Journal of Economics, Technology and Business (JETBIS)
Volume 3, Number 11 November 2024
p-ISSN 2964-903X; e-ISSN 2962-9330

Correlation Study of Shrinkage Expansion Potential of Clay Soil In PLTMH Cileunca, Pangalengan, Bandung, Indonesia

Indra Fajar Kurniawan[1], Ahmad Rizky Ananda Maulana[2], Muhammad Faris Naufal[3], Ingrid Multi Rezeki[4]
Universitas Swadaya Gunung Jati, Indonesia
*e-mail: fajarindra2002@gmail.com[1], rizkyahmad006@gmail.com[2], farisnaufal11.fn@gmail.com[3], multi.ingrid8@gmail.com[4]
*Correspondence: tira.roesdiana@gmail.com

KEYWORDS:
Expansive Soil Index Plasticity, Activity,Shrinkage Expansion, Pangalengan

ABSTRACT

Mini Hydro Power Plants (MHPs) utilize the potential of water to generate electrical energy. However, construction on clay soils that have the potential to expand and contract can affect the stability of the structure. This study aims to evaluate the potential for soil development in the Cileunca MHP. The methods used to determine soil development potential include Chen (1988), Skempton (1953), and Seeds (1962) methods. Mineral identification was conducted through X-Ray Diffraction (XRD) testing of soil samples taken by the handboring method. The results of the analysis showed that the Skempton method showed 67% of the samples had activity values > 0.75 ("high" category). The Chen method indicated 60% of the samples had a plasticity index (PI) > 35% ("very high" category). The Seeds method indicated 73% of the samples had a development potential > 25% (very high category). XRD testing indicated the dominant mineral was dehydrated Halloysite (Al2Si5(OH)4). The soil at the Cileunca MHP site has a high development potential that can damage building foundations. Foundation stability is strongly influenced by expansive soil properties, so soil stabilization treatment is needed to prevent structural damage. This study concludes that the soil at the Cileunca MHP site has a high development potential, which can cause structural problems. Therefore, soil stabilization treatment is highly recommended to ensure the stability of the building foundation.

INTRODUCTION

Pangalengan is a district in Bandung Regency, West Java, Indonesia. This region is located on a mountainous high plateau with steep and sloping land contours. This condition is caused by geological processes such as uplift and erosion. Steep slope conditions in Pangalengan have the potential to cause landslides (Kumalasari et al., 2019). On the other hand, the Pangalengan area is found to have many types of soil clay that has high swelling and shrinkage properties, with soil conditions that are not homogeneous and have no adhesion between soil layers coupled with steep slope conditions are very easy for landslide movements to occur (Ray et al., 2021). The swelling and shrinkage potential can damage all buildings that stand above it. The damage is in the form of massive cracks and can be fatal so that the building will not function normally.

MHP, or Mini Hydro Power Plant, is a generating system that converts potential water with medium height and discharge into electrical energy using water turbines and generators (Anisa et al., 2021; Boroomandnia et al., 2022; Sachdev et al., 2015). This MHP was built in Cileunca, Pangalengan District, Bandung, Indonesia, and is located on a type of clay soil that has the potential to expand and deflate due to changes in its water content. It is also located on a steep slope, so there is a possibility that expansive soil expansion and shrinkage processes can occur.

Expansive soil is a type of soil that is unstable, especially in terms of development or shrinkage caused by significant changes in moisture content (Vijayan & Parthiban, 2020). In wet conditions (rainy season), the soil tends to expand and become very soft, causing deformation both vertically and horizontally that can damage the building structure above it. Conversely, in dry conditions (dry season), the water in the soil evaporates, causing the soil to shrink, especially in the near-surface layer.

Plasticity Index (PI) is a measure of a soil's ability to deform without cracking. Soils with high PI values indicate greater development potential. The Activity (A) value, which is calculated from the ratio between the plasticity index and the percentage clay content, gives an indication of the development potential of the soil (Arel et al., 2018; Rubinić et al., 2020). The higher the activity value, the greater the potential for soil development. Soil development and shrinkage can affect the stability of building foundations, especially in areas such as Pangalengan that have high rainfall and considerable moisture variation.

According to research conducted by Akhmad (2021) on expansive soil shrinkage in Banjarmasin, the soil in the area is dominated by very soft clays, with shrinkage potential that can be assessed from the activity value (A) and the percentage of clay content (% clay) in the soil layer. The results show the classification of clay activity in Banjarmasin city which has moderate potential or in the “Marginal” category.

In Pangalengan, statistical data shows an increase in the frequency of building damage related to expansive soils in recent years. In the period 2020-2022, it was reported that about 30% of buildings constructed in areas with expansive soils experienced structural damage, caused by changes in soil moisture content. This highlights the importance of understanding soil characteristics and the need for mitigation measures to reduce the risks faced by infrastructure, especially at MHP sites that are sensitive to changes in soil conditions (Khosravi et al., 2023; Marino, 2015).

Steven & Suhendra (2023), have researched expansive soils in the Karawang and Cikarang areas explaining how to identify expansive soils, by determining the mineral content, Swelling Pressure value, and Swelling Potential by considering the correlation of soil parameters such as LL (Liquid Limit), PL (Plastic Limit), and PI (Plasticity Index). The results obtained in identifying expansive soils with this method are the level of swelling potential in the Karawang project area is included in the “medium” category and the Cikarang project area is included in the “very low” category. Some types of soils that have high swelling and shrinkage potential are soils that can change volume significantly with changes in moisture content. This type of soil is a clay soil that contains many minerals with high shrinkage potential. Soils with this condition are often referred to as expansive clays.

The purpose of this study is to evaluate the potential for expansive soil development at the Cileunca MHP site, focusing on the analysis of soil plasticity index, activity value, and soil shrinkage and development. This research is expected to provide recommendations for soil stabilization treatment to maintain the stability of building foundations and infrastructure in the area.

RESEARCH METHODS

In this research, the method used for data collecting and analyzing data is quantitative method with case study type. The location of this research is located at PLTMH Cileunca, Pangalengan, Bandung with sampling data in the form of Hand boring techniques. Primary data in this study were obtained from 2 drill location points with a distance of 90 meters between them. And for sample 1 depth data is 77 cm, and sample 2 is 74 cm. for secondary data obtained through several Index Properties tests, such as water content (ASTM D-2216-98), Content weight (ASTM D-854-83), Specific gravity (ASTM D-854-83), Atterberg Limits (ASTM D-4318), Grain Size Analysis (SNI 1968-1990-F), Hydrometer Analysis (SNI 03-3423-1994). Other data obtained in the form is Mineralogy Testing with XRD (X-Ray Diffraction) and consolidation testing. In the data processing method stage in determining the swelling potential, this research uses 3 methods, namely the Chen (1988), Skempton (1953), and Seeds (1988) methods.

Figure 1. Research Location, Pangalengan

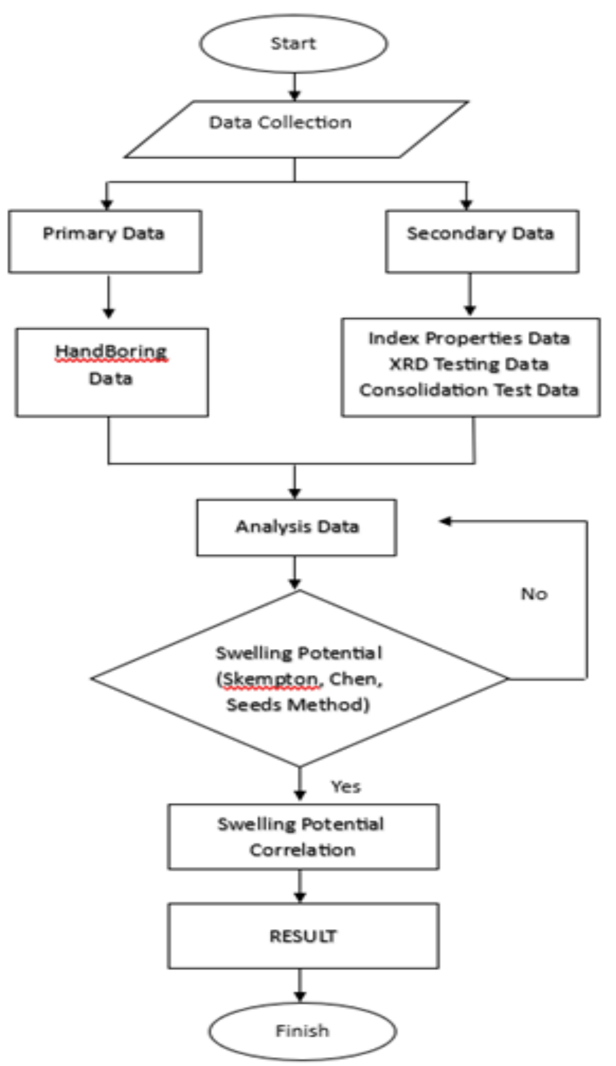

Figure 2. Flow Chart of Research

RESULTS AND DISCUSSION

A. Soil Investigation

Pangalengan sub-district is located at 107 29'-107 39' BT and 7 19'-7 6' LS. In terms of topography and geology, the area has a steep slope and is flanked by two shear faults. Climatically Pangalengan has rainfall 1,996 mm/year with an average of 5.47 mm/day.

In other cases, Pangalengan is an area surrounded by hills. These hills are meant to be areas that have a higher elevation than the surrounding areas and it is almost impossible to have standing water. This is because rainwater that falls from above flows directly to lower areas in accordance with the natural properties of water. This condition causes wetting due to rainwater to only occur on the surface, not into the soil. Because of the high rain intensity factor and many hills, the Pangalengan area may experience expansive soil expansion that will affect the building above it.

The soil samples used in this study to identify the swelling and shrinkage of expansive soil were collected at PLTMH Cileunca, Pangalengan, Bandung. When taking soil samples with the Hand boring method.

B. Index Properties

Index Properties testing includes moisture content, content weight, specific gravity, grain size analysis, Atterberg limits, and hydrometer analysis (Firomsa & Emer Tucay Quezon, 2019; Musbah et al., 2024; Saikia et al., 2017; Shrestha, 2016). The following are the test results of the Index Properties above.

Sample no	Depth	Water Content	Unit Weight	Specific Gravity	Grain size analysiis				Finner passing no.200	Atterberg Limit			
					Gravel	Sand	Silt	Clay		WL	WP	IP	Class
	(m)	(%)	(t/m3)	(gr/cm3)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	
BH 1	2,55 - 3	66,3	1,508	2,621	0	8,62	27,87	63,51	91,38	129,33	33,52	95,81	CH
BH 1	19 - 19,4	73,47	1,54	2,638	0	18,91	33,13	46,59	79,72	133,17	35,32	97,85	CH
BH 2	9 - 9,55	109,17	1,291	2,551	0	12,27	48,03	39,7	87,73	168,79	61,36	107,43	MH
BH 2	18,45 - 18,75	63,97	1,569	2,538	0,8	7,95	37,56	53,69	91,25	99,25	32,94	66,31	CH
BH 3	2,5 - 3	60,74	1,576	2,652	0	9,29	33,91	56,8	90,71	101,55	31,22	70,33	CH
BH 3	12,5 - 13	51,722	1,558	2,666	0	18,9	41,05	40,05	81,1	67,26	34,79	32,47	MH
SU 1	4,2 - 4,5	55,69	1,452	2,652	0	11,01	54,86	34,13	88,99	78,95	38,67	40,28	MH
SU 2	4,1 - 4,5	74,92	1,512	2,624	0	8,96	40,48	50,56	91,04	114,33	31,65	82,68	CH
SU 3	3,2 - 3,5	61,41	1,57	2,675	5,68	39,75	29,84	24,73	54,57	81,54	38,13	43,41	MH
SU 4	4,15 - 4,5	52,22	1,615	2,666	0	9,19	38,97	51,84	90,81	104,03	32,74	71,29	CH
SU 5	4,4 - 4,7	50,6	1,619	2,684	18,42	27,43	38,7	15,45	54,15	76,7	35,28	41,42	MH
SU 6	4,7 - 5	96,85	1,351	2,649	0	3,96	36,81	59,23	96,04	118,02	31,79	86,23	CH
SU 7	4,5 - 4,85	64,74	1,475	2,631	0	14,02	32,37	53,61	85,98	89,2	29,34	59,86	CH
SU 8	4,5 - 4,8	78,29	1,514	2,655	13,43	21,12	38,14	27,31	65,45	93,4	44,13	49,27	MH
SU 9	4,5 - 4,85	59,277	1,556	2,647	0	34,1	32,65	33,25	65,9	87,15	36,25	50,9	MH

Figure 3. Table Laboratory Testing Resume Results

C. Mechanical Properties

In this test, the sample are from sample 1 that located 26 meters from location of bor hole 3. The sampling uses the Handboring method with soil depth data of 77 cm, the test was conducted by PT Nur Straits Engineering (NSE) with the type of test in the form of a consolidation test.

1. Consolidation Test

This consolidation test uses sample 1 that has been taken at a predetermined location, the purpose of this test is to provide a gradual load to the soil and measure volume changes over time with test results in the form of soil compressibility properties expressed by the volume coefficient (Mv) or compression index (Cc) and can determine the consolidation characteristics expressed by the coefficient of consolidations (Cv).

Applied Pressure	Final Dial	Dial Change	2H (Final)	H_{dr} Averager	Void Ratio	T90	Cv
(kg/cm²)	mm	mm	mm	cm	(e)	(detik)	Cm²/det
0,00	10,000	0,000	21,28	-	1,608	-	
0,09	9,811	0,189	21,09	1,059	1,585	2940,0	0,3236
0,26	9,570	0,430	20,85	1,049	1,555	2856,6	0,3264
0,54	9,290	0,710	20,57	1,036	1,521	2940,0	0,3093
1,08	9,033	0,967	20,31	1,022	1,489	2856,6	0,3101
2,16	8,770	1,230	20,05	1,009	1,457	2693,4	0,3206
4,30	8,140	1,860	19,42	0,987	1,380	3285,6	0,2513
8,58	7,395	2,605	18,68	0,952	1,289	4437,6	0,1733
17,18	6,433	3,557	17,72	0,910	1,172	4233,6	0,1659
8,58	6,532	3,468	17,81	-	1,183	-	-
0,26	7,022	2,978	18,30	-	1,243	-	-

Figure 4. Table Consolidation Test Result Data

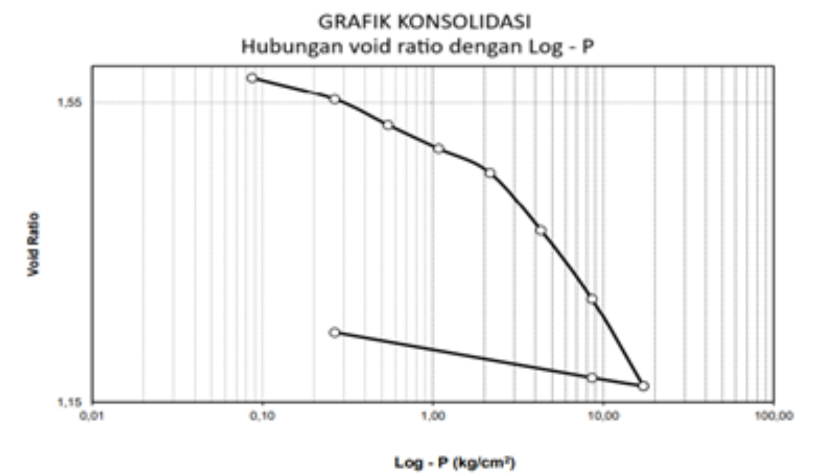

Figure 5. Relationship between Pore Number and Pressure

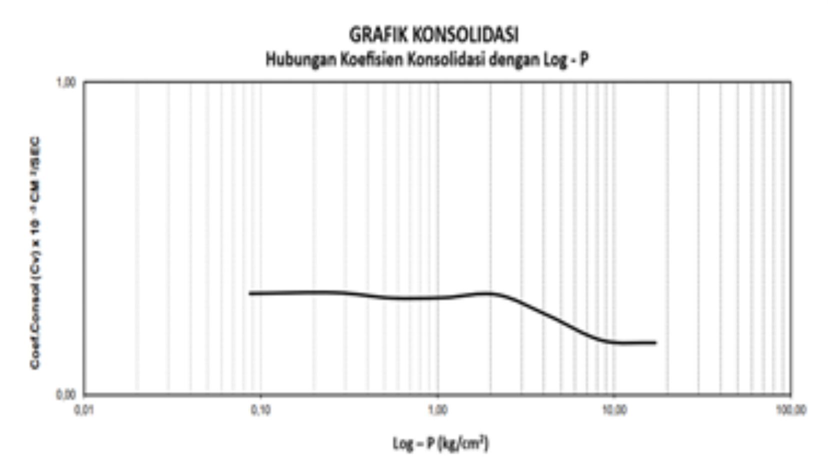

Figure 6. Value of Consolidation Coefficient (Cv)

D. MINERALOGICAL METHOD

In this study, clay minerals are tested using XRD (X Ray Diffraction) which will determine the type of minerals in the clay soil. The test was conducted by BBPMB tekMIRA,This test was carried out on sample 2 with a soil depth of 74 cm with a distance to the power house (Borehole 3) of the Cileunca PLTMH of about 102 meters, XRD Testing (X-Ray Diffraction)

This test is a mineral test to identify the crystal phase in the material by determining the lattice structure parameters and to obtain particle size, single crystal determination and crystal structure determination of unknown materials with reference to the test procedure, namely BS EN 13925-2: 2003.

No	Lab. No	Sample ID	Mineral Phase Identification	Mineral Chemical Formula	Quantitive Analysis (%)	Error On Fit (%)
1	3305/24	A	Halloysite	$Al_2Si_5(OH)_4$	30,6	1,18
			Goethite	FeO(OH)	22,5	0,79
			Tridymite	SiO_2	18,5	0,90
			Quartz	SiO_2	14,9	0,69
			Magnetite	Fe_3O_4	8,0	0,55
			Hematite	Fe_3O_3	5,5	0,67

Figure 7. Tablel Result Data of Mineral Constituents of Clay Soil

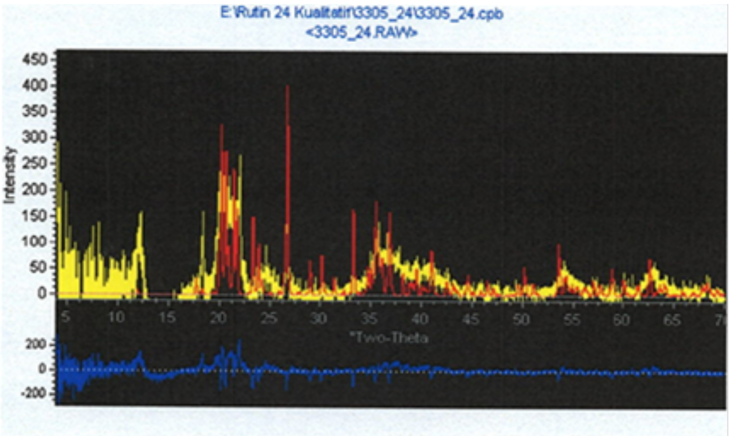

Figure 8. X-ray Intensity Irradiance Result

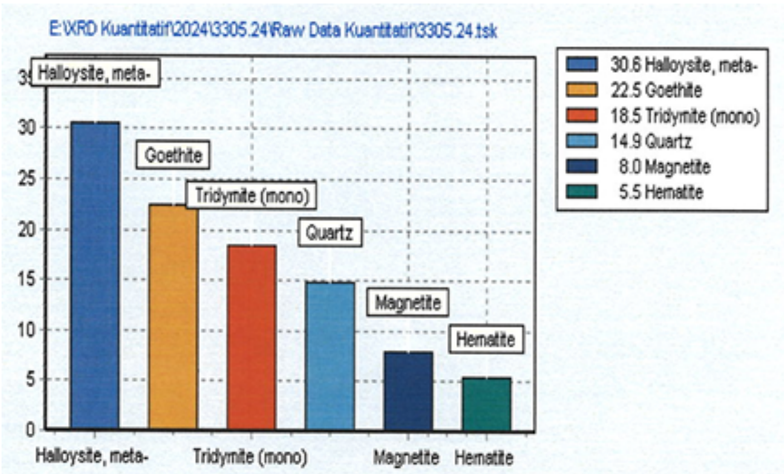

Figure 9. Soil Mineral Type Result Data

The graph above shows that the minerals in the test soil sample number 2 are dominant Halloysite Dehydrated clay minerals (Al2Si5(OH)4). Halloysite type clay minerals have a structural composition that is identical to other types of clay minerals, namely kaolinite. soil containing Halloysite has the ability to absorb water between the constituent sheets, so the water content is high and has a low density. If water enters the clay particles, then cations and a small amount of anions will swim between the particles, as if forming a diffuse double layer. Halloysite minerals include minerals that have low activity values. Where the activity value is used to identify the ability of expansive soil to swell. In general, the greater the swelling potential, the lower bearing capacity of the soil. Because of Halloysite have a good properties, if Halloysite forming a slope, it will have an angle steeper slopes than other lands. If a landslide occurs, the landslide is predominantly a shallow translational landslide with the causal factor being high intensity rain and/or long duration rain.

In general if the soil swelling it can cause shallow foundations, building floor plates and pile foundation to lift. If the foundation of a building is placed on expansive soil containing clay minerals with high expansion potential, the potential for differences in soil rise resulting in cracks in the building walls will be significant. Deformation due to soil expansion generally produces an irregular surface, and the resulting expansion pressure can cause serious damage to buildings. The problem that often arises with floor slabs on highly expansive soils is that the foundation at the edges is not deep enough, so it cannot withstand up and down movements due to soil-shrink swelling. In pile foundations, when the soil experiences wetting, the bearing capacity of the pile is reduced. The reduction in the bearing capacity of the pile depends on the type of soil and the length of the pile. When upward ground movement occurs, the pile experiences an upward lifting force. The magnitude of this lifting force depends on the length of the pole and the load acting on the pole. The longer the pole, the greater the upward force on the pole decreases. So, at a certain pole length, the pole will not be lifted due to soil expansion.

E. IDENTIFICATION METHOD

In this research, the method of identifying the swelling potential of clay soil located at Cileunca PLTMH uses the methods of Chen (1988), Skempton (1953), and Seeds (1962). The three methods will produce a category of swelling potential.

1. Chen (1988)

Chen explained one of the ways to identify expansive soil, is using the Plasticity Index (PI). Chen revealed that if the potential of swelling of the soil is high when the Plasticity Index value > 35%

Table 1. Plasticity Index With Sevelopment Value

PI	Swell
0 -15	Low
10 – 35	Medium
20-55	High
>35	Very High

Table 2. Testing Resume, Chen (1988)

Sample no	Atterberg Limit			Classification	Swelling Potential by Chen
	WL	WP	PI		
	%	%	%		
BH 1 A	129,33	33,52	95,81	CH	Very High
BH 1 B	133,17	35,32	97,85	CH	Very High
BH 2 A	168,79	61,36	107,43	MH	Very High
BH 2 B	99,25	32,94	66,31	CH	Very High
BH 3 A	101,55	31,22	70,33	CH	Very High
BH 3 B	67,26	34,79	32,47	MH	Medium

Sample no	Atterberg Limit			Classification	Swelling Potential by Chen
	WL	WP	PI		
	%	%	%		
SU1	78,95	38,67	40,28	MH	High
SU2	114,33	31,65	82,68	CH	Very High
SU3	81,54	38,13	43,41	MH	High
SU 4	104,03	32,74	71,29	CH	Very High
SU5	76,7	35,28	41,42	MH	High
SU6	118,02	31,79	86,23	CH	Very High
SU7	89,2	29,34	59,86	CH	Very High
SU8	93,4	44,13	49,27	MH	High
SU9	87,15	36,25	50,9	MH	High

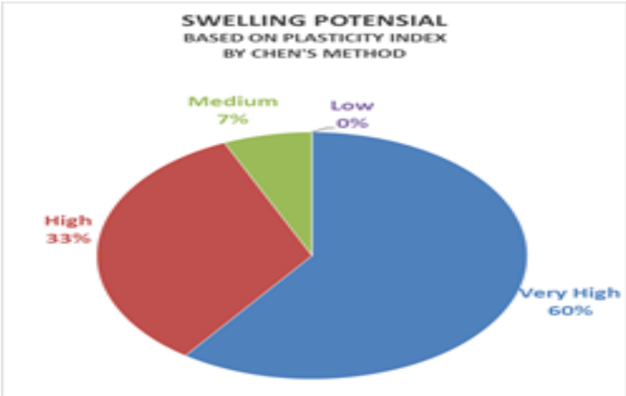

Figure 10. Chen Method Swelling Potential

The Graph is the result of the Swelling Potential test conducted by the method of Chen, (1988) can be presented in the form of a graph as follows, where Chen determined that the high and low swelling potential can be determined from the Plasticity Index (PI) value of the clay soil.

2. Skempton, (1953)

In this study the method used is the Skempton method, (1953). Skempton explains in this method that to identify expansive soils can be using the comparison between the Plasticity Index (PI) value and the percentage value of the clay fraction (CF), and Skempton says if the value of the swellin potential activity (AC) > 1.25% then the soil is considered to be very high and active potential expansion and shrinkage. The Index Properties data obtained previously that will be analyzed or calculated using this method are as follows:

$$Ac = \frac{PI}{CF}$$

Formula Description:

Ac : Activity

PI : Plasticity Index

CF : Percentage passing sieve no.200

Table 3. Activity Value with Swelling Potential

Soil Activity	Activity	Swelling
< 0,75	Inactive	Low
0,75 < Ac <	Active	Medium
> 1,25	Very	High

Table 4. Testing Resume, Skempton (1953)

Sample no	Grain Size Clay %	Atterberg Limit WL %	WP %	PI %	Classification	Activity $A = \frac{PI}{c}$	Swelling Potential By Skempton
BH 1 A	63,51	129,33	33,52	95,81	CH	1,509	High
BH 1 B	46,59	133,17	35,32	97,85	CH	0,758	High
BH 2 A	39,7	168,79	61,36	107,43	MH	2,706	High
BH 2 B	53,69	99,25	32,94	66,31	CH	1,235	Medium
BH 3 A	56,8	101,55	31,22	70,33	CH	1,238	Medium
BH 3 B	40,05	67,26	34,79	32,47	MH	0,811	Medium
SU 1	34,13	78,95	38,67	40,28	MH	1,180	Medium
SU 2	50,56	114,33	31,65	82,68	CH	1,635	High
SU 3	24,73	81,54	38,13	43,41	MH	1,755	High
SU 4	51,84	104,03	32,74	71,29	CH	1,375	High
SU 5	15,45	76,7	35,28	41,42	MH	2,681	High
SU 6	59,23	118,02	31,79	86,23	CH	1,456	High
SU 7	53,61	89,2	29,34	59,86	CH	1,117	Medium
SU 8	27,31	93,4	44,13	49,27	MH	1,804	High
SU 9	33,25	87,15	36,25	50,9	MH	1,531	High

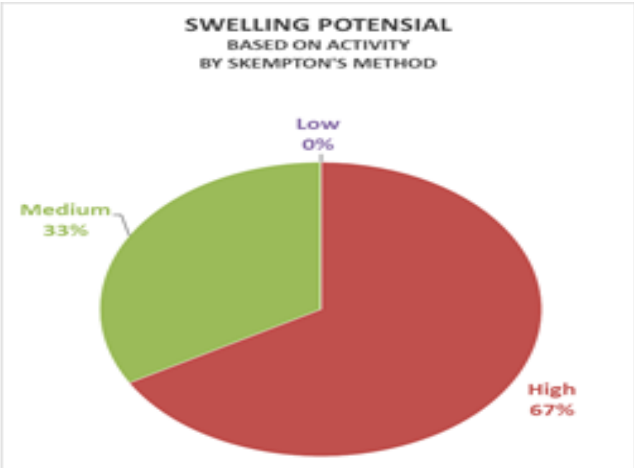

Figure 11. Swelling Potential Skempton Method

The graph beside the results of the Swelling Potential test conducted by the Skempton method, (1953) can be presented in the form of a graph as follows, where Skempton determined that the high and low swelling potential can be determined from the activity value of the clay soil.

3. Seeds, (1962)

In this research, the method used is the Seeds method, (1962). Seeds explained that swelling is a percentage caused by pressure on the soil with the maximum dry soil volume weight and ideal moisture content according to the AASHTO standard. Swelling tests can directly show that this relationship only applies to soils with clay content of 8 - 65% with an accuracy of about 33%.

As for the previously obtained Index Properties data that will be analyzed or calculated using this method, namely as follows with the Seeds formula which modifies the activity value of the Skempton method.

$$Ac = \frac{PI}{C-10}$$

Formula Description :
Ac : Actifity
PI : Plasticity Index
C : Percente weight of fraction Clay

The number 10 is the reduction factor.
S = 60 x K x PI2,44
Formula Description :
S : swelling potential
K : 3,6 X 10-5 (Constant Value)
PI : Plasticity Index

Table 5. Swelling Pressure Degree Level

Expansive Degree	Swelling Potential S(%)
Low	0 – 1,5
Medium	1,5 – 5
High	5 – 25
Very High	> 25

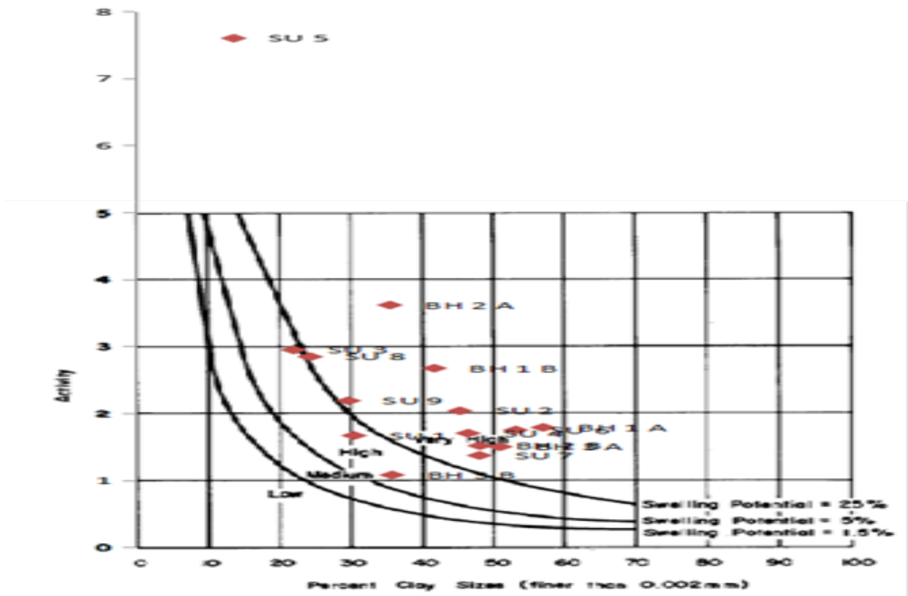

Figure 12. Relationship Graph between Soil Percentage and Activity

Table 6. Resume Testing, Seeds (1962)

Sample no	Depth	Grain Size Clay	Atterberg Limit			Classification	Activity	Potential Swelling by Seeds	
			WL	WP	PI		$A = \frac{PI}{(c-10)}$	Graph	S (%)
	m	%	%	%	%				$S=60 \times K \times PI^{2,44}$
BH 1 A	2,55 - 3	63,51	129,33	33,52	95,81	CH	1,791	Very High	147,603
BH 1 B	19 - 19,4	46,59	133,17	35,32	97,85	CH	2,674	Very High	155,390
BH 2 A	9 - 9,55	39,7	168,7	61,3	107,	MH	3,617	Very	195,164

Sample no	Depth	Grain Size Clay	Atterberg Limit			Classification	Activity	Potential Swelling by Seeds	
			WL	WP	PI		$A = \frac{PI}{(c-10)}$	Graph	S (%)
	m	%	%	%	%				$S = 60 \times K \times PI^{2,44}$
			9	6	43			High	
BH 2 B	18,45 - 18,75	53,69	99,25	32,94	66,31	CH	1,518	Very High	60,132
BH 3 A	2,5 - 3	56,8	101,55	31,22	70,33	CH	1,503	Very High	69,419
BH 3 B	12,5 - 13	40,05	67,26	34,79	32,47	MH	1,081	High	10,531
SU 1	4,2 - 4,5	34,13	78,95	38,67	40,28	MH	1,669	High	17,819
SU 2	4,1 - 4,5	50,56	114,33	31,65	82,68	CH	2,038	Very High	103,017
SU 3	3,2 - 3,5	24,73	81,54	38,13	43,41	MH	2,947	High	21,388
SU 4	4,15 - 4,5	51,84	104,03	32,74	71,29	CH	1,704	Very High	71,754
SU 5	4,4 - 4,7	15,45	76,7	35,28	41,42	MH	7,600	High	19,074
SU 6	4,7 – 5	59,23	118,02	31,79	86,23	CH	1,752	Very High	114,146
SU 7	4,5 - 4,85	53,61	89,2	29,34	59,86	CH	1,373	Very High	46,845
SU 8	4,5 - 4,8	27,31	93,4	44,13	49,27	MH	2,846	Very High	29,131
SU 9	4,5 - 4,85	33,25	87,15	36,25	50,9	MH	2,189	Very High	31,539

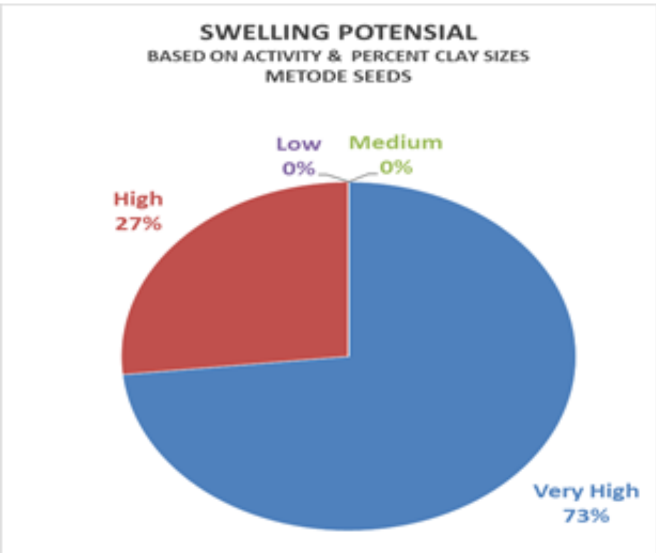

Figure 13. Swelling Potential Seeds Method

The results of the Swelling Potential test carried out by the Seeds method, (1962) can be presented in the following graphical form, where Seeds determined that the high and low swelling potential can be determined from the Activity value by clay fine sizes.

CONCLUSION

Based on the analysis of data obtained from the research of soil shrinkage expansion potential conducted at Cileunca MHP, Bandung Regency, as well as several laboratory tests, it can be concluded that in XRD (X-Ray Diffraction) testing, the soil contains 30.6% halloysite, 22.5% goethite, 18.5% tridymite, 14.9% quartz, 8% magnetite, and 5.5% hematite. According to researchers, soils containing halloysite have the ability to absorb water between the constituent layers, resulting in high moisture and low density. Water entering the clay particles causes cations and small amounts of anions to move between the particles, forming a diffusion double layer. Halloysite minerals fall into the category of minerals with low activity values, which identifies the ability of expansive clays to expand; the greater the soil development, the lower the bearing capacity of the soil. The consolidation test obtained a Consolidation Coefficient (Cv) value of 2.53 × 10^-3 m², which is used to determine the length of time for consolidation and the rate of settlement that will occur. The Compression Index (Cc) of 0.387 is used to calculate the settlement that occurs in the field due to soil consolidation, while the Reflection Compression Index (Cr) of 0.039 is used to calculate the settlement in consolidated clay. To analyze the expansion and shrinkage potential of the soil, three methods were used: Skempton (1953), Chen (1988), and Seeds (1962). The Skempton method showed that 67% of the samples were in the “high” category, the Chen method showed that 60% of the samples were in the “very high” category based on Plasticity Index (PI) values, and the Seeds method showed that 73% of the samples were in the “very high” category based on activity values and clay grain size.

BIBLIOGRAPHY

Akhmad, N. A. & M. (2021). *Jurnal Gradasi Teknik Sipil Politeknik Negeri Banjarmasin*.

Anisa, Z., Apprianda, A., Novianto, H., & Rachman, I. (2021). Micro-Hydro Power Plants (MHPP): Technical and analytical studies in creating experimental learning media for physics students. *Momentum: Physics Education Journal*, 53–64.

Arel, E., Önalp, A., & Olgun, G. C. (2018). The effect of clay mineral content on the dynamic response of reconstituted fine grained soil. *Bulletin of Earthquake Engineering*, *16*, 4515–4532.

Boroomandnia, A., Rismanchi, B., & Wu, W. (2022). A review of micro hydro systems in urban areas: opportunities and challenges. *Renewable and Sustainable Energy Reviews*, *169*, 112866.

Firomsa, W., & Emer Tucay Quezon, P. (2019). *Parametric modelling on the relationships between atterberg limits and compaction characteristics of fine-grained soils*.

Khosravi, K., Rezaie, F., Cooper, J. R., Kalantari, Z., Abolfathi, S., & Hatamiafkoueieh, J. (2023). Soil water erosion susceptibility assessment using deep learning algorithms. *Journal of Hydrology*, *618*, 129229.

Kumalasari, H., Koestoer, R. H., & Hasibuan, H. S. (2019). Disaster Risk Mitigation of Landslide for Sustainability of Geothermal Production in Bandung Regency, West Java Province, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *256*(1), 12020.

Marino, E. (2015). *Fierce climate, sacred ground: An ethnography of climate change in Shishmaref, Alaska*. University of Alaska Press.

Musbah, A., Mohammed, M., & Alfghia, A. (2024). The Effect of Mineral Composition and Quantity of Fines on the Atterberg Limits and Compaction Characteristics of Soils. *Open Journal of Civil Engineering*, *14*(2), 258–276.

Ray, A., Bharati, A. K., Rai, R., & Singh, T. (2021). Landslide occurrences in Himalayan residual soil: a review. *Himalayan Geology*, *42*(1), 189–204.

Rubinić, V., Ilijanić, N., Magdić, I., Bensa, A., Husnjak, S., & Krklec, K. (2020). Plasticity, mineralogy, and WRB classification of some typical clay soils along the two major rivers in Croatia. *Eurasian Soil Science*, *53*, 922–940.

Sachdev, H. S., Akella, A. K., & Kumar, N. (2015). Analysis and evaluation of small hydropower plants: A bibliographical survey. *Renewable and Sustainable Energy Reviews*, *51*, 1013–1022.

Saikia, A., Baruah, D., Das, K., Rabha, H. J., Dutta, A., & Saharia, A. (2017). Predicting compaction characteristics of fine-grained soils in terms of Atterberg limits. *International Journal of Geosynthetics and Ground Engineering*, *3*, 1–9.

Shrestha, S. (2016). *Study of effects of coarse grain contents on Atterberg limits and expansiveness of the clay*.

Suhendra, A. (2023). Studi Korelasi Muai Susut Tanah Ekspansif Di Daerah Karawang Dan Cikarang. *JMTS: Jurnal Mitra Teknik Sipil*, 805–818.

Vijayan, D. S., & Parthiban, D. (2020). Effect of Solid waste based stabilizing material for strengthening of Expansive soil-A review. *Environmental Technology & Innovation*, *20*, 101108.