International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 8 Issue 3, May-June 2024 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Enhancing the Properties of Expansive Soil Stabilized with Sisal Fibre and Fly Ash

Sunil Kumar[1], Er. Raj Bala[2]

[1]M Tech Scholar, Department of Civil Engineering, [2]Assistant Professor, Department of Civil Engineering,
[1,2]Jan Nayak Chaudhary Devi Lal Memorial College of Engineering, Sirsa, Haryana, India

ABSTRACT

This study delves into the efficacy of employing fly ash (FA) and sisal fibers (SF) as additives for soil stabilization, with a focus on the inherently fragile expansive soil found in the Sirsa, Haryana, region. Given the pressing need for stable soil in construction endeavors, the research examines both mechanical and chemical stabilization techniques. Through a series of experimental methods such as the California Bearing Ratio (CBR) test and Proctor compaction test, the study evaluates the impact of these additives on soil properties. Results reveal that the incorporation of FA leads to notable enhancements in both maximum dry density (MDD) and CBR value, whereas the introduction of SF, serving as a tensional reinforcement, decreases MDD while significantly augmenting CBR value, thus showcasing its potential for soil improvement.

How to cite this paper: Sunil Kumar | Er. Raj Bala "Enhancing the Properties of Expansive Soil Stabilized with Sisal Fibre and Fly Ash" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-8 | Issue-3, June 2024, pp.568-574, URL: www.ijtsrd.com/papers/ijtsrd64928.pdf

IJTSRD64928

I. INTRODUCTION

There has been a notable increase in construction endeavors globally, driven by the pressing demand for infrastructure development. This surge is primarily spurred by factors such as rapid population expansion, industrialization, and urbanization. In previous decades, construction projects predominantly utilized land with sufficient bearing capacity or structurally suitable terrain for erecting residential complexes and other large-scale infrastructures. However, the present scenario presents a challenge with a scarcity of suitable land due to the exponential population growth. This scarcity extends to lands suitable for the construction of essential transportation networks like roads, highways, railways, and airports, particularly as urban and rural areas merge.

Consequently, the construction industry is compelled to embark on projects utilizing any available land parcel. Addressing this challenge necessitates innovative approaches to enhance soil properties. This need stems from various factors, including the limited availability of land, stringent construction schedules, environmental considerations, high maintenance expenses, and the ongoing imperative for structural stability.

II. LITERATURE REVIEW

Priyanka Sharma et al. (2020) explored the strength and durability properties of soil when combined with an optimized ratio of rice husk ash (RHA) and sisal fiber (SF). The study evaluated various geotechnical properties such as unconfined compressive strength (UCS), compaction, and preliminary tests on soil samples with different proportions of RHA and SF. The findings indicated that the addition of SF and RHA led to improvements in maximum dry density and UCS, highlighting their potential for soil stabilization applications.

S.M Kavita et al. (2019) conducted research to examine the influence of sisal fiber on soil stabilization. Their findings revealed that the addition of sisal fiber led to a slight increase in the liquid limit of the soil. In contrast, the presence of polypropylene fiber did not affect the liquid limit due to the water-absorbing properties of sisal fibers. Yet, both sisal and polypropylene fibers led to a reduction in the optimal moisture content (OMC) and an elevation in the maximum dry density (γd, max) when compared to unstabilized soil. Moreover, a hybrid fiber combination consisting of 0.3% sisal and 0.3% polypropylene achieved the highest dry density. The inclusion of fibers also resulted in significant enhancements in unconfined compressive strength (UCC) and California Bearing Ratio (CBR) values, thereby improving soil stability. Overall, the hybrid fiber combination was deemed an excellent ground improvement technique in geotechnical engineering.

Anil Kumar Sharma et al. (2019) directed their attention toward augmenting the load-bearing capability of soil through the stabilization process involving bottom ash (BA) and reinforcement using sisal fibers. Given the cost and availability constraints associated with synthetic fibers, the study explored the use of waste product BA and sisal fibers as viable alternatives.

Soil samples containing different proportions of BA and sisal fibers underwent a series of laboratory experiments, including compaction and unconfined compression strength tests. The findings unequivocally favored sisal fibers over polyvinyl alcohol (PVA) fibers, emphasizing their effectiveness in soil stabilization.

Sachin N Bhavsar et al. (2013) meticulously conducted a series of comprehensive tests including Atterberg's limit tests, linear shrinkage tests, free swell index evaluations, and modified proctor tests. Their research focused on analyzing the behavior of black cotton soil in conjunction with marble dust sourced from Gandhi nagar.

Sabat et al. (2013) explored an in-depth investigation into the effects of blending quantities of QD (Quarry Dust) and FA (Fly Ash) across a range of proportions on the mechanical characteristics of expansive soil. They observed that with increasing proportions of both FA and QD, key parameters such as the California Bearing Ratio (CBR) and Maximum Dry Density (MDD), as well as the Optimum Moisture Content (OMC), experienced a decline. Additionally, the swell pressure exhibited a decreasing trend with the rise in the percentages of FA and QD. After thorough analysis, the study identified the most favorable blend of FA and QD to be at a proportion of 45%.

Sabat et al. (2012) conducted a comprehensive study focusing on expansive soils, wherein they performed a series of tests to evaluate different properties. These tests encompassed Atterberg's limit, compaction characteristics, and shear strength parameters. The study specifically examined the impact of blending expansive soils with an optimal quantity of Quarry Dust (QD), set at 45%. Through their experimentation, the researchers observed noteworthy trends.

They found that augmenting the lime content led to notable alterations in several key parameters of the soil. Notably, there were reductions in the liquid limit, plasticity index, and maximum dry density with increasing lime content. Conversely, other properties exhibited an upward trend. The plastic limit, shrinkage limit, cohesion, angle of internal friction, and Optimum Moisture Content (OMC) of the soil-QD blends all demonstrated increases.

This detailed investigation sheds light on the intricate interplay between lime content, Quarry Dust percentage, and various soil characteristics, providing valuable insights for soil stabilization and engineering applications.

Agarwal & Gupta (2011) highlighted the positive impact of adding QD to expansive soil to enhance stability, particularly in the highway sector.

III. MATERIAL USED

In this comprehensive study, the two distinct soil types are investigated, denoted as Soil1 and Soil2. A comprehensive compilation of the properties of the filler material utilized in the study, specifically Fly Ash (FA). For a thorough understanding of the reinforcing agent employed,

Soil Properties Comparison

Properties	Soil 1	Soil 2
Liquid limit value in (%)	32	48
Plastic limit value in (%)	12	23
Plasticity Index value in %	20	25
Maximum Dry Density (in g/cc)	1.42	1.57
OMC (in %)	21	24
Sand (%)	44	32
Silt (%)	18	22
Clay (%)	38	46
Unconfined Compressive Strength test (UCS) –kN/m^2	57.1	73.41

Filler

The study aims to economically incorporate fly ash into Soil 1 and Soil 2 blends, with a ratio of 70% fly ash to 30% soil. By doing so, the research aims to mitigate the environmental impact of fly ash disposal while simultaneously reducing the reliance on landfill space for waste management purposes

Properties of Fly Ash

Properties	Fly Ash
Liquid limit value in (%)	84%
Plastic limit value in (%)	Non plastic
Specific gravity	2.09
MDD (kN/m^3)	13.2
Optimum MoistureContent (%)	13
Gravel	00
Sand (%)	15.20
Silt (%)	82.65
Clay (%)	2.1

Properties of Sisal Fibre

Property	Value
Average Diameter (mm)	0.8 to 1.2
Average Tensile Strength (N/mm2)	385 to 728
Density (g/cc)	1.58

IV. EXPERIMENTAL PROCEDURE

CBR Test

The California Bearing Ratio (CBR) test, a fundamental procedure in geotechnical engineering, serves to assess soil strength and its capacity to bear loads, particularly pertinent in pavement design and construction endeavors

1. The California Bearing Ratio (CBR) test encompasses a detailed procedure for the preparation and soaking of specimens, ensuring accuracy in the assessment of soil strength. Here's an expanded breakdown of the steps involved:
2. Initially, the soil specimen undergoes sieving using a ¾ inch (19 mm) sieve. Any residue remaining on the sieve prompts an equal addition of material, comprised of particles passing through the sieve and retained on the #4 sieve, to the specimen.
3. Following sieving, three sample specimens, each comprising 6.8 kg (15 lb) of soil, are meticulously prepared, ensuring consistency and representativeness.
4. Compaction of the specimens is conducted with varying numbers of blows, tailored to achieve diverse percentages of maximum dry density, a critical factor influencing soil stability.
5. Throughout the process, optimal water content is maintained by carefully adding appropriate quantities of water to the specimens, ensuring uniformity and reliability in test results.
6. The assembly of the test mold begins by attaching it to the base plate with the extension collar, facilitating controlled compaction and measurement procedures. Prior to filling the mold, a spacer disk and filter paper are strategically placed inside.
7. The soil is then carefully layered within the mold in three distinct layers, with each layer compacted using a predetermined number of blows, ensuring uniform density distribution and eliminating air voids.
8. Post-compaction, the extension collar is removed, and any excess soil protruding from the mold's top surface is trimmed to ensure a smooth, even finish, minimizing potential irregularities in subsequent measurements.
9. Subsequent specimens are subjected to the same meticulous compaction procedure, maintaining consistency and accuracy across all samples.
10. Following compaction, the spacer disk and base plate are detached, and the combined weight of the mold and compacted soil is meticulously measured, providing crucial data for subsequent analysis.
11. The final step involves the inversion of the mold and soil assembly, with the base plate securely reattached to the mold using coarse filter paper, ensuring stability during subsequent testing phases and facilitating accurate measurement procedures.

For the soaking process:

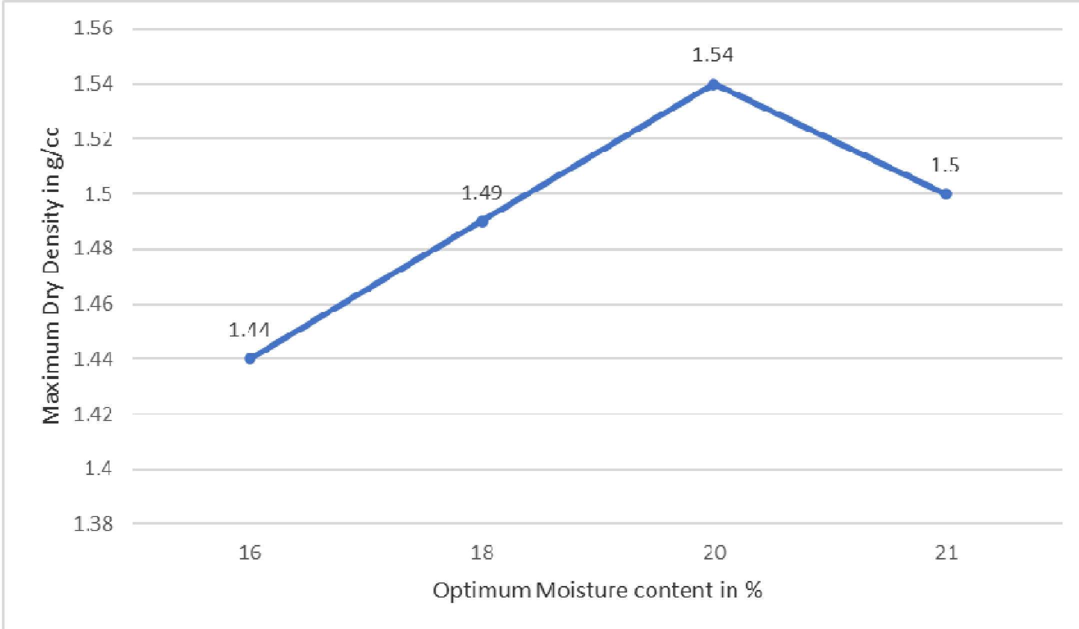
1. A predetermined amount of surcharge weight is carefully positioned on the top of the base plate.
2. The specimen undergoes immersion in a water tank for an approximate duration of 4 days, equivalent to 96 hours.
3. Both before and after the soaking period, the height of the specimen is meticulously measured to ascertain the swell percentage.
4. Following the soaking phase, the mold, along with the base plate, filter paper, and surcharge weights, are meticulously removed, and the combined mass of the mold and soil is meticulously determined.

V. RESULTS AND DISCUSSIONS

Influence of Maximum dry density of Soil 1 with Fly Ash

The results obtained from utilizing FA powder mixed with Soil 1 at a ratio of 70:30. The highest recorded maximum dry density achieved was 1.54 g/cc, accompanied by an optimal moisture content of 20%.

Sr. No.	OMC (%)	MDD (g/cc)
1	16	1.44
2	18	1.49
3	20	1.54
4	21	1.50



OMC-MDD Curve of Soil-1 with 70:30 FA

Influence of Maximum Dry Density of Soil 2 with Fly Ash

The FA powder with a 70:30 percentage of Soil 2 yielded the highest maximum dry density of 1.56g/cc, which corresponds to an ideal moisture content of 21%.

Sr. No.	OMC (%)	MDD (g/cc)
1	19	1.50
2	20	1.52
3	21	1.56
4	21.5	1.53

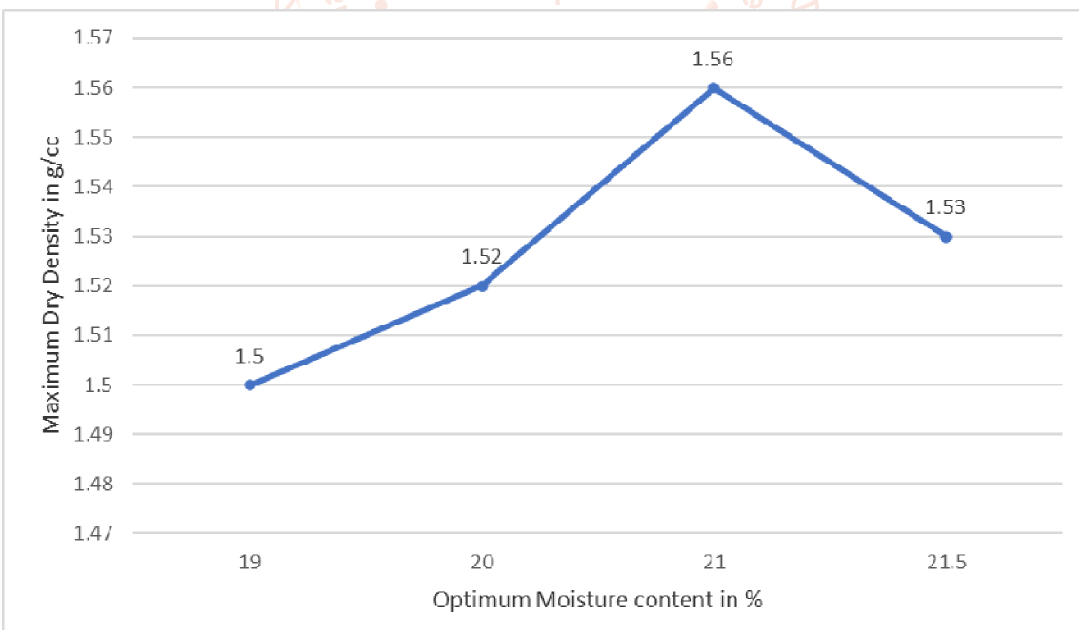
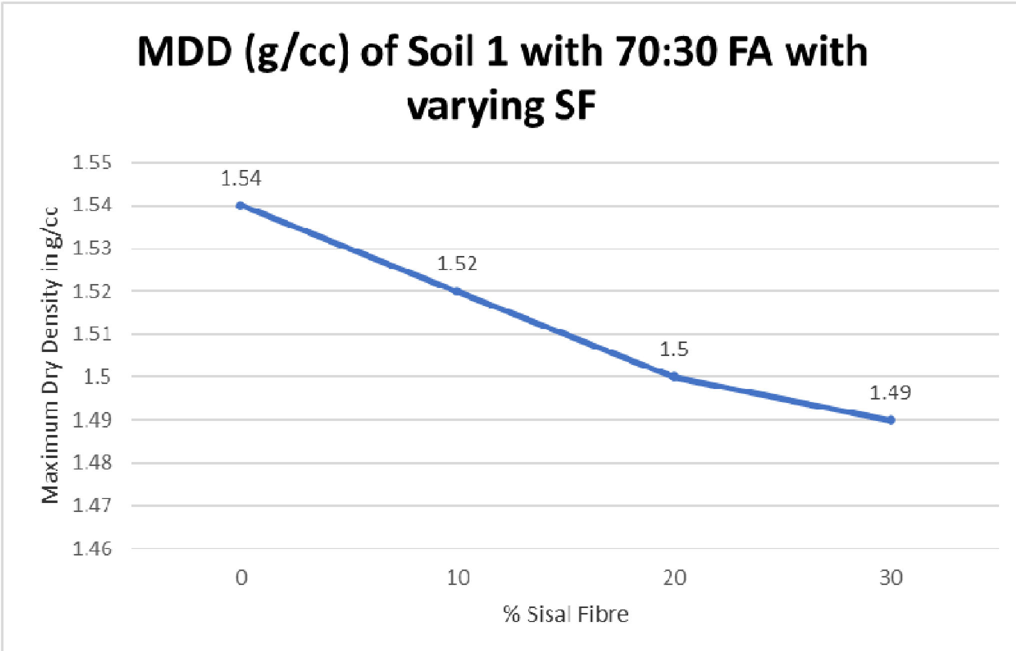


Figure Variation of OMC-MDD for Soil 2 with fly ash 70:30

Influence of Maximum dry density of Soil 1 with Fly Ash and SF

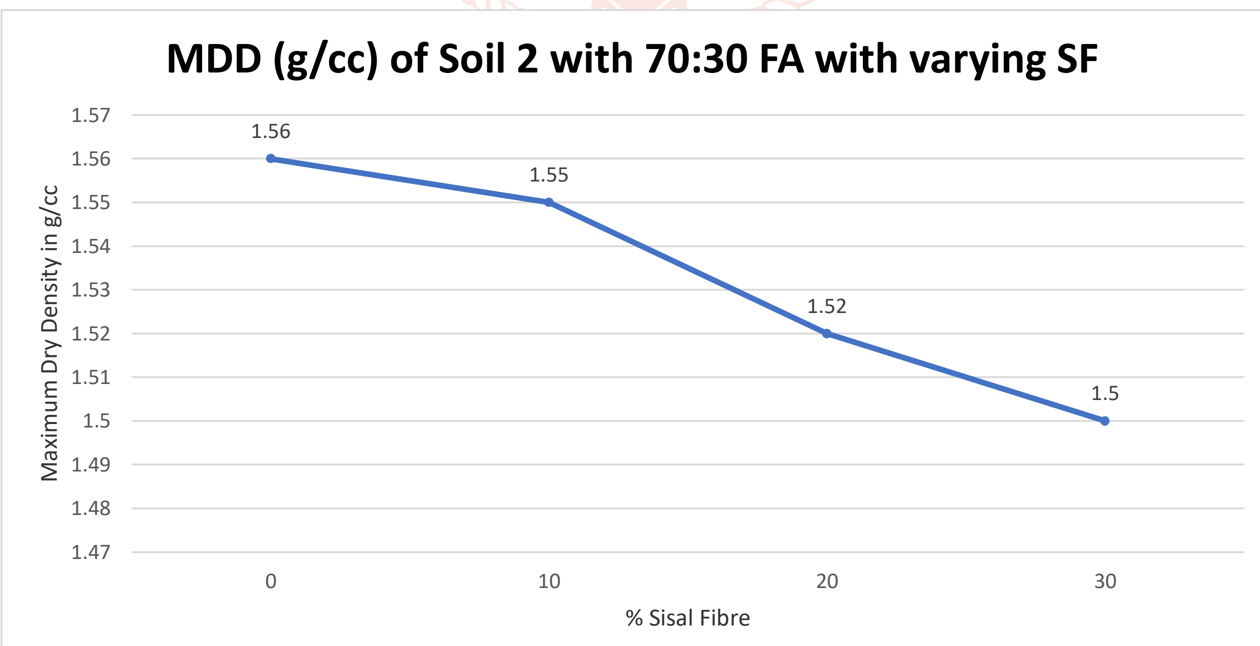
As per previous experiment we noted that the FA powder with a 70:30 percentage of Soil 1 yielded the highest maximum dry density of 1.54g/cc, which corresponds to an ideal moisture content of 20%

Soil1+FA+%SF.	OMC (%)	MDD (g/cc)
0	20	1.54
10	20	1.52
20	20	1.50
30	20	1.49



Influence of Maximum dry density of Soil 2 with Fly Ash and SF
As per previous experiment we noted that the FA powder with a 70:30 percentage of Soil 2 yielded the highest maximum dry density of 1.56g/cc, which corresponds to an ideal moisture content of 21%

Soil2+FA+%SF.	OMC (%)	MDD (g/cc)
0	21	1.56
10	21	1.55
20	21	1.52
30	21	1.50



In the soil testing procedure, a mold is initially filled with the soil specimen and compacted using a rammer. Subsequently, the mold is immersed in water for a specified duration. Following this, a loading machine is employed to exert force on a plunger, which penetrates the soil mold gradually under increasing load. Attached to the machine are a proving ring and a dial gauge; the former measures the applied load, while the latter indicates the depth of penetration. Corresponding load values are recorded for specific penetration depths, forming the basis for plotting a stress-versus-penetration curve.

From this curve, stress values corresponding to 1-inch (2.54 mm) and 2-inch (5.08 mm) penetrations are extracted. These stress values are then utilized in the relevant equation to compute the California Bearing Ratio (CBR) value.

The apparatus required for conducting the Laboratory California Bearing Ratio Test includes a loading machine, penetration piston, sieves, mold, spacer disk, and mixing tools.

In the subsequent section, the CBR values for Soil 1 and Soil 2, incorporating Fly Ash (FA) in a 70:30 ratio with varying percentages of Sisal Fiber, will be delineated.

VI. CONCLUSION

The expansive soil sample taken for this study is of fragile nature. The waste products like Sisal Fibre and FA that are abundantly available nearby sampling region under consideration. The soil samples were divided into two groups based on their compressibility: low (CL) and medium (CI). These groups are referred to as soil 1 and soil 2 respectively. The samples were mixed in various ratios of admixtures to produce the dry strength, which indirectly results in increased shear strength in terms of MDD.

Experimental methods, such as the CBR test and standard Proctor compaction test, are described for evaluating soil properties and the effects of additives. The results and discussions section presents the findings related to maximum dry density, optimum moisture content, and California Bearing Ratio (CBR) for different soil samples with and without additives. The following conclusions are drawn in light of the findings of the numerous tests.

- Addition of Fly ash results in increment of both MDD value and CBR value.
- But the addition of Sisal Fibres results in reduction of MDD and enhanced CBR value.
- Whereas, addition of FA and SF resulted in improvement of soil, economically as well as ecologically. This study suggest a promising way of soil stabilization.

VII. REFERENCES

[1] Abdrabbo, F., Gaaver, K., & Omer, E. A. (2008). Behavior of strip footings on reinforced and unreinforced sand slope. In *GeoCongress 2008: Geosustainability and Geohazard Mitigation* (pp. 25–32).

[2] Alamshahi, S., & Hataf, N. (2009). Bearing capacity of strip footings on sand slopes reinforced with geogrid and grid-anchor. *Geotextiles and Geomembranes*, *27*, 217–226.

[3] Alawaji, H. A. (2001). Settlement and bearing capacity of geogrid-reinforced sand over collapsible soil. *Geotextiles and geomembranes*, *19*, 75–88.

[4] Alonso, E. E., Pereira, J.-M., Vaunat, J., & Olivella, S. (2010). A microstructurally based effective stress for unsaturated soils. *Géotechnique*, *60*, 913–925.

[5] 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*, 681–687.

[6] Amadi, A. A., & Osu, A. S. (2018). Effect of curing time on strength development in black cotton soil–Quarry fines composite stabilized with cement kiln dust (CKD). *Journal of King Saud University-Engineering Sciences*, *30*, 305–312.

[7] Amu, O. O., Fajobi, A. B., & Afekhuai, S. O. (2005). Stabilizing potential of cement and fly ash mixture on expansive clay soil.

[8] Hossein Alavi, A., Hossein Gandomi, A., Mollahassani, A., Akbar Heshmati, A., & Rashed, A. (2010). Modeling of maximum dry density and optimum moisture content of stabilized soil using artificial neural networks. *Journal of Plant Nutrition and Soil Science*, *173*, 368–379.

[9] Marto, A., Hajihassani, M., & Momeni, E. (2014). Bearing capacity of shallow foundation's prediction through hybrid artificial neural networks. *Applied mechanics and materials*, *567*, 681–686.

[10] Muntohar, A. S., & Hantoro, G. (2000). Influence of rice husk ash and lime on

engineering properties of a clayey subgrade. *Electronic Journal of Geotechnical Engineering*, *5*, 1–13.

[11] Radhakrishnan, G., Kumar, M. A., & Raju, G. V. (2014). Swelling properties of expansive soils treated with chemicals and fly ash. *Am J Eng Res*, *3*, 245–250.

[12] Sabat, A. K. (2013). Prediction of California bearing ratio of a soil stabilized with lime and quarry dust using artificial neural network. *Electronic Journal of Geotechnical Engineering*, *18*, 3261–3272.

[13] Sabat, A. K. (2015). Prediction of California bearing ratio of a stabilized expansive soil using artificial neural network and support vector machine. *Electron. J. Geotech. Eng*, *20*, 981–991.

[14] Al-Rawas,AA,Hago,AW&Al-Sarmi,H2005,'Effectoflime,cement and Sarooj (artificial pozzolan) on the swelling potential of an expansive soil from Oman', Journal of Building and Environment, vol. 40, pp.681-687.

[15] Amu, OO, Fajobi, AB &Afekhuli, SO 2005, 'Stabilizing Potential of Cement and Fly Ash Mixture on Expansive Clay Soil', Journal ofAppliedSciences,vol.5,no.9,pp.1669-1673.

[16] Al-Sinaidi, AR & Ali, AH 2006, 'Improvement in Bearing Capacity of Soil by Geogrid -An Experimental Approach', IAEG

[17] Abdrabbo, FM, Gaaver, KE& Omar EA 2008, 'Behavior of Strip Footings on Reinforced and Unreinforced Sand Slope', ASCE GeoCongress,pp.25-32

[18] Alamshahi, S &Hataf, N 2009, 'Bearing Capacity of Strip Footings on Sand Slopes Reinforced with Geogrid and Grid-anchor', Journal of Geotextile and Geomembranes, vol. 27, pp.217-226.

[19] Amir Hossein Alavi, Amir Hossein Gandomi, Ali Mollahassani, AliAkbar Heshmati & Azadeh Rashed 2010, Modeling of maximum dry density and optimum moisture content of stabilized soil using artificial neural networks, Journal of Plant Nutrious Soil Science vol. 173, pp.368–379

[20] Alonso, EE, Pereira, J, Vaunat, MJ & Olivella, S2010. 'A microstructurally based effective stress for unsaturated soils', Geo technique, vol.60, no.12, pp.913-925.

[21] Ali, MS &Koranne SS 2011, 'Performance Analysis of Expansive Soil Treated With Jute fibres and Fly ash'. Electronic Journal of Geotechnical Engineering, Bund I, vol. 16, pp.973-982.

[22] Akshaya Kumar Sabat 2013, 'Prediction of California Bearing Ratio of a Soil Stabilized with Lime and Quarry Dust Using Artificial Neural Network', Electronic Journal of Geotechnical Engineering, vol.18, pp.3261-3272.

[23] Aminaton Marto, Mohsen Hajihassani & Ehsan Momeni 2014, 'Bearing Capacity of Shallow Foundation's Prediction through Hybrid Artificial Neural Networks', Applied Mechanics and Materials, vol. 567, pp.681-686.

[24] AliR, Khan H & Shah A A, 2014 'Expansive Soil Stabilization Using Marble Dust and Bagasse Ash,' International Journal of Science and Research, vol.3, no.6, pp.2812-2816.

[25] Amadi, A A & Osu, A S 2016, "Effect of curing time on strength development in black cotton soil – Quarry fines composite stabilized with cement kiln dust", Journal of King Saud University – Engineering Sciences.

[26] Amulya Gudla & Nukaraju Bharathi 2017, 'Comparative study on effect of burnt brick dust and woven Geotextile material on black cotton soil', Global Journal of Engineering Science and Researches, vol. 4, no.10, pp.89-93.

[27] Acharyya, R & Dey A2018, 'Assessment of bearing capacity for strip footing located near sloping surface considering ANN-model' Journal of Mountain Science, vol.15, no.12, pp.2766-2780.