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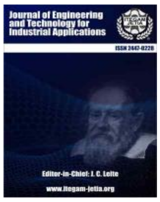

RESEARCH ARTICLE OPEN ACCESS

EVALUATION OF DAM FOUNDATION GROUTABILITY USING SECONDARY PERMEABILITY INDEX AND ROCK QUALITY DESIGN (CASE STUDY IN JLANTAH DAM, INDONESIA)

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ABSTRACT

The dam is a building that functions to hold air by blocking the flow of river water. Seepage under the foundation can occur through pores so needs to be cement injection. This research was carried out based on the Secondary Permeability Index (SPI) method in grouting evaluation which still needs to be carried out. The foundation of the Jlantah dam rests on lapilli tuff, agglomerate and volcanic breccia with different characteristics. At this research location there are four relationships between RQD and SPI. Relationship with Type A which shows SPI with Class A to B1 (Very Good to Good) with a low RQD value, caused by the high intensity of interlocking discontinuity areas, and no need for foundation repairs which are rarely found. Type B, which shows RQD is directly proportional to SPI, is found second most frequently. Type C, which shows SPI with Class B2 and C (Fair to Poor) with low RQD due to the high intensity of interlocked discontinuity areas that require cement injection, is the first. Type D shows SPI with Classes C and D (Poor to Very Poor) with high RQD values caused by several faults with the 3rd largest wide opening found.

I. INTRODUCTION

Dam is a building that functions as a water level rise and water storage area during the rainy season when river water flows in large quantities that exceed the need for irrigation, drinking water, industry, and others. Dam construction is built to hold back the rate of water into reservoirs, lakes, or tourist attractions [1]. The construction of this dam is carried out by calculating its stability so that construction failure does not occur [2]. Air seepage in the dam foundation is one of the critical factors in the calculation of the reservoir. Therefore, rock permeability is an important thing that needs to be considered in the replacement of foundation engineering so that leakage does not occur [3]. Calculating permeability values can be converted into Lugeon values (Lu), which can be divided into rock permeability levels [4]. This analysis was carried out based on compressed testing air on the rocks resulting in the degree of weathering of the airflow and its geometrical characteristics [5],[6]. The relationship between the airflow pattern and the injected semen has a relationship that results in differences that can be divided into low and high categories [7],[8]. Earlier researchers have widely studied the relationship between the permeability value and the volume of semen injected, but there is still much debate about the relationship between these two aspects [9],[10]. In evaluating grouting, there is the development of methods that can relate or classify rock masses in terms of their secondary permeability values and divide them into soil treatment zones for dam foundations based on rock quality class, namely the secondary permeability index (SPI) method [11]. The Secondary Permeability Index (SPI) method was introduced based on this debate. It can relate or classify rock masses in their secondary permeability and create dam foundation zones based on rock quality classes [11]. This method was used by defining the rock mass's quality based on the discontinuity's permeability value in the pressure water test. The development of this method was applied in evaluating cement injection to study the groutability of work results and planning foundation repairs with grouting at the Kamal-Saleh Dam [12].

Evaluation based on the cement injection value is related based on the Rock Mass Rating (RMR) value with the Geological Strength Index (GSI) to the lugeon method, which was previously under debate, the results obtained show the intensity of the discontinuity area a direct relationship with the Lugeon value based on the secondary permeability value to the groutability value of the rock masses in the Ostur Dam [13]. the results obtained at the Ostur Dam correlated SPI and Lugeon values. The research was carried out again on the Nargesi and Cheshmeh-Assheg Dams using empirical equations in correlating secondary permeability index and the Lugeon method (SPI), an indication of rock quality, and collection of cement at the dam site showed that areas with a similar or close trend did not require treatment. In contrast, areas with opposite trends required large amounts of cement injection [14]. Developments in conducting evaluations to look for relationships between Lugeon values, SPI values, and RQD values based on mathematical observations [15], as well as linking cement injection volume with Q-system values, Lugeon values, SPI values, and connection holes for obtained an empirical relationship to the Bakhtiri Dam in Iran [15]. this method is carried out on igneous rock types with surface geotechnical investigations [16].

Foundation repair with grouting cement injection requires volume analysis in planning grouting work, estimated cement volume can be predicted by performing a statistical analysis of the gaps together with injection pressure and SPI by looking for this relationship using multiple linear and linear equations [17]. Evaluation of recommendations for handling cement injection based on Lu, SPI values, and cement injection was carried out on conglomerate rock types [18]. The injection volume is influenced by several factors that affect the amount of cement injection volume so that the value of the empirical equation can be taken based on the SPI value, RQD value, fracture opening, and Groutakes [19]. Determining foundation improvement using a soil treatment classification based on SPI values requires considering the factors between discontinuity field mapping and RQD values [20]. The relationship between the RQD value and the SPI value can be divided to look for some characteristics of rock properties to cracks and their permeability values which can be an evaluation of the use of cement grouting mixtures [21].

Grouting was first applied in Indonesia on the Jatiluhur Dam in 1961 to repair the dam foundation. Grouting was also used in the K-3 Dam project (Karangkates, Kali Konto, and Riam) in 1962. The Wlingi Dam was built in 1975 and inaugurated in 1977 using foundation repairs with grouting due to poor rock conditions and permeability values. The construction of large reservoirs in Indonesia is urgently needed to reduce flooding, the need for clean water, hydroelectric power, and others. Therefore, in 2005, Indonesia made guidelines for methods of using grouting so that it can be used as a reference for work and to improve the safety factor of dams. Evaluation of grouting can be seen from the Lugeon value parameters, SPI values, and cement injection to provide recommendations for soil management [18].

Foundation repair with cement grouting injection requires volume analysis in planning grouting work. Semen volume estimation can be predicted by performing statistical analysis of cracking, injection pressure, and SPI by looking for these relationships using multiple linear equations and linear equations [22]. Several factors that affect cement injection volume influence this volume so empirical equation values can be taken based on SPI values, RQD values, Joint Gaps, and Groutakes [19],[23].

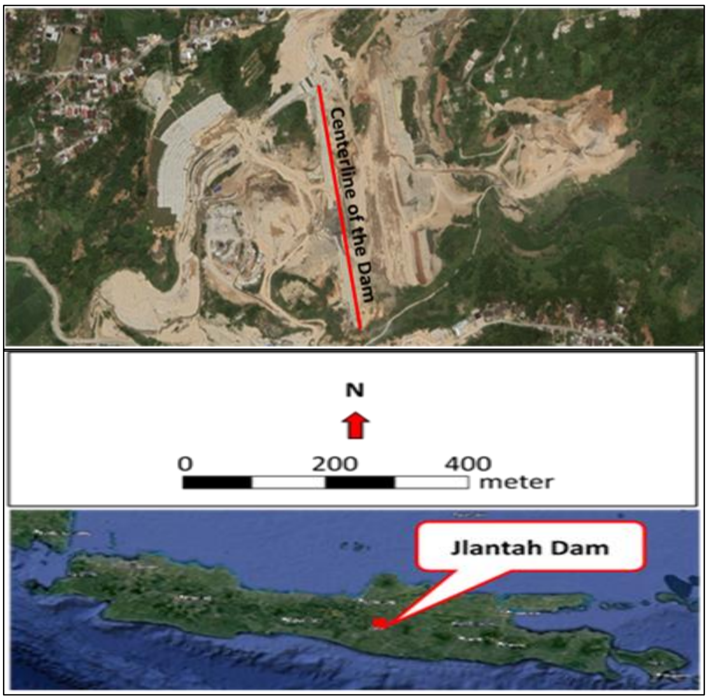

Figure 1: Location Map of Jlantah Dam (Accessed using Google Earth Pro on 11 August 2023 12.00 WIB).
Source: Authors, (2024).

The method for determining foundation repairs using soil treatment classification based on SPI values must consider the factors between discontinuity field mapping and RQD values [20]. The relationship between the RQD value and the SPI value can be divided to look for some characteristics of rock properties to cracks and their permeability values that can be used to evaluate the use of cement grouting mixtures [21]. The analysis aims to determine the ground treatment by injection of cement using the secondary permeability index (SPI) method and to find a relationship between the RQD value and the SPI value, which can determine the composition of cement mixtures globally.

II. MATERIALS AND METHODS

II.1 RESEARCH METHODS

This research was conducted at the Center line of the Jlantah Dam, Karangsarai Village, Jatiyoso District, Karanganyar Regency, Central Java, Indonesia (Figure 1). The data used is from 22 drill points in the Pilot Hole (rock samples and water pressure tests) with a depth of 25 meters to 55 meters during the 2020 to 2023 data collection period. Data processing is carried out using statistical analysis to determine ground treatment zoning with cement injection to determine the relationship between the SPI value and the RQD and thematic analysis in correlating SPI and RQD values. In the first stage (processing of investigative data), at this stage a rock description is carried out to classify rock types, conduct an RQD assessment of each drilling sample and calculate the SPI value from the results of the water pressure test at 5 meters intervals for each test depth. The second stage (data analysis), At this stage, the data that has been obtained from the results of the initial investigation are in the form of rock types, Rock RQD values, and SPI values which are then correlated for each drill point to produce geological thematic cross sections, RQD and SPI. Data resulting from the RQD and SPI values are used to find the relationship between the two values in the resulting grouping of rock characteristics. The third stage (Evaluation), At this stage, the thematic correlation results show a ground treatment zoning that requires foundation repair with cement injection. The ground treatment category includes needless, local, required, and extensive. Based on the thematic observations, the classification requires a suitable cement injection composition based on the results of rock characteristics obtained based on the relationship between RQD and SPI values. Evaluation based on thematic correlations and the relationship between RQD values and SPI can determine rock characteristics and describe the composition of the cement to be used.

II.2 ROCK QUALITY DESIGN (RQD)

Rock Quality Designation (RQD) is a valuable calculation method for measuring rock mass quality in core logs based on the length of intact rock samples. RQD is also a measurement of intact rock samples with a length of more than 100 mm to the total length of the drilled sample [24]. This rock class marking has several limitations in the length of the drilling sample, which can be caused by damage during the drilling process, which causes a decrease in the quality value of the rock [14]. The rock mass quality of the Jlantah Dam was carried out at 22 drilling points on the dam axis.

The RQD value of rock can be known using the formula, which can be seen in equation (1).

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$$RQD = \frac{\sum \text{Intact core cut length}}{\text{Total length of core retrieved}} \times 100\% \qquad (1)$$

Table 1: Classification of rock quality design.

RQD-Value	Rock Classification
0 - 25%	Very poor
25 - 50%	Poor
50 - 75%	Fair
75 - 90%	Good
90 - 100%	Excellent

Source: [24].

The formula described in equation (1) shows the percentage of intact rock sample length greater than 10mm from the drill sample length taken. The results of these calculations are included in the rock quality classification. The classification of rock mass quality can be seen in Table 1.

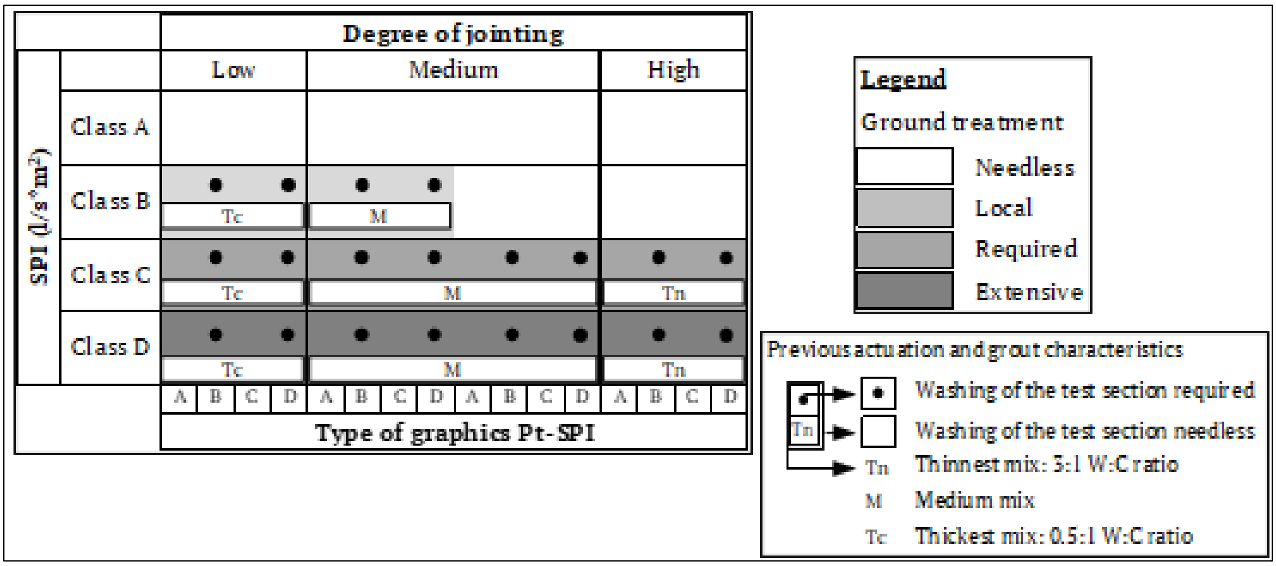

Figure 2: Ground treatment based on SPI value.
Source: [11].

The results of SPI calculations can be applied to divide rock mass classes into different ground treatment zones. Table 2 shows the classification of SPI values, which are divided into class A, class B, class C, and class D based on the rock quality, and the classification of ground treatment types is divided into four classes based on the need for grouting cement injection [11]. Classification of Ground treatment based on SPI value can be seen in Figure 2.

Table 2: Modification of rock mass classification based on SPI value and soil treatment.

Rock Mass	SPI (l/s.m²)	Clasification	Ground Treatment
A	< $2,16 \times 10^{-14}$	Excellent	Needless
B1	$2,16 \times 10^{-14}$ - 7.6×10^{-14}	Good	Needless
B2	$7,6 \times 10^{-14}$ - 1.7×10^{-13}	Fair	Local
C	$1,7 \times 10^{-13}$ - 1.7×10^{-12}	Poor	Required
D	> $1,7 \times 10^{-12}$	Very Poor	Extensive

Source: [11].

II.3 SECONDARY PERMEABILITY INDEX (SPI)

The secondary permeability index (SPI) is a method for converting the results of the water pressure test (WPT) into a rock mass permeability value that can classify the rock mass into the type of ground treatment using injection cement grouting [11]. The formula for finding the secondary permeability index value can be seen in equation (2).

$$SPI = C \times Ln \times \frac{2le}{r+1} \times \frac{Q}{H} \qquad (2)$$

The SPI value is the secondary permeability index (l/s.m2), and C is a constant on the viscosity with an assumed rock temperature of 10 °C = 1,49 x 10-10 [25]. le is the length of the section being tested (m), r is the radius of the borehole (m), Q of water flow absorbed by the rock mass (liters), H total water pressure (m), t duration of test for each pressure level (s). The classification based on the SPI value is divided into classes which can be seen in Table 2. Class A indicates that foundation maintenance does not need to be carried out regarding the RQD, SPI, and Pt-SPI patterns. Class B indicates the presence of treatment on the foundation locally at an RQD value of <50% with an SPI value of > 7,56 x 10-14 l/s.m². This local handling is based on the existence of a fracture with intensive activity. So, it is necessary to improve with a medium mixture with a ratio of 1:1 W/C at an RQD value of 25-50% or thick with a ratio of 0,5:1 W/C at an RQD value of <25%. For Pt-SPI patterns B and D, it is necessary to wash the test holes before cement injection. Classes C and D show moderately strong foundation damage. If the test section has a low fracture value, it indicates that at least one fracture has a very high conductivity. In this condition, use a viscous mixture with a ratio of 0.5:1 W/C. If the test section is very cracked with an RQD value < 25%, it is necessary to use a thin mixture ratio of 3:1 W/C [11].

II.4 RELATIONSHIP BETWEEN RQD AND SPI VALUES

The SPI value, in general, has similarities with the RQD value seen from the characteristics of the rock to the quality of the rock mass. Secondary permeability index values can be slammed with RQD. The better the quality of the rock, the permeability value of the rock is more impermeable. The relationship between the two values also shows a disproportionate relationship between the SPI and RQD. It can indicate abnormal conditions. Based on these differences, the relationship between these two values can be divided into several types of relationships. As in this study area, the low SPI values (Class A and Class B) and low RQD (Very Poor and Poor) may be due to the high intensity of interlocking discontinuities. SPI C and D classes with high RQD values (Excellent and Good) have areas of discontinuity with wide openings [21]. The relationship between SPI – RQD is shown in Table 3.

Table 3: Modification of the relationship between RQD and SPI values.

Type	Description	Ijection Cement
A	Class A SPI values with low RQD values are due to the high intensity of the discontinuity field	No need for foundation repair
B	The fracture intensity is proportional to the SPI value	Normal cement mixtures follow the SPI classification
C	Class B - C SPI values with low RQD values due to the high intensity of inter-locked discontinuity fields	Foundation repair with medium - the dilute mixture
D	Class C - D SPI values with high RQD values, there are areas of several fractures with wide openings	Foundation Repair with Thick mix

Source: [21].

Table 4: Example of the results of processing field studies and observations.

Hole Id	Stage	Top (m)	Bottom (m)	Rock Type	RQD (%)	Lu	Behavior	SPI
PH 1	1	0	5	Lapili tuff	24	29,5	Wash out	6,56E-13
	2	5	10	Lapili tuff	16	1,7	Lamination	3,74E-14
	3	10	15	Lapili tuff	16	5,9	Lamination	1,31E-13
	4	15	20	Volcanic breccia	70	1,7	Lamination	3,75E-14
	5	20	25	Volcanic breccia	50	1,4	Dilatation	3,17E-14
PH 2	1	0	5	Lapili tuff	15	29,9	Turbulent	6,64E-13
	2	5	10	Lapili tuff	43	29,0	Turbulent	6,44E-13
	3	10	15	Volcanic breccia	53	5.6	Lamination	1,24E-13
	4	15	20	Volcanic breccia	23	0,2	Lamination	4,92E-15
	5	20	25	Volcanic breccia	14	0,8	Lamination	1,72E-14
PH 3	1	0	5	Volcanic breccia	33,5	24,0	Turbulent	5,33E-13
	2	5	10	Volcanic breccia	15,1	9,7	Turbulent	2,16E-13
	3	10	15	Volcanic breccia	35	1,1	Lamination	2,40E-14
	4	15	20	Volcanic breccia	76	0,7	Lamination	1,49E-14

Source: Authors, (2024).

III. RESULTS AND DISCUSSIONS

III.1 RESULTS

Field observations were carried out in drill holes with a depth of 25 m and 55 meters each. The results of these observations are rock types, RQD values, Lugeon values, Lugeon values, and SPI values. An example of recording field data and observation results can be seen in Table 4. Correlation of rock types was carried out on the axis of the dam to surface appearance observations and samples from drilling results from PH drill holes of 22 points. The results of monitoring are shown in Table 4. Surface correlations were carried out to produce a geological map of the dam, as seen in Figure 3. The subsurface correlation results based on 22 drilling points can be seen in the geological cross-section of the Jlantah dam in Figure 4. Figure 2 shows four types of lithology: alluvial deposits, tuff lapilli, agglomerates, and volcanic breccia. In Figure 3, alluvial deposits are not found in the geological correlation to the drill points as a result of the investigation. The gray color indicates alluvial deposits, the purple color indicates lapilli tuff, the orange indicates agglomerates, and the brown indicates volcanic breccia. The dotted line boundaries in the correlation are considered boundaries, and the groundwater table is indicated by the blue line in Figure 4. The RQD and SPI values indicate the water absorption level and grouting requirements, which can be determined based on the rock characteristics [21].

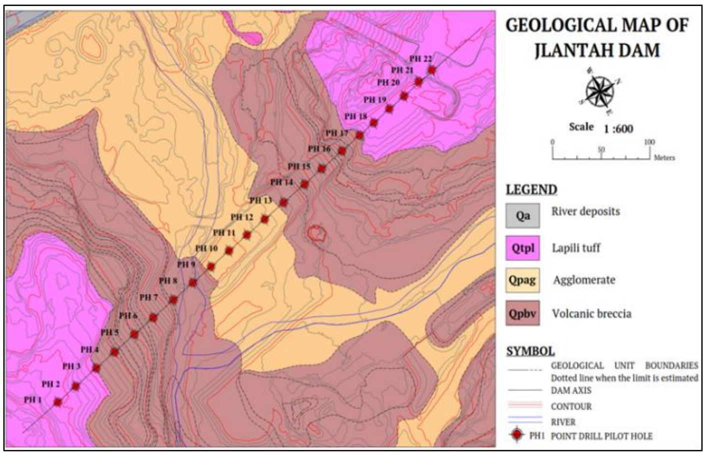

Figure 3: Geological Map of the Jlantah Dam Foundation.
Source: Authors, (2024).

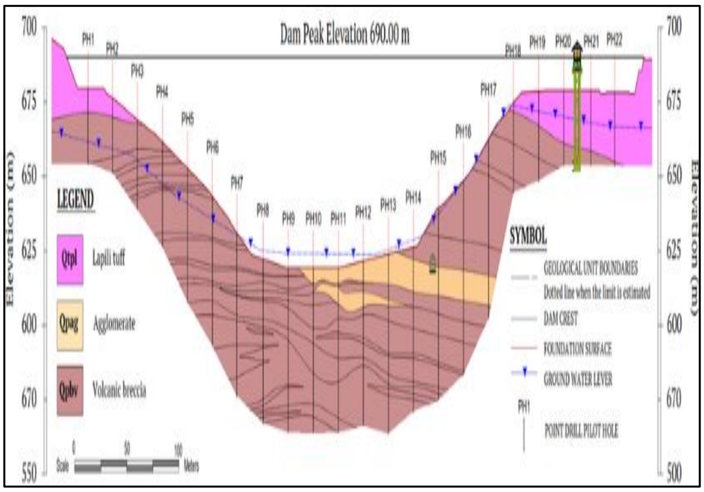

Figure 4: The geological cross-section of the Jlantah Dam.
Source: Authors, (2024).

Interpretation of ground treatment is carried out based on the RQD value and SPI value. The relationship between the two values can be seen in the graphic pattern between the SPI-RQD values and the drill hole depth, presented at the drill hole points PH1, PH2, and PH3. The three drill holes can represent four types of relationships between SPI and RQD. The graph can be seen in Figure 4. Figure 4 shows three lithology types: gray, indicating alluvial deposits. Purple indicates lapilli tuff, orange indicates agglomerates, and brown indicates volcanic breccias. The dotted line boundaries in the correlation are considered boundaries, and the groundwater table is indicated by the blue line in Figure 4. Based on the RQD and SPI values, rock characteristics related to the degree of water absorption and the need for grouting can be determined [21]. This can show the composition of the mixture between cement and water to be used.

The RQD value of the SPI value proves the interpretation of ground treatment based on the SPI value. An example of a graphical relationship between SPI-RQD value and borehole depth is presented at borehole points PH1, PH2, and PH3, which can represent four types of relationships between SPI and RQD values.

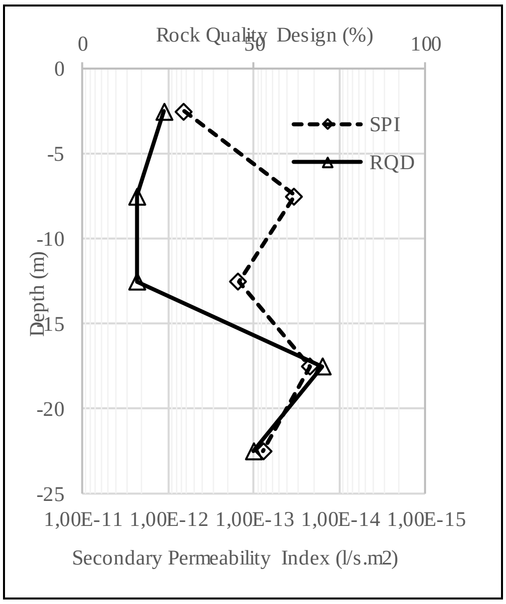

Figure 5: Relationship between SPI - RQD value and depth from Pilot Hole 1.
Source: Authors, (2024).

Figure 5 shows the relationship between the SPI and the RQD in the pilot hole one. RQD and SPI values are calculated at 5 meters intervals. That location shows a type A connection that does not require cement injection repair at a depth of 15 to 20 meters. The relationship between type B and the SPI value with the RQD value is directly proportional to the depth of 0 to 5 meters and 20 to 25 meters, so cement injection uses a normal mixture based on this type. Type C relationship with class B2-C SPI values (7,6 x 10-14 l/s.m² to 1,7 x 10-13 l/s.m²) has a low RQD value at a depth of 5 to 15 meters, so cement injection uses a fine mixture based on this type.

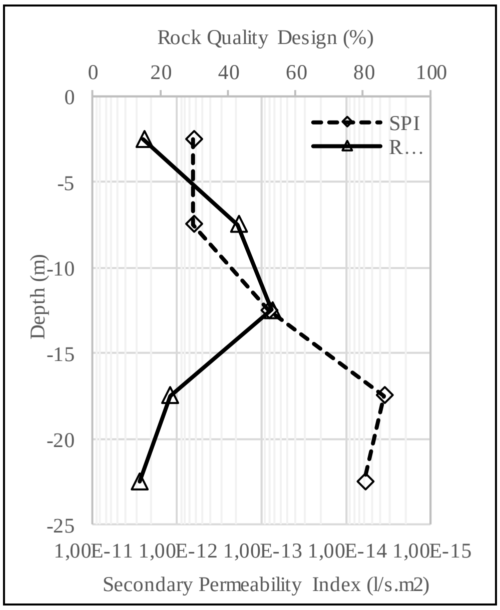

Figure 6: Relationship between SPI - RQD value and depth from Pilot Hole 2.
Source: Authors, (2024).

Figure 6 shows the graph of RQD-SPI values against borehole depth at point PH2 with a total depth of 25 meters. This location represents a type A joint that does not require cement injection repair at a depth of 15 to 25 meters. At this depth, it has a class A to B1 (<7,6 x 10-14 l/s.m²) SPI value with a low RQD value, which indicates that many fractures are interlocked or fractures that are not connected so that water cannot flow through the gaps. The relationship between type B and the SPI value with the RQD value is directly proportional to the depth of 10 to 15 meters so cement injection uses a normal mixture based on this type. Type C relationship with class B2 to C SPI values (7,6 x 10-14 l/s.m² to 1,7 x 10-13 l/s.m²) has a low RQD value at a depth of 1 to 5 meters, so cement injection uses a fine mixture based on this type. Type D relationship with class C to D (>1,7 x 10-13 l/s.m²) SPI values with medium to high RQD values is found at depths of 5 to 10 meters, indicating the presence of at least extensive fractures. Type D requires a thick injection cement mix to fill wide fracture gaps.

Figure 7 shows the graph of RQD-SPI values against borehole depth at point PH3 with a total depth of 25m. This location represents a type A joint that does not require cement injection repair at a depth of 15 to 25 meters. At this depth, it has a class A to B1 (<7,6 x 10-14 l/s.m²) SPI value with a low RQD value, which indicates that many fractures are interlocked or fractures that are not connected so that water cannot flow through the gaps. The relationship between type B and the SPI value with the RQD value is directly proportional to the depth of 0 to 5 meters so cement injection uses a normal mixture based on this type. Type C relationship with class B2-C SPI values (7,6 x 10-14 l/s.m² to 1,7 x 10-13 l/s.m²) has a low RQD value at a depth of 5 to 10 meters, so cement injection uses a fine mixture based on this type.

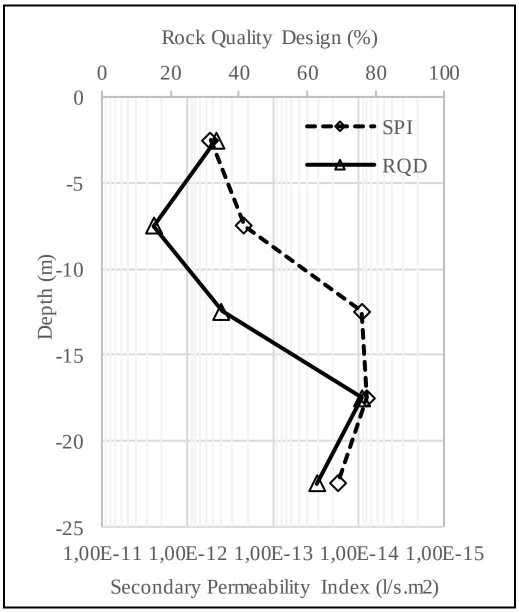

Figure 7: Relationship between SPI - RQD value and depth from Pilot Hole 3.
Source: Authors, (2024).

The results of the percentage grouping of data obtained from the relationship between RQD and SPI can be seen in Table 5. There were 20 points with a type A relationship of 9,71 %, 51 points with a type B relationship of 24,76 %, 117 points with a type C of 56,80 %, and 10 points with a type D of 4,85 %. Based on these data, the type C relationship dominates the Jlantah Dam foundation.

The relationship between RQD and SPI values on the Jlantah Dam axis is dominated by type C. The correlation between SPI values and ground treatment using the cement grouting injection method is shown in Figure 8. The SPI values were correlated at 22 points of the pilot hole drill holes, which have their respective depths. Each drill hole ranges from 25 m to 55 m with intervals of SPI values every 5 m.

The results are classified into four classes. Class A is shown in blue without the need for foundation repair, Class B in green with localized grouting, Class C in yellow, which is visible in sections requiring repair by grouting, and Class D in red requiring extensive grouting.

Table 5: Percentage of SPI-RQD types on the Jlantah Dam.

No	Type	Frequency	Percentage (%)
1	A	20	9,71
2	B	51	24,76
3	C	117	56,80
4	D	10	4,85

Source: Authors, (2024).

III.2 DISCUSSIONS

The Jlantah Dam is located at 7o 42' 44,05" LS and 111o 4' 47,51" BT. Geologically, this dam is located in the Ponorogo Sheet Geology. The foundation of this dam is supported by Quaternary-aged rocks on the left and right abutments in the form of lapilli tuff and volcanic breccia, and the foundation area of the river bed is in the form of agglomerate and volcanic breccia. The weathering condition of the rocks is moderate to light, which is highly influenced by the high rainfall rate. No significant faults were observed during the investigation, and the geological characteristics were evaluated using drilling data and field observations. The subsurface correlation in Figure 4 is arranged from the oldest to the youngest based on the regional age comparison. During the Pliocene epoch, volcanic breccia was deposited, followed by agglomerate deposited by interfingering. During the Holocene epoch, lapilli tuff was deposited parallel with volcanic breccia.

The volcanic rock has poor grain uniformity, which can cause very porous permeability values. The agglomerate has a dominant appearance of rounded fragments with sizes ranging from 64 mm to 1000 mm, which allows water to flow easily through the gaps between the fragments. The composition of the rock causes differences in the permeability values. It is influenced by the boundaries between rock layers with a mutually supportive relationship and the fractures in each rock. One of the factors that can affect the value of very porous or impermeable permeability is the level of rock quality, as seen from the primary and secondary structure of the rock itself. The relationship between rock mass quality and secondary permeability index values can be observed and classified based on the relationship between the RQD value and the SPI value [21]. Figure 5 at a 0 m to 15 m depth shows a low RQD value (Very Bad) with SPI values ranging from 2,16 x 10-14 l/s.m² to 1.7 x 10-12 l/s. m² (Class B to C). This relationship belongs to Type-C, caused by the high intensity of the interconnected discontinuity fields. Cement grouting mixtures in this type of connection require a medium to a fine mixture.

Figure 6 shows that the RQD class values are better than the SPI class values at 5 m to 15 m depth. The graphic pattern relationship between RQD and SPI shows several cracks with wide openings, so the grouting cement mixture uses a thick mixture to fill the cracks with wide openings. The analysis results of the relationship between the RQD value and the SPI value can be categorized into the percentage of the presence of the left abutment, riverbed, and right abutment. This percentage can determine the need for cement for the grouting. In addition, a comparison of the volume of cement with the standard mixture to the need for the cement mixture can be made based on the relationship between the RQD value and the SPI value.

This is useful in planning grouting work in calculating estimated cement requirements to be used. Figure 6 at a 0 m to 5 m depth shows a symmetrical pattern or value between the RQD value and the SPI value (Type A). This pattern indicates that the RQD value is directly proportional to the crack intensity, directly proportional to the secondary permeability value. The composition of the cement grouting mixture follows the composition specified in the ground treatment classification based on the SPI value. At a depth of 15 m to 20 m shows a low RQD value (Very Bad) with an SPI value of less than 2,16 x 10-14 l/s.m² (Class A). This relationship belongs to Type B, caused by the high intensity of the interconnected discontinuity fields. However, based on the SPI value in Class A, grouting is not required at that depth.

Table 5 shows the percentage of the type of relationship between the RQD value and the SPI value. Type A ranks second most from the entire area of the dam foundation by handling grouting cement injection using the same mixture ratio between cement and water. Type B is the smallest percentage of dam axis foundation locations that do not require grouting injection. Based on this, the volume of cement requirements can be estimated and compared with the grouting work plan, and all parts of the dam are dominated throughout dominated by Type C, so the use of cement grouting mixture using a medium-fine mixture to reduce the volume of cement needed. Finally, type D occupies the third highest order at the observation site. This type of ground treatment with grouting cement injection uses a thick cement mixture so that the volume of cement is more than the volume of water used. Therefore, cement requirements can be estimated and compared with the grouting work plan. The repair of the foundation was designed based on the RQD value and the SPI value, which were correlated to the axis cross-section of the Jlantah Dam (Figure 8). The results suggest that ground treatment in the Class A area of the Jlantah Dam does not require foundation repair.

Foundation repairs in Class C and D areas area urgently needed. Foundation repairs will be planned with a ratio of dam height to the grouting depth of 2/3 of the dam height, which refers to large dam construction standards. Cement injection blinds are urgently needed on riverbed foundations, which are dominated by Class C and D and require intensive repairs. On the right abutment area, which is dominated by Class B to C, local and thorough repairs are required. On the left abutments, which are seen to be dominated by Class A-B, some repairs are required on an ongoing basis, locally and slightly present at low depths at PH 1 to PH 3. The results of this study indicate similarities regarding the relationship between the RQD value and the SPI value, which has been carried out by modifying the relationship type boundaries that have been carried out by previous researchers [21]. This research was carried out on quaternary volcanic rocks. So, continuing previous research looks for a relationship between secondary permeability index values and rock quality design values to evaluate grouting on igneous rocks [16], conglomerates [18] and limestone [19].

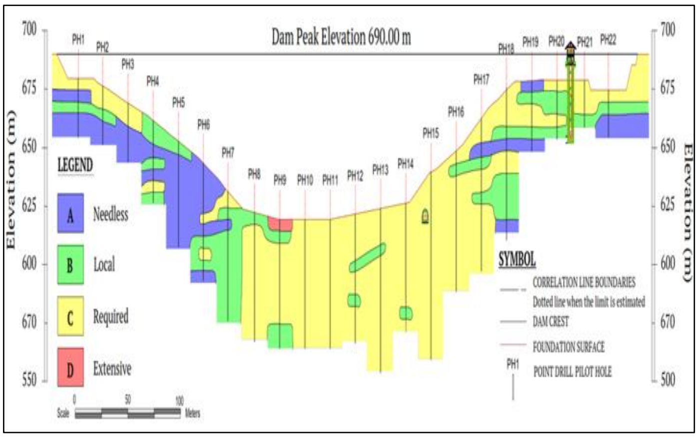

Figure 8: Cross section of the SPI-value axis Jlantah Dam.
Source: Authors, (2024).

IV. CONCLUSIONS

The foundation of the Jlantah Dam rests on volcanic breccias, agglomerates, and lapilli tuffs with different rock characteristics. On the left and right abutments that rest on tuff lapilli at a depth of 15 m to 25 meters, SPI class B that required local repair was found, and SPI class A that did not require grouting cement injection. At a depth of 0 to 15 meters, it has an SPI Class C value requiring grouting cement injection. The left abutment, which rests on volcanic breccia rock, is dominated by SPI class A which does not require grouting cement injection. The location of the river bed, which is based on volcanic breccias and agglomerates, needs to be repaired by cement grouting injection seen from the SPI values, which are included in classes C and D. At this research location, there are four relationships between RQD and SPI. Relationship with type A, which shows RQD is directly proportional to the SPI, is found to be the 2nd most. Type B, which shows SPI with Class A (Excellent) with a low RQD value, is caused by the high intensity of interlocking discontinuity areas, and no foundation repairs are needed very rarely found. Type C showing SPI with Class B and C (Good-Fair-Poor) with low RQD due to the high intensity of interlocked discontinuity areas requiring cement injection was found to be the 1st. Type D showing SPI with Class C and D (Poor-Very Poor) with a high RQD value caused by several fractures with wide openings found the 3rd most.

V. AUTHOR'S CONTRIBUTION

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