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Experimental Evaluation of Determining Optimum Dosage of Biochar to Clay Liners in Muncipal Solid Waste Landfill

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Abstract

The effectiveness of landfill liners is critical for preventing leachate migration and protecting groundwater in municipal solid waste (MSW) landfills. This study experimentally investigates the optimum dosage of biochar(Biochar is a carbon-rich material produced by the pyrolysis of organic biomass in a low-oxygen environment) as an additive to clay liners to enhance their hydraulic and contaminant retention properties. Clay-biochar mixtures were prepared with varying biochar contents and subjected to standard laboratory tests, including compaction, permeability, specific gravity, Freeswell index, Atterberg's limits. Results revealed that incorporating biochar reduced hydraulic conductivity and significantly improved the adsorption of heavy metals and organic contaminants. The optimal performance was observed at which biochar content, achieving the lowest permeability while maximizing contaminant retention without compromising the liner's structural integrity.These findings suggest that incorporating biochar at optimized levels can enhance landfill liner performance, contributing to more sustainable waste management practices.

Keywords: Biochar, Contaminant retention, Structural integrity, Pyrolsis, Lechate.

1. INTRODUCTION

Municipal Solid Waste (MSW) landfills play a critical role in waste management by providing a designated space for waste disposal. However, one of the biggest environmental concerns associated with landfills is the generation of leachate—a liquid that forms as waste decomposes and water percolates through it. If not properly managed, leachate can seep into the surrounding soil and groundwater, leading to severe environmental contamination. To mitigate this risk, landfills are equipped with engineered barriers known as liners. These liners, commonly made of compacted clay, act as protective barriers that prevent leachate from escaping into the environment. However, traditional clay liners have certain limitations, such as shrinkage, cracking, and limited adsorption capacity for contaminants. Recent research has explored the use of biochar as an additive to improve the performance of clay liners. Biochar is a carbon-rich material produced through the pyrolysis of organic biomass under limited oxygen conditions. Due to its highly porous structure and excellent adsorption properties, biochar has shown potential in enhancing the permeability, chemical resistance, and contaminant adsorption capacity of clay liners. However, determining the optimal dosage of biochar in clay liners is crucial to ensure that the material retains its essential barrier properties while maximizing its environmental benefits. This study aims to experimentally evaluate the optimum dosage of biochar to be incorporated into clay liners for municipal solid waste landfills. By systematically varying biochar content and assessing key parameters such as permeability, strength, shrinkage, and leachate adsorption efficiency, this research will identify the most effective biochar-clay composition for landfill applications. The findings will help optimize landfill liner design, improve leachate containment, and contribute to sustainable waste management practices.

2. METHODOLOGY

2.1 Preparation of Sample Clay

Preparation of Sample Clay: Upon collection, samples undergo careful preparation to ensure uniformity and accuracy in subsequent tests. This involves air-drying to remove excess moisture, followed by meticulous grinding or sieving to break down clumps and ensure homogeneity. Proper sample preparation is crucial for obtaining reliable test resultsthat reflect the true properties of the soil.

2.2 Testing of Sample for Various Properties

2.2.1Specfic gravity test

This test measures the density of soil particles relative to water.It involves weighing a known volume of soil sample and comparing it to the weight of an equal volume of water. The ratio of these weights provides the specificgravity of the soil.

2.2.2 Liquid Limit Test

This test determines the moisture content at which the soiltransitions from a plastic to a liquid state. A precise amount of water is incrementallyadded to the soil sample while it's mixed to maintain consistency. The penetration depth of a standardized cone into the soil is measured at each water addition until thesoil begins to flow. This establishes the liquid limit of the soil.

2.2.3 Plastic Limit Test

To determine the plastic limit, the soil sample is gradually kneadedwith water until it reaches a plastic state. The soil is then rolled into threads of uniformdiameter, and the moisture content at which these threads start to crumble defines theplastic limit.

2.2.4 Free Swell Index Test

The free swell index indicates the potential volume increase ofthe soil when exposed to water. The soil sample is saturated with water, and its volumeis measured at regular intervals to determine the extent of swelling over time.

2.2.5 Permeability Test

This test evaluates the soil's ability to transmit water and assesses its drainage characteristics. A constant head of water is applied to the soil sample, andthe rate of water flow through the sample is measured over time. This provides valuable insights into the soil's hydraulic conductivity.

2.2.6 Unconfined compression strength test

The Unconfined Compressive Strength (UCC) test is used to assess the strength and stability of soil or composites treated with biochar. It involves applying axial load to a cylindrical specimen without lateral confinement until failure. By testing different biochar dosages, the optimal amount is identified as the one that maximizes compressive strength while maintaining workability and durability. This helps determine the most effective biochar concentration for soil stabilization and structural enhancement.

2.3 Testing Sample in Different Biochar Dosages

The clay samples are then mixed with varying dosages of biochar to investigate the effects of biochar addition on soil properties.Different biochar concentrations are carefully selected to assess their impact on soil characteristics such as strength, plasticity, permeability, free swell index, and specific gravity.

2.4 Comparing the Properties

Following testing, the results are meticulously analyzed and compared. This comparative analysis allows for the identification of any changes or improvements in soil properties induced by biochar addition. It serves to elucidate the effectiveness of biochar as a soil amendment and informs decisions regarding its optimal application.

2.5 Finding Optimum Dosage

Based on the comparison of properties, the optimum dosage of biochar is determined. This dosage represents the concentration at which the soil exhibits the most desirable characteristics, such as enhanced strength, reduced plasticity,improved permeability, minimized free swell index, and optimized specific gravity. Finding the optimum dosage is crucial for maximizing the benefits of biochar while minimizing costs and environmental impact.

3. Properties of clay

Table 3.1 properties of clay

Properties	Standard clay sample	10% Biochar added clay	20% Biochar added clay	30% Biochar added clay
Specific gravity	2.76	2.732	2.714	2.705
Liquid limit(%)	45%	56%	60%	53%
Plastic limit(%)	22.09%	22.103%	24.21%	23.022%
Free swell index(%)	25%	34%	37%	35%
Optimum moisture content (%)	20%	22%	25%	24%
Permeability(m/s)	4.8*10^-6	4.03*10^-06	3.58*10^0-6	3.76*10^0-6
Unconfined compression test(kg/cm^2)	0.3358	0.3291	0.2879	0.2971

- Specific Gravity: Decreases with increasing biochar content, likely due to the lower density of biochar compared to clay.
- Liquid Limit increases up to 20% biochar (60%) but drops at 30% (53%), indicating biochar initially enhances water retention before reaching a saturation effect.
- Plastic Limit follows a similar trend, increasing with biochar addition.
- Free Swell Index rises with biochar content, peaking at 20% (37%) before slightly reducing at 30% (35%), showing increased expansiveness.
- Optimum Moisture Content (OMC) increases, meaning higher water demand for compaction.

- Permeability decreases, suggesting improved soil stability and reduced water movement.

4. CONCLUSION

The utilization of biochar in clay liners presents a viable solution to reduce the permeability of clay.Based on the analysis conducted in this report, the integration of biochar into clay demonstrates a significant potential for enhancing soil properties. Through a series of tests including specific gravity, liquid limit (LL), plastic limit (PL), and free swell index, the impact of biochar incorporation on clay characteristics was observed. It was evident that the addition of biochar resulted in notable alterations in theproperties of clay, with a marked reduction in permeability observed across varying percentages of biochar content. Particularly, at a dosage of 20% biochar, a substantial decrease in permeability by 25.4% was recorded, indicating an optimal threshold for biochar application in improving soil hydraulic conductivity. This finding underscores the critical importance of dosage optimization in achieving desired soil enhancement outcomes.Beginning with the collection of clay samples, this project embarked on a thorough investigation into the potential benefits of biochar integration for soil improvement. Theinitial phase involved conducting a series of tests, including specific gravity, liquid limit(LL), plastic limit (PL), and free swell index, to characterize the properties of the clay. Subsequently, varying percentages (10%, 20%, and 30%) of biochar were added to the clay samples, and the same tests were repeated to observe any changes induced by the biochar amendment. Following the characterization phase, permeability tests were conducted on both the untreated clay sample and the clay samples amended with 10%, 20%, and 30% biochar. Remarkably, a consistent decrease in permeability was observed across the biochar-amended samples, with the most significant reduction recorded at the 20% biochar dosage, resulting in a 25.4% decrease in permeability. This critical finding suggests an optimal dosage of 20% biochar for enhancing soil hydraulic conductivity.

In conclusion, this project highlights the transformative potential of biochar integration for soil improvement, as evidenced by the observed changes in clay characteristics and permeability. By systematically evaluating the impact of biochar dosage on soil properties, this study provides valuable insights for optimizing biochar application in sustainable soil management practices.

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