Design Of Pavement Using Buton Natural Rock Asphalt Stabilized Subgrade Soil

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Abstrak- The performance of pavements is governed by the strength of the subgrade, because subgrade is roadbed soil where the pavement structure is laid. If bearing capacity of the subgrade high, deformation of pavement will not occur and it is not easy to deteriorate. In the contrary, if bearing capacity of the subgrade low, pavement deformation will occur and pavement will deteriorate. This research have objectives to analysis the pavement structure of using existing subgrade soil and using subgrade stabilized with Buton Natural Rock Asphalt (BNRA). The road connecting Semarang - Purwodadi where always in worst condition was used for study in this research. Semarang – Purwodadi road is laid over montmorillonite expansive clay with lower bearing capacity or have low CBR value only 1 to 2 %. To analysis the pavement structure, both flexible and rigid pavement, AASHTO 1993 pavement design are used. The result show that flexible pavement structure laid over stabilized soil have thinner pavement structure compare to the one laid over the subgrade of original expansive clay soil. Similarly for rigid pavement, the thick of concrete slab over the subgrade of expansive clay is 30 cm, and if laid over the subgrade of stabilized expansive clay with Buton Natural Rock Asphalt (BNRA) is only 25cm. It can be concluded that Buton Natural Rock Asphalt (BNRA), have significant influence to the strength and bearing capacity of expansive clay soil.

***Keywords*: ** asbuton, stabilized subgrade, expansive clay soil, AASHTO

1. Introduction

1.1. Background

From the beginning of mankind, transportation, especially land transportation has been a main aspect in human lives. Communication and trade would not have been possible without it. For this purpose, thousands kilometres of road have been built over the world.

In its development, pavements can be broadly classified into two types, flexible and rigid pavement. Flexible pavement is the pavement where the surface or wearing course constructed using hot mix asphalt concrete, where rigid pavement the surface pavement constructed with the slab of cement concrete.

The purpose of a pavement is to provide a smooth surface over which vehicles may pass under all climatic conditions. In turn, the performance of the pavement is affected by the characteristics of the subgrade. Desirable properties that the subgrade should possess include strength, drainage, ease of compaction, permanency of compaction, and permanency of strength. Therefore, design of the pavement is depend on the quality of the subgrade.

1.2. The Objective of the research

From the above description, the objective of the research are as follows:

a. Make redesign of existing pavement a using unstabilized expansive clay soil as subgrade.
b. Make redesign the pavement Semarang – Purwodadi using BNRA Stabilized expansive clay soil as subgrade.
c. Comparing pavement design over existing subgrade and over stabilized subgrade

2. Design

2.1. Introduction

Pavement layer thickness depends on subgrade strength where the pavement structure laid. The higher bearing capacity of subgrade improves its strength. In this chapter the bearing capacity expressed in CBR value which will be calculate. The final result of the calculation will prove that the higher CBR value of the subgrade could make the pavement layer thinner or not, and the using of stabilized subgrade might has thinner pavement layer than the using of existing subgrade.

As described in the previous chapter, pavement layers were calculated by using AASHTO 1993 method both for pavement over the existing subgrade and for pavement over the stabilized subgrade.

2.2. Time constraints

The analysis period selected for this design was the maximum performance period or service live 15 years. There are two comprehension of period, analysis and performance period.

2.3. Performance period

Performance period is the period of time that an initial pavement structure will last before it needs rehabilitation. It also refers to the performance time between rehabilitation operations. The performance period is equivalent to the time elapsed as a new, reconstructed, or rehabilitated structure deteriorates from its initial serviceability to its terminal serviceability. For the performance period, the designer must select minimum and maximum bounds that are established by agency experience and policy.

2.4. Analysis Period

This refers to the period of time for which the analysis is to be constructed, i.e., the length of time that any design strategy must cover. The analysis period is analogous to the term design life used by designer in the past. Because of the consideration of the maximum performance period, it may be necessary to consider and plan for stage construction (i,e., an initial pavement structure followed by one or more rehabilitation operations) to achieve desired analysis period.

2.5. Traffic

Based on 2016 average daily traffic and axle weight data from Bina Marga Central Java Services (*Dinas Bina Marga Provinsi Jawa Tengah*) the estimated two-way 8.16 ton equivalent single axle load (ESAL) applications during the first year of the pavement's life is 11.2 x 10^6 and the projected growth rate is 9 percent per year. Data of the year 2016 average daily traffic is given in Table 1.

Tabel 1. Average Daily Traffic year 2016

Type of vehicle	Vehicle/day
Passenger car	19,942.38
Small bus	815.58
Bus	402.96
2 axle heavy truck	3367.20
3 axle heavy truck	140.76
Truck trailer	183.54
Total	24,852.42

The directional distribution factor (D_D) is assumed to be 50 percent and the lane distribution (D_L) for the facility is 50 percent.

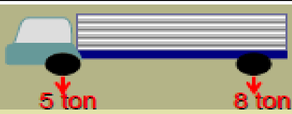
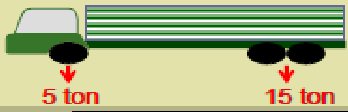
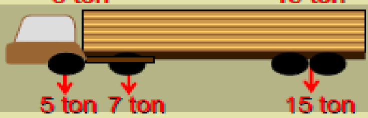
2.6. Calculation of Equivalent Single Axle Load (ESAL)

Table 2. Give number of equivalency (E) of axle load, and Table 3. Give load configuration for 8.16 ton ESAL

Table 2. Number of Equivalency (E) of axle load

Axle Load (t)	Number of Equivalency		Axle Load (t)	Number of Equivalency	
	Single	Tandem		Single	Tandem
1	0.0002	-	10	2.2555	0.194
2	0.0036	0.0003	11	3.3022	0.284
3	0.0183	0.0016	12	4.677	0.4022
4	0.0577	0.0050	13	6.4419	0.554
5	0.141	0.0121	14	8.6647	0.7452
6	0.2923	0.0251	15	11.4184	0.982
7	0.5415	0.0466	16	14.2712	1.2712
8	0.9238	0.0794	17	-	1.5672
8.16	1.0000	0.086	18	-	1.9156
9	14798	0.1273	19	-	2.3164

Table 3. Load Configuration for 8,16 Ton ESAL

CATEGORY	CONFIGURATION	
6B (trailer 2 sumbu) **1.2H**		**1.716**
7A (trailer 3 sumbu) **1.2.2**		**1.774**
7C1 (trailer 4 sumbu) **1.2+2.2**		**2.316**
7C2 (trailer 5 sumbu) **1.2+2.2.2**		**3.246**
7C3 (trailer 6 sumbu) **1.2.2+2.2.2**		**3.687**

VDF = Value damage factor

Use Table 2. and Table 3., number of equivalency for heavy vehicle (passenger car was neglected) can be determined as follows:

1. Light bus (8 ton) = 3 ton (front wheel) + 5 ton (rear wheel single axle)
   Number of equivalency = 0.0183 + 0.1410 = 0.1593
2. Bus (11 ton) = 5 ton (front wheel) + 8 ton (rear wheel single axle)
   Number of equivalency = 0,1410 + 0,9238 = 1,0648
3. Light Truck (11 ton) = 5 ton (front wheel) + 8 ton (rear wheel single axle)
   Number of equivalency = 0,1410 + 0,9238 = 1,0648
4. Heavy Truck (27 ton) = 5 ton (front wheel) + 7 ton (midle wheel single) + 15ton (rear wheel tandem axle)
   Number of equivapency = 0,1410 + 0,5415 + 0,9820 = 1,6645
5. Truck Trailer (32 ton) = 5 ton (front wheel) + 7 ton (midle wheel single) + 20ton (rear wheel triple axle)
   Number of equivalency = 0,1410 + 0,5415 + 2,3164 = 2,9989

Worksheet for calculating 8,16 ton ESAL applications for analysis period 15 years and assumed SN or D = 4" was given in Table 4.

Table 4 Worksheet for calculating 8.16 ton ESAL applications

Vehicle types	Current traffic (a)	Growth factors (b)	Design traffic (c)	ESAL factor (d)	Design ESAL (e)
Light bus	815.58	29.46	8769850.2	0.1593	1397037.134
Bus	402.96	29.46	4332988.6	1.0648	4613766.244

Light truck	2909.04	29.46	31280616	1.0648	33307600.15
Heavy truck	605.82	29.46	6514321.9	1.6645	10843088.77
Truck trailer	176.64	29.46	1899392.3	2.9989	5696087.437
All vehicles	4910.04		52797169		55857579.73

The equation to calculate the traffic during the first year is:

$$W_{8,16} = D_D \times D_L \times \text{Design ESAL} \tag{1}$$

Where:

D_D = a directional distribution factor, expressed as a ratio, that accounts for the distribution of ESAL units by direction
Mentioned above, in this design D_D was taken 50 percent

D_L = a lane distribution factor, expressed as a ratio, that accounts for distribution of traffic when two or more lanes are available in one direction. As mentioned above, in this design D_L was taken 50 percent

$\hat{w}_{8.16}$ = the cumulative two-directional 8.16-kip ESAL units predicted for a specific section of highway during the analysis period (from the planning group)

Thus, the traffic during the first year is:

= 0,5 x 0,5 x 55857579.73= 11.2 (8,16ton) ESAL

Traffic growth rate for road Semarang to Purwodadi is 9 percent per year constant. By using equation for traffic growth:

$$G_r = \frac{(1+r)^n - 1}{r} \tag{2}$$

The curve of traffic growth can be drawn, and given in Figure 4.

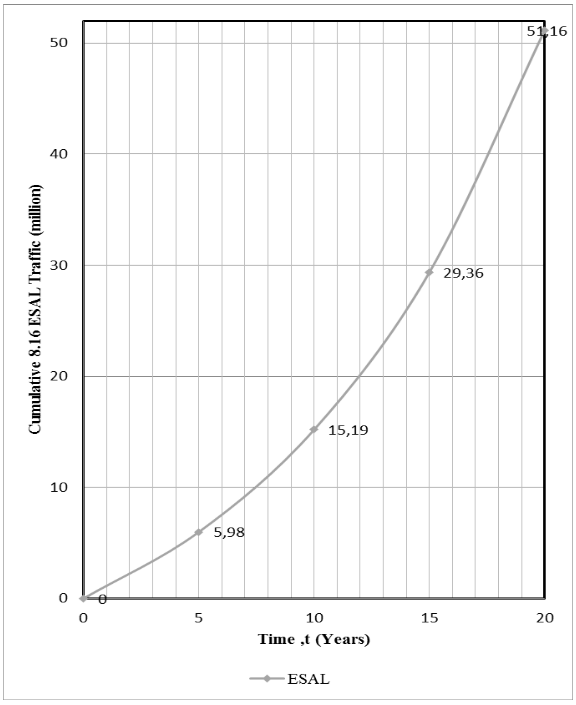


Figure 2.1. Plot of cumulative 8.16 ton – ESAL traffic vs time

2.7. Reliability

The road which the pavement structure is designing is in rural situation where daily traffic columns should never exceed half of its capacity. Thus 90 percent overall reliability level was selected for design.

Another criteria required for the consideration of reliability is the overall standard deviation (S_o). An appropriate value of 0.40 will be used for the design purposes of this problem.

Application of the reliability concept requires the requires the following steps :

1. Define the funtional classification of the facility and determine whether a rural or urban condition exists.
2. Select a reliability level from the range given in Table 2.3. the greater the value of reliability, the greater the value of reliability, the more pavement structure required.
3. A standard deviation (S_0) should be selected that is representative of local conditions.The range of value (S_0) 0,4 - 0,5

Based on this information, an overall reliability level of 90 percent was chosen for design, and from Tabel 2.4, of the value standard normal deviation of reliability can be found Z_R = -1,282, and the standard deviation S_O = 0,40.

Tabel 5. Suggested levels of reliability for various functional classifications

Functional/Classification of the Road	**Recommended level of Reliability**	
	Urban	**Rural**
Intersate and other freeways	85-99.9	80 - 99.9
principle arterials	80 - 99	75 - 95
Collector*	80 - 95	77 - 95*
Local	50 - 80	50 - 80

Table 6. Relation betwen Reliability and Standard Normal Deviate

Reliability, R%	Standard Normal Deviate, Z_R	Reliability, R%	Standard Normal Deviate, Z_R
50	0	93	-1.476
60	0.253	94	-1.555
70	0.254	95	-1.645
75	0.674	96	-1.751
80	0.841	97	-1.881
85	-1.037	98	-2.054
90	1.282	99	-2.327
91	1.34	99.9	-3.09
92	1.405	99.99	-3.75

2.8. Serviceability

Based on the traffic volume and functional classification of the facility (2 lane provincial road), a terminal serviceability (p_t) of 2.0 was selected. The initial serviceability (p_0) normally acheived for flexible pavements is take 2.2.

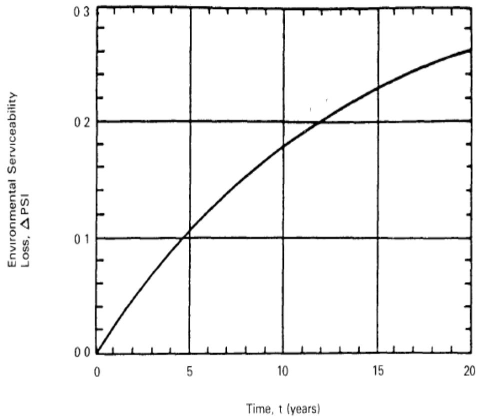


Figure 2. Environmental Serviceability

$$\Delta \text{ PSI} = p_0 - p_t = 4.2 - 2.0 = 2.2 \qquad (3)$$

2.9. Effective Roadbed Soil Resilient Modulus

The value of resilient modulus M_R for soil in Semarang – Purwodadi road is 1,500 psi for wet condition, and 3,000 for dry condition. These values are also reflective of the roadbed support that the moisture conditions provided by the "fair" drainage system.

2.10. Pavement Layer Materials Characterization

Three types of pavement materials will constitute the individual layers of the structure. The moduli for each, determined using recommended laboratory test procedures, are as follows:

- Asphalt Concrete : E_{AC} = 400,000 psi
- Concrete : E_C = 4,200,000 psi
- Granular Base : E_{BS} = 22,000 psi
- Subbase : E_{SB} = 11,000 psi
- Subgrade : E_{SG} = 3,000 psi

These values correspond to the average year-round moisture conditions that would be expected without any type of pavement drainage system.

2.11. Layer Coefficients

This section describes a method for estimating the AASHTO structural layer coefficient (a_1 values) required for standard flexible pavement structural design. A value for this coefficient is assigned to each layer material in the pavement structure in order to convert actual layer thicknesses into structural number (SN).

This layer coefficient expresses the empirical relathionship between SN and thickness and is a measure of the relative ability of the material to function as a structural component of the pavement.

The following general equation for structural number reflects the relative impact of the layer coefficients (a_1) and thickness (D_1).

a. Surface Layer

Provides a chart (Figure 2.6) that may be used to estimate the structural layer coefficient of a asphalt concrete surface course based on its elastic (resilient) modulus (E_{AC}) at 68°F.

Caution is recommended for modulus values above 400,000 psi. Although higher modulus asphalt concretes are stiffer and more resistant to bending, they are also more susceptible to thermal and fatigue cracking. Using the graph in Figure 4.6 retrieved surface layer coefficient 0.42

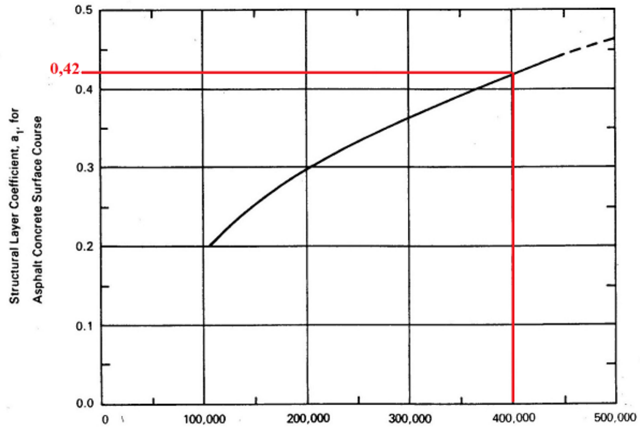


Figure 3. Chart to determine coefficient of surface layer

b. Base

Figure 2.7 provides a chart that may be used to estimate a structural layer coefficient, a_2 from one the four different laboratory test results on a granular base material, including base resilient modulus, E_{base}. The AASHTO Road Test Basis for these correlations is :

E_{base} = 22000 psi (from Figure 4.7) → CBR = 29.5 %
(4)

The following relationship may be used in lieu of Figure 2.2 to estimate the layer coefficient, a_2 for a granular base material from its elastic (resilient) modulus,

$$a_2 \quad = 0,249 (\log_{10} E_{base}) - 0,977$$

$= 0{,}249\ (\log_{10} 22000) – 0{,}977$
$= 1{,}08 – 0{,}977 = 0{,}09$

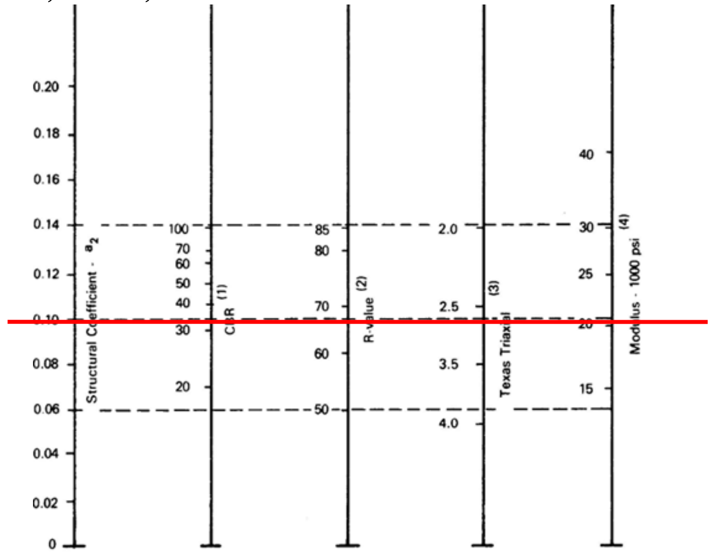


Figure 4. Chart above Foundation layer coefficient a2

c. Subbase

According on data, the land known to the value of the modulus of elasticity for the Foundation tier down is 3000 equations for the existing subgrade and 15000 for the stabilized subgrade

$a3 = 0{,}227\ (\log_{10} E_{subgrade}) – 0{,}839$
$= 0{,}227\ (\log_{10} 11000) – 0{,}839$
$= 0{,}91 – 0{,}839 = 0.08$

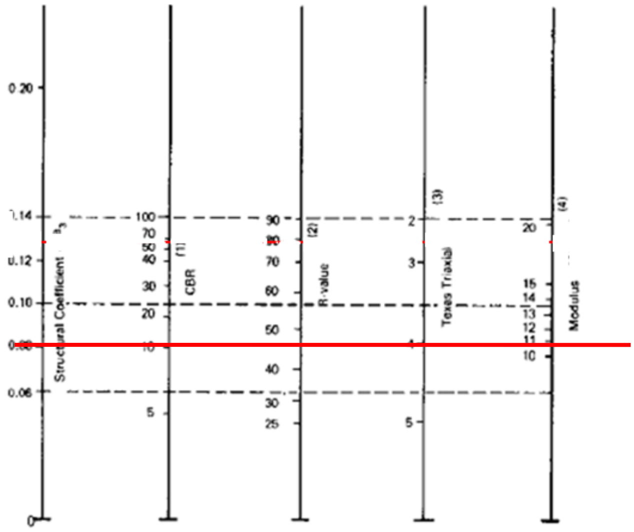


Figure 5. Chart coefficient subgrade a_3

2.12. Drainage Coefficient

This section describes the selection of inputs to treat the effects of certain levels of drainage on predicted pavements performance. Guidance is not provided here for any detailed drainage designs or contruction methods. Furthermore, criteria on the ability of various drainage methods to remove moisture from the pavement are not provided. it is up to the design engineer to identify what level(or quality) of drainage conditions. Below are the general definitions corresponding to different drainage levels from the pavement structure :

Tabel 7. Drainage levels from the pavemnet structure

Quality of Drainage	Water removed from the road surface within:
Excellent	2 hours
Good	1 day
Fair*	1 week*
Poor	1 month
Very Poor	water will not drain

Tabel 8. The quality of drainage based on humidity levels

Quality of drainage	Percent of time pavement structure is exposed to moisture level approaching saturation			
	<1%	1 - 5%	5 - 25%	>25%
Excellent	1.40 - 1.35	1.35 - 1.30	1.30 - 1.20	1.20
Good	1.35 - 1.25	1.20 - 1.15	1.15 - 1.00	1.00
Fair*	1.25 - 1.15	1.15 - 1.05	1.00 - 0.80*	0.80
Poor	1.15 - 1.05	1.05 - 0.95	0.80 - 0.60	0.60
Very Poor	1.05 - 0.95	0.95 - 0.75	0.75 - 0.40	0.40

For the quality of selected good-quality drainage with humidity levels >25%, so that the obtained values of drainage (m) is 0.8

3. Result

Using design chart, structural number SN for the layer structure over subgrade SN_3 was found = 6.2 The result is SN_1 = 3.4 and. The result is SN_2 = 4.4 and the thickness required is:

D^*_1 = $SN_1/a_1 = 3.4/0.42 = 8.09$ cm ~ 8 cm.

SN^*_1 = $a_1 \times D^*_1 = 0.42 \times 8 = 3.3$ cm

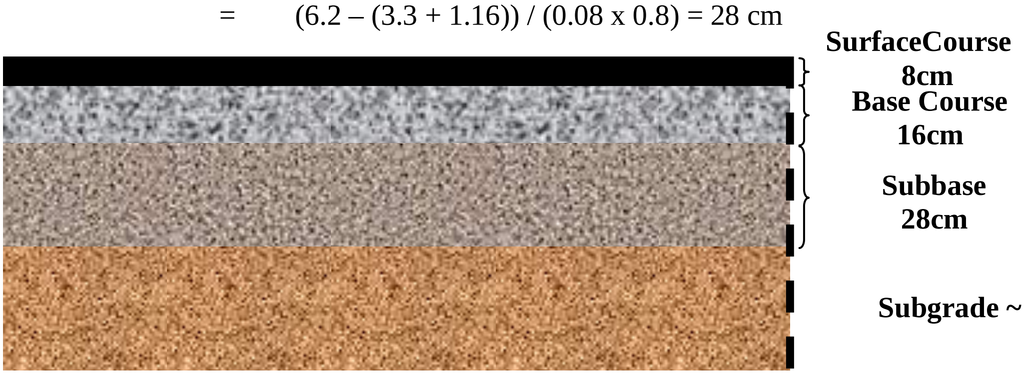
Figure 3.1 Flexible pavement structure layer thicknesses over existing subgrade

D^*_2 = $(SN_2 - SN^*_1) / (a_2 m_2) = (4.4 - 3.3) / (0.09 \times 0.8) = 16$cm

SN^*_2 = $16 \times 0.09 \times 0.8 = 1.16$

D^*_3 = $(SN_3 - (SN^*_1 + SN^*_2)) / (a_3 m_3)$

= $(6.2 - (3.3 + 1.16)) / (0.08 \times 0.8) = 28$ cm



Using design chart, structural number SN_3 for the layer structure over subgrade SN_3 was found = 3.9. Solve for SN_1, the result is SN_1 = 3.2 and SN_2 = 4. Thus, the thickness required is:

D^*_1 = SN_1/a_1 = 3.2/0.42 = 7.62 cm ~ 8 cm.

SN^*_1 = a_1 x D^*_1 = 0.42 x 8 = 3.3 cm

D^*_2 = $(SN_2 – SN^*_1) / (a_2m_2)$

= (4 – 3.3) / (0.09 x 0.8) = 9 cm

SN^*_2 = 9 x 0.09 x 0.8 = 0.6

D^*_3 = $(SN_3 – (SN^*_1 + SN^*_2)) / (a_3m_3)$

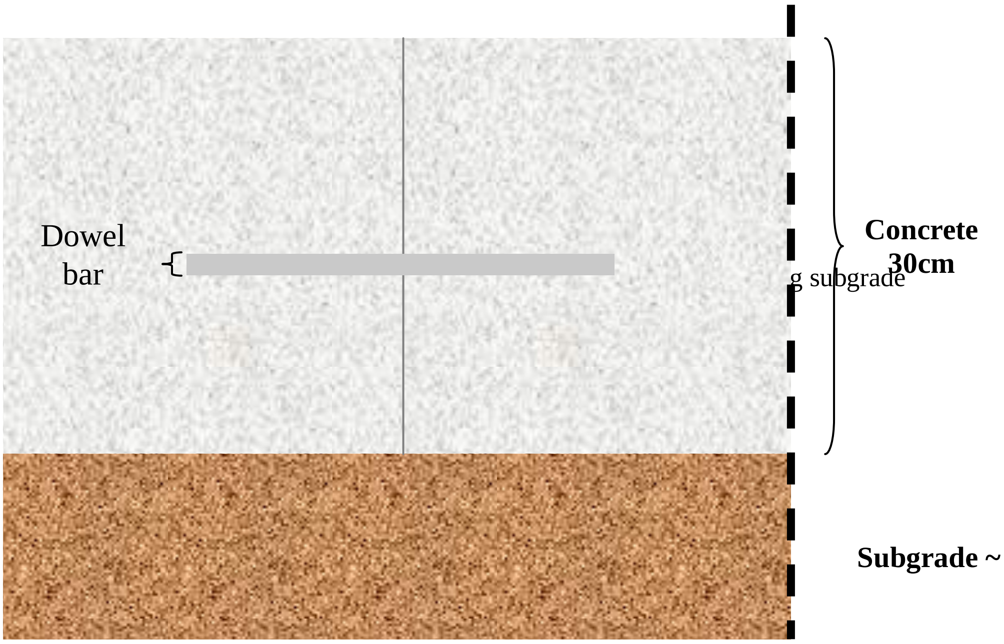
= (3.9 – (3.3 + 0.6)) / (0.08 x 0.8) = 0

For pavement structure over stabilized subgrade, the thickness of base layer take 9 cm and the subbase layer is eliminated. The cross section of the pavement is given in

Figure 6. Flexible pavement structure layer thicknesses over stabilized subgrade

From the calculation of flexible pavement design above has known that the total layer thickness of flexible pavement structure over existing subgrade is 52cm. Then, for the total layer thickness of flexible pavement structure over stabilized subgrade is 17cm.

Using design charts, the rigid pavement structure of concrete over the existing subgrade , the slab thickness has known 11.5 inch or 30 cm as shown in figure below:



For rigid pavement structure of concrete over stabilized subgrade, the slab thickness is 10inch or 30cm as shown in figure below:

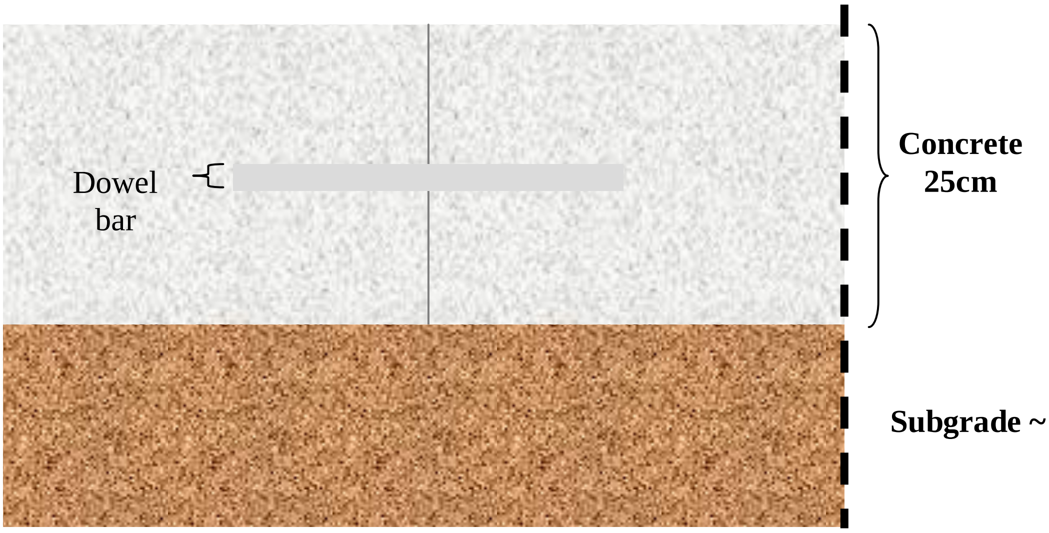


Figure 7. Rigid pavement structure layer thicknesses over stabilized subgrade

From the calculation of rigid pavement design above has known that the slab thickness of the rigid pavement structure over existing subgrade is 30cm. Then, for the slab thickness of rigid pavement structure over stabilized subgrade is 25cm.

4. Conclusions

From the results obtained in this study, the following conclusions can be drawn as follows:

1. The thickness of pavement structure over existing subgrade, for the flexible pavement is 52cm and for the rigid pavement is 30cm.
2. The thickness of pavement structure over stabilized subgrade, for the flexible pavement is 17cm and for the rigid pavement is 25cm.
3. Thicknesses of pavement structure over stabilized subgrade are less than the pavement structure over existing subgrade, both for the flexible pavement and rigid pavement.

The overall conclusion is that the using of soil stabilized with BNRA is good enough for flexible pavement and rigid pavement

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