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Optimizing Subgrade Soil Stability through Cow Dung Ash and Rice Husk Ash Incorporation

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ABSTRACT

The stability and load-bearing capacity of subgrade soils play a crucial role in the construction and maintenance of transportation infrastructure. In many regions, subgrade soils exhibit poor engineering properties, leading to detrimental effects such as excessive settlement, differential settlement, and pavement distress. Consequently, there is a pressing need to develop cost-effective and environmentally friendly solutions to enhance the stability of subgrade soils. This research investigates the feasibility of utilizing agricultural waste materials, namely cow dung ash (CDA) and rice husk ash (RHA), as soil stabilizers to improve the mechanical properties of subgrade soils. CDA and RHA are abundant byproducts in many agricultural communities and have the potential to be utilized as sustainable alternatives to traditional stabilizers. The experimental program involved characterizing the physical and geotechnical properties of the subgrade soil, CDA, and RHA. Various proportions of CDA and RHA were mixed with the subgrade soil to create stabilized soil mixtures. Tests were conducted to evaluate the effects of the additives on the compaction characteristics, California Bearing Ratio (CBR), and unconfined compressive strength (UCS) of the stabilized soils. Preliminary results indicated that the addition of CDA and RHA led to significant improvements in the engineering properties of the subgrade soil. The CBR values and UCS of the stabilized soils increased with increasing proportions of CDA and RHA, demonstrating enhanced load-bearing capacity and resistance to deformation. The improvements were attributed to the pozzolanic properties of CDA and RHA, which facilitated cementitious reactions and the formation of stable soil-aggregate bonds.

INTRODUCTION

The stability and performance of subgrade soils are critical factors in the design, construction, and maintenance of transportation infrastructure. Subgrade soils, which form the foundation for roadways and other structures, often exhibit poor engineering properties, including low strength, high compressibility, and susceptibility to moisture-induced changes. These unfavorable characteristics can result in excessive settlement, differential settlement, and pavement distress, leading to increased maintenance costs and reduced service life of the infrastructure. Therefore, finding sustainable and cost-effective solutions to enhance the stability and load-bearing capacity of subgrade soils is of paramount importance.

In recent years, there has been a growing interest in utilizing agricultural waste materials for various applications, including soil stabilization. Agricultural waste materials, such as cow dung ash (CDA) and rice husk ash (RHA), are abundantly available byproducts in many agricultural communities. The utilization of these waste materials not only helps in waste management but also presents an opportunity to improve the engineering properties of subgrade soils in an environmentally friendly manner.

Cow dung ash is obtained from the burning of cow dung, which is a common agricultural waste in many parts of the world. Rice husk ash, on the other hand, is a byproduct of rice milling operations and is generated in large quantities. Both CDA and RHA possess certain desirable properties that make them potential soil stabilizers. For instance, CDA contains silica, alumina, and lime, which can contribute to the pozzolanic reactions and improve the strength and durability of soil. RHA is rich in amorphous silica, which can enhance the binding properties of soil particles.

Several studies have investigated the use of CDA and RHA in various construction applications, including concrete production, brick making, and soil stabilization. However, limited research has focused specifically on their effectiveness in subgrade soil stabilization. Therefore, this study aims to fill this research gap by exploring the feasibility and potential benefits of utilizing CDA and RHA as soil stabilizers for subgrade soils.

The objectives of this research are to evaluate the effects of CDA and RHA on the engineering properties of subgrade soils, including compaction characteristics, California Bearing Ratio (CBR), and unconfined compressive strength (UCS). The study will involve laboratory testing and analysis of various mixtures of subgrade soil, CDA, and RHA to determine the optimum proportions for achieving improved soil stability.

By harnessing the potential of agricultural waste materials as soil stabilizers, this research has the potential to offer multiple advantages. It can provide a sustainable and eco-friendly alternative to traditional stabilizers, such as cement and lime, which have significant environmental impacts and require substantial energy consumption for production. Furthermore, utilizing CDA and RHA can contribute to waste reduction and promote the circular economy by repurposing agricultural byproducts that would otherwise be discarded. This study aims to investigate the potential of cow dung ash and rice husk ash as soil stabilizers for enhancing subgrade soil stability. By examining their effects on key engineering properties, this research seeks to provide valuable insights into sustainable soil stabilization techniques and contribute to the utilization of agricultural waste materials in infrastructure development.

SCOPE OF THE RESEARCH

The scope of this research encompasses the investigation of cow dung ash (CDA) and rice husk ash (RHA) as soil stabilizers for enhancing the stability and load-bearing capacity of subgrade soils. The research will focus on the following aspects:

Characterization of Materials: The physical and geotechnical properties of the subgrade soil, CDA, and RHA will be characterized through laboratory testing. This includes analyzing properties such as grain size distribution, Atterberg limits, specific gravity, compaction characteristics, and mineral composition.

Mixing Proportions: Various proportions of CDA and RHA will be mixed with the subgrade soil to create stabilized soil mixtures. The study will investigate different combinations and ratios to determine the optimal mixing proportions for achieving improved soil stability.

Laboratory Testing: The stabilized soil mixtures will undergo a series of laboratory tests to evaluate their engineering properties. These tests may include compaction tests, California Bearing Ratio (CBR) tests, and unconfined compressive strength (UCS) tests. The results will be compared with those of the untreated subgrade soil to assess the effectiveness of CDA and RHA as soil stabilizers.

Analysis and Interpretation of Results: The data obtained from the laboratory tests will be analyzed and interpreted to assess the effects of CDA and RHA on the mechanical properties of the stabilized soils. The improvements in CBR values, UCS, and other relevant parameters will be evaluated to determine the extent of soil stabilization achieved.

Environmental Considerations: The research will also consider the environmental aspects associated with the utilization of CDA and RHA as soil stabilizers. This includes assessing the environmental benefits of using agricultural waste materials compared to traditional stabilizers and evaluating their sustainability and impact on carbon footprints.

Limitations: The research will acknowledge and discuss any limitations encountered during the experimental program. Factors such as variations in the properties of CDA and RHA from different sources, potential variability in subgrade soil characteristics, and limitations of laboratory testing may influence the research outcomes.

Recommendations and Future Research: Based on the findings of the study, recommendations can be made regarding the optimum proportions of CDA and RHA for subgrade soil stabilization. Additionally, suggestions for further research directions, including long-term durability testing under field conditions and the feasibility of incorporating other additives or techniques, may be provided.

It is important to note that this research focuses specifically on the use of CDA and RHA as soil stabilizers for subgrade soils. The study does not encompass other soil stabilization methods or alternative materials. The scope of the research is limited to laboratory testing and analysis, and the findings may provide a foundation for future field studies and practical applications in the field of geotechnical engineering.

Application of Rice husk Ash

Rice husk ash (RHA) is a byproduct of rice milling operations and has gained attention as a valuable material in various applications. Its unique properties make it suitable for diverse fields, including construction, agriculture, and environmental remediation. Some notable applications of RHA are as follows:

Concrete and Cementitious Materials: RHA is widely used as a partial replacement for cement in concrete production. Due to its high silica content, RHA exhibits pozzolanic properties, which contribute to the formation of additional cementitious compounds. This leads to improved strength, durability, and reduced permeability of concrete. RHA can also be utilized in the production of cementitious composites, such as cement boards and bricks.

Soil Stabilization: RHA has shown promising results as a soil stabilizer. When mixed with soils, it enhances their engineering properties, such as strength, stability, and permeability. The pozzolanic reactions of RHA contribute to the formation of stable soil-aggregate bonds, reducing soil compressibility and increasing load-bearing capacity. This makes RHA an effective and sustainable option for stabilizing subgrade soils and improving the performance of transportation infrastructure.

Waste Water Treatment: The high silica content and surface area of RHA make it suitable for adsorption and filtration applications. It can effectively remove heavy metals, organic pollutants, and dyes from wastewater due to its adsorption capacity. RHA has also been used as a filter medium in constructed wetlands for water treatment, aiding in the removal of pollutants and improving water quality.

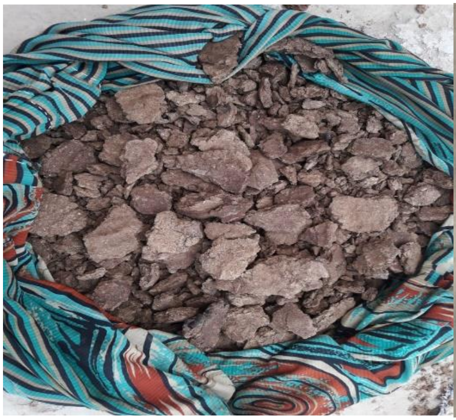
Agriculture and Horticulture: RHA can be beneficial in agriculture and horticulture practices. It serves as a source of silicon, which plays a vital role in plant nutrition and disease resistance. The application of RHA to soil can enhance nutrient availability, improve water retention, and regulate pH levels. RHA has also been used as a substrate for plant growth in hydroponic systems and as an additive to organic fertilizers.

Environmental Remediation: RHA has been explored for its potential in environmental remediation. It can be utilized in the treatment of contaminated soils and sediments, aiding in the immobilization and stabilization of heavy metals and organic pollutants. RHA has also been investigated for its use in the remediation of contaminated water bodies, such as lakes and rivers, by reducing nutrient loading and improving water quality.

The above applications demonstrate the versatility and potential of rice husk ash across various sectors. Its utilization not only provides economic and environmental benefits but also promotes sustainable practices by repurposing a waste material that would otherwise be disposed of. Continued research and development in utilizing RHA can further expand its applications and contribute to a more sustainable future.

Material Selection and Methodology

Cow dung ash is a byproduct that is derived from burning cow dung, which is the solid waste of cows. It has been used for centuries in various cultures as a natural resource with diverse applications. This organic substance, rich in nutrients, offers numerous benefits across different domains. One primary application of cow dung ash is in agriculture. Farmers have long recognized its potential as a natural fertilizer. The ash contains essential nutrients like nitrogen, phosphorus, and potassium, which are crucial for plant growth. When mixed with soil, it enhances its fertility, promoting healthier crops and increased yields. Additionally, cow dung ash acts as a natural pesticide, warding off pests and insects that can harm plants. Apart from agriculture, cow dung ash also finds its use in traditional medicine. Its antimicrobial and antifungal properties make it a valuable ingredient in herbal remedies. It is believed to possess healing properties and is used in treating various ailments, including skin disorders, digestive issues, and respiratory problems. The ash is often incorporated into medicinal pastes, powders, or decoctions. cow dung ash has cultural and religious significance in many societies. In some traditions, it is considered sacred and used during religious ceremonies and rituals. The ash is applied on the forehead as a mark of devotion or used to purify the surroundings. Its presence symbolizes fertility, purity, and prosperity, connecting humans with nature and spirituality.



(a) (b)

(c)

Figure 1: Process of cow dung ash (a) Cow dung (b) Burning process of cow dung (c) Cow dung ash

Uses of Rice Husk Ash as a stabilizer

Rice husk ash (RHA) is a byproduct obtained from the burning of rice husks, the protective outer layer of rice grains. It is a versatile material that has gained significant attention in various industries due to its stabilizing properties. RHA can be effectively utilized as a stabilizer in different applications, offering numerous benefits and sustainable solutions.

As a stabilizer, RHA has found wide application in the construction industry. When mixed with soil, it acts as a stabilizing agent, enhancing the soil's engineering properties and improving its load-bearing capacity. This makes it an ideal choice for road construction, embankments, and foundation works. The fine particles in RHA fill the gaps between soil particles, resulting in improved compaction and reduced settlement. This not only strengthens the structure but also increases its durability and resistance to erosion.

Moreover, RHA has been extensively studied as an additive in the manufacturing of concrete and other building materials. Its pozzolanic nature allows it to react with calcium hydroxide, a byproduct of cement hydration, forming additional cementitious compounds. This results in improved strength, reduced permeability, and enhanced durability of the concrete. The incorporation of RHA also helps in reducing the amount of cement required, leading to cost savings and a more sustainable construction practice.

In addition to its applications in the construction industry, RHA has also shown promise in the stabilization of waste materials, such as mine tailings and industrial sludge. Its binding properties enable the encapsulation of harmful contaminants, preventing their release into the environment and mitigating potential ecological risks.

Properties of RHA

Rice husk ash (RHA) possesses several unique properties that make it a valuable material in various applications. These properties contribute to its effectiveness as a stabilizer and its versatility in different industries.

One prominent property of RHA is its high silica content. Rice husks consist of approximately 90% silica, which is converted into amorphous silica during the burning process. This amorphous silica provides RHA with excellent pozzolanic properties. When RHA is mixed with calcium hydroxide, a byproduct of cement hydration, it undergoes a chemical reaction and forms additional cementitious compounds. This reaction contributes to the strength and durability of concrete and other construction materials. Another important property of RHA is its fine particle size. The ash particles are typically smaller than cement particles, which allows for better packing and filling of voids within the material matrix. The fine particles also contribute to improved compaction and reduced settlement when RHA is used as a stabilizing agent in soil. This property enhances the load-bearing capacity of soil and makes it suitable for construction purposes. Additionally, RHA exhibits good thermal insulation properties. Its low thermal conductivity makes it an effective insulating material, reducing heat transfer in applications such as refractory linings, insulation boards, and thermal barriers. RHA has a high pozzolanic reactivity, which means it reacts readily with calcium hydroxide and forms cementitious compounds at ambient temperature. This property makes it a valuable additive in the production of sustainable and low-carbon concrete, reducing the need for cement and lowering carbon emissions.

Physical properties

Rice husk ash (RHA) is a highly porous, fine-grained polymer, consisting of particles with sizes ranging from 5 to 75 microns [4]. Several physical characteristics of RHA have been identified by researchers, and these are summarized in Table 1 below.

Table1: Physical Properties of rice husk ash

Physical Properties	%	value
Mean Particle Size	-----	63.8µm
Specific Gravity	2.06	2.11
Fineness Passing45µm	99%	98%

With an annual production of 20 million tonnes of rice husk ash (RHA), India has emerged as the second-largest global producer of RHA. However, this substantial production has led to a significant environmental concern in recent years. When rice husks are burned under controlled temperatures, SiO2, primarily in its amorphous form, is generated as a byproduct. The high concentration of silica in RHA, along with its pozzolanic activity, makes it a valuable resource that can be utilized in multiple applications. One such application is the use of RHA as a source material in Geopolymer concrete. Geopolymer technology relies on the reaction between alumina silicate materials and alkaline solutions to form a binder with cement-like properties. RHA, with its high silica content, serves as an excellent precursor material for geopolymerization reactions, resulting in durable and environmentally friendly concrete structures.

Table 2:Rice husk ash properties produced from different burning conditions.

<table>
<tr><th rowspan="2">Burning Temperature</th><th rowspan="2">Hold Time</th><th rowspan="2">Furnace Environment</th><th colspan="2">Properties of Rice Husk Ash</th></tr>
<tr><th>Silica Form</th><th>Surface Area (m^2/g)</th></tr>
<tr><td rowspan="3">500-600ºC</td><td>1min</td><td rowspan="4">Moderately Oxidising</td><td rowspan="4">Amorphous</td><td>122</td></tr>
<tr><td>30min</td><td>97</td></tr>
<tr><td>2hr</td><td>76</td></tr>
<tr><td rowspan="2">700-800ºC</td><td>15min-1hr</td><td>100</td></tr>
<tr><td>>1hr</td><td rowspan="2">Highly Oxidizing</td><td>Partially crystalline</td><td>6-10</td></tr>
<tr><td>>800ºC</td><td>>1hr</td><td>Crystalline</td><td><5</td></tr>
</table>

Chemical Properties

The majority of the amorphous silica present in rice husk ash (RHA) is derived from the husk itself, which consists of approximately 50% cellulose, 25%–30% lignin, and 15%–20% silica When rice husks undergo oxidation, RHA is formed, and it typically contains a high silica content, ranging from 85% to 90%. Various publications have reported the chemical compositions of RHA, and these are summarized in Table 3 below.

Table 3: The chemical composition of RHA(by%0fWt.)

SiO_2	AL_2O3	Fe_2O_3	CaO	MgO	SO3	Na_2O	K_2O	LOI *
86.81	0.50	0.87	1.04	0.85	----	0.69	3.16	4.60
91.00	0.35	0.41	----	0.81	1.21	0.08	3.21	8.50
95.04	0.30	0.44	1.25	0.45	0.01	0.09	1.04	0.51
90.90	0.83	0.60	0.80	0.56	----	1.55		----
87.40	0.40	0.30	0.90	0.60	0.40	0.04		3.39
87.32	0.22	0.28	0.48	0.28	----	1.02	3.14	4.60

(LOI*-Loss on Ignition)

Results and Discussion

Physical and chemical properties of the rice husk ash and cow dung ash

Table 4: Properties of the natural soil before stabilization

Characteristics	Description
Natural Moisture Content (%)	22.7
Percent passing B.S Sieve NO 200	77
Liquid Limit (%)	49.5
Plastic Limit (%)	24.4
Plasticity Index (%)	25.1
Group Index	20
AASHTO Classification	A-7-6
Maximum Dry Density (Mg/m3)	1.482
Optimum Moisture Content (%)	18.38
Unconfined Compressive Strength (kN/m^2)	290
California Bearing Ratio (%) Unsoaked Soaked	8.5
Specific Gravity	2.69
Colour	Reddish-brown

Table 5 : Physical properties of cow dung ash (CDA) and rice husk ash (RHA).

S. No.	Property	Test result	
1	**Colour**	**CDA**	**RHA**
2	Specific gravity	Grey	Grey
3	Liquid limit	1.765	1.89
4	Plastic limit	42.85	44.3
5	Optimum moisture content(%)	Non-plastic	Non-plastic
6	Maximum dry density(gm/cm^3)	41.25	43.56

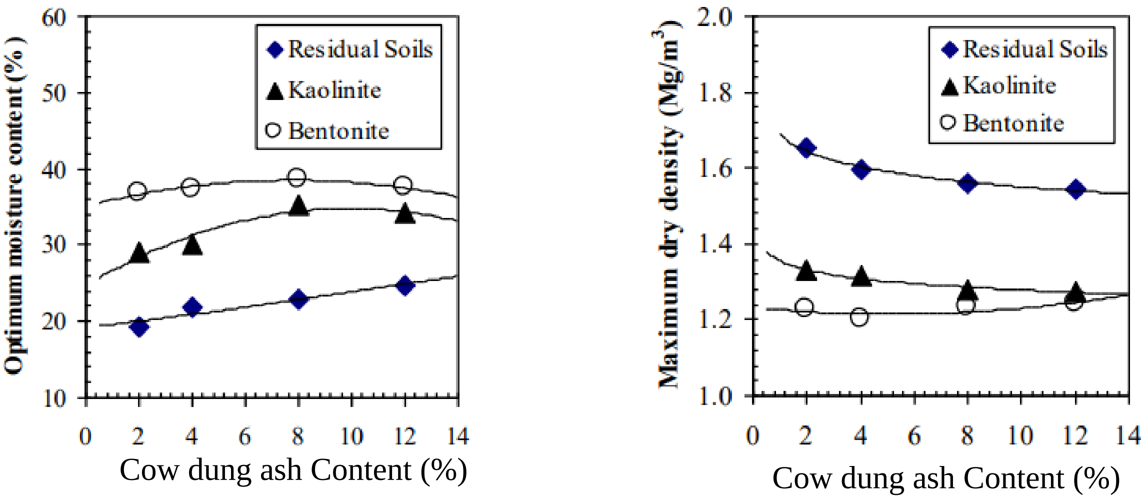


Figure 2: Variation of Compaction Characteristics of The Soils With rice husk ash

CONCLUSION

In conclusion, both cow dung ash and rice husk ash offer promising solutions for enhancing subgrade soil stability in construction projects. These organic materials possess unique properties that contribute to improved soil characteristics and increased load-bearing capacity. Cow dung ash, rich in nutrients and acting as a natural fertilizer, can enhance soil fertility and promote healthier plant growth. Its antimicrobial properties also help control pests and insects, ensuring the long-term stability of the subgrade soil. Additionally, cow dung ash holds cultural and religious significance, connecting humans with nature and spirituality in construction practices. On the other hand, rice husk ash, with its high silica content and pozzolanic activity, can serve as a stabilizing agent in subgrade soil. It enhances soil compaction, reduces settlement, and improves the soil's engineering properties. Moreover, rice husk ash can be utilized as a sustainable additive in the production of concrete, strengthening the overall structure and reducing the environmental impact. By incorporating cow dung ash and rice husk ash into construction practices, subgrade soil stability can be significantly enhanced, leading to improved infrastructure durability and performance. These organic materials offer environmentally friendly alternatives, minimizing the reliance on synthetic stabilizers and promoting sustainable development. However, it is important to note that proper testing, analysis, and engineering considerations should be undertaken to determine the appropriate ratios and application methods for optimal results. Further research and field studies are also necessary to explore the long-term effects and practical implementation of cow dung ash and rice husk ash in subgrade soil stabilization.

FUTURE WORK

In the realm of enhancing subgrade soil stability, there are several areas of future work that hold promise for further exploration and development of cow dung ash and rice husk ash as stabilizing agents. These areas of focus can contribute to advancing knowledge and improving the practical application of these organic materials in construction projects.

Performance assessment: Conducting long-term field studies and performance evaluations of subgrade soil stabilized with cow dung ash and rice husk ash will provide valuable insights into their effectiveness and durability. Monitoring factors such as load-bearing capacity, settlement, erosion resistance, and moisture control over an extended period will help validate their long-term stability and performance.

Optimal dosage and mixture design: Further research is needed to determine the optimal dosage and mixture design of cow dung ash and rice husk ash for different soil types and environmental conditions.

Investigating the effects of varying ash-to-soil ratios, curing time, and compaction methods will help establish guidelines and standards for achieving the desired soil stabilization outcomes.

Compatibility with other additives: Exploring the compatibility of cow dung ash and rice husk ash with other stabilizing additives, such as lime, cement, or chemical stabilizers, can open up possibilities for synergistic effects and improved performance. Investigating the combination of these materials and studying their compatibility, reactivity, and potential benefits will expand the range of soil stabilization options.

Environmental impact assessment: Assessing the environmental impact of utilizing cow dung ash and rice husk ash for subgrade soil stabilization is crucial. Conducting comprehensive studies on their effects on soil quality, water resources, and surrounding ecosystems will ensure that their usage aligns with sustainability goals and regulatory requirements.

Standardization and guidelines: Developing standardized testing methods, guidelines, and specifications specific to cow dung ash and rice husk ash stabilization techniques will promote consistent and reliable application. Establishing industry-wide protocols for testing, design, and construction practices will facilitate the adoption of these organic materials in mainstream engineering practices.

By addressing these future research areas, the potential benefits and practical implementation of cow dung ash and rice husk ash in subgrade soil stabilization can be further realized. This ongoing work will contribute to the advancement of sustainable construction practices, enhanced infrastructure durability, and the preservation of natural resources.

REFERENCES

Duong, N. T. (2022). effect of rice husk ash on unconfined compressive strength of soil-cement admixture. Suranaree Journal of Science & Technology, 29(1).

Amakye, S. Y., & Abbey, S. J. (2021). Understanding the performance of expansive subgrade materials treated with non-traditional stabilisers: A review. Cleaner Engineering and Technology, 4, 100159.

Jaffar, S. T. A., Muneeb Abid, M., Khan, S. Z., Jafri, T., Rehman, Z. U., Tariq, M. A. U. R., & Ng, A. W. (2022). Evaluation of conventional and sustainable modifiers to improve the stiffness behavior of weak sub-grade soil. Sustainability, 14(5), 2493.

Adetayo, O. A., Umego, O. M., Faluyi, F., Odetoye, A. O., Bucknor, A. O., Busari, A. A., & Sanni, A. (2022). Evaluation of pulverized cow bone ash and waste glass powder on the geotechnical properties of tropical laterite. Silicon, 14(5), 2097-2106.

Harisha Deepthi, J., & Satish, S. (2022, May). Possible Utilization of Expansive Soil Incorporated with Bagasse Ash and Bagasse Fibre. In Recent Advances in Civil Engineering: Proceedings of the 2nd International Conference on Sustainable Construction Technologies and Advancements in Civil Engineering (ScTACE 2021) (pp. 263-276). Singapore: Springer Nature Singapore.

Zhu, X., Li, L., Tian, B., Zhang, P., & Wang, J. (2023). Synergistic Effect of Yak Dung Fiber and Yak Dung Ash on the Mechanical and Shrinkage Properties of Cement Mortar. Materials, 16(2), 719.

Elemile, O. O., Ibitogbe, E. M., Aladegboye, O. J., Ejigboye, P. O., & Olajide, S. O. (2022). Effects of Gliricidia sepium ash for stabilization of abattoir polluted soils. Materials Today: Proceedings, 65, 2228-2235.

Vincevica-Gaile, Z., Teppand, T., Kriipsalu, M., Krievans, M., Jani, Y., Klavins, M., & Burlakovs, J. (2021). Towards sustainable soil stabilization in peatlands: Secondary raw materials as an alternative. Sustainability, 13(12), 6726.

Elbaz, A. A., Aboulfotoh, A. M., Dohdoh, A. M., & Wahba, A. M. (2019). Review of beneficial uses of cement kiln dust (CKD), fly ash (FA) and their mixture. J. Mater. Environ. Sci, 10(11), 1062-1073.