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Soil Improvement Method on Body Foundation Dam (Main Dam) with Grouting Method DAM Construction Project (Rababaka Kompleks, West Nusa Tenggara)

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ABSTRACT

Cement injection under pressure, also known as grouting, is a process in which a liquid mixture is injected into cavities, cracks, and fractures in rock or soil under controlled pressure. The injected liquid undergoes physical and chemical transformations, eventually solidifying. This study aimed to evaluate the performance of various cement-water mixture designs, determine the required volume of grout based on the Lugeon number (Lv), and assess effective spacing intervals between grouting points by calculating grout effectiveness in percentages. Jet grouting, a proven method in diverse soil conditions, employs specialized equipment to hydraulically mix soil with grout, enabling soil stabilization and modification. The system is particularly effective in erodible soils, such as granular soils, and even in cohesive plastic clays. At the Mila Dam, grouting tests were conducted along the centerline of the main dam, specifically at the left abutment (Bukit Tumpuan Kiri) and the riverbed. Core drilling results from the Pilot Hole (BH-01) at a depth of 30 m revealed stratigraphic characteristics. The left abutment rock along the centerline of the dam predominantly consists of gray lapilli tuff overlaid by breccia-tuff rock units, which are brownish in color.

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1. INTRODUCTION

DI extension Rababaka through the Rababaka Dam is not possible, because the potential for a large discharge of the Rababaka River is only during the rainy season and there are no more potential areas for the development of DI irrigation. SDA development by accommodating excess water during the rainy season in the Rababaka River is also not possible, because there is no ideal location for a dam along the Rababaka River. However, there are a number of things that need to be considered in development planning. The foundation is the most important part in planning construction. The foundation itself is a system that transmits the load so that it can be supported by the foundation, continuing its own weight into the soil and rock below [1] The foundation is not strong. causing the instability of a building on it, giving rise to the potential for failure of building infrastructure including Maindam buildings, grouting is a geotechnical remediation technique that is often applied to foundations in the construction of dams or earthen impoundments [2]. to close cavities in deep soil foundation layers, grouting is inserting semi-viscous material by injecting it into the soil or rock, which aims to close the construction, holes so that the strength of the soil increases. grouting point determination, permeability test (pressure water passing test), drilling and grouting [3] Pores and fractures are closed using injection grouting with adhesive material [4].

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METHOD

Increasing the carrying capacity of the soil to overcome the settlement of the foundation at the research site, using the *grouting* with the type of permeation *grouting* or also known as penetration cementation. *grouting* is a soil or rock improvement mechanism that aims to increase the carrying capacity of the soil. By reducing the pore structure of the soil, the permeability of the soil will also decrease, so that *grout* cannot completely prevent seepage, but is able to increase the soil load and compact or compact and increase soil cohesion. Grouting will affect soil properties, because *grouting* is composed of a mixture of cement, water and sand with a grain size of less than 0.2 mm. taking into account the results of the SD1 sondir test where it is known that the clay layer at the study site can be said to spread evenly and a firm consistency of soil has been found at a depth of 15 meters. Foundation repairs using *grouting* are carried out with a depth of 15 m – 25 m [5]. The results of the water permeability test show an anomaly between flow and pressure, then from the pressurized water permeability test chart can identify *displacement* that occurs, namely *plastic* or *elastic displacements* [6]. Pattern *grouting* is in accordance with the design plan of the elongated track pattern with the following details:

a) Blanket grouting

A total of 4 rows (4th Row grout), each occupying 2 tracks in the upstream maindam and 2 tracks in the downstream maindam with a distance of 3m between the grouting hole points and the depth 5m and a total of 74 points,

b) Subcurtain grouting

Consists of 2 lanes (2nd Row grout), each occupying 1 track in the upstream maindam and 1 track in the downstream maindam with a distance of 3m between grouting hole points with varying depths between 5m to 10m and a total of 120 point.

c) Curtain grouting

Consisting of 1 pass on As Maindam with a distance of 3m between grouting hole points with varying depths between 20m to 25 m with a total of 77 points, but in reality it was due to technical reasons where the rock quality contained lots of joints/fractures (RQD = 25% - 50%) then for the Curtain grouting holes it is added to 2 passes (2nd Row grout) in the upstream 1 pass and downstream 1 pass.

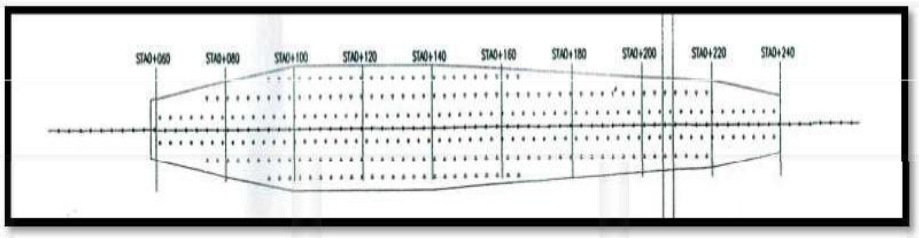

Figure 1a. Design of the Initial Grouting Point Drilling Plan

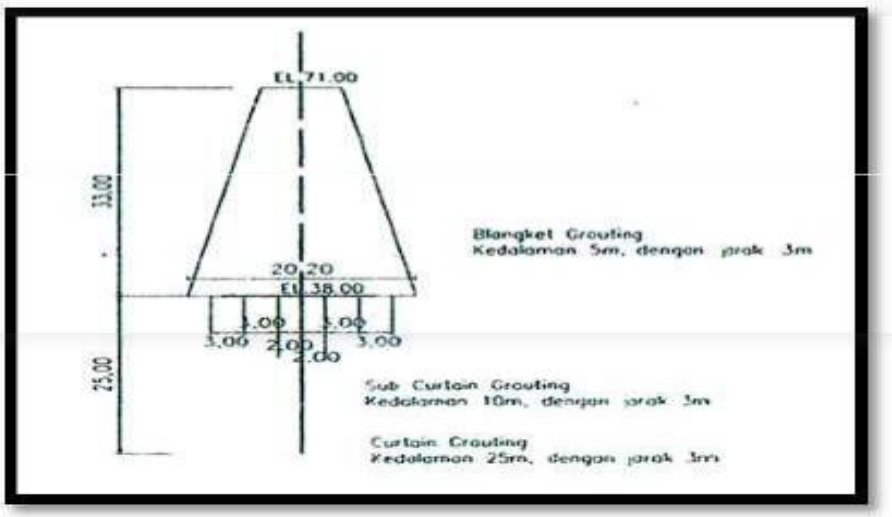

Figure 1b. Design of the Initial Grouting Point Drilling Plan

2.1. Research Location

For subgrade repair work on the dam body foundation (maindam) with the grouting method is located in Mila Village (Rababaka River Complex) located in Dompu district, West Nusa Tenggara Province (NTB). This can be seen in Fig. 2.

Figure 2. Location of Grouting in the Body of the Dam (Maindam)

2.2. Data Processing Techniques

In this study, two types of data were required, namely primary data and secondary data. Primary data was obtained through direct surveys in the field, while secondary data was obtained by requesting information or data from related government agencies.

2.3. Geological Conditions

Geology in the Mila Dam Site Area is divided into four rock units namely: Lapili Tuffa, Igneous Intrusion, Andesite, and other Volcanic Rocks (Breccia interspersed with sandstone). The Left Support and Right Support Hills were built by Tuffa Breccia and Volcanic Breccia units. The joint pattern structure measured from the rock outcrops found is as shown in the geological report.

2.4. Grouting Work

Compaction grouting is one of several basic soil improvement techniques developed in America by Ed Graf and Jim Warner especially in the California region since the 1950s. The soil compaction technique is carried out by injection of concrete mortar which has low mobility with a low slump value. The injected mortar lump will expand in the soil and will compact due to compression. In addition to improvements in the surrounding soil, the soil mass will also be stronger because of the mortar columns (grout columns) that are formed through injection and compaction. Application of this method will reduce settlement and increase the shear strength of the soil. This method is quite effective in reducing foundation settlement, reducing seismic settlement and liquefaction potential, construction safety by adding fill material to loosen granular fills, reducing settlement in collapsible soils, and reducing the potential for the formation of holes in the ground (sinkholes), especially in karst areas [13].

Compaction grouting techniques are very effective for improving soils at certain depth zones that you want to improve, and this method is less than optimal for achieving a significant increase in soil strength at depths above 8 ft. (2.5 m) from the ground level. In this procedure, the soil is first pumped at the top of the treatment zone. After the injection device is installed, a pipe is drilled into the bottom of the tool, then the additional material is injected. This procedure was repeated until the injection was complete at the bottom of the treatment zone. Injection rates generally range from 3 to 6 ft3/min (0.087 to 0.175 m3/min), depending on the type of soil being improved. If the injection rate is too fast, the pore pressure will be excessive, resulting in soil fracture, and this will reduce the effectiveness of the treatment.

The execution technique starts at the bottom of the zone to be repaired, and the injection process then moves upwards. Treatment does not have to be continued to the soil surface and can be stopped at the desired depth. The sequence of the process of implementing this method can be seen sequentially in the following figure.

2.5. Grouting

Materials The materials used for liquid injection (cementation slurry) in grouting work consist of: The water used is taken from the Mila River, before being used it is first stored in a water tank, then it must be free of impurities, organic matter, and other impurities. The cement used is Semen Tiga Roda, cement storage must

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be in an airtight and watertight warehouse so that cement quality is guaranteed. Sand This material is primarily used to deal with large surface leaks. If during the grouting process there is a surface leak, the grouting is stopped and the leaky area is covered with a mixture of sand and cement.

Table 1. Grouting Material Sand Requirements.

BS Sieve	Passing Items (%)
7	100
14	95-100
25	60-85
52	20-50
100	20-30
200	0-5

Source: Consultant of Bandung Irrigation Research and Development Center.

2.6. Grouting Tools

Table 2 shows the tools that used on this research.

Table 2. Grouting Tools.

No.	Type of Tool	Total	Brand / Type	Note.
1	Drilling Machine	6	Long Year Units, UD 5	
2	Diesel Drive	6	Dong Feng Units, 16 PK	
3	Water	Units	Sanchin Yanmar	
4	Machines *Grouting Pumping*	2	Tone NAS Units 3	
5	Mixers *Grouting*	2 Local Units	400 lt	
6	Single Core Bare dia.66 mm	4 Stem	Local	
7	Double Core Bare dia.73 mm	2 Stem	Local	
8	Drill @ 3 m	65 Stem	Local	
9	Drill @ 1 m	10 Stem	Local	
10	Mekanik *Packer*	20 Stem	Local	
11	Air Packer dia.66 and 76 mm	8	Local	
12	Casing dia.89 mm @ 3 m	20	Local	
13	Casing dia.89 mm @ 1.5 m	10	Local	
14	Hose *Grouting*	200 m	LN	
15	Equipment for Supporting *Grouting* Other			

2. RESULTS AND DISCUSSION

In accordance with one of the conditions in the construction of a dam, the permeability number (k) and the Lugeon unit value become a reference in determining the feasibility of grouting work. In the grouting manual for a dam from the Ministry of Public Works Directorate of Water Resources Directorate of Rivers, Lakes and Reservoirs (December 2005). It is stated that the permeability number (k) is $k \leq nx\ 10\text{-}5$ cm/second while for Lugeon unit values range from 1 to 5. In determining the grouting pattern planning, data must be obtained from the grouting test results. In carrying out the grouting test some data information will be obtained including:

a) Spacing of grouting that are considered effective
b) Depths of grouting holes that are considered effective
c) Volume of grouting
d) Appropriate and effective pressure of grouting into cavities, fractures, or pores of the rock to be grouted Appropriate grouting
e) coefficient Permeability mix
f) (k) and Lugeon unit price
g) Success effectiveness grouting plan pattern grouting:

Determines three points of grouting holes to form an equilateral triangle pattern with a distance between holes of 3 meters and a depth of 20 meters each. In determining the grouting pattern, the method used at Mila Dam is as we can see in Figure 3.

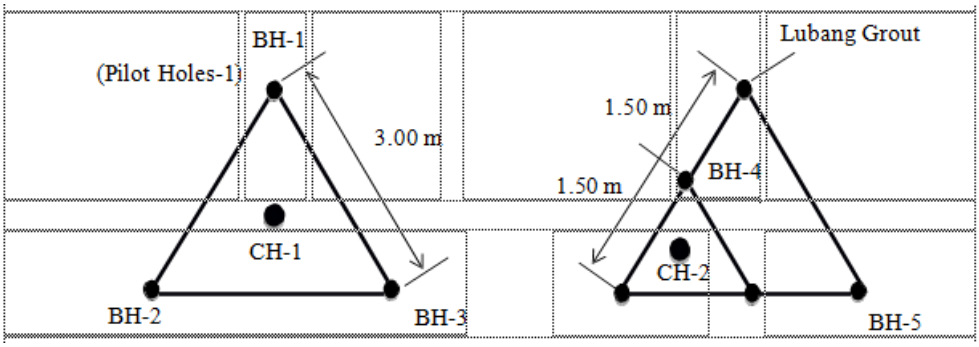

Figure 3. Grouting Scheme.

Work sequence *grouting* test:

a) Making *pilot Hole* to a depth of between 0 – 5 meters.
b) Followed by a Pressurized Water Test (WPT) continuing to a depth of 30 meters (BH-1). Every 5 meters the depth of the drilling hole is carried out by WPT.
c) Grouting *grouting* method *upstage* namely *was* which was carried out starting from the bottom of the hole at intervals of every 5 meters (from a depth of 30 – 25 meters).
d) When the condition of the cement solution is considered *settled* (more than 12 hours) *grouting* again for the *stage* (from a depth of 25 – 20 meters), carried out sequentially until it is finished.
e) Followed by drilling work on the next hole (BH-2), grouting is carried out as in the *Pilot holes*.
f) Hole *grouting* (BH-3).
g) Then do the *Check Hole* see picture above.
h) If the WPT results are in the *Check Hole* obtained permeability coefficient data k < nx 10^{-5} cm/second, meaning that the *grouting* with the distance determined as above is quite good. However, if the permeability coefficient k > nx 10^{-3} cm/second or k < nx 10^{-4} cm/second is obtained, then the *grouting* that has been carried out is less effective. So that the next hole must be added with a shorter distance than the previous grouting test hole.

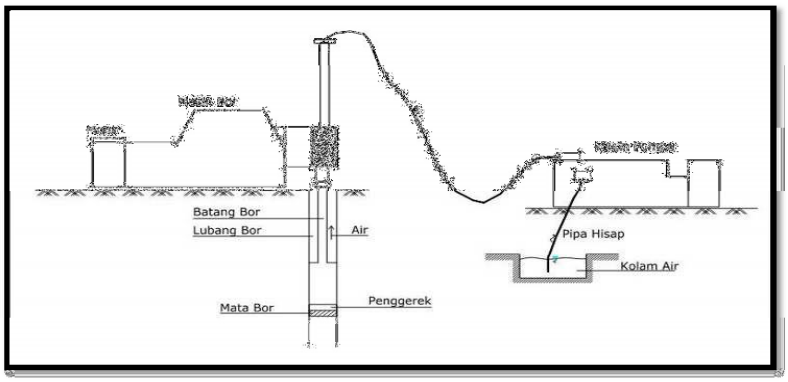

Figure 4a. Drilling Work Scheme.

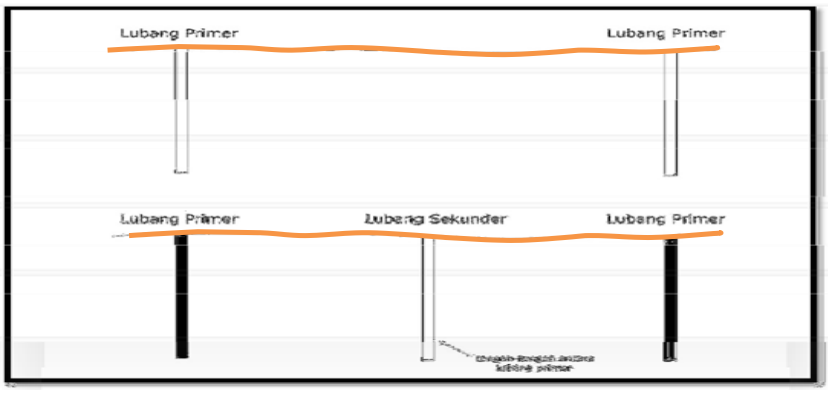

Figure 4b. Drilling Work Scheme.

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Table 3. The results of the grouting test.

NO	DATE	HOLE	STAGE	DEPTH (m)	Press (bar)	LUGE ON	Grout Mix	Semen (kg)	REMARKS
1	27-Apr-17	BH-1	1	0.00 – 5.00	0.5	28.00	1:10	325.20	PH
	27-Apr-17		2	5.00 – 10.00	1.0	21.00	1:10	320.05	
	27-Apr-17		3	10.00 – 15.00	1.5	19.00	1:10	215.50	
2	27-Apr-17	BH-2	1	0.00 – 5.00	0.5	26.00	1:10	280.22	
	27-Apr-17		2	5.00 – 10.00	1.0	25.00	1:10	275.30	
	27-Apr-17		3	10.00 – 15.00	1.5	10.00	1:10	160.45	
3	27-Apr-17	BH-3	1	0.00 – 5.00	0.5	24.00	1:10	260.20	
	27-Apr-17		2	5.00 – 10.00	1.0	20.00	1:10	255.30	
	27-Apr-17		3	10.00 – 15.00	1.5	12.00	1:10	138.40	
4	20-Sep-15	BH-4	1	0.00 – 5.00	0.5	4.40	1:10	6.64	- *CH*
	21-Sep-15		2	5.00 – 10.00	1.0	3.20	1:10	10.52	
	22-Sep-15		3	10.00 – 15.00	1.5	2.40	1:10	26.50	
TOTAL (meter) 60.00 m								TOTAL2,274.28 kg	

Method The grouting method carried out at Mila Dam is a double row curtain grouting pattern as shown on Figure 5.

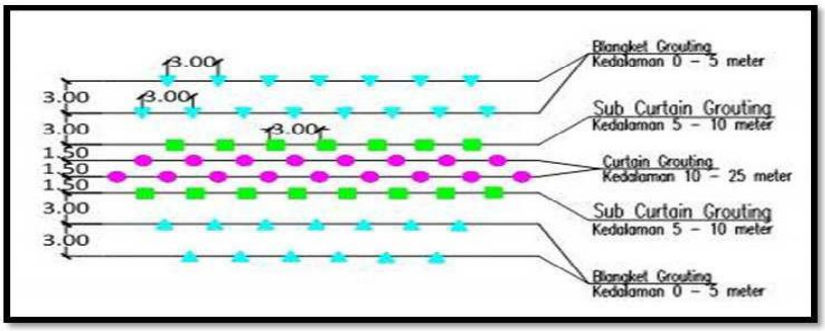

Figure 5. The Grouting Method.

In the double row curtain grouting pattern, the work starts from the outer row (Blanket) by grouting the primary holes first, followed by the secondary holes, and then the quarter hole. As a rule, drilling of secondary holes in any foundation zone shall not be carried out until the grouting of the primary holes has been completed. The grouting work for the Mila Dam maindam area starts from the blanket grouting hole, then the sub curtain hole, and finally the curtain hole. Priority provisions for working on grouting holes as described above are binding on both the sub curtain and curtain grouting work. In carrying out the grouting work at Mila Dam it is carried out using the Upstage and Downstage injection methods. If the rock layer does not collapse during drilling, it is carried out by upstage grouting, that is, the implementation starts from the bottom up. If rockfall occurs at the time of drilling, the downstage method is used, namely drilling is carried out to a depth of 3.00 m and then grouting is carried out. After the injection cement paste hardens for ± 6 hours, redrilling is carried out and so on until the specified drill depth is reached.

3. CONCLUSIONS

For subgrade repair work on the dam body foundation (maindam) with the grouting method located in Mila Village located in Dompu district, West Nusa Tenggara Province, there are two methods during drilling work because some of the soil contours contain brittle rock and fractures open and connected which makes it a little constrained during the implementation of the grouting. One solution that can be applied is when drilling using the Upstage method with an interval of 5 m, but in rocks that are brittle and have open fractures connected to each other using the Downstage method with an interval of 2.5 m.

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