STUDY OF STRENGTH CHARACTERISTICS OF BLACK COTTON SOIL TREATED WITH BAGASSE ASH AND LIME

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Abstract: *Black cotton soil is a type of expansive soil that has tendency of exciting massive volume change against water content fluctuations. Swelling and Shrinkage occur near the ground surface commonly, where it going to withstand the seasonal and environmental changes. Construction of structures in civil engineering on such soils involves high risk because their behavior of showing significant deformation. Frequent soil movements can generate cracks and damage residentials buildings, roads, and other civil structures constructed on this black cotton soil. The present study focused on the experimental examining the improvement in geotechnical properties that are achieved using an agro industrial waste (bagasse ash) combined with lime stabilization. The black cotton soil here taken for investigation is acquired from Oriental school Bhopal campus. The Stabilized sample contain vary contents of bagasse ash from 7% to 28% and hydrated lime from 4% to 10% by dry weight of black cotton soil. During this investigation various experiments are performed on natural soil and stabilized soil samples having varying content of additive and also seek the significance of curing at period of 0, 7, 28, 45 days. The outcomes of this investigation showed that there is the significant increase in strength characteristics that has its benefits in economical designs and safe designs of structures. Apart from this involving of agro waste in the stabilization technique has proven eco-utilization of waste.*

Keywords: **Black cotton soil, Bagasse ash, Lime, Stabilization, DFS, OMC, MDD, UCS.**

1. INTRODUCTION

Black cotton soils generally originated mainly from decomposed rocks and they mainly contains particles that are fine which result in swelling and shrinkage behaviour when exposed to varying moisture content. The black cotton soil accounts to have consists montmorillonite clay minerals as main portion which high tendency of showing change in volume when moisture content alter. Constructing the civil engineering structures on such soil, like highways, rail tracks, residential structures and bridges involves high risk as these soils are reactive when seasonal drying wetting cycles occur resulting in deformations, thus generate cracks and induce damage to building, roads, and other structures of civil engineering that are constructed directly on this soil. The annually average cost encounter because of destruction to structures associated with light structures and footing are significant as reported by many researchers. For example, annually average cost of destruction related with black cotton soil in India is several lakhs of rupees. To rectify these problems soil stabilization is adopted such as mechanical stabilization, chemical stabilization and other additive using stabilization like lime and cement stabilization that are commonly used. Recent years new prospect of stabilization of soil are in search to reduce reliability on lime and cement due to high cost involve in it, whereas, alternative additive that is been search used are waste before use like fly ash waste from thermal power plants, blast furnace slag from aluminum industries, bagasse ash from sugar processing industries, etc. In this study bagasse ash is taken as stabilizing material along with lime. Bagasse ash is a waste product generated in sugar processing plants that has found to have excellent pozzolanic property as it has silicate as the prime content in it. Bagasse ash is a huge waste in sugar processing industries which not wisely manage will result in environment impact after its importance in construction industries as additive material has grown up it has tremendous possibility in its usage even after being a waste. Using waste product as constructing material also has result in the overall material cost of stabilization in structures constructed on black cotton soils. Since lime is

proven stabilizing material any other material added that has same property of stabilization is just an advantage.

Liet Chi Dang,(2019), studied the enhancement in the geotechnical properties of expansive soil using bagasse ash, lime and bagasse fibre. His study include the index properties test, engineering properties test and the study at molecular level i.e. the morphological also conducted. In his study he soil sample was collected from Queensland, Australia and contents taken as 0-25% bagasse ash, 0-2% bagasse fibre and 0-6.25% lime by dry mass of expansive soil. These test also take consideration of the curing effect of 3,7,28,56 days. The study reveals that addition bagasse ash show decrease in linear shrinkage, free sell potential, swelling pressure where ash an increase in unconfined compressive stress and the CBR value.

Amruta P. Kulkarni, et.al., (2016), investigated expansive clay the properties when bagasse ash and lime used to stabilize it. Aim is to build the structure on the black cotton soil that can withstand the applied efficiently by improving its engineering properties economically. He discovered noticeable decrease of plasticity index and increase of CBR of Stabilized Black Cotton Soil when optimum ratio of Bagasse Ash to Lime was used which conclude that bagasse ash can be used in stabilization of black cotton soil. He also proposed the best proportion for stabilization for Black Cotton Soil is recommended to be 2:3 of Bagasse Ash: Lime.

Meron Wubshet and Samuel Tadesse (2014), classified A-7-5 soil on AASHTO Classification that is an acquired expansive soil from Addis Ababa, Bole sub city, was stabilized by taking 3% lime alone, 15% bagasse ash alone and 15% bagasse ash & with 3% lime by dry soil weight. They investigated the effect of additive in soil with respect to plasticity, compaction and California bearing ratio (CBR) tests. The results they obtained indicate an increase in optimum moisture content (OMC) and CBR value; and a decrement in MDD and soil plasticity for all admixtures. But in value of CBR a significant enhancement is seen in soil stabilized by certain percentage of lime and bagasse ash. This shows a potential of using bagasse ash as admixture in lime stabilized expansive soil.

2. MATERIALS USED

A. Black Cotton Soil

Black cotton soil is a type of expansive soil found prominently in Deccan trap of deccan plateau, Maharashtra, Malwa and some patches of Gujarat. For the experimental work of research, black cotton soil was collected from OIST Bhopal campus. Soil from field collected in semi-dry state. To make it suitably fit and right materials to be utilized in civil engineering, increase its compressive strength and bearing capacity certain admixture to be taken in consideration.

B. Bagasse Ash

The fibrous sugarcane bagasse ash was obtained from crushing and extracting sugarcane juice. This crushed wet bagasse in this study was taken from locally available vendors for further test using it. The bagasse was first dried in sunlight for48 hours and the burned to ash lately the bagasse ash is sieved using 425-microns sieve to get fine powdered ash that is used for research work.

C. Lime

Lime is calcium oxide or calcium hydroxide. The lime we used in the test is the hydrated lime. Lime stabilization is the most extensively used medium of chemically transmuting unstable soils into structurally stable construction foundations. The lime used in research is acquired from authorized dealers in Bhopal.

3. METHODLOGY

The steps under research involves.

1. Material procurement
2. Soil sample preparation
3. Natural soil sample are tested for geotechnical properties
4. Lime bagasse ash treated sample tested for geotechnical properties for different sample combinations.

1. Material Procurement

- Black cotton soil is acquired from OIST Bhopal campus and it is dried and sieved in 425 microns sieve for making the sample.
- Bagasse Ash is collected in form of wet bagasse from local sugarcane vendor in Bhopal and process into bagasse ash and sieved in 425 microns sieve for making the sample.
- Lime is acquired from the local authorized dealer in Bhopal

2. Soil Sample Combinations

The effects of variant percentage of bagasse ash and lime on the black cotton soil is studied for different aspect. Sixteen samples of varying bagasse and lime content by dry unit weight of black cotton soil, as shown in Table 4.1 were made for which engineering properties and also the effect of curing at varying curing period (7, 14, 28, 45 days) are determined.

Table 4.1 Sample Combination

S. No.	Sample Combinations
1	BC alone
2	BC+7%BA+4%L
3	BC+7%BA+6%L
4	BC+7%BA+8%L
5	BC+7%BA+10%L
6	BC+14%BA+4%L
7	BC+14%BA+6%L
8	BC+14%BA+8%L
9	BC+14%BA+10%L
10	BC+21%BA+4%L
12	BC+21%BA+6%L
13	BC+21%BA+8%L
14	BC+21%BA+10%L
15	BC+28%BA+4%L
16	BC+28%BA+6%L
17	BC+28%BA+8%L
18	BC+28%BA+10%L

Note: BC = Black cotton soil, BA = Bagasse ash, L = Lime

3. Test Conducted on Soil Sample Combinations

1. Differential free swell is determined as per IS: 2720 (Part - 40)- 1977.
2. Optimum Moisture Content (OMC) and Max. Dry Density (MDD) of black cotton soil was calculated by Indian standard proctor compaction test, as per to IS: 2720 (part 7)-1980.
3. Unconfined compressive strength of cohesive soil is determined as per IS: 2720 (part - 10) – 1991 (reaffirmed 1995) taking the strain rate of 1.25 mm/min.

4. RESULT AND DISCUSSIONS

The sample of black cotton soil collected in semi-dry state. Soil samples were tested for all geotechnical properties and corresponding results are calculated. The following are the results of the natural and treated soil samples are as below.

4.1. Natural Soil Characteristics

S. No.	Properties of Expansive Soil	Values
1	Specific Gravity	2.60
2	Gravel (%)	0
3	Sand (%)	5
4	Silt (%)	9
5	Clay (%)	86
6	Liquid Limit (LL)	62.50
7	Plastic Limit (PL)	32.13
8	Shrinkage Limit (%)	10.78
9	Indian Standard Soil Classification (ISSCS)	CH/High Expansive
10	Maximum Dry Density (MDD) (g/cc)	1.57
12	Optimum Moisture Content (OMC, %)	20.54
13	CBR, Soaked (%)	1.19
14	UCS, kN/m^2	127.52

4.2. Differential Free Swell Index

From the test it's found that for bagasse ash content (7, 14, 21 & 28%) when lime percentage vary from 4% to 8% significant decrease in DFS was observe. It is also observed that for bagasse ash content (7, 14, 21 & 28%) when lime increase from 8% to 10% marginal change in differential free swell. Least value of differential free swell is 2 at 28% bagasse ash and 10% lime. If we observe effect of curing for all samples at 7, 14, 28 & 45 days it is found that there is the marginal decrease in differential free swell index and least value after curing was 1 after 45 days curing. As shown in table 4.3.

Table 4.2 Degree of expansiveness on the basis of differential free swell (DFS) (IS-2911 Part III-1980)

S. No.	DFS Limit	Classifiaction
1	Less than 20	Low
2	20-35	Moderate
3	35-50	High
4	More than 50	Very High

Table 4.3 Differential free swell of Black Cotton Soil treated with Bagasse Ash and Lime

S. No.	Sample Combinations	Differential Free Swell (%)	Classifiaction
1	BC alone	43	High
2	BC+7%BA+4%L	39	High
3	BC+7%BA+6%L	32	Moderate
4	BC+7%BA+8%L	28	Moderate
5	BC+7%BA+10%L	27	Moderate
6	BC+14%BA+4%L	19	Low
7	BC+14%BA+6%L	14	Low
8	BC+14%BA+8%L	10	Low
9	BC+14%BA+10%L	8	Low
10	BC+21%BA+4%L	11	Low
12	BC+21%BA+6%L	7	Low
13	BC+21%BA+8%L	4	Low
14	BC+21%BA+10%L	4	Low
15	BC+28%BA+4%L	8	Low
16	BC+28%BA+6%L	5	Low
17	BC+28%BA+8%L	3	Low
18	BC+28%BA+10%L	2	Low

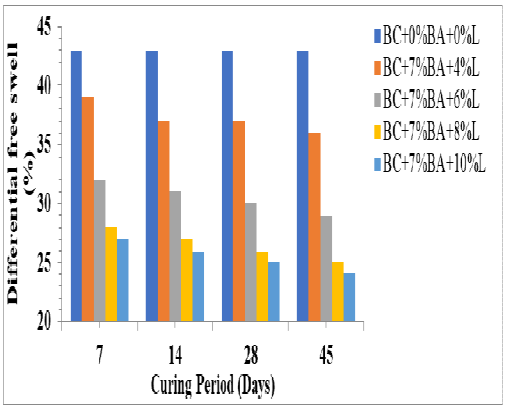

Figure 1

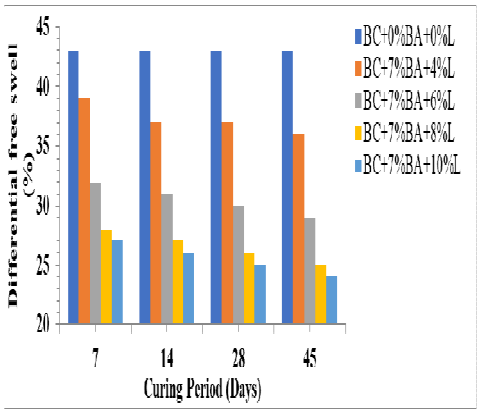

Figure 2

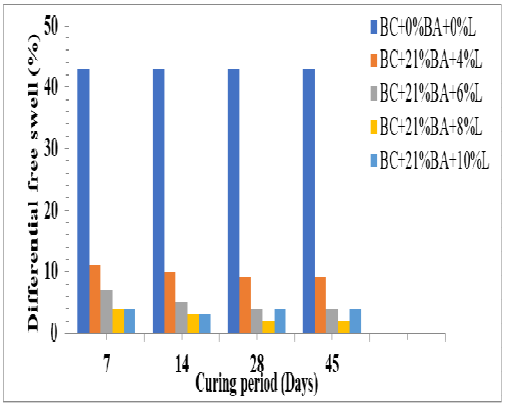

Figure 3

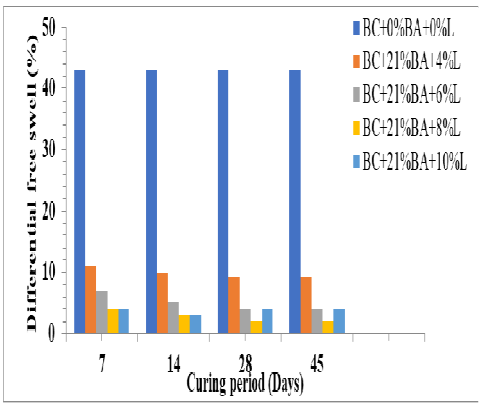

Figure 4

4.3. Compaction Test

The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of 21% bagasse ash and 8% lime treated black cotton soil recorded as 19.41% and 14.00 kN/m3 respectively for Standard Procter test found to be the prominent values of test. Taking constant percentage of bagasse ash and applying of various percentage of lime it is observed that MDD, for 7% bagasse ash and lime varying (4% to 8%) increases from 15.84 kN/m3 to 18.28 kN/m3, thereafter a marginal reduction when lime vary (8% to 10%) i.e. from 18.28 kN/m3 to 17.72 kN/m3 was noted, Similar trend is seen for 14%, 21% and 28% of bagasse as and the respected vary in lime percent on MDD. Taking constant percentage of bagasse ash and applying of various percentage of lime it is observed that OMC, for 7% bagasse ash and lime varying (4% to 8%) decreases from 21.25% to 17.86% thereafter a marginal increase when lime vary (8% to 10%) i.e. from 17.86% to 18.12%, Similar trend is seen for 14%, 21% and 28% of bagasse as and the respected vary in lime percent on OMC as shown in table 4.4 and figure 5,6,7,8.

Table 4.4 Compaction Characteristics of BC Soil treated with Bagasse Ash and Lime

S. No.	Sample Combination	Standard Proctor Test		
		OMC (%)	MDD (kN/m^3)	ZAV (kN/m^3)
1	BC+0%BA+0%L	23.50	15.52	16.87
2	BC+7%BA+4%L	21.25	15.84	17.21
3	BC+7%BA+6%L	18.25	17.70	18.90
4	BC+7%BA+8%L	17.86	18.28	19.29
5	BC+7%BA+10%L	18.12	17.72	19.07
6	BC+14%BA+4%L	21.76	15.98	17.33
7	BC+14%BA+6%L	17.60	16.40	18.12
8	BC+14%BA+8%L	14.24	19.13	20.87
9	BC+14%BA+10%L	15.25	18.26	19.98
10	BC+21%BA+4%L	19.56	17.97	19.27
11	BC+21%BA+6%L	15.00	18.22	20.17
12	BC+21%BA+8%L	14.00	19.41	20.87
13	BC+21%BA+10%L	16.00	18.72	19.98
14	BC+28%BA+4%L	17.78	16.41	18.12

15	BC+28%BA+6%L	15.55	18.22	19.12
16	BC+28%BA+8%L	13.61	19.06	20.80
17	BC+28%BA+10%L	14.33	17.47	19.60

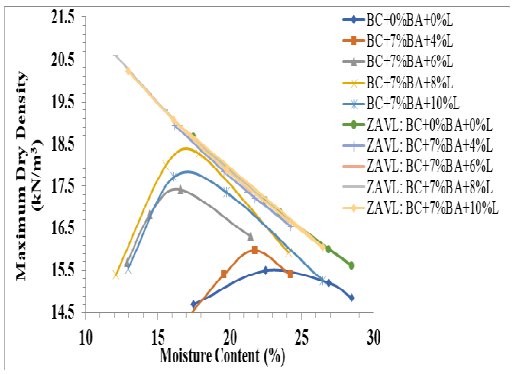

Figure 5

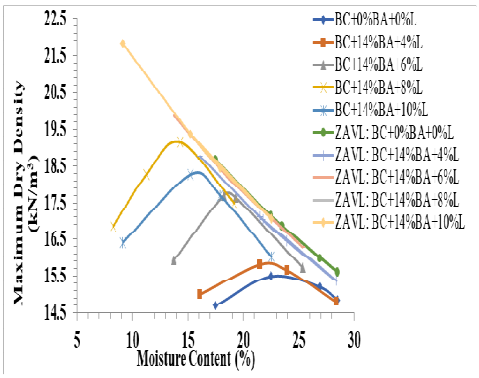

Figure 6

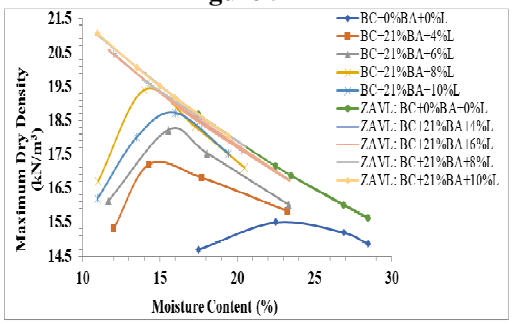

Figure 7

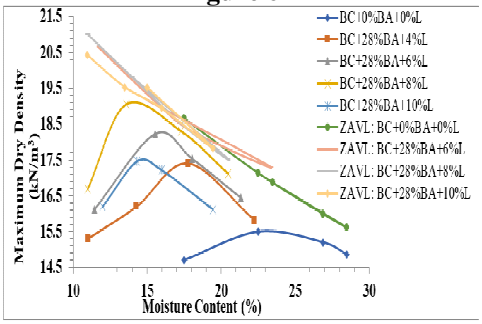

Figure 8

4.4. Unconfined Compressive Strength Test

The unconfined compressive strength of BC soil alone is found to be 127.5kN/m2 on immediate testing. Addition of bagasse ash, lime is taken by weight of black cotton soil, the unconfined compressive strength increases with increase in curing period. The maximum strength 392.38 kN/m2 was observed at 21% bagasse ash and 8% lime dosage for 45 days curing period, beyond 21% bagasse ash and 8% lime addition to black cotton soil the unconfined compressive strength decreases. Taking constant percentage of bagasse ash and applying of various percentage of lime it is observed that UCS, for 7% bagasse ash and lime varying (4% to 8%) increases from 135.12kN/m2 to 195.67kN/m2 thereafter a decrease is observed when lime vary (8% to 10%) i.e. from 195.67kN/m2 to 172.56 kN/m2, Similar trend is seen for 14%, 21% and 28% of bagasse as and the respected vary in lime percent on UCS values of treated soil. Further increase in bagasse ash and lime dosage there was reduction in unconfined compressive strength of the treated soil also curing period also not effective beyond 45 days as marginal change is noticed. The maximum strength 392.38 kN/m2 was observed at 21% bagasse ash and 8% lime dosage for 45 days curing period as indicated in Table 5.10 and Fig. 5,6,7,8 respectively.

Table 4.3 UCS Test on Black Cotton Soil treated with Bagasse Ash and Lime

S. No.	Sample Combination	Unconfined compressive strength (kN/m^2)				
		Curing period in days				
		0	7	14	28	45
1	BC+0%BA+0%L	127.52	127.52	127.68	127.68	127.72
2	BC+7%BA+4%L	135.12	158.34	183.45	207.45	210.48

3	BC+7%BA+6%L	146.78	173.45	197.43	217.98	220.13
4	BC+7%BA+8%L	195.67	247.45	267.11	288.88	292.11
5	BC+7%BA+10%L	172.56	228.45	248.35	268.32	279.35
6	BC+14%BA+4%L	142.23	179.46	202.42	228.5	238.27
7	BC+14%BA+6%L	184.56	228.65	258.79	284.24	289.35
8	BC+14%BA+8%L	197.23	292.18	325.76	345.23	350.29
9	BC+14%BA+10%L	191.56	269.52	298.89	318.65	335.21
10	BC+21%BA+4%L	175.21	235.21	273.27	292.56	310.23
11	BC+21%BA+6%L	193.45	255.64	289.66	308.88	339.78
12	BC+21%BA+8%L	222.15	345.04	383.87	389.12	392.38
13	BC+21%BA+10%L	202.89	315.45	356.25	362.45	369.45
14	BC+28%BA+4%L	166.77	245.39	282.82	295.9	305.61
15	BC+28%BA+6%L	176.65	275.65	296.65	305.12	324.15
16	BC+28%BA+8%L	193.25	312.45	337.15	343.11	348.28
17	BC+28%BA+10%L	187.78	285.25	311.58	330.35	339.25

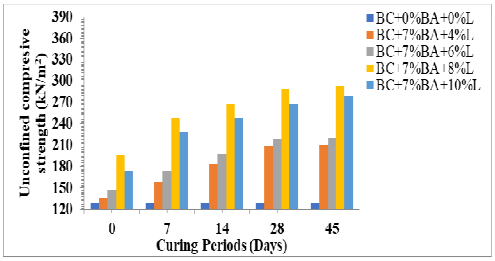

Figure 8

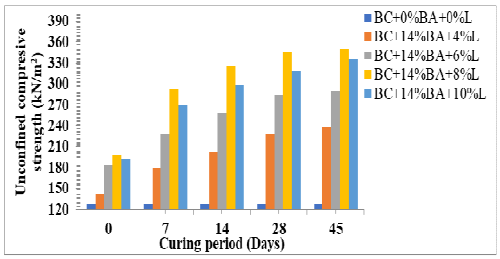

Figure 9

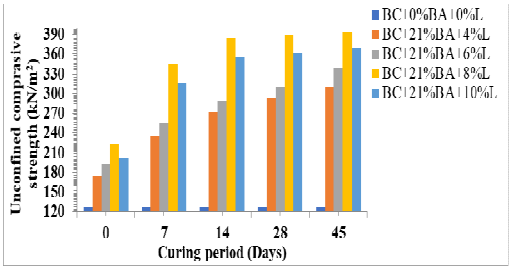

Figure 10

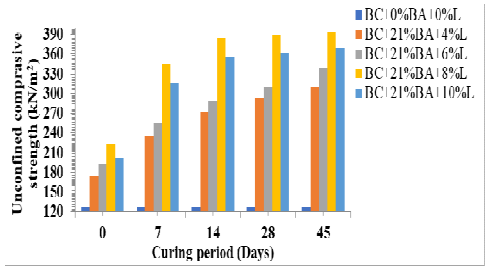

Figure 11

5. CONCLUSIONS

1. Using bagasse ash and lime as additive to stabilized the black cotton soil show positive results.
2. Prominent sample combination found to be 21% bagasse ash and 8% lime.
3. Differential free swell index decreases with increase in bagasse ash and lime content
4. Optimum moisture content is reduced whereas the maximum dry density is increase with increase in bagasse ash and lime content.
5. Unconfined compressive stress is increases with increase in bagasse ash and lime content.
6. Bagasse ash is locally available cost-free additive, hence economic benefits comes when it is used.
7. Bagasse ash dries very quickly which makes suitable for construction works in wet climatic conditions

REFERENCES

[1] *Dang, L.C. & Khabbaz, H. (2019), 'Experimental Investigation on the Compaction and Compressible Properties of Expansive Soil Reinforced with Bagasse Fibre and Lime', in J.S. McCartney & L.R. Hoyos (eds), Recent Advancements on Expansive Soils, Springer, Cham, pp. 64-78.*

[2] Dang, L.C., Khabbaz, H. & Fatahi, B. 2017c, 'An Experimental Study on Engineering Behaviour of Lime and Bagasse Fibre Reinforced Expansive Soils', 19th International Conference on Soil Mechanics and Geotechnical Engineering (19th ICSMGE), ISSMGE, Seoul, Republic of Korea, pp. 2497-500.

[3] Kulkarni, A. P., Sawant, M. K., Battul, V. V., Shindepatil, M. S., Aavani P., (2016), "Black Cotton Soil Stabilization Using Bagasse Ash and Lime", International Journal of Civil Engineering and Technology (IJCIET), Vol.7(6) , pp. 460–471 December 2016.

[4] Wubset, M. and Tadesse, S. (2014), "Stabilization of Expansive Soil Using Bagasse Ash and Lime" Journal of EEA, Vol. 32, pp. 21-25 December 2014.

[5] Alavez- Ramirez et al., "The use of Sugarcane Bagasse Ash and Lime to improve the Durability and Mechanical Properties of compacted soil blocks", Construction and Building Materials 34,296-305, 2012.

[6] Osinubi, K.J., Ijimdiya, T.S., and Nmadu, I., (2009), "Lime stabilization of black cotton soil using bagasse ash as admixture", Advanced Materials Research, Trans Tech Publications, Switzerland, Vols. 62-64, pp. 3-10, 2009.

[7] Vinod, B., Shende, P. and Baba, Md. H. (2016), "Geo-technical investigation on black cotton soils", Global Journal of Researches in Engineering: E Civil and Structural Engineering, 16 (2), pp. 1-5.

[8] Likos, W. J. (2008), "Vapor adsorption index for expansive soil classification", Journal of Geotechnical and Geoenvironmental Engineering, 134(7), pp.1005–1009.

[9] Komine, H. and Ogata, N. (2004), "Experimental study on swelling characteristics of compacted bentonite", Canadian Geotechnical Journal, 31(1), pp. 478-490. https://doi.org/10.1139/t94-057.

[10] Sombabu, Y., Aradhanarao, M., and Mohanarao, P.,(2019), "Stabilization of Expansive Soil with Bagasse Ash", International Journal of Advanced Research in Science,

[11] Engineering and Technology, ISSN: 2350-0328, Vol. 6(Special Issue), August 2019.

[12] Arpitha, Gowda, I.V., Guruprasada, M.D., Manoj, S., Manu, S., Nagaraj, K., and Goutham, D.R. (2019), "Experimental Investigation on Expansive Soil Stabilized

Using Bagasse Ash", International Journal of Innovative Research in Science, Engineering and Technology, ISSN(Online): 2319-8753, Vol. 8(6), June 2019.

[13]Shimola, K., (2018), " A Study on Soil Stabilization using Sugarcane Bagasse Ash", International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Vol. 8(2S), pp. 292-295.

[14]Jalal, F., Khan, S., Saheed, S., Ahmad, I., and Ullah, K., (2017), "Stabilization of Medium Expansive Soils in Pakistan Using Marble Industrial Waste and Bagasse Ash", International Journal of Earth Sciences and Engineering, ISSN 0974-5904, Vol. 10(4), 885-891, 2017.