The effect of water immersion on compressive strength of Senoni stone, East Kalimantan

Eswan¹, Adisasmita S A¹, Ramli M I¹ and Rauf S¹
¹Department of Civil Engineering, Faculty of Engineering, Universitas Hasanuddin, Gowa, South Sulawesi, Indonesia
Email: eswanstmt@gmail.com

Abstract. This study aims to analyze the compressive strength value of Senoni stone, East Kalimantan and its effect on water immersion. Free compressive strength testing is carried out at 25oC. The number of cylindrical and cube specimens for free compressive strength test each of 3 specimens. Compressive strength testing using the Universal Testing Machine (UTM). The results showed that the compressive strength of Senoni stones decreased due to water immersion. This shows that the stone of Senoni, East Kalimantan is not resistant to water.

1. Introduction

In general, not all regions have sufficient aggregate reserves in quantity and in accordance with applicable quality standards, so that to meet the increasing demand for road materials is done by bringing aggregates from other places, as has happened in East Kalimantan Province so far, where aggregates used in road works and other construction, imported from Central Sulawesi Province. As one of the developing provinces, one of the indicators and factors that can support equitable development is the availability of good infrastructure and land transportation infrastructure, so that the flow of people and goods can be faster and better.

As the main material in pavement, the aggregate has a very important role, where the aggregate occupies the largest proportion in the mixture which generally ranges from 75% - 85% of the total volume of the mixture, so one of the considerations in planning, design in the implementation of road works is the availability of aggregates, aggregate prices and aggregate quality that meets the requirements, whereas standard aggregates derived from nature such as rocks and sand are generally used as material for road foundation layers or asphalt mixtures [1].

According to Central Statistics Agency (BPS) data, East Kalimantan Province has a length of a National Road section, 1,493.68 km consisting of 1,357.25 km of paved roads, 63.27 km of roads with rigid pavement and 73.16 km of aggregated roads or land. This data, of course, continues to increase and is not covered, including roads managed by Regencies and Cities [2].

Characteristics of rock aggregate characteristics for road construction needs include Los Angeles abrasion value, specific gravity, water absorption rate, aggregate adhesion, broken grains on coarse aggregate, and aggregate flakes. While rock compressive strength parameters are not used as a physical characteristic to be an aggregate eligibility requirement. In rock mechanics and rock engineering, compressive strength is suggested to be one of the most important rock mechanical properties that is generally used to design the structure and characteristics of rock material [3]. Apart from the value of the compressive strength free of the next rock to determine rock resistance, one of the tests that can be applied is by water immersion [4].

Based on the above considerations, this study was conducted with the aim of analysing the effect of water immersion on the free compressive strength value of Senoni stones, East Kalimantan.
2. Materials and methods

2.1. Physical properties of Senoni stone, East Kalimantan

The table 1 shows the physical characteristics of the Senoni stone, East Kalimantan.

| Properties                              | (Crushed Stone) |
|-----------------------------------------|-----------------|
|                                         | 0.5 - 1 (cm)    | 1 - 2 (cm)    |
| Water absorption, %                     | 2.26            | 2.28          |
| Bulk specific gravity                   | 2.67            | 2.67          |
| Saturated surface dry specific gravity  | 2.69            | 2.69          |
| Apparent specific gravity               | 2.80            | 2.80          |
| Flakiness index, %                      | 22.10           | 11.38         |
| Abrasion aggregate, %                   | 20.92           | 18.56         |

2.2. Chemical properties of Senoni stone, East Kalimantan

Chemical characteristics of the Senoni stone are carried out by XRD (X-Ray Diffractometer) testing. Figure 1 shows the results of testing the chemical characteristics of the Senoni stone, East Kalimantan. Based on Figure 1 it can be seen that Senoni stone, East Kalimantan is dominated by Fe$_3$O$_4$ (Ferrooxide), which is at an intensity of around 20 cps, CaO (calcium oxide) at an intensity of about 15 cps, CaCO$_3$ (calcium carbonate) at an intensity of around 7 cps and Fe (ferro) at intensity of around 5 cps.

2.3. Compressive Strength Test

Compressive strength testing is carried out at 25°C. The number of cylindrical and cube specimens for free compressive strength test each of 3 specimens. Free compressive strength testing using the Universal Testing Machine (UTM). The Senoni stone free compressive strength testing scheme is shown in figure 2.
The previous study suggested testing of natural rock UCS using cube specimens with side sizes of 70 (± 5) mm or 50 (± 5) mm [6]. For free compressive strength testing using cylindrical specimens, according to Test Method T229, specimens which have a height and diameter ratio between 2-2.5 and the diameter of the specimen is not less than 45 mm.

The previous study also suggested that the ratio of height and diameter of cylindrical test specimens is between 2.5 - 3 and the minimum diameter of specimens are 54 mm [7]. However, others research was recommending that the ratio be between 2 - 2.5 and the diameter of the test specimen is around 47 mm [8].

The free compressive strength test sample of Senoni stone in this study is in the form of a cube with a size of 50 x 50 x 50 mm. Free compressive strength testing is carried out under dry conditions and immersion conditions for 1 x 24 and 2 x 24 hours. The number of test samples for each form of test specimen is 3 test specimens.

2.4. Compressive Strength Test
In general, the free compressive strength, calculated using equation (1).

$$\sigma = \frac{P}{A}$$

with:

- $\sigma$ = compressive strength of the test object (MPa)
- $P$ = maximum load (N)
- $A$ = Cross-sectional area (mm$^2$)

The free compressive strength of cube test specimens, $\sigma_k$, and the free compressive strength of cylindrical test specimens $\sigma_s$, can be calculated by equation (2).

$$\sigma_k = \frac{P}{t^2}$$

with:

- $\sigma_k$ = compressive strength of the test object of cube specimens (MPa)
- $P$ = maximum load (N)
- $A$ = Cross-sectional area (mm$^2$)

3. Results and discussion

3.1. Specific Gravity and Water Absorption
The density of a cube stone test object is relatively the same as the density of the coarse aggregate of the stone. Pseudo density, SSD specific gravity and bulk density of cube stone test specimens are 2.64 gr/cm$^3$, 2.70 gr/cm$^3$ and 2.83 gr/cm$^3$, respectively. The water absorption of cuboid Senoni stone specimens is 2.15%. Table 2 shows the value of specific gravity and water absorption of the cuboid Senoni stone.

| Properties                        | Senoni stone |
|-----------------------------------|--------------|
| Water absorption, %               | 2.15         |
| Bulk specific gravity             | 2.83         |
| Saturated surface dry specific gravity | 2.70     |
| Apparent specific gravity         | 2.64         |
3.2. Compressive Strength Test

The results of the free compressive strength test of cube test objects without immersion are shown in Table 3.

**Table 3. Results of the compressive strength of Senoni stone (cube specimens).**

| No. | Dimension of test object | Weight (gr) | Load (kN) | Compressive strength (MPa) |
|-----|--------------------------|-------------|-----------|---------------------------|
|     | P (mm) | L (mm) | T (mm) | 283.4 | 54.72 | 18.11 |
| 1   | 51      | 51     | 50     | 282.6 | 73.48 | 24.20 |
| 2   | 51      | 51     | 51     | 286.2 | 93.62 | 37.45 |
|     | Average |        |         |       |       | 26.58 |

Based on Table 3, it can be seen that the average compressive strength of cube-shaped specimens is 26.58 MPa. Based on the rock classification, the compressive strength of the Senoni stone used in this study is included in the category C category with the compressive strength of the free cube test specimens between 12-28 MPa [8].

3.3. Compressive Strength Test

**Table 4. Immersion effect of compressive strength value of Senoni stone (cube specimens).**

| No. | Dimension of test object | Weight (gr) | Load (kN) | Compressive strength (MPa) |
|-----|--------------------------|-------------|-----------|---------------------------|
|     | P (mm) | L (mm) | T (mm) | 282.4 | 11.46 | 9.13 |
| 1   | 50      | 50     | 51     | 281.6 | 11.54 | 5.97 |
| 2   | 50      | 50     | 50     | 284.3 | 11.54 | 5.83 |
|     | Average |        |         |       |       | 6.97 |

**Table 4. Immersion effect of compressive strength value of Senoni stone (cube specimens).**

**Table 4. Immersion effect of compressive strength value of Senoni stone (cube specimens).**

| No. | Dimension of test object | Weight (gr) | Load (kN) | Compressive strength (MPa) |
|-----|--------------------------|-------------|-----------|---------------------------|
|     | P (mm) | L (mm) | T (mm) | 282.7 | 28.86 | 4.26 |
| 1   | 50      | 50     | 50     | 281.6 | 17.86 | 1.68 |
| 2   | 50      | 50     | 51     | 289.8 | 26.52 | 3.68 |
|     | Average |        |         |       |       | 3.20 |

The results of the free compressive strength test of cube specimens with immersion for 1 × 24 and 2 × 24 hours are shown in Table 4.

By using equation (2), the average maximum free compressive strength of the dry cube test specimen is 65.49 MPa and the average maximum free compressive strength of the cube test object is 54.08 MPa. The ratio of the free compressive strength of immersion specimens to dry specimens was 0.83. Thus, the effect of immersion on cube specimens for 2 days caused a decrease in free compressive strength of 17%.

The modulus of elastic stiffness of the dry cube test specimen is 4,942 MPa, and the cube immersion test object is 4,702 MPa. The ratio of modulus of elastic stiffness of immersion test specimens to dry specimens is 0.95. Thus, the effect of immersion on cube test specimens for 2 days caused a decrease in elastic stiffness modulus of 5%.
The average maximum free compressive strength of the cube specimen with a side of 50 mm is 65.49 MPa. Meanwhile, by using equation (3), the average maximum free compressive strength of cylindrical specimens with a diameter of 45 mm and the ratio between height and diameter of 2.14 is 38.58 MPa. Therefore, the ratio of the compressive strength of the specimen to the cube specimen is 0.59 or the ratio of the compressive strength of the specimen to the specimen is 1.69. For specimens that use brittle or brittle material such as concrete, other studies have found that the compressive strength of 75 mm cores is 0.693 times the compressive strength of cubes (150 mm x 150 mm x 150 mm), The compressive strength of 75 mm diameter core specimens is 0.528 times that of cube test pieces (100 mm x 100 mm x 100 mm), and the compressive strength of 48mm diameter core specimens is 0.724 times the cube compressive strength (150 mm x 150 mm x 150 mm).

The average modulus of elastic stiffness of dry matter test specimens is 4,942 MPa. Using equation (8), the average rigidity of the cylindrical test specimen is 12,859 MPa. Therefore, the ratio of the modulus of rigidity of the cylindrical specimens to the cube specimens is 2.6 or the ratio of the modulus of elastic stiffness of the cube specimens to the modulus of rigidity of the specimens is 0.385.

4. Conclusions
The results showed that the compressive strength of the free Senoni stone is influenced by the influence of immersion and changes in the shape of the test specimens. As a result of immersion, the free compressive strength of Senoni stones was reduced to 83% of the dry conditions and the modulus of rigidity of the immersion test specimen was reduced to 95% of the dry specimens. Meanwhile, due to the difference in the shape of the test specimens, it was found that the compressive strength of cubeshaped Senoni stones was 1.69 times that of the cylindrical test specimens, and the modulus of rigidity of the Senoni cube stones was 38.5% of the modulus of rigidity of coronary Senoni stones.

References
[1] Rondonuwu F 2013 Pengaruh Sifat Fisik Agregat terhadap Rongga dalam Campuran Beraspal Panas, Jurnal Sipil Statik 1 (3): 1–6.
[2] AASHTO American Association of State Highway and Transportation Officials 1998 Standard Spesification for Transportation Materials and Methods of Sampling and Testing Part I Spesifications 19th edition Washington D C
[3] AASHTO American Association of State Highway and Transportation Officials 1998 Standard Spesification for Transportation Materials and Methods of Sampling and Testing Part II Tests 19th edition Washington D C
[4] PSDG-ESDM-RI 2013 Laporan Pemuktahiran Data dan Neraca Sumber Daya Mineral
[5] ASTM D 2938 79 1990 Standard Method of test for unconfined compressive strength of rock core specimens Annual book of ASTM Standard part 19 440-443
[6] EN 1926 2006 Natural stone test methods—determination of uniaxial compressive strength European Committee for Standardization 20p
[7] ISRM 1979 Suggested methods for determining the uniaxial compressive strength and deformability of rock materials Int J Rock Mech Min Sci 16 (1979) 135–140
[8] Bowen O E and Evans J R 1973 The Mineral Economic of The Carbonate Rock The Original Chemical and Mineral Content and Distinguishing Characteristics of limestone and dolomite Limestone and Dolomite Resource of California. Buletin 194 California Devison of Mines and Geology Sacramento