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The Investigation of Mudrock Disintegration: Case Study at Hambalang Area, Bogor, West Java

Investigasi Disintegrasi Batuan Lumpur: Studi Kasus Daerah Hambalang, Bogor, Jawa Barat

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Abstract - Many infrastructure buildings are on mudstone. The Hambalang area is an area that has projected infrastructure buildings such as the Puncak II road that is projected to connect the Bogor-Cianjur strategic area. Engineering issues may stem from a hazardous material related to existing mudrock. Mudrock can be studied through the disintegration behavior of wetting and drying processes. The research examined the mudrock disintegration of several samples in the studied area. Outcrops in the field were recorded and then sampled by the standard pack. This test mainly needs rock samples weighing 450-550 grams, dried in the sun for the length of the day. The sample was then immersed in a glass filled with water for 1 x 24 hours. The standard properties tests were also carried out to obtain such physical parameters from moisture content, dry density, and void ratio, until absorption. According to the disintegration parameter, the sample explicitly indicates the massive disintegration of each cycle. Most of the samples started to experience a marked disintegration after the first cycle and have mostly fragmented to an angular shape. With the application of the correlation line, dry density significantly affects the mudrock disintegration.

Keywords: Engineering issue, Hambalang, mudrock disintegration, wet-dry cycle.

Abstrak *- Banyak bangunan infrastruktur berada di atas batuan lumpur. Hambalang merupakan kawasan yang memiliki kegiatan infrastruktur seperti jalan Puncak II yang diproyeksikan untuk menghubungkan kawasan strategis Bogor-Cianjur. Isu keteknikan muncul berkaitan dengan material yang berbahaya dari batuan lumpur yang ada. Batuan lumpur dapat dipelajari melalui perilaku disintegrasi pada siklus pembasahan dan pengeringan. Penelitian ini mengkaji disintegrasi batuan lumpur dari beberapa sampel di daerah penelitian. Singkapan di lapangan dicatat dan kemudian diambil sampelnya dengan cara standar. Pengujian membutuhkan sampel batuan seberat 450-550 gram, untuk dikeringkan di bawah sinar matahari sepanjang hari. Sampel kemudian direndam dalam gelas berisi air selama 1 x 24 jam. Pengujian properti fisik juga dilakukan untuk mendapatkan parameter kadar air, densitas kering, dan angka pori, hingga absorpsi. Menurut parameter disintegrasi, sampel secara eksplisit menunjukkan disintegrasi masif dari setiap siklus. Sebagian besar sampel mulai mengalami disintegrasi yang nyata setelah siklus pertama dan sebagian besar terfragmentasi menjadi bentuk menyudut. Melalui analisis garis korelasi, densitas kering berpengaruh signifikan terhadap disintegrasi batuan lumpur.*

Kata kunci*: isu keteknikan, Hambalang, disintegrasi batuan, siklus kering-basah.*

BACKGROUND

In a construction project, mudrock is a soft sedimentary rock with fine grain material that rapidly breaks in a short period when experiencing contact with the hydrosphere and atmosphere (Dick &Shakoor, 1992; Gautam, 2013; Sadisun *et al*., 2005; Misbahudin & Sadisun, 2019). These rocks have severe problems for the engineering infrastructure before and after construction. Many engineering works are built on and in materials related to mud rock. Zhang & Gao (2020) revealed red-bed soft rocks that occupy significant areas in China and are often used as road embankment material. On the one hand, the disintegration of such rocks often causes serious impact problems on the bottom of the road and is the cause of the decline in infrastructure stability. On the other hand, the Hambalang area is an area that projects engineering work such as this area will be traversed by the Bogor-Cianjur strategic route, namely Puncak II Road. Sani *et al.* (2017) reported that the engineering problems mainly stem from hazardous material related to mud rock and derivated products.

Many suggestions have been proposed to investigate mudrock disintegration against weathering. The second cycle slake-durability index test standard (I_{d2}) is widely applied to determine rock durability (ISRM, 1981). This test's limitation is due to the overestimated value for the soft and weak rock. After the test reaches the second cycle, these samples will be slaked. This condition causes difficulty in obtaining detailed characteristics. Mud rocks can be investigated their characteristics in disintegration by wet-dry tests, and this test gives the minimalization of forces from apparatus (Moon and Beattie, 1995; Sadisun *et al*., 2005; Erguler, 2007; Erguler & Ulusay, 2009; Misbahudin & Sadisun, 2019).

Some researchers have carried out wetting and drying tests (Sadisun *et al*., 2005; Erguler and Ulusay, 2009; Misbahudin and Sadisun, 2019), each having modifications that are adapted to the state of the sample. Liu *et al.* (2022) state that disintegration affects many material properties. Rock with high durability would be related to a high degree of induration reflected by dry density and void ratio. On the other hand, the low durability of rock is related to a large amount of expansive mineral content, which is indicated by absorption (Dick *et al*., 1994).

This research intends to characterize the physical disintegration of mudrock samples to weathering by physical observation and quantitative assessment.

The research also includes the investigation of the influence of physical properties on the disintegration value.

Sampling Points

The research begins with the field investigation, carried out through undisturbed sampling. Yellow points in Figure 1 draw the location of the sampling. The outcrops of rock samples are on slopes and riverbeds.

The sampling location is included in the geological map of the Bogor Quadrangle with a scale of 1:100000 (Effendi *et al*., 1998) (Figure 2). The samples are part of the Jatiluhur Formation (Tmj) which consists of marl, clay-shale, and intercalation of quartz sandstones, increasingly sandy towards the east. This formation is Early Miocene in age.

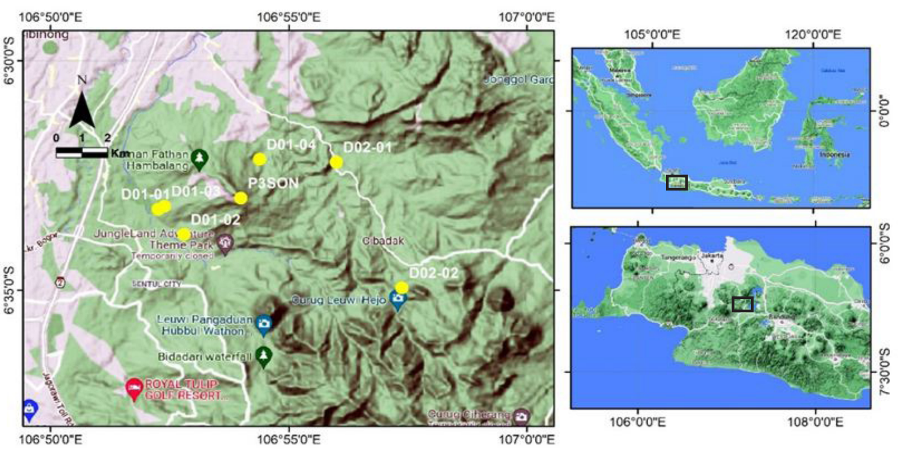
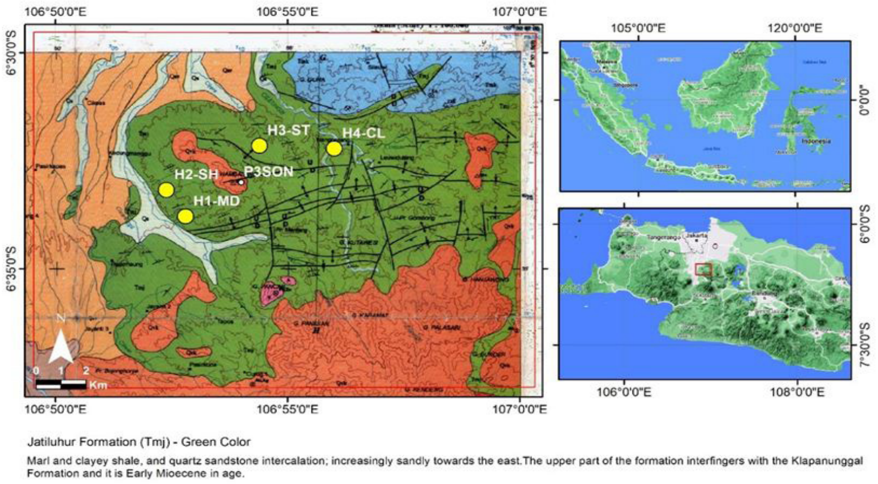


Figure 1. The location of the sampling is shown by a yellow point. Sampling was collected from Hambalang Area, Bogor, West Java, Indonesia (Map Data, 2021).



source: Effendi et al., 1998

Figure 2. The sample in this study is part of the Jatiluhur Formation, dominated by clayey content

METHODS

The sampling process followed the procedure by Clayton *et al*. (1987). Sampling is attempted not to take part in the colluvial. The sample is first excavated with a thickness of 0.5-1 m or a sample depth that does not show cracks. The bottom or top of the layer will be marked on the sample. The samples were then wrapped using wrap and aluminum foil. The sample consisted of weathered andesite soil, claystone, and siltstone. Standard megascopic descriptions observe the determination of rock names.

In the laboratory examination, each sample was prepared with a weight of 450-550 g. Dry-wet processes will test this sample. The test was carried out for up to 15 cycles and started with the sample in a dry condition that underwent sun-dry exposure for two days. The temperature ranges from 25-39°C. Each cycle starts from the dried sample, then undergoes immersion for 24 hours in a water-filled beaker at a temperature of 22-25°C. After the immersion is complete, the sample is dried again.

Samples that have passed each cycle will undergo further disintegration into large and small fragments. The fragments were then sieved using a 2 mm mesh (#10). The fragments retained in mesh #10 will be continued to the next cycle and processed for dry weight calculation. Physical observation of the wetting-drying process and disintegrated fragments is described for each cycle. The disintegration characteristic is evaluated through an index that is calculated by:

$$D_i = \frac{W_t}{W_o} x\ 100$$

Di is the disintegration index (%), Wt is the sun-dry weight of the sample retained on a 2 mm sieve after cycle (g), and Wo is the initial sun-dry weight (g).

In addition, the physical properties of rocks were tested. This testing standard refers to ISRM 2007 suggested methods (laboratory tests) part 1 SM for determining water content, porosity, density, absorption, and related properties.

RESULT AND DISCUSSION

Most samples undergo physical disintegration of the sample body into the angular fragment. However, the field's disintegration and the laboratory have different rates due to other treatment and environmental settings.

Field Characteristics

Sample D01-01 was found in the local mining site outcrop as a weathering product of the andesite. The soil is silty clay, yellowish-brown, soft, and with medium plasticity. Sample D01-02 is on a slope of Jalan Puncak II planning road in dry condition, and the outcrop shows surface erosion and a considerable amount of mudrock colluvial. The megascopic description is silty claystone, gray, layered, conchoidal, shaly, and brittle.

Sample D01-03 was collected at the riverbed located on the roadside. The road foundation is unstable due to the mudrock composition in the base that cracks and disintegrates. The sample is claystone, gray, conchoidal, brittle, and shaly. Sampling D01-4 was conducted on dry riverbeds in the local industrial area an outcrop of siltstone, gray, well-sorted, close-packed, conchoidal, and high compactness.

Sample D02-01 was taken at the riverbed exposed under the bridge as silty claystone, slightly wet, gray, and layered. The sample D02-02 is highly fractured with calcite veins located in the riverbed on the edge of rice fields. The sample was claystone, gray, slightly wet, conchoidal, and brittle. The condition of each of the outcrops is shown in Figure 3.

Dry-Wet Cycle Observation

During the initial drying, the predominant sample did not disintegrate. Therefore, the condition of the sample is virtually unchanged from the natural state. Sample D01-01 is still intact with a soft to moderately stiff consistency. The D01-02 sample is brittle characteristic, intact, and has no cracks. The sample D01-03 shows two hairline cracks same orientation with falling mud. D01- 04 high compactness, intact, and no cracks. D02-01 brittle, no cracks, minor spalling. D02-02 brittle, one crack, minor spalling. Figure 4 shows the sample condition after being dried for the initial step.

Furthermore, each sample was subjected to a dry-wet cycle or up to 15 cycles. At the beginning of immersion in cycle 1, most of the samples disintegrated. This deterioration may have been triggered by pores and previous cracks in the sample. They served as a pathway for water to enter the rock body and eventually disintegrate the sample. For example, sample D01-01 shows a few suspended mud particles, but the sample is still intact. Sample D01-02 shows two cracks, producing angular fragments and disintegration breaks to half of the body.

Sample D01-03 shows a small amount of suspended mud, much spalling, and two sets of cracks. Sample D01-04 has a little mud and one spalling fragment

Figure 3. Condition of outcrops where samples were collected. Mudrocks are mostly disintegrated, conchoidal, and intensely cracked

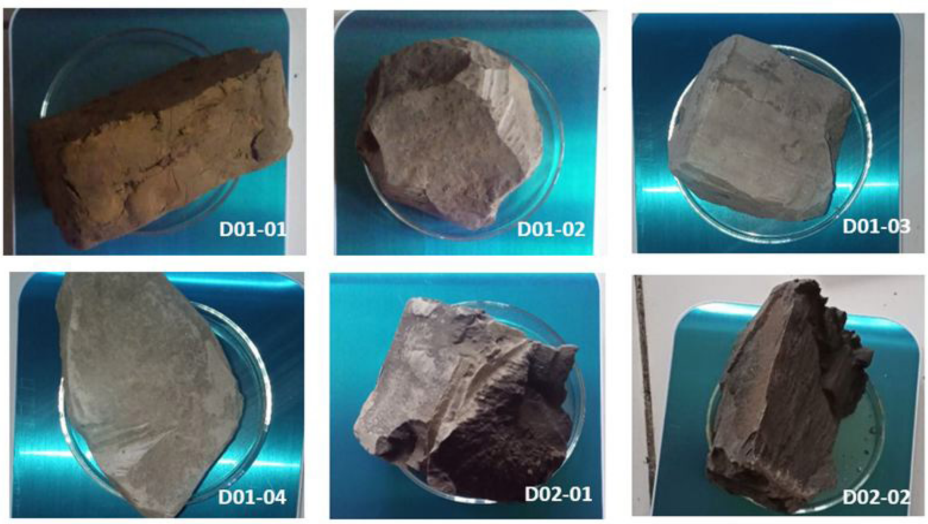


Figure 4. Samples that have been sun-dried before the dry-wet cycle test.

with two cracks, but most of the body is still intact. This condition differs from sample D02-01, which has noticeable suspended mud, major spalling with medium to large fragments, and two set cracks. The sample D02-02 shows noticeable mud, major spalling, small to medium fragments, angular, and multiple cracks. Figure 5 showed the condition of the sample when it was immersed in cycle 1.

The dry-wet test will show a different degree of disintegration in each sample. Most of the samples will experience complete disintegration after passing the first cycle. Sample D01-01 underwent complete disintegration after passing the second cycle. Sample D01-04 began to experience noticeable deterioration after passing the third cycle. Table 1 shows the condition of the dry sample after passing the 5th cycle, 10th cycle, and 15th cycle tests. Only D01-04 showed half of the intact rock that can still be observed in the last cycle, while others completed disintegration to small fragments. More cycles are tested, and smaller fragments are formed. It is applied to all samples.

Disintegration Index

The sample will be weighed to obtain the disintegration index value for each cycle after it is dried. Figure 6 shows the lower disintegration index value for almost all samples as the test cycle increases. Except for D01-04, the decrease in the disintegration index was not as significant as in the other samples. Sample D01-01 shows the most severe degree of disintegration.

Physical Properties

A physical properties correlation conducted is the factor that can affect the disintegration degree. Table 2 shows the physical properties data for all samples. The void ratio of all samples ranges from 0.15-0.74. The recapitulation for the dry density of all samples ranges from 2.12-3.90, while the water content has a high variation from 1.85-10.64%. Absorption of all samples has a value range of 5.77-10.87%. Sample D01-01 has the highest water content, void ratio, and absorption properties compared to other samples. Unlike these properties, Sample D02-02 has the highest value of dry density and D01-01 with the lowest one.

The influence of physical properties will be obtained by regression analysis, disintegration index, and physical properties. Based on the deterministic coefficients (Table 3), the physical properties of dry density strongly influence. Void ratio and absorption have a moderate effect. The natural water content of rocks does not strongly influence but correlates with the disintegration index.

Figure 7 shows the strong influence of dry density on rock disintegration. From the figure, the lower the dry density of a rock sample, the lower the disintegration index. This condition is related to the degree of rock induration. Rocks with high dry density will have a high induration, so the disintegration that occurs is low.

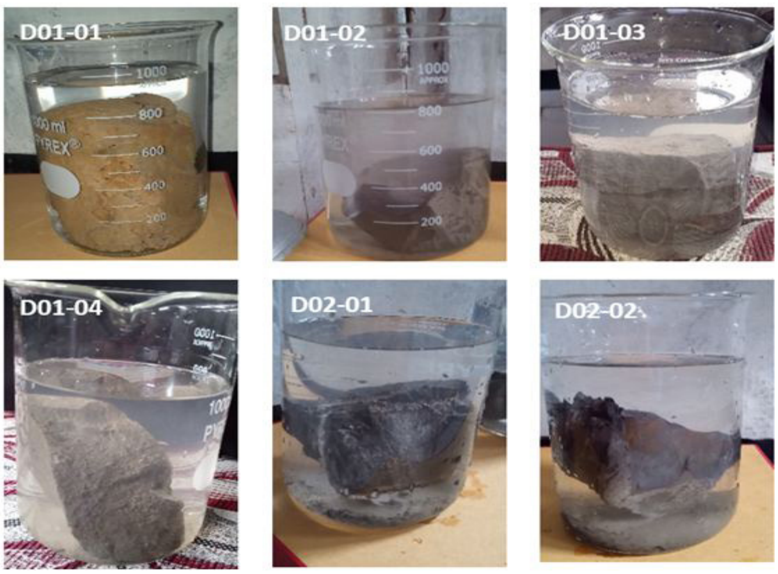
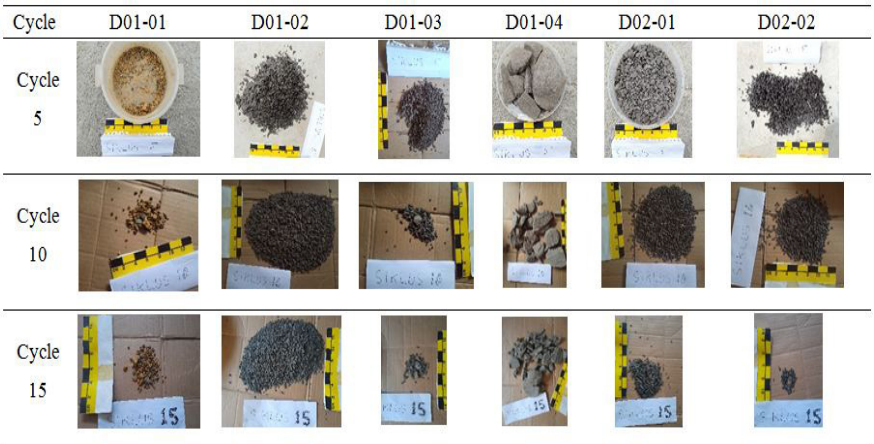


Figure 5. The sample underwent disintegration and broke into angular fragments.

Table 1. Dry condition of all samples after passing the dry-wet test of the 5th cycle, 10th cycle, and 15th cycle. The shape and size of the fragments vary due to the degree of physical disintegration



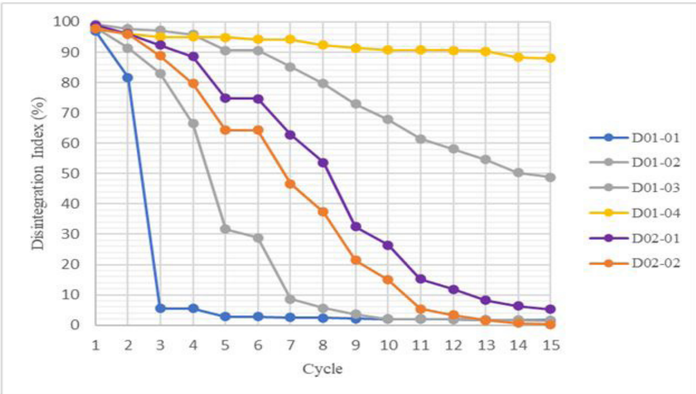


Figure 6. Progression of disintegration rock cycle increases. Sample D01-01 had a significant drop in disintegration, and D01-04 was the most resistant to wet-dry processes.

Table 2. Physical properties of void ratio, absorption, dry density, and natural water content

Sample	Water Content (%)	Void Ratio	Dry density (g/cm^3)	Absorption (%)
D01-02	10.64	0.47	2.99	10.64
D01-03	8	0.27	2.12	10
D01-04	3.85	0.15	2.21	5.77
D02-01	1.85	0.2	2.29	7.41
D02-02	8.7	0.74	3.9	10.87

Table 3. Deterministic coefficients of physical properties on the disintegration index

R2	DISINTEGRATION INDEX			
PHYSICAL PROPERTIES	**CYCLE 1**	**CYCLE 5**	**CYCLE 10**	**CYCLE 15**
WATER CONTENT	0.11	0.04	0.19	0.35
VOID RATIO	0.08	0.49	0.28	0.46
DRY DENSITY	0.65	0.84	0.71	0.7
ABSORPTION	0.5	0.6	0.31	0.46

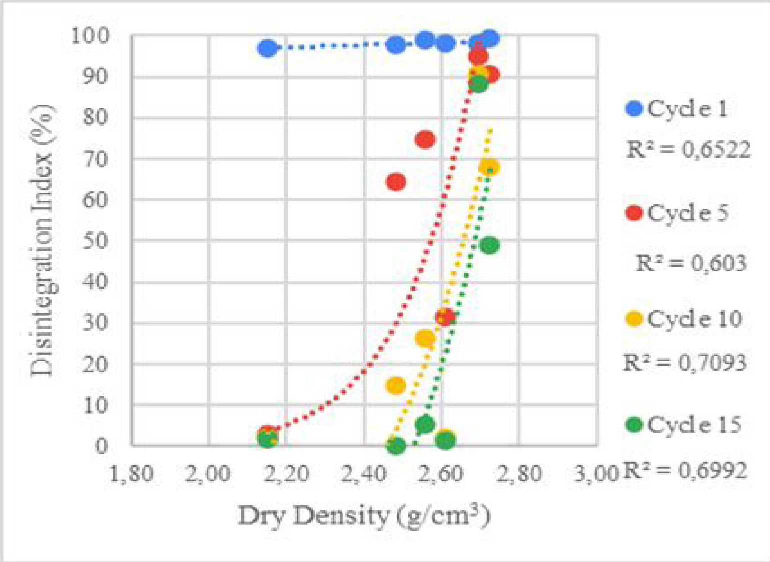


Figure 7. Plot of dry density values to rock disintegration index. The lower the dry density value, the more severe the disintegration rate.

CONCLUSION

Mudrock samples from the Hambalang area, Bogor undergo a progressive disintegration process until the 15th cycle. Through drying, all samples did not experience significant disintegration. This state is different when immersion is carried out; almost all samples experience high deterioration. Disintegration is observed visually with intensive cracks that cause the formation of angular fragments. Most of the samples were slaked after passing through the first cycle. D01-01 disintegrated after the second cycle, and D01-04 experienced noticeable disintegration after passing the third cycle. Factors that may affect the disintegration of the sample are dry density the lower the value of both properties, the lower the disintegration index. The dry-wet processes can identify the degree of mudrock disintegration to weathering. Test up to the 15th cycle can obtain the disintegration rate that occurs in each sample.

This study of the characteristics of mudrock disintegration can enrich the assessment method of mudrock in the engineering geology field. Conducting an assessment of disintegration for other rock types can be addressed related to different properties. In civil engineering, this study is the initial stage of the investigation to avoid infrastructure failures. In this study, direct observation and quantification are fast and inexpensive. Therefore, it can be essential to characterize mudrock's disintegrating behavior.

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