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ANALYSIS OF THE STABILITY OF THE TEMPORARY TUNNEL SUPPORT STRUCTURE IN THE EXCAVATION PHASE OF THE CIPANAS DAM TUNNEL

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ABSTRACT

Dams are generally equipped with bypass tunnels. The circumvention tunnel functions to maintain the safety of the dam and can reduce excessive water pressure around the dam. This can help prevent collapse or damage to the dam structure due to excess pressure. The objectives of this research are to determine the implementation of making temporary support structures in tunnels, to obtain the maximum stress values that occur in temporary tunnel support structures, to obtain deformation values that occur in tunnels and safety factors related to the use of steel H Beam as reinforcement, to find out the results of stability analysis. tunnel temporary support structure. Method for analyzing soil stability during the installation of steel supports during the implementation of bypass channel work using the 2D plaxis program approach. The main stress in the Cipanas dam tunnel is tensile stress. The maximum tensile stress occurs at the top of the tunnel due to gravity and groundwater loads. Axial deformation in the Cipanas dam tunnel is deformation that occurs in the direction of the tunnel axis. Maximum axial deformation occurs at the top of the tunnel due to gravity and groundwater loads. Data from stress analysis and deformation analysis at Sta. 0+180.76 total stress $-1.56*10^3 kN/m^2$ relative shear stresses 0.99 deformed mesh $34.84*10^{-9}$ m scealead up $100.00*10^6$ total displacement $34.86*10^{-9}$ E-mst 1.00, Sta. 0+280.76 total stress $-2.82*10^3 kN/m^2$ relative shear stresses 0.72 deformed mesh $613.16*10^{-6}$ m scealead up $10.00*10^3$ total displacement $613.16*10^{-6}$ E-mst 1.00, Sta. 0+480.76 total stress $-1.61*10^3 kN/m^2$ relative shear stresses 1.00 deformed mesh $2.19*10^6$ m scealead up $2.00*10^{-6}$ total displacement $2.19*10^6$ E-mst 1.938

Keyword: *Main Dam, Avoidance Tunnel, Stability.*

1. INTRODUCTION

The Cipanas Dam was built in Sumedang district, West Java, with a water source from the Cipanas river. Based on its water source, this dam is in the Cimanuk Cisanggarung river area. This dam was built with the aim of improving irrigation water services in the Cimanuk Cisanggarung River Basin area, with a planned irrigation area of 9,273 ha, raw water supply of 850 liters/second, with the potential for electricity development of 3.0 MW and a role in flood control. Dams are generally equipped with bypass tunnels which have a very important role. Evasion tunnels play a crucial role in maintaining the safety and reliability of dams. with an effective bypass tunnel, excessive water pressure around the dam can be reduced by channeling it through the tunnel. This helps prevent collapse or damage to the dam structure due to excessive pressure. Likewise with the Cipanas Dam which is equipped with a circumvention tunnel structure. The circumvention tunnel at Cipanas Dam is currently under construction which requires special attention to security aspects. In the process of constructing circumvention tunnels, safety measures must be taken to ensure that the work is carried out with a high level of safety. One important aspect that needs to be considered is tunnel excavation. In the excavation process, it is important to build a temporary support structure that functions to hold the soil and prevent landslides during the excavation

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and construction process. This support structure will provide protection to workers and also maintain the stability of the surrounding environment. In this way, the construction of the circumvention tunnel at Cipanas Dam can be carried out safely and avoid the risk of landslides which have the potential to endanger work and safety. Temporary support structures in the tunnel construction process play an important role in maintaining safety and stability. The safety of the supporting structure must be carefully ensured to ensure safety in the tunnel construction process. During the excavation and construction stages, there are potential risks such as landslides which can threaten the continuity of work and the safety of the construction team. Therefore, it is necessary to carry out an in-depth analysis of the stability of this temporary support structure. This research will discuss the stability analysis of tunnel temporary support structures, with the title "Stability Analysis of Tunnel Temporary Support Structures in the Cipanas Dam Tunnel Excavation Phase". This study aims to determine the implementation of the construction of temporary support structures in tunnels, including the steps and methods used to build the supports, and to obtain the maximum stress value that occurs in the temporary support structure of the tunnel.

2. RESEARCH METHODS

2.1 Research Methods

This research uses a combination method of direct data collection in the field and literature study analysis. The first stage involves observing the stability of the tunnel with structural geological surveys, topographic data collection, and geotechnical measurements. In addition, data about earthquake events in the tunnel area was also collected. The second stage involved a comprehensive literature study analysis of the methods and techniques used in previous research on tunnel stability.

2.2. Research Flow

1. Literatur review and data collection
2. Data management
3. Structural modeling with plaxis
4. Structural analysis
5. Making reports
6. Conclusions and suggestions

2.3. Research Location

The location of the Cipanas Dam is located in the upstream part of the Cipanas River which is in the Cibuluh Village area, Kec. Ujung Jaya, Kab. Sumedang, Prov. West Java. Location map of Cipanas Dam.

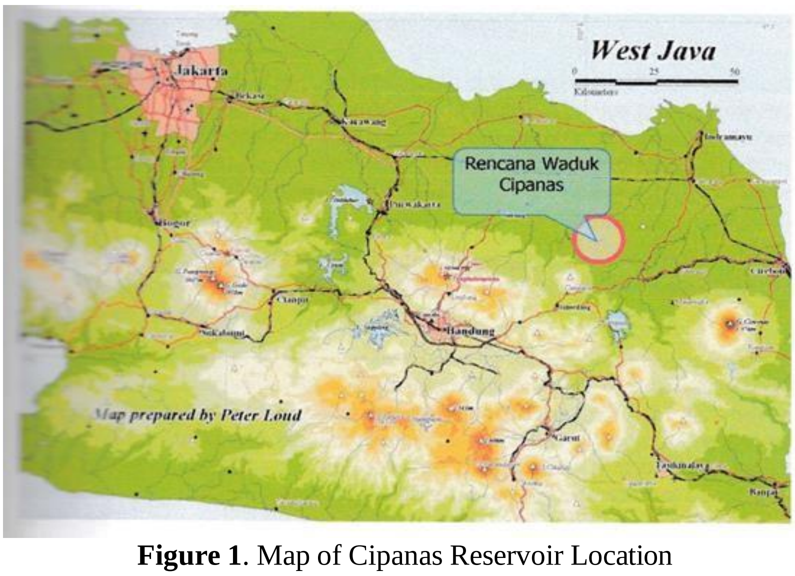

Figure 1. Map of Cipanas Reservoir Location

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2.4. Support Structure Analysis

2.4.1. Planning Data

Technical data of the diversion channel: the geology of the diversion channel is volcanic rock (pyroclastic) consisting of agglomerate, tuff breccia, tuff lapilli and tuff.

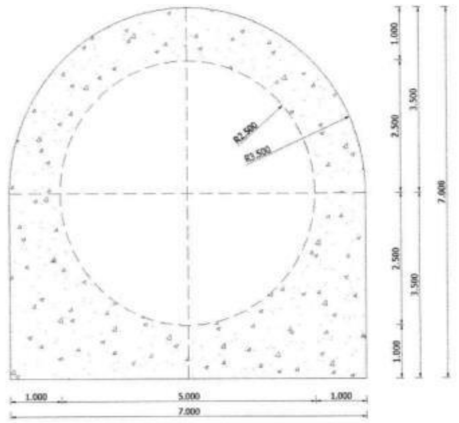

Figure 2. Typical diversion channel

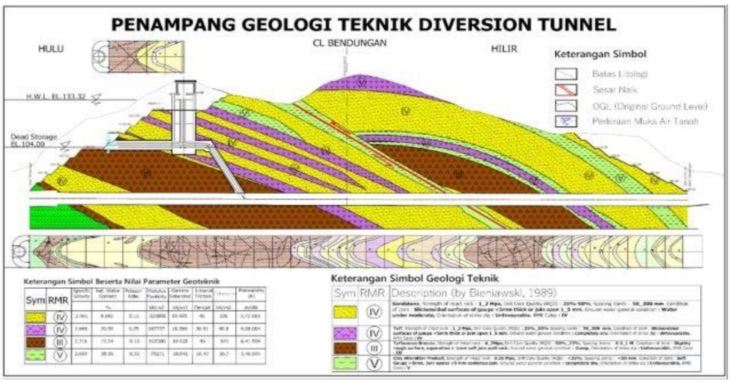

Figure 3. Geological cross section of the diversion tunnel engineering

2.4.2. Research implementation procedures

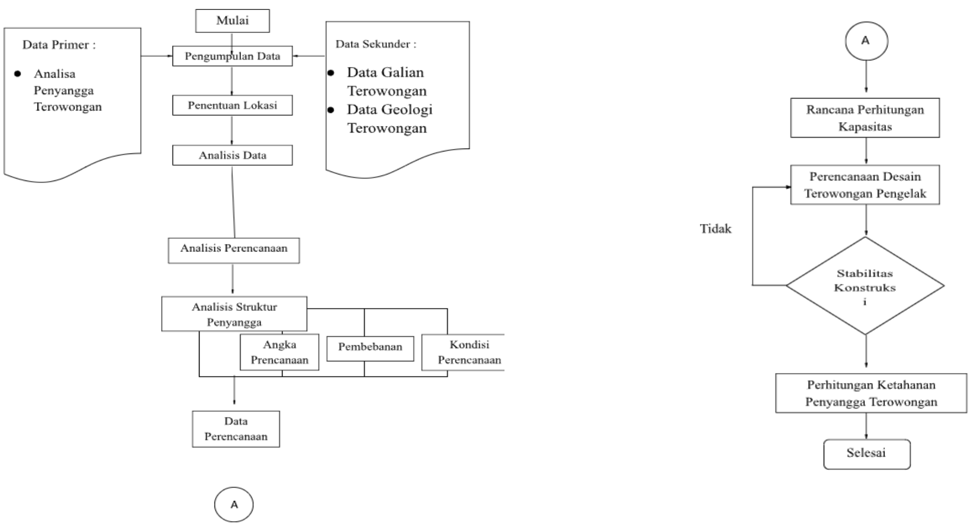

Figure 4. research implementation procedures

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3. RESULTS AND DISCUSSION

In conducting a stability analysis of the temporary tunnel support structure during the Cipanas tunnel excavation phase, several work stages need to be carried out, including:

3.1. Cipanas Dam Mapping Investigation

There are several ways to conduct a mapping investigation of the Cipanas dam, the following are the methods used to obtain mapping data for the Cipanas dam:

1. Geological mapping design planning

Mapping was carried out by the planning consultant based on the results of the log drilling at four main dam and tunnel drilling points.

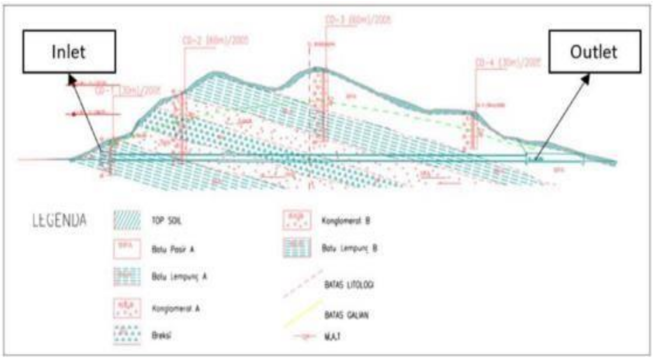

Figure 5. Geological mapping of planning

Based on the results of the log drilling at four points each with a depth of CD1 30 m, CD2 60 m, CD3 60 m, and CD4 60 m, it can be concluded that the rock lithology of the Cipanas dam project location is a medium rock class with a medium RMR value and class III. So that the excavation work is carried out using the blasting method.

2. Planning geology report

The morphology of the area around the Cipanas dam consists of wavy hills with rather steep cliffs and a U-shaped river, with a river width of around 30 m. On the left side of the river there is a slope with a gradient of 800, while the right side of the river is wavy. The following is a description of the morphology of the area around the Cipanas dam.

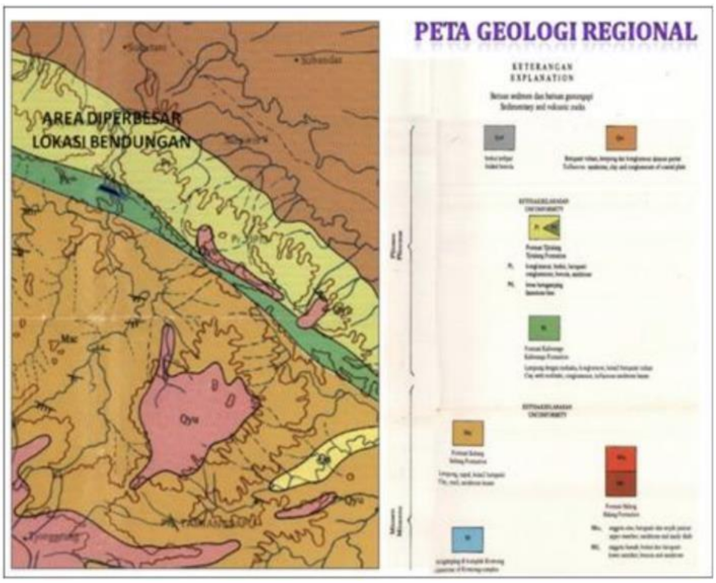

Figure 6. Regional geologi map of Cipanas and surrounding areas

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The geological conditions of the Cipanas dam area consist of bedrock and alluvial deposits, the rock cover layer is alluvial deposits and silty sand. The geological conditions of the planned foundation area along the dam axis from bedrock to cover layer (from old to young) are as follows:

a) Alluvial: Cipanas river deposits consist of gravel boulders, andesite material around 70%, claystone fragments, conglomerate, sandstone, basalt. While the sandbars are coarse sand-clay, silica composition.
b) Collovial: brown in color, subrounded gravel-boulder grain size (3-160 mm), with a composition of mudstone, sandstone, andesite, basalt, medium sand matrix.
c) Cover soil (sand): light brown, soft, coarse sand-silt size, weathered result of clay rock, dry, less plastic, cracked
d) Alternating sandstone units with mudstone and conglomerate inserts consist of mudstone A, sandstone B, conglomerate A, breccia, conglomerate B, with moderate to light weathering. Exposed to the bottom of the Cipanas River
e) Alternating conglomerate units of sandstone intercalated with mudstone consist of sandstone B, mudstone B, experiencing moderate to light weathering. Exposed to the bottom of the Cipanas River, has hard to very hard hardness which is included in the Kaliwangu Formation of Pliocene age.

In the inundation area there is a layer that has a relative slope to the north-northeast with an angle of between 18 - 29 degrees. This sedimentary rock layer (Citalang Formation and Kaliwangu Formation) is part of the northern wing of the anticlinorium system in the Bogor zone whose folding axis is west – east

a) Geology of bypass tunnels : Consisting of A sandstone and claystone units originating from conglomerate inserts
b) Geology of flooded areas : In the inundation area, it is divided into two, namely claystone units and conglomerate rocks. Conglomerate rocks are located at the top covering the claystone unit. The direction of the rock layers has a northwest-west or southeast- east direction with a rock slope angle of the north-northeast direction. The slope of the rocks ranges from 20 to 30 degrees. The claystone unit is a rock consisting of alternating claystone and sandstone. In accordance with the conditions of the geological structure which has a slope of the rock layer, the reservoir water pressure will follow the slope of the rock layer, the possibility of reservoir water seepage will pass through the boundary between the rock layers.

3. Engineering geology aspects

Cipanas Dam consists of undulating hills on the right side of the river with a peak elevation of 145 m and steep hills on the left side with a peak elevation of 150 m. In this area, it is combined by sandstone and claystone with conglomerate inserts.

a) Dam ace

The geological aspect of the dam axis is determined based on the results of geological investigations with 9 drill holes and it was found that the condition is dominated by A sandstone with hard conditions at the bottom of the river. Laboratory testing of physical and technical properties was carried out on drill holes CB-2 and CB-3, the lugeon value along the dam axis ranges from 5-20 with the upper part having a relatively larger lugeon value than the lower part. While the value of k = water permeability ranges from 10-4 cm/sec to 10-5 cm/sec.

b) Bypass tunnel

Based on the results of the core log drilling, the tunnel is located in the river section and through the A sandstone unit alternating with conglomerate inset mudstone. Laboratory testing for physical and technical properties was carried out on drill holes CD-1 and CD-2. Based on the results of water permeability testing using the constant head and packer test methods, water permeability along the bypass tunnel is between 10-4 to 10-5 cm/sec with a lugeon value between <5 to >20.

During the tunnel excavation process, a support system (support type) is required. To determine the support system, field investigations have been carried out in the form of core drilling, in-situ tests and laboratory tests. Field investigation data on the bypass tunnel route are core drilling of boreholes CD-1 CD-2, CD-3 and CD- 4. The support system used is the RMR system from Bieniawski (1989). The

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RMR system of the bypass tunnel based on boreholes CD-1, CD-2 and CD-3 shows the following RMR rating values:

Table 1. RMR Cipanas dam geological report planning consultant

No	Kriteria	Nilai	Rating
1	Kuat tekan batuan	2,75 Mpa – 5.52 Mpa	1
2	RQD (Rock Quality Designation)	16-25	3
3	Spasing diskontinuitas	200 - 600 mm	10
4	Kondisi bidang diskontinuiti	permukaan rata & licin	13
5	Kondisi Airtanah	basah (Lu=5-10)	10
6	Orientasi dari diskontinuitas	menguntungkan	-5
			32

The rock classification is sandstone, mudstone, breccia and conglomerate with RMR rating = 32, poor rock to good IV (Poor Rock). So it can be concluded that the tunnel area has a poor rock mass class.

c) Geological line mapping based on borlog

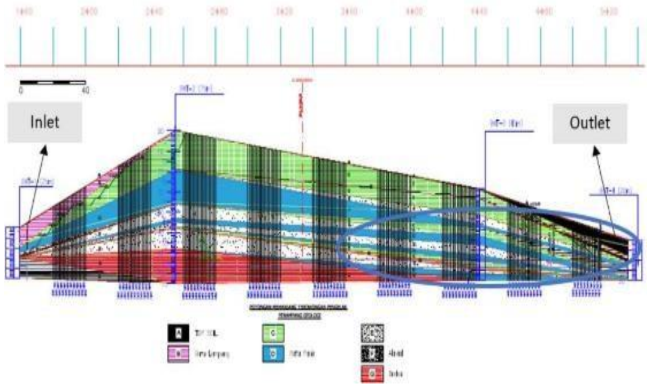

Figure 7. Soil layer mapping using drill logs

Mapping of soil layers with a drill log is used to estimate the position of the soil layer and the type of soil to be excavated by the contractor package 1. From the results of the drill log mapping, it was found that along the diversion tunnel there are estimated to be layers of breccia rock, siltstone, sandstone, and sand when digging the diversion channel data. Based on corebox data, the RQD and UCS in the drill log do not show massive rocks, because they have a quality of 10 - 30% along the excavation area ranging from 3.4 - 23.33 Mpa. It can be concluded that the soil in the dam area is more easily destroyed so that it will be very unstable in terms of the relationship between soil particles. Based on this analysis, it is estimated that the outlet area has poor stability and requires reinforcement (forepoling) between layers in the outlet tunnel section. This geological mapping is used as a basis for calculating plaxis to determine the thickness of the existing soil layer.

d) Pre-construction geological mapping

The pre-construction stage carried out stage 2 investigations by the contractor, during geological mapping using four borlog data, namely from the design of the planning consultant, the results of the drilling log of the supervisory consultant, the results of the drilling log of packages 1 and 2. The results of the drilling log are different from the drilling log from the planning consultant. It was found that in the inlet section of the tunnel it has an RMR value = 19 with a rock classification of class V, which is very weak, while in the middle of the tunnel the RMR value = 41 (class III) weak rock, then at the downstream end or outlet area the RMR value = 32 (class IV) weak rock. The results of this mapping show an interpretation based on rock formations, rock formations at the Cipanas Dam project site include the Citalang formation consisting of tuffaceous sandstone with conglomerate inserts and tuffaceous claystone. As for the Kaliwangu Formation, it consists of alternating sandstone inserts with claystone and conglomerate inserts. The layers along the tunnel are pyroclastic deposits, namely tuffaceous sandstone, breccia, pumice and lava. Based on the RMR value and the ability to excavate, the excavation method used for the tunnel is recommended not to use the blasting system method, and it is recommended to use the excavation method with an excavator or breaker to maintain the condition of the rock in the tunnel with moderate to weak rock conditions and not worsen the condition of the rock.

e) Mapping geological layers during construction

Geological mapping is done again after the main dam excavation work of Cipanas Dam has been carried out and is based on the visual condition of the attitude or condition of the open layer by geology. The condition of the attitude of the soil layer that is visible after the main dam excavation process can be seen in the picture.

Figure 8. main dam soil layer position

The visual geological investigation was conducted by observing the attitude in the right main dam section because the diversion tunnel is under the right main dam layer, so this attitude is considered representative of the condition of the layers in the tunnel. The following are the results of the analysis of the soil attitude on the right abutment.

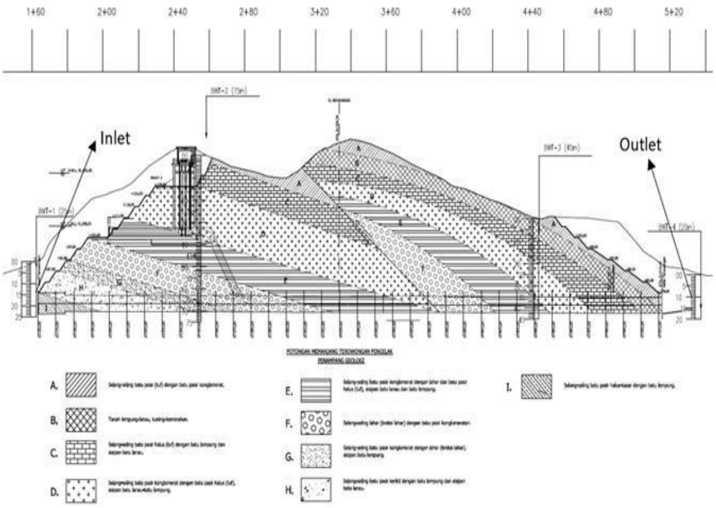

Figure 9. longitudinal section of the right support geological attitude

From the results of geological mapping, the number of layers obtained is more real compared to the planning design using log drilling. The type of rock layers at the location is dominated by fine tuffaceous sandstone, silt clay, conglomerate sandstone, and lava breccia.

f) Rock Mass Ratio (RMR)

Rock Mass Ratio is a method used to determine the rock mass class by using several rock parameters.

1) Unconfined compaction test

Rock strength tests are used to estimate whether the rocks we have have good strength or not. UCS tests are taken using data at depths around the bypass tunnel so that it is expected to be able to present the condition of the rocks around the tunnel in terms of how good the quality is.

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Table 2. UCS of rocks in tunnel excavation area

No	Posisi	Tekanan	Satuan
1	BWT 1	3.465	Mpa
2	BWT 2	21.34	Mpa
3	BWT 3	16,34	Mpa
4	BWT 4	23,45	Mpa

It was found that the score value of the existing rocks was not good based on the assessment of the RMR Bienawski 1989 method, ranging from 1-3.

2) RQD (rock quality designation)

RQD is a condition where the rock taken has integrity how good. The more intact the sample taken, the better the estimate of the rock, but the type of rock also affects the strength of the rock that will be excavated in the tunnel.

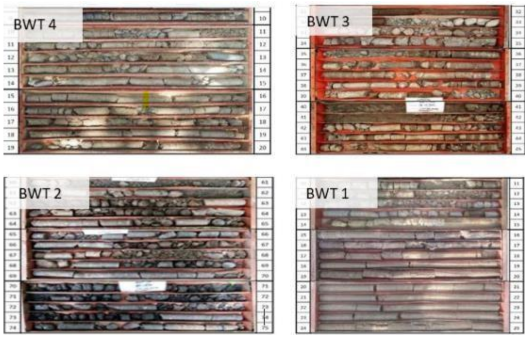

Figure 10. rock quality in the cipanas dam bypass tunnel area

The following is a table of RQD analysis of rocks in the Cipanas Dam

Table 3. ROQ of cipanas dam borloq data

No	Kedalaman	BWT1	Jenis	BWT 2	Jenis	BWT 3	Jenis	BWT 4	Jenis
1	1 - 5m	32%	Lempung	73%	Batu Lanau	53%	Lanau	42%	Pasir
2	6- 10m	31.4%	Lempung	74%	Batu Pasir	28%	Lempung	68%	Lempung
3	11 - 15m	23%	Pasir	65%	Pasir	24%	Lanau	52%	Pasir
4	16 - 20m	45%	Lempung	44%	Pasir	12%	Pasir	47%	Pasir
5	21 - 25m	42%	Lempung	64%	Batu Pasir	37%	Batu Pasir		
6	26 - 30m			36%	Batu Pasir	17%	Lanay		
7	30 - 35m			67%	Batu Pasir	5%	Pasir		
8	36 - 40m			5%	Pasir	41%	Batu Pasir		
9	41 - 45m			21%	Batu Pecahan Pasir	17%	Lanau		
10	46 - 50m			16%	PASIR				
11	51 - 60m			23%	Breksi Berpasir				
12	61 - 70m			32%	Breksi Berpasir				
13	71 - 75m			26%	Breksi Berpasir				

3) RMR calculation

The following Rock Mass Ratio is obtained from the detailed review of the geological mapping results. The following is an example of the calculation of RMR data in the data area of borlog number 4

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RMR factor (Rating)			Batu Pasir halus-lanau silang	Batu Pasir Konglomerat Hitam Putih
1	R1	Kuat Tekan Batuan	4	2
2	R2	RQD	8	3
3	R3	Jarak Rekahan	8	5
4	R4	Kondisi Rekahan	10	0
5	R5	Kondisi Air Tanah	7	7
6	R6	Orientasi Diskontinuitas	-2	-2
		RMR Rating	**39**	**15**
		RMR Range	**21-40**	**<20**
		Kelas Batuan	**IV**	**V**
		Deskripsi	**Lemah**	**Sangat Lemah**
		Jenis Batuan	**Batu Pasir halus-lanau silang siur**	**Batu Pasir kolongmerat hitam putih**
Rekomendasi Perkuatan (*Support*)			1. H-*Beam Support* jarak 0.75m 2. *Shotcrete Safety*	

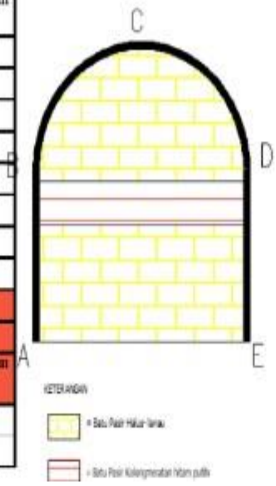

Figure 11. layout of mapping results of rock types at outlet

4) Laboratory test result data

The following are the results of the RMR classification analysis for rock masses in tunnels.

Table 4. RMR classification analysis for rock mass at the inlet of the cipanas dam tunnel (breccia rock)

No.	Parameter	Nilai	Rating
1	Kuat tekan batuan utuh *(Uniaxial Compressive Strength/UCS) (R1)*	10 - 25 MPa	2
2	*Rock Quality Designation (RQD) (R2)*	< 25%	3
3	Jarak antar (spasi) kekar (spacing of discontinuities) (R3)	<6cm atau <60mm	5
4	Kondisi kekar (condition of discontinuities) (R4)	Regangan 1-5mm	10
5	Kondisi air tanah (ground water conditions) (R5)	menetes	4
6	Orientasi kekar (orientation of discontinuities) (R6)	Biasa (sedang)	-5
Total Skor			**19**

Table 5. RMR classification analysis for rock mass in the middle of the Cipanas Dam Tunnel (breccia rock)

No.	Parameter	Nilai	Rating
1	Kuat tekan batuan utuh *(Uniaxial Compressive Strength/UCS) (R1)*	100 - 250 MPa	12
2	*Rock Quality Designation (RQD) (R2)*	75-90%	17
3	Jarak antar (spasi) kekar (spacing of discontinuities) (R3)	20-60 cm.	10
4	Kondisi kekar (condition of discontinuities) (R4)	Permukaan agak kasar <1mm sangat lapuk	20
5	Kondisi air tanah (ground water conditions) (R5)	menetes	4
6	Orientasi kekar (orientation of discontinuities) (R6)	Tidak mrnguntungkan	-10
Total Skor			**53**

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Table 6. RMR classification analysis for rock mass at the outlet of Cipanas Dam Tunnel (breccia rock)

No.	Parameter	Nilai	Rating
1	Kuat tekan batuan utuh *(Uniaxial Compressive Strength/UCS) (R1)*	25 - 50 MPa	4
2	*Rock Quality Designation (RQD) (R2)*	25-50%	8
3	Jarak antar (spasi) kekar (spacing of discontinuities) (R3)	6-20 cm.	8
4	Kondisi kekar (condition of discontinuities) (R4)	Regangan 1-5mm menerus	10
5	Kondisi air tanah (ground water conditions) (R5)	basah	7
6	Orientasi kekar (orientation of discontinuities) (R6)	Biasa (sedang)	-5
Total Skor			**32**

Table 7. Rock Mass Class, Cohesion ad Internal Friction Angle based on RMR value

Profil massa batuan	Deskripsi				
Rating	100 -81	80 - 61	60 - 41	40 – 21	20 – 0
Kelas massa batuan	Sangat Baik (I)	Baik (II)	Sedang (III)	Buruk (IV)	Sangat Buruk (V)
Kohesi (kPa)	> 400	300 – 400	200 – 300	100 – 200	< 100
Sudut geser dalam	> 45°	35° - 45°	25° - 35°	15° - 25°	< 15°

Table 8. Instructions for excavation and support of rock tunnels with RMR system

Kelas massa batuan	Teknik Penggalian	*Rock Bolts* (diameter 20mm, *fully grouted*)	*Shotcrete*	*Steel Sets*
I – Sangat baik RMR 81 – 100	*Full face*, 3 m ke dalam	Umumnya penyangga tidak diwajibkan kecuali ada sedikit *bolting*		
II-Baik RMR 61 – 80.	*Full face*, 1 – 1.5 m ke dalam. Penyangga lengkap 20 m dari muka.	Di tempat itu, *bolt* pada *crown* sepanjang 3 m, jarak 2.5 m dengan *wire mesh*	50 mm pada *crown* di tempat yang diharuskan.	Tidak ada
III – Sedang RMR 41 – 60	*Top heading and bench* 1.5 – 3 m ke dalam. Diperiksa setiap	*Bolt* sistematis sepanjang 4 m dengan jarak 1.5 – 2 m pada	50 – 100 mm pada *crown* dan 30 mm pada sisinya	Tidak ada
	selesai peledakan. Penyangga lengkap 10 m dari muka	*crown* dan dinding dengan *wire mesh* pada *crown*		
IV – Buruk RMR 21 – 40	*Top heading and bench* 1.0 – 1.5 m ke dalam. Pemasangan penyangga bersamaan dengan penggalian, 10 m dari muka	*bolt* sistematis sepanjang 4 – 5 m jarak 1 – 1.5 m pada *crown* dan dinding dengan *wire mesh* pada *crown*	100 – 150 mm pada *crown* dan 100 mm pada sisinya.	Sebaiknya mengguna kan medium ribs jarak 1.5 m di tempat yang diharuskan
V- sangat burukk RMR < 20	*Multiple drifts* 0,5 – 1,5 m ke dalam. Pemasangan pemnyangga bersamaan dengan penggalian. *Shortcrete* setelah peledakan	*Bolt* sistematis sepanjang 5-6 m sepanjanng 1-1,5 m pada *crown* dan dinding dengan *wiremesh* pada *crown*	140 – 200 mm pada *crown*, 150 mm pada sisinya, dan 50 mm di muka.	*Medium* untuk *heavy ribs* jarak 0.75 m dengan *steel lagging* dan *forepoling* jika diharuskan.

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The conclusion of the data explained above, based on the mass weighting proposed by Bieniawski (1984), the Cipanas dam tunnel has each RMR value, namely for Inlet RMR = 19 (grade V) with a stand-up time of approximately 0.5 hours and a span value without supports of 0.75 m. In the middle of the tunnel, the RMR value was 53 (grade III) with a stand-up of 102 hours with a span of 3m without supports, and at the downstream end with an RMR value of 32 (grade IV) has a stand-up time strength of approximately 1-2 hours with a span of 1m without supports.

The strength analysis of the rock mass in the Cipanas Dam tunnel is given based on the Coulomb equation as follows:

Table 9. Properties of rocks around the Cipanas Dam tunnel

SIFAT BATUAN	SIMBOL	INLET	MIDDLE	OUTLET	SATUAN
STA	±	0+161	0+320	0+513	-
Berat isi batuan	γ	2.0	2.75	2.0	gr/cm^3
		0.02	0.0275	0.02	Mn/m^3
Poisson's ratio	V	0.3	0,27	0.3	-
Sudut kuat geser batuan	θ	30	32	25	θ
Koef. Tegangan aktif	K aktif	0.4	0.45	0.50	-
Koef. Tegangan pasif	K pasif	1,5	1.75	2	-
Kuat tekan batuan intact	σ_{ci}	10	12	15	Mpa
Bobot RMR	RMR	19	53	32	-
Bobot GSI (RMR-5)	GSI	14	48	27	-
Rasio Kuat tekan	R atau ρ	1.5	1.8	2.0	*Poor*
Nilai M batuan utuh	m	15	20	25	*Rock type*
Tinggi terowongan	H	10	20	15	M
Lebar terowongan	B	10	12	14	M
Tinggi batuan di atas terowongan	h	10	15	20	M
Kohesi	c	0.2	0.25	0.3	Kg/cm^2
		20	25	30	Mn/m^2

After knowing the RMR along the tunnel, we can find out the pressure on the roof of the support based on the Hoek E. Brown formula.

a. Analysis of Stress Behavior in the Cipanas Dam Tunnel
   i. Finite Element Analysis on Stress Behavior in the Cipanas Dam Tunnel
   ii. Rock Material Properties

Table 10. material property values based on RMR value

No	Parameter	Simbol	Batuan							Satuan
			Top Soil	Batu Lempung	Batu Lanau	Batu Pasir	Pasir	Aluvial	Breksi	
1	Berat isi batuan diatas garis freatik	γ_{unsat}	8	21.6	25.5	22.55	17	25.5	27.5	kN/m3
2	Berat isi batuan dibawah garis freatik	γ_{sat}	11	23.6	28	25	21,5	27	28	kN/m3
3	Permeabilitas arah horizontal	k_x	9.64x10^{-1}	8.64x10^{-6}	8.64x10^{-5}	8.65x10^{-4}	7,64X10^{-1}	9,74X10^{-4}	8,64X10^{-5}	m/hari
4	Permeabilitas arah vertikal	k_y	9.64x10^{-2}	8.64x10^{-6}	7.64x10^{-5}	8.65x10^{-4}	7,64X10^{-2}	9,74X10^{-4}	8,64X10^{-5}	m/hari
5	Modulus Young	E_{ref}	3.5x10^5	1.96x10^7	2.746x10^6	1.96x10^7	1.02x10^4	1,765X10^6	2,943X10^7	kN/m2
6	Angka Poison	υ	0.3	0.3	0.3	0.25	0.3	0.3	0.3	-
7	Kohesi	c_{ref}	35	686,466	735,499	298,54	2	147,1	106.35	kN/m2
8	Sudut Geser	φ	15	27	32	31	29	25	33	°
9	Sudut Dilatansi	Ψ	-	-	-	-	-	-	-	°

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Table 11. steel support technical data

No	Parameter	Simbol		Satuan
1	Momen Inersia	I	4720	cm4
2	Elastisitas	EA	200000	n/mm2
			1270600	kn/m2
3	Elastisitas x Inersia	EI	9440	kN/m4
4	Berat	w	0.49	kN/m

iii. Plaxis Modeling

Review the stability loading of the steel support along the circumvention tunnel using Plaxis 2D 8.6 using technical data from the lab. Field and laboratory data processing is used to determine soil parameters and as reference data. Plaxis mapping took several point samples from along the tunnel because it has a typical cross-section so it is hoped that each sta represents the length of the sta that is expected based on the soil layer map.

iv. Stress Analysis

The results of stress analysis show that the stress distribution in the Cipanas dam tunnel is as follows:

a) Stress analysis in the cipanas dam tunnel sta. 0+180
- Main stress sta 0+180: The main stress in the Cipanas dam tunnel is tensile stress. The maximum tensile stress occurs at the top of the tunnel due to gravity and groundwater loads.
- Shear stress Sta. 0+180: Shear stress in the Cipanas dam tunnel is shear stress that acts on inclined planes. The maximum shear stress occurs at the bottom of the tunnel due to gravity loads.

b) Sress analysis in the cipanas dam tunnel sta. 0+180
- Main stress sta 0+480: The main stress in the Cipanas dam tunnel is tensile stress. The maximum tensile stress occurs at the top of the tunnel due to gravity and groundwater loads
- Shear stress sta 0+480: Shear stress in the Cipanas dam tunnel is a shear stress that acts on inclined planes. The maximum shear stress occurs at the bottom of the tunnel due to gravity loads

c) Deformation analysis
- Axial deformation sta 0+480: Axial deformation in the tunnel. Cipanas dam is deformation that occurs in the direction of the tunnel axis. Maximum axial deformation occurs at the top of the tunnel due to gravity and groundwater loads.
- Lateral deformation 0+480: Lateral deformation in the Cipanas dam tunnel is deformation that occurs in the direction perpendicular to the tunnel axis. Maximum lateral deformation occurs at the bottom of the tunnel due to gravity loads.
- Safety factor Sta. 0+480

Table 12. data from stress analysis and deformation analysis

	STA		
	0+180.76	**0+280.76**	**0+480.76**
Total Stres	$-1.56*10^3 kN/m^2$	$-2.82*10^3 kN/m^2$	$-1.61*10^3 kN/m^2$
Relative Shear Stresses	0.99	0.72	1.00
Deformed Mesh	$34.86*10^{-9}$ m	$613.16*10^{-6}$ m	$2.19*10^6$ m
Scalead Up	$100.00*10^6$	$10.00*10^3$	$2.00*10^{-6}$
Total Displacement	$34.86*10^{-9}$	$613.16*10^{-6}$	$2.19*10^6$
E-Mst	1.00	1.00	1.938.739

b. Circumvention Tunnel Support System

i. General

The tunnel is designed to take advantage of the rock's ability to support its own weight. The temporary support system involves shotcrete, rockbolts, and steel rib.

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ii. Bypass channel design

Circumvention channel design summary

a. Elevation inlet: +71,00 m
b. Elevation outlet: +70,00 m
c. Type: tunnel section combination of semicircular and square, 1 lane, reinforced concrete material
d. Dimensions: 7,5 m (b) x 7,35 m (h)
e. Long: 400 m

iii. Geological Information

Based on studies and investigations, the geology in the circumvention route consists of tuff sandstone. The RMR value at the end of the inlet tunnel is around 19 (Grade V). In the middle of the tunnel, the RMR value = 53 (Grade IV).

iv. Excavation method

Tunnels with tuffaceous sandstone and strongly weathered breccia can be excavated using roadheaders or manual methods. Manual methods require more support and work progress is slower. For class III rocks, excavation can be carried out using the blasting method.

5) Tunnel Geology

Temporary estimates of the geological condition of the circumvention tunnel vary, from Fair rock (Class III) to Poor rock (Class IV). In the U/S portal area, geological conditions include Very Poor Rock (Class V).

Table 13. Geomechanics classification

Class	Description	RMR Range
I	Very Good Rock	81-100
II	Good Rock	61-80
III	Fair Rock	41-60
IV	Poor Rock	21-40
V	Very Poor Rock	0-20

The relationship between the stand-up time of unsupported span tunnel excavation and geomechanics classification, for class III rocks (Fair Rock) the stand-up time is around 100 hours, and for class V rocks (poor rock) the stand-up time is around 1 hour.

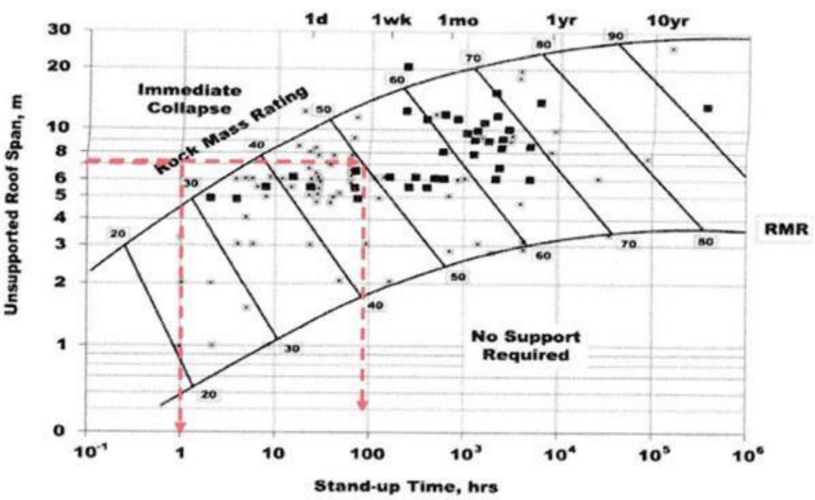

Figure 12. graph of the relationship between RMR and stand up time

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Based on the relationship graph, the recommended strengthening system is systematic bolting with shotcrete. Reinforcement involves systematically installing rock bolts 3 meters long and 1-1.2 meters apart. Shotcrete is used with thicknesses varying between 90-240 millimeters for roofs and 80-140 millimeters for walls. The plan design is the best choice because it has the lowest roof displacement compared to strengthening methods based on the RMR and Q system classifications.

6) Planning for Temporary Tunnel Support Systems

Temporary Supports are designed to prevent collapse and provide fast, strong and well-adhered load support. Installation of supports must be carried out within stand-up time to avoid significant rock mass movement. After the tunnel excavation is completed in one stage, the next steps are: First Shotcrete, Installation of rockbolts, Installation of Steel ribs. The following table shows the general relationship between geomechanical classification and support type:

Table 14. geomechanics classification for excavation and support rock tunnels

Rock mass class	Excavation	Rock bolts (20 mm diameter, fully grouted)	Shotcrete	Steel sets
I - Very good rock *RMR*: 81-100	Full face, 3 m advance.	Generally no support required except spot bolting.		
II - Good rock *RMR*: 61-80	Full face , 1-1.5 m advance. Complete support 20 m from face.	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh.	50 mm in crown where required.	None.
III - Fair rock *RMR*: 41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face.	Systematic bolts 4 m long, spaced 1.5 - 2 m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None.
IV - Poor rock *RMR*: 21-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face.	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wire mesh.	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V – Very poor rock *RMR*: < 20	Multiple drifts 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

7) Planning Conditions

a. Inner diameter (D) = 5.00 m
b. Lining thrickness = 1.00 m
c. Steel allowable stress (σs) = 4.100,00 kg/cm2 (Bj 55)
d. Steel modulus of elasticity = 2.10 x 10^6 kg/cm^2
e. Rock density = 2.00 t/m^3
f. Buffer = H-Beam 200 x 200 x 8 x12 Table 17 voltage calculation

8) Cipanas Dam Avoidance Tunnel Work Method

i. Methode NATM (New Austrian Tunneling Method)

Tunnel excavation method that replaces the excavated soil with supports, especially using steel supports. Geological mapping (mapping) is carried out to determine the geological conditions of the tunnel and the type of rock that will be used as support. If the rock conditions are weak, the recommendation is to do safety shotcrete before installing steel sibs. The output of geological mapping is RMR (rock mass rating) data, which takes into account discontinuity spacing and the condition of joints or mineral structures in rocks. The work steps start from Mapping, Marking, Excavation- scaling and safety shotcrete.

ii. Forepoling

The method used to protect and strengthen the tunnel so that it does not experience landslides again during excavation. This method is generally applied in areas that are prone to landslides. Mapping and marking are carried out before excavation.

a. Drilling Forepoling is carried out based on mapping and recommendations from geologists. The

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drilling machine is used with an inclination of 25 degrees to the horizontal axis. Placed in the soil layer to be excavated because this layer tends to be weak and often experiences landslides. The number of points is usually around 18 points per job.

b. Forepoling has 6 meters with an inclination angle of 25 degrees to the horizontal axis. After drilling, the perforated pipe was installed, and 6 meters of iron reinforcement was inserted. Next, the gap is filled with a cement mixture to strengthen the rock layers and bind the iron reinforcement. This process prepares the soil structure before further excavation is carried out.

9) Conclusion

Based on the data analysis that has been carried out, it can be concluded that

a. The main stress in the Cipanas dam tunnel is tensile stress. The maximum tensile stress occurs at the top of the tunnel due to gravity and groundwater loads. Shear stress in the Cipanas dam tunnel, stress that acts on inclined planes. The maximum shear stress occurs at the bottom of the tunnel due to gravity loads.
b. Axial deformation occurs in the direction of the tunnel axis. Maximum axial deformation occurs at the top of the tunnel due to gravity and groundwater loads. Lateral deformation occurs in the direction perpendicular to the tunnel axis. Maximum lateral deformation occurs at the bottom of the tunnel due to gravity loads
c. Stress and deformation analysis results:

Table 16. data from stress analysis and deformation analysis

	STA		
	0+180.76	**0+280.76**	**0+480.76**
Total Stres	- $1.56*10^3 kN/m^2$	- $2.82*10^3 kN/m^2$	- $1.61*10^3 kN/m^2$
Relative Shear Stresses	0.99	0.72	1.00
Deformed Mesh	$34.86*10^{-9}$ m	$613.16*10^{-6}$ m	$2.19*10^6$ m
Scalead Up	$100.00*10^6$	$10.00*10^3$	$2.00*10^{-6}$
Total Displacement	$34.86*10^{-9}$	$613.16*10^{-6}$	$2.19*10^6$
E-Mst	1.00	1.00	1.938.739

d. In the research area, the tunnel support reinforcement system is categorized as systematic bolting with Shotcrete. Reinforcement involves systematically installing rock bolts 3 meters long and 1 – 1,2 meters apart. In addition, shotcrete is applied with thicknesses varying between 90 to 240 millimeters on the roof and 80 to 140 millimeters on the walls. The strength factor value describes the ratio between the available rock mass strength and the stress induced at a point in the model. if the strength factor < 1, the material is in the overstress zone and requires a support system. Material failure zones indicate the potential for collapse of the tunnel roof or walls, as well as possible cracks or spalling in the material.

REFERENCES

[1] Carlina, Soetjiono. 2010. "*Gagasan Revitalisasi Bendungan urugan Dalam Mendukung Pengelolaan Sumber Daya Air" Jurnal Sumber Daya Air. Bandung.*

[2] Das, Braja, M. "*Mekanika Tanah (Prinsip-Prinsip Rekayasa Geoteknis)*" Erlangga. Jilid 1. Jakarta.

[3] Departemen Pekerjaan Umum. 1987. "*Petunjuk Pengukuran Peta Topografi Dengan*

P-ISSN : 2598-1277
E-ISSN : 2621-3966

Theodolite Modern" Yayasan Badan Penerbit PU. Jakarta.

[4] Balasubramanian. 2017. "*Studi Karakteristik Deformasi Terowongan*". Universitas Katolik Parahyangan. Bandung.

[5] Hardiman, Iman. 2007. "*Analisis Sistem Perkuatan Pada Desain Terowongan Piyungan-Gading*". Tesis Fakultas Teknik Sipil dan Lingkungan Institut Teknologi Bandung, Bandung.

[6] Hatmoko, 2017. "*Stabilitas Terowongan dengan Perkuatan Wiremesh dan rock bolt menggunakan metode elemen hingga pada proyek Pembangunan Jalur Ganda Kereta Api Notog"*. Purwokerto.

[7] Inti Mulya, Multikencana. 1997. "P*erencanaan Detail Waduk Lapangan Cikurantung, Cianjur, dan Cipaseh PWS, Ciujung-Ciliman"* Dirjen Pengairan. Jakarta.

[8] Iswanto, Almaretha, Mevia, Azizah, Putri. 2022. "*pemodelan Rembesan Pada Bendungan Urugan Dengan Berbagai Karakteristik Tanah Dasar"* Masters Thesis. Institut Teknologi Sepuluh Nopember. Surabaya.

[9] Merdalis. 1995. *"Metode Penelitian: Suatu Pendekatan Proposal"* Bumi Aksara. Jakarta.

[10] Sugiyono. 2016. "*Metode Penelitian Kuantitatif, Kualitatif dan R&D"* PT. Alfabet. Bandung.

[11] *Supranto, J. 2000*. "Teknik Sampling untuk Survei dan Eksperimen" Penerbit PT Rineka Cipta. Jakarta.

[12] Wally, Junaida. 2014. *"Pemodelan Terowongan pada Batuan dengan Metode Finite Element"*. Fakultas Teknik Universitas Komputer Indonesia, Bandung.

[13] Yatim, Riyanto. 2010. *"Metodologi Penelitian Pendidikan"* Penerbit SIC. Surabaya.

[14] Yulianto, Alfredo Joseph. 2016. *"Studi Perilaku Terowongan Bor di Bawah Pondasi Tiang Rakit Menggunakan Plaxis 8.6"*. Yogyakarta