Coconut Shell Fly-Ash Stabilized Soft Soil Characteristics; Utilization of Local Waste in Ternate

Jati Brono[#]

[#] *Department, University, Address, City, ZIP Code, Country*
E-mail: xxx@yyy.zzz

**Second Institution, Address, City, ZIP Code, Country*
E-mail: xxx@yyy.zzz

Abstract— **The problem of waste is a problem in almost all urban areas. In Ternate City, for example, one of the most common wastes is coconut waste. Coconut waste is often found in Ternate City because North Maluku, including Ternate City, is one of the largest coconut producers in Indonesia. However, many coconut traders and consumers are reluctant to dispose of coconut waste in a place provided by the government. In landfills, coconut waste that is burned causes a lot of air pollution due to large-scale burning. Therefore, there is a need for a solution to overcome this problem. One thing that can be done is to look for alternative uses of coconut waste to be used or processed into other forms. In this case, this research focuses on the byproduct of Fly Ash which is derived from coconut shells. Fly Ash in this study was used as an additive for stabilizing soft soil. The method used in this study includes observing changes in plasticity properties, compaction characteristics and CBR values for variations in Fly Ash content. The results showed that the addition of Fly Ash from coconut shell waste could increase the CBR value. Thus, coconut waste in Ternate City can provide benefits to the development of Ternate City.**

Keywords— **Put your keywords here, keywords are separated by semi colon.**

I. Introduction

Indonesia produced 17.13 million tons of coconut in 2019. Based on the World Atlas report, coconut production in Indonesia is the largest in the world. The Philippines ranks second with coconut production of 14.77 million tons. After that, there is India with coconut production of 14.68 million tons. Then, coconut production in Sri Lanka was recorded at 2.47 million tons. Meanwhile, Brazil is in fifth place with coconut production of 2.33 million tons. Referring to data from the Central Statistics Agency (BPS), coconut exports from Indonesia reached 1.53 million tons or US$ 819.26 million as of the third quarter of 2020. The countries that are the destinations for Indonesia's coconut exports include the United States, the Netherlands, South Korea, China, Japan, Singapore, the Philippines, and Malaysia.

Most of Indonesia's coconuts are produced in the form of copra and other derivative products. The main coconut producing areas in Indonesia include Riau, Jambi, North Sulawesi, West Java, East Java and North Maluku.

In early April 2022, the sky above the North Oba TPS was covered with smoke from burning piles of garbage. The flames at the TPS location engulfed plastic bags, bottles, gallon covers, jerry cans, food packaging boxes, cardboard boxes, to cans and used tires.

The non-organic waste is mixed with other types of organic waste, such as banana peels, leaves, and coconut shells and coir. There were also disposable medical masks that caught fire. Some of the garbage is charred, the rest is still intact. Not only fire and smoke can be seen, but the smell of rotten odor also comes from the piles of garbage in the Temporary Shelters or TPS in North Oba, the Tidore Islands City area.

North Oba is one of the Tidore Islands region out of a total of four sub-districts located on the mainland of Halmahera Island. North Oba has an area of about 24.25 percent of the total land area of Tidore Islands City of 1550.37 square kilometers.

With a narrow area and abundant coconut production, the problem of coconut waste is a case that needs special handling in Ternate City. Therefore, this study was conducted as an effort to overcome the problem of coconut waste, while at the same time creating an abundance of local alternative materials as supporting materials for sustainable development in Ternate.

II. Literature Review

A. North Maluku's Coconut Productivity

The Central Statistics Agency (BPS) noted that coconut production in Maluku fell 0.52 percent to 103.77 million tons in 2020. Although it declined, coconut production in the province remained the largest compared to other plantation commodities. The area of coconut plantations in Maluku is also the largest among other commodities, namely 115.16 million hectares in 2020.

However, in contrast to the declining production, the area of coconut plantations in Maluku actually increased by 0.64% compared to 2019 which amounted to 114.42 million hectares. By region, the most coconut production is in Southeast Maluku Regency, which is 20.9 million tons in 2020. Tanimbar Islands Regency and Central Maluku are in the next position with coconut production of 19.51 million tons and 18.77 million tons, respectively.

Maluku also produced 20.45 million tons of cloves in 2020. Sago and cocoa production in Maluku were 10.05 million tons and 8.15 million tons, respectively, in the same period. Then, the production of nutmeg in Maluku is 5.31 million tons. Then there are cashew nuts with a production of 982 thousand tons, coffee 393 thousand tons, and palm oil 86.70 thousand tons.

TABLE I
COCONUT PRODUCTION IN NORTH MALUKU REGIONS

Region	Production (Tons)
	Coconut
	2018
Halmahera Barat	35442.00
Halmahera Tengah	8675.00
Kepulauan Sula	31195.00
Halmahera Selatan	20476.00
Halmahera Utara	70702.00
Halmahera Timur	6783.00
Pulau Morotai	10721.00
Pulau Taliabu	37957.00
Ternate	702.00
Tidore Kepulauan	9554.00
Maluku Utara	232207.00

B. Coconut Waste Issues

Coconut husk waste is a severe task for the Ternate City Government to handle, as adding to obscuring views and disturbing activities.

The location, for instance, does not address the issue of abandoned coconut shells scattered in the roadway area of Ternate's Jatiland mall, despite the fact that the City Government, through the Department of Environment (DLH), has provided a nearby waste collection station. However, because they do not want to pay environmental retribution, coconut fruit traders are unwilling to dispose of coconut shell trash at a dumpsite [1] [2].

DLH not only provides a garbage collection site, but it also transports garbages every day. However, coconut traders are unwilling to put coconut shells in the collection and disposal center, preferring to leave the waste on the side of the highway near the culinary center area [3].

Fig. 1 Coconut Waste in Ternate City

C. Soft Soil

Soil is one of the most essential elements in the field of civil engineering construction since it supports the strength of the underlying basis of structures. A suitable soil for structures is one that has a high bearing capacity and can handle the loads that are placed on it. In the course of building construction, including structures and roads, poor soil conditions are frequently discovered. Clay is one of it.

Clay soils are considered tricky in civil engineering construction due to their extreme plasticity, which results in limited bearing capacity and easy deformation. Another disadvantage of clay is its limited permeability, relatively small pore volume, and high water content. Consolidation will occur in the soil that is loaded on it.

Consolidation is the process of reducing the volume or pore voids of a low-permeability saturated soil as a result of stress. Because of the poor permeability of clay soils, the consolidation process takes a significant period. As a result, the longer the consolidation process continues, the longer it will take for the soil to stabilize. Because of the extreme lowering, this might cause structural damage to the structure.

Based on the issues discussed above, clay soil is not suitable for use as a subgrade in building construction, hence soil stabilization is required to enhance its bearing capacity.

D. Soil Stabilization

Soil stabilization is an effort to enhance the mechanical qualities of soil by the use of certain materials [4] [5]. This procedure is often done by combining the dirt with other types of soil to get the correct gradation. Furthermore, soil mixing can be done using factory-made components to improve the functionalities of the soil [6] [7].

The fundamental purpose of soil stabilization is to improve the mechanical features of the soil itself, such as compressibility, bearing capacity, ease of work, permeability, responsiveness to water content, and ability to expand [8].

To achieve this purpose, the stabilization process can be carried out using basic ways like as compaction [9], or it can be carried out using more effective procedures that demand significant funds [10], such as combining soil with sand or cement, grouting or cement injection, fly ash, heating, and so on [11].

One type of soil stabilization that is regularly carried out in the community is the development process in the context of road pavement [12]. The objectives of this work is to enhance the material on local roads by employing mechanical stabilizing methods or adding new materials to the soil [13].

Road pavement design must first go through the design process. Each layer of material used in road pavement must also fulfill high quality standards. Of course, each component in the road pavement layer must be robust enough to endure excessive bending [14], which can cause the top layer to break, move soil, and prevent permanent excessive deformation caused by the constituent materials, solidified [15].

This stability is especially critical at construction sites. Because the heavy machinery used in the project, of course, need a strong enough work base and a road that meets the standards as a foundation [16]. As a consequence, work in projects may be completed more quickly and efficiently, with higher-quality outcomes [17].

Based on SNI 03-6414 (2002) defines fly ash or fly ash is waste from burning coal in a steam power plant furnace which is smooth, round, and pozzolanic. The pozzolanic nature in question is because fly ash contains pozzolanic materials, namely chemical silica (SiO2), alumina (Al2O3), ferrum (Fe2O3), and calcium oxide (CaO). In Figure 1 shows the shape of fly ash particles by Scanning Electron Microscop (SEM) testing. The smaller the fly ash particles, the more spherical the shape is compared to the large particles [18].

According to ASTM C-618 fly ash is divided into two classes, namely:

1. Class F fly ash produced from burning anthracite and bituminous coal, with low lime content (CaO < 10%). It has pozzolanic properties and to get cementitious properties it is necessary to add lime or cement.
2. Class C fly ash produced from burning lignite or subbituminous coal, with lime content (CaO > 10%). In addition to having pozzolanic properties, it also has self cementing properties, namely the ability to harden when reacted with water [19].

Chemical soil stabilization which is currently widely used to improve subgrade is stabilization with the addition of fly ash [20]. If fly ash is mixed with soil, a self-cementation process will occur due to the influence of pozzolans or the natural hardening properties of fly ash due to compaction and water conditions [21]. The reaction speed of pozzolans is not only dependent on time [22] but is also influenced by the reacting materials and also the temperature [23]. The result of this mixture of soil, fly ash, and water produces soil that has better technical properties or characteristics than before. The advantage of adding fly ash as a stabilizing agent is due to its high economic value [24] compared to other materials [25].

III. Methodology

Fine-grained soil was collected from the foothills of Mount Gamalama in Ternate for this investigation. Fly ash, which is utilized as a stabilizing agent, is made from burned and crushed coconut shell waste.

The research was started by conducting a literature study on testing soft soil stabilized with fly ash. The data collection was carried out as a consideration in this study, namely soil stabilization with the addition of fly ash to the CBR value as a parameter to determine the bearing capacity of the soil.

This research procedure consists of 4 stages, namely:

1. Soil Physical Properties Test
   The physical properties of the soil were tested on the original soil, including: water content, specific gravity, consistency limits (atterberg limit), and grain size distribution.
2. Fly Ash Mixing
   The soil sample used passed sieve no. 200 and mixed with variations in fly ash content of 0%, 5%, 10%, and 15% of the dry weight of the soil, then tested for compaction (standard proctor).
3. Standard Compaction Test
   The soil sample that has been mixed with fly ash is stirred until evenly distributed, then compaction test (standard proctor). Next, the sample is cured with curing period variations of 0 days, 7 days, and 14 days at room temperature
4. CBR (California Bearing Ratio) Test
   CBR testing on samples after curing.

IV. Result and Discussion

Based on the results of testing the physical properties of the original soil as shown in the following table, the soil classification for the soil samples used in this study included clay soil types with a high level of plasticity.

TABLE II
BASIC PROPERTIES TEST RESULT

Characteristics	Result
Water Content (w)	23,63%
Specific Gravity (Gs)	2,60%
Atterberg Limits: Liquid Limit (LL)	53,04%
Plastic Limit (PL)	24,85%
Plasticity Index (PI)	28,19%
Sieve Analysis: Passed Sieve #200	72,15%
Soil Classification AASHTO	A-7-6

USCS	CH

To determine the effect of fly ash on soft soil, the limit of soil consistency was tested. To determine the limits of soil consistency can be known by the liquid limit test (LL) and the plastic limit test (PL). Based on the results of the liquid limit test (LL), it decreased with increasing fly ash content in the soil. This is because the soil undergoes a cementation process by fly ash so that the soil becomes larger grains causing the attractive forces between the particles in the soil to decrease.

TABLE III
ATTERBERG LIMITS TEST RESULT

	LL (%)	*PL* (%)	*PI* (%)
Untreated Soil	53,04	24,85	28,19
Soil + 5% *Fly Ash*	37,68	23,28	14,40
Soil + 10% *Fly Ash*	33,95	22,77	11,18
Soil + 15% *Fly Ash*	30,51	21,49	9,02

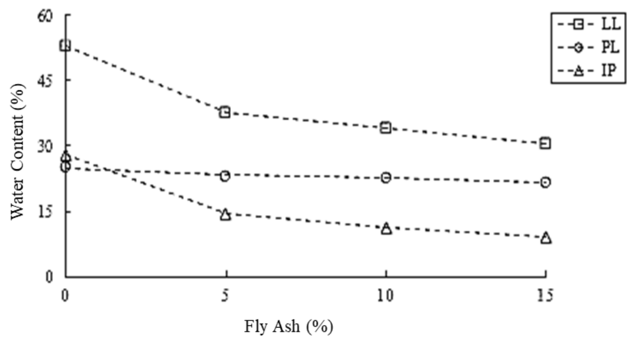

Fig. 2 Atterberg Limits Changes due to Fly Ash Content

The plastic limit test (PL) tends to decrease constantly when the addition of fly ash affects the plastic properties of the soil. The decrease in the liquid limit value (LL) affects the plasticity index (PI) value which decreases significantly when the fly ash is added. This shows that the higher the fly ash content mixed with soft soil, the better the soil mixture tends to be due to reduced soil plasticity.

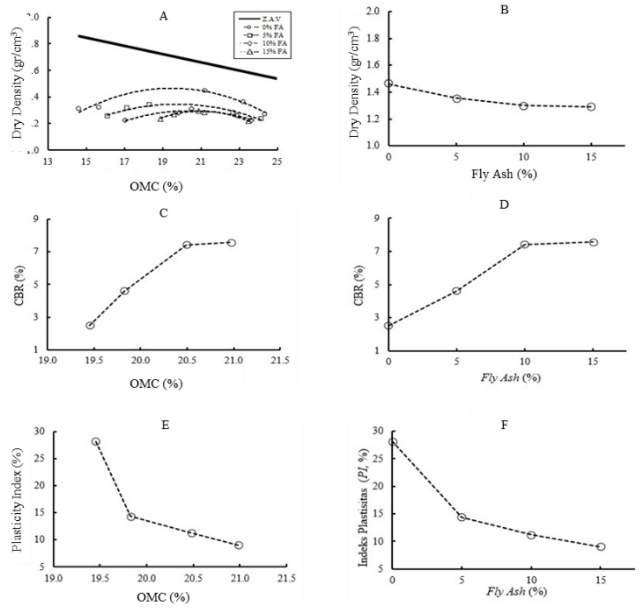

Fig. 3 Engineering Properties of Fly Ash Stabilized Soil (0 Days)

At 0 days of curing, the maximum dry density (γdmax) decreased and the optimum moisture content (wopt) increased with the addition of variations in fly ash content. This decrease in dry density occurs due to increased water entering the soil pores so that the water content value increases or increases. The dry density of the soil without the mixture is greater than the soil with the fly ash mixture, this is due to changes in soil gradation.

The CBR value increases with the increase in the optimum water content (wopt) due to the addition of fly ash content at room temperature conditions. This is due to the pozzolanic reaction so that the bonding capacity between soil grains increases to become harder and stiffer.

The condition of optimum water content (wopt) decreases the value of soil plasticity index (PI) as fly ash increases. The decrease in soil plasticity is associated with the Ca+ exchange process between the soil and fly ash.

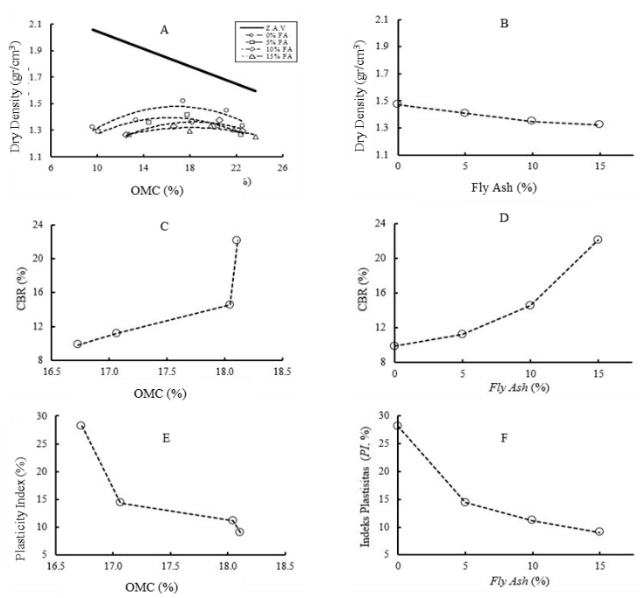

Fig. 4 Engineering Properties of Fly Ash Stabilized Soil (7 Days)

Optimum moisture content (wopt) increases with fly ash and decreases with curing time. The maximum dry weight (γdmax) decreased with fly ash and increased with curing time. This reflects that the high water absorption by fly ash and influenced by the duration of curing time, so that the density is increasing due to loss of water content.

The increase in CBR value occurred significantly at room temperature with a curing time of 7 days. The fly ash mixture at optimum water conditions increased soil strength in each mixture composition. This shows that it is proven that ripening and temperature have an effect on the increase in the CBR value of the soil. The condition of optimum water content (wopt) decreased the plasticity index (PI) of the soil to fly ash content, as previously described in the test without curing.

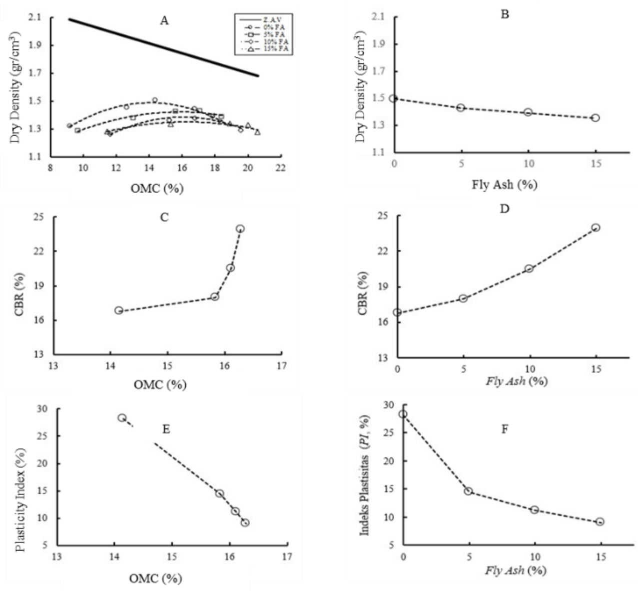

Fig. 5 Engineering Properties of Fly Ash Stabilized Soil (14 Days)

The dry density has an effect on the value of the soil moisture content, which will later have an impact on the CBR value of the soil, this is also influenced by the addition of fly ash content in the soil. The greater the dry density of the soil, the higher the CBR value of the soil, and a decrease in the percentage of soil water content. The compaction test results reflect the high water absorption by fly ash. This can be beneficial as it reduces the compaction effort required on site.

The addition of fly ash mixture into soft soil increases the CBR value so that the bearing capacity of the soil increases. The largest CBR value is the addition of an optimal level of 15% fly ash with a curing time of 14 days at room temperature conditions of 23.89%. That the long curing time affects the density level so that the air cavities in the soil are not filled with water. This research also proves that the reaction speed of fly ash's pozzolan is influenced by time and temperature. Fly ash also has a big role as a stabilizing agent when mixed with water, cementation will occur which is able to bind the soil so that the carrying capacity of the soil increases.

The results of the research showed that the plasticity index value showed the plasticity value of the soil mixture and the optimum fly ash content was 9.02%. The increase in the addition of fly ash mixed with soft soil causes the soil to tend to get better due to the reduced plasticity of the soil. This study shows that the soil is stabilized with fly ash, so the mixed soil can be used as a subgrade for road construction.

V. CONCLUSIONS

In conclusion, coconut waste found in the Ternate City area can be processed into soil stabilization material. In addition to reducing the accumulation of coconut waste, through this study it is also known that the use of Fly Ash from coconut waste can support soil stabilization. Based on the results obtained in this study, the soil mixture with the addition of fly ash had a positive effect on the physical properties of the soil, the results of testing the consistency limits decreased the value of the plasticity index (PI) of the soil. The addition of variations in fly ash content causes the water content to increase and the dry density to decrease, while the length of curing time causes the water content to decrease and the dry density to increase. The CBR value increased with the increase in fly ash content and the duration of curing at room temperature conditions. The largest CBR value was at the optimum level of 15% fly ash with 14 days curing time of 23.89%. Fly ash can work well as a mixture of subgrade improvement, because it can bind the soil so that the carrying capacity of the soil increases.

REFERENCES

[1] D. Purwiningsih, "Pengelolaan Sampah di Kota Ternate Provinsi Maluku Utara," 2014, Accessed: May 05, 2022. [Online]. Available: http://etd.repository.ugm.ac.id/home/detail_pencarian/70655

[2] M. Luth, E. Saleh, N. A.-A. J. Agribisnis, and undefined 2020, "Potential of Bioethanol Production from Local Agricultural Waste in North Maluku," *stipwunaraha.ac.id*, vol. 13, pp. 454–463, doi: 10.29239/j.agrikan.13.2.

[3] N. Nagu, E. A.-P. of the International, and undefined 2018, "Solid Waste Management: Mapping of Temporary Waste Sites and Potential Wild Solid Waste in Ternate City," *atlantis-press.com*, 2018, Accessed: May 05, 2022. [Online]. Available: https://www.atlantis-press.com/article/55910868.pdf

[4] A. A. Firoozi, C. Guney Olgun, A. A. Firoozi, and M. S. Baghini, "Fundamentals of soil stabilization," *Int. J. Geo-Engineering*, vol. 8, no. 1, Dec. 2017, doi: 10.1186/S40703-017-0064-9.

[5] N. Degirmenci, A. Okucu, A. T.-B. and environment, and undefined 2007, "Application of phosphogypsum in soil stabilization," *Elsevier*, Accessed: May 05, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0360132306002265

[6] O. Ingles and J. Metcalf, "Soil stabilization principles and practice," 1972, Accessed: May 05, 2022. [Online]. Available: https://trid.trb.org/view/137528

[7] T. L.-H. R. B. S. Report and undefined 1960, "Soil stabilization," *trid.trb.org*, Accessed: May 05, 2022. [Online]. Available: https://trid.trb.org/view/122617

[8] H. F. Winterkorn and S. Pamukcu, "Soil Stabilization and Grouting," *Found. Eng. Handb.*, pp. 317–378, 1991, doi: 10.1007/978-1-4757-5271-7_9.

[9] H. Winterkorn, S. P.-F. engineering handbook, and undefined 1991, "Soil stabilization and grouting," *Springer*, Accessed: May 05, 2022. [Online]. Available: https://link.springer.com/chapter/10.1007/978-1-4757-5271-7_9

[10] R. B.-I. J. of R. and R. in and undefined 2009, "Soil stabilization with fly ash and rice husk ash," *Citeseer*, vol. 1, no. 3, pp. 2076–7366, 2009, Accessed: May 05, 2022. [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.303.97

8&rep=rep1&type=pdf

[11] R. Karol, *Chemical grouting and soil stabilization*. 2003. Accessed: May 05, 2022. [Online]. Available: https://www.taylorfrancis.com/books/mono/10.1201/9780203911815/chemical-grouting-soil-stabilization-reuben-karol

[12] A. Firoozi, C. G. Olgun, … A. F.-I. J. of, and undefined 2017, "Fundamentals of soil stabilization," *Springer*, Accessed: May 05, 2022. [Online]. Available: https://link.springer.com/article/10.1186/s40703-017-0064-9

[13] A. Negi, M. Faizan, D. Siddharth, R. S.-I. journal of, and undefined 2013, "Soil stabilization using lime," *Citeseer*, vol. 1, no. 3, pp. 2076–7366, 2009, Accessed: May 05, 2022. [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1037.255&rep=rep1&type=pdf

[14] S. Singh, … S. A.-J. of R. in E. and, and undefined 2014, "Inclusion of coconut coir fiber in soil mixed with coal ash," *researchgate.net*, Accessed: May 05, 2022. [Online]. Available: https://www.researchgate.net/profile/Sanjay-Singh-130/publication/273301024_INCLUSION_OF_COCONUT_COIR_FIBER_IN_SOIL_MIXED_WITH_COAL_ASH/links/5e577c0e92851cefa1c7f9e6/INCLUSION-OF-COCONUT-COIR-FIBER-IN-SOIL-MIXED-WITH-COAL-ASH.pdf

[15] P. Sherwood, *Soil stabilization with cement and lime*. 1993. Accessed: May 05, 2022. [Online]. Available: https://trid.trb.org/view/389479?fbclid=IwAR3agFB7FM9UrRJ__MAnWFkWshlIjLCXwDaaqUPwvsP-nl3pKrUut_lB4I

[16] C. I.-G. and G. Engineering and undefined 2019, "Comparative assessment of the stabilization of lime-stabilized lateritic soil as subbase material using coconut shell ash and coconut husk ash," *Springer*, Accessed: May 05, 2022. [Online]. Available: https://link.springer.com/article/10.1007/s10706-019-00825-0

[17] H. A.-J. of T. E. and Technology and undefined 2017, "A review on different types soil stabilization techniques," *researchgate.net*, Accessed: May 05, 2022. [Online]. Available: https://www.researchgate.net/profile/Habiba-Afrin/publication/326417250_A_Review_on_Different_Types_Soil_Stabilization_Techniques/links/60177f20299bf1b33e3d47af/A-Review-on-Different-Types-Soil-Stabilization-Techniques.pdf

[18] C. C. Ikeagwuani, "Comparative Assessment of the Stabilization of Lime-Stabilized Lateritic Soil as Subbase Material Using Coconut Shell Ash and Coconut Husk Ash," *Geotech. Geol. Eng.*, vol. 37, no. 4, pp. 3065–3076, Aug. 2019, doi: 10.1007/S10706-019-00825-0.

[19] M. Kavya Dharsini, K. Akalya, P. S. Ragul, K. Sathyaseelan, N. Narayanan, and S. Kumar, "Enhancement of soil properties using bottom ash, fly ash and coconut ash-An application of waste to wealth," *iopscience.iop.org*, doi: 10.1088/1757-899X/955/1/012090.

[20] B. Soundara, … S. S.-G. E. J. S., and undefined 2020, "Laboratory study on natural fibre amended fly ash as an expansive soil stabilizer," *academia.edu*, Accessed: May 05, 2022. [Online]. Available: https://www.academia.edu/download/67839194/Pages_from_Paper_ID_22_FIN.pdf

[21] S. Prasanna, P. K.-J. of C. E. and, and undefined 2017, "Soil reinforcement using coconut shell ash: a case study of Indian soil," *xpublication.com*, Accessed: May 05, 2022. [Online]. Available: http://xpublication.com/index.php/jcec/article/view/37

[22] J. Prabakar, N. Dendorkar, R. M.-C. and Building, and undefined 2004, "Influence of fly ash on strength behavior of typical soils," *Elsevier*, Accessed: May 05, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0950061803001399

[23] H. Danso, D. M.-C. S. in C. Materials, and undefined 2020, "Influence of coconut fibres and lime on the properties of soil-cement mortar," *Elsevier*, Accessed: May 05, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2214509519304188

[24] W. Isah, R. S.-J. of B. and Applied, and undefined 2015, "Soil stabilization using calcium carbide resiude and coconut shell ash," *researchgate.net*, Accessed: May 05, 2022. [Online]. Available: https://www.researchgate.net/profile/Balarabe-Isah-2/publication/328738928_Soil_Stabilization_Using_Calcium_Carbide_Residue_and_Coconut_Shell_Ash/links/5be0232b299bf1124fbbe392/Soil-Stabilization-Using-Calcium-Carbide-Residue-and-Coconut-Shell-Ash.pdf

[25] V. Kumar, … J. V.-J. O. E. and S. (IJES), and undefined 2014, "Application of Coconut Coir and Fly ash in Sub grade strengthening," *academia.edu*, Accessed: May 05, 2022. [Online]. Available: https://www.academia.edu/download/36989371/H031203048054.pdf