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Engineering Geology of Diversion Tunnel Area at the Meninting Dam Construction, West Lombok, Province of West Nusa Tenggara, Indonesia

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ABSTRACT. Meninting Dam is constructed to resolve the water needs in Meninting Watershed, West Lombok, Province of West Nusa Tenggara, Indonesia. Therefore, creating a diversion tunnel is imperative to divert the river flow as the dam project commences. Also, engineering geology work on the soil and rocks, including the classification of physical and mechanical properties, was conducted in the intended tunnel site. These considerations were necessary because of the unavailability of rock identification data using the GSI (Geological Strength Index) method to design the portal slopes as a significant factor in tunnel safety. The results show the proposed diversion tunnel construction area is in the lithology of the polymict breccia and the lapilli tuff units, and the soil conditions were included in the SM category (silty sand). The level of surface rock weathering was divided into 3 units, including highly weathered residual soil tuff, highly and moderately weathered polymict breccias. Meanwhile, 4 units were identified on the rock cores (subsurface) comprising highly weathered residual soil of lapilli tuff and highly, moderately, and slightly weathered polymict breccias. Based on the GSI (Geological Strength Index) of rock and surface data from the area of study, the rock quality was grouped as poor (GSI values: 21–40) to very poor (GSI values: 0–20). However, drilling data classified the mass quality subsurface rocks as fair (GSI values 41–55), poor (GSI values: 21–40), particularly in tunnels, and very poor (GSI values 0–20). Therefore, the rock mass quality is possibly used to design the slope of the tunnel portal as 45–55° to ensure safety.

Keywords: Meninting Dam · Lithology · Soil classification · Rock mass quality · GSI · Tunnel portal slope.

1 INTRODUCTION

The availability of water on the island of Lombok is not distributed well. The western part of the island of Lombok, including the watershed (Meninting Watershed), has the potential for relatively sufficient water to meet water needs in its region. On the other hand, the southern part of Lombok Island has a large enough potential area, but water availability is very limited. Therefore, the construction work of the Meninting Dam needs to be carried out so that the potential water can be well distributed to meet agricultural needs on the island of Lombok (Anonymous, 2014).

The dam's construction is supported by constructing a diversion tunnel to divert the river's flow during construction. A diversion tunnel construction requires special attention because it is an underground construction that must be planned carefully and consider many factors. One of the factors being considered in tunnel work is engineering geology at the tunnel site.

Research related to regional geology and engineering geology has been carried out by several researchers, such as; Mangga *et al.* (1994), who produced the Geological Map of the Island

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of Lombok, Nusa Tenggara; Anonymous (2013) in the Meninting Dam Feasibility Study who shows a general description of the location of work, and Anonymous (2014) in the Detail Design of the Meninting Dam in West Lombok Regency who displays an engineering geology investigation as a basis for the technical planning of the dam. The geological investigation that PT. Indra Karya (Persero) has carried out, is a geological mapping on the axes and inundation areas, core drilling, test wells, undisturbed sampling, permeability testing, laboratory testing, and determination of rock mass rating qualifications with Rock Mass Rating (RMR). However, detailed engineering geology research has not been conducted in the planned construction of the Meninting Dam diversion tunnel. This study will identify and assess rock mass quality using the Geological Strength Index (GSI).

The study area is in the Meninting Dam's planned area, West Lombok, West Nusa Tenggara. The research location is focused on the planned route of the diversion tunnel. This tunnel will be applied to drain the Meninting River during the dam's construction. The coordinates of the location of the tunnel are 8°31′11″ LS and 116°9′10″ LE, which is about 15 km from the city of Mataram, to the north towards Bukit Tinggi Village, Lingsar District. The research location can be seen in Figure Figure 1.

2 REGIONAL GEOLOGY

Physiographically, Lombok Island is part of the Lesser Sunda Islands' inner arc, known as the Nusa Tenggara Islands (van Bemmelen, 1949). Therefore, the physiography of Lombok Island is strongly influenced by old and young volcanisms. Based on these conditions, van Bemmelen (1949) divides the physiography of Lombok Island into two parts, namely the northern part, a group of young volcanic products, and the southern part, a group of old rock products and partly covered by alluvial deposits. Referring to the physiographic division, the studied area is included in the northern physiography composed of young volcanic products.

The western regional geological map of the Lombok Island sheet (Mangga *et al.*, 1994) in Figure Figure 2 shows the oldest formation to the youngest formation of the area, namely the Kawangan Formation, the Rolling Mill, the Breakthrough Rocks, the Kalipalung Formation, Kalibabak Formation, Lekopiko Formation, Inseparable Volcanic Rocks and Alluvium. Referring to the regional geological map, the study area is in the Lekopiko Formation (Qvl), characterized by pumice tuff, lava breccias, and lava.

3 METHODOLOGY

Primary data of this study were collected from surface geological data of 41 observation points, surface Geological Strenght Index (GSI) measurements of the observation points, and subsurface GSI measurements (on the core drill of 5 drill points), 7 points surface rock sampling and 3 points of subsurface rock sampling, 4 points of the disturbed and undisturbed soil sample. Meanwhile, the core drill observations and subsurface rock laboratory results were collected as secondary data.

The soil and rock index property tests were conducted following the Indonesian National Standard (SNI Standard Nasional Indonesia) and the American Society for Testing and Materials (ASTM). The Direct Shear test was carried out on undisturbed soil samples by SNI. The Point Load test on surface and subsurface rock samples corresponded to the SNI, ASTM, and UCS (Uniaxial Compression Strength) test of core drill samples was under SNI dan ASTM.

The classification of soil type is based on the Unified Soil Classification System (USCS), while determining the classification of rock mass quality by the GSI (Geological Strength Index) surface method was based on Marinos and Hoek (2000) and subsurface GSI based on Hoek *et al.* (2013) by using RQD (Rock Quality Designation) and joint condition parameters. The rock engineering characteristics and surface rock mass quality are used to create engineering geology maps.

The rock bearing capacity at the diversion tunnel can be determined using the RMR (Rock Mass Rating) classification using Table 1, which is the design parameters and rock mass engineering properties according to Bieniawski (1993) in Singh and Goel (2011). According to Hoek and Brown (1997), GSI values can be converted to RMR provided that they cannot be used on rocks of very poor quality (GSI <25) using Equation 1.

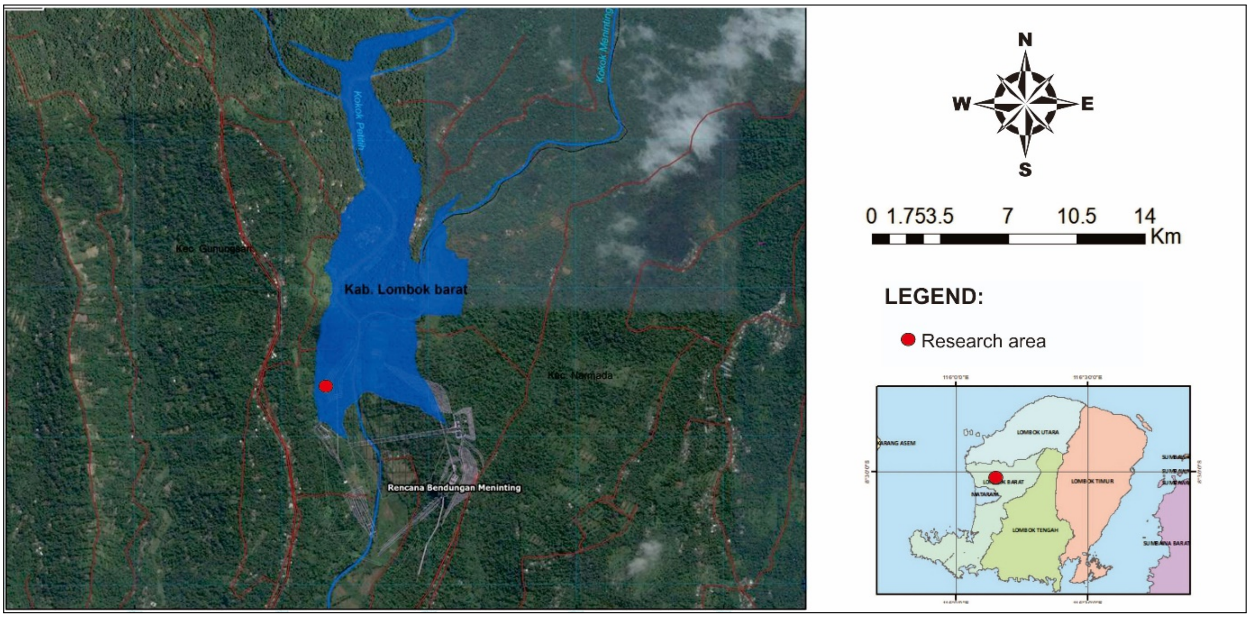


FIGURE 1. The research site is located in the Meninting Dam Construction Plan area (Anonymous, 2016).

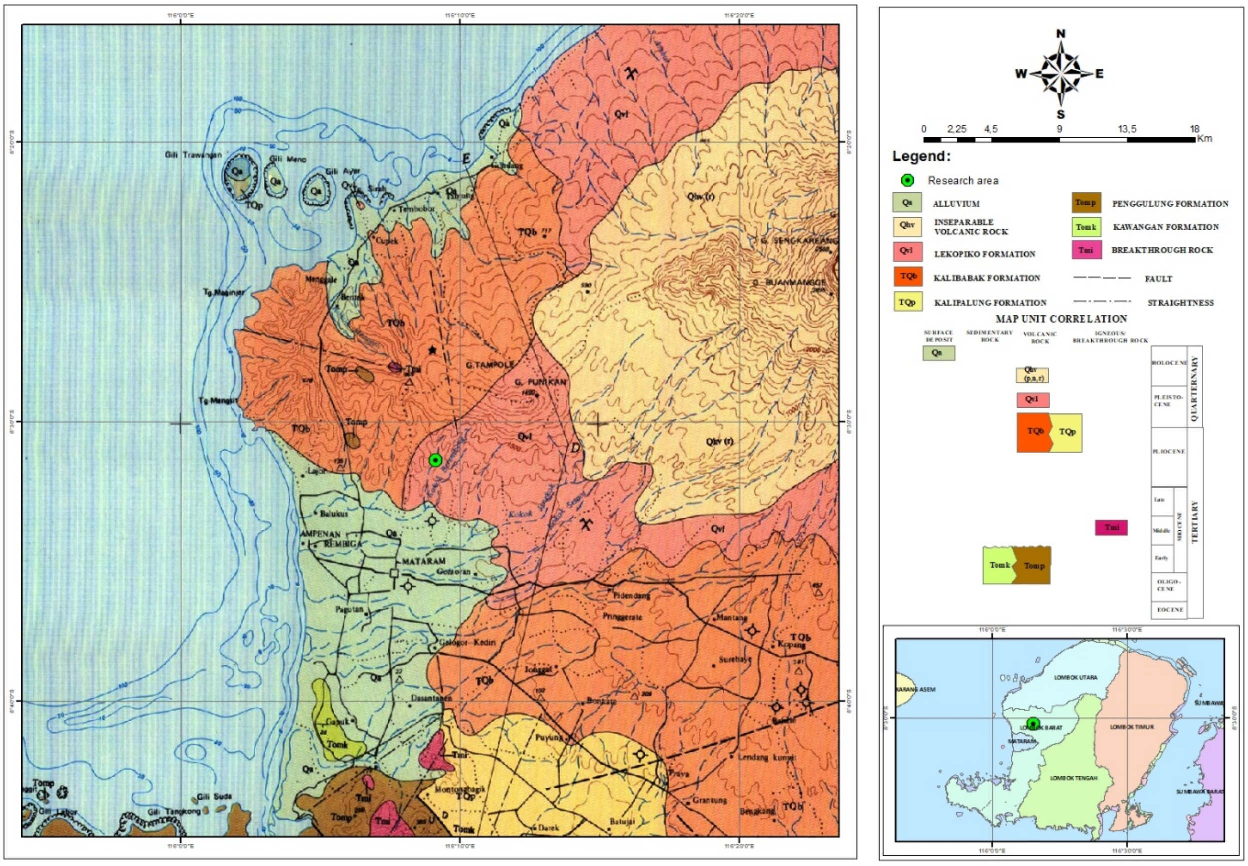


FIGURE 2. Regional Geological Map of the western part of Lombok Island (Mangga *et al.*, 1994) and the location of the studied area.

$$GSI = RMR_{89} - 5 \quad (1)$$

4 RESULTS

4.1 Lithological Conditions

The lithology that compiles the research area at the planned construction site of the diversion tunnel at the Meninting Dam construction, which is from the older to the younger, is the polymict breccia unit and the lapilli tuff unit (Figure 3).

a. Polymict breccia unit. Polymict breccia units are exposed on hillsides and along river streams in the studied area. This unit is on the bottom of a tuff lapilli unit (Figure 4a). Field identification of the polymict breccia unit shows a grayish-brown color in moderately weathered conditions to brown color for highly weathered (Figure 4b-c). The matrix of this lithology ranges from clay to sand, and the structural lithology is massive. The rock texture is poorly sortation, matrix-supported, with subrounded-angular grains. Polymict breccia fragments consisted of andesite and pumice, and the drilling data shows wood fragments (Figure 4e). Polymict breccia matrix is composed of various materials, *i.e.*, plagioclase, opaque minerals, and lithic. Petrographic observations on the polymict breccia matrix of the subsurface rock sample showed that the constituent material was still relatively fresh (Figure 5a-c).

In contrast, the matrix of the surface rock sample the matrix was dominated by weathered materials (Figure 5d-f). Stratigraphically, the polymict breccia unit is on the bottom of the tuff lapilli unit (Figure 4a), so it can be interpreted that the polymict breccia unit is a relatively older rock unit compared to the tuff lapilli unit. The polymict breccia unit has similar characteristics to the Lekopilo Formation, a unit composed of breccia lithology with fragments of andesite, so this unit can be compared to the Lekopiko Formation (Qvl), which is in Quaternary age.

b. Lapilli tuff unit. Outcrops of lapilli tuff units show this unit is on the top of the polymict breccia unit (Figure 4a). The lapilli tuff unit has a fairly wide area of about 65% of the studied area (Figure 3) and occupies the ridges of the hill. Field identification of the lapilli tuff unit shows brownish white (Figure 4d), with an outcrop thickness, between 0.3 m – 2 m. This unit has not been well consolidated, making it less compact (loose) and easy to pass through water. The lapilli tuff is characterized by a fragment grain size of 1 mm – 5 cm and a matrix grain size of sand, with rock texture is poorly sortation, matrix-supported, and subrounded-angular grains. The pumice fragments dominated the lapilli tuff, and the matrix is composed of various materials, *i.e.*, plagioclase, pumice, lithic, and opaque mineral (Figure 5g-i). The naming of this lithology refers to the classification proposed by Fisher (1966). As outcrop data on the field shows that the lapilli tuff unit is on the top of the polymict breccia unit, it can be interpreted that the lapilli tuff unit is relatively younger than the polymict breccia unit. Based on the similar characteristics of lapilli tuff to the Lekopilo Formation, a unit composed of rocky tuff, this unit can be compared to the Lekopiko Formation (Qvl), which is in the Quaternary age.

4.2 Soil Classification

Soil classification is obtained from soil sample identification and classified using the Unified Soil classification system (ASTM, 2000). Based on this classification, soil samples from the study area can be categorized as SM (silty sand). The characteristics of silty sand (SM) are coarse graded soil (passed sieve of 200 is <50 %), with sand (fraction passed sieve of >4 is >50 %), dirty sand (soil passed sieve of >200 is >5 %) and gravel is <5% (Tabel 2).

4.3 Classification of Rock Mass Quality

4.3.1 Rock weathering level

Qualitative assessment of the rock weathering level on surface outcrops at the site of the diversion tunnel construction plan of Meninting Dam construction based on the classification of rock mechanics (ISRM – International Society for Rock Mechanics, 1978) can be grouped into 3 rock units: lapilli tuff – residual soil, highly weathered polymict breccia and moderately weathered polymict breccia units (Figure 6). On the other hand, the classification of the subsur-

TABLE 1. Design parameters and properties of rock mass engineering (Bienawski, 1993 in Singh and Goel, 2011).

No.	Parameter/Properties of rock mass	Rock Mass Rating (Rock Class)				
		100-81 (I)	80-61 (II)	60-41 (III)	40-21 (IV)	<20 (V)
1	Classification of rock mass	Very good	Good	Fair	Poor	Very Poor
2	Average stand up	20 years for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hours for 2.5 m span	30 minutes for 1 m span
3	Cohesion of rock mass (MPa)	<0.4	0.3–0.4	0.2–0.3	0.1–0.2	<0.1
4	Angle of internal friction of rock mass (°)	>45	35–45	25–35	15–25	<15
5	Allowable bearing pressure (T/m^2)	600–440	440–280	280–135	135–45	45–30
6	Safe cut slope (°)	>70	65	55	45	<40

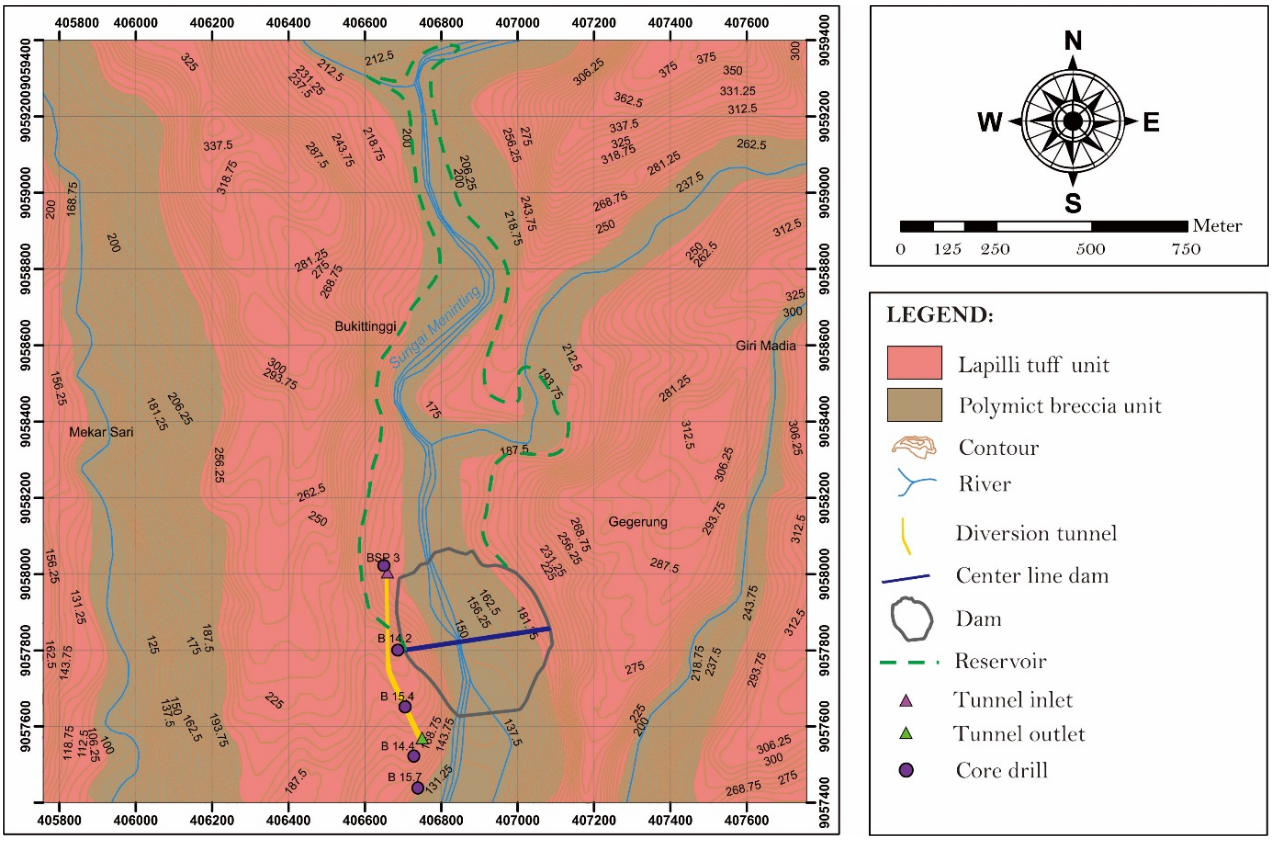
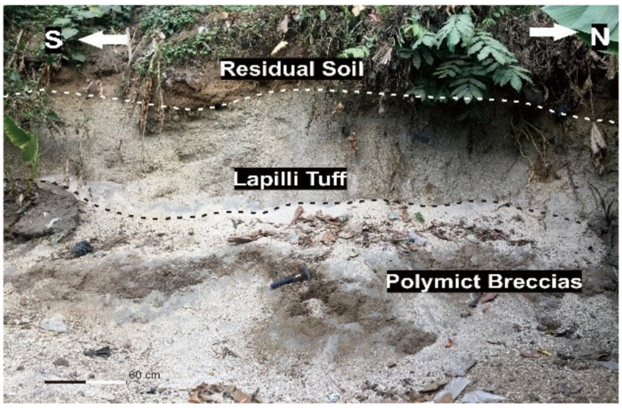


FIGURE 3. Geological map of the studied area.



(a) STA 12

(b) STA18

(c) STA 40

(d) STA 04

(e) Core drill

(f) Core drill sample

FIGURE 4. Outcrop and rock appearances of the studied area (a) Lapilli tuff is on the top and contact with highly weathered polymict breccias at observation station 12; (b) and (c) Moderately weathered polymict breccias at observation stations 18 and 40, respectively; (d) Highly weathered lapilli tuff was observed at station number 4; (e). Core drill appearances; (f) Core drill sample with wood chips.

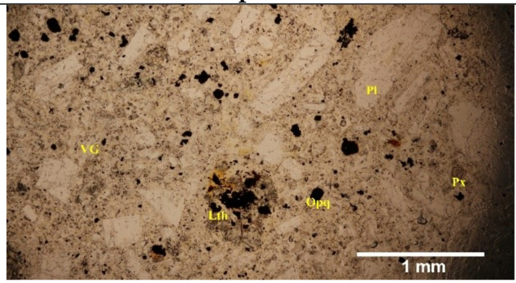
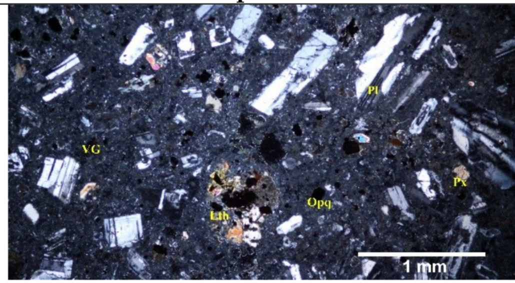
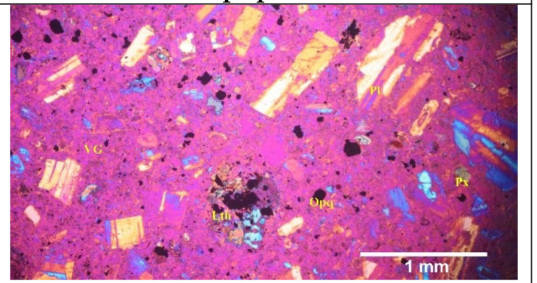
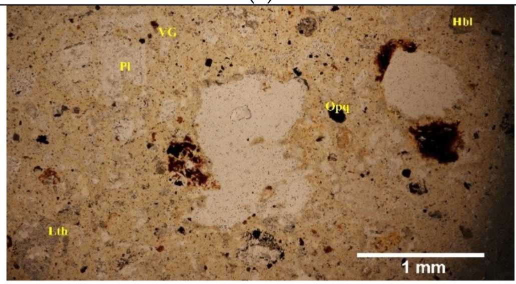
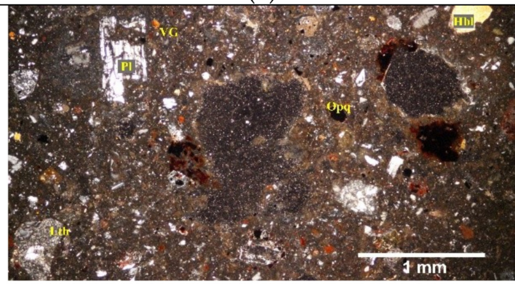
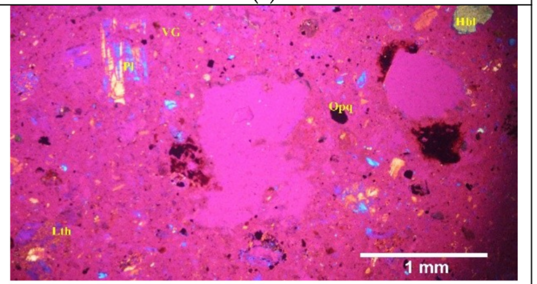
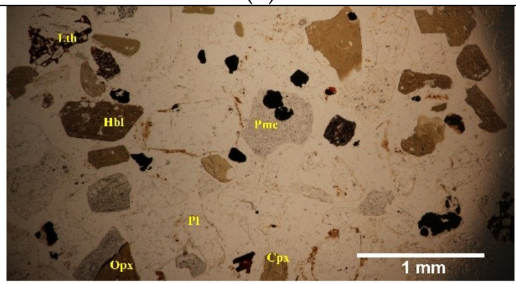
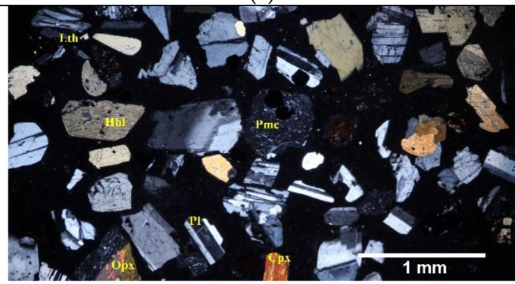
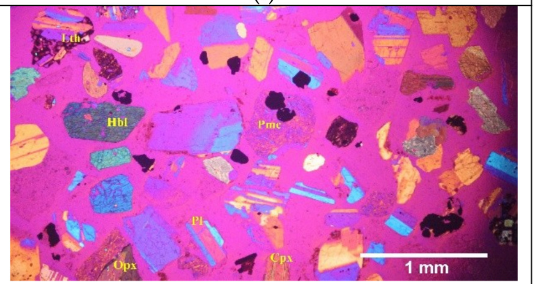
No.	Rock Unit	Type of observation		
		Parallel polarisation	Crossed polarisastion	Gips plaster
1.	Polymict breccia (subsurfac e rock)	 (a)	 (b)	 (c)
2.	Polymict breccia (surface rock)	 (d)	 (e)	 (f)
3.	Lapilli tuff	 (g)	 (h)	 (i)

FIGURE 5. (a), (b), (c) Matrix photomicrograph of the polymict breccia of sample B 14.2 Box 4 depth 19-20 m of subsurface rock in the parallel polarisation appearance, crossed polarisation and gips plaster, respectively; (d), (e), (f) Photomicrographs on the polymict breccia matrix of SY 16 surface rock samples in the parallel polarisation appearance, crossed polarisation and gips plaster, respectively; (g), (h), (i) Photographic matrix lapillary tuff sample SY 04-2 surface rocks in the parallel polarisation appearance, crossed polarisation and gips plaster, respectively. Note: plagioclase (Pl), pumice (Pmc), lithic (Lth), volcanic glass (VG), opaque mineral (Opq), hornblende (Hbl), clinopyroxene (Cpx), and orthopyroxene (Opx).

face rocks on core drill samples can be grouped into 4 rock units: lapilli tuff - residual soil, highly weathered polymict breccia, moderately weathered polymict breccia and slightly weathered polymict breccia units. The characteristics of these rock units are summarized in Table 2 and can be explained as follows:

a. Lapilli tuff – residual soil unit
Outcrops of lapilli tuff are characterized by white-gray to brownish-yellow rocks due to a mixture of residual soil (Figure 4d). The thickness of the lithology layer is from 0.3 to 2.0 meters, with subrounded-sub angular grains, matrix-supported, and porosity type of interparticle. The intact rock strength of lapilli tuff is <1 MPa with a GSI value of 0–7. Lapilli tuff index is water content (w) of 0.2–20.2 %, dry density (ρd) of 0.7 g/cm^3, specific gravity (Sg) of 2.44–2.57 g/cm^3, pore ratio (e) of 2.74–3.67, porosity (n) of 73.26–78.60 and saturation (S) of 0.22–14.59 %. Meanwhile, the residual soil is characterized by water content (w) of 4–30.6 %, dry density (ρd) of 1.0–1.6 g/cm^3, specific gravity (Sg) of 2.27–2.62 g/cm^3, pore ratio (e) of 1.12–1.81, saturation degree (S) of 7.58–62.09 %, liquid limit (LL) of 23.37–33.87 %, plastic limit (PL) of 20.83–30.0 %, grain size distribution of 1.36–88.22 % coarse (gravel 0.67–2.07 % and sand 79.51–86.61 %), 11.78–18.64 % fair (silt 9.88–15.93 % and clay 1.66–4.41 %), named as silty sand and symbolized as SM (ASTM, 2000).

b. Highly weathered polymict breccia unit
Outcrops contact of polymict breccia unit and the lapilli tuff unit can be seen in Figure 4a. The polymict breccia unit is characterized by brown color, fragment grain size of 0.01–2 m, and matrix grain size of <0.04 mm, with structural rocks massive. Textural rock is poorly sortation, matrix-supported grain shape of subrounded-angular, and porosity type of interparticle. Rock fragments (60%) are composed of andesite and tuff, and matrix (40%) is composed of sandy material. The intact rock strength of the high weathered polymict breccia unit is 1.93–5.56 MPa with a GSI value of 15–24. The nature of this lithology index is water content (w) of 8.8–17.7 %, dry density (ρd) of 1.0 g/cm^3, specific gravity (Sg) of 2.52–2.54 g/cm^3, pore ratio (e) of 1.72–2.1, and porosity (n) of 63.20–67.72.

c. Moderately weathered polymict breccia unit
Weathered polymict breccia moderately unit (Figures 4b and 4c) is characterized by brown color, the fragment grain size of 0.01–2 m, and matrix grain size of <0.04 mm, with structural rocks of massive. Textural rock is poorly sortation, matrix-supported, grain shape of subrounded-angular, and porosity interparticle. The intact rock strength of the moderately weathered polymict breccia unit is 15.15–16.69 MPa, with a GSI value of 20–56. The nature of this lithology index is water content (w) of 2.17–18.8 %, dry density (ρd) of 1.1–2.8 g/cm^3, specific gravity (Sg) of 2.31–2.62 g/cm^3, pore ratio (e) of 1.07–1.96, and porosity (n) of 51.62–66.16.

d. Slightly weathered polymict breccia unit
A slightly weathered polymict breccia unit was identified from a core drill of B 15.4 with a depth of 70–75m (Figure 4e) which is characterized by grayish-brown color, fragment grain size of 0.01–0.04 m, matrix grain size of <0.04 mm, with structural rocks of massive. Textural rock is poorly sortation, matrix-supported, grain shape of subrounded-angular, and porosity types of interparticle and fracture. Rock fragments (60 %) are composed of andesite and tuff, and matrix (40 %) is composed of sandy material. The intact rock strength of the low weathered polymict breccia unit is 35.35 MPa, and the GSI value is 37.50–57. The nature of this lithology index is water content (w) of 3.89 %, dry density (ρd) of 2.02 g/cm^3, specific gravity (Sg) of 2.95 g/cm^3, pore ratio (e) of 30.57, and porosity (n) of 0.44.

4.3.2 *Geological Strength Index (GSI) of surface rocks*

Geological Strength Index (GSI) assessment of surface rocks was obtained from direct observation of rock outcrops in the field by referring to the GSI Table according to Marinos and Hoek

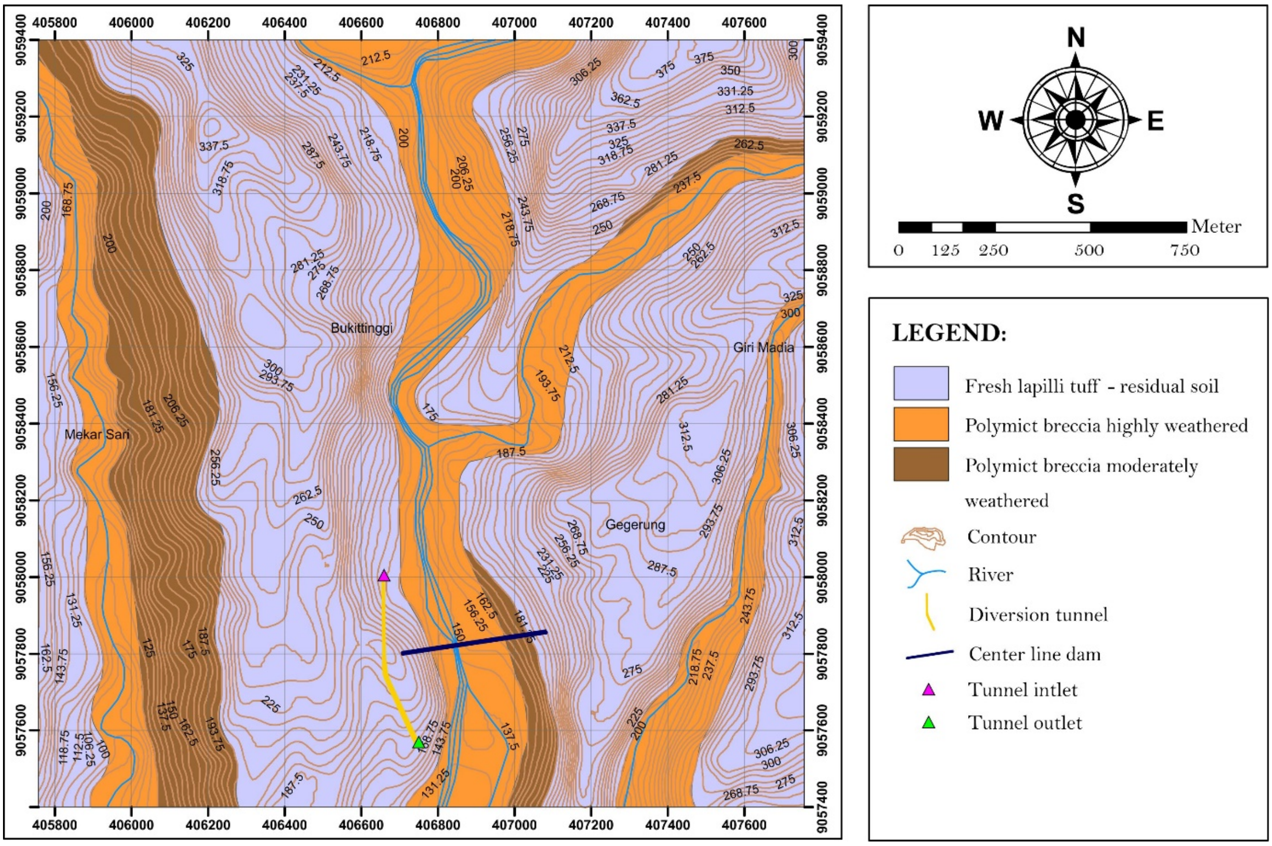


FIGURE 6. Map of surface rock weathering level in the studied area.

TABLE 2. Summary of identification and measurement results of rock mechanics on rock units in the studied area.

No.	Technic parameters	Unit				
		Lapilli tuff		Polymict breccia		
		Lapilli tuff–residual soil		Highly weathered	Moderately weathered	Slightly weathered
		Lapilli tuff	Residual soil			
1	Intact rock strength	<1 MPa		1.93–5.56 MPa	15.15–16.69 MPa	35.35 MPa
2	GSI value	0–7		15–24	20–56	37.50–57
3	Water content (w)	0.2–20.2%	4–30.6 %	8.8–17.7 %	2.17–18.8%	3.89%
4	Dry density (ρd)	0.7 g/cm^3	1.0–1.6 g/cm^3	1.0 g/cm^3	1.1–2.8 g/cm^3	2.02 g/cm^3
5	Specific gravity (Sg)	2.44–2.57 g/cm^3	2.27–2.62 g/cm^3	2.52–2.54 g/cm^3	2.31–2.62 g/cm^3	2.95 g/cm^3
6	Pore ratio (e)	2.74–3.67	1.12–1.81	1.72–2.1	1.07–1.96	30.57
7	Porosity (n)	73.26–78.60		63.20–67.72	51.62–66.16	0.44
8	Saturation degree (S)		7.58–62.09 %			
9	Liquid limit (LL)		23.37–33.87%			
10	Plastic limit (PL)		20.83–30.00%			
11	Grain distribution of coarse		1.36–88.22%			
12	Grain distribution of fine		11.78–18.64%			
13	Group name (ASTM, 2000)		SM (silty sand)			

(2000). GSI values are obtained from surface rock condition assessment based on weathering of intact rock (ISRM, 1978) and whole structural rock. GSI surface rock assessment was carried out at 41 observation stations. GSI values of surface rock of lapilli tuff and polymict breccia units are 0–15 and 10–35 (Table 3). Referring to the GSI classification of Sivakugan *et al.* (2013), surface rock mass quality is divided into 2 (two) classes: very poor rocks quality (GSI value of 0–20) and poor rocks quality (GSI value of 21–40). Surface rock in the study area is dominated by very poor rock (Figure 7).

4.3.3 *Geological Strength Index (GSI) of subsurface rocks*

The Geological Strength Index (GSI) of subsurface rocks was assessed on the drill core from the site of the diversion tunnel of the Meninting Dam construction. The assessment is based on Hoek *et al.* (2013) by calculating RQD (Rock Quality Designation) and joint condition (Bieniawski, 1989) per 1 meter. Core drill observation result shows that GSI values of subsurface rock of lapilli tuff and polymict breccia are 0–7 and 15–55, respectively (Table 3). RMR (Rock Mass Rating) value of the subsurface rock was obtained from a calculation using Formula (1), where the GSI value of >25 for the polymict breccia moderately weathered and slightly weathered can be converted to an RMR value of 30–59. The subsurface rock can be classified into 3 classes of rock mass (GSI classification) which are very poor rock quality (GSI value of 0–20), poor rock quality (GSI value of 21–40), and fair rocks quality with GSI value of 41–55. The quality condition of rock mass on the tunnel portal is drawn in Figure 8. The figure shows that the tunnel inlet consists of poor rock and fair rock identified from core drill B 14.2 and has a GSI value of 28–50 or equal to RMR value 33–55. While tunnel outlet consists of poor rock, which was identified from core drill B 15.4 and has a GSI value of 26 or equal to RMR value 31.

5 DISCUSSION

Based on the results of the geological mapping work, it can be seen that the lithology of the studied area is a polymict breccia unit exposed on hillsides and along river streams and lapilli tuff unit that extend almost across the surface of the studied area. A comparison of the polymict breccia and the lapilli tuff units and the characteristics of the Lekopiko Formation (Mangga *et al.*, 1994) show a similarity between the lithology units composed of pumice tuff, lava breccia, and lava. Therefore, the lithology units of the studied area can be correlated to the Lekopiko Formation (Qvl), which is in the Quaternary age. Soil identification results show that the soil in the studied area can be classified as the SM category (silty sand) with the characteristics of coarse graded soil (passed sieve of 200 is <50 %), with sand (coarse fraction passed sieve of >4 is >50 %), dirty sand (soil passed sieve of >200 is >5 %) and lots of gravel is <5 % (Table 2).

The rock weathering level on surface outcrops at the diversion tunnel construction plan site is grouped into 3 rock units: lapilli tuff – residual soil, highly weathered polymict breccia, and moderately weathered polymict breccia units (Table 3). On the other hand, the rock weathering level of the subsurface rocks is classified into 4 rock units: lapilli tuff – residual soil, highly weathered polymict breccia, moderately weathered polymict breccia, and slightly weathered polymict breccia units. The rock mass quality of Geological Strength Index (GSI) on surface rocks was grouped into 2 (two) classes which are very poor rocks quality (GSI value of 0–20) and poor rocks quality (GSI value of 21–40). Assessment result of the surface rocks shows that surface rocks of the studied area are dominated by very poor rock (GSI value of 0–20). The rock mass quality of subsurface rocks (drill core) at the site of diversion tunnel construction is dominated by fair rock quality (GSI value of 41–55), and some areas are poor rock quality (GSI value of 21–40). By referring to ISRM (International Society for Rock Mechanics, 1978) to assess the field qualitatively for rock weathering level, it is shown that the studied area consists of 3 rock units: lapilli tuff – residual soil which distributes dominantly on the surface; highly and moderately weathered polymict breccias which spread on the hillsides.

Factors that are very influential on the quality of rocks are rock weathering levels. This shows that rock mass quality will be higher if

TABLE 3. Quality of surface and subsurface rocks at the studied area based on weathering rate, rock mass quality, GSI (Geological Strength Index) value, and RMR (Rock Mass Rating) value, in comparison with properties of rock mass engineering and design parameter referring to Bienawski (1993) in Singh and Goel (2011).

Lithology unit	Location	Quality rocks of the studied area					Properties of rock mass engineering and design parameter (Bienawski, 1993 in Singh and Goel, 2011)		
		Weathering rate	Rock mass quality GSI	GSI value	RMR value	Note	Rock Class (RMR)	Classification of rock mass	Safe cut slope (°)
Lapilli tuff	Surface	Highly weathered	Very poor	0–15	–	It cannot be used for GSI <25			
	Subsurface	Highly weathered	Very poor	0–7	–	It cannot be used for GSI <25			
Polymict breccia	Surface	Highly weathered	Very poor	10–15	–	It cannot be used for GSI <25			
		Moderately weathered	Poor	25–35	30–40		40–21(IV)	Poor	45
	Subsurface	Highly weathered	Very poor and poor	15–24	–	It cannot be used for GSI <25			
		Moderately weathered	Poor and fair	20–54	30–59	Inlet and outlet tunnel position	40–21(IV) & 60–41(III)	Poor and fair	45–55
		Slightly weathered	Fair	37.5–55	42.5–60		60–41(III)	Fair	55

: Slope design recommendation for the tunnel portal

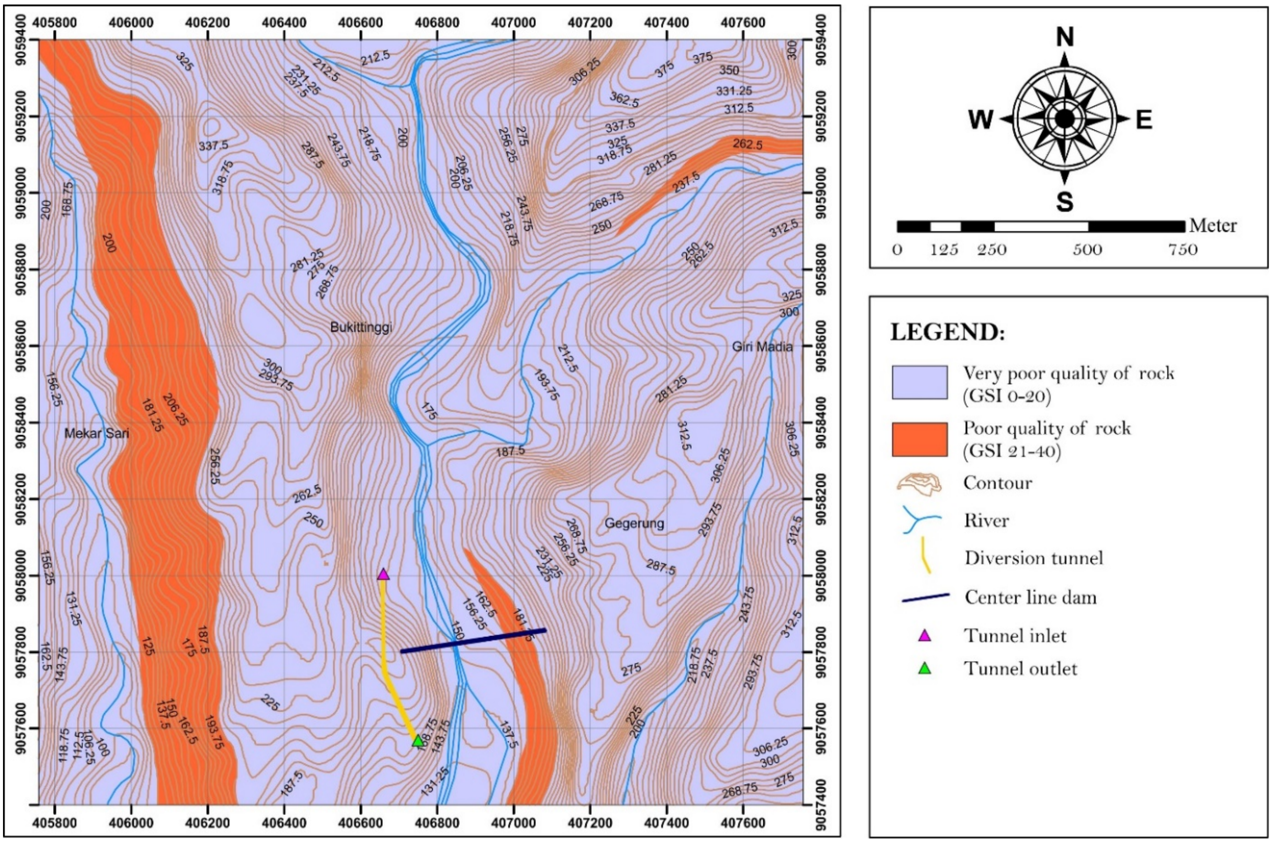


FIGURE 7. Map rock mass quality based on surface rock Geological Strength Index (GSI).

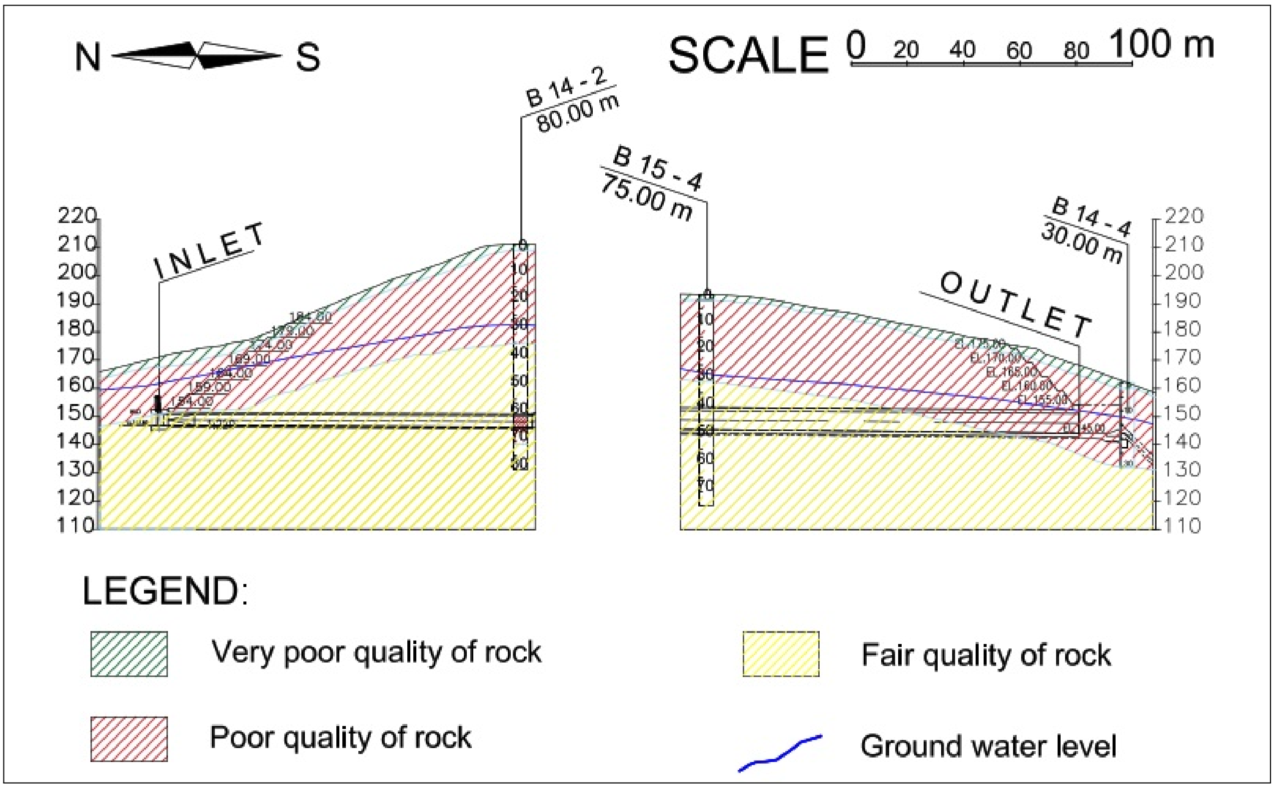


FIGURE 8. Rock mass quality of inlet and outlet of diversion tunnel at the studied area.

the rock weathering level is lower. Another factor that affects rock quality is the structure of rock mass, where the more intact or massive rock (interlocking with minor discontinuity), consequently the quality of rock mass will be higher. In contrast, when rock mass structure experiences a decrease in the level of interlocking caused by discontinuity or weathering, the quality of rock mass will be lower. Another important thing to know is that rocks on low weathering levels will have better engineering characteristics than those on high. This shows that the value of intact rock strength and rock mass quality (GSI) will decrease consistently with increasing rock weathering levels.

In the implementation of the construction of the diversion tunnel, it is necessary to beware of the type of lithology of the study area, the type of soil that dominates the rock mass quality, and its weathering level. The engineering geology data that has been produced from this research is an important parameter to consider in supporting the design of diversion tunnel construction, specifically the design of the slope stability of the tunnel portal (critical strength reduction factor/SRF). The strength Reduction Factor (SRF) is the value of the safety factor used to determine the safety factor for slope stability and deformation in the tunnel portal section. Referring to Table 1 of design parameters and properties of rock mass engineering (Bienawski, 1993 in Singh and Goel, 2011) and by comparing the quality of surface and subsurface rocks at the studied area based on weathering rate, rock mass quality, GSI value and RMR value with the properties of rock mass engineering and design parameter (Bienawski1993 in Singh and Goel, 2011) shows that the quality of rock mass at inlet and outlet tunnel is categorized as poor rock mass quality and fair rock mass quality then a suitable tunnel portal slope are recommended at 45º and 55º (Table 3). Slope safety can be further analyzed by numerical methods and by considering other parameters, as shown in Table 2.

6 CONCLUSION

The planned area of the diversion tunnel at the Meninting Dam construction in West Lombok Regency is composed of a polymict breccia rock unit and lapilli tuff unit. The inlet and outlet tunnel rocks have poor and fair rock mass quality. The quality of the subsurface rock mass on the tunnel inlet is categorized as poor and fair quality with a GSI value of 28–50 or equivalent to a value of RMR 33–55 (poor–fair). On the tunnel, the outlet is categorized as poor quality with a GSI value of 26 equivalents to a value of RMR 31 (poor). Therefore, the characteristics of rock mass engineering can be recommended for slope design at the diversion tunnel portal from 45º to 55º to get a stable slope and ensure safety.

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