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Effect Of Water-Fly Ash-Cement Grouting On The Clayey Subgrade Soil Characteristics of The Tuban-Babat Lamongan-Gresik National Road

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ABSTRACT

The Tuban-Babat-Lamongan-Gresik road section is one of the northern coast sections of Java, Indonesia that experienced road damage that have a low CBR value of around 1.7%-2.9%. In this study, the soil improvement method used is Water Fly Ash Cement Grouting which will be tested on a laboratory scale. Variations in addition to the quantity of grouting material are 3%, 5%, and 7% of dry weight in the test sample, water binder ratio (w/b) variations of 1, 1.5 and 2 with 3 binder composition variations, namely 90% Cement + 10% Fly Ash, 80% Cement + 20% Fly Ash, and 70% Cement + 30% Fly Ash. The selection of the use of Fly Ash in addition to utilizing waste from coal burning activities, relatively cheap prices and effectiveness which has been proven in previous studies.The results show that Water Fly Ash Cement Grouting can affect properties of the sample. The plasticity index which was originally 45.09% to 25.08% and the CBR value which was originally 0.14% to 1.92% at the quantity of grouting material 7% of the dry weight of the test sample, Water Binder ratio (w/b) 1 with a binder composition of 90% Cement + 10% Fly Ash.

Keywords : CBR, Grouting Water Cement, Fly Ash, Subgrade, Grouting Spread

INTRODUCTION

Infrastructure Asset Management can be imagined as tasks that the infrastructure manager should do in order to maintain the infrastructure function and it deals with the infrastructure present condition. Infrastructure is built to execute certain particular function. Road is one of the important infrastructure that has the main function to flow traffic (Suprayitno and Soemitro,2018).

The Tuban-Babat-Lamongan-Gresik road section in Indonesia at Sta. 32+000 until Sta.39+650 had road damage in the form of potholes and bumps as shown in Figure 1 and had an IRI (International roughness index) value of 7.7. Road damage on this road is not only caused by overloading vehicles where the average daily traffic volume is high, which is 49,284 vehicles/day and the subgrade condition of the road has a low CBR (California Bearing Ratio) value of around 1.7%-2.9%. From the results of soil investigations, it was found that the soil on this segment has a percentage of grains that pass the filter no. 200 more than 90% and has a high Plasticity Index value, which ranges from 40%-45% so that it is included in the category of high swelling potential and can be classified into clay of high plasticity (CH).

Figure 1. Road Damage On The Tuban–Babat–Lamongan–Gresik Road Section, Indonesia
source: BBPJN East Java – Bali, 2021

In general, the role of the subgrade is to accept the pressure due to the traffic load on it so that it must have an optimal carrying capacity and be able to accept the forces due to traffic loads without experiencing significant changes and damage. Subgrade as the foundation of the pavement structure has play an important role in supporting the structure (Soemitro,2022).

so it must have a strong soil bearing capacity. If the soil on the road subgrade has a low CBR value, it is necessary to repair it. The soil improvement method implemented in the field is water cement grouting. The grouting method was chosen because it is a soil improvement method with a relatively short and simple implementation time, does not damage the existing pavement too much, and other soil improvement methods are difficult to implement because there is already an existing pavement with a high Average Daily Traffic value.

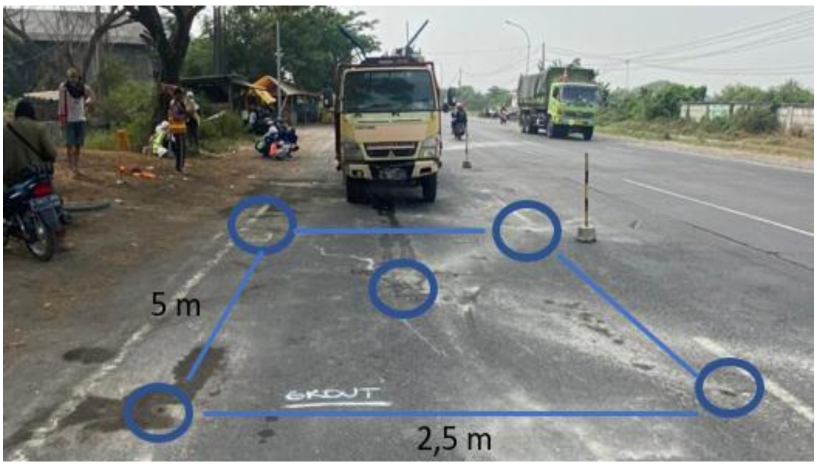

Figure 2. Grouting Hole Patterns
source: BBPJN East Java – Bali, 2021

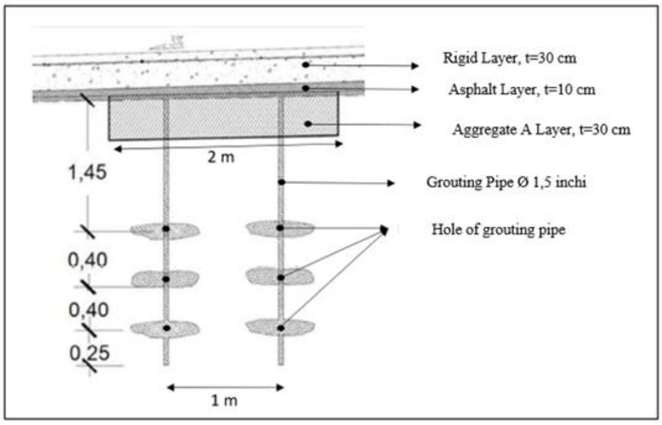

Figure 3. Water Cement Grouting Method Details
source: BBPJN East Java – Bali, 2021

Grouting is carried out on the inner side of the road section adjacent to the median road by stripping the asphalt as wide as 2 meters from a total road width of 7 meters followed by making a grouting hole with a rectangular pattern with 1 additional point in the middle where the distance between the holes is 2.5 m and 5 m as shown in Figure 2 then insert a 1.5 inch diameter perforated pipe with a total length of 2.5 m which has 3 holes with 3 different depths, namely at a depth of 1.45 m, 1.85 m and 2.25 m into the subgrade layer as shown in Figure 3 above. Then the water-cement material is injected (grouting) into the pipe and then spreads through the pipe hole into the subgrade soil layer. with field density by cutting the test object into 2 parts on a laboratory scale.

The use of grouting material in the form of water cement alone requires a relatively high cost, it can be minimized by adding Fly Ash to the grouting material. So that in this study a laboratory experiment of water Fly Ash cement grouting will be carried out which will be reviewed for the efficiency of the mixture content to achieve optimization of improvement in physical parameters, mechanical parameters, CBR and expansive properties. The selection of additional use of Fly Ash in addition to supporting environmental conservation by utilizing waste from coal burning activities is also based on other aspects, namely the availability of abundant materials, ease of obtaining materials, relatively cheap prices and effectiveness from the proven results. Where experiments of water fly ash cement grouting with the addition of 7% grouting material and a binder composition of 70% cement + 30% fly ash can increase the CBR value which was originally 2% to 7% with a water binder ratio (w/b) of 1.33 (Teck Shang Goh & Osamu Takashi, 2014). Whereas water cement grouting with the addition of 7% grouting material can increase the CBR value which was originally 0.14% increased to 1.96% with a water cement ratio (w/c) of 1(Edwin, 2023).

Because of that, this research was conducted with the configuration of the quantity of grouting material is 3%,5%, and 7% of dry weight in the test sample, Water Binder ratio (w/b) is varied 1, 1.5 and 2. While the composition of the binder is varied by 3 types, namely 90% Cement + 10 % Fly Ash, 80% Cement + 20% Fly Ash, and 70% Cement + 30% Fly Ash.

RESEARCH METHODS

Soil samples that have been taken are carried out laboratory tests to determine the physical, mechanical and expansive parameters in the initial soil conditions. Then the test object is made with the same density value as the density value in the field and then injected with grouting material in the form of water fly ash cement with a syringe. The configuration of the quantity of grouting material is 3%,5%, and 7% of dry weight in the test sample, Water Binder ratio (w/b) is varied 1, 1.5 and 2. While the composition of the binder is varied by 3 types, namely 90% Cement + 10 % Fly Ash, 80% Cement + 20% Fly Ash, and 70% Cement + 30% Fly Ash. Then the curing evaluation is carried out to determine the optimal curing time duration in the curing process. After that, several laboratory tests were carried out to determine the addition of water Fly Ash cement grouting on the test object. In addition, the observation of the distribution pattern of the water Fly Ash cement grouting that is injected into the test object with field density by cutting the test object into 2 parts. In Figure 4 can be seen the flow chart of this research.

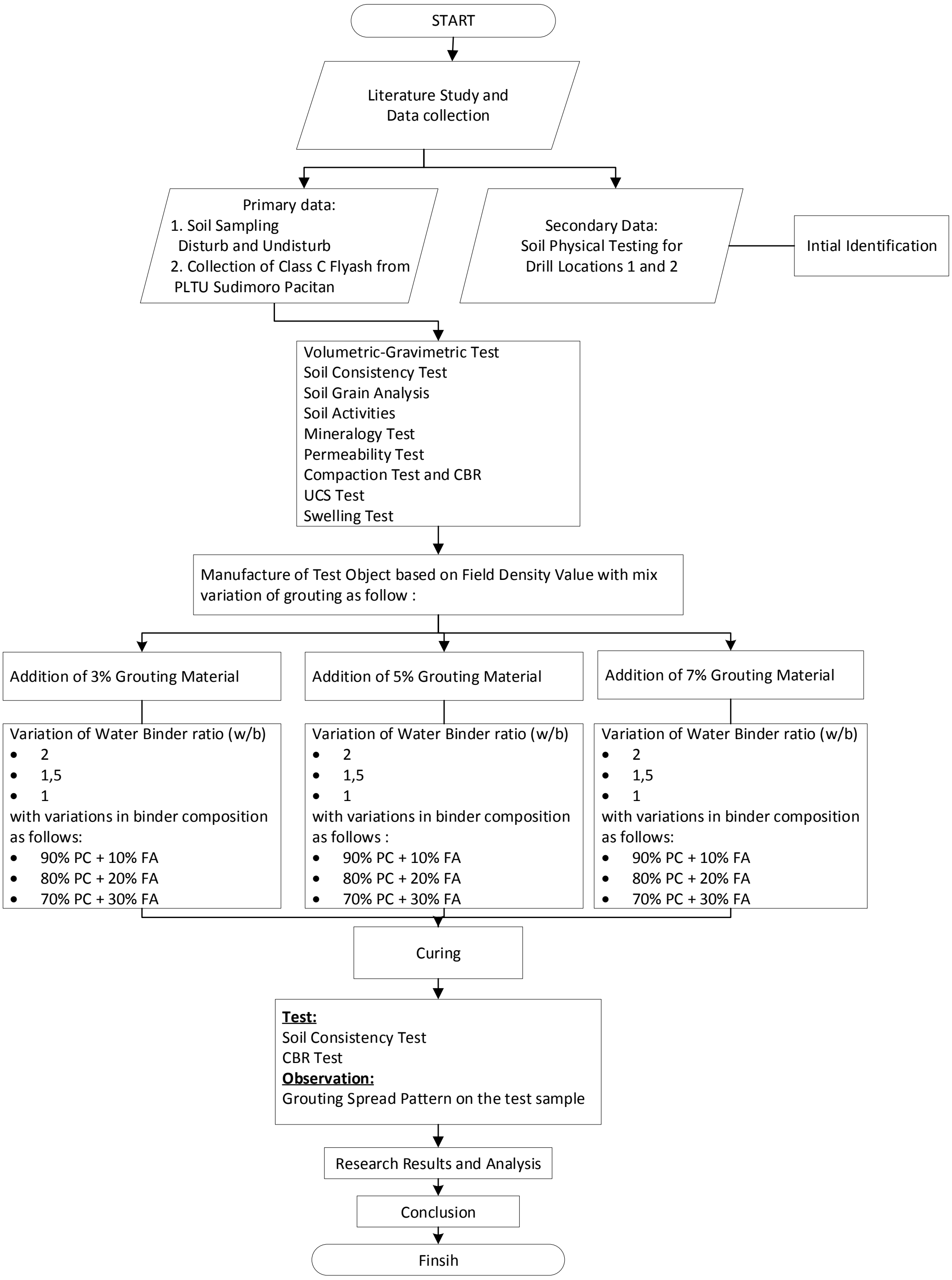

Figure 4. Research Flowchart
source : Author's Data, 2022

Primary data

Soil sampling on the subgrade layer of Jalan Tuban–Babat–Lamongan–Gresik in Indonesia was carried out with a drill for undisturb soil samples and direct sampling for disturbing soil samples which were then tested at the Soil and Rock Mechanics Laboratory, ITS Surabaya. Undisturb and Disturb sampling locations is carried out at Sta 35+000 as shown in Figure 5.

Figure 5. Sample at Sta 35+000
source : Author's Data, 2022

RESEARCH ANALYSIS

Soil Properties Test

Based on the results of the soil properties test, the subgrade soil samples taken from Sta. 35+000 is a clay silt type. The data on the results of the tested properties can be seen in Table 1 below.

Table 1. Soil Properties Test

No	Type of Test	Unit	Sta 35+000
1	**Soil Physical Properties Test**		
a	Grain Size Analysis		
	Gravel	%	0.68
	Sand	%	9.52
	Silt	%	76.09
	Clay	%	13.71
b	Consistency		
	Liquid Limit (LL)	%	75.27
	Plastic Limit (PL)	%	30.18
	Plasticity Index (PI)	%	45.09
c	Volumetric - Gravimetric		
	Water Content	%	60.98
	Spesific Gravity (G_s)		2.56
	Volume Weight	gr/ cm^3	1.59
	Dry Volume Weight	gr/ cm^3	0.99
	Void Ratio		1.59
	Porosity	%	61.28
2	**Soil Classification**		
	USCS		CH
	AASHTO		A-7-5

No	Type of Test	Unit	Sta 35+000
3	**Activity**		3.29
4	**Soil Mechanical Properties Test**		
	Unconfined Compression Strength (q_u)	kg/cm^2	1.25
	Cohesion (C_u)	kg/cm^2	0.62
	Density		
	(γ_d) max	gr/ cm^3	1.60
	w Optimum	%	20.18
5	**CBR at field density**	%	0.14
6	**Permeability**		
	k	cm/s	2.40E-08
7	**Swelling test**		
	Swelling Potential	%	5.00
	Swelling Pressure	gr/cm^2	209.9

source : Author's Data, 2022

So from the results above it can be concluded that clay soil of the Tuban-Babat-Lamongan-Gresik National Road is classified as clay with high plasticity (CH) according to USCS and A-7-5 according to AAHSTO.

X-Ray Diffraction Mineralogy Test

The test results of the X-Ray Diffraction (XRD) minerological tests carried out at the Department of Materials and Metallurgy ITS Surabaya at Sta 35+000 can be seen in Table 2 below.

Table 2. Original soil mineralogy test results

STA	Mineral	Content
35+000	Quartz	44%
	Anorthite Sodian	45%
	Nacrite 2M2	11%

source : Department of Materials and Metallurgy ITS Surabaya, 2022

From the results above it can be concluded that clay soil of the Tuban-Babat-Lamongan-Gresik National Road is not an expansive soil because no clay minerals containing montmorillonite were found.

Sample Testing with Water Fly Ash Cement Grouting

Subgrade modeling was carried out on a laboratory scale test by making CBR specimens according to the density of the field, $\gamma_{dry} = 0{,}99\ \mathrm{gr/cm^3}$ and the water content is 60,98% then injected with variations in the quantity of grouting material, water Fly Ash cement, water binder ratio (w/b), and Fly Ash content.

Curing Time Evaluation

The curing time evaluation was carried out to determine the optimal curing time duration in the curing process. Curing aims to provide time for the test object to react with the addition of water Fly Ash cement grouting. The evaluation of curing time was only carried out on modeling variations that had a high cement content, namely the addition of 7% grouting material with a binder composition of 90% Cement + 10% Fly Ash. The results of the evaluation of the curing time can be seen in Figure 6 as follows.

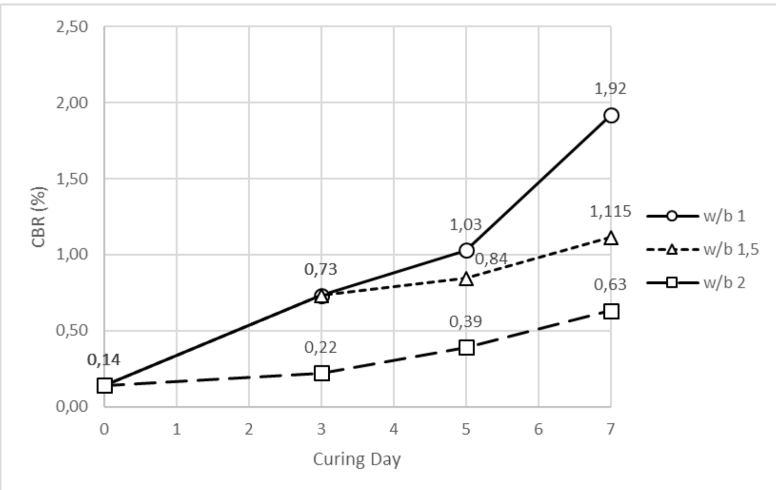

Figure 6. Curing time evaluation
source : Author's Data, 2022

From the results of the evaluation of the curing time, it was found that the longer the curing duration, the higher the CBR value obtained, so that the curing duration of the test object in this study was chosen 7 days.

CBR Test (California Bearing Ratio)

The general behavior of changes in the CBR value of the test sample after being injected with Water Fly Ash Cement Grouting can be seen in Figure 7 below, where the more grouting material the CBR value increases while the higher water binder (w/b) ratio and the higher the Fly Ash content, the lower the CBR value. This research is also in line with the research of Teck Shang Goh and Osamu Takashi, 2014 with the research title Laboratory Study On Grout Injection for Improving Subgrade of Airfield Pavements which shows that the greater the ratio of water to cement, the CBR value also decreases.

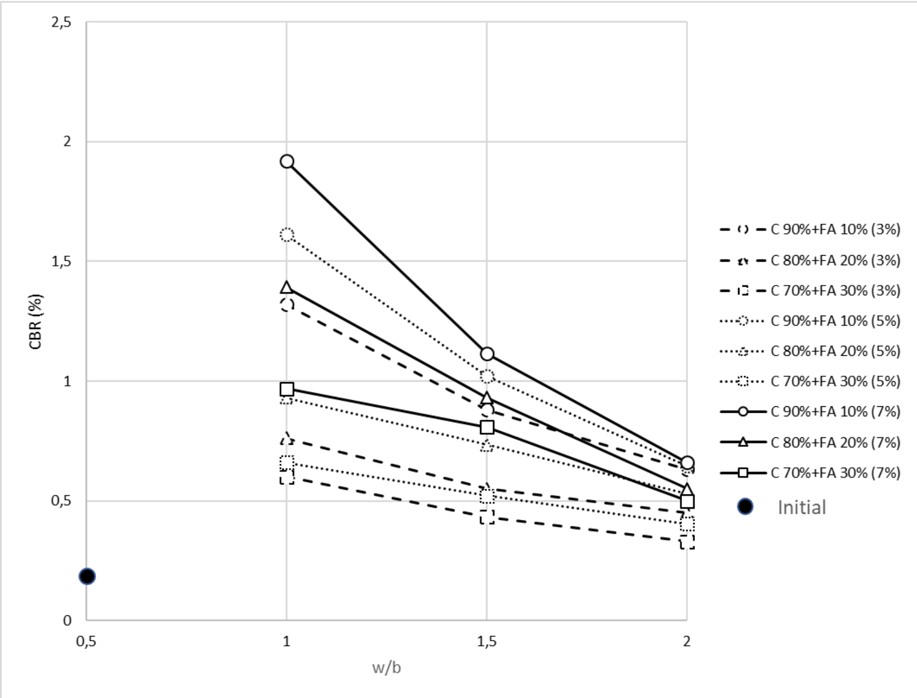

Figure 7. CBR Test Results
source : Author's Data, 2022

The most significant change in the CBR value occurred in the quantity of grouting material 7% of the dry weight of the test sample, Water Binder ratio (w/b) 1 with a binder composition of 90% Cement + 10% Fly Ash where the CBR value which was initially 0.14% increased to 1.92% or about 12 times. The CBR value is still classified as Very Poor referring to (Bowles, 1992). If these results are compared with research conducted by Edwin, 2023 with the research title Evaluasi Daya Dukung Tanah (CBR) Dan Lapisan Bawah Permukaan Pada Subgrade Yang Diperbaiki Dengan Metode Grouting Water Cement Di Ruas Jalan Nasional Tuban-Babat-Lamongan-Gresik where the CBR values are initially 0.14% increased to 1.96% or about 13 times, it can be concluded that the use of fly ash material can increase the CBR value close to the mixture of grouting materials using only cement.

Because the Water Fly Ash Cement liquid is not able to enter the soil layer so that it forms a layer on the surface because the permeability value of the sample soil is very low, namely k = 2.4 x 10^{-8} cm/second. So the change in CBR value is very dependent on the strength of the paste layer on the surface of the test object. Where every increase in the value of the water binder, the CBR value decreases. The increase in the value of the water binder means that there is an increase in the amount of water in the grouting material mixture so that there is an excess of water in the paste which causes pores to appear which can weaken the strength of the paste layer on the surface.

Atterberg Limits Test

The general behavior of the change in the Plasticity Index (PI) value of the test sample after being injected with Water Fly Ash Cement Grouting can be seen in Figure 8 below, where the more grouting material, the lower PI value. This occurs due to the cation exchange reaction process where calcium ions are released from the addition of cement and Fly Ash which replaces other cations around the surface of the clay particles which causes a decrease in the thickness of the double layer, while another general behavior is the higher value of water binder (w/b) ratio and higher Fly Ash content, the higher PI value.

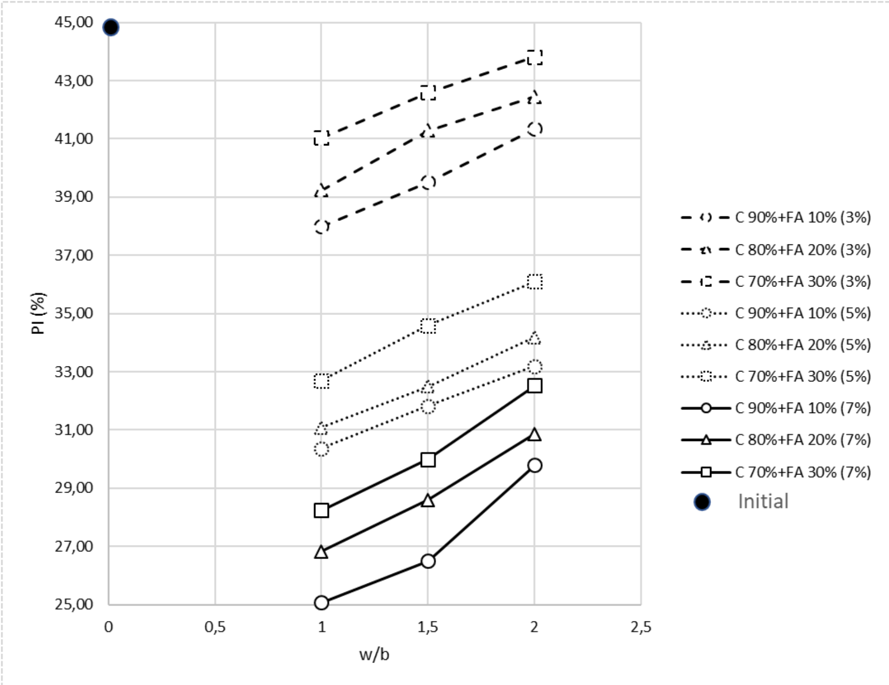

Figure 8. Plasticity Index on the test object
source : Author's Data, 2022

This research is also in line with the research of Zulnasri, 2021 with the research title Perubahan Nilai Kuat Tekan Lempung Lunak Distabilisasi Dengan Kapur Dan Limbah Pembakaran Batubara which shows a decrease in the plasticity index (PI) due to a cation exchange reaction process in which calcium ions are released from the addition of a stabilizing agent that replaces other cations around the surface of clay particles.

The most significant change in the Plasticity Index (PI) value occurred in the quantity of grouting material 7% of the dry weight of the test sample, Water Binder ratio (w/b) 1 with a binder composition of 90% Cement + 10% Fly Ash where the plasticity index which was originally 45.09% decreased to 25.08% or about 44%. This value includes a low level of development based on SNI 03-6795-2002.

Observation of Water Fly Ash Cement Grouting Spread Pattern

Based on observations of the distribution of Water Fly Ash Cement Grouting, it was found that the Water Fly Ash Cement liquid was unable to enter the soil layer so that it formed a layer on the surface because the permeability value of the soil sample was very low, namely $k = 2.4 \times 10^{-8}$ cm/second. The Figure of the Distribution Pattern of Water Fly Ash Cement Grouting on the sample soil can be seen in **Figure 9** below.

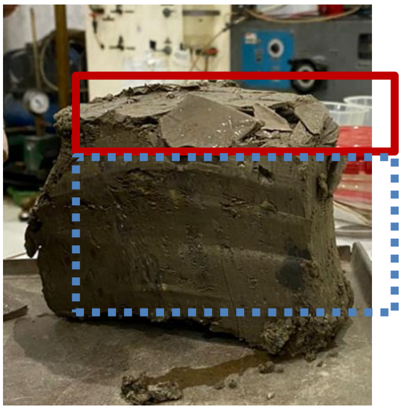

Figure 9. Water Fly Ash Cement Grouting Spread Pattern
source : Author's Data, 2022

CONCLUSION

Based on the overall results of the analysis that has been carried above, the following conclusions can be drawn :

1. The clay soil of the Tuban-Babat-Lamongan-Gresik National Road is classified as clay with high plasticity (CH) according to USCS and A-7-5 according to AAHSTO. Has a high Plasticity Index value of 40% and has a low CBR value 0.14%.
2. From the 27 variations of adding Water Fly Ash Cement Grouting that were carried out, the optimal variation was obtained, namely 7% grouting material, Water Binder ratio (w/b) 1 with a binder composition of 90% Cement + 10% Fly Ash. Where the initial CBR value of 0.14% increases to 1.92% or about 12 times.
3. The results of observing the spread of Water Fly Ash Cement Grouting on a laboratory scale found that the Water Fly Ash Cement liquid did not mix homogeneously with the sample soil and was not able to enter into the soil layer so as to form a layer on the surface because the permeability value of the sample soil was very low, namely $k = 2.4 \times 10^{-8}$ cm/sec. From these results it can be concluded that the method of soil improvement by injection of grouting water Fly Ash cement is less effective to implement.

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