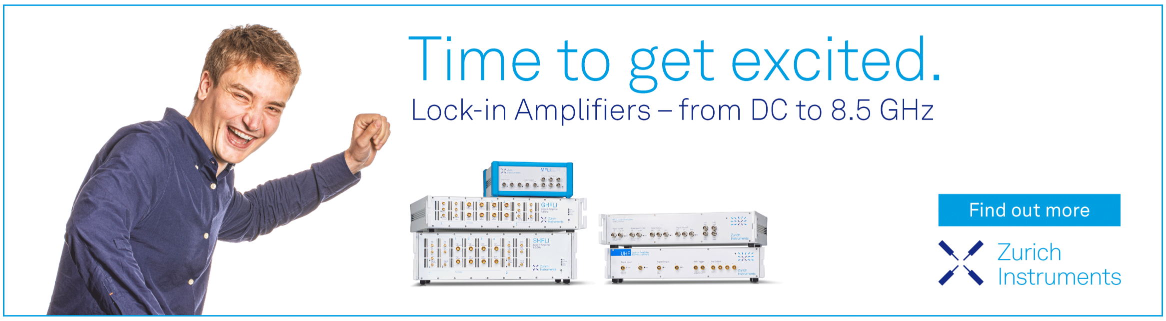
RESEARCH ARTICLE | MAY 16 2023

The relationship of asphalt-bearing rocks and the asphalt quality at Sandangpangan Area, Buton Island, Southeast Sulawesi

Tri Winarno ✉; Reddy Setyawan; Edo Istimawan Adiputra

AIP Conference Proceedings 2683, 020003 (2023)
https://doi.org/10.1063/5.0124934



The Relationship of Asphalt-Bearing Rocks and the Asphalt Quality at Sandangpangan Area, Buton Island, Southeast Sulawesi

Tri Winarno[1, a)], Reddy Setyawan[1, b)], and Edo Istimawan Adiputra[1, c)]

[1] *Geological Engineering Department, Diponegoro University, Jalan Prof. Soedarto, SH, Tembalang, Semarang, 50275, Indonesia*

a) Corresponding author: tri.winarno@live.undip.ac.id
b) reddy@live.undip.ac.id
c) Edoistimawan36@gmail.com

Abstract. Buton asphalt is one of the largest natural asphalt deposits in the world. The Asphalt-bearing rocks in Buton Island are calcarenite limestone, bioclastic limestone, and crystalline limestone. This research aims to determine the relationship between asphalt-bearing rocks and asphalt quality. This research uses several methods: the soxhlet extraction method to determine bitumen and water content, XRF analysis to determine the chemical content of asphalt, and petrographic observations to determine rock composition and rock porosity. The result shows that, in general, the quality of the asphalt-bearing rocks was influenced by their porosity. With the increase of the porosity of the asphalt-bearing rocks, it will be easier for asphalt liquid to penetrate the rocks. The greater porosity of the rocks will produce the higher quality of the asphalt. The asphalt-bearing rock in the research area with the best bitumen quality is calcarenite limestone, which has the highest porosity level.

INTRODUCTION

Indonesia has one of the world's natural asphalt potentials, namely Buton asphalt, referred to locally as Aspal Buton (ASBUTON) [1]. The potential of Buton asphalt is one of the largest natural asphalt reserves in the world, estimated at 677 million tons or equivalent to 170 million tons of oil asphalt [1]. The advantages of Buton asphalt include higher pavement stability compared to oil asphalt. Buton asphalt is also more resistant to cracking due to weather and the environment, is considered to save pavement thickness, and has side products with great benefits such as high oil, bentonite, and minerals (phosphate and carbonate) [2].

There are various kinds of lithology found in the Buton area, so it is necessary to analyze the differences of asphalt content in each of these different asphalt-bearing rocks [3]. The analysis carried out in this research were bitumen and moisture content using soxhlet methods, XRF, and petrographic analysis to determine the characteristics of asphalt content in each type of asphalt-bearing rock.

The research was carried out at an asphalt quarry at Sandangpangan area, South Buton Island, Southeast Sulawesi (Figure 1). The purpose of this research is to determine the quality of asphalt based on bitumen and moisture content, XRF, and petrographic analysis in asphalt-bearing rocks.

The 6th International Conference on Energy, Environment, Epidemiology and Information System (ICENIS) 2021
AIP Conf. Proc. 2683, 020003-1–020003-7; https://doi.org/10.1063/5.0124934
Published by AIP Publishing. 978-0-7354-4517-8/$30.00

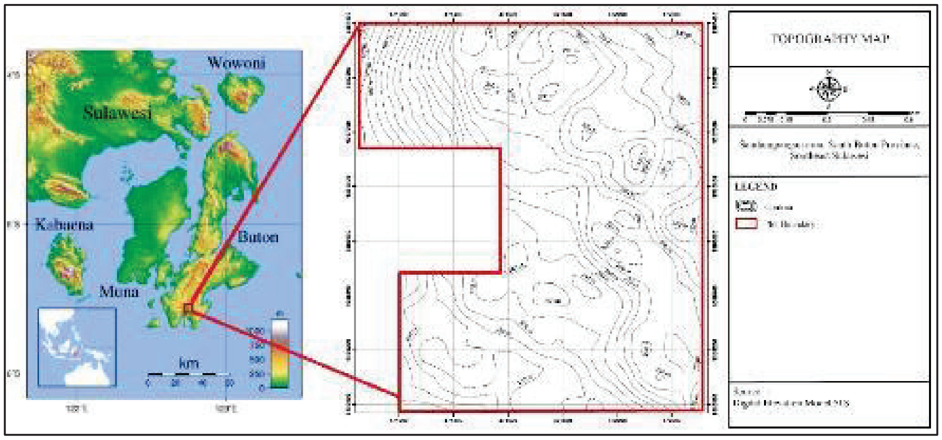


FIGURE 1. The research area location.

LITERATURE REVIEW

Regional Geology

The Buton area is composed of rock units which can be grouped into Mesozoic and Cenozoic rocks. The Mesozoic rock groups are Triassic to Upper Cretaceous, while the Cenozoic groups are Miocene and Pleistocene. Rock groups including the Mesozoic consist of the Winto Formation (Trw), the Ogena Formation (Jo), the Rumu Formation (Jr) and the Tobelo Formation (KTt), which were deposited from the Triassic to the Late Cretaceous. Sedimentary rock groups, including the Cenozoic, then cover most of Buton, which consist of the Tondo Formation (Tmtc), the Sampolakosa Formation (Tmps) and the Wapulaka Formation (Qpw), which were deposited in the Early Miocene to the Pleistocene [4].

The asphalt quarry at Sandangpangan area was included in Sampolakosa Formation (Tmps) and the Wapulaka Formation (Qpw) (Fig. 2), which were deposited in the Early Miocene to the Pleistocene [4].

1. Sampolakosa Formation (Tmps)

The Sampolakosa Formation consists mainly of marl and calcareous sandstones intercalated with thin layered calcarenite. The marl is light grey, compact, generally massive to layered, and separated by a thin layer of calcarenite. The Sampolakosa Formation is deposited in a neritic to the bathyal environment, with ages from Upper Miocene to Lower Pliocene.

2. The Wapulaka Formation (Qpw)

This formation is deposited conformally above the Sampolakosa Formation, but in some parts, it shows the relationship is an unconformity. This formation consists of algae and coral reef limestones, showing ancient coastal steps or karst topography, crushed reef deposits, limestone, calcarenite limestone, calcareous sandstone, claystone, and marl rich in planktonic foraminifera. This formation is Pleistocene, which is deposited in a lagoon-littoral environment.

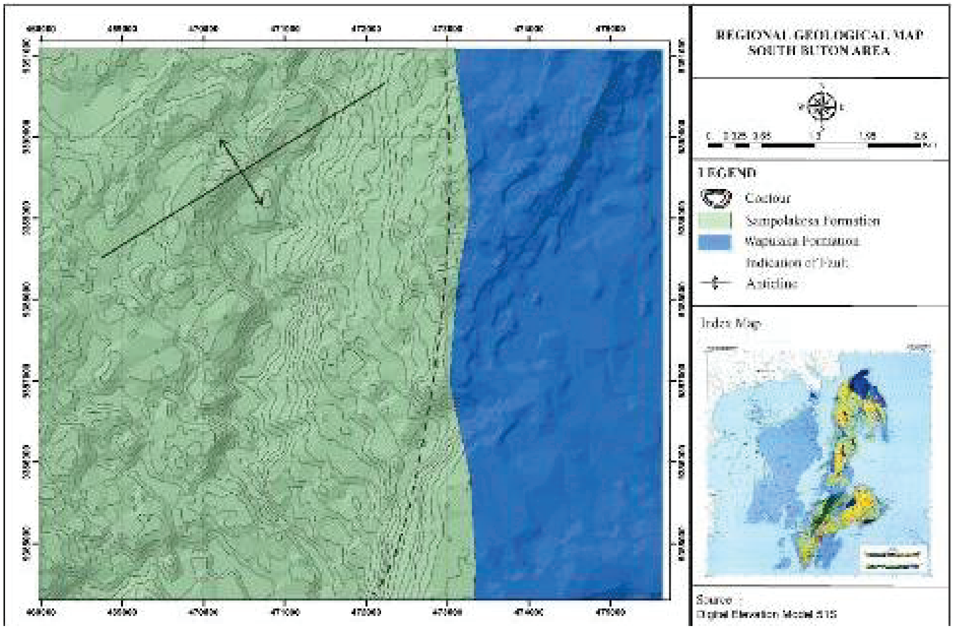


FIGURE 2. Regional geology map of Buton Island.

Asphalt Types

Asphalts are the varieties of naturally-occurring bitumen. Asphalts are also produced as a petroleum byproduct. Both substances are black and primarily soluble in carbon disulphide. They are of variable consistency, ranging from highly viscous fluid to a solid. Asphalts occur with or without mineral matter. Many types of asphalts occur as viscous impregnations in sandstones, silt stones, and lime stones. After treatment to remove water and volatile constituents, the asphalts are fused at 54–60 °C and contain about 83% carbon. Most of the asphalts are of marine origin, and consist of the high-molecular-weight compounds usually present in petroleum residue [5].

Based on where it is obtained, asphalt can be divided into two types [6], they are:

1. Natural asphalt

Natural asphalt is asphalt obtained somewhere in nature and can be used directly or with processing. Natural asphalt is obtained in the mountains, such as asphalt on Buton Island, called Buton Asphalt. *Buton asphalt* is a rock that contains asphalt. Because button asphalt is a natural material, the bitumen content varies widely from low to high.

2. Oil asphalt

Oil asphalt is asphalt which is the residue of petroleum distillation. Each petroleum oil can produce residues of asphaltic base crude oil which contains much asphalt, paraffin base crude oil, which contains much paraffin, or mixed base crude oil which contains a mixture of paraffin and asphalt [7].

METHODOLOGY

The methods used in this research are soxhlet extraction methods, X-Ray Fluorescence (XRF) analysis, and petrographic analysis.

Soxhlet Extraction

Soxhlet extraction has traditionally been used for a solid sample with limited solubility in a solvent in the presence of insoluble impurities [8]. This method was used to determine the bitumen and water/moisture content in Buton asphalt.

This soxhlet method was carried out in the ASBUTONAS laboratory. The soxhlet method is a method/process of separating a component in a solid material by repeated filtering using a particular solvent. All the desired components will be isolated. Usually, a solid material containing some of the desired compounds is placed in a glove made of thick filter paper, loaded into the main chamber of the soxhlet extractor. The soxhlet extractor is placed into a bottle containing the extraction solvent. The soxhlet is then equipped with a condenser. With this method, the percentage of the bitumen content of asphalt can be obtained. With the higher bitumen content in asphalt, the quality of the asphalt is better [8].

The water content test was carried out in the ASBUTONAS laboratory. The asphalt sample was mixed with 100 ml of Xylol solution and distilling it. The results of this distillation obtained the percentage of water content in each sample. The higher the water content in asphalt, the quality of asphalt is worse.

X-Ray Fluorescence (XRF)

X-ray fluorescence (XRF) was conducted to determine the chemical compositions of rocks. The method is fast, accurate, non-destructive, and usually requires only a minimum of sample preparation [9].

The XRF analysis was carried out in the Hasanuddin University laboratory, Makasar. This technique can be used to determine the concentration of an element based on the wavelength and the number of X-rays re-emitted after high-energy X-rays have hit the material. The test material can be in solid, liquid, powder, filtered materials or the other phase.

Petographic Analysis

Petrographic Analysis was conducted to determine the optical description of the rock. Thin section samples were prepared to identify mineralogical and petrographical characteristics under a polarizing microscope. The rock samples from the research area were polished to make the thin sections. The thin sections were analyzed using a polarization microscope. This analysis aims to determine the character of the rock and the microscopic composition of each sample's rock composition, and the porosity of the rock [10].

The thin section of rocks was polished in the Gadjah Mada University laboratory with blue dye fluid on the thin section and observed in the Paleontology, Remote Sensing, and Geooptic Laboratory of the Department of Geological Engineering, Diponegoro University. Blue dye fluid was observed with a polarizing microscope will reveal the porosity of the thin section. By showing the porosity can determine the percentage of the porosity in the rock samples.

RESULTS AND DISCUSSION

Lithology

The lithology in the research area is limestone which consists of calcarenite limestone from the Sampolakosa Formation and bioclastic limestone and semi-crystalline limestone from the Wapulaka Formation.

Calcarenite Limestone

Calcarenite limestone is the most dominant lithology in the research area, about 50%. The physical characteristic of calcarenite limestone is brown to whitish brown colour, with a grain size of fine sand (0.125 mm - 0.25 mm) to coarse sand (0.5 mm - 1 mm), rounded grain shape, open packaging, and poorly sorted and composed of medium to fine sand fragments, fossil shells with the presence of black asphalt (Figure 3(a)).

Based on petrographic observation, the thin rock section is composed of fragments (skeletal grain and non-skeletal grain), matrix and cement. The skeletal grain consists of foraminifera (15%) and bioclast (10%). The non-skeletal grain consists of ooid (5%), the matrix consists of micrite (25%) and the cement of sparry calcite (30%). The rock's porosity is 15% filled with black asphalt (Figure 4(a)). Based on the petrographic observation, the rock is classified into wackestone [11].

Bioclastic Limestone

Bioclastic limestone covers about 10% of the research area. The physical characteristic of bioclastic limestone is greyish white, open packaging, and poorly sorted and contained with black asphalt (Figure 3(b)).

Based on petrographic observation, the thin rock section is composed of fragments of skeletal grain and matrix. The skeletal grain consists of foraminifera (20%) and bioclast (20%). The matrix consists of micrite (50%) and sparry calcite cement (5%). The rock's porosity is 5% filled with black asphalt (Figure 4(b)). Based on the petrographic observation, the rock is classified into wackestone [11].

Semi-crystalline Limestone

Semi-crystalline limestone covers about 40% of the research area. The physical characteristic of semi-crystalline limestone is greyish white colour, with a grain size of fine sand (0.125 mm - 0.25 mm), rounded grain shape and composed of calcite, foraminifera shell with the presence of black asphalt (Figure 3(c)).

Based on petrographic observation, the thin section of rock is composed of bioclast, matrix and cement. The skeletal grain consists of bioclast (20%). The matrix consists of micrite (30%) and sparry calcite cement (40%). The rock's porosity is 10% filled with black asphalt (Figure 4(c)). Based on the petrographic observation, the rock is classified into grainstone [11].

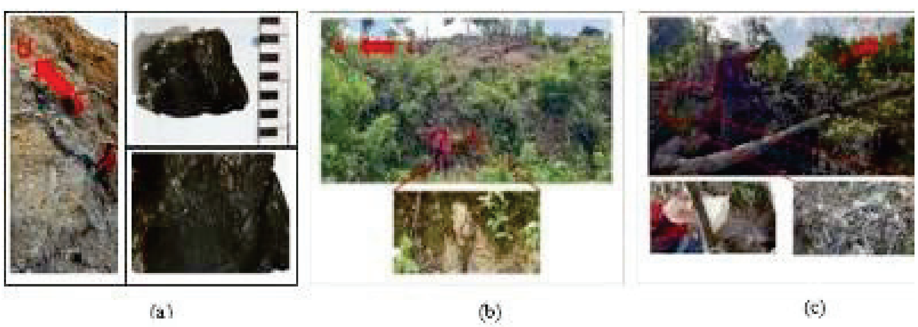


FIGURE 3. The outcrop of calcarenite limestone (a), bioclastic limestone (b) and semi-crystalline limestone (c).

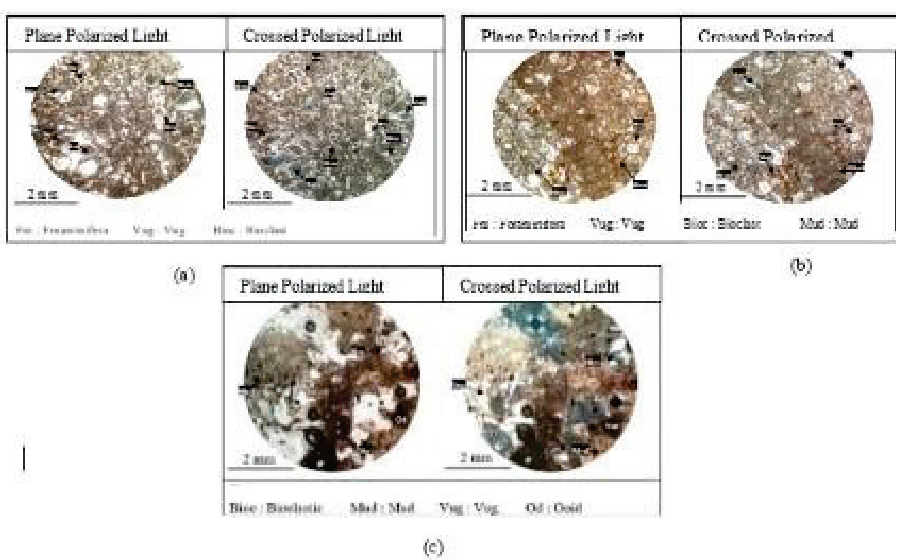


FIGURE 4. Thin section of calcarenite limestone (a), bioclastic limestone (b), and semi-crystalline limestone (c).

Asphalt Quality of Research Area

The determination of asphalt quality in the research area based on the result of bitumen test and water content test with soxhlet method, XRF analysis, and petrographic observation of the asphalt-bearing rocks (Table 1).

TABLE 1. Bitumen content.

Sample	Type of asphalt-bearing Rock	Bitumen content (%)	Water content (%)	CaO content (%)	Porosit y (%)
Sample 1	Calcarenite limestone	4.5	2.3	90.38	17
Sample 2	Calcarenite limestone	38.8	2.3	63.78	20
Sample 3	Calcarenite limestone	22.1	2.4	68.53	15
Sample 4	Bioclastic limestone	14.6	1.3	92.08	7
Sample 5	Bioclastic limestone	3.8	0.6	99.13	8
Sample 6	Semi-crystalline limestone	14.6	2.0	95.38	10

Bitumen Content Analysis

The bitumen content was analyzed with soxhlet methods. There are six samples from different asphalt-bearing rocks being analyzed for the bitumen content (Table 1).

Based on [12], rocks with a bitumen content of 18-24% were categorized as “good”. The asphalt-bearing rocks in the research area with good bitumen content are sample 2 and sample 3, calcarenite limestone. So rocks from sample 2 and sample 3 are perfect for further exploration and exploitation. In contrast, sample 1, sample 4, sample 5 and sample 6 are not suitable for further exploration and exploitation because the bitumen content is less than 18%.

XRF Analysis

The XRF analysis was carried out to determine the CaO content of each sample. There are six samples from different asphalt-bearing rocks being analysed for the CaO content (Table 1).

The asphalt-bearing rocks in the research area are carbonate rocks which a CaO content of more than 50%. All samples show high content of CaO, but samples two and sample 3 have relative low CaO content compared to other samples. It is interpreted that there is a change in the element of CaO due to the influence of porosity. The developing structure and exogenous processes influence the porosity. The less CaO content in the rock matches, the higher porosity. So, based on the XRF analysis, sample 2 and sample 3, which are calcarenite limestone, are suitable for further exploration and exploitation of asphalt processing.

Petrographic Analysis

The petrographic analysis was carried out to determine the porosity content of each sample. There are six samples from different types of asphalt-bearing rocks being analysed the porosity (Table 1).

The porosity of the rock significantly affects the bitumen content of asphalt. With greater porosity, the asphalt bitumen should fill the asphalt-bearing rock. Based on the petrographic analysis, sample 1, sample 2 and sample 3, which are calcarenite limestone, have high porosity values. So, the location of sample 1, sample 2 and sample 3 are very suitable for further exploration and exploitation.

The previous research of Buton asphalt from different locations at Bungi Village, Buton Island using the same method showed the bitumen content ranged from 22.63% - 25.73% and the water content ranged from 6.8% - 7, 50% [3]. The bitumen content of Buton asphalt from Bungi Village is similar to the bitumen content from the Sandangpangan area, which ranged from 18 – 24%, but the water content of Buton asphalt from Bungi Village is higher than the water content of Buton asphalt from the Sandangpangan area which ranged from 0.6% - 2.3%. No data is available for the lithology of asphalt-bearing rocks, the CaO content and porosity from Bungi Village.

CONCLUSIONS

The lithology of the research area is limestone which consists of calcarenite limestone, bioclastic limestone, and semi-crystalline limestone. The bitumen content of calcarenite limestone is 4.5-38.8%, bioclastic limestone is 3.8-14.6%, and semi-crystalline limestone is 14.6%. The water content of calcarenite limestone is 2.3-2.4%, bioclastic limestone is 0.6-1.3%, and semi-crystalline limestone is 2.0%. The CaO content of calcarenite limestone is 63.78-90.38%, bioclastic limestone is 92.8-99.13%, and semi-crystalline limestone is 95.38%. The porosity of calcarenite limestone is 15-20%, bioclastic limestone is 7-8%, and semi-crystalline limestone is 10%. Based on the analysis, the lithology which has high asphalt quality is calcarenite.

The authors wish to thank Diponegoro University, especially to Faculty of Engineering that has supported the research fund in the scheme of Strategic Research 2021. The authors also thank the support of PT Forma Ventura Mineral for allowing the authors to get the data.

REFERENCES

1. S. P. Hadiwardoyo, E. S. Sinaga, H. Fikri. The influence of Buton asphalt additive on skid resistance based on penetration index and temperature, Construction and Building Materials, 42, 5-10 (2013)
2. Sumiati, Mahmuda, Puryanto. Keunggulan Asbuton pracampuran dan Aspal Shell pada Campuran Aspal Buton (AC-BC), Jurnal POLI-TEKNOLOGI, 18 (1), (2019)
3. Tamrin. Analisis Kadar Air Dan Kadar Bitumen Aspal Buton (ASBUTON) Desa Bungi Dengan Metode Sokhlet. Jurusan Fisika Fakultas Sains Dan Teknologi Universitas Islam Negeri Alauidin Makasar (2016)
4. N. Sikumbang, P. Sanyoto, Peta geologi lembar Buton dan Muna, Sulawesi Tenggara, Sekala 1 : 250.000, S81-4, Pusat Penelitian dan Pengembangan Geologi Bandung (1995)
5. H. B. Singh, K. A. Bharati. Handbook of natural dyes and pigments, Woodhead Publishing India in textiles (2014)
6. H. Fannisa, M. Wahyudi, Perencanaan campuran aspal beton dengan menggunakan Filler Kapur Padam, Program Studi Diploma III Teknik Sipil Fakultas Teknik Universitas Diponegoro, Semarang (2010)
7. Harmein, Rahman, Evaluasi model modulus bitumen Asbuton dan model modulus campuran yang mengandung Bitumen Asbuon, Laporan Disertasi, Institut Teknologi Bandung (2010)
8. J.Kim, K.Choi, D.S.Chung. Sample Preparation for capillary electrophoretic Applications. Analytical Techniques for Scientists, 3, 701-721(2012)
9. A. Jamaluddin, M. A. Darwis, Massinai, X-Ray Fluorescence (XRF) to identify chemical analysis of minerals in Buton island, SE Sulawesi, Indonesia, Global Colloquium on GeoSciences and Engineering (2017)
10. Clough, T. H. McK., A. R. Woolley, Petrography and stone implements, World Archaeology, 17 (1), 90–100 (1985)
11. R. J. Dunham, Classification of Carbonate Rocks According to Depositional Texture. The American Association of Petroleum Geologists Bulletin (1962)
12. Badan Standardisasi Nasional. Metode Pengujian kadar beraspal dengan cara ekstraksi menggunakan alat soklet, SNI 03-3640-1994, (Jakarta, 1994)