FINAL PROJECT

COMPARATIVE ANALYSIS OF FLEXIBLE PAVEMENT STRUCTURE DESIGN WITH VISCOELASTIC AND ELASTIC APPROACH ON THE STA 10+500 – STA 11+000 OF SENTOLO-NANGGULAN-DEKSO ROAD

Submitted to Islamic University of Indonesia Yogyakarta to Fulfil the Partial Requirements for a bachelor's degree in Civil Engineering

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CIVIL ENGINEERING STUDY PROGRAM
FACULTY OF CIVIL ENGINEERING AND PLANNING
ISLAMIC UNIVERSITY OF INDONESIA
YOGYAKARTA
2022

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PLAGIARISM FREE STATEMENT

I hereby solemnly declare that the Final Project report that I compiled as part of the Bachelor program at the Civil Engineering Study Program, Faculty of Civil Engineering and Planning, Islamic University of Indonesia is my own work. Certain parts of the Final Project report that I quoted from the work of others were written clearly in the source in accordance with the norms, rules, and ethics of writing scientific papers. If it is discovered in the future that all or part of this Final Project report was not the result of my own work, or that there is plagiarism in certain sections, I am willing to accept sanctions, including the revocation of my academic degree, in accordance with applicable laws and regulations.

Yogyakarta, 29 August 2022

Who make the statement.

Muchammad Rizky Anugrah

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PREFACE

Assalamu'alaikum Warahmatullahi Wabarakatuh

Alhamdulillahirabbil'alamin, All praise from the author to almighty Allah, whom has bestowed his grace, knowledge, and guidance, through his blessing the author could finish this Final Project to the best of his abilities. This Final Project Proposal is one of the academic requirements in completing Bachelor Degree studies at the Civil Engineering Study Program, Faculty of Civil Engineering and Planning, Islamic University of Indonesia.

1. Dr. Ir. Sri Amini Yuni Astuti, M.T., as Head of Bachelo Degree Civil Engineering study program Islamic University of Indonesia,
2. Mrs. Miftahul Fauziah, S.T., M.T., Ph.D.. as Lecturer, who have been very kind and patient in giving me advice, and guidance
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6. Civil engineering class of 2017 for being such a friendly companion during the time of the author undergraduate studies,
7. Civil engineering class of 2017 international program students for being such a great classmate during the time of the author undergraduate studies.

The author is fully aware that this Final Project is far from perfect, caused by the author's lack of experience and knowledge. The author hope that this Final

Project can benefit and help other academic writers and serves as reliable reference for the sake of knowledge.

Yogyakarta, 29 August 2022

Muchammad Rizky Anugrah
(17511213)

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LIST OF NOTATION AND ABBREVIATION

AC – WC = *Asphalt Concrete-Wearing Course*

AC-BC = *Asphalt Concrete-Binder Course*

AC-Base = *Asphalt Concrete-Base*

CBR = *California Bearing Ratio*

CESA = *Cumulative Equivalent Standard Axle*

Cm = Centimeter

CP = *Contact Pressure*

CR = *Contact Radius*

d = *Double Wheel Spacing*

DD = *Directional Distribution Factor*

DL = *Lane Distribution Factor*

E = *Elasticity Modulus*

ESA = *Equivalent Standard Axle*

ESAL = *Equivalent Standard Axle Load*

f4, f5 = *Permanent Deformation Coefficient Criteria*

i = *Traffic Growth Factor*

kg = Kilogram

kPa = Kilo Pascal

ADT = Average Daily Traffic

Base Course = Top Foundation Layer

MKJI = Manual Kapasitas Jalan Indonesia

m = Meter

Nd = Number of Repetitions of Standard Load Triggering Permanent Deformation

Nf = Number of Repetitions of Standard Load Triggering Fatigue Cracking

Nr	= Number of Repetitions of Standard Load Triggering Rutting
P	= Wheel center load
R	= Traffic growth multiplier
UR	= Planned Aged
VDF	= *Vehicle Damage Factor*
ε	= Strain
σ	= Tension
μ	= *poisson ratio*

ABSTRACT

The Sentolo - Nanggulan - Dekso - Klangon road section is an alternative route that connects Yogyakarta International Airport with the Borobudur Temple area. The section, which has the status of a provincial road, is included as one of the supporting lines for the Borobudur National Tourism Strategic Area. The goal of this study was to find wether 2017 Bina Marga method optimum in holding the vehicle load within the planned timeframe, and to compare the design of existing pavement structure and the new design to estimate what damage occurred first.

In designing the pavement structure of Sentolo – Nanggulan - Dekso Street, data is collected from National Road Planning and Supervision of D.I. Yogyakarta 2020. In this research, the pavement thickness is designed using two Mechanistic - Empirical methods which are Bina Marga 2017 method with Manual Perkerasan Jalan Nomor 02/M/BM/2017 guidance and supported by Kenpave program with Viscoelastic and Linier Elastic approaches.

The analysis utilizing Bina Marga 2017 methodology yields the following pavement alternatives in thickness: AC-WC 4 cm, AC-BC 6 cm, AC-Base 14,5 cm, and A class Base Course 20,5 cm. With the exception of the AC-Base layer and class A Base Course , which is only 20 cm and 15 cm thick, these values are equal to the pavement's current thickness. After the flexible pavement alternative's design has been completed using the Kenpave program, axle load repetition continues for about 34,704,817.14 ESAL with the Linier Elastic approach and for about 33,856,927.47 ESAL with the Viscoelastic approach before permanent deformation occurs. With respect to that axle road repetition, the service life of a flexible pavement alternative is 35 years for a viscoelastic method and 36 years for a linier elastic approach. This simulation demonstrates that an alternative to rigid pavement

Keyword: Mechanistic – Empirical method, Bina Marga 2017, Kenpave Program, Damage

CHAPTER I

INTRODUCTION

1.1 Background

Roads are one of the important infrastructures in meeting the needs of the community. Along with the development of the era, the use of motorized vehicles is increasingly widespread which causes the existing roads to be unable to accommodate vehicles and withstand a lot of vehicle loads. So that many people take the initiative to use alternative roads to pass through traffic jams..

The Sentolo - Nanggulan - Dekso - Klangon road section is an alternative route that connects Yogyakarta International Airport with the Borobudur Temple area. The section, which has the status of a provincial road, is included as one of the supporting lines for the Borobudur National Tourism Strategic Area. It has an existing condition of 5 meters wide, so it needs to be increased to meet the national road standard with a width of 7 meters. The widening of the Sentolo - Nanggulan - Dekso - Klangon road was carried out with an effective length of 15.6 km where its divided into part of work, where from STA 0+000 to STA 9+000 is worked by PT. Aneka Dharma Persada whilst from the STA 10+000 until finished is worked by PT. Suradi Sejahtera Rerata.

This road segment is later expected to be able to accommodate a larger volume of vehicles, especially on holidays and be able to withstand the burden of heavy transportation that passes. To develop and improve road performance in the implementation of road construction work in order to ensure the quality of the road pavement, it is necessary to approach the planning and design of the pavement. This is intended to provide pavement that has a high level of comfort and safety with a long design life. To avoid losses caused by the pavement being unable to withstand overload, it is necessary to review the road pavement planning.

In this study, the location used is road from STA 10+500 to STA 11+000 where the comparison is between the existing pavement and the alternative pavement designed by the author,. the flexible pavement design planning using 2 Mechanistic - Empirical methods, namely Bina Marga 2017 with Road Pavement Design Manual Number 04/SE/Db/2017 and using the Kenpave program.The comparison will be carried out with 2 approach namely elastic approach and viscoelastic approach. Viscoelastic approach is a combination of elastic and viscous behaviour where the applied stress results in an instantaneous elastic strain followed by a viscous, time-dependent strain while the the Elastic approach doesn't have any viscosity factor. Also to investigate about the service life, service life means when the pavement can withstand any 3 types of damage namely rutting, fatigue cracking and permanent deformation, so when the 1st structural damage occurs this means that is the cutoff of the service life.

1.2 Problem Statement

Based on the aforementioned background, it can be concluded the problem statement of this research are as follows:

1. Is to investigate wether the existing flexible pavement design and the alternative pavement design method optimum in holding the vehicle load within the planned timeframe using the Kenpave program?
2. How is the comparison between the Bina Marga 2017 method and the Kenpave Program using a viscoelastic and elastic approach when based on concepts, input design parameters?
3. How does the 2017 Bina Marga method compare with the Kenpave Program using a viscoelastic and elastic approach when based on service life?

1.3 Objective

The objective of this research are as follows:

1. Investigating the optimum capability of the existing flexible pavement and alternative pavement to withstand vehicle loads within the planned time span using the Kenpave program.
2. Investigating the comparison of the Bina Marga 2017 method and the Kenpave Program using a viscoelastic and elastic approach when viewed based on concepts, input design parameters, and working procedures
3. To investigate the service life based on elastic and viscoelastic approach

1.4 Benefits

1. Provide an alternative pavement thickness design calculation with a new method.
2. Can provide anticipation for ongoing damage to the Sentolo-Nanggulan-Dekso road section.
3. Increase knowledge about the calculation of road stress and strain with the Kenpave program

1.5 Limitations

1. Layout and research location is only at the Sentolo-Nanggulan-Dekso road STA 10+500 – 11+000.
2. The data used for analysis uses data obtained from the DIY National Road Implementation Unit Office (2017 and 2019) without taking measurements in the field.
3. Soil Calculation of flexible pavement design using Bina Marga 2017 method with Road Pavement Design Manual.
4. Calculation of the response of stress and strain using the Kenpave program.
5. Calculations with Mechanistic - Empirical methods use viscoelastic analysis and elastic analysis approaches.

CHAPTER II

LITERATURE REVIEW

2.1 Evaluation of Flexible Pavement Thickness Using Bina Marga 2017

Sumarsono (2018) has conducted research on the Jalan Jatibarang – Langut, West Java. The analysis in this study uses the Bina marga 2017 and AASHTO 1993 methods where these two methods are used to analyze the thickness of the pavement which will be compared so that the results of the pavement thickness can be optimal and efficient. From the results of this study, it was found that the CESA calculation value was significantly different with a value of 151,479,002 for Bina Marga 2017 and 53,641,295 for AASHTO 1993. This difference was due to the VDF value, where the VDF value of the 2017 Bina Marga method was adjusted to the condition of the existing vehicle. in Indonesia by conducting the WIM Survey. The results of the analysis of the calculation of added thickness on arterial roads through deflection using the FWD tool, the AASHTO 1993 method with different CESA values, obtained the Bina Marga 2017 method with a CESA value of 151,479,002 obtained 47.42 cm and ASSHTO 1993 with a CESA value of 53,641,295 obtained 38.74 cm.

2.2 Evaluation of Flexible Pavement Thickness Using the Kenpave Program

Widiastuti (2018) has conducted research on the Legundi – Kanigoro – Planjan Road Section. This research was conducted using the Bina Marga 2017 method for the pavement thickness design and using the Kenpave program to obtain stress-strain so that it can calculate the service life of the road. From the results of the study, it was found that the maximum stress-strain response that caused permanent deformation occurred at a critical point on the subgrade surface, so that an axle load calculation of 8000 kg was carried out with a result of 139,684,993

ESAL and obtained a service life of 28 years where this value exceeds the planned service life . The planned service life span at Bina Marga 2017 is 20 years.

2.3 Evaluation of Flexible Pavement Thickness Using Bina Marga 2013

Ramadhani (2018) has conducted research on the Jogja – Solo Road Section using the Bina Marga 2013 Mechanistic - Empirical method and assisted by the Kenpave Program. In this research, the planner added three alternative thickness designs from the Bina Marga 2013 which are controlled by the Kenpave program to determine the thickness of the design that was safe and meets the requirements. From the results of the study, it was found that the thickness of the pavement with the surface layer of AC WC is 4 cm, AC-BC is 15.5 cm, the top foundation layer using CTB is 15 cm and the lower foundation layer using BASE COURSE class A is 15 cm. After that, the pavement design control was carried out using the Kenpave program and it was concluded that the pavement was able to withstand the load for 20 years.

2.4 Road Pavement Thickness Planning

Simanjuntak (2014), states that the flexural layer construction consists of layers, where the layer serves to receive traffic loads and spread it to the layers below. The nature of the distribution of forces received by each layer is different where the lower you go, the smaller it gets. The result of the asphalt mixture layer technology design that was first implemented was macadam asphalt. Pavement structure design technology has also progressed. Advances have been achieved in modeling the behavior of pavement materials and structures supported by advances in computer technology, so structural analysis designs, namely stress strain and deflection, have begun to be widely used. In pavement engineering, several methods of pavement design have been proposed in theory, experience or experiment or a combination of the two.

2.5 Comparison with Previous Study

From the collection of research found during the literature review that somewhat relates and have some kind of similarities to the topic of this study, similarities and differences can be seen below.

Table 2.1 Comparison of Previous Study

No	Researcher (Year)	Research Title	Research Method	Research Result
1	Simanjuntak (2014)	Evaluasi Tebal Lapis Perkerasan Lentur Manual Desain Perkerasan Jalan No.22.2/Kpts/Db/2012 Dengan Menggunakan Program Kenpave	Mechanistic - Empirical Method with Kenpave software	From the evaluation results for type A pavement, the number of load repetitions is smaller than the planned number of load repetitions, and for type B pavement thickness, the number of load repetitions is much greater than the planned number of load repetitions.
2	Sumarsono (2018)	Perbandingan Analisa Perkerasan Metode Bina Marga 2017 dan AASHTO 1993 Ruas Jalan Jatibarang-Langut	Bina Marga 2017, AASHTO 1993 Method	Pavement thickness using the 1993 AASHTO Method and the 2017 Bina Marga method obtained a significantly different CESA number, namely 151,479,002 for the 2017 Bina Marga and 53,641,295.

Table 2.2 Continuation from Comparison of Previous Study

No	Researcher (Year)	Research Title	Research Method	Research Result
3	Widiastuti (2017)	Analisis Perbandingan Desain Struktur Perkerasan Lentur Menggunakan Metode Empiris dan Metode Mekanistik Empiris Pada Ruas Jalan Legundi – Kanigoro – Planjan.	Bina Marga 2017 Method and Kenpave Program	The maximum stress and strain response that causes permanent deformation occurs at a critical point on the subgrade surface, thus calculating the axle load of 8,000 kg with the result of 139,684,993 Esal and it can be obtained that the pavement life is 28 years where this figure exceeds the design age figure. has been planned by Bina Marga 2017 which is 20 years
4	Ramadhani (2018)	Evaluasi Tebal Perkerasan Lentur dengan Metode Bina Marga 2013 dan Metode Mekanistik Empiris Menggunakan Program Kenpave Pada Ruas Jalan Jogja – Solo	Bina Marga 2013 Method and Kenpave Program	The flexible pavement design using Bina Marga 2013 obtained the thickness of AC-WC of 4 cm, AC-BC of 15.5 cm, the upper foundation layer using CTB of 15 cm and the lower foundation layer using BASE COURSE class A of 15 cm. Then based on the results of the Kenpave program, predictions of the sequence of damage that occur from all alternatives based on the strains that occur are rutting, fatigue crack, then permanent deformation.

Based on Table 2.1 and Table 2.2, several similarities and differences between the research mentioned above and the research conducted can be concluded as follows:

1. The similarities between this study and research conducted by Simanjuntak (2014) is that both research uses the same method the Mechanistic - Empirical Method with Kenpave software. While the difference between the two are the result of the research where Simanjuntak is more focused on the thickness of the flexible pavement, where the author focused not only the thickness of the layer but also the life plan of the pavement itself.
2. The similarities between this study and research conducted by Sumarsono (2018) is that both project uses the same method of Bina Marga 2017. While the difference between both research is the location where the project under study is located, both research uses a different different method to compare where Sumarsono (2018) compared it with AASHTO 1993 Method, the author compared it with the Kenpave Program with Elastic and Viscoelastic approach
3. The similarities between this study and research conducted by Widiastuti (2017) is that both project uses the same method of Bina Marga 2017 and Kenpave Program. While the difference between both research is the location where the project under study is located
4. The similarities between this study and research conducted by Ramadhani (2018) is that both project uses the same method of Kenpave Program. While the difference between both research is the location where the project under study is located and the Kenpave program only predict the sequence of damage, not the age of the pavement and it is not used to evaluate the pavement layer thickness

This final project is a new research to find comparative analysis of flexible pavement structure design with viscoelastic and elastic approach on the sta 10+500 – sta 11+000 of sentolo-nanggulan-dekso road .

CHAPTER III

THEORETICAL BASIS

3.1 Flexible Pavement

Flexible pavement is a pavement that uses a mixture of asphalt as a surface layer and a granular material for the undercoat. In general, the components that make up a pavement consist of a surface layer, a top layer of foundation and a bottom layer of foundation. Sukirman (1992) gives the arrangement of each layer as follows.

1. Surface Course
2. Base Course
3. Sub Base Course
4. Subgrade

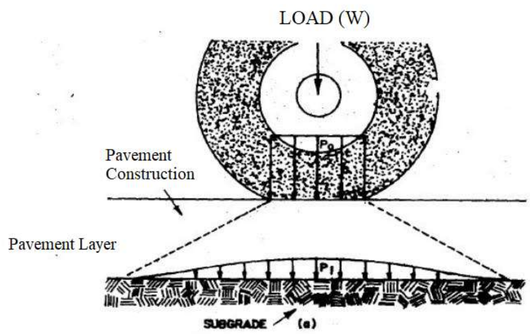

Figure 3.1 Distribution of wheel loads through the pavement

(Source: Sukirman, 1992)

Based on Figure 3.1 the traffic load acting on the pavement construction such as vehicle loads in the form of vertical forces, vehicle brake forces in the form of horizontal forces and vehicle wheel blows in the form of vibrations. The load received by each layer is different and the lower it gets, the smaller it is because of the nature of the distribution of forces. The surface layer must be able to accept all types of working forces, the top layer of foundation receives vertical forces and vibrations, while the subgrade is considered to only receive vertical force loads. Therefore there are different requirements that must be met by each layer.

3.1.1 Surface Course

The surface course layer is the topmost layer of a flexible pavement. The surface layer has several functions as follows.

1. The pavement layer that supports the vehicle wheel load, during the service life of the layer has a high stability to withstand the wheel load.
2. The waterproof layer, so that rainwater that falls on it does not seep into the layer below and weakens the layers.
3. Wearing Course, layers that directly receive friction due to vehicle brakes so they are easy to wear.
4. Layer that spreads the load to the bottom layer, so that it can be carried by another layer that has a weaker bearing capacity.

In order to fulfill the above functions, generally the surface layer is made using asphalt binder so as to produce a waterproof layer with high stability and long durability. However, due to direct contact with vehicle wheels, rain, cold, and heat, the top layer quickly becomes worn and damaged, so it is called the wear layer. The layer below the wear layer that uses asphalt as a binder is called the binder course, which functions to carry the traffic load and distribute it to the foundation layer. Thus the surface layer can be divided into the following.

1. Wearing course, is a surface layer that is in contact with vehicle wheels and weather changes
2. The binder course is the surface layer that lies below the wear layer and above the foundation layer

3.1.2 Base Course

The Base layer is a pavement layer that is located between the subbase layer and the surface layer. The functions of the top layer of the foundation include the following.

1. The part of the pavement that resists the transverse forces of the wheel load and transmits the load to the layer below it.
2. Infiltration layer for sub-base layer
3. Bearing against the surface layer.

3.1.3 SubBase Course

The subbase layer is a pavement layer that is located between the top foundation layer and the subgrade. The functions of the sub-base layer are as follows.

1. Part of the pavement construction that spreads the wheel load to the subgrade.
2. The efficiency of the use of materials, and the sub-base material is relatively cheaper than the layer above it.
3. As an infiltration layer so that groundwater does not collect in the foundation.
4. As the first layer so that the work can run smoothly. This is related to field conditions which force the subgrade to be immediately covered from the effects of the weather or the weak bearing capacity of the subgrade to hold the wheels of large tools.
5. As a layer to prevent fine particles from the subgrade from rising to the top foundation layer.

3.2 Flexible Pavement Design with Mechanistic - Empirical Method

Mechanistic – Empirical method design methods are based on material mechanics dealing with required data such as wheel load, pavement response such as stress and strain. This response value is used to predict stress from field performance data and laboratory tests. Observations on pavement performance really need to be done because the theory is considered not sufficiently proven for realistic pavement design (Huang, 2014).

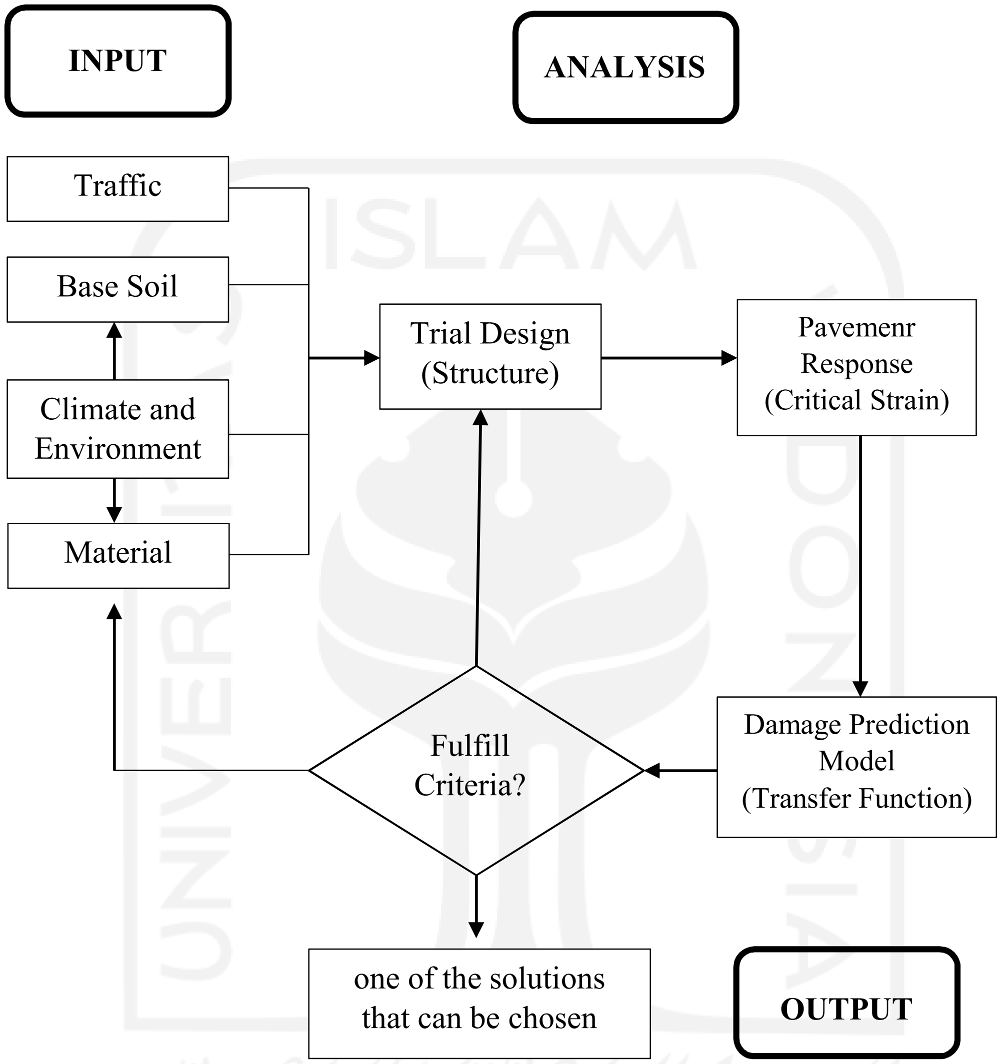

Figure 3.2 Work System for Mechanistic – Empirical Method

(Source : Bina Marga, 2017)

From Figure 3.2, it can be seen that in designing flexible pavement using Mechanistic - Empirical methods, the pavement is influenced by several input aspects such as traffic, subgrade, environment and material. So that initially the pavement is assumed to be able to withstand the design load within the specified time after which a pavement design trial (iterative) is carried out. Furthermore, an analysis is carried out to prove whether the pavement is able or not to withstand the design load within the specified time. If the pavement is proven to be able to withstand the load within the specified time then the pavement is considered suitable for use. Meanwhile, if the results of the analysis show that there is only one critical strain which proves that the pavement is unable to withstand the load, it is necessary to repair or change the structure (changes in material or dimensions can be made, or even both).

In the Mechanistic - Empirical method there is an analytical solution called the Multilayer Elastic System. This system uses assumptions to calculate structural responses such as stress, strain and deflection due to the response of vehicle wheel loads. The assumptions used according to Yodder and Witczak (1975) are as follows.

1. The material properties of each pavement layer are considered homogeneous.
2. Each layer has a thickness limit.
3. Between each layer using Interface friction.
4. There is no shear force on the surface.

3.3 Multi - Layered System Concept

Flexible pavement is a layered system with the higher the material the better and cannot be represented by a homogeneous mass. This layered system solution was first developed by Burnister (1943) with a two-layer system and extended by Burnister (1945) to a three-layer system. With the ability of computers, the theory can be applied to a multi-layered system with any number of layers (Huang, 1967). The following are some of the assumptions used to calculate the structural response in a multi-layered system (Huang, 2004).

1. Each pavement layer is homogeneous and isotropic.
2. The pavement material for each layer has a weight limit and the thickness and width of each layer is considered unlimited.
3. Uniform pressure is applied to the surface layer exposed to the load cross-sectional area (interface).

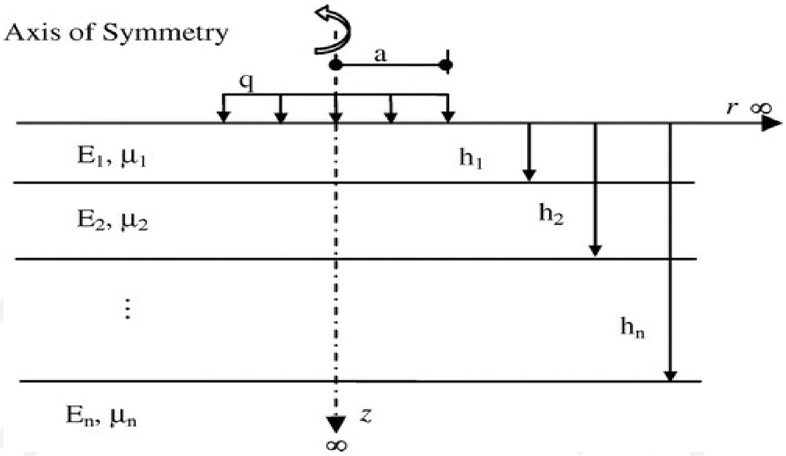

Figure 3.3 Multi-layered Viscoelastic System

(Source : Huang, 2004)

Based on Figure 3.2 each layer of pavement has a different depth and has a different value of modulus of elasticity and poisson ratio. This is due to the different types of materials used. The normal stress (σ) acts perpendicular to the surface, while the shear stress (τ) acts parallel to the surface. Under conditions of static equilibrium, it is shown that the shear stress acting on each surface is the same, so it can be said that the resultant shear stress is zero. The strain that occurs is formulated in Equations 3.1 to 3.3 below.

$$\varepsilon_z = \frac{1}{E}\left[\sigma_z - \mu(\sigma_r + \sigma_t)\right] \qquad (3.1)$$

$$\varepsilon_r = \frac{1}{E}\left[\sigma_r - \mu(\sigma_t + \sigma_z)\right] \qquad (3.2)$$

$$\varepsilon_t = \frac{1}{E}\left[\sigma_t - \mu(\sigma_z + \sigma_r)\right] \qquad (3.3)$$

With :

ε = strain

q(t) = even load

h_m = depth of each layer

E = modulus elasticity of each layer

μ = poisson ratio value of each layer σ = normal tension

τ = shear stress

3.4 Material Characteristics

In the pavement can use several material characteristics. The following are the characteristics of the material.

3.4.1 Viscoelastic Layer

To analyze the asphalt layer that applied viscoelastic properties where the loading time affects the behavior of the asphalt. The solution of this viscoelastic layer is obtained through the correspondence elastic - viscoelastic principle by applying the laplace transform to eliminate the time variable (Huang, 2004). The method for characterizing viscoelastic materials is through creep compliances specifications. Recommended temperatures for creep compliances are used for input to Layernip. The standard temperature on flexible pavement can be displayed in equation 3.4 below:

$$D(t) = \frac{1}{E_0}\left(1 + \frac{t}{T_0}\right) + \sum_{i=1}^{n} \frac{1}{E_1}\left[1 - \exp\left(\frac{-t}{T_1}\right)\right] \tag{3.4}$$

To measure creep compliance, it is calculated using 11 different time durations, including 0.001; 0.003 ; 0.01 ; 0.03 ; 0.1 ; 0.3 ; 1 ; 3 ; 10 ; 30 ; and 100 seconds.

3.4.2 Elastic Linear Layers

Linear elastic layer modeling can be used to calculate stress, strain and deflection in the pavement structure whose surface has been loaded. For linear elastic layers, each layer of the pavement structure is homogeneous, isotropic, and linearly elastic (Huang, 2004).

3.5 Design of Flexible Pavement Method of Bina Marga 2017

The Bina Marga 2017 is a draft issued by the Government of Indonesia through the Ministry of Public Works, Directorate General of Highways. This Bina Marga 2017 contains technical provisions for the implementation of road pavement design work which includes new pavement and pavement rehabilitation. Several parameters are used as a reference for the calculation, such as design age, lane factor, traffic load and traffic growth rate.

3.5.1 Planned Age

The design life of a highway is the exact amount of time from the time the road is opened until it is deemed necessary to rehabilitate or repair the road. Based on Bina Marga 2017, the design life is taken by considering the lowest discounted lifecycle cost analysis used to determine the type of pavement layer. The terms of the planned age presented in Bina Marga 2017 will be shown in Table 3.1 below.

Table 3.1 New Pavement Plan Age

Pavement Type	Pavement Element	Planned Age (Year)
Flexible Pavement	Asphalt coating and granular coating	20
	Road Foundation	40
	All pavements for areas where overlay is not possible, such as: urban roads, underpasses, bridges and tunnels.	
	Cement Treated Base (CTB)	
Rigid Pavement	Upper foundation layer, lower foundation layer, cement concrete layer and road foundation.	
Road Without Cover	All elements (including road foundations)	Minimum 10

(Source : Bina Marga, 2017)

From Table 3.1, it can be seen the relationship between each design age and the type of pavement used. For a design life of 10 years, the type of pavement is used without cover, while for a design age of 20 years, it is more recommended to use flexible pavement where this type of pavement is more often used for urban roads. For the design life of 40 years using rigid pavement because rigid pavement is a type of pavement that is resistant but has a low level of comfort.

3.5.2 Traffic

Traffic data plays the most important role in pavement thickness planning because this traffic data is needed to calculate the planned traffic load to be borne by the road. This calculated traffic load will be projected according to the design life. The following are some aspects of the traffic that will be used to carry out the pavement design.

1. Traffic Volume

   Traffic volume can be defined as the number of vehicles that pass an observation point on the road during one unit of time (minutes, hours or days). The traffic volume data used in this pavement design can be in the form of daily traffic (ADT) observed for 30 days and annual average traffic (ADT) observed for the whole year.

2. Traffic Growth Factor

   This traffic growth factor is directly influenced by historical growth data or correlation formulas with other applicable growth factors. Traffic growth factors that can be used in 2015-2035 are available in the Road Pavement Design Manual Number 04/SE/Db/2017, which can be seen in Table 3.2 below.

Table 3.2 Traffic Growth Factor (i) (%)

	Java	Sumatra	Kalimantan	Indonesia Average
Arteries and cities	4.80	4.83	5.14	4.75
Rural Collector	3.50	3.50	3.50	3.50
Village Road	1.00	1.00	1.00	1.00

(Source : Bina Marga, 2017)

To calculate traffic growth over the design life, the Road Pavement Design Manual Number 04/SE/Db/2017 provides the following formula.

$$R = \frac{(1+0,01\ i)^{UR}-1}{0,01} \tag{3.2}$$

With :

R = Traffic growth multiplier

i = Annual traffic growth rate, and

UR = Planned Age (Year)

3.5.3 Line Distribution Factor

Planned lane is a road segment where one lane accommodates the largest commercial vehicle traffic (trucks and buses). The traffic load on the design lane is expressed in cumulative standard axle loads (ESA) by taking into account the direction distribution factor (DD) and the commercial vehicle lane distribution factor (DL). In general, the directional distribution factor (DD) is taken to be 0.50 on two-way roads except for locations where the number of commercial vehicles tends to be higher in one particular direction.

For the lane distribution factor (DL), the Road Pavement Design Manual Number 04/SE/Db/2017 has determined based on the number of lanes in each direction. The column distribution factor (DL) can be seen in Table 3.3 below.

Table 3.3 Lane Distribution Factor (DL)

Number of Lanes each direction	Commercial vehicles in design lane (% of commercial vehicle population)
1	100
2	80
3	60
4	50

(Source : Bina Marga, 2017)

3.5.4 Load Equivalent Factor (Vehicle Damage Factor)

The load equivalent factor (Vehicle damage factor) is used to convert the traffic load into a standard load (ESA) in the pavement design. Based on the Road Pavement Design Manual Number 04/SE/Db/2017 traffic load calculations can be carried out using a static weighbridge study (direct survey) or regional WIM data issued directly by the Directorate General of Highways.

If an axle load survey is not possible by the planner and previous axle load survey data are not available, then the VDF values in tables 3.4 and 3.5 can be used to calculate the ESA. Table 3.4 shows the regional VDF values for each type of commercial vehicle processed from the WIM study data conducted by the Directorate General of Highways in 2012-2013. The data needs to be updated regularly for at least 5 years. For VDF in Table 3.5 it can be used if the traffic survey can identify the type and load of commercial vehicles. For the factual load period (until 2020), real load VDF is used, while for the normal (controlled) load period VDF is used with the heaviest axle load of 12 tons.

Table 3.4 VDF Value of each Commercial Vehicle

Jenis kenderaan	Sumatera				Jawa				Kalimantan				Sulawesi				Bali, Nusa Tenggara, Maluku dan Papua			
	Beban aktual		Normal		Beban aktual		Normal		Beban aktual		Normal		Beban aktual		Normal		Beban aktual		Normal	
	VDF 4	VDF 5	VDF 4	VDF 5	VDF 4	VDF 5	VDF 4	VDF 5	VDF 4	VDF 5	VDF 4	VDF 5	VDF 4	VDF 5	VDF 4	VDF 5	VDF 4	VDF 5	VDF 4	VDF 5
5B	1.0	1,0	1,0	1,0	1,0	1,0	1.0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
6A	0.55	0.5	0.55	0.5	0.55	0.5	0.55	0.5	0.55	0.5	0.55	0.5	0.55	0.5	0.55	0.5	0.55	0.5	0.55	0.5
6B	4,5	7,4	3,4	4,6	5,3	9,2	4,0	5,1	4,8	8,5	3,4	4,7	4,9	9,0	2,9	4,0	3,0	4,0	2,5	3,0
7A1	10,1	18,4	5,4	7,4	8,2	14,4	4,7	6,4	9,9	18,3	4,1	5,3	7,2	11,4	4,9	6,7	-	-	-	-
7A2	10,5	20,0	4,3	5,6	10,2	19,0	4,3	5,6	9,6	17,7	4,2	5,4	9,4	19,1	3,8	4,8	4,9	9,7	3,9	6,0
7B1	-	-	-	-	11,8	18,2	9,4	13,0	-	-	-	-	-	-	-	-	-	-	-	-
7B2	-	-	-	-	13,7	21,8	12,6	17,8	-	-	-	-	-	-	-	-	-	-	-	-
7C1	15,9	29,5	7.0	9,6	11,0	19,8	7,4	9,7	11,7	20,4	7,0	10,2	13,2	25,5	6,5	8,8	8,0	11,9	6,5	8,8
7C2A	19,8	39,0	6,1	8,1	17,7	33,0	7,6	10,2	8,2	14,7	4,0	5,2	20,2	42,0	6,6	8,5	-	-	-	-
7C2B	20,7	42,8	6,1	8,0	13,4	24,2	6,5	8,5	-	-	-	-	17,0	28,8	9,3	13,5	-	-	-	-
7C3	24,5	51,7	6,4	8,0	18,1	34,4	6,1	7,7	13,5	22,9	9,8	15,0	28,7	59,6	6,9	8,8	-	-	-	-

(Source : Bina Marga, 2017)

Table 3.5 Standard VDF Value

	Jenis Kendaraan		Uraian	Konfigurasi sumbu	Muatan[2] yang diangkut	Kelompok sumbu	Distribusi tipikal (%)		Faktor Ekivalen Beban (VDF) (ESA / kendaraan)	
	Klasifikasi Lama	Alternatif					Semua kendaraan bermotor	Semua kendaraan bermotor kecuali sepeda motor	VDF4 Pangkat 4	VDF5 Pangkat 5
	1	1	Sepeda motor	1.1		2	30,4			
	2, 3, 4	2, 3, 4	Sedan / Angkot / Pickup / Station wagon	1.1		2	51,7	74,3		
KENDARAAN NIAGA	5a	5a	Bus kecil	1.2		2	3,5	5,00	0,3	0,2
	5b	5b	Bus besar	1.2		2	0,1	0,20	1,0	1,0
	6a.1	6.1	Truk 2 sumbu – cargo ringan	1.1	muatan umum	2	4,6	6,60	0,3	0,2
	6a.2	6.2	Truk 2 sumbu – ringan	1.2	tanah, pasir, besi, semen	2			0,8	0,8
	6b1.1	7.1	Truk 2 sumbu – cargo sedang	1.2	muatan umum	2	-	-	0,7	0,7
	6b1.2	7.2	Truk 2 sumbu – sedang	1.2	tanah, pasir, besi, semen	2			1,6	1,7
	6b2.1	8.1	Truk 2 sumbu – berat	1.2	muatan umum	2	3,8	5,50	0,9	0,8
	6b2.2	8.2	Truk 2 sumbu – berat	1.2	tanah, pasir, besi, semen	2			7,3	11,2
	7a1	9.1	Truk 3 sumbu – ringan	1.22	muatan umum	2	3,9	5,60	7,6	11,2
	7a2	9.2	Truk 3 sumbu – sedang	11.2	tanah, pasir, besi, semen	2			28,1	64,4
	7a3	9.3	Truk 3 sumbu – berat	1.222		2	0,1	0,10	28,9	62,2
	7b	10	Truk 2 sumbu dan trailer penarik 2 sumbu	1.2-2.2		4	0,5	0,70	36,9	90,4
	7c1	11	Truk 4 sumbu - trailer	1.2-22		3	0,3	0,50	13,6	24,0
	7c2.1	12	Truk 5 sumbu - trailer	1.2-22		3	0,7	1,00	19,0	33,2
	7c2.2	13	Truk 5 sumbu - trailer	1.2-222		3			30,3	69,7
	7c3	14	Truk 6 sumbu - trailer	1.22-222		3	0,3	0,50	41,6	93,7

(Source : Bina Marga, 2017)

3.5.5 Traffic Load

The traffic load is the vehicle load that is passed on to the road pavement through the tire encounters the surface layer that occurs repeatedly. The understanding of the vehicle load on the pavement greatly affects the results of the pavement structure construction planning and the robustness of the road structure during the service period.

1. Standard Axle Load

   Axle load of 100 kN is permitted in some sections, namely for class I roads. However, the CESA value is always determined based on the standard axle load of 80 kN.

2. Axis Load Control

   The current (actual) loading rate is assumed to last only until 2020. After 2020, it is assumed to be a controlled overload with a nominal axle load of 120 kN.

3. Cumulative Standard Axis Load

   Cumulative Equivalent Single Axle Load (CESA) is the cumulative amount of design traffic axle load on the design lane during the design life, which is determined as follows

   $$\text{ESA} = (\text{ADT}_{type\ of\ vehicle} \text{ x VDF}) \text{ x } 365 \text{ x DD x DL x R} \quad (3.3)$$

   With :

   ESA = equivalent standard axle trajectory for 1 day,

   ADT = average daily traffic for each type of commercial vehicle (unit of vehicle per day),

   R = traffic growth multiplier (3.2),

   VDF = Load Equivalent Factor (Vehicle Damage Factor) for each type of commercial vehicle Table 3.4 and Table 3.5,

   DD = the directional distribution factor, and

   DL = the lane distribution factors (Table 3.3).

3.5.6 Pavement Design

In road pavement design there are several variations of pavement types which are determined based on traffic volume, design age and road foundation conditions. The selection of design alternatives based on this manual must be based on the lowest discounted lifecycle cost and of course by looking at the resulting CESA4 value. The provisions for selecting the type of pavement design can be seen in Table 3.6.

Table 3.6 Pavement Design Types

Struktur Perkerasan	Bagan Desain	ESA (juta) dalam 20 tahun (pangkat 4 kecuali ditentukan lain)				
		0 – 0,5	0,1 – 4	>4 - 10	>10 – 30	>30 - 200
Perkerasan kaku dengan lalu lintas berat (di atas tanah dengan CBR ≥ 2,5%)	4	-	-	2	2	2
Perkerasan kaku dengan lalu lintas rendah (daerah pedesaan dan perkotaan)	4A	-	1, 2	-	-	-
AC WC modifikasi atau SMA modifikasi dengan CTB (ESA pangkat 5)	3	-	-	-	2	2
AC dengan CTB (ESA pangkat 5)	3	-	-	-	2	2
AC tebal ≥ 100 mm dengan lapis fondasi berbutir (ESA pangkat 5)	3B	-	1, 2	1, 2	2	2
AC atau HRS tipis di atas lapis fondasi berbutir (ESA pangkat 5)	3A	-	1, 2	-	-	-
Burda atau Burtu dengan LFA Kelas A atau batuan asli	5	3	3	-	-	-
Lapis Fondasi *Soil Cement*	6	1	1	-	-	-
Perkerasan tanpa penutup (Japat, jalan kerikil)	7	1	-	-	-	-

(Source : Bina Marga, 2017)

Note :

Level of difficulty:

1. small to medium contractor
2. large contractor with adequate resources
3. requires specialized skills and expertise – specialist contractor required Burda

The limitations in Table 3.6 are not absolute, the planner must still considering the lowest cost over the life of the plan, limitations and practicality of implementation. However, modified asphalt is recommended for use on roads that experience traffic repetition for 20 years > 10 million ESA. The use of modified asphalt is very good for extending service life, resistance to deformation and fatigue life of the surface layer due to heavy traffic loads.

After determining the type of pavement to be used, the thickness of the pavement can be determined according to the CESA5 value. To find out the pavement thickness design, it can be seen in Table 3.7 and Table 3.8 which explains that the aggregate foundation layer A can be adjusted to the CBR value.

Table 3.7 Flexible Pavement Design – Asphalt with Grained Foundation

	STRUKTUR PERKERASAN							
	FFF1	FFF2	FFF3	FFF4	FFF5	FFF6	FFF7	FFF8
Solusi yang dipilih				**Lihat Catatan 2**				
Kumulatif beban sumbu 20 tahun pada lajur rencana (10^6 ESA5)	< 2	≥ 2 - 7	> 7 - 10	> 10 - 20	> 20 - 30	> 30 - 50	> 50 - 100	> 100 - 200
KETEBALAN LAPIS PERKERASAN (mm)								
AC WC	40	40	40	40	40	40	40	40
AC BC	60	60	60	60	60	60	60	60
AC Base	0	80	105	145	160	180	210	245
LFA Kelas A	400	300	300	300	300	300	300	300
Catatan	1	2		3				

(Source : Bina Marga, 2017)

Table 3.8 Adjustment of Aggregate Foundation Layer Thickness A for CBR Subgrade > 7%

	STRUKTUR PERKERASAN								
	FFF1	FFF2	FFF3	FFF4	FFF5	FFF6	FFF7	FFF8	FFF9
Kumulatif beban sumbu 20 tahun pada lajur rencana (10^6 CESA5)	< 2	≥ 2 – 4	> 4 – 7	> 7 – 10	> 10 – 20	> 20 – 30	> 30 - 50	> 50 - 100	> 100 – 200
TEBAL LFA A (mm) PENYESUAIAN TERHADAP BAGAN DESAIN - 3B									
Subgrade CBR > 6 - 7	400	300	300	300	300	300	300	300	300
Subgrade CBR > 7- 10	330	220	215	210	205	200	200	200	200
Subgrade CBR > 10 – 15	260	150	150	150	150	150	150	150	150
Subgrade CBR > 15	200	150	150	150	150	150	150	150	150

(Source : Bina Marga, 2017)

3.6 Flexible Pavement Design Using Kenpave Program Program

The Kenpave program is a software based on pavement design design with the function to analyze flexible and rigid pavements more easily and flexibly which was developed by Dr. Kenpave. Yang Huang, P.E. Professor Emeritus of Civil Engineering University of Kentucky. To run the *Kenpave* program, you need data such as pavement and material characteristics such as modulus, poisson ratio of each layer, wheel load, tire pressure and coordinates where stress and strain are required. This software is divided into four separate programs such as Layernip, Kenlayer, Slabinp, and Kenslab. In this research, the Layernip and Kenlayer programs which focus on flexible pavement will be used.

3.6.1 *Kenpave* Program

In its use, the Kenpave program has main menus for designing and analyzing pavements. The menu display provided by the Kenpave Program can be seen in Figure 3.4 below.

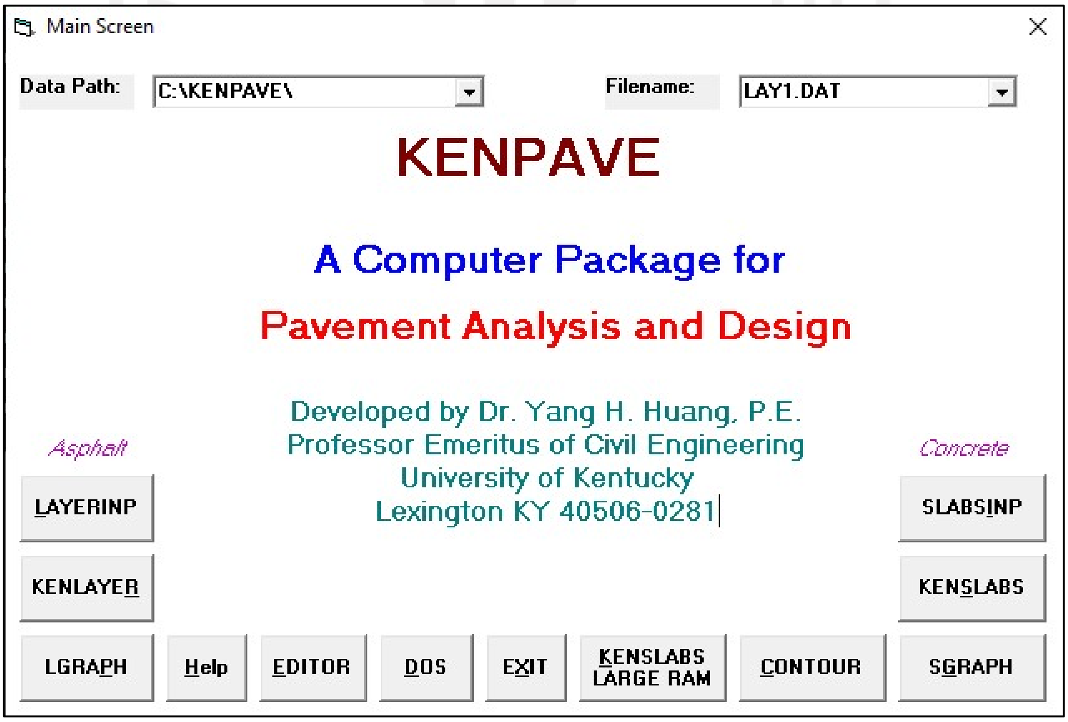

Figure 3.4 *Kenpave* Program Menu Display

In modeling the road pavement layer with this elastic layer model, data is needed for input for stress and strain on the pavement structure and response to loads. The parameters used are as follows.

1. Parameters for each layer such as modulus of elasticity and Poisson ratio.
   a. The modulus of elasticity is the ratio between the stress and strain of an object. The modulus of elasticity can also be called Young's modulus which is denoted by E. The formula for the modulus of elasticity is:

   $$E = \frac{\sigma}{\varepsilon}$$

   With :

   E = Modulus Elasticity (Psi or kPa)

   σ = Tension (kPa), and

   ε = Strain

   The value of the modulus of elasticity for several types of pavement materials can be seen in Table 3.9 below.

Table 3.9 Value of Modulus Elasticity Based on Pavement Material

<table>
<tr><th>Type of Material</th><th>Elastic Modulus (MPa)</th><th>Poisson's Ratio</th><th>Relative Coefficient</th></tr>
<tr><td>HRS WC</td><td>800</td><td rowspan="5">0,40</td><td rowspan="8">Based on PdT-01-2002-B</td></tr>
<tr><td>HRS BC</td><td>900</td></tr>
<tr><td>AC WC</td><td>1100</td></tr>
<tr><td>AC BC (upper layer)</td><td>1200</td></tr>
<tr><td>AC Base or AC BC (as base)</td><td>1600</td></tr>
<tr><td>AC-BASE(CTB)</td><td>500</td><td>0.2 (smooth)
0.35 (cracked)</td></tr>
<tr><td rowspan="2">Base Soil</td><td rowspan="2">10 x CBR</td><td>0.45
(Cohesive Soil)</td></tr>
<tr><td>0.35
(non cohesive soil)</td></tr>
</table>

(Source : Bina Marga 2017)

b. Poisson Ratio, is the ratio between horizontal strain (lateral strain) and vertical strain (axial strain) caused by parallel axis load and axial strain. The value of the Poisson ratio can be seen in Table 3.10 below.

Table 3.10 *Poisson* Ratio Value

Material	v Value	V Typical
Hot mix asphalt	0.30 – 0.40	0.35
Portland cement concrete	0.15 – 0.20	0.15
Untreated granular material	0.30 – 0.40	0.35
Cement treated granular material	0.10 – 0.20	0.15
Cement treated fine grained material	0.15 – 0.35	0.25
Lime stabilizied material	0.10 – 0.25	0.2
Lime flyash mixture	0.10 – 0.15	0.15
Loose sand / silty sand	0.20 – 0.40	0.3
Dense sand	0.30 – 0.45	0.35
Fine grained soil	0.30 – 0.50	0.4
Saturated soft clay	0.40 – 0.40	0.45

(Source : Huang, 2004)

2. The thickness of each layer.

In the multilayer elastic theory, the thickness of each pavement layer is required as input in the completion using the program. The unit used for the thickness of each layer is mm or inch.

3. Load Conditions

This data consists of wheel load data, P (kN/Lbs), tire pressure, q (Kpa/Psi) and specifically for the rear axle the distance between the double wheels, d (mm/inch). The P value is influenced by the goods transported by the vehicle so that the load on the front axle and rear axle is different. As for the values of q and d, it is determined according to the technical specification data of the vehicle used.

3.6.2 *Kenlayer* Program

This Kenlayer program is a program that can only be used on flexible pavements. The Kenlayer program is useful for determining the pavement flexural damage ratio using stress models. Distress model is deformation and cracking that can be used to predict pavement life by assuming the pavement configuration.

The Kenlayer program begins by inputting data via the Layernip menu in the Kenpave program as shown in Figure 3.4. Layerinp has 11 menus that must be filled with existing data. The following is an explanation of these menus.

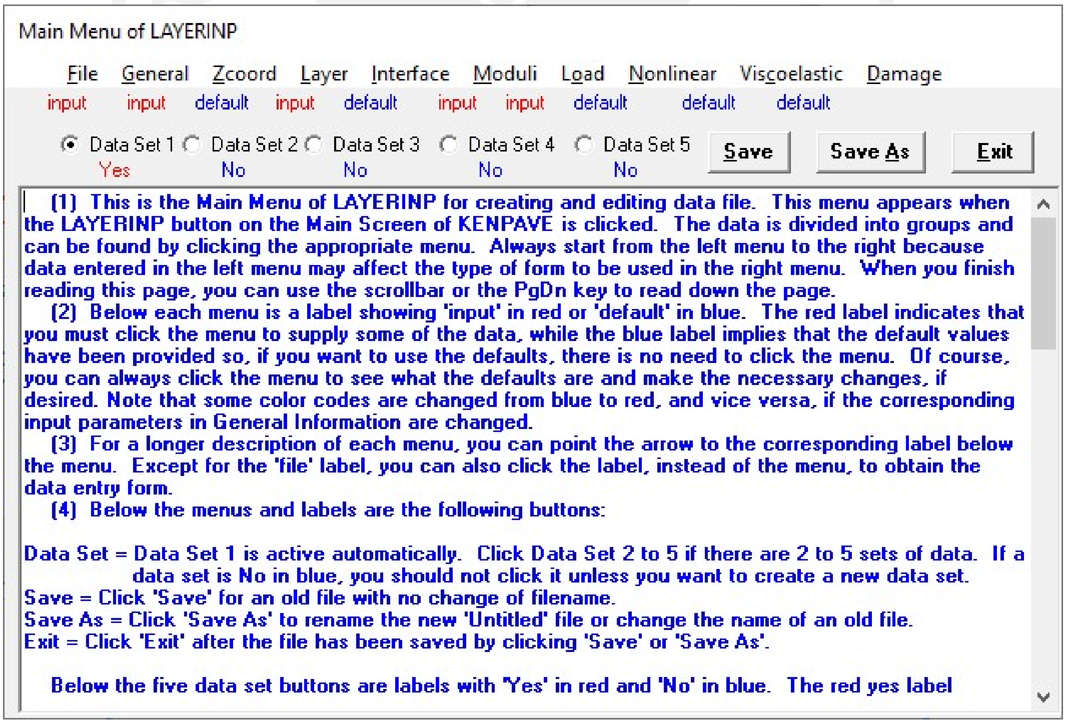

Figure 3.5 Layerinp Menu Display

The data required for the Kenlayer program is pavement structure data to analyze the pavement thickness planning. The data include pavement thickness, modulus of elasticity, Poisson ratio, and load conditions.

The value of pavement thickness is obtained through the calculation of the thickness of the road pavement using the Bina Marga 2017 method. The value of the modulus of elasticity can be seen in Table 3.9, for the Poisson ratio value is obtained in Table 3.10 while the load condition value consists of wheel load data (P), tire pressure data (P). q), and data on the distance between the double wheels (d) which can be seen in Figure 3.5.

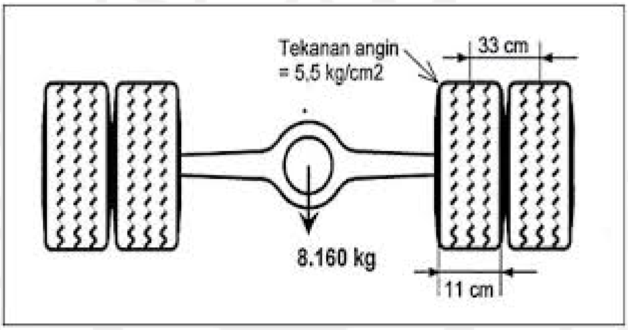

Figure 3.6 Equivalent Standard Axis
(Source : Sukirman, 1992)

3.7 Pavement Damage Analyisis

Pavement damage that occurs is usually caused by vehicle loads. In calculations using the Kenpave program, the stress and strain values of the flexible pavement will be generated, where the stress and strain values will be used to predict damage to the pavement. The analysis of road pavement damage that will be discussed is fatigue cracking, rutting and permanent deformation.

3.7.1 Fatigue Cracking

The fatigue crack equation for flexible pavement to determine the number of load repetitions based on the tensile strain under the surface layer is as follows.

$$N_f = 0,0796\ (\varepsilon_t)^{-3,921}\ |E|^{-0,854} \quad (3.3)$$

With :

N_f = Number of allowable repetition loads to control fatigue cracking

ε_t = Tensile strain at the critical review location calculated based on the response of the structural model or tensile strain at the bottom of the surface layer

E = Modulus Elasticity on the surface layer or HMA layer

3.7.2 Rutting

The equation for the rutting crack to determine the number of repetitions of the load based on the compressive strain under the subbase layer is as follows.

$$N_d = f_4 (\varepsilon_c)^{-f5} \quad (3.4)$$

With :

N_d = the number of repetitions of the allowable load to control the rutting,

ε_c = vertical compressive strain above the base layer,

f_5 = coefficient of permanent deformation criteria, and

f_4 = coefficient of permanent deformation criteria

3.7.3 Permanent Deformation

The permanent deformation equation to determine the number of repetitions of the load on flexible pavement is as follows.

$$N_d = f_4 (\varepsilon_c)^{-f5} \quad (3.4)$$

With :

N_d = the number of repetitions of the allowable load to control the rutting,

ε_c = vertical compressive strain above the base layer,

f_5 = coefficient of permanent deformation criteria, and

f_4 = coefficient of permanent deformation criteria

For the values of f_4 and f_5 follow the recommendations of the Asphalt Institute 1970 with a value of f_4 = 1.365 x 10-9 and f_5 = 4.477.

CHAPTER IV

RESEARCH METHODOLOGY

4.1 Research Method

This study uses a case study method where in this study the author wanted to comprehensively understand in depth regarding the object of study. A case study is a detailed examination of one background or one subject in an intensive and detailed manner so that later the researcher will achieve a deep understanding and not only to explain what the object under study are like, but to explain how the existence and why the case can occur. In other words, case study research is not just answering research questions about what the object under study is, but also about how and why the object of study can occur and is formed as and can be viewed as a case.

4.2 Data Collection

The important stage in the research process is data collection, because only by getting the right data, the research process will continue until the researcher gets the answer from the formulation of the problem that has been determined. The data we are looking for must be in accordance with the research objectives. The types of data that can be used are primary data and secondary data. Primary data is data that we can only get from the original or first source, while secondary data is data that is already available so we just need to find and collect. Primary data is a data that we can only obtain from the original or main source, while secondary data is data that is already available and are ready to collect and use. In this study the type of data used is only secondary data.

Stages of research regarding this study includes the stage of determining the problem, determining the objectives and study environment, collecting secondary data, organizing the secondary data obtained, analysing, as well as determining results and conclusions. In the analysis of this research, the data used is secondary data obtained from P2JN Special Region of Yogyakarta. The data obtained from P2JN Special Region of Yogyakarta are as follows:

1. research location (Map),
2. traffic load Data
3. subgrade data, (cbr),
4. material properties data, and
5. pavement structure data, such as road geometry (road length, lane width, median width, road shoulder, number of directions and lanes).

4.3 Case Study Locations

The location that is reviewed as the object of the case study in this research is the STA 10+500 – STA 11+000 of the Sentolo - Nanggulan - Dekso - Klangon Road widening project. The location map can be seen in Figure 4.1 below.

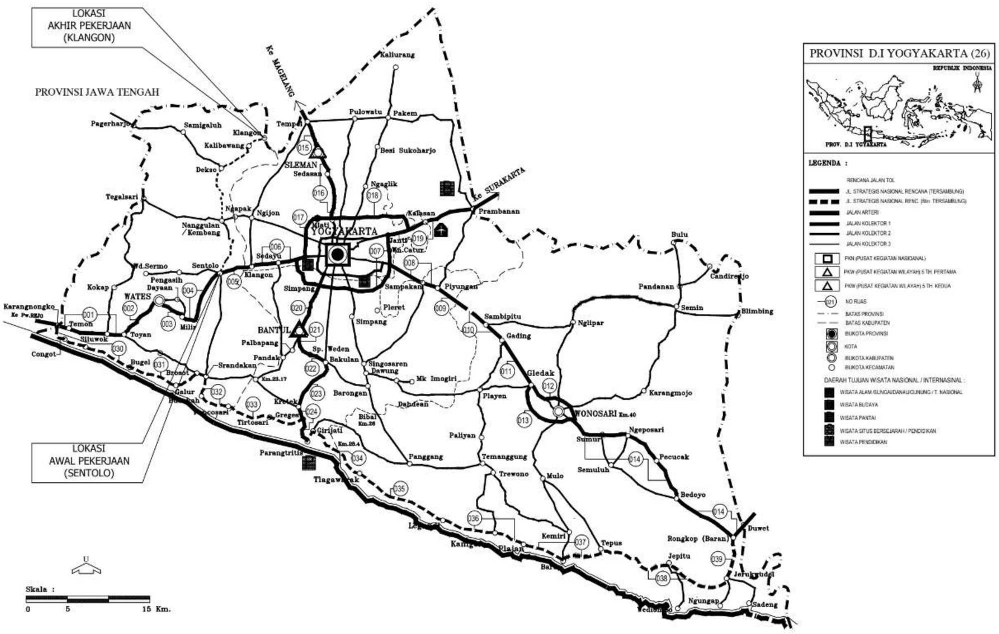

Figure 4.1 Case Study Locations Sentolo - Nanggulan - Dekso - Klangon Roads
(Source : DED of Sentolo-Nanggulan-Dekso Road Widening Project 2020)

4.4 Research Flowchart

In order to make it easier for the author to conduct this analysis and easier for the reader to understand the procedure, an analysis procedure flowchart was made. Several flowcharts in the research carried out are as follows.

1. Research Method
2. Flexible Pavement Design Procedure using Bina Marga 2017 method
3. *Kenpave* Method

4.4.1 Research Method

The research stages can be seen in the flow chart in Figure 4.2 below.

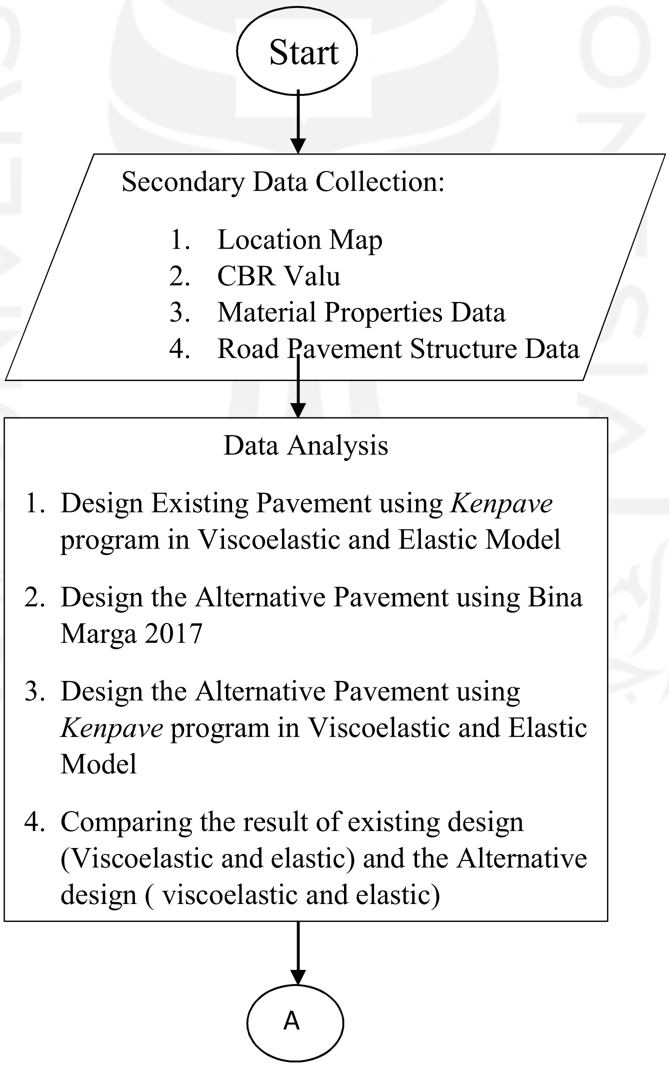

Figure 4.2 Research Flowchart

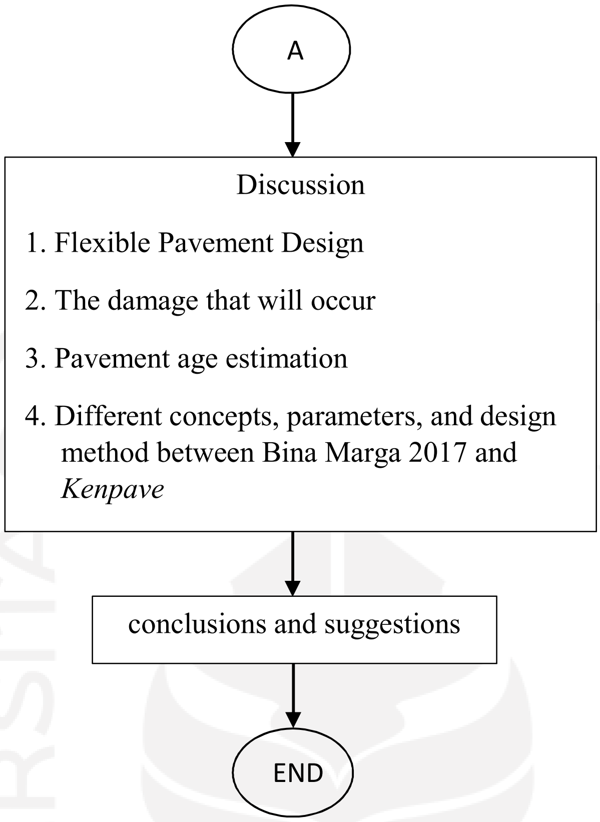

Figure 4.2 Continuation of Research Flowchart

4.4.2 Flexible Pavement Design Procedure using Bina Marga 2017 Method

Based on Road Pavement Design Manual Number 04/SE/Db/2017, the flexible pavement design procedure are as follows:

1. Determine the life of the plan by considering the elements of the plan based on the lowest discounted whole of life cost analysis,
2. Determine the traffic growth multiplier (R),
3. Determine *VDF* value,
4. Determine the value of the direction distribution factor (DD) and the commercial vehicle lane distribution factor (DL),
5. Determine *CESA* value according to age and traffic plan,
6. Determine the type of pavement based on the ability of the service provider and preferred solution as well as environmental conditions, and
7. Determine pavement thickness using CESA5 by reviewing Base Course considerations based on CBR values.

As for making it easier to understand the procedure in using the Road Pavement Design Manual Number 04/SE/Db/2017 for flexible pavement design, a flow chart is made as shown in Figure 4.3 below.

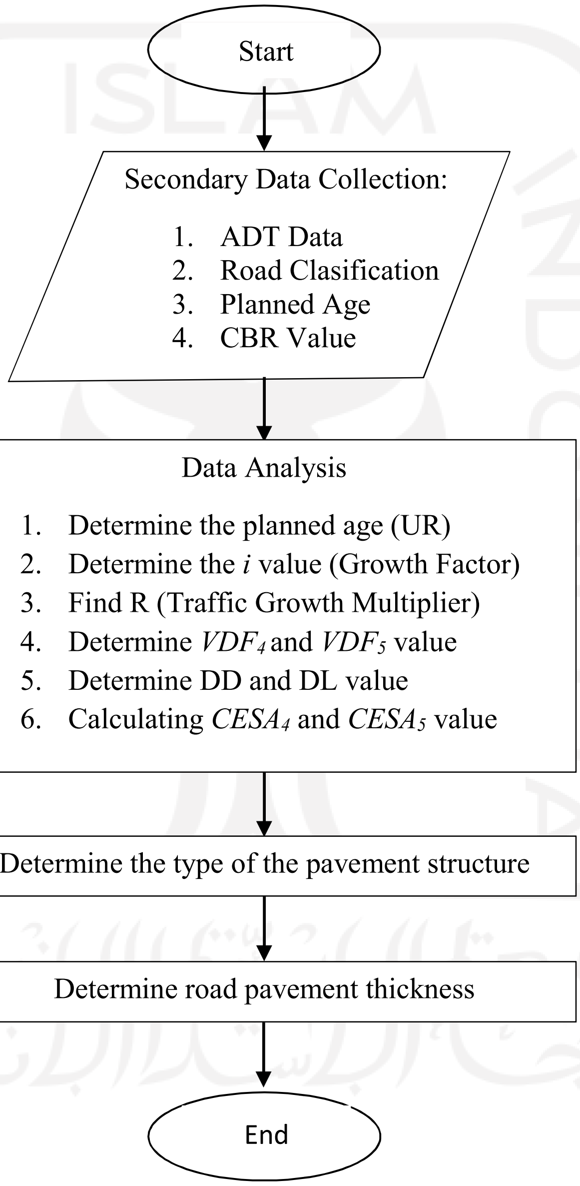

Figure 4.3 Flexible Pavement Design Procedure using Bina Marga 2017

4.4.3 *Kenpave* Method

As for modeling the pavement structure with the Kenpave program and flexible pavement with Kenlayer for standard axle loads, the following are the steps:

1. Determine material properties data for structural modeling, including:
   a. thickness of each pavement layer,
   b. the modulus elasticity (E) of each pavement layer,
   c. *poisson's ratio* value for each layer
2. Analyze the traffic data, including:
   a. determine the time period for the pavement analysis review,
   b. calculate Equivalent Single Axle Load (ESAL),
   c. determine the details of the axle and wheel loads,
3. Perform pavement structure modeling with the Kenpave program and for layer pavement using the Kenlayer sub program using two modeling namely Viscoelastic and Elastic modeling.
4. Determining the output of the Kenlayer program used to determine the stress-strain response that occurs due to traffic loads, and
5. Analyzing the repetition of traffic loads generated by the Kenpave program and analyzing the pavement life of the two models.

As for making it easier to understand the procedure in using the *Kenpave* method, a flow chart is made as shown in Figure 4.4 below.

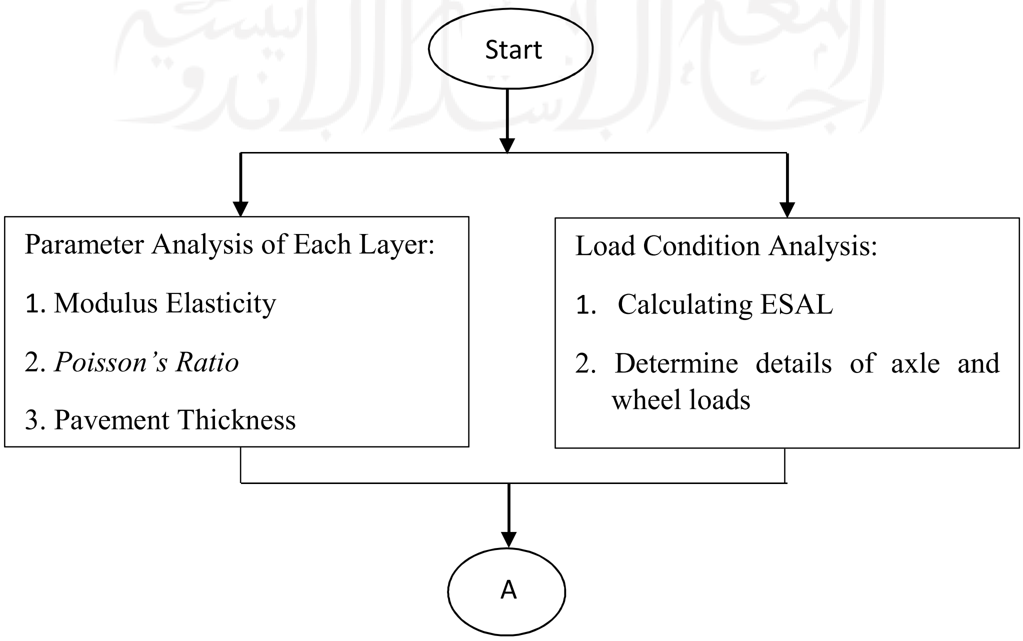

Figure 4.4 Kenpave Method Flowchart

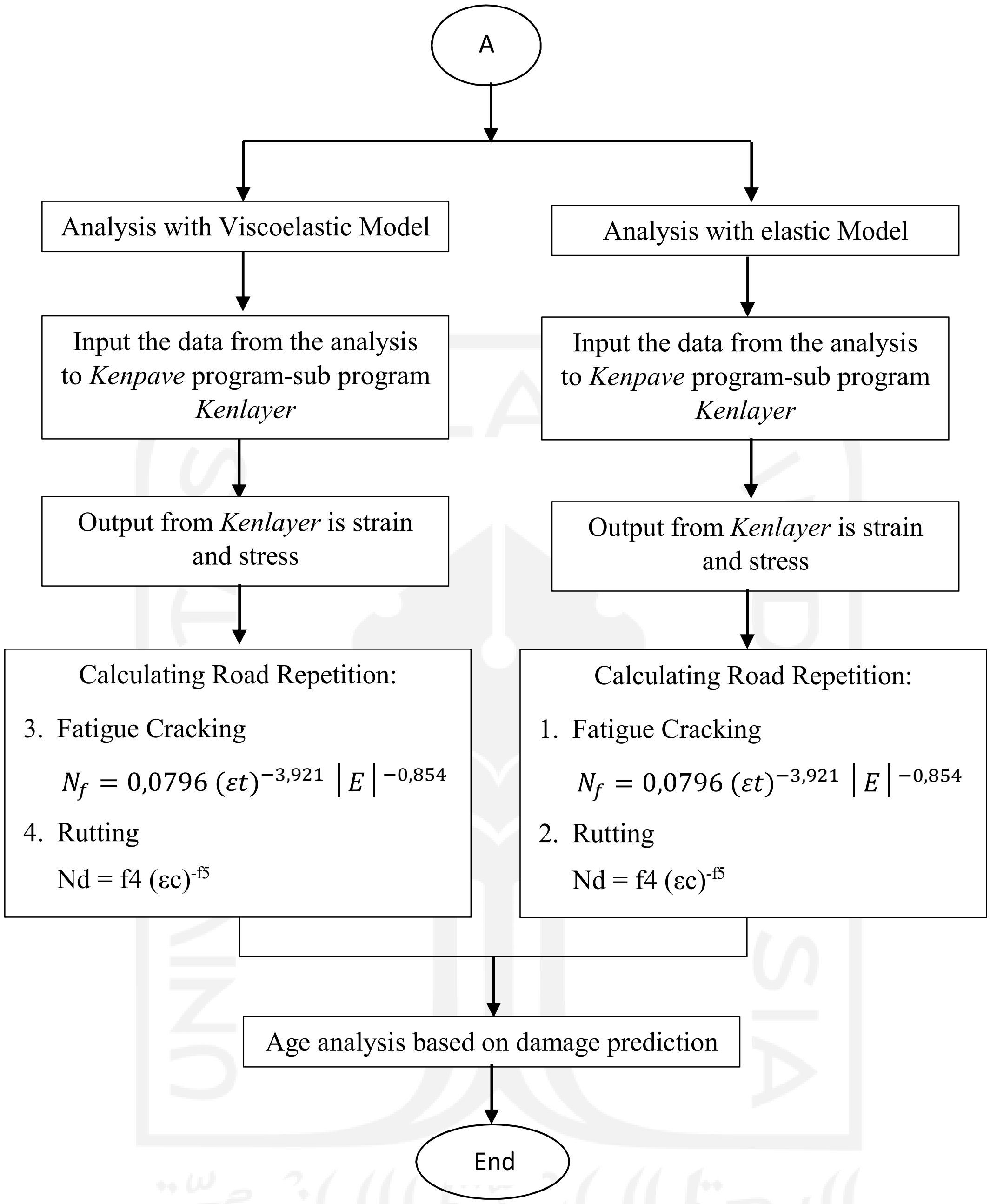

Figure 4.4 Continuation of Kenpave Method Flowchart

CHAPTER V

ANALYSIS AND DISCUSSION

5.1 Research Data

There are several types of research data to carry out road design such as traffic data, CBR (California Bearing Ratio) values.

5.1.1 Traffic Data

The traffic data of Sentolo - Nanggulan - Dekso road is a secondary data obtained from the National Road Planning and Supervision of D.I. Yogyakarta year 2019. The Sentolo - Nanggulan - Dekso road section is an alternative route that connects Yogyakarta International Airport with the Borobudur Temple area. The section, which has the status of a provincial road, is included as one of the supporting lines for the Borobudur KSPN. It has an existing national road standard with a width of 7 meters. Based on secondary data from National Road Planning and Supervision of D.I. Yogyakarta year 2019 the results of traffic calculations based on vehicle classes can be seen in Table 5.1 below.

Table 5.1 Average Daily Traffic on Sentolo - Nanggulan - Dekso road

No	Types of Vehicle	ADT 2019 (veh/day)
1	1	3690
2	2	1422
3	3	96
4	4	448
5	5A	75
6	5B	59
7	6A	147
8	6B	387
9	7A1	46
10	7B1	0
11	7C1	9
12	8	27

(Source: National Road Planning and Supervision of D.I. Yogyakarta 2019.)

5.1.2 CBR Data

CBR value data is secondary data obtained from the National Road Planning and Supervision of D.I. Yogyakarta 2020. The CBR value used is 7.66%.

5.1.3 Existing Pavement Data

Based on data obtained from the National Road Planning and Supervision of D.I. Yogyakarta 2020, the pavement thickness for The STA 10+500 – STA 11+000 of Sentolo – Nanggulan – Dekso road is as follows.

AC-WC = 4 cm

AC-BC = 6 cm

AC-Base = 20 cm

LFA = 15 cm

5.2 Flexible Pavement Design

The pavement design that will be carried out includes the existing pavement design using the Kenpave program, alternative pavement designs using the 2017 Bina marga method and using the Kenpave program.

5.2.1 Existing Flexible Pavement Design Using Kenpave Program Viscoelastic Modeling

The existing pavement thickness data that has been obtained from the Yogyakarta National Road Planning and Supervision Work Unit can be processed directly using the Kenpave program to determine the amount of damage that occurred.

1. Data Analysis

a. Wheel axle load details

The wheel axis detail data used is taken based on Figure 3.6 which is the wheel axis detail data in Indonesia according to Sukirman (1992), as follows.

1) The standard axle load of the vehicle is 18,000 pounds or 8.16 tons.

2) The wheel pressure for one tire is 0.55 kg/cm2 = 0.55 MPa.

3) The radius of the contact area is 11 cm.

4) The distance between each double axle is 33 cm.

b. Parameters of each pavement layer

In the analysis of the surface layer of this pavement using a viscoelastic material, so this calculation is carried out based on creep compliances. Meanwhile, the foundation layer and subgrade layer are assumed to use linear elastic material. So in this calculation only the elastic modulus and Poisson ratio parameters are used, which can be seen in Table 5.4 below.

Table 5.2 Parameter of Each Pavement Layer

AC-WC	Elastic Moduli(E)	1100 MPa
	Poison Ratio	0.4
AC-BC	Elastic Moduli(E)	1200 MPa
	Poison Ratio	0.4
AC-BASE(CTB)	Elastic Moduli(E)	500 MPa
	Poison Ratio	0.2
BASE COURSE	Elastic Moduli(E)	1600 MPa
	Poison Ratio	0.4
Base Soil	Elastic Moduli(E)	76.6 MPa
	Poison Ratio	0.45

2. Kenpave program input

a. Layernip Input

In this Layernip menu, several options are provided to fill in the required data according to the material properties of the flexible pavement being analyzed.

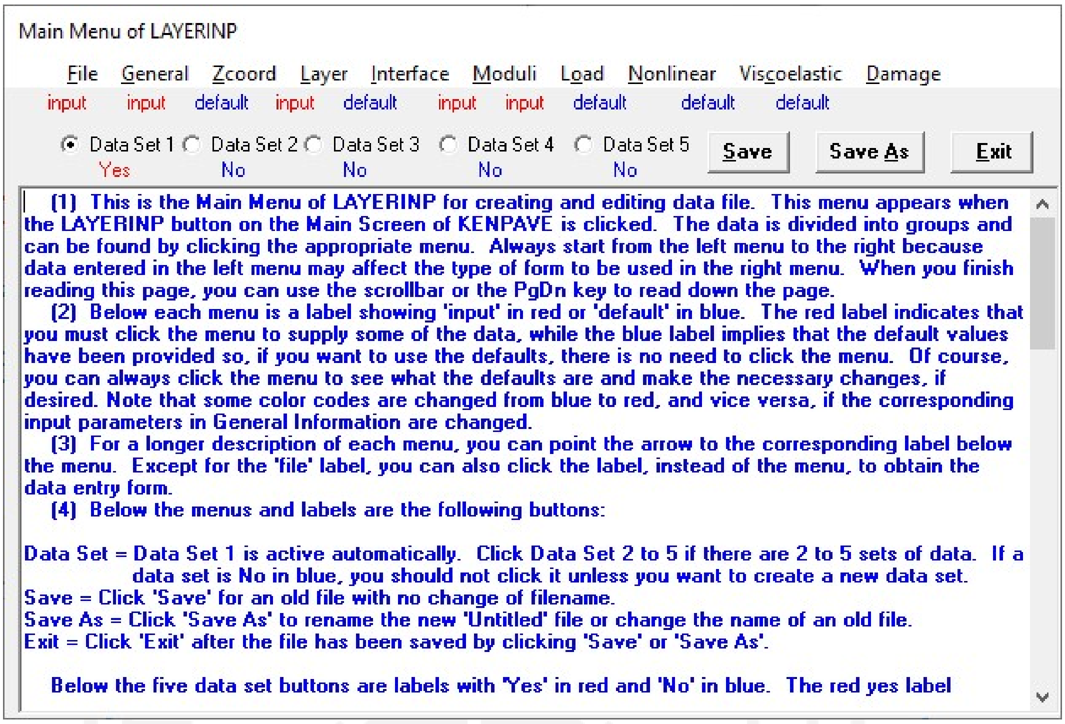

Figure 5.1 Layernip View

To start a new page on Layernip click file and click new. Then the inputted data will return to default.

b. General

After that input the general data as can be seen in the Table 5.5 below.

Table 5.3 General Input

Title	Trial	Explanation
MATL	3	Pavement Layer is Viscoelastic
NDAMA	0	No damage analysis in the beginning
NPY	1	Following Kenpave
NLG	1	Following Kenpave
DEL	0.001	Analysis Accuracy
NL	5	Number of Pavement Layer(AC-WC,AC-BC, AC-BASE,BASE COURSE ,Subgrade)
NZ	5	Number of Damage Review Points
ICL	80	Maximum number of integration cycles
NSDT	9	For the results of the vertical displacement analysis, the stress and strain values
NBOND	1	All Pavement Layers are Bound to Each Other
NLBT	0	
NLTC	0	
NUNIT	1	International Standard Units

c. Zcoord

Entering the depth data of the point that will be reviewed for damage, as can be seen in Figure 5.2 below.

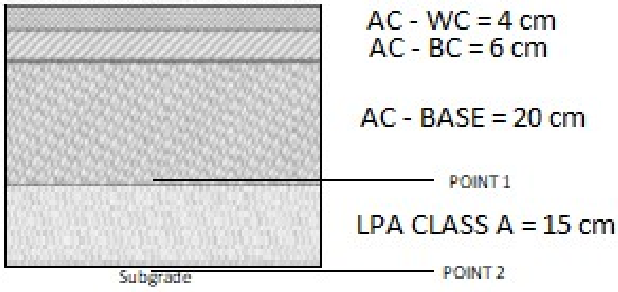

Figure 5.2 Damage Review Point Depth

From the picture above, it can be seen that there are two points of damage review, where point 1 is the depth of review of fatigue cracking and rutting damage. The difference is for fatigue cracks it use horizontal strain while rutting cracks use vertical strain. While point 2 is the depth of the review of permanent deformation damage. Details of the Zcoord input depth can be seen in Table 5.4 below.

Table 5.4 Zcoord Input

No	Depth (cm)	Explanation
1	0	Surface of the Pavement Layer
2	29.995	Pavement Base
3	30.005	Foundation Layer Surface
4	44.995	Foundation Layer Base
5	45.005	Subgrade

d. Layer

This layer menu functions to input pavement parameter data in the form of pavement thickness and Poisson's ratio. The parameter values are obtained from Bina Marga 2017 and can be seen in Table 5.5 below.

Table 5.5 Layer Parameter Input

Layer No	Thickness(cm)	Poisson's Ratio	Explanation
1	4	0.4	AC-WC
2	6	0.4	AC-BC
3	20	0.2	AC-BASE
4	15	0.4	BASE COURSE
5	∞	0.45	Subgrade

e. Moduli

The moduli menu is used to input pavement parameters in the form of resilient modulus or elastic modulus. This elastic modulus value is obtained from Bina Marga 2017 and can be seen in Table 5.6 below.

Table 5.6 Moduli Input

No	Elastic Moduli (KPa)
1	1,100,000
2	1,200,000
3	500,000
4	1,600,000
5	76,600

f. Load

In the Load menu, the axle load data that will be received by the pavement will be entered.

1) Load = 1 (single axle road, double axle wheel)
2) CR, based on the value of the distance between tires = 11 cm
3) CP, based on The wheel pressure = 0.55 MPa = 550 KPa
4) YW and XW, is a single axle dual tires wheel then the value of YW = 33 and XW = 0

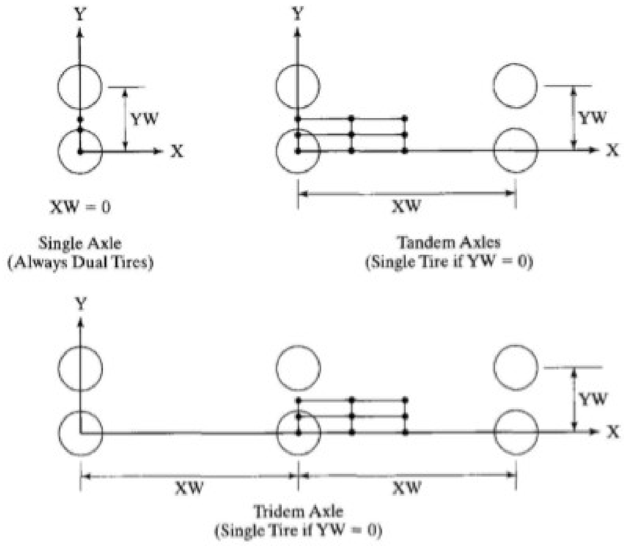

Figure 5.3 Plan View of Multiple Wheels
(Source : Huang, 2004)

5) NPT, the value of the coordinates of the NPT under review is 3, with the values of the X and Y coordinates as shown in Table 5.7 below.

Table 5.7 NPT Coordinate

X	Y
0	0
0	10
0	16.5

g. Viscoelastic

1) General

Load Duration (Dur) = 0.1

Number of Viscoelastic Layer = 3

Number of time durations for creep compliance = 11

2) Time

Creep compliances were calculated using 11 time variations and can be seen in Table 5.8 below.

Table 5.8 Time Durations For Creep Compliance

Sequence	Time
1	0.001
2	0.003
3	0.01
4	0.03
5	0.1
6	0.3
7	1
8	3
9	10
10	30
11	100

(Source : Huang, 2004)

3) Layer

Beta Value (β) = 0,113 (Huang, 2004)

Temperature = 25°C

4) Creep Compliance

In the creep menu, creep compliances value values will be automatically filled in this menu. Creep compliances value is the same as NTYME on Viscoelastic General Information. Unit on NTYME time will be converted automatically to KPa in this menu. The value of creep compliances can be seen in Table 5.9 below.

Table 5.9 Creep Compliance Value

Time	Creep
0.001	$3 X 10^{-10}$
0.003	$9 X 10^{-10}$
0.01	$3 X 10^{-9}$
0.03	$9 X 10^{-9}$
0.1	$2.9 X 10^{-8}$
0.3	$8.2 X 10^{-8}$
1	$2.5 X 10^{-7}$
3	$3.33 X 10^{-7}$
10	$3.63 X 10^{-7}$
30	$3.63 X 10^{-7}$
100	$3.63 X 10^{-7}$

(Source : Huang, 2004)

5) Temperature

In the menu the temperature is the same as the temperature on the layer menu, which is 25ºC.

3. Analysis Result

The results of the analysis carried out by Kenlayer issued an analysis output in the form of stresses and strains that occur in the flexible pavement. The response given for single axle load in this analysis is in the form of vertical compressive strain found on the subgrade surface and radial (tangential) tensile strain located at the bottom of the asphalt. The stresses and strains in Table 5.10 are obtained when the pavement structure is loaded. Meanwhile, Table 5.11 is a recapitulation of the largest stress and strain values for each layer.

Table 5.10 Existing Analysis Results of Viscoelastic Modeling

Point	Vertical Coordinate	Vertical Strain	Horizontal Stress
1	0	550	940.269
		-3.530×10^{-6}	3.45×10^{-6}
	29.995	4.083	-527.050
		1.839×10^{-6}	-3.72×10^{-6}
	30.005	4.080	-5.702
		5.504×10^{-6}	-3.73×10^{-6}
	44.995	1.698	-12.494
		7.536×10^{-6}	-5.74×10^{-6}
	45.005	1.698	0.662
		1.449×10^{-5}	-5.74×10^{-6}
2	0	550	979.324
		-4.239×10^{-6}	3.41×10^{-6}
	29.995	4.137	-521.132
		1.903×10^{-6}	-3.93×10^{-6}
	30.005	4.134	-5.775
		5.702×10^{-6}	-3.94×10^{-6}
	44.995	1.737	-13.227
		7.888×10^{-6}	-5.92×10^{-6}
	45.005	1.737	0.666
		1.504×10^{-5}	-5.92×10^{-6}

Table 5.11 Continuation of Existing Analysis Results of Viscoelastic Modeling and Maximum Strain Recapitulation

Point	Vertical Coordinate	Vertical Strain	Horizontal Stress
3	0	0	945.722
		-4.149×10^{-6}	3.38×10^{-6}
	29.995	4.122	-521.803
		1.914×10^{-4}	-4.01×10^{-4}
	30.005	4.119	-5.824
		5.742×10^{-6}	-4.01×10^{-6}
	44.995	1.776	-13.514
		8.050×10^{-6}	-6.03×10^{-6}
	45.005	1.776	0.683
		1.536×10^{-4}	-6.03×10^{-6}
Load	Horizontal Stress 29.995 m	Vertical Strain 29.995 m	Vertical Strain 45.005 m
	3.72×10^{-6}	1.839×10^{-6}	1.449×10^{-5}
	3.93×10^{-6}	1.903×10^{-6}	1.504×10^{-5}
	4.01×10^{-4}	1.914×10^{-4}	1.536×10^{-4}
Max	4.01×10^{-4}	1.91×10^{-4}	1.54×10^{-4}

From table 5.10 above can be seen the results of the Kenpave Program analysis in the form of stresses and strains experienced by the pavement. The displayed voltage corresponds to each input depth. Then in Table 5.11 it can be seen that the maximum stress resulting from each damage will be used to control the number of axle loads and service life.

4. Axle Load Control

After obtaining the stress and strain values, then proceed with analyzing the damage of fatigue cracking, permanent deformation and rutting as a form of control for predicting the service life of the road. This control is carried out by calculating the value of Nf (number of allowable repetition load values for repetition load to control fatigue cracking) and Nd (number of allowable repetition load values for repetition to control permanent deformation and rutting) must be greater than the predicted CESA. For the values of f4 and f5 follow the recommendations of the Asphalt Institute.

a. Nf value calculation (fatigue cracking)

The number of allowable repetition loads to control fatigue cracking.

$Nf = 0.0796\ (\varepsilon t)^{-3.921}\ |E|^{-0.854}$

$Nf = 0.0796\ (4.01\ \times 10^{-4})^{-3.921}\ |500{,}000|^{-0.854}$

$Nf = 22{,}567{,}752.35$ ESAL

b. Nd value calculation (rutting)

The number of allowable repetition loads to control rutting.

$Nd = f4\ (\varepsilon c)^{-f5}$

$Nd = 1.365\ \times\ 10^{-9}\ (1.91\ \times\ 10^{-4})^{-4.477}$

$Nd = 60{,}377{,}985.03$ ESAL

c. Nd value calculation (permanent deformation)

The number of allowable repetition loads to control permanent deformation.

$Nd = f4\ (\varepsilon c)^{-f5}$

$Nd = 1.365\ \times\ 10^{-9}\ (1.54\ \times\ 10^{-4})^{-4.477}$

$Nd = 161{,}681{,}071.5$ ESAL

5. Road Service Life Prediction Control

From the calculation results of the Kenlayer program analysis, it is known that the Sentolo – Nanggulan – Dekso Road experienced fatigue cracking damage after being passed by an axle load of 22,567,752.35 ESAL, for rutting damage that occurred after an axle load of 60,377,985.03 ESAL and while permanent deformation damage occurred after an axle load of 161,681,071.5 ESAL was passed. From these results, it can be seen that the damage that occurred the first time was a fatigue cracking. So from this axle load, it can be calculated predicting the service life of Sentolo – Nanggulan – Dekso road against damage using ADT, VDF data, direction distribution factor, lane distribution factor and also the value of traffic growth factor. Here is the description.

$$CESA_{Deform} \quad = \sum\left(ADT_{vehicle\ type} \times\ VDF\right) \times 365\ DD \times DL \times \frac{(1+0.01i)^{UR}-1}{0.01\ x\ 4.8}$$

$$22{,}567{,}752.35 \quad = (5656X\ 0) \times\ 365 \times\ 0.5\ \times\ 1\ \times\ \frac{(1+0.01(3.5\%))^{UR}-1}{0.01\ x\ (3.5\%)} +$$

$$(75\times\ 0.2)\times\ 365\ \times\ 0.5\ \times\ 1\ \times\ \frac{(1+0.01(3.5\%))^{UR}-1}{0.01\ x\ (3.5\%)}+$$

$$(59\times\ 1)\times\ 365\ \times\ 0.5\ \times\ 1\ \times\ \frac{(1+0.01(3.5\%))^{UR}-1}{0.01\ x\ (3.5\%)}+$$

$$(147\times\ 0.5)\times\ 365\ \times\ 0.5\ \times\ 1\ \times\ \frac{(1+0.01(3.5\%))^{UR}-1}{0.01\ x\ (3.5\%)}+$$

$$(387\times\ 5.1)\times\ 365\ \times\ 0.5\ \times\ 1\ \times\ \frac{(1+0.01(3.5\%))^{UR}-1}{0.01\ x\ (3.5\%)}+$$

$$(46\times\ 6.4)\times\ 365\ \times\ 0.5\ \times\ 1\ \times\ \frac{(1+0.01(3.5\%))^{UR}-1}{0.01\ x\ (3.5\%)}+$$

$$(9\times\ 9.7)\times\ 365\ \times\ 0.5\ \times\ 1\ \times\ \frac{(1+0.01(3.5\%))^{UR}-1}{0.01\ x\ (3.5\%)}+$$

$$(27\times\ 7.7)\times\ 365\ \times\ 0.5\ \times\ 1\ \times\ \frac{(1+0.01(3.5\%))^{UR}-1}{0.01\ x\ (3.5\%)}$$

= 27.73 Year

= 28 Year

From the analysis of the existing flexible pavement using Viscoelastic modeling, the output is in the form of the maximum axle load that can be resisted by STA 10+500 – STA 11+000 of Sentolo – Nanggulan – Dekso road from any damage that occurs and the design life which shows the length of time that Sentolo – Nanggulan – Dekso can withstand the maximum axle load until damage occurs. The recapitulation value of the maximum axle load and the service life of the axle load can be seen in Table 5.12 below.

Table 5.12 Recapitulation of Existing Flexural Pavement Analysis Viscoelastic Modeling

Type of Damage	Maximum Double Load (ESAL)	Service Life (Year)
Fatigue Cracking	22,567,752.35	28
Rutting	60,377,985.03	48
Permanent Deformation	161,681,071.5	73

From the table above, it can be seen that the first damage to Sentolo - Nanggulan – Dekso road was fatigue cracking with a maximum axle load of 22,567,752.35 ESAL with a service life of 28 years. From these results it can be said that the existing flexible pavement thickness with viscoelastic modeling is able to withstand vehicle loads until the planned service life is 20 years. From the table above, it can also be seen that before the design life of Sentolo - Nanggulan –Dekso road will also able to withstand rutting damage. Lastly for fatigue cracking, this road is considered to be very capable of withstanding this load.

5.2.2 Existing Flexible Pavement Design Using Kenpave Program Linear Elastic Modeling

The existing pavement thickness data that has been obtained from the Yogyakarta National Road Planning and Supervision Work Unit can be processed directly using the Kenpave program to determine the amount of damage that occurred.

1. Data Analysis
   a. Wheel axle load details
      The wheel axis detail data used is taken based on Figure 3.6 which is the wheel axis detail data in Indonesia according to Sukirman (1992), as follows.
      1) The standard axle load of the vehicle is 18,000 pounds or 8.16 tons.
      2) The wheel pressure for one tire is 0.55 kg/cm2 = 0.55 MPa.
      3) The radius of the contact area is 11 cm.
      4) The distance between each double axle is 33 cm.
   b. Parameters of each pavement layer
      In the analysis of the surface layer of this pavement using a viscoelastic material, so this calculation is carried out based on creep compliances. Meanwhile, the foundation layer and subgrade layer are assumed to use linear elastic material. So in this calculation only the elastic modulus and Poisson ratio parameters are used, which can be seen in Table 5.13 below.

Table 5.13 Parameter of Each Pavement Layer

AC-WC	Elastic Moduli(E)	1100 MPa
	Poison Ratio	0.4
AC-BC	Elastic Moduli(E)	1200 MPa
	Poison Ratio	0.4
AC-BASE(CTB)	Elastic Moduli(E)	500 MPa
	Poison Ratio	0.2
BASE COURSE	Elastic Moduli(E)	1600 MPa
	Poison Ratio	0.4
Base Soil	Elastic Moduli(E)	76.6 MPa
	Poison Ratio	0.45

2. Kenpave program input

   a. Layernip Input

   In this Layernip menu, several options are provided to fill in the required data according to the material properties of the flexible pavement being analyzed.

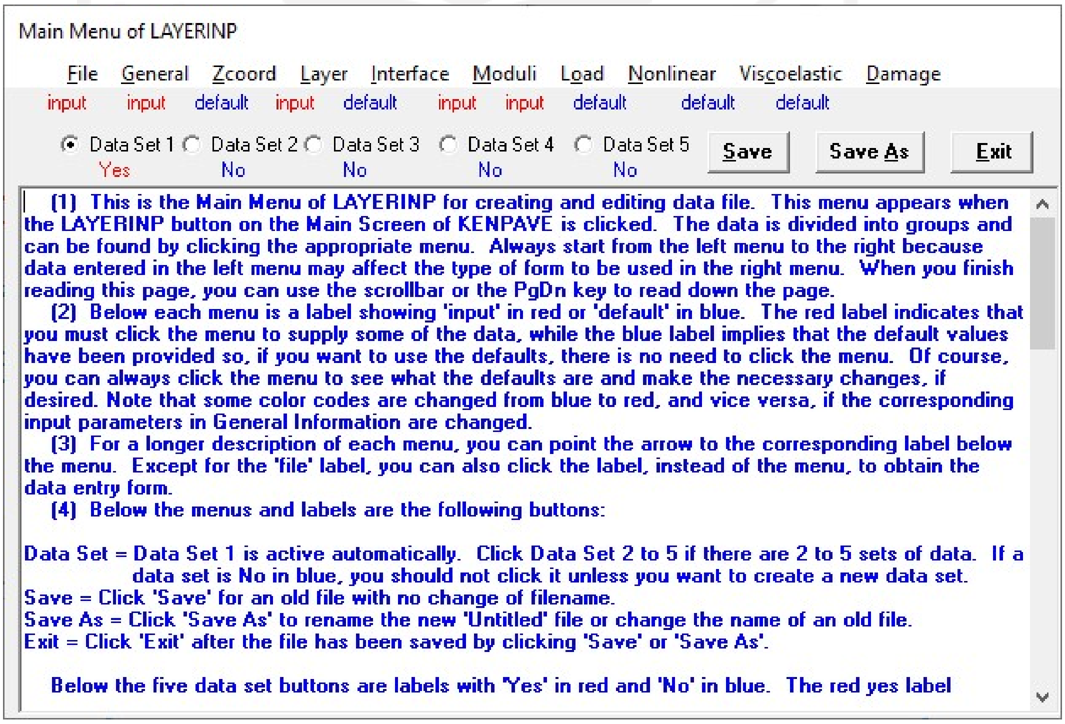

Figure 5.4 Layernip View

To start a new page on Layernip click file and click new. Then the inputted data will return to default.

b. General

After that input the general data as can be seen in the Table 5.14 below.

Table 5.14 General Input

Title	Trial	Explanation
MATL	1	Pavement Layer is Liniar Elastic
NDAMA	0	No damage analysis in the beginning
NPY	1	Following Kenpave
NLG	1	Following Kenpave
DEL	0.001	Analysis Accuracy
NL	5	Number of Pavement Layer(AC-WC,AC-BC, AC-BASE,Base Course ,Subgrade)
NZ	5	Number of Damage Review Points
ICL	80	Maximum number of integration cycles
NSDT	9	For the results of the vertical displacement analysis, the stress and strain values
NBOND	1	All Pavement Layers are Bound to Each Other
NLBT	0	
NLTC	0	
NUNIT	1	International Standard Units

c. Zcoord

Entering the depth data of the point that will be reviewed for damage, as can be seen in Figure 5.2 below.

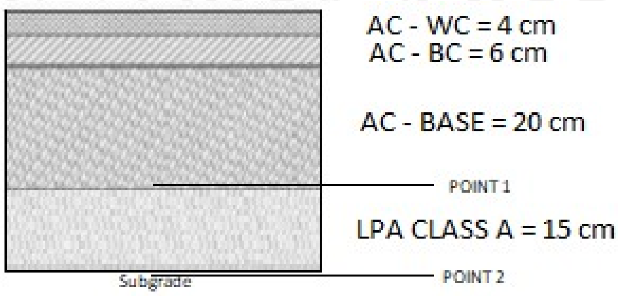

Figure 5.5 Damage Review Point Depth

From the picture above, it can be seen that there are two points of damage review, where point 1 is the depth of review of fatigue cracking and rutting damage. The difference is for fatigue cracks it use horizontal strain while rutting cracks use vertical strain. While point 2 is the depth of the review of permanent deformation damage. Details of the Zcoord input depth can be seen in Table 5.15 below.

Table 5.15 Zcoord Input

No	Depth (cm)	Explanation
1	0	Surface of the Pavement Layer
2	29.995	Pavement Base
3	30.005	Foundation Layer Surface
4	44.995	Foundation Layer Base
5	45.005	Subgrade

d. Layer

This layer menu functions to input pavement parameter data in the form of pavement thickness and Poisson's ratio. The parameter values are obtained from Bina Marga 2017 and can be seen in Table 5.16 below.

Table 5.16 Layer Parameter Input

Layer No	Thickness(cm)	Poisson's Ratio	Explanation
1	4	0.4	AC-WC
2	6	0.4	AC-BC
3	20	0.2	AC-BASE
4	15	0.4	BASE COURSE
5	∞	0.45	Subgrade

e. Moduli

The moduli menu is used to input pavement parameters in the form of resilient modulus or elastic modulus. This elastic modulus value is obtained from Bina Marga 2017 and can be seen in Table 5.17 below.

Table 5.17 Moduli Input

No	Elastic Moduli (KPa)
1	1,100,000
2	1,200,000
3	500,000
4	1,600,000
5	76,600

f. Load

In the Load menu, the axle load data that will be received by the pavement will be entered.

1) Load = 1 (single axle road, double axle wheel)
2) CR, based on the value of the distance between tires = 11 cm
3) CP, based on The wheel pressure = 0.55 MPa = 550 KPa
4) YW and XW, is a single axle dual tires wheel then the value of YW = 33 and XW = 0

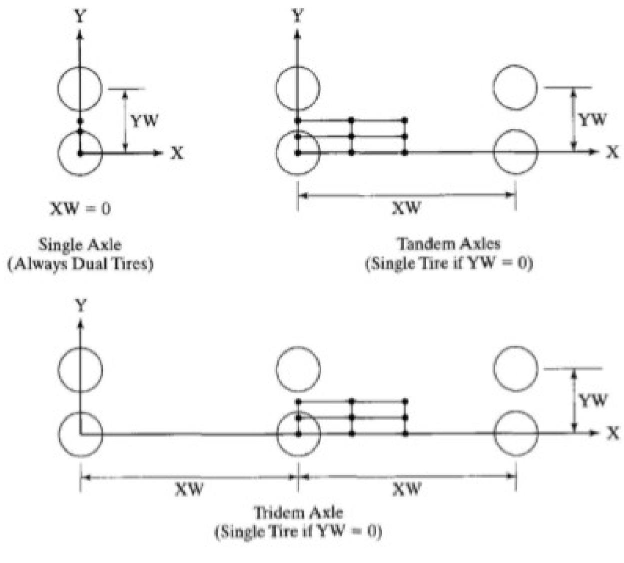

Figure 5.6 Plan View of Multiple Wheels
(Source : Huang, 2004)

5) NPT, the value of the coordinates of the NPT under review is 3, with the values of the X and Y coordinates as shown in Table 5.18 below.

Table 5.18 NPT Coordinate

X	Y
0	0
0	10
0	16.5

After all data has been filled in each display menu, then it is saved and then returns to the Kenpave main menu. The data will be run by clicking the Kenlayer menu. Then to see the results of the analysis of stress and strain values, click the Editor menu and open the file name.

3. Analysis Result

The following are the results of the output stress and strain on linear elastic modeling using the Kenlayer program.

Table 5.19 Results of Existing Pavement Analysis using Linear Elastic Modeling

Point	Vertical Coordinate	Vertical Strain	Horizontal Stress
1	0	550	897.514
		2.332×10^{-5}	2.15×10^{-4}
	29.995	78.990	9.099
		1.497×10^{-4}	-1.80×10^{-5}
	30.005	78.926	9.081
		4.312×10^{-5}	-1.80×10^{-5}
	44.995	21.577	-183.466
		1.124×10^{-4}	-9.22×10^{-5}
	45.005	21.573	6.786
		2.045×10^{-4}	-9.23×10^{-5}
2	0	550	483.060
		-4.971×10^{-5}	1.24×10^{-4}
	29.995	79.332	12.675
		1.496×10^{-4}	-1.88×10^{-4}
	30.005	79.281	21.548
		4.124×10^{-5}	-1.87×10^{-5}
	44.995	22.943	-202.057
		1.218×10^{-4}	-9.76×10^{-5}
	45.005	22.939	7.269
		2.203×10^{-4}	-9.76×10^{-5}

Table 5.20 Continuation of Existing Analysis Results of Liniar Elastic Modeling and Maximum Strain Recapitulation

Point	Vertical Coordinate	Vertical Strain	Horizontal Stress
3	0	0	378.764
		-5.967 x10^{-5}	1.01 x10^{-4}
	29.995	77.591	13.949
		1.460 x10^{-5}	-1.87 x10^{-5}
	30.005	77.542	24.590
		3.959 x10^{-5}	-1.87 x10^{-5}
	44.995	23.174	-204.996
		1.233 x10^{-4}	-9.86 x10^{-5}
	45.005	23.170	7363
		2.229 x10^{-4}	-9.86 x10^{-4}
Load	Horizontal Stress 29.995 m	Vertical Strain 29.995 m	Vertical Strain 45.005 m
	1.800 x10^{-5}	1.497 x10^{-4}	2.045 x10^{-4}
	1.880 x10^{-4}	1.496 x10^{-4}	2.203 x10^{-4}
	1.870 x10^{-5}	1.460 x10^{-4}	2.229 x10^{-4}
Max	1.880 x10^{-4}	1.497 x10^{-4}	2.229 x10^{-4}

From table 5.19 above can be seen the results of the Kenpave Program analysis in the form of stresses and strains experienced by the pavement. The displayed voltage corresponds to each input depth. Then in Table 5.20 it can be seen that the maximum stress resulting from each damage will be used to control the number of axle loads and service life.

4. Axle Load Control

After obtaining the stress and strain values, then proceed with analyzing the damage of fatigue cracking, permanent deformation and rutting as a form of control for predicting the service life of the road. This control is carried out by calculating the value of Nf (number of allowable repetition load values for repetition load to control fatigue cracking) and Nd (number of allowable repetition load values for repetition to control permanent deformation and rutting) must be greater than the predicted CESA. For the values of f4 and f5 follow the recommendations of the Asphalt Institute.

a. Nf value calculation (fatigue cracking)

The number of allowable repetition loads to control fatigue cracking.

$Nf = 0.0796\ (\varepsilon t)^{-3.921}\ |E|^{-0.854}$

$Nf = 0.0796\ (1.880\ \times 10^{-4})^{-3.921}\ |500{,}000|^{-0.854}$

$Nf = 444{,}175{,}598.6$ ESAL

b. Nd value calculation (rutting)

The number of allowable repetition loads to control rutting.

$Nd = f4\ (\varepsilon c)^{-f5}$

$Nd = 1.365\ \times\ 10^{-9}\ (1.497\ \times\ 10^{-4})^{-4.477}$

$Nd = 181{,}411{,}431.9$ ESAL

c. Nd value calculation (permanent deformation)

The number of allowable repetition loads to control permanent deformation.

$Nd = f4\ (\varepsilon c)^{-f5}$

$Nd = 1.365\ \times\ 10^{-9}\ (2.229\ \times\ 10^{-4})^{-4.477}$

$Nd = 30{,}524{,}170.78$ ESAL

5. Road Service Life Prediction Control

From the calculation results of the Kenlayer program analysis, it is known that the Sentolo – Nanggulan – Dekso Road experienced fatigue cracking damage after being passed by an axle load of 444,175,598.6 ESAL, for rutting damage that occurred after an axle load of 181,411,431.9 ESAL and while permanent deformation damage occurred after an axle load of 30,524,170.78 ESAL was passed. From these results, it can be seen that the damage that occurred the first time was a permanent deformation. So from this axle load, it can be calculated predicting the service life of Sentolo – Nanggulan – Dekso road against damage using ADT, VDF data, direction distribution factor, lane distribution factor and also the value of traffic growth factor. Here is the description.

$$CESA_{Deform} = \sum(ADT_{ve\quad type} \times VDF) \times 365 \times DD \times DL \times \frac{(1 + 0.01i)^{UR} - 1}{0.01\ \times\ 4.8}$$

$$30{,}524{,}170.78 = (5656 \times 0) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$
$$(75 \times 0.2) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$
$$(59 \times 1) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$
$$(147 \times 0.5) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$
$$(387 \times 5.1) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$
$$(46 \times 6.4) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$
$$(9 \times 9.7) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$
$$(27 \times 7.7) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)}$$

= 33.448 Year

= 34 Year

From the analysis of the existing flexible pavement using Viscoelastic modeling, the output is in the form of the maximum axle load that can be resisted by Sentolo – Nanggulan – Dekso road from any damage that occurs and the design life which shows the length of time that Sentolo – Nanggulan – Dekso can withstand the maximum axle load until damage occurs. The recapitulation value of the maximum axle load and the service life of the axle load can be seen in Table 5.21 below.

Table 5.21 Recapitulation of Existing Flexural Pavement Analysis Liniar Elastic Modeling

Type of Damage	Maximum Double Load (ESAL)	Service Life (Year)
Fatigue Cracking	444,175,598.6	101
Rutting	181,411,431.9	78
Permanent Deformation	30,524,170.78	34

From the table above, it can be seen that the first damage to Sentolo - Nanggulan – Dekso road was permanent deformation with a maximum axle load of 30,524,170.78 ESAL with a service life of 34 years. From these results it can be said that the existing flexible pavement thickness with viscoelastic modeling is able to withstand vehicle loads until the planned service life is 20 years. From the table above, it can also be seen that before the design life of Sentolo - Nanggulan –Dekso road will also able to withstand rutting damage. Lastly for fatigue cracking, this road is considered to be very capable of withstanding this load.

5.2.3 Alternative Flexible Pavement Design Using Bina Marga 2017

In designing alternative flexible pavement designs using the Road Pavement Design Manual Number 04/SE/Db/2017, several stages of work are needed. The stages of this method are as follows.

1. Planned Age

   Based on Table 3.1, in the design of flexible pavement using asphalt pavement, it has been determined using a design life of 20 years from 2019 so that the service period will expire in 2038.

2. Value of traffic growth rate factor (i)

   Based on Table 3.2, Sentolo – Nanggulan – Dekso road can be categorized as a rural road because it is located in a rural area so that the traffic growth factor (i) is 3.5%.

3. Traffic growth multiplier value (R)

   For the value of this traffic growth multiplier, it is divided into two, namely $R_{factual}$ used for calculations under 2020 and R_{normal} used for calculations above 2020.

   $$R_{factual} = \frac{(1+0{,}01\ )^{UR}-1}{0{,}01}$$

   $$= \frac{(1+0{,}01(3{,}5\%))^{2}-1}{0{,}01(3{,}5\%)}$$

   $$= 2{,}00035$$

   $$R_{normal} = \frac{(1+0{,}01i)^{UR}-1}{0{,}01}$$

   $$= \frac{(1+0{,}01(3{,}5\%))^{18}-1}{0{,}01(3{,}5\%)}$$

   $$= 18.05365$$

4. Value of directional distribution factor (DD) and lane distribution factor (DL)

   For Sentolo – Nanggulan – Dekso road using a two-way system so that the distribution factor (DD) is generally taken as 0.5. As for the lane distribution factor (DL) the value of 100% is taken based on Table 3.3 because the number of lanes per direction is 1.

5. Vehicle Damage Factor (VDF)

This vehicle damage factor is needed to obtain an overview of the vehicle axle load and the configuration of the existing vehicle axle. In the Flexible Road Pavement Design Manual No. 02/M/BM/2017 VDF is divided into VDF4 and VDF5 and each has a factual value (≤2020) and a normal value (>2020) so that later it will distinguish the results of the Cumulative Equivalent Single Axle load (CESA) became $CESA_4$ and $CESA_5$. The $CESA_4$ value is used to determine the choice of pavement type while $CESA_5$ is used to determine the thickness of the flexible pavement used based on the Flexible Road Pavement Design Manual No 02/M/BM/2017. For details of the VDF_4 and VDF_5 values for the Java region, it can be seen in Table 5.22 below.

Table 5.22 Value of VDF_4 and VDF_5

Vehicle Type	Factual VDF_4	Normal VDF_4	Factual VDF_5	Normal VDF_5
(a)	(d)	(e)	(f)	(g)
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5A	0.3	0.3	0.2	0.2
5B	1	1	1	1
6A	0.55	0.55	0.5	0.5
6B	5.3	4	9.2	5.1
7A1	8.2	4.7	14.4	6.4
7B1	11.8	9.4	18.2	13
7C1	11	7.4	19.8	9.7
8	18.1	6.1	34.4	7.7

From the data that has been given above, it can be calculated the planned number of vehicles in a period of 20 years. For example calculations will be given the calculation of Equivalent Single Axle Load (ESA_4 and ESA_5) on 5B class vehicles.

$ESA_{4factual}$ $= \left(\sum ADT_{Vehicletype}\ X\ VDF_4\right) X\ 365\ X\ DD\ X\ DL\ X\ R$

= (59 x 1) x 365 x 0,5 x 1 x 2,00035

= 21538.7686

$ESA_{4normal}$ $= \left(\sum ADT_{Vehicletype}\ X\ VDF_4\right) X\ 365\ X\ DD\ X\ DL\ X\ R$

= (66 x 1) x 365 x 0,5 x 1 x 18.05365

= 215526.6362

$ESA_{5factual}$ $= \left(\sum ADT_{Vehicletype}\, X\, VDF_5\right) X\ 365\ X\ DD\ X\ DL\ X\ R$

= (59 x 1) x 365 x 0,5 x 1 x 2,00035

= 21538.7686

$ESA_{5normal}$ $= \left(\sum ADT_{Vehicletype}\, X\, VDF_5\right) X\ 365\ X\ DD\ X\ DL\ X\ R$

= (66 x 1) x 365 x 0,5 x 1 x 18.05365

= 215526.6362

For a recap of the calculation of the vehicle load for other groups, it can be seen in Table 5.23 below.

Table 5.23 Prediction of Total Axle Load During Pavement Life

Vehicle Type	ADT 2019	ADT 2021(Reopen)	Factual VDF4	Normal VDF4	Factual VDF5	Normal VDF5	ESA4(19-20)	ESA4(21-38)	ESA5(19-20)	ESA5(21-38)
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
1	3690	4091.168959	0	0	0	0	0	0	0	0
2	1422	1576.596818	0	0	0	0	0	0	0	0
3	96	106.436916	0	0	0	0	0	0	0	0
4	448	496.705608	0	0	0	0	0	0	0	0
5A	75	83.15384063	0.3	0.3	0.2	0.2	8213.93719	82192.3612	5475.95813	54794.9075
5B	59	65.41435463	1	1	1	1	21538.7686	215526.636	21538.7686	215526.636
6A	147	162.9815276	0.55	0.55	0.5	0.5	29515.4143	295344.551	26832.1948	268495.047
6B	387	429.0738176	5.3	4	9.2	5.1	748782.514	5654834.45	1299773.42	7209913.93
7A1	46	51.00102225	8.2	4.7	14.4	6.4	137702.094	789777.267	241818.311	1075441.38
7B1	0	0	11.8	9.4	18.2	13	0	0	0	0
7C1	9	9.978460875	11	7.4	19.8	9.7	36141.3236	243289.389	65054.3825	318906.362
8	27	29.93538263	18.1	6.1	34.4	7.7	178406.716	601648.084	339071.327	759457.418
Total ESA4							1160300.77	7882612.74	1999564.36	9902535.68
CESA							9042913.51		11902100.05	

So based on Table 5.23 above the value of $CESA_4$ and $CESA_5$ are :

$CESA_4$ = 9042913.51 ESAL

$CESA_5$ = 11902100.05 ESAL

6. Determining pavement type

   In determining the type of pavement, it is influenced by the Cumulative Equivalent Single Axle Load (CESA) which has been obtained previously. From the CESA4 value of 9,042,913.51ESAL if synchronized with Table 3.6, the type of pavement obtained is AC thickness ≥ 100 mm with a grained foundation layer (ESA5) with the requirement to use a large contractor with adequate resources.

7. Pavement thickness design

   To determine the pavement thickness design, it is based on Table 3.7 using the CESA5 value of 11,902,100.05 ESAL. Because The CBR value used is 7,66% > 7% so BASE COURSE value is adjusted based on the Table 3.8. So that the thickness of the pavement layer is obtained as follows.

   AC-WC = 4 cm
   AC-BC = 6 cm
   AC-Base = 14,5 cm
   BASE COURSE = 20,5 cm

   From the alternative pavement thickness data above, it is found that there is a difference in thickness in the AC Base layer when compared to the existing pavement.

5.2.4 Alternative Flexible Pavement Design Using Viscoelastic Modeling Kenpave Program

The existing pavement thickness data that has been obtained from the Yogyakarta National Road Planning and Supervision Work Unit can be processed directly using the Kenpave program to determine the amount of damage that occurred.

1. Data Analysis

a. Wheel axle load details

The wheel axis detail data used is taken based on Figure 3.6 which is the wheel axis detail data in Indonesia according to Sukirman (1992), as follows.

1) The standard axle load of the vehicle is 18,000 pounds or 8.16 tons.

2) The wheel pressure for one tire is 0.55 kg/cm2 = 0.55 MPa.

3) The radius of the contact area is 11 cm.

4) The distance between each double axle is 33 cm.

b. Parameters of each pavement layer

In the analysis of the surface layer of this pavement using a viscoelastic material, so this calculation is carried out based on creep compliances. Meanwhile, the foundation layer and subgrade layer are assumed to use linear elastic material. So in this calculation only the elastic modulus and Poisson ratio parameters are used, which can be seen in Table 5.24 below.

Table 5.24 Parameter of Each Pavement Layer

AC-WC	Elastic Moduli(E)	1100 MPa
	Poison Ratio	0.4
AC-BC	Elastic Moduli(E)	1200 MPa
	Poison Ratio	0.4
AC-BASE(CTB)	Elastic Moduli(E)	500 MPa
	Poison Ratio	0.2
BASE COURSE	Elastic Moduli(E)	1600 MPa
	Poison Ratio	0.4
Base Soil	Elastic Moduli(E)	76.6 MPa
	Poison Ratio	0.45

2. Kenpave program input

a. Layernip Input

In this Layernip menu, several options are provided to fill in the required data according to the material properties of the flexible pavement being analyzed.

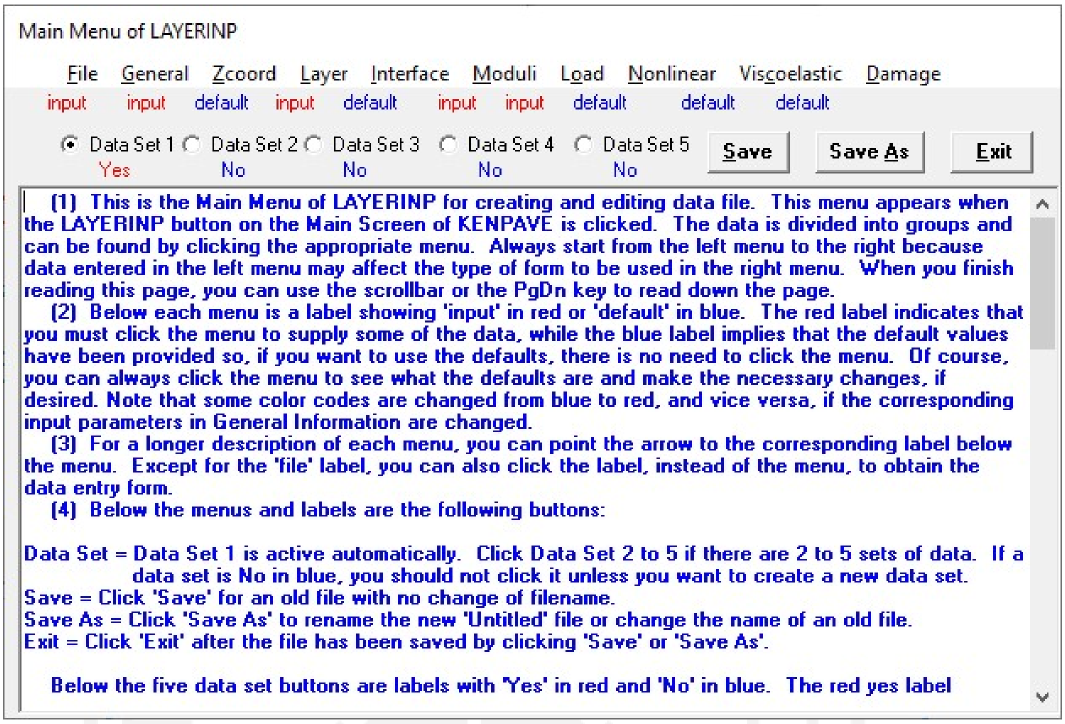

Figure 5.7 Layernip View

To start a new page on Layernip click file and click new. Then the inputted data will return to default.

b. General

After that input the general data as can be seen in the Table 5.25 below.

Table 5.25 General Input

Title	Trial	Explanation
MATL	3	Pavement Layer is Viscoelastic
NDAMA	0	No damage analysis in the beginning
NPY	1	Following Kenpave
NLG	1	Following Kenpave
DEL	0.001	Analysis Accuracy
NL	5	Number of Pavement Layer(AC-WC,AC-BC, AC-BASE,BASE COURSE ,Subgrade)
NZ	5	Number of Damage Review Points
ICL	80	Maximum number of integration cycles
NSDT	9	For the results of the vertical displacement analysis, the stress and strain values
NBOND	1	All Pavement Layers are Bound to Each Other
NLBT	0	
NLTC	0	
NUNIT	1	International Standard Units

c. Zcoord

Entering the depth data of the point that will be reviewed for damage, as can be seen in Figure 5.9 below.

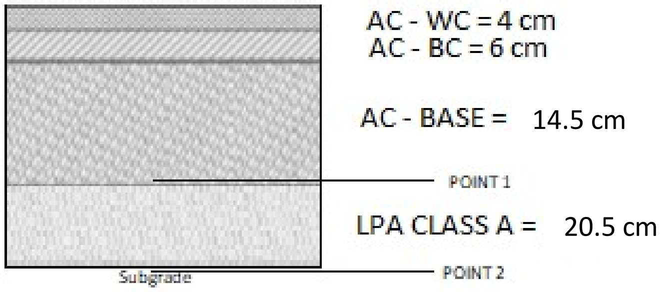

Figure 5.8 Damage Review Point Depth

From the picture above, it can be seen that there are two points of damage review, where point 1 is the depth of review of fatigue cracking and rutting damage. The difference is for fatigue cracks it use horizontal strain while rutting cracks use vertical strain. While point 2 is the depth of the review of permanent deformation damage. Details of the Zcoord input depth can be seen in Table 5.26 below.

Table 5.26 Zcoord Input

No	Depth (cm)	Explanation
1	0	Surface of the Pavement Layer
2	24.495	Pavement Base
3	25.505	Foundation Layer Surface
4	44.995	Foundation Layer Base
5	45.005	Subgrade

d. Layer

This layer menu functions to input pavement parameter data in the form of pavement thickness and Poisson's ratio. The parameter values are obtained from Bina Marga 2017 and can be seen in Table 5.27 below.

Table 5.27 Layer Parameter Input

Layer No	Thickness(cm)	Poisson's Ratio	Explanation
1	4	0.4	AC-WC
2	6	0.4	AC-BC
3	14.5	0.2	AC-BASE
4	20.5	0.4	BASE COURSE
5	∞	0.45	Subgrade

e. Moduli

The moduli menu is used to input pavement parameters in the form of resilient modulus or elastic modulus. This elastic modulus value is obtained from Bina Marga 2017 and can be seen in Table 5.28 below.

Table 5.28 Moduli Input

No	Elastic Moduli (KPa)
1	1,100,000
2	1,200,000
3	500,000
4	1,600,000
5	76,600

f. Load

In the Load menu, the axle load data that will be received by the pavement will be entered.

1) Load = 1 (single axle road, double axle wheel)
2) CR, based on the value of the distance between tires = 11 cm
3) CP, based on The wheel pressure = 0.55 MPa = 550 KPa
4) YW and XW, is a single axle dual tires wheel then the value of YW = 33 and XW = 0

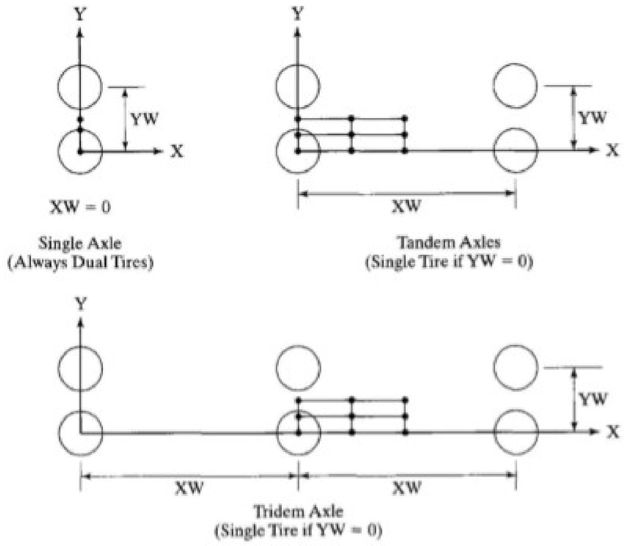

Figure 5.9 Plan View of Multiple Wheels
(Source : Huang, 2004)

5) NPT, the value of the coordinates of the NPT under review is 3, with the values of the X and Y coordinates as shown in Table 5.29 below.

Table 5.29 NPT Coordinate

X	Y
0	0
0	10
0	16.5

g. Viscoelastic

1) General

Load Duration (Dur) = 0.1

Number of Viscoelastic Layer = 3

Number of time durations for creep compliance = 11

2) Time

Creep compliances were calculated using 11 time variations and can be seen in Table 5.30 below.

Table 5.30 Time Durations For Creep Compliance

Sequence	Time
1	0.001
2	0.003
3	0.01
4	0.03
5	0.1
6	0.3
7	1
8	3
9	10
10	30
11	100

(Source : Huang, 2004)

3) Layer

Beta Value (β) = 0,113 (Huang, 2004)

Temperature = 25°C

4) Creep Compliance

In the creep menu, creep compliances value values will be automatically filled in this menu. Creep compliances value is the same as NTYME on Viscoelastic General Information. Unit on NTYME time will be converted automatically to KPa in this menu. The value of creep compliances can be seen in Table 5.31 below.

Table 5.31 Creep Compliance Value

Time	Creep
0.001	3×10^{-10}
0.003	9×10^{-10}
0.01	3×10^{-9}
0.03	9×10^{-9}
0.1	2.9×10^{-8}
0.3	8.2×10^{-8}
1	2.5×10^{-7}
3	3.33×10^{-7}
10	3.63×10^{-7}
30	3.63×10^{-7}
100	3.63×10^{-7}

(Source : Huang, 2004)

5) Temperature

In the menu the temperature is the same as the temperature on the layer menu, which is 25ºC.

3. Analysis Result

The results of the analysis carried out by Kenlayer issued an analysis output in the form of stresses and strains that occur in the flexible pavement. The response given for single axle load in this analysis is in the form of vertical compressive strain found on the subgrade surface and radial (tangential) tensile strain located at the bottom of the asphalt. The stresses and strains in Table 5.32 are obtained when the pavement structure is loaded. Meanwhile, Table 5.33 is a recapitulation of the largest stress and strain values for each layer.

Table 5.32 Alternative Analysis Results of Viscoelastic Modeling

Point	Vertical Coordinate	Vertical Strain	Horizontal Stress
1	0	550	717.194
		-3.853×10^{-6}	3.65×10^{-6}
	24.495	7.325	-687.022
		2.516×10^{-6}	-4.99×10^{-6}
	25.505	6.848	-6.783
		7.760×10^{-6}	-5.00×10^{-6}
	44.995	2.140	-18.099
		1.068×10^{-5}	-8.13×10^{-6}
	45.005	2.140	0.711
		1.970×10^{-5}	-8.13×10^{-6}
2	0	550	662.159
		-4.507×10^{-6}	3.55×10^{-6}
	24.495	7.574	-543.797
		2.094×10^{-4}	-4.002×10^{-6}
	25.505	7.119	-7.259
		8.407×10^{-6}	-5.61×10^{-6}
	44.995	2.392	-20.012
		1.173×10^{-5}	-8.75×10^{-6}
	45.005	2.392	0.823
		2.178×10^{-4}	-8.75×10^{-6}

Table 5.33 Continuation of Alternative Analysis Results of Viscoelastic Modeling and Maximum Strain Recapitulation

Point	Vertical Coordinate	Vertical Strain	Horizontal Stress
3	0	0	683.591
		-4.370×10^{-6}	3.53×10^{-6}
	24.495	7.330	-583.968
		2.578×10^{-6}	-5.53×10^{-6}
	25.505	6.910	-6.811
		8.102×10^{-6}	-5.51×10^{-6}
	44.995	2.318	-19.738
		1.154×10^{-5}	-8.60×10^{-6}
	45.005	2.318	0.782
		2.131×10^{-5}	-8.60×10^{-6}
Load	Horizontal Stress 24.495 m	Vertical Strain 24.495 m	Vertical Strain 45.005 m
	4.990×10^{-6}	2.516×10^{-6}	1.970×10^{-5}
	4.002×10^{-4}	2.094×10^{-4}	2.178×10^{-4}
	5.530×10^{-6}	2.578×10^{-6}	2.131×10^{-5}
Max	4.002×10^{-4}	2.09×10^{-4}	2.18×10^{-4}

From table 5.32 above can be seen the results of the Kenpave Program analysis in the form of stresses and strains experienced by the pavement. The displayed voltage corresponds to each input depth. Then in Table 5.33 it can be seen that the maximum stress resulting from each damage will be used to control the number of axle loads and service life.

4. Axle Load Control

After obtaining the stress and strain values, then proceed with analyzing the damage of fatigue cracking, permanent deformation and rutting as a form of control for predicting the service life of the road. This control is carried out by calculating the value of Nf (number of allowable repetition load values for repetition load to control fatigue cracking) and Nd (number of allowable repetition load values for repetition to control permanent deformation and rutting) must be greater than the predicted CESA. For the values of f4 and f5 follow the recommendations of the Asphalt Institute.

a. Nf value calculation (fatigue cracking)

The number of allowable repetition loads to control fatigue cracking.

$Nf = 0.0796\ (\varepsilon t)^{-3.921}\ |E|^{-0.854}$

$Nf = 0.0796\ (4.002\ \times 10^{-4})^{-3.921}\ |500{,}000|^{-0.854}$

$Nf = 22{,}722{,}925.08$ ESAL

b. Nd value calculation (rutting)

The number of allowable repetition loads to control rutting.

$Nd = f4\ (\varepsilon c)^{-f5}$

$Nd = 1.365\ \times\ 10^{-9}\ (2.09\ \times\ 10^{-4})^{-4.477}$

$Nd = 40{,}375{,}700.19$ ESAL

c. Nd value calculation (permanent deformation)

The number of allowable repetition loads to control permanent deformation.

$Nd = f4\ (\varepsilon c)^{-f5}$

$Nd = 1.365\ \times\ 10^{-9}\ (2.18 \times\ 10^{-4})^{-4.477}$

$Nd = 33{,}856{,}927.47$ ESAL

5. Road Service Life Prediction Control

From the calculation results of the Kenlayer program analysis, it is known that the Sentolo – Nanggulan – Dekso Road experienced fatigue cracking damage after being passed by an axle load of 22,722,925.08 ESAL, for rutting damage that occurred after an axle load of 40,375,700.19 ESAL and while permanent deformation damage occurred after an axle load of 33,856,927.47 ESAL was passed. From these results, it can be seen that the damage that occurred the first time was a fatigue cracking. So from this axle load, it can be calculated predicting the service life of Sentolo – Nanggulan – Dekso road against damage using ADT, VDF data, direction distribution factor, lane distribution factor and also the value of traffic growth factor. Here is the description.

$$CESA_{Deform} = \sum(ADT_{vehicle\ type} \times VDF) \times 365 \times DD \times DL \times \frac{(1 + 0.01i)^{UR} - 1}{0.01\ \times\ 4.8}$$

$$22{,}722{,}925.08 = (5656 \times\ 0) \times 365\ \times 0.5\ \times 1\ \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(75 \times 0.2) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(59 \times 1) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(147 \times 0.5) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(387 \times 5.1) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(46 \times 6.4) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(9 \times 9.7) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(27 \times 7.7) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)}$$

= 27.85 Year

= 28 Year

From the analysis of the existing flexible pavement using Viscoelastic modeling, the output is in the form of the maximum axle load that can be resisted by Sentolo – Nanggulan – Dekso road from any damage that occurs and the design life which shows the length of time that Sentolo – Nanggulan – Dekso can withstand the maximum axle load until damage occurs. The recapitulation value of the maximum axle load and the service life of the axle load can be seen in Table 5.34 below.

Table 5.34 Recapitulation of Alternative Flexural Pavement Analysis Viscoelastic Modeling

Type of Damage	Maximum Double Load (ESAL)	Service Life (Year)
Fatigue Cracking	22,722,925.08	28
Rutting	40,375,700.19	40
Permanent Deformation	33,856,927.47	35

From the table above, it can be seen that the first damage to Sentolo - Nanggulan – Dekso road was fatigue cracking with a maximum axle load of 22,722,925.08 ESAL with a service life of 28 years. From these results it can be said that the existing flexible pavement thickness with viscoelastic modeling is able to withstand vehicle loads until the planned service life is 20 years. From the table above, it can also be seen that before the design life of Sentolo - Nanggulan –Dekso road will also able to withstand rutting damage. Lastly for fatigue cracking, this road is considered to be very capable of withstanding this load.

5.2.5 Alternative Flexible Pavement Design Using Elastic Linear Modeling Kenpave Program

The existing pavement thickness data that has been obtained from the Yogyakarta National Road Planning and Supervision Work Unit can be processed directly using the Kenpave program to determine the amount of damage that occurred.

1. Data Analysis
   a. Wheel axle load details

   The wheel axis detail data used is taken based on Figure 3.6 which is the wheel axis detail data in Indonesia according to Sukirman (1992), as follows.

   1) The standard axle load of the vehicle is 18,000 pounds or 8.16 tons.
   2) The wheel pressure for one tire is 0.55 kg/cm2 = 0.55 MPa.
   3) The radius of the contact area is 11 cm.
   4) The distance between each double axle is 33 cm.

   b. Parameters of each pavement layer

   In the analysis of the surface layer of this pavement using a viscoelastic material, so this calculation is carried out based on creep compliances. Meanwhile, the foundation layer and subgrade layer are assumed to use linear elastic material. So in this calculation only the elastic modulus and Poisson ratio parameters are used, which can be seen in Table 5.35 below.

Table 5.35 Parameter of Each Pavement Layer

AC-WC	Elastic Moduli(E)	1100 MPa
	Poison Ratio	0.4
AC-BC	Elastic Moduli(E)	1200 MPa
	Poison Ratio	0.4
AC-BASE(CTB)	Elastic Moduli(E)	500 MPa
	Poison Ratio	0.2
BASE COURSE	Elastic Moduli(E)	1600 MPa
	Poison Ratio	0.4
Base Soil	Elastic Moduli(E)	76.6 MPa
	Poison Ratio	0.45

2. Kenpave program input

   a. Layernip Input

   In this Layernip menu, several options are provided to fill in the required data according to the material properties of the flexible pavement being analyzed.

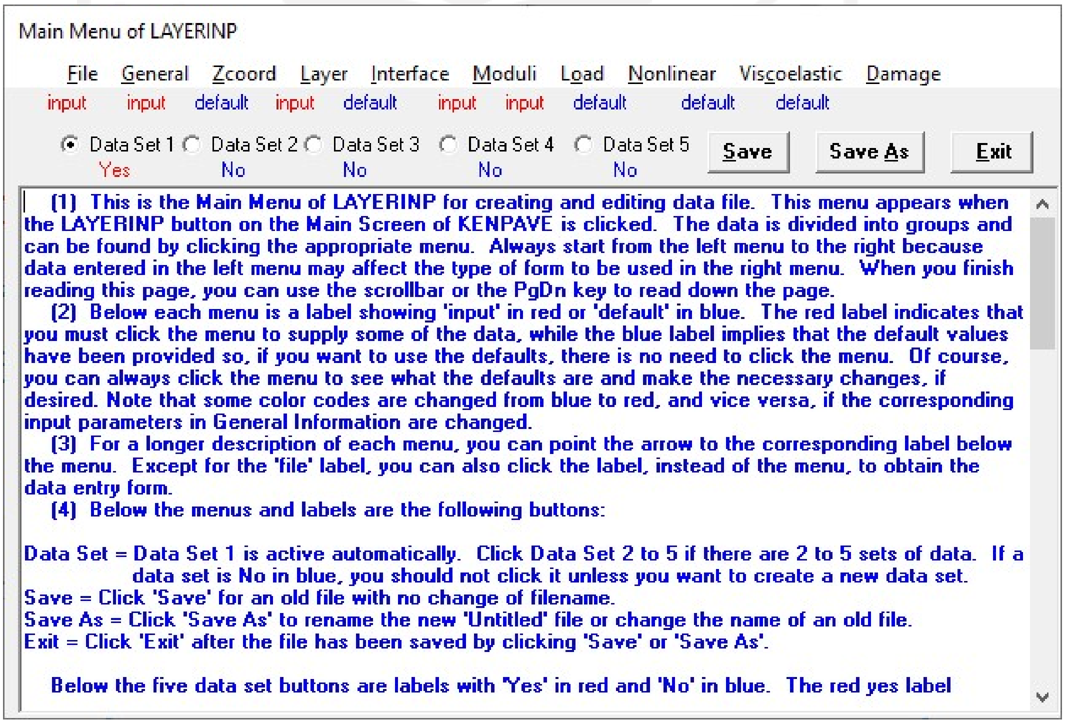

Figure 5.10 Layernip View

To start a new page on Layernip click file and click new. Then the inputted data will return to default.

b. General

After that input the general data as can be seen in the Table 5.36 below.

Table 5.36 General Input

Title	Trial	Explanation
MATL	1	Pavement Layer is Liniar Elastic
NDAMA	0	No damage analysis in the beginning
NPY	1	Following Kenpave
NLG	1	Following Kenpave
DEL	0.001	Analysis Accuracy
NL	5	Number of Pavement Layer(AC-WC,AC-BC, AC-BASE,BASE COURSE ,Subgrade)
NZ	5	Number of Damage Review Points
ICL	80	Maximum number of integration cycles
NSDT	9	For the results of the vertical displacement analysis, the stress and strain values
NBOND	1	All Pavement Layers are Bound to Each Other
NLBT	0	
NLTC	0	
NUNIT	1	International Standard Units

c. Zcoord

Entering the depth data of the point that will be reviewed for damage, as can be seen in Figure 5.2 below.

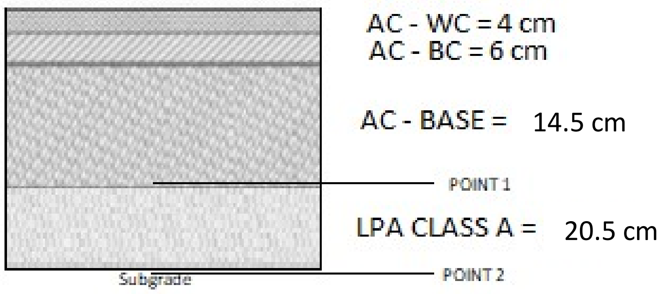

Figure 5.11 Damage Review Point Depth

From the picture above, it can be seen that there are two points of damage review, where point 1 is the depth of review of fatigue cracking and rutting damage. The difference is for fatigue cracks it use horizontal strain while rutting cracks use vertical strain. While point 2 is the depth of the review of permanent deformation damage. Details of the Zcoord input depth can be seen in Table 5.37 below.

Table 5.37 Zcoord Input

No	Depth (cm)	Explanation
1	0	Surface of the Pavement Layer
2	24.495	Pavement Base
3	25.505	Foundation Layer Surface
4	44.995	Foundation Layer Base
5	45.005	Subgrade

d. Layer

This layer menu functions to input pavement parameter data in the form of pavement thickness and Poisson's ratio. The parameter values are obtained from Bina Marga 2017 and can be seen in Table 5.38 below.

Table 5.38 Layer Parameter Input

Layer No	Thickness(cm)	Poisson's Ratio	Explanation
1	4	0.4	AC-WC
2	6	0.4	AC-BC
3	14.5	0.2	AC-BASE
4	20.5	0.4	BASE COURSE
5	∞	0.45	Subgrade

e. Moduli

The moduli menu is used to input pavement parameters in the form of resilient modulus or elastic modulus. This elastic modulus value is obtained from Bina Marga 2017 and can be seen in Table 5.39 below.

Table 5.39 Moduli Input

No	Elastic Moduli (KPa)
1	1,100,000
2	1,200,000
3	500,000
4	1,600,000
5	76,600

f. Load

In the Load menu, the axle load data that will be received by the pavement will be entered.

6) Load = 1 (single axle road, double axle wheel)
7) CR, based on the value of the distance between tires = 11 cm
8) CP, based on The wheel pressure = 0.55 MPa = 550 KPa
9) YW and XW, is a single axle dual tires wheel then the value of YW = 33 and XW = 0

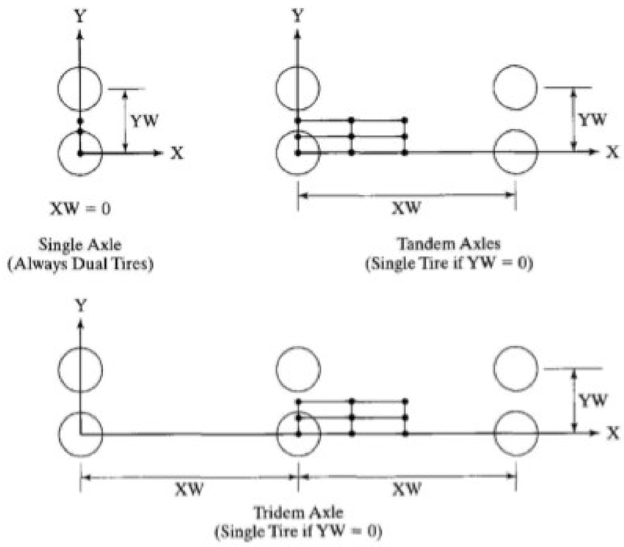

Figure 5.12 Plan View of Multiple Wheels
(Source : Huang, 2004)

10) NPT, the value of the coordinates of the NPT under review is 3, with the values of the X and Y coordinates as shown in Table 5.40 below.

Table 5.40 NPT Coordinate

X	Y
0	0
0	10
0	16.5

After all data has been filled in each display menu, then it is saved and then returns to the Kenpave main menu. The data will be run by clicking the Kenlayer menu. Then to see the results of the analysis of stress and strain values, click the Editor menu and open the file name.

3. Analysis Result

The following are the results of the output stress and strain on linear elastic modeling using the Kenlayer program.

Table 5.41 Results of Alternative Pavement Analysis using Linear Elastic Modeling

Point	Vertical Coordinate	Vertical Strain	Horizontal Stress
1	0	550	880.093
		3.644×10^{-5}	2.05×10^{-4}
	24.495	121.126	22.905
		2.227×10^{-4}	-1.30×10^{-4}
	25.505	112.995	38.912
		4.894×10^{-5}	-1.59×10^{-5}
	44.995	20.513	-181.975
		1.108×10^{-4}	-9.09×10^{-5}
	45.005	20.509	6.050
		1.993×10^{-4}	-9.09×10^{-5}
2	0	550	466.733
		-3.687×10^{-5}	1.16×10^{-4}
	24.495	113.885	29.589
		2.070×10^{-4}	-1.31×10^{-4}
	25.505	107.683	60.951
		4.161×10^{-5}	-1.64×10^{-5}
	44.995	21.749	-199.918
		1.198×10^{-4}	-9.61×10^{-5}
	45.005	21.745	6.450
		2.142×10^{-4}	-9.62×10^{-5}

Table 5.42 Continuation of Alternative Analysis Results of Liniar Elastic Modeling and Maximum Strain Recapitulation

Point	Vertical Coordinate	Vertical Strain	Horizontal Stress
3	0	0	363.631
		-4.732×10^{-5}	9.38×10^{-5}
	24.495	107.811	30.593
		1.949×10^{-4}	-1.27×10^{-4}
	25.505	102.658	65.667
		3.735×10^{-5}	-1.61×10^{-5}
	44.995	21.954	-202.717
		1.213×10^{-4}	-9.71×10^{-5}
	45.005	21.950	6.528
		2.166×10^{-4}	-9.71×10^{-5}
Load	Horizontal Stress 24.495 m	Vertical Strain 24.495 m	Vertical Strain 45.005 m
	1.30×10^{-4}	2.227×10^{-4}	1.993×10^{-4}
	1.310×10^{-4}	2.070×10^{-4}	2.142×10^{-4}
	1.27×10^{-4}	1.949×10^{-4}	2.166×10^{-4}
Max	1.310×10^{-4}	2.23×10^{-4}	2.17×10^{-4}

From table 5.41 above can be seen the results of the Kenpave Program analysis in the form of stresses and strains experienced by the pavement. The displayed voltage corresponds to each input depth. Then in Table 5.42 it can be seen that the maximum stress resulting from each damage will be used to control the number of axle loads and service life.

4. Axle Load Control

After obtaining the stress and strain values, then proceed with analyzing the damage of fatigue cracking, permanent deformation and rutting as a form of control for predicting the service life of the road. This control is carried out by calculating the value of Nf (number of allowable repetition load values for repetition load to control fatigue cracking) and Nd (number of allowable repetition load values for repetition to control permanent deformation and rutting) must be greater than the predicted CESA. For the values of f4 and f5 follow the recommendations of the Asphalt Institute.

d. Nf value calculation (fatigue cracking)

The number of allowable repetition loads to control fatigue cracking.

$Nf = 0.0796\ (\varepsilon t)^{-3.921}\ |E|^{-0.854}$

$Nf = 0.0796\ (1.310 \times 10^{-4})^{-3.921}\ |500{,}000|^{-0.854}$

$Nf =$ 1,812,057,330 ESAL

e. Nd value calculation (rutting)

The number of allowable repetition loads to control rutting.

$Nd = f4\ (\varepsilon c)^{-f5}$

$Nd = 1.365\ \times\ 10^{-9}\ (1.497 \times\times\ 10^{-4})^{-4.477}$

$Nd =$ 30,647,089.72 ESAL

f. Nd value calculation (permanent deformation)

The number of allowable repetition loads to control permanent deformation.

$Nd = f4\ (\varepsilon c)^{-f5}$

$Nd = 1.365\ \times\ 10^{-9}\ (2.229\ \times\ 10^{-4})^{-4.477}$

$Nd =$ 34,704,817.14 ESAL

5. Road Service Life Prediction Control

From the calculation results of the Kenlayer program analysis, it is known that the Sentolo – Nanggulan – Dekso Road experienced fatigue cracking damage after being passed by an axle load of 1,812,057,330 ESAL, for rutting damage that occurred after an axle load of 30,647,089.72 ESAL and while permanent deformation damage occurred after an axle load of 34,704,817.14 ESAL was passed. From these results, it can be seen that the damage that occurred the first time was a rutting. So from this axle load, it can be calculated predicting the service life of Sentolo – Nanggulan – Dekso road against damage using ADT, VDF data, direction distribution factor, lane distribution factor and also the value of traffic growth factor. Here is the description.

$$CESA_{Deform} \quad = \sum\left(ADT_{vehicle\ type} \times\ VDF\right) \times 365 \times DD \times\ DL \times \frac{(1 + 0.01i)^{UR} - 1}{0.01\ x\ 4.8}$$

$$30{,}647{,}089.72\ =\ (5656 \times\ 0)\ 365\ \times\ 0.5 \times\ 1\ \times\ \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(75 \times 0.2) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(59 \times 1) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(147 \times 0.5) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(387 \times 5.1) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(46 \times 6.4) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(9 \times 9.7) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)} +$$

$$(27 \times 7.7) \times 365 \times 0.5 \times 1 \times \frac{(1+0.01(3.5\%))^{UR}-1}{0.01 \times (3.5\%)}$$

= 33.5207 Year

= 34 Year

From the analysis of the existing flexible pavement using Viscoelastic modeling, the output is in the form of the maximum axle load that can be resisted by Sentolo – Nanggulan – Dekso road from any damage that occurs and the design life which shows the length of time that Sentolo – Nanggulan – Dekso can withstand the maximum axle load until damage occurs. The recapitulation value of the maximum axle load and the service life of the axle load can be seen in Table 5.21 below.

Table 5.43 Recapitulation of Alternative Flexural Pavement Analysis Liniar Elastic Modeling

Type of Damage	Maximum Double Load (ESAL)	Service Life (Year)
Fatigue Cracking	1,812,057,330	142
Rutting	30,647,089.72	34
Permanent Deformation	34,704,817.14	36

From the table above, it can be seen that the first damage to Sentolo - Nanggulan – Dekso road was rutting with a maximum axle load of 30,647,089.72 ESAL with a service life of 34 years. From these results it can be said that the existing flexible pavement thickness with viscoelastic modeling is able to withstand vehicle loads until the planned service life is 20 years. From the table above, it can also be seen that before the design life of Sentolo - Nanggulan –Dekso road will also able to withstand rutting damage. Lastly for fatigue cracking, this road is considered to be very capable of withstanding this load.

5.3 Discussion

After analyzing the flexible pavement design for Sentolo – Nanggulan – Dekso road using Mechanistic - Empirical methods, the following results were obtained.

1. The design of the existing flexible pavement structure and the alternative for Sentolo – Nanggulan – Dekso road was carried out using an Mechanistic - Empirical method, namely the Road Pavement Design Manual Number 02/M/BM/2017.
2. The stress and strain values of existing and alternative flexible pavements from Sentolo – Nanggulan – Dekso road with Mechanistic - Empirical methods assisted by the Kenpave-Kenlayer program using Viscoelastic and Linear Elastic modeling.
3. Comparison of estimated service life of existing and alternative pavement structures using Bina Marga 2017.
4. Comparison of differences in concepts, design parameters, and design procedures between two Mechanistic - Empirical methods, namely Bina Marga 2017 and Kenpave Program.

5.3.1 The design of the existing and alternative flexible pavement structures for Sentolo – Nanggulan – Dekso using Bina Marga 2017

Based on data obtained from the National Road Planning and Supervision of D.I. Yogyakarta 2020, the pavement thickness for Sentolo – Nanggulan – Dekso road is as follows.

AC-WC = 4 cm

AC-BC = 6 cm

AC-Base = 20 cm

LFA = 15 cm

In addition, using ADT data, alternative pavements can also be obtained based on the 2017 Highways. In determining the type of pavement, it is influenced by the Cumulative Equivalent Single Axle Load (CESA) which has been obtained previously. From the CESA4 value of 9,042,913.51ESAL if synchronized with Table 3.6, the type of pavement obtained is AC thickness ≥ 100 mm with a grained foundation layer (ESA5) with the requirement to use a large contractor with adequate resources. To determine the pavement thickness design, it is based on Table 3.7 using the CESA5 value of 11,902,100.05 ESAL. Because The CBR value used is 7,66% > 7% so BASE COURSE value is adjusted based on the Table 3.8. So that the thickness of the pavement layer is obtained as follows.

AC-WC = 4 cm

AC-BC = 6 cm

AC-Base = 14,5 cm

BASE COURSE = 20,5 cm

From the alternative pavement thickness data above, it is found that there is a difference in thickness in the AC Base layer when compared to the existing pavement where the alternative pavement has a thinner layer than the existing pavement. Although the difference in thickness is not very significant, this can have a major impact on the ability of Sentolo – Nanggulan – Dekso to withstand the weight of passing vehicles.

5.3.2 The stress and strain values of existing and alternative flexible pavements from the Kenpave program using Viscoelastic and Linear Elastic modeling

This Kenpave-Kenlayer program helps users to estimate the level of pavement damage which refers to the physical properties of the pavement such as modulus of elasticity, poisson ratio, environmental factors and pavement thickness. The pavement properties are used to calculate the pavement response in the form of stress and strain from each layer. To find out how the pavement is able to withstand the load that crosses it, the stress and strain values are included as important parameters.

In reading the value of this stress and strain is different in each damage. For the existing pavement, the damage value for fatigue cracking is read at a tangential stress depth of 29,995 cm, namely at the bottom surface layer, the damage value for rutting damage is read at a vertical stress depth of 29,995 cm. While the damage to permanent deformation is read at a vertical stress depth of 45.005 cm, namely the upper subgrade (Huang, 2004). For more details can be seen in Figure 5.14 below.

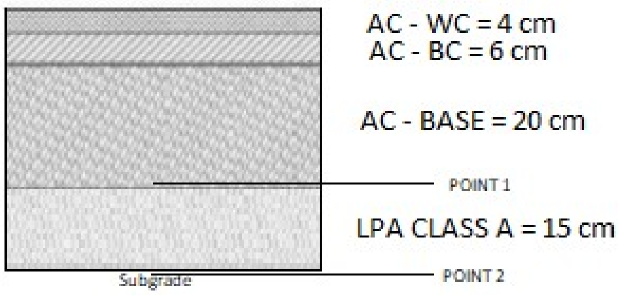

Figure 5.13 Location of Existing Flexible Pavement Damage Review Points

From the calculation results, it can be seen that the existing flexible pavement of the Viscoelastic model is able to accommodate the repetition axle load of 22,567,752.35 ESAL until fatigue cracking occurs, 60,377,985.03 ESAL until rutting occurs and 161,681,071.5 ESAL until permanent deformation occurs. For the existing flexible pavement, Linear Elastic modeling is able to accommodate the repetition axle load of 444,175,598.6 ESAL until fatigue cracking occurs, 181,411,431.9 ESAL until rutting occurs and 30,524,170.78 ESAL until permanent deformation occurs.

For the alternative pavement, the damage value for fatigue cracking is read at a tangential stress depth of 24,495 cm, namely at the bottom surface layer, the damage value for rutting damage is read at a vertical stress depth of 24,495 cm. While the damage to permanent deformation is read at a vertical stress depth of 45.005 cm, namely the upper subgrade (Huang, 2004). For more details can be seen in Figure 5.14 below.

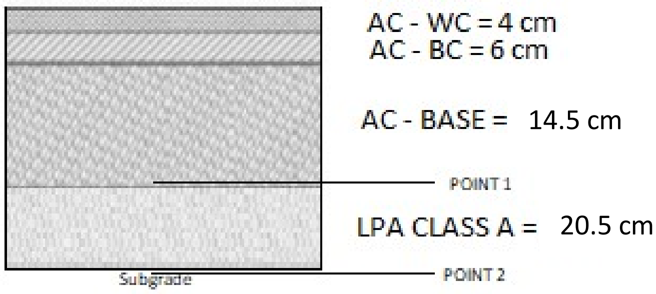

Figure 5.14 Location of Alternative Flexible Pavement Damage Review Points

From the calculation results, it can be seen that the alternative flexible pavement of the Viscoelastic model is able to accommodate the repetition axle load of 22,722,925.08 ESAL until fatigue cracking occurs, 40,375,700.19 ESAL until rutting occurs and 33,856,927.47 ESAL until permanent deformation occurs. For the alternative flexible pavement, Linear Elastic modeling is able to accommodate the repetition axle load of 1,812,057,330 ESAL until fatigue cracking occurs, 30,647,089.72 ESAL until rutting occurs and 34,704,817.14 ESAL until permanent deformation occurs.

5.3.3 Comparison of estimated service life of existing and alternative pavement structures using Bina Marga 2017

In this study, the service life of a certain pavement thickness can be predicted using the number of repetitions of each damage so that the service life can be known until each damage occurs. To get the service life, this is done by processing the axle load figures for each damage using existing data in the 2017 Highways such as ADT, VDF, direction distribution factor, lane distribution factor and traffic growth factor value.

For the existing flexible pavement with viscoelastic modeling with pavement thickness of each layer AC-WC 4 cm, AC-BC 6 cm, AC-Base 20 cm and Base Course 15 cm, the maximum repetition load was 22,567,752.35 ESAL (fatigue cracking) with service life 28 years, 60,377,985.03 ESAL (rutting) with a service life of 48 years and 161,681,071.5 ESAL (permanent deformation) with a service life of 73 years. While the existing flexible pavement with linear elastic modeling obtained a maximum repetition load of 444,175,598.6 ESAL (fatigue cracking) with a service life of 101 years, 181,411,431.9 ESAL (rutting) with a service life of 78 years and 30,524,170.78 ESAL (permanent deformation) with a service life 34 years.

For the Alternative flexible pavement with viscoelastic modeling with pavement thickness of each layer AC-WC 4 cm, AC-BC 6 cm, AC-Base 14.5 cm and Base Course 20.5 cm, the maximum repetition load was 22,722,925.08 ESAL (fatigue cracking) with service life 28 years, 40,375,700.19 ESAL (rutting) with a service life of 40 years and 33,856,927.47 ESAL (permanent deformation) with a service life of 35 years. While the alternative flexible pavement with linear elastic modeling obtained a maximum repetition load of 1,812,057,330 ESAL (fatigue cracking) with a service life of 142 years, 30,647,089.72 ESAL (rutting) with a service life of 34 years and 34,704,817.14 ESAL (permanent deformation) with a service life 36 years.

5.3.4 Comparison of differences in concepts, design parameters, and design procedures between, Bina Marga 2017 and Kenpave Program

After analyzing the flexible pavement using the Bina Marga 2017 method and using the Kenpave program, it was found that there were several comparisons such as concepts, parameters and procedures which will be explained as follows.

1. Design Concept

In this study, it can be clearly seen that the flexible pavement analysis using the 2017 Bina Marga method and the Kenpave Program has a significant difference in concept. Basically the Bina Marga 2017 method uses the concept of pavement analysis by using a traffic volume survey which is used to calculate the traffic load that will be borne by the road during the life of the plan. In the pavement analysis of the 2017 Bina Marga method, it is also strengthened by factors such as traffic growth, which was previously carried out by a survey by Bina Marga itself and can be seen in the Design Manual. Road Pavement Number 02/M/BM/2017. The bearing capacity of the soil is also used by checking the CBR value of the subgrade. Determination of the bearing capacity of the subgrade accurately and the design of the pavement foundation are important requirements to produce a good performance pavement. For example, a pavement with a thin layer of pavement can significantly reduce service life if there is an error in the evaluation of the subgrade.

Different from the 2017 Highways method, which mostly uses survey results, the Kenpave Program adheres to a multilayer elastic and vicoelastic multilayer system with respect to stress, strain and deflection. Then this system is also based on material mechanics where it takes several input materials in the form of tire pressure, distance between tires, tire contact area, modulus of elasticity and Poisson ratio values. So basically the Kenpave program processes the assumptions of pavement thickness by using certain parameters that produce stresses and strains that occur on the road.

2. Design Parameter

There are several differences in the parameters used between the Bina Marga 2017 method and the Kenpave Program. In Bina Marga 2017 the fixed vehicle method is used, namely calculating the thickness of the pavement based on the number of repetitions of a predetermined standard vehicle load of 18 kip. So the load on a vehicle consisting of tandem/tridem must be changed to match the standard load repetition using a load equivalent factor (Vehicle Damage Factor). While the Kenpave Program uses parameters in the form of materials that are in direct contact with the road such as tire pressure, contact area, distance between tires and distance between axes that are taken into account.

Another parameter that is also influential is the parameter of each layer used in each method. In Bina marga 2017 the foundation and subgrade layers are only based on the CBR number and for the surface layer based on laboratory results and the cumulative number of design traffic axle loads in each lane (CESA). In contrast to the Kenpave program, this method calculates stress and strain using parameters from each layer in the form of modulus of elasticity (E) and Poisson's ratio. The Kenpave program also has two models, viscoelastic and linear elastic. If in viscoelastic modeling, the pavement layer is assumed to have the characteristics of viscoelastic material and the foundation has elastic properties so that the calculation of creep compliances is required.

The next parameter is the determination of pavement thickness. In the Bina Marga 2017 method, the thickness of the pavement is determined by the CESA4 and CESA5 values. The CESA4 value is used to determine the type of pavement used, while the CESA5 value is used to determine the thickness of the pavement used. While in the Kenpave Program, the pavement thickness is assumed first and an analysis is carried out so that the stress and strain values are obtained. The stress and strain values are processed so that the value of the number of repetitions of the load that occurs for each damage (Nf, Nr and Nd) is obtained to prove the assumption that the pavement thickness used is safe.

3. Design Procedure

Comparison of the flexible pavement design procedure of the 2017 Bina marga method and the Kenpave Program of viscoelastic and linear elastic approaches. The Bina Marga 2017 method used Several parameters as a reference for the calculation, such as design age, lane factor, traffic load and traffic growth rate to design the alternative pavement. While in Kenpave program, it uses data such as pavement and material characteristics such as modulus, poisson ratio of each layer, wheel load, tire pressure and coordinates to calculate the stress and strain that occurred inside the pavement layers

CHAPTER VI

CONCLUSION AND SUGGESTION

6.1 Conclusion

After analyzing the flexible pavement for the STA 10+500 – STA 11+000 of Sentolo – Nanggulan – Dekso road using the Mechanistic - Empirical method, several important points were obtained as follows.

1. From the research above, the result showed that both the existing pavement and alternative pavement were optimum in holding the vehicle load within the planned life of 20 years. The result for the existing pavement and alternative pavement can be seen in Table 6.1 and Table 6.2 below

Table 6.1 The Service Life and ESAL Value of Existing Pavement

Type of Damage	Existing Pavement			
	Viscoelastic		Liniar Elastic	
Fatigue Cracking	28 Year	22,567,752.35 ESAL	101 Year	444,175,598.6 ESAL
Rutting	48 Year	60,377,985.03 ESAL	78 Year	181,411,431.9 ESAL
Permanent Deformation	73 Year	161,681,071.5 ESAL	34 Year	30,524,170.78 ESAL

Table 6.2 The Service Life and ESAL Value of Alternative Pavement

Type of Damage	Alternative Pavement Bina Marga 2017			
	Viscoelastic		Liniar Elastic	
Fatigue Cracking	28 Year	22,722,925.08 ESAL	142 Year	1,812,057,330 ESAL
Rutting	40 Year	40,375,700.19 ESAL	34 Year	30,647,089.72 ESAL
Permanent Deformation	35 Year	33,856,927.47 ESAL	36 Year	34,704,817.14 ESAL

2. The Comparison Between The Bina Marga 2017 Method And The Kenpave Program Using A Viscoelastic And Elastic Approach

a. There are significant differences in stress, strain and axle load repetitions for each damage in the analysis of existing and alternative flexible pavements using the Kenpave program for viscoelastic modeling. In the existing pavement, the stress and strain response to permanent deformation damage at a depth of 45.005 cm was 0.00612 kPa, rutting damage to a depth of 29.995 was 0.00622 kPa and fatigue cracking damage at a depth of 29.995 was 0.00625 kPa. The damage will occur at a repetition load of 22,567,752.35 ESAL until fatigue cracking occurs, 60,377,985.03 ESAL until rutting occurs and 161,681,071,5 ESAL until permanent deformation occurs. Meanwhile, alternative pavements found that the stress and strain response to permanent deformation damage at a depth of 45.005 cm was 0.00794 kPa, rutting damage at a depth of 24.495 was 0.00811 kPa and fatigue cracking damage at a depth of 24.495 was 0.00962 kPa. The damage will occur at repetition loads of 22,722,925.08 ESAL until fatigue cracking occurs, 40,375,700.19 ESAL until rutting occurs and 33,856,927.47 ESAL until permanent deformation occurs.

b. Using the Linear Elastic model, in the existing pavement, the stress and strain response to permanent deformation damage at a depth of 45.005 cm was 0.02752 kPa, rutting damage to a depth of 29.995 was 0.02859 kPa and fatigue cracking damage at a depth of 29.995 was 0.02934 kPa. The damage will occur at a repetition load of 444,175,598.6 ESAL until fatigue cracking occurs, 181,411,431.9 ESAL until rutting occurs and 30,524,170.78 ESAL until permanent deformation occurs. Meanwhile, alternative pavements found that the stress and strain response to permanent deformation damage at a depth of 45.005 cm was 0.02692 kPa, rutting damage at a depth of 24.495 was 0.02832 kPa and fatigue cracking damage at a depth of 24.495 was 0.02900 kPa. The damage will occur at repetition loads of 1,812,057,330 ESAL until fatigue cracking occurs, 30,647,089.72 ESAL until rutting occurs and 34,704,817.14 ESAL until permanent deformation occurs.

3. The service life of each pavement using viscoelastic and linear elastic modeling can be seen in Table 6.2 below.

Table 6.3 Service Life of Existing and Alternative Flexible Pavement

Type of Damage	Existing Pavement (Year)		Alternative Pavement Bina Marga 2017 (Year)	
	Viscoelastic	Liniar Elastic	Viscoelastic	Liniar Elastic
Fatigue Cracking	28	101	28	142
Rutting	48	78	40	34
Permanent Deformation	73	34	35	36

4. The differences between the design of flexible pavement using the 2017 Highways and Kenpave methods are as follows.

   a. Concept, these two methods both determine the feasibility of the pavement thickness, but what makes the difference is the concept used. Bina Marga 2017 uses more reference to material characteristics and mechanistic structural analysis because it is considered to be able to evaluate pavement responses related to specific pavement damage modes. Kenpave adheres to an elastic multilayer system with respect to stress, strain, and deflection, which uses several assumptions in calculating the structural response such as the material properties of each layer are considered homogeneous and isotropic.
   b. Input parameters, these two methods almost entirely use different input parameters. In 2017 Bina Marga uses parameters such as average daily traffic (ADT), traffic growth value, CBR value, and CESA4 and CESA5 numbers. While the Kenpave Program uses parameters in the form of

material characteristics such as modulus of elasticity (E), poisson ratio, tire width, distance between tires and creep compliances.

5. There are differences in the thickness of the existing pavement and the thickness of the alternative pavement using the 2017 Highways method which can be seen in Table 6.1 below.

Table 6.4 Thickness of Existing and Alternative Flexible Pavement

LAYER	Existing Pavement (cm)	Bina Marga 2017 Alternative Pavement (cm)
AC-WC	4	4
AC-BC	6	6
AC-BASE	20	14.5
BASE COURSE	15	20.5

6.2 Suggestion

From the results of the analysis that has been done, some suggestions are given as follows.

1. Cases of overloading should be considered. Because in Indonesia there are often cases of overloading which causes the pavement age to almost never match the planned pavement age.
2. The planner still needs to plan the thickness of the pavement using several different methods so that it can provide many safer and more efficient alternatives.
3. It is also necessary to do a comparative calculation based on costs so that it can find out financially which pavement is more efficient and effective.

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APPENDIX

APPENDIX 1 AVERAGE DAILY TRAFFIC VALUE

No	Nama Ruas	Volume Kendaraan Rata-Rata Golongan Kendaraan Binamarga (kend/hari)												Prosentase Kendaraan					Volume Kendaraan (kend/hari)	LHRT (kend/hari)
		1	2	3	4	5A	5B	6A	6B	7A	7B	7C	8	MC	LV	MHV	HV	UM		
1	Sentolo - Klangon	3690	1422	96	448	75	59	147	387	46	0	9	27	57.85%	30.69%	3.47%	7.82%	0.42%	6406	2687