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Improvement of subgrade CBR value by using Bagasse ash and Eggshell powder

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Abstract: In many situations, soils in natural state do not present adequate geotechnical properties to be used as road service layers. In order to improve their geotechnical parameters to meet the requirements of technical specifications of construction industry, soil stabilization techniques are normally emphasized. This study aims to improve subgrade CBR value by using sugarcane bagasse ash and eggshell powder at varying percentages respectively and to find out the optimum percentage of both admixtures beyond which CBR value decreases of soil. Soil is treated with sugarcane bagasse ash and eggshell powder using different percentages up to CBR value increases. Soil is treated with sugarcane bagasse ash by weight (1%, 3%, 5%, 7%, 9%, and 11%) and eggshell powder using different percentage (1%, 3%, 5%, 7%, 9%, 11% and 13%). The results of conducted shows that initially the optimum moisture content of soil is 13.8% and for addition of bagasse ash upto 11% it has become in increase upto 15.20%. For addition of eggshell powder upto 13% the initial optimum moisture content of soil has become in increase upto 15.25%. Initially the CBR value of soil is 6.47%. For addition of bagasse ash upto 9% the CBR value of soil has become in increase upto 13.85% and after then for addition of 11% bagasse ash it has become in decrease 13.28%. For addition of eggshell powder upto 11% the CBR value of soil has become in increase upto 9.52% and after then for addition of 13% eggshell powder it has become in decrease 9.38%.

Keywords*: Sugarcane bagasse ash, Eggshell Powder, Optimum Moisture Content, CBR value*

1. Introduction:

Soil is the basic construction material. It supports the substructure of any structure and it is the subgrade which supports the subbase and base in the pavement. A road pavement may be defined as relatively stable layer or crust constructed over the natural soil. The main function of pavement is to support and distribute the heavy wheel loads of vehicles over a wide area of the underlying subgrade soil and permitting the deformations within elastic or allowable range and to provide an adequate surface. Subgrade performance is a function of a soil's strength and its behaviour under traffic loading. The subgrade should be sufficiently stable to prevent excessive rutting and shoving during construction, provide good support for placement and compaction of pavement layers. The existing soil at a particular location may not be suitable for the construction due to poor bearing capacity and higher compressibility or even sometimes excessive swelling in case of expansive soils. So it is also necessary to determine the strength characteristics of the subgrade for the design of pavements. To achieve above all these characteristics, it is very important to have a pre-knowledge about subgrade soil properties and to suggest suitable methods to improve the subgrade soil properties if necessary.The properties of soil can be improved by stabilization with admixtures. For many years admixtures such as lime, cement and cement kiln dust are used to improve the qualities of various types of soils such as Lateritic Soil, Clayey soil. However, the cost of introducing these admixtures has also increased in recent years. This has opened the door for researchers to find alternate admixtures such as plastic, fibers, fly ash, sugarcane bagasse ash, Eggshell powder etc. Locally available Soil is treated with sugarcane Bagasse Ash using different percentage up to CBR values increases. (Kanchan Lata Singh and S M Ali Jawaid, 2013). Soil is treated with instead of using only 7% lime by using 4% lime and 3% ESP and same soaked CBR value can be found. (Amu et al, 2005). With addition of ESP, there was a considerable decrease in Atterberg's Limits, and after 20% the value seems to be almost constant .The optimum moisture content increases and maximum dry density decreases, permeability increases, coefficient of consolidation increases and compression index decreases with increase in percentage of ESP. (Paul et al, 2014). The influences of adding each of fly-ash and eggshell powder on the Atterberg Limits, Cohesion and Angle of Internal Friction of the tested soil. The geotechnical properties of lateritic soil modified with sugarcane straw ash with a view to obtaining a cheaper and effective replacement for the conventional soil stabilizers. Preliminary tests were performed on three samples A, B and C for identification and classification purposes followed by the consistency limit tests. The results showed that optimum moisture content increased from 19.0 to 20.5%, 13.3 to 15.7% and 11.7 to 17.0%, CBR increased from 6.31 to 23.3%, 6.24 to 14.88% and 6.24 to 24.88% and unconfined compression strength increased from 79.64 to 284.66 kN/m^2, 204.86 to 350.10 kN/m^2 and 240.4 to 564.6 kN/m^2 in samples A, B and C respectively. (Amu et al, 2011). Lime and fly ash as the admixtures or stabilizers improve some engineering Properties of Black cotton (BC) soils. This experimental program evaluates the effect of the

lime and fly ash on the some basic engineering properties of BC soil such as Liquid limit, plastic limit and compaction of BC soil and California bearing ratio (CBR) of BC Soil. (Anil Kumar et al, 2013). A 2% cement stabilized lateritic soil possess similar characteristic as 2%, 4%, 6% and 8% eggshell-stabilized lateritic soil as they are all in the class of inorganic clay of medium plasticity. From compaction test result, it is seen that both eggshell powder and cement significantly increased the optimum moisture content and maximum dry density of the soil. (Akinlolu et al, 2011). Laboratory experiments are carried out for different percentages (4%, 8% and 12%) of bagasse ash and additive mix proportions. It is observed that, CBR and UCS increased. (Kiran R.G., Kiran L, 2013). Another paper showed an increase maximum dry density with increasing dosage of Groundnut shell ash up to about 4% of GSA. (Oriola Folagbade and Moses George, 2010). It was observed that although the strength of sugarcane bagasse ash laterised concrete decreases as the replacement levels increased as compared with the control specimen. It was observed that sugarcane bagasse ash laterised concrete gained strength at a little lower rate than the control concrete as represented by the ratio of its 7 days to that of 28 days strength. (Nyomboic et al, 2014). Soil was stabilized using 4% and 6% cement with variations of bagasse ash., there is a general reduction in the maximum dry density while there is an increase in the maximum dry density with increase in bagasse ash content at 6% cement content. The optimum moisture content generally increased with increase in the bagasse ash content. There was also a tremendous improvement in the CBR with bagasse ash compared to the natural soil. (Ken C. Onyelowe, 2012). The addition of bagasse ash to expansive soil decreases the MDD and increases the OMC of the expansive soil. Addition of lime sludge to each expansive soil-bagasse ash mixes decreases the MDD and increases the OMC of the expansive soil. The optimum proportion of soil: bagasse ash: lime sludge is found to be 76:8:16. (Akshaya Kumar Sabat, 2012). In another paper sand-clay mixes using different percentages of clay (10%, 20%, 30%, 40% and 50%) are selected for investigation. The maximum dry density of sand clay mix increases with the increase in clay content up to 40% of clay in the mix. The CBR value increases with the increase of clay content up to a certain limit (up to 25% clay content in the mix. (Md. Rakib Hossain and Abdullah Al Masum, 2011). The soil used in this investigation is high plasticity silty clay with liquid limit of 52 and plasticity index of 29. (M. A. Ansary and K. A. Hasan, 2011). Among the above researches, it has been observed that local soil, lateritic soil and black cotton soil have been used in some researches. Lime, Lime sludge have been used as additive with bagasse ash to improve the geotechnical properties of soil such as Unconfined compressive strength, plasticity index, optimum moisture content and CBR value of that soil. In some other research papers, lime, quarry dusts have been used as additive with eggshell powder. Moreover, in some other researches bagasse ash has been used as partial replacement of cement & eggshell powder has been used as a partial replacement of industrial lime. But in this research, another type of soil has been used with varying percentages of bagasse ash and eggshell powder to improve subgrade CBR value & to find out the optimum percentage of bagasse ash & eggshell powder, which has not been done before.

2. Materials and Methods:

Soil used in this study was collected from Tanore Upazila in the district of Rajshahi in Bangladesh. It was collected from 2 feet below from the top surface. The soil sample was taken in the laboratory and dried for 24 hours. Then the soil sample was subjected to various laboratory tests including specific gravity test, liquid limit test, plastic limit test, shrinkage limit test, modified proctor test and California bearing ratio test to find out the engineering properties related to various purposes. The engineering properties of soil were determined according to procedure specified by AASHTO, ASTM standards.

Sugarcane bagasse ash is one of the organic wastes obtained from sugar industry during the process of sugar manufacturing. It is a by-product of sugar factories found after burning sugarcane bagasse which itself is found after the extraction of all economical sugar from sugarcane. It is used in agriculture as organic fertilizer for crop production. It is as a good source of micronutrients like, Fe, Mn, Zn, and Cu. It can also be used as soil additive in agriculture due to its capacity to supply the plants with small amounts of nutrients. In this study, bagasse ash sample was collected from Rajshahi Sugar Mill and its chemical properties were investigated. Eggshell powder (ESP) has not being in use as a stabilizing material and it could be a good replacement for industrial lime, since it's chemical composition is similar to that of lime. Chicken eggshell is a waste material from domestic sources such as fast food joints and homes. Literature has shown that eggshell powder primarily contains CaO (99.83%) and the remaining consists of Al_2O_3, SiO_2, Cl, Cr_2O_3, MnO and CuO. The eggshell waste was washed and dried before grinding. The eggshell powder was sieved using IS Seive No. 200 (75μ), and the powder passing the sieve was used. This sieve was chosen in order to achieve a uniform powdery.

3.1 General properties of soil sample:

The soil sample was thoroughly oven dried, weighed and stored in sacks at room temperature. The general properties of the soil were thoroughly studied in the laboratory. The soil was tested for liquid limit, plastic limit, optimum moisture content, maximum dry density, California bearing ratio etc. For the soil, the general properties obtained are tabulated as follows:

Table 1: Fundamental engineering properties of soil

Properties	Value
Textural classification	Clay Loam
Sand content (%)	40
Silt content (%)	31
Clay content (%)	29
Specific gravity	2.78
Liquid limit (%)	29.41
Plastic limit (%)	15.18
Shrinkage limit (%)	11.87
Plasticity index (%)	14.23
Optimum moisture content (%)	14.10
Maximum dry density (gm/cm^3)	1.92
California bearing ratio (%)	6.47

3.2 Preparation of sugarcane bagasse ash:

At first sugarcane bagasse was collected from Rajshahi sugar mill. Then it was dried in air for 3-4 days. Then it was burnt into fire. After burning sugarcane bagasse was turned into ash form. Then it was sieved through IS Seive No. 200 (75µ). This sieve was chosen in order to achieve a uniform powdery.

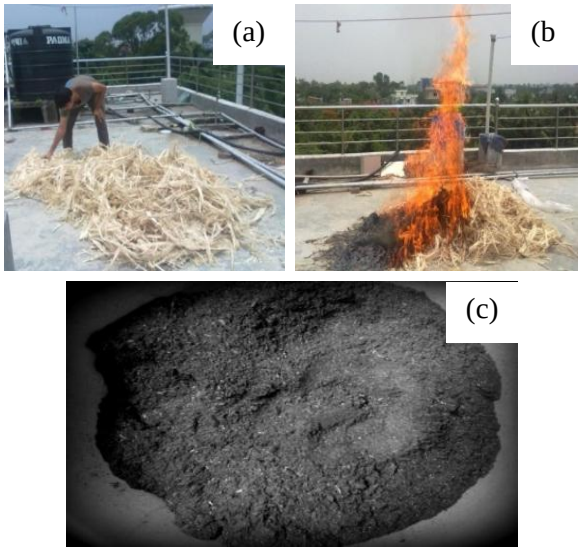

Figure 1: (a) Sugarcane bagasse, (b) Burning into fire, (c) Bagasse ash

Table 2: Chemical composition of sugarcane bagasse ash (Source: Fri'as and Concrete Research, 2005)

Chemical composition	% by weight
Silica (SiO_2)	62.43
Fe_2O_3	6.98
Al_2O_3	4.38
LOI	4.73
K_2O	3.53
CaO	2.51
SO_3	1.48
Mn	0.50
Zn	0.30
Cu	0.10

3.3 Preparation of eggshell powder

At first eggshell was collected and then it was oven dried. After that it was grinded by using a blender. Then it was turned into powder form. Then it was sieved through IS Sieve No. 200 (75µ). This sieve was chosen in order to achieve a uniform powdery.

Figure 2: (a) Eggshell, (b) Blender, (c) Preparing for grinding, (d) Eggshell powder

3.3 Results and Discussions:

The following grain size distribution curve is found by using the data obtained from sieve analysis and hydrometer analysis of soil.

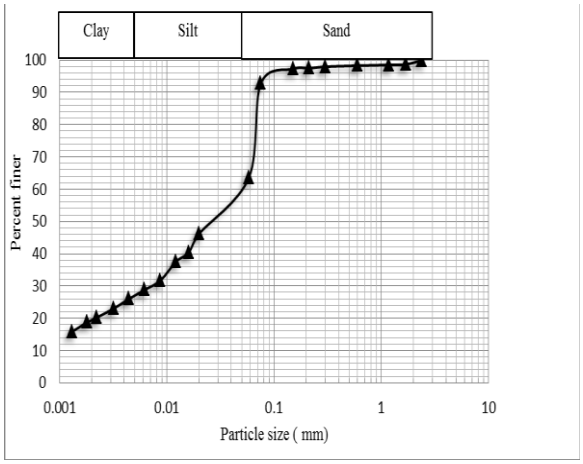

Figure 3: Grain size distribution curve

According to Textural classification (U.S. Bureau of Soil and Public Road Administration (PRA) classification) from grain size distribution curve it is found that the soil sample is clay loam. As the liquid limit of soil is within the range of 0 to 35% and plasticity index is 14.23% from the plasticity chart, it has been found that it is a low plastic soil.

Table 3: Variation of moisture content and dry density of soil with different percentage of admixture

	Properties	Optimum Moisture Content (%)	Maximum dry density (gm/cm^3)
	Soil	13.80	1.920
Soil + % Bagasse Ash	1%	13.95	1.910
	3%	14.24	1.892
	5%	14.62	1.884
	7%	14.75	1.880
	9%	15.05	1.864
	11%	15.20	1.862
Soil + % Egg Shell Powder	1%	14.05	1.917
	3%	14.20	1.904
	5%	14.40	1.888
	7%	14.80	1.872
	9%	15.10	1.867
	11%	15.20	1.862
	13%	15.25	1.857

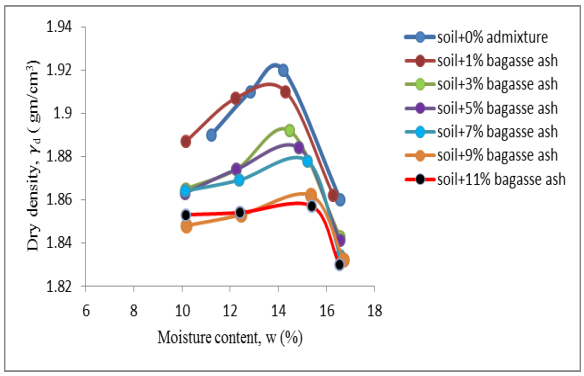

Figure 4: Variation of moisture content and dry density of soil with different percentage of bagasse ash

The addition of bagasse ash by weight (0% , 1% , 3%, 5% , 7% , 9% ,11%) to the soil sample caused an increase in the optimum moisture content at the rates of 13.80%, 13.95%, 14.24%, 14.62%, 14.75%, 15.05%, 15.20 respectively and caused a decrease in maximum dry density at the rates of (1.920, 1.910, 1.892, 1.884, 1.880, 1.864, 1.862) gm/cm^3 respectively.

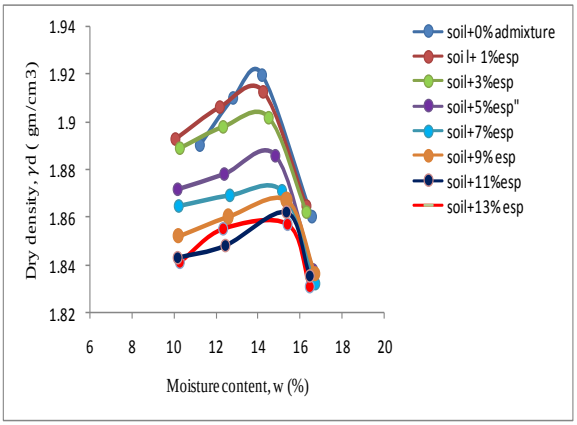

Figure 5: Variation of moisture content and dry density of soil with different percentage of eggshell powder

The addition of eggshell powder by weight (0%, 1%, 3%, 5%, 7%, 9%, 11%, 13%) to the soil samples caused an increase in the optimum moisture content at the rates of 13.80%, 14.05%, 14.20%, 14.40%, 14.80%, 15.10%, 15.20%, 15.25% respectively and caused a decrease in maximum dry density at the rates of (1.920, 1.917, 1.904,1.888, 1.872, 1.867, 1.862, 1.857) gm/cm^3 respectively.

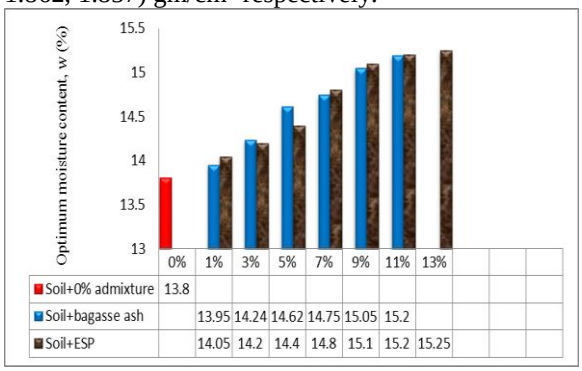

Figure 6: Variation of optimum moisture content of soil with various percentages of both admixtures

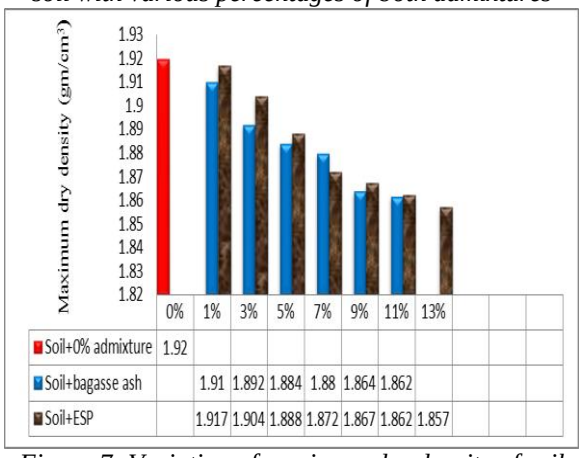

Figure 7: Variation of maximum dry density of soil with various percentages of both admixtures

The California Bearing Ratio test of soil is conducted with various percentages of sugarcane bagasse ash and eggshell powder. In case of variation of unit load with respect to penetration of soil with same percentages of both admixtures the obtained curves are shown below:

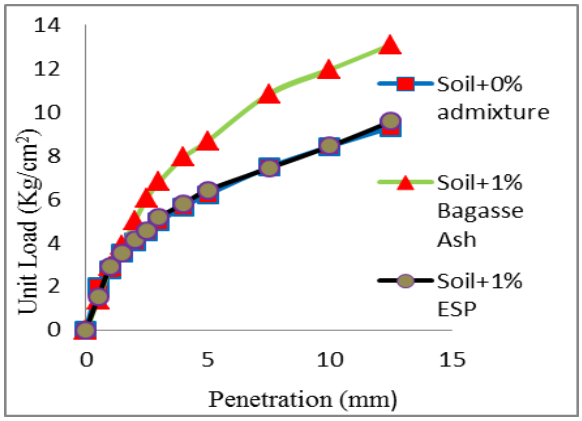

Figure 8: Variation of unit load for 1% of both admixtures

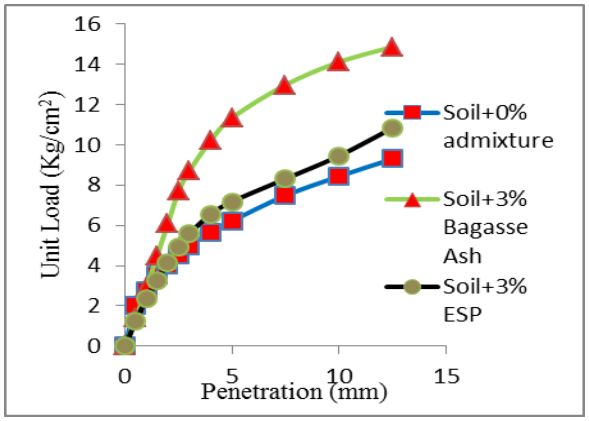

Figure 9: Variation of unit load for 3% of both admixtures

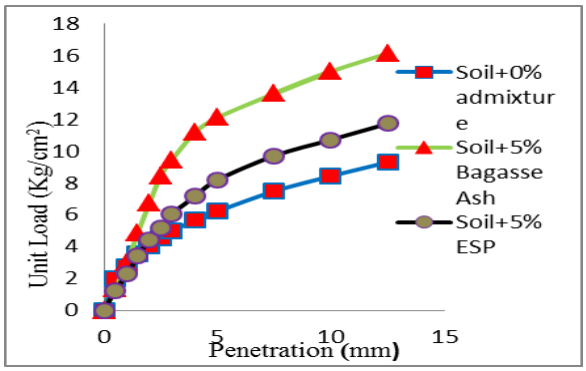

Figure 10: Variation of unit load for 5% of both admixtures

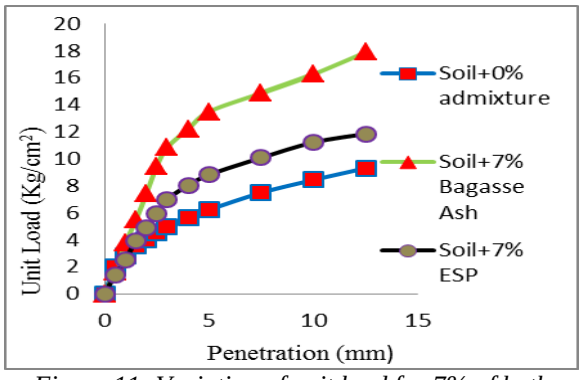

Figure 11: Variation of unit load for 7% of both admixtures

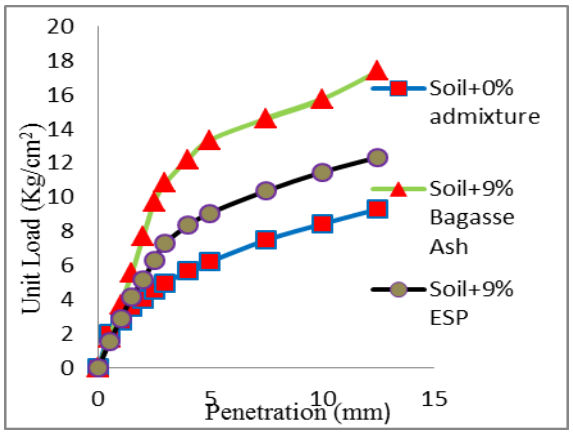

Figure 12: Variation of unit load for 9% of both admixtures

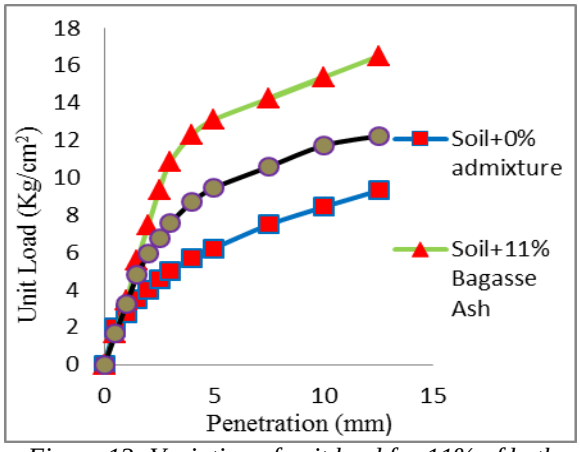

Figure 13: Variation of unit load for 11% of both admixtures

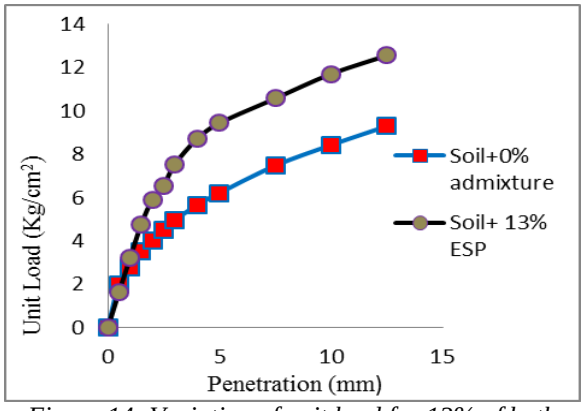

Figure 14: Variation of unit load for 13% of both admixtures

From above curves it is clearly observed that the unit load carrying capacity of soil increases with the addition of sugarcane bagasse ash and eggshell powder. It is also noticed that the unit load carrying capacity of soil with bagasse ash is more than that of soil with eggshell powder in case of addition of same percentage of both admixtures.

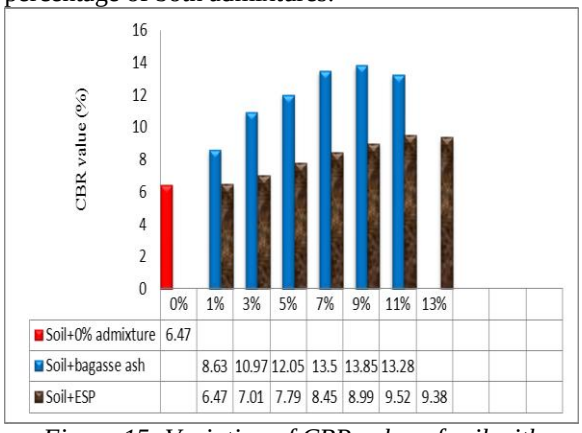

Figure 15: Variation of CBR value of soil with different percentage of both admixtures.

The addition of bagasse ash up to weight of (0%, 1%, 3%, 5%, 7%, 9%) to the soil samples caused an increase in CBR value at the rate of 6.47 %, 8.63%, 10.97%, 12.05%, 13.5%, 13.85% respectively and at the addition of 11% bagasse ash CBR value decreased 13.28%. So 9% is the optimum percentage

of bagasse ash for CBR value. The addition of eggshell powder up to weight of 0%, 1%, 3%, 5%, 7%, 9%, 11% to the soil samples caused an increase in CBR value at the rate of 6.47%, 6.47%, 7.01%, 7.79%, 8.45%, 8.99%, 9.68%) respectively and at the addition of 13% eggshell powder CBR value decreased 9.38 %. So 11% is the optimum percentage of eggshell powder for CBR value. It has been also seen that the rate of increment of CBR value for addition of bagasse ash is greater than that of eggshell powder.

3. Conclusion:

From the test results it is found that properties of the soil have been improved by the addition of bagasse ash and eggshell powder by comparing the behaviour of soil sample with and without both admixtures. The maximum dry density decreases and the optimum moisture content increases with the addition of bagasse ash and eggshell powder. The results of the tests also draw another conclusion that the more percentage of bagasse ash and eggshell powder we add to the soil upto optimum percentage, the CBR value increases gradually and after optimum percentage the CBR value decreases. From the test results it has found that the optimum percentage of bagasse ash is 9% and the optimum percentage of eggshell powder is 11%.

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