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Comparative Study on Performances of Clay - Bentonite and Bentonite - Quarry Dust Mixture as Landfill Liner

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ABSTRACT
Landfills are the man- made places on land, where the wastes collected are dumped. In today's world landfills are a serious environmental pollution factor because of the emission of toxic gases and groundwater contamination. Major component of a landfill is its liner and to avoid such environmental health hazards, liner material should possess certain standard properties. Hence in this study, an attempt has been made to consider two kinds of mixes, namely, the clay-bentonite mix and the bentonite-quarry dust mix. The properties such as permeability and compressive strength of the mixes were determined.

Keywords – Bentonite, clay, contamination, landfill.

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I. INTRODUCTION

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. Thus the long term option available to manage the waste generated is to dispose it on the earth's surface. When waste is stored on land, it becomes a part of the hydrological cycle. During the infiltration of water through waste, numerous contaminants are removed from the waste to the adjacent areas as well as to the strata below. This action of water along with the action of wind can have significant impact on the adjacent environment. To minimize the impact of waste on the environment, final disposal is done in "Engineered Landfills". Landfill offers an environmentally sustainable methodology for disposing waste on land.

Landfills are thus designed considering various parameters to meet their requirements. Conventional landfills were made of clay. Even though various new model liners like geosynthetics are available, they are not preferred in certain places due to economical constraints. Thus in this study two different types of mixtures were prepared to compare and arrive at a suitable design mix for a compacted landfill liner.

II. SPECIFICATIONS FOR LINERS

Landfill liners are essential for protecting the environment from landfill waste contamination. It is always necessary use the best quality landfill liner materials. Best liner material can help prevent the migration of leachate and toxic byproducts into top soil, and can guard against the contamination of other local water sources. Thus a landfill must be designed to meet the required conditions to prevent pollution of environment and efficient leachate collection system.

Table1. Requirements of a landfill liner

PROPERTIES	REQUIREMENTS
Liquid limit	30% - 50%
Plasticity index	10-31
UCS	>=20kN/m^2
Permeability	$1*10^{-6}$ mm/s

III. MATERIALS

3.1 Clay

Clay is a finely-grained natural rock or soil material. It mainly consists of one or more clay minerals with traces of metal oxides and organic matter. Clay has the smallest particle size of any soil type. Normal clay was chosen for the study. The following table shows various properties of the clay.

PROPERTIES	VALUES
Liquid limit	28%
Plastic limit	22%
Permeability	$1.86*10^{-7}$cm/s
Unconfined compressive strength	25 kN/m^2
Maximum dry density	1.71g/cc
Optimum moisture content	24%

3.2 Bentonite

Bentonite is absorbent aluminium phyllosilicate clay consisting mostly of montmorillonite. Bentonite is hence exploited for various purposes due to its distinctive properties. Some of them are mentioned below.

Table 3. Properties of bentonite

PROPERTIES	VALUES
Liquid limit	360%
Plastic limit	70%
Maximum dry density	1.5g/cc
Optimum moisture content	20%
Permeability	$4.88*10^{-8}$ mm/s

3.3 Quarry Dust

Rock quarry dust or quarry dust is produced as solid wastes during crushing of rocks to obtain aggregates. Geotechnical characterization of quarry dust and its interaction behavior with soils can lead to a viable solution for its large scale utilization and disposal.

Table 4. Properties of quarry dust

MATERIAL	PERMEABILITY IN mm/s
Clay	$1.95*10^{-9}$
Clay + 3% Bentonite	$2.80*10^{-10}$
Clay + 5% bentonite	$8.67*10^{-10}$
Clay + 7% bentonite	$9.79*10^{-10}$

IV. METHODOLOGY

The project work was divided mainly into three phases in which the first phase includes the determination of individual properties such as liquid limit, optimum moisture content, water content, dry density of clay, bentonite and quarry dust . The second phase comprised of testing of the mixture prepared by adding bentonite into clay at 3%, 5% and 7%. The hydraulic conductivity was the property mainly checked. Then the third phase included the testing of bentonite-quarry dust mixture at 10%, 20% and 30% mix proportions.

Table 2. Properties of clay

V. EXPERIMENTAL STUDY

5.1 Hydraulic Conductivity

Hydraulic conductivity is an engineering property of soil and is a function of type of soil. It is affected by many factors mainly the particle size. As particle size reduces, void ratio reduces. For a given soil, lower the void ratio, lower is the coefficient of hydraulic conductivity. The significant characteristic of a landfill liner is its capacity to remain impermeable in due course of time. This may ensure the durability for the landfill. Thus in this study the hydraulic conductivity of the liner material was chosen as a prime criteria to establish the comparison between the two mixes.

Normal clay particles have very low permeability range and further, to relate with the properties of a good liner, the normal clay was blended with bentonite at 3%, 5%, 7% proportions.

Table 5. Variation in hydraulic conductivity of clay mixes.

MATERIAL	PERMEABILITY IN mm/s
Clay	$1.95*10^{-9}$
Clay + 3% Bentonite	$2.80*10^{-10}$
Clay + 5% bentonite	$8.67*10^{-10}$
Clay + 7% bentonite	$9.79*10^{-10}$

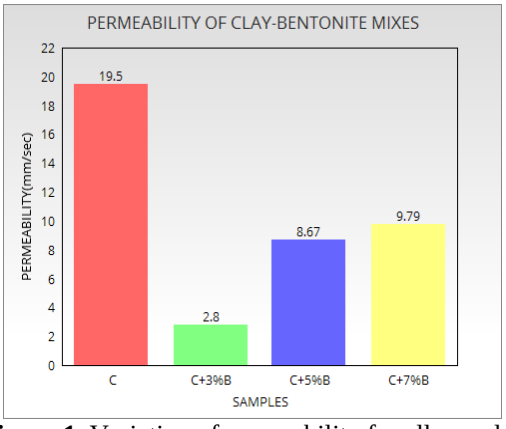

Figure 1. Variation of permeability for all samples of clay-bentonite mix.

From the above graph, it was inferred that, minimum hydraulic conductivity was obtained for the mix containing clay with 3% bentonite. The value was found to be $2.8*10^{-10}$ mm/s which would satisfy the liner criteria.

The bentonite having very low permeability range but with a very less compressive strength will not be able to satisfy the liner specifications. Hence

to increase the compressive strength of the mix, bentonite was mixed with quarry dust at 10%, 20%, 30% proportions and the hydraulic conductivity for all the mixes were analysed from the graph below.

Table 6. Variation in hydraulic conductivity for bentonite-quarry dust mixture

MATERIAL	PERMEABILITY in mm/s
Bentonite	$4.88*10^{-8}$
Bentonite + 10% quarry dust	$5.21*10^{-8}$
Bentonite + 20% quarry dust	$5.89*10^{-8}$
Bentonite +30% quarry dust	$6.31*10^{-8}$

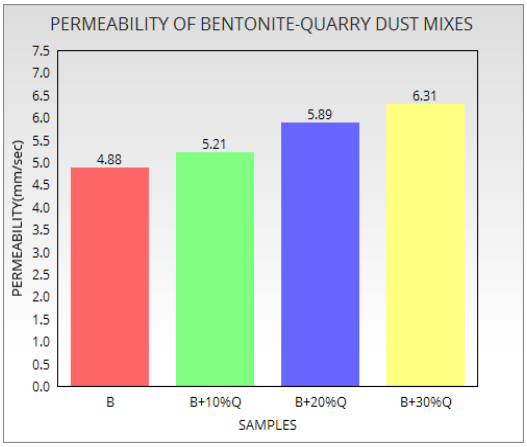

Figure 2. Graph showing permeability of bentonite-quarry dust mixture.

The quarry dust is a highly permeable material and from the graph, it is clear that the hydraulic conductivity of the mix significantly increases with the increase in percentage addition of quarry dust with bentonite.

Therefore, by comparing the values of hydraulic conductivity of both the mixes(clay-bentonite and bentonite-quarry dust), it was inferred that the suitable mix satisfying the liner criteria could be the clay mixed with 3% bentonite.

5.2 Unconfined Compressive Strength

Unconfined compressive strength is the second significant criteria while designing the landfill liners. Since the hydraulic conductivity of the bentonite-quarry dust mix seems to increase with the increase in quarry dust proportion, to obtain a clear idea on the liner specifications, unconfined compressive strength was determined for all the samples. It was found that, among all the clay-bentonite mixes, the greater compressive strength was obtained by clay mixed with 3% bentonite proportion which is equal to 47.28 kN/m^2 .

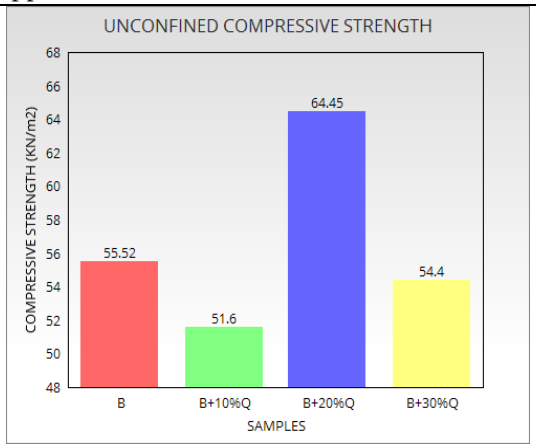

Figure 3. Graph showing variation of unconfied compressive strength for bentonite-quarry dust mixture.

In case of bentonite-quarry dust mix, the highest compressive strength was attained by the 20% mix proportion and the value was found to be 64.45 kN/m^2 as shown above.

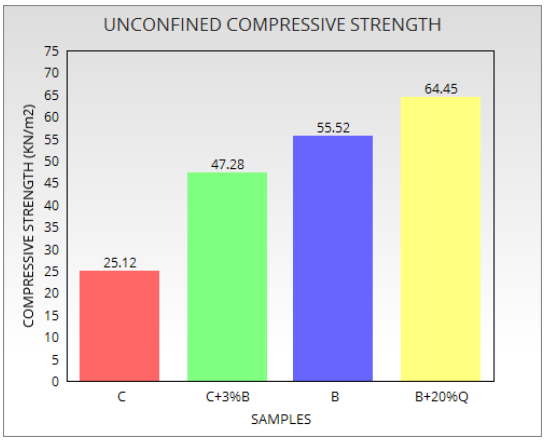

Figure 4. Graph showing comparison of UCS of clay-bentonite and bentonite-quarry dust mixture.

Therefore, while comparing the clay-bentonite and bentonite-quarry dust mixes, the compressive strength of clay blended with bentonite at 3% proportion was found to be very less compared to the bentonite mixed with 20% quarry dust mixture. Hence 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.

VI. CONCLUSION

1) Hydraulic conductivity of the clay when mixed with 3% bentonite was found to be $2.80*10^{-10}$ mm/s and it is the least value among all other clay-bentonite samples.

2) When quarry dust was added to bentonite, the hydraulic conductivity started to increase drastically. Also, the values of all the other samples remained within the range spec6ified for the liner material. Hence to attain a suitable liner material, the unconfined compressive strength was also checked.

3) Thus by determining the unconfined compressive strength of all the samples, it was seen that the bentonite mixed with 20% quary dust mix exhibited the highest value of compressive strength, ie., 64.45 kN/m^2. This value was found to be greater than the clay-bentonite mix at 3% proportion. Hence bentonite added to 20% quarry dust has been chosen as the best proportion for making the landfill liner and its hydraulic conductivity is $5.89*10^{-10}$mm/s.

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