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Effect of Bagasse Ash on the Properties of the Expansive Soil

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***Abstract*: In India nearly 20% of land has covered by expansive soil. These soil nature is expand when it contact with moisture and it also shrunk when it in dry weather and volume change due to nature of expansive soil harmful for heavy structure. So due to reaction load carrying capacity of soil is reducing and also observed unnatural settlement in structure. So it is very dangerous for life. In other hand, in sugar mill produce bagasse fiber in many tons. It is very useful in improve engineering properties of expansive soil. In the study use bagasse ash and lime as stabilizing material with different ratio of bagasse ash (2.5%, 5%, 7.5%, 10%) and lime with fix ratio 3% and improve its properties.**

The load bearing capacity, compressive stress and shear stress are computed by curve. By these curve observed, when mix bagasse ash and bagasse ash with lime by 2.5% to 7.5% then all above properties increase continuously but after mix 10% additive material then observed increase is continue but it increase percentage is less. So by this study find out best ratio of bagasse ash and bagasse ash with lime is 7.5%.

***Keywords*: Expensive soil, Stabilization, Bagasse ash.**

1. Introduction

Expensive soil originated from decomposed of rock. Main content of black cotton soil is fine grained particle, it knows as expansive soil. Expansive soil show big volume change when it contact with rain water, dewatering waste, evaporation, moisture content and supply water pipe leak etc. These are major reason of expend and shrinkage of expansive soil. Generally, change in volume of expansive soil seen near to ground surface because it is more effectively due to seasonal and environmental ups and downs and other above reasons.

Due to nature of expansive soils are challenges for engineers everywhere in the world and more challenge in tropical countries like India because of wide variation in temperature and dry and wet seasons and variations in moisture content of soils. The following problems generally occur in expansive soil.

According to research (Chakarborty et al. 2016; Bajaj and kumar 2016; Osinube at al. 2009) soil stabilization do by lime and many agricultural or industrial wastes. It also effectively, economically and also green material use for sustainable construction development. In agricultural and industrial (agro industrial) waste product include rise husk ash, bottom ash, silica fume, fly ash, bagasse ash, blast furnace slag, bagasse fiber, textile etc. these agro industrial wastes increase day by day and it problem create to disposal land space and also living society near disposal site. In present time sugar requirement for public is big amount and it waste also in big amount. Then major problem disposed to sugar bagasse. In present time it use as a sustainable material. Bagasse ash used as construction material and ground improvement material. This method is better practical solution then simple land filling by waste.

The property of expansive soils, in general, soil is very hard when in dry state, but they lose all of their strength when it contacts water content. One of the most important aspects for construction purposes is soil stabilization, which is used widely in foundation and road pavement constructions. This is because such a stabilization regime improves engineering properties of the soil, such as volume stability, strength and durability. In this process, removal or replacing of the problematic soil is done, replacement is done by a better quality material, or the soil is treated with an additive material.

Several goals are expected to be achieved in the investigation. The main goal is use agro industrial waste bagasse ash. It obtained from sugar refilling industry. Agricultural applications having some potential benefit. That not only facilitates preventing the potential environment issue related to their disposal but also effect of expansive soil inducing damage highway and residual building.

2. Material and Methodology

The experimental set up designed for this study is to investigate the potential benefits of lime and bagasse ash on expansive soil for improving the bearing capacity, unconfined compressive strength and shear strength to reduce the settlement of foundations. In this investigation lime or bagasse ash are used as the stabilization material in expansive soil. The tests are carried out on the 3% lime and 2.5%, 5%, 7.5%, 10% bagasse ash with varying ratio.

A. *Sample Preparation*

At first, expansive soil, bagasse ash and lime were collected. Then, expansive soil air dried in laboratory. After that bagasse ash in proportion of 2.5 to 10% (multiple of 2.5) by weight of soil were homogenously mixed with water at optimum moisture content. After that again bagasse ash in proportion of 2.5 to 10% (multiple of 2.5) by weight of soil and 3% lime as additive were homogenously mixed with water at optimum moisture content.

Table 1
Bagasse Ash and Lime Ratio Mix in the Sample

Mix No.	Bagasse Ash %
1	0
2	2.5
3	5
4	7.5
5	10
	(Bagasse Ash + Lime) %
6	(2.5+3)
7	(5+ 3)
8	(7.5+3)
9	(10+3)

3. Result and Discussion

At first all tests performed without bagasse ash and lime and after that performed with only bagasse ash and after that mixed bagasse ash with lime. Now Standard Proctor test performed with only bagasse ash ratio 2.5% to 10% by dry weight of expansive soil. After that 2.5% bagasse ash add with lime 3% ratio fix and subsequently bagasse ash were increased with multiply of 2.5 up-to 10%. Now again performed Standard Proctor according to – IS 2720 (Part 7) – 1980 and repeat the above procedure. Find out MDD for treated soil sample at different ratio of only bagasse ash and bagasse ash with 3% lime. Result present in the graph b/w dry density and water content.

Now performed Unconfined compressive strength (UCS) test according to – IS 2720 (Part 10) – 1991 on the normal soil and treated soil with only bagasse ash, bagasse ash with lime. At first mixed only bagasse ash ratio 2.5% to 10% and performed UCS test. After that Bagasse ash increased with multiply of 2.5 up-to 10% with 3%lime and repeat the above procedure. Find out unconfined compressive strength for treated soil sample and result present in graphical form.

Now performed California bearing ratio (CBR) test according to – IS 2720 (Part 16) – 1987. At first CBR test performed with bagasse ash ratio 2.5% to 10%. After that additive material lime 3% fix and bagasse ash increase with multiply of 2.5 up-to 10% and repeat the above procedure. Find out CBR Value for treated soil sample with different ratio of bagasse ash and also fix 3% lime. Now as well as performed direct shear test according to – IS 2720-PART-13–1986.

A. *Maximum Dry Density and Optimum Water Content*

Result of proctor density test presented in the form of dry density and water content graph in fig. 1 the maximum dry density and optimum water content were found out for normal expansive soil.

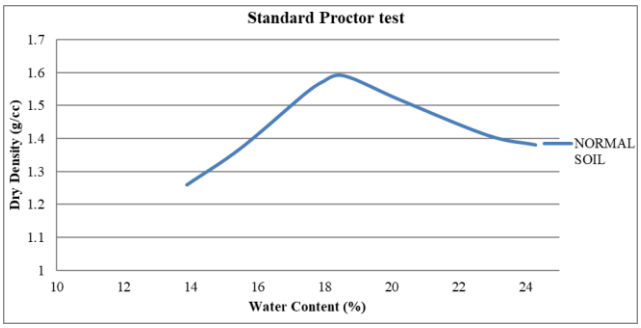

Fig. 1. Standard Proctor test for normal expansive soil

Fig. 1 shows water content and dry density curve for normal expansive soil, the dry density is 1.59gm/cc is max at that point so it called maximum dry density and at same dry density the moisture content is 18.57%. That called optimum moisture content. After that at the same optimum water content, the maximum dry densities were found out for different proportions of bagasse ash by weight of soil.

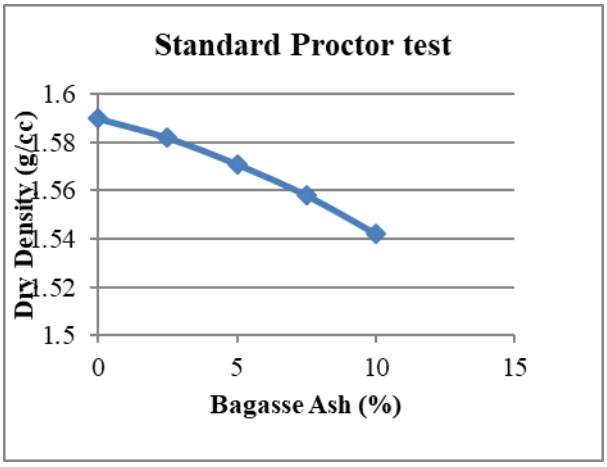

Fig. 2. Effect of Bagasse Ash

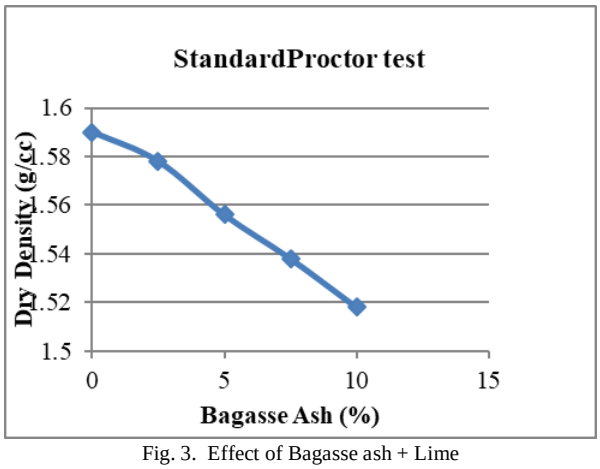

Fig. 3. Effect of Bagasse ash + Lime

At first 2.5% bagasse ash mixed in soil and performed test. Its maximum dry density is 1.582gm/cc. It reduces 0.503%

from maximum dry density of normal soil. After that mix 5% bagasse ash, it maximum dry density is 1.571gm/cc. that is 1.194% less from normal soil's maximum dry density. Then, mix 7.5% bagasse ash in normal expansive soil. Its maximum dry density is 1.558gm/cc. It is reduced 2.01% from normal soil maximum dry density, after that mixing of 10% bagasse ash in normal soil. It MDD is 1.542gm/cc. That is 3.01% reduced from normal expansive soil.

At first 2.5% bagasse ash and 3% lime mix in soil and its maximum dry density is 1.578gm/cc. It reduces 0.75% from maximum dry density of normal soil. After that mix 5% bagasse ash and 3% lime, it maximum dry density is 1.556gm/cc. that is 2.13% less from normal soil's maximum dry density. Then, mix 7.5% bagasse ash and 3% lime in normal expansive soil. Its maximum dry density is 1.538gm/cc. It is reduced 3.27% from normal soil maximum dry density. After that mix 10% bagasse ash and 3% lime in normal soil. It MDD is 1.518gm/cc. That is 4.52% reduced from normal expansive soil.

The formation of the course particles occupying the lager spaces in the soil matrix increases the void volume and hence reduces the dry density of the treated soil mixtures. Another reason of the MDD reduction of the treated soil mixtures bagasse ash and lime has lower specific gravity in comparison with that of untreated soil.

B. Compressive Strength

The test result of unconfined compressive strength is shown in Fig.4 and 5. This Fig. illustrates the stress-strain behavior of normal soil and BA+L treated soil under vertical load.

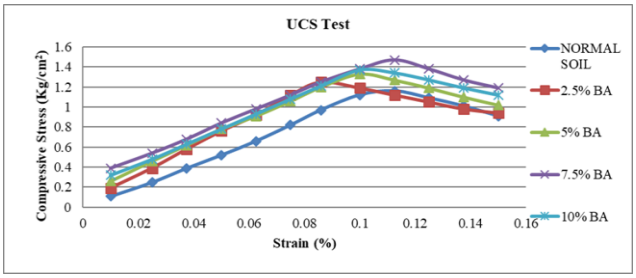

Fig. 4. UCS Test with Bagasse Ash

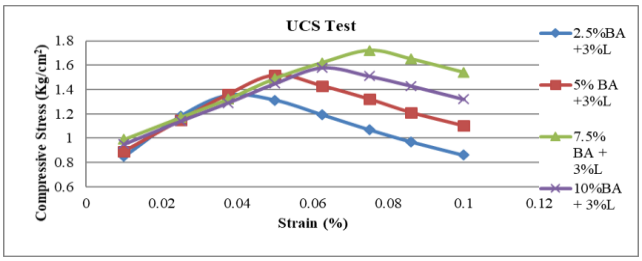

Fig. 5. UCS Test with Bagasse Ash and Lime

Fig. 4. Shows that initially stress is rapidly increases with the increase of strain. After peak stress, it decreases with the increase of strain. For normal soil maximum stress is 1.16kg/cm2 and strain is 0.1125%. At first 2.5% bagasse ash mixed in soil and its maximum compressive stress is 1.25kg/cm2. It upgrade by 7.75% from maximum compressive stress of normal soil. After that mix 5% bagasse ash, it compressive stress is 1.33kg/cm2. That is 14.655% max from normal soil's compressive stress. Then, mix 7.5% bagasse ash in normal expansive soil. Its compressive stress is 1.47kg/cm2. It is maximize 26.72% from normal soil compressive stress. After, mix 10% bagasse ash in normal soil. It compressive stress is 1.37gm/cc. That is 18.10% maximize from normal expansive soil.

After that mix 2.5% bagasse ash and 3% lime in normal expansive soil. It stress is 1.35kg/cm2. That is increased 16.37% from normal soil. After that mix 5% bagasse ash and 3% lime in normal soil and find stress. It is 1.52kg/cm2 that is increased by 31.03% from normal soil stress. After that mix 7.5% bagasse ash and 3% lime in soil. It stress is 1.72%kg/cm2 that increased 48.27% from normal soil. After that mix 10% bagasse ash and 3% lime and stress is 1.58kg/cm2 that is increased 36.20% from normal expansive soil. It shows brittle failure, which implies that the samples are becoming hardened from its original ductile nature.

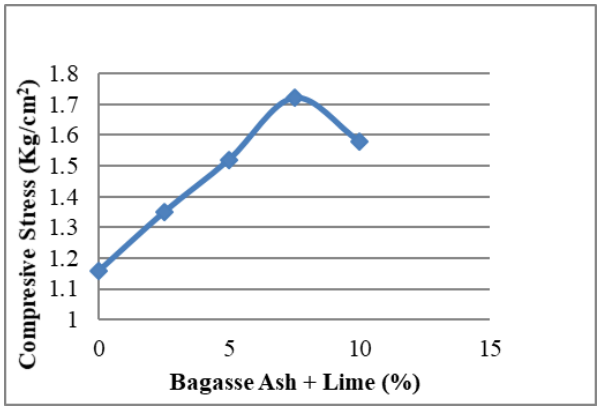

Fig. 6. Effect of Bagasse Ash

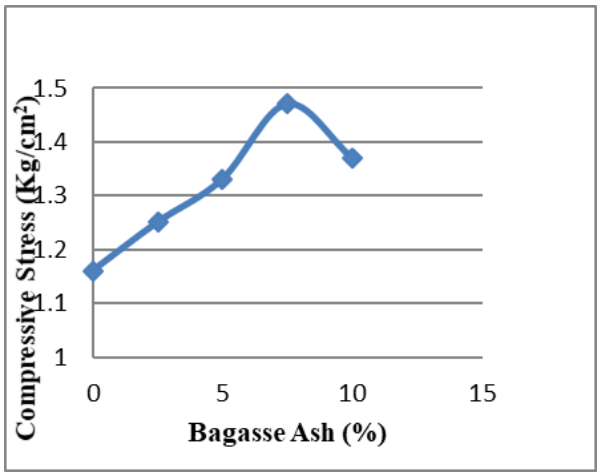

Fig. 7. Effect of Bagasse Ash + Lime

The additions of bagasse ash, lime, and their combination effectively contribute to the expansive soil. The improvement is more effectively when the combination of lime and bagasse

ash is used in soil. When such minerals are exposed to water, alumina and silica chemically react with free lime in bagasse ash and form cementitious compounds distributed between clay particles, enhancing the compressive strength of bagasse ash of treated soil. Correspondingly, the addition of lime adds in accelerating the reactivity of the pozzolan available in further enhancing the compressive strength of the treated soil. The more pozzolanic reactions of lime-bagasse ash admixture, the better compressive strength of the admixture would be.

C. California Bearing Ratio (CBR)

The strength and bearing capacity of sub grade materials are essential design criteria in pavement engineering. California bearing ratio (CBR) test is one of the most common tests used to assess the quality of base and subgrade materials for highway and road construction and design purposes.

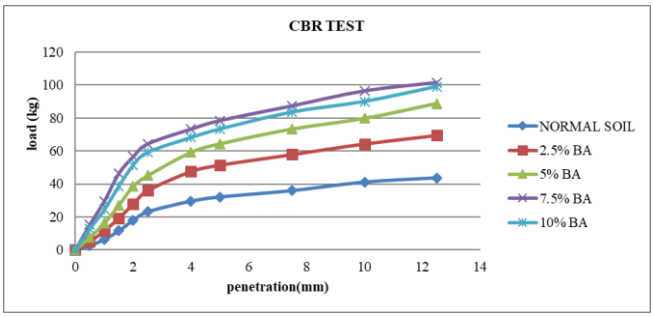

Fig. 8. CBR Test with Bagasse Ash

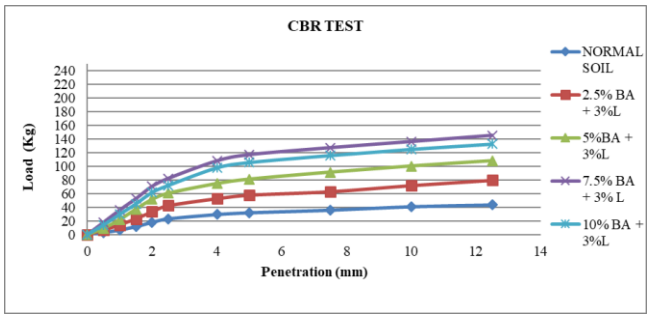

Fig. 9. CBR Test with Bagasse Ash +Lime

The result represents in graph plot between load and penetration. In the graph, CBR value at penetration of 2.5mm is 1.685% and CBR value at 5mm penetration is 1.560%. So CBR value is 1.685%. After that increase in bagasse ash 2.5% then CBR value at 2.5mm penetration is 2.621% and CBR value 5mm penetration is 2.496%. So CBR value is 2.621%. That is increased by 55.54% from basic CBR value. After that mix 5% bagasse ash and find CBR value at 2.5mm penetration is 3.276% and 5mm penetration CBR value is 3.120%. So CBR value is 3.276% that is increased by 93.42% from basic CBR value at 2.5 and 5mm penetration. After that mix 7.5% bagasse ash in expensive soil by dry weight of soil and CBR value at 2.5mm penetration is 4.680% and CBR value at 5mm penetration is 3.806%. So CBR value is4.680% that is increased by 177.74% from basic CBR value. After that mix 10% bagasse ash and CBR value at 2.5mm penetration is 4.390% and CBR value at 5mm penetration is 3.557%. So CBR value is 4.390% that is increased by 160.53% from normal expansive soil CBR value at 2.5 and 5mm penetration.

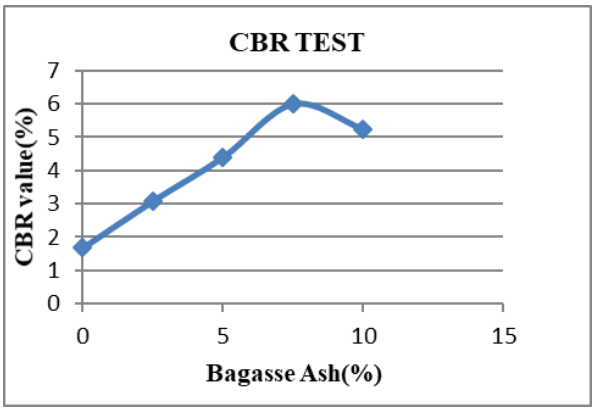

Fig. 10. Effect of Bagasse Ash

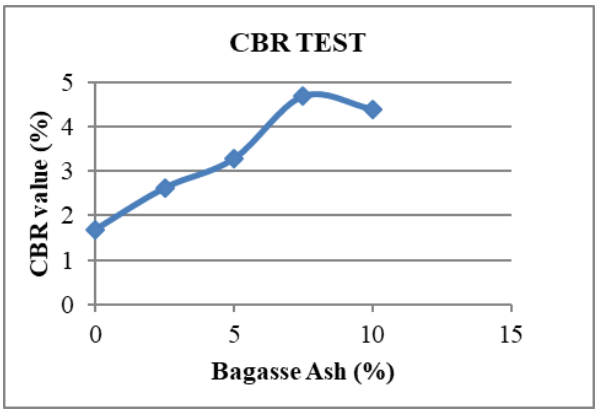

Fig. 11. Effect of Bagasse Ash + Lime

After that increase in bagasse ash 2.5% with 3% lime then CBR value at 2.5mm penetration is 3.089% and CBR value 5mm penetration is 2.808%. So CBR value is 3.089% that is increased by 83.33% from basic CBR value. After that mix 5% bagasse ash with 3% lime and find CBR value at 2.5mm penetration is 4.399% and 5mm penetration CBR value is 3.931%. So CBR value is 4.399% that is increased by 161.06% from basic CBR value. After that mix 7.5% bagasse ash with 3% lime in expensive soil by dry weight of soil and CBR value at 2.5mm penetration is 5.991% and CBR value at 5mm penetration is 5.679%. So CBR value is 5.991% that is increased by 255.54% from basic CBR value. After that mix 10% bagasse ash 3% lime and CBR value at 2.5mm penetration is 5.242% and 5mm penetration is 5.117%. So CBR value is 5.242% that is increased by 211.09% from normal expansive soil CBR value at 2.5 and 5mm penetration. The increase in CBR value might be due to the formation of new cementations compounds contributed from bagasse ash and lime.

D. Shear Strength

The value internal frictional angle and cohesion of the soil

are required for design of many engineering problems such as foundation, retaining wall, sheet pilling, and bridge.

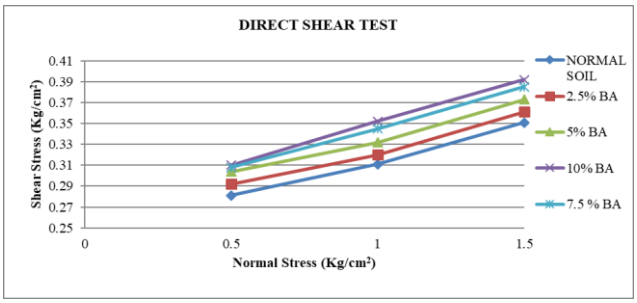

Fig. 10. Direct Shear test with Bagasse Ash

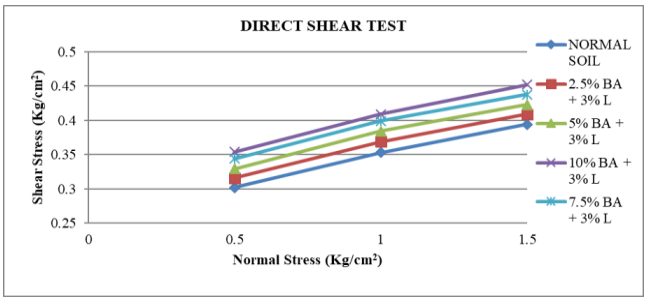

Fig. 11. Direct Shear test with Bagasse Ash + Lime

Fig 10 shows that shear stress is 0.351Kg/cm^2 for normal expansive soil. After that mix 2.5% bagasse ash in normal soil, for that proportions shear stress is 0.365 Kg/cm^2. It shows that shear stress is increased by 3.83%respectively. After that mix 5% bagasse ash in normal soil, for that proportions shear stress is 0.378 Kg/cm2. It shows shear stress increased by7.14%. After that mix 7.5% bagasse ash in normal soil, for that proportions shear stress is 0.392 Kg/cm2. It shows shear stress increased by 10.45%. After that mix 10% bagasse ash in normal soil and corresponding shear stress is 0.385 Kg/cm2.That increased by 8.83% from normal soil shear stress.

After that mix 2.5% bagasse ash with 3% lime in normal soil, for that proportions shear stress is 0.409 Kg/cm^2. It shows that shear stress is increased by 14.18%. Aafter that mix 5% bagasse ash with 3% lime in normal soil, for that proportions shear stress is 0.423 Kg/cm^2. It shows shear stress increased 17.02%. After that mix 7.5% bagasse ash with 3% lime in normal soil, for that proportions shear stress is 0.452 Kg/cm2. It shows shear stress increased by 22.34%. After that mix 10% bagasse ash with 3% lime in normal soil and corresponding shear stress is 0.438 kg/cm2 that increased by 19.86% from normal soil shear stress.

4. Conclusion

In this work, the performance of bagasse ash and mixture of bagasse ash with lime on expansive soil has been studied based on series of experimental tests. This study has been carried out to understand the effect of only bagasse ash and mixture of bagasse ash and lime with particular ratio on expansive soil. The results of the entire experiment test have been discussed in previous chapter. On the basis of discussion of results, following conclusion is made:

- According to study, at first mix only bagasse ash in to expansive soil with particular ratio 2.5%, 5%, 7.5%, 10%) then was noticed increase in compressive strength, shear strength and load bearing capacity till 7.5% Bagasse Ash and decrease in dry density of expansive soil at a particular optimum moisture content. But after 7.5% ratio of bagasse ash suddenly all the properties decrease. The optimum ratio of bagasse ash is 7.5% by weight of expansive soil.
- After that mix of bagasse ash with lime in to expansive soil and test are performed on different additive material (2.5%, 5%, 7.5%, 10%) and find out above engineering properties of expansive soil, increase in compressive strength, shear strength and load bearing capacity till 7.5% Bagasse and decrease in dry density of expansive soil at a particular optimum moisture content. In the result notice at first all properties increase UP TO 7.5% Bagasse Ash. After that at (7.5+3) % ratio suddenly properties decrease. The optimum ratio of bagasse ash is 7.5% with 3% lime fix ratio by weight of expansive soil.
- The best ratio of bagasse ash is 7.5% and the best ratio in bagasse ash with lime is (7.5 + 3) % by weight of expansive soil.

References

[1] A. Kumar, B. Singh Walia and A.Bajaj (2007). Influence of Fly Ash, Lime, and Polyester Fibers on Compaction and Strength Properties of Expansive Soil.*American Society for Civil Engineering*, Vol. 19, pp 242–248.

[2] Ahmed, B., Alim, A., & Sayeed, A. (2013). Improvement of soil strength using cement and lime Admixtures. *Earth Science*, *2*(6), 139-144.

[3] Al-Rawas, A. A., Hago, A. W., & Al-Sarmi, H. (2005). Effect of lime, cement and Sarooj (artificial pozzolan) on the swelling potential of an expansive soil from Oman. *Building and Environment*, *40*(5), 681-687.

[4] Alavéz-Ramírez, R., Montes-García, P., Martínez-Reyes, J., Altamirano-Juárez, D.C. & Gochi-Ponce, Y. (2012). The use of sugarcane bagasse ash and lime to improve the durability and mechanical properties of compacted soil blocks. Construction and Building Materials, vol. 34, no. 0, pp. 296-305.

[5] Anupam, A.K., Kumar, P. & Ransinchung, G.D. 2013. Use of Various Agricultural andIndustrial Waste Materials in Road Construction, Procedia. *Social and Behavioral Sciences*, vol. 104, pp. 264-73.

[6] A.V. Narasimha Rao and M Chittaranjan (2011). Applications of agricultural and domestic wastes in Geotechnical Applications. *Journal of Environmental Research and Development*, January-March, vol. 5, No. 3.

[7] Bajaj, J., Singh, V. K., Bajaj, J., & Singh, V. K. (2016). Performance Evaluation of Block Cotton Soil Stabilized with Sugarcane Bagasse Ash and Randomly Distributed Core fibres. *International Journal*, *2*, 493-498.

[8] Barazesh, A., Saba, H., &Gharib, M. (2012). The Effect of Adding Iron Powder on Atterberg Limits of Clay Soils. *International Research Journal of Applied and Basic Sciences*, *3*(11), 2349-2354.

[9] Bello, A. O. (2014). Bagasse Ash Stabilization of Black Cotton Soil Using Cement Kiln Dust as an Activator. *Unpublished M.Sc Thesis submitted to the Department of Civil Engineering, Ahmadu Bello University, Zaria*.

[10] Brooks, R., Udoeyo, F. &Takkalapelli, K. (2011). Geotechnical Properties of Problem Soils Stabilized with Fly Ash and Limestone Dust in Philadelphia. *Journal of Materials in Civil Engineering*, vol. 23, no. 5, pp. 711-6.

[11] Cai, Y., Shi, B., Ng, C.W.W. & Tang, C.S. (2006). Effect of polypropylene fiber and lime admixture on engineering properties of clayey soil. *Engineering Geology*, vol. 87, no. 3-4, pp. 230-40.
[12] Chakraborty, A., Borah, A., &Sharmah, D. (2016). Stabilization of Expansive Soil using Sugarcane Straw Ash (SCSA). *ADBU Journal of Engineering Technology*, *4*.
[13] Christopher, I. C., &Chimobi, N. D. (2019). Emerging trends in expansive soil stabilisation: A review. *Journal of Rock Mechanics and Geotechnical Engineering*.
[14] Dang, L.C., (2019). Enhancing the engineering properties of expansive soil using bagasse ash, bagasse fibre and hydrated lime (*Doctoral dissertation*).
[15] Dang, L.C., Hasan, H., Fatahi, B., Jones, R. and Khabbaz, H., (2016). Enhancing the engineering properties of expansive soil using bagasse ash and hydrated lime. *International journal of GEOMATE*, *11*(25), pp.2447-2454.
[16] Dang, L.C., Fatahi, B. &Khabbaz, H. (2016). Behaviour of Expansive Soils Stabilized with Hydrated Lime and Bagasse Fibres.*Procedia Engineering*, vol. 143, pp. 658-65.
[17] Dang, L.C., Hasan, H., Fatahi, B., Jones, R. &Khabbaz, H. (2016). Enhancing the Engineering Properties of Expansive Soil Using Bagasse Ash and Hydrated Lime. *International Journal of GEOMATE*, vol. 11, no. 25, pp. 2447-54.
[18] Dang, L., Hasan, H., Fatahi, B., &Khabbaz, H. (2015). Influence of bagasse ash and hydrated lime on strength and mechanical behaviour of stabilised expansive soil. *GEOQuebec*.
[19] D.N. John, and J.M. Debora, (1992). Expansive Soils-Problems and practice in foundation and pavement engineering. *John Wiley & Sons. Inc*., New York.
[20] Gandhi, K. S. (2012). Expansive soil stabilization using bagasse ash. *International Journal of Engineering Research & Technology (IJERT)*, *1*(5), 2278-0181.
[21] Hasan, H., Dang, L., Khabbaz, H., Fatahi, B. &Terzaghi, S. (2016). Remediation of Expansive Soils Using Agricultural Waste Bagasse Ash. *Procedia Engineering*, vol. 143, pp. 1368-75.
[22] Jamsawang, P., Poorahong, H., Yoobanpot, N., Songpiriyakij, S. & Jongpradist, P. (2017). Improvement of soft clay with cement and bagasse ash waste. *Construction and Building Materials*, vol. 154, pp. 61-71.
[23] Jayasree, P., Balan, K., Peter, L. & Nisha, K. (2015). Volume Change Behavior of Expansive Soil Stabilized with Coir Waste.*Journal of Materials in Civil Engineering*, vol. 27, no. 6, p. 04014195.
[24] Jian-Long Zheng, Rui Zhang, and He-Ping Yang (2009). Highway Sub grade Construction in Expansive SoilAreas. *American Society for Civil Engineering*, pp 154 -162.
[25] Kanchan Lata Singh and S.M. Ali Jawaid (2013). Geotechnical Properties of Soil Stabilized with Bagasse Ash", *IJBSTR*, Vol.1, issue 9.
[26] Kiran R. G. and Kiran L., (2013). Analysis of Strength Characteristics of Black Cotton Soil Using Bagasse Ash and Additives as Stabilizer. *International Journal of Engineering Research & Technology*, 2(7), pp. 2240-2246.
[27] Ken C. Onyelowe, (2012). Cement Stabilized Akwuete Lateritic Soil and the Use of Bagasse Ash *IJSEI*, Vol. 1, Issue 2, pp. 16-20.
[28] Kharade, A.S., Suryavanshi, V.V., Gujar, B.S. and Deshmukh, R.R., (2014). Waste product bagasse ash from sugar industry can be used as stabilizing material for expansive soils. *International Journal of Research in Engineering and Technology*, *3*(3), pp.506- 512.
[29] Kulkarni, A. P. Mithun. K. Sawant, Vaishnavi V. Battul, Mahesh S. Shindepatil and Aavani P., (2016). Black Cotton Soil Stabilization Using Bagasse Ash and Lime. *International Journal of Civil Engineering and Technology (IJCIET)*, *7*(6).
[30] Kumar, A., Walia, B. & Bajaj, A. (2007). Influence of Fly Ash, Lime, and Polyester Fibers on Compaction and Strength Properties of Expansive Soil.*Journal of Materials in Civil Engineering*, vol. 19, no. 3, pp. 242-8.
[31] K. V. Madurwar, P. P. Dahale, A. N. Burile (2013). Comparative Study of Black Cotton Soil Stabilization with RBI Grade 81 and Sodium Silicate. *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 2, Issue 2.
[32] M. Chittaranjan, M. Vijay and D. Keerthi (2011). Agricultural wastes as soil stabilizers. *International Journal of Earth Sciences and Engineering*, Vol. 04, issue 6, SPL, pp. 50-51.
[33] Manikandan, A. & Moganraj, M. (2014). Consolidation and Rebound Characteristics of Expansive Soil by Using Lime and Bagasse Ash', *International Journal of Research in Engineering and Technology*, vol. 03, no. 04.
[34] Mitchell, J.K. & Hooper, D.R. (1961). Influence of time between mixing and compaction on properties of a lime-stabilized expansive clay. *Highway Research Board Bulletin*, no. 304, pp. 14-31.
[35] Mohamed, A.E.M.K. (2013). Improvement of swelling clay properties using hay fibers. *Construction and Building Materials*, vol. 38, pp. 242-7. pp. 403-11.
[36] Mokhtari, M. & Dehghani, M. (2012). Swell-shrink behavior of expansive soils, damage and control.*Electronic Journal of Geotechnical Engineering*, vol. 17, pp. 2673-82.
[37] Moses G. and Osinubi K. J. (2013). Influence of compactive efforts on cement bagasse ash treatment of expansive black cotton soil. *World Academy of Science, Engineering and Technology*, pp. 1559-1566.
[38] Nelson, J., & Miller, D. J. (1997). Expansive soils: problems and practice in foundation and pavement engineering. *John Wiley & Sons.*
[39] Onésippe, C., Passe-Coutrin, N., Toro, F., Delvasto, S., Bilba, K., &Arsène, M. A. (2010). Sugar cane bagasse fibres reinforced cement composites: thermal considerations. *Composites Part A: Applied Science and Manufacturing*, *41*(4), 549-556.
[40] Osinubi, K.J., Ijimdiya, T.S. &Nmadu, I. (2009). Lime Stabilization of Black Cotton Soil Using Bagasse Ash as Admixture. *Advanced Materials Research*, vol. 62-64, pp. 3-10.
[41] Osinubi, K.J., (1995). "Lime modification of black cotton soil" *Spectrum Journal, Kaduna*, Vol.2, Nos. 1 and 2, pp, 112 – 122.
[42] OsinubiK. J. (1999). Evaluation of admixture stabilization of Nigerian black cotton soil. *Nigeria Society of Engineers Technical Transactions*, Vol 34, No. 3, pp 88 – 96
[43] Otoko, G. R. (2014). Use of Bagasse Ash as Partial Replacement of Cement in Concrete. *International Journal of Innovative Research and Development*, *3*, 285-289.
[44] Prasad P. Dahale, P.B. Nagarnaik, A. R. Gajbhiye (2012). Utilization of Solid Waste for Soil Stabilization. Vol. 17
[45] Punthutaecha, K., Puppala, A., Vanapalli, S. &Inyang, H. (2006) Volume Change Behaviors of Expansive Soils Stabilized with Recycled Ashes and Fibers.*Journal of Materials in Civil Engineering*, vol. 18, no. 2, pp. 295-306.
[46] Ramadas, T.L. Kumar, N. Darga, Aparna, G. (2010). Swelling and Strength Characteristics of Expansive Soil Treated with Stone Dust and Fly Ash.*Indian Geotechnical Conference*.
[47] Sadeeq et.al, (2015). Effect of Bagasse Ash On Lime Stabilized Lateritic Soil. *Jordan Journal of Civil Engineering*, Vol. 9, No. 2, pp. 203-213.
[48] Sarkar, G., Islam, M. R., Alamgir, M., & Rokonuzzaman, M. D. (2012). Study on the geotechnical properties of cement based composite fine-grained soil. *International Journal of Advanced Structures and Geotechnical Engineering*, *1*(2), 42-49.
[49] Shailendraet.aj, (2015). Stabilization of Black Cotton Soil Using Lime. *IJSR*, Vol. 4, Issue 5, pp. 2090-2094.
[50] Sharma, R., Phanikumar, B. & Rao, B. (2008). Engineering Behavior of a Remolded Expansive Clay Blended with Lime, Calcium Chloride, and Rice-Husk Ash. *Journal of Materials in Civil Engineering*, vol. 20, no. 8, pp. 509-15
[51] Sivakumar Babu, G.L., Vasudevan, A.K. &Sayida, M.K. (2008). Use of Coir Fibers for Improving the Engineering Properties of Expansive Soils.*Journal of Natural Fibers*,vol. 5, no.1, pp. 61-75.
[52] Solanki, P., Khoury, N. & Zaman, M. (2009). Engineering Properties and Moisture Susceptibility of Silty Clay Stabilized with Lime, Class C Fly Ash, and Cement Kiln Dust. *Journal of Materials in Civil Engineering*, vol. 21, no. 12, pp. 749-57.
[53] Sohail Ali andShubhada Sunil Koranne (2011). Performance Analysis of Expansive Soil Treated with Stone Dust and Fly Ash. *EDJE*, Vol. 16, 2011.
[54] Udayashankar D. Hakari, S. C. Puranik (2012). Stabilization of Black Cotton Soils Using Fly Ash, Hubballi. *Dharwad Municipal Corporation Area. Karnataka, India*, Vol.12, Issue 2.
[55] W. G. Holtz and H. J. Gibbs (1956). Engineering properties of expansive clays. *ASCE*, pp. 121, 641-677.
[56] Zha, F., Liu, S., Du, Y. & Cui, K. (2008). Behavior of expansive soils stabilized with fly ash.*Natural Hazards*, vol. 47, no. 3, pp. 509-23.