Analysis Of Behavior And Chemical Stabilization Of Highly Plastic Local Excavated Soil for Embankments In The IKN Highway Project Segment 3A From Karangjoang To KKT Kariangau

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ABSTRACT

The development of IKN Nusantara (Indonesia's New Capital City) in phase I, 2022-2024, focuses on basic infrastructure development, one of which is the IKN Toll Road Segment 3A Karangjoang - KKT Kariangau (STA 14+000 - STA 25+909) in Balikpapan. This development will add back to Indonesia's infrastructure assets, especially the Ministry of Public Works and Public Housing. One of the main works in the construction of this toll road is excavation and embankment work, the need for a lot of embankment material is a problem in itself so that the excavated soil as much as possible is sought to be used as embankment soil by mixing the excavated soil with fly ash and bottom ash from Balikpapan Steam Power Plant, this is one form of soil stabilization experiment. The mixture testing was carried out by making 3 types of mixture variations namely soil + fly ash, soil + bottom ash, and soil + fly ash & bottom ash, the 3 types of mixtures were tested by standard proctor test and then continued with soaked CBR testing with 0, 7 and 14 days of curing. From these mixes, the highest soaked CBR test result value was 6.013% from the soil + BA 15% mix with 0 days of curing and the lowest value was 0.709% from the soil + FABA 10% mix with 14 days of curing. Due to the negative trend of the soaked CBR test results where the average value is below 6%, the mixed material is not recommended for use.

Keyword : Balikpapan, Indonesia, infrastructure assets, excavated soil, fly ash, bottom ash, standard proctor test, soaked CBR

INTRODUCTION

The State Capital called the Nusantara and hereinafter referred to as the Nusantara Capital is a special regional government unit at the provincial level whose territory is the seat of the State Capital as stipulated and regulated by this Law (Article 1 point 2 of Law Number 3 of 2022 concerning the National Capital). On February 15, 2022, Law Number 3 on the State Capital was officially promulgated by the Indonesian Parliament and the Government as the legal basis for the construction of the new capital city of Nusantara in Penajam Paser Utara Regency, East Kalimantan as shown in Figure 1.

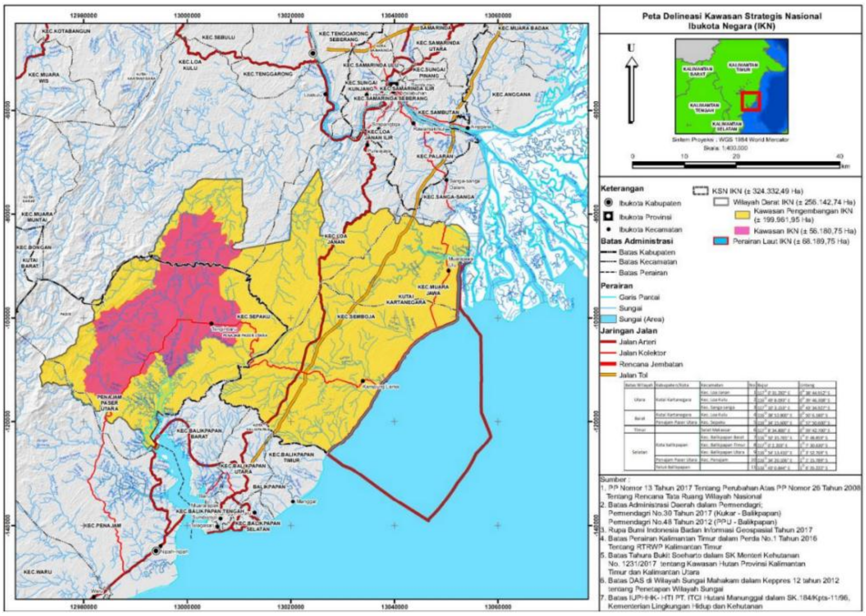

Figure 1. Delineation Map of the National Capital Strategic Area

(Source:Annex I of Law of the Republic of Indonesia Number 3 of 2022 on the National Capital)

The development of the Nusantara Capital City itself will be carried out in 5 stages which are divided into stage I in 2022-2024, stage II in 2025-2029, stage III 2030-2034, stage IV 2035-2039, and stage V in 2040-2045. Phase I, which is carried out in 2022-2024, focuses on basic infrastructure development ranging from improving access roads, providing drinking water, electricity, to waste management. According to Soemitro & Suprayitno (2020), Road Network Infrastructure covers a specific service area. For example, an urban road network consists of roads, bridges, tunnels, intersections, road drainage systems, pedestrian facilities, and road facilities and equipment, such as road markings, road signs, signals, bus stops, and parking lots. The road itself can be classified into several classifications, namely toll and non-toll roads, primary and secondary road networks, road functions, road status, and road classes. Maulidha, Zefira Wisna, et.al, (2022) stated that infrastructure is important for the progress and future of a region and country, which is why the condition of infrastructure must always be in good condition, especially in terms of function. In addition, infrastructure must also follow the main principle of infrastructure asset management. Therefore, Richard Jimoh, et al. (2021) also said that stakeholders have a major role concerning sustainable construction practices and all parties must work together to achieve the common goal of sustainable construction practices. Modu, et.al. (2021) suggested that the most appropriate Facility Management implementation and arrangement for a particular organization can be determined by several important factors that can be categorized according to organizational characteristics, facility features, business sector, and environmental factors. Thus, a facility manager or practitioner can respond differently to different environments rather than be limited to certain general standards and best practices.

The planning of road infrastructure development often passes through locations of problematic soils. Problematic soils can be soft soils, expansive soils, peat soils, etc. where the soil becomes one of the important factors causing disruption of the stability of both road and bridge construction. Soil in road construction functions as a subgrade that supports the construction load and traffic above it. One of the ongoing infrastructure developments in phase 1 of the IKN Nusantara development is the construction of the IKN Access Toll Road connected to the Balikpapan - Samarinda Toll Road, namely the IKN Access Toll Road Segment 3A Karangjoang-KKT Kariangau, with a length of 13.4 Km as shown in Figure 2. All supporting infrastructure is targeted by the Ministry of Public Works and Public Housing to be completed in 2024.

Figure 2. Location Map of IKN Toll Road Segment 3A Karangjoang - KKT Kariangau (STA 14+000 - STA 25+909)
(Source: IKN Toll Road Segment 3A Package Information)

In the construction of the IKN Toll Road Segment 3A Karangjoang - KKT Kariangau, the main work that has the largest portion is excavation and embankment work, with an excavation volume of ± 2,967,844.33 m^3 and an embankment volume of ± 1,626,578.03 m^3. From this work, the need for embankment work requires a lot of material, so in the initial planning the results of the excavation are planned to be reused in the embankment work area by reinforcing geotextiles. The utilization of local excavated soil material is important so that the material requirements for the embankment can be fulfilled, but the excavated soil cannot be fully utilized as embankment soil material due to the condition of the excavated soil which has high plasticity and most of it is also classified as CH soil based on the Unified Soil Classification System as can be seen in Table 1 below where the soil has a plasticity index ranging from 21% to 54%. According to Chen (1975), soils with a plasticity index > 17% are classified as high plasticity, soils classified as having high plasticity, and based on the 2018 General Specifications for Road and Bridge Construction Works (Revision 2) of the Ministry of Public Works and Housing the backfill soil material should not include high plasticity soils classified as A-7-6 according to SNI-03-6797-2022 (AASHTO M145-91 (2012)) or as CH according to the "Unified or Casagrande Soil Classification System". In addition, the CBR of the backfill soil must have a value of not less than 6% (CBR after 4 days of soaking when compacted to 100% maximum dry density (MDD/Maximum Dry Density) as determined by SNI 1742: 2008). From the soil investigation data, by referring to the 2018 General Specifications for Road and Bridge Construction Work (Revision 2) from the Ministry of Public Works and Housing, the excavated soil is classified as non-standard soil that does not comply with existing embankment soil standards. According to Shoffiana et.al. (2022) Unstable embankment slopes can potentially lead to landslides that can cause damage to the infrastructure built on it.

Table 1. Recap of Soil Characteristic Test Results at Excavation Site STA 15+425 up to STA 15+900

Num.	Description		Unit	Results			
1	**BH 4 OP 6 - STA24+150**			**1,50 - 2,00 (U)**	**3,50 - 4,00 (U)**	**17,00 - 17,63 (C)**	**22,48 - 23,00 (C)**
	Gradations	Gravel	%	-	-	-	-
		Sand	%	50.00	28.00	6.00	7.00
		Silt	%	14.00	41.00	41.00	38.00
		Clay	%	36.00	31.00	53.00	55.00
	Atterberg	LL	%	57.00	58.00	73.00	78.50
		PL	%	32.66	25.94	23.51	23.42
		PI	%	24.34	32.06	49.49	55.08
		Soil Type		MH	CH	CH	CH
		Water Content	%	20.10	18.25	14.58	14.51
		γd	t/m^3	1.741	1.806	1.607	1.809
		γsat	t/m^3	2.091	2.136	1.841	2.071
		Cohesion	Kg/cm^2	0.57	0.19	-	-
		Friction Angle	°	10.80	12.70	-	-
		Activity Value		0.68	1.03	0.93	1.00
			Average				0.91
2	**BH 5 OP 6 - STA24+175**			**1,50 - 2,00 (U)**	**17,70 - 17,82 (C)**	**29.20 - 29,85 (C)**	
	Gradations	Gravel	%	15.00	-	-	
		Sand	%	27.00	4.00	11.00	
		Silt	%	20.00	48.00	36.00	
		Clay	%	38.00	48.00	53.00	
	Atterberg	LL	%	52.00	68.00	72.00	
		PL	%	30.42	28.50	28.75	
		PI	%	21.58	39.50	43.25	-
		Soil Type		MH	CH	CH	
		Water Content	%	30.33	16.78	11.47	
		γd	t/m^3	1.548	1.761	2.018	
		γsat	t/m^3	2.017	2.056	2.249	
		Cohesion	Kg/cm^2	0.62			
		Friction Angle	°	12.50			
		Activity Value		0.57	0.82	0.82	
			Average				0.74
3	**BH 6 OP 6 - STA24+200**			**1,50 - 2,00 (U)**	**5,50 - 6,00 (U)**	**11,50 - 12,00 (U)**	**19,50 - 20,00 (U)**
	Gradations	Gravel	%	-	-	-	-
		Sand	%	35.00	34.00	5.00	6.00
		Silt	%	35.00	34.00	36.00	37.00
		Clay	%	30.00	32.00	59.00	57.00
	Atterberg	LL	%	67.00	70.00	70.00	70.00
		PL	%	23.82	17.61	24.87	23.91
		PI	%	43.18	52.39	45.13	46.09
		Soil Type		CH	CH	CH	CH
		Water Content	%	8.61	19.48	17.66	16.20
		γd	t/m^3	1.794	1.635	1.827	1.785
		γsat	t/m^3	1.949	1.954	2.150	2.074
		Cohesion	Kg/cm^2	0.53	0.09	3.48	0.39
		Friction Angle	°	2.50	6.90	6.80	9.70
		Activity Value		1.44	1.64	0.76	0.81
			Average				1.16

Testing of excavated soil related to the CBR value that can be achieved, then the standard proctor test in order to find out what are the maximum γd value and optimum moisture content of the excavated soil has also not been carried out. This is why this research was raised as one of the considerations of what kind of material can be used as embankment and can meet the 2018 General Specifications for Road and Bridge Construction Work (Revision 2). In addition, stabilization of locally excavated soil mixed with fly ash and bottom ash materials sourced from Balikpapan Steam Power Plant is also one of the methods in soil improvement so that the soil to be used in embankment construction can later become a soil that can be used as embankment soil with better physical and mechanical characteristics than its original condition with an increase in the bearing capacity and density of the soil. It is also one of the methods so that the utilization of local excavated soil material can be reused and can meet the needs of existing embankments in the IKN toll road work segment 3A Karangjoang - KKT Kariangau.

RESEARCH METHOD

In this study, related to the research flow that will be carried out is as follows:

Literature Study and Secondary Data Collection

Secondary data related to the IKN Access Toll Project Segment 3A Karangjoang-KKT Kariangau is obtained from Hutama - Adhi - Abipraya KSO as the contractor working on this project under the coordination of the Balikpapan Toll Road PPK - P. Balang - IKN Section 3A. The data obtained are DED (Detailed Engineering Design) data of IKN Access Toll Project Segment 3A Karangjoang-KKT Kariangau and field soil investigation data CPT (Cone Penetration Test), SPT (Standard Penetration Test), laboratory test results related to soil characteristics (physical and mechanical).

Determination of Review Point

Because the main work that has the largest portion is excavation and embankment work, therefore the author decided to take 1 location for the excavation work area, namely at STA 15 + 600 so that the review of this research can be limited so that it is not too broad.

Sampling

Sampling of excavated soil both disturbed and undisturbed will be carried out in the field at the location of excavation work at STA 15+600. Meanwhile, the fly ash material will be taken from PLTU Teluk Balikpapan.

Laboratory Testing For Soil, Fly Ash and Bottom Ash

Physical and mechanical properties testing of excavated soil and XRF (X-Ray Fluorescence) testing of fly ash. The tests were carried out in the laboratory as a form of research conducted and the results of the laboratory tests will be used as primary data that strengthens the basis of the analysis. Advanced testing related to soil characteristics, such as physical testing i.e. gravimetric volumetric testing, Atterberg limit testing, grain gradation testing, and mechanical testing i.e. standard proctor test, CBR (California Bearing Ratio) testing, UU (Unconsolidated Undrained) Triaxial Testing

Standard Proctor Test

The preparation of excavated soil samples without mixture and also the mixture of soil stabilization from excavation + fly ash and bottom ash material is carried out with the following mixture levels:

1. Excavated soil without mixture.
2. Soil stabilization mix + 10% fly ash.
3. Soil stabilization mix + 15% fly ash.
4. Soil stabilization mix + 20% fly ash.
5. Soil stabilization mix + 10% bottom ash.
6. Soil stabilization mix + 15% bottom ash.
7. Soil stabilization mix + 20% bottom ash.
8. Soil stabilization mix + 10% fly ash & bottom ash.
9. Soil stabilization mix + 15% fly ash & bottom ash.
10. Soil stabilization mix + 20% fly ash & bottom ash.

The samples were prepared to obtain the optimum moisture content and maximum dry density of each sample.

Determination of Optimum Mix Content

From the variation of Standard Proctor Test experiments that have been carried out, it will then be determined what is the most optimum mixture level (the composition of the excavated soil mixture ratio with fly ash and bottom ash levels) that can be used as a stabilization mixture to then proceed to CBR testing with 0, 7 and 14 days of curing.

CBR Testing of Excavated Soil Stabilization + Fly Ash

The experiment of stabilization of Excavated Soil + Fly Ash is carried out with the most optimum mixture and 3 variations, curing for 0 days, 7 days, and 14 days and then it will be tested how much the soaked CBR value of the mixture variation is.

CBR Testing of Excavated Soil Stabilization + Bottom Ash

Stabilization experiments of Excavated Soil + Bottom Ash were carried out with the most optimum mixture and 3 variations, curing for 0 days, 7 days, and 14 days and then it will be tested how much the soaked CBR value of the mixture variation is.

CBR Testing of Excavated Soil Stabilization + Fly Ash + Bottom Ash

The stabilization experiment of Excavated Soil + Fly Ash + Bottom Ash is carried out with the most optimum mixture and 3 variations, curing for 0 days, 7 days, and 14 days and then it will be tested how much the soaked CBR value of the mixture variation is.

Physical and Mechanical Properties Testing

Advanced testing of excavated soil that has been stabilized with the optimum mix rate related to soil characteristics, such as physical testing i.e. gravimetric volumetric testing, Atterberg limit testing, grain gradation testing, and mechanical Testing i.e. UU (Unconsolidated Undrained) Triaxial Testing

DATA COLLECTION

Laboratory testing includes testing the physical and mechanical characteristics of excavated soil and excavated soil mixed with fly ash and bottom ash materials such as soil grain analysis, Atterberg Limit, γs, γd, optimum w (moisture content), Ø (soil shear angle), C (cohesion), CBR (California Bearing Ratio) value, and others. Samples of excavated materials were taken from the location of STA 15+600 both disturbed and undisturbed samples.

XRF (X-Ray Fluorescence) Testing Results of Fly Ash and Bottom Ash Materials

For fly ash and bottom ash samples from Balikpapan Steam Power Plant, XRF (X-ray fluorescence) testing has been carried out at PT Superintending Company of Indonesia (Sucofindo) Samarinda Branch. Based on the test results, the fly ash material is classified as class F fly ash with the analysis results in Table 2 below. The classification of fly ash material refers to SNI 2460: 2014.

Table 2. Classification Analysis Result of Fly Ash Material of Balikpapan Steam Power Plant

FLY ASH

NUM.	PARAMETER	UNIT	RESULT	DESC.	CLASSIFICATION
1	SiO_2 (Silicon Dioxide)	% wt	31.97	$SiO_2 + Al_2O_3 + Fe_2O_3$ = 76.56 % wt	**Class F fly ash** because the content is >70%
2	Al_2O_3 (Aluminium Oxide)	% wt	18.00		
3	Fe_2O_3 (Iron Trioxide)	% wt	26.59		
4	CaO (Calcium Oxide)	% wt	9.18		**Class F fly ash** because CaO < 10%
5	MgO (Magnesium Oxide)	% wt	3.32		
6	Na_2O (Sodium Oxide)	% wt	0.21		
7	K_2O (Potassium Oxide)	% wt	1.08		
8	TiO_2 (Titanium Oxide)	% wt	0.77		
9	MnO_2 (Manganese Dioxide)	% wt	0.35		
10	Cr_2O_3 (Chromium Trioxide)	% wt	-		
11	P_2O_5 (Diphosphorus Pentoxide)	% wt	0.41		
12	SO_3 (Sulphur Trioxide)	% wt	7.49		More than Max requirement
13	Loss on Ignition (LOI)	% wt	-		
14	Carbon, Dry Basis	% wt	-		
15	Moisture Content	% wt	-		
16	Oil Content	% wt	-		

Standard Proctor Test Results

The standard proctor test which refers to SNI 1742-2008 is carried out to find the optimum moisture content and maximum dry density (γd maximum) of the excavated soil material and the soil resulting from mixing the excavated soil with fly ash and bottom ash material. The results of the standard proctor test of these materials are presented in Table 3 below.

Table 3. Standard Proctor Test Results

Num.	Description	Unit	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
1	EXCAVATED SOIL (INITIAL)								
	Max Dry Density (γd)	gr/cm3	1.5706871	**1.6563056**	1.5252087	1.4499837	1.286581		
	Water Content	%	15.08	**20.08**	25.51	28.71	36.76		
2	EXCAVATED SOIL + FA 10%								
	Max Dry Density (γd)	gr/cm3	1.6567191	**1.6931286**	1.5958706	1.4683862	1.3486744		
	Water Content	%	13.93	**18.41**	23.62	28.18	34.42		
3	EXCAVATED SOIL + FA 15%								
	Max Dry Density (γd)	gr/cm3	1.5882255	1.6193735	1.5893957	1.4852698	1.3570531		
	Water Content	%	14.48	19.52	24.13	27.44	33.20		
4	EXCAVATED SOIL + FA 20%								
	Max Dry Density (γd)	gr/cm3	1.5703433	1.6119614	1.5941704	1.4728775	1.358201		
	Water Content	%	14.43	18.75	23.76	28.15	33.48		
5	EXCAVATED SOIL + BA 10%								
	Max Dry Density (γd)	gr/cm3	1.6745485	1.7247853	1.6056771	1.4704204	1.3672371		
	Water Content	%	12.99	18.71	22.18	27.22	33.29		
6	EXCAVATED SOIL + BA 15%								
	Max Dry Density (γd)	gr/cm3	1.7034409	**1.8121024**	1.708679	1.5422641	1.4431309		
	Water Content	%	11.08	**15.36**	19.21	24.42	29.63		
7	EXCAVATED SOIL + BA 20%								
	Max Dry Density (γd)	gr/cm3	1.6704511	1.6980334	1.7113909	1.7507454	1.5688158		
	Water Content	%	7.89	11.11	16.20	17.87	25.08		
8	EXCAVATED SOIL + FABA 10%								
	Max Dry Density (γd)	gr/cm3	1.6026211	1.6404342	1.6886743	**1.6911366**	1.4994344		
	Water Content	%	9.37	11.09	12.68	**18.54**	25.12		
9	EXCAVATED SOIL + FABA 15%								
	Max Dry Density (γd)	gr/cm3	1.552261	1.4939016	1.5300058	1.6794794	1.6057761		
	Water Content	%	9.12	11.94	13.16	18.41	24.17		
10	EXCAVATED SOIL + FABA 20%								
	Max Dry Density (γd)	gr/cm3	1.5490115	1.5655974	1.5847993	1.609817	1.6645552	1.6402966	1.3907865
	Water Content	%	10.38	12.30	14.66	15.87	17.86	20.91	31.42

Soaked California Bearing Ratio Test Results

From the results of the standard proctor test that has been carried out, the largest maximum dry density (γd maximum) value of each material will be used as a reference and continued with soaked CBR testing. The results of the soaked CBR test of these materials are presented in Table 4 as follows.

Table 4. Soaked CBR Test Results

Num.	Description	CBR Test Results (%)		
		CBR 0,1 inch	CBR 0,2 inch	CBR Value
1	Excavated Soil (Initial)	3.263	3.618	3.618
2	Excavated Soil + FA 10%	3.373	3.887	3.887
3	Excavated Soil + BA 15%	6.013	5.867	6.013
4	Excavated Soil + FABA 10%	1.815	2.200	2.200
5	Excavated Soil + FA 10% 7 Days Curing	2.163	2.933	2.933
6	Excavated Soil + BA 15% 7 Days Curing	4.400	4.058	4.400
7	Excavated Soil + FABA 10% 7 Days Curing	1.540	1.467	1.540

Table 4. Soaked CBR Test Results (Continued)

Num.	Description	CBR Test Results (%)		
		CBR 0,1 inch	CBR 0,2 inch	CBR Value
8	Excavated Soil + FA 10% 14 Days Curing	0.788	0.978	0.978
9	Excavated Soil + BA 15% 14 Days Curing	0.880	1.027	1.027
10	Excavated Soil + FABA 10% 14 Days Curing	0.568	0.709	0.709

Atterberg Limit Test Results

The following are the Atterberg limit test results of excavated soil and excavated soil mixed with fly ash and bottom ash.

Table 5. Atterberg Limit Test Results

Desc.	Excavated Soil (%)	Excavated Soil + FA 10% (%)	Excavated Soil + BA 15% (%)	Excavated Soil + FABA 10% (%)
LL	54.03%	38.59%	35.14%	45.95%
PL	21.36%	18.92%	18.03%	21.01%
PI	32.67%	19.68%	17.11%	24.94%

From the Atterberg limit test results in Table 4, it can be seen that there is a change in the Plasticity Index which tends to decrease along with the addition of a mixture of fly ash and bottom ash materials.

Sieve Analysis Test Results

From the results of the sieve analysis, using the USCS method for excavated soil, the material passes the #200 sieve by 56.07%, then from the Atterberg limit test results, the PI value is 32.67% and LL is 54.03% which is entered into the USCS Plasticity Chart. From the results of the USCS plasticity chart in Figure 3 point 1, the soil is classified into CH. The second one, sieve analysis for excavated soil + FA 10% mixture, the material passing sieve #200 is 38.08% and retained sieve #4 is 11.47%, so the soil is classified as sand, then from the Atterberg limit test results, the PI value is 19.68% and LL is 38.59% which is entered into the USCS Plasticity Chart. From the results of the USCS plasticity chart in Figure 3 point 2, the soil is classified as SC.

The third one, sieve analysis for excavated soil + BA 15% mixture, the material passing sieve #200 is 27.95% and retained sieve #4 is 8.65%, so the soil is classified as sand, then from the Atterberg limit test results, the PI value is 17.11% and LL is 35.14% which is entered into the USCS Plasticity Chart. From the results of the USCS plasticity chart in Figure 3 point 3, the soil is classified as SC. The fourth one, sieve analysis for excavated soil + FABA 10% mixture, the material passing sieve #200 is 33.09% and retained sieve #4 is 7.85%, so the soil is classified as sand, then from the Atterberg limit test results, the PI value is 24.94% and LL is 45.95% which is entered into the USCS Plasticity Chart. From the results of the USCS plasticity chart in Figure 3 point 4, the soil is classified as SC.

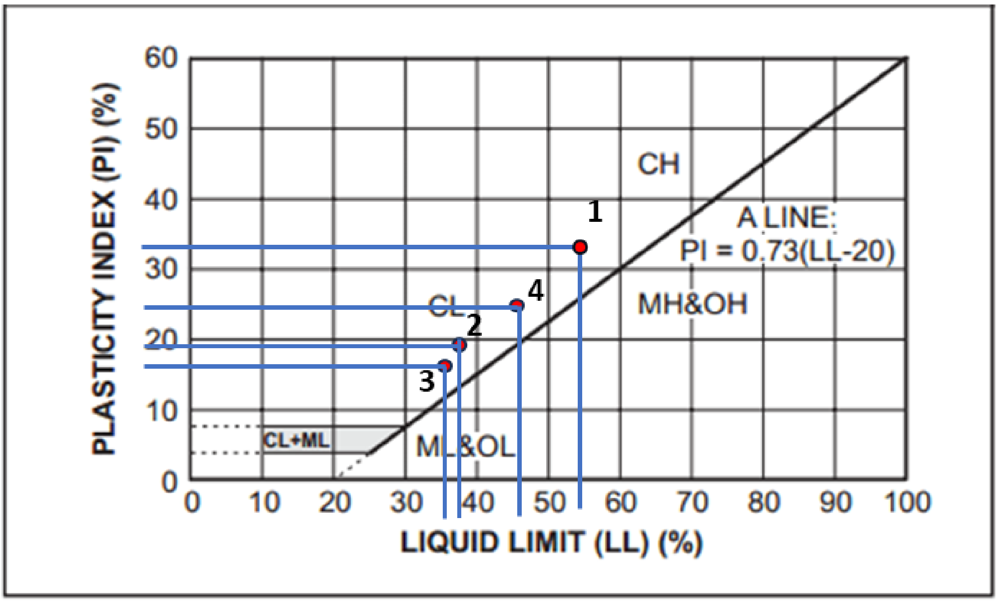

Figure 3. USCS Plasticity Chart of Excavated Soil and Mixed Soil

1. USCS Plasticity Chart of Excavated Soil
2. USCS Plasticity Chart of Excavated Soil + FA 10% Mixture
3. USCS Plasticity Chart of Excavated Soil + BA 15% Mixture
4. USCS Plasticity Chart of Excavated Soil + FABA 10% Mixture

Volumetric and Gravimetric Test Results

These volumetric and gravimetric tests are related to the tests to obtain the particle specific gravity (Gs) and also the density (γ) of the material. The results of this test are presented in Table 6 below.

Table 6. Volumetric and Gravimetric Test Results

Description	Unit	Excavated Soil	Soil + FA 10%	Soil + BA 15%	Soil + FABA 10%
Soil Density (γt)	gr/cc	1.878	1.925	1.982	1.967
Dry Density (γd)	gr/cc	1.467	1.572	1.695	1.652
Void Ratio (e)		0.884	0.694	0.601	0.675
Spesific Gravitiy (GS)		2.756	2.700	2.722	2.768

Triaxial Test Results

Triaxial testing in this thesis uses the Unconsolidated Undrained (UU) Triaxial Test method. From the test results, it can be seen in Table 6 below what is the value of the inner shear angle (Ø) and cohesion (c) of the existing material. The material used in this triaxial test itself is a remolded material that is reshaped from mixing materials with the desired moisture content and made into cylindrical test objects according to the predetermined volume weight. The UU Triaxial Testing carried out is testing with unsaturated sample conditions, so that with these conditions the value of $ø \neq 0$, because the value of $ø = 0$ occurs in UU triaxial testing with saturated sample conditions.

Table 7. Triaxial UU Test Results

Num.	Description	Triaxial Test Results			Information
		Cohesion (C)	Shear Strength (ø)	Modulus of Elasticity (E_{50})	
		Kg/cm^2	°	Kg/cm^2	
1	Excavated Soil	0.08	29.90	81.43	Undisturbed Sample
2	Soil + FA 10%	2.00	11.60	386.79	Remoulded Sample
3	Soil + BA 15%	0.96	52.70	508.75	Remoulded Sample
4	Soil + FABA 10%	0.47	50.40	203.00	Remoulded Sample
5	Soil + FA 10% 7 Days Curing	0.55	49.60	211.10	Remoulded Sample
6	Soil + BA 15% 7 Days Curing	1.58	31.90	335.82	Remoulded Sample
7	Soil + FABA 10% 7 Days Curing	1.59	31.20	253.74	Remoulded Sample
8	Soil + FA 10% 14 Days Curing	1.32	35.80	226.90	Remoulded Sample
9	Soil + BA 15% 14 Days Curing	1.15	36.70	234.59	Remoulded Sample
10	Soil + FABA 10% 14 Days Curing	2.42	15.80	203.21	Remoulded Sample

From the triaxial test results, the values of inner shear angle (Ø) and cohesion (c), Young's Modulus (E) and Poisson's ratio of each material have been obtained, these data are used to calculate the overall stability of the embankment with the use of each type of material that has been tested. Related to the UU triaxial test results, there was an increase in the parameters of cohesion, soil shear angle and Modulus of Elasticity after mixing the soil with fly ash and bottom ash materials.

RESEARCH ANALYSIS

Standard Proctor Test Results

From the results of standard proctor test, it was found that the soil without mixture, soil mixture material with fly ash material as well as bottom ash with the largest maximum dry density were found in the mixture material as follows:

1. In the soil without mixture with a value of γd max 1.656 t/m^3.
2. In the soil mixture + FA 10% (fly ash content 10%) with a value of γd max 1.693 t/m^3.
3. In soil mixture + BA 15% (bottom ash content 15%) with a γd max value of 1.812 t/m^3.
4. In the soil mixture material + FABA 10% (fly ash + bottom ash content 10%) with a γd max value of 1.691 t/m^3.

It can be seen that the results of mixing soil with fly ash and bottom ash materials have succeeded in improving the value of γd soil and with these conditions the mixed soil can become denser.

Soaked CBR Test Results

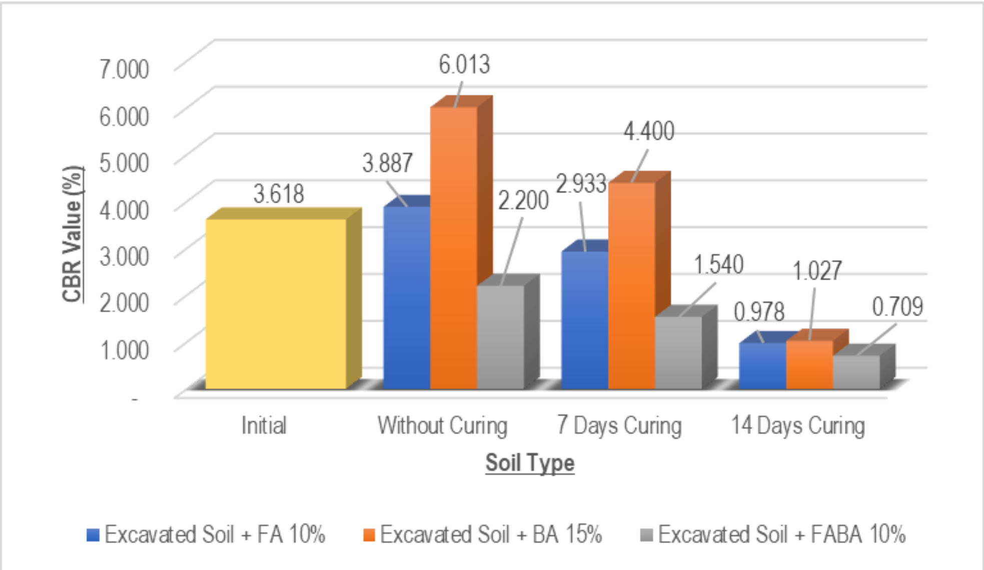

Figure 4. Graph of The Results of The Soaked CBR Value of Excavated Soil and Mixed Soil Testing

It can be seen in figure 7 that there is a change in the CBR value of the excavated soil without any mixture compared to the excavated soil which is mixed with fly ash and bottom ash materials. Especially for the mixed soil material with fly ash and bottom ash (FABA) at 10%, the CBR value after mixing with 0, 7 and 14 days of curing conditions actually makes the CBR value decrease. This is likely due to the absence of cementitious reaction in the mixture of excavated soil with fly ash and bottom ash material where the fly ash that is used in this mixture is classified into class F with CaO content of 9.18%. Zimar Z. et al. (2022) said that class C fly ash material which has Calcium Oxide (CaO) content of more than 20%

has pozolanic ability without the need for activators, while Sivapullaiah et al. (1998) said that class F material which has CaO content of less than 10% requires activators such as cement or lime to form cementitious reactions.

Soewignjo Agus Nugroho et al. (2022) conducted research related to changes in CBR values to the addition of fly ash and bottom ash in clay soil. In the study, clay soil stabilization was stabilized with a mixture of lime, fly ash and bottom ash where the fly ash that is used in this research is classified as class F fly ash from Steam Power Plant Tenayan Raya, Pekanbaru, Riau. The mixture made in the study consisted of a mixture of lime as much as 5% and fly ash and bottom ash with a mixture variation of 5% to 20%, besides that curing was carried out with variations of 0, 14 and 28 days. From the results of this study, a significant increase was obtained in mixed soil with a soil composition of 60%, fly ash 20%, bottom ash 15% and lime 5% with a curing period of 28 days which resulted in a soaked CBR value of 75.37%. While the smallest CBR value is obtained in mixed soil with 80% soil composition, 5% fly ash, 10% bottom ash, and 5% lime with a 0-day curing period which produces an unsoaked CBR value of 12.85%. On the other hand, in a research conducted by Pandian et al. (2001), the increase of CBR value on CH soil mixed with FFA material (class F fly ash), obtained the result that the maximum CBR value was observed at two peak values with an increasing percentage of fly ash usage gradually from 0% to 100%. The maximum CBR value in the unsoaked condition is 11% with a 20% fly ash addition composition. Then the CBR value decreased further in the four-day soaking condition with the highest soaked CBR value of 5%. Therefore, the addition of FFA material to the soil only resulted in a slight increase in the CBR value. From these studies, it can be seen that mixing soil with class F fly ash material does not cause a significant increase in CBR value, an increase in CBR value is obtained when class F fly ash material is also mixed with lime or other materials such as cement which makes a cementitious reaction.

CONCLUSION

From the results of this study, several conclusions can be concluded as follows:

1. The results of the sieve analysis of the excavated soil based on the USCS method of excavated soil belong to CH soil, the soil has an LL value of 54.03%, PL 21.36%, PI 32.67%, then for the excavated soil γs value is 1.878 t/m^3, the γd value is 1.467 t/m^3 and the GS value is 2.756. From the results of the soil density test, the γd max reached was 1.656 t/m^3 with an optimum moisture content of 20.08% and the soaked CBR value of the γd max condition was found to be 3.618%. For the Triaxial UU test results, the Cu value of 7.94 kN/m^2 and øu 29.9° were obtained, then for the E50 value of 7,985.85 kN/m^2.
2. Based on the test results of fly ash and bottom ash materials that have been conducted at PT Sucofindo Samarinda Branch, fly ash from Balikpapan PLTU is classified as class F fly ash material referring to SNI 2460:2014. This class F fly ash itself based on SNI 2460:2014 has pozolanic properties but is not cementitious.
3. From the results of the standard proctor test, it was found that the soil mixture material and fly ash material as well as bottom ash with the largest maximum dry density were found in the mixture material as follows:
   - In the soil mixture + FA 10% (fly ash content 10%) with a value of γd max 1.693 t/m^3.
   - In soil mixture + BA 15% (bottom ash content 15%) with a γd max value of 1.812 t/m^3.
   - In the soil mixture material + FABA 10% (fly ash + bottom ash content 10%) with a γd max value of 1.691 t/m^3.

4. It can be seen that the results of mixing soil with fly ash and bottom ash materials have succeeded in improving the value of γd soil and with these conditions the mixed soil can become denser.
5. Regarding the results of the soaked CBR test, there was a decrease in the CBR value after mixing the excavated soil with fly ash and bottom ash materials. It can also be assessed that the possibility of mixing results with fly ash and bottom ash materials does not experience cementation, this can be caused by the fly ash material used is a class F fly ash material where the CaO content in this fly ash is only 9.18% (class F fly ash CaO content < 10%), then the fly ash requires an activator in the form of Portland cement or lime to form a cementitious reaction.
6. It is suggested from the results of this research that the excavated soil material and the excavated soil mixed with fly ash and bottom ash material from Balikpapan Steam Power Plant should not be used as backfill material. This is related to the negative trend that occurs during the soaked CBR test that has been carried out and the small soaked CBR average value which is below 6%.

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