

# Residual Shear Strength, Slake Durability And Mineralogy In Clay Shale And Rock On Ungaran - Salatiga Toll Road, Bawen, Semarang

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**Abstract:** The Bawen - Semarang Toll Road, located in Central Java, is a road that connects Bawen District to Semarang Regency. Geologically, the location of the Indonesian territory, which is traversed by three main tectonic plates, namely the Europe-Asia, India-Australia and the Pacific Plate, makes Indonesia a lot of active volcanoes and prone to disasters. The purpose of this study is the physical, mechanical and mineralogy characteristics of clay shale and rock. The methodology is the sample used in sun-exposed conditions and the tests properties rock, direct shear test, durability test, and mineralogy test. The conclusion from the results of the analysis on direct shear, it is found that the value of the residual effective shear angle ( $\phi'$ ) ranges from 4.77 - 9.78 ° and the effective cohesion value ( $c'$ ) is 5.97 - 17.95 kN/m<sup>2</sup> and can it is said that in geological engineering for materials that are susceptible to weathering processes, rock resistance based on the slake durability classification, samples L 1 and L 4 are classified as Low Durability, so it can be interpreted that the sample is very prone to weathering when exposed directly to weather changes, L 2 is classified Medium Durability, and L 3, are classified as Medium High Durability, so that it can be interpreted as L 2 and L 3, it takes a long time to experience the weathering process. Meanwhile, the mineralogy composition of the residual clay shale by XRD testing was obtained the composition of 24.7% montmorillonite, 31.2% kaolinite and 10.3% mica.

**Keywords :** Residual, Clay Shale, Slake Durability, Shear Strength, Mineralogy

## 1. INTRODUCTION

Toll Bawen - Semarang, located in Central Java, precisely in Bawen sub-district dan geologically, the location of the Indonesian territory, which is traversed by three main tectonic plates, namely the Europe-Asia, India-Australia, and the Pacific Plate, makes Indonesia many active volcanoes and prone to disasters. This different relief is caused by the geological activity of the earth it self, plate moves (converges) or moves away (diverges), resulting in a push or pull on the rock on the surface. Factors controlling mass movement include geomorphology, geological structures, rock lithology, land use, and geohydrology[1]. Based on its formation, the rocks are divided into 3 (three) major groups according to [2], namely: igneous rock, metamorphic rock and sedimentary rock.

First, soil tests were carried out to determine the physical and mechanical characteristics of clay shale and rock in the book Principles of Geotechnical Engineering [3]. Residual shear strength consists of two parameters namely residual shear angle ( $\phi'$ ) and residual cohesion ( $c'$ ) which can be used for long-term analysis of slope stability and excavation[4], second, the rock resistance test was first proposed by [5] assessing the resistance caused by rock samples to weaken and / or disintegration when cycled from drying and wetting with standard measurements of the weight of loss of rock properties when repeatedly rotated through the interface. air and water with Gamble's Slake Durability Classification[6]) in Table 1 and third, mineral tests with XRD.

**Table 1** Gamble's Slake Durability Classification[6]

Durabilitas	SDI 1 <sup>st</sup> Cycle	SDI 2 <sup>nd</sup> Cycle
Very High Durability	> 99	>98
High Durability i	98 – 99	95 – 98
Medium High Durability	95 – 98	85 – 95
Medium Durability	85 – 95	60 – 85
Low Durability	60 – 85	30 – 60
Very Low Durability	< 60	0 – 30

The strength of the clay shale flakes drops dramatically until they become very soft when they are wet and submerged. When clay shale is subjected to repeated loads, its strength gradually decreases from very soft until it reaches residual strength [7], [8], [9], conducted research on clay shale soils, with residual shear angle values.

## 2. MATERIAL AND METHODS

Clay shale test samples were taken at five points, located on the Semarang - Bawen toll road. The real conditions of all samples taken have been exposed to sunlight in Figure 1 and the coordinates of each sample location point in Table 2. The test samples were taken from clay shale or rocks exposed to sunlight, already weathered, how to store samples without and with paraffin at a depth of - 0.00 - 0.50 m. Then the following tests were carried out : water content[10], Specific Gravity [11], Atterberg Limit Test [12], [13], Slake Durability Test – ASTM D4644-08 (ASTM International, 2008), Direct Shear Test Residual [15].

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**Figure 1** Sampling Location

**Table 2** Coordinates of test soil sample locations

Sample	South Latitude	East Longitude	Location
L1	7°14'10.0"	110°27'13.2"	Kandangan Village
L2	7°14'12.0"	110°27'13.3"	Kandangan Village
L3	7°14'00.7"	110°27'11.5"	Kandangan Village
L4	7°14'11.5"	110°27'10.6"	Kandangan Village

### 3. RESULTS AND DISCUSSION

The results of the rock properties index testing carried out on the specimen from the point of extraction at L 2 and L 3 are shown in Table 3

**Table 3** Results of rock properties index testing L 2 and L 3

Sample	TTK 2		TTK 3	
	Paraffin	Non-Paraffin	Paraffin	Non-Paraffin
Kadar Air (%)	13,30	9,24	12,25	8,20
Specific Gravity ( $G_s$ )	2,730	2,707	2,833	2,821
Gravel (%)	67,41	63,04	71,99	66,86
Sand (%)	32,59	36,96	28,01	33,14
Silt and Clay (%)	1,33	1,28	1,87	0,84
Pass sieve No. 4 (%)	64,07	82,05	64,05	66,17
Pass sieve No. 10 (%)	32,59	36,96	28,01	33,14
Pass sieve No. 40 (%)	20,93	13,45	13,61	18,87
Pass sieve No. 200 (%)	1,33	1,28	1,87	0,84
D10 (mm)	0,153	0,200	0,284	0,157
D30 (mm)	1,500	1,500	2,250	1,160
D60 (mm)	4,350	3,000	4,500	4,100
Cu	44,231	16,750	18,182	35,333
Cc	2,261	2,522	1,823	2,361

Referring to Table 3, the USCS Classification System, the GW group, i.e. well-graded gravel and a mixture of sand gravel, contains little or no fine grains. AASHTO Classification System, group A-1-a, namely crushed stone,

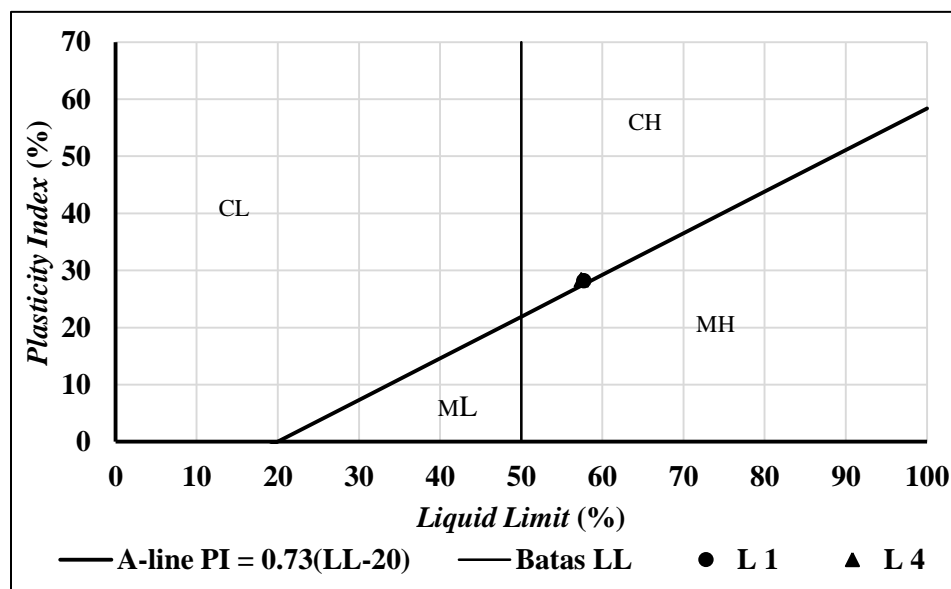
gravel, and sand.[3] and the results of testing the properties index of clay shale carried out on the test object from the point of collection at L 1 and L 4 are shown in Table 4.

**Table 4** Results of clay shale properties index testing L 2 and L 3

Sample	TTK 1		TTK 4	
	Paraffin	Non-Paraffin	Paraffin	Non-Paraffin
Kadar Air (%)	18,38	13,25	16,39	11,63
Wet Density ( $\gamma_b$ )	2,091	2,08	2,098	2,094
Specific Gravity ( $G_s$ )	2,66	2,65	2,63	2,65
Liquid Limit (%)	57,63	57,85	57,85	57,00
Plastic Limit (%)	29,31	29,74	29,5	28,58
Plasticity Index (%)	28,32	28,11	28,35	28,42
Pass sieve No. 40 (%)	100	100	99,9	99,89
Pass sieve No. 200 (%)	97,89	91,83	89,86	91,69
Clay fraction(%)	78,26	70,71	75,87	53,54

Based on Table 4, the USCS Classification System, the OH group, is an organic clay with moderate to high plasticity. The AASHTO Classification System, group A-7-6, i.e. clay soil.

[3]and if the LL and PI values are plotted into the Plasticity Graph according to Das and Sobhan (2014) from Table 4, it can be seen in Figure 2 and Figure 3



**Figure 2** Plasticity graph of L 1 and L 4 samples according to USCS Classification.[3]

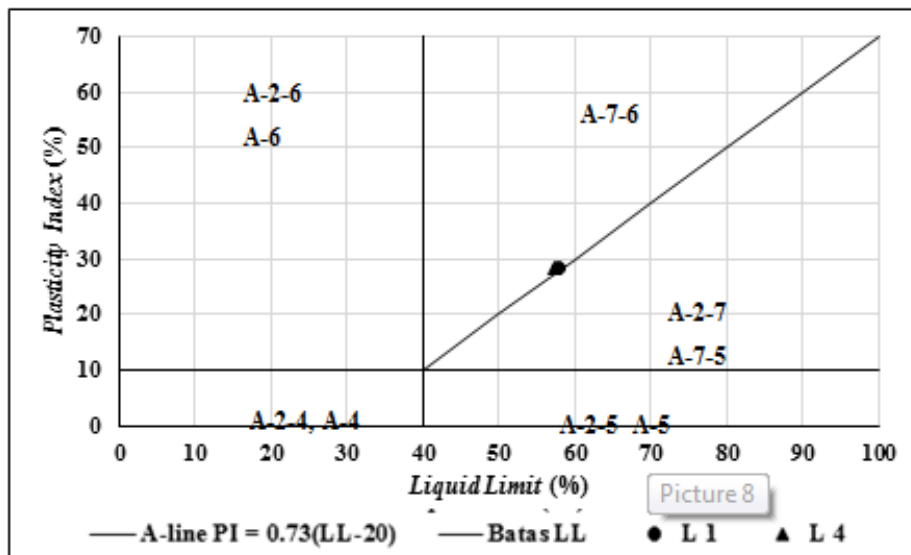


Figure 3 Plasticity graph of L 1 and L 4 samples according to AASHTO Classification.[3]

The residual direct shear test is only carried out on clay shale soil only aims to determine the values of the effective parameter of residual shear strength, where the permeability is low, i.e. the test is carried out with the slow test type.. The notation used in the sample code, PL = Plasticity Limit, 1PL15x = Location 1 at water content Original limit plasticity

with 15 x Blow, 1PL + 5% 15 = Location 1 at water content Original limit plasticity + 5% moisture content with 15 x Blow , 1PL + 10% 15 = Location 1 at water content Original limit plasticity + 10% moisture content with 15 x Blow, that's the same thing as in Location 4 on Table 5.

Table 5 The residual value of effective cohesion (c ') and effective shear angle (φ'r) for 15 times the blow(L.1,L 4)

Sample	φ'r	c'
	(°)	(kN/m <sup>2</sup> )
L1	1PL15x	9.85
	1PL+5%15x	8.88
	1PL+10%15x	10.11
L4	4PL15x	17.12
	4PL+5%15x	16.98
	4PL+10%15x	17.95

Likewise the notation for both locations on 25x blows on Table 6

Table 6 The residual value of effective cohesion (c ') and effective shear angle (φ'r) for 25 x blow(L 4) [8]

Sample	φ'r	c'
	(°)	(kN/m <sup>2</sup> )
L 1	1PL25x	5.97
	1PL+5%25x	7.69
	1PL+10%25x	9.37
L 4	4PL25x	15.52
	4PL+5%25x	13.51
	4PL+10%25x	12.59

Test results of mechanical properties of clay shale soils, residual shear angles are plotted graphs in Figure 4, figure 5, figure 6, figure 7 [7] and Figure 8, figure 9, figure 10, figure 11[8], on 15x and 25x blow.

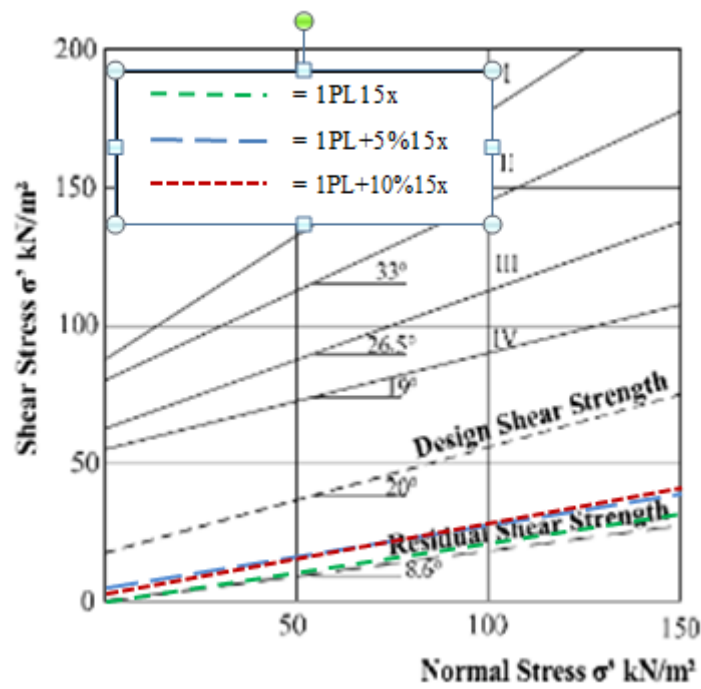


Figure 4 The residual value of effective cohesion ( $c'$ ) and effective shear angle ( $\phi'r$ ) for 15 x blow(L 1)[7]

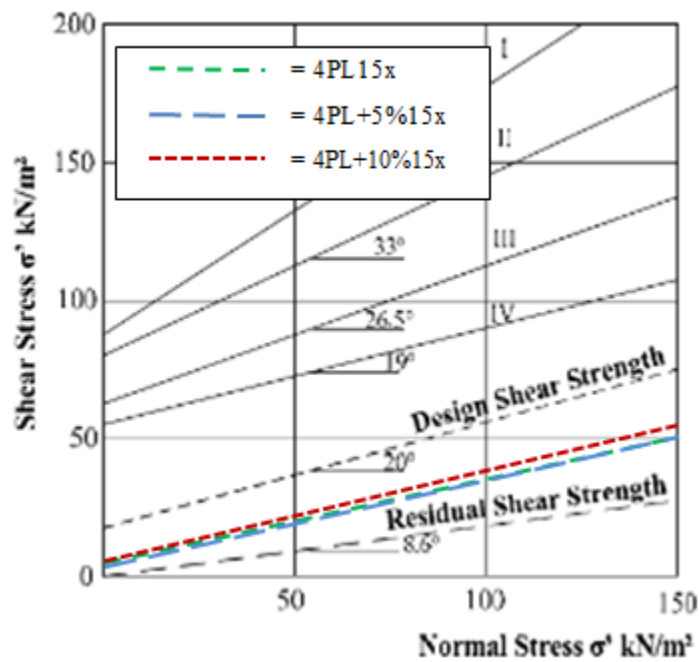


Figure 5 The residual value of effective cohesion ( $c'$ ) and effective shear angle ( $\phi'r$ ) for 15 x blow(L 4) [7]

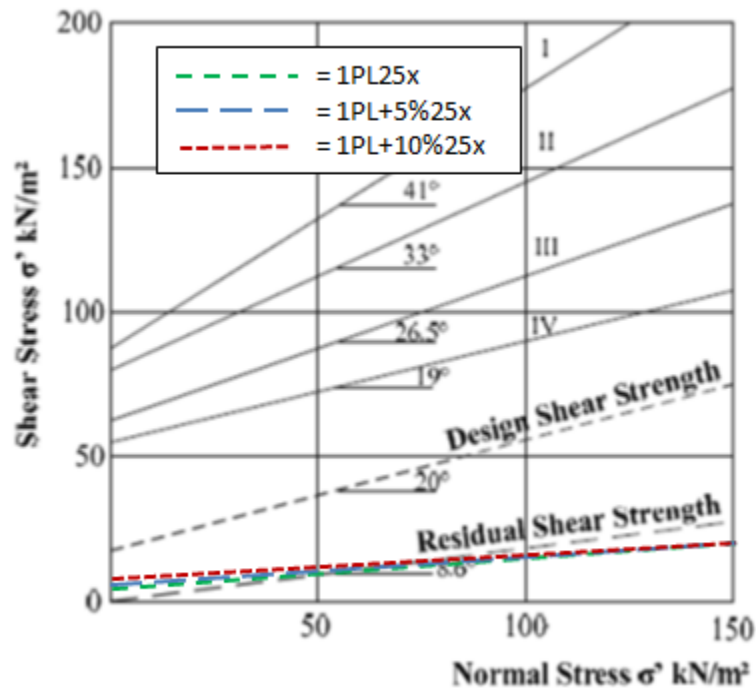


Figure 6 The residual value of effective cohesion ( $c'$ ) and effective shear angle ( $\phi'r$ ) for 25 x blow(L 1) [7]

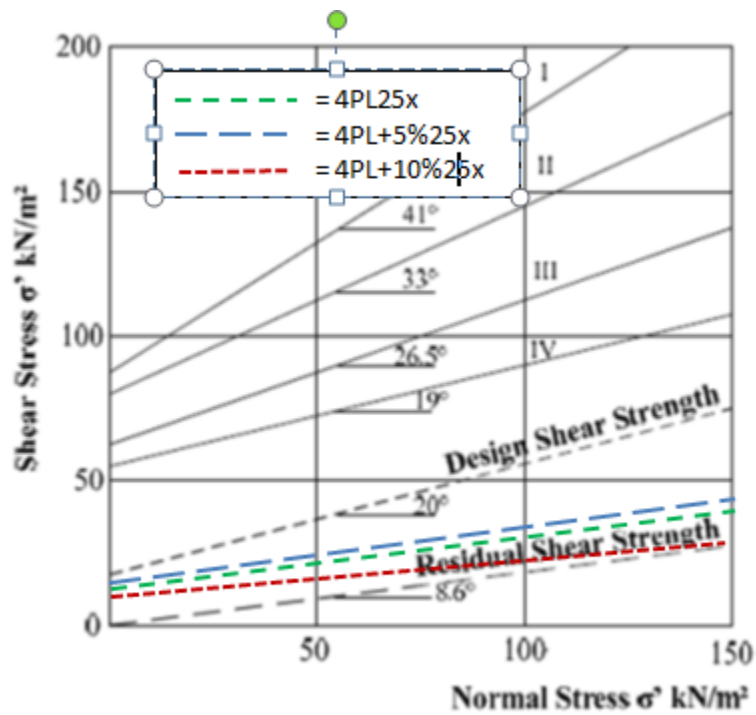
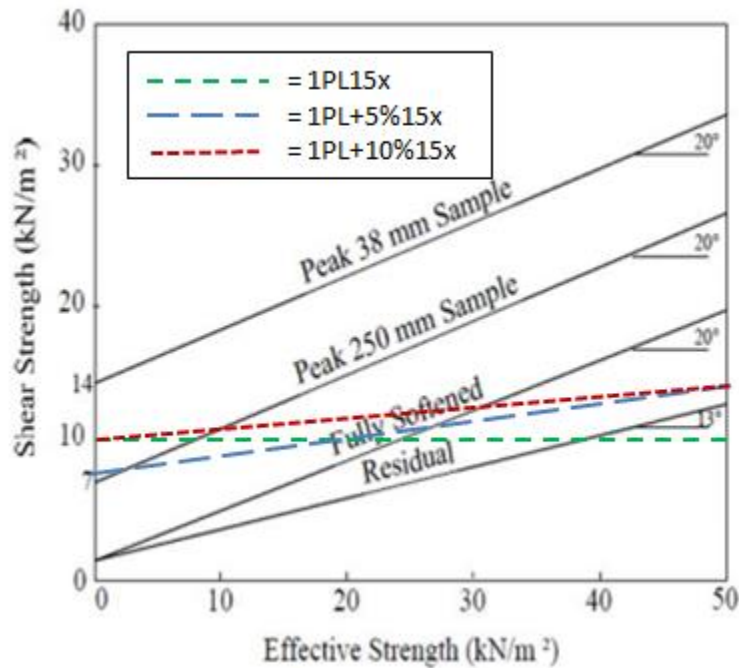
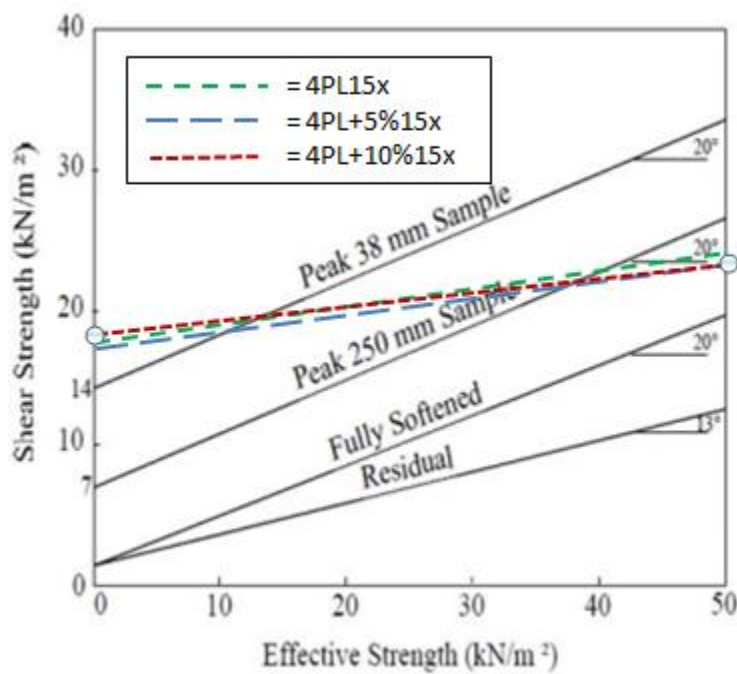


Figure 7 The residual value of effective cohesion ( $c'$ ) and effective shear angle ( $\phi'r$ ) for 25 x blow(L 4) [7]

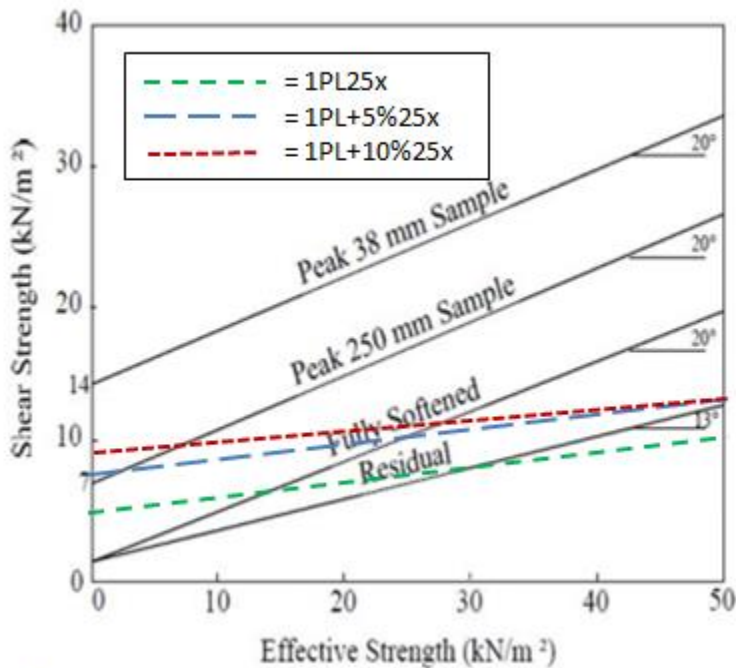
The results of the mechanical properties of clay shale soil, the remaining shear angle according to Gartung (1966) in the residual area



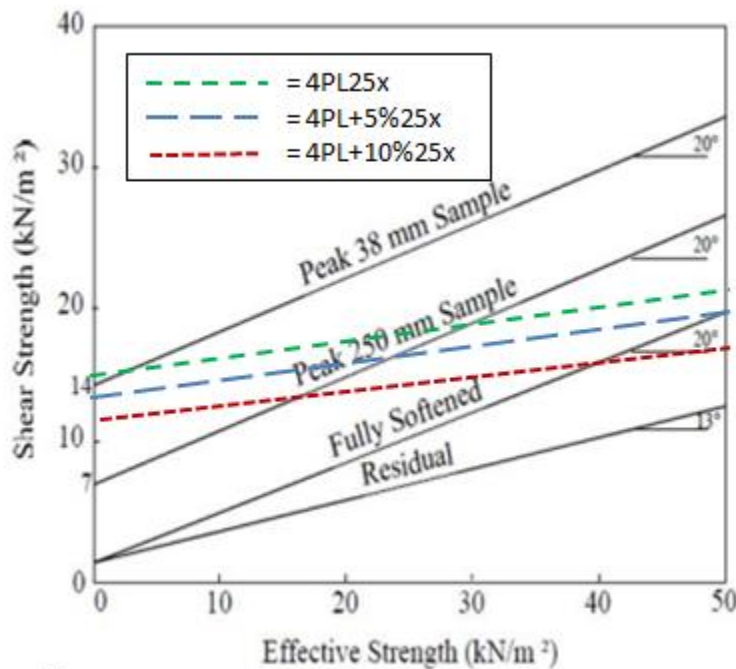
**Figure 8** The residual value of effective cohesion ( $c'$ ) and effective shear angle ( $\phi'_r$ ) for 15 x blow(L 1) [8]



**Figure 9** The residual value of effective cohesion ( $c'$ ) and effective shear angle ( $\phi'_r$ ) for 15 x blow(L 4) [8]



**Figure 10** The residual value of effective cohesion ( $c'$ ) and effective shear angle ( $\phi'r$ ) for 25 x blow(L 1)[8]



**Figure 11** The residual value of effective cohesion ( $c'$ ) and effective shear angle ( $\phi'r$ ) for 25 x blow(L 4)[8]

While the results of the mechanical properties of clay shale soil, the remaining shear angle according to Skempton (1985), experienced significant changes. The results of

mechanical properties of clay shale soils, residual shear angles, are plotted graphs in Figure 8. [9]



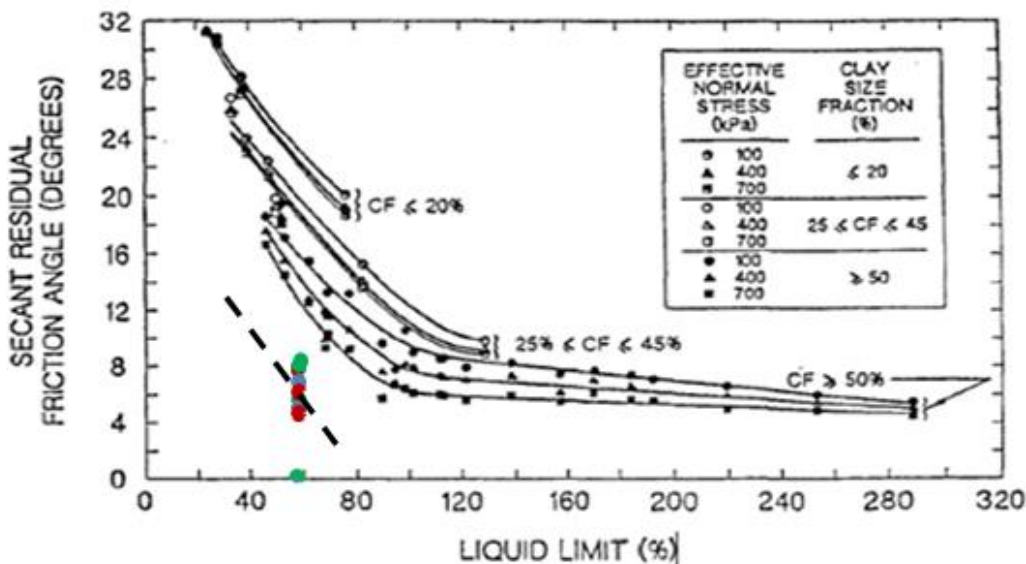


Figure 12 Plotting score shear angle on the graph of effective strength and shear strength [9]

The results obtained indicate that the relationship between the liquid limit and the residual shear angle is directly proportional to the test according to Stark and Eid (1994), at the position below the graph. From the research results obtained rock

classification with and without paraffin according to Gamble's Slake Durability Classification by Goodman (1980) in Table 7 and Table 8. [6]

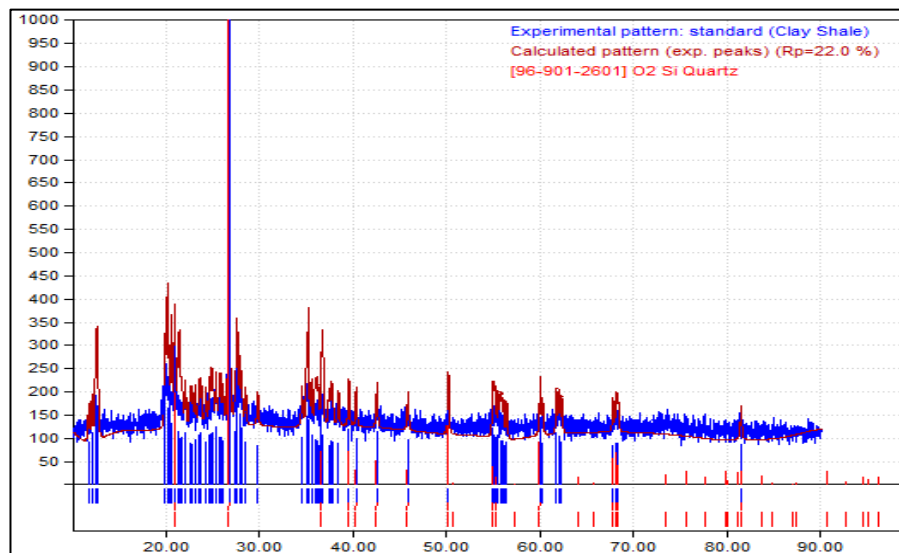
Table 7 Paraffin Slake Durability Test Results[6]

Sample	Initial Weight (gram)	Weight Restrained 1 <sup>st</sup> Cycle (gram)	Weight Restrained 2 <sup>nd</sup> Cycle (gram)	% Restrained 1 <sup>st</sup> Cycle	% Lasted 2 <sup>nd</sup> Cycle	Calcification
L 1	568.43	437.355	172.97	76.964	30.438	Low durability
L 2	527.865	452.86	322.675	85.812	61.154	Medium durability
L 3	565.925	547.335	538.695	96.723	95.187	Medium high durability
L 4	537.065	417.985	169.35	77.861	31.574	Low durability

Table 8 Non-Paraffin Slake Durability Test Results[6]

Sample	Initial Weight (gram)	Weight Restrained 1 <sup>st</sup> Cycle (gram)	Weight Restrained 2 <sup>nd</sup> Cycle (gram)	% Restrained 1 <sup>st</sup> Cycle	% % Lasted 2 <sup>nd</sup> Cycle	Calcification
1	556.33	420.37	167.395	75.536	30.087	Low durability
2	492.295	400.11	298.36	81.278	60.608	Medium durability
3	576.115	556.235	541.65	96.556	94.008	Medium high durability
4	570.96	432.77	175.52	75.818	30.768	Low durability

From the mineralogy results of the XRD test at the Undip Integrated Laboratory, it can be seen in Figure 15



**Figure 13** UNDIP Integrated Laboratory XRD Test Results

The data from mineralogy study (X-Ray Diffraction), can be read through the Match! Program. Copyright © 2003-2014 CRYSTAL IMPACT, Bonn, Germany obtained a composition of 24.7% montmorillonite, 31.2% kaolinite and 10.3% mica.

#### 4. CONCLUSION

The conclusion from the results of the analysis on direct shear, it is found that the value of the residual effective shear angle ( $\phi'_{r}$ ) ranges from 4.77 - 9.78 ° and the effective cohesion value ( $c'$ ) is 5.97 - 17.95 kN / m<sup>2</sup> and can it is said that in geological engineering for materials that are susceptible to weathering processes, rock resistance based on the slake durability classification, samples L 1 and L 4 are classified as Low Durability, so it can be interpreted that the sample is very prone to weathering when exposed directly to weather changes ,, L 2 is classified Medium Durability, and L 3, are classified as Medium High Durability, so that it can be interpreted as L 2 and L 3, it takes a long time to experience the weathering process Meanwhile, the mineralogy composition of the residual clay shale by XRD testing was obtained the composition of 24.7% montmorillonite, 31.2% kaolinite and 10.3% mica.

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