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Physiochemical characterization of lateritic bauxite mining soil

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Abstract. Physiochemical characteristics play a significant role in evaluating the engineering behaviour of soil material and its suitability for foundation. Investigation upon the physical and chemical characteristics of lateritic bauxite soils were done on samples collected from three ex-mining bauxite sites (Bukit Goh, Semambu and Indera Mahkota) in Kuantan District, Pahang, Malaysia. The presence of chemical element was evaluated based on the elemental mineral composition content identified through X-Ray Fluorescence (XRF). The results revealed that Semambu lateritic bauxite soil has the highest content of alumina (Al_2O_3), 25.54%. The alumina content enrichment is one of the effects from the laterization of bauxite process. In addition, the physical testing included are moisture content, specific gravity and Atterberg Limit. Further investigation on the physical properties of the soil has found that Semambu has the highest MC, 33.27%, but at the same time PI is less than 12%. This is as a key indicator that lateritic bauxite is prone to surface erosion and unsuitable for construction purposes in its natural condition. The risk of the surface erosion and settlement of the ground causes it requires stabilizer that can rapid the curing time. Additionally, the high moisture content is likely to have higher chance to experience liquefaction and causes foundation problem to future infrastructures that may be built in the studied area.

1. Introduction

Bauxite deposits form when source rocks rich in alumino-silicate minerals are altered and chemically weathered. A number of authors have looked into the genetic modelling, changes in mass, element mobility, and the textures of ore in the bauxite deposits all around the world. Bauxite are classified into three categories based on its mineralogy, geochemistry, and bedrock lithology: (1) Lateritic-type bauxites, (2) Tikhvin-type bauxites, and (3) Tikhvin and Karstic-type. Lateritic bauxites are formed by in-situ lateritization from the underlying alumosilicate rocks, where mobile minerals been leached and immobile element such as Al_2O_3 and Fe_2O_3 remained to form bauxites [1]–[3]. The most critical elements in determining the extent and grade of bauxites are parent rock composition, climate, drainage, topography, groundwater chemistry, microbial activity, water table location, and the duration of weathering processes [1].

In Kuantan, Pahang, Malaysia, bauxite ex-mining land is in a critical stage, with eroded soil causing enormous erosion. According to reports, the earth that was disturbed using the open pit method was left naked, with no revegetation protection in place for rehabilitation purposes [4]. Either common mining heritage or inheritance, both contribute to landslide occurrences and problematic soils for the geotechnical engineer to contend with in subsurface and surface areas [5]. The bare ground surfaces are highly subjected to wind and water forces which exposed the soil structures to micro-aggregation instability. However, physiochemical properties of the lateritic bauxite soil are not popular to be discussed in the previous literatures compared to bauxite residue. Among all previous research, a single study that characterize lateritic bauxite soil from ex-mining sites is unclear. Therefore, characterization of the lateritic bauxite soil at the bauxite ex-mining sites is necessary to investigate the soil characteristics as well as to predict its engineering behaviour.

Besides that, as the population and construction sector develop at a quick pace, demand for bauxite output products has increased. The most common post-mining land use purposes include agriculture, forestry, recreation, construction, conservation and lakes [6, 7]. Effort studying on problematic soils has also expanded considerably [8, 9], since the natural resources business has long been recognised as the cornerstone in the design and building of a variety of creative constructions, infrastructures, and facilities aimed at improving global society [10]. Thus, physiochemical soil characterization at ex-mining areas is required to be studied, to predict its potential for foundation design and construction.

2. Material and methods

The lateritic bauxite samples were tested for physical and chemical characterization. The physical properties, including moisture content, Atterberg Limit, and specific gravity of the lateritic bauxite were tested based on the British Standard procedures as shown Table 1. Meanwhile, for the chemical elements in the lateritic bauxite were tested using XRF. Following figures show the ground conditions of the sites. Most of the eroded area are bare and no vegetation grown on top.

Table 1. Physical properties lateritic bauxite of each site

Properties	Standards
Natural moisture content	BS EN ISO 17892-1:2018
Specific gravity	BS EN ISO 17891-3:2018
Atterberg Limit	BS EN ISO 17892-12:2018

The lateritic bauxite samples were collected from Bukit Goh, Semambu and Indera Mahkota. About 0.5 m of topsoil been removed before samples are taken. The sampling areas were chosen based on display trace of bauxite open pit mining activities. These areas display uncovered disturbed surface which exposed to potential soil surface erosion as per shown in Figure 1, Figure 2 and Figure 3.

Figure 1. Ground condition at site Bukit Goh.

Figure 2. Ground condition at Indera Mahkota.

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Figure 3. Ground condition at Semambu.

3. Results and discussion

The results of the physiochemical properties of the lateritic bauxite soil are presented and discussed in this section.

3.1. Physical properties of the lateritic bauxite

The results of the natural moisture content (MC), specific gravity (SG) and Atterberg Limit for each site are presented in following table. Results of Atterberg Limit are indicated as LL (liquid limit), PL (plastic limit), PI (plasticity index) and LS (linear shrinkage) in the Table 2.

Table 2. Physical properties lateritic bauxite of each site

	MC (%)	SG	LL (%)	PL (%)	PI (%)	LS (%)
Bukit Goh	21.74	2.93	46.25	37.80	8.45	7.81
Semambu	33.27	2.79	54.66	46.90	7.76	7.19
Indera Mahkota	13.07	2.61	31.62	25.59	6.03	8.08

Summary of the physical properties are shown in Table 2. It shows that the soil sample from Semambu has the highest LL value compared to Bukit Goh and Indera Mahkota. As referred to standard specifications of materials for roads by Federal Ministry of Works (1970), the absence or very low contents of montmorillonite clay minerals in the soils are shown from the LL value [11]. Even though the moisture content is highest, the LL for Semambu show its significantly low content of clay minerals. The value of the PI of all samples are less than 12%, and thus may be classified as having low swelling potentials [12].

3.2. Chemical properties based on XRF Analysis

The mineral composition of the bauxite is verified using the XRF data received from the soil samples collected at each site. Bauxite is a deposit that contains aluminium minerals in general [13]. Oxide concentrations, Fe concentration variations in weathering profiles, mineral leaching degree, and element geochemistry have all played a part in the distribution of trace and rare earth elements during lateritic bauxite weathering [14]. Hence, results from each sites are presented and discussed in the following section.

Based on Table 3, alumina is largely prominent in the bauxite soil from Semambu. Alumina is present in greater than 20% of all locations. Iron (Fe) is the second most abundant element in the samples. As a result of the dominance of alumina and iron in these soil samples, it may be determined that they are all bauxite [13], [14].

Table 3. Major element in soil sample

Samples	Major Element (%)			
	Alumina, Al_2O_3	Iron, Fe_2O_3	Titanium, Ti	Silica oxide, SiO_2
Bukit Goh	22.79	18.26	4.31	9.52
Semambu	25.54	15.31	3.36	15.65
Indera Mahkota	20.58	21.71	5.14	9.07

4. Conclusion

Several laboratory experiments were performed on lateritic bauxite samples collected from Kuantan, Pahang. The following conclusions are drawn from the findings of the study, characterising the physiochemical characteristics of the lateritic bauxite. The lateritic bauxite has poor to moderate physical properties that need improvement before used for construction purposes. The lateritic bauxite has alumina content of 20% to 26%, iron content 15% to 22% and silica oxide 9% to 16%. The alumina and iron content in the lateritic bauxite sample remained in the soil as immobile element, whilst silica oxide has been leached during the laterization and thus lead to bauxisation process. The MC is more than 10% which shown that the lateritic bauxite from these sites is not suitable for construction as in its natural condition. But may require soil stabilizer especially for soil performance improvement. Moreover, more extensive research shall be done on characterizing the lateritic bauxite soil prior proceed for the foundation design and construction.

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