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Development of Landfill Liner Material Using Recycled Concrete Aggregate

Ms. Hridya P
Assistant Professor
Department Of Civil Engineering
Vimal Jyothi Engineering College
Chemperi, Kannur (District), Kerala, India

Athulraj KP, Christy Jose, Felix Sabi, Gopika Gangadharan, UG student, Vimal Jyothi Engineering College Chemperi (Autonomous) Kannur (District), Kerala, India

***Abstract*—Landfills are crucial components of waste management systems, necessitating effective liner materials to mitigate environmental contamination risks. This project focuses on the development of an innovative landfill liner material utilizing recycled concrete aggregate (RCA) as a sustainable alternative to conventional clay-based liners. By replacing varying proportions of clay with RCA, the project aims to investigate the feasibility, mechanical properties, and environmental performance of the resulting composite material through comprehensive testing.**

This research aims to contribute to sustainable waste management practices by repurposing construction waste materials like RCA in landfill liner construction. The findings will provide insights into the feasibility and performance of RCA-clay composite liners, offering a cost-effective and environmentally friendly alternative to traditional clay liners. Additionally, the project underscores the importance of recycling and repurposing construction waste to reduce environmental impact and promote circular economy principles in the construction industry

***Keywords*—Recycled concrete Aggregate, Landfill, Clay soil**

Abbreviations**:** RCA-Recycled Concrete Aggregate, UCS-Unconfined compressive strength, EPA -Environmental Protection Agencies, MDD- Maximum dry density, OMC-Optimum moisture content

I. INTRODUCTION

The development of landfill liner materials using recycled concrete presents a sustainable solution to waste management challenges by repurposing construction waste and reducing the burden on landfills. By leveraging recycled concrete, this initiative conserves resources, minimizes environmental pollution, and promotes the principles of the circular economy. Through innovative research and collaboration, this project aims to create cost-effective and efficient landfill liners that protect the environment while aligning with global sustainability objectives...

II. OBJECTIVES

The main objective of this project is to establish the basis for the development and implementation of waste concrete aggregate recycling with the application of clay soil to make effective landfill liner material and to reduce the requirement of clay in landfill liner. Thus, make it more cost effective compared to purchasing traditional liner materials for landfill liner construction. And contribute to the long term sustainability of landfills by enhancing their structural and environmental performance.

III. SCOPE OF THE STUDY

The study aims to develop landfill liner material utilizing recycled concrete aggregate (RCA), focusing on its potential environmental and engineering benefits. Beginning with a comprehensive review of existing literature, the research will assess the suitability of RCA for landfill liner applications, considering its physical, mechanical, and chemical properties. Laboratory experiments will be conducted to characterize RCA and formulate different blends for the liners, with an emphasis on optimizing performance and durability. Subsequent testing will evaluate key parameters such as permeability, compaction properties, and resistance to degradation, comparing RCA-based liners to conventional alternatives. Environmental impact assessments and cost analyses will further elucidate the feasibility and sustainability of implementing RCA-based liners. Ultimately, the study aims to provide valuable insights for advancing sustainable waste management practices by utilizing recycled materials effectively while meeting engineering requirements and regulatory standards.

A. Methodology

The first phase of the project is planning. It includes identifying the objectives, selection of the materials and availability of the materials. Secondly, the site visit helps in collecting the data and understanding the fixation of landfill liners. Tests to be conducted for this purpose are then determined, ensuring they meet regulatory requirements.

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1. Planning

- Identify the project scope, objectives, and the type of landfill liner required.
- Assess the availability of clay and recycled concrete aggregate (RCA) materials
- Conduct a feasibility study to ensure that the project is economically & environmentally viable. .

2. Material Selection

- Clay soil has specific properties that make it well-suited for use as a landfill liner material. These properties include low permeability, high plasticity, and swelling potential
- RCA is the primary material for your project. It's essential to ensure that the recycled concrete aggregate is of high quality and free from contaminants. The source and processing of the recycled concrete are critical to its performance. Consider factors such as particle size, cleanliness, and gradation.

3. Preparation of Sample

In this project, the clay soil is replaced with different amounts of recycled concrete aggregate.

Table 1: Preparation of samples

SAMPLES	WEIGHT OF CLAY (%)	WEIGHT OF RECYCLED CONCRETE AGGREGATE (%)
Sample 1	90	10
Sample 2	80	20
Sample 3	70	30
Sample 4	60	40
Sample 5	50	50
Sample 6	40	60
Sample 7	30	70
Sample 8	20	80
Sample 9	10	90

IV. CONDUCTION OF TESTS

1. Atterberg Limit
   Determine the liquid limit, plastic limit and plasticity index of the liner.
2. Standard Proctor Test
   Evaluates the compaction characteristics of liner materials to ensure proper compaction during installation.
3. pH Test
   Determines the pH of the liner material to assess its chemical compatibility with the waste being disposed of.
4. Swelling Test
   Assesses the potential for liner materials, like clay, to swell when exposed to water.
5. Unconfined Compression Test
   Determine the strength of clay - RCA mixture. Static compaction was used to compact the samples at OMC and MDD states in accordance with relevant standards and they were stressed at 30mm/hr strain rate.
6. Permeability Test
   Determines the liner' s ability to resist the flow of liquid.

V. RESULTS AND DISCUSSIONS

1. Atterberg Limit
   Results for plastic limit, liquid limit and plasticity index is shown in table

Table 2: Results of Atterberg Limit

SAMPLE	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)
10% RCA + 90% clay	14.6	32	17.4
20% RCA + 80% clay	15.3	31	15.7
30% RCA + 70% clay	15.3	30.5	15.2
40% RCA + 60% clay	15.6	26.08	10.48
50% RCA + 50% clay	15.7	21.5	5.8
60% RCA + 40% clay	16	26	10
70% RCA + 30% clay	-	25	-

The results (table 2) show that the plastic limit is below 30% for every sample which is the standard range. Plastic limit increases with the increase of recycled concrete aggregate in the sample. When the amount of recycled concrete aggregate is more than 70%, material does not show plastic behavior.

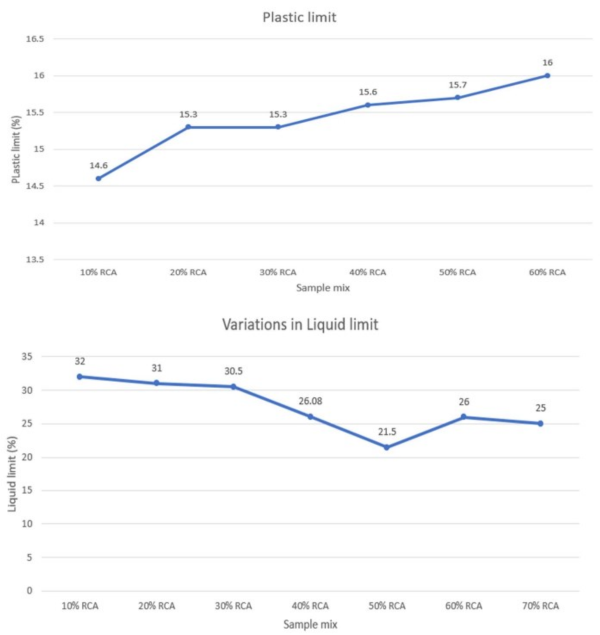

Figure 1 : Results of Atterberg Limits

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The required liquid limit according to standards is greater than 30%. Liquid limits of samples 1 (10% RCA), 2 (20% RCA) and 3 (30% RCA) are within required range (fig). Samples having RCA greater than 30% have liquid limits less than 30%. Sample 1 shows maximum liquid limit. With RCA greater than 70% shows extreme liquid behavior even when a small amount of water is added.

2. Standard Proctor Test

Results for maximum dry density & optimum moisture content of each sample are given in the table.

Table 3: Results of Standard Proctor Test

SAMPLE	MAXIMUM DRY DENSITY (g/cc)	OPTIMUM MOISTURE CONTENT (%)
10% RCA + 90% clay	1.63	17.94
20% RCA + 80% clay	1.74	13.33
30% RCA + 70% clay	1.76	15.8
40% RCA + 60% clay	1.67	22.5
50% RCA + 50% clay	1.84	14.5
60% RCA + 40% clay	1.85	14.3
70% RCA + 30% clay	1.85	16
80% RCA + 20% clay	1.79	19.2
90% RCA + 10% clay	1.79	16.27

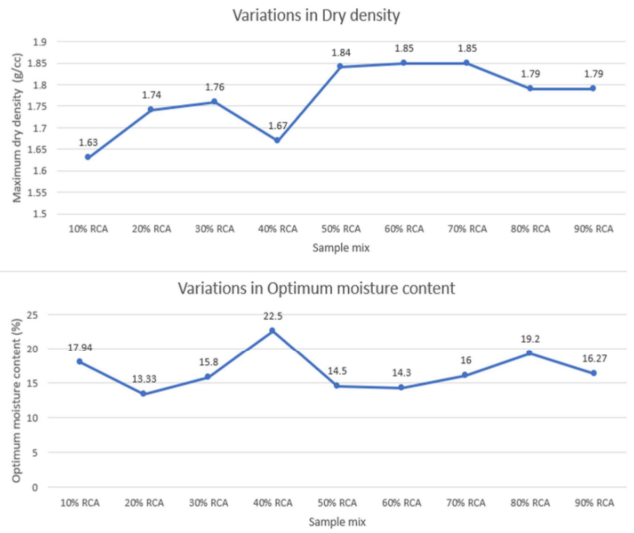

Figure 2: Results of Standard Proctor Test

All samples have required maximum dry density (>1.5g/cc). Samples with 60% and 70% RCA possess the highest maximum dry density of 1.85 g/cc (fig 2). Maximum dry density values fluctuate while increasing the amount of RCA. Sample 1 with 10% RCA shows the lowest maximum dry density value. Considering the optimum moisture content, samples 2, 5 and 6 (fig 2) do not have the required OMC. All other samples are within the range (>15%). Sample with 40% RCA has the highest optimum moisture content.

3. Swell Index

Results for swelling test of each sample is shown in table

Table 4: Results of Swell Index

SAMPLE	FREE SWELL INDEX (%)
10% RCA + 90% clay	46.66
20% RCA + 80% clay	9.09
30% RCA + 70% clay	5
40% RCA + 60% clay	0
50% RCA + 50% clay	0
60% RCA + 40% clay	0
70% RCA + 30% clay	0
80% RCA + 20% clay	0
90% RCA + 10% clay	0

Figure 3: Results of Swell index

In this experiment, only samples with 10% RCA, 20% RCA and 30% RCA undergoes swelling. Only the 1st sample is out of range. Samples having RCA greater than 30% do not undergo swelling.

4. pH Test

Results of pH for different samples are shown in figure below.

Table 5: Results of pH

Sample No.	pH meter
10%RCA + 90% CLAY	8.4
20%RCA + 80% CLAY	9.3
30%RCA +70% CLAY	8.7
40%RCA + 60% CLAY	8.68
50%RCA + 50% CLAY	9.07
60%RCA + 40% CLAY	9.17
70%RCA + 30% CLAY	9.3
80%RCA + 20% CLAY	9.7
90%RCA + 10% CLAY	9.8

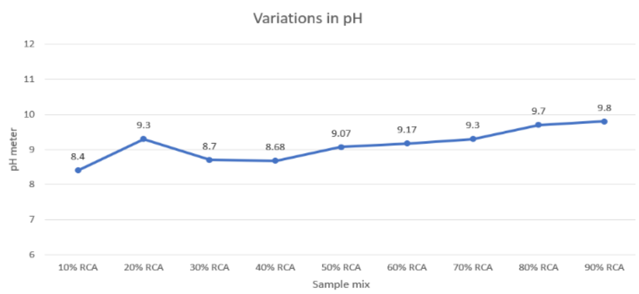

Figure 4: Results of pH test

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The pH range should be compatible with the waste chemistry, typically within the range of 6 to 8 for general landfill applications. Here the obtained values are out of the range. However, it can vary based on specific waste characteristics.

5. Unconfined Compression Test

Table 6: Results of UCC

SAMPLE	UNCONFINED COMPRESSIVE STRENGTH (kg/cm²)
10% RCA + 90% clay	0.74
20% RCA + 80% clay	1.21
30% RCA + 70% clay	1.27
40% RCA + 60% clay	2.09
50% RCA + 50% clay	1.09
60% RCA + 40% clay	0.22
70% RCA + 30% clay	0.70
80% RCA + 20% clay	1.08
90% RCA + 10% clay	0.83

Results for the unconfined Compression Test of each sample is shown in table 6.

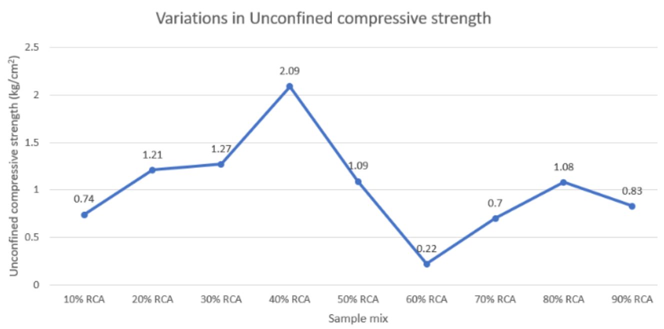

Figure 5: Results of UCC

The unconfined compressive strength of the material should be greater than 1.83kg/cm². In this experiment, only the sample with 40% RCA comes under the range.

6. Permeability test

Table 7: results of Permeability test

SAMPLE	COEFFICIENT OF PERMEABILITY (x 10^{-7} cm/s)
10% RCA + 90% clay	2.3
20% RCA + 80% clay	1.8
30% RCA + 70% clay	1.5
40% RCA + 60% clay	1.2
50% RCA + 50% clay	1.3
60% RCA + 40% clay	1.5
70% RCA + 30% clay	1.6
80% RCA + 20% clay	2.1
90% RCA + 10% clay	2.4

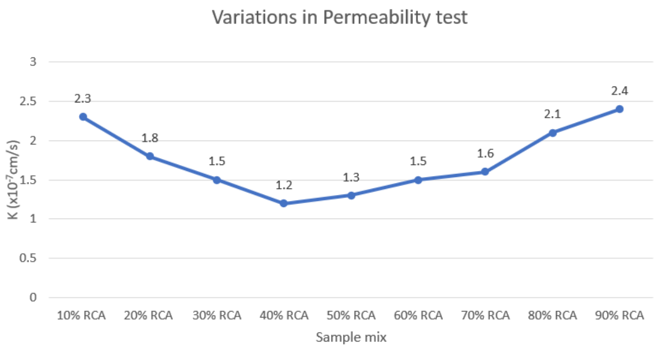

Figure 6: Results of Permeability test

Range of coefficient of permeability of landfill liner is $1x10^{-7}$ to $1x\ 10^{-9}$ cm/s. Here the values are out of the range. But permeability of 40% RCA is closer to standard range and has low permeability.

VI. CONCLUSION

The graph of test results shows a similar trend in almost 3 to 4 experiments that the samples 3, 4 and 5 have favorable properties and other samples are outliers. It might be because of adding the smaller particle sized RCA gives better compaction properties and less permeability to the samples 3, 4 and 5 and adding further RCA could reduce the amount of clay and therefore the cohesion and bonding between clay soil is minimized so the properties may become out of the range. The results of various tests that we have done conclude that only sample 3 with 30% RCA and sample 4 with 40% RCA are showing properties closer to the required range. Out of these 2 samples we concluded that sample 4 is more superior because it has less permeability than that of sample 3. Even though sample 3 has more dry density than sample 4, still sample 4 is superior in the aspects of pH value and swelling. Sample 4 has zero swell index and sample 3 has swell index 5, this clearly shows sample 4 (40% RCA) is better than the other samples.

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