quantity of RHA that could cause an increase in the plastic limit (PL) but there's a significant decreased in times of liquid limit (LL) and plasticity index (PI). P.I is used to relate to how expansive the clays. P.I is lower than 20 to 24 was commonly a safe area but higher than that we would have to react swelling clay conditions. It has observed that when the RHA has added to the soil, the plastic limit increases, liquid limit decreases, and plasticity index also decreases. The increment in the percentage of RHA provides a significant reduction in Liquid limit by volume filled by the RHA between soil particles. From the high potential swell classification of the untreated soil with a liquid limit of 68.81 % and Plasticity Index of 43.38%, with the extension of 12% RHA, The Liquid limit decreases to 51.1% with the Plasticity index of 19.6% which classified as Medium for its Potential Swell.

The types of eggshell were utilized to add up to the soil to provide results of liquid limit (LL) test, plastic limit (PL) test and plasticity index (PI). It has shown that the trend line in the liquid limit continued to decrease while the plasticity index has its lowest and plastic limit has its peak, in the S+20% CESP mixture. The liquid limit has reduced with the addition of 20% eggshell powder due to the absorption capacity of the eggshell powder because of its porous property. The liquid limit decrease from 68.81% to 54.7%. There was a higher increase in the plastic limit of the soil when 20% of Chicken Eggshell powder added. Change in liquid limit and plastic limit accordingly affects the P.I. of the soil. When the liquid limit increases permeability, compressibility, and the toughness and dry strength decrease. The plasticity index of the soil reduced from 43.38% to 25.1%.

Table 3. Liquid Limit, Plastic limit and Plasticity Index of Soil added with combination of ESP and RHA

Quantity of Additives (%)	Liquid Limit	Plastic Limit	Plasticity Index
6 % RHA and 20 % CESP	41.9 %	36.3 %	5.6 %
10 % RHA and 20 % CESP	52.6 %	39.3 %	13.3 %
12 % RHA and 20 % CESP	65.4 %	37.5 %	37.5 %
6 % RHA and 20 % DESP	61.4 %	29.3 %	27.9 %
10 % RHA and 20 % DESP	64.7 %	32.2 %	32.5 %
12 % RHA and 20 % DESP	63.1 %	29.9 %	33.2 %

Table 3 presents the quantity of the combination of ESP and RHA with its corresponding results. From the Liquid limit of 68.81% natural soil to 41.9% and the Plasticity Index of 43.3% to 5.9%. RHA is a pozzolans materials which react with calcium hydroxides at ordinary temperature forms mixtures possessing cementitious compounds. Eggshells are a source of calcium and contain lime-like ingredients. The reduction in the moisture is due to the water absorption of the ESP and RHA.

Table 4. Liquid Limit, Plastic limit and Plasticity Index of soil and all design mixtures

Design Mix	Liquid Limit	Plastic Limit	Plasticity Index
NS	68.81 %	25.42%	43.39%
M1 (20% CESP)	57.1 %	32%	25.1%
M2 (20% DESP)	54.7 %	26.5%	28.2%
M3 (6% RHA)	60.3 %	29.5%	30.8%
M4 (10% RHA)	59.8%	31%	28.8%
M5 (12% RHA)	51.1%	31.5%	19.6%
M6 (6% RHA+20%CESP)	41.9 %	36.3%	5.6%
M7 (10% RHA+20%CESP)	52.6%	39.3%	13.3%
M8 (12% RHA+20%CESP)	65.4 %	37.5%	37.5%
M9 (6% RHA+20%DESP)	61.4%	29.3%	27.9%
M10 (10% RHA+20%DESP)	64.7 %	32.2%	32.5%
M11 (12% RHA+20%DESP)	63.1%	29.9%	33.2%

As the result of the Atterberg limits that have been conducted, in all design mixtures, it has observed that the blend of 6% RHA and 20% CESP provides optimum values in terms of Liquid Limit, Plastic Limit, and P.I. To alter the potential swell classification from high to low of expansive soil that possesses a high plasticity index often shows a very noticeable reduction in bearing capacity with an increase in moisture content.

Table 5. Unconfined Compressive Strength of Soil and all design mixtures, with and without Curing

Specimen	Unconfined Compressive Strength (kPa)			
	0 days	4 days	7 days	14 days
Control	51.06			
M1 (20% CESP)	44.15	48.35	69.08	73.02
M2 (20% DESP)	40.22	42.18	45.75	55.05
M3 (6% RHA)	30.28	32.36	34.46	39.24
M4 (10% RHA)	34.32	37.89	40.04	44.6
M5 (12% RHA)	43.24	60.06	62.82	67.6
M6 (6% RHA+20%CESP) CESP	57.06	61.49	78.65	89.37
M7 (10% RHA+20%CESP)	47.13	52.19	57.27	64.83
M8 (12% RHA+20%CESP)	42.18	45.43	48.35	56.48
M9 (6% RHA+20%DESP)	44.33	48.48	53.6	64.83
M10 (10% RHA+20%DESP)	40.75	46.47	50.19	60.77
M11 (12% RHA+20%DESP)	32.17	38.61	44.61	53.62

Based on the data of the study for unconfined compressive strength test (UCS) of 11 design mixtures, it has found out that when the soil added with 6% and 10% RHA, its unconfined compressive strength decreases but with the additional material of 20% ESP, it increases to a certain point. With the mixture of 6% RHA and 20% CESP, the unconfined compression strength increases up to 73.6% for 14 days curing period. It has also observed that as the curing time increases, the unconfined compression strength of the treated soil also increases up to an average of 46.7% from the time of casting to 14 days.

Table 6. Cohesion, Internal Friction and Shear Strength of Soil mix with RHA and ESP

Specimen	Cohesion, c (kPa)	Internal Friction, ϕ	Shear Strength, τ (kPa)
Control	68.81	12.19	139.09
M1 (20% CESP)	39.12	14.57	143.12
M2 (20% DESP)	34.53	15.99	149.17
M3 (6% RHA)	44.4	12.58	131.03
M4 (10% RHA)	35.85	15.55	147.16
M5 (12% RHA)	32.39	16.47	165.97
M6 (6% RHA+20%CESP)	52.67	18.37	163.28
M7 (10% RHA+20%CESP)	23.88	24.4	205.61
M8 (12% RHA+20%CESP)	38.51	19.41	179.41
M9 (6% RHA+20%DESP)	31.58	16.91	153.18
M10 (10% RHA+20%DESP)	35.85	19.69	178.99
M11 (12% RHA+20%DESP)	35.02	18.04	165.3

The results from shear strength test, cohesion and internal friction of the soil added with the combination 20% ESP and different percentages of RHA tabulated, the effect of RHA and ESP combination with shear strength parameters of the expansive soil, the direct shear test conducted and the result obtained can be seen in table 6. It can be observed that with the addition of a combined 10 % RHA and 20% ESP, it gives an optimum value. From 139.09 kPa shear strength, it increases to 205.61kPa which is about 23.9%. From the internal friction of 12.19, it expands to 24.4 and cohesion reduced from 52.67 kPa to 23.88 kPa. The gain in strength is due to the production of secondary cementitious compounds with the CaOH obtained from the hydration of ESP. There is a difference of result obtained between the addition of ESP and DESP in which DESP gives lesser value compared to ESP, and it is due to the value of calcium that ESP content which is higher than the DESP wherein calcium is the main elements that needed in forming a cementitious compound. It can also be observed that after the addition of 10% of RHA, the value decreases. It is mainly because of the excess amount of RHA that didn't form into a compound due to the proportion of ESP and RHA.

Table 7. Summary of findings on the use of some waste materials in expansive soil stabilization

Sources	Material (content %)	Optimal (content %)	Findings
Sharmer and Sivapullaiah (2012)	GGBS (10-90)	20	UCS at 28 d increased by about 100%, and initial tangent modulus increased from 20 MPa to 60 MPa
Gobinath et al. (2016)	Precipitated silica (10-70)		UCS, and unsoaked CBR attained peak values at 10% additive content, soaked CBR reached the peak at 50% content, and consolidation coefficient increased from about 0.3_10_3 cm2 s_1 to 2.7_10_3 cm2 s_1
Shukla and Parihar (2016)	Micro fine slag (3-15)	6	UCS at 7 d and unsoaked CBR increased by approximately 325% and 186%, respectively; while the increase in soaked CBR was marginal
Dharan (2016)	Waste paper sludge ash (4-12)	8	CBR at 14 d increased from 5% to 25%, while UCS at 28 d increased from 150 kPa to about 450 kPa
Latifi and Meehan (2017)	Calcium carbide residue (3-15)	9	Natural soil UCS of about 200 kPa increased by approximately 250%, 1000% and 1800% at respective curing periods of 7 d, 28 d, and 90 d
Al-Sharif and Attom (2000)	Burned sewage sludge (2.5-15)	7.5	UCS marginally increased at 7 d curing, while the swelling pressure reduced by 60% and 28 d curing did not affect UCS
Anupam et al. (2014)	Rice husk ash, RHA (5-35)	25	Tests were performed at various curing periods (7 d, 14 d, 28 d, 56 d, and 128 d), and all results showed a similar trend. At 28 d, CBR increased from 2% to 13%, and the UCS, cohesion and friction angle increased respectively by 94%, 31%, and 150%. Also, the split tensile strength increased from 15 kPa to 23.5 kPa. At stress-strength ratios 0.5 and 0.8, the resilient modulus of the soil increased by 94.5% and 94.2%, respectively
Osinubi et al. (2016)	Locust bean waste ash (2.5-15)		Three compaction energies, British Standard Light (BSL), West African Standard (WAS), and British Standard Heavy (BSH) and also curing periods of 7 d, 14 d and 28 d (for UCS) were used. At all curing periods, UCS significantly improved using BSL, and all peak values of UCS progressively increased with curing period. CBR significantly increased for all compaction energies, and a similar trend was observed for the resistance to loss in strength
Butt et al. (2016)	Sawdust ash (SDA) (4-12)	4	UCS and unsoaked CBR increased by 26% and 103%, respectively
Sivasubramani et al. (2017)	Bagasse ash (5-25) and ESP (3)	25	CBR increased from 0.58% to 12.23%, and cost reduction of 23.4% was obtained after comparative analysis of subgrade pavement design using stabilized and natural soils
Signes et al. (2016)	Crumb rubber particles		Swelling potential reduced from 3.71% to 1.37% while friction angle increased from 28.5° to 48.5°
Ikeagwuani (2016)	SDA (2-10) and lime (4)		Overall improvement in the plasticity and compressibility characteristics of the soil
Present study	CESP and RHA		The plasticity index of the soil was reduced from 43.39% to 5.6% with the addition of Blend of CESP and RHA
	RHA (6) and CESP (20)		UCS value improved for about 75% when soil is added 6%RHA with 20%CESP for 14 days curing

4. CONCLUSION

The standard experiment was carried out first on the natural soil. The expansive soil is identified as clay with high plasticity (CH) according to USCS Soil Classification System. It has a high potential swell classification, the unconfined compressive stress of 51.48 kN/m2 and shear strength of 139.09 kN/m2. Soil with 12% RHA only and that with 10% RHA and 20% CESP both reduced in its swell potential. However, soil with 6% RHA and 20% CESP showed the most significant decrease in swell potential. Soil added with ESP only and that with both RHA and ESP have increased its unconfined compressive strength. The mixture of 6% RHA and 29% CESP, however, gave the highest increase from 51.48 kPa of natural soil to 89.37 kPa under 14 days curing period Soil added with RHA decreases its internal friction but increases its cohesion. With the addition of ESP and RHA and that ESP only to the soil, it increases the shear strength; however, 10% RHA and 20 % CESP gives the highest value from 139.09 kPa to 205.61 kPa. The curing period increases the unconfined compressive strength of the treated soil up to an average of 46.7% from the time of casting to 14 days. CESP along with RHA used in combination possessed specific properties which enables it to be used economically for improvement of Expansive clayey soil. Since Eggshell and

Rice Husk are waste products, usage of the same reduces the environmental problems. Generally, the study concluded that adding up RHA along with CESP had improved the unconfined compressive strength (UCS), shear strength, and it also reduces the swell potential of the expansive clay soil. Therefore, the proposed mixed materials are suitable for geotechnical applications thus offering innovative use of waste materials and a contribution to sustainable construction.

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