JICE Journal Innovation of Civil Engineering

Vol. 5, No. 2, pp. 162-171, 2024
Submit: 1-10-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

RIGID PAVEMENT DESIGN WITH AASHTO 1993 IN SUBAIM – BULI ROAD

Gilang Ramadan Kololikiye[1*], Abdul Gaus[2], Muhammad Taufiq Yuda Saputra[3]

[1] Civil Engineering Department, Universitas Islam Malang, Malang, 65144, Indonesia
[2,3] Civil Engineering Department, University of Khairun, Ternate, 97728, Indonesia

email: gilangft@unisma.ac.id

ABSTRACT
The condition of transportation in Indonesia concern due to the limited road and bridge infrastructure which can obstruct mobility. Regional Government must focus on improving the provision of regional transportation infrastructure. The construction of Subaim – Buli Road Section was carried out to enhance shore transportation infrastructure as a connection to Maba. The road section has a length of 10,700 m and a width of 3 x 2 m. CBR value of 6.23%, design life of 20 years and other design parameters required by AASHTO 1993. From the calculation results obtained plate thickness (D) = 7.335 cm < 15 cm. This indicates that with ESAL load = 129978 in 2037 there is still no need to use rigid pavement.

Keywords: *AASHTO 1993; Rigid Pavement; Subaim-Buli Road.*

1. Introduction

Roads are essential to support economic growth as the need for transport facilities that can reach areas that are central to agricultural production increases. The Subaim - Buli road, for example, is the main access to connect sub-districts and areas in East Halmahera Regency with the district capital.

The existence of the Subaim - Buli Road which is the main access to East Halmahera Regency is seen from the role of its distribution services. This road network system has changed its function from local to arterial or road network that serves long-distance transport with high average speeds ranging from 40 - 70 km/h and acts as a distribution for the development of all regions at the national level with all distribution service nodes which then take the form of cities. With this, the quantity of vehicles will increase so that the calculation of the service life of the pavement at a certain time must be considered. It is intended that the load received on a particular road section is not excessive (according to its function) so that it can be one of the causes of damage to road construction before reaching the service life.

The type of pavement used on this section of Subaim - Buli Road is flexible pavement. Since the change of function of the Subaim - Buli road section from local to arterial has caused some damage caused by overloading and poor soil bearing capacity. One of the damages to flexible pavement construction can be caused by increased traffic from the average daily traffic (LHR) designed at the time the road was built. While damage due to subgrade can be caused by several factors, namely during ineffective soil compaction and due to cracks in the road surface layer, causing water seepage into the subgrade layer. In addition, in terms of thickness, it is estimated that the thickness of construction for flexible pavement will be thicker than rigid pavement construction [7], to facilitate traffic flow in the Paringin-Muara Pitap area, a road needs to be planned for connecting the area. For this reason, a flexible road pavement was designed using the Pt T-01-2002-B method which refers to AASHTO 1993.

Implementing a preservation program requires proper management so that the preservation program can be carried out effectively and efficiently [3]. Management that needs to be done includes: management regarding the prioritisation of roads to be repaired first and management regarding the volume of traffic passing over them as one of the causes of damage to prevent severe

Vol. 5, No. 2, pp. 162-171, 2024
Submit: 1-10-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

damage. Structural evaluation of road sections that have high traffic volumes with the help of FWD deflection data using the 1993 AASHTO method.

The use of rigid pavement design compared to flexible pavements is due to the high traffic volume (the cost and design life of rigid pavements is high, 15 - 40 years) [10]. However, rigid pavement is very effective and durable at the designed construction life. Pavement designing on Abdul Wahab Road using the 1993 AASHTO method found that the thickness of the pavement plate will increase according to the growth of equivalent traffic during the design life [8], otherwise the thickness of the plate will decrease with the reduction of equivalent traffic volume.

The importance of pavement on the Subaim-Buli road section is very supportive of the rate of economic growth along with the increasing need for transport facilities that can reach remote areas that are central to agricultural production. In general, the existing pavement in Indonesia is flexible pavement, the application in the use of rigid pavement in road construction is still very minimal. Therefore, with the existing road conditions on the Subaim-Buli author tries to apply the road, the rigid on the Subaim - Buli Road, Uni-Uni Road Section, East Halmahera Regency using the 1993 AASHTO method.type of pavement.

2. Material and Methods

The research location is on Subaim - Buli Road, Uni-Uni Road Section, East Halmahera Regency, North Maluku Province with a total road section length of ± 10.9 km which is precisely located at KM 18 ± 700 to KM 29 ± 600 Subaim - Buli Road [2] as shown in **Figure 1**.

Figure 1. Study Location

The research analysis was limited to data on LHR, CBR, road geometrics, and traffic growth on Subaim - Buli Road, Uni-uni Road Section, East Halmahera Regency, North Maluku Province.

2.1. Methods

This stage is followed by the collection of references related to planning, namely:

a. Average daily traffic (LHR);
b. *California Bearing Ratio* (CBR) data was collected using a *Dynamic Cone Penetrometer* (DCP) at 100 m;
c. Road geometric data are road width, number of lanes and number of directions;
d. Growth data of public transportation.

2.2. Literature Review

Based on the existing data, rigid pavement planning using the AASHTO 1993 method [1] with the following designing parameters analysed :

a. Traffic Analysis

Traffic analysis is used to determine ESAL (W_{18}) based on LHR data which is then made in a table at the beginning and end of the planned life of the road to be planned based on the general ESAL formula. The ESAL value *(Equivalent Single Axel Load)* is calculated using the formula:

JICE Journal Innovation of Civil Engineering
Vol. 5, No. 2, pp. 162-171, 2024
Submit: 1-10-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

$$W18 = \sum_{N1}^{Nn} LHRj \times VDFj \times DD \times DL \times 365 \quad (1)$$

where :

LHRj = Total 2-way average LHR for the vehicle type (the product of the traffic growth factor using the formula (1+i)n) with a value of i = 8%.
VDF = Vehicle type
DD = Directional distribution factor
DL = Lane distributor factor
N1 = Traffic in the first year of opening
Nn = Traffic at the end of the life design

b. CBR (*California Bearing Ratio*)

Can be determined based on values from CBR field (DCP Testing) to obtain segment CBR values, either analytically or graphically determined.

c. Pavement Construction Materials

The pavement construction material used is a concrete slab where the existing values have been determined based on job specifications commonly used in Indonesia. The pavement material used with associated parameters in pavement planning for concrete slabs *flexural strenght* (Sc') = 45 kg/cm^2, while the value compressive strength (15 x 30 cylindrical specimen) fc' = 350 kg/cm^2 (recommended). Sc' is used to determine the parameter *flexural strenght,* and fc' is used to determine the concrete modulus of elasticity (Ec) parameter.

d. Reliability

Reliability is the probability value of the likelihood that the level of service can be maintained over the service life in terms of the road user. Reliability is the amount of assurance that the expected traffic load that will use the road is met. Reliability is expressed as a level of reliability. The R, is shown in *level of reliability* **Table 1** [6].

Table 1. Recommended Levels of Reliability for Different Road Classifications

Road classification	Recommended level of reliability	
	Urban	Inter-city
Barrier-free	85-99.9	80-99.9
Arteries	80-99	75-95
Collector	80-95	75-95
Local	50-80	50-80

For a given level of reliability (R), the *reliability factor* is a function of the *overall standard deviation (S_o)* for the possible variations in traffic forecasts and performance forecasts for a given W18. In the rigid pavement design equations, the *level of reliability (R)* is accommodated by the parameter *standard normal deviation (ZR)* serviceability **Table 2** shows the ZR values for a given [6]. The application of the concept *level of reliability* should consider the following steps:

i. Define the functional classification of roads and determine whether they are urban roads or inter-city roads;
ii. Select the reliability level from the range given in the table;
iii. The standard deviation (S_o) should be chosen to be representative of local conditions. The range of values is usually chosen between 0.35-0.45.

Vol. 5, No. 2, pp. 162-171, 2024
Submit: 1-10-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

Tabel 2. Standard Normal Deviate Values for Spesific Realiability Level

Realiability, R (%)	Standar normal deviation, Z_R
50	0,000
60	-0,253
70	-0,524
75	-0,674
80	-0,841
85	-1,037
90	-1,282
91	-1,340
92	-1,405
93	-1,476
94	-1,555
95	-1,645
96	-1,751
97	-1,881
98	-2,054
99	-2,327
99,9	-3,090
99,99	-3,750

e. Serviceability

The value of the decrease in the level of service can be determined after the deduction of the surface index at the beginning of the planned life and at the end of the planned life referring to AASHTO 1993. The decrease in the level of service is the difference between the surface index value at the beginning of the plan life (IPo) and at the end of the plan life (IPt).

$$\Delta \text{ IP} = \text{IPo} - \text{Ipt} \quad (2)$$

Surface index is a number used to express the value of flatness / wear and sturdiness of the surface associated with the level of service for passing traffic. In determining the initial design surface index (IPo), it is necessary to consider the type of road surface (flatness / wear and sturdiness) at the beginning of the design life as shown in **Table 3** [6].

Tabel 3. Surface Index at the Beginning of the Design Life (IPo)

Type of pavement layer	IPo	Unevenness (IRI, m/km)
LASTON	≥ 4	≤1,0
	3,9 – 3,5	>1,0
LASBUTAG	3,9 – 3,5	≤ 2,0
	3,4 – 3,0	>2,0
LAPEN	3,4 – 3,0	≤3,0
	2,9 – 2,5	>3,0

In determining the surface index (IP) at the end of the designed life, it is necessary to consider the road functional classification factors as shown in **Table 4.**

Vol. 5, No. 2, pp. 162-171, 2024
Submit: 1-10-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

Table 4. Surface Index at End of Design Life (IPt)

LER = Plan Equivalent Traffic	Road Classification			
	Local	Collector	Arteries	Toll
<10	2,0-1,5	1,5	1,5-2,0	-
10-100	1,5	1,5-2,0	2,0	-
100-1000	1,5-2,0	2,0	2,0-2,5	-
>1000	-	2,0-2,5	2,5	2,5

Some IPt values and their meanings are as mentioned below:

a. IPt = 1.0 : states that the road surface is in a state of severe disrepair so that it greatly interferes with vehicle traffic
b. IPt = 1.5 : the lowest level of service possible (road not broken)
c. IPt = 2.0 : lowest level of road service for roads that are still stable
d. IPt = 2.5: states that the road surface is still quite stable and good.

f. Modulus Reaction of Subgrade (k)

It can be determined using a chart subgrade reaction modulus based on subgrade CBR requirements determination.

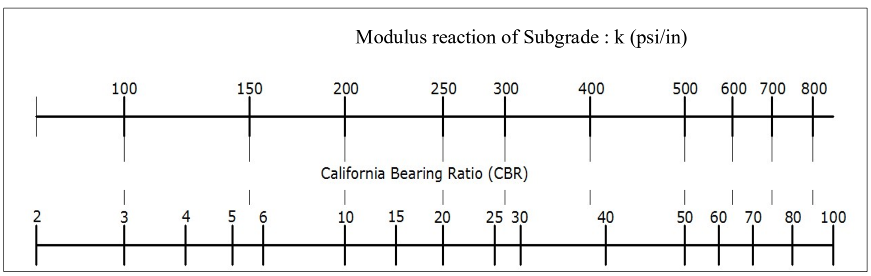

Figure 2. Relationship between k and CBR Value

g. Modulus of Elasticity of Concrete, Function of Concrete Strength

Can be determined by existing formulas according to job specifications commonly used in Indonesia.

$$E_c = 57.000\sqrt{f_c'} \quad (3)$$

where :

Ec = Modulus of elasticity of concrete (psi)
fc' = Concrete compressive strength, cylinder (psi)

The concrete compressive strength fc' is determined according to the job specification (if available in the specification). In Indonesia it is currently commonly used: f_c' = 350 kg/cm^2.

h. Flexural Strength

Determined in accordance with the work specification, with the values used in general use to date. *Flexural strength (Modulus of Rupture) is* determined in accordance with the job specification. *Flexural strength* is generally used: Sc' = 45 kg/cm^2 = 640 psi.

i. Drainage Coefficient (Cd)

Determined based on observations of conditions in drainage the field and determined based on values from **Table 5** [10].

JICE Journal Innovation of Civil Engineering
Vol. 5, No. 2, pp. 162-171, 2024
Submit: 1-10-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

Table 5. Coefficient of Drainage (Cd).

	Percent of time pavement structure is exposed To moisture levels approaching saturation			
Quality of drainage	**< 1 %**	**1 – 5 %**	**5- 25 %**	**>25 %**
Excellent	1.25 – 1.20	1.20 – 1.15	1.15 – 1.10	1.10
Good	1.20 – 1.15	1.15 – 1.10	1.10 – 1.00	1.00
Fair	1.15 – 1.10	1.10 – 1.00	1.00 – 0.90	0.90
Poor	1.10 – 1.00	1.00 – 0.90	0.90 – 0.80	0.80
Very poor	1.00 – 0.90	0.90 – 0.80	0.80 – 0.70	0.70

j. Load Transfer Coefficient (J)
Load transfer coefficient (J) based on **Table 6** [4].

Table 6. Load Transfer Coefficient (J)

Road Shoulder	**Asphalt**		**Portland cement concrete slab bonded**	
Load transfer tool Pavement type	**Yes**	**No**	**Yes**	**No**
Jointed unreinforced concrete pavement (JPCP) and jointed reinforced concrete pavement (JRCP)	3.2	3.8 - 4.4	2.5 - 3.1	3.6 - 4.2
Continuous reinforced concrete pavement (CRCP)	2.9 - 3.2	N/A	2.3 - 2.9	N/A

Parameter setting approach based on AASHTO 1993 *load transfer joint* with *dowel*: J = 2.5 - 3.1, For design *overlay* : J = 2,1 - 2,6.

k. Pavement Thickness Analysis
After all existing planning parameters are met, the thickness can be determined using existing formulas by pavement by assuming the initial pavement thickness for calculation. Trial and error of plate thickness determination (D) :

$$\log_{10} W_{18} = Z_R S_0 + 7.35\log_{10}(D+1) - 0.06 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.5-1.5}\right]}{1+\frac{1.624\times 10^7}{(D+1)^{8.46}}} + (4.22 - 0.32\,pt) \times \log_{10} \frac{S'_C Cd \times \left[D^{0.75}\right]}{21563 \times J \times \left[D^{0.75} \frac{18.42}{(Ec:k)^{0.25}}\right]} \quad \text{.......(4)}$$

where:
W18 = Cumulative standard axle load over the planning life (ESAL)
ZR = Standard normal deviation
So = Standard deviation
D = Thickness of concrete slab
ΔPSI = Serviceability loss = $p_o - p_t$
Po = Initial serviceability
Pt = Terminal serviceability index
S'c = Modulus of rupture in accordance with job specifications (psi)
Ec = Modulus of elasticity (psi)

3. Result and Discussion

3.1. Traffic Analysis

In the review of rigid pavement design on Subaim-Buli Road, it is based on traffic-related data, namely the type of vehicle and the number of vehicles per direction. For designing on this road section, LHR data is taken on the Subaim - Buli Road section as in **Table 7**.

Table 7. Subaim-Buli LHR Data at 2015

No.	Vehicle Type	Number of Vehicles/ directions
1	Light Vehicle 2 tonnes (1.1)	269
2	9 tonne Pick Up (1.2)	356
3	18 tonne 2 axle truck (1.2H)	21
4	3 axle 25 tonne truck (1.2.2)	1
	Total	**647**

3.2. California Bearing Ratio (CBR)

Testing was carried out using the tool DCP. The data collection distance between points is 100 m, so the number of observation points obtained is 108 which are summarised in **Table 8.**

Table 8. Segment CBR Value Determination

Number of observation points = 108			
No.	**CBR Value (%)**	**Amount equal to or**	**Percent equal or greater (%)**
1	6.111	108	108/108*100 = 100
2	6.438	89	89/108*100 = 82.407
3	6.602	65	65/108*100 = 60.185
4	6.839	52	52/108*100 = 48.148
5	6.874	47	47/108*100 = 43.519
6	7.167	31	31/108*100 = 28.704
7	7.482	18	18/108*100 = 16.667
8	7.823	12	12/108*100 = 11.111
9	8.192	8	8/108*100 = 7.407

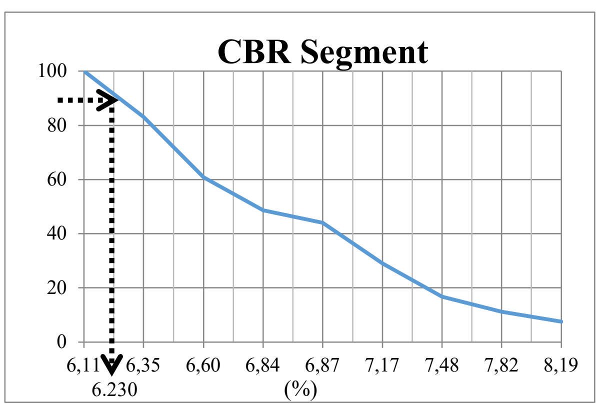

Figure 3. Segment CBR Graph

Vol. 5, No. 2, pp. 162-171, 2024
Submit: 1-10-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

The data that has been sorted, obtained CBR values from the smallest to the largest and the percentage of equal or greater values. From values these, a CBR graph was made to determine the CBR value of the 90% segment with a value of 6.23% which can e seen in **Figure 3.**

3.3. Parameters and Design

Based on the data obtained in the field, further analysis is carried out to obtain the desired results, namely:

a. **Traffic Analysis**
   In traffic analysis To determine ESAL (W_{18}) based on the above LHR data, it is made in a table at the beginning and end of the planned life of the road to be designed based on the general ESAL formula. The ESAL value *(Equivalent Single Exel Load)* is calculated using the formula.
b. **Reaction Modulus of Subgrade**
   For effective correction of the modulus of subgrade reaction using the graph in shown . The approach to the value of the Modulus of Subgrade Reaction (k) can use the relationship between the CBR value and *k* as shown in Figure 2, the value of k = 160 Psi is obtained.**Figure 2.**
c. **Serviceability**
   Total loss of serviceability *:* (ΔPSI) = Po – Pt = 4.5 – 2 = 2.5.
d. **Elasticity Modulus of Concrete**
   With the modulus of elasticity of concrete (E_c') = $57000\sqrt{f_c'}$ then,
   $E_c' = 57000\sqrt{4978} = 57000 \text{ x } 70.555 = 4021632$ psi
e. **Kuat Tarik Hancur (Flexural Strength)**
   Flexural Strength (S_c') = 45 kg/cm^2 ≈ 640 psi (recommended specification).
f. **Drainage Coefficient**
   Drainage Coefficient (Cd) = 1,1 ([2]).
g. **Load Transfer Coefficient**
   Load Transfer Coefficient (J) = 2,6 ([1]).

3.4. Pavement Thickness Analysis

With data design that is:

Road function = Local roadl;
Terrain type = Mountanious;
Road class = III C;
Design speed = 20 - 30 km/jam;
Typical pavement = HRS WC 3 cm, HRS BASE 4 cm, Agregat of grade A 12 cm, Agregat of grade B 15 cm;
Lane width = 6 m dan ;
Width of road shoulder = 1.5 m

A recapitulation of the parameters that have been analysed can be seen in **Table 9**.

Table 9. Design Parameters

No.	Parameters	Analysis Result	Unit
1	Design Life	20	Year
2	ESAL (W_{18})	129978	-
3	Road Classification	2-way arterial2-lane	-
4	*Terminal Serviceability* (pt)	2.0	-
5	*Initial Serviceability* (po)	4.5	-
6	*Serviceability Loss* (ΔPSI)	2.5	-
7	*Realiability* (R)	85	%

JICE Journal Innovation of Civil Engineering
Vol. 5, No. 2, pp. 162-171, 2024
Submit: 1-10-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

No.	Parameters	Analysis Result	Unit
8	*Standard Normal Deviation (ZR)*	- 1,037	-
9	*Standard Deviation (So)*	0.35	-
10	*Modulus of Reaction of Subgrade (k)*	160	psi
11	*Modulus of Elasticity of Concrete (Ec)*	4021632	psi
12	*Flexural Strength (S'c)*	640	psi
13	*Drainage Coefficien (Cd)*	1,1	-
14	*Load Transfer Coefficient (J)*	2,60	-

With a value of $Log_{10}W_{18}$ = 129978 so that $log_{10}(129978)$ = 5,114. To determine the thickness of the rigid pavement plate used formula (1) tried (D) = 2.8878 inches, so obtained 5.114 = 1145. From the calculation results obtained plate thickness (D) = 2.8878 inch ≈ 7.335 cm (rounded = 7.5 cm) < AASHTO 1993 minimum plate thickness of 6 inch ≈ 15 cm. This indicates that with a load of ESAL = 129978 in 2037 it is still not necessary to use rigid pavement.

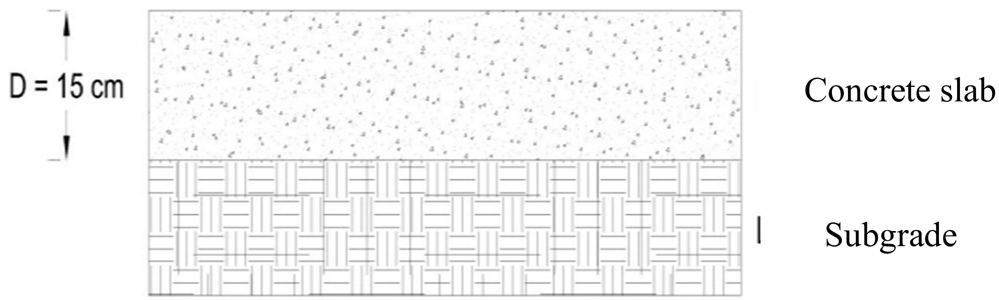

Figure 4. Rigid Pavement Thickness

4. Conclusions

Based on the results of analysis and calculations on planning the thickness of rigid on the Subaim - Buli Road using the 1993 AASHTO Method, it can be concluded that the Uni-Uni Road section is 10,700 m long and 3 x 2 m wide. CBR value of 6.23% with a life design of 20 years and other design parameters required by AASHTO 1993. From the calculation results obtained plate thickness (D) = 2.8878 inch ≈ 7.335 cm (rounded = 7.5 cm) < AASHTO 1993 minimum plate thickness of 6 inch ≈ 15 cm. This indicates that with a load of ESAL = 129978 in 2037 there is still no need to use rigid pavement.

Reference to a Book:
[1] AASHTO, *American Association of State Highway and Transportation Officials, Guide for design of pavement structures* 1993.
[2] Dinas Perhubungan dan Komunikasi Halmahera Timur. 2015. Data Lalu Lintas Harian Rata – Rata Subaim - Buli Tahun 2015. Maluku Utara.

Reference to a Journal Publication:
[3] Effendy, A.F., Widyawati, R., Kustiani, I. 2022. Manajemen Pemeliharaan Perkerasan Lentur pada Program Preservasi Jalan. *Prosiding Seminar Nasional Keinsinyuran (SNIP)*, 5 (3).
[4] Hardiyatmo, H. C. 2011. *Perancangan Perkerasan Jalan & Penyelidikan Tanah.* Penerbit Gadjah Mada University Press, Yogyakarta.
[5] Nofrianto, H. 2013. *Perencana Perkerasan Jalan Raya*. Penerbit Yogyakarta Andi, Yogyakarta.
[6] Suryawan, A. 2015. *Perkerasan Jalan Beton Semen Portland*. Penerbit Beta Offset,Yogyakarta.

Vol. 5, No. 2, pp. 162-171, 2024
Submit: 1-10-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

Reference in Proceeding:

[7] Maharani, A. 2018. Perbandingan Perkerasan Kaku dan Perkerasan Lentur (Studi Kasus Ruas Jalan Raya Pantai Prigi – Popoh Kab. Tulungangung). *Jurnal Perencanaan dan Rekayasa Sipil*, 6(3), 89-94.

[8] Syahrudi, E., Saputra, H., Alamsyah. 2018. Perbandingan Tebal Perkerasan Kaku dengan Metode Bina Marga 2003 dan 2017 (Studi Kasus : Jalan Kelemantan – Sekodi). *Seminar Nasional Industri dan Teknologi (SNIT)*, 10 (1), 463 – 472.8

[9] Ahmad R., Roza A., Murni D. 2020. Dampak Kelebihan Muatan Terhadap Umur Rencana Perkerasan Jalan. *Jurnal Ilmiah Rekayasa Sipil,* 17 (2), 2655 - 2124

[10] Hamid, A., Wildan, H,. 2020. Perencanaan Perkerasan Kaku (Rigid Pavement) untuk Peningkatan Ruas Jalan Brebes – Jatibarang Kabupaten Brebes. *Infratech Building Journal (IJB)*, 1 (1), 1 - 10