© 2018 IJSRSET | Volume 4 | Issue 1 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Bukho Stone Feasibility (Nias) As A Layer Subbase Course on The Pavement

Oloan Sitohang
Lecturer, Civil Engineering Department of University Chatolic Saint Thomas North Sumatra, Medan, Indonesia

ABSTRACT

North Nias regency contains a significant amount of rock aggregate deposits, namely Bukho stone. To optimize the potential of the material source of the road, it will be conducted the Bukho stone feasibility test as the bottom layer material (subbase course) on the pavement.This study aims to find out whether the bukho stone is eligible and suitable for use as a subbase course material of road pavement according to SNI 03-6388-2000 and laboratory CBR value. The tests are: Sieve Analysis, Abrasion (SNI 03-2417-1991), Liquid Limit (SNI 03-1967-1990), Plastic Limit (SNI 03-1967-1990), and Plasticity Index testing (SNI 1966-2008). Then testing Modified Compaction (SNI 03-1743-1989), resulting in a graph of the relationship of dry weighted (γd) and optimum water content (wopt). Furthermore, testing support of materials by means of CBR laboratory (SNI 03-1744-1989). The result of the research is Abrasion of 28,44%, Plasticity Index 1,056%, Laboratory CBR value on gradation A, B and C respectively 58,33%, 40,68%, and 20,34% meet the minimum requirement of CBRsubbase course that is ≥ 20% according to the guidance of thickness planning of the bending of the highway pavement (SKBI 378 / KPTS / 1987). While on the gradations of D, E, and F obtained the value of CBR laboratory respectively of 15.149%, 18.87%, and 15.439%.Bukho stone test results can be used and feasible as subbase course materials using gradations A, B, and C.

Keywords : Bukho Stone, Subbase Course, CBR

I. INTRODUCTION

1.1 Background

Nias is an archipelago located west of Sumatra Island, Indonesia, and is administratively located in the province of North Sumatra. This island is the largest island among jejeran islands on the west coast of Sumatra, inhabited by the majority of Nias tribe (Ono Niha) and has a megalithic culture. The area has important tourist attractions such as surfing (surfing), custome traditional house, diving, and stone jumping (hombo stone). Nias Island is geographically located at coordinates 1°6'LU-97°32'BT with an area of 5,625 km2 and a population of nearly 900,000 inhabitants.

In the District of Lahewa there is a very useful and valuable rock for local people called "Batu Bukho". Visually Bukho stone has characteristics: generally white colour, the structure of the rock a little porous and its mass rather light compared to the stone times / mountain.

These bedrocks spread throughout in Lahewa District, but one village that has the largest Bukho stone content is Holi Village. The existence of this Bukho stone comes from a hill that is located not too far from the settlement of the residents. From its the hill the local community mining Bukho rock by digging and splitting it into various sizes in accordance with the request of the users. This stone breaking is done by the community manually using a hammer. Bukho stone selling price is relatively cheaper compared to stone / mountain because it is easily obtained and used as a material embankment.

According to Head of North Nias Public Works Office, Yulius Zai, ST., M.Eng stated that with the more increasing of road widening project and opening new road especially in North Nias and the more difficult to get material for development from river [16], subbase course material and base course material (base course)[12]. However, the material used on the road works has never been feasibility testing whether the material meets the standards indicated (Erlingsson, S., Rahman, S., &Salour, F. :201).

1.2 Problem Formulation

Based on the above description, then the problems in this study are:

1. What is the characteristic of the bukho stone material?
2. Does the bukho stone material meet the standard as subbase course material on the pavement?
3. What is the CBR value of the bukho material?

1.3 Research Objectives

The purpose of this study is to test whether the bukho stone is eligible and suitable for use as subbase course material on road pavement in accordance with SNI 03-6388-2000 in terms of laboratory CBR value.

1.4 Research Benefits

The benefits of this research will be useful directly to the North Nias Kabuptaen Government and in general the Nias Islands. Because the results show that Bukho stone can be used as sub base course material.

II. FRAMEWORK FOR THINKING AND HYPOTHESES

2.1. Framework

2.1.1. Subbase Course Layer

The subbase course layer of is part of the flexible pavement structure located between the bottom and the upper layer [7]. Usually composed of compacted, stabilized or unstable grained material (granular material), or a stabilized soil layer. The functions of the subbase course layers are[2]:

- ✓ Part of the pavement construction to spread the wheel load to the base soil. This layer is quite strong, has a CBR ≥ 20% and Plasticity Index (PI) ≤ 10%
- ✓ Material efficiency is relatively cheap compared to the pavement layers above it, and at the same time reduces the thickness of the layers above it
- ✓ To prevent the fine particles from the base soil from rising to the upper layer, the filter requirements must be met

$$\frac{D_{15}\text{subbase}}{D_{15}\text{subgrade}} \geq 5 \text{ and } \frac{D_{15}\text{subbase}}{D_{85}\text{subgrade}} < 5 \quad \text{.....(1)}$$

Where: D15 = grain diameter on the percentage of passes = 15%, and D85 = grain diameter on the percentage of passes = 85%.

2.1.2. Aggregate Classification

According to The Asphalt Institute in Sukirman [23], aggregates are distinguished by: Aggregate coarse (suspended filter 8), fine aggregate (pass filter No. 8), filler (pass filter 30).

The aggregate is distinguished by: Aggregate coarse (retained filter No. 4), fine aggregate (pass sieve No. 4), and Filler (pass sieve No. 200) not less than 75% by weight.

A. **Coarse Aggregate*:*** Ministry of Highways (2009) requires aggregate to be eligible according to: SNI 03-2417-1991, SNI 03-2439-1991, SNI 03-6877-1991, ASTM D-4791 and SNI 03-4142-1996.

B. **Fine Aggregate:** Ministry of Highways (2009) requires fine aggregate to be eligible according to: SNI 03-4428-1997, SNI 03-4142-1996 and SNI 03-6877-2002.

C. **Filler :** The filler comprises stone ash, limestone ash, lime blackout, cement (PC) or other non-plastic materials [9].

2.1.3. Technical Requirements for Subbase Course Material Testing

These requirements are stipulated in Indonesian Building Construction Standard (SKBI) Number: 378 / KPTS / 1987 issued by Ministry of Public Works. Based on the aggregate specification of subbase course SNI 03-6388-2000 [8], the material tested are: wear, compaction, liquid limit, plastic limit, and laboratory CBR.

A. Abrasion of material

Coarse Aggregate resistance test for abrasion may be performed in one of the following seven (7) ways:

1. Method A (Gradation A): passes 37.5 mm to 9.5 mm. Number of balls 12 pieces with 500 rounds;
2. Method B (Gradation B): passes 19 mm to 9.5 mm. Number of balls 11 pieces with 500 rounds;
3. Method C (Gradation C), passes 9.5 mm to 4.75 mm (no.4), Number of balls 8 pieces with 500 rounds;
4. Method D (Gradation D): passes 4.75 mm (no.4) to 2.36 mm (no.8). Number of balls 6 pieces with 500 rounds;
5. Method E (Gradation E): passes 75 mm to 37.5 mm. Number of balls 12 pieces with 1000 rounds;
6. Method F (Gradation F): passes 50 mm to 25 mm. Number of balls 12 pieces with 1000 rounds;
7. Method G (Gradation G): passes 37.5 mm to 19 mm. Number of balls 12 pieces with 1000 rounds;

Thus, the abrasion value can be calculated by the following equation:

$$\text{abrasion} = \frac{a - b}{a} \times 100\,\% \qquad \text{........................(2)}$$

With: a = the weight of the initial specimen (gram) and b = the weight of the test object is retained filter no. 12 (gram).

B. Gradation

Based on a dry sieve analysis (AASHTO T27-82) or wet analyzer (AASHTO T11-82), the continuous aggregate gradation boundaries of the mixture can be seen in Table 1 below.

Table 1. Gradation Requirement of Subbase Course Layer

Sieve Size		**Percent Weight Passes**					
Standard (mm)	**Alternative**	**Gradation**					
		A	**B**	**C**	**D**	**E**	**F**
50	2 in	100	100	-	-	-	-
25	1 in	-	75-95	100	100	100	100
9,5	3/8 in	30-65	40-75	50-85	60-100	-	-
4,75	No.4	25-55	30-60	35-65	50-85	55-100	70-100
2	No.10	15-40	20-45	25-50	40-70	40-100	55-100
0,425	No.40	8-20	15-30	15-30	25-45	20-50	30-70
0,075	No.200	2-8	5-20	5-15	5 - 20	6-20	8-25

Source: Pustran-Balitbang PU "SpesifikasiAgregat Lapis PondasiBawah, Lapis PondasiAtasdan Lapis Permukaan (SNI 03-6388-2000)

C. Compaction

The result of compaction produces a water content relationship curve with a dry volume weight as shown in Figure 1 below.

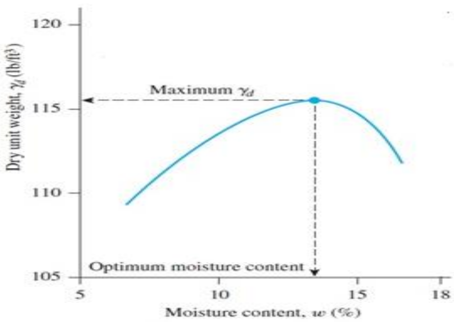


Figure 1. Water Content Relation Curve with Dry Unit Weight

Resources : Principles of Geotechnical Engineering 7 Ed - Braja M. Das.

Calculation of moisture content (w):

$$w = \frac{(A - B)}{(B - C)} x100\% \quad \text{...(2)}$$

With: w = moisture content (%), A = mass of gram and wet test object (gram), B = mass of gram and dry specimen (gram) and C = mass of cup.

D. Atterberg Limits

Determination of Atterberg limits through sieve. Number 40. For subbase layers, the value of Plasticity Index (PI) ≤ 10%.

E. CBR Laboratory

Laboratory CBR testing according to SNI 03-1744-1989. CBR value its search is CBR laboratorum value.

$$\text{CBR Value (\%)} = \frac{load\ 0{,}1''}{3x1000} x100 \quad \text{...(4)}$$

$$\text{CBR Value (\%)} = \frac{load\ 0{,}2''}{3x1500} x100 \quad \text{...(5)}$$

The CBR value requirements of materials on the pavement can be seen in Table 2 below.

Table 2. CBR Value Subbase Course Layer

No.	Material (Subbase Course) on Pavement	CBR Value (%)
1	Sand Rock / Pitrun Class A	70
2	Sand Rock/ Pitrun Class B	50
3	Sand Rock / Pitrun Class C	30
4	SandClay	20

Resources : Departemen Pekerjaan Umum, SKBI 378/KPTS/1987

2.2. Research Methodology

The research steps are carried out in accordance with Figure 2 below. Beginning with Pilot Survey in the form of survey location and sampling (Zhang, Y., Ishikawa, T., Tokoro, T., & Nishimura, T. :2014). After that initial inspection to find out abrasion, plastic index and the angularity of the material whether eligible. If fulfilled then proceed with Advanced Examination in the form of:gradation (design of a mixture of coarse aggregate, fine aggregate and filler) as well as sample preparation), and Density Test (obtained by ɤdry relationship with Wopt). Finally is the Final Test in the form of CBR Test with the steps of sample preparation and CBR test and obtained the reading of CBR value.

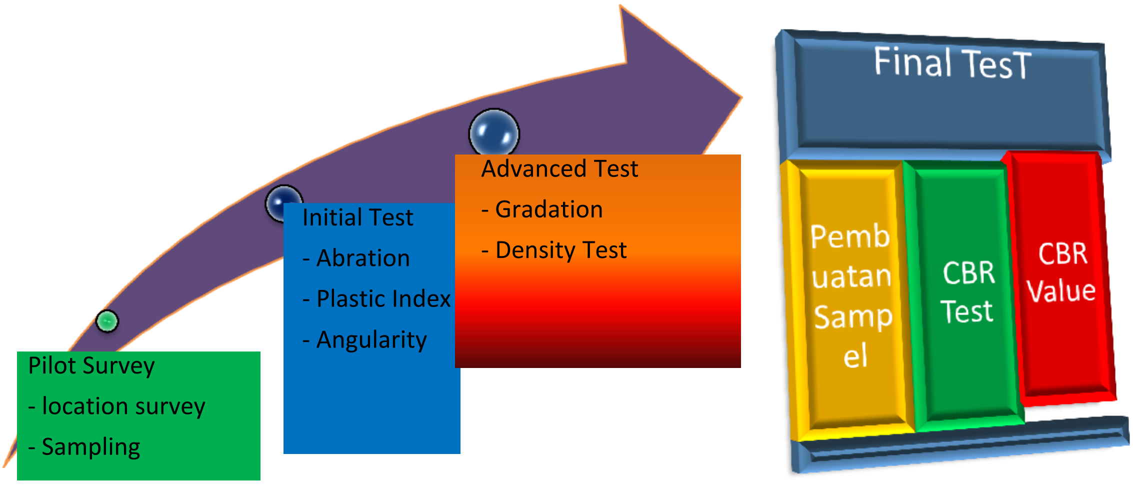


Figure 2. Research Procedure

2.2.1. Sampling Test Method

A. Abration Test/Los Angeles Test (SNI 03-2417-1991)

Abration testing is done in 2 (two) ways, namely: Method C (Gradation C) and Method D (Gradation D). The abration value calculated using equation (2) above is obtained an average of 28.44% <50% (the abration value is eligible).

B. Compaction Test

This test is intended to determine the relationship between moisture content and the unit of the soil content by compaction of 4.54 kg (10 lb) poultry and the falling height of 45.7 cm (18 ") in a specified cylinder mold. This research uses the method of A Ø-4 "mold, passing material No. 4. sieve and calculated:

- Wet density (ρ) : $\rho = \frac{(B_2 - B_1)}{V}$ ....(6)
- Water content (w) : $w = \frac{(A - B)}{(B - C)} x100\%$ ....(7)
- Dry density (ρd) : $\rho d = \frac{(\rho)}{(100 + w)} x100\%$ ....(8)

Where: B1 = mass of mold and base slice (gram); B2 = mold mass, base pad, and specimen (gram); V = volume of mold or specimen (cm3); and A = the mass of the saucer and the wetness test object (gram); B = masses of grains and dry specimens (grams) and C = cup mass.

C. Liquid Limit (SNI 03-1967-1990)

Testing of plastic limit according to SNI 03-1966-1990 with:

$Ip = W_1 - Wp$ ....(9)

Where: Ip = Index of plasticity; W1 = Limit of liquid and Wp = Limit of plastic.

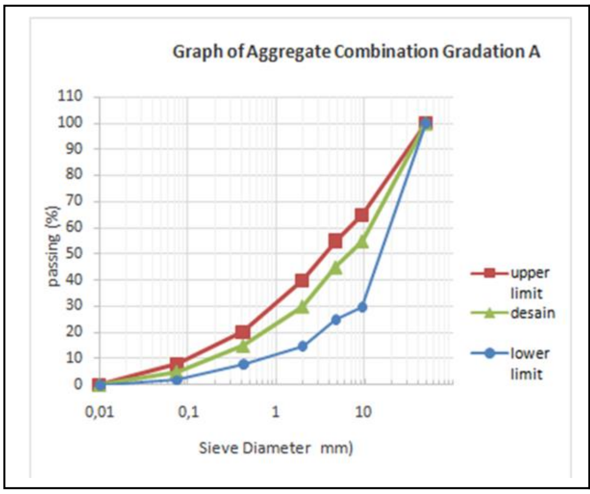
2.2.2. CBR Testing Laboratory

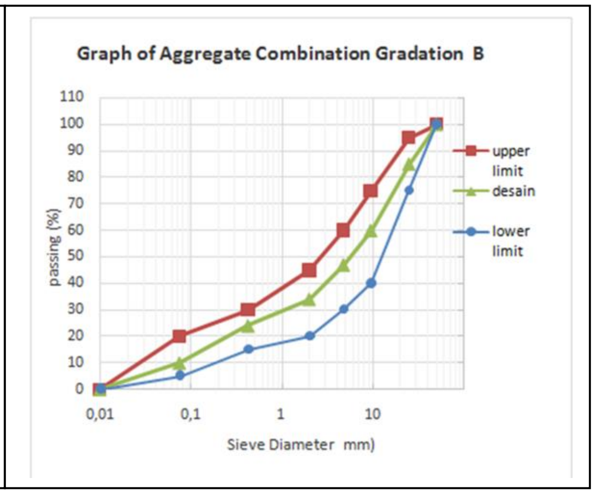
CBR immersion test according to SNI 03-1744-1989 CBR value will be obtained by dividing the load that occurs each with the standard load of 1000 psi and 1500 psi and multiply the penetration intermediate of 0.1 "and penetration 0.2" divided by the standard load its corresponding

III. ANALYSIS AND DISCUSSION

3.1 Aggregate Combination Based on Sieve Analysis

The aggregate combination design represented by Gradation C and Gradation D as shown in Graph 1 and Graph 2 below:





Graph 1. Combination Aggregate Gradation A **Graph 2.** Combination Aggregate Gradation B

In Graph 1 and Graph 2 above is a graph of the aggregate combination of gradation A and gradation B where the aggregate percentage meets the specified boundary condition as it is between the upper and lower limits. Equal aggregate proportion with CA = 55%, FA = 40%, and filler 5%) for Gradation A, For gradation B (CA = 53%, FA = 37%, and filler 10%) and combination gradation C (CA = 47 %, FA = 43%, and filler 10%). The aggregate proportion of the three gradations is well graded.While the aggregate gradation combinations D, E and F fulfill the defined gradation boundary conditions between the upper and lower limits but unequal aggregate proportions where CA = 33%, FA = 55%, and filler 12% for gradation D, for gradation E (CA = 25%, FA = 65%, and filler 10%), and gradation F (CA = 15%, FA = 75%, and filler 10%) and the aggregate proportions of the three gradations are graded poorly.

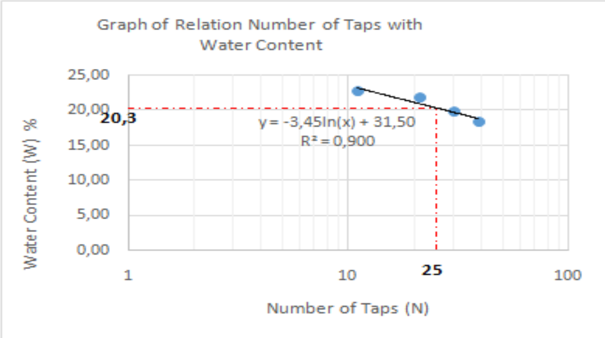
3.2 Bukho Stone Material Testing

3.2.1 Liquid Limit and Plastic Limit Tests

The results of liquid limit and plastic limit testing can be seen in Graph 3

Plastis Limit, PL (%)	**19,315**
Liquid Limit, LL (%)	**20,371**
Plasticity Index, PI = LL – PL	**1,056 %**

Source: Laboratory Test Results



Graph 3. Relationship of Number of Taps with Water Content

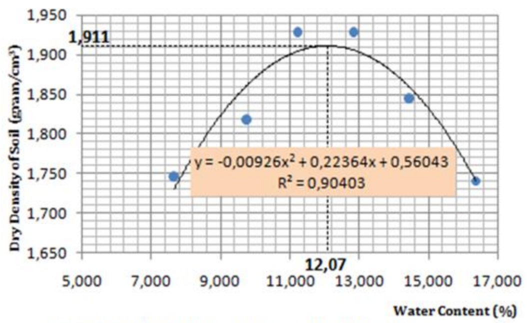
3.3 Compaction Testing

Sample Result I:

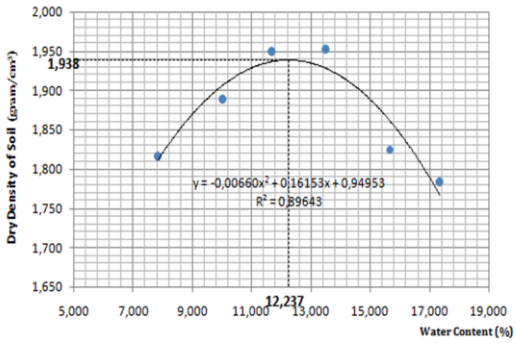
✓ wet density $(\rho) = \dfrac{(B_2 - B_1)}{V} = \dfrac{(6010 - 4230)}{947{,}39} = 1{,}879\, gr/m^3$

✓ water content $(w) = \dfrac{(A - B)}{(B - C)} x100\% = \dfrac{(29{,}2 - 27{,}3)}{(27{,}3 - 2{,}5)} x100\% = 7{,}661\%$

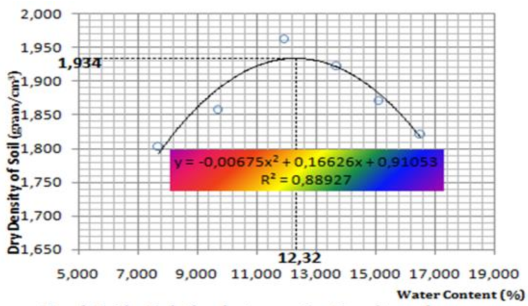
✓ dry density $(\rho d) = \dfrac{(\rho)}{(100 + w)} x100\% = \dfrac{(1{,}879)}{(100 + 7{,}661)} x100\% = 1{,}745\, gr/cm^3$



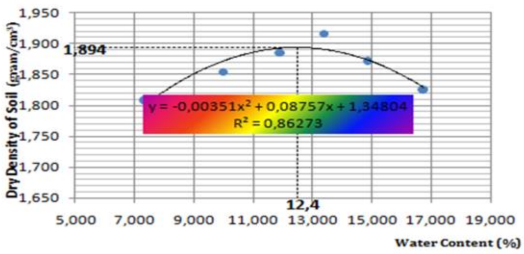
Graph 4. The Relation between Dry Density and Water Content for Method A



Graph 5. The Relation between Dry Density and Water Content for Method B



Graph 6. The Relation between Dry Density and Water Content for Method C



Graph 7. The Relation between Dry Density and Water Content for Method D

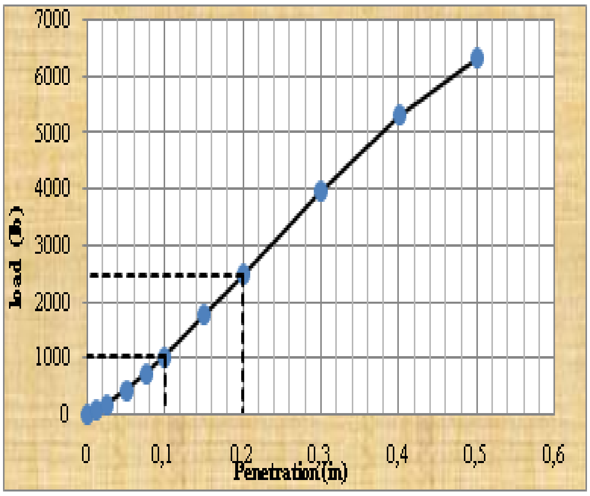
From each test Modified Proctor Compaction Test obtained the optimum water content as follows: Method A (Wopt = 12.08%), Method B (Wopt 12.24%), Method C (Wopt = 12.32%) and Method D (Wopt = 12.47%).

3.4 Testing CBR of Laboratory

The results of laboratory CBR testing can be seen in Table 3 below and plotted on the graph of the relationship between load and penetration.

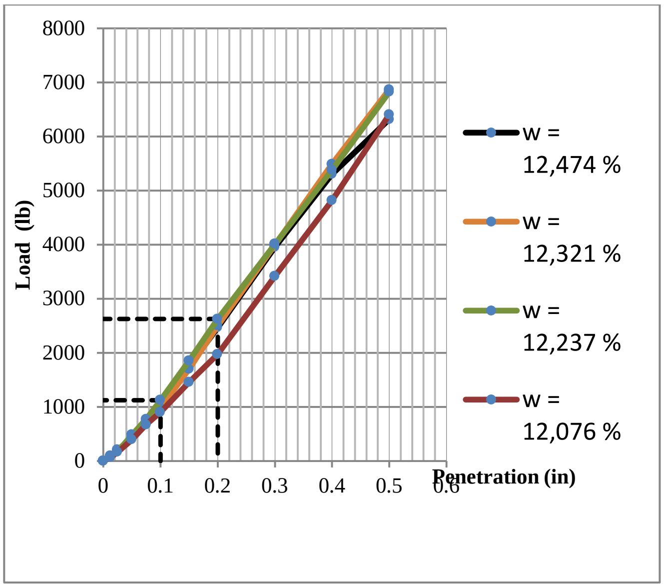
Table 3. CBR Value for Various Wopt For Gradation A

Penetration (in)	Formulation	Gradation A (w_{opt} = 12,474 %)		Gradation A (w_{opt} = 12,321 %)		Gradation A (w_{opt} = 12,237 %)		Gradation A (w_{opt} = 12,076 %)	
		Penetration load (lb)	CBR Value (%)	Penetration load (lb)	CBR Value (%)	Penetration load (lb)	CBR Value (%)	Penetration load (lb)	CBR Value (%)
0,1”	$\frac{\text{load } 0{,}1"}{3000}$x100	1025,604	34,187	981,492	**32,716**	1124,856	**37,495**	904,296	**30,143**
0,2”	$\frac{\text{load } 0{,}2 \text{ in}}{4500}$x100	2470,272	54,895	2503,356	**55,630**	2624,664	**58,326**	1974,012	**43,867**



Graph 8. Load Relationship with Penetration on Grade A on Wopt = 12.474%.

In Graph 8 on penetration 0,1 in got load value = 1025,604 lb and CBR = 34,187% and at penetration 0,2 in got load value = 2470,272 lb and CBR = 54,895%. Furthermore, as reference CBR is penetration 0.2 in = 54.895%. According to SKBI 378 / KPTS / 1987 with CBR = 54.895% ≥ 20% can meet the requirements. A further explanation of the graph of the gradation penetration load relation A can be seen in the aggregate graph of Graph 9.



Graph 9. Load Reationship with Penetration (Gradation A) with Various Wopt

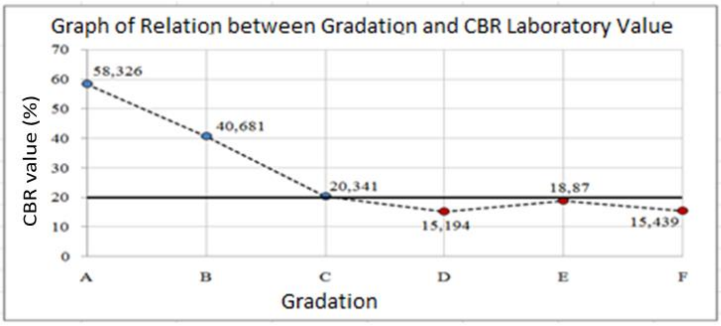
The results of CBR Laboratory testing for gradation B up to gradation F are performed in the sameway, with the same optimum moisture content, and the same calculation. The CBR values at 0.1 in and 0.2 in. Penetration loads for gradation B up to F grading are performed in the same manner, with the same optimum moisture content. Overall the results obtained in Table 4.

Table 4. CBR value (%) for Grades A, B, C, D, E and F

No.	Gradation	CBR Value(%)		The actual CBR value (%)	Information
		Penetration 0,1 in	Penetration 0,2 in		
1	A	37,495	58,326	58,326	≥ 20%, eligible then eligible for use
2	B	23,343	40,681	40,681	≥ 20%, eligible then eligible for use
3	C	10,477	20,341	20,341	≥ 20%, eligible then eligible for use
4	D	10,293	15,194	15,194	≤ 20%, not eligible.
5	E	11,396	18,870	18,870	≤ 20%, not eligible
6	F	10,293	15,439	15,439	≤ 20%, not eligible

3.5 Parameter Testing Discussion

Based on the testing of the wear of the Bukho stone material, the material abration rate is obtained with an average of 28.44% where the abration rate is <50% (SNI 03-2417-199), while the liquid limit test and plastic limit is obtained plasticity index 1.056% (plasticity low with soil type ie silt, and partially cohesive) where the plasticity index value is <10% (Ministry of Public Works, SKBI 378 / KPTS / 1987). Therefore, this Nias stone bukho material qualifies the plasticity index to be used in the subbase course on the pavement and is suitable for use. CBR value of material obtained by each gradation are: Gradation A = 58,326%, Gradation B = 40,681%, Gradation C = 20,341%, Gradation D = 15,194%, Gradation E = 18,870% and Gradation F = 15,439% presented in Graph 10 that the value of each CBR per gradation is compared with the reference value given by SKBI 378 / KPTS / 1987.



Graph 10. Relation between Gradation and CBR Laboratory Value

In the gradation of A obtained laboratory CBR value of 58.326%.This shows that gradation A has the largest CBR laboratory value of all gradations tested. This means that the value of CBR of gradation laboratory A is 58,326% fulfilling the requirement of minimum CBR value in subbase course on road pavement that is ≥ 20% (Department of Public Works, SKBI 378 / KPTS / 1987).

In the gradation B, the laboratory value of CBR of 40.681% indicates that the type of material in the form of sirtu / pitrun class C qualifies the minimum CBR value in the subbase course on the pavement ie ≥ 20% according to the Department of Public Works, SKBI 378 / KPTS / 1987).

In the C grading, the laboratory CBR value of 20.341% indicates that the material type in the form of loam clay qualifies the minimum CBR value in the subbase course on the pavement ie ≥ 20% according to the Public Works Department, SKBI 378 / KPTS / 1987.

In the gradations D, E, and F obtained the value of CBR laboratory respectively of 15.149%, 18.870%, and 15.439% that according to the Department of Public Works, SKBI 378 / KPTS / 1987 did not enter any type of material so that gradation material D, E, and F is not eligible for use as subbase course material because it has a CBR value less than 20%.

In this research, it can be concluded that the material of agro-rock of Bukho origin of Nias is feasible to be used as subbase course material on pavement using a mixture of coarse aggregate and fine aggregate with balanced portion to obtain a well-graded and well graded) ie by using gradations A, B, and C.

IV. CONCLUSIONS

Based on the results of research, can be drawn some conclusions namely:

1. Average abration rate 28.44% <50% (SNI 03-2417-1991), Plasticity Index Value = 1.056% (low plasticity, partial cohesion) <10% (Ministry of Public Works, SKBI 378 / KPTS / 1987), Wopt = 12%, Laboratory CBR values at gradations A, B, and C were 58.326%, 40.681%, and 20.341% respectively, fulfilling the minimum requirement of CBRsubbase course ≥ 20% according to the guidance of thickness planning of pavement bending of highways (Ministry Public Works, SKBI 378 / KPTS / 1987).

2. According to the Department of Public Works, SKBI 378 / KPTS / 1987, Grade A with CBR value = 58.326% is classified in Class B grade grade with a minimum CBR value of 50% and graded B with CBR = 40.681% material sirtu / pitrun Class C with a minimum CBR value of 30%. While the gradation of C with the value of CBR of 20.341% belong to the class of aggregate material clay sand with a minimum CBR value of 20%.
3. Bukho Stone from Nias suitable for use as subbase course layer material on road pavement with as gradation of A, B, and C.

V. RECOMMENDATIONS

Some suggestions given by researchers on the results obtained are:

1. Further research is needed to find out the influence of Bukho stone from Nias as base layer material or surface layer material on pavement.
2. In the gradations D, E, and F do not meet the minimum CBR value in the subbase course of the pavement, it is necessary to stabilize and further research is needed.

VI. REFERENCES

[1]. Arshad, M., & Ahmed, M. F. (2017). Potential use of reclaimed asphalt pavement and recycled concrete aggregate in base/subbase layers of flexible pavements. Construction and Building Materials, 151, 83-97.

[2]. Arulrajah, A., Disfani, M. M., Horpibulsuk, S., Suksiripattanapong, C., &Prongmanee, N. (2014). Physical properties and shear strength responses of recycled construction and demolition materials in unbound pavement base/subbase applications. Construction and Building Materials, 58, 245-257.

[3]. Behiry, A. E. A. E. M. (2013). Evaluation of steel slag and crushed limestone mixtures as subbase material in flexible pavement. Ain Shams Engineering Journal, 4(1), 43-53.

[4]. del Valle-Zermeño, R., Formosa, J., Prieto, M., Nadal, R., Niubó, M., &Chimenos, J. M. (2014). Pilot-scale road subbase made with granular material formulated with MSWI bottom ash and stabilized APC fly ash: Environmental impact assessment. Journal of hazardous materials, 266, 132-140.

[5]. Erlingsson, S., Rahman, S., &Salour, F. (2017).Characteristic of unbound granular materials and subgrades based on multi stage RLT testing. Transportation Geotechnics, 13, 28-42.

[6]. Kambole, C., Paige-Green, P., Kupolati, W. K., Ndambuki, J. M., &Adeboje, A. O. (2017). Basic oxygen furnace slag for road pavements: A review of material characteristics and performance for effective utilisation in southern Africa.Construction and Building Materials, 148, 618-631.

[7]. Montepara, A., Tebaldi, G., Marradi, A., &Betti, G. (2012).Effect on pavement performance of a subbase layer composed by natural aggregate and RAP. Procedia-Social and Behavioral Sciences, 53, 980-989.

[8]. Poon, C. S., & Chan, D. (2006).Feasible use of recycled concrete aggregates and crushed clay brick as unbound road sub-base. Construction and Building Materials, 20(8), 578-585.

[9]. Saltan, M., &Fındık, F. S. (2008).Stabilization of subbase layer materials with waste pumice in flexible pavement.Building and Environment, 43(4), 415-421.

[10]. Zhang, Y., Ishikawa, T., Tokoro, T., & Nishimura, T. (2014).Influences of degree of saturation and strain rate on strength characteristics of unsaturated granular subbase course material. Transportation Geotechnics, 1(2), 74-89.

[11]. Balitbang Department of Public Works. 2015. General Specification of Road and Bridge Fields.

[12]. LPKM-ITB, 2010. Anaysis of Road Pavement Structure. Bandung : ITB.

[13]. M. Das, Braja, 2014. Principles of Geotechnical Engineering.

[14]. Ministry of Public Works, Directorate General of Highways. 2006. Road Works Works.
[15]. Purba, Brian Rifvaldo, 2012. Aggregate Feasibility Test from Saoka Sorong as Aggregate Road Base Material
[16]. SKBI 378 / KPTS / 1987. Planning Guidance for Bold Pavement Thickness of Highways (Ministry of Public Works)
[17]. SNI 03-1744-1989 / 1744-2012. CBR Laboratory Test Method.
[18]. SNI 03-2417-1991. Test Method of Aggregate Wear with Los Angeles Abrasion Machine.
[19]. SNI 03-6388-2000. Bottom Bound Aggregate Specification, Upper Layer, and Surface Layer
[20]. SNI 03-1743-1989. The Modified Proctor Test.
[21]. SNI 03-1966-1990. Method of Plastic Limit Testing
[22]. SNI 03-1967-1990. Method of Testing Liquid Limit With Casagrande Tool.
[23]. Sukirman, Silvia. 1992. Highway Pavement Flexibility. Jakarta: Nova.