

Suitability of demolition waste as a landfillliner material – an experimental approach.

Idoneidad de los residuos de demolición como material de revestimiento de vertederos: un enfoque experimental

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ABSTRACT

Waste management is the term that refers to the collection, processing, recycling, transport and monitoring of waste products. Various methods of waste management like incineration and recycling have been introduced recently. A landfill liner, or composite liner, is a low permeable barrier, which is laid down under engineered landfill sites. Until it deteriorates, the liner retards migration of leachate, and its toxic constituents, into underlying aquifers or nearby rivers, causing spoliation of the local water. The efficient use of low cost, reliable and durable materials is very much essential for modern practices of construction. Demolition waste is the waste debris obtained from destruction of buildings, roads, bridges or other structures. Bentonite is a type of clay that has an ability to swell and gel when dispersed in water which is used in construction, mainly in excavation and foundation works. Dredged marine clay is a type of clay found in coastal regions across the world. This can be obtained from coastal and marine areas with the help of dredgers. This project includes an investigation into the feasibility of combining demolished waste materials with dredged marine clay and bentonite to study the suitability of a landfill liner by experimental approach. When demolished waste was mixed with dredged marine clay, it did not satisfy the conditions required for the landfill but when combining the demolition waste with bentonite, the criteria was satisfied and the perfect mix was obtained.

Keywords: Dredged marine clay, Bentonite, Demolition waste, Landfill, Landfill liner.

RESUMEN

La gestión de residuos es el término que se refiere a la recogida, procesamiento, reciclaje, transporte y seguimiento de los productos de desecho. Recientemente se han introducido varios métodos de gestión de residuos como la incineración y el reciclaje. Un revestimiento de relleno sanitario, o revestimiento compuesto, es una barrera de baja permeabilidad, que se coloca debajo de los vertederos de ingeniería. Hasta que se deteriora, el revestimiento retarda la migración del lixiviado y sus constituyentes tóxicos hacia los acuíferos subyacentes o los ríos

cercanos, lo que provoca la expoliación del agua local. El uso eficiente de materiales de bajo costo, confiables y duraderos es muy esencial para las prácticas modernas de construcción. Los desechos de demolición son los desechos que se obtienen de la destrucción de edificios, carreteras, puentes u otras estructuras. La bentonita es un tipo de arcilla que tiene la capacidad de hincharse y gelificarse cuando se dispersa en agua que se utiliza en la construcción, principalmente en trabajos de excavación y cimentación. La arcilla marina dragada es un tipo de arcilla que se encuentra en las regiones costeras de todo el mundo. Esto se puede obtener de áreas costeras y marinas con la ayuda de dragas. Este proyecto incluye una investigación sobre la viabilidad de combinar materiales de desecho demolidos con arcilla marina dragada y bentonita para estudiar la idoneidad de un revestimiento de relleno sanitario mediante un enfoque experimental. Cuando los residuos demolidos se mezclaron con arcilla marina dragada, no cumplieron las condiciones requeridas para el relleno sanitario, pero al combinar los residuos de demolición con bentonita, se cumplió el criterio y se obtuvo la mezcla perfecta.

Palabras clave: Arcilla marina dragada, Bentonita, Residuos de demolición, Relleno sanitario, Revestimiento de relleno sanitario.

INTRODUCTION

Waste management is the collection, transport, processing, recycling, disposal and monitoring of waste materials. The term waste management usually relates to materials produced by human activity, and is generally undertaken to reduce the effect of waste on health, the environment or aesthetics. Waste management is also carried out to recover resources from waste materials. Waste management practices differ for developed and developing nations, for urban and rural areas, and for residential and industrial producers. The different methods of waste disposal commonly in practice are landfill, incineration and recycling. Disposing of waste in a landfill involves burying the waste, and this remains a common practice in most countries. Landfills were often established in abandoned or unused quarries, mining voids or borrow pits. A properly designed and well managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials. [Spooner and Giusti,1999]

A landfill is a site for the disposal of waste materials by burial and is the oldest form of waste treatment method. Many landfills are also used for other waste management purposes, such as the temporary storage, consolidation and transfer or processing of waste materials. Landfill is a carefully designed structure built into or on top of the ground, in which trash is separated from the area around it. It may have a slight resemblance to a dump, which is actually an open hole in the ground where trash is buried and where animals often swarm. Dumps offer no environmental protection and are not regulated. But in the case of landfills, they are carefully designed and monitored structures that isolates trash from the surrounding

environment e.g., groundwater, air, rain. This isolation is accomplished with the use of a bottom liner and daily covering of soil. Landfills contain garbage and serve to prevent contamination between the waste and the surrounding environment, especially groundwater.

Landfills are not designed to break down trash, but merely to bury it. That's because they contain minimal amounts of oxygen and moisture, which prevents trash from breaking down rapidly. So, landfills are carefully filled, monitored and maintained while they are active and for up to 30 years after they are closed. Converting landfill gas to energy is how mature landfills deal with the issue of gases created within their facilities. It is an effective means of recycling and reusing a valuable resource. In fact, the U.S. Environmental Protection Agency (EPA) has endorsed landfill gas as an environment friendly energy resource that reduces our reliance on fossil fuels, such as coal and oil [Environmental Protection Agency act 1992]. Leachate is defined as liquid that has percolated through the years of waste material decomposition. For the landfill to absorb the leachate, a barrier known as a landfill liner is provided.

A landfill liner, or composite liner, is a low permeable barrier which is laid down under engineered landfill sites. Until it deteriorates, the liner retards migration of leachate and its toxic constituents, into underlying aquifers or nearby rivers, causing spoilation of the local water. An effective liner in a landfill system should be able to control leachate in terms of movement and thus provides protection to the environment. [Shyla Joseph. and Megha Varghese,2017] The liner is usually constructed by using organic materials such as clay, bentonite etc. The purpose of landfilling is to bury the chemical composition of the waste so that they do not impose any threat to the environment or public health. Compacted clay is generally used for making the landfill liner as it is less permeable. Permeability of compacted clays is usually less than 1×10^{-7} cm/s. In order to lower the permeability of the clay liner, certain materials can be added to it. The most common materials include bentonite, geotextile, geomembrane, micro silica etc. The aim of this project is to study the suitability of demolition waste to be used as a landfill liner material. The following are the objectives of the study.

1. To collect dredged marine clay, bentonite and demolition waste.
2. To analyze the engineering and index properties of these materials.
3. To prepare mixes of 15%, 30%, and 45% of bentonite with demolition waste and to analyze the suitability of mixes to be used as landfill liner.
4. To analyse the effect of leachate on properties of mixes at 15 days, 20 days and 25 days.
5. To propose best suitable mix.

The concept of landfill can be introduced in Kerala, which is devoid of liners. While garbage is disposed in dump yards, the landfills create a much cleaner environment, since the waste is covered with top soil.

MATERIALS AND METHODS

The methodology adopted for this study is as follows:

1. Literature survey - This helps to understand many ideas regarding the project work. Many research papers and journals were collected and they helped in completion of the project work.
2. Collection of materials - The materials for the project work were collected to find out the properties. These include bentonite, demolition waste and leachate.

Bentonite: Bentonite is an absorbent aluminium phyllosilicate clay consisting mostly of montmorillonite. It was named by Wilbur C. Knight in 1898. The different types of bentonite are each named after the respective dominant element, such as potassium (K), sodium (Na), calcium (Ca), and aluminium (Al). [Karunaratne] Bentonite usually forms from weathering of volcanic ash, most often in the presence of water. For industrial purposes, two main classes of bentonite exist, they are sodium and calcium bentonite. The bentonite used for this project was sodium bentonite which is brown in colour.

Table.1. Properties of bentonite

Property	Value
Specific gravity	2.8
Liquid limit (%)	410
Plastic limit (%)	45
Plasticity index (%)	365
Permeability (cm/s)	1×10^{-12}
pH	7.4



Fig.1 Bentonite

Demolition Waste: Demolition waste is waste debris from destruction of buildings, roads, bridges, or other structures. Debris varies in composition, but the major components, by weight, include concrete, wood products, asphalt shingles, brick and clay tile, steel etc. But throughout this project only the plastering portions in the demolition waste of the walls of building were used.



Fig.2. Demolition Waste

Leachate: A leachate is any liquid that, in the course of passing through matter, extracts soluble or suspended solids, or any other component of the material through which it has passed. When water percolates through waste, it promotes and assists the process of decomposition by bacteria and fungi. These processes in turn release by-products of decomposition and rapidly use up any available oxygen, creating an anoxic environment. In actively decomposing waste, the temperature rises and the pH falls rapidly with the result that many metal ions that are relatively insoluble at neutral pH become dissolved in the developing leachate.

In a landfill that receives a mixture of municipal, commercial, and mixed industrial waste but excludes significant amounts of concentrated chemical waste, landfill leachate may be characterized as a water-based solution of four groups of contaminants: dissolved organic matter (alcohols, acids, aldehydes, short chain sugars etc.), inorganic macro components (common cations and anions including sulphate, chloride, iron, aluminium, zinc and ammonia), heavy metals (Pb, Ni, Cu, Hg), and xenobiotic organic compounds such as halogenated

organics, (PCBs, dioxins, etc.).[6]

The physical appearance of leachate when it emerges from a typical landfill site is a strongly odoured black-, yellow- or orange-coloured cloudy liquid. The smell is acidic and offensive and may be very pervasive because of hydrogen, nitrogen- and sulphur-rich organic species.

Table.2. Properties of leachate

Sl no	Parameters	Unit	Method	Result
1	p H @ 25°C	-	IS: 3025 (Pt.11)	8.62
2	Suspended Solids	mg/l	IS: 3025 (Pt.17)	519.7
3	BOD @ 27° C	mg/l	IS: 3025 (Pt.44)	715
4	COD	mg/l	IS: 3025 (Pt.58)	7311
5	Oil & Grease	mg/l	IS: 3025 (Pt.39)	17.6



Fig.3. Leachate collected from Brahmapuram waste treatment plant, Kochi

3. Testing of materials - Various tests were performed to find out the engineering properties of dredged marine clay, bentonite and demolition waste. The tests include specific gravity, constant and falling head permeability tests, Atterberg limits, unconfined compression test, direct shear test and light compaction test.

4. Preparing the mix for the landfill liner layer - After determining the engineering properties, the ratio for the mix is prepared. These mixes are prepared by combining 15%, 30% and 45% of bentonite with 85%, 70% and 55% of demolition waste respectively.

5. Testing of mixes to find out the effect of leachate - The mixes are tested using various

experiments such as permeability test, Atterberg limits, light compaction test and unconfined compression test for 15, 20 and 25 days.

6. Results & Discussion - The best mix is determined based on the landfill requirement criteria, Environment Protection Agency Act, 1992, Ireland. The final values are tabulated and graphs are plotted.

7. Conclusion - The project is concluded by suggesting the optimum mix which satisfy the criteria and also by providing future scope and ideas.

RESULTS AND DISCUSSION

Individual properties of the materials have been checked by experimentation. The perfect mix for the landfill liner is to be found out. The perfect mix should satisfy the basic conditions. There are three main conditions to be satisfied to use any material as a landfill liner. Those conditions are the permeability which is the ability of a material to pass water through it and it should be between 10^{-4} to 10^{-7} cm/s, shear strength which is the strength of material or component against the type of yield or structural failure when the material or component fails in shear and it should be above 200 kPa and the plasticity index which is the difference between liquid limit and plastic limit and it should be between 12-30%.

The sodium bentonite which is very much fine grained in nature was taken. Then plastering portions of the demolition waste which was crushed to smaller particles using mechanical crushers and sieved through 420 micron sieve was combined with the sodium bentonite to make three mixes in such a way that the first mix contains 15% of bentonite and 85% of demolition waste, second mix contains 30% of bentonite and 70% of demolition waste and the third mix contains 45% of bentonite and 55% of demolition waste.



Fig.4. Mixes without leachate



Fig.5. Mixes added with leachate

Table.3. Types of mixes and their nomenclature

Mix	Bentonite (%)	Demolition waste (%)
B15 D85	15	85
B30 D70	30	70
B45 D55	45	55

Atterberg limits: After preparing bentonite and demolition waste mixes containing 15%, 30%, 45% of bentonite and 85%, 70%, 55% of demolition waste respectively, each of these mixes were tested for liquid limit, plastic limit, permeability and shear strength after these mixes were allowed to react with the leachate by about 25 days and the mixes were tested for the above-mentioned properties at 15th day, 20th day and 25th day. After obtaining the properties, a comparison was done on each of these three mixes in their properties and an efficient mix which satisfies all the criteria was found out. The liquid limit (LL) and plastic limit (PL) of the bentonite and demolition waste mixes before the addition of leachate were found out. The liquid limit, plastic limit and the plasticity index values showed an increase when the bentonite percentage increased. The Plasticity Index (PI) was found out by subtracting the plastic limit from the liquid limit. For B15 D85 mix, on the 25th day, the plasticity index was found to be 12.91% and it satisfies the range of 12 – 30% as per landfill liner criteria.

Table.4. Plasticity Index values

Mix	Plasticity Index before the addition of leachate (%)	Plasticity Index after the addition of leachate (%)			Ref Value
		At 15 th day	At 20 th day	At 25 th day	
B15 D85	12.92	12.84	12.9	12.91	12%-30%
B30 D70	52.17	15.85	16.01	16.2	
B45 D55	91.58	17.08	17.21	17.24	

Optimum Moisture Content

Table.5. OMC & Dry density

Mix	Optimum moisture content (%)	Maximum dry density (g/cm ³)
B15 D85	21.4	1.61
B30 D70	21.8	1.64
B45 D55	22.2	1.86

Optimum moisture content was determined as per IS 2720(Part 7):1980 for both the materials and the mixes. The OMC of mixes before the addition of leachate were found out. These values are required for performing unconfined compression test, since the moisture content obtained is used for the mixes.

Permeability: The property of soil by virtue of which water can flow through it is called its permeability. This test is suitable for fine grained Soil. The test can be carried out in a falling head permeability cell or in an oedometer cell. Before starting the flow measurements, the soil sample is saturated and the standpipes are filled with de-aired water to a given level. The test then starts 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. Often, the standpipe is refilled and the test is repeated for couple of times. The permeability using falling head method was determined as per IS 2720 (Part 17): 1986 [IS 2720 (Part 17):1986].

Table.6 Permeability values before and after addition of leachate

Mix	Permeability before adding leachate (cm/s)	Permeability after the addition of leachate (cm/s)			Reference Value
		At 15 th day	At 20 th day	At 25 th day	
B15 D85	1.625×10^{-5}	1.625×10^{-5}	1.62×10^{-4}	1.66×10^{-5}	10^{-4} to 10^{-7}
B30 D70	2.05×10^{-5}	4.5×10^{-5}	4.5×10^{-5}	4.85×10^{-6}	
B45 D55	2.34×10^{-5}	2.522×10^{-5}	3.27×10^{-5}	4.09×10^{-6}	

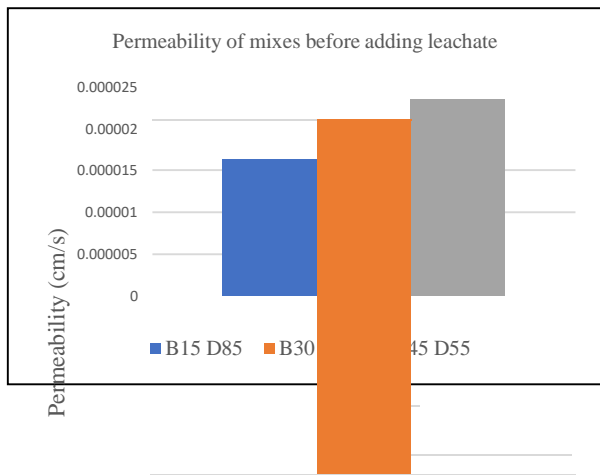


Fig.6. Permeability values of mixes before the addition of leachate.

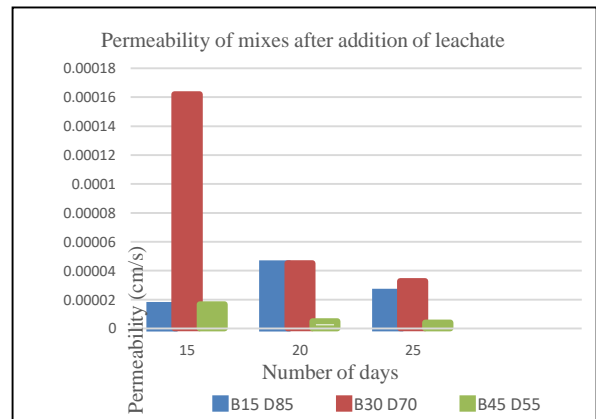


Fig.7. Comparison of permeability values of mixes after addition of leachate

Unconfined Compression test: The unconfined compression test for a landfill liner should be greater than or equal to 200kN. For the bentonite - demolition waste mixes, the values obtained were above 200kN.

Table.7 Shear strength of various mixes before and after addition of leachate

Mix	Shear strength before addition of leachate (kPa)	Shear strength after addition of leachate (kPa)		
		At 15 th day	At 20 th day	At 25 th day
B15 D85	216.609	213.59	214.57	223.278
B30 D70	228.41	208.81	212.55	214.29
B45 D55	269.828	211.14	207.871	207.609

For the project, three mixes for bentonite and demolition waste were prepared. It is clear that the B15 D85 mix is perfect for the landfill liner, since it is the cost-effective mix which satisfies all the criteria mentioned for a landfill liner. The permeability of the B15 D85 mix before the addition of leachate was 1.625×10^{-5} cm/s and the plasticity index was 12.92%. The optimum moisture content obtained was 21.42% and the maximum dry density was 1.611g/cm^3 . The shear strength value was above 200kPa for all mixes.

As conclusion, landfill liners are constructed with very low permeable clay. Local soils are mixed with medium to high plasticity clays like bentonite, kaolinite or similar products to

form soil liners. For a clay liner, the permeability should lie in the range 10^{-4} – 10^{-7} cm/s. The plasticity index for a landfill liner is usually between 12% – 30%. The shear strength should not be less than 200 kPa. The addition of leachate has brought tremendous changes in its geotechnical properties. Soils with low permeability like bentonite, kaolinite, zeolite etc added to demolition waste or even on laterite soil can reduce the overall permeability.

Hence it can be concluded that the mix with 15 % bentonite and 85 % demolition waste can be used as a landfill liner. Hence it is also proved that the demolition waste with bentonite is a suitable material for replacing the clay layer in any landfill liner. The study can be extended by increasing the days of testing after the reaction with leachate since in this project reaction of leachate only up to 25 days is reported. This project can be improved by considering various layers in a landfill liner instead of taking only the clay layer. Also, the efficiency of landfill liner layer with demolition waste can be improved by proper quantification in the demolition waste material since only the plastering portions of the demolition waste was used for the project.

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