Efficacy of Almond Shell Ash Inclusion on the Geotechnical Behavior of Lime Blended Kaolinitic Soil

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Abstract. The current study focuses on studying the effect of almond shell ash (ASA) inclusion along with lime in addressing issues related to strength and volume change behavior of a typical problematic soil. Experiments were carried out on both natural as well as amended soil mixtures having varying percentages of lime and ASA (added based on dry weight of soil). The addition of ASA reduced the plasticity characteristics of selected kaolinite rich clay. Of all the mixtures, the mixture containing 1% ASA and 0.5% lime exhibited maximum OMC (optimum moisture content) and lowest value of MDD (maximum dry density). Upon curing to 28 days, the same mixture exhibited Unconfined compression strength (UCS) value 76 kN/m2. The results pertaining to UCS values indicated that, the rate of gain of strength increased proportionally up to 1% ASA addition, followed by which there was consistent decrease in the rate of gain of strength even in the presence of lime and is attributed to pore saturation with ASA. The addition of lime aids in better binding between non plastic ASA particles and kaolinite rich clay which was confirmed by scanning electron microscopic (SEM) images and X – Ray Diffraction (XRD) studies. SEM images confirmed the presence of agglomerated particles with homogenous mass exhibiting reduced pore opening size for mixture containing both ASA and lime.

Keywords: Almond shell ash, Unconfined Compression strength test, Scanning Electron Microscopy, X- Ray Diffraction.

1 Introduction

Globalization has led to the development of ideas and innovations to meet the demands of ever growing world, technology has actuated towards utilizing materials of mere negligible importance for achieving comfort in many engineering spheres. Soil poses many intimidating situations when exposed to loads, making soil engineering open its approach to improve engineering properties by different options, both in materials and methods to assure improvement in the strength. The overall intention would be to make the soil capable in withstanding the loads or any kind of situations prone. Since the world is moving towards sustainable methods of development, use of easily available materials for stabilization of soil is proposed. The present work is an attempt to use Almond Shell Ash as a soil stabilizer.

Since use of ash in the stabilization is widely proclaimed since the ash has got cementitious properties, the use of fly ash, Rice husk ash, Wood ash, Saw Dust ash, groundnut shell ash, Municipal Solid Waste Incinerator ash [1], Waste paper sludge ash etc. are some examples of ashes used for soil stabilization. Lime is a well-known material used for stabilization of soil, Lime as a soil stabilizer assures increase in strength after aging of soil lime mix. Lime is used as additional binder along ASA in the present study, moreover lime is used as soil stabilizer since time immemorial [2]. Improvement in properties of the soil was observed when it treated with Cashew nut shell ash blended with lime. Keeping the lime content constant soil is treated with cashew nut shell ash, results showed that the increase in density, strength and CBR value is due to the formation of Pozzolonic compounds formed during the reaction between lime and ash which stabilizes the soil matrix [3].

2 Materials and Methods

2.1 Soil

The soil sample was obtained from agricultural land in Chikbalapur district (13.3908678o N, 77.8980191o E) of Karnataka. The soil under study is kaolinitic with quartz and silica as major components. The soil was tested for the properties and the following parameters were obtained.

Table 1. Properties of soil

Property	Value	Standard Specifications
Colour	Red	
Natural water content/%	20.86	ASTM D4959(ASTM 2000a)
Specific gravity	2.45	ASTM D854(ASTM 2002)
Liquid limit/%	71.5	ASTM D4318(ASTM 2005)
Plastic limit/%	30.51	ASTM D4318(ASTM 2005)
Plasticity Index/%	40.99	ASTM D4318(ASTM 2005)
Classification (USCS)	CH	ASTM D2487(ASTM 2006)
Optimum water content/%	23.49	ASTM D1557(ASTM 2012)
Maximum dry density (kN/m^3)	15.30	
Unconfined compressive strength (kN/m^2)	39.1	ASTM D2166(ASTM 2000b)

2.2 Almond Shells

The Almond Shells were procured from the state of Jammu and Kashmir, the rigid shell covering the edible part of the almond fruit is the material taken for the study. Almond shell is a rigid material having hard fibrous texture and usually utilized to produce heat.

The almond shell ash was produced by exposing the crushed almond shells to a temperature of 800^o C to 850^o C in muffle furnace for four hours and the ash passing through 425μ sieve was used as an additive in the present study.

Fig. 1. Almond Shells

Fig. 2. Almond shell ash

2.3 Lime

Lime being utilized in this work is procured commercially, since use of lime with ASA is tested for its behavior and the reference to the work carried out on these materials prior to this attempt was not well established, hence the quantity of lime used in this work is restricted to a maximum of 1.1%. The effectiveness of ASA needs to be ascertained with a small quantity of lime along this additive.

3 Methodology

The soil passing through 4.75 mm sieve was used for testing after all the degradable matter was removed. Index properties of the soil were determined in accordance with the respective ASTM standards [4-9]; the results of the same are presented in the Table. 1. The tests were conducted on both untreated and treated soil, the proportion of soil and stabilizer is kept as soil, Almond shell ash and 0.5 % lime.

The oven dried soil was spread on a non-perforated surface and the additives (ASA and Lime) in the desired quantities were sprinkled over the maximum area of the dried soil and eventually the dry soil was mixed rigorously to get homogeneous mix for conducting the tests. Targeted geotechnical properties viz., Maximum dry density, Optimum moisture content, Plasticity characteristics and Unconfined compressive strength were studied with the addition of stabilizer.

4 Results and Discussions

The addition of almond shell ash has shown a typical variation in geotechnical parameters of the soil. With the increase in % of ASA the specific gravity of the soil mix was decreased (Figure. 3), this is attributed to the lesser density of ASA getting homogenized in the soil eventually decreasing the density of overall soil mass. It is proclaimed that ashes like rice husk ash have a greater surface area which is another factor causing decrease in the specific gravity of the soil [10,15]. ASA can also be considered having greater surface area and is found to reduce the specific gravity of soil with increase in percentage of ASA content. Figure. 4 shows the variation in Maximum dry density (MDD) and Optimum Moisture Content with the variation in the ASA percentage. It is observed that decrease in MDD of soil amended with ash is due to decrease in specific gravity.

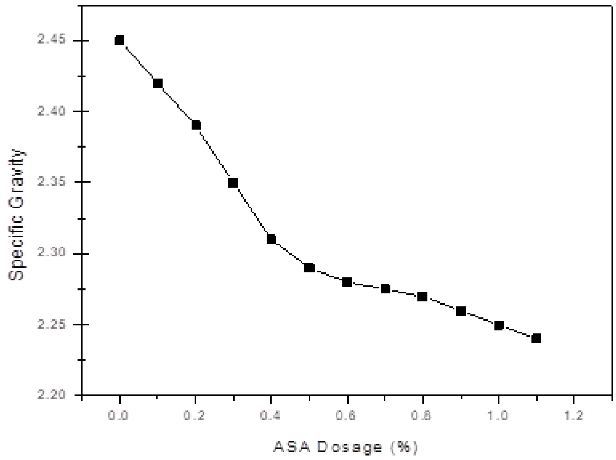


Fig. 3. Variation of Specific Gravity with increase in the ASA Dosage

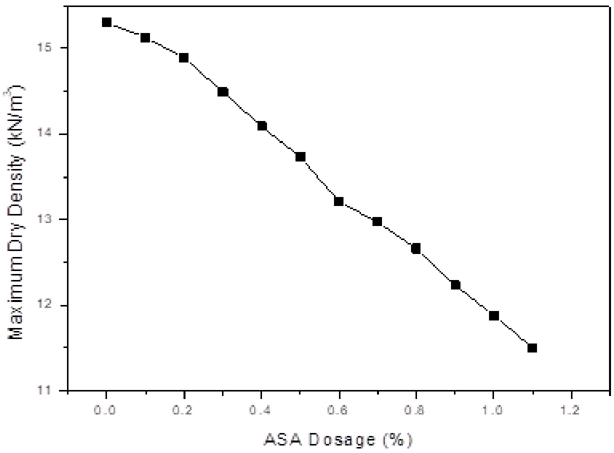


Fig. 4. Variation of MDD with increase in the ASA Dosage

Figure 5. Shows that the amount of moisture required to get maximum dry density increases with increase in the Dosage of ASA in the soil. This is attributed to the properties of ash which demand greater amount of water for making the whole ash content to get homogenized with the soil or for the sake getting hydrated [1] further the more amount of moisture needed to make the soil mass compacted to the maximum since the voids in the soil mass increase with increase in the Dosage of finer.

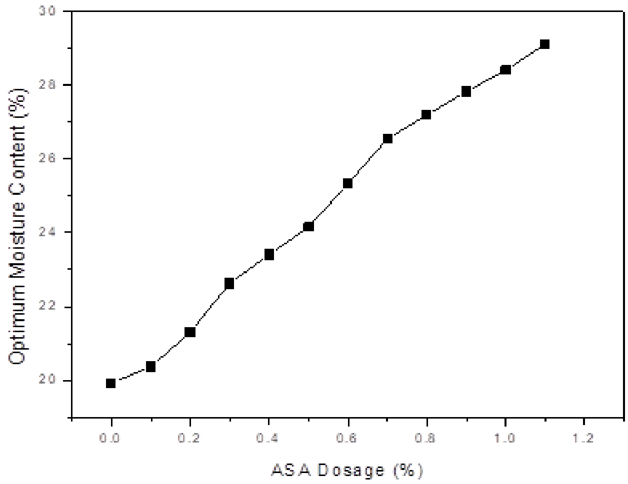


Fig. 5. Variation of OMC with increase in the ASA Dosage

4.1 Effect of ASA on the plasticity characteristics of the soil

Table 1. shows the plasticity index of the soil reduces gradually with the increase of the ASA percentage, since increase in the ASA Dosage with 0.5% lime demands more water to achieve MDD. The decrease in plasticity index can be caused due to the increase in capacity of the soil amended with lime and ASA to hold greater amount of water in the voids [11] i.e., before the pore saturation level is nearing and when the gel is formed in the voids.

The extent to which the soil continues to be plastic is expressed by the Plasticity index (PI), which is the difference between liquid limit and plastic limit [12]. Table1. Shows that the plastic limit of the soil increases from 30.51% to 57.31%, which is an increase of 26.74% when 1.1% by weight of ASA in comparison with PL of soil alone, this increase in plastic limit and reduction in LL resulting in the reduction in PI [10], this scenario indicates the improvement of strength of soil. The decrease in the value of PI is a strong favour to the strength of the soil ascertaining the improvement in performance of soil against loads [13]. The addition of greater volume of water in the soil develops risk of reduction in strength because the addition of water increases the value of Plasticity index leading to shrinking of the soil mass and reducing the strength [14].

4.2 Effect of ASA on strength of the soil

The strength performance of the mixture of the soil and ASA along with lime is represented in the Figure 6. It can be observed that the UCS values are increasing with increase in the ASA % till the Dosage of ASA is found to be 1 % and with further increase in the ASA % the strength decreases. The Dosage of additives which seems to show the maximum strength is soil+0.5% Lime+1% ASA.

Table 2. Summary of Results

ASA %	Specific Gravity	LL %	PL%	PI	MDD (kN/m^3)	OMC %
0	2.45	71.5	30.51	40.99	15.3	23.49
0.1	2.42	69.3	31.13	38.17	15.13	20.37
0.2	2.39	68.4	31.73	36.67	14.89	21.31
0.3	2.35	67.1	32.27	34.83	14.49	22.63
0.4	2.31	66.3	32.81	33.49	14.09	23.41
0.5	2.29	65.5	33.33	32.17	13.73	24.16
0.6	2.28	64.3	36.52	27.78	13.21	25.33
0.7	2.275	63.2	40.28	22.92	12.97	26.55
0.8	2.27	61.5	45.51	15.99	12.66	27.19
0.9	2.26	60.3	49.32	10.98	12.23	27.83
1	2.25	59.57	54.23	5.34	11.88	28.41
1.1	2.24	58.7	57.31	1.39	11.5	29.11

Further the UCS specimen with age of 28 days portrayed the maximum strength, the amount of increase of the strength for 28 days is found to be 64.78 % when compared with 0 days curing and an increase of 26 % strength is observed in the specimen aged 28 days in comparison with the 21 days old specimen for 1% ASA. Lime plays an important role in the bonding of the soil particles together with the ASA leading to a better performance of the amended soil. The increase in UCS value with increase of the ASA along lime is caused due to the formation of a gel like substance between the soil particles when the lime and ASA combine and start reacting and the gel depicts cementitious behavior strengthening the bonds between the soil grains. Further the increase in the moisture added to the specimen also paves the way to the increase in the UCS value of the soil since the moisture helps the lime and ASA to react completely resulting in through involvement of the entire additive mass in the specimen. Increase in the ASA content i.e., more than 1% leads to a decrease in the strength, the reason for this decrease in strength is due to the formation of weak bonds between the soil and the gel formed, the excess formation of the gel leading to the decrease in the compressive strength of the soil is termed as pore saturation. Overall performance of the soil with the addition of the ASA portrays the usual results which are observed when soils are amended with other kinds of ashes.

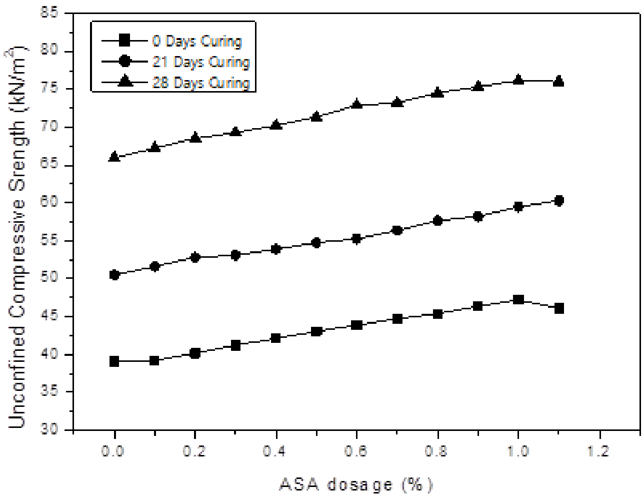
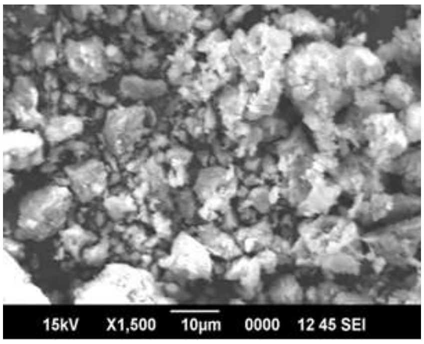


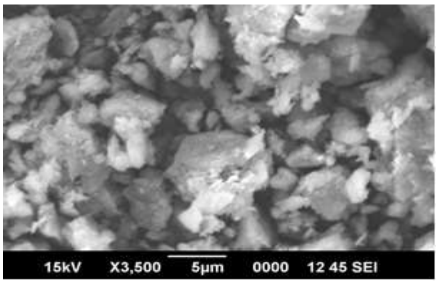
Fig. 6. Variation of UCS results with increase in the ASA Dosage along 0.5 % lime for different curing periods

4.3 Scanning Electron Microscopy Analysis

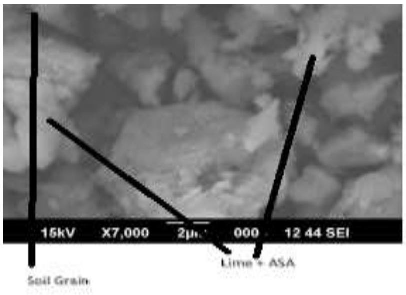
Scanning electron microscope (SEM) images of the soil, Lime and ASA mixture shown in Figure 7. Depicts three resolutions i.e., 10 µm, 5 µm and 2 µm respectively of Soil amended with 0.5% ASA and 0.5 % Lime, the image with 2 µm resolution helps to distinguish the soil grains and the gel formed in the voids. In Figure 7 (c) the soil particles indicated as "Soil Grain" surrounded by the smaller lumps indicated as "Lime + ASA" explains the scenario wherein the voids between the soil grains are filled by the gel formed by reaction of ASA and Lime, the gel seen in the SEM image appears as a cloudy mass partly filling in the voids paving the way for through bonding of the soil grains and eventually developing the strength confirming the claims made in the research. The Dosage of ASA percentage decides the amount of voids between the soil particles getting filled, for mix with lesser amount of additives the Lime and ASA gel gets glued to the soil grains and develops bonding where ever the contact of the soil grains is possible, with the increase in the Dosage of additives till the optimum quantity i.e., 1% ASA and 0.5% lime the voids get filled to the maximum which portrays maximum strength of the soil, and further increase of the Dosage of ASA paves the way to pore saturation making entire soil mass to accommodate lumpy masses of ASA and lime decreasing the strength of the soil.



(a)



(b)



(c)

Fig. 7.(a), (b) and (c) SEM Images of the Soil sample with 0.5 % ASA and 0.5% Lime

Fig. 8. Is the SEM image with resolution of 2 μm for the combination of soil with 1 % ASA and 0.5 % Lime, the image shows the soil grains covered completely by the gel formed by the ASA and lime it can be observed that the image majorly depicts the cloudy mass in even at the sharp edges of the angular soil grains. And it even indi-

cates the formation perfect homogenized appearance assuring proper bonding of all the soil particles. Fig. 9. Shows the Powder XRD of soil specimen with ASA to understand the mineral composition of mixture it was found that the soil is predominantly kaolinite with minerals being alumina and quartz. Since the almond ash is an organic element, it was beyond the scope of XRD to detect it.

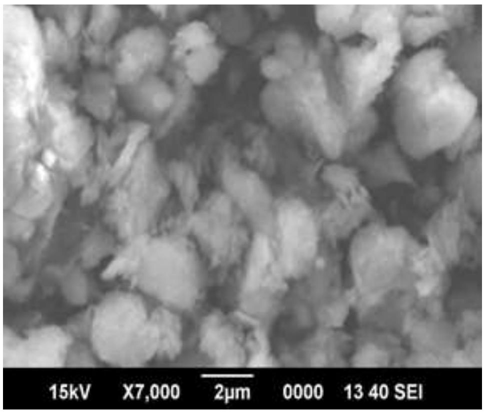


Fig. 8. SEM Images of the Soil sample with 1 % ASA and 0.5% Lime

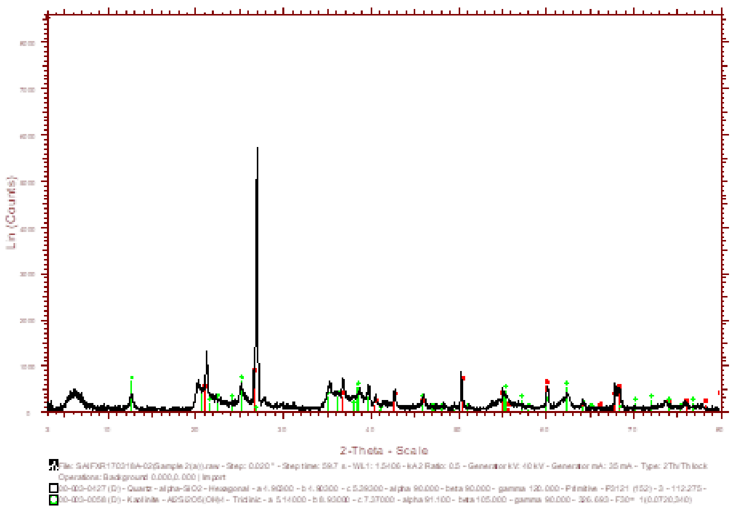


Fig. 9. XRD Image of the Soil sample with 1 % ASA.

Conclusions

The study taken up gives the experimental results for the soil amended with 0.5 % lime and ASA varying from 0.1 to 1.1 % with an increment of 0.1% by weight of dry soil. The following conclusions are drawn:

- ASA is found to be a potential soil stabilizer meeting the demands of sustainable development, since the production of ASA is abundant in some parts of the world.
- 1% of ASA by dry weight of the soil mass along 0.5 % of lime is found most suitable for obtaining the maximum strength and further addition of ASA resulted in decrease in UCS value.
- ASA even reduced the PI of the soil indicating its suitability to improve strength by increasing the plasticity of soil.

Use of ASA with Lime can be a potential combination for soil stabilization in the countries where production of ASA is abundant like California, Spain and Kashmir, and it may also achieve the mark of development of sustainable techniques avoiding issues concerned with disposal of ASA.

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