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Research Paper

Study of the Physical Properties and Compressive Strength of Karst Rocks in the Leang Londrong Cave Area Bantimurung Bulusaraung National Park

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Abstract: Research has been carried out on the physical properties and compressive strength of karst rocks in the Leang Londrong cave area. The purpose of this research was to analyzr the value of physical properties and compressive strength of rocks including density and porosity and also calssify limestone types based on the value of physical properties and compressive strength. The compressive strength value obtained from a non-destructive method, namely by using a Schmidt Hammer. The process starts from taking 30 rock samples in the Leang Lonrong cave area at 10 predetermined points. Based on the physical properties test of karst rocks in the Leang Londrong cave area, the rock density values are in the range of 2,60 $gr\ cm^{-3}$ to 2,62 $gr\ cm^{-3}$, while the porosity value are in the range 0-6 %. So that the type of rock in the Leang Londrong cave area is dolomite limestone. The compressive strength value of the rock is obtained from the conversion of the Schmidt Hammer rebound value. The value of the compressive strength of karst rocks is obtained in the range of values fro, 20 MPa to 62 MPa. So that the rocks in the Leang Londrong cave area are quite hard or medium types of rock.

Keywords: Density; Porosity; Compressive Strength; Pangkep Karst; Schmidt Hammer

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INTRODUCTION

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 party formed by carbonate rocks scattered in the north. The carbonat rocks are mostly an area that has a distincive morphology known as karst morphology (Arsyad et al., 2020). Leang Londrong is included in the management area of the Bantimurung Bulusaraung National Park, where the water source is used by the community as a bathing tourist attraction (Hayati, 2019). Especially in the Leang Londrong cave tourist area which has a characteristic that is a karst area (Soma, 2020). The controlling 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) (Palloan et al., 2013).

Limestone 2 physical properties and mechanical properties. Physical properties of rocsk, namely density, water content, degree of saturation, porosity and void ratio. While the mechanical properties of the rock were obtained by non-destructive testing using the Schmidt Hammer Test tool (Ariyanto et al., 2020).

Porosity is the ability to absorb fluids in rocks or formations or spaces filled with fluids between solids or minerals in a rock (Rosari & Arsyad, 2018). According (Olhoeft, 1989) density is a physical property that changes significantly between different rock types due to differences in mineralogy and porosity. Density

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is a physical property that describes the bonding density of rock-forming materials. The rock density level is influenced by the type and amount of minerals and their presentation, rock porosity and cavity filling fluid. Rock density includes natural density, which is the density of the rock in its original state, dry density is the density of rock in a state of shrinkage after the rock is heated and saturated density is the density of rock in a saturates state after the rock is saturated in a fluid (Ridha & Darminto, 2016). Natural density is the ratio of the natural weight of the rock to volume of the rock. Dry density is the ratio of dry rock weight to its total volume. Saturated density is the ratio of the saturated weight of the rock to its total volume (Prasetya, 2013).

Compressive strength is the ability of rocks to accept loads until they break when given a load and pressure. Although the UCS laboratory test is the most relieable method, the UCS laboratory test method is time consuming and expensive. Another method that can be used to determine the compressive strength of rocks is to use the Schmidt Hammer Test tool. Testing with a Schmidt Hammer can be carried out directly in the field or in the laboratory. The Schmidt Hammer was developed in the late 1940s an index of equipment for the non-destructive testing of concrete (Purwanto, Abdul Muhaimin, Djamaluddin, Ratna Husain, 2017). Previous researchers have done a lot of grouping the physical and mechanical properties of various types of intact rock. Attewel and Farmer (1976) stated that the uniaxial strength of limestone is 30-250 MPa. In general, this value can be used as a preliminary knowledge of limestone strength (Winonazada et al., 2020).

METHOD

This research focuses on the physical properties and compressive strength of rocks. Rock physical proeperties include porosity and density, while the compressive strength is obtained by using a non-destructive method with a hammer test tool. The data will be directly taken in the fiels and then anlyzed. The steps in the research are:

Study of literature

Study the literature or theories related to the physical properties and compressive strength of rocks, as well as related research journals that discuss the physical properties and compressive strength of rocks.

Rock sampling and field testing.

Carry out rock sampling at 10 predetermined location points. 3 rock samples will be taken from each point, so the total sample is 30 rock samples. And then take data directly in the field, namely the rebound of the Schmidt Hammer. There are 10 points of data collection, each point has 10 data. So, there are 100 test data using the Schmidt hammer test tool. Point of location for smapling as shown in Figure 1.

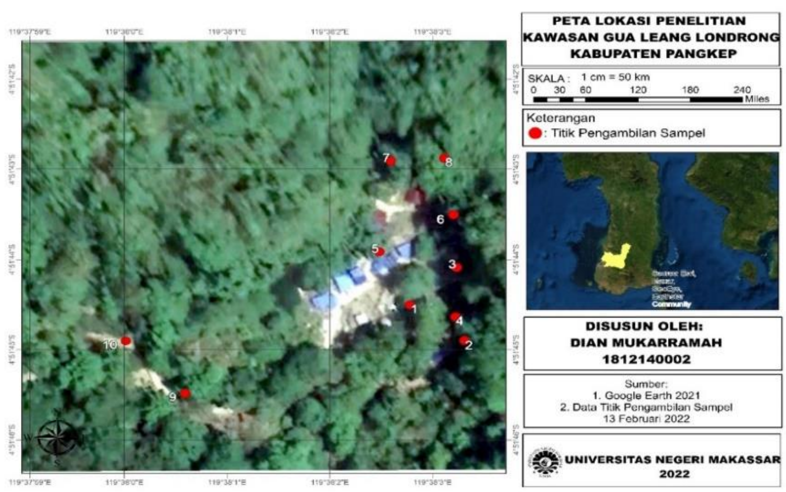

Figure 1. Rock Sampling location

Rock sample testing in the laboratory.

Testing of physical properties which include porosity and density was carried out at the physics laboratory of the State University of Makassar.

Data analysis

Porosity and density values obtained from samples test data in the laboratory. Porosity values are calculated based on the following equation:

$$n = \frac{Ww - Wo}{Ww - Ws} x\ 100\% \quad (1)$$

Where n = porosity, Wo = dry weight (g), $Ww = Saturated\ weight\ (g)$, and Ws = weight depens on water (g).

The density values are calculated based on the following equation

$$\rho_n = \frac{w_n}{w_w - w_s} \quad (2)$$

$$\rho_d = \frac{w_0}{w_w - w_s} \quad (3)$$

$$\rho_s = \frac{w_w}{w_w - w_s} \quad (4)$$

Where ρ_n = natural density(gcm^{-3}), $\rho_d = dry\ density\ (gcm^{-3})$, $\rho_s = saturated\ density\ (gcm^{-3}), W_n$ = natural weight (g).

The estimated value of the uniaxial compressive strength of rocks is obtained from test data directly in the field using the Schmidt Hammer Test tool. Uniaxial compressive strength is calculated based on the equation:

$$\text{UCS} = 2{,}208e^{0{,}067R} \quad (5)$$

Where UCS = uniaxial compressive strength (MPa), R = Schmidt hammer rebound.

Table1. Porosity Values of Varius rock materials

No	Material	α (%)
Sediment is not compact		
1	gravel	25 – 40
2	Sand	25 – 50
3	Silt	35 – 50
4	Clay	40 – 70
Rock		
5	Fractured basalt	5 – 50
6	Modified limestone	5 – 50
7	Sandstone	5 – 30
8	Dolomite limestone	0 – 20
9	Shale	0 – 10
10	Fractured Crystalline rock	0 – 10
11	Dense Crystalline rock	0 – 5

(Acworth, 2001).

Tabel 2. Density values of various rocks

Rock Type	ρ (gcm^{-3})
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

(Telford et al., 1990)

Table 3. Approximate Strength Classification of Rocks

Description	Uniaxial compressive strength, MPa	Point load strength $I_{s(50)}, MPa$	Schmidt Hammer N-Type, 'R'	Caracteristic rocks
Very weak rock – crumbles under shrap blows with geological pick point, can be cut with pocket knife.	1-25	0,04-1,0	10-35	Weathered weakly Compacted sedimentary rocsk-chalk, rock salt
Weak rock – shallow cuts or scraping with pocket knife with difficulty, pick point indents deeply with firm blow	25-50	1,0-1,5	35-40	Weakly cemented Sedimentary rocks – coal siltstone. Also schist
Moderately strong rock – knife cannot be used to scrape or peel surface, shallow indentation under firm blow form pick point	50-100	1,5-4,0	40-50	Competent sedimentary rocks – sandstone shale, slate
Strong rock – hand-held sample breaks with one m firm blow from hammer end of geological pick				
Very strong rock – requires many blows a from geological pick to break intact sample	100-200	4,0-10,0	50- 60	Competent igneous and metamorphic rocks – marble, granite, gneiss
	>200	>2	>60	Dense fine-grained igneous and metamorphic rocks-quartzite, dolerite, gabbro, basalt.

(Saptono et al., 2013)

RESULT AND DISCUSSION

Rock physical properties

The porosity value of 29 rock samples is in the range of 0-5 %, based on table 1 the rock type is dolomite limestone. While for sample 3c is the only sample that has a porosity value above 5%, namely 6,33%, it means that is sample rock type is *Modified limestone*. *Table 4 is the porosity value grouped by elevation.*

Table 4. The Results od Grouping Porosity by Elevation

Location	Elevetion (m)	Number			Porosity (%)
	287	9	2,89	3,30	3,65
I	283	10	3,87	0,80	1,64
	362	4	0,92	4,79	1,36
	366	1	1,83	2,55	3,42
	367	3	2,14	3,31	6,33
II	367	5	1,52	3,48	2,54
	371	2	3,87	0,80	1,64
III	383	7	2,42	3,93	3,16
	390	6	2,90	2,16	2,45
IV	396	8	2,04	3,49	3,06

Location 1 with an elevation of 283 to 287 meters has a porosity range of 0,80% to 3,87%. Furthermore, location II with an elevation of 362 to 367 meters has a porosity range of 0,92% to 6,33%. Location III with an elevation of 371 to 383 meters has a porosity range of 0,80 % to 3,93%. While location IV with an elevation 390 meters to 396 meters has a porosity value of 2,04% to 3,49%.

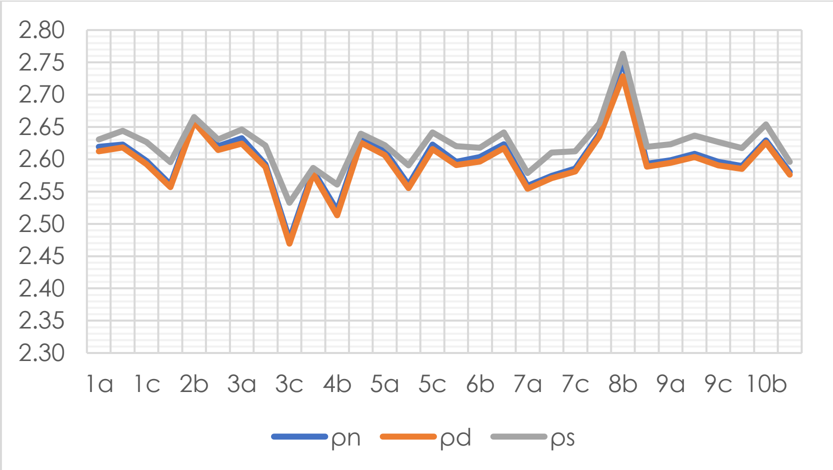

Figure 2. Graph of the relationship between natural density (ρ_n), dry density (ρ_d) and saturation density (ρ_s.

From figure 2, it can be concluded that the relationship between the three densities is directly proportional. The results of natural density measurements are in range 2,48 gcm^{-3} to 2,75 gcm^{-3}. While the dry density is in the range 2,47 gcm^{-3} to 2,73 gcm^{-3}. And saturation density based on the calculation results are in the range 2,53 gcm^{-3} to 2,76 gcm^{-3}. From the matching the density values with table 2, it is found that the rock samples are of the dolomite and limestone types.

Table 5. Density value that has been grouped by elevation

Location	Elevation (m)	Number	Density								
			ρ_n (gcm^{-3})			ρ_d (gcm^{-3})			ρ_s (gcm^{-3})		
	287	9	2,60	2,61	2,60	2,59	2,60	2,59	2,62	2,64	2,63
I	283	10	2,59	2,63	2,58	2,58	2,63	2,58	2,62	2,65	2,60
	362	4	2,58	2,52	2,63	2,58	2,51	2,63	2,59	2,56	2,64
	366	1	2,62	2,62	2,60	2,61	2,62	2,59	2,63	2,64	2,63
	367	3	2,63	2,59	2,48	2,62	2,59	2,47	2,65	2,62	2,53
II	367	5	2,61	2,56	2,62	2,61	2,56	2,62	2,62	2,59	2,64
	371	2	2,56	2,66	2,62	2,56	2,66	2,61	2,60	2,67	2,63
III	383	7	2,56	2,57	2,59	2,55	2,57	2,58	2,58	2,61	2,61
	390	6	2,60	2,60	2,62	2,59	2,60	2,60	2,62	2,62	2,64
IV	396	8	2,64	2,75	2,59	2,63	2,73	2,59	2,66	2,76	2,62

From Table 5 provides information that location 1 is at an elevation of 283 to 287 meters has a natural density of 2,58 gcm^{-3} to 2,63 gcm^{-3}, dry density is in the range 2,58 gcm^{-3} to 2,63 gcm^{-3} and saturation density is 2,60 gcm^{-3} to 2,65 gcm^{-3}. Location II is at an altitude of 362 m to 367 m with a natural density range of 2,48 gcm^{-3} to 2,63 gcm^{-3}, dry density is 2,51 gcm^{-3} to 2,63 gcm^{-3} and saturation density is in the range 2,53 gcm^{-3} to 2,65 gcm^{-3}. While location III is at elevation of 371 m to 383 m and has a natural density 2,56 gcm^{-3} to 2,66 gcm^{-3}, dry density 2,55 gcm^{-3} to 2,66 gcm^{-3} and saturation density is 2,58 gcm^{-3} to 2,67 gcm^{-3}. And location IV is at elevation 390 m to 396 m has a natural density is 2,59 gcm^{-3} to 2,75 gcm^{-3}, dry density is 2,59 gcm^{-3} to 2,73 gcm^{-3} and saturation density ia 2,62 gcm^{-3} to 2,76 gcm^{-3}.

Rock compressive strength

Table 6 provides information on the compressive strength of rocks in the Leang Londrong cave area. The strength value is obtained, the value is in the range of 20 MPa to 65 MPa. It has been done 10 times the Schmidt hammer rebound data collection for each point with difference in data collection distance is a maximum of 25 mm. The location of data collection must be flat so that researchers conduct tests on cave walls and cliffs that are flat. Based on table 6 it is found that point 10 has a compressive strength of 21,4 MP. From matching with table 3, it is obtained that the rock types are very weak rock. Rock characteristics are weathered weakly compacted sedimentary rocks-chalk. Point 10 is far from the mouth of the cave, about 200 meters from the mouth of the cave. This point is not an area that humans usually step on, because it is a towering mountain wall. So that what needs to be considered is the collapse or landslide of the point 10 area because it is the main road to the Leang Londrong cave area. Even though it has the tittle of very weak rock, in the process of cutting rock samples at this point it is no different from other points.

Table 6. The results of the calculation of the compressive strength of the karst rock

Point	R Average	UCS (MPa)	UCS (Kg/cm^2)
1	50	62,5	637
2	46	48,5	494
3	37	27,1	279
4	39	30,7	313
5	50	64,6	659
6	41	33,8	344
7	42	36,3	370
8	41	33,8	344
9	43	38,8	396
10	34	21,4	218

Points 2, 3, 4, 6, 7, 8 and 9 have a compressive strength range of 25 MPa to 50 MPa. From the table 3 types of rock at this point are weak rock, and rock characteristics is weakly cemented sedimentary rocks, coal siltstone also schist. Point 2 is the mouth of the area with a compressive strength value of 48,5 MPa, which means it is a safe area for humans and this area is the area most often in contact with humans. Points 3 and 4 are the most accessible areas for tourists and are the closest points to food vendors. This point has a compressive strength of 27,1 MPa and 30,7 MPa, so it is still safe for tourists to stand in this area. At this point the researchers took data on the walls of the karst mountain. Point 6 is a point that is vert close to the gazebo on the left of the road has a compressive strength value 33,8 MPa and is a safe area for humans. Points 7 and 8 are areas that are far from the Leang Londrong cave tourist area. In this area data collection on the mountain wall with a compressive strength of 36,3 MPa and 33,8 MPa. Points 1 and 5 have a compressive strength of 62,5 MPa and 64,6 MPa, this point is the blood that most people come into contact with. The rock types in this area are moderately strong rock, and rock characteristics are competent sedimentary rocks, sandstone shale and slate.

CONCLUSION

Based on the results of the research that has been done, it is conclude that the porosity value of 30 rock samples are in the range of 0,92% to 6,33 %. Rock density values are in the range 2,51 gcm^{-3} to 2,76 gcm^{-3}. So that the type of rock in the Leang Londrong cave area is dolomite karst rock. Compressive strength testing using the Schmidt Hammer Test, the compressive strength values of the rock are in the range of 20 MPa to 62 MPa. So based on the compressive strength values of rock samples of various 3 rocks, namely very weak rock at point 10, weak rock at points 2,3,4,5,6,7,8 and 9 and moderately strong rock at points 1 and 5.

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