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Abstract. Panaikang, Biraeng Village, Minasate'ne District is one of the villages in the Pangkep karst area which has a topographical morphology with many cracks, fissures, and cavities on the surface. The formation of karst from the process of dissolving water against carbonate rocks. Analysis of physical and mechanical properties is important to know. This study aims to determine the value of porosity, density and rock compressive strength values in the karst region of the Pangkep Regency. The testing of physical and mechanical properties was carried out to obtain rock conditions and quality using engineering methods. The number of samples used 10 rock samples with a minimum distance of each sample ± 10 meters using a random method. The results obtained by the rock type at the site are dolomite limestone with a porosity range value of 0–5% and a modified limestone with a porosity range value of 5–50%. Rock density is in the range of values 2.2-2.7 gr/cm^3. Rock compressive strength testing shows that the rock in the area has weak strength quality with a range of values of 5-25 MPa and medium strength quality with a value range of 25-50 MPa.

1. Introduction

Indonesia is known for its vast karst topography stretching along Java Island and other islands. Its distribution covers almost the entire Indonesian archipelago with an area of approximately 15.4 million hectares [1]. In South Sulawesi, there are districts where some areas consist of karst areas, namely Maros Regency, Pangkep, and other regions. The Maros and Pangkep Regencies are partly formed by carbonate rocks scattered in the north. The carbonate rocks are mostly an area that has a distinctive morphology known as karst morphology [2, 3].

The form of karst morphology is the result of the process of dissolving water against carbonate rocks. The nature of carbonate or dolomite rocks which are the main constituents of karst landscapes is to have many cracks, gaps, and cavities on the surface. This section is called the epicarst zone. This zone is a water catchment zone that falls in that place [4]. The controlling component of the development of karst topography and limestone formation is largely determined by rainfall, temperature, relief, CO_2 pressure, rock stratigraphy, dissolved rock thickness, and vegetation. High rainfall accompanied by temperature and high CO_2 pressure can accelerate the process of dissolving limestone (karstification) [5].

Vegetation plays a role in the weathering process, especially organic acids resulting from the decomposition of plant parts and the results of excretion of plant roots such as lactate, citrate, and

oxalate can accelerate weathering of rocks. In general, limestone minerals in the Karst Region are Calcite ($CaCO_3$), Aragonite ($CaCO_3$), Dolomite ($CaMg(CO_3)_2$), and Chalchedony (SiO_2) [6].

Rock has two properties namely physical and mechanical properties. The physical properties of rocks are obtained from non-destructive testing. The physical properties of rocks are density, specific gravity, water content, degree of saturation, porosity, and pore number. Whereas mechanical properties are obtained from destructive testing. Mechanical properties obtained from laboratory testing include compressive strength and tensile strength tests [7].

The method for knowing the physical and mechanical properties of rock is by following with the ASTM (American Standard Testing and Material) standard because in ASTM there are provisions for experimental steps that must be carried out to obtain the physical and mechanical properties of a material. The ASTM method used is by measuring the sample weight that has been manipulated (dry samples, wet samples, natural samples, water-dependent samples) and calculations using equations to obtain physical properties (porosity, water content, density, and other parameters [8]. The method used in knowing the mechanical properties of a rock (compressive strength, tensile strength) ie the rock sample is given a load force (F) until the sample is destroyed and uses related equations to obtain the mechanical properties (compressive strength, tensile strength) of the sample [9, 10].

One area of Pangkep Regency that is easily accessible and has a karst topography is Panaikang, Biraeng Village, Minasate'ne District, which has a morphological process, karst formation process, and the existence of transportation access (road) to the location. Based on the background, the objective to be achieved is to determine the value of porosity, density, and rock compressive strength in the karst region of Pangkep Regency.

2. Method

This research was conducted in Panaikang Village, Biraeng Sub-District, Minasatene District, Pangkep Regency, South Sulawesi Province, coordinating at 04°50’20” LS - 119°35’35” BT. Data collection is carried out in two types, namely field data, and laboratory data. Field data is obtained by visiting the field directly and then the coordinates and location of the sample source are obtained. Laboratory data were obtained by testing rock samples obtained at the sampling location. The method used in data analysis is the descriptive quantitative method.

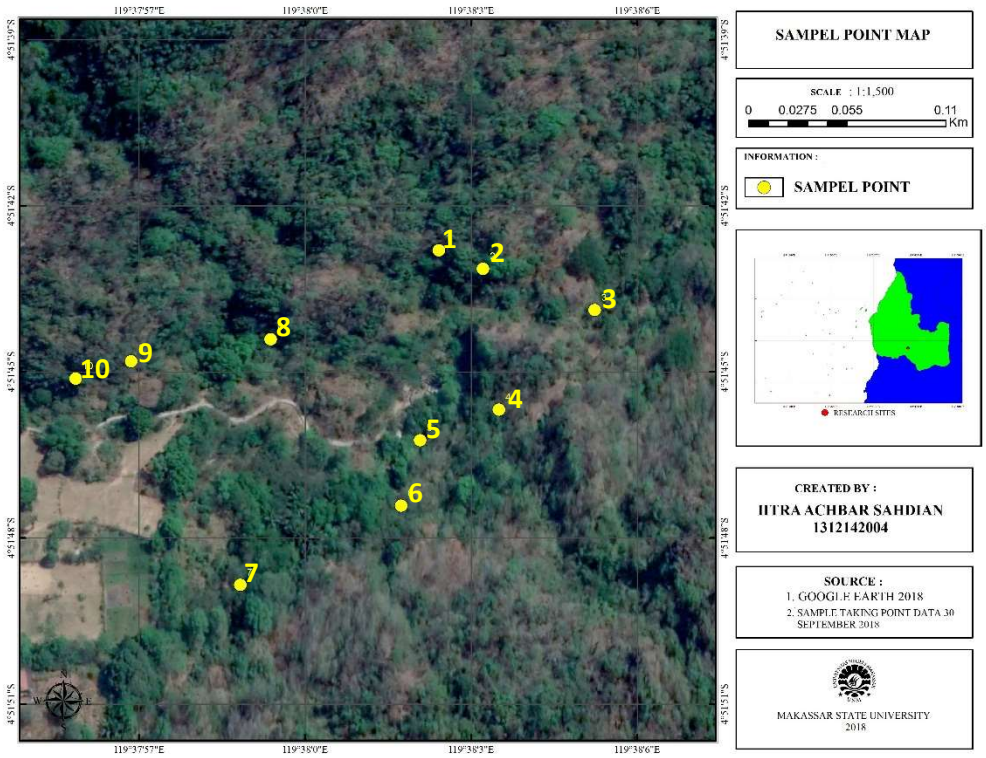

Figure 1. Map of the location of sampling points from Pangkep karst rocks.

2.1. Sampling

Sampling was carried out in the karst area of Pangkep Regency. Rock samples are samples attached to the Karst Pangkep wall using a random method with a minimum distance of taking each rock sample of 10 meters. The number of samples taken at these locations is 10 samples as shown in figure 1. This is due to the type of rock samples taken only one type of rock so that it can represent the karstic rocks that exist in the region (figure 2).

2.2. Testing physical properties

The sample was weighed using a digital balance to obtain natural rock mass (Wn). Rock samples were heated with a duration of ± 24 hours at a temperature of 110 ± 5°C. Allow the sample to reach room temperature and weigh the mass of dry rock samples (Wo).

Rock samples were soaked for ± 24 hours into a soaking tub that had been filled with water, then weighed the mass of rock samples (Ws). After that, dried with a towel and weighed the mass of rock samples (Ww). Next, calculate the value of density and porosity for each rock sample using equations (1) and (2). The calculation results were matched with the values of porosity and density in tables 1 and 2 to find out the type of rock. Porosity values are calculated based on the following equation:

$$\alpha = \frac{W_w - W_o}{W_w - W_s} \times 100\% \quad (1)$$

where α = porosity, Wo = dry weight (g), Ww = Saturated weight (g), and Ws = weight depends on water (g).

Figure 2. A sampling of Pangkep karst rocks.

The density value is calculated based on the following equation:

$$\rho = \frac{m}{V} \tag{2}$$

where ρ = density (g/cm^3), m = mass (g), and V = volume (cm^3).

Table 1. The porosity value of various materials[1].

Material	α (%)
Sediments are not compact:	
Gravel	25 – 40
Sand	25 – 50
Silt	35 – 50
Clay	40 – 70
Rocks:	
Fractured basalt	5 – 50
Modified limestone	5 – 50
Sandstone	5 – 30
Dolomite limestone	0 – 20
Shale	0 – 10
Fractured Crystalline rock	0 – 10
Dense Crystalline rock	0 – 5

Table 2. The density value of various rocks[11].

Material	ρ (%)
Alluvium	1.96 – 2.00
Clay	1.63 – 2.60
Gravel	1.70 – 2.40
Loess	1.40 – 1.93
Silt	1.80 – 2.20
Soil	1.20 – 2.40
Sand	1.70 – 2.30
Sandstone	1.61 – 2.76
Shale	1.77 – 3.20
Limestone	1.93 – 2.90
Dolomite	2.28 – 2.90
Chalk	1.53 – 2.60
Halite	2.10 – 2.60
Glacier ice	0.88 – 0.92

2.3. Testing of mechanical properties

Rock samples formed by cubes with dimensions of length, height, and width are 1 (± 4 cm): 1 (± 4 cm): 1 (± 4 cm). Measurement of compressive strength using a centric UCS machine with a flat surface. The method is to load until the test sample is destroyed. Next, calculate the value of the compressive strength of rock samples using equation (3). Furthermore, the calculation results were adjusted to rock quality based on the compressive strength values in table 3.

$$\sigma_c = \frac{F}{A} \tag{3}$$

where σ_c = rock compressive strength (MPa), F = force acting when crushed rock sample (kN), and A = straight cross-sectional area in the direction of force (mm).

Table 3. Rock quality classification based on rock compressive strength[12].

Material	σ_c (%)
Soil	$\sigma_c < 0.25$
Extremely low strength	0.25 – 1
Very low strength	1 – 5
Low strength	5 – 25
Medium strength	25 – 50
High strength	50 – 100
Very high strength	100 – 250
Extremely high strength	$\sigma_c > 250$

3. Result and Discussion

The following are the results of the analysis of physical properties (porosity and density values) and mechanical (compressive strength value) karst rock samples.

Table 4. The results of the calculation of the value of porosity and density of karst rocks in Pangkep Regency.

Sample	Porosity (%)	Porosity Scale (%)	Density (gr/cm^3)
1	2.5	0-5	2.59
2	2.3	0-5	2.49
3	4.8	0-5	2.33
4	2.4	0-5	2.71
5	4.1	0-5	2.21
6	2.3	0-5	2.38
7	2.4	0-5	2.30
8	9.7	5-50	2.26
9	2.3	0-5	2.45
10	8.6	5-50	2.43

Table 5. The results of the analysis of the compressive strength of karst rocks in the Karst Pangkep area.

Sample	r (mm)	F (kN)	A (mm^2)	σ_c (MPa)
1	43.1	50	1857.6	26.92
2	45.0	78	2025.0	38.52
3	44.9	49	2016.0	24.31
4	43.2	86.5	1866.2	46.35
5	43.8	64	1918.4	33.36
6	45.8	65.5	2097.6	31.22
7	45.7	93	2088.4	44.53
8	43.4	42.5	1883.5	22.56
9	45.1	51	2034.0	25.07
10	44.3	59.5	1962.4	30.32

The results of the analysis obtained in testing the porosity of karst rocks are eight rock samples having a porosity range of 0-5%. Two other rock samples have a porosity range of 5-50%. The way to determine the rock porosity scale is by referring to table 1 and the theory according to [1]. The choice of the 5% range due to table 1, the value of the porosity of the limestone has a value range of 5–50%. Then for dolomite limestone has a value range of 0-20. Viewed from table 5, the porosity values of eight rock samples (samples 1, 2, 3, 4, 5, 6, 7, 9) are in the range of 2.3-4.8%. To further facilitate the classification of karst rocks according to table 1, the range values are changed to 0–5%.

From table 4 shows rock samples that are samples 1, 2, 3, 4, 5, 6, 7, and 9 are dolomite limestone types, because these samples have a porosity range value of 0–5%. For the other two samples, samples 8 and 10 are limestone because the porosity values of the two rock samples are in the range of 5-50%. According to [1], the results obtained in this study indicate the type of porosity that occurs in karstic rocks in the Karst Pangkep area is secondary porosity. These are rock samples that represent the type of dolomite limestone, while the other two samples are types of limestone which are examples of rocks containing secondary porosity. Secondary porosity is porosity formed due to the continuation of the process after deposition in the form of dissolution or solid on these rocks [1]. In this study, besides testing porosity for karstic rocks, there is also a test of the density of the karst rock. The results of parameter analysis of physical density data obtained at Pangkep karst showed values of 2.2–2.7 gr/cm^3. By following table 2, according to [10], the rock samples 1, 2, 3, 4, 6, 7, 9, 10 are dolomite rocks. Stone samples 5 and 8 are types of limestone.

The relationship between porosity and density is inversely proportional. The greater the porosity value owned by a rock, the smaller the value of the density of a rock. Porosity is a physical property

parameter that is closely related to the number of pores in the rock, so that the more pores or gaps in a rock, the greater the ability of a rock to absorb fluid. Conversely, the greater the mass density (density) of rocks, the smaller the ability of rocks to absorb rocks [13].

From the results of testing the rock compressive strength in the Karst Pangkep Region also, we can determine the size of the quality (strength) of the rock that can be seen in table 3. Comparative analysis of table 3 with the compressive strength of each rock sample shows that rock samples 3 and 8 are weak strength rock. This is due to the value of rock compressive strength possessed by the two samples between the values of 5-25 MPa (table 3). Then for rock samples 1, 2, 4, 5, 6, 7, 9, and 10 are classified in medium strength rocks because the compressive strength of the sample of the karst rock is between the values of 25-50 MPa.

The relationship between porosity and compressive strength of rock is inversely proportional. The greater the value of porosity of a rock, the smaller the compressive strength value of a rock. A large number of pores possessed by the rock causes the rock to be fragile, so the compressive strength of the rock becomes low. The smaller the porosity value of rocks, the higher the compressive strength of rocks. The high value of rock mass density and the small number of pores causes the compressive strength of rocks to increase. Meanwhile, the relationship between mass density and the compressive strength of rocks is directly proportional. The greater the value of rock density, the greater the rock compressive strength value. High rock mass density causes a higher compressive strength of rock [13].

Based on geological conditions, Pangkep Regency is a merger between the Camba Formation, Tonasa Formation, and the Camba Volcano Formation. Apart from that, there are also several variations such as Qac, Qpt, and Basalt (b). Whereas for other classifications of Pangkep Regency is dominated by Bantimala Tectonic Complex (Melange Complex, Ultrabasa Rock, and Diorite).

4. Conclusion

Based on the results and discussion it can be concluded that the porosity value of rocks in the Karst Region of Pangkep Regency is 0–5% and 5–50%, where the type of rock is modified and dolomite limestones. The value of density (density) of rocks is 2.2–2.7 kg/cm^3, where the types of rocks are limestone and dolomite. The value of rock compressive strength shows two types of quality namely weak strength rock quality 5-25 MPa which is shown by samples 3 and 8, as well as medium strength rock 25-50 MPa is shown by samples 1, 2, 4, 5, 6, 7, 9, 10. Thus, the karst area, especially in Panaikang Village, Biraeng Village, Minasate'ne District which is dominated by weak to moderate strength limestone has the potential to be a mining area or rock excavation used as raw material for cement, carbide, bleaching material in making soda ash, acidity neutralizing soil fertilizer, ceramics industry, rubber, and tire industry, etc.

5. References

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