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Performance of Kenaf for Landfill Liner System Improvement

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Abstract: A landfill is a site to dispose of materials that threaten the environment, such as leachate, poisons, or greenhouse gases. Leachate is a liquid that can contribute to water pollution if there is a leakage of flow into groundwater sources from landfill waste or other outside water sources. Leachate is a liquid accumulated from landfill waste and other outside water sources. To prevent this leachate from mixing with water resources when it flows into the soil, the behavior of Kenaf (Hibiscus Cannabinus) as a landfill liner system is investigated and understood thoroughly on how permeability properties can increase with the soil. In addition, the herbaceous plants known as Kenaf have beneficial mechanical properties, and they do not pose any threat to the health of human beings. Kenaf has significant potential for commercial usage because of the ease with which it can be cultivated and the low prices at which it can be harvested. In addition, Kenaf can contribute to infrastructure and innovation for economic growth and development (SDG 9.0), where it can reduce the usage of clay linear and simultaneously, increase the Permeability of the soil properties to resist the flow of leaches into the soil. This admixture is gaining popularity as a result of the fact that it has a relatively low cost and is simple to apply. In this investigation, Kenaf was used because of its reputation as a good absorbent product that can hold up to six times its weight and has a leaching capability of less than one percent. The results of laboratory work are presented to demonstrate that this material is suitable for usage in landfills to solve the leachate problem.
Keywords: Landfill, Leachate, Kenaf, Soft soil.

1 Introduction

The landfill is a place to dump materials facing leachate, toxins, and greenhouse gas problems. Leachate is a liquid that accumulates from landfill waste and outside water sources that can contribute to water pollution if leakage of flow occurs to the groundwater sources. Malaysia is a Southeast Asian country where landfills are important, and waste management needs improvement. With a total surface area of 329,700 km2, it comprises Thirteen (13) states and Three (3) federal territories. [1]. Landfilling is preferred in Malaysia over other garbage disposal methods due to its low cost, availability of land, and environmental friendliness. Even though landfilling is common in Malaysia, practically all are known as dump sites [2]. This research focuses on the behavior of Kenaf as liner properties mixed with soft soil for landfill application to overcome the leachate problem. Kenaf is a herbaceous plant with good mechanical properties and is safe for humanity's health. Kenaf has a high potential for commercial use since it grows quickly and has low harvested production costs. This plant is available in various weather conditions, including Malaysia.

Kenaf comprises the Kenaf plant with two major components: the bast (outer) and core (inner). The previous study used Kenaf core as it is also known.

As a good absorbent product up to six times its weight and has less than 1% leaching capability [3]. A landfill liner system is a layer that protects leachate from seeping into soil layers; mixing with groundwater can cause contamination. In this study, the Kenaf plant was mixed with soft soil to improve performance as an absorbent and reduce groundwater contamination due to leachate infiltration. This study evaluates the soil mixer's effectiveness with different percentages of Kenaf core in increasing its capability as an adsorbent material. Hence, using Kenaf can improve landfill quality in terms of environmental factors, life expectancy, and cost efficiency.

2 Literature Review

Landfilling is the most common form of garbage disposal in the world. It is seen as a critical alternative now and shortly, particularly in low- and middle-income nations, because it is the simplest and least expensive technology accessible [4]. The production of municipal solid waste (MSW) is on the rise due to rising populations and rapid

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urbanization, and this is a global issue. Nothing beats landfilling when it comes to getting rid of this type of MSW. In many developing countries, most municipal solid waste (MSW) is disposed of in landfills [5]. Landfills in Malaysia are fast filling up because of the present.

According to government statistics, the daily creation of around 30,000 tons of municipal solid waste [6]. When this is the case, improved landfilling procedures are needed urgently because sustainable landfilling technology has not yet been developed in this country. To dispose of waste in Malaysia, landfilling is the most cost-effective and environmentally beneficial option. Most of Malaysia's landfills are referred to as "dump sites." Over 250 dumping grounds have been documented, with 150 of them still in use and most of them lacking adequate environmental safeguards [7]. One hundred and twenty-eight are not considered hygienic landfills. No bioreactor landfill concept has been used in any sanitary landfills, which are all dry-tomb types.

Table 1: Generation of MSW in major urban areas in Peninsular Malaysia (1970-2010). [8]

Urban centre	Solid waste generated (tons day^{-1})						
	1970	*1980*	*1990*	*2002*	*2006**	*2009**	*2010**
Kuala Lumpur	98.9	310.5	586.8	2754	3100	3387	3489
Johor Bharu (Johor)	41.1	99.6	174.8	215	242	264	272
Ipoh (Perak)	22.5	82.7	162.2	208	234	256	264
Georgetown (P.Pinang)	53.4	83.0	137.2	221	249	272	280
Klang (Selangor)	18.0	65.0	122.8	478	538	588	606
Kuala Terengganu (Terengganu)	8.7	61.8	121.0	137	154	168	173
Kota Bharu (Kelantan)	9.1	56.5	102.9	129.5	146	160	165
Kuantan (Pahang)	7.1	45.2	85.3	174	196	214	220
Seremban (N.Sembilan)	13.4	45.1	85.2	165	186	203	209
Melaka	14.4	29.1	46.8	562	632	691	712

The most popular method of rubbish disposal in the world is landfilling. Because it is the simplest and least expensive technology available, it is a key alternative now and soon, particularly in low- and middle-income countries [9]. Due to financial constraints and lack of expertise, landfills in Malaysia typically lack environmental abatement or technology such as a leachate collection system and lining materials. One of the common methods of landfilling in Malaysia is open dumping. This is due to the lack of funds, and it is one of the easiest methods to implement in Malaysia [2]. This is true because open dumping requires less high-technological equipment and types of machinery to operate. However, in some countries, this method is expensive or comparable to other methods due to government policy and the availability of land. In addition, another influential problem in landfills is their lifespan. According to research by Akyen [10], the average life expectancy of a landfill is between 20 and 30 years. Therefore, it is important to estimate the lifespan of landfills.

Lifespan accurately to explore the risk of acquiring new land for landfills. By estimating the landfill lifespan with proper methodology, local authorities and developers can further arrange proper landfill site proposals and management to prevent unnecessarily wasted land that can be used for other purposes.

According to Razali [11], groundwater quality is also threatened by leachate from municipal landfills, domestic wastewater, and polluted stormwater discharges into mining pits and lakes. The liquid effluent produced by the interaction of rainwater and waste breakdown products is leachate. To transform waste materials into a wide variety of compounds that are then transferred to percolating rainwater, a combination of physical (precipitation, percolation, runoff, infiltration, evaporation), chemical (oxidation, complexation, precipitation, dissolution), and biological (acetogenesis, methanogenesis, nitrification) processes are used [12]. Figure 1 below shows the conceptual model of leachate generation in landfills. When landfill leachate is not properly collected, processed, or disposed of, it can pollute soil, surface water, groundwater, and human health. Ammonia, heavy metals, and other organic compounds are in considerable concentrations [12]. Leachate from landfills can harm the environment and humans, as portrayed in Figure 1. Therefore, using Kenaf as a liner for landfills can protect the earth from being polluted with leachate, thus causing harm to human life (SDG 15).

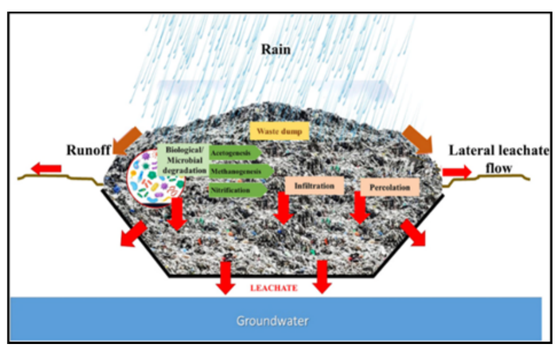

Fig. 1: Conceptual model for leachate generation. [12].

3 Research Methodology

To achieve the objectives of this research, a series of laboratory tests were carried out to produce a comprehensive and reliable result that can be presented systematically. All the tests were conducted based on British Standards as references. This testing procedure can be separated into two stages.

The first stage, the preliminary test, assesses the soil's physical characteristics, while the second stage is the engineering test.

The samples were taken at Pengkalan Nelayan Sementa, Klang, Selangor, with coordinates of 3°405'79.92"N; 76°22'73.75"E. This area is covered by soft soil near the Sungai Sementa Besar riverbank. The disturbed sample was taken and placed in polyethylene bags. To avoid the loss of moisture content, the bags containing the sample must be carefully tied and brought back to the soil laboratory as soon as possible. Laboratory tests were then conducted using appropriate quantities of the soil sample collected. Important physical and engineering properties were determined using appropriate types of equipment in the laboratory.

To obtain the Kenaf plant, with the cooperation of Lembaga Kenaf and Tembakau Negara (LKTN) based in Klang Valley, the sample was collected about 5 kg in the form of fiber. This Kenaf plant was obtained within the combination of core and fiber and carefully prepared to dry by natural drying using direct heat from the sun. The fiber cannot be dried in over-dried because it will deteriorate the natural characteristics of the plant. Since the Kenaf was obtained with a combination of core and fiber, the plant was properly cut with a 1.0 cm to 2.0 cm range to obtain a standardized sizing for preparing the materials. A special apparatus was designed consisting of a wooden block and comb attached with a pair of nails, which is used to ease cutting the kenaf fiber and ensure standard size measurement was obtained. Each subsequent cut was measured with a plastic ruler measuring the 1.0 to 2.0 cm range for each successive cut, as shown in Fig. 2 below.

Fig. 2 : Process of cutting Kenaf fiber.

After that, the kenaf plant was mixed with a soft soil sample with an average optimum moisture content (OMC) of 12%. Mixing with OMC of 12% is the best state condition of the sample in minimum void and maximum shear strength. The value of OMC of 12% is used with the 2 kg soft soil sample for every percentage (%) of Kenaf for testing. In this procedure, about 4, 8, and 12 % Kenaf is mixed with the soft soil sample, as shown in Fig 3.

Fig. 3: Sample preparation of Kenaf Fiber mixing with soft soil sample.

4 Results and Discussions

Based on the physical properties test that had been done, the soil is classified as clayey SILT of Intermediate Plasticity, MI. Results reveal that for the wet sieving test, the soil passing through the sieve of 0.063mm is about 97.3 %, while about 2.7 % was retained on the sieve. The moisture content of the specimens is 68.5 %, while the specific gravity is 2.33. In addition, the Liquid Limit of the specimens is 34 %, with Plastic Limit is 28 %, and the Plasticity Index is 6 %. Table 2 shows the physical test data conducted with the compaction test parameters, which are OMC and MDD, while Fig.3 shows the Cone Penetration Test and Compaction Curve consecutively.

Table 2: Index Properties of Soft Soil Sample.

Soil properties		Value
Particle size distribution	Gravel (60 mm - 2 mm)	0 %
	Sand (2 mm – 0.06 mm)	2.7 %
	Silt (0.06 mm – 0.002 mm)	75,2 %
	Clay (< 0.002 mm)	22.1 %
Specific gravity		2.33
Moisture content		68.5 %
Atterberg limits	Liquid Limit (L.L.)	34.0 %
	Plastic Limit (P.L.)	28.0 %
	Plasticity Index (P.I.)	6.0 %
Compaction properties	Maximum dry density (MDD)	1.59 Mg/m^3
	Optimum moisture content (OMC)	12.0 %

On the other hand, engineering properties, specifically from the permeability test, reveal that mixing with Kenaf and soft soil can increase the soil's permeability properties, which can be applied as a liner system in the sanitary landfill. Thus, it can slow down the flow of leaches throughout the soil and prevent polluting the river basin used to supply raw water to consumers. Nevertheless, Permeability through soil is important for designing a landfill site and investigating contaminated land.

Permeability is a measure of the ease with which water flows in soils. The permeability coefficient (k) may be defined as the flow velocity produced by a hydraulic unity gradient. 'k' is generally expressed in cm/sec or m/sec [13]. The coefficient of Permeability, k, can be measured using field tests or tests conducted in the laboratory known as the Falling or Constant Head Test. Results of the permeability properties mixing with different percentages (%) of Kenaf fiber are tabulated consecutively in Table 3.

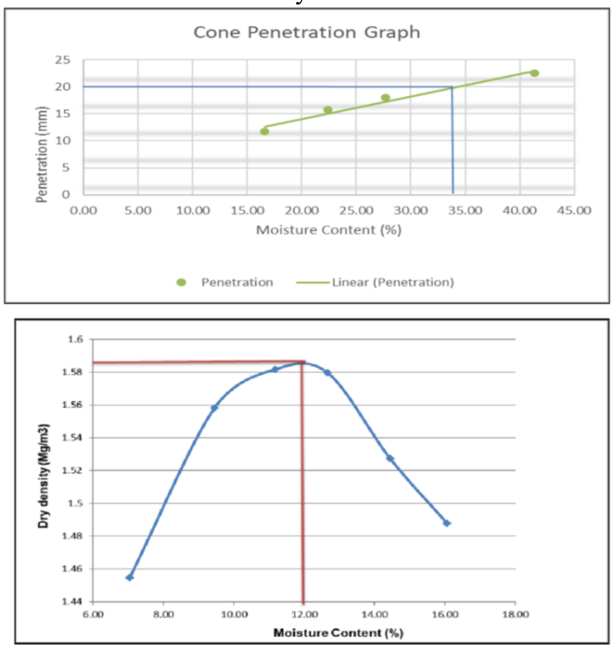

Fig. 4: Cone Penetration and Compaction curves.

Table 3: Permeability properties Vs (%) of Kenaf fiber

Test No.	Standpipe No.	a cm²	h_1 cm	h_2 cm	t sec	A cm²	L cm	k cm/sec
1	1	0.01	52.3	51.5	1200	78.54	7.5	1.227×10^{-8}
2	2	0.05	48.5	48	2700	78.54	7.5	1.833×10^{-8}
3	3	0.2	52.2	49.4	8700	78.54	7.5	1.21×10^{-7}
							Average	5.054×10^{-8}

Test No.	Standpipe No.	a cm²	h_1 cm	h_2 cm	t sec	A cm²	L cm	k cm/sec
1	1	0.01	16.5	12.3	2400	78.54	7.5	1.169×10^{-7}
2	2	0.05	62.7	59.6	4800	78.54	7.5	5.044×10^{-8}
3	3	0.2	62.3	59.5	8100	78.54	7.5	1.084×10^{-7}
							Average	9.192×10^{-8}

Test No.	Standpipe No.	a cm²	h_1 cm	h_2 cm	t sec	A cm²	L cm	k cm/sec
1	1	0.01	61	59.6	1320	78.54	7.5	1.68×10^{-8}
2	2	0.05	55.8	54.9	1800	78.54	7.5	4.313×10^{-8}
3	3	0.2	60.8	60	3600	78.54	7.5	7.27×10^{-8}
							Average	4.34×10^{-8}

Table 3 shows the coefficients of Permeability, k, for 4, 8, and 12 % kenaf mixing with soft soil.

Results reveal that the control specimen's permeability coefficient, k, was about 3.074 x 10-6 cm/sec. This is an average permeability coefficient value, k, for normal sanitary landfills with soil properties. However, the Kenaf admixture blends with soft soil can improve the permeability value where the coefficient of Permeability, k, started to increase for about 5.054 x 10-8 cm/sec for an additional 4 % of Kenaf fiber. Additionally, when the percentage of Kenaf increases to 8 % mixing, the value of the coefficient of Permeability, k, tremendously increases to 9.192 x 10-8. When mixing with Kenaf increases to 12 %, the coefficient of Permeability, k, remains constant at the same value of 4.34 x 10-8. Overall, results indicated that water flow is getting slower in soil samples with the addition of Kenaf, which is a good direction to show that Kenaf can be important as an element to slower the flow of leaches into the soil. From this analysis, it can be concluded that the percentage % of Kenaf at 8% is the most optimum value to be used.

As a result, it showed that this mixing value gave a better value. According to the coefficient of Permeability, k chart from Quadri [14], as shown in Table 4, the value of k for the control specimen was 3.074 x 10-6 cm/sec, which is in the condition of Silt and Clay mixture where these properties having very low degree of Permeability and poor to impervious drainage characteristics. However, with the addition of Kenaf mixing with a soft soil sample, the values increase tremendously for all the coefficients of Permeability, k. Thus, this permeability coefficient, k, is considered very good and achieves this research objective.

Based on the coefficient chart, the soil added with Kenaf admixture will have a very low impermeable degree of Permeability and impervious drainage characteristics, which are very good for implementing in landfill design to act as a second layer of defenses to prevent the infiltration of leachate into the groundwater Table 4.

Table 4: Drainage characteristics Vs k Coefficient

Soil type	Degree of Permeability	K cm/sec	Drainage Characteristics
Clean Gravel	High	1-10	Good
Clean Sand, Sand with a Gravel mix	Medium	$1 - 10^{-3}$	Good
Fine sand, Silt	Low	$10^{-3} - 10^{-5}$	Fair – Poor
Sand – Silt – Clay Mixture	Very low	$10^{-4} - 10^{-7}$	Poor – Impervious
Homogeneous Clay	Very low impermeable	Less than 10^{-7}	Impervious

The coefficient of Permeability, k, of a landfill is the most important factor in determining the amount of leachate, and it is strongly related to the waste's depth and unit weight.

Numerous researchers studied the permeability coefficient in the field and laboratory [15]. From this study, a few findings from previous researchers were compared to the value of the coefficient of Permeability, k at 8 % of Kenaf, to evaluate the effectiveness in preventing the leaches flow into the soil capillary and compared to other rates of Permeability of Municipal Solid Waste (MSW) in the landfill area. Table 5 summarizes test results in terms of coefficient of Permeability, k.

Table 5: Permeability of MSW in Landfill in the Previous studies

Source	Coefficient of Permeability, *k* (cm/sec)	Location of soil sample taken for the testing
(Yang et al., 2016) [15]	1.0 x 10^{-7}	Jiangcungou Landfill, Shaanxi, China
(Penmethsa, 2007) [7]	6.11 x 10^{-5} to 5.4 x 10^{-6}	Keele Valley Landfill, Toronto, Canada
(Kuokkanen et al., 2008) [16]	1.0 x 10^{-7} to 1.0 10^{-8}	Stora Enso Oyj Oulu Landfill, Northern Finland.

Results from the table above indicate that 8 % of Kenaf gave more promising outcomes as the results for Permeability is 9.192 x 10-8 cm/sec, which is very low compared to other permeability values tested in landfills in previous studies. Adding 8% of Kenaf can ensure that leachate is almost impervious, which will help the groundwater table from contamination due to infiltration of leachate.

5 Conclusion

Kenaf is a type of plant that can be utilized for an admixture to change the properties of the soil, where it can be a more effective filter to prevent groundwater contamination. Therefore, converting natural sources into construction products can improve the diversity of crop function per the National Commodity Policy to make the versatile plant a contributor to the national economy by the year 2020.

As a potential absorbent material, Kenaf admixtures have been subjected to several different laboratory tests. According to the findings of physical and engineering properties, the percentages of kenaf admixture in fine soil tend to affect the soil's fluidity index, which tends to increase as the percentages increase. According to the findings from these studies, an admixture of soft soil with 8 % Kenaf was the most effective ratio for layer prevention material in landfills.

All the objectives for this research have been obtained and analyzed. The following conclusions are based on the experiments and analysis that were conducted:

i. The physical properties of soft soil had been obtained through laboratory testing, and soft soil can be classified as clayey SILT with Intermediate Plasticity.

ii. The maximum dry density (MDD) and optimum moisture content (OMC) were obtained through a standard proctor test called the Compaction Test. The OMC value of 12 % was used to refer to the water content to produce a compaction procedure mixing with Kenaf.

iii. The Permeability of soft soil mixed with 4 %, 8 %, and 12 % of Kenaf was analyzed, and the optimum value obtained for the permeability testing was 8 % of Kenaf.

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