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STABILIZATION OF RIMBO PANJANG PEAT SOIL USING LIGHTWEIGHT MATERIALS MIXED WITH CEMENT AS SUBGRADE FOR ROAD PAVEMENT

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ABSTRACT: Most of the road constructions in Riau Province are built on problematic and poor peat soil that resulted in the roads in this province do not last long according to their design. The aim of this research is to improve the engineering properties of the peat soil obtained from Rimbo Panjang, by using lightweight materials such as Bagasse and Sawdust Ash mixed with Portland Cement so that they meet the conditions stipulated as subgrade for road pavement layer. The tests conducted include determination of the physical properties of the peat soil such as Moisture Content, Organic Content, Ash Content, Unit Weight, Specific Gravity, Atterberg Limit and Dry Density, and engineering properties such as CBR and Unconfined Compressive Strength. A total of 18 CBR and 24 Unconfined Compressive Strength samples were prepared and tested. Results obtained showed the increases in the Dry Density, CBR value, and Unconfined Compressive Strength value. The highest increment is observed on peat soils that mixed with 15% Cement with Unconfined Compressive Strength of 92 kN/m^2, Dry Density of 0.53 gr/cm^3, and CBR value of 4.67 %. It is followed by peat soils that mixed with 15% Cement and 30% Bagasse Ash with Unconfined Compressive Strength of 90 kN/m^2, Dry Density of 0.5 gr/cm^3, and CBR value of 4.56%. It can be concluded that Bagasse Ash shows a better result than Sawdust Ash in stabilizing Rimbo Panjang peat soils.

Keywords: Stabilization, Bagasse Ash, Sawdust Ash, Cement, CBR, Unconfined Compressive Strength

1. INTRODUCTION

Peat soil is soft soil with an organic content of >75% (Department of Settlement and Regional Infrastructure, 2004). Peat soil has low bearing capacity, high compressibility, and low shear strength [1].

Most of the road constructions in the Riau Province area are built on peat soil, resulted in roads in the Riau Province that do not last long. During the rainy season, peat soil will be saturated with water, while in the dry season, peat soil will compress due to the loss of water from the pores. It causes damage to the road construction due to the expansion and shrinkage of the soil surface. Typical illustration of peat soil can be seen in fig. 1 below.

Fig.1 Peat Soil at Rimbo Panjang, Riau Province

For this reason, peat soils found in the Riau Province, especially in the Rimbo Panjang area, need to be stabilized and improved so that they are in accordance with the conditions stipulated as subgrade for pavement layers. One of the stabilizing methods is by using lightweight materials. Bagasse ash and sawdust ash as lightweight materials mixed with Portland Cement were chosen to be investigated in this research. Mixing the peat soil with lightweight materials were not expected to add the weight of the peat soil itself. Moreover, the purpose of adding cement to the mixes is to increase the binder properties of the peat soil mixtures.

The objective of this investigation is to study the properties of stabilizing peat soils with lightweight materials, namely Bagasse Ash (BA) and Sawdust Ash (SA) mixed with Portland Cement (PC). Also, the study aims to determine to what extent can these new mixtures improve the engineering properties, i.e., California Bearing Ratio (CBR) and unconfined compressive strength (UCS), as subgrade for pavement layers.

2. LITERATURE REVIEW

Soil, which in its original state is poor, can be changed through compaction, adding aggregates or other materials so that it can be used as subgrade for pavement. Soil stabilization is one of the common methods used to improve the properties of existing soil to meet the technical demands [2]. According to the Department of Settlements and Regional Infrastructure (2002d), there are five methods to improve the subgrade properties that have been accepted and applied in Indonesia. Such as material replacement, counter berms, surcharging, for stage construction, and the use of lightweight material [3].

Department of Settlement and Regional Infrastructure defines peat as a part of soft soil consisting of inorganic clay and organic clay [4], forms mainly of plant debris in various levels of decomposition [5], and has a density ranges from 1.4 to 1.5 [2]. Peat also has a dark brown to black color, distinctively scented with decaying plants, hollow consistency without showing obvious plasticity and fibrous to the amorphous texture [5].

Weathering of organic materials is the main process that forms this soil [6]. Due to this, the content of organic matter in peat soil is higher than 75%, consisting of fibrous material produced by the accumulation of half decaying plant debris in an environment with a low oxygen level [1]. This type of soil has a field CBR value of less than 2% [7].

Higher groundwater levels resulting in higher water content of the peat soil. It can be visualized, identified, and observed by their dark brown color.

Sawdust used in this research was obtained from a factory that manufactures frames, doors, and windows. Sawdust ash is a lightweight material; thus, it is expected not to overburden the load on peat soil. Then, it was found that the use of sawdust ash increases the value of the UCS and cohesion of clay soil.

The optimum value 12% of SA into the soil has been investigated and increase Dry Density by 7.8%, as well as shrinkage limit. Further, it reduced the permeability by 71.8. Moreover, the 12% SA has also increased the friction angle by 22.14%, and shear strength parameters were improved significantly [8] [9].

Sawdust Ash used in this study can be seen in Figure 2.

Fig. 2 Sawdust Ash (SA)

Workability, compressive strength, physical properties as well as its chemical composition of the concrete containing 5%, 10%, 15%, 20% and 25% of SA by weight of ordinary Portland cement has been investigated. It can be concluded that SA is a very good pozzolan combined with SiO2, Al2O3, and Fe2O3 of 73.07% as per IS 3812:2003 [10].

Moreover, as a fly ash replacement to produce Geopolymer concrete, SA achieved the satisfactory results of Compressive Strength by testing standard cubes at 7 days and 28 days at 5% replacement of Sawdust ash [11] [12].

Bagasse ash (BA) used in this research was obtained from sugar cane drinks seller at a local market. The use of BA produced from the remnants of sugar cane helps in reducing the environmental impact caused by garbage dumping on the street and open areas. Similar to SA, BA is also a lightweight material that might not increase the load on peat soil. BA used in this study can be seen in Figure 3.

Fig. 3 Bagasse Ash (BA)

Bagasse Ash has been combined with lime, PC and gypsum to improve the expansive soil in Bojonegoro area, east Java Indonesia. In doing so, it resulted in less swelling and high strength of soil, for a combination of 8%BA and 6% of the dry weight of lime/PC/ gypsum [13].

Moreover, Bagasse Ash and hydrated lime were investigated to improve expansive soil. Thus, it has been proven that the use of BA can increase strength and bearing capacity and meanwhile it reduces the shrinkage of the treated soil expansive [14].

Whereas, a mixture of BA and cement increases the compressive strength and maximum dry weight of clay soil [15].

Bagasse ash has been studied as a partial replacement of 20% and 40% in pavement concrete. It showed good durability in terms of abrasion resistance and acid resistance and resulted in a compressive strength of more than 17.5 MPa as per ACI 211 [16].

3. RESEARCH METHODOLOGY

The research was carried out at the Material Testing Technical Implementation Unit of the Public Works and Spatial Planning of Riau

Province. BA, SA, and Cement are varied to be mixed with peat soil in order to achieve higher CBR value and unconfined compressive strength (q_u) values for pavement subgrade.

Peat soil was collected from Km. 18. Pekanbaru-Bangkinang road, Riau Province, which is ± 100 m from the main road. Peat soil used in this investigation is in a disturbed condition, taken at a depth of 40 cm to 60 cm. Peat soil is dried for four weeks, and the roots are removed then filtered with sieve no. 4.

Peat soil was mixed with various materials such as bagasse ash, sawdust ash, and cement in different percentage variations, as seen in Table 1.

Table 1: Variation of materials studied

SAMPLES	Portland Cement (PC) in Peat	Baggage Ash (BA) in Peat	Sawdust Ash (SA) in Peat
P	-	-	-
P15BA	-	15%	
P15PC	15%	-	
P15PC10BA	15%	10%	
P15PC20BA	15%	20%	
P15PC30BA	15%	30%	
P15SA	-	-	15%
P15PC10SA	15%		10%

Bagasse ash used in this investigation was derived from the surrounding waste. Bagasse ash was air-dried then burnt in the drum. The ash derived is then ground with 12 kg grinder for 10 minutes. The use of bagasse ash as additional material to stabilize the peat soil was then implemented according to the Guidelines issued by the Department of Settlements and Regional Infrastructure No: Pt T-10-2002-B regarding Geotechnical Guidelines 4 Road Construction Design and Construction in Soft Soil [4].

The sawdust ash was derived from the wood cutting process from the sawmilling process. The use of sawdust ash to stabilize the peat soils was implemented according to the Guidelines issued by the Department of Settlements and Regional Infrastructure using the same guideline mentioned above. As with bagasse ash, sawdust ash was also through the process of burning and grinding.

Cement used in this investigation was Type 1 Portland Cement from Padang Cement Factory based on the Procedure of Land Stabilization with Portland Cement for Roads and Base Coarse Manual, Road Book no. 6 Department of Public Works Directorate General of Highways No: 002-06/BM/2006.

4. RESULTS AND DISCUSSIONS

Based on the results, Rimbo Panjang peat soils can be categorized as 'high ash' due to the ash content of >15%. Moreover, from the previous report by the Department of Settlements and Regional Infrastructure (2004) [7], it classifies the Rimbo Panjang peat soil as organic clay because of the organic content was in the range of 25% -75%.

The physical and mechanical properties of the peat can be seen in Table 2.

Table 2. Properties of Rimbo Panjang Peat Soil

Parameter	Value
CBR Lab, (%)	4.50
UCS, q_u (kN/m^2)	52
Undrained Shear Strength, S_u (kN/m^2)	26
Maximum Dry Density, ρ_d (gr/cm^3)	0.48
Optimum Water Content, w (%)	106.50
Liquid Limit	131.10
Plastic Limit	101.24
Plasticity Index	29.86
Natural Water Content (%)	324.66
Dry Air Water Content (%)	21.50
Ash Content (%)	66.34
Organic Content (%)	33.66
Specific Gravity	1.5
Weight/Volume (gr/cm^3)	0.4

4.1 Dry Density vs. Moisture Content

Figure 4 shows the relationship between the moisture content against the dry density for various variations of peat soils stabilized with bagasse ash and Portland cement.

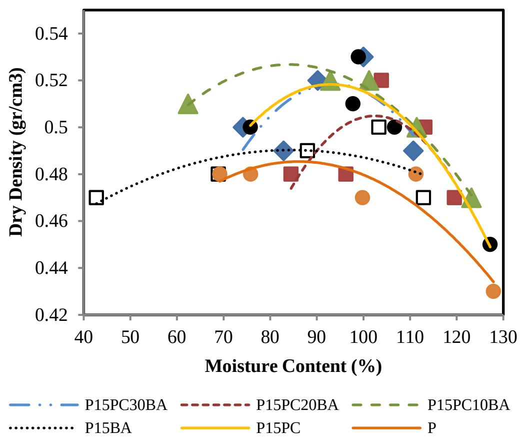

Fig. 4 Dry Density vs. Moisture Content of Peat Stabilized with BA and PC

It can be seen from Figure 4 that the maximum dry density increases in all mixes compared to the control sample. The highest increment is observed in peat soil + 15% PC + 10% BA, where the value increases from 0.480 gr/ cm^3 to 0.528 gr/cm^3, obtained at optimum moisture content (w) of 84%.

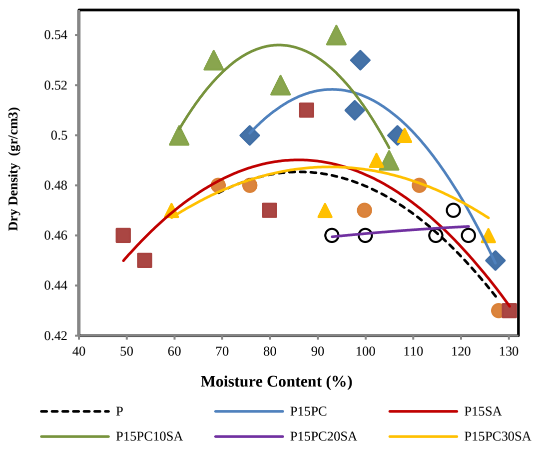

Fig. 5. Dry Density vs. Moisture Content of Peat Soil Stabilized with SA and PC.

Figure 5 shows the relationship between the moisture content against the dry density for various variations of peat soils stabilized with SA and PC from the compaction test.

It can be seen that the maximum dry density increases in all mixes. The highest increment is observed in peat soil + 15% PC + 10% SA, where the value increases from 0.480 gr/ cm^3 to 11.67 gr/cm^3, obtained at optimum moisture content (w) of 81%.

4.2 Relationship Between CBR Value (%) and Dry Density (gr/cm^3)

Figure 6 shows the relationship between CBR value and dry density. It can be observed that the CBR value and dry density increase in all mixes.

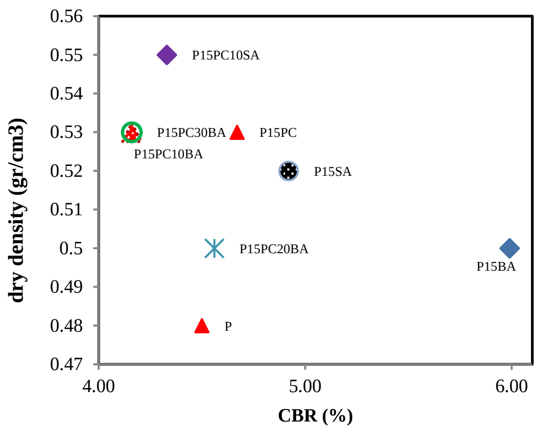

Fig. 6 Relationship Between CBR Value and Dry Density of Peat Soil Stabilized with BA and PC.

The highest increment is observed in peat soil + 15% BA (P15BA), where the CBR value rises by 1.49% from 4.50% to 5.99%, and the maximum dry density increases by 4.17 % from 0.48 gr/cm^3 to 0.50 gr/cm^3. Meanwhile, Peat soil stabilizes with 15%PC, and 10%SA achieved the highest density at 4.3%CBR value, which is above the minimum value of the CBR subgrade, i.e., 3%.

4.3 Relationship between UCS, q (kN/m^2) value and Dry Density (gr/cm^3)

Figure 7 shows the relationship between dry density and UCS. It can be seen that the UCS and the dry density increases in all mixes.

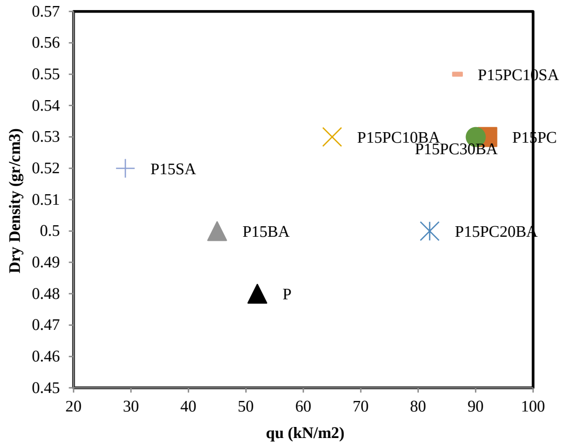

Fig. 7 Relationship Between UCS and Dry Density of Peat Soil Stabilized With BA, SA, and PC

The highest value of the UCS is 92 kN /m^2 observed in a mixture of peat soil + 15% PC. This a 76% increment compared to the UCS of Peat soil without stabilization at 52 kN/m^2. Moreover, the highest value of the maximum dry density is 0.55gr/cm^3 occurs in a mixture of peat soil + 15% PC + 10% SA, which was increasing by 15 gr/cm^3.

Thus, it can be concluded that the variation with the highest dry density and UCS achieved at Peat soil stabilize with 15%PC+10%SA.

4.4 Relationship Between CBR Value (%) and UCS, q_u (kN/m^2)

Figure 8 shows the UCS and the CBR value increase in all stabilize variation mixes. The highest value of UCS is observed at 92 kN/m^2 occurs in a mixture of peat+15%PC, which is increased by 40 kN/m^2 compared to the CBR value of Peat soil.

Meanwhile, the highest value of CBR occurred in a mixture of peat soil + 15%BA, whereas the CBR value increased by 1.49% from 4.50% to 5.99%.

As shown in Fig.8, for the same mixture (P15PC10SA) achieved a CBR value of 4.33%, which is above the minimum value of CBR design for pavement thickness. Moreover, referring to Fig. 7, peat soil stabilizes with 15%PC+10SA (P15PC10SA) achieved the highest value of dry density.

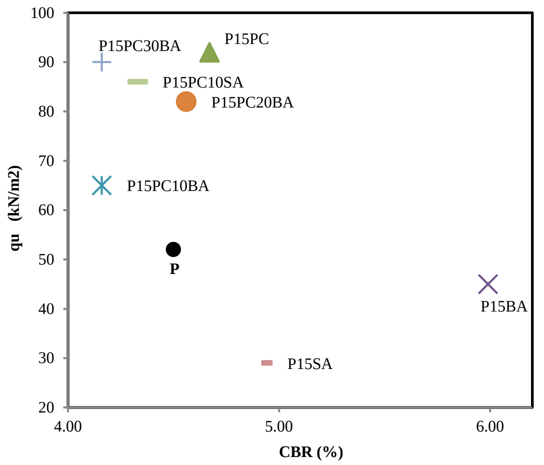

Fig. 8 Relationship Between CBR Value and UCS for Peat Soil Stabilized with BA, SA, and PC.

4.5 Stress and Strain Relationship

The relationships between stress and strain for various variations of the mixture of peat and cement were presented in Fig. 9, where the increase in UCS is observed in all combinations, except P15SA and P15BA. The highest increment is observed on peat soil+15% PC at 92 kN/m^2, an increase by 40 kN/m^2 of the lowest strength of Peat soil with a value of 52 kN /m^2.

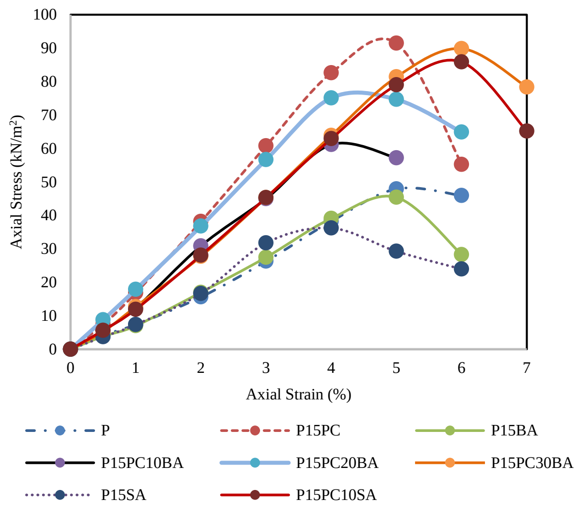

Fig. 9 Stress and Strain Relationship for Peat Soils Stabilized with PC, BA, and SA.

The higher increment is also observed on peat soil+15% PC+ 30%BA at 90 kN/m^2, an increase by 38 kN/m^2 compared to 52 kN/m^2 of Peat without any stabilization.

4.6 Cross-Examination of the Values of UCS, Dry Density, and CBR.

In this study, a cross-examination was carried out to determine which of the mix variations could be implemented in the field, as summarized in Table 3. For comparison purposes, the control sample is also included.

Table 3. Cross-examination of the Values of UCS (q_u), Dry Density and CBR

No	Mix Variation	q_u (kN/m^2)	C_u	Dry Density (gr/cm^3)	CBR (%)
1	Peat Soil	52	26	0.48	4.50
2	Peat Soil + 15%PC	92	46	0.53	4.67
3	Peat Soil + 15% BA	45	22.5	0.5	5.99
4	Peat Soil + 15%PC+10% BA	65	32.5	0.53	4.16
5	Peat Soil + 15%PC+20% BA	82	41	0.5	4.56
6	Peat Soil + 15%PC+30% BA	90	45	0.53	4.16
7	Peat Soil + 15% SA	28	14	0.52	4.92
8	Peat Soil + 15%PC+10% SA	86	43	0.55	4.33

As can be seen from table 3, for UCS test, the Peat soil stabilize with various Bagasse Ash in the mixture increases as the BA increases. As well as the mixture stabilize with SA, as the SA increases in the mixture, the UCS value was also increases.

However, peat soil+15% PC having the highest unconfined compressive strength of 92 kN/m^2 with a dry density of 0.53 gr /cm^3 and a CBR value of 4.67 %. Fortunately, it follows by the peat soil+15%PC+30%BA (P15PC30BA) having an unconfined compressive strength value of 90 kN/m^2, with a dry density of 0.5 gr /cm^3 and CBR value of 4.56 %. So, the purpose of this study to find a lightweight material to strengthen peat soils has been achieved that is using bagasse ash.

With the higher value of UCS for BA mixture due to its cementing properties, that is impart resistance to concrete against elevated temperature [17].

5. CONCLUSIONS

From the results of research and discussion, some conclusions can be drawn;

- An increase in observed in the value of dry density, CBR value, and unconfined compressive strength of the peat soil for all mixes.
- The most optimum mixture is peat soil + 15% PC with unconfined compressive strength of 92 kN/m^2, dry density of 0.53 gr /cm^3 and CBR value of 4.67 %, followed by peat soil + 15% PC + 30% BA with unconfined compressive strength of 90 kN/m^2, dry density of 0.53 gr/cm^3 and CBR value of 4.16 %.
- The addition of bagasse ash gives better results than sawdust ash in stabilizing peat soil.

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