STABILIZATION OF EXPANSIVE CLAY SOIL USING BUTON ROCK ASPHALT THE OTHER UTILIZATION OF BUTON ROCK ASPHALT

Gatot Rusbintardjo
Department of Civil and Environment Engineering Faculty of Engineering
Universitas Islam Sultan Agung (UNISSULA) Semarang Indonesia.
E-mail: gatotrsb@gmail.com

ABSTRACT

Subgrade is the lowest layer of the pavement that must eventually support all the loads that come onto the pavement structure. Therefore, it is essential to make sure that the layer is stable and has sufficient shearing strength to withstand the traffic induced stresses without excessive deformation. If the subgrade soil is poor, sufficient shearing strength, then it must be stabilized to improve its properties. In this paper Buton Rock Asphalt (BRA) was studied to stabilize the expansive clay subgrade soil of Semarang-Purwodadi road in North-East Central Java Province of Indonesia. Amount of 2%, 4%, 6%, and 8% of BRA by weight of soil were added. As comparison or control, natural sand in amount of 5 to 25% in increments of 5% by weight of soil was also added. Laboratory works show that BRA can improve bearing capacity of soil far higher than the natural sand resulted. By adding 8% by weight of soil, BRA can improve bearing capacity of those of expansive clay soil, measure by using CBR, from the value of CBR 1.6% to 5.97% or increase 373%, while 20% of sand only increasing the CBR of soil become 3.90% or increase 244%. Increasing of CBR by adding BRA is in linear line with the line equiation y = 51.54x + 2.126. This mean if the percentage of BRA also 20% the CBR value of BRA-stabilized soil is 12.43% and suitable as well as very good for subgrade material.

Keyword: Buton Rock Asphalt, Stabilizer, expansive soil, improve, bearing capacity, strength.

1. INTRODUCTION

Soil is one of nature's most abundant construction materials. Almost all construction is built with or upon soil. Found from Aggrebind.com/wp-content/…./10/Soil-Stabilization-from-Caterpilar.pdf. Introduction to Soil Stabilization (2010), when unsuitable construction conditions are encountered, the following four options can be selected to be conducted: (1) Find a new construction site; (2) Redesign the structure so it can be constructed on the poor soil; (3) Remove the poor soil and replace it with good soil; (4) Improve the engineering properties of the site soil. Option (4) is being used more often today and is expected to dramatically increase in the future.

Improving on-site (in-situ) soil's engineering properties is referred to as either "soil modification" or "soil stabilization" The term of "modification" implies a minor change in the properties of soil, while stabilization means that the engineering properties of the soil have been changed enough to allow field construction to take place.

There are two primary methods of soil stabilization used today:, namely mechanical and chemical or additive method. The most common form of "mechanical" soil stabilization is compaction of soil, while the addition of cement, lime, bituminous, or other agents is referred to as a "chemical" or "additive" method of soil stabilization.

There are two basic types additives used during chemical soil stabilization: mechanical additives and chemical additives. Mechanical additives such as soil cement mechanically alter the soil by adding a quantity of material that has the engineering characteristics to upgrade the load-bearing capacity of the existing soil. Chemical additives such as lime chemically alter the soil itself, thereby improving the load-bearing capacity of the soil.

Buton Rock Asphalt (BRA), the natural asphalt discovered in Buton island located in South-East of Sulawesi Island of Indonesia, that consider as the new soil stabilizer was studied to use as soil stabilizer and will be described in this paper (Buton Asphalt Indonesia, Co. Ltd. 2006). How much the influence of BRA in improving the properties of soil as soil additive will be described in this paper, and will compare with sand, the other natural material that have been used as soil stabilizer.

2. OBJECTIVE OF THE RESEARCH

The objective of this paper is to promote the suitability of BRA in providing sufficient strength to the expansive subgrade soil, in order suitable to be used as good subgrade.

3. BUTON ROCK ASPHALT (BRA)

BRA is the natural asphalt discovered in Buton Island located in South-East Sulawesi. The areas in Buton Island which have much deposit of rock asphalt are Lawele, Kabungka, Waisnu, Wariti, and Epe. From those five areas, Lawele and Kabungka have much rock asphalt. Natural rock asphalt is found firstly in 1926 by Hetzel, a Dutch geologist. Survey conducted by Ministry of Energy and Mineral Resources Republic of Indonesia show that deposit of natural rock asphalt are estimated around 650 to 700 million tones (Buton Asphalt Indonesia, Co. Ltd. 2006). Deposit of rock asphalt can only be found in 1 to 1.5 meter depth from the land surface as shown in the Figure 1, and bitumen content in the rock asphalt range about 10 to 40%. Since the first time are discovered and mined, still only 3.4 million tons of rock asphalt has been explored.
For this research, BRA was supplied by Buton Aspal Indonesia (BAI) Co. Ltd. in form of coarse grain and was packed in bag contains 25kg per bag (Figure 2). BAI Co. Ltd. takes BRA from Lawelle quarry. Gradation of BRA and it other properties were shown in Table 1.

Figure 1 Rock asphalt in Lawelle quarry of Buton Island

Figure 2: BRA in bag (left) and coarse grains of BRA (right)

Table 1: Gradation and Properties of BRA (Buton Indonesia Co. Ltd. 2006)

No.	Test	Test Method	Result	Specification	Unit
1	Gradation	ASTM C 136			
	Sieve No. 16		100		% passing
	Sieve No. 30		54.02		% passing
	Sieve No. 50		16.97		% passing
	Sieve No. 100		3.75		% passing
	Sieve No. 200		1.82		% passing
2	Bitumen content	ASTM D 1856	22.52	18 – 22	%
3	Solubility in C_2HCL3	ASTM D 2042	18.72	Minimum 18	-
4	Specific gravity	ASTM D 854	1.976	1.70 – 1.90	-
5	Flash point	ASTM D 9272	232	Minimum 230	^{0}C
6	Water content	ASTM D 1461	0.81	Maximum 1	%
7	Volatile content by distillation	ASTM D 402	0.20	-	%

4. RESEARCH METHODOLOGY

This research was conducted in the Geotechnical Laboratory, Faculty of Engineering, Universitas Islam Sultan Agung (UNISSULA) of Semarang, Indonesia. Soil to be stabilized is expansive clay soil take from the subgrade of Semarang-Purwodadi road, the 64 km length of provincial road located in North-East Central Java Province of Indonesia.

To be able to get the correct conclusion that BRA is suitable for soil stabilizer, sand, another natural material was also used to stabilize the same soil. The improvement of strength and properties of soil after adding with stabilizer material was determined by using Atterberg Limit, California Bearing Ratio, and Direct Shear Test tests.

The amount of 2 to 8% in increments of 2% of BRA and 5 to 25% in increments of 5% of natural sand by weight of soil were added.

5. LABORATORY EXPERIMENTS

5.1 Expansive soil

Laboratory works was commenced with Atterberg Limit test for original soil, which the result is given in Table 2, and shows that Plasticity Index (PI) value is 33.9% is categorized high, and the soil can be classified as expansive clay.

Table 2: The results of Atterberg Limit tests for the expansive soil

Test	Result
Liquid Limit (LL)	75.9%
Plastic Limit (PL)	42%
Plasticity Index (PI) = LL – PL	= (75.9 – 42)% = 33.9%

5.2 Soil - BRA and soil-sand stabilization

Laboratory works of Soil–BRA stabilization was commenced by activating bitumen that contain in the BRA in order to be able to blend with soil. Activated bitumen in the BRA was conducted by adding bunker oil. Bunker oil is, used ship lubricating oil, adds to the BRA, mixed and then keeps in the shady place for 48 hours. After 48 hours, bitumen in the BRA will melt, and the particles of BRA

become soft. As have been mentioned, amount of 2, 4, 6, and 8% of this melt and soft BRA then were added to the soil used as additive or stabilizer.
Laboratory test of the mix of soil-BRA and soil-sand were also commenced with Atterberg Limit test, and followed with CBR and Direct Shear test.

6. RESULT AND ANALYSIS

6.1 Soil-BRA Stabilization

6.1.1 Atterberg Limit

The Atterberg test results were given in Table 3 and Figure 3 show that the values of Plasticity Index (PI) lower with increasing of BRA content in the soil. These results correspond to the hypothesis that the lower of PI value, the less potential of soil to become expansive. This means that the more BRA adding, the less expansive of the soil. Decreasing of PI value is caused by decreasing of pores in the soil.

Table 3: Plasticity Index (PI) of soil-BRA

% of Buton-NRA	LL	PL	PI
0%	75.9	42	33.9
2%	71	39	32
4%	69	38	32
6%	69	4	25
8%	68	44	24

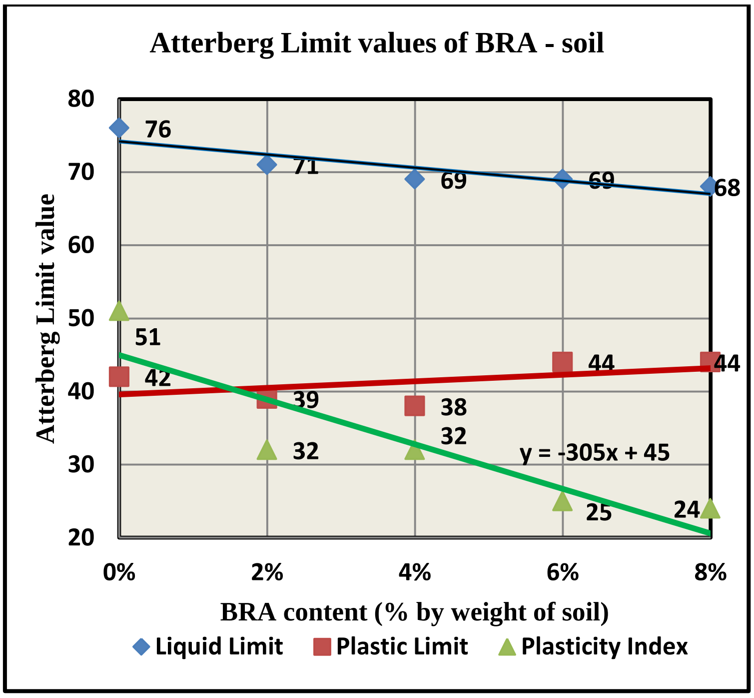

Figure 3 Atterberg values of soil-BRA

6.1.2 California Bearing Ratio (CBR) test

The results of CBR test for BRA stabilize expansive soil were given in Table 4 and shown statistically in Figure 4. The hypothesis said that the more BRA content, the higher the CBR value is. Regression model give coefficient of determination, R-square, R^2 = 0.9662 and coefficient of correlation R = 0.9830. Those values of regression model show that between BRA content and CBR have strong correlation, and the contribution of BRA to CBR value is above 90%, and can be concluded that the CBR value of Soil-BRA is fit with the hypothesis.
CBR values of BRA stabilized soil also have linear line with line equation y = 51.45x + 2.126. This mean, if the BRA content adds to 20%, the CBR value will become 12.43%, suitable and very good for subgrade material.

Table 4: CBR value of soil-BRA

% BRA	CBR (%)
0%	1.6
2%	3.5
4%	4.8
6%	5.05
8%	5.97

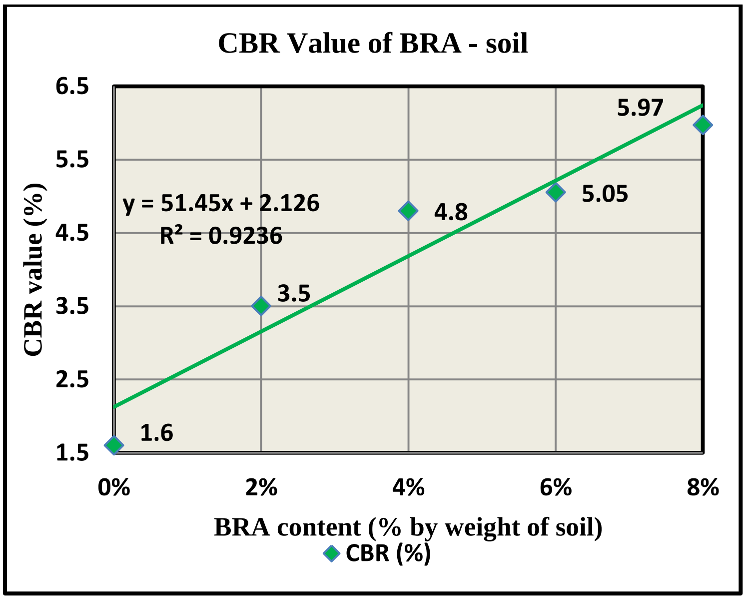

Figure 4: CBR value of soil-BRA

6.1.3 Direct shear test

The results of direct shear test of BRA stabilized soil given in Table 5 and graphically show in Figure 5 and Figure 6 both for cohesion value and angle of internal friction Ø value respectively. Attention should be paid to this direct shear test results. Normally, the higher value of cohesion of soil, the lower value of Ø is. However, soil-stabilized with BRA show the different result, where the higher cohesion also the higher angle of internal friction Ø. This result can be explained as follows: when BRA was added to the soil and thoroughly blend, the particles of soil will be bind by melt bitumen of BRA because the mix of soil-BRA becomes cohesive. Nevertheless, this cohesion is false cohesion, since the rocks particles contain in BRA make the particles of BRA – soil mixtures are clotted, hard, and make it like granular material. That is why the angle of internal friction Ø higher if the BRA content high.

Table 5: Cohesion and angle of internal friction of soil-BRA

% of BRA	Cohesion (c) (kg/cm^2)	Angle of internal friction Ø
0%	0.49	14
2%	0.31	37
4%	0.40	41
6%	0.51	43
8%	0.73	46

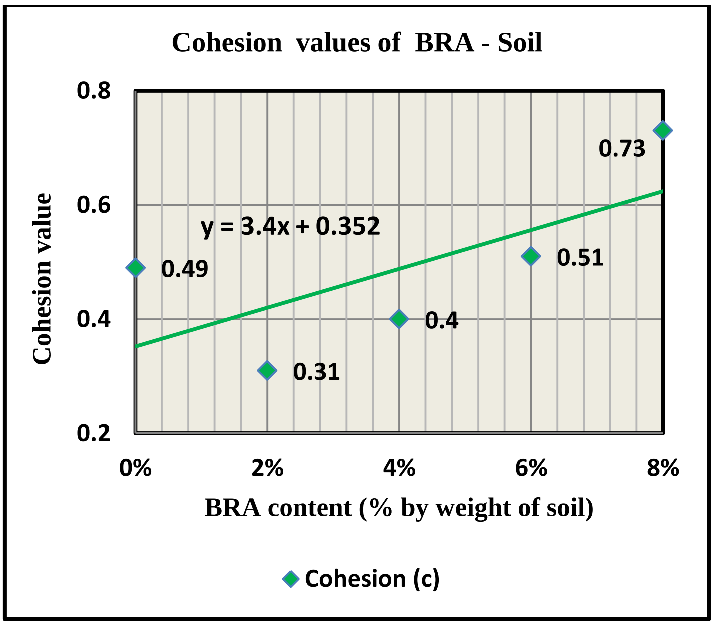

Figure 5: Cohesion value of soil-BRA

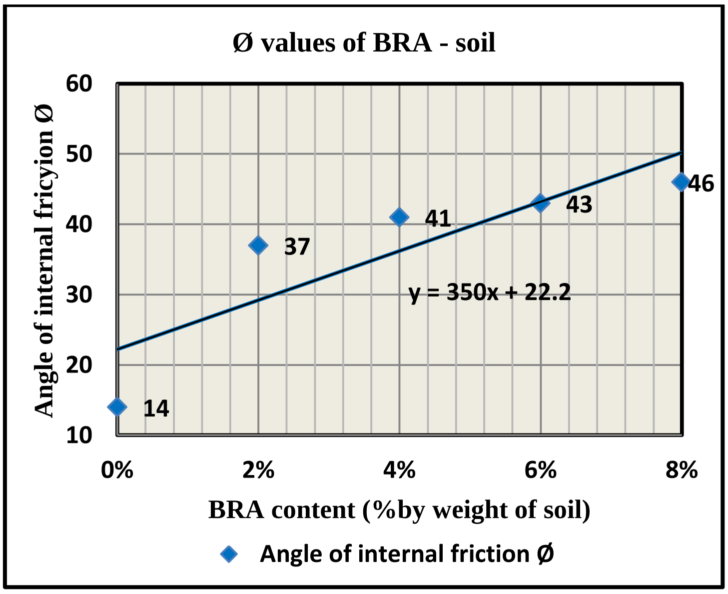

Figure 6: Angle of internal friction of soil-BRA

6.2 Soil-Sand Stabilization

6.2.1 Atterberg Limit

Similar to the soil-BRA, Plasticity Index (PI) lower with increasing of sand content in the soil. The Atterberg test results of soil-sand were given in Table 6 and Figure 7 also show that the values of PI decrease with increasing of percentage of sand content. These results correspond to the hypothesis that the lower of PI value, the less potential of soil to become expansive. This means that the more sand adding, the less expansive of the soil. Decreasing of PI value is caused by decreasing of pores in the soil.

Table 6: Plasticity Index (PI) of soil-sand

% of BRA	LL	PL	PI
0%	75.9	42	33.9
5%	72	46.3	25.7
10%	71	33.31	37.9
15%	60	31.79	28.21
20%	59	29.15	29.85
25%	52	28.18	23.82

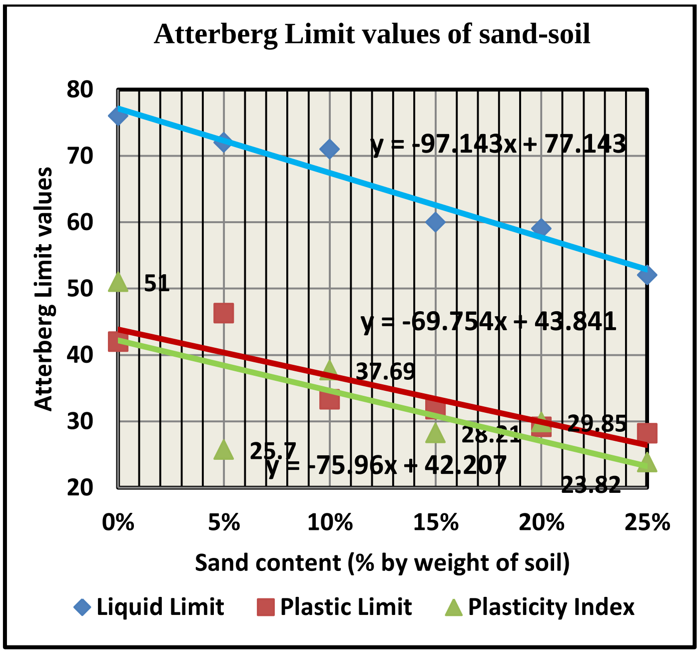

Figure 7: Atterberg Limit value of soil-sand

6.2.2 California Bearing Ratio (CBR) test

The results of CBR test for sand stabilize expansive soil shown statistically in Table 7 and Figure 8. The hypothesis said that the more stabilizer content, the higher the CBR value is. Regression model give coefficient of determination, R-square, R^2 = 0.8527 and coefficient of correlation R = 0.9234. Those values of regression model show that between sand content and CBR have strong correlation, and the contribution of sand to CBR value is 85%, and can be concluded that the CBR value is fit with the hypothesis.

Table 7: CBR value of soil-sand

% BRA	CBR (%)
0%	1.6
5%	2.7
10%	2.95
15%	3.58
20%	3.9
25%	4.92

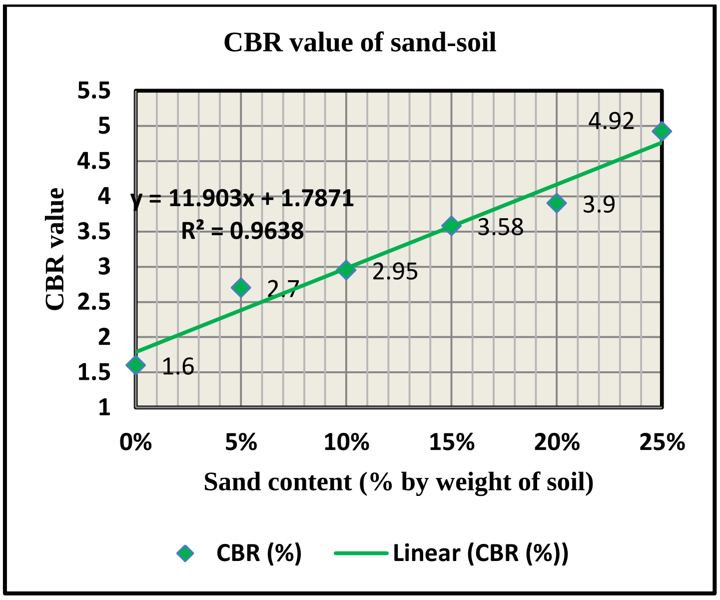

Figure 8: CBR value of sand stabilized soil

6.2.3 Direct shear test

The results of direct shear test for sand stabilized soil given in Table 8 and Figure 9 as well as Figure 10 both for cohesion value and angle of internal friction Ø respectively. The results show the normal value where the higher cohesion value, the lower angle of internal friction Ø. Original soil (0% sand content) have cohesion value 0.49 kg/cm^2 and angle of internal friction Ø = 14°. The more sand content, the lower cohesion value and the higher Ø value is, since sand is naturally cohesion less material

Table 8: Cohesion and angle of internal friction of soil-sand

% of BRA	Cohesion (c) (kg/cm^2)	Angle of internal friction Ø^0
0%	0.49	14
5%	0.31	15
10%	0.29	16
15%	0.27	17
20%	0.24	20
25%	0.20	24

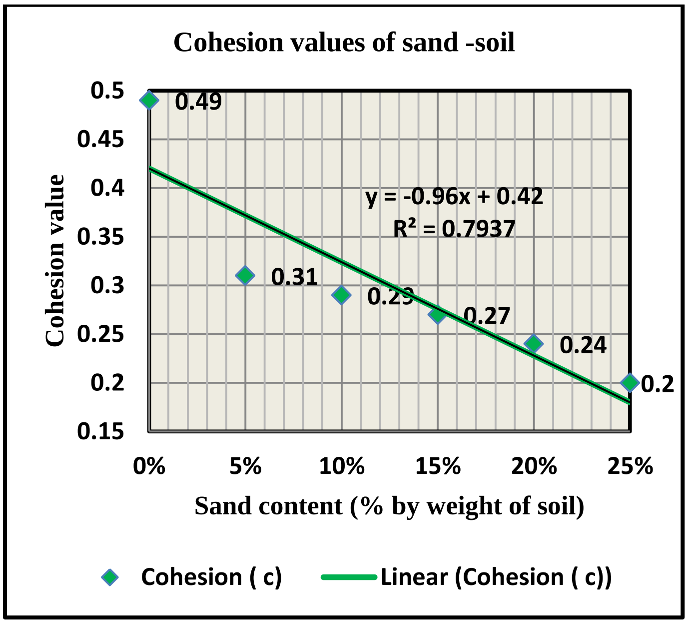

Figure 9: Cohesion values of sand stabilized soil

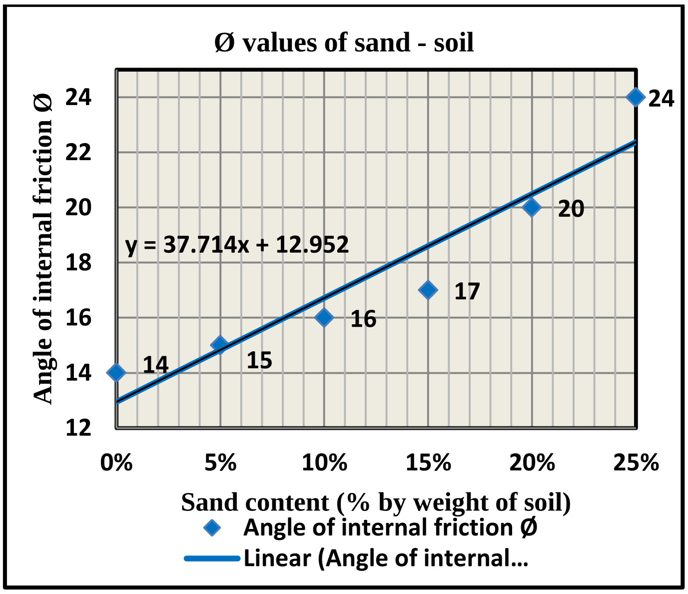

Figure 10: Angle of Internal Friction Ø values of sand stabilized soil

7. CONCLUSION

From the entire test results of those two soil stabilizer, the conclusions can be drawn as follows:

1. Plasticity Index (PI). With 8% of BRA content in the soil, soil-BRA have PI value 24 similar to the 25% of sand content in the soil-sand where PI value is 23.82 ~ 24. Since the PI have linear value, where the higher stabilizer content, the lower of PI value, and the lower of PI, the less expansive of soil, therefore the higher of BRA content, the less expansive of the soil-BRA will be.

2. BRA increase CBR of expansive clay soil significantly and according to AASHTO soil classification categorized as good material for subgrade pavement.

3. The cohesion value of soil-BRA high with the higher of BRA content. But this condition cannot be concluded that soil become more cohesive if the BRA is added. As has been explained above and referring to the conclusion point 1 above as well as the angle of internal friction value, the cohesion value of soil-BRA is false value. When bitumen in the BRA become dry, the particles of BRA become clotted and hard, the soil-BRA become a granular material and not cohesive.

4. Angle of internal friction Ø. Ø value show that the soil is not cohesive, the higher Ø value, and the less cohesive of soil. The results of the research show that the higher BRA, the higher of the Ø value.

8. SUGGESTIONS AND RECOMMENDATIONS

From the above test results and conclusions, the author considered to recommends and suggests using BRA to stabilize expansive subgrade soil of the entire road pavement, flexible or rigid, because:

1. Many road pavement structures deteriorate early because there was no strengthening of subgrade soil.

2. BRA has naturally ready and low cost because not require industrial process compare to cement, lime or petroleum asphalt.

3. More than 600 hundred million deposit of BRA still have not explored yet.

4. Using other methods which have been used to strengthen subgrade soil, like geotextile was proved not succeeding.

9. REFERENCES

AggreBind. Aggreebind.com/wp-content/…/10/Soil-Stabilization-from-Caterpilar.pdf. Introduction to Soil-Stabilization. R. *Understandingthe Basics of Soil Stabilization.* An overview of Materials and Techniques.

Buton Asphalt Indonesia, Co. Ltd. (2006). The Private Company of Buton Asphalt in Indonesia who explores and sells Buton Asphalt

Donald P. Coduto (1994). *Foundation Design – Principles and Practice.* PRENTICE HALL. Engewood Cliffs, N.J. 07632 page 606.

Liu C. and Evett J.B. (2004) *Soils and Foundations*. Pearson Prentice Hall. 6th Edition.

Wright P.H. and Dixon K.K. (2004) *Higway Engineering*, John Wiley & Sons, Inc.

Yoder, E.J. and Witczak, M.W. (1975) *Principles of Pavement Design*. A. Wiley-Interscience Publication. John Wiley & Sons, Inc. New York, London, Sydney. Toronto. Second Edition.