A Dissertation Report On

"Evaluation of bentonite-quarry dust mix for its application in land fill liners"

Submitted in Partial Fulfillment of the Requirement for the Award of the Degree of

MASTER OF TECHNOLOGY
In

CIVIL ENGINEERING
(*With specialization in Geotechnical Engineering)*

Of

Assam Science & Technology University

Session: 2023-2025

By

MADHURJYA SARMA

Roll no : PG/C/23/07

ASTU Regd No:36170118

Under the guidance of

Prof. Malaya Chetia

Department of Civil Engineering,

Assam Engineering College,

Jalukbari, Guwahati-781013

CERTIFICATE OF SUPERVISION

This is to certify that the work presented in this report entitled **— Evaluation of bentonite-quarry dust mix for its application in land fill liners** is carried out by Madhurjya Sarma, Roll No: PG/C/23/07, a student of M.Tech 3rd semester, Department of Civil Engineering, Assam Engineering College, under my guidance and supervision and submitted in the partial fulfillment of the requirement for the award of the Degree of Master of Technology in Civil Engineering with specialization in Geotechnical Engineering under Assam Science and Technology University.

Date:

Place:

MRS. MALAYA CHETIA

Professor, Department of Civil Engineering, Assam Engineering College,

Jalukbari, Guwahati-781013

CERTIFICATE FROM HEAD OF THE DEPARTMENT

This is to certify that the work presented in this report entitled **— Evaluation of bentonite-quarry dust mix for its application in land fill liners** is carried out by Madhurjya Sarma, Roll No: PG/C/23/07, a student of M.Tech 3rd semester, Department of Civil Engineering, Assam Engineering College, under my guidance and supervision and submitted in the partial fulfillment of the requirement for the award of the Degree of Master of Technology in Civil Engineering with specialization in Geotechnical Engineering under Assam Science and Technology University.

Date :

Place :

DR. JAYANTA PATHAK

(Professor and Head of Department)

Department of Civil Engineering

Assam Engineering College

Guwahati – 781013

DECLARATION

I hereby declare that the mini project ―**Evaluation of bentonite-quarry dust mix for its application in land fill liners**‖ in partial fulfillment of the requirement for the award of the degree of ― MASTER OF TECHNOLOGY‖ in Civil Engineering (With specialization in Geotechnical Engineering), submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati-13 under Assam Science & Technology University, is a real record of the work carried out in the said college for six months under the supervision of Prof. Malaya Chetia, Associate Professor, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati-13.

Do hereby declare that this project report is solemnly done by me and is my effort and that no part of it has been plagiarized without citation.

Date : MADHURJYA SARMA

This is to certify that the above statement made by the candidate is correct to the best of my knowledge

Date:

Malaya Chetia
Professor, Department of Civil Engineering,
Assam Engineering College, Jalukbari,
Guwahati-781013

ACKNOWLEDGEMENT

I would like to express my sincere appreciation to my supervisor Prof. Malaya Chetia, Associate Professor, Department of Civil Engineering of Assam Engineering College for his extensive support and encouragement throughout the project work. I am highly indebted for his guidance and constant supervision as well as for providing necessary information regarding the project work. Working under him has indeed been a great experience and inspiration for me.

This project would not have been possible without the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

I express my gratitude to Dr. Jayanta Pathak, Professor and Head of the Department of Civil Engineering of Assam Engineering College and also to the entire fraternity of the Department of Civil Engineering of Assam Engineering College.

Date:

Place:

Madhurjya Sarma

M.Tech, 3rd Semester,

Geotechnical Engineering,

Department of Civil Engineering,

Assam Engineering College

Jalukbari, Guwahati-13

ABSTRACT

Compacted liners are required to minimize the migration of contaminants to the surrounding geoenvironment and ground water. To achieve this the hydraulic conductivity of the compacted liners has to be restricted within a permissible limit of 10^{-7}cm/sec. Also, there is a criteria that the UCS of greater than 200 Kpa is desirable for liner materials. The bentonite – sand(B-S) mixture is commonly used as a liner material in landfills. As sand is a scare material, hence it is suitable to find suitable alternatives for sand. The rock quarry dust is a waste material which can substitute sand to improve the geotechnical properties of soil. The objective of the study is to determine compaction parameters, UCS characteristics and hydraulic conductivity of Bentonite-Quarry dust (B-Q) mix when 30% bentonite is blended with 70% quarry dust.

LIST OF TABLES

LIST OF FIGURES

LIST OF CONTENT

CHAPTER 1

Introduction

1.1 Background

Disposal of waste is one of the greatest challenges to mankind for all times. With the rapid increase in urbanization, the world population is increasing, and the usage of various new commodities lead to drastic increase in the waste production. The wate generated can be categorize into Municipal Solid Waste (MSW) , Hazardous waste , Industrial waste and Construction and demolition waste . the waste management essentially comprises of collection, transport, disposal incineration of wastes . A sustainable waste management is founded on 3 Rs principle Reduce, Reuse and Recycle so that the quantity of waste to be disposed on land is reduced.

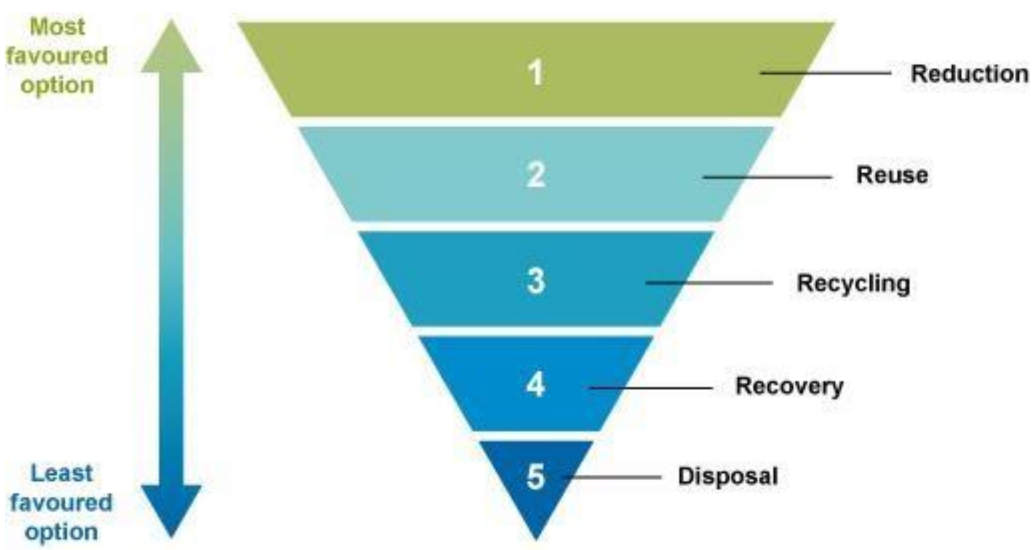

Figure 1: The waste Hierarchy

When the waste is disposed on to the land, the percolating rainwater interacts with it and produces liquid known as leachate. The leachate so produced percolates through the soil and finally reaches the groundwater. This gave way to the development of engineered waste disposal facilities known as landfills.

Open dumps and landfills are two methods of waste disposal, but they differ significantly in terms of design, environmental impact, and management practices. Below is a detailed comparison to highlight their key differences and implications.

1.1.1 Open Dumps

Open dumps are unregulated waste disposal sites where garbage is deposited without engineering controls or environmental safeguards. There are no liners, leachate management, or gas collection systems and no measures to prevent contamination of soil, air, or water.

1.1.2 Landfills

Landfills are engineered waste disposal facilities designed to safely manage and contain waste while minimizing environmental and health risks. They are a cornerstone of modern waste disposal strategies.

Table 1: Comparison between Open Dumps and Landfills.

Aspect	Open Dumps	Landfills
Design	Unregulated, no engineering controls.	. Engineered with liners and protective systems.
Environmental Impact	High pollution risk (soil, air, water).	Minimal risk with proper safeguards
Leachate Management	Leachate freely seeps into soil.	Collected and treated through systems
Gas Management	Uncontrolled gas emissions.	Gas is captured and managed for safety or energy use.

Odor Control	Strong odors persist.	Odor minimized with daily cover and management.
Health Risks	High: As it attracts pests, spreads diseases.	Low: Controlled environment reduces risks.
Cost	Little to no investment	Significant engineering and operational costs.

1.2 Containment Landfill:

A Containment landfill is a carefully designed structure for the disposal of solid waste, aimed at minimizing environmental impacts and protecting human health. It incorporates engineering principles and management practices to isolate waste from the environment and control pollution. An engineered landfill essentially consists of a barrier layer or liner which is a low permeable zone to prevent the leaching from the waste of landfill. A drainage layer is place over the liner which collects the leachate from the waste for the treatment. The third layer of the landfill is the cover to the landfill. The capacity is planned, and the site is chosen based on an environmental risk assessment study.

The components of a Containment landfill are listed below:

I. Bottom Liner System: The bottom liner acts as a barrier to prevent leachate from contaminating the soil and groundwater.

II. Leachate Collection System: Pipes and drainage layers collect and transport leachate (liquid generated by decomposing waste and water infiltration) to a treatment facility.

III. Gas Collection System: Methane and other landfill gases produced by the decomposition of organic matter are captured and either flared or used for energy production

IV. Daily Cover: A layer of soil or other material is placed over the waste daily to reduce odors, pests, and litter, and to enhance site aesthetics.

V. Monitoring Systems: Groundwater, surface water, and gas monitoring systems ensure that the landfill is operating within environmental compliance standards.

VI. Capping and Closure: Once a landfill reaches its capacity, it is capped with a final cover system, which typically includes an impermeable layer to prevent water infiltration and promote vegetation growth.

1.3 Advantages of Containment Landfill:

- Reduces groundwater contamination and air pollution compared to open dumping.
- Provides an organized and regulated method for waste disposal.
- Landfill gas can be captured and utilized as a renewable energy source.
- Daily covering and proper waste management reduce the risk of pests and diseases.
- Suitable for managing waste from urban and industrial areas.

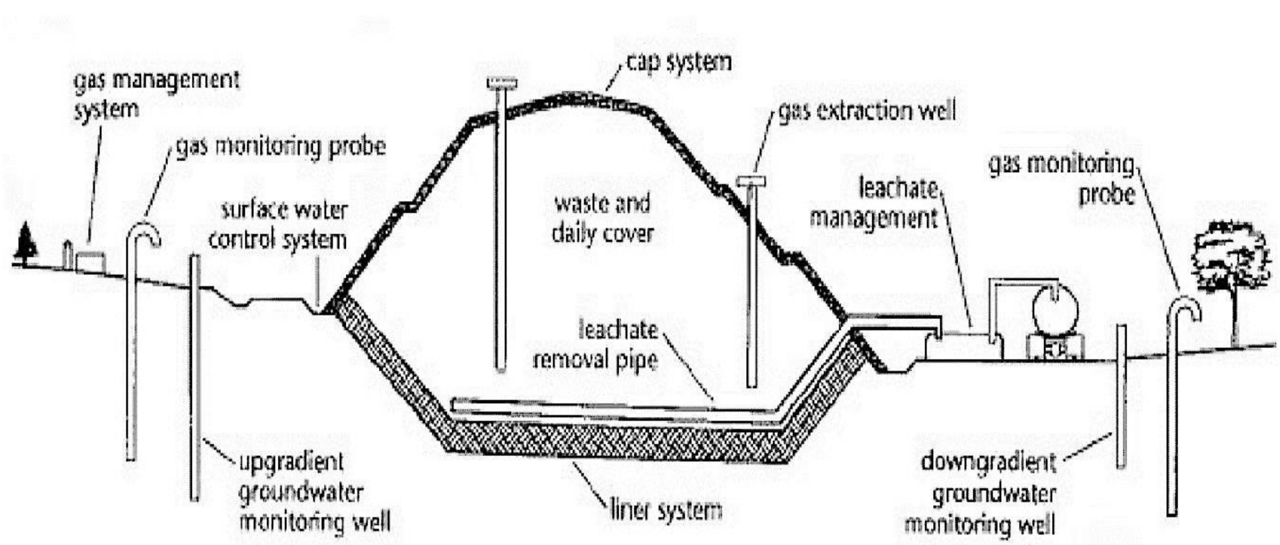

Figure 2: A typical Engineered landfill

1.4 Challenges and Concerns

The first and foremost task in the planning of engineered landfills is its site selection. There are several environmental, social and economic concerns that need to be addressed.

I. Space Requirements: Large tracts of land are needed for construction, making them challenging to implement in densely populated areas.

II. Environmental Risks: There is potential for liner failure leading to leachate leakage and groundwater contamination and risk of gas migration causing explosions or greenhouse gas emissions if not properly managed.

III. Cost Implications: High initial investment in construction, operation, and maintenance and long-term monitoring and post-closure care add to the costs.

IV. Public Perception: Landfills are often met with opposition due to concerns about odor, aesthetics, and potential environmental hazards.

V. Climate Impact: Despite methane capture systems, some emissions may still escape, contributing to climate change

1.5 Significance of the study

This study holds significance for several reasons.

A landfill liner is relatively thick structure of compacted natural clay soil or manufactured material i.e. geomembrane or geosynthetic clay liners. The liner should satisfy the hydraulic conductivity and thickness requirement for the protection of geoenvironment and also it should have sufficient shear strength.

I. Compacted Sand -Bentonite mixtures have been treated as a good substitute hydraulic barrier material to compacted clays when clayey soils were not accessible. According to Akgun (2016) the sand component of a compacted sand-bentonite mixture contributed to the strength, whereas the bentonite component fills the pore space between the sand grains to decrease the hydraulic conductivity

II. The use of sand is not only limited to geotechnical and geoenvironment application it is also used in the construction industries. Hence, sand has become a valuable and scarce material. So, it is important to find suitable substitutes for sand. The rock quarry dust , which is obtained a solid waste during crushing of stones to obtain aggregates can be used as substitute for sand to be used as landfill liner material.

III. Hydraulic conductivity: Hydraulic conductivity of soil is one of the most essential conditions which must be satisfied to be used as land fill liner and cover. From many previous research works we have come to the conclusion that the hydraulic conductivity value for municipal solid waste and hazardous wate have set as 10^{-7} and 10^{-9} cm/sec respectively.

IV. Shear strength: Catastrophic slope failure of municipal solid waste landfill was responsible due to the low shear strength of landfill material. The non uniform settlement of waste materials in landfills may cause excessive deformation and cracking in the cover and undermine the long-term performance of the landfill system. Therefore, it is required that the compacted clay liners must have an adequate internal shear strength to maintain the stability of landfill liner. Daniel and Wu (1993) suggested that a minimum unconfined compressive strength (UCS) of 200 kPa.

1.6 Objective of the study

- To determine the compaction properties and unconfined compressive strength (UCS) of bentonite –sand and bentonite-quarry dust mixes in the ration of 30:70 and compare the results obtained so that we can achieved the objective of replacing bentonite with sand in compacted liners.
- To ensure the workability and to maintain the quality of the liners.
- To determine a satisfactory zone on the wet side of the OMC where hydraulic conductivity and Unconfined Compressive Strength (UCS) values are within desirable limits for landfill liners

CHAPTER 2

2.1 Landfill Liners.

Landfill liners are engineered barriers designed to prevent the migration of leachate and gases from a landfill into the surrounding soil, groundwater, and air. They are a critical component of modern landfill design, ensuring environmental safety and regulatory compliance. In order to provide sustainable waste management, prevent contamination of the environment, and dispose of garbage safely, landfill liners are essential. Liner performance, durability, and efficiency are continuously being improved by advances in material science and engineering, making them essential in contemporary landfill systems.

The different types of Landfill liners are listed below:

I. Natural Liners: Natural liners are materials derived from the earth, typically compacted soils with low permeability, that serve as barriers to prevent the migration of leachate and contaminants from landfills into surrounding soil and groundwater. These liners are often used in isolation or as part of composite liner systems in engineered landfills.

II. Synthetic Liners: They are made from engineered materials such as geomembranes (e.g., HDPE or LLDPE). Highly impermeable and resistant to chemicals, ensuring superior containment.

III. Composite Liners: Composite liners are advanced barrier systems used in landfills and other containment applications to prevent the migration of leachate and gases into the surrounding environment. They combine multiple layers of natural and synthetic materials, providing superior containment by leveraging the strengths of each component. Typically consist of a geomembrane overlying a layer of compacted clay or geosynthetic clay liner (GCL).

2.1.1 Materials Used in Landfill Liners

1. Geomembranes.
    - High-density polyethylene (HDPE): Most commonly used, offering excellent chemical resistance and durability.
    - Linear low-density polyethylene (LLDPE): More flexible than HDPE, suitable

for sites with uneven settlement.

- PVC and EPDM: Used for specific applications requiring flexibility.

2. Compacted Clay.
   - Natural material with very low permeability.
   - Susceptible to cracking under dry conditions or structural stresses.

2.Geosynthetic Clay Liners (GCLs).
   - Manufactured liners consisting of a layer of bentonite clay sandwiched between geotextiles or geomembranes.
   - Provide enhanced containment with easy installation.

2.2 Compacted Clay Liner

Soils used for compacted liners include natural clays, glacial till, residual soil, mud, bentonite. Generally, locally available soils with clay content are preferred over commercial soil like bentonite due to their cost effectiveness. In the absence of suitable natural soil, swelling clays like bentonite is mixed with locally available soil, fly ash, sand etc. However, in recent years geosynthetic materials have been used along with clays to enhance the performance of the liners due to their low permeability.

The simplest liner is that of compacted clay liner (CCL), which is widely used as hydraulic barriers for water and waste migration stoppage. The other configuration of liners include single multiple and composite layers are used depending on the vulnerability of waste. The thickness of liner varies from 60 cm for ordinary solid waste facility to 300 cm for highly hazardous waste.

It is very important to access the suitability of geomaterial for compacted liner construction. The two most important universally accepted criteria for selection of liner material are hydraulic conductivity value of less than 10^{-7} cm/sec and UCS value should be greater than 200 kPa. Bentonite-Sand mixtures have been utilized as liner material in several engineering applications.

Due to its high swelling, lower hydraulic conductivity and contaminant adsorption capacity,

bentonite forms an integral part of a liner and buffer material. However, high compressibility, high desiccation shrinkage, low shear strength and low compaction density are reasons of concern.

Table 2: Advantages and Limitations of Compacted Clay Liners.

Sl No.	Advantages	Limitations
1	Natural material minimizes environmental impact.	Natural soils may have inconsistencies, leading to localized leakage if not carefully prepared.
2	When properly installed and maintained, they provide effective containment for decades.	Desiccation (drying) or freeze-thaw cycles can cause cracks, increasing permeability.
3	Small cracks can reseal through hydration and swelling, especially in high-plasticity clays like bentonite.	To ensure performance, significant thickness is needed, increasing installation time and material volume.
4	Readily available and inexpensive compared to synthetic liners.	Requires meticulous preparation, compaction, and quality control to achieve the desired performance.

2.3 Major Factors impacting liner system.

The major problems encountered in the barrier or liner system have been discussed below.

2.3.1 Hydraulic Conductivity

Hydraulic conductivity of the soil is one of the most important conditions which must be satisfied in order for it to be used as liner and over material at the landfill. For a municipal solid waste facility, the hydraulic conductivity of liner material has been fixed to a value of 10^{-7} cm/sec. The addition of different cohesionless materials such as sand, fly ash, quarry dust improve the strength and reduce the shrinkage behavior of bentonite but at the same time would increase hydraulic conductivity. Therefore, it is important to know a range of water content that would satisfy the regulatory requirements for a compacted liner.

2.3.2 Settlement

The settlement is one of the important factors that use poor performance of final covers. Design estimates of both total settlement and differential settlement are required to analyze long term functionality and stability of the final cover. The non -uniform settlement of waste materials in landfills may cause excessive deformation and cracking in the cover.

2.3.3 Slope Instability

Final overs are always sloped to maximize waste volume and to promote runoff. sometimes, slopes are very steep , approaching grades of 50 % . Catastrophic slope failure of MSW landfill was responsible due to the lower shear strength of landfill material. Therefore, it is required that the compacted clay liners must have adequate internal shear strength to maintain the stability of landfill liners.

2.3.4 Desiccation Cracking

Desiccation is the phenomenon by which moist soil undergoes reduction in volume due to rise in temperature to attain a thermal equilibrium. Reduction in volume induces cracks on the soil surface which further propagates downwards. Crack induced failure of topsoil of various earthen structures is most commonly seen in arid and semi-arid climatic regions. Crack induced failure of earthen structures such as landfill liners and covers. Desiccation induced cracks formed on the surface encourage the rainwater infiltration to higher extents and results in adverse conditions.

The phenomenon of desiccation is more likely to be affected by the amount of clay content, moisture content, soil density, foreign matter, rate of change in temperature. During compaction, water is added to soil for lubrication purposes. Compacting soils at optimum moisture content yields maximum dry density. However, this moisture content may result in volumetric shrinkage of soil mass. Hence balancing the right amount of moisture content to satisfy both the maximum density and minimum shrinkage requirement is a critical task in geotechnical engineering applications particularly in Landfill liners.

CHAPTER 3

3.1 Review of available literatures

N.K. Ameta et al. (2008) provides an insight into the permeability behavior of dune sand-bentonite mixtures. One dimensional consolidation and falling head permeability tests were conducted on 2%, 4%, 6%,8% and 10% bentonite content by weight in dune sand. The findings are that the coefficient of consolidation decreases inversely proportional with lower bentonite/dune sand ratios. The permeability is greatly affected by adding bentonite and reportedly reduced from 10^{-4} cm/sec to 10^{-8} cm/sec after addition of 10% bentonite with compaction at maximum dry density and at optimum moisture content.

Devrim Alkaya and Barıs Esener (2011) aimed to create an impermeable fill mix using bentonite and cement as admixtures and sand as the main material. The choice of bentonite and cement is due to their impermeability and accessibility. Sand is chosen for its low price and use of available sand pits in Yenicekent, Denizli. The study found that a 10% bentonite + 90% sand mixture is the most economical solution, meeting the limits needed for clay cores in earth fill dams and solid waste storage areas. Results show that permeability decreases significantly when sand is added to bentonite-cement mixtures, proving its use in fillings like solid waste storage sites and earth fill dams. When bentonite is mixed with sand, the dry density increases significantly. The mixing ratio of bentonite to sand and cement significantly influences maximum dry density and optimum moisture content. As the ratio changes from 10% to 40%, the maximum dry density increases and the corresponding optimum moisture content decreases.

M.M Younus and S. Sreedeep (2012) suggested that the addition of fly ash would improve the strength and reduce the shrinkage behavior of bentonite but at the same time would increase the hydraulic conductivity (K). Therefore, it is important to determine the range of water content and dry unit weight for different bentonite fly ash mix that would satisfy the regulatory requirements for a compacted liner. For all compaction states of fly ash, K is greater than the acceptable value of 10^{-7} cm/sec. Except for the dry OMC point of B30:F70 mix, all other compaction states of mixes meet the K criteria for landfill liners. Their study indicates that all the bentonite fly ash mixes compacted at optimum moisture content using standard proctor effort satisfy the landfill requirement criteria.

According to the study, it can be noted that the maximum weight percentage of fly ash that an be mixed with bentonite is up to 70%.

K Tripathi and B.V.S. Viswanadham (2012) Presented the laboratory evaluation of permeability of sand bentonite mix by varying bentonite content from 5 -25% by dry weight. With an increase in bentonite content up to 15% a steep decrease in hydraulic conductivity is observed, beyond 15% the variation are marginal. They also suggested that the value of hydraulic conductivity depends upon the type of permeability test used.

V Srikanth and A.K. Mishra (2016) explored the effects of the particle size of the sand on the behavior of various sand-bentonite mixtures mixed in different proportions. They used various mixes of fine sand -bentonite and medium sand-bentonite by varying the sand content from 50% to 90% by dry weight of the mix. The mixtures were tested for Atterberg limits, compaction characteristics, swelling and hydraulic behavior. The results indicated that variation in liquid limit is not linear even though the clay content in the mixes varied linearly. For any given proportion of sand-bentonite mixtures, fine sand mixes were observed to be more plastic and high swelling than MS mixes. Bentonite mixed with fine sand exhibits relatively lower hydraulic conductivity value. Swelling characteristics obtained from the tests showed that bentonite content of less than 20% was insufficient in filling the voids created by sand matrix.

Krishanu Mukherjee & Anil Kumar Mishra (2016) addressed the problem of desiccation cracking in liners due to shrinkage of bentonite which eventually results in the increase hydraulic conductivity. To deal with the issue of desiccation cracking they used glass fibre as a reinforcing agent in the mixture. The glass fibre of 10 mm length was added in the proportion of 0.5% and 1% to different sand bentonite mixes with one layer of GCL. About 10, 20.and 30% bentonite was added to sand by their dry weight. The results showed that due to the inclusion of the fibre, the swelling potential decreased. However, the inclusion of fibre increases the hydraulic conductivity of the mixes as the presence glass fibre in the soil matrix provides extra drainage path to the flow of water.

Krishanu Mukherjee & Anil Kumar Mishra (2018) used waste tyre chips as reinforcing material in the sand -bentonite mixture to deal with cracks formed in the landfill liner due to desiccation .In this study, consolidation and consolidated undrained test were performed to study the hydraulic and mechanical behaviour of sand bentonite mixture mixed in proportion of 80: 20 and mixed with 0,5,10 and 15% of waste tyre chips. They found that with increase in tyre hips content maximum dry density (MDD) was decreased, whereas the optical moisture content (OMC) remained constant. Swelling potential and pressure were reduced due to addition of tyre chips whereas hydraulic conductivity increases. The research recommended that 5 to 10 % tyre chips with sand bentonite in the ratio of 80;20 would be used as bottom liner.

Hemanga Das et al. (2018) made efforts to find suitable substitutes for sand in landfill liners. They used rock quarry dust for this purpose and performed tests to determine the compaction properties an unconfined compressive strength (UCS) of bentonite -sand -rock quarry dust mixes. The study evaluates the optimum bentonite -sand, bentonite quarry dust and bentonite -sand-quarry dust mixes. The study found that the optimum mix which contains 30% bentonite and 70 % quarry dust yields UCS value much greater than 200 kPa which is desirable for landfill liners.

Lins Paul Kuriakose et al. (2018) investigated landfill properties such as permeability and compressive strength of clay- bentonite and bentonite-quarry dust mixes. The normal clay was blended with bentonite at 3%, 5%, 7% proportions and bentonite-quarry dust mixture at 10%, 20% and 30% mix proportions and tests are performed accordingly. The research work suggested that th the bentonite blended with 20% quarry dust is found to be the most suitable mix proportion in terms of compressive strength of a landfill liner.

Dr. V.Giridhar, S.Dharani (2018) studied the characteristics of bentonite quarry dust and clay mixtures with bentonite percent of 3, 6, 9, 12 and 15 and 10 % quarry dust with clay. The samples were prepared by the combination of Clayey Soil, Bentonite and Quarry Dust. The percentage of Bentonite was taken at 3, 6, 9, 12 & 15% and 10% of Quarry dust with OMC. It was found the addition of 15 % of bentonite clay, clayey soil behaved as a good barrier. Also, with increasing the bentonite percent the UCS and permeability values showed increment.

Ankit Garg et al. (2020) assessed fly ash-bentonite composites' thickness, hydraulic conductivity, and compressive strength as potential landfill liners. The composite satisfies strength and permeability requirements since it is composed of 70% fly ash and 30% bentonite. According to numerical calculations, the composite minimizes heavy metal leaching and has an ideal thickness of 126–154 cm. The composite is essential in lowering the leaching of heavy metals in five key pollutants, according to the study. According to the results, fly ash-bentonite composite can be utilized to reduce contamination in ponds and low-lying areas while also providing a sustainable solution to real-world problems.

Yeu Qin, Dongsheng Xu et al. (2021) studied the effects of bentonite content, hydration time and effective confining pressure on the static properties of a sand-bentonite mix. Under the same bentonite and the same confining pressure, the shear strength of the sand-bentonite mix was decreased gradually with the increasing bentonite content. Peak Shear Stress of calcium bentonite was higher than that of sodium bentonite in the mix under the same hydration time and bentonite content.

Islam, Kalita & Chetia (2021) evaluated that in landfill construction, bentonite-sand (B:S) mixtures—which are mostly obtained from riverbanks—are frequently utilized as liner or barrier material. But too much use of natural sand makes it scarce. In order to solve this problem, the study investigates how the unconfined compressive strength (UCS) of B:S mixtures at various curing times is affected when sand is completely replaced by waste material rock quarry dust. According to the findings, for varying curing times, the UCS of B: Q mixes is higher than that of B:S mixes. The inclusion of waste tire dust (TD) to improve the UCS of B:S and B: Q mixtures at various curing times is also examined in this study. The highest UCS value for both the B:S and B: Q mixes was recorded at TD = 14%. The mixes' UCS went up.

Darshan C, Harshith Arekal Vijay (2021) studied the desiccation phenomenon of compacted soil in landfill liners. During compaction, water is added to soil for lubrication purpose. Compacting soils at optimum moisture content yields maximum dry density. However, this moisture content may result in volumetric shrinkage of soil mass. Hence balancing the right amount of moisture content to satisfy both the maximum density and minimum shrinkage requirement is a critical task in geotechnical engineering applications particularly in Landfill liners. To reduce the shrinkage or desiccation cracks, optimum moisture content was reduced by 5% for locally available soil and volumetric shrinkage was found at 8.1%. The study also founded that the hydraulic conductivity of the liner before adding bentonite at (OMC-5 %) 2.85 x 10-5 cm/sec. After adding bentonite at 6%, the hydraulic conductivity of the liner reduced to (OMC -10 %) 2.9 ×10-8 cm/s. From the above discussions, it may be concluded that reduction in OMC will lead to reduction in both linear and volumetric shrinkage.

Hrithik Nath, et al. (2023) blended local locally available clay soil with bentonite in different proportions of 5%,10 %,15% and 20%and studied the geotechnical properties. Results demonstrated that the addition of bentonite significantly influenced the geotechnical properties of the mixes. Taking both hydraulic conductivity and strength properties into account, the local soil can be employed as a landfill liner with at least 10% bentonite.

A.S. Devapriya, T. Thyagaraj (2023) evaluates the suitability of an Indian red soil enhanced with bentonite as a liner material. a series of experiments were carried out using locally available red soil and bentonite**.** The red soil was mixed with bentonite contents of 10%, 20% and 30%, and the red soil-bentonite mixtures were evaluated for their suitability for liners in their compacted states. The experimental results showed that the red soil met all the selection criteria**.** The experimental results reveal that even though the selected red soil satisfied the selection criteria based on the index properties for clay liners according to different EPAs, it failed to satisfy the hydraulic conductivity criterion. Hence, to deal th the problem the red soil is blended with different proportions of bentonite. The addition of bentonite to the red soil increased the micropores volume in the compacted red soil bentonite specimens, which in turn led to the macrostructural hardening during loading and increased the UCS. The compacted red soil- bentonite mixtures were subjected to five alternative cycles of wetting and drying, until the specimens reached the volumetric equilibrium, and the hydraulic conductivity measured. It was found from the study that red soil – bentonite mixes in the ratio of 80:20 and 70:30 can be used as liner material as they satisfy the hydraulic conductivity criteria.

Ankush Kumar Jain (2024) analysed the various proportions of bentonite with fly ash and marble dust, evaluating their impact on liner performance in comparison to Bentonite-sand mixtures. A wide range of physical properties were being tested which includes Atterberg's limits, compaction characteristics, free swell index, modified free swell index, California bearing ratio, cohesion, and angle of internal friction. The results found that with increasing the bentonite content in the various mixes a reduction in the maximum dry density (MDD) .

The reduction in MDD with increasing bentonite content can be attributed because bentonite particles absorb water, they become hydrated and expand. The researchers conducted the permeability of marble dust, sand and fly-ash with varying bentonite content (B) from 0% to 40%. The experimental results showcase a systematic reduction in permeability with increasing percentages of Bentonite in the mixture of sand (S-B), marble dust (MD-B), and fly ash (FA-B), suggesting a clear trend in the effectiveness of the mixture for a landfill liner application. The decrease in permeability can be elucidated by the unique properties of Bentonite, a clay known for its exceptional swelling capacity upon hydration. The fine particles of Bentonite fill voids between the larger particles, leading to a reduction in overall porosity. The inclusion of waste marble dust and fly ash as alternative materials in landfill liners, in place of traditional sand, presents intriguing possibilities and challenges.

CHAPTER 4

Material and Methodology

4.1 Material

The details of the different materials used in the project work has been mentioned below.

4.1.1 Bentonite

Bentonite is a kind of soft clay produced by weathering and erosion of volcanic ash with the major mineral composition of montmorillonite. It is clay composed if two tetrahedral and one octahedral flake in a ratio of 2:1. The high plasticity of bentonite makes it an ideal admixture to improve the liquefaction resistance of the sand. Bentonites are generally of two types of Na- montmorillonites and Ca- montmorillonite. As a swelling clay, bentonite has the ability to absorb large quantities of water, which increases its volume by up to a factor of eight which makes bentonite beds unsuitable for building and road construction. However, this the swelling property is used to advantage in drilling mud and groundwater sealants. Since bentonite is a natural material, its mineral composition, chemical state and grain size distribution varies considerably from one source to another. The Bentonite used in the study was procured from Barmer, Rajasthan and is sodium based. Table 3 represents the physical properties of bentonite.

Table 3: Physical properties of bentonite

Sl.No.	**Property**	**Bentonite**
1	Specific Gravity	2.82
2	Liquid Limit	259.3%
3	Plastic Limit	58%
4	Free Swelling	142.85%

4.1.2 Sand

Air dried Brahmaputra River sand of zone III as per grading mentioned in IS: 383-1970 is used. The

Basic properties of sand are listed in table 4.

Table 4: Basic properties of sand

Sand	**Values**
D_{60} (mm)	0.50
D_{30} (mm)	0.33
D_{10} (mm)	0.19
Coefficient of Uniformity (Cu)	2.63
Coefficient of curvature (Cc)	1.11
Classification of Sand	SP

4.1.3 Quarry Dust

The rock quarry dust is a waste product produced in large amount of rock quarry activity. Based on past studies it is known that rock quarry dust can be good alternative for sand in construction activities. The Rock quarry dust was collected from the rock quarry site at Patharkuchi Village of Meghalaya. The Basic properties of quarry dust are listed in table 5.

Table 5: Basic properties of quarry dust.

Quarry Dust	**Values**
D_{60} (mm)	0.82
D_{30} (mm)	0.24
D_{10} (mm)	0.10
Coefficient of Uniformity (Cu)	7.65
Coefficient of curvature (Cc)	0.63
Classification of Sand	SP

4.2 Methodology

This section deals with the methodology adopted to conduct the Atterberg's limit test, free swelling, standard compaction, Unconfined Compressive Strength Test and failing head permeability test.

4.2.1 Preparation of samples

Bentonite-Sand (BS) and Bentonite-Quarry dust (BQ) mixture are mixed in a proportion of 30:70 by their dry weight.

4.2.2 Atterberg's Limit Test

The Specific gravity is done by density bottle method according to test specified in IS: 2720(Part 4)-1985. The liquid limit of bentonite was found through Casagrande apparatus as per IS:2720(Part 5)-1985.

4.2.2 Free Swelling Test

The free swelling test of bentonite (100) , bentonite-sand (30:70) and bentonite-quarry dust(30:70) are done as per IS 2720 (Part-40): 1977.About 5g of oven dried sample of each mix is taken and put in two separate 100 ml measuring cylinders. One of the two cylinders is filled with distil water and the other with kerosene and kept undisturbed for about 24 hours. After 24 hours the reading in each cylinder is measured and noted.

4.2.3 Standard Proctor Compaction Test

The proctor compaction test is performed as per the IS:2720 (part 7)-1985 guidelines to determine the maximum dry density and optimum moisture content. For the compaction test air dried samples are taken. The dried samples of bentonite-sand(BS) and bentonite-quarry dust (BQ) are then mixed thoroughly with each other in the proposed proportion of 30:70. After that water is added to the soil as prescribed in the code and kept for 24 hours in airtight plastic bags for the uniform distribution of moisture. The process is repeated 3 to 5 times with increasing water content .The test is conducted in mould of height 12.73 cm and diameter of 10 cm.

4.2.4 Unconfined Compressive Strength Test

The UCS tests were conducted according to IS:2720 (part 10)-1991 guidelines. The UCS tests were conducted for each determination number of the corresponding proctor test. After completion of one proctor determination, the sample for the UCS test is collected with the help of sample. A sample of diameter 38mm and height of 76mm is extracted and proceed for the test. The UCS tests were performed under deformation rate of 1.25 mm/min.

4.2.5 Permeability Test.

To determine the hydraulic conductivity the permeability test is conducted as per the IS 2720-(PART-17)-1986 guidelines. In this study the falling head permeability test has been adopted. For the permeability test, the samples are compacted in optimum moisture content (OMC) and maximum dry density (MDD) for both bentonite-sand(BS) and bentonite-quarry dust (BQ) . Before starting the flow measurements, the soil sample is saturated for at least 14 days. After saturation phase is done the test is then started by allowing water to flow through the sample until the water in the standpipe reaches a given lower limit. The time required for the water in the standpipe to drop from the upper to the lower level is recorded. The time required to get a drop of 10 units is noted for the calculation.

On the basis of the test results, the permeability of the sample can be calculated as:

$K=[2.3\ a.L / (A.\Delta t)].Log(h_i / h_f)$, where

L: the height of the soil sample column

A: the sample cross section

a: the cross section of the standpipe

Δt: the recorded time for the water column to flow though the sample

h_i and h_f the upper and lower water level in the standpipe .

CHAPTER 5

Result and Discussion

5.1 Sieve Analysis of Sand

Total mass of oven Dried sample= 500 g

Table 6: Particle size distribution of sand.

sieve (mm)	Weight retained g	% retained	cumulative % retained	% passing
4.75	9.18	1.84	1.84	98.16
2.36	13.08	2.62	4.46	95.54
1.18	14.96	2.99	7.45	92.55
0.6	74.98	15.00	22.45	77.55
0.3	262.03	52.41	74.86	25.14
0.15	105.82	21.16	96.02	3.98
0.075	10.97	2.19	98.21	1.79

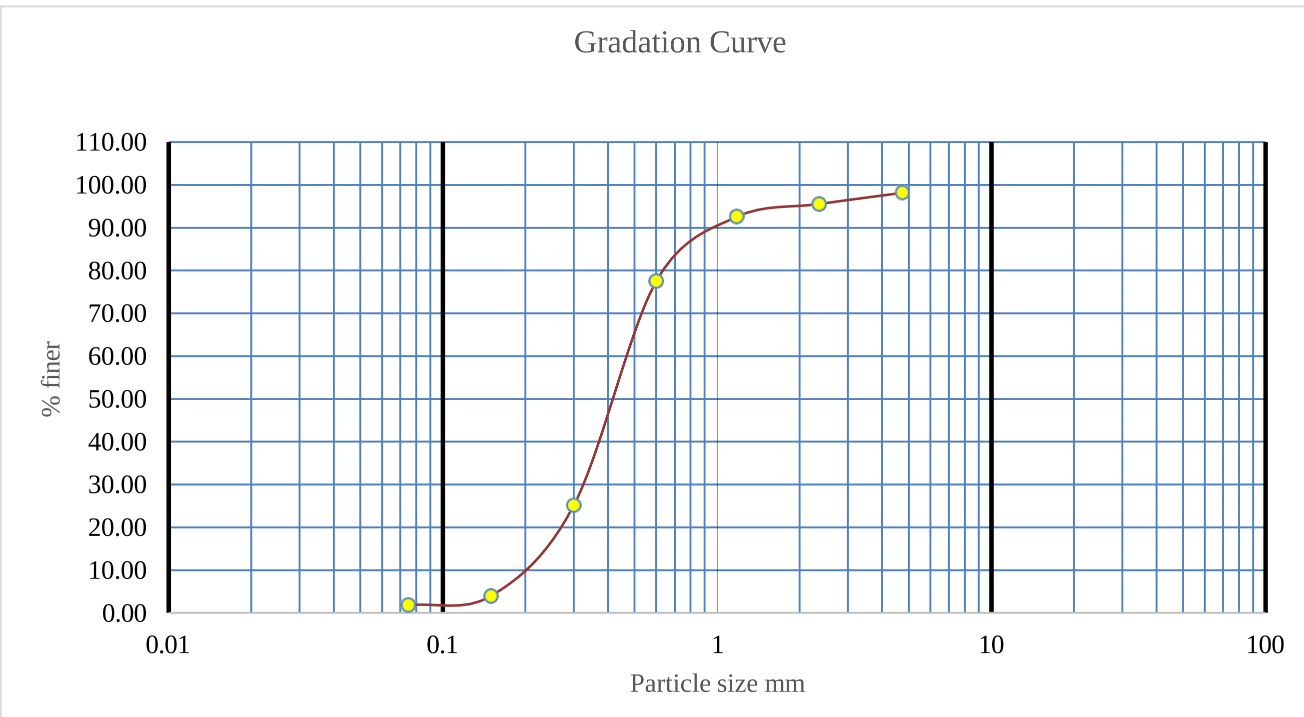

Figure 3: Particle size distribution curve of sand

5.2 Sieve Analysis of Quarry Dust

Total mass of oven dried sample =500 g

Table 7: Particle size distribution of quarry dust.

Sieve (mm)	Weight retained g	% retained	cumulative % retained	%Finer
4.5	18	3.6	3.6	96.4
2.36	78	15.6	19.2	80.8
1.18	66	13.2	32.4	67.6
0.6	60	12	44.4	55.6
0.3	80	16	60.4	39.6
0.15	106	21.2	81.6	18.4
0.075	72	14.4	96	4

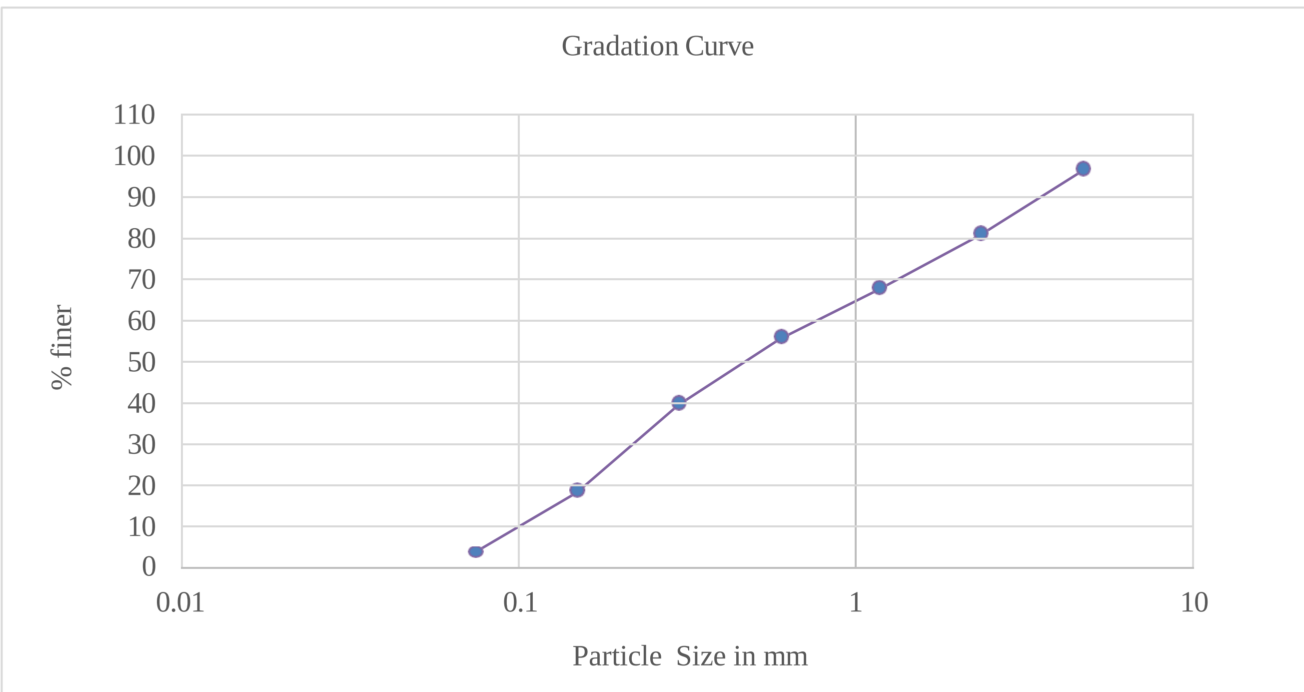

Figure 4: Particle size distribution curve of quarry dust.

5.3 Compation Characteristics

The figure 5 shows the compaction characteristics of all bentonite-sand(BS) and bentonite-quarry dust(BQ) mixes.

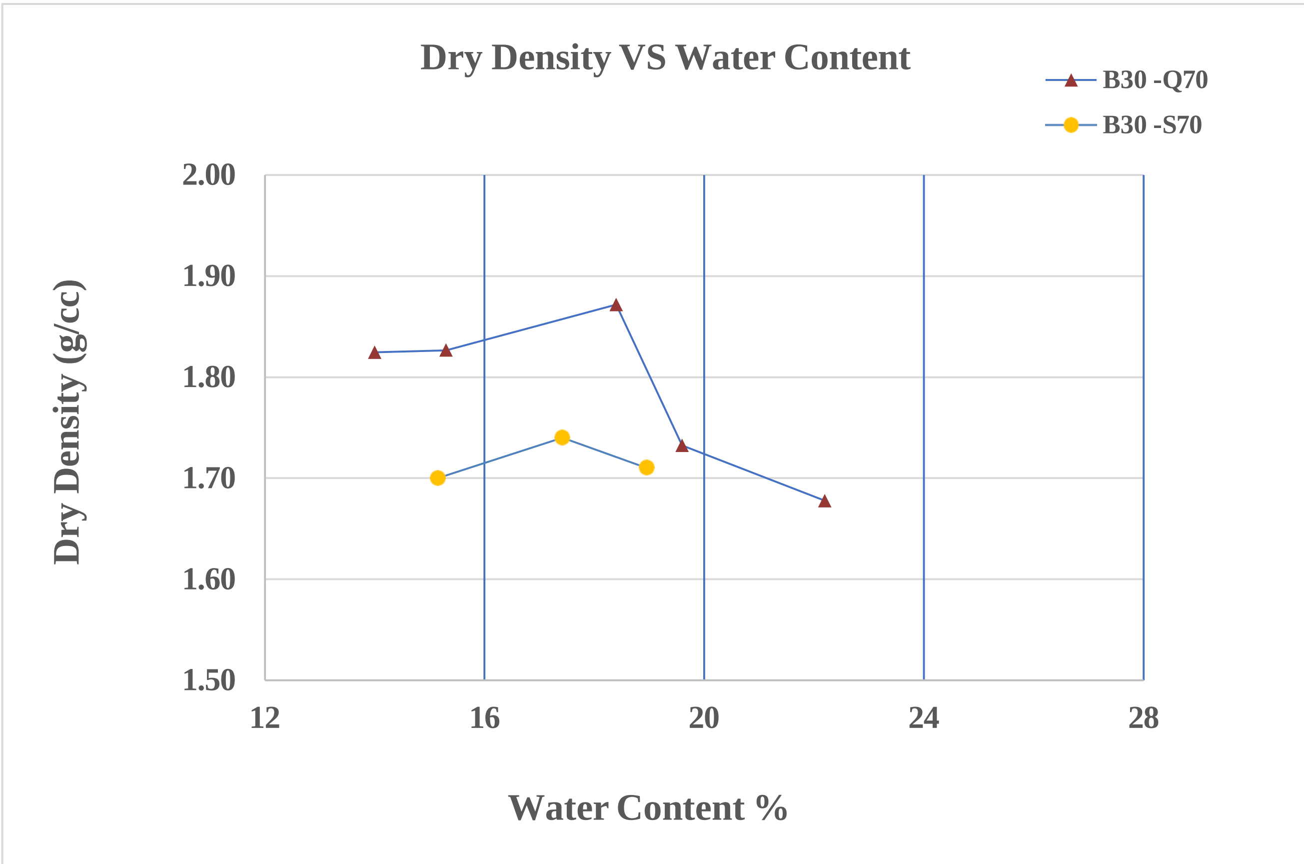

Figure 5: Drydensity variation agaist moisture content.

From the figure it is ovserved that the bentonite -quarry dust mix exihibits higher maximum dry density than the bentonite-sand mix of same proportion of 30:70. However,there is little difference in the OMC between the two mixes.

5.4 Unconfined Compresiive Strength Test

The figure 6 shows the UCS values agaisnt the moisture content values obtained from the corresponding proctor samples. From the figure it is evident that the UCS values of bentonite-quarry dust mixes are all within the deriserd range for landfill liners i.e. greater than 200 kPa except for last point on the wet side of optimum moisture content. The maximum value of UCS is obatined at the water content corresponding to the OMC point. Whereas with the bentonite-sand, the UCSs values are not satisfactory as all are below 200 kPa.

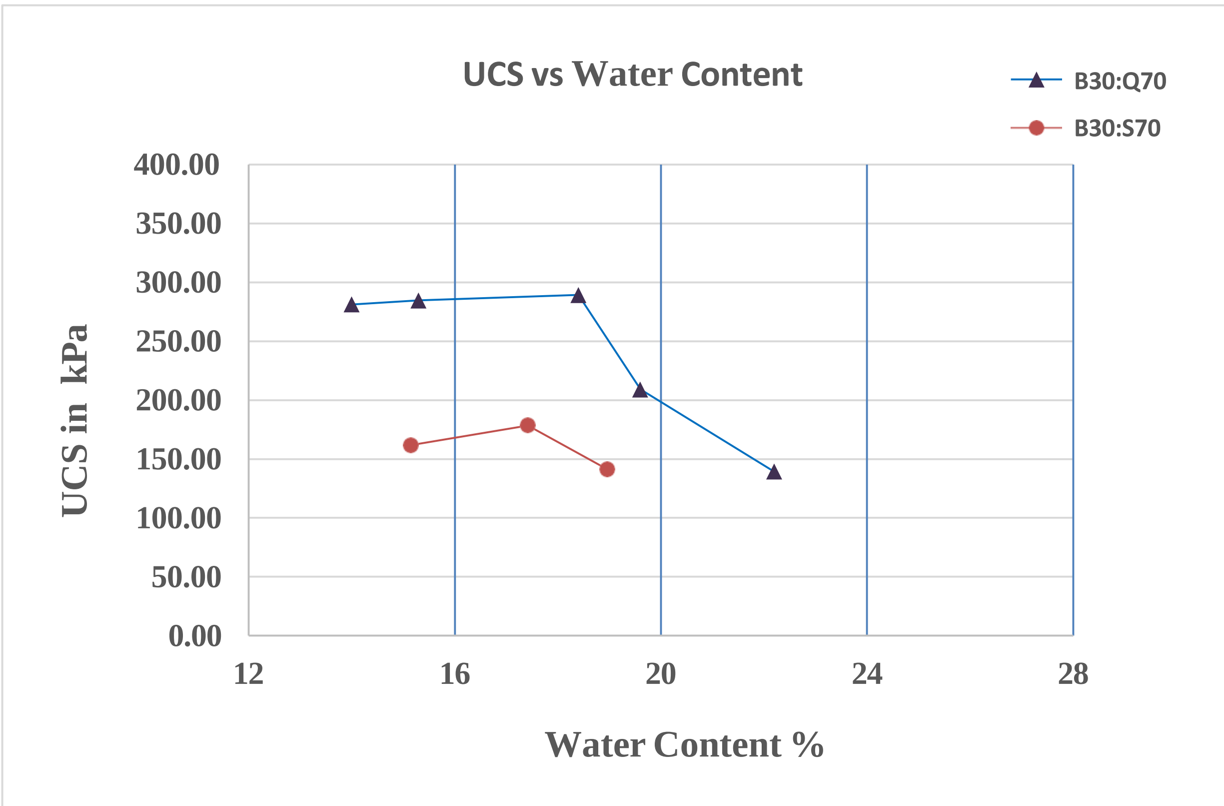

Figure 6. UCS variation against the mositure content.

Table 8: Compaction Characteristics and UCS values of Bentonite-Sand , B30:S70 Mix.

Sl No.	Water Content(%)	Dry Density (g/cc)	UCS (kPa)
1	15.15	1.70	161.8
2	17.42	1.74	178.5
3	18.96	1.71	141.2

The table 8 shows that the OMC and MDD of B30:S70 mix are 17.42% and 1.74 g/cc respectively.

Table 9: Compaction Characteristics and UCS values of Bentonite-Quarry Dust , B30:Q70 Mix

Sl No.	Water Content(%)	Dry Density (g/cc)	UCS (kPa)
1	14	1.82	281.24
2	15.3	1.83	284.65
3	18.4	1.87	289.17
4	19.6	1.73	209.06
5	22.2	1.68	139.38

From table 9 we get OMC and MDD values of 18.4 % and 1.87 g/cc respetively for B30:Q70 mix.

5.5 Permeability test

The permeabilty test is done in the mould of 10 cm diamter and height of 12.73 cm.The sample is saturated by a pipe of 6 mm

Length of the sapmle (L) = 12.73 cm

Area of the pipe (a) = π/4 * (0.6)^2

= 0.2827 sq.cm

Area of the sample (A) = 78.53 sq cm

$K=[2.3\ a.L / (A.\Delta t)].Log(h_i / h_f)$, where h_i and h_f the upper and lower water level in the standpipe

Table 10: Permaeability test values of different mix at OMC and MDD

Mix	OMC(%)	MDD(g/cc)	h_i (cm)	h_f (cm)	t (hours)	K (cm/sec)
B30:S70	17.42%	1.74	194.5	184.5	23	2.92×10^{-8}
B30:Q70	18.4	1.87	190.9	180.9	22.26	3.07×10^{-8}

The permeability is measured at +3% and +5% on wet side of OMC for B30:Q70 mix.

Table 11: Permeability test at 1.03 and 1.05 times of OMC of B30:Q70 mix

Mix	Water content(%)	Dry Desnity(g/cc)	h_i (cm)	h_f (cm)	t (hours)	K (cm/sec)
B30:Q70	18.95	1.82	194.5	184,5	37	1.46×10^{-8}
	19.32	1.8	192	182	46	1.48×10^{-8}

Thus it can be conlude from table 11 that the permeability value is very low on wet side of optimum.

CHAPTER 6

6.1 Conclusion

The study deals with laboratory testing and eavluation of bentonite -quarry dust mixes for their application in compacted ladfill liner replacling the conventional bentonite -sand mix in the liners. Based on the experiments conduted the onclusion made from the study are as follows.

1. The free swelling of bentonite , decreases when bentonite is mixed with sand sand qaurry dust. It observed that the free swelling index of bentonite-sand mix decreaes by 11.1% from that of 100% bentonite and for bentonite-quarry dust mix the decrease was 30%.
2. The maximum dry density (MDD) increases when quarry dust replaced sand in the sand-bentonite (B30:S70) mix.
3. The repcaement of sand with quarry dust in the bentonite-sand mix improved the UCS results. The UCS performed with B30:S70 mix exhibit values less than the required value of 200 kPa. However, when the UCS is performed with B30:Q70 , the values are within the desired range.
4. The hydraulic Conductivity values are within the acceptable range for both the mixes.

6.2 Scope For Future study

The scope for future studies on the topic of laboratory testing and evaluation of bentonite-quarry dust mixes for landfill liner applications can be outlined as follows:

1. Given that the physical characteristics of quarry dust can differ depending on the source, further research could examine the impact of quarry dust from various locations or quarries. More generalized findings for different sites may be obtained by examining the effects of different types of quarry dust on the behaviour of the bentonite-quarry dust mix, particularly regarding free swelling, MDD, UCS, and hydraulic conductivity.
2. Future research might examine the behaviour of bentonite-quarry dust mixes in the presence of organic material-containing leachate, which landfill liners frequently

have to address. When evaluating the mix's performance in the actual world, the effect of the leachate composition on the swelling behaviour, UCS, and hydraulic conductivity may be crucial.

3. Field tests of the bentonite-quarry dust mixtures in actual landfill liner applications would be beneficial. In addition to offering insights into real-world issues like mixing ease, compaction behaviour, and long-term performance in real landfill sites, this would enable the validation of laboratory results.

References

1. Devapriya, A., &Thyagaraj, T. (2023). Evaluation of red soil-bentonite mixtures for compacted clay liners. Journal of Rock Mechanics and Geotechnical Engineering, *16*(2), 697–710.
2. Devrim, A., & A, B. E. (2011). Usability of sand-bentonite-cement mixture in the construction of unpermeable layer. *Scientific Research and Essays*, *6*(21), 4492–4503. https://doi.org/10.5897/sre10.1189.
3. Garg, A., Reddy, N. G., Huang, H., Buragohain, P., & Kushvaha, V. (2020). Modelling contaminant transport in fly ash–bentonite composite landfill liner: mechanism of different types of ions. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-68198-6
4. Hemanga Das ,Et al. (2018). Compaction and strength characteristics of bentonite-sand-rock quarry dust mixes. CID 2018.
5. Hrithik Nath Et al.(2023). Geotechnical Properties and applicability of bentonite –modified local soil as land fill and environmental sustainability liners.
6. Islam, N., Kalita, T., & Chetia, M. (2021). Effect of tyre waste addition on UCS of Bentonite–Sand and Bentonite-Rock quarry dust mixes. In *Lecture notes in civil engineering* (pp. 395–407). https://doi.org/10.1007/978-981-16-3383-6_36
7. IS: 2720-Part 7: Determination of water content- dry density relation using light compaction- Indian standard methods of tests for soils, Bureau of Indian Standards, New Delhi :1980
8. IS 2720-Part 41 Methods of test for soils -Determination of unconfined compressive strength, Bureau of Indian Standards, New Delhi :1977
9. IS 2720-Part 10: Methods of test for soils -Determination of unconfined compressive strength, Bureau of Indian Standards, New Delhi :1991
10. IS 2720-Part 17: Methods of test for soils-Laboratory determination of permeability, Bureau of Indian Standards, New Delhi :1986
11. Jain, A. K. (2024). Exploring the viability of Bentonite-amended blends incorporating marble dust, sand, and fly ash for the creation of an environmentally sustainable landfill liner system. *International Journal of Geo-Engineering*, *15*(1). https://doi.org/10.1186/s40703-024-00214-4
12. Krishanu Mukherjee . Anil Kumar Mishra (2018).Hydraulic and mechanical characteristics of compacted sand-bentonite :tyre chips mix for its land fill application. Springer 2018.

13. Mukherjee, K., & Mishra, A. K. (2019). Evaluation of Hydraulic and Strength Characteristics of Sand-Bentonite Mixtures with Added Tire Fiber for Landfill Application. *Journal of Environmental Engineering*, *145*(6). https://doi.org/10.1061/(asce)ee.1943-7870.0001537
14. Mukherjee, K., & Mishra, A. K. (2019). Evaluation of Hydraulic and Strength Characteristics of Sand-Bentonite Mixtures with Added Tire Fiber for Landfill Application. *Journal of Environmental Engineering*, *145*(6). https://doi.org/10.1061/(asce)ee.1943-7870.0001537
15. N.K.Ameeta Et .al (2008) Effect of Bentonite on Permeability of Dune Sand.
16. Qin, Y., Xu, D., & Lalit, B. (2021). Effect of bentonite content and hydration time on mechanical properties of Sand–Bentonite mixture. *Applied Sciences*, *11*(24), 12001. https://doi.org/10.3390/app112412001
17. Srikanth, V., & Mishra, A. K. (2016). A laboratory study on the geotechnical characteristics of Sand–Bentonite mixtures and the role of particle size of sand. *International Journal of Geosynthetics and Ground Engineering*, *2*(1). https://doi.org/10.1007/s40891-015-0043-1
18. Tripathi, K. K., & Viswanadham, B. V. S. (2012). Evaluation of the permeability behaviour of Sand-Bentonite mixtures through laboratory tests. *Indian Geotechnical Journal*. https://doi.org/10.1007/s40098-012-0020-8

.

19. Younus, M. M., & Sreedeep, S. (2012). Evaluation of Bentonite-Fly ash mix for its application in landfill liners. *Journal of Testing and Evaluation*, *40*(3), 357–362. https://doi.org/10.1520/jte104161.
20. Younus, M. M., & Sreedeep, S. (2012). Reevaluation and modification of Plasticity-Based criterion for assessing the suitability of material as compacted landfill liners. *Journal of Materials in Civil Engineering*, *24*(11), 1396–1402. https://doi.org/10.1061/(asce)mt.1943-5533.0000522.