The Relevancy of Mineral Composition to Rock Shear Strength in Kaliwadas Hills, Karangsambung, Kebumen

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Abstract. The occurrence of landslides on the slopes due to a decrease in shear strength in the area of landslides in the limestone hills of Kaliwadas, Kebumen, Central Java, causes public facilities to be damaged and disrupting the activities of everyday citizens. Factors that influence rock shear strength are cohesion value and internal friction angle, while mineralogy and grain size is one of the factors derived from the environment which also affects the shear strength value. This study aims to determine the effect of mineral composition and grain size on rock shear strength. A number of rock samples were taken from the study site to be prepared, cylindrical samples for direct shear and petrographic strength tests with thin incision samples. Direct shear test results provide cohesion values and deep shear angles in limestone with peak and residual conditions of 0.22 Mpa and 39.73 ° respectively; 36.61 kPa and 29.28 ° while in claystone 67.86 kPa and 25.36 °; 13.41 kPa and 16.17 °. Petrographic analysis of rocks shows that limestone contains calcite (88%) and quartz minerals (5%), while claystone contains calcite (91%) and quartz minerals (2%). Based on the mineral content of limestone and claystone and their effect on rock shear strength, it can be concluded that limestones have a quartz mineral composition, cohesion values and deep shear angles that are better and larger when compared to rock shear strength in claystone and believed to be the cause of the slip field in the research location.

Keyword : slope, direct shear, mineralogy, thin section, petrography

1. Introduction
Karangsambung is a Sub-District in Kebumen Regency, which is an area that have a geological phenomena and various rare and unique types of rocks such as igneous, sedimentary and metamorphic rocks [1]. The rock has different types of minerals, for examples : calcite, chromite [2], quartz, kaolin and other minerals that can be used as natural resources as a raw material to synthesis inorganic material by various methods, for example hydrothermal method [3]. The inorganic material that has been synthesized can be used as textile dyes adsorbent [4], catalyst [5,6] or photocatalyst [7,8,9] for drying agents depend on their chemical and physical properties. On the other hand, the mechanical strength of rocks come from strength properties or resistance to external forces, the strength of rock depends on the composition of the mineral. Each mineral that compose rock has specific different for chemical and physical properties [10]. Among minerals that contained in rocks, quartz is a compact mineral with compressive strength reaching more than 500 MPa. Generally, the strength of rock in line with higher mineral content of quartz in rocks. Hardness and strength of rock are classified by the Fredrich van Mohs scale (1882). This study aims to determine the effect of mineral composition on
rock shear strength. The mechanical strength of rock were measured directly using shear strength test to get cohesion value (c) and deep shear angle (°). Petrographic analysis was carried out to determine the mineralogical composition contained in rocks [11].

2. Research Methodology
2.1. Sampling of Rocks
Samples of rocks obtained were taken in various outcrops around the limestone hills of Kaliwadas, Karangsambung, Kebumen, Central Java. The location of research sample point can be seen in Figure 1.

![Figure 1. The sampling location of rocks](image1.png)

2.2. Rock Sample Preparation
Samples that have been taken from the research location then prepared according to the testing requirement. For direct shear strength test, the sample is prepared in a cylindrical form with a coring tool which is carried out in the Trisakti geomechanics laboratory, Jakarta which can be seen in Figure 2.

![Figure 2. Sample in the cylindrical shape for testing shear strength](image2.png)

Figure 3. Samples with Thin Section
Petrographic analysis, the sample was sliced by sharpening the rock until thickness of sample reach ± 0.03 mm [12]. Sample prepared in the Obsidian laboratory, Bandung which can be seen in Figure 3.

2.3. Results of Rocks physical Properties Test

The results of rocks physical properties test in both lithology, namely limestone and claystone. The obtained physical properties of rocks such as natural content weight, dry content weight, saturated content weight, original moisture content, and porosity. These data is used as a parameter for the analysis of slope stability [13] and its relevancy to the mineral composition of rock in the research site which can be seen in Table 1.

| No | Rocks         | Real content weight (gram/cm³) | Saturated content weight (gram/cm³) | Dry content weight (gram/cm³) | Real water content (%) | Porosity (%) |
|----|---------------|--------------------------------|------------------------------------|-------------------------------|------------------------|--------------|
| 1  | Limestone 1   | 2.02                           | 2.06                               | 1.85                          | 9.61                   | 21.77        |
| 2  | Limestone A   | 2.13                           | 2.21                               | 1.89                          | 12.55                  | 31.65        |
| 3  | Limestone B   | 2.07                           | 2.15                               | 1.84                          | 12.16                  | 30.6         |
| 4  | Limestone C   | 2.03                           | 2.08                               | 1.76                          | 15.47                  | 32.27        |
| 5  | Claystone     | 1.65                           | 1.73                               | 1.32                          | 24.45                  | 40.45        |

Based on the results of physical properties, there are differences in the weight value of the content of limestone and claystone due to lithological differences, in which claystone absorbs free water and expands in such a way that it becomes softer. The longer the clay is submerged, the condition becomes softer, thus decreasing the stability of the slope. This condition is critical for slopes which have a thick clay layer at the bottom of the slope.

2.4. Results of Rock Shear Strength Test

From the test results, the direct shear strength of the rock can be seen in Table 2. The cohesion and deep shear angle values for limestone at peak conditions ranged from 180 to 270 kPa for cohesion and 36 ° to 42 ° while in residual conditions 29 to 45 kPa for cohesion and 26 ° to 32 ° respectively. Claystone at peak conditions ranged from 58 to 77 kPa for cohesion and 24 ° to 27 ° while in residual conditions 12 to 15 kPa for cohesion and 15 ° to 17 °. From the results of the direct shear strength test obtained in two lithologies namely limestone and claystone there is a significant difference in value where in claystone is very low compared to limestone which is believed that claystone is the slip field on slopes that experience landslides [14].

| Unit   | Sample Code | Peak | Residual |
|--------|-------------|------|----------|
|        |             | C (kPa) | Φ (°) | C (kPa) | Φ (°) |
| Limestone | BG-1        | 268.87 | 41.57  | 45.41  | 29.83 |
|         | BG-A        | 221.44 | 40.80  | 34.78  | 31.93 |
|         | BG-B        | 184.18 | 36.57  | 29.02  | 26.57 |
|         | BG-C        | 205.63 | 40.00  | 37.24  | 28.80 |
| Claystone | CL-1        | 77.28  | 26.50  | 14.82  | 16.83 |
|         | CL-2        | 24.21  | 24.21  | 12.00  | 15.51 |
2.5. Results of Petrographic Analysis

From the results of petrographic analysis, observations were made with a special microscope, namely polarized light microscopy [15]. This method used polarized light at the bottom of the microscope that fired towards the objective lens.

The difference between polarized light microscopy with other is that there are 2 methods of observation in the form of plane polarized light and cross polarized light. The study used Nikon eclipse E200 Microscope. Observations can be seen in Figure 4 and Table 3 for mineral composition. Based on petrographic observations on limestone, the mineral composition of calcite ranges from 85% to 90% and quartz minerals 4% to 6% while claystone has 91% calcite minerals and 2% quartz minerals. Based on those result, there isn’t clear difference between both lithologies, namely limestone and claystone, quartz mineral limestone is greater than + 3% from claystone, indicating that quartz mineral has the most role in rock shear strength compared to calcite minerals.

| No | Lithology | Mineral Composition |
|----|-----------|---------------------|
|    |           | Quartz (SiO₂) | Calcite (CaCO₃) | Other Minerals |
| 1  | Claystone | 2%            | 91%            | 7%             |
| 2  | Limestone 1 | 6%        | 88%            | 6%             |
| 3  | Limestone A | 5%        | 87%            | 8%             |
| 4  | Limestone B | 4%        | 90%            | 6%             |
| 5  | Limestone C | 5%        | 85%            | 10%            |

Figure 4. Petrographic Observation on Limestone Samples

3. Analysis and Discussion

Based on the results of direct rock shear strength test and petrographic observations on each rock sample, can be assembled into a graph to determine the effects of rock mineral composition on rock shear strength.

Based on the results of calcite mineral composition on limestone and claystone lithology, it was found that the difference of mineral composition percentage was not too great at 85% to 90% in limestone and claystone at 91%. From the value of limestone cohesion and claystone has a significant difference that limestone has cohesion value of 184 kPa up to 270 kPa and claystone 77 kPa for cohesion. Based on the influence of calcite mineral composition with rock cohesion in Figure 5, it was
not very influential because calcite mineral has a hardness level of Mohs’ scale of 3 including minerals that are soft enough.

![Graphic of Relevancy Calcite Mineral vs. Rock Cohesion Value](image1)

**Figure 5.** Graphic of Relevancy Calcite Mineral vs. Rock Cohesion Value

Based on the results of quartz mineral composition in limestone and claystone lithology, evidently it has a different mineral composition in limestone of 4% -6% and claystone is only 2%. From the value of limestone and claystone cohesion has a significant difference that limestone has cohesion value of 184 kPa up to 270 kPa and claystone 77 kPa.

![Graphic of Relevancy Quartz Mineral vs. Rock Cohesion Value](image2)

**Figure 6.** Graphic of Relevancy Quartz Mineral vs. Rock Cohesion Value

Based on the effect of quartz mineral composition with the value of rock cohesion in Figure 6, it caused a strong relevancy, an increase in quartz minerals causing an increase in the value of cohesion because quartz minerals are stable minerals and have a hardness level of 7 Mohs’, including hard enough minerals.
4. Conclusion
Based on the results of the analysis, some conclusions can be drawn as follows:
1. Results of direct shear test provide cohesion and shear angle values in limestone at peak and residual conditions of 220 kPa and 39.73 °; and 37 kPa and 29.28° respectively,
2. Results of direct shear test provide cohesion and shear angle values in claystone at peak and residual conditions of 67.86 kPa and 25.36 °; 13.41 kPa and 16.17° respectively,
3. Based on the effect of calcite mineral composition (CaCO₃) with the value of rock cohesion it is not very influential because calcite minerals have a level of mohs’ scale hardness of 3 including soft enough minerals.
4. The increase in quartz mineral (SiO₂) causes an increase in of the cohesion value because the quartz mineral is a stable mineral and has a hardness level of 7 mohs including minerals that are quite hard

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