ANALYSIS EFFECT OF LEACHATE ON SANDY CLAY SOIL

I Nyoman Aribudiman[1*], I Wayan Redana[2], Kadek Diana Harmayani[3], Yenni Ciawi[4]

[1]Doctoral Study Program of Engineering Science, Faculty of Engineering, Udayana University
Kampus Sudirman, Denpasar-Bali, Indonesia.
[2,3,4] Civil Engineering Department, Faculty of Engineering, Udayana University
Kampus Sudirman, Denpasar-Bali, Indonesia.
*Email: naribudiman@unud.ac.id

Abstract- Soil as a place of establishment of building can be very vulnerable to experiencing changes, especially by the influence of surrounding environment. Leachate has definition of waste water that formed from waste seepage water roomates is Often found in a dumpsite. The difference in the effect of leachate levels on soil characteristics soil changes may results. The aim of the research is to know the effect of leachate on soil characteristic in landfill Temesi, Gianyar. This is at the sampling site Because there is untreated leachate pollutes soil roomates around dumpsite. In testing the soil characteristics in the form of physical properties, mechanical properties, and soil permeability, the sample collected from the landfill leachate Temesi and determined by level variations with a percentage of 0%, 20%, 40%, 60%, 80% and 100% to water added to sandy clay soil with Atterberg limits test to Obtain Data on soil physical properties in the form of liquid limit values, plastic limits, and shrinkage limits. The CD (Consolidated Drained) triaxial tests to Obtain Data on soil mechanical properties in the form of cohesion values (c) and internal friction angle (φ). The test was Carried at Soil Mechanics Laboratory of the Faculty of Engineering Udayana University. The result of Atterberg limits test with 0% to 100% leachate Increased by 39.91% to 57.18% for liquid limit, 22.81% to 43.63% for plastic limit, and 34.23% to 50.41% for shrinkage limit with average increase of 8.65% for liquid limit , 18:26% for plastic limit, and 9:45% for shrinkage limit. For the result of CD triaxial tests with 0% to 100% leachate Decreased by 5.6 ° to 12.2 ° internal friction angle (φ) and 0. 349 kg/cm^2 to 0249 kg/cm^2 for cohesion values (c) with average decline 10.82% for internal friction angle (φ) and 5.73% for cohesion value (c). The permeability value with 0% to 100% leachate Decreased by 0.000163 cm/seconds to 0.000075 cm/seconds with average decline 10.79%.

Keywords: sandy loam, soil characteristics, leachate, Consolidated Drained

I. INTRODUCTION

Gianyar regency which is one of the administrative areas in the province of Bali, with an area of 368 km^2 and a population density of 1,232 inhabitants/km^2 [1]. The growth rate of the population from year to year would also be accompanied by an increase in the volume of waste. So if this problem is left unchecked it will cause new problems both environmental issues and social issues, such as the pungent odor around the landfill, and the emergence of various epidemic diseases that harm society.

Stacking solid waste in the landfill area with a large volume Temesi create new problems in the form of leachate. The impact of leachate contamination there are various kinds of impacts on aquatic life, impact on groundwater quality, health impacts, and impacts on environmental aesthetics.

Leakage of leachate into the ground due to the failure of processing leachate will certainly have an impact on the soil characteristics. Leakage of leachate into the soil depends on the soil type, for types of clays time required leachate to react relatively long compared to the land of sand and silt caused by the permeability of clay smaller than sand and silt so that the permeation of leachate require considerable time. Leachate has the main content of the form: BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), and across a range of organic and other inorganic.

Based on these conditions need to perpetration of landfill leachate influence research Temesi Gianyar on sandy loam soil to changes in soil characteristics.

II. LITERATURE REVIEW

A. Soil

Soil is a natural phenomenon that occurs on the land surface layer, forming a zone (zone) called pedosphere, composed of a loose mass of rock mixed fractions and lapukan organic material. In pedosphere overlap between the lithosphere, atmosphere, hydrosphere and biosphere, so land can be called a cross-border phenomenon among various natural phenomena of the earth's surface [2].

Soil is a complex material composed of a large rock weathering. Soil formation is a geological cycle that continuously occur on the surface of the soil. This cycle includes; weathering, transportation, deposition or plating, and so on, which are influenced by weathering and weather [3].

B. Sandy Clay Soil

Sandy clay soil contains mostly clay particles and contains little sand and other sediments that make up the composition of the soil. Sandy loam soil is determined by particle size granules and liquid limit levels in the soil. Sandy clay soil has a fine grain with 50% or more of its structure qualify strain no. 200 and the value of their liquid limit of 50% or less [4].

C. Leachate

Leachate is caused by mixing a solution of rainfall runoff water (either through infiltration or percolation process) with rotting garbage and contain very fine suspended substances and pathogenic microbes. Leachate has a cohesive properties and high viscosity that can affect the soil directly or indirectly, so any content of the leachate would affect the characteristics of the soil.

D. Identification of Sandy Clay Soil

In identifying the land, there are two ways: Identification of Mineralogy and identification with Indirect [5]. For such identification is necessary to test the physical and mechanical properties of soil is done by testing specific gravity (Gs), consistency limits (Atterberg), free compressive strength test (UCT), moisture content, compaction with standard proctor, permeability and triaxial test.

III. RESEARCH METHOD

A. Determining Object Study

The study was obtained from the study of sandy loam soil in the landfill area Temesi Village, Gianyar. For leachate samples taken directly used bottles from the landfill leachate tank Temesi, Gianyar.

B. Data Collection

Collecting data from this study is the collection of primary data is data collected based on the results of research conducted in the laboratory of Soil Mechanics Department of Civil Engineering, Engineering Faculty, Udayana University and the Laboratory of Analytical Unit Kampus Bukit Jimbaran.

C. Data collection technique

Experiments were conducted on the leachate influence research on the characteristics of sandy loam soil with leachate preparing soil samples and then mixed with a pre-determined percentage. Next will compare sandy clay soil characteristics without leachate as control variables with the characteristics of sandy clay soil with leachate as experimental variables.

D. Flowchart of Research

The research activity is based on research methodology that includes data collection, testing samples and forwarded to the conclusion. There are five (5) stages penelitikan conducted as follows:

1. Preliminary stages, ie determine the studies and sampling to be used as a specimen in the study mentioned in the landfill area Temesi, Gianyar and leachate in the landfill Temesi. Gianyar.
2. Then the study of literature by studying the method to be implemented in the study.
3. Tools and materials are prepared in the laboratory test
4. Then Do research the characteristics of sandy loam soil and landfill leachate are in Temesi. Further research on the characteristics of the leachate influence sandy loam soil.
5. After the study, performed the analysis of the research results.

IV. RESULTS AND DISCUSSION

A. General

This study sampled soil in landfill Temesi, Temesi, Gianyar. The results of this study are expected to provide some information regarding the characteristics of the soil in the landfill area Temesi Gianyar, the physical properties of the soil, and to obtain information about changes in soil characteristics in the presence of leachate. Research conducted at the Laboratory of Soil Mechanics Civil Engineering Program Faculty of Engineering, Universitas Udayana and Analytical Laboratory Unit Bukit Jimbaran Campus. Soil samples in this study were mixed liquor with high levels of 0%, 20%, 40%, 60%, 80% and 100%.

B. Soil Water Content

The test results showed that the soil water content in the soil Temesi landfill has a moisture content of 35.89% for disturbed soil samples, 36.09% for undisturbed soil samples, and 38.88% for the sample undisturbed leachate soil.

C. The Content of Leachate

Leachate or wastewater used in the study was the leachate from the landfill Temesi. The leachate taken from the tank leachate in the landfill Temesi. The following Table 1 shows the results of leachate content test.

Table 1. Testing results the content of leachate

Parameter	Unit	group	
		I	II
temperatures	C	38	40
TDS	mg / L	2000	4000
TSS	mg / L	200	400
pH	-	6.0 to 9.0	6.0 to 9.0
BOD5	mg / L	50	150
COD	mg / L	100	300
Oil and fat	mg / L	10	20

Source: Laboratory Analytical Unit Bukit Jimbaran Campus (2019)

Table 2 Wastewater quality standard business and/or activities domestic.

No.	Parameter	Method	Unit	result
1	DO	Titrimerti	mg / L	0.221
2	BOD5	Titrimerti	mg / L	989
3	COD	Titrimerti	mg / L	3920
4	TSS	gravimetry	mg / L	2989.26
5	TDS	gravimetry	mg / L	260
6	Oil	gravimetry	mg / L	40
7	pH	pH Metri	-	6.48

Source: Regulation of the Minister of Environment 5 2014

From the results in Table 2, when compared with the table of sweets Environment no. 5 of 2014 [6] on Wastewater Quality Standard in Table 2, it can affect the characteristics of the soil due to contaminate soil if processing tools are in the landfill leachate Temesi already broken and not maintained.

D. Sieve analysis

The size of granules in the soil was determined by wet sieve analysis. In this test sieve sieve size sorted from No. 4 to 200. Land that pass the sieve No. 200 and accommodated in the pan will be tested again using a hydrometer analysis. In Table 3 are then translated graphically in Figure 1.

Table 3. Sieve Analysis Test Results

Sieve size		Percentage (%)	
No. Filter	mm	bated	Get away
4	4.75	0	100.00
10	2	0.98	99.02
20	0.85	0.74	98.28
40	0.425	1:17	97.11
60	0.25	1:26	95.85
80	0.18	0.82	95.03
100	0.15	0.65	94.38
200	0.075	6.74	87.64
pan		87.64	0:00

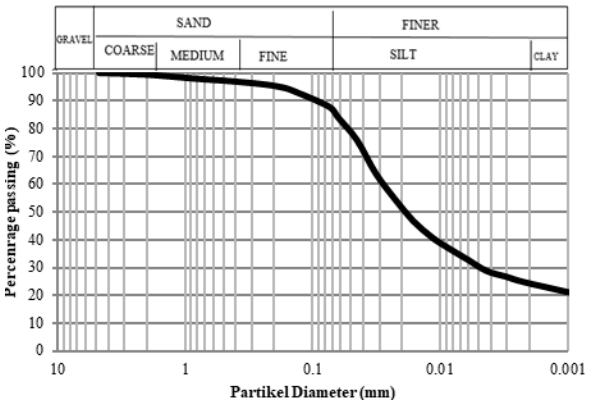

Figure 1. Graph sieve analysis and hydrometer

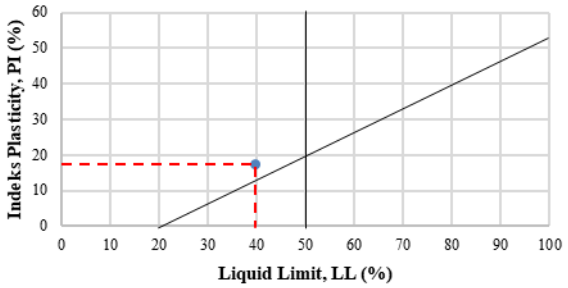

Figure 2. Diagram plasticity

Based on the classification USCS, the number of gradations percentage based on Figure 2 are as follows:

1. Sand: 12:46% (grain diameter> 0075 mm)
2. Silt: 61.81% (grain diameter of 0.074 mm - 0.002 mm)
3. Clay: 25.73% (grain diameter of 0.002 mm)

Soil sieve No. 200 has a percentage of 87.64% and based on Figure 3, liquid limit soil was 39.91%, which is less than 50% with an index of 17.10% ground plastic that shows the type of sandy loam soil was organic with low plasticity (CL).

E. Specific Gravity

The results of the testing showed that the density of land adjacent to the landfill Temesi has a specific gravity of 2.68 were classified as non organic clay which has a specific gravity value of 2.68 to 2.75 [4].

F. Atterberg Limits

Tests conducted at the Soil Mechanics Laboratory yield limit value - limit Atterberg as in Table 4.

Table 4. Results of Testing Analysis Atterberg limits

Lindi Percentage (%)	Liquid Limit (LL) (%)	Plastic Limit (PL) (%)	Limit Losses (SL) (%)	Plastic Index (PI) (%)
0	39.91	22.81	34.23	17.10
20	45.38	26.59	38.76	18.78
40	50.80	36.11	40.62	14.69
60	54.16	38.36	47.07	15.80
80	56.17	39.78	48.40	16.39
100	57.18	43.63	50.41	13.56

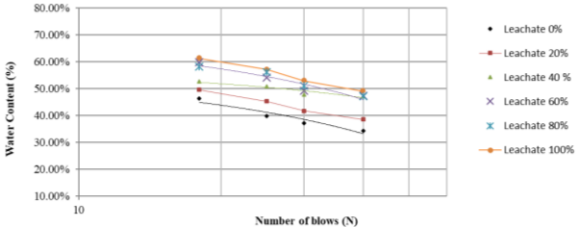

Figure 3. Graph relationship between water content additions and number punch on liquid limit

Atterberg limits the increase in value from 0% to 100% of leachate obtained at 43.27% with an average increase of 8.65% to the value of the liquid limit, 91.28% with an average increase of 18.26% to the value of plastic limit, and 47.27% with an average increase of 9.45% to the value of shrinkage limit. From the result of this increase, based on the statistical results with SPSS shows that the results obtained are significant with the increase of the equation $y=41.88+0.174x$ for liquid limit value, $y=21.124+0.208x$ for the value of plastic limit, and $y=33.896+0.18x$ for shrinkage limit value. This occurs because of the influence of leachate containing oil into the slit pore made more slippery soil particles resulting in the increase. Soil plasticity index overall average above 11% so that the soil is classified into types of sandy loam.

G. Soil compaction (Standard Proctor)

In a standard compaction test (standard proctor) in leachate percentage variation of 0%, 20%, 40%, 60%, 80%, and 100% shown in the results in Table 5.

Table 5. Results of Analysis of Compaction Test Standard (Standard Proctor)

Lindi Percentage (%)	γd (gr / cm^3)	Moisture opt. (%)
0	1.33	29.74
20	1.32	29.89
40	1.29	30.99
60	1.27	32.31
80	1.26	38.39
100	1.25	38.65

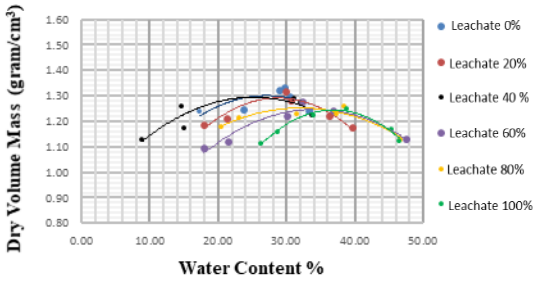

Figure 4. Graph relationship between water content addition to the mass volume dry (γd) of soil

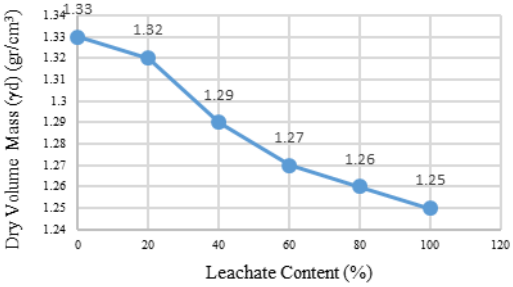

Figure 5. Graph relationship between addition of leachate against dry volume weight (γd) of soil

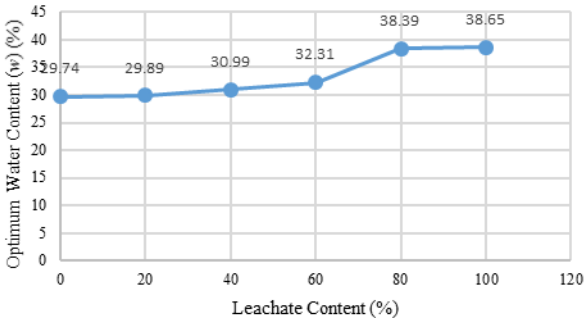

Figure 6. Graph Relationship Between Addition of leachate Against Optimum Moisture Content (w) Land

Defend on Figure 4, Figure 5, Figure 6 the test results of compaction dry density decreased by 6.02% with an average reduction of 1.20% and an increase in the optimum water content of 29.96% with an average increase of 5.99% from the leachate levels of 0% to 100%. From these results, based on the statistical results with SPSS program showed that the significant results obtained by the equation of y=1.33-0.000857x for the weight of the dry volume (γd) of soil and y=28.23+0.102x for optimum water content. This happens because the oil content in leachate reduce the stickiness of the soil so dry volume weight of soil and improve its optimum levels.

H. Unconfined Compression Test

Testing of undisturbed soil, the soil is distinguished by soil with leachate and without leachate. The test results undisturbed soil shown in Figure 7 and Table 6.

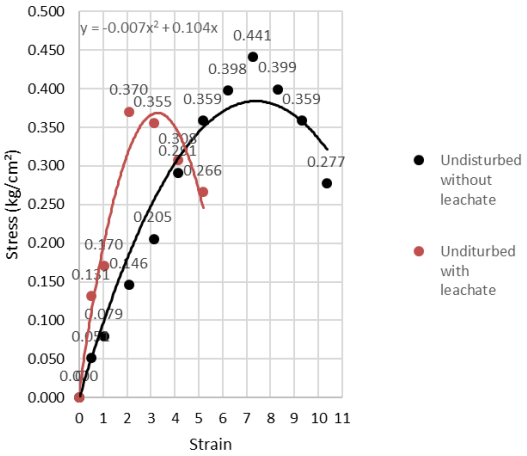

Figure 7. Graph relation between strain and stress at UCT test with the undisturbed soil

Table 6. Results of testing analysis unconfined compression test

Parameter	Qu Compressive Strength (kg / cm²)	Cohesion C (kg / cm²)
without Leachate	0.441	0.221
with Leachate	0.370	0.185

From the test results free compressive strength test performed on undisturbed soils, A decrease in shear strength value of 16.09% and the cohesion of 16.29% due to the influence of liquor. This happens because the oil content in the leachate entrance slit pore make the soil particles slicker, reducing soil compressive strength (qu) and cohesion (c).

From the results of artificial soil (remolded), the soil sample was added to the leachate 0%, 20%, 40%, 60%, 80%, and 100% at the optimum moisture content has been determined. Here in Table 7 artificial soil test results (remolded).

Table 7. Results of testing analysis unconfined compression test remolded sample

Lindi Percentage (%)	Qu Compressive Strength (kg / cm2)	Cohesion c (kg / cm2)
0	.793	0,397
20	0.758	0.379
40	0.685	0.342
60	0.663	0.332
80	0.586	0,293
100	0.529	0.264

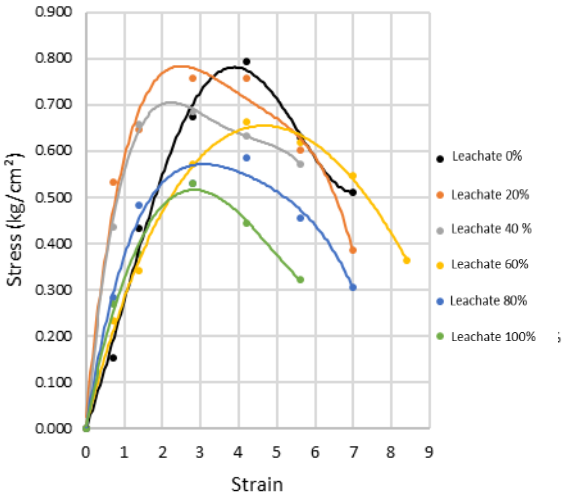

Table 8. Graph relation between strain and stress at UCT test with remolded sample

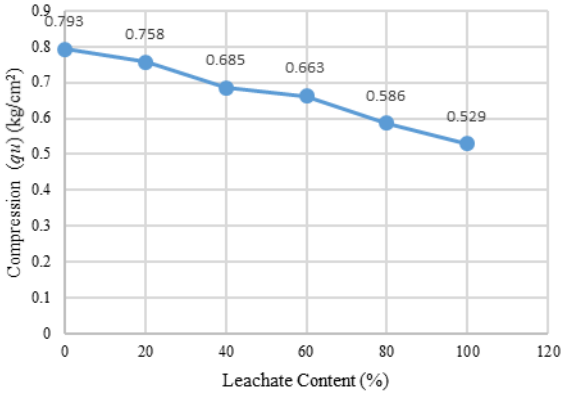

Figure 9. Graph relationship between compressive strength (qu) against the addition of leachate

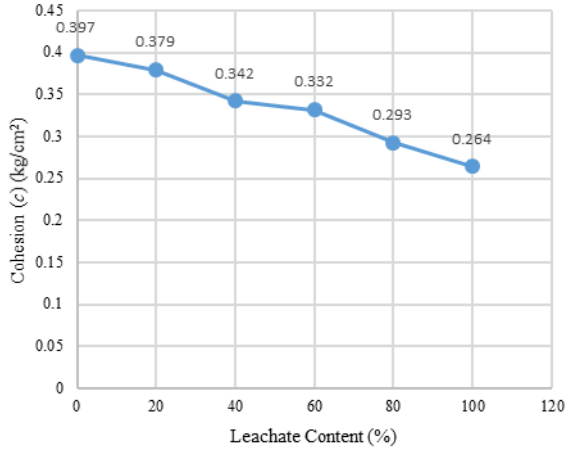

Figure 10. Graph relationship between cohesion (c) against the addition of leachate

The compressive strength of the test results performed on the free artificial soil, decrease the compressive strength of 33.29% with an average decrease of 6.66% and the cohesion of 33.50% with an average decrease of 6.70% due to the addition leachate from 0% to 100%. From these results, based on the statistical results with SPSS program showed that the significant results obtained by the equation of $y=0.802-0.002654x$ for the compressive strength (*qu*) of soil and $y=0.401-0.001333x$ for the value of cohesion (*c*). Just like in undisturbed soils, this happens because the oil content in the leachate entrance slit pore make the soil particles slicker, reducing soil compressive strength (*qu*) and cohesion (*c*).

I. Permeability

Tests conducted on soil samples with the addition of leachate at 0%, 20%, 40%, 60%, 80% and 100%. Needs its moisture content adjusted to the required water content sourced from standard proctor test results. Permeability results shown in Table 8.

Table 8. Results of permeability testing analysis

Leachate Percentage (%)	Koef. Permeability (cm / sec)
0	0.000163
20	0.000131
40	0.000109
60	0.000095
80	0.000088
100	0.000075

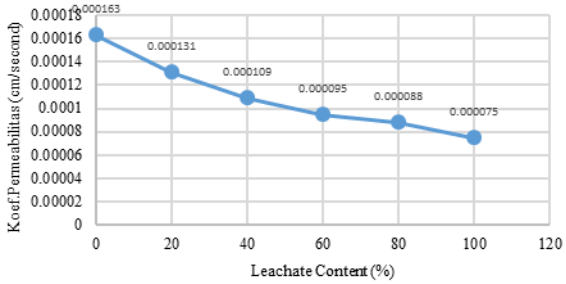

Figure 11. Graph addition relationship between soil permeability coefficient against leachate

From the data in Table 8 and Figure 11 shows the decrease in permeability of 53.99% with an average reduction of 10.79% in a soil sample mixed with leachate from 0% to 100%. This is due to the influence of liquor with high viscosity properties thereby reducing the permeability of the soil. Based on the statistical results with a model of SPSS showed that the results obtained are significant by the equation of $y=0.000152-0.83286.10^{-7}x$.

J. Triaxial Test (Consolidated Drained (CD))

Testing of undisturbed soil (undisturbed), the soil is distinguished by soil with leachate and without leachate. The test results undisturbed soil are shown in Table 9.

Table 9. Analysis CD triaxial testing undisturbed soil

Parameter	In the Slide angle (φ) (°)	Cohesion (C) (kg / cm2)
without Lindi	8.6	0.271
with Lindi	6.1	0.237

CD triaxial test results performed on undisturbed soils, a decline of 29.07% friction angle and cohesion of 12.54% due to the influence of liquor. Just like testing UCT, this happens because the oil content in the leachate entrance slit pore made more slippery soil particles thereby lowering the shear angle in the soil (φ) and cohesion (c).

In testing the artificial soil (remolded), a soil sample was added leachate 0%, 20%, 40%, 60%, 80%, and 100% and the optimum water content has previously been determined. CD triaxial test results of artificial soil (remolded) shown in Table 10.

Table 10. Results of Analysis CD triaxial testing of Remolded Soil

Lindi Percentage (%)	In the Slide angle (φ) (°)	Cohesion (C) (kg / cm2)
0	12.2	0,349
20	10.7	0.342
40	10.1	0.306
60	8.6	.278
80	6.5	0.254
100	5.6	0,249

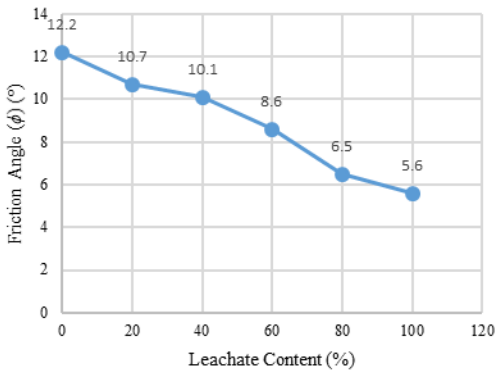

Figure 12. Graph addition leachate against relationship between friction angle (φ) in soil

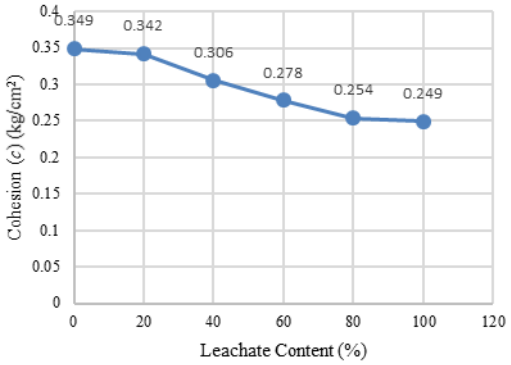

Figure 13. Graph addition leachate against relationship between cohesion (c) in soil

Based on CD triaxial testing conducted on samples of artificial soil, there is a decrease in the friction angle of 54.09% with an average decrease of 10.82% and amounted to 28.65% of cohesion with the average decrease of 5.73% as a result of the addition of leachate. From these results, based on the statistical results with SPSS program results obtained indicate that significant by the equation of for the value of the shear angle (φ) of land and for value of cohesion (c). Just like in undisturbed soils, this happens because the oil content in the leachate entrance slit pore made more slippery soil particles thereby lowering the shear angle in the soil (φ) and cohesion (c).

K. Recapitulation Leachate Testing Results Effect on Changes in Soil Characteristics

The test results of leachate influence on sandy loam soil mixed liquor with a variation of 0%, 20%, 40%, 60%, 80% and 100%. summarized in Table 11 and Table 12.

Table 11. Summary of Results of Testing Soil (undisturbed)

Parameter	without Lindi	with Lindi
Compressive Strength (kg / cm2)	.441	.370
Cohesion (UCT) (kg / cm2)	0.221	0.185
Cohesion (triaxial) (kg / cm2)	0.271	0.237
In the Slide angle (°)	8.6	6.1

Table 12. Summary of Results of Artificial Soil Testing (remolded)

Lindi Percentage (%)	0	20	40	60	80	100
Liquid Limit (LL) (%)	39.91	45.38	50.80	54.16	56.17	57.18
Plastic Limit (PL) (%)	22.81	26.59	36.11	38.36	39.78	43.63
Limit Losses (SL) (%)	34.23	38.76	40.62	47.07	48.40	50.41
Dry Density (gr / cm3)	1:33	1.32	1.29	1:27	1:26	1:25
Optimum Water Content (%)	29.74	29.89	30.99	32.31	38,39	38.65
Compressive Strength (kg / cm2)	.793	0.758	0.685	.663	0.586	0.529
Cohesion (UCT) (kg / cm2)	0,397	.379	0.342	0.332	0,293	.264
Cohesion (triaxial) (kg / cm2)	0,349	0.342	0.306	.278	0.254	0,249
In the Slide angle (°)	12.2	10.7	10.1	8.6	6.5	5.6
Koef. Permeability (cm / sec)	0.000163	0.000131	0.000109	0.000095	0.000088	0.000075

V. CONCLUSIONS AND SUGGESTIONSTS

A. Conclusions

Based on the research that has been done, it is concluded as follows:

1. Characteristics of the soil in the landfill area Temesi Gianyar is as follows:
   - The water content of the original soil (undisturbed) in the region amounted to 36.09% Temesi groundwater and native (undisturbed) with leachate amounted to 38.88%.
   - In sieve analysis test, test and test hydrometer Atterberg limit land classified as sandy loam soil inorganic with low plasticity of 39.91% on the liquid limit value and 17.01% for the index value of the plastic.
   - Temesi landfill soil density obtained amounted to 2,68 and classed as inorganic clay.
   - In the standard proctor compaction obtained 29.74% optimum moisture content and dry volume weight of 1.33 g/cm^3.
   - In the compression test free (unconfined compression test) obtained compressive strength (*qu*) of 0.441 kg/cm^3 to undisturbed soils are not polluted leachate, 0.370 kg/cm^3 to undisturbed soils contaminated leachate, and 0.793 kg/cm^3 for disturbed land was polluted leachate , While the value of cohesion (c) obtained at 0.221 kg/cm^2 for undisturbed soils not contaminated leachate, 0.185 kg/cm^2 for undisturbed soils contaminated by leachate, and 0,397 kg/cm^2 for the soil is disturbed.
   - From permeability testing ground in the area of the landfill Temesi obtained 0.000163 cm/sec.
   - From CD triaxial testing (Consolidated Drained) obtained shear angle (φ) of 8.6 ° to undisturbed soils not contaminated leachate, 6.1 ° to undisturbed soils not contaminated leachate, and 12.2 ° for the soil is disturbed. While the value of cohesion (c) obtained at 0.271 kg/cm^2 for unpolluted soil undisturbed, 0.237 kg/cm^2 for undisturbed soils contaminated leachate, and 0,349 kg/cm^2 for the soil is disturbed.
2. Characteristics of landfill leachate Gianyar Temesi obtained amount of content with following parameters:
   - Dissolved Oxygen (DO) obtained 0.221 mg/L.
   - BOD5 (Biochemical Oxygen Demand) obtained 989 mg/L.
   - COD (Chemical Oxygen Demand) was obtained 3920 mg/L.
   - TSS obtained 2989.26 mg/L.
   - TDS obtained 260 mg/L.

- Oil gained 40 mg/L.
- a pH of 6.48 was obtained.

3. Effect of leachate with a variation of 0%, 20%, 40%, 60%, 80%, and 100% of the characteristics of the soil in the landfill area Temesi Gianyar.
   - On Atterberg limit test research has increased by 0% to 100% of leachate by 39.91% to 57.18% for the liquid limit, 22.81% to 43.63% for the plastic limit, and 34.23% to 50.41% to limit shrinkage. And the percentage of the increase of 43.27% with an average increase of 8.65% to the value of the liquid limit, 91.28% with an average increase of 18.26% to the value of plastic limit, and 47.27% with an average increase of 9.45% for shrinkage limit value.
   - The results of standard proctor compaction test has decreased the volume of dry density (*γd*) of soil mixed with 0% leaching of 1.330 g/cm^3 be 1.250 g/cm^3 at ground state liquor mixed with a percentage of 100% and a 6.02% decrease in average reduction of 1, 20%. As for the value of the optimum moisture content increased from 29.74% to land with leachate 0% to 38.65% for the soil with leachate 100% with a percentage increase of 29.96% and an average reduction of 5.99%.
   - In the study pressure test free (unconfined compression test) decrease the compressive strength (*qu*) of 0.793 kg/cm^2 when the leachate 0% to 0.529 kg/cm^2 when leachate 100%, with a percentage of 33.29% and a decrease in the average decline of 6 , 66%. As for the value of cohesion (*c*) decreased from 0,397 kg/cm^2 at the time of the leachate 0% to 0.264 kg/cm^2 at the time of leachate 100%, with a percentage of 33.50% and a decrease in the average decline of 6.7%.
   - The test results permeability decreased permeability coefficient of 0.000163 cm / sec in the state drained soil leachate 0% to 0.000075 cm / sec in the state drained soil leachate 100%, with a percentage of 53.99% and a decrease in the average decline 10.79%.
   - In research triaxial CD (Consolidated Drained) shear angle (φ) obtained decreased. In the mixed state of leachate 0% earned 12.2 ° to 5.6 ° when mixed liquor of 100% with a percentage of 54.09% and a decrease in average reduction of 10.82%. As for cohesion (c) decreased from 0,349 kg/cm^2 for the soil with leachate 0% to 0.249 kg/cm^2 for the soil with leachate 100% with the percentage of 28.65% and a decrease in average reduction of 5.73%.

B. Suggestion

The following advice can be given based on the results from this research were made:

1. The need for a further study to acquire other things that result in changes to the characteristics of the soil in the landfill area Temesi Gianyar.
2. There needs to be more research on the parameters in the leachate that affect the characteristics of the soil in the landfill Temesi.
3. The need for additional research with the ripening variety and amount of leachate variables.

REFERENCES

[1] Badan Pusat Statistik Jakarta Pusat. *Statistik Indonesia Tahun 2010*. Jakarta Pusat: Badan Pusat Statistik. 2010.

[2] Notohadiprawiro. *Pengelolaan Kesuburan Tanah dan Peningkatan Efisiensi Pemoukan.* Universitas Gadjah Mada. 2006.

[3] Redana, I W. 2011. *Mekanika Tanah*. Denpasar: Udayana University Press.

[4] Hardiyatmo, Harry Christady. *Mekanika Tanah 1*. Yogyakarta: Gajahmada University Press. 2012.

[5] Chen, F.H. *Foundations on Expansive Soils*, Esevier Scientific Publishing Company, Amsterdam. 1975.

[6] Kementerian Lingkungan Hidup. *Peraturan Menteri Lingkungan Hidup No 5 Tahun 2014 Tentang Baku Mutu Air Limbah*. Jakarta. 2014.