

Drying Wetting Effect On The Physical Characteristics of Bobonaro Clay

(Case Study: East Nusa Tenggara Province, Indonesia)

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ABSTRACT

The Motaain-Henes-Motamasin route, which forms the eastern boundary between the Republic of Indonesia and the Democratic Republic of Timor Leste, includes Dafala-Laktutus STA.149+140. This route is managed by the East Nusa Tenggara BPJN. In the East Nusa Tenggara province, numerous road projects close to the border between RI and Timor Leste were constructed on challenging clay soil from the Bobonaro clay deposit. This suggests that a landslide has occurred along the road portion. Thus, it is crucial to investigate the properties of this Bobonaro clay. Drying and wetting experiments were conducted on a laboratory scale for a maximum of three (3) cycles in this study. Soil samples in the remolded disturb condition—the starting circumstances of the first undisturbed soil test results with wetting-drying test intervals per 25% moisture content (w)—were used to create the specimens for the wetting-drying test. Volumetric gravimetric testing and suction testing using the ASTM D 5298-03 Soil Suction Method with Filter Paper are used to determine the physical characteristics of the soil. The physical characteristics of Bobonaro clay usually decrease over the wetting-drying cycle. Between the first and third cycles, the dry volume weight, γ_d [kN/m³], fell by 4.043%, the void ratio, e , increased by 13.82%, and the negative pore water pressure ($-U_w$) reduced by 66.71%. The Bobonaro clay exhibits strong swelling and shrinkage capabilities, akin to expansive soil behavior, as evidenced by notable variations in the water content (w), void ratio (e), and negative pore water pressure ($-U_w$).

Keywords : Bobonaro clay, landslides, drying-wetting cycle, soil physical parameters, volumetric gravimetric, suction, swelling and shrinkage, expansive soil.

INTRODUCTION

The Bobonaro Clay formation has the motaain-Henes-Motamasin STA road section 149+140, which comprises a significant portion of the eastern portion of the Indonesia-Democratic Republic of Timor Leste border. Since landslides are known to occur frequently in the tropics, the soil in this area is likely impacted by weather oscillations between rain and dryness, which are predicted to lower the parameters of the soil. This is seen in Figure 1 below.



Figure 1. Current Motaain-Henes-Motamasin Road STA.149+140 Landslides
Source: East Nusa Tenggara Province P2JN, 2020

According to soil data from P2JN East Nusa Tenggara Province, the N-SPT value is generally good, ranging from > 25 strokes/30 cm starting at a depth of 2 meters and larger in deeper conditions. The average volume dry weight (γ_d) ± 1.9 gr/cm³, specific gravity > 2.6 , porosity (n) ± 0.22 , void ratio (e) ± 0.3 kg/cm², cohesiveness ± 0.3 kg/cm², and inner shear angle (ϕ) $\pm 13^\circ$ are all good physical features of the soil. Nonetheless, the road segment is still prone to landslides.

There is still a lack of research discussing Bobonaro clay. This is shown below by a number of studies of Bobonaro clay:

1. G.J. Winston Fernandez, "Soil characteristics," 2017.
2. G.J. Winston Fernandez, Managing the Road Subbase (2017).
3. Eduardo Amaral Vong (2017) on the properties of soil.
4. Diah Affandi, regarding the characteristics of soil.

Additionally located in the tropics is the Motaain-Henes-Motamasin STA. 149+140 road segment, may be impacted by weather variations between the rainy and dry seasons, which weaken the soil's strength and physical characteristics and cause landslides on the slopes. According to earlier research, the soil's mechanical and physical properties can be changed by weather-related drying and wetting processes, which affects soil strength. For example, Rizka Adi Ariesnawan (2015) suggested that Tuban shale clay's physical characteristics are influenced by the wetting-drying cycle. The structure or pore space of the clay shale changes as a result of the wetting-drying cycle, expanding and contracting to alter the pore number (e) and density. When the clay shale is wetted once (1 cycle), or 13.75%, the pore number (e) increases dramatically. The pore value (e) of Tuban clay shale rose by 15.47% from the starting conditions at the conclusion of the second round. According to Muntaha et al. (2016), cohesiveness in the third residual soil was similarly impacted by variations in water content; wetting conditions resulted in a higher water content (w_c) value followed by a lower soil cohesion value. However, when the soil dried, cohesiveness increased. According to Trihanyndio Rendy Satrya, Ria Asih Aryani Soemitro, Toshifumi Mukunoki, and Indarto (2017), the soil's dry density progressively dropped from 14.46 kN/m³ to 11.95 kN/m³ over the third cycle, a decline of about 17.36%.

Given some of the aforementioned contexts, it is crucial to carry out studies on how tropical weather—both dry and rainy—affects Bobonaro clay soil properties.

RESEARCH METHOD

Figure 2 shows a flowchart for conducting laboratory tests to examine how drying wetness influences the usual Features of clay soil in Bobonaro, East Nusa Tenggara Province.

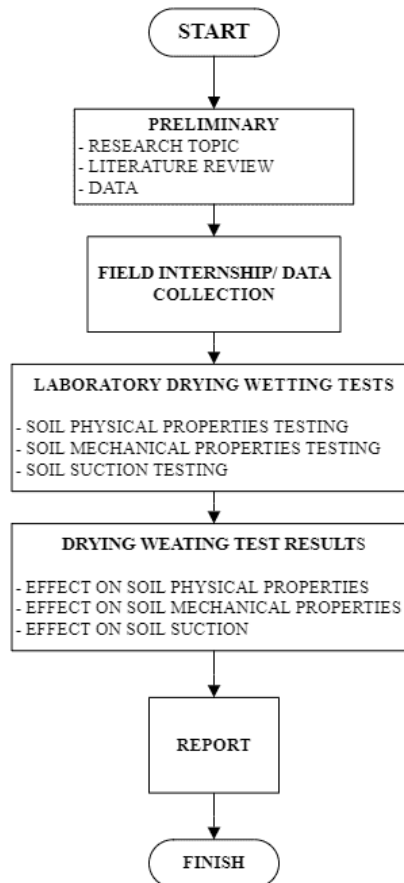


Figure 2. Research Diagram (Flow Chart)

Source: Author Data, 2022

According to Figure 2 above, the phases of this investigation include:

1. Introduction

The introduction's goal is to outline the research topic, literature review, and data that will be used to identify issues and potential solutions.

2. Data collection and field visits

Field visits were conducted for this project in order to gather primary and secondary information in the form of:

- Secondary Data

The National Road Planning and Supervision Unit of East Nusa Tenggara Province and the Nusa Tenggara II River Basin Office of the East Nusa Tenggara BPJN provided the secondary data used in this study:

- The Motaain-Henes-Motamasin Road stretch, Kab. Belu, NTT, has DED (Detailed Engineering Design) data.
- The Motaain-Henes-Motamasin, Kab. Belu, NTT laboratory test findings and records.

- Primary data

This study's major data came from testing at the ITS Soil and Rock Mechanics laboratory, field documentation, and collection of disturbed and undisturbed soil samples.

3. Laboratory testing of drying-wetting cycles

Soil samples collected during the internship—both disturbed and undisturbed—are used to analyze the drying-wetting cycle. This test was conducted at Surabaya's Sepuluh Nopember Institute of Technology (ITS) Soil Mechanics Laboratory. Figure 3 below depicts the testing phases.

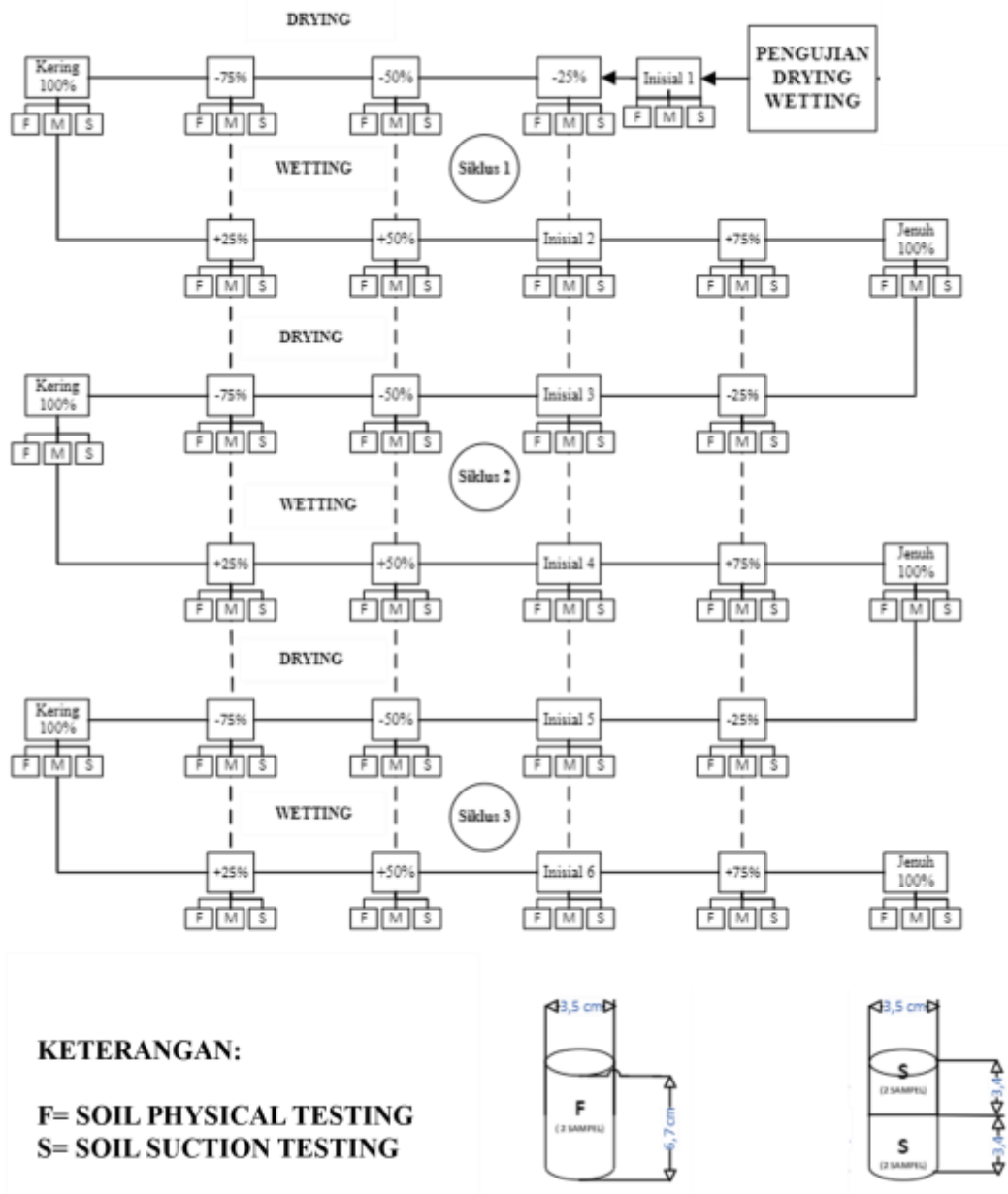


Figure 3. Drying-Wetting Testing Stages

Source: Author Data, 2022

The following are the procedures for the dry-wetting test:

- There were three (3) rounds of drying and soaking.
- The following processes make up the drying process with a 25% water content reduction:
 - W_i (initial sample weight)

- $W_{25\%} = W_i - 25\% (W_{sat} - W_i)$
- $W_{50\%} = W_i - 50\% (W_{sat} - W_i)$
- $W_{75\%} = W_i - 75\% (W_{sat} - W_i)$
- $W_{100\%} = W_i - 100\% (W_{sat} - W_i)$
- The latter phases of the interval wetting procedure include a 25% water content addition:
 - W_i (initial sample weight)
 - $W_{25\%} = W_i + 25\% (W_{sat} - W_i)$
 - $W_{50\%} = W_i + 50\% (W_{sat} - W_i)$
 - $W_{75\%} = W_i + 75\% (W_{sat} - W_i)$
 - $W_{100\%} = W_i + 100\% (W_{sat} - W_i)$
 - A total of 261 samples (disturb samples) will be created by remolding the findings of soil testing under 29 conditions in natural settings (undisturbed samples), where one condition equals nine samples.
 - Suction testing (S) and volumetric-gravimetric testing are used in the To evaluate the physical properties of soil, use ASTM D 5298-03 Soil Suction Method with Filter Paper (F). The Whatman No. 42 filter weight calibration chart will be utilized to calibrate the Whatman No. 42 filter paper used in this experiment. To establish a connection between the suction value (kN/m²) and the volumetric content of soil water (W_c, %)
- 4. The physical characteristics of the soil and the suction values for each water content condition are included in the drying-wetting test findings.
- 5. Reports

ANALYSIS AND DISCUSSION

In accordance with the original test results of the undisturbed sample, which were as follows: Remolding disrupt soil produced the test sample, which had a dry unit weight (γ_d 1.631 gr/cm³), specific gravity (G_s 2.593), and water content (W_c disturb soil) of 18.183%. The mold was shaped like a PVC pipe and measured Ø 3.75 cm x 8 cm high, V = 28.490 grams. is also depicted in Figure 4 below.

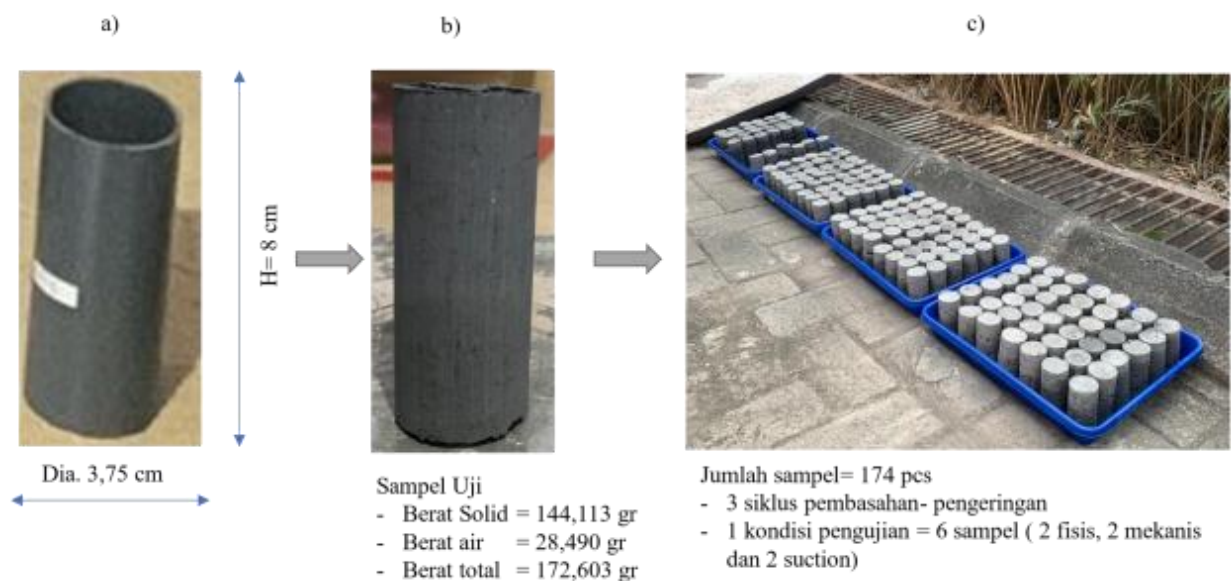


Figure 4. a) Sample mold b) Test sample printouts c) Total Test Items Printed

Source: Author Data, 2022

The Bobonaro clay specimens' water content changed as a result of wetting and drying testing. As indicated in **Table 1** below, the experiments for wetting and drying were conducted by varying the weight of water in each sample at intervals of 25% of the water content.

Table 1. Regarding the Water Weight Addition for Every Test Object

NO	Condition	Water Content (%)		Water Weight (gr)	+ Water (gr)	Soil+Water (gr)
1	Airdry	2.986	0.02986	4.303	0.000	148.417
2	25	7.925	0.07925	11.421	7.117	155.534
3	50	12.864	0.12864	18.538	7.117	162.652
4	75	17.802	0.17802	25.655	7.117	169.769
5	Initial	19.769	0.19769	28.490	2.835	172.604
6	100	22.741	0.22741	32.773	4.283	176.886

Source: Author Data, 2022

Wetting-drying studies for up to three (three) cycles yielded a number of relationship curves that describe how applying the cycle affects the physical features of Bobonaro clay, as shown in the following Figure 5.

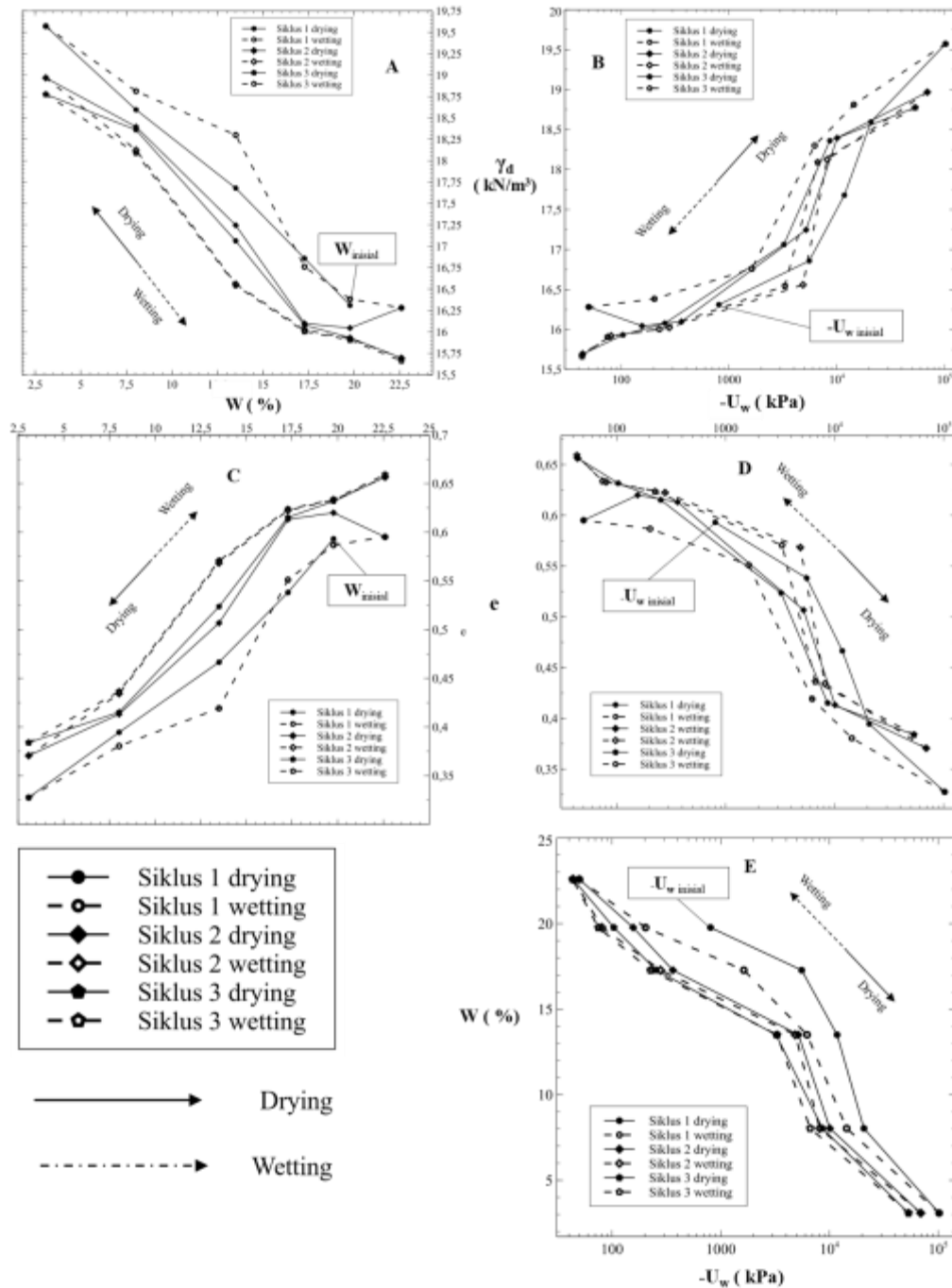


Figure 5. Bobonaro clay's physical characteristics are affected by the wetting and drying cycle. Relationships exist between water content and dry unit weight of soil (A), water content and void ratio (C), negative pore water pressure and void ratio (D), and negative pore water pressure and water content (E).

Source: Author Data, 2022

The curves of Bobonaro clay's various physical characteristics are combined in Figure 5. The combined curves' general behavior demonstrates that the Bobonaro clay's physical properties have decreased due to the cycle of drying and wetting. Together, these graphs show how changes in water content (w) affect the soil's void ratio (e), dry unit weight (γ_d), and negative pore water pressure ($-U_w$). A drop in water content (w) during the drying process causes a rise in dry unit weight. The negative pore water pressure ($-U_w$) and dry unit weight (γ_d) of this Bobonaro clay decrease during the wetting process due to an increase in pore

number (e) that correlates with an increase in water content (w). On the other hand, a drop in the void ratio (e) follows soil (γ_d) and negative pore water pressure (-Uw).

The soil dry unit weight (γ_d) decreases as the water content (w) increases when drying wetness is applied from cycle 1 to cycle 3, and visa versa (Figure 5). A). At beginning circumstances, the soil had 16.31 kN/m³ is the dry unit weight (γ_d) and a moisture content (w) of 19.769%. During the drying process, the soil's dry unit weight rises till it dries by air and has a moisture 3.082% content. (γ_d) to 19.57 kN/m³. The dry unit weight parameter decreased by an average of 3.674% between cycles 1 and 2, 4.043% between cycles 1 and 3, and only an average of 0.38% between cycles 2 and 3.

Figure 5. B) demonstrates that in Bobonaro clay, a rise in soil dry unit weight (γ_d) coincides with an increase in negative pore water pressure (-Uw). Under initial conditions, the soil's negative pore water pressure (-Uw) was 804.978 kPa and its dry unit weight (γ_d) was 16.31 kN/m³. Its negative pore water pressure (-Uw) increased to 102,103.544 kPa and it reached 19.57 kN/m³. However, the application of the drying wetting cycle reduced the dry unit weight parameter of soil (γ_d) by 3.674% between cycles 1 and 2 and 4.043% between cycles 1 and 3. Additionally, from cycle 1 to cycle 2 and cycle 1 to cycle 3, decreased by 53.43% and 62.45%, respectively, in the negative pore water pressure (-Uw).

Figure 5. C) shows how an increase in water content (w) causes the Bobonaro clay's void ratio (e) to climb. It is clear from the starting conditions of cycle 1, where the e was 0.593 and the water content (w) was 19.769%. After drying until the water content (w) was 3.082%, the e decreased to 0.328; however, after wetting until it was saturated with water (w) of 22.591%, the void ratio (e) increased to 0.595. At condition 50, with a water content (Wc) of 13.5%, significant alterations started to be observed. The drying wetting cycle increased the void ratio (e), with an average increase of 12.56% between the first and second cycles, 13.82% between the first and third cycles, and comparatively little between cycles two and three..

As seen in Figure 5D), Negative pore water pressure (-Uw) changes as a result of the drying wetting cycle. As was seen under beginning conditions with a void ratio (e) of 0.593, while drying to air dry conditions, the void ratio (e) dropped to 0.328 and the negative pore water pressure (-Uw) increased from 804.978 kPa to 102,103.544 kPa. Negative pore water pressure (-Uw) decreases as the void ratio (e) rises. Between cycles 1 and 2, the void ratio (e) increased by 12.56% while There was a 53.43% drop in the negative pore water pressure (-Uw). The void ratio (e) rose by 13.82% between cycles 1 and 3, and after that, the negative pore water pressure (-Uw) dropped by 62.45%.

Figure 5E) demonstrates the relationship between negative pore water pressure (-Uw) and water content (w). When the water content (w) falls, the negative pore water pressure (-Uw) increases. At initial circumstances, it displays a water content (w) of 19.769% and 804.978 kPa of negative pore water pressure (-Uw). At 102,103.544 kPa, the negative pore water pressure (-Uw) increases after it dries to a moisture content (w) of 3.082%. Negative pore water pressure (-Uw) dropped by 53.43% between cycles 1 and 2 and by 62.45% between cycles 1 and 3 when the drying wetting cycle, as shown in the preceding figure, was applied.

Regarding some comparative research on how soil physical characteristics affect the drying-wetting cycle and the outcomes of Bobonaro clay testing, as indicated in **Table 2** below.

Table 2. Comparing the Physical Properties of Soil from Various Wetting-Drying Test Results

No	Author/ Research Title	Changes in Soil Physical Parameters		
		e (%)	γ_d (%)	-U _w (%)
1	Rizka A. Ariesnawan, "The Mechanical and Dynamic Properties of Tuban Clay Shale Due to Changes in Water Content," 2015	+ 15,47	-	- 73,95
2	North Balikpapan Residual Soil's Mechanical and Physical Characteristics, Muntaha dkk, 2016 Due to the Effects of Variations in Water Content	+ 42,25	-	-
3	Trihanyndio Rendy Satria dkk, 2017/Drying-Wetting Cycles Affect Soil Properties on the Bengawan Solo River Embankment		- 22,49	
4	Saleh, 2023/Slope Stability Analysis Examining Bobonaro Clays' Wetting-Drying and Rainwater Infiltration Aspects	+13,82	-4,043	- 62,45

Source: Author Data, 2022

CONCLUSION

The test findings and data analysis allow for the following deductions:

1. The Bobonaro clay's physical characteristics often decline due to the cycle of wetting and drying.
2. The soil's pore space is altered by the drying and wetting cycle, altering its density and void ratio. While the void ratio (e) grew by 13.82% and stayed relatively steady between cycles 2 and 3, the dry unit weight (γ_d) decreased by 4.043% between cycles 1 and 3. Furthermore, during cycles 1 and 3, the negative pore water pressure (-U_w) decreased by 66.71%.
3. The Bobonaro clay exhibits strong swelling and shrinking properties, including expansive soil behavior, as evidenced by significant fluctuations in the void ratio (e) and water content (w) to negative pore water pressure (-U_w).

REFERENCES

- [1] Agus Tugas Sudjianto, et al. (2011). *The Effect of Water Content Change And Suction in Behaviour Volumetric Swelling of Expansive Soil*. Dinamika TEKNIK SIPIL/Vol. 11/No. 2/Mei 2011.
- [2] Ariesnawan, A Rizka, (2005). Karakteristik Mekanis dan Dinamik Clay Shale Kabupaten Tuban Terhadap Perubahan Kadar Air. *Master Thesis*, Program Pasca Sarjana, Teknik Sipil ITS.
- [3] Badawi, B. and Indarto, (2010). *Behaviour of expansive undisturbed and remolded soil under drying wetting cycles*. National Conference VI 2010 Civil Engineering ITS, pp. 105-112, 2010.
- [4] Eduardo A Vong, (2017). *Studi Efek Pengembangan Terhadap Kuat Geser Dan Perubahan Volume Tanah Lempung Bobonaro*, NTT, jurnal UNPAR, Bandung
- [5] Fernades W, (2017). *Kajian Karakteristik Lempung Bobonaro di Provinsi NTT*, jurnal Pusjatan PUPR, Bandung

- [6] Halim.A.M. Abd, (2019). *Study of Modulus of Elasticity of The Ground Roughness Due to Wet and Dry Cycle*. Faculty of Engineering University of Hasanuddin. Makassar.
- [7] Muntaha dkk, (2016). “Karakteristik Fisis Dan Mekanik Tanah Residual Balikpapan Utara”, *CINIA Journal*.
- [8] Myers, D. (2005). *Expansive Clays and Road Subgrade an Analysis*. www.godismyjudgeok, 31 Agustus 2007.
- [9] SNI 03-1967-1990. (1990). *Metode pengujian batas cair tanah dengan alat Cassagrande*, Badan Standardisasi Nasional, Jakarta.
- [10] SNI 1964:2008, (2008). *Cara uji berat jenis tanah tanah. Revisi dari SNI 03- 1964-1990*. Badan Standardisasi Nasional, Jakarta.
- [11] SNI 1965:2008, (2008). *Cara uji penentuan kadar air untuk tanah dan batuan di laboratorium*. Badan Standardisasi Nasional, Jakarta.
- [12] SNI 1966:2008, (2008). *Cara uji penentuan batas plastis dan indeks plastisitas tanah. Revisi dari SNI 03-1966- 1990*. Badan Standardisasi Nasional, Jakarta.
- [13] SNI 3423:2008, (2008). *Cara uji analisis ukuran butir tanah. Revisi dari SNI 03- 3423- 1994*. Badan Standardisasi Nasional, Jakarta.
- [14] Sudjianto, A.T., Suryolelono, K.B., Rifa'i, A. and Mochtar, I.B. (2008). *Behaviour of Vertical and Lateral Swelling Pressure on Disturbed Highly Expansive Clay Under Water Content Variation Condition, International Conference on Geotechnical and Highway Engineering*. Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia, 2008, Paper no G 21.
- [15] Tjandra, D., Indarto, & Soemitro, R. (2013). *The Effects of Water Content Variation on Adhesion Factor of Pile Foundation in Expansive Soil*. Civil Engineering Dimension. Vol. 15, No. 2.
- [16] Tjandra, D., Indarto, & Soemitro, R. (2015). *Behavior of Expansive Soil under Water Content Variation and Its Impact to Adhesion Factor on Friction Capacity of Pile Foundation*. International Journal of Applied Engineering Research. Vol. 10, No. 18, 38913-38917.
- [17] Tjandra, D., Indarto, & Soemitro, R. (2015). “Effect of Drying-Wetting Process on Friction Capacity and Adhesion Factor of Pile Foundation in Clayey Soil”. *Jurnal Teknologi*. Vol. 77, No. 11-150.
- [18] Trihanyndio R.S etc, (2017). “Change Of Soil Properties in The Begawan Solo River Embankment Due to Drying-Wetting Cycles”. Researchgate journal.
- [19] Tripathy S, Subba Rao KS, Fredlund DG. (2002). “Water content–void ratio swell-shrink paths of compacted expansive clays”. *Can Geotech J* 39(4):938–959
- [20] Tang CS, Wang DY, Shi B, Li J. (2016). *Efect of wetting-drying cycles on prople mechanical behavior of soils with diferent initial conditions*. CATENA 139:105–116
- [21] Zhao NF, Ye WM, Chen YG, Chen B, Cui YJ. (2019). *Investigation on swelling-shrinkage behavior of unsaturated compacted GMZ bentonite on wetting-drying cycles*. Bull Eng Geol Environ 78(1):617–627.
- [22] Zhao, et al. (2021). *Evolution of mechanical behaviours of an expansive soil during drying-wetting, freeze–thaw, and drying-wetting-freeze–thaw cycles*. Bulletin of Engineering Geology and the Environment. Springer-Verlag GmbH Germany, part of Springer Nature 2021.