Formosa Journal of Science and Technology (FJST)
Vol. 5, No. 8, 2026: 2077-2096

The Relationship of Mineral Composition to the Mechanical Properties of Rocks in Loli Saluran Area Donggala District Central Sulawesi Province

Muslimin U. Botjing[1]*, Bey Nida'ul Hasanah[2], Nunik Rezkiarti Janat[3]
Geological Engineering Study Program, Civil Engineering Department, Engineering Faculty, Tadulako University
Corresponding Author: Muslimin U. Botjing, muslimin@untad.ac.id

ARTICLE INFO

Keywords: Correlation, Mineral, Rock Mechanical Properties.

Received : 27, June
Revised : 29, July
Accepted: 25, August

ABSTRACT

This study was conducted in the Loli Saluran area, Donggala District, Central Sulawesi Province, located within the Tinombo Formation and dominated by andesite. Rock quality can be assessed through mechanical properties controlled by mineral composition. This study examines the relationship between mineral composition and compressive strength, Young's modulus, and Poisson's ratio using X-Ray Diffraction, Uniaxial Compressive Strength, petrography, regression, and correlation analyses. Three samples were tested to represent eleven data points. Petrographic analysis identified porphyritic meta-andesite and diorite composed mainly of plagioclase, quartz, and chlorite. Correlation results show that plagioclase has a very strong positive relationship with mechanical properties, whereas quartz and chlorite have very strong negative relationships. Thus, mineral composition reflects rock mechanical properties and can indicate rock quality

ISSN-E: 2964-6804
DOI: https://doi.org/10.55927/fjst.v5i8.125
https://journalfjst.my.id/index.php/fjst

INTRODUCTION

Good rock quality can be viewed from various aspects, including rock compressive strength, the level of weathering experienced by a rock, discontinuities found in rocks and groundwater conditions. Uniaxial compressive strength of rocks has several parameters, namely the UCS (Uniaxial Compressive Strength) value, elastic modulus, and Poisson's ratio. Compressive strength testing on rocks aims to determine the strength of rocks against maximum pressure. The higher the compressive strength value of a rock, the better its quality (Noor, 2021).

A rock is composed of various minerals which are the main characteristics of the rock itself. The mineral composition contained in the rock may change depending on the geological conditions experienced, which can also affect the quality of the rock. Tugrul and Zarif (1999) said that the engineering properties and minerals contained in a rock can determine the strength value of the rock. Another study conducted by Keikha and Keykha (2013) explained that rock strength from the results of mechanical testing of samples is generally related to various petrographic parameters, one of which is the mineral composition of the rock.

This research aims to determine the relationship between mineral composition and the mechanical properties value of rocks using the Uniaxial Comressive Strenght (UCS), X-Ray Diffraction (XRD), correlation and regression methods.

Location

Administratively, the research area is located in Loli Saluran area, Banawa sub-district, Donggala district, Central Sulawesi province. Geographically, the research area is bordered by Loli Tasi Buri Village in the north, Loli Oge Village in the south, Powela Village in the west and bordered by Palu Bay in the east. Based on its astronomical location, the area is located at 121°47'16.8” - 121°47'31.2” east longitude and 0°47'9.6” - 0°47'16.8'' South latitude.

The area is mapped on the 1:50,000 scale Indonesian Landform Map Sheet 2015-23 (Palu) published by the National Survey and Mapping Coordinating Agency (Bakosurtanal) in the first edition of 1991, with a research area of approximately 9.97 hectares.

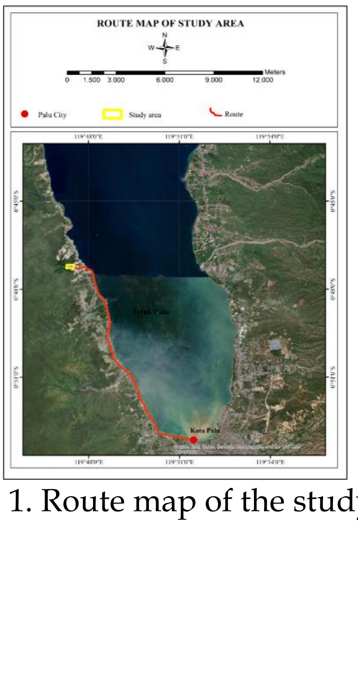


Figure 1. Route map of the study area

Geological setting

Geomorfologi regional mandala Geologi Sulawesi The regional geomorphology of the Western Sulawesi Geological mandala Sukamto (1973) explains that the Palu area consists of a western mountain range and an eastern mountain range, both of which run north-south and are separated by the Palu Valley (Fosa Sarasina). The western mountain range is near Palu with a height of more than 2000 m, but in Donggala it decreases to mukalaut. The eastern mountain range with peaks from 400 m to 1900 m high connects the mountains of Central Sulawesi with the northern arm (Sukamto, 1973).

The regional stratigraphy of the study area is in the Tinombo Formation. According to Sukamto (1973), based on observations of several generations of intrusions, the andesite and small basalt intrusions on the Donggala peninsula are the oldest intrusions. These intrusions are probably the result of the activity of volcanic rocks in the Tinombo Formation. This sequence is widely exposed in both the east and west ranges. It overlies a complex of metamorphic rocks in a misaligned manner. They contain debris derived from metamorphic rocks. The deposits consist of shale, sandstone, conglomerate, limestone, radiolarian chert and volcanic rocks deposited in a marine depositional environment.

Advokaat, et al (2017) said that the Tinombo Formation has volcanic rocks that are usually porphyritic in texture and generally have a composition of basalt and andesite with a small possibility of producing dacite and rhyolite rocks based on the results of research by Van Leeuwen, et al (2016) aged Middle Eocene - Late Eocene.

The regional geological structure is dominated by the northwest-southeast trending Palu-Koro Fault. The Palu-Koro Fault cuts through western and central Sulawesi, continuing northward to the North Sulawesi Trough which is the continental margin in the Sulawesi Sea. The Palu-Koro Fault is a sinistral horizontal fault with a displacement of more than 750 km (Tjia and Zakaria, 1974 in Surono and Hartanto, 2013).

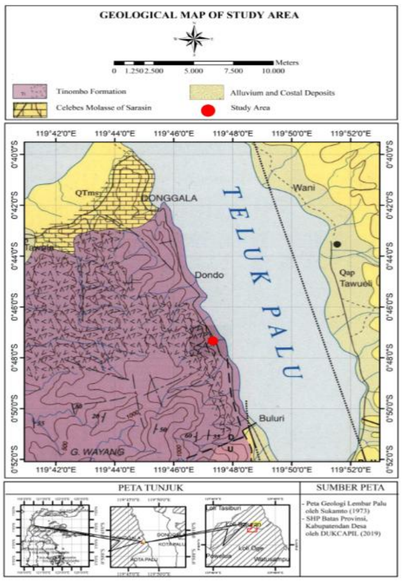


Figure 2. Regional geological map of the research area (Modified from Sukamto, 1973)

LITERATURE REVIEW

Minerals can be defined as naturally occurring inorganic solid materials, consisting of chemical elements in a certain ratio, where the atoms are arranged in a systematic pattern. Minerals can take the form of rocks, soil, or sand. Minerals have certain properties and shapes in their solid state, as a manifestation of the orderly arrangement within them. If conditions permit, they will be bounded by flat planes, and are assumed to be regular shapes known as crystals (Noor, 2009).

There are many types of rocks that have been recognized, these rocks are composed by main minerals, accompanying minerals to secondary minerals. Graha (1987) classifies these minerals can be classified into two major groups, namely the black mineral group or mafic minerals and the white mineral group or felsic minerals. Black minerals for example are hornblende, olivine pyroxine and many others. While white minerals such as quartz, feldspar group, feldspatoid group and others.

The mechanical properties of rocks are used to determine their compressive strength (σ), elastic modulus (E), and Poisson's ratio (ν). This test is performed by pressing a specimen between two plates that will induce stress to the specimen. Axial stress is the independent controlled variable, while axial strain is the dependent variable. Changes in the specimen can be measured using a dial gauge placed axially to measure changes in the distance between the pressing plates and laterally to measure changes in the specimen horizontally (Rai et al., 2014).

The uniaxial compressive strength (σ_c) value is a description of the maximum stress value that can be borne by the rock shortly before the rock collapses (failure) (Rai et al., 2014). The equation for the uniaxial compressive strength of rock can be seen in Equation 1.

$$\sigma_c = \frac{F}{A} \qquad (1)$$

Where :

σ_c = uniaxial compressive strenght (MPa)

F = force (kN)

A = surface area (mm^2)

The compressive strength value of rocks produced from laboratory testing results can be categorized with the Stapledon (1986) classification which can be seen in Table 1.

Table 1 Classification of load materials based on their compressive strength by Stapledon (1986) in (Noor, 2021)

Unconfined Compression Strength **(Kg/cm²)**	**Description**
< 70	Very weak
70-200	Weak
200-700	Medium strong
700-1400	Strong
>1400	Very strong

Young's modulus or modulus of elasticity is the ability of a rock to maintain its elastic state. In the uniaxial compressive strength test, the stressed rock specimen will undergo several stages of deformation, namely elastic deformation and plastic deformation.

The modulus of elasticity can be determined using Equation 2 (Rai et al., 2014).

$$E = \frac{\Delta\sigma}{\Delta\varepsilon a} \tag{2}$$

Keterangan:
E = modulus of elasticity (Mpa)
Δσ = stress difference (MPa)
Δεa = differential axial strain (%)

Poisson's ratio (ν) is the absolute value of the ratio of lateral strain to axial strain. If a material is stretched in one direction, it tends to shrink and rarely expands in the other two directions. Conversely, if a material is pressed, the material will expand and rarely contract in the other two directions (Arif, 2016). The Poisson ratio equation can be seen in Equation 3.

$$\nu = \frac{\varepsilon \text{ lateral}}{\varepsilon \text{ aksial}} \tag{3}$$

Where :
υ = poisson ratio
εlateral = lateral strain (mm)
εaksial = axial strain (mm)

Gercek (2007) in Rai, et al (2014) clusters the value of the Poisson ratio which can be seen in Table 2.

Table 2 Classification of load materials based on their compressive strength by Gercek (2007) in Rai, et al (2014)

Category	Very Low	Low	Medium	High	Very High
NP (v)	0 < v < 0.1	0.1 < v < 0.2	0.2 < v < 0.3	0.3 < v < 0.4	0.4 < v < 0.5

Branada, et al (2019) said that the value of Poisson's ratio in homogeneous, isotropic, and elastic materials ranges from 0 to 0.5. The occurrence of Poisson's ratio values higher than 0.5 may be very significant in inhomogeneous materials. The analysis conducted by Dmitriev and Shigenari (2001) concluded that materials with Poisson's ratio values exceeding the conventional upper limit of elasticity (σ = 0.5) can be found not only for single crystals but also for polycrystals.

Engineering properties and mineralogical analysis of rocks are very important to know to determine the strength value of rocks (Tugrul and Zarif, 1999). Variations in petrographic characteristics in rocks affect each other and are interrelated (Ginnakopoulou et al., 2018). Therefore, to correlate the two variables, in this case mineral composition with uniaxial compressive strength, simple regression analysis was used.

Nuryadi, et al (2017) say that regression analysis aims to determine a good regression equation that can be used to estimate the value of the dependent variable. the form of the equation to be determined is in accordance with equation 4.

$$Y = a + bX \tag{4}$$

$$a = \frac{\sum Y \sum X^2 - \sum X \sum XY}{n \sum X^2 - (\sum X)^2} \tag{5}$$

$$b = \frac{n \sum XY - \sum X \sum Y}{n \sum X^2 - (\sum X)^2} \tag{6}$$

Where :
A = constant (Y if X = 0)
b = regression coefficient (estimated change in Y value if X changes by one unit)
Y = *dependent variable*
X = (*independent variable*)

Sugiyono (2017) provides guidelines for interpreting the correlation coefficient, which are as follows:

Table 3 Interpretation of the correlation coefficient according to Sugiyono (2017)

Correlation Coefficient Interval	Degree of Relationship
0,00 – 0,199	Very Low
0,20 – 0,399	Low
0,40 – 0,599	Medium
0,60 – 0,799	High
8,00 – 1,000	Very High

The correlation coefficient (r) is a number that shows the closeness of the relationship between two variables that affect each other. The general equation of the correlation coefficient is shown in Equation 7 (Sugiyono, 2017).

$$r = \frac{n \sum XY - (\sum X)(\sum Y)}{\sqrt{\{n \sum X^2 - (\sum X)^2\}\{n \sum Y^2 - (\sum Y)^2\}}} \tag{7}$$

Where :
r = Correlation coefficient
n = Number of point pairs X, Y
X = Variable value of X
Y = Variable value of Y

The effect of variable X on the value of variable Y can be calculated using the coefficient of determination or determination (coefficient of determination) written with the symbol r². The coefficient of determination is basically the square of the correlation coefficient (Paiman 2019).

METHODOLOGY

The research methods used in this study are Uniaxial Comressive Strenght (UCS), X-Ray Diffraction (XRD), correlation and regression petrography.

Uniaxial Comressive Strenght (UCS)

Samples collected tested to laboratory testing in the form of uniaxial compressive strength tests to obtain UCS values, young's modulus or modulus of elasticity and Poisson ratio. Samples to be tested for UCS were prepared in the form of blocks with dimensions of length, width and height in a ratio of 1:1:2 with a size of not less than 4 cm. In this study, 3 test samples were selected that were considered to represent 11 observation stations, station 02 with dioite lithology and stations 06 and 09 with porphyry meta-andesite lithology. The dimension table of the sample preparation results can be seen in Table 4, the appearance of the sample after preparation can be seen in Figure 3.

Tabel 4 Dimensi sampel setelah dipreparasi

Sampels code	Lithology	Dimension (cm)		
		p	l	t
ST 02	Diorite	5	5	10
ST 06	Meta-andesit porfiri	5	5	10
ST 09	Meta-andesit porfiri	5	5	10

Figure 3. Samples ready for uniaxial compressive strength testing

The prepared samples were subjected to uniaxial compressive strength testing. In this test, the sample is subjected to a force that continuously increases until the sample breaks. In this test, lateral strain and axial strain are obtained which are used to calculate the value of young's modulus and Poisson ratio. A picture of the uniaxial compressive strength test can be seen in Figure 4.

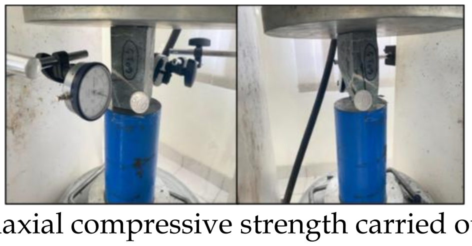


Figure 4 Testing of uniaxial compressive strength carried out on ST 09 samples of porphyry meta- andesite lithology

X-Ray Diffraction (XRD)

The XRD test was used to determine the mineral percentage of each rock sample tested. XRD testing was carried out on samples from the same station as the uniaxial compressive strength test, namely samples at stations 02, 06, and 09 with the type of lithology of porphyry meta-andesite and dioite. Rock samples that will be XRD tested are prepared in powder form with a weight of ± 5 grams. From the results of this test, a diffraction graph and mineral percentage of the tested sample will be obtained. Samples ready for XRD testing can be seen in Figure 5.

Figure 5 Samples ready for XRD testing

Petrography

Petrographic testing is intended to determine the name of the rock microscopically. This is done to validate rock discoveries made megascopically with mineral composition parameters which are then named based on Travis (1955) and USGS (2007) classifications.

Sample preparation for rock thin sections was carried out on 2 rock samples, namely rock samples at station 02 and station 09. These thin sections were then observed with a polarizing microscope to observe visible minerals as a basis for naming rocks. rock thin sections and petrographic observations can be seen in Figure 6.

Petrographic testing is intended to determine the name of the rock microscopically. This is done to validate the rock naming done megascopically with mineral composition parameters which are then named based on Travis (1955) and USGS (2007) classifications.

Sample preparation for rock thin sections was carried out on 2 rock samples, namely rock samples at station 02 and station 09. These thin sections were then observed with a polarizing microscope to observe visible minerals as a basis for naming rocks. rock thin sections and petrographic observations can be seen in Figure 6.

Figure 6 Petrographical investigation using a polarizing microscope

Regression and Correlation

From the results of laboratory testing and observations as well as data processing and data analysis, the values of mineral composition, elastic modulus, Poisson's ratio and UCS of rocks are obtained, then the data interpretation stage is carried out using the regression and correlation methods. The regression method is used to determine the relationship between the parameters used. With the regression equation obtained, it can predict other possibilities of the parameter values used. While the statistical method in the form of correlation is used to determine how much the relationship between these parameters is. The results of this correlation are in the form of the correlation coefficient (r) and the coefficient of determination (r2) which are then compared with the classification of correlation coefficient interpretation according to Sugiyono (2017) which can reflect how much influence and relationship of the parameters used.

RESEARCH RESULT AND DISCUSSION

After observations, 11 data collection points were obtained which can be seen in Figure 7.

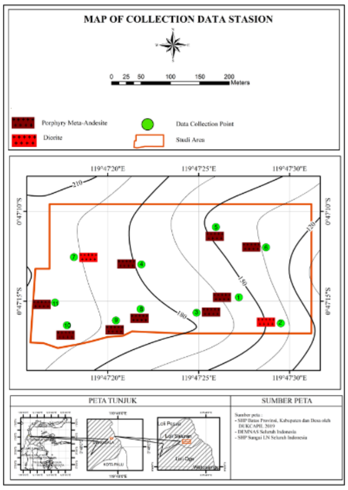


Figure 7. Map of collection data station

Based on morphographic analysis on the topographic map, the relative height of the research location is obtained in the range of 50-200 meters from sea level which has a low hilly morphological type based on the classification of Van Zuidam (1985).


Figure 8. Relief of undulating peaks in the study area with a photographing direction of N240°E

The stratigraphy of the research site is composed of porphyry meta-andesite and diorite. Porphyry meta-andesite in the study area is found at stations 01, 03, 04, 05, 06, 08, 09, 10 and 11. This lithology has megascopic physical characteristics of blackish gray, afanitic porphyry texture and massive structure. This lithology has a mineral composition in the form of basic mass and plagioclase. The appearance of the meta-andesite porphyry sample megascopically can be seen in Figure 9. Microscopically, this lithology has gray-white characteristics in the appearance of parallel niches and blackish gray in the appearance of cross niches. This sample has a blastoporphic texture, massive structure, constituent mineral size 0.01 - 2.8 mm. This lithology consists of basic period, plagioclase, hornblende, quartz, opaque (Figure 10).

Figure 9. Porphyry meta-andesite at station 06 with photo direction N 253° E

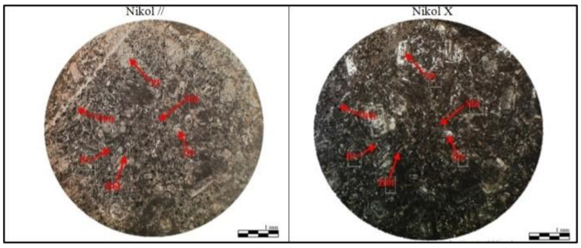


Figure 10. Thin section view of porphyry meta-andesite at station 06 with 4x magnification which has a mineral composition of basic mass (55%), plagioclase (30%), hornblende (3%), quartz (6%) opaque (2%) and biotite (4%).

Diorite is found in two stations, namely station 02 and station 07. This lithology has physical characteristics of gray-white color, has a faneritic texture and a massive structure. The mineral composition in this lithology is plagioclase, biotite, and quartz. Figure 11 shows a hand specimen photo of diorite in the study area. Microscopically, this lithology has yellowish white characteristics in the appearance of parallel nicols and blackish gray in the appearance of cross nicols, Holocrystalline crystallinity, faneritic granularity, euhedral -.anhedral mineral shape, equigranular relations, massive structure, constituent mineral size 0.04 - 4.6 mm. Consists of plagioclase, quartz, biotite, opaque and pyroxine minerals (Figure 12).

Figure 11. Appearance of diorite at station 02 with photo direction N 17° E

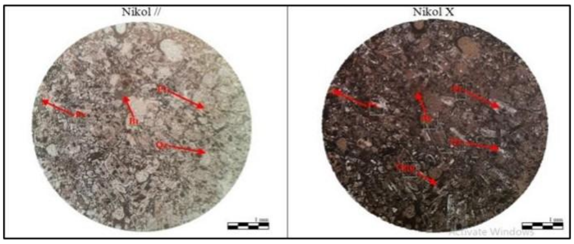


Figure 12. Thin section view of diorite at station 2 with 4x magnification which has a mineral composition of plagioclase (67%), quartz (6%) opaque (2%) and biotite (18%) and pyroxine (5%).

Geological structures found at the research site are systematic joint. Systematic joint is bridging that is generally always found in the form of pairs. The systematic joint in the study area can be seen in Figure 13.

Figure 13. The appearance of a systematic joint structure found in the porphy mta-andesite lithology at station 5 with a photo direction of N 23°E.

The percentage of minerals in rocks that are used as independent variables of this study is obtained from the results of X-ray Diffraction (XRD) testing. X-ray Diffraction (XRD) is one of the tools used to characterize the crystal structure, crystal size of a solid material. All materials containing certain crystals when analyzed using XRD will bring up specific peaks (Mukti, 2012). From the results of XRD testing, it will produce the percentage of each mineral contained in a rock sample.

In this study, XRD testing was carried out on 3 rock samples consisting of 2 samples of porphyry meta-andesite which are ST 06 and ST 09 and 1 sample of diorite which is ST 02. The selection of these samples is considered to represent the different characteristics of the 11 observation stations. When tabulated, the mineral composition of the 3 XRD test samples can be seen in Table 5.

Table 5. Mineral composition of rock based on XRD test

Sampel Code	Lithology	Mineral composition	Mineral Percentage (%)
ST 02	Diorite	Albite	51,6
		Quartz	33,1
		Chlorite	15,3
ST 06	porphyry meta-andesite	Oligoclase	59,7
		Quartz	29,7
		Chorite	8,4
		Hornblende	2,2
ST 09	porphyry meta-andesite	Labradorite	56,1
		Quartz	31,9
		chamosite	8,2
		heulandite	3,8

The compressive strength test applied to samples is the uniaxial compressive strength (UCS) test. UCS testing was applied on 3 samples consisting of 2 samples of porphyry meta-andesite which are ST 06 and ST 09 and 1 sample of which is ST 02. The results of the UCS test resulted in 3 parameters. They are compressive strength, young modulus and poisson ratio which can be seen in Table 6.

Table 6. Uniaxial compressive strength test results on 3 samples

Sampel Code	Lithology	Mechanical properties		
		UCS (Mpa)	Young's Modulus (Mpa)	Poisson ratio
ST 02	Diorite	4.02	842.67	0.57
ST 06	porphyry meta-andesite	24.33	2839.11	4.02
ST 09	porphyry meta-andesite	13.48	2080.71	2,.8

From the table above, it can be seen that each test station has a different clustering of compressive strength values. Based on Stapledon's (1986) classification in (Noor, 2021), ST 06 has a medium strong category. While ST 02 and 09 have a weak category. The young's modulus of the test samples has a much different ratio. From the results of the young's modulus analysis obtained, it shows that the most easily deformed is the test sample at ST 02. This happens because ST 02 has the smallest young's modulus value among the three test samples. While the ST 06 has the largest young modulus value among the three test samples which indicates that the station ST 06 is difficult to deform among the three test samples. The poisson ratio value obtained is not included in the clustering of poisson ratio values by Gercek (2007) in Rai, et al (2014). This is thought to be because the rocks at the study site are heterogeneous due to the presence of brittle planes in the test sample outcrops. This is relevant to the results of research conducted by Cahyono, et al (2020) who said that the nature of intact rocks that should be homogeneous, becomes heterogeneous due to the presence of a joint.

After XRD testing, the percentage of rock constituent minerals from the samples that have been tested is obtained. XRD results show that there are only 3 minerals that can be regressed and correlated, are plagioclase, quartz and chlorite minerals. The other minerals read on XRD testing can not be regressed and correlated due to the absence of these minerals in each test sample. The mineral composition and UCS test results that were regressed and correlated can be seen in Table 7.

Table 7. Mineral composition and UCS test results regressed and correlated

Sampel Code	**Mineral composition (%)**			**Mechanical properties**		
	pl	**Qz**	**Chl**	**σc (Mpa)**	**E (Mpa)**	**υ**
ST 02	51.6	33.1	15.3	4.02	842.67	0.57
ST 06	59.7	29.7	8.4	24.33	2839.11	4.02
ST 09	56.1	31.9	8.2	13.48	2080.71	2.8

From the mineral composition and uniaxial compressive strength test results, regression and correlation graphs were obtained. This graph will produce a regression equation that can reflect the effect of the independent variable on the dependent variable. While the resulting coefficient of determination will reflect how much influence the independent variable has on the dependent variable, which in this case is the percentage of minerals that make up the rock and the UCS test results.

Regression and correlation graphs between plagioclase minerals and compressive strength, young's modulus and poisson ratio can be depicted through scatter diagrams that form a linear pattern. This shows that these two variables are positively correlated which can be seen in Figure 14, Figure 15, and 16.

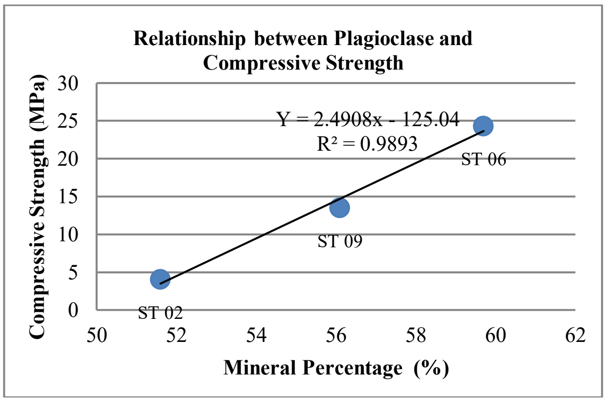


Figure 14. Graph of the relationship between the plagioclase and compressive strength

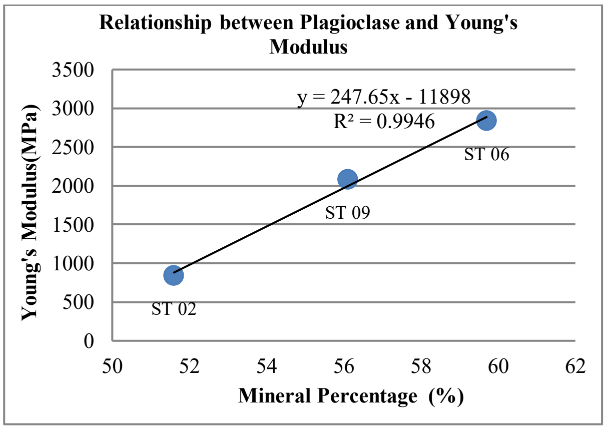


Figure 15. Graph of the relationship between plagioclase and young's modulus

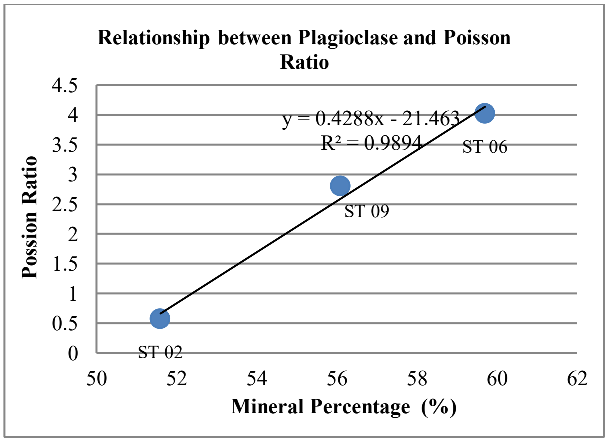


Figure 16. Graph of the relationship between plagioclase and poisson ratio

In contrast to the plagioclase mineral, the regression and correlation analysis of the quartz against the UCS value of the rock forms a linear scatter pattern that is negatively correlated. it can be shown in the graph below.

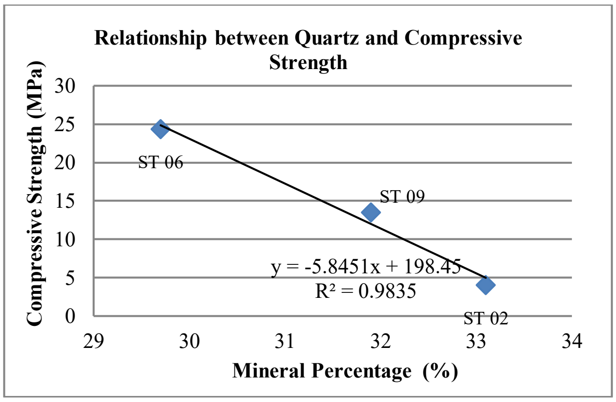


Figure 17. Graph of the relationship between quarzt and compressive strength

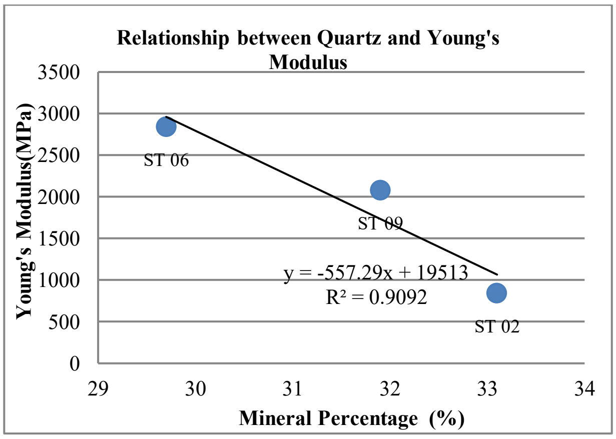


Figure 18. Graph of the relationship between quarzt and young's modulus

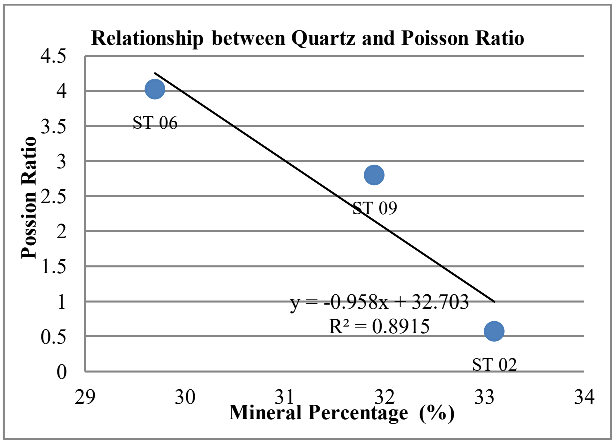


Figure 19. Graph of the relationship between quartz and poisson ratio

Similar to quartz minerals, the regression and correlation analysis of chorite on the Mechanical properties forms a linear scatter pattern that is negatively correlated. This can be shown in the graph below.

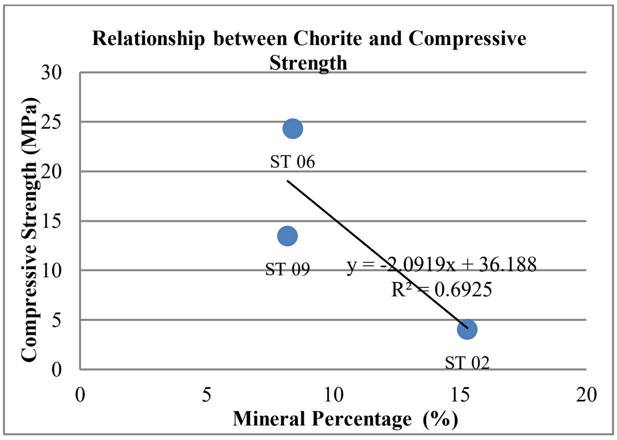
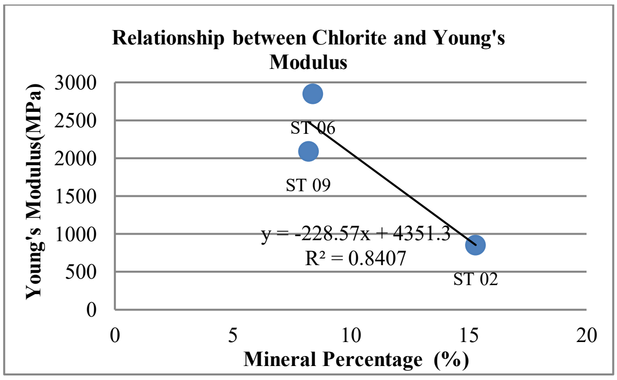
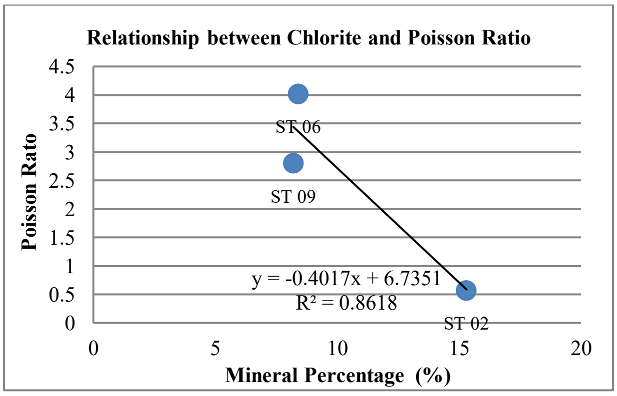


Figure 20. Graph of the relationship between Chorite and compressive strength



Gambar 21. Graph of the relationship between Chorite and young's modulus



Gambar 22. Graph of the relationship between Chorite and poisson ratio

From the results of regression and correlation analysis, it can be seen the relationship between the mineral composition of plagioclase, quartz and chlorite to rock compressive strength, young modulus and poisson ratio. Plagioclase minerals have a correlation coefficient interval between 0.994 - 0.997 on compressive strength, young modulus and poisson ratio. it indicates that the level of relationship between the presence of plagioclase minerals on rock compressive strength, young modulus and poisson ratio based on the classification of the level of relationship by Sugiyono (2017) is very strong. The influence of the presence of plagioclase on compressive strength, young modulus and poisson ratio can be known from the coefficient of determination, which are

98.93%, 99.45% and 98.35%. The results of this analysis also show that these two variables are positively correlated. The higher percentage of palgioclase determine the higher value of Mechanical properties.

In contrast, quartz are negatively correlated with compressive strength, young's modulus and poisson ratio. The less the presence of quartz in the rock, the higher the compressive strength, young's modulus and poisson ratio. Quartz has a correlation coefficient interval between - 0.944 to - 0.992 on compressive strength, young's modulus and poisson ratio. This indicates that the level of relationship between the presence of quartz minerals on rock compressive strength, young modulus and poisson ratio based on the classification of the level of relationship by Sugiyono (2017) is very strong. The influence of the presence of quartz on compressive strength, young modulus and poisson ratio can be known from the coefficient of determination, which is 98.35%, 90.92% and 89.15%. Quartz mineral is a mineral that is resistant to geological processes which in the Mohs Scale has a higher strength value than plagioclase minerals. But from the results of this study, the presence of quartz minerals is considered to reduce the compressive strength of rocks. this is thought to be closely related to the texture of the rock. Quartz minerals are present in the sample as phenocrysts that cause the creation of gaps between minerals that can reduce the compressive strength of the rock. the presence of quartz minerals in the sample can be seen in Figure 23.

Figure 23. Quartz mineral occurrence as phenocrysts in porphyry meta-andesite (a) and diorite (b)

Correlation results of chlorite to compressive strength, young's modulus and Poisson ratio are very strongly correlated. This is based on the resulting correlation coefficient which has an interval of - 0.832 to - 0.928. From the acquisition of this correlation coefficient value, it can also be seen that the presence of chlorite minerals has a negative correlation with rock compressive strength, young modulus and poisson ratio. The higher the presence of chlorite minerals in a rock, the lower the value of rock compressive strength, young modulus and poisson ratio. Based on previous research by Han, et al (1986); He, et al (2019) Jizba, (1992); Tembe, et al (2010) In Chen (2023) said that an increase in chlorite content in rocks can reduce rock strength. This happens because chlorite is a clay mineral that is formed from the alteration of pre-existing minerals. The formation process of chlorite minerals is usually caused by weathering. Chlorite minerals in the test sample have the least amount but have a strong effect on rock strength. The influence of the presence of quartz minerals on compressive strength, young modulus and Poisson ratio can be known from the coefficient of determination which is 69.25%, 84.07% and 86.18%.

When viewed from the density of rocks, plagioclase have a greater density than quartz because plagioclase have a number of metal elements such as sodium (Na), calcium (Ca), silica (Si) and oxygen (O). While quartz minerals contain silica (Si) and oxygen (O). same with chlorite which has chemical elements in the form of iron (Fe), magnesium (Mg) and aluminum (Al). According to Nesse (2000), minerals with heavy metal elements tend to have a higher density due to the greater atomic mass of the metal and a denser crystal structure.

When related to the mechanical properties of rocks, the higher the density of the rock, the greater the density of a material, usually the greater the compressive strength (or compression strength) of the material. But this is not the only factor that affects compressive strength. A high density often indicates that the material has a greater density in a given volume (Baud, et al., 2013). Therefore, to determine the relationship between density and mineral composition, further testing of rock density is required.

CONCLUSIONS AND RECOMMENDATIONS

The mineral composition of ST 02 consists of plagioclase 51.6%, quartz 33.1%, chlorite 15.3%. ST 06 consists of plagioclase 59.7%, quartz 29.7%, chlorite 8.4% and hornblende 2.2%. ST 09 consists of plagioclase 56.1%, quartz 31.9% chamosite 8.2% and heuliandite 3.8%. This mineral composition used as variable x is the mineral plagioclase, quartz and chlorite because these three minerals are present in each test sample.

The uniaxial compressive strength test results show that the compressive strength value of ST 02 is 4.02 MPa, young modulus 842.67 MPa, poisson ratio 0.57. The compressive strength value of ST 06 is 24.33 MPa, young modulus 2839.11 MPa, poisson ratio 4.02. ST 09 has a compressive strength value of 13.48 MPa, young modulus 2839.11 MPa and poisson ratio 2.8. The UCS test results became variable Y or the dependent variable of the study. The poisson ratio value obtained is not included in the poisson ratio classification by Gercek (2007) in Rai, et al (2014) because the test sample is classified into polycrystalline and heterogeneous materials.

The results of regression and correlation analysis show that mineral composition has a very strong effect on the compressive strength value of young's modulus and poisson ratio. The higher percentage of palgioclase determine the higher value of mechanical properties. Instead, the higher percentage of quartz and chlorite determine the lower value of mechanical properties.

ADVANCED RESEARCH

Future research is recommended to conduct mechanical property testing on multiple samples dominated by a particular mineral to isolate and evaluate the influence of each mineral on rock mechanical properties. A larger number of test samples should also be included to improve the accuracy and reliability of the results. Furthermore, future studies may examine other lithological types, such as metamorphic rocks, sedimentary rocks, and other igneous rocks, to increase the variety of minerals that can be correlated with mechanical properties. Additional factors that may influence rock mechanical properties, including rock density, porosity, weathering conditions, and discontinuities at the research location, should also be investigated.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to all parties who supported the fieldwork, laboratory testing, data analysis, and completion of this research. Appreciation is also extended to the institutions and individuals who provided facilities, guidance, and valuable assistance throughout the study.

REFERENCES

Advokaat, E. L., Hall, R., White, L. T., Watkinson, I. M., Rudyawan, A., & BouDagher-Fadel, M. K. (2017). Miocene to recent extension in NW Sulawesi, Indonesia. Journal of Asian Earth Sciences, 147, 378–401. https://doi.org/10.1016/j.jseaes.2017.07.023

Arif, I. (2016). Geoteknik tambang. Gramedia Pustaka Utama.

Arsdin, D. D. A., Purwanto, P., & Ramli, M. (2022). Pengaruh material penyusun lereng batuan terhadap nilai kuat tekan di Daerah Malino, Provinsi Sulawesi Selatan. Jurnal Geocelebes, 6(1), 12–23.

Badan Koordinasi Survei dan Pemetaan Nasional. (1991). Peta rupa bumi Indonesia lembar 2015-32 Palu [Peta, skala 1:50.000].

Baud, P., Wong, T.-F., & Zhu, W. (2014). Effects of porosity and crack density on the compressive strength of rocks. International Journal of Rock Mechanics and Mining Sciences, 67, 202–211.

Brnada, S., Šomođi, Ž., & Kovačević, S. (2019). A new method for determination of Poisson's ratio of woven fabric at higher stresses. Journal of Engineered Fibers and Fabrics, 14, 1–13. https://doi.org/10.1177/1558925019856225

Cahyono, Y. D. G., Utamakno, L., Sasti, S. A., Gabriela, V. Y., Fathurrosyidi, M., & Allobunga, S. (2020). Analisis pengaruh skala terhadap uji kuat tekan uniaksial pada batu andesit. In Seminar Nasional Sains dan Teknologi Terapan VIII 2020 (pp. 77–82). Institut Teknologi Adhi Tama Surabaya. https://ejurnal.itats.ac.id/sntekpan/article/download/1218/982

Chen, Z.-L., Shi, H.-Z., Xiong, C., He, W.-H., Wang, H.-Z., Wang, B., Dubinya, N., & Ge, K.-Q. (2023). Effects of mineralogical composition on uniaxial compressive strengths of sedimentary rocks. Petroleum Science, 20(5), 3062–3073. https://doi.org/10.1016/j.petsci.2023.03.028

Dmitriev, S. V., Shigenari, T., & Abe, K. (2001). Poisson ratio beyond the limits of the elasticity theory. Journal of the Physical Society of Japan, 70(5), 1431–1432. https://doi.org/10.1143/JPSJ.70.1431

Eugster, H. P. (1980). Norman Levi Bowen, 1887–1956. In Biographical memoirs (Vol. 52, pp. 35–79). National Academy of Sciences.

Fenton, C. L., & Fenton, M. A. (1940). The rock book. Doubleday, Doran & Company.

Giannakopoulou, P. P., Petrounias, P., Tsikouras, B., Kalaitzidis, S., Rogkala, A., Hatzipanagiotou, K., & Tombros, S. F. (2018). Using factor analysis to determine the interrelationships between the engineering properties of aggregates from igneous rocks in Greece. Minerals, 8(12), Article 580.

Graha, D. S. (1987). Batuan dan mineral. Nova.

Hamilton, W. B. (1979). Tectonics of the Indonesian region (U.S. Geological Survey Professional Paper 1078). U.S. Geological Survey.

Hanifah, D. A., Santoso, E., & Kartini, K. (2020). Analisis pengaruh tingkat pelapukan terhadap kekuatan batuan: Studi kasus pada batulempung dari Formasi Warukin. Jurnal Himasapta, 5(3), 89–92.

Hinze, W. J., von Frese, R. R. B., & Saad, A. H. (2013). Gravity and magnetic exploration: Principles, practices, and applications. Cambridge University Press. https://doi.org/10.1017/CBO9780511843129

Keikha, T., & Keykha, H. A. (2013). Correlation between mineralogical characteristics and engineering properties of granitic rocks. Electronic Journal of Geotechnical Engineering, 18, 4055–4065.

Mukti, K. (2012). Fabrikasi dan karakterisasi XRD (X-ray diffractometer) [Makalah]. Jurusan Fisika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Sebelas Maret.

Mundir. (2012). Statistik pendidikan. STAIN Jember Press.

Noor, D. (2009). Pengantar geologi. Graha Ilmu.

Noor, D. (2021). Kualitas batuan andesit Gunung Cipinang, Desa Mekarsari, Kecamatan Cikalong Kulon, Kabupaten Cianjur, Jawa Barat sebagai bahan baku konstruksi dasar [Laporan penelitian]. Program Studi Teknik Geologi, Fakultas Teknik, Universitas Pakuan.

Nuryadi, Astuti, T. D., Utami, E. S., & Budiantara, M. (2017). Dasar-dasar statistik penelitian. Sibuku Media.

Paiman. (2019). Teknik analisis korelasi dan regresi ilmu-ilmu pertanian. UPY Press.

Rai, M. A., Kramadibrata, S., & Wattimena, R. K. (2014). Mekanika batuan. Institut Teknologi Bandung.

Sugiyono. (2017). Metode penelitian kuantitatif, kualitatif, dan R&D. Alfabeta.

Sukamto, R. (1973). Peta geologi tinjau lembar Palu, Sulawesi [Peta geologi, skala 1:250.000]. Pusat Penelitian dan Pengembangan Geologi.

Surono, & Hartono, U. (2013). Geologi Sulawesi. LIPI Press.

Travis, R. B. (1955). Classification of rocks. Quarterly of the Colorado School of Mines, 50(1), 1–98.

Tuğrul, A., & Zarif, I. H. (1999). Correlation of mineralogical and textural characteristics with engineering properties of selected granitic rocks from Turkey. Engineering Geology, 51(4), 303–317.

U.S. Geological Survey. (2007). Facing tomorrow's challenges—U.S. Geological Survey science in the decade 2007–2017 (U.S. Geological Survey Circular

van Bemmelen, R. W. (1949). The geology of Indonesia: Vol. IA. General geology of Indonesia and adjacent archipelagoes. Government Printing Office.

van Zuidam, R. A. (1985). Guide to geomorphologic aerial photographic interpretation and mapping. International Institute for Aerospace Survey and Earth Sciences.