The resilience of asbuton material strength with immersion time used as core layer on a dam

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Abstract. In order to increase the use of domestic materials, asbuton material which has a substantial reserve of 662,960 million tons in Buton Island becomes an alternative choice for using as a core layer on the dam. The asbuton material to be used in this research is Lawele Granular Asphalt (LGA). The laboratory result data to be analyzed relationship between the stability value with the immersion time, residual stability value with the immersion time and the value of the flow with the time of immersion of asbuton material. The results showed that the value of stability and flow of asbuton material after soaking tends to be stable, it indicates that the strength and flexibility of asbuton material are not affected by water immersion. The percentage of residual stability to each immersion time varies and the value of stability loss is relatively small, so until the 56th-day immersion the remaining percentage of stability loss is less.

1. Introduction

In Indonesia, the existing dam is generally embankment dam type. Embankment dam type is divided into three types, namely: homogeneous, zonal and membrane type. For a homogeneous dam, the dominant material of the dam is the soil. A Zonal dam, material forming of the dam consists of several types of materials, escaped the water and waterproof materials. Membrane dam is an embankment dam with water pass material, the upper part is given a waterproof layer.

The zonal type is the embankment dam, which most of the material of dams are stones, that serve as a major supporter of dam stability. For the waterproof zone, installed the watertight layer by waterproof membrane upstream of the upper slope or inside the dam body in the form of a layer of the waterproof core. Generally, the waterproof material using in Indonesia is clay. While abroad, besides clay is used as a concrete asphalt mix (hot mix) also.

Indonesia has a very large natural asphalt reserve, which is asphalt buton (asbuton) in Buton Island Southeast Sulawesi Province. The reserves of asbuton material according to an assessment undertaken by the Alberta Research Council in the 1980s and validated by the Pusjatan Ministry of Public Works in 2010-2013 amounted to 662,960 million tons [1].

The advantage of asphalt-containing materials compared to clay soils used as a watertight core layer in the zonal type constellation as follows [2]:

- The risk of leakage is less.
- The risk is smaller if there is an earthquake. The risk of an earthquake is a decisive factor for dam design. From previous studies and experiences, zonal type dams containing asphalt material as a core layer have proven to be the right choice in earthquake-prone areas. Asphalt is a viscoelastic material with better adaptability when there is movement including large earthquakes.
• Shorter construction time. Zonal type contains asphalt material as the core layer can be built more quickly and efficiently, even in areas with high rainfall. In contrast to dams that use clay soil as the core layer, where construction time is often dramatically prolonged due to rain conditions.
• Maintenance is easier. The core layer containing asphalt material in the dam body is protected from oxidation and plasticity, so asphalt does not change with time. Besides that, the asphalt is not a dangerous material for the environment, so that water from the dam is safe for drinking and irrigation purposes.

2. Theoretical basis

2.1 Asbuton
Asbuton is a natural asphalt found on the island of Buton, Southeast Sulawesi. Asbutons are generally solid in shape formed naturally by geological processes. The process of formation of asbutons derived from petroleum driven to the surface infiltrated between porous rocks. Asbuton has a very large reserve, is the largest natural asphalt deposit in the world. Asbuton deposit is spread from Sampolawa bay to Lawele bay along 75 km with a width 12 km plus Enreke region which belongs to Regency of Muna. Illustration of the location of the asbuton deposit, shown in figure 1.

![Figure 1. Location map of asbuton distribution.](image)

The corresponding asbuton reserves studied by the Alberta Research Council in the 1980s and validated by the Pusjatan Ministry of Public Works in 2010 - 2013 amounted to 662.960 million tonnes [3].

| No. | Location | Large (m²) | Thick (m) | Deposits (ton) |
|-----|----------|------------|-----------|----------------|
| 1   | Rongi    | 57.755.0   | 78        | 226.165.670    |
| 2   | Kabungka | 181.004.0  | 78        | 312.718.460    |
| 3   | Lawele   | 130.906.0  | 78        | 99.786.080     |
| 4   | Epe      | 1.720.00   | 78        | 2.011.157      |
| 5   | Rota     | 4.530.00   | 78        | 19.596.780     |
| 6   | Madullah | 620.000    | 78        | 2.682.120      |
|     | Total    | 376.537.8  |           | 662.960.267    |
2.2 Physical properties of asbuton asphalt

The physical properties of asphalt depending on the area where the asbuton is obtained. Until now only two areas are mined, namely in the area of Kabungka and Lawele. Asphalt content of asphalt (bituminous) at Lawele area is 25-35%, while in Kabungka area about 12-20%. Asphalt contained in asbuton is different from asphalt oil obtained from the distillation process. Asphalt on the asbuton is obtained by extraction, so there is still a resin and a mild fraction contained therein, so the characteristics of these two types of asphalt are different. Inside the asbutons there are two main elements, namely asphalt, and minerals. The physical properties of Asbuton Lawele asphalt extracted by the Center for Road and Bridge Development and Research of Directorate of Highways Ministry of Public Works in 2006 can be seen in table 2.

Based on its physical properties, Asbuton Lawele has an asphalt content and a fairly soft point. This shows that asbutons have good aggregate viscosity and are suitable for tropical climates [4].

| Types of Testing                              | Result         |
|-----------------------------------------------|----------------|
| Asphalt Content, %                            | 30.08          |
| Penetration, 25°C, 100 gr, 5 second, 0.1 mm   | 36             |
| Mushy Point, °C                               | 59             |
| Daktility, 25°C, 5cm/second, cm               | >140           |
| Solubility in C2HCL3, %                       | 99.6           |
| Flash Point, °C                               | 198            |
| Specific Gravity                              | 1.037          |
| Weigh Loss (TFOT), 163°C, 5 jam               | 0.31           |
| Penetration after TFOT, % asli                | 94             |
| Mushy Point after TFOT, °C                    | 62             |
| Daktility after TFOT, cm                      | >140           |

2.3 Asbuton asphalt chemical properties

The chemical properties of asbuton asphalt are similar to their physical properties depending on which area the asbuton is obtained. The chemical properties of Asbuton Lawele asphalt extracted by the Center for Road and Bridge Development and Research of Directorate of Highways Ministry of Public Works in 2006 can be seen in table 3.
### Table 3. Chemical properties of asbuton asphalt Lawele.

| Types of Testing | Result  |
|------------------|---------|
| Nitrogen (N), %   | 30.08   |
| Acidafins (A1), % | 6.60    |
| Acidafins (A2), % | 8.43    |
| Parafin (P), %    | 8.86    |
| Parameter Maltene | 2.06    |
| Nitrogen/Parafin, N/P | 3.28 |
| Asphaltene content, % | 46.92 |

Judging from the chemical properties of Asbuton Lawele asphalt, asphalt asbuton has a fairly high Nitrogen compound and good malten parameters. This shows that asbutons have good adhesion with sufficient aggregate and durability [5].

#### 2.4 Granular asbuton for core layer material

Grain asbuton is the result of the processing of solid-shaped asbutons that are broken with a stone crusher or other suitable crackers so as to have a specific grain size. The raw material for making grain asbuton can be obtained from solid asbuton chunks. Through this treatment is expected to eliminate the weaknesses of asbuton use so far, namely the uniformity of bitumen content and water content as well as by making a finer grain size, it further simplifies the mobilized of asbuton bitumen from within the mineral grains. Grain asbuton should be in packing bags or other containers that are water-resistant. The asbuton of the grain should be placed in a dry, roofed place so that the asbutons are protected from rain or direct sunlight. The height of the accumulation of grain asbuton shall not exceed 2 meters [6].

### 3. Research methodology

#### 3.1 Research plan

The study design which is a major component of the study is included in the research flowchart in figure 3. Test methods conducted in this study based on the Indonesian National Standard (SNI).

![Figure 3. Flowchart Research](image-url)
3.2 Marshall test
The testing procedure of the Marshall Test asbuton material refers to SNI 06-2489-1991. Marshall Test is performed to obtain the stability and flow value of the asbuton material to be used as the core layer of the dam [8]. The maximum load that occurs when the specimen is destroyed is expressed with stability, while the deformation occurring at the maximum load is expressed in flowing [9, 10]. In this marshall test, tested the stability and flowing value of asbuton material at several different temperatures [11]. The highest water surface temperature during the day is 60°C, so the temperature variation is temperature 30°C (room temperature), temperature 40°C, temperature 50°C, and temperature 60°C. According to ICOLD, the value of the eligible stability for the core layer is 250 kg.

4. Data and analysis

4.1. Data

4.1.1. Results of asbuton material stability durability testing with time
The testing of the strength of the asbuton material strength over time is performed to determine the survival of asbuton material in submerged position due to the influence of both the load and the load above the core layer during the life of the dam construction. Loss of stability resulting from immersion in water is a measure of resistance to the strength of the asbuton material to time. The result of the durability of the strength of the asbuton material over time is presented in table 4.

| No | Description          | Unit | Value   |
|----|----------------------|------|---------|
| 1  | Immersion Time       | days | 0 3 7 14 21 28 35 42 49 56 |
| 2  | Stability            | kg   | 1806 1740 1698 1789 1752 1801 1693 1733 1765 1758 |
| 3  | Residual Stability   | %    | 100 96 94 99 97 100 94 96 98 97 |

4.1.2. Result of asbuton material flow durability testing with soaking time
The asbuton material flow time-tolerance test is conducted to determine the resilience of the asbuton material in the submerged position of water due to the influence of both the load and the load above the core layer during the life of the dam construction. The results of the asbuton material strength resistance test with time are presented in table 5.

| No | Description      | Unit | Value   |
|----|-----------------|------|---------|
| 1  | Soaking Time    | days | 0 3 7 14 21 28 35 42 49 56 |
| 2  | Flow            | mm   | 9.82 9.91 9.43 9.79 9.67 9.95 9.33 9.66 9.83 9.74 |

4.2. Data analysis
The result data of the endurance test of stability and the asbuton material flowing resistance over time will be analyzed by connecting the stability value with the immersion time, the residual stability value with the immersion time and the flowing value with the immersion time.

4.2.1. Relationship between stability value with immersion time
The relationship between the stability value and the immersion time is shown in figure 4. The relationship indicates that the stability value tends to be stable, although the immersion time increases,
it indicates that the strength of the asbuton material is not affected by the immersion in the water, making it suitable for the core layer material of the dam.

![Figure 4. Relationship of stability with immersion time](image)

The relationship between the residual stability value and the immersion time is shown in figure 5. The relationship indicates that the remaining percentage of stability loss at each immersion time varies and the value of stability loss is relatively small, so until the 56th-day immersion the remaining percentage of small stability loss.

![Figure 5. Relationship of residual stability with immersion time.](image)

The resistance index and residual strength values obtained on the results of testing the strength of the asbuton material to the time according to the formula Craus are as follows:

- first resistance index (r) = 1.02%
- second resistance index (a) = 3.08%
- residual strength value (Sa) = 96.92%
Based on the value of residual strength obtained, that is equal to 96.92%, then asbuton material is strong enough to maintain its strength during its lifetime as the core layer in the dam.

4.2.2. Relationship between flow value with immersion time

The relationship between the flow value and the time of immersion of the asbuton material is shown in figure 6. The figure shows that the flow value tends to be stable as does the stability value, although the immersion time increases, indicating that the splint of the asbuton material is not affected by water immersion. Given the nature of flexibility possessed by asbuton material, it is more of a value compared to clay soil material, because in the event of an earthquake the asbuton material can still maintain itself to indirectly collapse (flexible).

![Figure 6. Relationship of flow value with immersion time.](image)

5. Conclusions

- The value of stability of the asbuton material after soaking tends to be stable, indicating that the strength of the asbuton material is not affected by water immersion.
- The remaining percentage of stability loss at each immersion time varies and the value of stability loss is relatively small, so until the 56th-day immersion the remaining percentage of small stability loss. The residual strength value (Sa) of the asbuton material is 96.92%.
- The value of asbuton material flowing after soaking tends to be stable, indicating that asbuton material is not affected by water immersion.

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