FINAL PROJECT

EVALUATION OF FLEXIBLE PAVEMENT STRUCTURE DESIGN USING MECHANISTIC-EMPIRICAL METHODS WITH BINA MARGA 2017 AND KENPAVE PROGRAM WITH ON THE SENTOLO-NANGGULAN-DEKSO ROAD SECTION STA 3+635 – STA 6+750

Submitted to Universitas Islam Indonesia Yogyakarta to Meet the Requirements for a Sarjana Teknik in Civil Engineering

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FACULTY OF CIVIL ENGINEERING AND PLANNING
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PLAGIARISM STATEMENT

I testify that this Final Project Report, titled EVALUATION OF FLEXIBLE PAVEMENT STRUCTURE DESIGN USING MECHANISTIC-EMPIRICAL METHODS WITH BINA MARGA 2017 AND KENPAVE PROGRAM WITH ON THE SENTOLO-NANGGULAN-DEKSO ROAD SECTION STA 3+635 – STA 6+750, which is submitted as a partial fulfilment to the Sarjana Teknik degree to Civil Engineering Study Program of Universitas Islam Indonesia is my own work. All parts in writing the Final Project Report that I quoted from work of others has been given credit in accordance with the norms, rules, and ethics of scientific writing. If later it is found that all or part of this Final Project Report is not my own work or there is plagiarism in certain parts, I am willing to accept sanctions, in accordance with applicable laws.

Yogyakarta, July 2022

Who make the statement,

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PREFACE

Gratitude for the presence of Allah SWT who has bestowed His grace, knowledge, and guidance, so that the author can complete this Final Project Report as well as possible. This Final Project Report is one of the academic requirements in completing undergraduate studies at the Civil Engineering Study Program, Faculty of Civil Engineering and Planning, Islamic University of Indonesia.

In the preparation of this Final Project Report there were many obstacles faced by the writer, but thanks to suggestions, criticism, and encouragement from various parties, Alhamdulillah this Final Project was resolved. In this connection, the author would like to express his deep gratitude to:

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The author is fully aware that this Final Project Report is far from perfect, because of limited knowledge and experience. Finally, the authors hope that this Final Project Report can provide benefits for compilers and for readers in general.

Yogyakarta, July 2022

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ABSTRACT

Road is the infrastructure used to cross that is very necessary to reach various regions. The Sentolo-Nanggulan-Dekso road section used as a route of the Borobudur National Tourism Strategic Area. In 2021 based on a direct survey, there was an increase in traffic volume of heavy vehicles up to 15.94% of the total volume, where according to traffic data in 2019 only 7.82%.

To improve and develop road performance, a pavement planning and design approach is needed. This research was conducted to determine alternative flexible pavement thickness using Mechanistic – Empiric method with Bina Marga 2017 and Kenpave program to obtain the most suitable alternative pavement.

The existing pavement has total thickness of 50 cm and can accommodates load repetition until damage occur below than life plan which is 20th. Alternative pavement resulted 2 alternatives, alternative 1 has total thickness of 54.5 consisting of AC WC 4 cm, AC BC 6 cm, AC Base 14.5 cm, and Class A foundation 30 cm. Alternative 2 has total thickness of 47.5 cm consisting of AC WC 4 cm, AC BC 6 cm, AC Base 7.5 cm, CTB 15 cm, and class A aggregate foundation of 15 cm thick. With viscoelastic model alternative 1 can accommodate load repetitions of 20,472,951.01 ESAL until rutting, and alternative 2 is 18,559,551.33 ESAL until rutting. With linear elastic model alternative 1 load repetition is 49,261,433.02 ESAL until rutting, and alternative 2 is 24,415,302.83 ESAL until deformation, where both alternatives can accommodate load repetitions up to the design life.

Keyword: Mechanistic Empiric, Bina Marga 2017, KENPAVE

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AADT	=	Annual Average Daily Traffic
AASHTO	=	American Association of State highway and Transportation Officials
AC BC	=	Asphalt Concrete Binder Coarse
AC WC	=	Asphalt Concrete Wearing Course
ADT	=	Annual Daily Traffic
CBR	=	California Bearing Ratio
CESA	=	Cumulative Equivalent Standard Axle
CP	=	Contact Pressure on Circular Loaded Area
CR	=	Contact Radius on Circular Loaded Area
CTB	=	Cement Treated Base
DCP	=	Dynamic Cone Penetration
DD	=	Direction Distribution
DL	=	Lane Distribution
ESA	=	Equivalent Standard Axle
ESAL	=	Equivalent Standard Axle Load
i	=	Traffic Growth Rate
LPA	=	Top Foundation Layer
Nd	=	Load repetition until permanent deformation occurs
Nf	=	Load repetition until fatigue cracking occurs
Nr	=	Load repetition until rutting occurs
R	=	Multiply Factor of Traffic Growth Rate
SL	=	Service Life
VDF	=	Vehicle Damage Factor
XW	=	Center to center spacing between two axles along the X axis
σ	=	Stress
τ	=	Shear Stress
μ	=	Poisson’s Ratio
ɵ	=	Number of primary stress
ε	=	Strain

CHAPTER 1
INTRODUCTION

1.1 Background

Road is the infrastructure used by the community to cross, either by using a vehicle or by other means. Roads are infrastructure intended for land transportation, including sections of roads, various buildings, and equipment for traffic, above ground and below ground and or water, except for railways, lorries, and cable roads. The existence of roads is very necessary to support the rate of economic growth in line with the increasing need for transportation facilities that can reach various regions.

The Sentolo - Nanggulan - Dekso road section is a provincial road and functions as a primary collector road for 26.5 km. This road section is used as a route of the Borobudur National Tourism Strategic Area or in Indonesian called as *Kawasan Strategis Nasional Borobudur* (KSPN Borobudur), where this area is a super priority in Indonesia. On the other hand, with the construction of Yogyakarta International Airport (YIA) in Kulon Progo Regency, connectivity is needed from YIA to KSPN Borobudur, However, the Sentolo - Nanggulan - Dekso road section has a road width of less than 7 meters that is 5 meters wide, where the existing width does not meet the minimum standard for provincial roads that function as primary collector roads. Therefore, the Ministry of Public Works and Housing, abbreviated Kemen PUPR is carrying out the work of widening the Sentolo - Nanggulan - Dekso - Klangon road in Kulon Progo Regency.

With the use of the Sentolo - Nanggulan - Dekso road section as the route for the Borobudur National Tourism Area which connects the Yogyakarta region with the Borobudur area, especially from Yogyakarta International Airport (YIA), it is likely that this road will be busier with vehicles than before, (Satker PPJN Provinsi DIY/PPK DIY, 2019) stated that the average volume of heavy vehicles for group 5B is 59 vehicles/day, 6B is 387 vehicles/day, 7A is 46 vehicles/day, and 7C is 9 vehicles/day where the percentage of heavy vehicles is 7.82% of the total average vehicle average volume in 2019. In 2022 based on a direct survey, there was an increase in the volume of heavy vehicles up to 15.94% of the total volume of vehicles in 2021, with 5B group of 225 vehicles/day, 6B of 391 vehicles/day, 7A of 139 vehicles/day, and 7C of 20 vehicles/day. This shows that there is an increase in traffic activity by heavy vehicles passing through these roads and with existing road pavement consisting of AC - WC 40 mm, AC - Base 60 mm, and Class A foundation 400 mm, it must be supported by a good road structure design according to standards. Therefore, periodic evaluation of road conditions is required to determine the type of road maintenance.

Road pavement consists of two types, namely flexible pavement, and rigid pavement. In Indonesia, especially the Sentolo - Nanggulan - Dekso road section uses flexible pavement but is then combined with rigid pavement.

To improve and develop road performance for the implementation of road construction activities to ensure the quality of the pavement, a pavement planning and design approach is needed. This research was conducted to add alternatives to the flexible pavement thickness on the Sentolo - Nanggulan - Dekso road. Calculation of pavement thickness using Mechanistic – Empirical Method by using the Bina Marga 2017 analysis method and Kenpave program to obtain the alternatives thickness of the pavement structure that can be recommended the most suitable to be applied to the Sentolo - Nanggulan - Dekso road section.

1.2 Research Questions

Based on explanation on the background, it can be describing the main problems as follows.

1. How does the existing pavement structure perform in the face of current traffic?
2. How thick is the alternative pavement layer for the Sentolo - Nanggulan - Dekso road if calculated using the 2017 Bina Marga method and KENPAVE program?
3. What are the stress and strain responses that occur in the existing and alternative pavements?

4. What is the service life available from the Sentolo – Nanggulan – Dekso road by using the 2017 Bina Marga method and KENPAVE program?

1.3 Objectives

The objectives of this study are as follows.

1. Investigate the performance of the existing pavement on the Sentolo - Nanggulan - Dekso road section such as the stress strain responses and service life prediction.
2. Calculate the thickness of the pavement layer on the Sentolo - Nanggulan - Dekso road segment if calculated using the 2017 Bina Marga method and KENPAVE program.
3. Investigate the stress and strain responses that occurs in the existing and alternative pavements.
4. Investigate the prediction of service life available from the Sentolo – Nanggulan – Dekso road by using the 2017 Bina Marga method and KENPAVE program.

1.4 Research Benefits

The research benefits are as follows.

1. Result of this research are expected to be used as input for consideration to relate agencies, especially the Satuan Kerja Pelaksanan Jalan Nasional Wilayah Provinsi DIY and Balai Besar Pelaksanaan Jalan Nasional VII Direktorat Jenderal Bina Marga as the manager of national and provincial road maintenance in formulating techniques and patterns for handling maintenance activities of the Sentolo - Nanggulan - Dekso road sections.
2. Result of this research are expected to be used as alternative approach to determine the load repetitions that can be accommodated until damage occurs and can be used to determine service life predictions until damage occurs.

1.5 Research Limitation

Research limitations that will be discussed based on the problems are as follows.

1. The research object is the Sentolo - Nanggulan - Dekso road section STA 3+635 – STA 6+750 .
2. The calculation of the flexible pavement thickness uses the 2017 Bina Marga method.
3. The calculation of stress and strain that occurs due to traffic loads on it is carried out with the KENPAVE program.
4. Engineering properties of pavement materials such as modulus of elasticity, Poisson ratio, and others are determined form Bina Marga 2017 Book and Pavement Design and Analysis Book by Huang.
5. The data used in the analysis used primary data and secondary data obtained from PPK 1.1 DIY and BBPJN VII in 2018 -2020 and direct survey in 2021.

CHAPTER 2
LITERATURE REVIEW

2.1 Evaluation of Flexible Pavement Thickness Using the Bina Marga 2017 Method

Sumarsono & Gultom (2018) has conducted research on 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 analyse the thickness of the pavement which will later 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 figure 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.

Mahmudin (2019) examined the comparative analysis of flexible pavement thickness planning and the Structural Number (SN) with the Bina Marga 1993, Bina Marga 2013, Bina Marga 2017 methods, and AASHTO 1993 by using KENPAVE program. The purpose of this study was to determine the comparison of the pavement thickness of road and the structural number with the Bina Marga 1993, Bina Marga 2013, Bina Marga 2017 methods, and AASHTO 1993 by using KENPAVE program. Analysis of the thickness of the flexible pavement plan using the KENPAVE program obtained a minimum extreme thickness of 5 cm for Bina Marga 1987 and AASHTO 1993. Meanwhile, for analysis using the Bina Marga 2013 and 2017 Bina Marga methods, the minimum extreme thickness is 7 cm. The comparison between manual analysis and KENPAVE analysis shows that the results of the analysis of the Structural Number (SN) thickness of the flexible pavement layer are not too far apart. In manual calculations and KENPAVE using the Bina Marga 1987 method, a large difference is produced, namely 15.04, while the Bina Marga 2013 and Bina Marga 2017 methods are small, namely 1.05. For AASHTO 1993 the difference in SN values was 2.05. The results of the largest SN value are those obtained from the analysis using the Bina Marga 1987 method.

Mantiri et al. (2019) examined the comparison of the analysis of flexible pavement thickness planning using the AASHTO 1993 and Bina Marga 2017 methods on new roads in the Manado area. The purpose of this study is to compare the flexible pavement thickness using the AASHTO 1993 and Bina Marga 2017 methods and to analyse the sensitivity of the new flexible pavement thickness using the traffic load value and the CBR subgrade value. The results obtained are that the difference in pavement thickness with the AASHTO 1993 method obtained a greater value of pavement thickness for the upper foundation layer (Granular Treated Base), namely the CBR variation and the vehicle axle load obtained 44 cm - 62.5 cm. Meanwhile, if using the 2017 Bina Marga method, the results are 44 cm - 51.5 cm. For the top layer of foundation (Cement Treated Base) with CBR variations using the AASHTO 1993 method, the thickness ranges from 45.5 to 51.5 cm and for the 2017 Bina Marga method the same pavement thickness results for all CBR variations of 47.5 cm.

2.2 Evaluation of Flexible Pavement Thickness Using the KENPAVE program

Rind et al. (2017) examined the analysis and design of flexible pavements using empirical mechanistic based on the KENPAVE software. The purpose of this study is to reduce the level of failure risk in designing flexible pavements using the mechanistic-empirical method based on the KENPAVE program. The various possible cross-sections that can be used in Pakistan for usage courses and basic courses are considered by varying the thicknesses of + 25% and -25%. By doing this a total of 10 cross-sections will be analysed. These 10 cross sections are analysed for the number of allowable load repetitions in terms of rutting (Nr) and fatigue (N_f) depending on maximum ESAL permitted on the N-55 road. The results showed that most of the failure-resistant pavement sections in terms of pavement were allowed. The number of repetitions of the load to prevent rutting damage (Nr) and fatigue (N_f) was crossection-5 and crossection-10 construction of section 5 and section 10 which are designed almost the same. However, the cross-section-10 is economical in terms of design life and failure to hold properties.

2.3 Comparison Between Bina Marga 2017 and KENPAVE Program

Based on Widiastuti (2018) research, Analysis of the planning calculation of flexible pavement thickness using the 2017 Bina Marga method and the mechanistic-empirical method with the KENPAVE Program obtained several comparisons as follows.

1. Comparison in terms of design concepts

   The pavement design in the Bina Marga 2017 method is more referring to material characteristics and mechanistic structural analysis because it can evaluate the pavement response related to the specific pavement damage mode. While KENPAVE adheres to an elastic multi-layer system with respect to stress, strain, and deflection, namely using several assumptions in calculating the structural response, such as the material properties of each layer considered homogeneous and isotropic.

2. Comparison in terms of design parameters

   a. For Bina Marga 2017 traffic conditions, it takes CESA into account as the cumulative amount of axle load considering the VDF value, while KENPAVE considers ESA as the cumulative amount of axle load by considering tires, contact area, tire area, distance between tires, and distance between axles.

   b. For Bina Marga 2017 the parameters for each layer use CBR immersion or subgrade, while for the surface layer and top foundation based on the cumulative amount of design traffic axis loads in each lane and type of soil, while KENPAVE uses elastic modulus and different Poisson's Ratio values for each layer. However, there is a parameter of creep compliances on the viscoelastic surface layer

c. For Bina Marga 2017, the pavement thickness uses the CESA5 number, while KENPAVE is assumed first with the output stress and strain values.

To simplify the explanation above, the comparison of the two methods can be seen in table 2.1 below.

Table 2.1 Comparison between Bina Marga 2017 and KENPAVE

Comparison	Bina Marga 2017 Method	Mechanistic Empiric Method using KENPAVE
Design Concept	More referring to material characteristics and mechanistic structural analysis because it can evaluate the pavement response related to the specific pavement damage mode.	Adheres to an elastic multi-layer system with respect to stress, strain, and deflection, namely using several assumptions in calculating the structural response, such as the material properties of each layer considered homogeneous and isotropic.
Design Parameters	a. Takes CESA into account as the cumulative amount of axle load considering the VDF value. b. The parameters for each layer use CBR immersion or subgrade, while for the surface layer and top foundation based on the cumulative amount of design traffic axis loads in each lane and type of soil	a. Considers ESA as the cumulative amount of axle load by considering tires, contact area, tire area, distance between tires, and distance between axles. b. Uses elastic modulus and different Poisson's Ratio values for each layer. However, there is a parameter of creep compliances on the viscoelastic surface layer

Source: Widiastuti (2018)

2.4 Research Comparison

From the collections of previous studies that have been described, when compared with the research to be carried out, there are some similarities and some differences. The summary of previous research can be seen in Table 2.2.

Table 2.2 Previous Research

Author (Year)	Sumarsono and Gultom (2018)	Mahmudin (2019)	Mantiri, Sendow, and Manoppo (2019)	Rind, Memon, and Qureshi (2017)
Title	Comparison of Pavement Analysis Method Revised June 2017 and AASHTO 1993 (Case Study on Preservation Plan Work for the Jatibarang-Langut Road FY 2017)	Evaluation of Flexible Pavement Thickness by Using Empiric and Mechanistic-Empiric Methods by Using KENPAVE Program	Analysis of New Road Flexible Pavement Thickness with Bina Marga 2017 Compared to AASHTO 1993 Method	Analysis and Design of Flexible Pavement Using Empirical-Mechanistic Based Software (KENPAVE)
Research Methods	Bina Marga 2017 and AASHTO 1993	Bina Marga 1987, Bina Marga 2013, Bina Marga 2017, AASHTO 1993, and Kenpave	Bina Marga 2017 and AASHTO 1993	Empirical Mechanistic Base Kenpave Program
Location	Jatibarang-Langut Road	East Imogiri Road, Bantul, Special Region of Yogyakarta	Manado National Road	Jamshoro to Sehwan Road Section
Result	Pavement thickness using the 1993 AASHTO Method and the 2017 Bina Marga method obtained a significantly	Calculation of the empirical mechanistic method using Kenpave obtained a minimum extreme thickness of 5 cm. The	The thickness for the upper foundation layer (Granular Treated Base), by using AASHTO 1993 obtained	The optimal cross section that satisfies the failure resistance condition is section number 10, so the section that is permitted

Continuation of Table 2.2 Previous Research

Result	different CESA number, namely 151,479,002 for the 2017 Bina Marga and 53,641,295.	calculation of the Bina Marga 2013 and 2017 methods obtained a minimum extreme thickness of 7 cm. The results of the comparison of SN using Bina Marga 2013 and 2017 methods have a difference of 1,05. AASHTO 1993 has a difference in SN value of 2,05 while Kenpave with Bina Marga 1987 is 15,04.	44 cm - 62.5 cm, while using Bina Marga 2017 obtained 44 cm - 51.5 cm. For the top layer of foundation (CTB) by using AASHTO obtained 45.5 – 51.5 cm, while Bina Marga 2017 obtained 47.5 cm.	to be built on NHA roads is section number 10. With 3.75 cm of AC Wearing Course, 24,05 cm AC Base Course, 30 cm of Aggregate Base Course, 30 cm fill material, and Sub grade.

Source: Mahmudin (2019); Mantiri et al. (2019); Rind et al. (2017); Sumarsono & Gultom (2018)

From Table 2.2 above, it can be concluded that the similarities and differences between this study and previous research are as follows.

1. The similarity with researchers Sumarsono & Gultom (2018) is that this study analyses pavement using the 2017 Bina Marga method. However, the difference in this study compares the 2017 Bina Marga method with the 1993 AASHTO method by focusing on the causes of road pavement damage and does not evaluate the analysis of alternative pavement designs. service life, and analysis using empirical mechanistic methods with Kenpave program.
2. The similarity of Mahmudin (2019) is to plan the thickness of flexible pavement using the 2017 Bina Marga method and the Kenpave program. The difference from this research is that Mahmudin (2019) uses the 1987 Bina Marga, 2013 Bina Marga, and 1993 AASHTO methods as well as by analysing the Structural Number but does not analyse the condition of the existing flexible pavement.
3. The similarity of the Mantiri et al. (2019) is to analyse flexible pavement using the 2017 Bina Marga method. The difference from this study is that it only analyses flexible pavement for new roads using the 2017 Bina Marga and 1993 AASHTO methods in various variations of CBR so there are no analysis existing road conditions, remaining service life, stress and strain response, and the use of empirical mechanistic methods using the Kenpave program.
4. The research equation from Rind et al. (2017) is to analyse flexible pavement using empirical mechanistic methods with the Kenpave program. The difference from this research is that it only focuses on using empirical mechanistic methods with the Kenpave program and the accuracy in planning a flexible pavement.

CHAPTER 3
THEORETICAL BACKGROUND

3.1 Flexible Pavement

Flexible pavements are constructed of bituminous and granular materials Huang (2004). In general, flexible pavements are used for roads that serve light to moderate traffic loads, such as urban roads, roads with a utilization system located under road pavements, road clothing pavements, or pavements with gradual construction (Sukirman,1999).

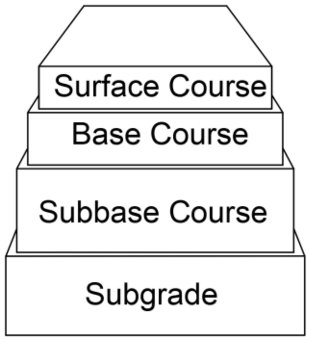


Figure 3.1 Flexible Pavement Layer

Flexible pavement construction generally has several layers, namely as follows.

3.1.1 Surface Layer

In general, 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. Binder course, is the surface layer that lies below the wear layer and above the foundation layer.

The surface layer has several functions as follows.

1. Wheel load bearing pavement layer, the layer has high stability to withstand wheel loads during the service life.
2. The layer is waterproof, so that rainwater that falls on it does not seep into the layer below and weakens the layers.
3. Wearing course, a layer that directly receives friction due to vehicle brakes so that it is easy to wear out.
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.

3.1.2 Base Course

The base course layer is the pavement layer that is located between the subbase layer and the surface layer. This top foundation layer serves as:

1. pavement that resists the transverse forces of wheel loads and transmits the load to the layers beneath.
2. Bearing against the surface layer.

3.1.3 Subbase Course

The subbase course is the part of the pavement located between the subgrade and the top pavement. Thus the subbase course is the foundation that supports the top pavement and surface layer. The function of the subbase course is as follows.

1. Part of the pavement construction to spread wheel loads to the subgrade.
2. Infiltration layer so that groundwater does not collect in the foundation.
3. As the first layer so that the work can run smoothly. This is related to field conditions that force the subgrade to be immediately covered from the effects of the weather, or the weak bearing capacity of the subgrade to withstand the wheels of large equipment.

The types of subbase courses, both upper and lower subbase courses, are as follows.

1. Aggregate Foundation

   There are three types of aggregate foundation layers, namely class A, class B, and class C. Class A aggregate foundation layer is the top foundation layer located under the asphalt layer, class B is for the subbase layer, while class S is used for the shoulder of the road without a cover.

2. Cement Treated Base (CTB)

   Cement Treated Base (CTB) is a material for the foundation layer on flexible pavement. CTB utilizes Portland cement as a binding material. CTB itself is a concrete mixture with a slump soma value of zero or can be said to be semi-dry concrete. CTBs offer significant savings over grain foundation paving for roads in medium and heavy traffic.

3.1.4 Subgrade

Subgrade is a very important part of road construction, which supports the subbase course, base course, and surface course or supports the road pavement. The subgrade can be in the form of native soil compacted if the original soil is not good, soil imported from elsewhere and compacted, or soil stabilized with lime or other materials. Good compaction is obtained if it is carried out at the optimum moisture content and the moisture content is kept constant throughout the design life. This can be achieved with adequate drainage equipment. Subgrades can be distinguished as excavated soil subgrade, embankment subgrade, native soil subgrade.

3.2 Pavement Design using the 2017 Bina Marga Method

In planning pavement thickness, several indicators and data are needed to analyse pavement thickness. The following is an explanation of the pavement thickness design using the 2017 Bina Marga method.

3.2.1 Life Plan

In planning the thickness of the pavement layer, it is necessary to have a planned age of the road that can still be used. The design life is the number of times in years calculated from the time the road is opened until heavy repairs or a new surface coating are required. The age of the new pavement plan can be seen in Table 3.1 below.

Table 3.1 Life Plan of New Pavement

Pavement Type	Pavement Element	Life Plan (Year)
Flexible Pavement	Asphalt layer and grained layer	20
	Road foundation	40
	All types of pavements for overlay areas where overlay is not possible, such as: Urban roads, underpasses, bridges, tunnels	
	Cement Treated Based (CTB)	
Rigid Pavement	Upper foundation layer, lower foundation layer, cement concrete layer, and road foundation layer	
Road without cover	All elements (include road foundation)	Minimum 10

Source: Bina Marga (2017)

3.2.2 Traffic

In designing a flexible pavement layer thickness, the following data are required.

1. Traffic data such as traffic volume, average daily traffic (LHRT), vehicle type.
2. Traffic growth factors, based on historical growth data or correlation formulations with other valid growth factors, if none exist then Table 3.2 is used as the minimum value.

Table 3.2 Traffic Growth Rate Factor (i) (%)

	Java	Sumatera	Kalimantan	Average Indonesia
Artery and Urban	4,8	4,83	5,14	4,75
Rural Collectoral	3,5	3,50	3,50	3,50
Village Road	1,00	1,00	1,00	1,00

Source: Bina Marga (2017)

Traffic growth during the design life is calculated using Cumulative Growth Factor as the following Equation 3.1.

$$R = \frac{(1+0{,}01\ i)^{UR}-1}{0{,}01\ i} \tag{3.1}$$

Where:

R	=	Multiplier of cumulative traffic growth
i	=	Annual traffic growth rate (%)
UR	=	Life plan (years)

3. Traffic lanes on planned lanes, for two-way roads, the directional distribution factor (DD) is generally taken as 0.50 except for locations where the number of vehicles is available commerce tends higher in one direction. Whereas lane distribution is used to adjust the cumulative load (ESA) on roads with two or more steps in one direction. The lane distribution factor can be seen in Table 3.3 below.

Table 3.3 Lane Distribution Factor (DL)

The number of lanes per direction	Commercial vehicles in design lane (% of commercial vehicle population)
1	100
2	80
3	60
4	50

Source: Bina Marga (2017)

4. Vehicle Damage Factor, Traffic load is converted to standard load (ESA) by using Vehicle Damage Factor. Accurate design requires an accurate calculation of traffic loads as well and if axle load surveys are not possible for planners and prior survey data is not available then the VDF values in Tables 3.4 and 3.5 below can be used to calculate ESA.
5. Equivalent factor of load, standard axis load and standard axis load cumulative. Cumulative standard axis load or Cumulative Equivalent Single Axle Load (CESA) is the cumulative amount of axle load of traffic design in the design

strip during the design life, which is determined by Equations (3.2) and (3.3) below.

$$ESA = \Sigma_{vehicle\ type\ AADT} \times VDF \tag{3.2}$$

$$CESA = ESA \times 365 \times DD \times DL \times R \tag{3.3}$$

Where:

ESA	=	Equivalent Standard Axle
AADT	=	Annual Average Daily Traffic for certain type of vehicle
CESA	=	Cumulative Equivalent Standard Axle for certain life plan
DD	=	Direction Distribution factor
DL	=	Lane Distribution factor
R	=	Multiplier of cumulative traffic growth

6. Estimated axle loads for low-traffic areas can be referred to Table 3.6 below,

Table 3.4 Vehicle Damage Factor

Vehicle Type	Sumatera				Jawa				Kalimantan				Sulawesi				Bali. Nusa Tenggara. Maluku dan Papua			
	Actual Load		Normal		Actual Load		Normal		Actual Load		Normal		Actual Load		Normal		Actual Load		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	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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	5.1	4.8	8.5	3.4	4.7	4.9	9	2.9	4	3	4	2.5	3
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	4.3	5.6	10.2	19	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
7B1	-	-	-	-	11.8	18.2	9.4	13	-	-	-	-	-	-	-	-	-	-	-	-
7B2	-	-	-	-	13.7	21.8	12.6	17.8	-	-	-	-	-	-	-	-	-	-	-	-
7C1	15.9	29.5	7	9.6	11	19.8	7.4	9.7	11.7	20.4	7	10.2	13.2	25.5	6.5	8.8	8	11.9	6.5	8.8
7C2A	19.8	39	6.1	8.1	17.7	33	7.6	10.2	8.2	14.7	4	5.2	20.2	42	6.6	8.5	-	-	-	-
7C2B	20.7	42.8	6.1	8	13.4	24.2	6.5	8.5	-	-	-	-	17	28.8	9.3	13.5	-	-	-	-
7C3	24.5	51.7	6.4	8	18.1	34.4	6.1	7.7	13.5	22.9	9.8	15	28.7	59.6	6.9	8.8	-	-	-	-

Source: Bina Marga (2017)

Table 3.5 VDF value of each type of commercial vehicle based on the type of vehicle and cargo

	Vehicle Type		Description	Axis Configuration	Cargo being transported	Axis Group	Typical Distribution (%)		Load Equivalent Factor (VDF) (ESA / vehicle)	
	Previous Classification	Alternative					All motorized vehicles	All motorized vehicles except motorbikes	VDF4 Power of 4	VDF5 Power of 5
	1	1	Motorcycle	1.1		2	30,4			
	2, 3 ,4	2, 3, 4	Sedan / Angkot / Pickup / Station wagon	1.1		2	51,7	74,3		
Commercial Vehicle	5a	5a	Small bus	1.2		2	3,5	5,00	0,3	0,2
	5b	5b	Big bus	1.2		2	0,1	0,20	1,0	1,0
	6a.1	6.1	2 axle truck - light cargo	1.1	general payload	2	4,6	6,60	0,3	0,2
	6a.2	6.2	2-axle truck - light	1.2	soil, sand, iron, cement	2			0,8	0,8
	6b1.1	7.1	2 axis truck - medium cargo	1.2	general payload	2	-	-	0,7	0,7
	6b1.2	7.2	2-axle truck - medium	1.2	soil, sand, iron, cement	2			1,6	1,7
	6b2.1	8.1	2 axle truck - heavy	1.2	general payload	2	3,8	5,50	0,9	0,8
	6b2.2	8.2	2 axle truck - heavy	1.2	soil, sand, iron, cement	2			7,3	11,2
	7a1	9.1	3 axle truck - light	1.22	general payload	2	3,9	5,60	7,6	11,2
	7a2	9.2	3-axle truck - medium	11.2	soil, sand, iron, cement	2			28,1	64,4
	7a3	9.3	3 axle truck - heavy	1.222		2	0,1	0,10	28,9	62,2
	7b	10	2 axle truck and trailer 2 axis puller	1.2-2.2		4	0,5	0,70	36,9	90,4
	7c1	11	4 axle truck - trailer	1.2-22		3	0,3	0,50	13,6	24,0
	7c2.1	12	5 axle truck - trailer	1.2-22		3	0,7	1,00	19,0	33,2
	7c2.2	13	5 axle truck - trailer	1.2-222		3			30,3	69,7
	7c3	14	6 axle truck - trailer	1.22-222		3	0,3	0,50	41,6	93,7

Source: Bina Marga (2017)

Table 3.6 Traffic Estimates for Low Traffic Roads

Road Type	2-direction ADT (veh/day)	Heavy Vehicle (% from traffic)	Life Plan (years)	Traffic Growth (%)	Traffic Cumulative Growth Multiplier	Axis Groups / Heavy Vehicles	Cumulative HVAG (axis group)	ESA / HVAG factor	Design Traffic Load (actual) (ESA4)
Minor village roads with limited heavy vehicle access	30	3	20	1	22	2	14.454	3,16	$4{,}5 \times 10^4$
Two-way road	90	3	20	1	22	2	21.691	3,16	7×10^4
Local road	500	6	20	1	22	2,1	252.945	3,16	8×10^5
Access local industrial areas or query	500	8	20	3,5	28,2	2,3	473.478	3,16	$1{,}5 \times 10^6$
Collector road	2000	7	20	3,5	28,2	2,2	1.585.122	3,16	5×10^6

Source: Bina Marga (2017)

3.2.3 Selection of Pavement Structure

The choice of pavement type will vary according to traffic estimates, design age, and road foundation conditions. Selection of pavement types can be seen in Table 3.7 below.

Table 3.7 Selection of Pavement Type

Pavement Structure	Chart Design	ESA (million) in 20 years (Power of 4 unless otherwise specified)				
		0 – 0,5	0,1 - 4	>4 - 10	>10 - 30	>30 - 200
Rigid pavement with heavy traffic (above ground with CBR ≥2.5%)	4	-	-	2	2	2
Rigid pavement with low traffic (rural and urban areas)	4A	-	1,2	-	-	-
AC WC modification or modified SMA with CTB (ESA power of 5)	3	-	-	-	2	2
AC with CTB (ESA power of 5)	3	-	-	-	2	2
AC ≥ 100 mm thick with a grained foundation layer (ESA power of 5)	3B	-	1,2	1,2	2	2
AC or HRS thin over grained foundation layer (ESA power of 5)	3A	-	1,2	-	-	-
Burda or Burtu with LFA Class A or natural rock	5	3	3	-	-	-
Soil Cement Foundation Layers	6	1	1	-	-	-
AC or HRS thin over grained foundation layer (ESA power of 5)	3A	-	1,2	-	-	-

Source: Bina Marga (2017)

3.2.4 Road Foundation Design

Determination of the accurate subgrade strength values and foundation design proper is a major requirement for obtaining a pavement design good. The three most important factors in pavement design are traffic, subgrade, and influence of water. If soil research can be carried out, then the steps to determine the CBR of subgrade design are as follows.

1. Determination of uniform subgrade segments

Roads that are designed must be grouped based on the similarity of the segment they are designed to represents subgrade conditions which can be considered uniform (without distinction significant). The initial grouping can be done based on the results of table studies and field investigations on the basis of similarities in geology, paedology, drainage conditions and topography, as well as geotechnical characteristics (such as gradation and plasticity). To calculate CBR characteristics are described as follows.

a. The percentile method

The calculation procedure for the 10th percentile is as follows.

1) Arrange the CBR data in order from the smallest to the largest value.
2) Calculate the total number of CBR value data (n).
3) Calculate 10% of (n), the value obtained is called an index.
4) If the index obtained from step (3) is a fraction, proceed round to the nearest number and proceed to step (5). If that index resulting in an integer, go to step (6).
5) From the sorted data set (step 1), count starting from the smallest data until you reach the sequential data obtained from (step 3). The CBR value of the sequence this is the 10th percentile CBR value.
6) From the sorted data set (step 1), count starting from the smallest data until reaching the sequential data obtained from (step 3). The
7) 10th percentile CBR value is the average value of the two CBR values, namely the CBR in that sequence and the next sequence.

The minimum road foundation design can be seen in the Table 3.8 below.

Table 3.8 Minimum Road Foundation Design

Subgrade CBR (%)	Subgrade Strength Class	Description of the Foundation Structure	Flexible pavement			Rigid Pavement
			Traffic load on the planned lane with a design life of 40 years (ESA5)			Cement Stabilization
			< 2	2 - 4	> 4	
			Minimum thickness of subgrade improvement			
≥ 6	SG6	Subgrade improvement can be in the form of cement or optional embankment material (according to the requirements of General Specification, 3rd Division - Earthwork) (compaction layer ≥ 200 mm loose thickness)	No repairs are needed			150 mm stabilization over 150 mm of selected pile
5	SG5		-	-	100	
4	SG4		100	150	200	
3	SG3		150	200	300	
2,5	SG2.5		175	250	350	
Expansive soil (potential for expansion> 5%)			400	500	600	The same provisions apply to flexible pavement foundations
Pavement on soft soil	SG1	Support layer	1000	1100	1200	
		-or- support layer and geogrid	650	750	850	
Peat soils with HRS or DBST for pavement for motorways (minimum value - other provisions apply)		Grained support layer	1000	1250	1500	

Source: Bina Marga (2017)

3.2.5 Pavement Thickness Design

Calculation of pavement thickness for flexible pavement is calculated based on the CESAL value of the design age then the thickness of the pavement structure uses Design Chart 3 and Design Chart 4 at Bina Marga 2017. The following are the following is a pavement thickness design chart table that can be used based on Bina Marga 2017 that can be seen in Table 3.9, Table 3.10, and Table 3.11 below.

Table 3.9 Design Chart-3. Design of Flexible Pavement Design Minimum Cost Option with CTB

	F1[2]	F2	F3	F4	F4
	For traffic under 10 million ESA5 see Design Charts-3A, 3B,	See Design Chart-4 for alternatives to rigid pavement			
20 years cumulative axis load reps in the plan lane (10^6	> 10 - 30	> 30 - 50	> 50 - 100	> 100 - 200	> 200 - 500
Bonded surface type	AC	AC			
Type of foundation layer	Cement Treated Base (CTB)				
AC WC	40	40	40	50	50
AC BC[4]	60	60	60	60	60
AC BC or AC Base	75	100	125	160	220
CTB[3]	150	150	150	150	150
Class A Aggregate Foundation	150	150	150	150	150

Source: Bina Marga (2017)

Table 3.10 Design Chart-3B. Design of Flexible-Asphalt Pavement with Grained Foundation Layers

	FFF1	FFF2	FFF3	FFF4	FFF5	FFF6	FFF7	FFF8
Choosen Solution				See note 2				
Cumulative 20 year axle load in the plan lane (10^5 ESA 5)	< 2	≥ 2 - 7	> 7 - 10	> 10 - 20	> 20 - 30	> 30 - 50	> 50 - 100	> 100 - 200
PAVEMENT LAYER THICKNESS (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 A-class	400	300	300	300	300	300	300	300
Note	1	2		3				

Source: Bina Marga (2017)

Table 3.11 Design Chart-4A Rigid Pavement for Roads with Low Traffic Loads

	Soft Soil with Support Layers		Compacted normally	
Tied shoulder	Yes	No	Yes	No
	Concrete Plate Thickness (mm)			
Access is limited to passenger cars and motorbikes	160	175	135	150
Accessible by truck	180	200	160	175
Crack distribution reinforcement	Yes		Yes, if the bearing capacity of the foundation is not uniform	
Dowel	Not needed			
LMC	Not needed			
Class A Foundation (maximum nominal grain size of 30 mm)	125 mm			
Transverse joint distance	4 m			

Source: Bina Marga (2017)

The 2017 Highways Method Design Procedure for details can be seen in the Figure 3.2 below.

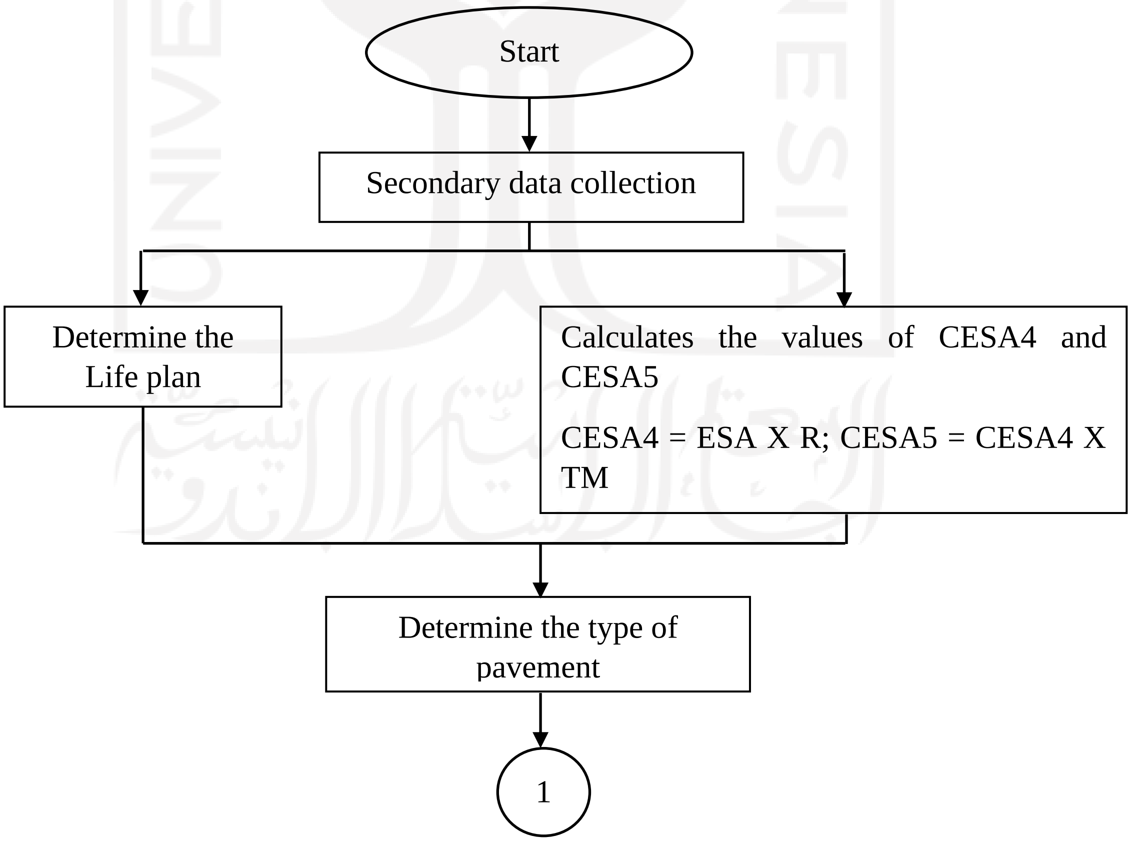


Figure 3.2 Bina Marga 2017 Pavement Design

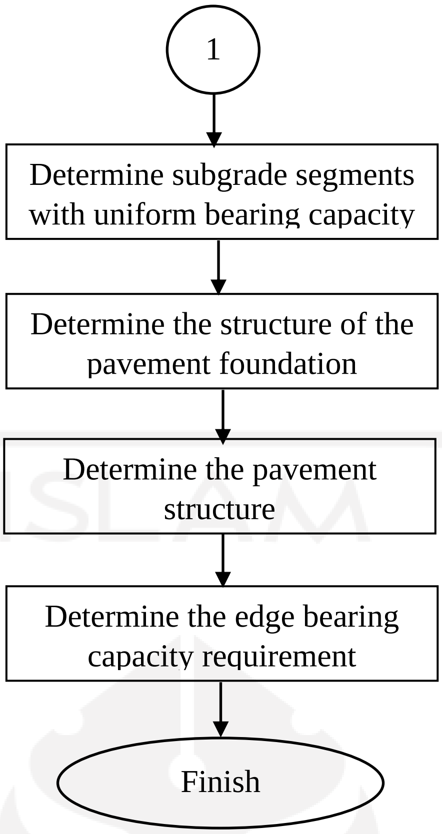


Figure 3.3 Continuation of Bina Marga 2017 Pavement Design

3.3 Pavement Design with Mechanistic-Empirical Method

This method is a method based on the principles of road pavement planning developed from a combination of mechanistic and empirical methods. Based on Huang, (2004) The empirical mechanistic design method is based on material mechanics dealing with wheel load, pavement response, such as stress and strain. The response values are used to predict distress from laboratory-test and field-performance data. The mechanistic-empirical method for pavement design requires two calculation stages, namely as follows.

1. Calculating the pavement response in the form of compressive stress, stress strain, and deflection of each layer using a mechanistic analysis method based on the principles of elastic theory.
2. Predict the performance of the structural condition and function of the pavement in the future. Performance indicators for flexible pavement include fatigue cracking and rutting. The function of performance for all types of pavements is time dependent in relation to the era in predicting the IRI (International Roughness Index) climate to be the main determining factor.

The advantages in using the mechanistic-empirical pavement design method compared to other methods are as follows.

1. Can be used for the reconstruction of existing pavements and construction of new pavements.
2. Can accommodate changes in traffic load types.
3. Material characteristics can be adjusted according to the material to be used, both local and new materials.
4. Accommodating the environmental effects of the pavement material.

Another advantage of the mechanistic-empirical approach is its ability to accurately describe the characteristics of the in-situ material including subgrade and pavement structure. This is usually done by using a portable device such as a FWD to measure the actual field deflection of the existing pavement structure or what is called a back calculation and the estimated remaining life of the pavement. This allows for a more realistic design for natural conditions.

3.3.2 Stress and Strain in Flexible Pavement

1. Multilayer Elastic System

Multilayer Elastic System is one solution in the analysis of the mechanistic method. In this multilayer structure system, it is related to stress, strain, and deflection which is the response of the pavement to the vehicle wheel load that passes on it.

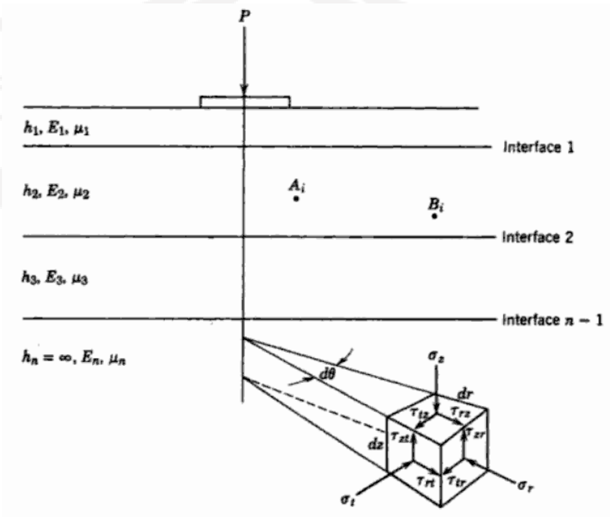


Figure 3.4 Multi Layered Elastic System
(**Source:** Yoder, E.J. & Witczak 1975)

In a multi-layered elastic system, using several assumptions in calculating the response of the structure as mentioned above, among others.

a. The material properties of each pavement layer are considered homogeneous.
b. Each layer has a thickness limit.
c. Each layer is considered isotopic, that is, the properties of the material at a certain point.
d. The friction that occurs between layers is at the interface.
e. The material properties are represented by two structural parameters, namely the resilient modulus and the Poisson's ratio.

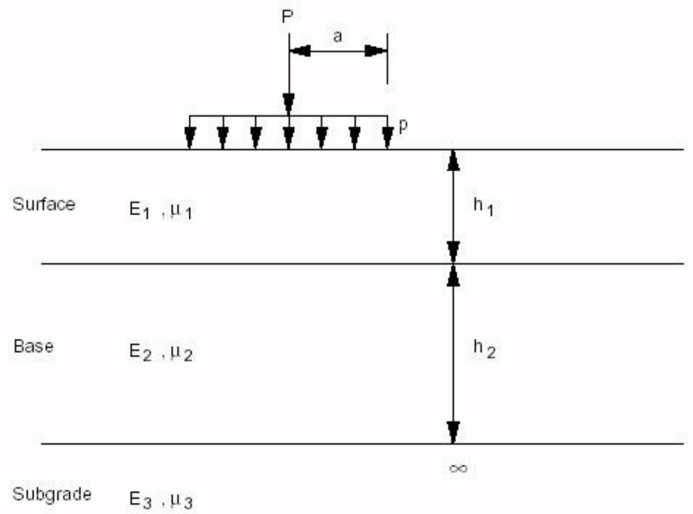


Figure 3.5 Layered Elastic Input

Based on Figure 3.4 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 the 3.4 – 3.6 below.

$$\varepsilon_Z = \frac{1}{E}[\,\sigma_Z - \mu(\sigma_r + \sigma_t)] \tag{3.4}$$

$$\varepsilon_r = \frac{1}{E}[\,\sigma_r - \mu(\sigma_\tau + \sigma_Z)] \tag{3.5}$$

$$\varepsilon_\tau = \frac{1}{E}[\,\sigma_\tau - \mu(\sigma_Z + \sigma_r)] \tag{3.6}$$

Where:

ε	:	Strain
q(t)	:	Distributed load
h_n	:	Depth of each layer
E	:	Modulus of Elasticity (kPa or Psi)
μ	:	Poisson's ratio of each layer
σ	:	Normal stress
T	:	Shear tress

3.3.3 Material Characteristic

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

1. Viscoelastic Layer

Viscoelastic properties are applied to analyze the asphalt layer. The behavior of asphalt depends on the loading time, so the normal viscoelastic theory is used. 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 to characterize the viscoelastic material is through the specification of creep compliances. Recommended temperatures for creep compliances are used for input to LATERINP. The standard temperature on flexible pavement can be displayed as follows.

$$D(t) = \frac{1}{E_o}\left(1 - \frac{1}{T_o}\right) + \sum_{i=1}^{n} \frac{1}{E_i}(1 + exp\,\frac{1}{T_o}) \quad (3.7)$$

$$D(t) = \frac{1}{E_o}(1 - e^{-0,833t}) \quad (3.8)$$

Creep compliances were measured with 11time variations, including: 0.001; 0.003; 0.01; 0.03; 0.1; 0.3; 1; 3; 10; 30; and 100 seconds.

2. Elastic Non-linear Layer

It is known that granular materials and subgrades are non-linear with modulus of elasticity due to various levels of stress. The modulus of elasticity used with the layered system is the modulus of resilience. The resilience modulus of granular materials increases with increasing stress intensity.

3. Elastic Linear Layer

Linear elastic layer modelling can calculate stress, strain, and deflection in the pavement structure whose surface has been loaded. Elastic linear layers assume that each layer of the pavement structure is homogeneous, isotropic, and linearly elastic.

3.3.4 KENPAVE Program

The KENPAVE program is a pavement planning design software developed by Dr. Yang H Huang, P.E. Professor Emeritus of Civil Engineering University of Kentucky. This software is written in Visual Basic and can be run with Windows 95 or later versions.

This software is divided into four programs, namely LAYERINP, KENLAYER, SLABINP, and KENSLABs. LAYERINO and KENLAYER are flexible pavement analysis programs based on the multi-layer system theory. Meanwhile, SLABINP and are analysis programs for rigid pavement based on the finite element method.

This study uses the KENPAVE program with KENLAYER as an analysis program that will be carried out by calculating the multi-layer system on flexible pavement. This program is quite interactive and can be used to calculate strain, stress, and deflection of pavement surfaces due to certain loads.

In modelling the pavement layer with the flexible layer model, input data are needed for stress and strain on the pavement structure and response to loads. The parameters used are as follows.

1. Parameter for each layer such as Elastic Modulus and Poisson’s Ratio
   a. Modulus of Elasticity

      The elastic modulus is the ratio between the stress and strain of an object. The elastic modulus is also called Young's modulus and is denoted by the symbol E. To find the elasticity, you can use the Equation 3.9 below.

$$E = \frac{\tau}{\varepsilon} \quad (3.9)$$

Where:

E : Modulus of Elasticity (kPa or Psi)

τ : Stress (kPa)

ε : Strain

The elastic modulus for an object has its elastic strain and stress limits. For the elastic modulus values of several types of pavement materials can be seen in the Table 3.12 below.

Table 3.12 Modulus Elasticity for each Pavement Material

Material	Modulus of Elasticity	
	Psi	kPa
Cement-treated Granular Base	$1x10^6 – 2x10^6$	$7x10^6 – 14x10^6$
Cemented aggregate mixture	$5x10^5 – 1x10^6$	$35x10^5 – 7x10^6$
Asphalt treated base	$7x10^4 – 45x10^4$	$49x10^5 – 3x10^6$
Asphalt concrete	$2x10^4 – 2x10^6$	$14x10^4 – 14x10^6$
Bituminous stabilized mixture	$4x10^4 – 3x10^5$	$28x10^4 – 21x10^5$
Lime stabilized	$2x10^4 – 7x10^4$	$14x10^4 – 49x10^4$
Unbound granular materials	$15x10^3 – 45x10^3$	$105x10^3 – 315x10^3$
Fine grained or natural subgrade materials	$3x10^3 – 4x10^4$	$21x10^3 – 28x10^4$

Source: Huang (2004)

b. Poisson’s Ratio

Poisson's Ratio is a ratio between the lateral strain and axial strain caused by axial load and axial strain. Poisson ratio value can be seen in the Table 3.13 below.

Table 3.13 Poisson’s 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 fine grained material	0,10 – 0,20	0,15
Cemented treated fine-grained material	0,15 – 0,35	0,25

Continuation of Table 3.13 Poisson's Ratio Value

Material	v Value	v Typical
Lime stabilized material	0,10 – 0,25	0,20
Lime fly ash mixture	0,10 – 0,15	0,15
Loose sand/silty sand	0,20 – 0,40	0,30
Dense sand	0,30 – 0,45	0,35
Fine grained soil	0,30 – 0,50	0,40
Saturated soft clay	0,40 – 0,40	0,45

Source: Huang (2004)

2. Layer thickness

The thickness of each layer is required in the multilayer elastic theory as input in the solution using the program. The thickness of each layer is in mm or inch.

3. Load condition

This data consists of easing load, P (kN / lbs), tire pressure, q (kPa / Psi) and specifically for the rear axle, the distance between the dual wheels, d (mm / inch). The values of q and d in principle can be determined according to the technical specification data of the vehicle used. The P value is influenced by the goods carried by the vehicle so that the rear axle and front axle are different. The pavement structural analysis that will be carried out in the next step also requires the radius of the contact area, a (mm/inch) between the vehicle wheels and the pavement surface which is circular. The contact radius can be calculated by the Equation 3.10 below.

$$a = \sqrt{\frac{p}{\pi \times q}} \tag{3.10}$$

Where:

a : contact area radius (mm)

π : vehicle load (kM/lbs)

q : Load pressure (kPa/Psi)

The values that will be generated from the pavement layer modelling with the multilayer system are the stress, strain, and deflection values.

a. Stress, which is the internal intensity within the pavement structure at various points with units (N/m2, Pa, or Psi)

b. Strain is the ratio of deformation from the original shape (mm / mm or inch / inch), because the strain in other pavements is exceedingly small, it is expressed in macrostrain.

c. Deflection / deflection is a linear change in a form which is expressed in units of length (μm or inch or mm).

Using KENPAVE will simplify the calculation of stress, strain, and deflection at various points on the pavement structure. However, there are several important points or locations commonly used in pavement analysis which are presented in Table 3.14 and Figure 3.5.

Table 3.14 Pavement Structure Analysis

Location	**Response**	**Reason for Use**
Pavement Surface	Deflection	Used in imposing load restrictions during spring thaw and overlay design (for example)
Bottom of HMA layer	Horizontal Tensile Strain	Used to predict fatigue failure in the HMA
Top of Intermediate Layer (Base or Subbase)	Vertical Compressive Strain	Used to predict rutting failure in the base or subbase
Top of Subgrade	Vertical Compressive Strain	Used to predict rutting failure in the subgrade

Source: ARA (2004); pavement interactive (2010)

Illustrations of important or critical locations that are often used for pavement analysis can be seen in Figure 3.6.

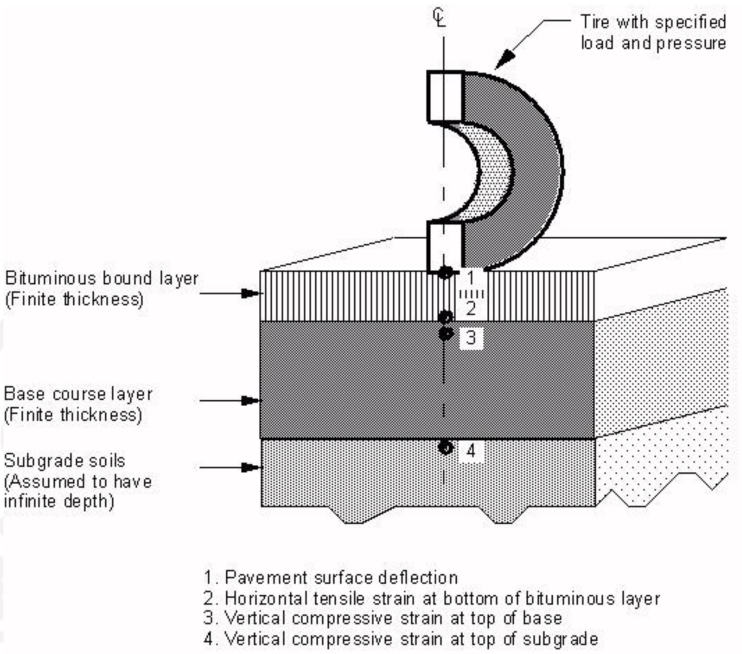


Figure 3.6 Critical Analysis Location in Pavement Structure

The initial display of the KENPAVE program can be seen in Figure 3.7 below.

Figure 3.7 KENPAVE Program Initial Display
(**Source:** KENPAVE, 1993)

The following is an explanation of the Menu on the KENPAVE program.

1. Data Path

Data Path is a data storage place. In the KENPAVE program, the Data Path is filled in by default with C: \ KENPAVE \ according to the location during the installation process.

2. Filename

The Filename will show you the new files created for analysis using LAYERINP and SLABSINP. The file will automatically appear in the filename column, so there is no need to enter a name. All files have a DAT extension. The file names shown in the box will be used in other files generated during the analysis using KENLAYER and KENSLABS.

3. Help

The help menu is a help that explains input parameters and guides to using the program correctly. Some menus have help menus or buttons that you must click if you want to read them.

4. Editor

The Editor is a menu that can be used to edit, examine, and print file data. It is highly recommended to use LAYERINP and SLABINP to use the editor menu. After the analysis is done, click exit to close the KENPAVE program.

5. LAYERINP and SLABINP

LAYERING and SLABING are used to create data files before the KEY LAYER and KENSLABS can be run.

6. KENLAYER and KENSLABS

KENLAYER and KENSLABS are the main programs used to analyze pavements and can be used after the data files have been filled. This program will read the data that has been previously filled in.

7. LGRAPH and SGRAPH

LGRAPH and SGRAPH are used to display pavement plan graphs and cross sections with various information about inputs and outputs.

8. CONTOUR

CONTOUR is used to plot the pressure contour or moment at x or y direction. Contour Plot is for rigid pavement.

3.3.5 KENLAYER Program

KENLAYER is a program for analyzing flexible pavements. KENLAYER functions to determine the damage ratio using a distress model. KENLAYER is a program for analyzing flexible pavements. KENLAYER can be applied to different coating behavior, such as linear, non-linear, or viscoelastic and also four types of axles, namely single axle single wheel, single axle double wheel, tandem axle and triple axle.

The data required for the KENLAYER program is pavement structure data to analyze the pavement thickness planning. The data include pavement thickness, elastic modulus, position ratio, and load conditions.

The KENLAYER program starts from data input through the LAYERINP menu in the KENPAVE program. The LAYERINP program display can be seen in the Figure 3.8 below.

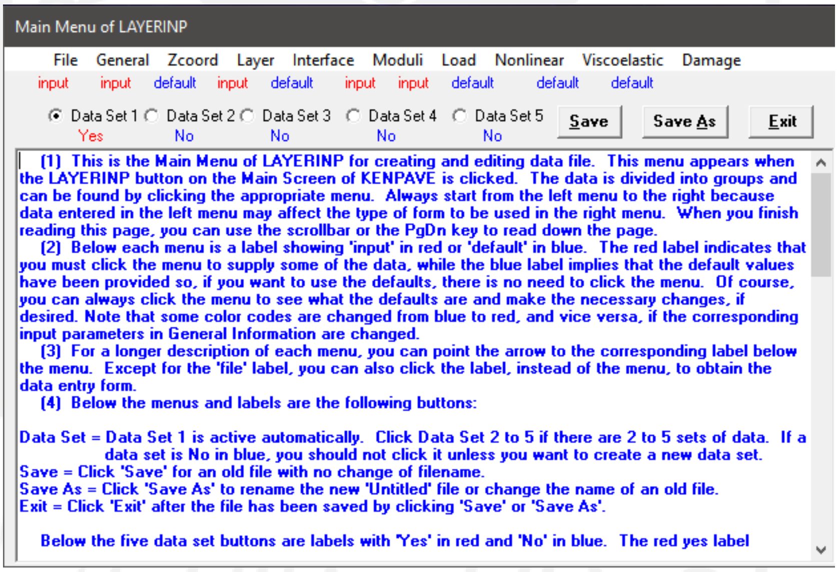


Figure 3.8 LAYERINP Display
(**Source:** KENPAVE, 1993)

The following is an explanation of the Menu on the KENLAYER program.

1. File

   This menu is used to start a new file (New) and open an existing file (Old).

2. General

The general menu description can be seen in Figure 3.9. The General menu has several menus that must be inputted are as follows.

a. Title : Enter the title of the analysis

b. MATL : Choose the type of material. (1) if the layer is linear elastic, (2) if the layer is non-linear elastic, (3) if the layer is viscoelastic, (4) if the layer is a mixture of the three layers above.

c. NDAMA : Choose damage analysis (0) if there is no damage analysis, (1) there is damage analysis and there are printout results, (2) there is damage analysis and there are more detailed printout results

d. DEL : The value of the accuracy of the analysis results. Standard accuracy 0.001

e. NL : Number of layers/layers, maximum 19 layers

f. NZ : The location of the z-direction coordinates to be analysed if NDAMA = 1 or 2, then NZ = 0 because the program will analyse the coordinates that are experiencing damage analysis

g. NTSD : (1) For vertical displacement, for vertical displacement and stress values, (5) for vertical displacement, stress and strain values.

h. NBOND : (1) If all layers are bonded to each other, (2) if each layer is not bonded or shear forces are neglected.

i. NUNIT : Units used (0) English units (1) SI. units

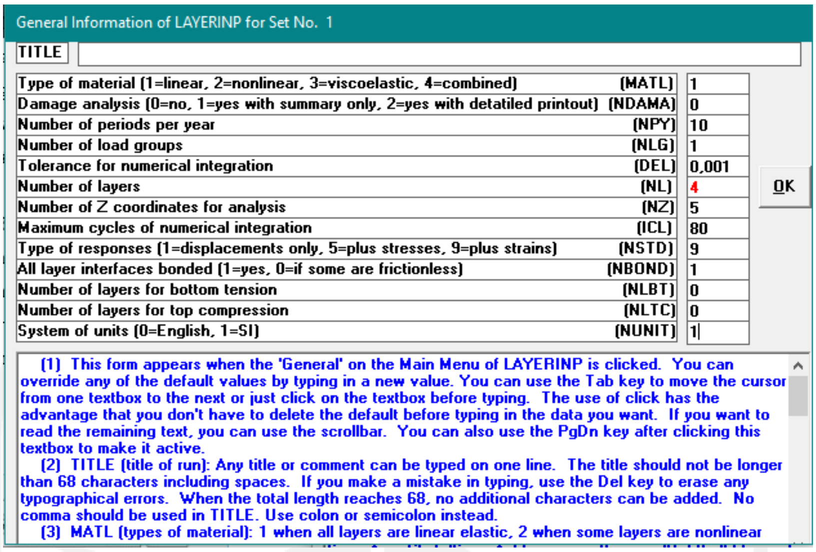


Figure 3.9 General Menu Display
(**Source:** KENPAVE, 1993)

3. Zcoord

Zcoord is a menu used to analyse pavement layers at Z coordinates. The number of points in this menu is the same as the number of NZ in the general menu. ZC is the vertical distance or distance in the Z direction to be analysed by the program. The Zcoord menu can be seen in Figure 3.10.

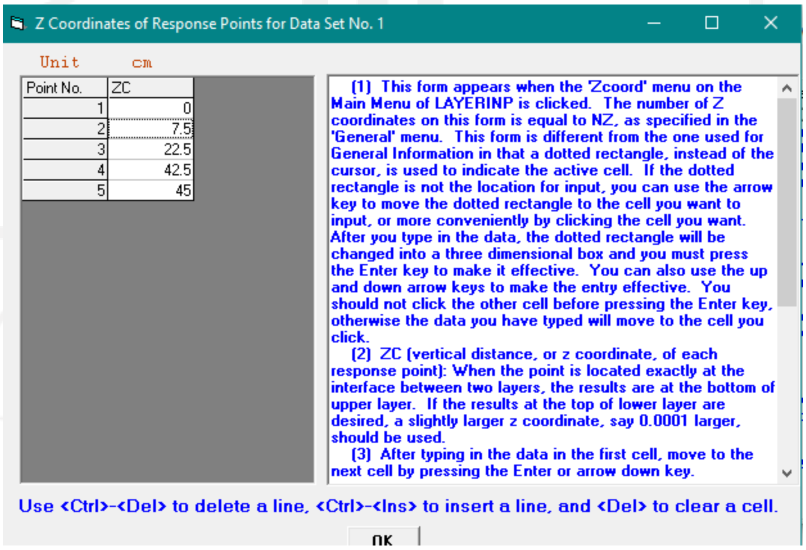


Figure 3.10 Zcoord Menu Display
(**Source:** KENPAVE, 1993)

4. Layer

Layer is a menu used to enter data in the form of the number of pavement layers. TH is the thickness of each layer or layers. PR is Poisson's Ratio for each layer. Layer menu can be seen in Figure 3.11.

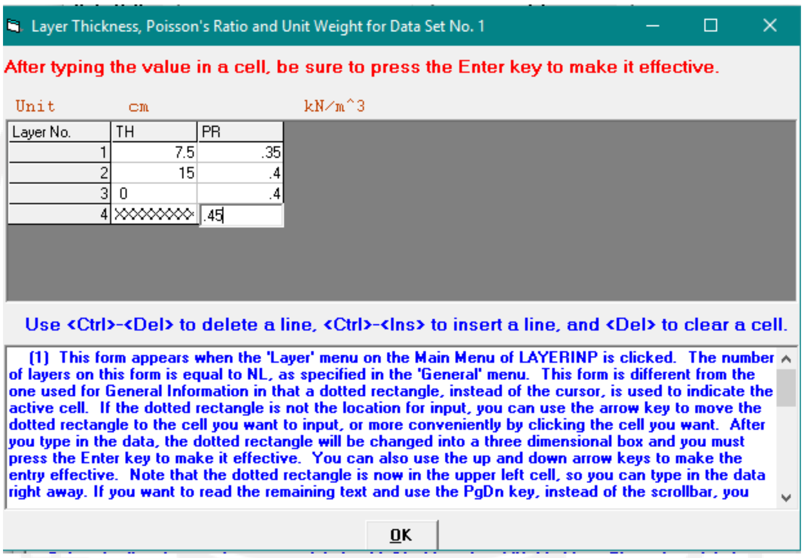


Figure 3.11 Layer Menu Display
(**Source:** KENPAVE, 1993)

5. Interface

This interface menu is related to NBIND which is in the general menu. If NBOND=1 then the interface menu will default and cannot be opened. If NBOND = 2 then the interface menu will appear as shown in Figure 3.12.

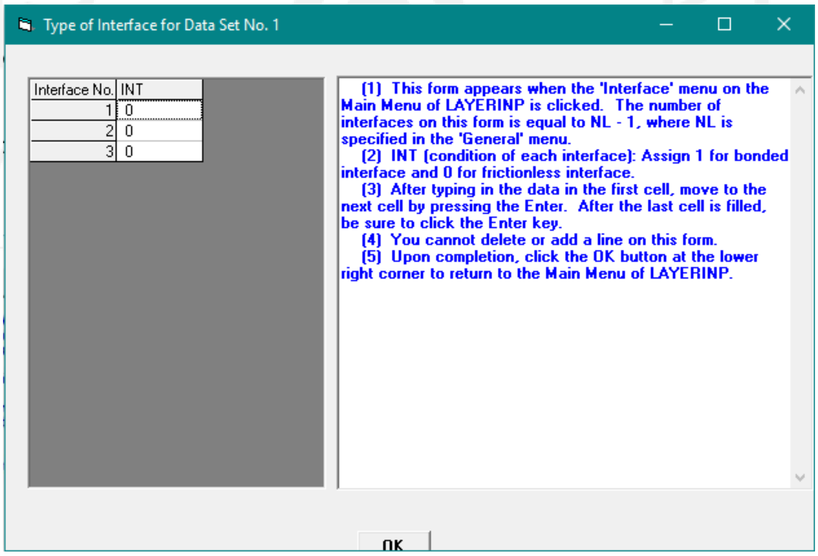


Figure 3.12 Interface Menu Display
(**Source:** KENPAVE, 1993)

6. Moduli

The number of periods in this menu is the same as the number of NPY in the general menu. The maximum period in this menu is 12. E is the modulus of elasticity for each layer. The moduli screen display can be seen in Figure 3.13 and the moduli for period screen display is in Figure 3.14.

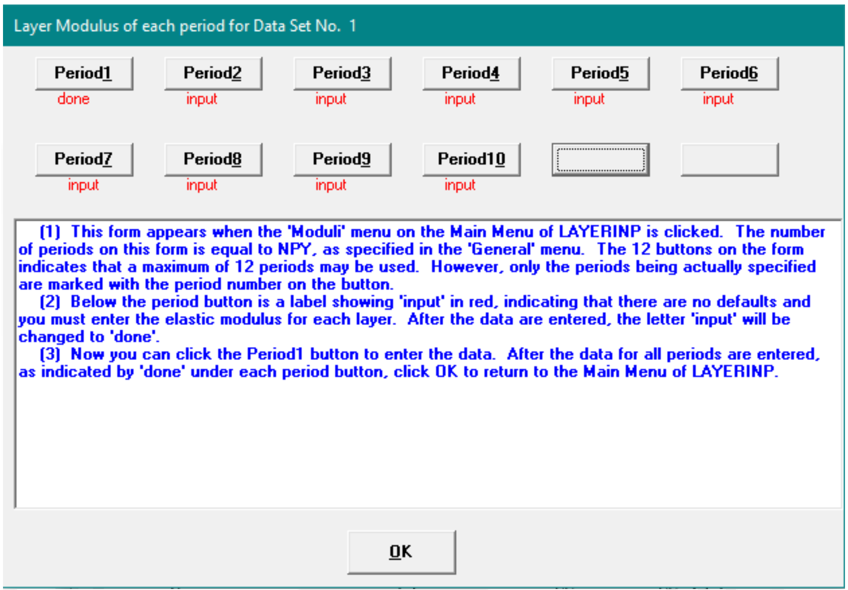


Figure 3.13 Moduli Menu Display
(**Source:** KENPAVE, 1993)

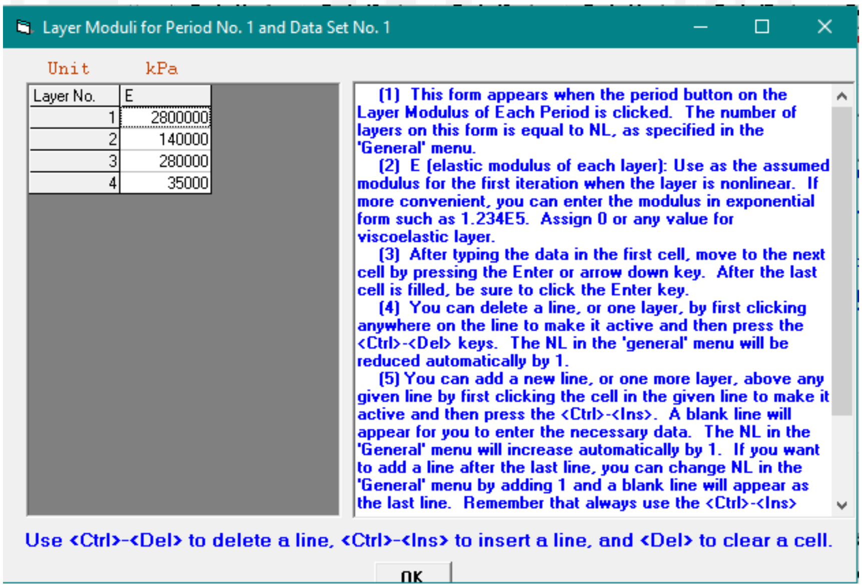


Figure 3.14 Moduli of Period Menu Display
(**Source:** KENPAVE, 1993)

7. Load

The number of units in this menu is the same as the number of NPY in the general menu. For Load column (0) for single axle single wheel, (1) for single axle dual wheel, (2) for tandem axle, (3) for triple axel. The CR column is the load contact radius. The CP column is the load value. The YW and XW columns are the distance between the wheels in the y direction and the x direction. If column load = 0, then column YW and XW = 0. NR is the number of radial coordinates analysed based on one wheel. NPT is the number of analysed x and y coordinate points based on multiple wheels. The load menu screen display can be seen in Figure 3.15.

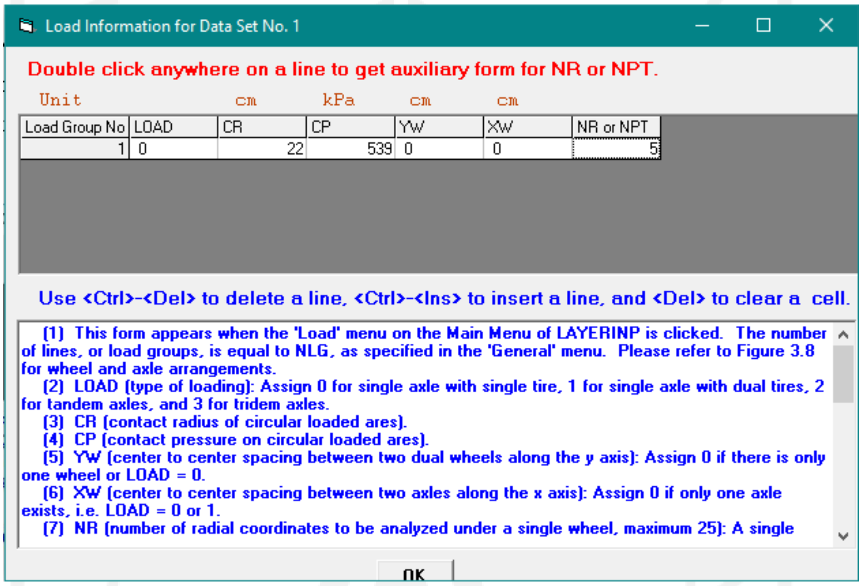


Figure 3.15 Load Menu Display
(**Source:** KENPAVE, 1993)

8. Other Parameters

Other parameters such as Nonlinear, Viscoelastic, Damage, and Mohr-Coulomb will follow their own values according to the input values entered before this data.

The value of pavement thickness is obtained by calculating the thickness of the pavement using the 2017 Highways method. The elastic modulus is obtained using equation 3.2 and the Poisson ratio value is obtained in Table 3.13. Meanwhile, the load condition values consist of wheel load data (P), tire pressure data (q), double wheel distance data (d), and contact area radius data (a) which can be seen in Figure 3.16 below.

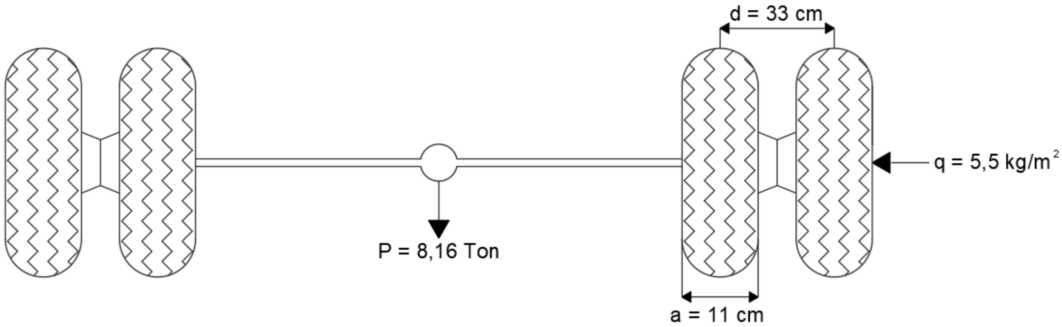


Figure 3.16 Equivalent Standard Axis
(**Source:** Sukirman, 1999)

After the data input is complete, the KENLAYER program is run. The output of this program is vertical displacement, vertical stress, major principal stress, minor principal stress, intermediate principal stress, vertical strain, major principal strain, minor principal strain, and horizontal principal strain.

In this study, the output used is vertical strain and horizontal principal strain for further use in calculating the number of repetitions of the load based on the analysis of fatigue and rutting damage. The following is a KENPAVE procedure chart which can be seen in the Figure 3.17 below.

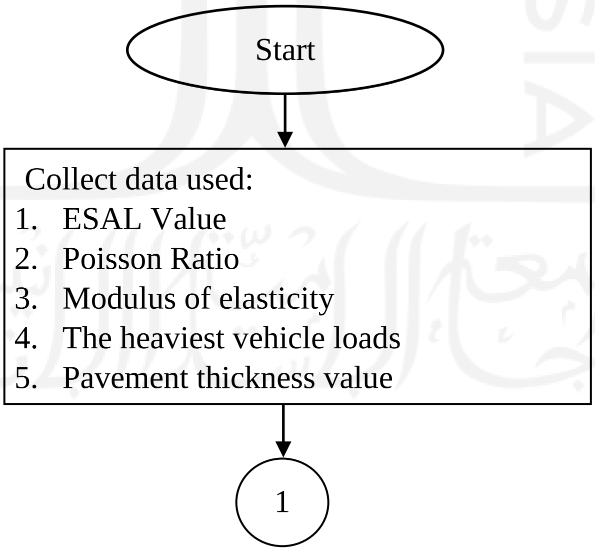


Figure 3.17 KENPAVE Design Procedure

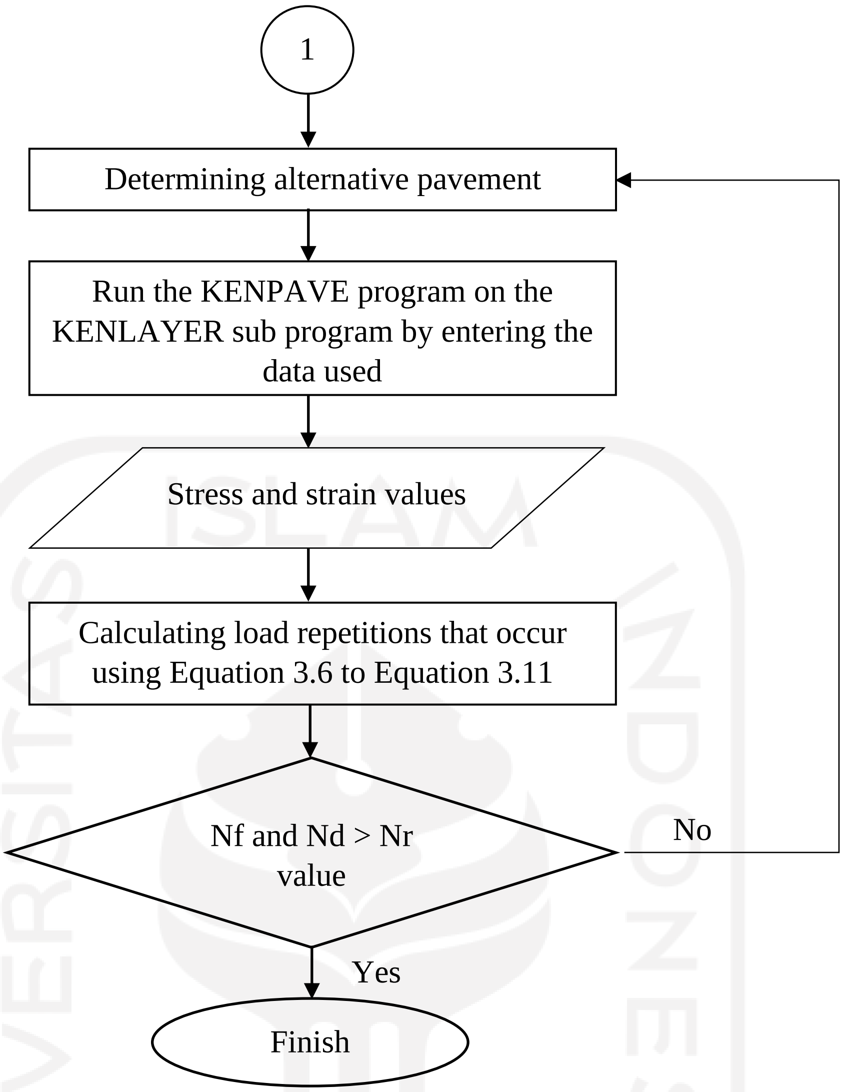


Figure 3.18 Continuation of KENPAVE Design Procedure

3.3.6 Pavement Damage Analysis

Analysis of pavement damage that will be discussed is fatigue cracking, rutting, and permanent deformation on subgrade surface. Pavement damage is caused by vehicle loads and weather influences. The type of fatigue crack damage is seen based on the value of the horizontal strain on the lower asphalt surface layer due to the load on the pavement surface and the type of rutting damage is seen based on the compressive strain value at the top of the subgrade layer or below the subbase layer. Here is the equation of the damage according to the Asphalt Institute.

1. Fatigue Cracking

Fatigue cracking is caused by repeated loads experienced by the pavement surface layer. Reloading that occurs continuously can cause the material to become tired and can cause cracking even though the stress that occurs is still below its ultimate limit.

For pavement materials, repetitive loads come from vehicle load paths that occur continuously, with different intensities and depend on the type of vehicle and occur randomly. The fatigue crack equation for flexible pavement to determine the number of load repetitions based on the tensile strain under the surface layer can be seen on Equation 3.11 below.

$$N_f = 0{,}0976\ (\varepsilon_t)^{-3{,}921}|E^*|^{-0{,}854} \quad (3.11)$$

Where:

N_f : Allowable value of repetition load to control the fatigue cracking

ε_t : Horizontal tensile strain at the bottom of the asphalt

$|E^*|$: Elastic modulus in the surface layer or HMA layer

2. Rutting

Rutting or groove cracking on the pavement surface is the accumulation of all plastic deformation that occurs, both from the asphalt layer, foundation layer, and base soil layer. The groove crack criterion is the second criterion used in the mechanistic analytical method, to express the failure of the pavement structure due to repeated loads.

The maximum rutting value must be limited so as not to endanger the rider when passing through the rutting location, especially at high speeds. Permanent deformation can be detected at every layer of the structure, making groove cracks more difficult to predict than fatigue cracking. The failure measures available are intended for grooves that can be aimed mostly at a weak pavement structure. It is generally expressed in terms of the vertical strain above the subgrade.

The equation to determine the number of repetitions of the load based on the compressive strain under the foundation layer can be seen in Equation 3.12 below.

$$N_d = 1{,}365\ \times\ 10^{-9}(\varepsilon_c)^{-4{,}47} \quad (3.12)$$

Where:

N_d : Number of permissible load reps to control rutting

ε_c : Vertical compressive strain over the base layer

3. Permanent Deformation

Permanent deformation can be detected in every layer of the structure, thus making it more difficult to predict than fatigue cracking. The existing failure measures are intended for grooves that most can be demonstrated in a weak pavement structure. It is generally expressed in terms of the vertical strain above the subgrade. The number of repetitions of the load is calculated using the following Equation 3.13.

$$N_d = f_4(\varepsilon_c)^{-f_5} \tag{3.13}$$

Where:

N_d : Number of permissible load reps to control rutting

ε_c : Vertical compressive strain over the base layer

f_5 : Permanent deformation criterion coefficient

f_4 : Permanent deformation criterion coefficient

The values of f4 and f5 follow the recommendations of the Asphalt Institute 1970 with values of $f_4 = 1{,}365 \times 10^{-9}$ and $f_5 = 4{,}477$.

3.4 Service Life Prediction Analysis of Road Pavement

Road pavement service life analysis is the estimated number of years measured based on the latest condition survey up to the projection when further pavement rehabilitation activities are needed (G. Y. Baladi ; T. A. Dawson ; C. M. Dean ; S. W. Haider ; and K. Chatti, 2011). A schematic or illustration of how the remaining service life of the pavement is applied can be seen in Figure 3.19 below.

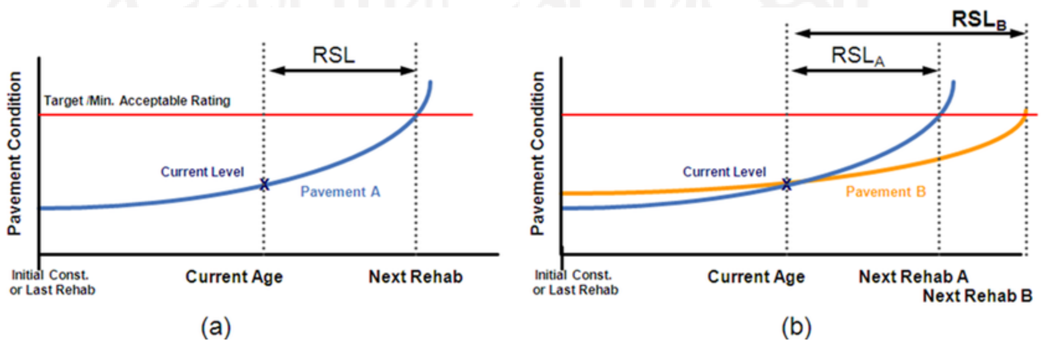


Figure 3.19 Remining Service Life of Road Pavement
(**Source:** Mack et al. 2014)

To calculate the remaining service life must find the number actual pavement traffic and the amount of pavement traffic at the end of the design life or the number of repetitions of the permit load when it reaches a failure condition due to fatigue and rutting expressed in 18-Kip ESAL units. The difference between these values is the value of the remaining service life expressed as a percentage of the amount of traffic at the time of the breakdown. According to AASHTO 1993 the equation to find the remaining service life is to use the following Equation 3.14.

$$SL = 100 \times \left(1 - \frac{N_p}{N1.5}\right) \tag{3.14}$$

With:

SL	:	Service Life (%)
N_P	:	Total Traffic to date ($CESA_5$)
N1.5	:	Total Traffic to pavement failure

In addition, to find the service life of the road pavement until damage occurs, it can be obtained by using the equation approach to find the Equivalent Standard Axle found in the Bina Marga 2017 which can be seen in the following equation 3.15.

$$LP = \ln\left[\frac{ESA}{(\Sigma ADT \times VDF) \times 365 \times DD \times DL}\right] \times 0.01i + 1 \tag{3.15}$$

With:

LP	:	Life Plan to pavement failure
ESA	:	Equivalent Standard Axle
ADT	:	Average Daily Traffic
VDF	:	Vehicle Damage Factor
DD	:	Direction Distribution
DL	:	Lane Distribution
i	:	Traffic Growth Rate Factor

Another way to find out the remaining service life of the pavement is to compare the load repetitions according to the average daily traffic that occurs with the load repetitions from the pavement damage analysis.

CHAPTER 4
RESEARCH METHODS

4.1 Research Method

The preparation of this final project uses a case study method where in this study the researcher wants to explore in depth the related study object. 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 looks 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 more comprehensively and comprehensively about how and why the object occurs and is formed as and can be viewed as a case.

4.2 Data Collection

The stage in the research process that is important 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. If we can obtain secondary data more easily and quickly because it is already available, for example in libraries, companies, trade organizations, central statistical bureaus, and government offices, then we must take primary data directly from the original source. through direct surveys in the field or through appropriate sources and who we make respondents in our research. In this study, the type of data used is primary and secondary data.

The stage of research work includes the stage of determining the problem, determining the objectives and study environment, collecting primary and secondary data, compiling data, analysing, determining results and conclusions. In the analysis of this research, the data used are primary and secondary data, primary data obtained by survey the existing road and the traffic data. The secondary data was obtained from P2JN of the Special Region of Yogyakarta. The data used in the research analysis of the Sentolo – Nanggulan – Dekso road were obtained from site survey and P2JN of the Special Region of Yogyakarta are as follows.

1. Traffic Data.
2. Location Maps and Detailed Engineering Drawing.
3. CBR data.
4. Material properties.
5. Pavement structure data, such as road geometry (road length, lane width, median width, road shoulder, number of road directions and lanes).

4.3 Research Sites

The location that is reviewed as the object of the case study in this research is the Sentolo - Nanggulan - Dekso road, Kulon Progo Regency, Special Region which can be seen in Figure 4.1 below.

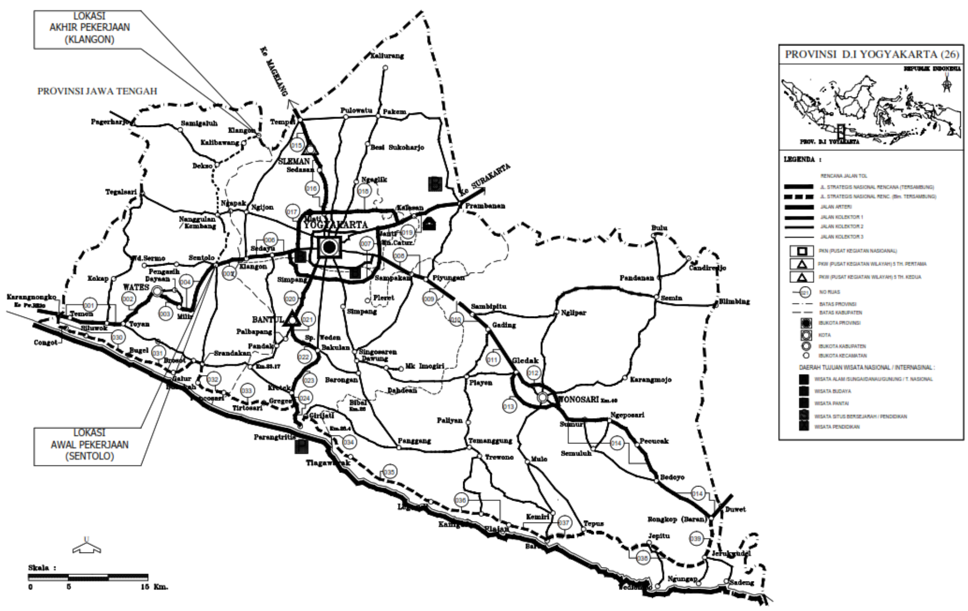


Figure 4.1 Location Map
Location: (Satker PPJN Provinsi DIY, 2020)

4.4 Survey

Surveys conducted in the field, obtained primary data needed for analysis. Primary data in this research are data obtained from direct observations in the study area. The survey conducted is as follows.

4.4.1 Traffic Survey

The traffic survey for this research refers to the 2017 Bina Marga in the traffic sub-chapter. It was stated that the traffic survey was carried out manually referring to the *Pedoman Survei Pencacahan Lalu Lintas* (Pd T-19-2004-B). In conducting a traffic survey, the things that need to be prepared are as follows.

1. Equipment

   Traffic counting equipment manually does not require special equipment, the equipment required includes:

   a. Main Equipment, consisting of.
      1) counter and set form,
      2) pencil stationery,
      3) eraser Tool,
      4) hand board, and
      5) auxiliary equipment, namely handheld counters.

   b. Supporting equipment, which consists of
      1) raincoat,
      2) flashlight,
      3) another lighting tools, and
      4) plastic bag.

   c. All equipment used is ensured to function properly, not easily damaged, easy to operate and meet the requirements for recording.

2. Survey Form

   The survey form consists of a field form and a collection form, the form must be accompanied by an identity, as follows:

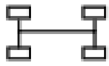
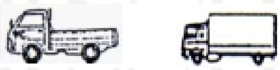
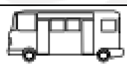
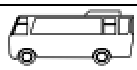
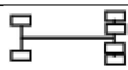
   a. Information regarding the location, survey implementation, and weather conditions, including.
      1) number of sheets,

2) province name,
3) postal number,
4) post location,
5) date,
6) traffic direction,
7) description / weather, and
8) note-taker.

3. Vehicle Type

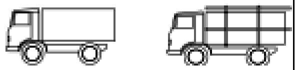
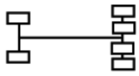
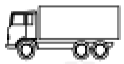
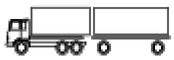
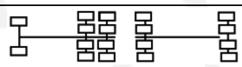
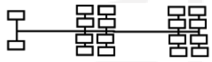
The traffic count is broadly divided into 8 groups, each group consisting of several types of vehicles, as shown in the Table 4.1 below.

Table 4.1 Vehicle Types and Groups

Class	**Vehicle Type Group**	**Vehicle Type**	**Axis Configuration**	**Code**
1	Motorcycles, 3-wheeled vehicles			
2	Sedan, jeep station wagon			1.1
3	Medium passenger transport			1.1
4	Pickups, micro trucks, and delivery cars			1.1
5a	Small bus			1.1
5b	Big bus			1.2
6a	2 axle light truck			1.1

Source: Departemen Permukiman dan Prasarana Wilayah (2004)

Continuation of Table 4.1 Vehicle Types and Groups

Class	Vehicle Type Group	Vehicle Type	Axis Configuration	Code
6b	2 axle medium truck			1.2
7a	3 axle truck			1.2.2
7b	Trailer truck			1.2.2-2.2
7c	Semitrailer truck			1.2.2.2.
8	Unmotorized vehicle			

Source: Departemen Permukiman dan Prasarana Wilayah (2004)

4. Survey Time

   The survey was carried out for 7 days, from Monday to Sunday which includes normal working days and weekends on the Sentolo - Nanggulan - Dekso road section.

   The survey was carried out in the morning until the afternoon, namely at 06:00 WIB to 18:00 WIB, where in that time span there were several resident activities, such as going to school, going to work, trading activities, tourism trips, package delivery, and in the afternoon, there are activities after work, the completion of trading activities, and other activities.

5. Determination of Survey Post

   The determination of the survey post on the Sentolo - Nanggulan - Dekso road section is as follows.

   a. traffic is not affected by shuttle traffic,
   b. the post has sufficient distance and visibility in both directions,
   c. the traffic movement character represents the traffic movement on the road,
   d. at STA 0+025 it is located on Jalan Nanggulan Mendut, close to Samudraraksa Gate, and

e. at STA 3+625 which is located on Jalan Nanggulan Mendut, close to KUA Kapanewon Kalibawang.

6. Determination of the Number and Duties of Surveyors

In carrying out the traffic survey on the Sentolo - Nanggulan - Dekso road section, 2 surveyors were selected for each direction at each post and divided into 2 shifts because one shift cannot exceed 8 hours, so the total surveyor is 8 with the details of the tasks as follows.

a. surveyor 1 recorded vehicle classes 1, 2, 3, 4, and
b. surveyor 2 recorded vehicle classes 5, 6, 7, and 8.

7. Survey Implementation Stages

a. Preliminary survey are as follows.
   1) observation and determination of survey post placement,
   2) recruitment/mobilization of surveyors, and
   3) training for surveyors as a debriefing in survey procedures,
b. Counting Survey are as follows.
   1) prepare survey forms and brief instructions,
   2) fill in a description of the situation and conditions at the time of the survey such as a description of the survey area, postal location, weather conditions, street names, traffic directions, and date,
   3) each surveyor records the passing vehicles in accordance with the respective division of tasks on the form,
   4) survey activity photos, and
   5) after the survey is complete, correction and recording is carried out on each data.

4.5 Design Procedure

To make it easier for the author to do the analysis, a design procedure flow was made. Some of the flowcharts in the research carried out are as follows.

1. research stages,
2. procedure for flexible pavement design Manual Road Pavement Design for Highways 2017, and
3. design procedure using Kenpave program.

4.5.2 Research Stage

The research stages in general can be seen in the order in the flow chart as shown in Figure 4.2 below.

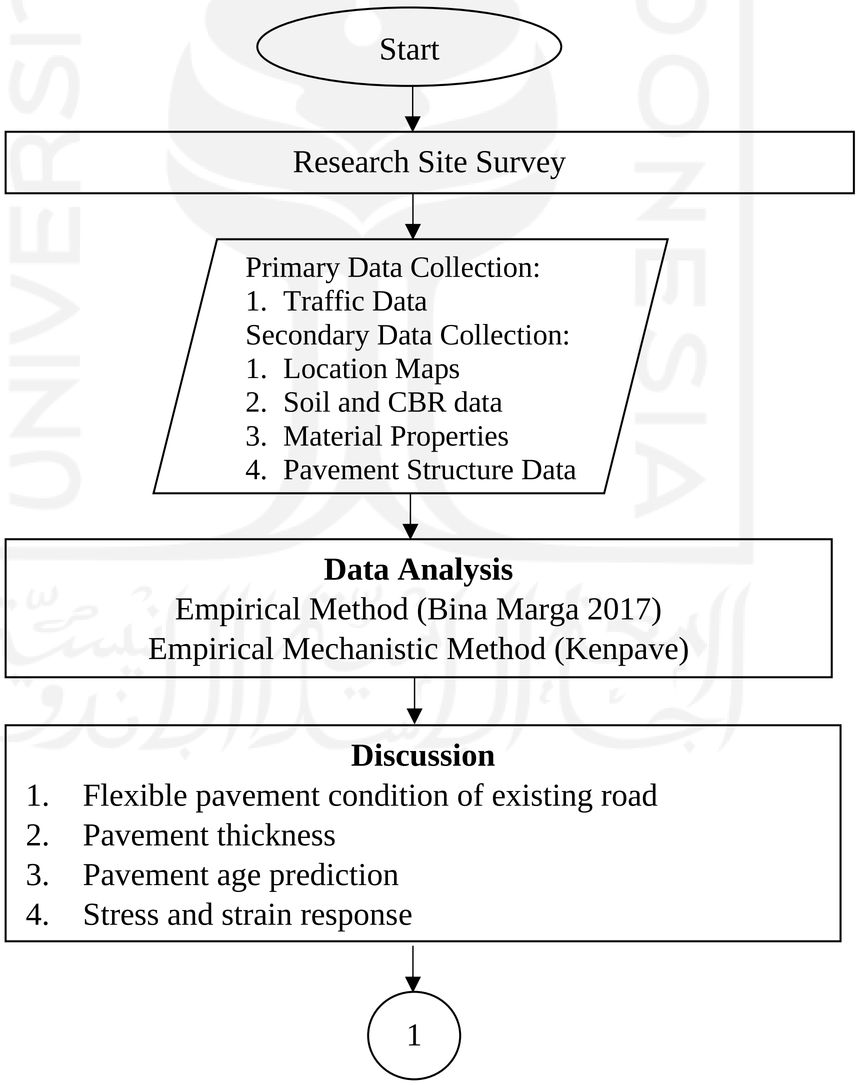


Figure 4.2 Research Flowchart

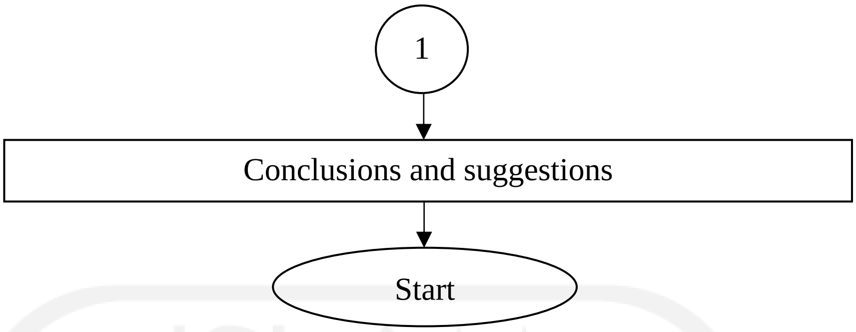


Figure 4.3 Continuation of Research Flowchart

4.5.3 Pavement Design Procedure using Bina Marga 2017

The procedures for using the Road Pavement Design Manual Number 04/SE/Db/2017 for flexible pavement design are as follows.

1. determine the design life by considering the pavement elements based on the lowest discounted whole of life cost analysis from Table 3.1,
2. determine the traffic growth multiplier (R),
3. determine the value of VDF,
4. determine the value of the direction distribution factor (DD) and the commercial vehicle lane distribution factor (DL),
5. determine the CESA value according to the 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 the thickness of the pavement using CESA5 by reviewing the LPA considerations based on the CBR value.

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 4.4 below.

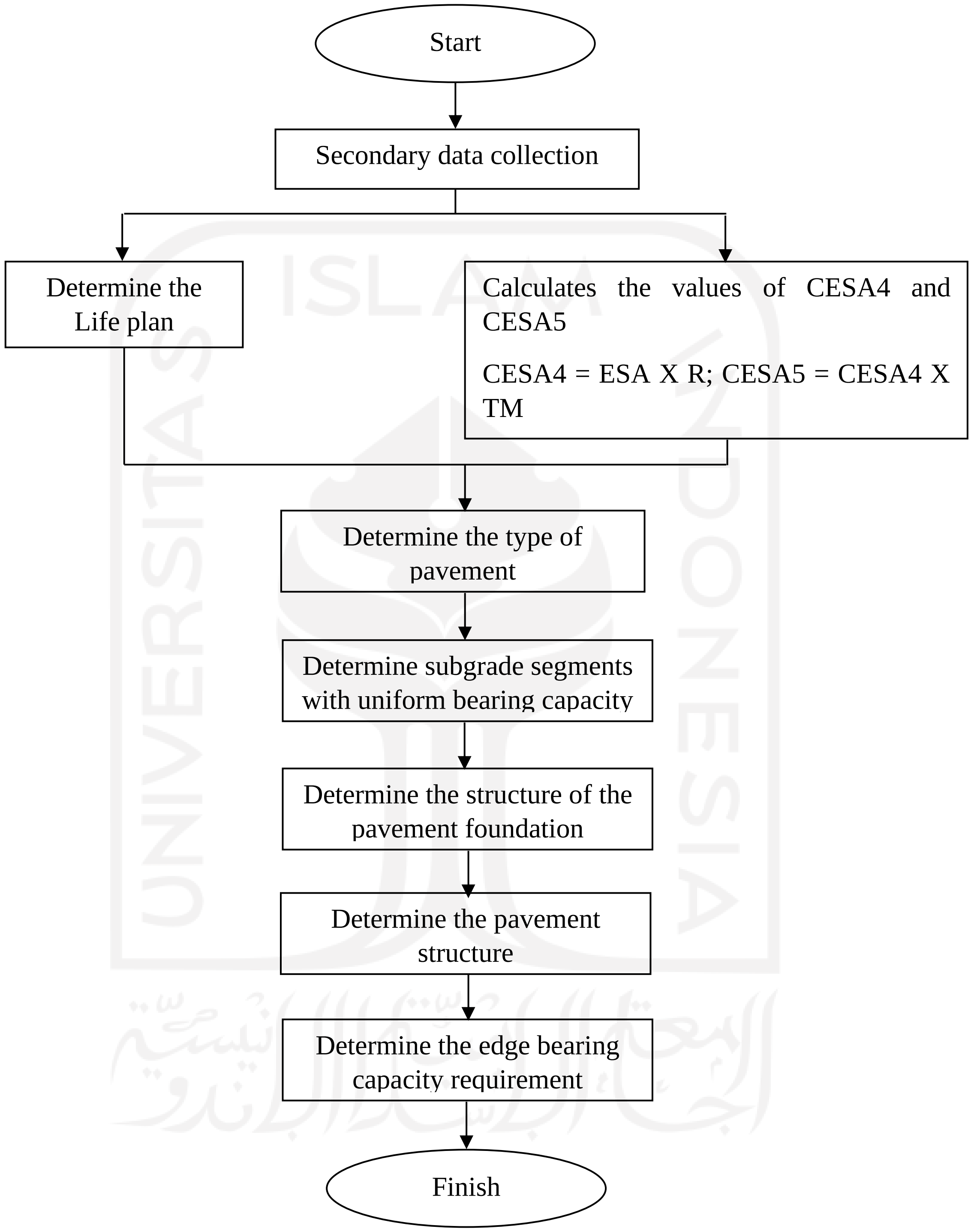


Figure 4.4 Bina Marga 2017 Pavement Design

4.5.4 Kenpave Method Procedure

The procedures for modelling the pavement structure using the Kenpave program and flexible pavement with Kenlayer for standard axle loads are as follows.

1. Determine material properties data for structural modelling, including.
   a. thickness of each layer of pavement,
   b. value of the modulus of elasticity (E) for each layer of pavement, and
   c. Poisson's ratio value for each layer of pavement.
2. Analysing traffic data include.
   a. determine the time period for the pavement analysis review,
   b. calculate Equivalent Single Axle Load (ESAL), and
   c. determine the detail of the axle load.
3. Modelling the pavement structure using the Kenpave program and for layer pavement using the Kenlayer sub-program using two modelling namely Viscoelastic and Elastic modelling.
4. Determining the output of the Kenlayer program is used to determine the stress-strain response that occurs due to traffic loads from the two models.
5. Analyse the repetition of traffic loads generated by the Kenpave program and analyse the pavement life of the two models.

To make it easier to understand the procedure for using the Kenpave Program, a flow chart is made as shown in Figure 4.5 below.

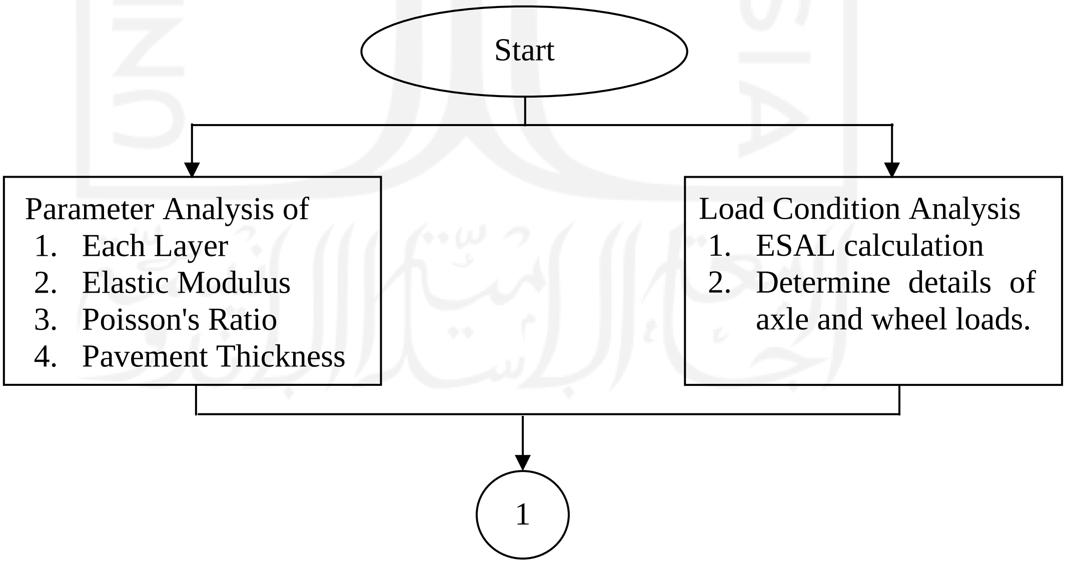


Figure 4.5 Kenpave Pavement Design

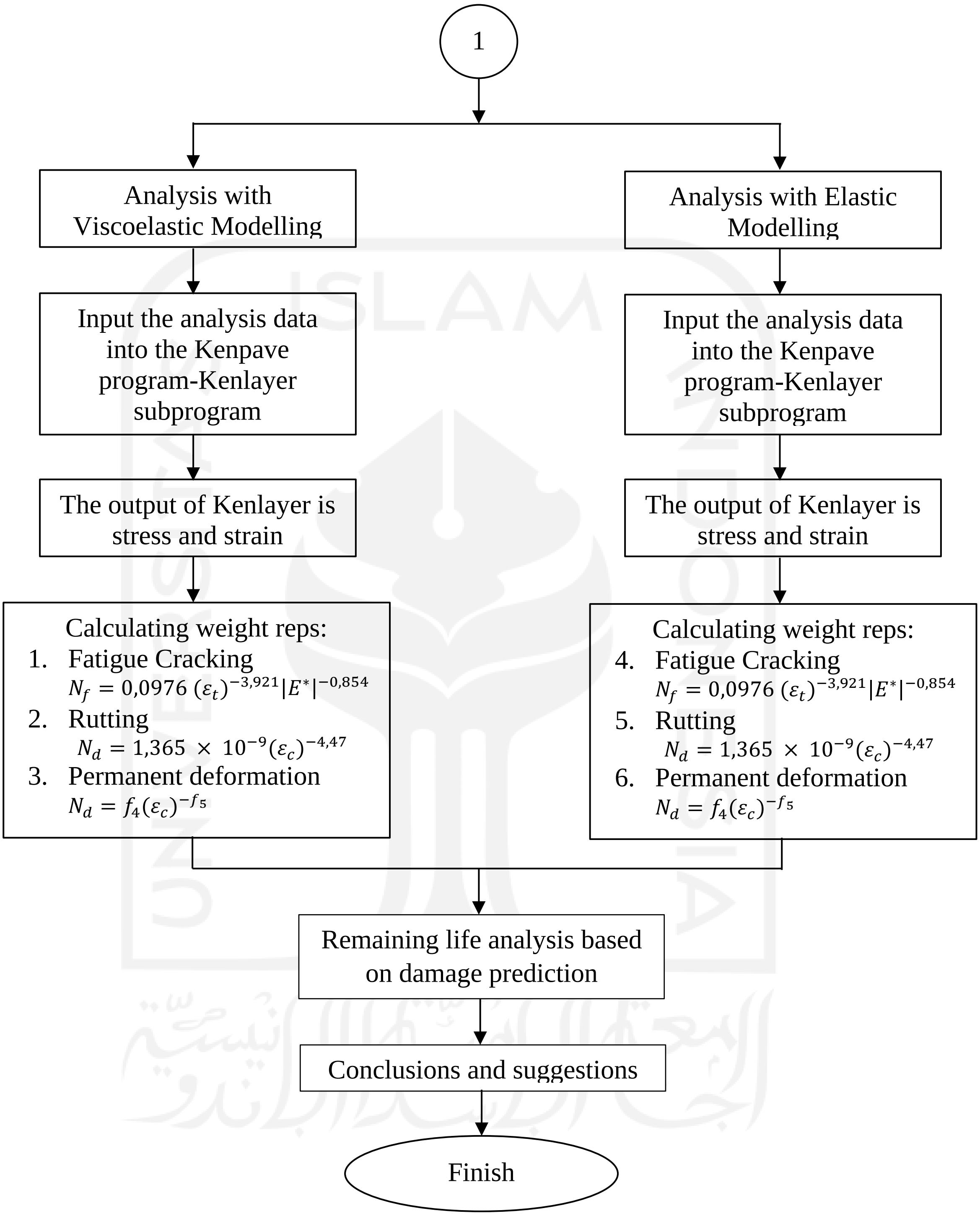


Figure 4.6 Continuation of Kenpave Pavement Design

CHAPTER 5
ANALYSIS AND DISCUSSION

5.1 Research Data

5.1.1 Existing General Data

Existing data for the Sentolo - Nanggulan - Dekso road section are consists of primary and secondary data. Primary data was obtained from direct observation and secondary data was obtained from the D.I.Yogyakarta National Road Planning and Supervision Work Unit for the 2017 fiscal year. The Sentolo - Nanggulan - Dekso road section is a road segment that connects Yogyakarta with Magelang which is the road to the National Tourism Priority Area and YIA airport. The following is the primary data obtained.

Road Segment : Sentolo – Nanggulan – Dekso
Road Class : Provincial Road
Traffic Growth : 3.5 %
Life/Service Plan : 20 Year
Vehicle Distribution : 2 lane road – one road for each direction

5.1.2 Existing Traffic

The results of observations and traffic survey based on vehicle classes can be seen in Table 5.1 below.

Table 5.1 Average Daily Traffic 2021

Class	Vehicle Type	ADT (vehicle/day)
1	Motorcycles, 3-wheeled vehicles	1982
2	Sedan, jeep station wagon	583
3	Medium passenger transport	431
4	Pickups, micro trucks, and delivery cars	432
5a	Small bus	287

Continuation of Table 5.1 Average Daily Traffic

Class	Vehicle Type	ADT (vehicle/day)
5b	Big bus	225
6a	2 axle light truck	342
6b	2 axle medium truck	391
7a	3 axle truck	139
7b	Trailer truck	0
7c	Semitrailer truck	20
8	Unmotorized vehicle	31

From the average daily traffic data in table 5.1 above, the percentage for motorcycles Cycle (MC) which consists of class 1 vehicles is 40.76%, Light Vehicle (LV) which consists of vehicles of class 2,3, and 4 is 29.74%. , Medium Heavy Vehicle (MHV) which consists of vehicle class 5A and 6A is 12.94%, Heavy Vehicle which consist of vehicle class 5B, 6B, 7A, 7B, and 7C is 15.94% and for Unmotorized (UM) which consists of vehicle class 8 is 0.63%.

5.1.3 Existing Pavement

Road pavement on the Sentolo - Nanggulan - Dekso section has undergone major rehabilitation in 2018 (BBPJN VII, 2018) and widening in 2020 to support the Borobudur National Strategic Area. The pavement layer on this road section consists of 2 types, namely the flexible layer in the middle and the rigid pavement layer on the widening section of the road. In this study, only the flexible pavement layer will be analyzed. The thickness of the flexible pavement layer was obtained from direct observation with the consultant during the road widening work on this road segment. The existing flexible pavement layers on the Sentolo - Nanggulan - Dekso road section are as follows.

AC WC = 40 mm
AC Base = 60 mm
Class A Foundation = 400 mm
Subgreade = ∞

Meanwhile, the thickness of rigid pavement for the road widening section on the Sentolo - Nanggulan - Dekso section is as follows.

AC – WC	=	40 mm
Concrete Pavement with single reinforcement woven	=	200 mm
Foundation Layer	=	150 mm
Subgrade	=	∞

The CBR values for the selected pile, subgrade, and LPA are as follows.

Selected Pile	=	15.00 %
Subgrade	=	7.66 %
Foundation Layer	=	92.00 %

5.2 Existing Pavement Evaluation Using Kenpave Program

Evaluation of the existing pavement for the Sentolo - Nanggulan - Dekso road section using the Kenpave program is to determine the damage that occurred and the remaining service life. The evaluation stage of the existing pavement can be seen as follows.

5.2.1 Evaluation using Viscoelastic Model

1. Data Used for Analysis

   The data that will be used for analysis is wheel axle load and data for each layer of pavement. The explanation is as follows.

   a. Axle Load

      The wheel axle load data is based on Figure 3.16 where the wheel axle load is axle load data in Indonesia. The load condition values consist of wheel load data (P), tire pressure data (q), double wheel distance data (d), and contact area radius data (a) as follows.

      1) The standard axle load (P) of the vehicle is 8.16 tons.
      2) Wheel pressure (q) for one tire is 0.55 MPa.
      3) The distance between each double wheel axle is 33 cm.
      4) The radius of the contact area (a) is 11 cm.

b. Pavement Layer Data

The analysis carried out in this study uses viscoelastic material, the foundation layer and subgrade layer are assumed to use linear elastic material. So that in this calculation only the Elastic Modulus and Poisson Ratio parameters are used, which can be seen in Table 5.2 below.

Table 5.2 Pavement Layer Parameter

AC – WC	Modulus of Elasticity (E)	1,100,000 KPa
	Poisson Ratio	0.4
AC – Base	Modulus of Elasticity (E)	1,600,000 KPa
	Poisson Ratio	0.4
Foundation Layer	Modulus of Elasticity (E)	350,000 KPa
	Poisson Ratio	0.35
Subgrade	Modulus of Elasticity (E)	150,000 KPa
	Poisson Ratio	0.45

Source: Bina Marga (2017)

2. Input Data to Kenpave

The following is the input data used to analyze the existing pavement with the results of the analysis in the form of stress and strain values.

a. Layernip

Layerinp menu is used for flexible pavement analysis. In the Layerinp menu there are several menus to fill in the data needed for analysis. Layerinp view can be seen in Figure 5.1 below.

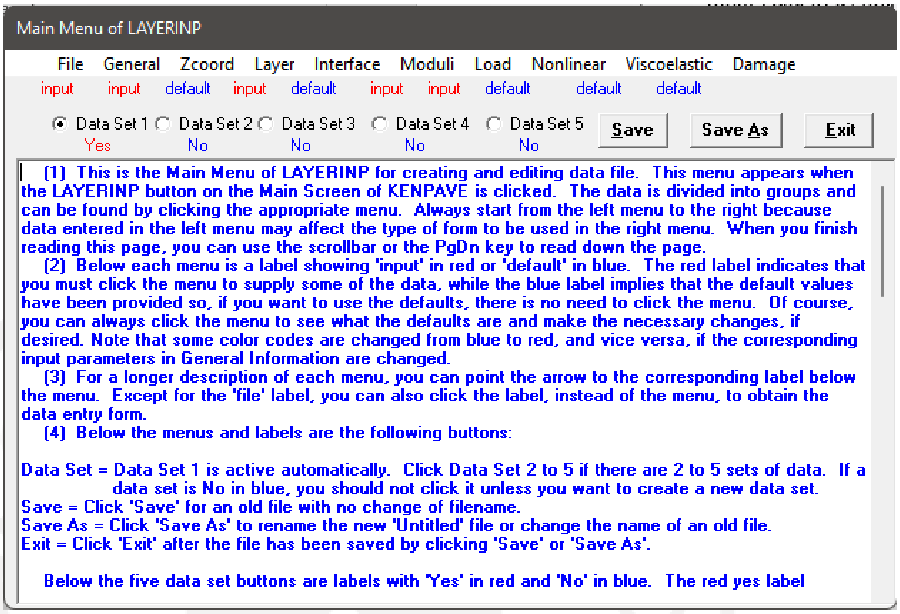


Figure 5.1 Layerinp

The next step is to click the File menu and select New to input new data.

b. General

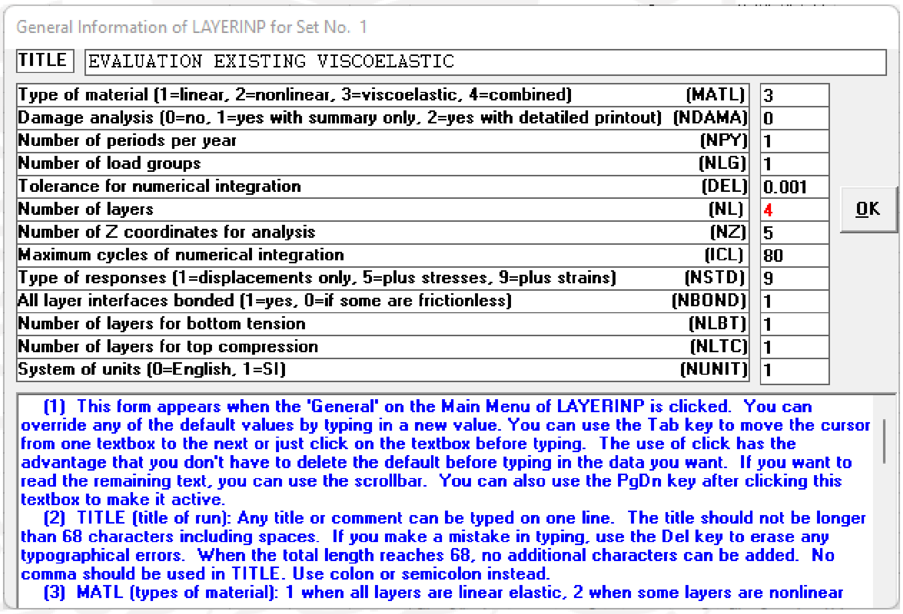
In the General menu, fill in the values based on the data listed as shown in the following Table 5.3 and Figure 5.2.

Table 5.3 General Menu Input Parameter

Parameter	Value	Description
Title	TRIAL EXISTING VISCOELASTIC	Any title or comment can be typed on one line
MATL	3	In the analysis, the type of viscoelastic material is selected
NDAMA	0	In this analysis, do not use damage analysis
NPY	1	Following the defaults in the program
NLG	1	Following the defaults in the program
DEL	0.001	Accuration standard
NL	5	The number of pavement layers to be analyzed is 5 (surface, base, subbase, subgrade)

Continuation of Table 5.3 General Menu Input Parameter

Parameter	Value	Description
NZ	5	The location of the Z coordinates to be analyzed
ICL	80	Following the defaults in the program
NSDT	9	To run damage analysis in the form of vertical displacement, four stress and four strains
NBONT	1	All interfaces are bonded
NLBT	1	Following the defaults in the program
NLTC	1	Following the defaults in the program
NUNIT	1	The unit used is SI (International Standard)



General Information of LAYERINP for Set No. 1

TITLE: EVALUATION EXISTING VISCOELASTIC

Type of material (1=linear, 2=nonlinear, 3=viscoelastic, 4=combined)	(MATL)	3
Damage analysis (0=no, 1=yes with summary only, 2=yes with detatiled printout)	(NDAMA)	0
Number of periods per year	(NPY)	1
Number of load groups	(NLG)	1
Tolerance for numerical integration	(DEL)	0.001
Number of layers	(NL)	4
Number of Z coordinates for analysis	(NZ)	5
Maximum cycles of numerical integration	(ICL)	80
Type of responses (1=displacements only, 5=plus stresses, 9=plus strains)	(NSTD)	9
All layer interfaces bonded (1=yes, 0=if some are frictionless)	(NBOND)	1
Number of layers for bottom tension	(NLBT)	1
Number of layers for top compression	(NLTC)	1
System of units (0=English, 1=SI)	(NUNIT)	1

OK

(1) This form appears when the 'General' on the Main Menu of LAYERINP is clicked. You can override any of the default values by typing in a new value. You can use the Tab key to move the cursor from one textbox to the next or just click on the textbox before typing. The use of click has the advantage that you don't have to delete the default before typing in the data you want. If you want to read the remaining text, you can use the scrollbar. You can also use the PgDn key after clicking this textbox to make it active.
(2) TITLE (title of run): Any title or comment can be typed on one line. The title should not be longer than 68 characters including spaces. If you make a mistake in typing, use the Del key to erase any typographical errors. When the total length reaches 68, no additional characters can be added. No comma should be used in TITLE. Use colon or semicolon instead.
(3) MATL (types of material): 1 when all layers are linear elastic, 2 when some layers are nonlinear

Figure 5.2 General Input Data

c. Zcoord

The Zcoord data entered is the depth of the point where the damage will be repaired. In the research, the depth data that will be input is the depth of the pavement surface, flexible pavement base, foundation layer surface, foundation layer base, and subgrade as shown in Figure 5.3 below.

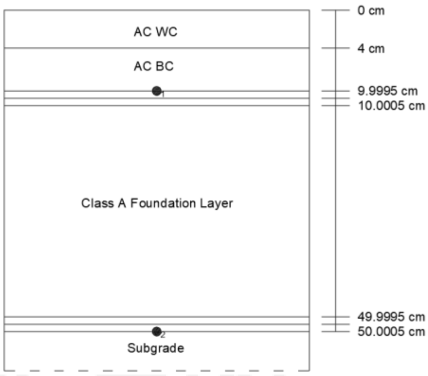


Figure 5.3 Damage Analysis Point Depth

Point one is the first point of view which is located at the base of the surface layer and point two is the second point of view which is located on the surface of the subgrade. The base of the surface layer is the location of fatigue crack damage while the subgrade surface is the location of the rutting and deformation damage. For the depth of each layer under review, it can be seen in Table 5.4 and Figure 5.4 below.

Table 5.4 Zcoord Input Data

No.	Depth (cm)	Description
1	0	Pavement surface
2	9.9995	Pavement base
3	10.0005	Foundation layer surface
4	49.9995	Base layer foundation
5	50.0005	Subgrade

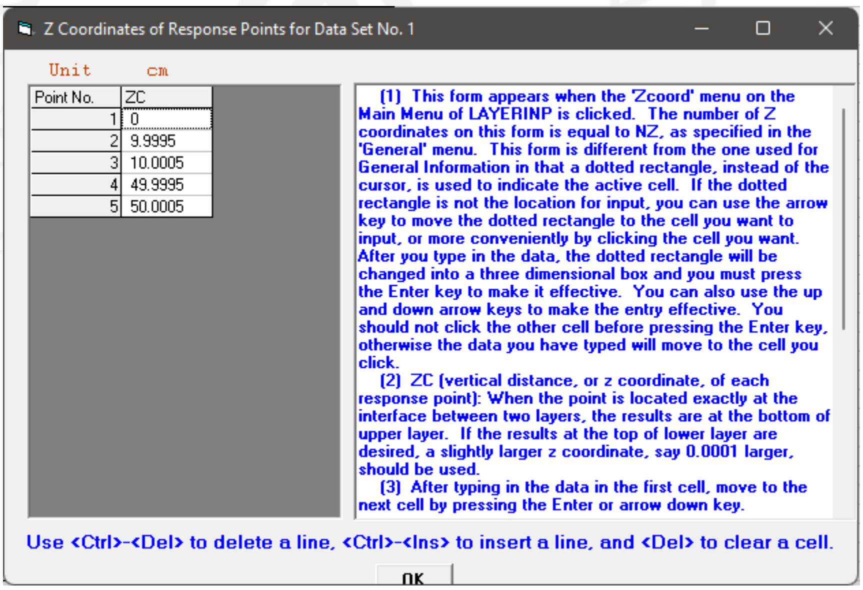


Figure 5.4 Zcoord Input Data

d. Layer

The Layer menu is used to input pavement thickness data and the Poisson's ratio value on the pavement to be analyzed. The Poisson's ratio value is obtained based on Table 5.2 Pavement Layer Parameters sourced from Bina Marga 2017. The input data for the Layer menu can be seen in Table 5.5 and Figure 5.5 below.

Table 5.5 Layer Input Data

No Layer	Thickness (cm)	Poisson's Ratio	Description
1	4	0.4	AC-WC
2	6	0.4	AC-BC
4	40	0.35	LFA A class
5	∞	0.45	Subgrade

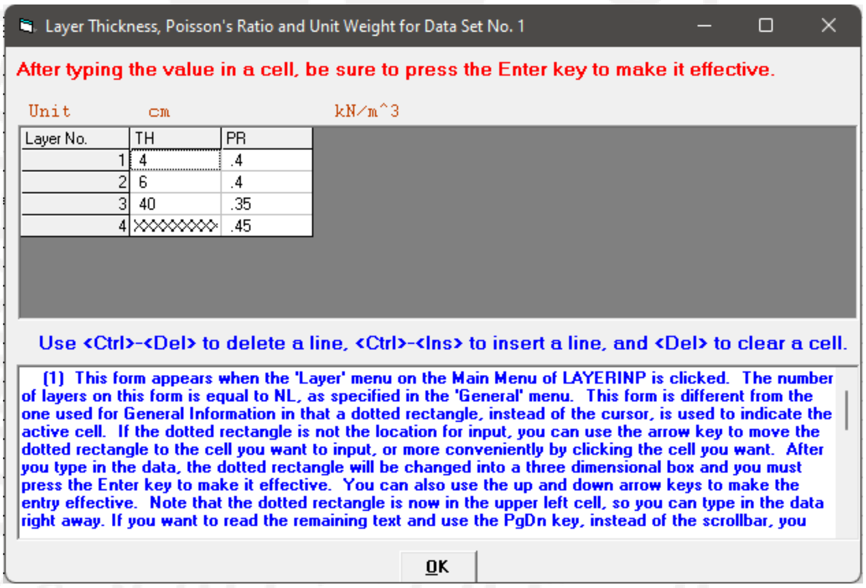


Figure 5.5 Layer Input Data

e. Moduli

The data inputted in the Moduli menu is the elastic modulus value of each pavement layer. The elastic modulus value used is based on Table 5.2 Pavement Layer Parameters sourced from Bina Marga 2017. The input data for the Moduli menu can be seen in Table 5.6 and Figure 5.6 below.

Table 5.6 Moduli Input Data

No.	Modulus of Elasticity (kPa)
1	1100000
2	1200000
3	1600000
4	250000
5	150000

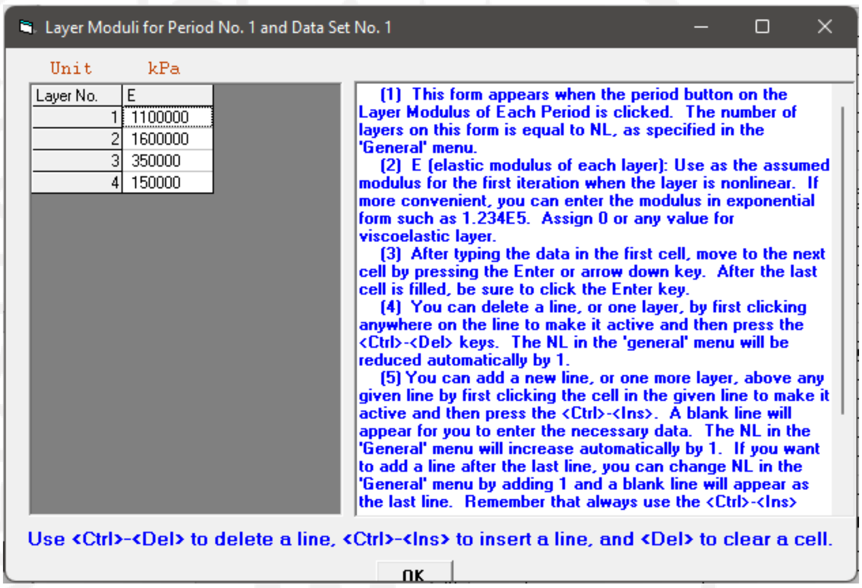


Figure 5.6 Moduli Input Data

f. Load

In this Load menu, you need data on the dimensions of the vehicle axle, tire pressure, and tire distance on dual wheels. The inputted data is based on Figure 3.16 Equivalent Standard Axis which is a load condition based on data used in Indonesia sourced from Sukirman (1993). The inputted data is as follows.

1) The standard axle load (P) of the vehicle is 8.16 tons.
2) Wheel pressure (q) for one tire is 0.55 MPa.
3) The distance between each double wheel axle is 33 cm.
4) The radius of the contact area (a) is 11 cm.

Then to input data on the Load Menu can be seen in Table 5.7 and Figure 5.7 below.

Table 5.7 Load Input Data

Parameter	Value	Description
LOAD	1	1 for single axle with dual tires
CR	11	Contact radius of circular loaded ares
CP	550	Contact pressure on circular loaded ares
YW	33	Center to center spacing between two dual wheels along the y axis
XW	0	Center to center spacing between two axles along the x axis
NR or NPT	3	Number of points in x and y coordinates to be analyzed under multiple wheels

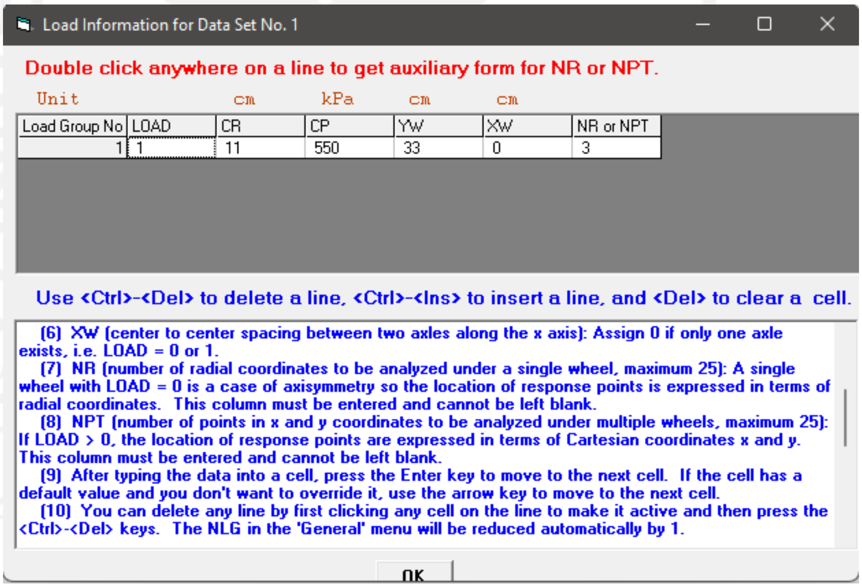


Figure 5.7 Load Input Data

5) Then for the NPT value itself, the coordinate value under review is 3, with the X and Y coordinate values which can be seen in Table 5.8 below and Figure 5.8 below.

Table 5.8 NPT Coordinate

X (cm)	Y (cm)
0	0
0	10
0	16.5

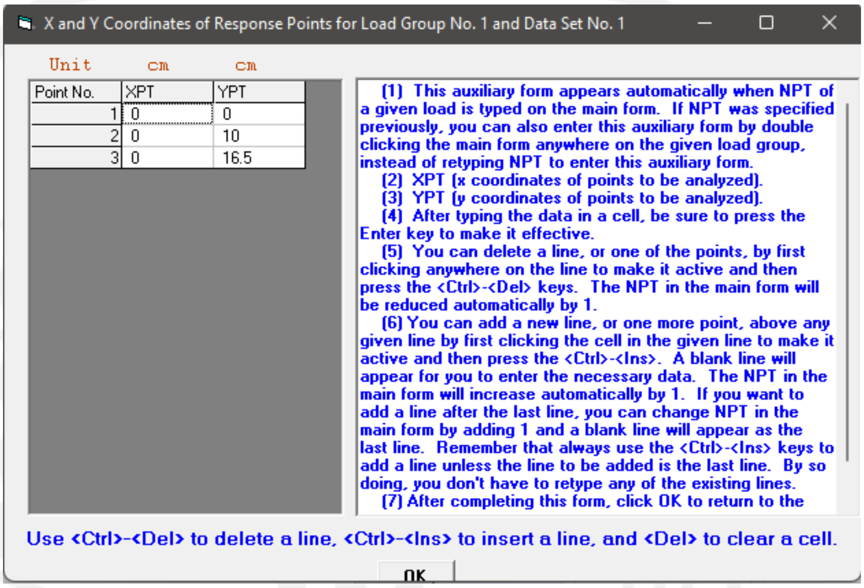


Figure 5.8 NPT Coordinate Input Data

g. Viscoelastic

Because this analysis uses Viscoelastic modelling, the Viscoelastic menu is filled with the following input data.

1) General

On the General menu there are several parameters that must be inputted as follows.

a) Load Duration (DUR) = 0.1

b) Number of viscoelastic layers = 3

c) Number of time durations for creep compliances = 11

2) Time

The Time menu contains Creep Compliances input data which is calculated using 11-time variations as shown in Table 5.9 below.

Table 5.9 Creep Compliances Time Duration

Sequences	Time (second)
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

In the Layer menu, there are input data for temperature shift coefficient (BETA) and reference temperature for each layer, which is a layer of viscoelastic material as follows.

a) BETA = 0.113 Huang (2004)

b) TEMPREF = 25^{o}C

4) Creep Compliances

Creep compliance is ratio between variation of strain or the total load strain and constant stress. The number of creep compliances on this form is equal to NTYME, as specified in the Viscoelastic General Information. TYME is the time at which the creep compliance is needed. The value of creep compliances can be seen in Table 5.10 below.

Table 5.10 Creep Compliances Value

Time	Creep (per kPa)
0.001	9.162×10^{-7}
0.003	9.303×10^{-7}
0.01	9.778×10^{-7}
0.03	1.098×10^{-6}
0.1	1.393×10^{-6}
0.3	1.746×10^{-6}
1	2.152×10^{-6}
3	2.599×10^{-6}
10	3.276×10^{-6}
30	5.095×10^{-6}
100	1.146×10^{-5}

Source: Huang (2004)

5) Temperature

In the Temperature menu, the input data is the same as the temperature in the input in the previous menu, 25^{o}C.

3. Analysis Results

The results of the Kenpave program analysis in this study are in the form of stress and strain values that occur at the review point of the flexible pavement layer. The first review point is at the base of the surface layer there is a radial (tangential) tensile strain response, while at the second review point located on the subgrade surface there is a vertical compressive strain response. The following is a recapitulation of the analysis results in the form of stress and strain which can be seen in Table 5.11 below.

Table 5.11 Stress and Strain Value for Existing Viscoelastic Modelling

Load Point (X)	Horizontal P Strain	Vertical Strain	Vertical Strain
	at 9.9995 cm	at 9.9995 cm	at 50.0005 cm
1	0.0002157	0.0002971	0.0002374
2	0.0001921	0.0001765	0.0002597
3	0.0001641	0.00004082	0.0002636
Maximum Value	0.0002157	0.0002971	0.0002636

From the analysis data, the horizontal principal strain value under the surface layer or HMA is 0.0002157 which is used to analyze the type of fatigue cracking damage, while for the vertical strain which is used to analyze the type of rutting and permanent deformation, it is 0.0002971 and 0.0002636.

4. Axle Load Control

Control of the number of axle loads is carried out by calculating the values of fatigue cracking (Nf), rutting ($Nd_{rutting}$), and permanent deformation ($Nd_{permanent}$) where the values from the three analyzes must be greater than the predicted CESA.

a. Fatigue cracking calculation

$$N_f = 0{,}0976\,(\varepsilon_t)^{-3{,}921}|E^*|^{-0{,}854}$$

$$N_f = 0{,}0976\,(0.0002157)^{-3{,}921}|1600000|^{-0{,}854}$$

$$N_f = 370{,}457{,}386.47\ ESAL$$

b. Rutting calculation

$$N_r = 1{,}365 \times 10^{-9}(\varepsilon_c)^{-4{,}47}$$

$$N_r = 1{,}365 \times 10^{-9}(0.0002971)^{-4{,}47}$$

$$N_r = 8{,}432{,}327.77\ ESAL$$

c. Permanent Deformation calculation

$$N_d = f_4(\varepsilon_c)^{-f_5}$$

$$N_d = 1{,}365 \times 10^{-9}(0.0002636)^{-4{,}477}$$

$$N_d = 14{,}406{,}552.59\ ESAL$$

From the above calculation, it is found that the condition of the existing pavement can accommodate the load repetition of 370,457,386.47 ESAL until Fatigue cracking occurs. This existing road pavement can also accommodate load repetitions of 8,432,327.77 ESAL until Rutting occurs and can accommodate load repetitions of 14,406,552.59 ESAL until permanent deformation occurs. Based on result above, the first distress occurs due to loading is rutting, this means that the road service life without any distress is until this time.

5.2.2 Evaluation using Linier Elastic Model

1. Data Used for Analysis

The data that will be used for analysis is wheel axle load and data for each layer of pavement. The explanation is as follows.

a. Axle Load

The wheel axle load data is based on Figure 3.16 where the wheel axle load is axle load data in Indonesia. The load condition values consist of wheel load data (P), tire pressure data (q), double wheel distance data (d), and contact area radius data (a) as follows.

5) The standard axle load (P) of the vehicle is 8.16 tons.
6) Wheel pressure (q) for one tire is 0.55 MPa.
7) The distance between each double wheel axle is 33 cm.
8) The radius of the contact area (a) is 11 cm.

c. Pavement Layer Data

In this analysis the HMA layer, foundation layer, and subgrade are assumed to use linear elastic materials. So that in this calculation only the Elastic Modulus and Poisson Ratio parameters are used, which can be seen in Table 5.12 below.

Table 5.12 Pavement Layer Parameter

AC – WC	Modulus of Elasticity (E)	1,100,000 KPa
	Poisson Ratio	0.4
AC – BC	Modulus of Elasticity (E)	1,200,000 KPa
	Poisson Ratio	0.4
AC – Base	Modulus of Elasticity (E)	1,600,000 KPa
	Poisson Ratio	0.4
Foundation Layer	Modulus of Elasticity (E)	250,000 KPa
	Poisson Ratio	0.35
Subgrade	Modulus of Elasticity (E)	150,000 KPa
	Poisson Ratio	0.45

Source: Bina Marga (2017)

2. Input Data to Kenpave

The following is the input data used to analyze the existing pavement with the results of the analysis in the form of stress and strain values.

a. Layernip

Layerinp menu is used for flexible pavement analysis. In the Layerinp menu there are several menus to fill in the data needed for analysis. Layerinp view can be seen in Figure 5.9 below.

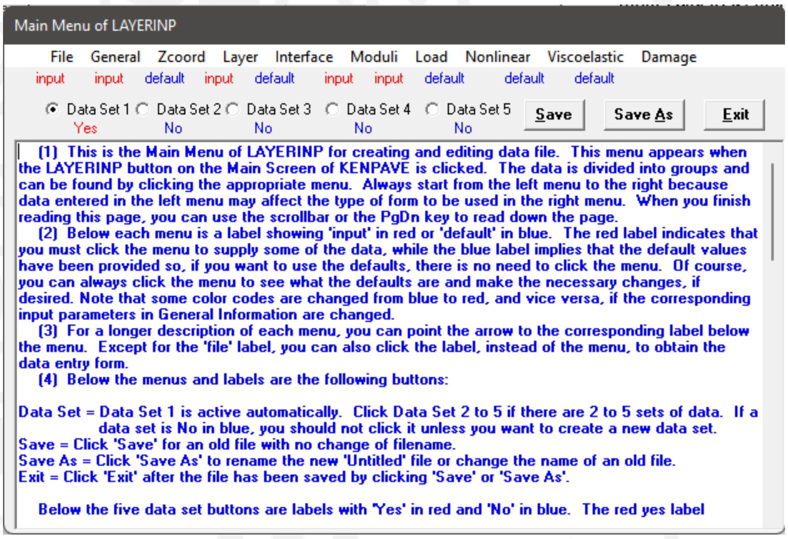


Figure 5.9 Layerinp

The next step is to click the File menu and select New to input new data.

b. General

In the General menu, fill in the values based on the data listed as shown in the following Table 5.13 and Figure 5.10 below.

Table 5.13 General Menu Input Parameter

Parameter	Value	Description
Title	TRIAL EXISTING ELASTIC	Any title or comment can be typed on one line
MATL	1	In the analysis, the type of linear elastic material is selected
NDAMA	0	In this analysis, do not use damage analysis
NPY	1	Following the defaults in the program
NLG	1	Following the defaults in the program

Continuation of Table 5.13 General Menu Input Parameter

Parameter	Value	Description
DEL	0.001	Accuration standard
NL	5	The number of pavement layers to be analyzed is 5 (surface, base, subbase, subgrade)
NZ	5	The location of the Z coordinates to be analyzed
ICL	80	Following the defaults in the program
NSDT	9	To run damage analysis in the form of vertical displacement, four stress and four strains
NBONT	1	All interfaces are bonded
NLBT	1	Following the defaults in the program
NLTC	1	Following the defaults in the program
NUNIT	1	The unit used is SI (International Standard)

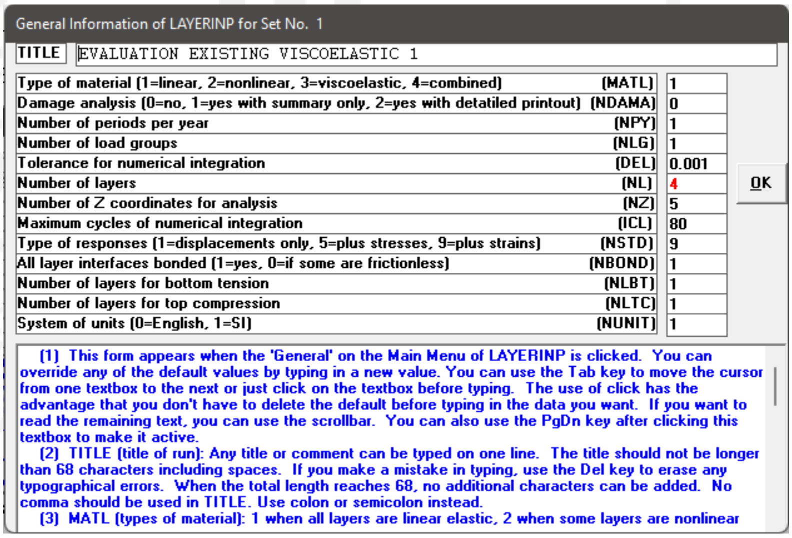


Figure 5.10 General Input Data

c. Zcoord

The Zcoord data entered is the depth of the point where the damage will be repaired. In the research, the depth data that will be input is the depth of the pavement surface, flexible pavement base, foundation layer surface, foundation layer base, and subgrade as shown in Figure 5.11 below.

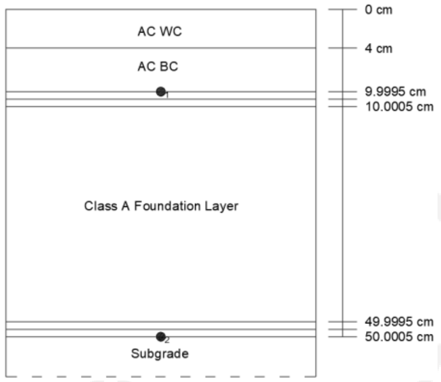


Figure 5.11 Damage Analysis Point Depth

Point one is the first point of view which is located at the base of the surface layer and point two is the second point of view which is located on the surface of the subgrade. The base of the surface layer is the location of fatigue crack damage while the subgrade surface is the location of the rutting and deformation damage. For the depth of each layer under review, it can be seen in Table 5.14 and Figure 5.12 below.

Table 5.14 Zcoord Input Data

No.	Depth (cm)	Description
1	0	Pavement surface
2	9.9995	Pavement base
3	10.0005	Foundation layer surface
4	49.9995	Base layer foundation
5	50.0005	Subgrade

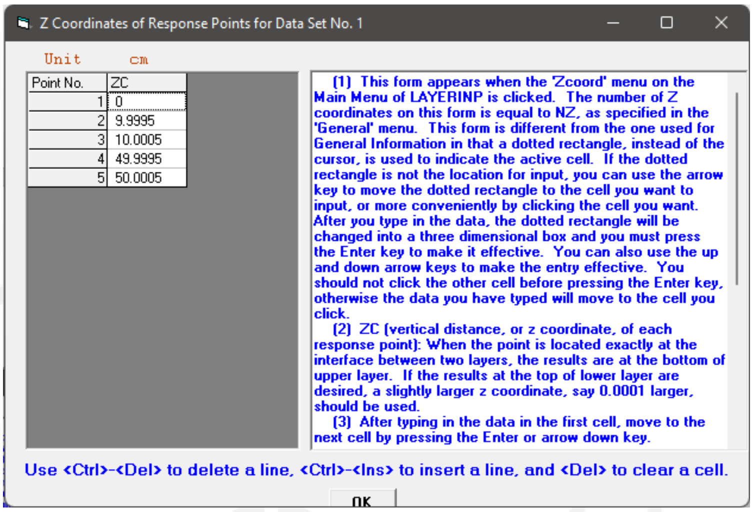


Figure 5.12 Zcoord Input Data

d. Layer

The Layer menu is used to input pavement thickness data and the Poisson's ratio value on the pavement to be analyzed. The Poisson's ratio value is obtained based on Table 5.2 Pavement Layer Parameters sourced from Bina Marga 2017. The input data for the Layer menu can be seen in Table 5.15 and Figure 5.13 below.

Table 5.15 Layer Input Data

No Layer	Thickness (cm)	Poisson's Ratio	Description
1	4	0.4	AC-WC
2	6	0.4	AC-BC
4	40	0.35	LFA A class
5	∞	0.45	Subgrade

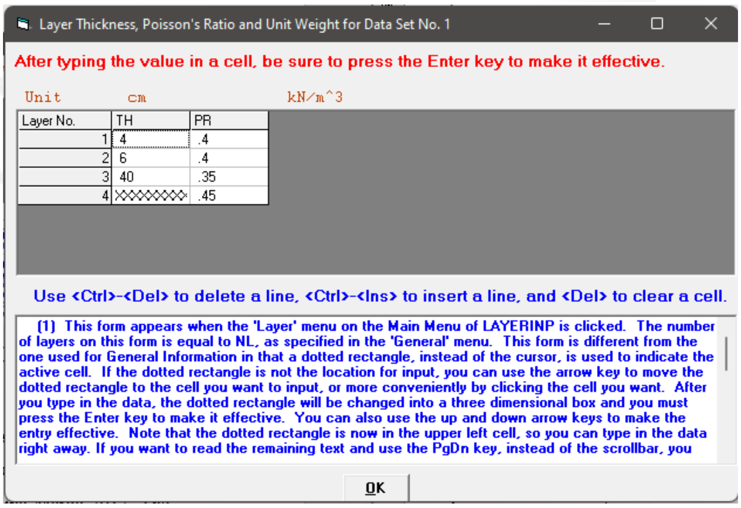


Figure 5.13 Layer Input Data

e. Moduli

The data inputted in the Moduli menu is the elastic modulus value of each pavement layer. The elastic modulus value used is based on Table 5.2 Pavement Layer Parameters sourced from Bina Marga 2017. The input data for the Moduli menu can be seen in Table 5.16 and Figure 5.14 below.

Table 5.16 Moduli Input Data

No.	Modulus of Elasticity (kPa)
1	1100000
2	1200000
3	1600000
4	250000
5	150000

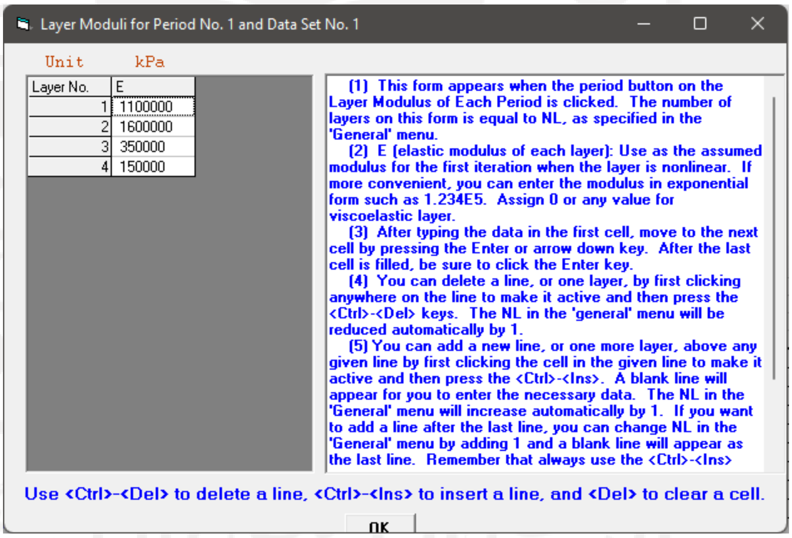


Figure 5.14 Moduli Input Data

f. Load

In this Load menu, you need data on the dimensions of the vehicle axle, tire pressure, and tire distance on dual wheels. The inputted data is based on Figure 3.16 Equivalent Standard Axis which is a load condition based on data used in Indonesia sourced from Sukirman (1993). The inputted data is as follows.

6) The standard axle load (P) of the vehicle is 8.16 tons.

7) Wheel pressure (q) for one tire is 0.55 MPa.

8) The distance between each double wheel axle is 33 cm.

9) The radius of the contact area (a) is 11 cm.

Then to input data on the Load Menu can be seen in Table 5.17 and Figure 5.15 below.

Table 5.17 Load Input Data

Parameter	Value	Description
LOAD	1	1 for single axle with dual tires
CR	11	Contact radius of circular loaded ares
YW	33	Center to center spacing between two dual wheels along the y axis
XW	0	Center to center spacing between two axles along the x axis
NR or NPT	3	Number of points in x and y coordinates to be analyzed under multiple wheels

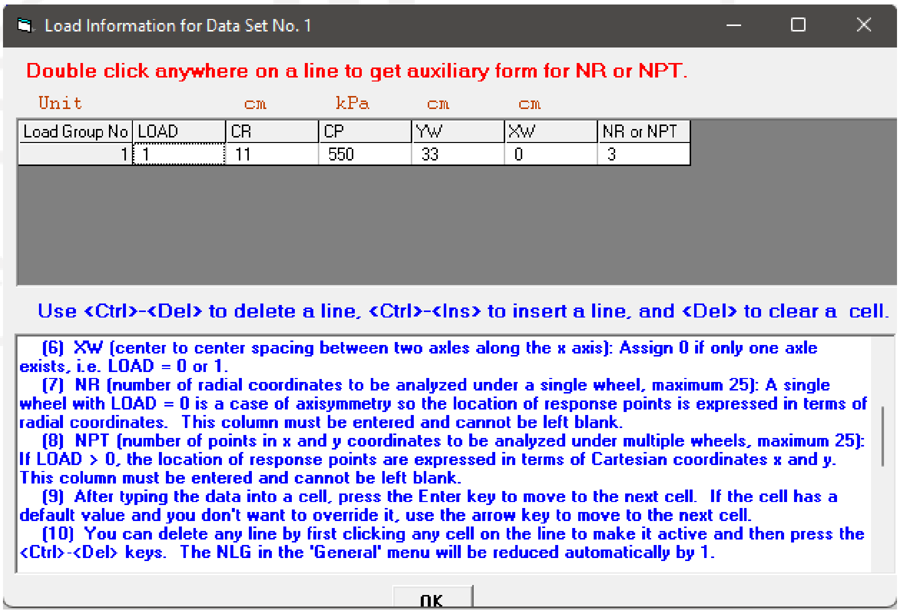


Figure 5.15 Load Input Data

10) Then for the NPT value itself, the coordinate value under review is 3, with the X and Y coordinate values which can be seen in Table 5.18 and Figure 5.16 below.

Table 5.18 NPT Coordinate

X (cm)	Y (cm)
0	0
0	10
0	16.5

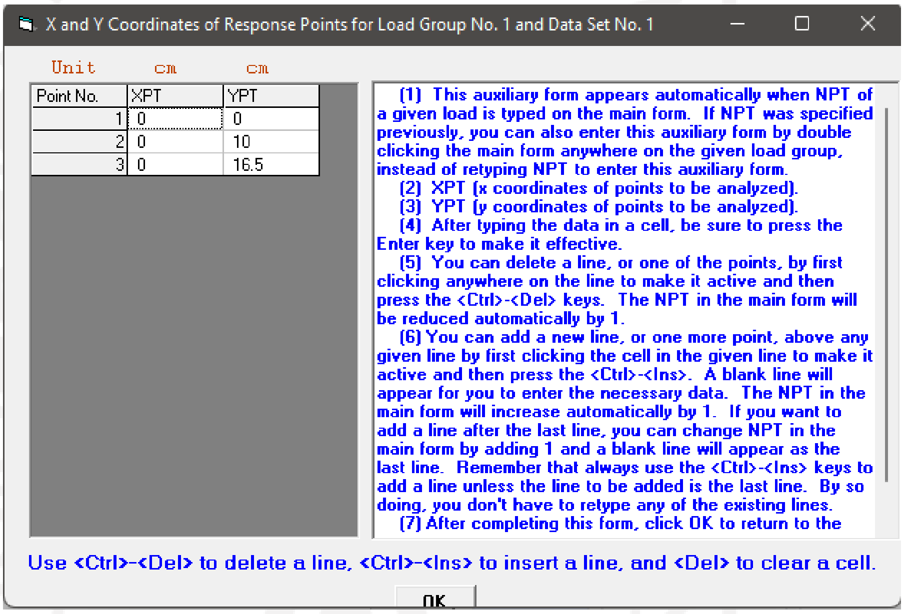


Figure 5.16 NPT Coordinate Input Data

3. Analysis Results

The results of the Kenpave program analysis in this study are in the form of stress and strain values that occur at the review point of the flexible pavement layer. The first review point is at the base of the surface layer there is a radial (tangential) tensile strain response, while at the second review point located on the subgrade surface there is a vertical compressive strain response. The following is a recapitulation of the analysis results in the form of stress and strain which can be seen in Table 5.19 below.

Table 5.19 Stress and Strain Value for Existing Linier Elastic Modelling

Load Point (X)	Horizontal P Strain	Vertical Strain	Vertical Strain
	at 9.9995 cm	at 9.9995 cm	at 50.0005 cm
1	0.0002399	0.0002823	0.0002236
2	0.0002208	0.0002004	0.0002445
3	0.0001983	0.00008963	0.0002482
Maximum Value	0.0002399	0.0002823	0.0002482

From the analysis data, the horizontal principal strain value under the surface layer or HMA is 0.0002399 which is used to analyze the type of fatigue cracking damage, while for the vertical strain which is used to analyze the type of rutting and permanent deformation, it is 0.0002823 and 0.0002482.

4. Axle Load Control

Control of the number of axle loads is carried out by calculating the values of fatigue cracking ($N_{Fatigue}$), rutting ($N_{Rutting}$), and permanent deformation ($N_{Deformation}$) where the values from the three analyzes must be greater than the predicted CESA.

d. Fatigue cracking calculation

$$N_f = 0{,}0976\ (\varepsilon_t)^{-3{,}921}|E^*|^{-0{,}854}$$

$$N_f = 0{,}0976\ (0.0002399)^{-3{,}921}|1600000|^{-0{,}854}$$

$$N_f = 229{,}181{,}921.12\ \ ESAL$$

e. Rutting calculation

$$N_r = 1{,}365\ \times\ 10^{-9}(\varepsilon_c)^{-4{,}47}$$

$$N_r = 1{,}365\ \times\ 10^{-9}(0.0002823)^{-4{,}47}$$

$$N_r = 10{,}599{,}858.06\ \text{ESAL}$$

f. Permanent Deformation calculation

$$N_d = f_4(\varepsilon_c)^{-f_5}$$

$$N_d = 1{,}365\ \times\ 10^{-9}(0.0002482)^{-4{,}477}$$

$$N_d = 18{,}862{,}753.74\ ESAL$$

From the above calculation, it is found that the condition of the existing pavement can accommodate the load repetition of 229,181,921.12 ESAL until Fatigue cracking occurs. This existing road pavement can also accommodate load repetitions of 10,599,858.06 ESAL until Rutting occurs and can accommodate load repetitions of 18,862,753.74 ESAL until permanent deformation occurs. Based on result above, the first distress occurs due to loading is rutting, this means that the road service life without any distress is until this time.

5.2.3 Comparison of Stress Strain

The results of the stress strain analysis of the existing pavement with both approaches can be seen in the Table 5.20 below.

Table 5.20 Stress Strain Value for Viscoelastic and Linear Elastic Approach

Analysis Approach	Maximum Value		
	Horizontal P Strain at 9.9995 cm	Vertical Strain at 9.9995 cm	Vertical Strain at 50.0005 cm
Viscoelastic	0.0002157	0.0002971	0.0002636
Linear Elastic	0.0002399	0.0002823	0.0002482

The results of the analysis using viscoelastic modelling for the existing pavement resulted in a tensile strain value that caused fatigue damage of 0.0002157 and the tensile strain value for rutting damage of 0.0002971, and the compressive strain value for permanent deformation damage of 0.0002636. Meanwhile, the results of the analysis using linear elastic modelling for the existing pavement resulted in a stress value causing fatigue damage of 0.0002399, strain value for rutting damage of 0.0002823, and permanent deformation damage of 0.0002482. The viscoelastic approach has a higher vertical strain than the linear elastic approach, it causes rutting damage and permanent deformation to occur first compared to the linear elastic approach and the strain value results in smaller axle load repetitions compared to the axle load repetitions from the linear elastic approach.

5.2.4 Road Service Life Prediction for Existing Pavement

From the analysis of the existing pavement with empirical mechanistic methods using the KENPAVE program, the value of each damage that occurs after repeated loads is obtained which can be seen in the Table 5.21 below.

Table 5.21 Load Repetition for Existing

Damage Type	Viscoelastic Model	Linear Elastic Model
	ESAL	ESAL
Fatigue ($N_{Fatigue}$)	370,457,386.47	229,181,921.12
Rutting ($N_{Rutting}$)	8,432,327.77	10,599,858.06
Permanent Deformation ($N_{Deformation}$)	14,406,552.59	18,862,753.74

If the load repetition results from the KENPAVE analysis are compared with the Cumulative Equivalent Standard Axle (CESA 5) value based on load repetitions according to traffic data, the comparison results can be seen in Table 5.22 below.

Table 5.22 Load Repetition Comparison for Viscoelastic Model

SL	**CESA 5 PLAN**	**CESA 5 Damage Analysis**		**DESCRIPTION**			
1	644,225.00	($N_{Fatigue}$)	370,457,386.47	($N_{Fatigue}$)	>	(N_{Plan})	YES
	644,225.00	($N_{Rutting}$)	8,432,327.77	($N_{Rutting}$)	>	(N_{Plan})	YES
	644,225.00	($N_{Deformation}$)	14,406,552.59	($N_{Deformation}$)	>	(N_{Plan})	YES
2	1,288,675.48	($N_{Fatigue}$)	370,457,386.47	($N_{Fatigue}$)	>	(N_{Plan})	YES
	1,288,675.48	($N_{Rutting}$)	8,432,327.77	($N_{Rutting}$)	>	(N_{Plan})	YES
	1,288,675.48	($N_{Deformation}$)	14,406,552.59	($N_{Deformation}$)	>	(N_{Plan})	YES
3	1,933,351.52	($N_{Fatigue}$)	370,457,386.47	($N_{Fatigue}$)	>	(N_{Plan})	YES
	1,933,351.52	($N_{Rutting}$)	8,432,327.77	($N_{Rutting}$)	>	(N_{Plan})	YES
	1,933,351.52	($N_{Deformation}$)	14,406,552.59	($N_{Deformation}$)	>	(N_{Plan})	YES
4	2,578,253.19	($N_{Fatigue}$)	370,457,386.47	($N_{Fatigue}$)	>	(N_{Plan})	YES
	2,578,253.19	($N_{Rutting}$)	8,432,327.77	($N_{Rutting}$)	>	(N_{Plan})	YES
	2,578,253.19	($N_{Deformation}$)	14,406,552.59	($N_{Deformation}$)	>	(N_{Plan})	YES

Continuation of Table 5.22 Load Repetition Comparison for Viscoelastic Model

SL	CESA 5 PLAN	CESA 5 DAMAGE		DESCRIPTION			
5	3,223,380.58	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue})$	>	(N_{Plan})	YES
	3,223,380.58	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting})$	>	(N_{Plan})	YES
	3,223,380.58	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation})$	>	(N_{Plan})	YES
6	3,868,733.76	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue})$	>	(N_{Plan})	YES
	3,868,733.76	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting})$	>	(N_{Plan})	YES
	3,868,733.76	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation})$	>	(N_{Plan})	YES
7	4,514,312.82	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue})$	>	(N_{Plan})	YES
	4,514,312.82	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting})$	>	(N_{Plan})	YES
	4,514,312.82	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation})$	>	(N_{Plan})	YES
8	5,160,117.83	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue})$	>	(N_{Plan})	YES
	5,160,117.83	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting})$	>	(N_{Plan})	YES
	5,160,117.83	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation})$	>	(N_{Plan})	YES
9	5,806,148.87	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue})$	>	(N_{Plan})	YES
	5,806,148.87	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting})$	>	(N_{Plan})	YES
	5,806,148.87	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation})$	>	(N_{Plan})	YES
10	6,452,406.02	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue})$	>	(N_{Plan})	YES
	6,452,406.02	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting})$	>	(N_{Plan})	YES
	6,452,406.02	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation})$	>	(N_{Plan})	YES
11	7,098,889.36	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue})$	>	(N_{Plan})	YES
	7,098,889.36	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting})$	>	(N_{Plan})	YES
	7,098,889.36	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation})$	>	(N_{Plan})	YES
12	7,745,598.97	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue})$	>	(N_{Plan})	YES
	7,745,598.97	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting})$	>	(N_{Plan})	YES
	7,745,598.97	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation})$	>	(N_{Plan})	YES
13	8,392,534.93	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue})$	>	(N_{Plan})	YES
	8,392,534.93	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting})$	>	(N_{Plan})	YES
	8,392,534.93	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation})$	>	(N_{Plan})	YES

Continuation of Table 5.21 Load Repetition Comparison for Viscoelastic Model

SL	CESA 5 PLAN	CESA 5 DAMAGE		DESCRIPTION	
14	9,039,697.32	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue}) > (N_{Plan})$	YES
	9,039,697.32	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting}) < (N_{Plan})$	NO
	9,039,697.32	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation}) > (N_{Plan})$	YES
15	9,687,086.21	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue}) > (N_{Plan})$	YES
	9,687,086.21	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting}) < (N_{Plan})$	NO
	9,687,086.21	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation}) > (N_{Plan})$	YES
16	10,334,701.69	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue}) > (N_{Plan})$	YES
	10,334,701.69	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting}) < (N_{Plan})$	NO
	10,334,701.69	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation}) > (N_{Plan})$	YES
17	10,982,543.84	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue}) > (N_{Plan})$	YES
	10,982,543.84	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting}) < (N_{Plan})$	NO
	10,982,543.84	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation}) > (N_{Plan})$	YES
18	11,630,612.73	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue}) > (N_{Plan})$	YES
	11,630,612.73	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting}) < (N_{Plan})$	NO
	11,630,612.73	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation}) > (N_{Plan})$	YES
19	12,278,908.44	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue}) > (N_{Plan})$	YES
	12,278,908.44	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting}) < (N_{Plan})$	NO
	12,278,908.44	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation}) > (N_{Plan})$	YES
20	12,927,431.06	$(N_{Fatigue})$	370,457,386.47	$(N_{Fatigue}) > (N_{Plan})$	YES
	12,927,431.06	$(N_{Rutting})$	8,432,327.77	$(N_{Rutting}) < (N_{Plan})$	NO
	12,927,431.06	$(N_{Deformation})$	14,406,552.59	$(N_{Deformation}) > (N_{Plan})$	YES

From the comparison for Viscoelastic Model results in table 5.20 it can be seen that the pavement conditions are able to accommodate the load repetitions until the damage occurs for the first time, namely in the 14th year with load repetitions that occur at 9,687,086.21 ESA and load repetitions until damage occurs at

8,432,327.77 ESA with the first damage being rutting. As for the load repetition comparison with the Linear Elastic model, it can be seen in Table 5.23 below.

Table 5.23 Load Repetition Comparison for Linear Elastic Model

SL	CESA 5 PLAN	CESA 5 DAMAGE		DESCRIPTION			
1	644,225.00	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	644,225.00	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	644,225.00	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
2	1,288,675.48	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	1,288,675.48	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	1,288,675.48	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
3	1,933,351.52	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	1,933,351.52	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	1,933,351.52	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
4	2,578,253.19	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	2,578,253.19	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	2,578,253.19	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
5	3,223,380.58	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	3,223,380.58	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	3,223,380.58	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
6	3,868,733.76	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	3,868,733.76	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	3,868,733.76	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
7	4,514,312.82	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	4,514,312.82	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	4,514,312.82	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
8	5,160,117.83	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	5,160,117.83	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	5,160,117.83	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
9	5,806,148.87	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	5,806,148.87	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	5,806,148.87	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES

Continuation of Table 5.23 Load Repetition Comparison for Linear Elastic Model

SL	CESA 5 PLAN	CESA 5 DAMAGE		DESCRIPTION			
10	6,452,406.02	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	6,452,406.02	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	6,452,406.02	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
11	7,098,889.36	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	7,098,889.36	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	7,098,889.36	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
12	7,745,598.97	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	7,745,598.97	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	7,745,598.97	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
13	8,392,534.93	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	8,392,534.93	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	8,392,534.93	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
14	9,039,697.32	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	9,039,697.32	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	9,039,697.32	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
15	9,687,086.21	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	9,687,086.21	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	9,687,086.21	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
16	10,334,701.69	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	10,334,701.69	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	>	(N_{Plam})	YES
	10,334,701.69	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
17	10,982,543.84	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	10,982,543.84	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	<	(N_{Plam})	NO
	10,982,543.84	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES
18	11,630,612.73	$(N_{Fatigue})$	229,181,921.12	$(N_{Fatigue})$	>	(N_{Plam})	YES
	11,630,612.73	$(N_{Rutting})$	10,599,858.06	$(N_{Rutting})$	<	(N_{Plam})	NO
	11,630,612.73	$(N_{Deformation})$	18,862,753.74	$(N_{Deformation})$	>	(N_{Plam})	YES

Continuation of Table 5.23 Load Repetition Comparison for Linear Elastic Model

SL	CESA 5 PLAN	CESA 5 DAMAGE		DESCRIPTION			
19	12,278,908.44	($N_{Fatigue}$)	229,181,921.12	($N_{Fatigue}$)	>	(N_{Plam})	YES
	12,278,908.44	($N_{Rutting}$)	10,599,858.06	($N_{Rutting}$)	<	(N_{Plam})	NO
	12,278,908.44	($N_{Deformation}$)	18,862,753.74	($N_{Deformation}$)	>	(N_{Plam})	YES
20	12,927,431.06	($N_{Fatigue}$)	229,181,921.12	($N_{Fatigue}$)	>	(N_{Plam})	YES
	12,927,431.06	($N_{Rutting}$)	10,599,858.06	($N_{Rutting}$)	<	(N_{Plam})	NO
	12,927,431.06	($N_{Deformation}$)	18,862,753.74	($N_{Deformation}$)	>	(N_{Plam})	YES

From the comparison for Linear Elastic Model results in table 5.21 it can be seen that the pavement conditions are able to accommodate the load repetitions until the damage occurs for the first time, namely in the 17th year with load repetitions that occur at 11,630,612.73 ESA and load repetitions until damage occurs at 10,599,858.06 ESA with the first damage being rutting.

While the analysis of the service life of the existing road pavement viscoelastic model using equation 3.13 are as follows.

$$SL_{Fatigue} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$SL_{Fatigue} = 100 \times \left(1 - \frac{644225.00}{370{,}457{,}386.47}\right)$$

$$SL_{Fatigue} = 99.83\%$$

$$SL_{Rutting} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$SL_{Rutting} = 100 \times \left(1 - \frac{644225.00}{8{,}432{,}327.77}\right)$$

$$SL_{Rutting} = 92.36\%$$

$$SL_{P\ Deformation} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$SL_{P\ Deformation} = 100 \times \left(1 - \frac{644225.00}{8{,}432{,}327.77}\right)$$

$$SL_{P\ Deformation} = 92.36\%$$

With the same calculation carried out until the design life is 20 years, the results of the recapitulation of the analysis of the service life prediction of the existing pavement can be seen in the Figure 5.17 below.

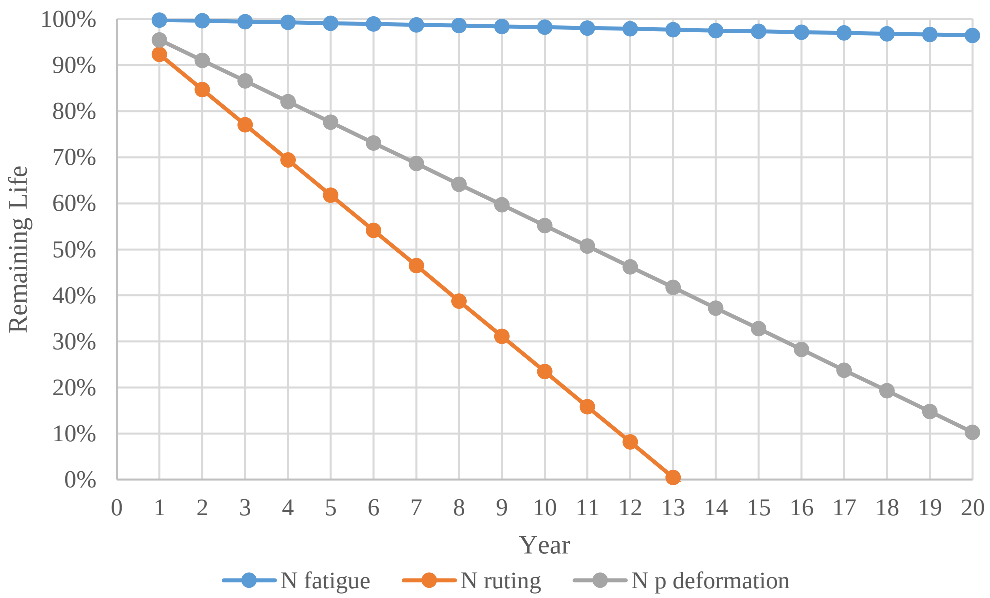


Figure 5.17 Service Life Prediction Existing Viscoelastic Model

From these results, it can be seen in the graph above that the service life prediction of the existing pavement with viscoelastic modelling is throughout the design life, namely the 20th year, the damage that occurs is fatigue cracking damage by producing a remaining service life of 96.51% and permanent deformation damage by producing a remaining service life of 10.27%, while the rutting damage occurs until the 13th age of the 20-year plan life with the remaining service life of 0.47%.

For the analysis of the service life prediction of the existing road pavement linear elastic model by using the same equation, the results of the recapitulation of the analysis of the service life prediction of the existing pavement can be seen in the Figure 5.18 below.

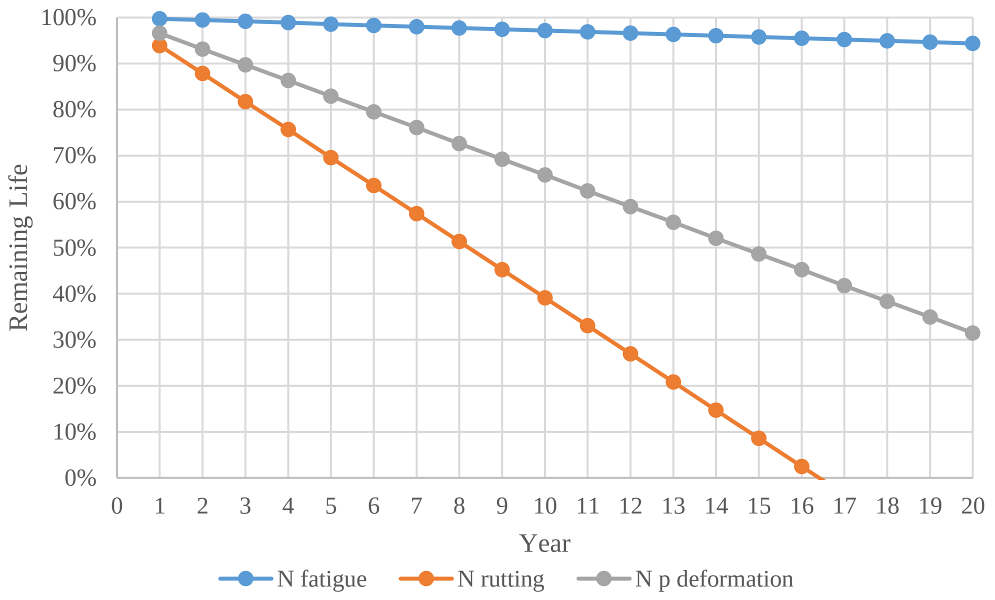


Figure 5.18 Service Life Prediction Existing Linear Model

From these results, it can be seen in the graph above that the service life prediction of the existing pavement with linear elastic modelling is throughout the design life, namely the 20th year, the damage that occurs is fatigue cracking damage by producing a remaining service life of 94.36% and permanent deformation damage by producing a remaining service life of 31.47%, while the rutting damage occurs until the 13th age of the 20-year plan life with the remaining service life of 2.50%.

Another way is to approach using equation 3.14, where the smallest load repetition is used in the calculation. In the results of the analysis with viscoelastic modelling, it produces the smallest load repetition of 8,432,327.77 ESAL where the load occurs rutting damage. The calculation is as follows.

$$\text{ESAL}_{\text{rutting}} = \Sigma_{vehicle\ type\ AADT} \times VDF \times 365 \times DD \times DL \times \frac{(1 + 0{,}01\ i)^{UR} - 1}{0{,}01\ i}$$

$$8{,}432{,}327.77 = 3428 \times 0 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$$

$$= 287 \times 0.2 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$$

$$= 225 \times 1 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$$

= $342 \times 0.5 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $391 \times 5.1 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $139 \times 6.4 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $0 \times 13 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $20 \times 9.7 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

SL = 11 Year

For the service life of the existing pavement, linear elastic modelling with the equation 3.14 approach is calculated as follows.

ESAL $_{rutting}$ = $\Sigma_{vehicle\ type\ AADT} \times VDF \times 365 \times DD \times DL \times \frac{(1 + 0{,}01\ i)^{UR} - 1}{0{,}01\ i}$

10,599,858.06 = $3428 \times 0 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $287 \times 0.2 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $225 \times 1 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $342 \times 0.5 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $391 \times 5.1 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $139 \times 6.4 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $0 \times 13 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

= $20 \times 9.7 \times 365 \times 0.5 \times 1 \times \frac{(1 + 0{,}01 \times 3.5)^{UR} - 1}{0{,}01 \times 3.5} +$

SL = 13 Year

From the results of the comparison of load repetitions and the calculation of the service life prediction, it was found that the first damage that occurred was rutting damage where the damage occurred between the 11th year to the 17th year where in that year the remaining service life of the pavement had reached the smallest value. Therefore, an alternative design is needed.

5.3 Alternative Pavement Design Using Bina Marga 2017

In designing the flexible pavement design using the 2017 Bina Marga method, several stages of work are needed as follows.

5.3.1 Traffic Analysis

In traffic analysis, there are two conditions that will be used as a design reference, namely conditions where there is average traffic data and no traffic data, which assumes that the road has low traffic. The analysis for these two conditions is as follows.

1. Traffic Analysis for first condition

   Primary data regarding vehicle distribution and traffic composition can be seen in the Table 5.23 below.

Table 5.24 Average Daily Traffic Data 2021

Vehicle Type	ADT (vehicle/day)
1	1982
2	583
3	431
4	432
5a	287
5b	225
6a	342
6b	391
7a	139
7b	0
7c	20
8	0

After that, based on the existing procedure, the parameter parameters that will be used to design the thickness of the pavement structure are determined, the results are as shown in Table 5.25 below.

Table 5.25 Data for Traffic Analysis Calculations

New Road Section	Lane	Direction
	2	2
DD	0.5	
DL	100 %	

Continuation of Table 5.25 Data for Traffic Analysis Calculations

New Road Section	Lane	Direction
	2	2
Location	Kulon Progo	
Survey	2017	
Constructed	2020	
Open	2021	
Life Plan	20	
End	2040	
i	3.5 %	
R	20.07	

Source: Bina Marga (2017)

From the available data, the Equivalent Standard Axle (ESA) can be calculated using Equations 3.2 and 3.3. The results of the calculation of this equation can be seen in the Table 5.26 below.

Table 5.26 Recapitulation of Equivalent Standard Axle Load Calculation

No	**Vehicle Type**	**LHR (2021)**	**VDF 4 ('21-'40)**	**VDF 5 ('21-'40)**	**ESA 4 ('21-'40)**	**ESA 5 ('21-'40)**
			N	N	N	N
	1	2	3	4	5	6
1	1,2,3,4	3428	0	0	0.00	0.00
2	5A	287	0.3	0.2	315,155.18	210,103.45
3	5B	225	1	1	825,555.90	825,555.90
4	6A	344	0.55	0.5	689,428.11	626,752.83
5	6B	599	4	5.1	5,725,528.35	7,300,048.65
6	7A	253	4.7	6.4	2,390,031.41	3,254,510.85
7	7B	0	9.4	13	0.00	0.00
8	7C	20	7.4	9.7	541,999.94	710,459.38
			CESA		10,487,698.89	12,927,431.06
			CESA (million)		10.49	12.93
					CESA4	**CESA5**

5.3.2 Selection of Pavement Structure

The selection of the structure is carried out based on Table 3.7 based on the ESA value in 20 years which results in several Design Chart options which are the basis for selecting the pavement structure. The results of the selection of pavement structures can be seen in Table 5.27 below.

Table 5.27 Pavement Structure Selection

Parameter		Value
CESA 4		10.49×10^6
CESA 5		12.93×10^6
Design Chart		**Difficulty Level**
AC WC modification or modified SMA with CTB (ESA power of 5)	3	2
AC with CTB (ESA power of 5)	3	2
AC ≥ 100 mm thick with a grained foundation layer (ESA power of 5)	3B	2

Source: Bina Marga (2017)

5.3.3 Foundation Design

Accurate determination of the strength of the subgrade and proper foundation design can produce a good pavement design. Pavement damage often occurs in the rainy season where a lot of puddles of water can absorb into the soil. The road foundation design is determined based on the CBR value and traffic load on the planned lane (million ESA5). In the Sentolo - Nanggulan - Dekso area, the CBR value of subgrade soils varies, in the area near the rice fields it has a CBR of around 2.5 % so it is necessary to improve the soil. CBR design in this analysis is 7.66 %. Determination of the foundation using Chart Design-2 Minimum Road Foundation Design Bina Marga (2017), the results of the foundation design for the two conditions can be seen in the Table 5.28 below.

Table 5.28 Foundation Design for First and Second Condition

CBR	7.66 %
Class	SG6
Traffic Load	12,927,431.06
Minimum thickness of subgrade	Flexible Pavement (mm)
	No Needed

Source: Bina Marga (2017)

5.3.4 Selection of Pavement Thickness

The selection of pavement thickness is based on the Design Chart Table that has been determined in the discussion of the selection of structures which get several design charts options, namely Chart 3 and Chart 3B at Bina Marga 2017. After getting the choice of the design chart used, the next step is to choose the pavement thickness based on the ESA5 value that has been calculated in the traffic analysis. The following are the results of selecting the pavement thickness based on the design chart as shown in Table 5.29 and Table 5.30 below.

Table 5.29 Pavement Thickness Design based on Design Chart-3

$F1^2$	
Layer Types	Thickness (mm)
AC WC	40
AC BC	60
AC Base	75
CTB	150
Foundation Aggregate Class A	150

There are some notes for pavement thickness design using Design Chart 3 as follows.

1. CTB may not be economical for roads < 10 million ESA5, refer to sections Design Chart-3A and Design Chart-3B
2. Design Chart-4 as an alternative to rigid pavement solutions on plain flat ground.

Table 5.30 Pavement Thickness Design based on Design Chart-3B

FFF4	
Layer Types	Thickness (mm)
AC WC	40
AC BC	60
AC Base	145
Foundation Aggregate Class A	300

There are some notes for pavement thickness design using Design Chart 3 as follows.

1. Chart Design-3B is used when the CTB is difficult to implement

2. The Foundation Layer Thickness according to Chart Design-3B can be reduced for a subgrade with a higher bearing capacity and a well-draining pavement structure.

Because the CBR design used is 7.66 %, it is necessary to adjust the Aggregate Base Class A thickness according to Design-3C Chart. Adjustment of Aggregate Foundation Layer Thickness A for CBR Subgrade> 6% (only for Design Chart-3B). The adjusted LFA can be seen in the Table 5.31 below.

Table 5.31 Adjusted LFA A Thickness for 1st Condition

CBR of Subgrade	Adjusted LFA A Thickness
7.66 %	300

5.3.5 Road Shoulder Design

From the previous calculation, it was found that the cumulative axle load of 20 years was equal to 15.51 x 10^6 ESA4 and 19.49 x 10^6 ESA5. The main pavement structure is above 300 mm of support layer.

From these results, to calculate the planned load on the shoulder of the road, by multiplying the 20 years' cumulative axle load by 10% as in the following calculation

$$Road\ shoulder\ plan\ load = 10\% \times \text{cumulative axle load}$$

$$Road\ shoulder\ plan\ load = 10\% \times 10.49 \text{ x } 10^6$$

$$Road\ shoulder\ plan\ load \approx 1.049 \text{ x } 10^6$$

Furthermore, based on Design Chart-7 for a load of 1.049 x 10^6 ESA4 and a CBR of 7.66% a cover of 390 mm thick is required. The total thickness of the main lane pavement for flexible pavement is 545 mm, which is greater than the minimum thickness of pavement required for shoulder roads of 400 mm.

The thickness of the main lane asphalt layer is 245 mm, so the surface of the shoulder is used in the form of an aggregate foundation layer of class S 200 mm thick. To ensure that surface water that seeps into the surface can be flowed, the pair of class A foundation layers under LFA class S is 345 mm thick where the requirements are 200 mm - 500 mm.

5.4 Alternative Pavement Design Using KENPAVE Program

Alternative pavements with empirical mechanistic methods using the KENPAVE program are also needed to determine the damage and the stress and strain values that occur. In this analysis, the pavement thickness is taken based on the Bina Marga 2017 method, after which after analyzing the damage, alternative pavements with other pavement thicknesses will be sought in order to obtain optimum results. Analysis of alternative pavement thickness using KENPAVE is as follows.

5.4.1 Pavement Alternative 1

With the same steps as in the existing pavement analysis using the KENPAVE program, the analysis is as follows.

1. Viscoelastic Model
   a. Data Used for Analysis

      The data that will be used for analysis is wheel axle load and data for each layer of pavement. The explanation is as follows.

      1) Axle Load

         The wheel axle load data is based on Figure 3.16 where the wheel axle load is axle load data in Indonesia. The load condition values consist of wheel load data (P), tire pressure data (q), double wheel distance data (d), and contact area radius data (a) as follows.

         a) The standard axle load (P) of the vehicle is 8.16 tons.
         b) Wheel pressure (q) for one tire is 0.55 MPa.
         c) The distance between each double wheel axle is 33 cm.
         d) The radius of the contact area (a) is 11 cm.

      2) Pavement Layer Data

         The analysis carried out in this study uses viscoelastic material, the foundation layer and subgrade layer are assumed to use linear elastic material. So that in this calculation only the Elastic Modulus and Poisson Ratio parameters are used, which can be seen in Table 5.32 below.

Table 5.32 Pavement Layer Parameter

AC – WC	Modulus of Elasticity (E)	1,100,000 KPa
	Poisson Ratio	0.4
AC – Base	Modulus of Elasticity (E)	1,600,000 KPa
	Poisson Ratio	0.4
Foundation Layer	Modulus of Elasticity (E)	150,000 KPa
	Poisson Ratio	0.35
Subgrade	Modulus of Elasticity (E)	150,000 KPa
	Poisson Ratio	0.45

Source: Bina Marga (2017)

b. Input Data to Kenpave

The following is the input data used to analyze the existing pavement with the results of the analysis in the form of stress and strain values.

1) Layernip

Layerinp menu is used for flexible pavement analysis. In the Layerinp menu there are several menus to fill in the data needed for analysis. Layerinp view can be seen in Figure 5.19 below.

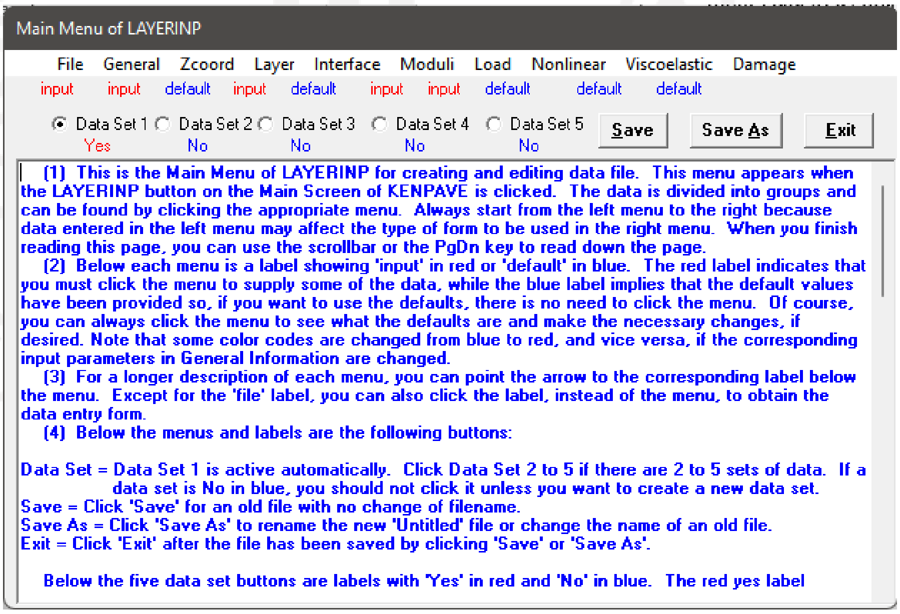


Figure 5.19 Layerinp

The next step is to click the File menu and select New to input new data.

2) General

In the General menu, fill in the values based on the data listed as shown in the following Table 5.33 below

Table 5.33 General Menu Input Parameter

Parameter	Value	Description
Title	TRIAL EXISTING VISCOELASTIC	Any title or comment can be typed on one line
MATL	3	In the analysis, the type of viscoelastic material is selected
NDAMA	0	In this analysis, do not use damage analysis
NPY	1	Following the defaults in the program
NLG	1	Following the defaults in the program
DEL	0.001	Accuration standard
NL	5	The number of pavement layers to be analyzed is 5 (surface, base, subbase, subgrade)
NZ	5	The location of the Z coordinates to be analyzed
ICL	80	Following the defaults in the program
NSDT	9	To run damage analysis in the form of vertical displacement, four stress and four strains
NBONT	1	All interfaces are bonded
NLBT	1	Following the defaults in the program
NLTC	1	Following the defaults in the program
NUNIT	1	The unit used is SI (International Standard)

3) Zcoord

The Zcoord data entered is the depth of the point where the damage will be repaired. In the research, the depth data that will be input is the depth of the pavement surface, flexible pavement base, foundation layer surface, foundation layer base, and subgrade as shown in Figure 5.20 below.

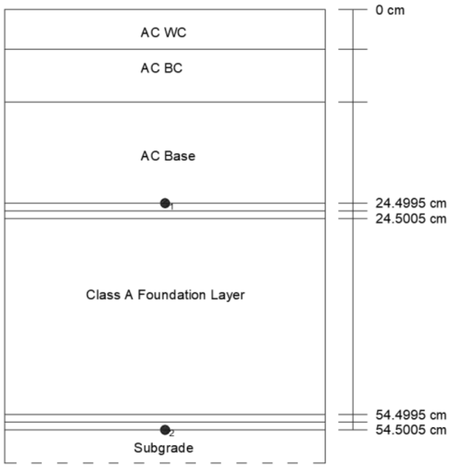


Figure 5.20 Damage Analysis Point Depth

Point one is the first point of view which is located at the base of the surface layer and point two is the second point of view which is located on the surface of the subgrade. The base of the surface layer is the location of fatigue crack damage while the subgrade surface is the location of the rutting and deformation damage. For the depth of each layer under review, it can be seen in Table 5.34 below.

Table 5.34 Zcoord Input Data

No.	Depth (cm)	Description
1	0	Pavement surface
2	24.4995	Pavement base
3	24.5005	Foundation layer surface
4	54.4995	Base layer foundation
5	54.5005	Subgrade

4) Layer

The Layer menu is used to input pavement thickness data and the Poisson's ratio value on the pavement to be analyzed. The Poisson's ratio value is obtained based on Table 5.2 Pavement Layer Parameters sourced from Bina Marga 2017. The input data for the Layer menu can be seen in Table 5.35 below.

Table 5.35 Layer Input Data

No Layer	Thickness (cm)	Poisson's Ratio	Description
1	4	0.4	AC-WC
2	6	0.4	AC-BC
3	14.5	0.4	AC-Base
4	30	0.35	LFA A class
5	∞	0.45	Subgrade

5) Moduli

The data inputted in the Moduli menu is the elastic modulus value of each pavement layer. The elastic modulus value used is based on Table 5.2 Pavement Layer Parameters sourced from Bina Marga 2017. The input data for the Moduli menu can be seen in Table 5.36 below.

Table 5.36 Moduli Input Data

No.	Modulus of Elasticity (kPa)
1	1100000
2	1200000
3	1600000
4	150000
5	150000

6) Load

In this Load menu, you need data on the dimensions of the vehicle axle, tire pressure, and tire distance on dual wheels. The inputted data is based on Figure 3.16 Equivalent Standard Axis which is a load condition based on data used in Indonesia sourced from Sukirman (1993). The inputted data is as follows.

a) The standard axle load (P) of the vehicle is 8.16 tons.
b) Wheel pressure (q) for one tire is 0.55 MPa.
c) The distance between each double wheel axle is 33 cm.
d) The radius of the contact area (a) is 11 cm.

Then to input data on the Load Menu can be seen in Table 5.37 below.

Table 5.37 Load Input Data

Parameter	Value	Description
LOAD	1	1 for single axle with dual tires
CR	11	Contact radius of circular loaded ares
CP	550	Contact pressure on circular loaded ares
YW	33	Center to center spacing between two dual wheels along the y axis
XW	0	Center to center spacing between two axles along the x axis
NR or NPT	3	Number of points in x and y coordinates to be analyzed under multiple wheels

e) Then for the NPT value itself, the coordinate value under review is 3, with the X and Y coordinate values which can be seen in Table 5.38 below.

Table 5.38 NPT Coordinate

X (cm)	Y (cm)
0	0
0	10
0	16.5

7) Viscoelastic

Because this analysis uses Viscoelastic modelling, the Viscoelastic menu is filled with the following input data.

a) General

On the General menu there are several parameters that must be inputted as follows.

1) Load Duration (DUR) = 0.1
2) Number of viscoelastic layers = 3

3) Number of time durations for creep compliances = 11

b) Time

The Time menu contains Creep Compliances input data which is calculated using 11-time variations as shown in Table 5.39 below.

Table 5.39 Creep Compliances Time Duration

Sequences	Time (second)
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)

c) Layer

In the Layer menu, there are input data for temperature shift coefficient (BETA) and reference temperature for each layer, which is a layer of viscoelastic material as follows.

1) BETA = 0.113 Huang (2004)
2) TEMPREF = 25^{o}C
3) Creep Compliances

Creep compliance is ratio between variation of strain or the total load strain and constant stress. The number of creep compliances on this form is equal to NTYME, as specified in the Viscoelastic General Information. TYME is the time at which the creep compliance is needed. The value of creep compliances can be seen in Table 5.40 below.

Table 5.40 Creep Compliances Value

Time	**Creep (per kPa)**
0.001	9.162×10^{-7}
0.003	9.303×10^{-7}
0.01	9.778×10^{-7}
0.03	1.098×10^{-6}
0.1	1.393×10^{-6}
0.3	1.746×10^{-6}
1	2.152×10^{-6}
3	2.599×10^{-6}
10	3.276×10^{-6}
30	5.095×10^{-6}
100	1.146×10^{-5}

Source: Huang (2004)

4) Temperature

In the Temperature menu, the input data is the same as the temperature in the input in the previous menu, 25^{o}C.

c. Analysis Results

The results of the Kenpave program analysis in this study are in the form of stress and strain values that occur at the review point of the flexible pavement layer. The first review point is at the base of the surface layer there is a radial (tangential) tensile strain response, while at the second review point located on the subgrade surface there is a vertical compressive strain response. The following is a recapitulation of the analysis results in the form of stress and strain which can be seen in Table 5.41 below.

Table 5.41 Stress Strain of Alternative 1 Viscoelastic Modelling

Load Point (X)	Horizontal P Strain	Vertical Strain	Vertical Strain
	at 24.4995 cm	at 24.4995 cm	at 54.5005 cm
1	0.0001840	0.0002437	0.0001986
2	0.0001941	0.0002356	0.0002154
3	0.0001944	0.0002256	0.0002185
Maximum Value	0.0001944	0.0002437	0.0002185

From the analysis data, the horizontal principal strain value under the surface layer or HMA is 0.0001944 which is used to analyze the type of fatigue cracking damage, while for the vertical strain which is used to analyze the type of rutting and permanent deformation, it is 0.0002437 and 0.0002185.

d. Axle Load Control

Control of the number of axle loads is carried out by calculating the values of fatigue cracking (Nf), rutting ($Nd_{rutting}$), and permanent deformation ($Nd_{permanent}$) where the values from the three analyzes must be greater than the predicted CESA.

1) Fatigue cracking calculation

$$N_f = 0{,}0976\ (\varepsilon_t)^{-3{,}921} |E^*|^{-0{,}854}$$

$$N_f = 0{,}0976\ (0.0001944)^{-3{,}921} |1600000|^{-0{,}854}$$

$$N_f = 142{,}763{,}295.59\ ESAL$$

2) Rutting calculation

$$N_r = 1{,}365 \times 10^{-9} (\varepsilon_c)^{-4{,}47}$$

$$N_r = 1{,}365 \times 10^{-9} (0.0002437)^{-4{,}47}$$

$$N_r = 20{,}472{,}951.01\ ESAL$$

3) Permanent Deformation calculation

$$N_d = f_4 (\varepsilon_c)^{-f_5}$$

$$N_d = 1{,}365 \times 10^{-9} (0.0002185)^{-4{,}477}$$

$$N_d = 33{,}374{,}022.06\ ESAL$$

From the above calculation, it is found that the condition of the existing pavement can accommodate the load repetition of 142,763,295.59 ESAL until Fatigue cracking occurs. This existing road pavement can also accommodate load repetitions of 20,472,951.01 ESAL until Rutting occurs and can accommodate load repetitions of 33,374,022.06 ESAL until permanent deformation occurs.

2. Linear Elastic Model

a. Data Used for Analysis

The data that will be used for analysis is wheel axle load and data for each layer of pavement. The explanation is as follows.

1) Axle Load

The wheel axle load data is based on Figure 3.16 where the wheel axle load is axle load data in Indonesia. The load condition values consist of wheel load data (P), tire pressure data (q), double wheel distance data (d), and contact area radius data (a) as follows.

e) The standard axle load (P) of the vehicle is 8.16 tons.

f) Wheel pressure (q) for one tire is 0.55 MPa.

g) The distance between each double wheel axle is 33 cm.

h) The radius of the contact area (a) is 11 cm.

2) Pavement Layer Data

The analysis carried out in this study uses viscoelastic material, the foundation layer and subgrade layer are assumed to use linear elastic material. So that in this calculation only the Elastic Modulus and Poisson Ratio parameters are used, which can be seen in Table 5.42 below.

Table 5.42 Pavement Layer Parameter

AC – WC	Modulus of Elasticity (E)	1,100,000 KPa
	Poisson Ratio	0.4

Continuation of Table 5.41 Pavement Layer Parameter

AC – Base	Modulus of Elasticity (E)	1,600,000 KPa
	Poisson Ratio	0.4
Foundation Layer	Modulus of Elasticity (E)	150,000 KPa
	Poisson Ratio	0.35
Subgrade	Modulus of Elasticity (E)	150,000 KPa
	Poisson Ratio	0.45

Source: Bina Marga (2017)

b. Input Data to Kenpave

The following is the input data used to analyze the existing pavement with the results of the analysis in the form of stress and strain values.

1) Layernip

Layerinp menu is used for flexible pavement analysis. In the Layerinp menu there are several menus to fill in the data needed for analysis. Layerinp view can be seen in Figure 5.21 below.

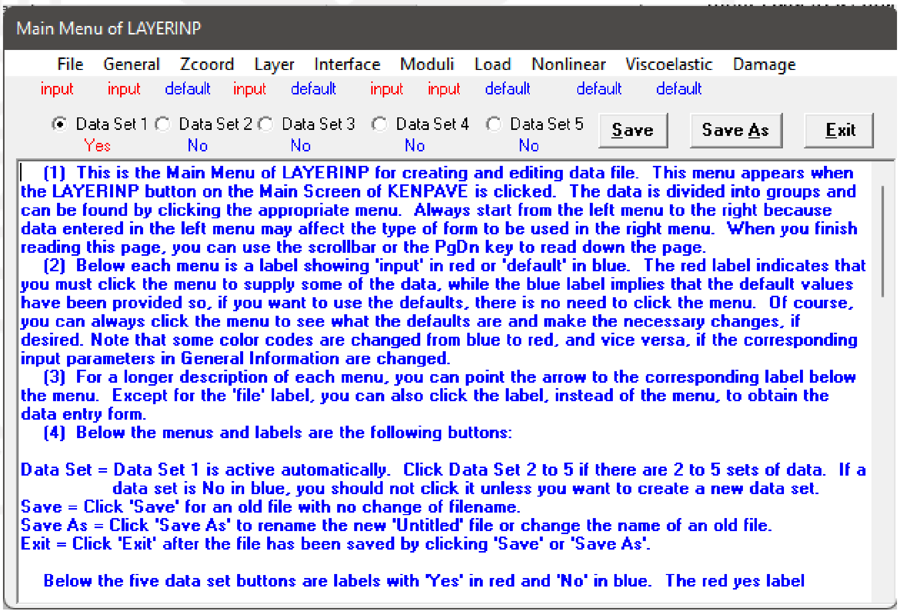


Figure 5.21 Layerinp

The next step is to click the File menu and select New to input new data.

2) General

In the General menu, fill in the values based on the data listed as shown in the following Table 5.43 below.

Table 5.43 General Menu Input Parameter

Parameter	Value	Description
Title	TRIAL EXISTING VISCOELASTIC	Any title or comment can be typed on one line
MATL	3	In the analysis, the type of viscoelastic material is selected
NDAMA	0	In this analysis, do not use damage analysis
NPY	1	Following the defaults in the program
NLG	1	Following the defaults in the program
DEL	0.001	Accuration standard
NL	5	The number of pavement layers to be analyzed is 5 (surface, base, subbase, subgrade)
NZ	5	The location of the Z coordinates to be analyzed
ICL	80	Following the defaults in the program
NSDT	9	To run damage analysis in the form of vertical displacement, four stress and four strains
NBONT	1	All interfaces are bonded
NLBT	1	Following the defaults in the program
NLTC	1	Following the defaults in the program
NUNIT	1	The unit used is SI (International Standard)

3) Zcoord

The Zcoord data entered is the depth of the point where the damage will be repaired. In the research, the depth data that will be input is the depth of the pavement surface, flexible pavement base, foundation layer surface, foundation layer base, and subgrade as shown in Figure 5.22 below.

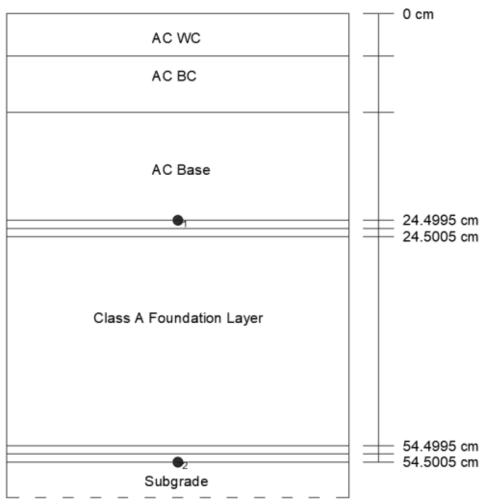


Figure 5.22 Damage Analysis Point Depth

Point one is the first point of view which is located at the base of the surface layer and point two is the second point of view which is located on the surface of the subgrade. The base of the surface layer is the location of fatigue crack damage while the subgrade surface is the location of the rutting and deformation damage. For the depth of each layer under review, it can be seen in Table 5.44 below.

Table 5.44 Zcoord Input Data

No.	Depth (cm)	Description
1	0	Pavement surface
2	24.4995	Pavement base
3	24.5005	Foundation layer surface
4	54.4995	Base layer foundation
5	54.5005	Subgrade

4) Layer

The Layer menu is used to input pavement thickness data and the Poisson's ratio value on the pavement to be analyzed. The Poisson's ratio value is obtained based on Table 5.2 Pavement Layer Parameters sourced from Bina Marga 2017. The input data for the Layer menu can be seen in Table 5.45 below.

Table 5.45 Layer Input Data

No Layer	Thickness (cm)	Poisson's Ratio	Description
1	4	0.4	AC-WC
2	6	0.4	AC-BC
3	14.5	0.4	AC-Base
4	30	0.35	LFA A class
5	∞	0.45	Subgrade

5) Moduli

The data inputted in the Moduli menu is the elastic modulus value of each pavement layer. The elastic modulus value used is based on Table 5.2 Pavement Layer Parameters sourced from Bina Marga 2017. The input data for the Moduli menu can be seen in Table 5.46 below.

Table 5.46 Moduli Input Data

No.	Modulus of Elasticity (kPa)
1	1100000
2	1200000
3	1600000
4	150000
5	150000

6) Load

In this Load menu, you need data on the dimensions of the vehicle axle, tire pressure, and tire distance on dual wheels. The inputted data is based on Figure 3.16 Equivalent Standard Axis which is a load condition based on data used in Indonesia sourced from Sukirman (1993). The inputted data is as follows.

a) The standard axle load (P) of the vehicle is 8.16 tons.
b) Wheel pressure (q) for one tire is 0.55 MPa.
c) The distance between each double wheel axle is 33 cm.
d) The radius of the contact area (a) is 11 cm.

Then to input data on the Load Menu can be seen in Table 5.47 below.

Table 5.47 Load Input Data

Parameter	Value	Description
LOAD	1	1 for single axle with dual tires
CR	11	Contact radius of circular loaded ares
CP	550	Contact pressure on circular loaded ares
YW	33	Center to center spacing between two dual wheels along the y axis
XW	0	Center to center spacing between two axles along the x axis
NR or NPT	3	Number of points in x and y coordinates to be analyzed under multiple wheels

e) Then for the NPT value itself, the coordinate value under review is 3, with the X and Y coordinate values which can be seen in Table 5.48 below.

Table 5.48 NPT Coordinate

X (cm)	Y (cm)
0	0
0	10
0	16.5

c. Analysis Results

The results of the Kenpave program analysis in this study are in the form of stress and strain values that occur at the review point of the flexible pavement layer. The first review point is at the base of the surface layer there is a radial (tangential) tensile strain response, while at the second review point located on the subgrade surface there is a vertical compressive strain response. The following is a recapitulation of the analysis results in the form of stress and strain which can be seen in Table 5.49 below.

Table 5.49 Stress Strain of Alternative 1 Linear Elastic Modelling

Load Point (X)	Horizontal P Strain	Vertical Strain	Vertical Strain
	at 24.4995 cm	at 24.4995 cm	at 54.5005 cm
1	0.0001657	0.0002003	0.0001702
2	0.0001740	0.0001937	0.0001831
3	0.0001741	0.0001856	0.0001855
Maximum Value	0.0001741	0.0002003	0.0001855

From the analysis data, the horizontal principal strain value under the surface layer or HMA is 0.0001741 which is used to analyze the type of fatigue cracking damage, while for the vertical strain which is used to analyze the type of rutting and permanent deformation, it is 0.0002003 and 0.0001855.

d. Axle Load Control

Control of the number of axle loads is carried out by calculating the values of fatigue cracking (Nf), rutting (Nd $_{rutting}$), and permanent deformation (Nd $_{permanent}$) where the values from the three analyzes must be greater than the predicted CESA.

4) Fatigue cracking calculation

$$N_f = 0{,}0976\ (\varepsilon_t)^{-3{,}921}|E^*|^{-0{,}854}$$

$$N_f = 0{,}0976\ (0.0001741)^{-3{,}921}|1600000|^{-0{,}854}$$

$$N_f = 219{,}999{,}969.70\ ESAL$$

5) Rutting calculation

$$N_r = 1{,}365\ \times\ 10^{-9}(\varepsilon_c)^{-4{,}47}$$

$$N_r = 1{,}365\ \times\ 10^{-9}(0.0002003)^{-4{,}47}$$

$$N_r = 49{,}261{,}433.02\ ESAL$$

6) Permanent Deformation calculation

$$N_d = f_4(\varepsilon_c)^{-f_5}$$

$$N_d = 1{,}365\ \times\ 10^{-9}(0.0001855)^{-4{,}477}$$

$$N_d = 69{,}463{,}545.85\ ESAL$$

From the above calculation, it is found that the condition of the alternative pavement 1 can accommodates the load repetition of 219,999,969.70 ESAL until Fatigue cracking occurs. This alternative pavement 1 can also accommodate load repetitions of 49,261,433.02 ESAL until Rutting occurs and can accommodate load repetitions of 69,463,545.85 ESAL until permanent deformation occurs.

5.4.2 Pavement Alternative 2

Alternative 1 pavement is pavement with F1^2 code, the result of analysis using Bina Marga 2017. With the same analytical steps as the previous analysis, the results obtained from the analysis of pavement alternatives 2 are as follows.

1. Viscoelastic Model

a. Analysis Result

The results of the Kenpave program analysis in this study are in the form of stress and strain values that occur at the review point of the flexible pavement layer. The first review point is at the base of the surface layer there is a radial (tangential) tensile strain response, while at the second review point located on the subgrade surface there is a vertical compressive strain response. The following is a recapitulation of the analysis results in the form of stress and strain which can be seen in Table 5.49 below.

Table 5.50 Stress Strain of Alternative 2 Viscoelastic Modelling

Load Point (X)	Horizontal P Strain	Vertical Strain	Vertical Strain
	at 17.4995 cm	at 17.4995 cm	at 47.5005 cm
1	0.0001459	0.0002491	0.0002221
2	0.0001449	0.0001911	0.0002428
3	0.0001405	0.0001563	0.0002464
Maximum Value	0.0001459	0.0002491	0.0002464

From the analysis data, the horizontal principal strain value under the surface layer or HMA is 0.0001459 which is used to analyze the type of fatigue cracking damage, while for the vertical strain which is used to analyze the type of rutting and permanent deformation, it is 0.0002491 and 0.0002464.

b. Axle Load Control

Control of the number of axle loads is carried out by calculating the values of fatigue cracking (Nf), rutting ($Nd_{rutting}$), and permanent deformation ($Nd_{permanent}$) where the values from the three analyzes must be greater than the predicted CESA.

1) Fatigue cracking calculation

$$N_f = 0{,}0976\ (\varepsilon_t)^{-3{,}921}|E^*|^{-0{,}854}$$

$$N_f = 0{,}0976\ (0.0001459)^{-3{,}921}|1600000|^{-0{,}854}$$

$$N_f = 439{,}879{,}581.34\ ESAL$$

2) Rutting calculation

$$N_r = 1{,}365\ \times\ 10^{-9}(\varepsilon_c)^{-4{,}47}$$

$$N_r = 1{,}365\ \times\ 10^{-9}(0.0002491)^{-4{,}47}$$

$$N_r = 18{,}559{,}551.33\ ESAL$$

3) Permanent Deformation calculation

$$N_d = f_4(\varepsilon_c)^{-f_5}$$

$$N_d = 1{,}365\ \times\ 10^{-9}(0.0002464)^{-4{,}477}$$

$$N_d = 19{,}487{,}549.07\ ESAL$$

From the above calculation, it is found that the condition of the existing pavement can accommodate the load repetition of 439,879,581.34 ESAL until Fatigue cracking occurs. This existing road pavement can also accommodate load repetitions of 18,559,551.33 ESAL until Rutting occurs and can accommodate load repetitions of 19,487,549.07 ESAL until permanent deformation occurs.

2. Linear Elastic Model

a. Analysis Result

The results of the Kenpave program analysis in this study are in the form of stress and strain values that occur at the review point of the flexible pavement layer. The first review point is at the base of the surface layer there is a radial (tangential) tensile strain response, while at the second review point located on the subgrade surface there is a vertical compressive strain response. The following is a recapitulation of the analysis results in the form of stress and strain which can be seen in Table 5.51 below.

Table 5.51 Stress Strain of Alternative 2 Linear Elastic Modelling

Load Point (X)	Horizontal P Strain	Vertical Strain	Vertical Strain
	at 17.4995 cm	at 17.4995 cm	at 47.5005 cm
1	0.0001401	0.0002012	0.0002131
2	0.000139	0.000153	0.0002312
3	0.0001349	0.0001244	0.0002343
Maximum Value	0.0001401	0.0002012	0.0002343

From the analysis data, the horizontal principal strain value under the surface layer or HMA is 0.0001401 which is used to analyze the type of fatigue cracking damage, while for the vertical strain which is used to analyze the type of rutting and permanent deformation, it is 0.0002012 and 0.0002343.

b. Axle Load Control

Control of the number of axle loads is carried out by calculating the values of fatigue cracking (Nf), rutting ($Nd_{rutting}$), and permanent deformation ($Nd_{permanent}$) where the values from the three analyzes must be greater than the predicted CESA.

1) Fatigue cracking calculation

$$N_f = 0{,}0976\ (\varepsilon_t)^{-3{,}921} |E^*|^{-0{,}854}$$

$$N_f = 0{,}0976\ (0.0001401)^{-3{,}921} |1600000|^{-0{,}854}$$

$$N_f = 515{,}716{,}081.42\ ESAL$$

2) Rutting calculation

$$N_r = 1{,}365 \times 10^{-9} (\varepsilon_c)^{-4{,}47}$$

$$N_r = 1{,}365 \times 10^{-9} (0.0002012)^{-4{,}47}$$

$$N_r = 48{,}282{,}550.24\ ESAL$$

3) Permanent Deformation calculation

$$N_d = f_4 (\varepsilon_c)^{-f_5}$$

$$N_d = 1{,}365 \times 10^{-9}(0.0002343)^{-4{,}477}$$

$$N_d = 24{,}415{,}302.83\ ESAL$$

From the above calculation, it is found that the condition of the alternative pavement 2 can accommodate the load repetition of 515,716,081.42 ESAL until Fatigue cracking occurs. This alternative pavement 2 can also accommodate load repetitions of 48,282,550.24 ESAL until Rutting occurs and can accommodate load repetitions of 24,415,302.83 ESAL until permanent deformation occurs.

5.5 Road Service Life Prediction for Alternative Pavement Design

From the analysis of the alternative pavement with empirical mechanistic methods using the KENPAVE program, the value of each damage that occurs after repeated loads is obtained which can be seen in the Table 5.52 and Table 5.53 below.

Table 5.52 Load Repetition for Alternative 1

Damage Type	Viscoelastic Model	Linear Elastic Model
	ESAL	ESAL
Fatigue ($N_{Fatigue}$)	142,763,295.59	219,999,969.70
Rutting ($N_{Rutting}$)	20,472,951.01	49,261,433.02
Permanent Deformation ($N_{Deformation}$)	33,374,022.06	69,463,545.85

Table 5.53 Load Repetition for Alternative 2

Damage Type	Viscoelastic Model	Linear Elastic Model
	ESAL	ESAL
Fatigue ($N_{Fatigue}$)	439,879,581.34	515,716,081.42
Rutting ($N_{Rutting}$)	18,559,551.33	48,282,550.24
Permanent Deformation ($N_{Deformation}$)	19,487,549.07	24,415,302.83

The analysis of the remaining service life of the alternative road pavement viscoelastic model using equation 3.13 are as follows.

5.5.1 Service Life Prediction for Alternative 1

The analysis of the service life of the alternative road pavement viscoelastic model using equation 3.13 are as follows.

1. Alternative 1 with Viscoelastic Model

$$SL_{Fatigue} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$SL_{Fatigue} = 100 \times \left(1 - \frac{644225.00}{142,763,295.59}\right)$$

$$SL_{Fatigue} = 99.55\%$$

$$SL_{Rutting} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$SL_{Rutting} = 100 \times \left(1 - \frac{644225.00}{20,472,951.01}\right)$$

$$SL_{Rutting} = 96.85\%$$

$$SL_{P\ Deformation} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$SL_{P\ Deformation} = 100 \times \left(1 - \frac{644225.00}{33,374,022.06}\right)$$

$$SL_{P\ Deformation} = 98.07\%$$

With the same calculation carried out until the design life is 20 years, the results of the recapitulation of the analysis of the remaining service life of the existing pavement can be seen in the Figure 5.23 below.

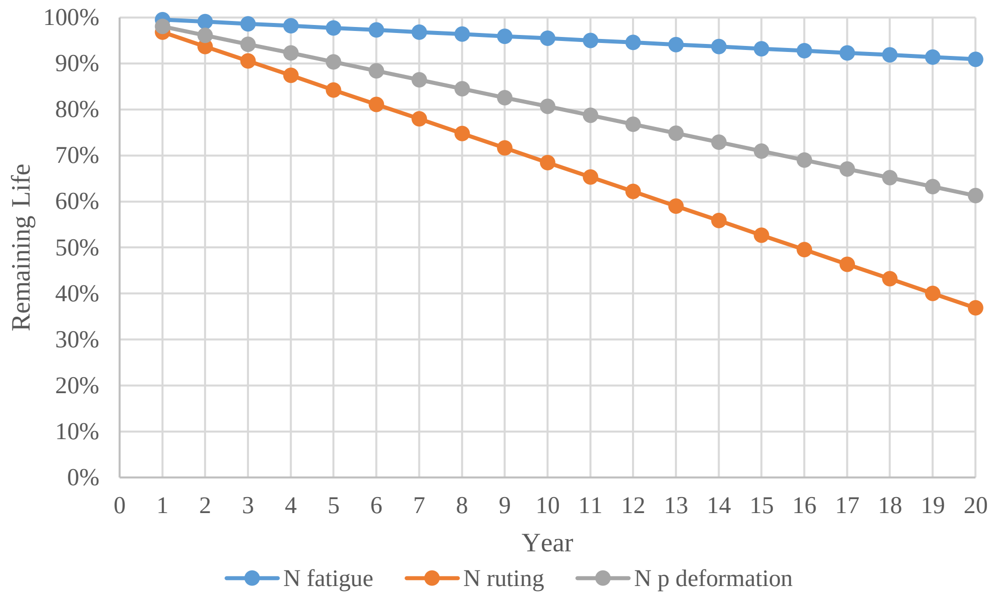


Figure 5.23 Service Life Prediction Alternative 1 Viscoelastic Model

From these results, it can be seen in the graph above that the service life prediction of the existing pavement with viscoelastic modelling is throughout the design life, namely the 20th year, the damage that occurs is fatigue cracking damage by producing a remaining service life of 90.94% and permanent deformation damage by producing a remaining service life of 61.26%, while the rutting damage occurs until the last life plan is 36.86%.

2. Alternative 1 with Linear Elastic Model

$$RL_{Fatigue} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$RL_{Fatigue} = 100 \times \left(1 - \frac{644225.00}{219,999,969.70}\right)$$

$$RL_{Fatigue} = 99.71\%$$

$$RL_{Rutting} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$RL_{Rutting} = 100 \times \left(1 - \frac{644225.00}{49,261,433.02}\right)$$

$$RL_{Rutting} = 98.69\%$$

$$RL_{P\ Deformation} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$RL_{P\ Deformation} = 100 \times \left(1 - \frac{644225.00}{69{,}463{,}545.85}\right)$$

$$RL_{P\ Deformation} = 99.07\%$$

With the same calculation carried out until the design life is 20 years, the results of the recapitulation of the analysis of the remaining service life of the existing pavement can be seen in the Figure 5.24 below.

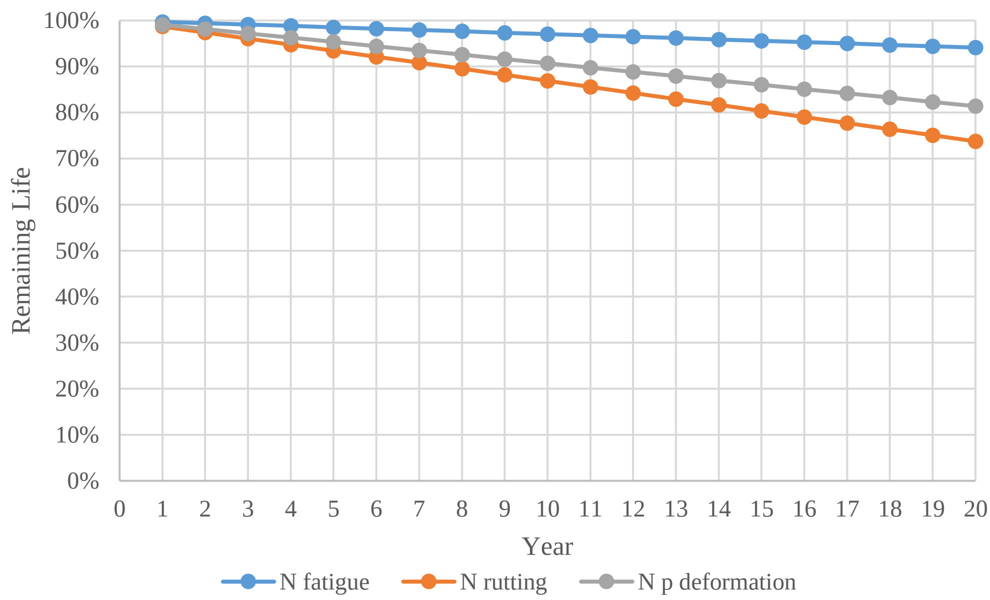


Figure 5.24 Service Life Prediction Alternative 1 Linear Elastic Model

From these results, it can be seen in the graph above that the service life prediction of the existing pavement with viscoelastic modelling is throughout the design life, namely the 20th year, the damage that occurs is fatigue cracking damage by producing a remaining service life of 94.12% and permanent deformation damage by producing a remaining service life of 81.39%, while the rutting damage occurs until the last life plan is 73.76%.

5.5.2 Service Life Prediction for Alternative 2

The analysis of the service life of the alternative road pavement viscoelastic model using equation 3.13 are as follows.

1. Alternative 2 with Viscoelastic Model

$$RL_{Fatigue} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$RL_{Fatigue} = 100 \times \left(1 - \frac{644225.00}{439,879,581.34}\right)$$

$$RL_{Fatigue} = 99.85\%$$

$$RL_{Rutting} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$RL_{Rutting} = 100 \times \left(1 - \frac{644225.00}{18,559,551.33}\right)$$

$$RL_{Rutting} = 96.53\%$$

$$RL_{P\ Deformation} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$RL_{P\ Deformation} = 100 \times \left(1 - \frac{644225.00}{19,487,549.07}\right)$$

$$RL_{P\ Deformation} = 96.69\%$$

With the same calculation carried out until the design life is 20 years, the results of the recapitulation of the analysis of the service life of the existing pavement can be seen in the Figure 5.25 below.

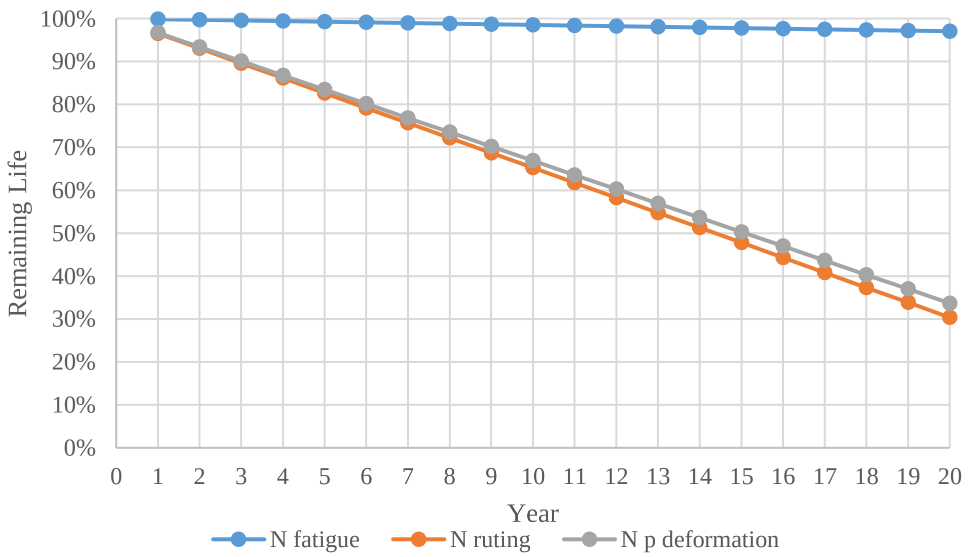


Figure 5.25 Service Life Prediction Alternative 2 Viscoelastic Model

From these results, it can be seen in the graph above that the service life prediction of the existing pavement with viscoelastic modelling is throughout the design life, namely the 20th year, the damage that occurs is fatigue cracking damage by producing a remaining service life of 97.06% and permanent deformation damage by producing a remaining service life of 33.66%, while the rutting damage occurs until the last life plan is 30.35%.

2. Alternative 2 with Linear Elastic Model

$$RL_{Fatigue} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$RL_{Fatigue} = 100 \times \left(1 - \frac{644225.00}{515{,}716{,}081.42}\right)$$

$$RL_{Fatigue} = 99.88\%$$

$$RL_{Rutting} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$RL_{Rutting} = 100 \times \left(1 - \frac{644225.00}{48{,}282{,}550.24}\right)$$

$$RL_{Rutting} = 98.67\%$$

$$RL_{P\ Deformation} = 100 \times \left(1 - \frac{N_p}{N1.5}\right)$$

$$RL_{P\ Deformation} = 100 \times \left(1 - \frac{644225.00}{24{,}415{,}302.83}\right)$$

$$RL_{P\ Deformation} = 97.36\%$$

With the same calculation carried out until the design life is 20 years, the results of the recapitulation of the analysis of the service life of the existing pavement can be seen in the Figure 5.26 below.

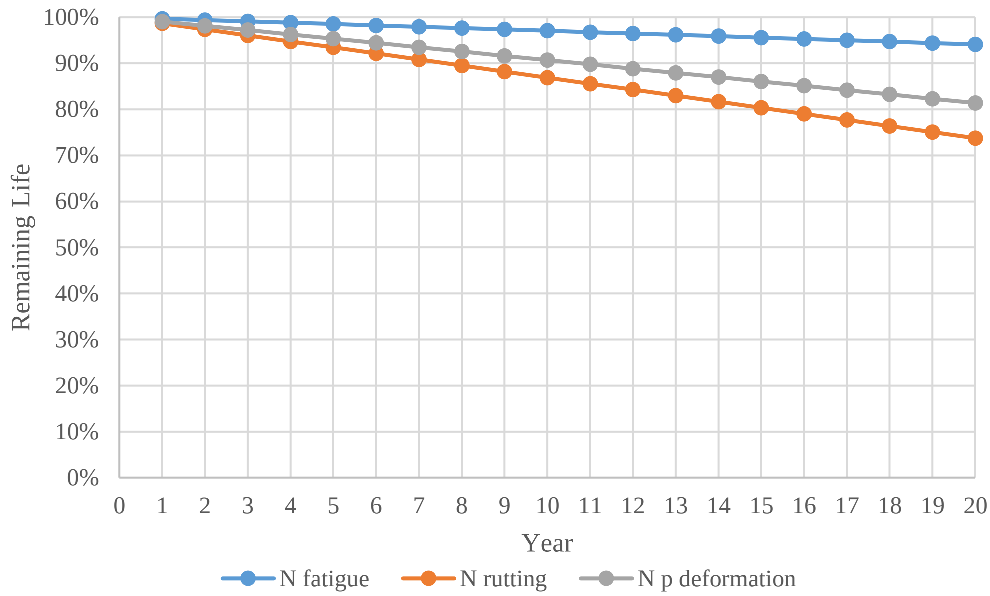


Figure 5.26 Service Life Prediction Alternative 1 Linear Elastic Model

From these results, it can be seen in the graph above that the service life prediction of the existing pavement with viscoelastic modelling is throughout the design life, namely the 20th year, the damage that occurs is fatigue cracking damage by producing a remaining service life of 97.49% and permanent deformation damage by producing a remaining service life of 47.05%, while the rutting damage occurs until the last life plan is 73.23%.

5.6 Comparison of Existing Pavement and Alternative Pavement

From the analysis of the evaluation of the pavement structure on the Sentolo-Nanggulan-Dekso road section using the 2017 Bina Marga method and the empirical mechanistic method with the KENPAVE program, the following results are obtained.

5.6.1 Pavement Thickness

Evaluation of the existing pavement is carried out using the KENPAVE program to obtain the results of the analysis of the damage that has occurred which is useful for determining the ability and remaining service life of the existing pavement. The existing road pavement has surface thickness of 10 cm which consists of a layer of AC WC 4 cm thick, AC BC 6 cm thick, and A class top foundation layer of 40 cm thick where the total thickness of the existing pavement structure is 50 cm.

The design of the new pavement structure is made as an alternative to the existing pavement using the 2017 Bina Marga method and empirical mechanistic using the KENPAVE program. This new design consists of 2 Alternative Pavement with varying thickness of each layer.

Pavement alternative 1 has a surface thickness of 24.5 cm which consists of AC WC layer thickness of 4 cm, AC BC with a thickness of 6 cm, AC Base with a thickness of 14.5 cm, and Class A top foundation layer with a thickness of 30 cm with a total thickness of pavement structure for alternative 1 is 54.5 cm. Meanwhile alternative pavement 2 has a surface thickness of 17.5 cm which consists of AC WC with a thickness of 4 cm, AC BC with a thickness of 6 cm, AC Base with a thickness of 7.5 cm, Subbase consist of CTB with a thickness of 15 cm, and a class A foundation layer of 15 cm thickness with a total pavement structure thickness of 47.5 cm. The comparison between the 3 pavement structure designs can be seen in the Table 5.54 and Figure 5.27 below.

Table 5.54 Existing and Alternative Pavement Layer Thickness

Pavement	Structure	Thickness (cm)
Existing	AC WC	4
	AC BC	6
	Top Foundation Layer Class A	40
Alternative 1	AC WC	4
	AC BC	6
	AC Base	14.5
	Top Foundation Layer Class A	30
Alternative 2	AC WC	4
	AC BC	6
	AC Base	7.5
	CTB	15
	Agg. Foundation Class A	15

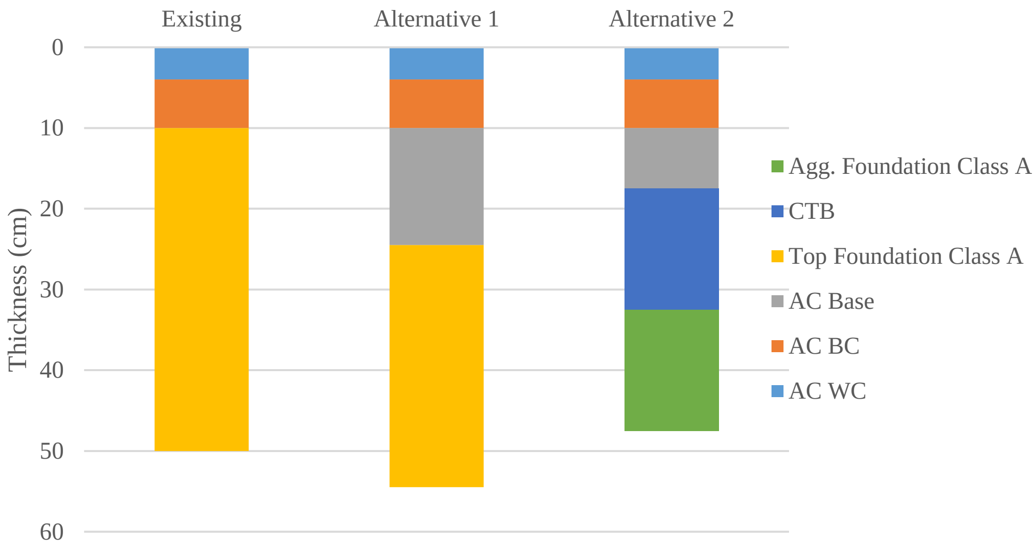


Figure 5.27 Existing and Alternative Pavement Thickness

In the figure above, can be sees variations in the thickness of the existing and alternative pavement layers. Alternative 1 pavement is thicker than the existing pavement but can accommodate repetition of loads due to damage until the end of the design life, as well as alternative 2 which has a thinner pavement layer than existing and alternative 1 can accommodate repetition of loads due to damage until the end of the planning year. With the same pavement structure, the result of alternative pavement 1 has a thickness that is greater than the previous research by Mahmudin (2019), with the location of the case study in Imogiri, D.I.Yogyakarta which is 50.5 cm thick and pavement thickness in previous studies by Mantiri et al. (2019), with the location of the case study on the Manado national road with a maximum thickness of 51.5 cm. The alternative pavement structure in this case study can use the same thickness with Mahmudin (2019), but the pavement structure with that thickness results in rutting damage that does not meet the design criteria, so that the thickness of the pavement is not used as an alternative pavement structure in this case study. However, with the existence of a second alternative pavement which has a smaller thickness than the existing and alternative 1 pavement, it can provide a more effective pavement thickness but with a different pavement structure.

5.6.2 Stress Strain Response

Analysis of existing and alternative pavements carried out by empirical mechanistic methods using the KENPAVE program produces outputs, one of which is stress and strain values which will be used for pavement damage analysis.

The results of the analysis using viscoelastic modelling for the existing pavement resulted in a tensile strain value that caused fatigue damage of 0.0002157 and the tensile strain value for rutting damage of 0.0002971, and the compressive strain value for permanent deformation damage of 0.0002636. Meanwhile, the results of the analysis using linear elastic modelling for the existing pavement resulted in a stress value causing fatigue damage of 0.0002399, strain value for rutting damage of 0.0002823, and permanent deformation damage of 0.0002482.

The results of the analysis using viscoelastic modelling for the Alternative pavement 1 resulted in a tensile strain value that caused fatigue damage of 0.0001944, the tensile strain value for rutting damage of 0.0002437, and the compressive strain value for permanent deformation damage of 0.0002185. Meanwhile, the results of the analysis using linear elastic modelling for the existing pavement resulted in a strain value causing fatigue damage of 0.0001741, rutting damage of 0.0002003, and permanent deformation damage of 0.0001855.

The results of the analysis using viscoelastic modelling for the Alternative pavement 2 resulted in a strain value that caused fatigue damage of 0.0001459, the strain value for rutting damage of 0.0002491, and the strain value for permanent deformation damage of 0.0002464. Meanwhile, the results of the analysis using linear elastic modelling for the existing pavement resulted in a stress value causing fatigue damage of 0.0001401, strain value for rutting damage of 0.0002012, and permanent deformation damage of 0.0002343. The results of the recapitulation of the pavement strain values can be seen in the Figure 5.28, Figure 5.29, and Figure 5.30 below.

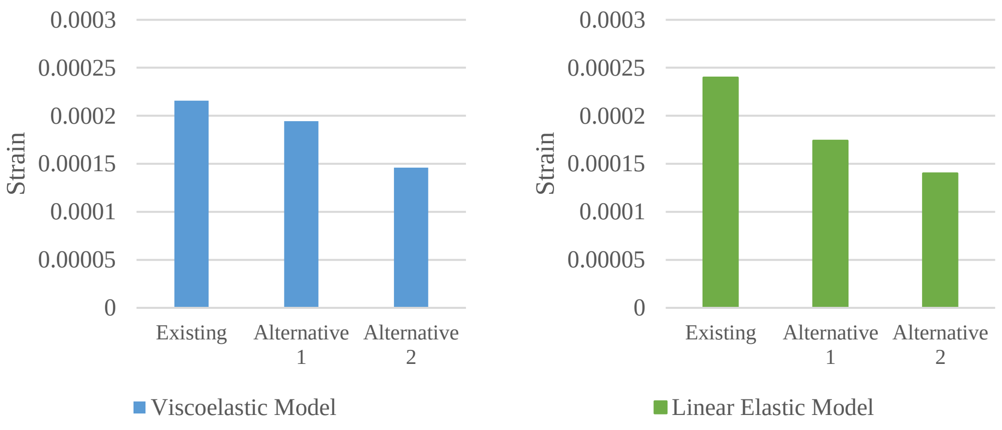


Figure 5.28 Tensile Strain Value at Bottom Asphalt Layer Causes Fatigue Cracking

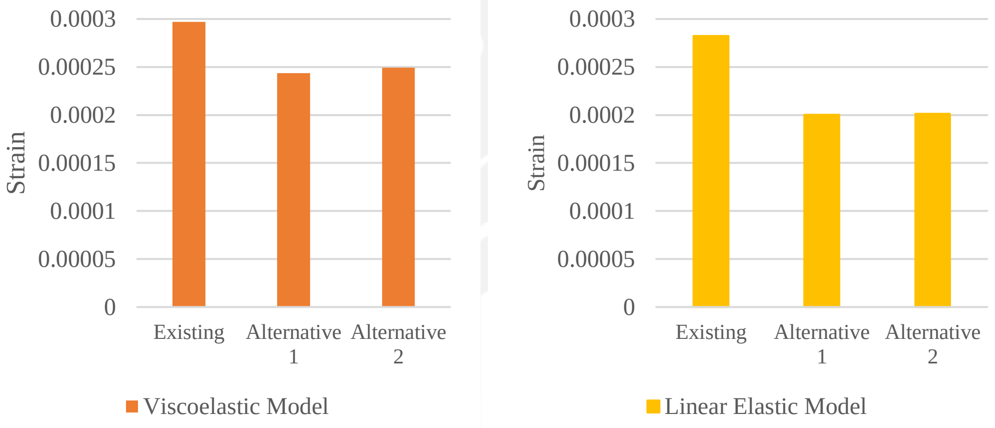


Figure 5.29 Compressive Strain Value at Bottom Foundation Causes Rutting

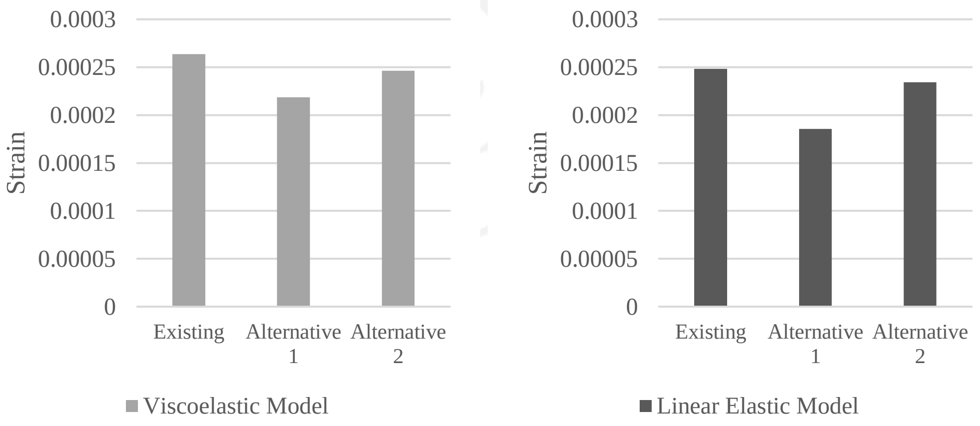


Figure 5.30 Vertical Strain Value at Above Subgrade Causes Permanent Deformation

The results of stress analysis at point 1 which is located at 0 cm from observation point, point 2 which is located at 10 cm from observation point, point 3 which is located at 16.5 cm from observation point for existing pavement can be seen in the Figure 5.31 and 5.32 below.

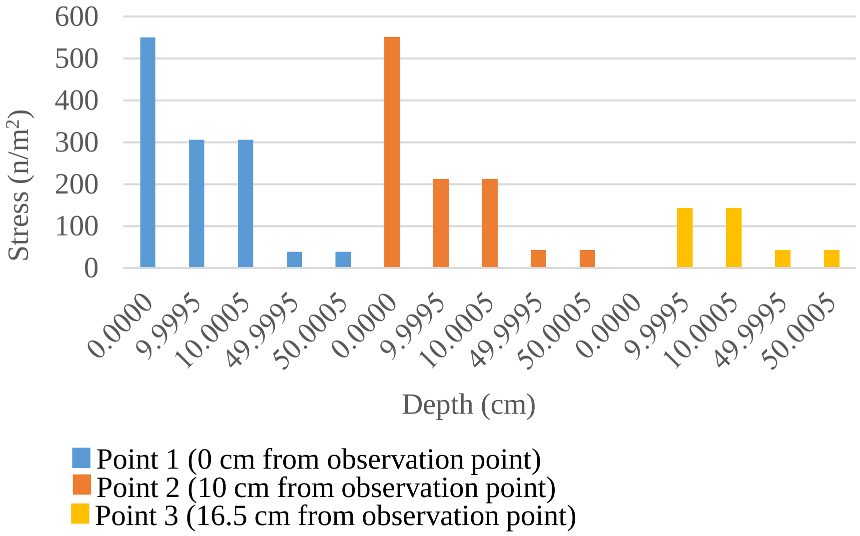


Figure 5.31 Stress Value for Viscoelastic Model

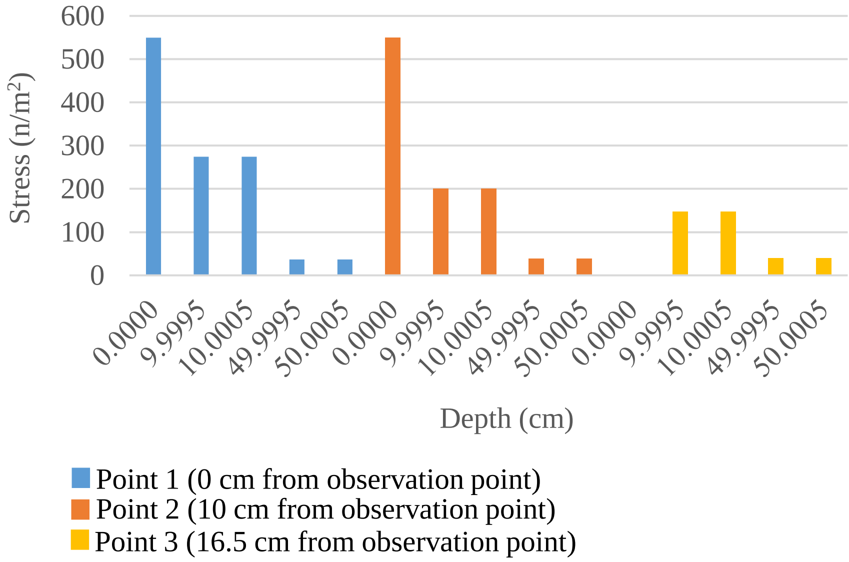


Figure 5.32 Stress Value for Linear Elastic Model

The results of stress analysis at point 1 which is located at 0 cm from observation point, point 2 which is located at 10 cm from observation point, point

3 which is located at 16.5 cm from observation point for alternative pavement 1 can be seen in the Figure 5.33 and 5.34 below.

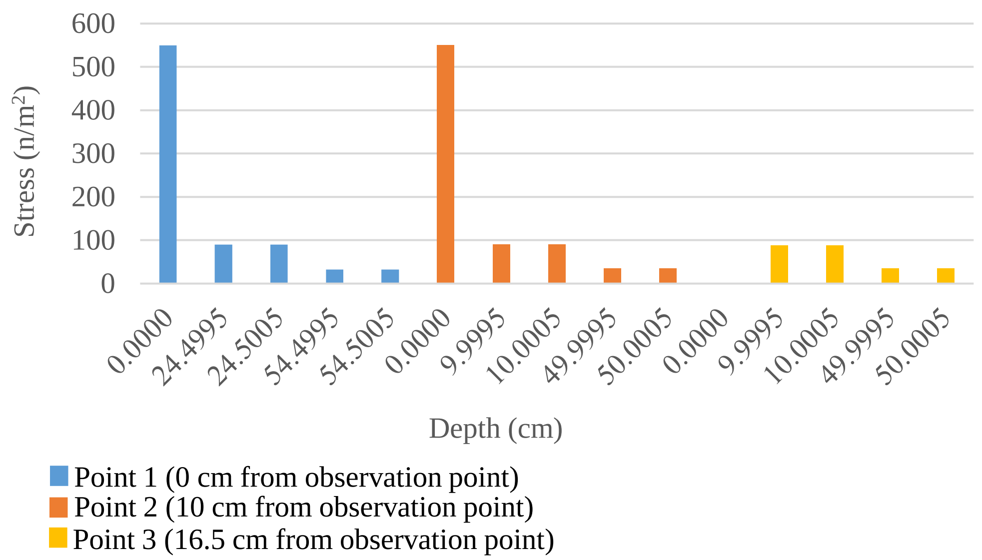


Figure 5.33 Stress Value for Viscoelastic Model

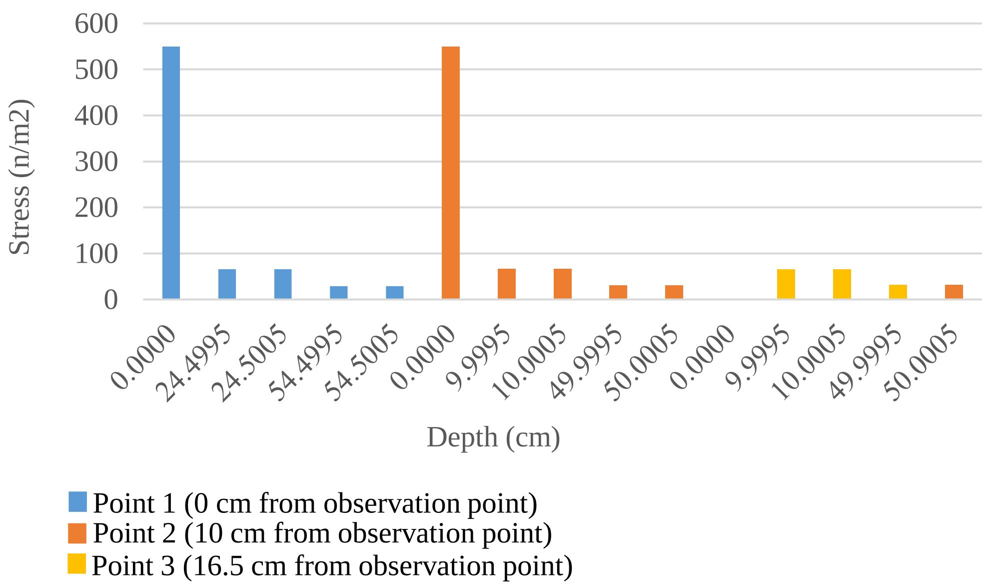


Figure 5.34 Stress Value for Linear Elastic Model

The results of stress analysis at point 1 which is located at 0 cm from observation point, point 2 which is located at 10 cm from observation point, point 3 which is located at 16.5 cm from observation point for alternative pavement 2 can be seen in the Figure 5.35 and 5.36 below.

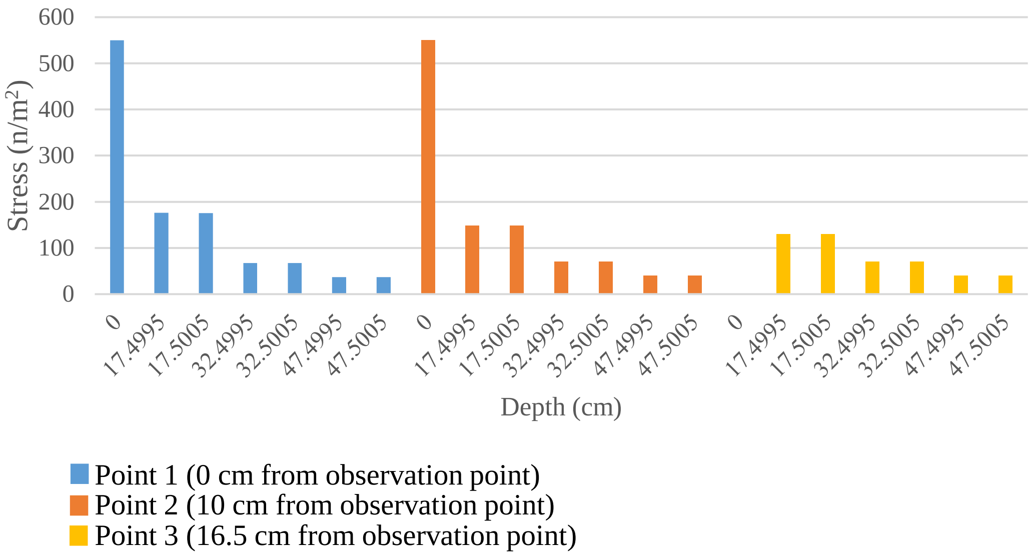


Figure 5.35 Stress Value for Viscoelastic Model

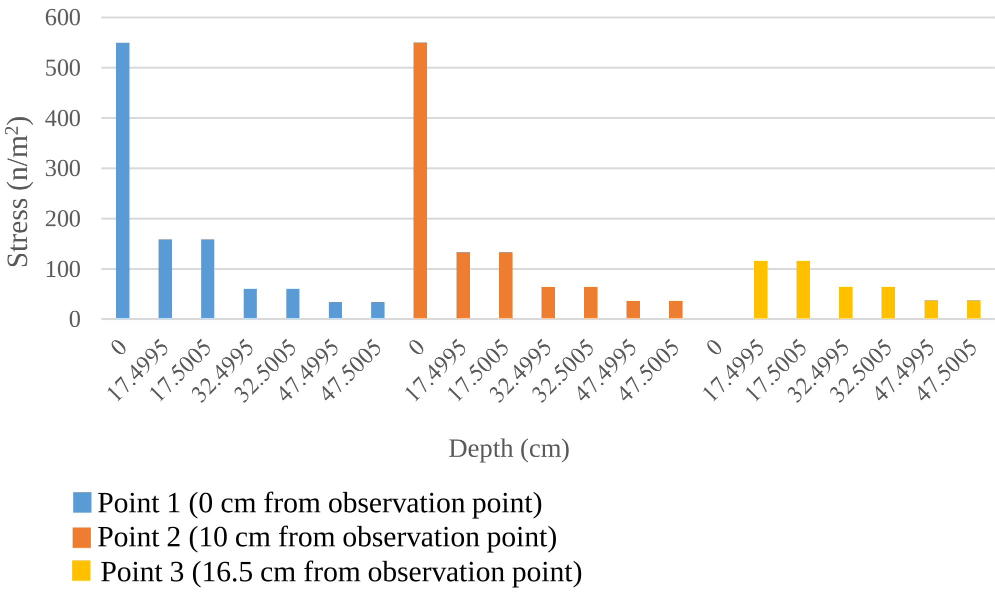


Figure 5.36 Stress Value for Linear Elastic Model

When viewed from the stress value generated at the 3 observation points, the existing stress value has the largest value where the viscoelastic modelling has a greater value than the stress value with the linear elastic modelling.

The stress value on alternative 1 pavement has a much smaller value compared to existing and alternative 2, this is due to one of the reasons for the different thickness of the pavement compared to the existing pavement and alternative pavement 2.

5.6.3 Service Life Prediction of Pavement

The remaining service life due to damage that occurs in the existing and alternative pavements has different values. For a comparison of the remaining service life of the existing and alternative pavements, see the Table 5.55 below.

Table 5.55 Recapitulation of Service Life Prediction

Layer Thickness	$N_{fatigue}$		$N_{rutting}$		$N_{p\ deform}$	
	Elastic	Viscoelastic	Elastic	Viscoelastic	Elastic	Viscoelastic
Existing	75	89	17	14	25	22
Alternative 1	74	63	38	22	45	30
Alternative 2	98	90	37	21	24	21

From the table above, it can be seen that on the existing pavement there will be rutting damage before the design life, namely in the 13th year, but other damage has not occurred until the end of the 20-year service life. For alternatives 1 and 2, it can be seen that fatigue, rutting, and permanent deformation occurred after the design life of 20 years so that the pavement can be said to be a better alternative than the existing one based on the repetition of the load. Among the previous studies, which analyzed the remaining service life or predicted service life, only research conducted by Mahmudin (2019), which has a pavement layer thickness of 50.5 cm where with viscoelastic modeling, the damage analyzed occurred in years earlier than the current study, as well as linear elastic modeling.

CHAPTER 6
CONCLUSION AND SUGGESTION

6.1 Conclusion

Based on the results of the analysis that has been carried out using the Bina Marga 2017 method and the empirical mechanistic method with the KENPAVE program, conclusion are as follows.

1. From the stress and strain results, an analysis of the service life prediction for the existing pavement was obtained with the first damage occurring was rutting damage, where the damage occurred before the design life, which was about 13 to 17 years, then followed by permanent deformation and fatigue cracking where the two damages occurred after design life of 20 years. This indicates that alternative pavement is needed to improve performance to face current traffic.
2. Alternative pavement using the Bina Marga 2017 method and empirical mechanistic methods using the KENPAVE program resulted in 2 alternatives, which is alternative 1 with a total thickness of 54.5 Alternative 1 pavement has a thickness greater than the existing pavement. Meanwhile, alternative pavement 2 has a thickness that is smaller than the existing pavement and alternative pavement 1 with total thickness of 47.5 cm.
3. The tensile strain value under the asphalt layer on the existing pavement has the biggest value compared to the strain value of alternatives 1 and 2. The value of vertical strain under the foundation layer alternative 1 has the smallest value compared to the existing and alternative 2. Thicker pavement layers produce smaller horizontal tensile strains under the surface layer and compressive strains under foundation layer, but if there is an additional thickness of the foundation it will increase the value of vertical strains.
4. By getting the stress strain values on the existing pavement which is greater than that of alternative pavements 1 and 2, the resulting load repetition value

until damage occurs to the existing pavement is smaller than alternatives 1 and 2, with a load repetition value until damage occurs smaller than the life span the existing pavement service becomes shorter or there will be damage before the design life of 20 years, namely rutting damage that occurs around the 13th to 17th years, which in turn will cause permanent deformation and fatigue cracking damage before the design life. Alternative pavements 1 and 2 have a load repetition value until damage occurs, which is greater than the existing pavement resulting in a longer remaining service life or pavement damage occurs after the design life of 20 years.

6.2 Suggestion

Based on the results of the analysis that has been carried out using the Bina Marga 2017 method and the empirical mechanistic method with the KENPAVE program, suggestion are as follows.

1. Alternative pavement analysis results in the current case study with alternative pavement 1 and alternative pavement 2 can be used as input for consideration in the selection of road pavement plans in the future, where alternative pavement 2 has an effective and optimal thickness because it has a thickness that is smaller than the thickness of alternative pavement 1 but can accommodate all types of damage analyzed according to the design life. However, for future research, further evaluation of alternative pavements is needed in this current case study both damage analysis and other analyzes according to the needs of each road segment.
2. Further research is needed to consider current traffic data and added updates to several analytical parameters such as poison’s ratio and modulus of elasticity values so that they could provide evaluation results for existing pavements more optimal and accurate.
3. For further research, the pavement thickness design analysis can be added with methods and or analysis using programs other than KENPAVE to increase the variation in thickness results and as a comparison for the value of damage that occurs so as to produce an optimal thickness of the pavement structure layer.

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APPENDIX

Appendix 1 Traffic Survey Sentolo-Nanggulan-Dekso Road

			Lokasi Pos	:	
Lembar ke	: 1	dari 14	Tanggal	: 11 Oktober 2021	
Nama Propinsi	: D.I.Yogyakarta		Nama Jalan	: Nanggulan Mendut	
No Propinsi	:		Arah Lalu Lintas	: Nanggulan	Ke Klangon
Nomor Pos	:		Periode	:	

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	4	2	1	2	1	1	1	0	1	0	0	1
06:15 - 06.30	5	2	1	1	1	1	0	1	1	0	1	0
06:30 - 06:45	5	3	1	1	1	1	1	2	0	0	0	0
06:45 - 07:00	13	5	1	2	1	1	1	1	1	0	0	0
07:00 - 07:15	11	5	2	2	2	2	2	2	1	0	0	0
07:15 - 07:30	8	3	2	2	2	1	2	2	0	0	0	0
07:30 - 07:45	7	3	3	2	2	1	2	1	1	0	1	1
07:45 - 08:00	8	4	3	3	2	1	2	2	2	0	0	0
08:00 - 08:15	6	2	2	2	1	1	2	1	0	0	0	0
08:15 - 08:30	9	2	3	1	1	1	2	2	2	0	0	0
08:30 - 08:45	6	1	2	1	1	1	2	2	2	0	0	1
08:45 - 09:00	8	1	3	2	1	1	1	1	2	0	0	0
09:00 - 09:15	5	2	1	2	1	1	0	2	0	0	0	0
09:15 - 09:30	8	2	1	1	1	1	2	1	1	0	0	0
09:30 - 09:45	7	1	2	1	1	1	2	1	0	0	0	0
09:45 - 10:00	7	2	2	1	1	1	2	1	1	0	0	0
10:00 - 10:15	6	2	1	2	1	1	1	2	2	0	0	0
10:15 - 10:30	4	1	2	1	1	1	1	1	2	0	1	0
10:30 - 10:45	5	1	1	1	1	1	2	1	0	0	0	0
10:45 - 11:00	7	1	1	1	1	1	0	1	2	0	0	0
11:00 - 11:15	4	2	1	1	1	1	1	2	0	0	0	0
11:15 - 11:30	3	3	2	1	1	1	2	2	2	0	0	0
11:30 - 11:45	5	2	2	1	1	1	2	1	0	0	0	0
11:45 - 12:00	4	2	2	1	1	1	1	2	1	0	0	0
12:00 - 12:15	3	2	3	1	1	1	1	1	2	0	0	0
12:15 - 12:30	7	3	2	1	1	1	2	1	2	0	0	0
12:30 - 12:45	6	1	2	1	2	1	2	1	1	0	0	0
12:45 - 13:00	5	2	2	1	2	1	1	2	2	0	0	0
13:00 - 13:15	7	1	1	1	2	1	0	2	2	0	0	0
13:15 - 13:30	4	1	1	1	1	1	1	2	0	0	0	0
13:30 - 13:45	5	1	1	2	1	1	2	1	2	0	0	0
13:45 - 14:00	8	2	2	2	1	1	2	1	2	0	0	0
14:00 - 14:15	10	2	1	3	2	1	2	2	2	0	0	0
14:15 - 14:30	9	1	1	3	1	1	2	2	2	0	1	0
14:30 - 14:45	10	1	2	2	1	1	2	1	1	0	0	0
14:45 - 15:00	12	1	1	3	1	1	2	2	1	0	0	1
15:00 - 15:15	11	5	2	3	2	1	2	2	1	0	0	0
15:15 - 15:30	12	6	3	2	1	1	2	2	2	0	0	0
15:30 - 15:45	13	5	3	2	1	1	2	1	0	0	0	0
15:45 - 16:00	10	7	4	2	2	2	3	2	2	0	1	0
16:00 - 16:15	9	5	3	3	2	1	2	2	0	0	0	0
16:15 - 16:30	11	4	2	2	2	2	2	1	2	0	0	0
16:30 - 16:45	10	5	3	1	2	1	2	2	1	0	0	0
16:45 - 17:00	8	4	3	1	2	2	2	2	2	0	0	0
17:00 - 17:15	5	3	3	2	2	2	2	2	1	0	0	0
17:15 - 17:30	5	4	2	1	1	1	2	1	1	0	0	0
17:30 - 17:45	3	5	3	1	1	1	2	1	1	0	0	0
17:45 - 18:00	5	3	2	1	1	1	1	2	2	0	0	0

Lembar ke : 2 dari 14		Lokasi Pos :	
Nama Propinsi : D.I.Yogyakarta		Tanggal : 11 Oktober 2021	
No Propinsi :		Nama Jalan : Nanggulan Mendut	
Nomor Pos :		Arah Lalu Lintas : Klangon	Ke Nanggulan
		Periode :	

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	3	1	1	2	2	1	1	1	0	0	0	1
06:15 - 06.30	4	1	1	1	2	1	0	1	1	0	1	0
06:30 - 06:45	4	2	1	2	1	1	1	2	0	0	0	2
06:45 - 07:00	5	3	1	2	2	2	1	1	0	0	0	0
07:00 - 07:15	6	3	2	3	3	2	2	3	0	0	1	1
07:15 - 07:30	8	2	2	3	3	1	3	3	0	0	0	1
07:30 - 07:45	9	2	3	2	3	1	3	1	0	0	0	0
07:45 - 08:00	7	2	3	3	3	1	0	2	1	0	0	2
08:00 - 08:15	5	1	2	2	2	1	2	1	0	0	0	0
08:15 - 08:30	10	1	3	1	2	1	3	2	0	0	0	0
08:30 - 08:45	9	1	2	2	2	1	2	3	0	0	0	1
08:45 - 09:00	5	1	3	2	1	1	1	2	0	0	1	0
09:00 - 09:15	4	1	1	2	2	1	1	2	0	0	0	0
09:15 - 09:30	5	1	1	2	1	1	2	2	1	0	0	1
09:30 - 09:45	9	1	2	1	2	1	3	1	0	0	0	0
09:45 - 10:00	10	1	2	2	2	1	2	2	0	0	0	0
10:00 - 10:15	5	1	1	2	1	1	2	2	0	0	0	1
10:15 - 10:30	7	1	2	1	2	1	1	2	0	0	0	0
10:30 - 10:45	5	1	1	1	2	2	2	1	0	0	0	0
10:45 - 11:00	4	1	1	2	2	1	0	0	0	0	0	0
11:00 - 11:15	5	1	1	2	1	1	1	2	0	0	0	1
11:15 - 11:30	9	2	2	1	2	1	2	2	1	0	0	0
11:30 - 11:45	6	1	2	2	2	1	2	2	1	0	0	1
11:45 - 12:00	6	1	2	2	2	1	1	2	0	0	0	0
12:00 - 12:15	7	1	3	1	1	1	2	2	0	0	0	0
12:15 - 12:30	6	2	2	1	2	1	2	1	0	0	0	0
12:30 - 12:45	10	1	2	2	3	1	3	2	0	0	0	0
12:45 - 13:00	6	1	2	2	3	1	1	2	0	0	0	1
13:00 - 13:15	6	1	1	1	3	1	1	3	0	0	0	0
13:15 - 13:30	6	1	1	1	2	1	1	2	0	0	0	0
13:30 - 13:45	4	2	3	1	1	1	2	2	1	0	0	1
13:45 - 14:00	7	1	1	3	1	1	1	2	0	0	1	0
14:00 - 14:15	7	1	2	3	1	2	2	2	0	0	0	0
14:15 - 14:30	8	1	3	2	1	1	2	2	0	0	1	0
14:30 - 14:45	7	1	3	1	1	1	1	1	0	0	0	0
14:45 - 15:00	6	1	1	2	1	1	1	1	1	0	0	1
15:00 - 15:15	3	3	2	3	3	1	2	2	0	0	1	0
15:15 - 15:30	4	3	3	2	2	1	4	3	0	0	0	0
15:30 - 15:45	7	3	3	2	1	1	3	2	0	0	0	1
15:45 - 16:00	6	3	3	2	3	2	4	3	1	0	0	0
16:00 - 16:15	7	3	3	3	3	1	3	3	0	0	0	0
16:15 - 16:30	6	2	2	2	3	2	4	1	0	0	0	0
16:30 - 16:45	5	3	3	2	4	1	3	2	0	0	0	0
16:45 - 17:00	3	2	3	1	3	2	4	3	0	0	0	0
17:00 - 17:15	3	2	3	2	3	2	3	3	0	0	0	0
17:15 - 17:30	2	2	2	1	2	1	3	1	0	0	0	0
17:30 - 17:45	3	3	3	1	1	2	3	2	0	0	0	0
17:45 - 18:00	2	2	2	2	2	1	2	2	0	0	0	0

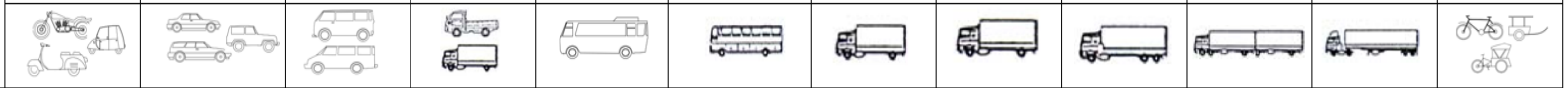
				Lokasi Pos	:
Lembar ke	: 3	dari	14	Tanggal	: 12 Oktober 2021
Nama Propinsi	: D.I.Yogyakarta			Nama Jalan	: Nanggulan Mendut
No Propinsi	:			Arah Lalu Lintas	: Nanggulan Ke Klangon
Nomor Pos	:			Periode	:

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	3	1	1	2	1	1	1	2	1	0	0	1
06:15 - 06:30	4	1	1	3	1	1	1	1	1	0	0	1
06:30 - 06:45	3	1	1	2	1	0	1	2	2	0	0	1
06:45 - 07:00	4	2	1	3	1	1	2	2	0	0	0	0
07:00 - 07:15	5	2	2	2	2	1	1	2	1	0	0	0
07:15 - 07:30	6	3	1	3	1	1	2	2	0	0	0	0
07:30 - 07:45	8	3	1	3	2	1	1	2	1	0	0	0
07:45 - 08:00	9	3	1	2	1	1	1	1	1	0	0	0
08:00 - 08:15	9	3	1	2	1	1	1	1	2	0	0	1
08:15 - 08:30	8	2	1	2	1	1	1	2	0	0	1	0
08:30 - 08:45	9	2	1	3	0	1	1	1	1	0	0	0
08:45 - 09:00	8	2	1	2	1	1	1	1	0	0	0	0
09:00 - 09:15	6	2	1	3	1	1	2	1	1	0	0	0
09:15 - 09:30	6	3	1	2	1	1	1	2	1	0	0	0
09:30 - 09:45	7	3	1	2	1	1	1	1	0	0	1	0
09:45 - 10:00	8	3	1	1	1	1	1	1	2	0	0	0
10:00 - 10:15	7	3	1	2	0	1	1	1	0	0	0	0
10:15 - 10:30	8	4	1	2	1	1	1	1	2	0	0	0
10:30 - 10:45	8	4	1	3	1	1	1	2	1	0	0	0
10:45 - 11:00	7	4	1	2	1	0	2	2	0	0	0	0
11:00 - 11:15	6	3	1	2	1	1	1	1	1	0	0	0
11:15 - 11:30	6	2	1	1	1	1	1	2	1	0	0	0
11:30 - 11:45	5	3	1	1	1	1	1	2	0	0	0	0
11:45 - 12:00	4	2	1	1	0	0	1	2	2	0	0	0
12:00 - 12:15	6	3	1	2	1	1	1	1	0	0	0	0
12:15 - 12:30	8	3	1	2	1	1	1	1	1	0	0	0
12:30 - 12:45	7	2	1	2	1	1	1	1	0	0	0	0
12:45 - 13:00	6	2	1	3	0	1	1	1	0	0	0	0
13:00 - 13:15	5	1	1	2	1	0	0	2	1	0	0	0
13:15 - 13:30	10	1	1	1	1	1	1	0	0	0	0	0
13:30 - 13:45	12	2	2	1	0	1	1	2	1	0	0	0
13:45 - 14:00	11	2	2	1	0	1	0	1	0	0	1	1
14:00 - 14:15	10	1	1	2	1	1	1	1	0	0	0	0
14:15 - 14:30	9	2	1	1	0	1	0	1	1	0	1	1
14:30 - 14:45	10	2	1	1	1	0	1	2	1	0	0	0
14:45 - 15:00	11	2	2	1	0	1	1	1	0	0	0	0
15:00 - 15:15	12	2	2	2	1	0	1	0	2	0	0	0
15:15 - 15:30	13	2	2	2	2	1	2	2	0	0	0	0
15:30 - 15:45	11	2	2	2	2	1	1	0	1	0	0	1
15:45 - 16:00	10	1	3	3	1	1	0	2	0	0	0	0
16:00 - 16:15	9	3	2	3	1	0	1	2	1	0	0	0
16:15 - 16:30	11	3	2	3	0	1	1	1	1	0	0	0
16:30 - 16:45	9	3	2	2	1	1	2	1	0	0	0	1
16:45 - 17:00	7	3	2	2	1	1	0	1	1	0	0	0
17:00 - 17:15	8	2	2	2	1	1	1	2	1	0	0	0
17:15 - 17:30	7	2	2	1	1	0	1	2	0	0	0	0
17:30 - 17:45	7	1	2	1	1	1	1	1	1	0	0	1
17:45 - 18:00	3	1	2	1	1	1	1	1	1	0	0	0

Lembar ke	: 4	dari	14	Lokasi Pos	:
Nama Propinsi	: D.I.Yogyakarta			Tanggal	: 12 Oktober 2021
No Propinsi	:			Nama Jalan	: Nanggulan Mendut
Nomor Pos	:			Arah Lalu Lintas	: Klangon Ke Nanggulan
				Periode	:

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	2	1	1	2	1	1	2	2	1	0	0	1
06:15 - 06.30	3	1	1	3	1	1	1	1	1	0	0	1
06:30 - 06:45	3	1	1	2	2	0	2	3	1	0	0	1
06:45 - 07:00	3	1	1	3	2	1	3	2	0	0	0	1
07:00 - 07:15	3	2	2	2	3	1	2	3	1	0	0	1
07:15 - 07:30	4	2	1	2	2	1	3	3	0	0	0	0
07:30 - 07:45	6	2	1	3	3	1	1	2	1	0	0	0
07:45 - 08:00	6	2	1	2	1	1	2	1	0	0	0	0
08:00 - 08:15	6	2	1	2	1	1	2	2	1	0	1	1
08:15 - 08:30	5	1	1	2	1	1	2	2	0	0	0	1
08:30 - 08:45	6	2	1	3	0	1	0	2	1	0	0	0
08:45 - 09:00	6	2	1	2	1	1	2	1	0	0	0	0
09:00 - 09:15	4	1	1	2	2	0	3	2	0	0	0	0
09:15 - 09:30	4	2	1	2	2	1	1	2	1	0	0	0
09:30 - 09:45	5	2	1	1	1	1	2	2	0	0	0	1
09:45 - 10:00	6	2	1	1	0	1	0	1	2	0	0	0
10:00 - 10:15	5	2	1	2	2	1	2	1	0	0	0	0
10:15 - 10:30	6	2	1	2	2	1	2	2	1	0	0	0
10:30 - 10:45	5	2	1	3	1	1	2	2	1	0	0	1
10:45 - 11:00	5	2	1	2	1	0	3	2	0	0	0	0
11:00 - 11:15	4	2	1	1	1	0	2	1	1	0	0	0
11:15 - 11:30	4	1	1	1	2	1	2	2	0	0	0	0
11:30 - 11:45	3	2	1	1	2	1	2	2	0	0	0	1
11:45 - 12:00	3	2	1	1	0	0	1	3	1	0	0	0
12:00 - 12:15	5	2	1	1	1	1	1	2	0	0	0	0
12:15 - 12:30	6	2	1	2	2	1	0	1	1	0	0	0
12:30 - 12:45	5	1	1	2	1	1	2	1	0	0	0	0
12:45 - 13:00	4	1	1	3	0	0	2	2	0	0	0	1
13:00 - 13:15	3	1	1	1	1	0	0	2	1	0	0	0
13:15 - 13:30	7	1	1	1	2	1	2	2	0	0	0	0
13:30 - 13:45	7	1	2	2	0	0	0	0	0	0	1	0
13:45 - 14:00	8	2	4	1	1	0	2	2	0	0	0	1
14:00 - 14:15	11	1	4	3	1	0	1	2	0	0	1	0
14:15 - 14:30	10	1	2	2	1	0	0	3	0	0	0	1
14:30 - 14:45	7	1	3	2	1	0	1	2	0	0	0	0
14:45 - 15:00	12	1	5	1	1	0	1	2	0	0	0	0
15:00 - 15:15	9	1	2	1	2	0	2	2	1	0	0	0
15:15 - 15:30	9	1	2	2	3	1	3	2	0	0	0	0
15:30 - 15:45	8	2	3	2	3	1	2	1	1	0	0	1
15:45 - 16:00	7	1	4	2	2	1	0	0	0	0	0	0
16:00 - 16:15	6	2	2	3	1	0	1	2	1	0	0	0
16:15 - 16:30	7	2	3	3	0	0	2	2	0	0	0	0
16:30 - 16:45	6	2	2	2	2	1	3	2	0	0	0	1
16:45 - 17:00	5	2	2	2	2	1	2	1	1	0	0	0
17:00 - 17:15	6	1	3	1	1	1	2	0	1	0	0	0
17:15 - 17:30	5	1	2	1	2	0	2	2	0	0	0	0
17:30 - 17:45	5	1	2	1	1	1	1	1	1	0	0	1
17:45 - 18:00	2	1	2	1	0	1	1	2	0	0	0	0

Lembar ke	: 5	dari 14	Lokasi Pos	:	
Nama Propinsi	: D.I.Yogyakarta		Tanggal	: 13 Oktober 2021	
No Propinsi	:		Nama Jalan	: Nanggulan Mendut	
Nomor Pos	:		Arah Lalu Lintas	: Nanggulan	Ke Klangon
			Periode	:	



GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	4	1	1	2	1	1	1	2	1	0	0	1
06:15 - 06:30	5	1	1	2	1	1	2	1	0	0	0	0
06:30 - 06:45	6	2	1	2	1	0	1	1	2	0	0	0
06:45 - 07:00	8	1	1	1	1	1	2	2	1	0	0	1
07:00 - 07:15	13	2	2	1	1	0	2	1	1	0	0	0
07:15 - 07:30	11	3	2	2	2	1	1	2	0	0	1	0
07:30 - 07:45	11	6	1	1	1	1	1	1	2	0	0	0
07:45 - 08:00	9	5	1	1	1	0	1	2	0	0	0	0
08:00 - 08:15	8	3	1	1	1	1	2	1	1	0	0	0
08:15 - 08:30	6	2	1	1	1	0	1	2	0	0	1	0
08:30 - 08:45	4	2	1	1	1	1	1	2	1	0	0	0
08:45 - 09:00	7	1	1	1	1	0	0	1	0	0	0	1
09:00 - 09:15	8	3	1	1	1	1	1	0	1	0	0	0
09:15 - 09:30	7	2	1	1	1	1	2	2	1	0	0	0
09:30 - 09:45	9	2	1	1	1	1	1	2	1	0	0	0
09:45 - 10:00	5	2	1	1	1	1	2	2	1	0	0	0
10:00 - 10:15	8	2	1	2	1	0	0	2	2	0	0	0
10:15 - 10:30	7	2	1	1	1	1	1	1	0	0	0	0
10:30 - 10:45	9	2	2	1	1	1	0	1	1	0	0	0
10:45 - 11:00	10	2	1	1	1	0	2	0	1	0	0	0
11:00 - 11:15	12	2	1	1	1	1	0	1	0	0	0	0
11:15 - 11:30	14	2	2	2	1	1	0	2	0	0	0	0
11:30 - 11:45	16	4	1	2	1	0	1	2	1	0	0	0
11:45 - 12:00	11	3	1	1	0	1	1	1	0	0	0	0
12:00 - 12:15	11	2	1	1	1	0	1	2	1	0	0	0
12:15 - 12:30	13	2	2	1	1	1	1	1	2	0	0	0
12:30 - 12:45	10	2	1	1	0	0	1	2	0	0	0	0
12:45 - 13:00	8	3	1	0	1	1	0	2	1	0	0	0
13:00 - 13:15	8	2	1	1	1	0	0	1	0	0	1	0
13:15 - 13:30	8	2	1	1	0	0	0	1	1	0	0	0
13:30 - 13:45	8	2	1	1	0	0	1	1	0	0	0	0
13:45 - 14:00	7	3	1	1	2	1	0	0	0	0	0	0
14:00 - 14:15	6	3	1	1	1	1	0	1	0	0	0	0
14:15 - 14:30	8	2	1	2	0	0	2	0	1	0	0	0
14:30 - 14:45	3	2	1	2	1	0	2	2	0	0	0	1
14:45 - 15:00	8	3	1	2	1	1	1	2	1	0	0	0
15:00 - 15:15	12	2	1	1	2	1	0	2	0	0	0	0
15:15 - 15:30	11	2	1	1	0	0	2	0	1	0	0	0
15:30 - 15:45	6	3	1	1	1	0	0	2	1	0	0	0
15:45 - 16:00	5	4	1	2	1	1	2	2	0	0	0	0
16:00 - 16:15	6	4	1	1	1	1	0	2	0	0	0	1
16:15 - 16:30	3	3	1	1	0	1	1	2	1	0	0	0
16:30 - 16:45	3	3	1	1	1	0	0	0	0	0	0	0
16:45 - 17:00	3	2	1	1	1	0	2	2	1	0	0	0
17:00 - 17:15	2	2	1	1	1	0	0	0	0	0	0	0
17:15 - 17:30	3	2	1	0	1	1	2	1	1	0	0	0
17:30 - 17:45	3	1	1	1	1	0	0	1	0	0	0	0
17:45 - 18:00	2	1	1	0	1	1	2	2	1	0	0	0

Lembar ke	: 6	dari 14	Lokasi Pos	:	
Nama Propinsi	: D.I.Yogyakarta		Tanggal	: 13 Oktober 2021	
No Propinsi	:		Nama Jalan	: Nanggulan Mendut	
Nomor Pos	:		Arah Lalu Lintas	: Klangon	Ke Nanggulan
			Periode	:	

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	6	1	2	2	1	1	2	2	1	0	0	0
06:15 - 06.30	8	2	1	3	1	1	3	2	0	0	0	0
06:30 - 06:45	9	2	2	3	2	0	2	1	1	0	0	0
06:45 - 07:00	14	1	2	2	1	1	3	3	1	0	0	0
07:00 - 07:15	22	2	2	2	2	0	3	2	1	0	0	0
07:15 - 07:30	18	4	3	3	2	1	2	4	0	0	0	0
07:30 - 07:45	18	8	2	2	2	1	2	0	1	0	0	0
07:45 - 08:00	16	7	2	1	1	0	2	2	0	0	0	0
08:00 - 08:15	14	4	1	1	1	2	4	1	1	0	0	0
08:15 - 08:30	10	2	2	2	0	0	2	3	0	0	0	0
08:30 - 08:45	6	2	2	2	1	2	1	2	1	0	0	0
08:45 - 09:00	12	2	1	2	2	0	1	2	0	0	0	0
09:00 - 09:15	14	4	1	2	1	1	2	0	1	0	0	0
09:15 - 09:30	12	3	2	1	2	1	3	3	1	0	0	0
09:30 - 09:45	15	3	1	2	2	2	2	3	1	0	0	0
09:45 - 10:00	8	2	2	2	2	1	4	4	1	0	0	0
10:00 - 10:15	13	2	2	3	1	0	0	2	1	0	0	0
10:15 - 10:30	12	2	2	1	2	2	2	1	0	0	0	0
10:30 - 10:45	15	3	3	2	1	1	1	2	1	0	0	0
10:45 - 11:00	17	3	2	2	1	0	3	2	1	0	0	0
11:00 - 11:15	20	3	2	2	1	1	0	1	0	0	0	0
11:15 - 11:30	17	1	1	2	1	1	1	1	0	0	1	1
11:30 - 11:45	15	2	2	1	1	1	1	1	1	0	0	0
11:45 - 12:00	14	2	3	1	1	1	0	2	0	0	0	0
12:00 - 12:15	11	1	2	1	1	0	1	2	1	0	1	0
12:15 - 12:30	11	2	1	1	1	1	1	2	1	0	1	0
12:30 - 12:45	14	1	2	1	0	1	0	1	0	0	1	0
12:45 - 13:00	11	1	3	1	1	1	1	1	0	0	1	0
13:00 - 13:15	7	2	2	1	1	0	1	1	0	0	0	0
13:15 - 13:30	12	2	2	1	0	1	1	1	1	0	0	1
13:30 - 13:45	9	2	2	2	1	1	1	2	0	0	0	0
13:45 - 14:00	12	4	2	2	2	1	1	1	1	0	0	0
14:00 - 14:15	11	4	1	2	1	1	1	2	0	0	0	0
14:15 - 14:30	13	3	1	2	1	0	3	2	1	0	0	0
14:30 - 14:45	6	3	2	3	1	0	3	3	0	0	0	0
14:45 - 15:00	14	4	2	3	2	1	2	3	1	0	0	0
15:00 - 15:15	20	3	2	1	2	1	2	0	0	0	0	0
15:15 - 15:30	19	3	1	2	1	0	3	2	0	0	0	0
15:30 - 15:45	10	4	1	1	0	0	0	3	1	0	0	0
15:45 - 16:00	8	5	2	2	1	2	3	2	0	0	0	0
16:00 - 16:15	9	6	1	2	1	1	1	3	1	0	0	0
16:15 - 16:30	5	4	1	1	1	1	1	4	1	0	0	0
16:30 - 16:45	5	4	2	1	1	1	1	0	1	0	0	0
16:45 - 17:00	5	2	2	2	1	1	3	2	1	0	0	0
17:00 - 17:15	4	2	2	1	1	1	0	1	0	0	0	0
17:15 - 17:30	5	3	1	0	1	1	3	2	1	0	0	0
17:30 - 17:45	5	2	2	1	0	0	0	2	0	0	0	0
17:45 - 18:00	3	1	1	0	0	1	3	3	1	0	0	0

				Lokasi Pos	:
Lembar ke	: 7	dari	14	Tanggal	: 14 Oktober 2021
Nama Propinsi	: D.I.Yogyakarta			Nama Jalan	: Nanggulan Mendut
No Propinsi	:			Arah Lalu Lintas	: Nanggulan Ke Klangon
Nomor Pos	:			Periode	:

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	4	2	1	2	1	1	1	2	1	0	0	2
06:15 - 06.30	4	2	1	2	2	2	1	1	1	0	0	1
06:30 - 06:45	3	3	1	3	1	1	2	3	2	0	0	1
06:45 - 07:00	6	5	1	1	1	2	2	2	0	0	0	0
07:00 - 07:15	8	2	2	4	2	2	1	3	1	0	0	0
07:15 - 07:30	10	3	2	4	2	2	3	3	0	0	0	0
07:30 - 07:45	11	3	2	3	3	1	1	2	1	0	0	0
07:45 - 08:00	12	3	3	2	2	1	1	1	1	0	0	0
08:00 - 08:15	13	2	1	3	1	1	2	1	0	0	0	0
08:15 - 08:30	10	1	1	4	1	1	3	2	2	0	0	0
08:30 - 08:45	7	1	1	3	1	1	3	3	3	0	0	1
08:45 - 09:00	9	2	1	4	2	1	2	2	2	0	0	0
09:00 - 09:15	8	3	1	1	1	1	0	2	0	0	0	0
09:15 - 09:30	6	2	1	2	2	1	2	2	2	0	0	0
09:30 - 09:45	7	2	2	2	2	1	3	1	0	0	0	0
09:45 - 10:00	5	2	1	2	2	1	2	2	1	0	0	0
10:00 - 10:15	6	3	1	1	1	1	2	2	2	0	0	0
10:15 - 10:30	7	4	2	1	2	2	1	2	2	0	1	0
10:30 - 10:45	11	4	2	2	1	2	3	1	0	0	0	0
10:45 - 11:00	6	4	1	1	2	2	0	1	3	0	0	0
11:00 - 11:15	7	2	2	2	1	1	1	1	1	0	0	0
11:15 - 11:30	7	2	2	1	1	1	2	2	1	0	0	0
11:30 - 11:45	6	4	2	2	1	1	2	2	0	0	0	0
11:45 - 12:00	10	3	1	1	2	1	1	3	2	0	0	0
12:00 - 12:15	5	2	2	2	1	1	1	2	0	0	0	0
12:15 - 12:30	7	3	2	2	2	2	2	1	1	0	0	0
12:30 - 12:45	11	1	3	3	2	1	1	1	0	0	0	0
12:45 - 13:00	7	2	3	4	2	1	2	2	0	0	0	0
13:00 - 13:15	10	2	2	2	1	1	0	2	1	0	0	0
13:15 - 13:30	9	2	1	1	0	1	1	0	0	0	0	0
13:30 - 13:45	9	3	1	1	0	1	1	2	1	0	0	0
13:45 - 14:00	8	3	1	2	2	1	0	1	0	0	1	1
14:00 - 14:15	7	2	2	2	1	1	1	1	0	0	0	0
14:15 - 14:30	7	2	2	2	1	1	0	1	1	0	1	1
14:30 - 14:45	10	2	1	1	1	1	0	2	0	0	0	0
14:45 - 15:00	11	3	1	1	2	1	1	2	0	0	0	0
15:00 - 15:15	12	2	2	0	2	1	0	1	0	0	0	0
15:15 - 15:30	15	3	1	0	1	1	0	3	0	0	1	0
15:30 - 15:45	8	3	1	1	1	2	1	2	0	0	0	0
15:45 - 16:00	8	3	1	1	1	2	0	1	0	0	0	1
16:00 - 16:15	6	2	2	1	0	2	0	1	0	0	0	0
16:15 - 16:30	6	2	2	0	3	2	0	1	0	0	0	0
16:30 - 16:45	7	2	2	0	3	1	0	1	0	0	0	0
16:45 - 17:00	4	2	1	2	2	2	0	1	1	0	0	0
17:00 - 17:15	3	1	1	2	2	2	1	3	2	0	0	0
17:15 - 17:30	3	2	1	1	2	2	1	2	0	0	0	0
17:30 - 17:45	3	1	1	1	1	2	1	1	1	0	0	1
17:45 - 18:00	2	2	1	1	2	1	1	2	1	0	0	0

Lembar ke	: 8	dari 14	Lokasi Pos	:	
Nama Propinsi	: D.I.Yogyakarta		Tanggal	: 14 Oktober 2021	
No Propinsi	:		Nama Jalan	: Nanggulan Mendut	
Nomor Pos	:		Arah Lalu Lintas	: Klangon	Ke Nanggulan
			Periode	:	

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	7	2	2	3	2	2	2	3	1	0	0	0
06:15 - 06.30	6	3	1	4	2	3	2	2	0	0	0	0
06:30 - 06:45	5	4	1	4	1	2	3	4	1	0	0	0
06:45 - 07:00	10	7	2	2	2	3	4	3	0	0	0	0
07:00 - 07:15	14	3	3	6	3	4	2	5	1	0	0	0
07:15 - 07:30	17	4	3	7	3	3	4	5	0	0	0	0
07:30 - 07:45	18	4	4	4	4	2	2	0	1	0	0	0
07:45 - 08:00	20	5	5	4	2	2	2	2	0	0	0	0
08:00 - 08:15	22	3	1	4	1	1	4	2	0	0	0	0
08:15 - 08:30	17	2	2	7	0	2	5	4	0	0	0	0
08:30 - 08:45	12	2	2	5	2	2	4	5	1	0	0	0
08:45 - 09:00	15	3	1	6	2	2	1	3	0	0	0	0
09:00 - 09:15	14	4	2	1	2	1	0	0	0	0	0	0
09:15 - 09:30	10	3	2	2	2	2	4	3	1	0	0	0
09:30 - 09:45	13	3	2	3	3	2	5	2	0	0	0	0
09:45 - 10:00	8	2	1	4	2	1	4	3	1	0	0	0
10:00 - 10:15	10	4	2	1	2	2	0	4	2	0	0	0
10:15 - 10:30	11	5	3	2	3	3	2	3	0	0	0	0
10:30 - 10:45	18	6	3	3	2	3	1	2	0	0	0	0
10:45 - 11:00	11	6	2	2	3	3	0	2	2	0	0	0
11:00 - 11:15	11	3	3	3	1	2	2	2	0	0	0	0
11:15 - 11:30	17	1	1	2	2	1	1	1	0	0	1	1
11:30 - 11:45	15	2	2	1	2	1	1	1	1	0	0	0
11:45 - 12:00	14	2	3	1	1	1	0	2	0	0	0	0
12:00 - 12:15	11	1	2	1	2	0	1	2	0	0	1	0
12:15 - 12:30	11	2	1	1	3	1	1	2	1	0	1	0
12:30 - 12:45	14	1	2	1	3	1	0	1	0	0	1	0
12:45 - 13:00	11	1	3	1	3	1	1	1	0	0	1	0
13:00 - 13:15	7	2	2	1	1	0	1	1	0	0	0	0
13:15 - 13:30	12	2	2	1	0	1	1	1	0	0	0	1
13:30 - 13:45	9	2	2	2	1	1	1	2	0	0	0	0
13:45 - 14:00	14	4	2	2	3	2	1	1	1	0	0	0
14:00 - 14:15	11	3	3	4	2	2	1	2	0	0	0	0
14:15 - 14:30	12	2	2	3	1	1	0	2	1	0	0	0
14:30 - 14:45	12	2	1	1	0	0	1	1	0	0	0	0
14:45 - 15:00	9	1	4	1	0	0	1	1	0	0	1	0
15:00 - 15:15	13	1	2	1	0	0	1	1	1	0	0	0
15:15 - 15:30	15	1	3	1	0	0	1	1	0	0	0	0
15:30 - 15:45	14	1	2	1	0	0	0	1	0	0	1	0
15:45 - 16:00	12	1	3	2	0	0	0	1	1	0	1	0
16:00 - 16:15	13	1	1	1	0	0	1	1	1	0	1	0
16:15 - 16:30	13	2	3	1	0	0	1	2	0	0	0	0
16:30 - 16:45	15	2	2	1	0	0	1	1	0	0	0	0
16:45 - 17:00	7	2	2	4	3	1	0	2	1	0	0	0
17:00 - 17:15	5	1	2	3	3	1	0	1	0	0	0	0
17:15 - 17:30	5	2	1	2	2	3	2	3	0	0	0	0
17:30 - 17:45	5	2	2	1	0	3	2	2	0	0	0	0
17:45 - 18:00	3	2	1	2	0	2	2	3	1	0	0	0

Lembar ke	: 9	dari 14	Lokasi Pos	:		
Nama Propinsi	: D.I.Yogyakarta		Tanggal	: 15 Oktober 2021		
No Propinsi	:		Nama Jalan	: Nanggulan Mendut		
Nomor Pos	:		Arah Lalu Lintas	: Nanggulan	Ke Klangon	
			Periode	:		

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	7	3	1	3	2	2	2	3	2	0	0	3
06:15 - 06.30	6	3	1	4	2	2	1	2	2	0	0	1
06:30 - 06:45	4	5	1	4	1	1	3	4	3	0	0	1
06:45 - 07:00	10	8	2	2	2	3	3	3	0	0	0	0
07:00 - 07:15	13	4	3	4	3	2	3	4	0	0	0	0
07:15 - 07:30	11	5	4	3	3	2	4	2	1	0	1	1
07:30 - 07:45	12	6	5	4	2	1	3	2	2	0	0	0
07:45 - 08:00	12	3	3	3	2	2	2	2	0	0	0	0
08:00 - 08:15	13	3	4	2	2	2	3	3	3	0	0	0
08:15 - 08:30	13	3	2	2	1	0	2	3	0	0	1	0
08:30 - 08:45	14	2	2	2	2	2	1	2	1	0	0	0
08:45 - 09:00	19	2	1	2	2	0	0	2	0	0	0	1
09:00 - 09:15	20	5	1	2	1	1	2	0	2	0	0	0
09:15 - 09:30	20	4	2	1	2	1	3	3	2	0	0	0
09:30 - 09:45	11	3	1	2	2	2	2	3	2	0	0	0
09:45 - 10:00	12	2	2	2	2	1	3	4	1	0	0	0
10:00 - 10:15	14	3	2	3	1	0	0	2	2	0	0	0
10:15 - 10:30	10	6	2	2	3	3	1	3	3	0	1	0
10:30 - 10:45	17	7	3	3	2	3	4	2	0	0	0	0
10:45 - 11:00	10	7	2	2	3	2	0	2	4	0	0	0
11:00 - 11:15	11	3	2	3	1	2	2	2	2	0	0	0
11:15 - 11:30	12	3	3	2	2	2	2	3	2	0	0	0
11:30 - 11:45	9	7	2	2	2	2	3	4	0	0	0	0
11:45 - 12:00	9	4	3	3	2	2	1	3	0	0	0	0
12:00 - 12:15	18	3	2	2	1	0	1	3	2	0	0	0
12:15 - 12:30	17	3	3	2	1	1	1	2	2	0	0	0
12:30 - 12:45	15	2	2	2	0	0	1	2	0	0	0	0
12:45 - 13:00	13	4	1	0	1	1	0	2	2	0	0	0
13:00 - 13:15	14	4	2	1	1	0	0	2	0	0	1	0
13:15 - 13:30	13	4	1	2	0	0	0	1	2	0	0	0
13:30 - 13:45	14	3	1	1	0	0	1	2	0	0	0	0
13:45 - 14:00	15	5	2	2	2	1	0	0	0	0	0	0
14:00 - 14:15	16	4	2	4	2	2	2	3	3	0	0	0
14:15 - 14:30	15	2	2	5	2	1	3	3	2	0	1	0
14:30 - 14:45	15	2	2	4	2	2	3	2	2	0	0	0
14:45 - 15:00	19	2	2	4	2	1	4	2	1	0	0	1
15:00 - 15:15	18	8	4	4	2	2	2	3	2	0	0	0
15:15 - 15:30	19	9	5	3	2	1	4	3	3	0	0	0
15:30 - 15:45	21	9	5	3	1	2	3	2	0	0	0	0
15:45 - 16:00	16	11	6	3	3	2	4	3	3	0	1	0
16:00 - 16:15	14	4	3	4	1	0	1	3	1	0	0	0
16:15 - 16:30	17	5	3	5	0	1	2	2	1	0	0	0
16:30 - 16:45	14	5	3	3	2	1	2	2	0	0	0	1
16:45 - 17:00	11	4	3	3	2	1	0	2	2	0	0	0
17:00 - 17:15	13	3	4	2	1	1	1	3	2	0	0	0
17:15 - 17:30	11	2	3	1	2	0	1	2	0	0	0	0
17:30 - 17:45	10	1	3	1	1	1	1	2	1	0	0	1
17:45 - 18:00	5	2	2	2	1	1	1	2	1	0	0	0

Lembar ke	: 10	dari 14	Lokasi Pos	:	
Nama Propinsi	: D.I.Yogyakarta		Tanggal	: 15 Oktober 2021	
No Propinsi	:		Nama Jalan	: Nanggulan Mendut	
Nomor Pos	:		Arah Lalu Lintas	: Klangon	Ke Nanggulan
			Periode	:	

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	11	3	2	5	3	3	3	5	1	0	0	0
06:15 - 06.30	9	5	1	6	3	4	2	3	0	0	0	0
06:30 - 06:45	7	6	1	6	1	2	5	7	2	0	0	0
06:45 - 07:00	16	11	2	3	3	5	6	5	0	0	0	0
07:00 - 07:15	16	6	4	6	3	3	6	6	0	0	0	0
07:15 - 07:30	12	7	7	5	4	2	6	2	0	0	0	0
07:30 - 07:45	13	8	8	6	3	2	6	0	2	0	0	0
07:45 - 08:00	13	5	5	4	2	3	4	2	0	0	0	0
08:00 - 08:15	11	4	7	3	3	2	6	4	2	0	0	0
08:15 - 08:30	12	4	3	3	0	0	3	5	0	0	0	0
08:30 - 08:45	19	3	3	3	2	2	2	3	1	0	0	0
08:45 - 09:00	13	3	2	2	2	0	1	2	0	0	0	0
09:00 - 09:15	18	6	2	3	2	2	3	0	1	0	0	0
09:15 - 09:30	19	5	2	2	3	1	5	4	1	0	0	0
09:30 - 09:45	10	4	2	3	3	3	3	5	1	0	0	0
09:45 - 10:00	12	3	3	3	2	2	6	6	1	0	0	0
10:00 - 10:15	24	3	3	4	2	0	0	3	2	0	0	0
10:15 - 10:30	17	8	4	3	4	4	2	4	0	0	0	0
10:30 - 10:45	16	9	5	4	3	5	1	2	0	0	0	0
10:45 - 11:00	17	10	3	3	4	4	0	2	3	0	0	0
11:00 - 11:15	18	4	4	5	2	3	3	3	0	0	0	0
11:15 - 11:30	17	1	1	2	3	1	1	1	0	0	1	1
11:30 - 11:45	15	2	2	1	3	1	1	1	1	0	0	0
11:45 - 12:00	14	2	3	1	1	1	0	2	0	0	0	0
12:00 - 12:15	11	1	2	1	1	0	1	2	1	0	1	0
12:15 - 12:30	11	2	1	1	1	1	1	2	2	0	1	0
12:30 - 12:45	14	1	2	1	0	1	0	1	0	0	1	0
12:45 - 13:00	11	1	3	1	2	1	1	1	0	0	1	0
13:00 - 13:15	14	2	2	1	1	0	1	1	0	0	0	0
13:15 - 13:30	17	2	2	1	0	1	1	1	1	0	0	1
13:30 - 13:45	15	2	2	2	1	1	1	2	0	0	0	0
13:45 - 14:00	24	6	2	3	3	1	1	1	1	0	0	0
14:00 - 14:15	27	5	3	7	3	4	1	5	0	0	0	0
14:15 - 14:30	25	3	3	8	1	2	5	2	2	0	0	0
14:30 - 14:45	11	1	5	2	2	2	1	2	0	0	0	0
14:45 - 15:00	9	2	2	3	2	1	1	2	1	0	0	1
15:00 - 15:15	14	4	3	5	4	2	4	3	0	0	1	0
15:15 - 15:30	13	5	4	3	3	1	6	4	0	0	0	0
15:30 - 15:45	13	4	5	3	2	2	4	2	0	0	0	1
15:45 - 16:00	12	5	5	3	4	2	6	4	1	0	0	0
16:00 - 16:15	10	3	3	4	2	0	2	4	1	0	0	0
16:15 - 16:30	12	3	4	4	0	0	3	3	0	0	0	0
16:30 - 16:45	10	3	3	3	3	1	4	3	0	0	0	1
16:45 - 17:00	19	6	5	4	3	1	0	2	1	0	0	0
17:00 - 17:15	22	3	6	4	1	1	0	1	0	0	0	0
17:15 - 17:30	19	3	4	2	2	0	2	3	0	0	0	0
17:30 - 17:45	17	1	4	1	0	1	2	2	0	0	0	0
17:45 - 18:00	8	2	4	2	0	1	2	3	1	0	0	0

Lembar ke	:	11	dari	14	Lokasi Pos	:		
Nama Propinsi	: D.I.Yogyakarta				Tanggal	: 16 Oktober 2021		
No Propinsi	:				Nama Jalan	: Nanggulan Mendut		
Nomor Pos	:				Arah Lalu Lintas	: Nanggulan	Ke Klangon	
					Periode	:		

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	8	3	2	4	2	2	2	4	3	0	0	4
06:15 - 06.30	7	4	1	4	3	3	2	3	2	0	0	2
06:30 - 06:45	5	6	1	5	1	2	4	5	4	0	0	1
06:45 - 07:00	12	10	2	2	2	4	4	4	0	0	0	0
07:00 - 07:15	17	5	3	5	3	2	4	5	0	0	0	0
07:15 - 07:30	15	6	5	4	3	2	5	2	1	0	1	1
07:30 - 07:45	16	7	6	5	3	1	4	3	3	0	0	0
07:45 - 08:00	16	4	4	3	2	2	3	2	0	0	0	0
08:00 - 08:15	16	4	5	2	3	2	4	3	3	0	0	0
08:15 - 08:30	17	3	3	2	1	0	2	4	0	0	1	0
08:30 - 08:45	9	2	2	4	2	2	3	4	4	0	0	1
08:45 - 09:00	12	3	1	5	2	1	2	2	3	0	0	0
09:00 - 09:15	11	4	2	1	1	1	0	3	0	0	0	0
09:15 - 09:30	7	3	2	2	2	1	3	2	2	0	0	0
09:30 - 09:45	10	3	2	2	2	2	4	1	0	0	0	0
09:45 - 10:00	6	2	1	3	2	1	3	2	1	0	0	0
10:00 - 10:15	10	3	2	2	1	1	2	2	2	0	0	0
10:15 - 10:30	8	1	2	1	2	2	1	2	2	0	1	0
10:30 - 10:45	9	2	1	1	1	2	2	1	0	0	0	0
10:45 - 11:00	10	1	1	2	2	1	0	1	3	0	0	0
11:00 - 11:15	6	3	2	2	1	1	2	2	0	0	0	0
11:15 - 11:30	5	3	2	1	1	1	2	2	3	0	0	0
11:30 - 11:45	7	2	2	2	1	1	2	2	0	0	0	0
11:45 - 12:00	7	3	3	2	2	1	1	2	2	0	0	0
12:00 - 12:15	4	3	4	1	1	1	2	2	2	0	0	0
12:15 - 12:30	9	3	3	1	2	2	2	1	2	0	0	0
12:30 - 12:45	12	2	2	0	0	1	1	1	0	0	0	0
12:45 - 13:00	9	3	1	0	0	1	0	1	0	0	0	0
13:00 - 13:15	12	3	1	0	0	0	0	1	0	0	0	0
13:15 - 13:30	11	3	1	0	1	0	0	1	0	0	0	0
13:30 - 13:45	9	3	2	0	1	0	0	1	0	0	0	0
13:45 - 14:00	11	3	2	1	0	0	0	1	0	0	0	0
14:00 - 14:15	11	2	2	0	0	0	0	1	0	0	0	0
14:15 - 14:30	10	5	2	1	0	0	0	1	0	0	0	0
14:30 - 14:45	10	4	1	0	0	0	0	1	0	0	0	0
14:45 - 15:00	15	2	2	2	0	1	1	2	0	0	0	0
15:00 - 15:15	16	2	2	2	1	0	2	0	2	0	0	0
15:15 - 15:30	17	2	2	2	2	1	2	2	0	0	0	0
15:30 - 15:45	15	3	3	3	2	1	2	0	2	0	0	1
15:45 - 16:00	13	2	4	3	1	1	0	3	0	0	0	0
16:00 - 16:15	12	3	2	4	1	0	1	2	1	0	0	0
16:15 - 16:30	14	4	3	4	0	1	2	2	1	0	0	0
16:30 - 16:45	11	4	2	2	1	1	2	2	0	0	0	1
16:45 - 17:00	9	4	2	2	2	1	0	1	1	0	0	0
17:00 - 17:15	11	2	3	2	1	1	1	3	2	0	0	0
17:15 - 17:30	9	2	2	1	1	0	1	2	0	0	0	0
17:30 - 17:45	8	1	2	1	1	1	1	1	1	0	0	1
17:45 - 18:00	4	1	2	1	1	1	1	2	1	0	0	0

Lembar ke	: 12	dari 14	Lokasi Pos	:	
Nama Propinsi	: D.I.Yogyakarta		Tanggal	: 16 Oktober 2021	
No Propinsi	:		Nama Jalan	: Nanggulan Mendut	
Nomor Pos	:		Arah Lalu Lintas	: Klangon	Ke Nanggulan
			Periode	:	

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	10	4	3	7	3	3	4	6	2	0	0	0
06:15 - 06.30	9	6	1	7	4	5	3	4	0	0	0	0
06:30 - 06:45	7	8	2	8	2	3	6	9	2	0	0	0
06:45 - 07:00	15	14	3	4	3	6	7	6	0	0	0	0
07:00 - 07:15	20	8	6	8	4	3	7	7	0	0	0	0
07:15 - 07:30	18	9	8	6	5	3	8	3	0	0	0	0
07:30 - 07:45	20	10	10	8	4	2	7	0	2	0	0	0
07:45 - 08:00	19	6	7	5	2	4	5	3	0	0	0	0
08:00 - 08:15	20	5	8	3	4	3	7	5	2	0	0	0
08:15 - 08:30	21	5	4	3	0	0	4	6	0	0	0	0
08:30 - 08:45	11	2	2	6	2	3	5	6	1	0	0	0
08:45 - 09:00	14	4	1	8	3	2	1	3	0	0	0	0
09:00 - 09:15	13	5	3	2	2	1	0	0	0	0	0	0
09:15 - 09:30	9	4	2	3	3	2	5	3	1	0	0	0
09:30 - 09:45	12	4	3	3	3	3	7	2	0	0	0	0
09:45 - 10:00	7	3	2	5	3	1	5	3	1	0	0	0
10:00 - 10:15	12	4	3	3	1	1	0	3	1	0	0	0
10:15 - 10:30	10	2	3	1	2	3	2	2	0	0	0	0
10:30 - 10:45	11	2	2	2	2	3	1	1	0	0	0	0
10:45 - 11:00	13	2	2	2	2	2	0	2	2	0	0	0
11:00 - 11:15	8	4	3	2	1	2	2	3	0	0	0	0
11:15 - 11:30	6	1	1	2	2	1	1	1	0	0	1	1
11:30 - 11:45	9	2	2	1	2	1	1	1	1	0	0	0
11:45 - 12:00	8	2	3	1	1	1	0	2	0	0	0	0
12:00 - 12:15	5	1	2	1	1	0	1	2	1	0	1	0
12:15 - 12:30	11	2	1	1	2	1	1	2	1	0	1	0
12:30 - 12:45	15	2	4	2	0	0	0	2	0	0	0	0
12:45 - 13:00	11	1	4	1	0	0	0	1	1	0	1	0
13:00 - 13:15	15	2	4	1	0	0	1	0	1	0	0	0
13:15 - 13:30	14	2	2	1	0	0	1	1	1	0	1	0
13:30 - 13:45	11	3	2	2	0	0	0	1	0	0	0	0
13:45 - 14:00	13	2	3	2	0	1	0	1	0	0	0	0
14:00 - 14:15	14	3	2	1	0	0	1	1	0	0	0	0
14:15 - 14:30	12	3	4	2	0	0	0	0	0	0	0	0
14:30 - 14:45	12	2	3	2	0	0	1	1	0	0	0	0
14:45 - 15:00	18	1	8	2	1	0	2	3	0	0	0	0
15:00 - 15:15	20	2	3	2	2	0	3	2	2	0	0	0
15:15 - 15:30	21	2	3	2	4	1	5	3	0	0	0	0
15:30 - 15:45	18	2	4	3	4	1	3	2	2	0	0	1
15:45 - 16:00	15	1	5	3	3	1	0	0	0	0	0	0
16:00 - 16:15	14	9	1	3	2	2	1	5	1	0	0	0
16:15 - 16:30	17	6	2	2	2	1	2	6	1	0	0	0
16:30 - 16:45	14	6	3	1	1	1	2	0	1	0	0	0
16:45 - 17:00	11	5	4	3	2	1	0	2	1	0	0	0
17:00 - 17:15	13	3	5	3	1	1	0	1	0	0	0	0
17:15 - 17:30	11	3	3	2	2	0	2	3	0	0	0	0
17:30 - 17:45	10	1	3	1	0	1	1	2	0	0	0	0
17:45 - 18:00	5	2	3	2	0	1	1	2	1	0	0	0

Lembar ke	: 13	dari 14	Lokasi Pos	:	
Nama Propinsi	: D.I.Yogyakarta		Tanggal	: 17 Oktober 2021	
No Propinsi	:		Nama Jalan	: Nanggulan Mendut	
Nomor Pos	:		Arah Lalu Lintas	: Nanggulan	Ke Klangon
			Periode	:	

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	6	4	2	5	3	3	3	5	3	0	0	5
06:15 - 06.30	6	6	1	6	4	4	2	3	2	0	0	2
06:30 - 06:45	5	8	2	6	2	2	5	7	5	0	0	1
06:45 - 07:00	6	14	3	3	3	5	6	5	0	0	0	0
07:00 - 07:15	10	7	5	6	4	3	6	6	0	0	0	0
07:15 - 07:30	8	9	7	5	5	2	6	2	2	0	1	1
07:30 - 07:45	10	10	8	7	4	2	6	4	4	0	0	0
07:45 - 08:00	18	6	6	4	2	3	4	2	0	0	0	0
08:00 - 08:15	19	3	3	2	1	2	2	1	0	0	0	0
08:15 - 08:30	11	3	3	2	2	1	3	2	2	0	0	0
08:30 - 08:45	13	2	3	2	2	1	2	3	3	0	0	1
08:45 - 09:00	16	2	4	2	1	1	2	2	2	0	0	0
09:00 - 09:15	15	3	2	2	2	2	0	2	0	0	0	0
09:15 - 09:30	15	3	2	2	1	1	2	2	2	0	0	0
09:30 - 09:45	15	2	3	1	1	1	3	1	0	0	0	0
09:45 - 10:00	17	2	2	2	2	1	2	2	1	0	0	0
10:00 - 10:15	14	4	1	3	0	1	1	1	0	0	0	0
10:15 - 10:30	14	5	2	3	2	2	2	2	2	0	0	0
10:30 - 10:45	17	6	1	4	1	1	2	2	2	0	0	0
10:45 - 11:00	14	6	1	3	1	0	2	2	0	0	0	0
11:00 - 11:15	15	4	2	2	1	1	1	1	1	0	0	0
11:15 - 11:30	16	2	2	1	1	1	2	2	1	0	0	0
11:30 - 11:45	6	4	2	2	2	1	2	2	0	0	0	0
11:45 - 12:00	12	3	2	1	0	0	1	3	2	0	0	0
12:00 - 12:15	13	3	2	1	1	0	1	3	1	0	0	0
12:15 - 12:30	13	2	2	1	1	1	1	2	2	0	0	0
12:30 - 12:45	14	2	1	2	0	0	1	2	0	0	0	0
12:45 - 13:00	15	3	1	0	1	1	0	2	2	0	0	0
13:00 - 13:15	17	3	2	1	1	0	0	1	0	0	1	0
13:15 - 13:30	17	3	1	2	0	0	0	1	1	0	0	0
13:30 - 13:45	17	3	1	1	0	0	1	1	0	0	0	0
13:45 - 14:00	17	4	1	2	2	1	0	0	0	0	0	0
14:00 - 14:15	16	3	3	3	2	1	1	2	0	0	0	0
14:15 - 14:30	18	2	2	2	1	1	0	1	1	0	1	1
14:30 - 14:45	16	3	2	1	2	1	0	2	0	0	0	0
14:45 - 15:00	20	4	1	2	3	1	1	2	0	0	0	0
15:00 - 15:15	17	3	2	0	3	2	0	1	0	0	0	0
15:15 - 15:30	17	4	1	0	1	2	0	4	0	0	1	0
15:30 - 15:45	15	3	2	2	1	2	1	3	0	0	0	0
15:45 - 16:00	14	4	2	1	2	3	0	1	0	0	0	1
16:00 - 16:15	12	6	4	6	2	0	1	3	1	0	0	0
16:15 - 16:30	9	6	4	6	0	1	2	2	1	0	0	0
16:30 - 16:45	8	7	4	4	2	1	3	2	0	0	0	1
16:45 - 17:00	7	6	4	3	2	2	0	2	2	0	0	0
17:00 - 17:15	7	3	5	3	1	1	2	4	2	0	0	0
17:15 - 17:30	5	3	3	2	2	0	2	3	0	0	0	0
17:30 - 17:45	4	1	3	1	1	1	1	2	1	0	0	2
17:45 - 18:00	3	2	3	2	1	1	1	2	1	0	0	0

Lembar ke	:	14	dari	14	Lokasi Pos	:
Nama Propinsi	:	D.I.Yogyakarta			Tanggal	: 17 Oktober 2021
No Propinsi	:				Nama Jalan	: Nanggulan Mendut
Nomor Pos	:				Arah Lalu Lintas	: Klangon Ke Nanggulan
					Periode	:

GOL	1	2	3	4	5a	5b	6a	6b	7a	7b	7c	8
Waktu	Sepeda Motor, sekuter sepeda kumbang dan roda 3	Sedan, jeep & station wagon	Opelet, pick-up opelet, suburban, combi, dan minibus	Pick-up, micro truk, dan mobil hantaran	Bus Kecil	Bus Besar	Truk Ringan 2 sumbu	Truk Sedang 2 sumbu	Truk 3 sumbu	Truk Gandeng	Truk Semi trailer	Kendaraan tidak bermotor
06:00 - 06:15	7	6	4	9	5	5	5	9	2	0	0	0
06:15 - 06.30	8	8	2	10	5	7	4	5	0	0	0	0
06:30 - 06:45	6	11	2	11	2	4	8	12	3	0	0	0
06:45 - 07:00	7	19	4	5	5	9	10	9	0	0	0	0
07:00 - 07:15	12	10	8	11	6	5	10	10	0	0	0	0
07:15 - 07:30	10	12	11	8	6	4	11	4	0	0	0	0
07:30 - 07:45	13	14	13	11	5	3	10	0	2	0	0	0
07:45 - 08:00	22	8	9	7	3	5	7	4	0	0	0	0
08:00 - 08:15	23	4	5	4	2	3	4	2	0	0	0	0
08:15 - 08:30	13	3	6	2	0	2	5	4	0	0	0	0
08:30 - 08:45	15	2	4	3	2	1	4	5	1	0	0	0
08:45 - 09:00	19	2	6	4	1	2	1	3	0	0	0	0
09:00 - 09:15	18	4	2	3	2	2	0	0	0	0	0	0
09:15 - 09:30	18	4	3	3	1	1	4	3	1	0	0	0
09:30 - 09:45	18	2	4	2	2	2	5	2	0	0	0	0
09:45 - 10:00	20	3	3	3	2	2	4	3	1	0	0	0
10:00 - 10:15	17	6	2	5	0	1	0	1	0	0	0	0
10:15 - 10:30	17	7	2	5	2	3	2	3	0	0	0	0
10:30 - 10:45	21	8	1	6	2	2	1	4	1	0	0	0
10:45 - 11:00	17	8	2	5	1	0	4	2	0	0	0	0
11:00 - 11:15	18	5	2	3	1	1	2	2	0	0	0	0
11:15 - 11:30	20	1	1	2	2	1	1	1	0	0	1	1
11:30 - 11:45	7	2	2	1	2	1	1	1	1	0	0	0
11:45 - 12:00	14	2	3	1	1	1	0	2	0	0	0	0
12:00 - 12:15	16	1	2	1	1	0	1	2	1	0	1	0
12:15 - 12:30	15	2	1	1	1	1	1	2	1	0	1	0
12:30 - 12:45	17	2	4	2	0	0	0	2	0	0	0	0
12:45 - 13:00	19	1	4	1	0	0	0	1	1	0	1	0
13:00 - 13:15	21	2	4	1	0	0	1	0	1	0	0	0
13:15 - 13:30	21	2	2	1	0	0	1	1	1	0	1	0
13:30 - 13:45	21	3	2	2	0	0	0	1	0	0	0	0
13:45 - 14:00	21	2	3	2	0	1	0	1	0	0	0	0
14:00 - 14:15	20	3	2	1	0	0	1	1	0	0	0	0
14:15 - 14:30	22	3	4	2	0	0	0	0	0	0	0	0
14:30 - 14:45	20	2	3	2	0	0	1	1	0	0	0	0
14:45 - 15:00	25	7	3	4	3	2	3	4	1	0	0	0
15:00 - 15:15	21	4	3	2	3	2	2	0	0	0	0	0
15:15 - 15:30	21	4	2	2	1	0	4	3	0	0	0	0
15:30 - 15:45	18	5	2	2	0	0	0	4	1	0	0	0
15:45 - 16:00	18	8	3	4	2	2	5	3	0	0	0	0
16:00 - 16:15	14	2	2	2	0	0	1	2	1	0	1	0
16:15 - 16:30	11	3	5	2	0	0	1	2	0	0	0	0
16:30 - 16:45	9	3	4	1	0	0	1	2	0	0	0	0
16:45 - 17:00	9	8	6	5	3	1	0	3	1	0	0	0
17:00 - 17:15	9	5	8	5	2	1	0	1	0	0	0	0
17:15 - 17:30	7	4	5	2	3	0	3	5	0	0	0	0
17:30 - 17:45	5	2	5	1	0	2	2	3	0	0	0	0
17:45 - 18:00	4	3	5	3	0	1	2	4	1	0	0	0

Appendix 2 Survey Activities Sentolo-Nanggulan-Dekso Road

Figure A-2.1 Survey activities (1)

Figure A-2.2 Survey activities (3)

Appendix 3 Analysis Result of Existing Pavement using KENPAVE Program with Viscoelastic Model

```
INPUT FILE NAME  -C:\KENPAVE\EVALUATION EXISTING VISCOELASTIC_6.DAT

NUMBER OF PROBLEMS TO BE SOLVED =  1

TITLE -EVALUATION EXISTING VISCOELASTIC 1

MATL = 3 FOR VISCOELASTIC LAYERED SYSTEM
NDAMA = 0, SO DAMAGE ANALYSIS WILL NOT BE PERFORMED
NUMBER OF PERIODS PER YEAR (NPY) =  1
NUMBER OF LOAD GROUPS (NLG) =  1
TOLERANCE FOR INTEGRATION (DEL) -- =  0.001
NUMBER OF LAYERS (NL)------------- =  4
NUMBER OF Z COORDINATES (NZ)------ =  5
LIMIT OF INTEGRATION CYCLES (ICL)- =  80
COMPUTING CODE (NSTD)------------- =  9
SYSTEM OF UNITS (NUNIT)------------=  1

Length and displacement in cm, stress and modulus in kPa
unit weight in kN/m^3, and temperature in C

THICKNESSES OF LAYERS (TH) ARE : 4  6  40
POISSON'S RATIOS OF LAYERS (PR) ARE : 0.4  0.4  0.35  0.45
VERTICAL COORDINATES OF POINTS (ZC) ARE:  0  9.9995  10.0005  49.9995
 50.0005
ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE :    1  1.100E+06   2  1.600E+06
   3  2.500E+05   4  1.500E+05

LOAD GROUP NO. 1  HAS 2  CONTACT AREAS
CONTACT RADIUS (CR)--------------- =  11
CONTACT PRESSURE (CP)------------- =  550
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- =  3
WHEEL SPACING ALONG X-AXIS (XW)------------------- =  0
WHEEL SPACING ALONG Y-AXIS (YW)------------------- =  33

RESPONSE PT. NO. AND (XPT, YPT) ARE:  1   0.000   0.000  2   0.000  10.000
  3   0.000  16.500

DURATION OF MOVING LOAD (DUR) =  0.1
NUMBER OF VISCOELASTIC LAYER (NVL)          =  2
LAYER NUMBERS WHICH ARE VISCOELASTIC (LNV) =  1  2
CREEP TIMES (TYME) ARE: 0.001  0.003  0.01  0.03  0.1  0.3  1  3  10  30  100

FOR LAYER 1  TIME TEMPERATURE SHIFT FACTOR (BETA) =  0.113
REFERENCE TEMPERATURE (TEMREF) =  25

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 25  ARE:
  9.162E-07  9.303E-07  9.778E-07  1.098E-06  1.393E-06  1.746E-06  2.152E-06
  2.599E-02  3.276E-06  5.095E-06  1.146E-05

FOR LAYER 2  TIME TEMPERATURE SHIFT FACTOR (BETA) =  0.113
REFERENCE TEMPERATURE (TEMREF) =  25

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 25  ARE:
  9.162E-07  9.303E-07  9.778E-07  1.098E-06  1.393E-06  1.746E-06  2.430E-05
  2.599E-06  3.276E-06  5.059E-06  1.146E-05

LAYER NO. 1  DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 25  ARE:
```

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1.372E-02 -3.534E-02 4.063E-02 -4.924E-02 5.031E-02 -2.093E-02 1.888E-03

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 25 ARE:
5.357E-04 -2.166E-04 -1.031E-03 1.143E-03 -2.230E-05 -4.460E-03 9.060E-03
1.777E-02 5.400E-03 -3.305E-03 1.143E-03

LAYER NO. 2 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 25 ARE:
-1.152E-05 2.708E-05 -2.357E-05 -9.569E-06 3.787E-05 -3.391E-05 1.360E-05

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 25 ARE:
4.403E-07 1.116E-06 1.906E-06 1.285E-07 9.385E-07 8.522E-06 1.155E-05
1.050E-05 3.239E-06 3.016E-06 1.240E-05

FOR PERIOD NO. 1 LAYER NO. AND TEMPERATURE ARE: 1 25 2 25

CREEP COMPLIANCES (CREEP) OF LAYER 1 AT TEMPERATURE (TEMP) OF 25 ARE:
5.357E-04 -2.166E-04 -1.031E-03 1.143E-03 -2.230E-05 -4.460E-03 9.060E-03
1.777E-02 5.400E-03 -3.305E-03 1.143E-03

CREEP COMPLIANCES (CREEP) OF LAYER 2 AT TEMPERATURE (TEMP) OF 25 ARE:
4.403E-07 1.116E-06 1.906E-06 1.285E-07 9.385E-07 8.522E-06 1.155E-05
1.050E-05 3.239E-06 3.016E-06 1.240E-05

PERIOD NO. 1 LOAD GROUP NO. 1

POINT NO.	VERTICAL COORDINATE	VERTICAL DISP.	VERTICAL STRESS (STRAIN)	MAJOR PRINCIPAL STRESS (STRAIN)	MINOR PRINCIAL STRESS (STRAIN)	INTERMEDIATE P. STRESS (HORIZONTAL P. STRAIN)
1	0.00000	0.66119	550.000	558.903	331.337	332.191
	(STRAIN)		1.754E-01	1.754E-01	-1.348E-02	-1.390E-02
1	9.99950	0.03242	305.451	305.686	-839.998	-697.389
	(STRAIN)		2.97E-04	3.598E-04	-2.157E-04	-2.157E-04
1	10.00050	0.03242	305.449	306.502	54.790	65.800
	(STRAIN)		7.511E-04	7.551E-04	-2.158E-04	-2.158E-04
1	49.99950	0.01912	38.941	39.602	-39.363	-30.566
	(STRAIN)		1.805E-04	1.831E-04	-1.215E-04	-1.215E-04
1	50.00050	0.01912	38.941	40.264	1.811	4.261
	(STRAIN)		2.374E-04	2.502E-04	-1.215E-04	-1.215E-04
2	0.00000	0.36108	550.000	287.626	160.009	185.439
	(STRAIN)		8.364E-02	8.364E-02	-1.663E-02	-2.493E-02
2	9.99950	0.03166	212.045	234.936	-639.790	-221.418
	(STRAIN)		1.765E-04	2.004E-04	-1.696E-04	-1.921E-04
2	10.00050	0.03166	212.040	234.073	41.233	75.916
	(STRAIN)		4.666E-04	5.516E-04	-1.922E-04	-1.922E-04
2	49.99950	0.01985	42.121	42.220	-42.536	-34.408
	(STRAIN)		1.972E-04	1.976E-04	-1.293E-04	-1.293E-04
2	50.00050	0.01985	42.120	42.323	1.872	4.951
	(STRAIN)		2.597E-04	2.617E-04	-1.293E-04	-1.293E-04
3	0.00000	-0.04577	0.000	71.681	-9.904	4.414
	(STRAIN)		-2.349E-02	3.674E-02	-2.313E-02	-2.981E-02
3	9.99950	0.03061	143.057	197.972	-487.300	73.299
	(STRAIN)		4.082E-05	1.774E-04	-1.641E-04	-1.641E-04
3	10.00050	0.03061	143.031	154.879	34.676	108.288
	(STRAIN)		2.538E-04	2.995E-04	-1.641E-04	-1.641E-04
3	49.99950	0.01999	42.688	42.688	-43.108	-35.048
	(STRAIN)		2.001E-04	2.001E-04	-1.308E-04	-1.308E-04
3	50.00050	0.01998	42.687	42.687	1.883	5.099
	(STRAIN)		2.636E-04	2.636E-04	-1.308E-04	-1.308E-04

Appendix 4 Analysis Result of Existing Pavement using KENPAVE Program with Linear Elastic Model

INPUT FILE NAME -C:\KENPAVE\EVALUATION EXISTING LINEAR ELASTIC_1.DAT

NUMBER OF PROBLEMS TO BE SOLVED = 1

TITLE -EVALUATION EXISTING LINEAR ELASTIC 1

MATL = 1 FOR LINEAR ELASTIC LAYERED SYSTEM
NDAMA = 0, SO DAMAGE ANALYSIS WILL NOT BE PERFORMED
NUMBER OF PERIODS PER YEAR (NPY) = 1
NUMBER OF LOAD GROUPS (NLG) = 1
TOLERANCE FOR INTEGRATION (DEL) -- = 0.001
NUMBER OF LAYERS (NL)------------- = 4
NUMBER OF Z COORDINATES (NZ)------ = 5
LIMIT OF INTEGRATION CYCLES (ICL)- = 80
COMPUTING CODE (NSTD)------------- = 9
SYSTEM OF UNITS (NUNIT)------------= 1

Length and displacement in cm, stress and modulus in kPa
unit weight in kN/m^3, and temperature in C

THICKNESSES OF LAYERS (TH) ARE : 4 6 40
POISSON'S RATIOS OF LAYERS (PR) ARE : 0.4 0.4 0.35 0.45
VERTICAL COORDINATES OF POINTS (ZC) ARE: 0 9.9995 10.0005 49.9995
50.0005
ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE : 1 1.100E+06 2 1.600E+06
3 2.500E+05 4 1.500E+05

LOAD GROUP NO. 1 HAS 2 CONTACT AREAS
CONTACT RADIUS (CR)--------------- = 11
CONTACT PRESSURE (CP)------------- = 550
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- = 3
WHEEL SPACING ALONG X-AXIS (XW)------------------- = 0
WHEEL SPACING ALONG Y-AXIS (YW)------------------- = 33

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 10.000
3 0.000 16.500

PERIOD NO. 1 LOAD GROUP NO. 1

POINT NO.	VERTICAL COORDINATE	VERTICAL DISP.	VERTICAL STRESS (STRAIN)	MAJOR PRINCIPAL STRESS (STRAIN)	MINOR PRINCIAL STRESS (STRAIN)	INTERMEDIATE P. STRESS (HORIZONTAL P. STRAIN)
1	0.00000	0.03424	550.000	975.051	750.838	955.282
	(STRAIN)		-1.936E-05	2.660E-04	-1.936E-05	2.408E-04
1	9.99950	0.03080	274.681	275.111	-408.779	-337.633
	(STRAIN)		2.82E-04	3.585E-04	-2.399E-04	-2.399E-04
1	10.00050	0.03080	274.662	275.797	27.472	42.577
	(STRAIN)		7.136E-04	7.179E-04	-2.399E-04	-2.399E-04
1	49.99950	0.01845	36.386	36.997	-37.234	-29.273
	(STRAIN)		1.699E-04	1.722E-04	-1.141E-04	-1.141E-04
1	50.00050	0.01845	36.386	37.610	1.448	3.644
	(STRAIN)		2.236E-04	2.355E-04	-1.141E-04	-1.141E-04
2	0.00000	0.03205	550.000	591.335	353.797	521.994
	(STRAIN)		-8.321E-05	2.191E-04	-8.321E-05	1.309E-04
2	9.99950	0.03046	200.152	207.335	-281.239	-27.103
	(STRAIN)		2.004E-04	2.067E-04	-2.208E-04	-2.208E-04

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2	10.00050	0.03046	200.159	212.444	20.769	67.761
	(STRAIN)		4.711E-04	5.185E-04	-2.209E-04	-2.209E-04
2	49.99950	0.01912	39.311	39.404	-40.184	-32.981
	(STRAIN)		1.854E-04	1.857E-04	-1.212E-04	-1.212E-04
2	50.00050	0.01912	39.310	39.501	1.481	4.201
	(STRAIN)		2.445E-04	2.463E-04	-1.212E-04	-1.212E-04
3	0.00000	0.03127	0.000	512.155	276.442	411.259
	(STRAIN)		-8.448E-05	2.155E-04	-8.448E-05	8.711E-05
3	9.99950	0.02970	146.977	190.965	-182.034	146.977
	(STRAIN)		8.963E-05	1.281E-04	-1.983E-04	-1.983E-04
3	10.00050	0.02970	146.979	146.979	17.942	102.564
	(STRAIN)		2.994E-04	2.994E-04	-1.983E-04	-1.983E-04
3	49.99950	0.01925	39.840	39.840	-40.723	-33.621
	(STRAIN)		1.882E-04	1.882E-04	-1.226E-04	-1.226E-04
3	50.00050	0.01925	39.839	39.839	1.486	4.319
	(STRAIN)		2.482E-04	2.482E-04	-1.226E-04	-1.226E-04

```
INPUT FILE NAME  -C:\KENPAVE\EVALUATION EXISTING LINEAR ELASTIC_1.DAT

NUMBER OF PROBLEMS TO BE SOLVED =  1

TITLE -EVALUATION EXISTING LINEAR ELASTIC 1

MATL = 1 FOR LINEAR ELASTIC LAYERED SYSTEM
NDAMA = 0, SO DAMAGE ANALYSIS WILL NOT BE PERFORMED
NUMBER OF PERIODS PER YEAR (NPY) =  1
NUMBER OF LOAD GROUPS (NLG) =  1
TOLERANCE FOR INTEGRATION (DEL) -- =  0.001
NUMBER OF LAYERS (NL)------------- =  4
NUMBER OF Z COORDINATES (NZ)------ =  5
LIMIT OF INTEGRATION CYCLES (ICL)- =  80
COMPUTING CODE (NSTD)------------- =  9
SYSTEM OF UNITS (NUNIT)------------=  1

Length and displacement in cm, stress and modulus in kPa
unit weight in kN/m^3, and temperature in C

THICKNESSES OF LAYERS (TH) ARE : 4  6  40
POISSON'S RATIOS OF LAYERS (PR) ARE : 0.4  0.4  0.35  0.45
VERTICAL COORDINATES OF POINTS (ZC) ARE:  0  9.9995  10.0005  49.9995
 50.0005
ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE :    1  1.100E+06   2  1.600E+06
   3  2.500E+05   4  1.500E+05

LOAD GROUP NO. 1  HAS 2  CONTACT AREAS
CONTACT RADIUS (CR)--------------- =  11
CONTACT PRESSURE (CP)------------- =  550
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- =  3
WHEEL SPACING ALONG X-AXIS (XW)------------------- =  0
WHEEL SPACING ALONG Y-AXIS (YW)------------------- =  33

RESPONSE PT. NO. AND (XPT, YPT) ARE:  1   0.000   0.000  2   0.000  10.000
  3   0.000  16.500

PERIOD NO.  1   LOAD GROUP NO.  1
```

POINT NO.	VERTICAL COORDINATE	VERTICAL DISP.	VERTICAL STRESS (STRAIN)	MAJOR PRINCIPAL STRESS (STRAIN)	MINOR PRINCIAL STRESS (STRAIN)	INTERMEDIATE P. STRESS (HORIZONTAL P. STRAIN)
1	0.00000	0.03424	550.000	975.051	750.838	955.282
	(STRAIN)		-1.936E-05	2.660E-04	-1.936E-05	2.408E-04
1	9.99950	0.03080	274.681	275.111	-408.779	-337.633
	(STRAIN)		2.82E-04	3.585E-04	-2.399E-04	-2.399E-04
1	10.00050	0.03080	274.662	275.797	27.472	42.577
	(STRAIN)		7.136E-04	7.179E-04	-2.399E-04	-2.399E-04
1	49.99950	0.01845	36.386	36.997	-37.234	-29.273
	(STRAIN)		1.699E-04	1.722E-04	-1.141E-04	-1.141E-04
1	50.00050	0.01845	36.386	37.610	1.448	3.644
	(STRAIN)		2.236E-04	2.355E-04	-1.141E-04	-1.141E-04
2	0.00000	0.03205	550.000	591.335	353.797	521.994
	(STRAIN)		-8.321E-05	2.191E-04	-8.321E-05	1.309E-04
2	9.99950	0.03046	200.152	207.335	-281.239	-27.103
	(STRAIN)		2.004E-04	2.067E-04	-2.208E-04	-2.208E-04

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2	10.00050	0.03046	200.159	212.444	20.769	67.761
	(STRAIN)		4.711E-04	5.185E-04	-2.209E-04	-2.209E-04
2	49.99950	0.01912	39.311	39.404	-40.184	-32.981
	(STRAIN)		1.854E-04	1.857E-04	-1.212E-04	-1.212E-04
2	50.00050	0.01912	39.310	39.501	1.481	4.201
	(STRAIN)		2.445E-04	2.463E-04	-1.212E-04	-1.212E-04
3	0.00000	0.03127	0.000	512.155	276.442	411.259
	(STRAIN)		-8.448E-05	2.155E-04	-8.448E-05	8.711E-05
3	9.99950	0.02970	146.977	190.965	-182.034	146.977
	(STRAIN)		8.963E-05	1.281E-04	-1.983E-04	-1.983E-04
3	10.00050	0.02970	146.979	146.979	17.942	102.564
	(STRAIN)		2.994E-04	2.994E-04	-1.983E-04	-1.983E-04
3	49.99950	0.01925	39.840	39.840	-40.723	-33.621
	(STRAIN)		1.882E-04	1.882E-04	-1.226E-04	-1.226E-04
3	50.00050	0.01925	39.839	39.839	1.486	4.319
	(STRAIN)		2.482E-04	2.482E-04	-1.226E-04	-1.226E-04

Appendix 5 Analysis Result of Alternative Pavement 1 using KENPAVE Program with Viscoelastic Model

```
INPUT FILE NAME  -C:\KENPAVE\REDESIGN VISCOELASTIC ALT-1_2.DAT

NUMBER OF PROBLEMS TO BE SOLVED =  1

TITLE -REDESIGN VISCOELASTIC ALT.1

MATL = 3 FOR VISCOELASTIC LAYERED SYSTEM
NDAMA = 0, SO DAMAGE ANALYSIS WILL NOT BE PERFORMED
NUMBER OF PERIODS PER YEAR (NPY) =  1
NUMBER OF LOAD GROUPS (NLG) =  1
TOLERANCE FOR INTEGRATION (DEL) -- =  0.001
NUMBER OF LAYERS (NL)------------- =  5
NUMBER OF Z COORDINATES (NZ)------ =  5
LIMIT OF INTEGRATION CYCLES (ICL)- =  80
COMPUTING CODE (NSTD)------------- =  9
SYSTEM OF UNITS (NUNIT)------------=  1

Length and displacement in cm, stress and modulus in kPa
unit weight in kN/m^3, and temperature in C

THICKNESSES OF LAYERS (TH) ARE : 4  6  14.5  30
POISSON'S RATIOS OF LAYERS (PR) ARE : 0.4  0.4  0.4  0.35  0.45
VERTICAL COORDINATES OF POINTS (ZC) ARE:  0  24.4995  24.5005  54.4995
 54.5005
ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE :    1  1.100E+06   2  1.200E+06
   3  1.600E+06   4  1.500E+05   5  1.500E+05

LOAD GROUP NO. 1  HAS 2  CONTACT AREAS
CONTACT RADIUS (CR)--------------- =  11
CONTACT PRESSURE (CP)------------- =  550
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- =  3
WHEEL SPACING ALONG X-AXIS (XW)------------------- =  0
WHEEL SPACING ALONG Y-AXIS (YW)------------------- =  33

RESPONSE PT. NO. AND (XPT, YPT) ARE:  1   0.000   0.000  2   0.000  10.000
  3   0.000  16.500

DURATION OF MOVING LOAD (DUR) =  0.1
NUMBER OF VISCOELASTIC LAYER (NVL)          =  3
LAYER NUMBERS WHICH ARE VISCOELASTIC (LNV) =  1  2  3
CREEP TIMES (TYME) ARE: 0.001  0.003  0.01  0.03  0.1  0.3  1  3  10  30  100

FOR LAYER 1  TIME TEMPERATURE SHIFT FACTOR (BETA) =  0.113
REFERENCE TEMPERATURE (TEMREF) =  25

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 25  ARE:
  9.162E-07  9.303E-07  9.778E-07  1.098E-06  1.393E-06  1.746E-06  2.152E-06
  2.599E-02  3.276E-06  5.095E-06  1.146E-05

FOR LAYER 2  TIME TEMPERATURE SHIFT FACTOR (BETA) =  0.113
REFERENCE TEMPERATURE (TEMREF) =  25

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 25  ARE:
  9.162E-07  9.303E-07  9.778E-07  1.098E-06  1.393E-06  1.746E-06  2.430E-05
  2.599E-06  3.276E-06  5.059E-06  1.146E-05

FOR LAYER 3  TIME TEMPERATURE SHIFT FACTOR (BETA) =  0.113
REFERENCE TEMPERATURE (TEMREF) =  25

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 25  ARE:
  9.162E-07  9.303E-07  9.778E-07  1.098E-06  1.393E-06  1.746E-06  2.152E-06
  2.599E-06  3.276E-06  5.095E-06  1.146E-05
```

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LAYER NO. 1 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 25 ARE:
1.372E-02 -3.534E-02 4.063E-02 -4.924E-02 5.031E-02 -2.093E-02 1.888E-03

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 25 ARE:
5.357E-04 -2.166E-04 -1.031E-03 1.143E-03 -2.230E-05 -4.460E-03 9.060E-03
1.777E-02 5.400E-03 -3.305E-03 1.143E-03

LAYER NO. 2 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 25 ARE:
-1.152E-05 2.708E-05 -2.357E-05 -9.569E-06 3.787E-05 -3.391E-05 1.360E-05

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 25 ARE:
4.403E-07 1.116E-06 1.906E-06 1.285E-07 9.385E-07 8.522E-06 1.155E-05
1.050E-05 3.239E-06 3.016E-06 1.240E-05

LAYER NO. 3 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 25 ARE:
4.399E-07 -1.133E-06 6.852E-07 -2.827E-06 9.932E-06 -1.801E-05 1.186E-05

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 25 ARE:
9.334E-07 9.233E-07 9.445E-07 1.135E-06 1.392E-06 1.603E-06 2.383E-06
2.777E-06 2.606E-06 5.728E-06 1.122E-05

FOR PERIOD NO. 1 LAYER NO. AND TEMPERATURE ARE: 1 25 2 25 3 25

CREEP COMPLIANCES (CREEP) OF LAYER 1 AT TEMPERATURE (TEMP) OF 25 ARE:
5.357E-04 -2.166E-04 -1.031E-03 1.143E-03 -2.230E-05 -4.460E-03 9.060E-03
1.777E-02 5.400E-03 -3.305E-03 1.143E-03

CREEP COMPLIANCES (CREEP) OF LAYER 2 AT TEMPERATURE (TEMP) OF 25 ARE:
4.403E-07 1.116E-06 1.906E-06 1.285E-07 9.385E-07 8.522E-06 1.155E-05
1.050E-05 3.239E-06 3.016E-06 1.240E-05

CREEP COMPLIANCES (CREEP) OF LAYER 3 AT TEMPERATURE (TEMP) OF 25 ARE:
9.334E-07 9.233E-07 9.445E-07 1.135E-06 1.392E-06 1.603E-06 2.383E-06
2.777E-06 2.606E-06 5.728E-06 1.122E-05

PERIOD NO. 1 LOAD GROUP NO. 1

POINT NO.	VERTICAL COORDINATE	VERTICAL DISP.	VERTICAL STRESS (STRAIN)	MAJOR PRINCIPAL STRESS (STRAIN)	MINOR PRINCIAL STRESS (STRAIN)	INTERMEDIATE P. STRESS (HORIZONTAL P. STRAIN)
1	0.00000	0.62832	550.000	500.556	279.048	279.859
	(STRAIN)		1.627E-01	1.627E-01	-2.002E-02	-2.035E-02
1	24.49950	0.02575	89.821	90.728	-197.763	-150.802
	(STRAIN)		2.437E-04	2.451E-04	-1.840E-04	-1.840E-04
1	24.50050	0.02575	89.819	92.329	-5.160	3.351
	(STRAIN)		4.265E-04	4.427E-04	-1.840E-04	-1.840E-04
1	54.49950	0.01769	32.387	33.072	-12.425	-9.339
	(STRAIN)		1.894E-04	1.938E-04	-9.872E-05	-9.872E-05
1	54.50050	0.01769	32.387	33.364	1.626	3.155
	(STRAIN)		1.986E-04	2.081E-04	-9.872E-05	-9.872E-05
2	0.00000	0.35879	550.000	287.630	160.081	185.381
	(STRAIN)		8.368E-02	8.368E-02	-1.672E-02	-2.492E-02
2	24.49950	0.02681	90.302	90.330	-198.300	-128.131
	(STRAIN)		2.356E-04	2.357E-04	-1.941E-04	-1.941E-04
2	24.50050	0.02681	90.297	90.368	-5.449	10.551
	(STRAIN)		4.214E-04	4.218E-04	-1.941E-04	-1.941E-04
2	54.49950	0.01826	34.720	34.827	-13.281	-10.397
	(STRAIN)		2.046E-04	2.053E-04	-1.040E-04	-1.040E-04
2	54.50050	0.01826	34.719	34.874	1.682	3.515
	(STRAIN)		2.154E-04	2.169E-04	-1.040E-04	-1.040E-04
3	0.00000	-0.07983	0.000	97.796	16.465	25.584
	(STRAIN)		-3.115E-02	2.938E-02	-3.079E-02	-3.718E-02
3	24.49950	0.02693	88.302	88.302	-193.553	-113.690

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	(STRAIN)		2.256E-04	2.256E-04	-1.944E-04	-1.944E-04
3	24.50050	0.02693	88.296	88.296	-5.444	12.813
	(STRAIN)		4.082E-04	4.082E-04	-1.944E-04	-1.944E-04
3	54.49950	0.01837	35.152	35.152	-13.441	-10.587
	(STRAIN)		2.074E-04	2.074E-04	-1.049E-04	-1.049E-04
3	54.50050	0.01837	35.151	35.151	1.692	3.590
	(STRAIN)		2.185E-04	2.185E-04	-1.049E-04	-1.049E-04

Appendix 6 Analysis Result of Alternative Pavement 1 using KENPAVE Program with Linear Elastic Model

```
INPUT FILE NAME  -C:\KENPAVE\REDESIGN LINEAR ELASTIC ALT-1_1.DAT

NUMBER OF PROBLEMS TO BE SOLVED =  1

TITLE -REDESIGN lINEAR ELASTIC ALT.1

MATL = 1 FOR LINEAR ELASTIC LAYERED SYSTEM
NDAMA = 0, SO DAMAGE ANALYSIS WILL NOT BE PERFORMED
NUMBER OF PERIODS PER YEAR (NPY) =  1
NUMBER OF LOAD GROUPS (NLG) =  1
TOLERANCE FOR INTEGRATION (DEL) -- =  0.001
NUMBER OF LAYERS (NL)------------- =  5
NUMBER OF Z COORDINATES (NZ)------ =  5
LIMIT OF INTEGRATION CYCLES (ICL)- =  80
COMPUTING CODE (NSTD)------------- =  9
SYSTEM OF UNITS (NUNIT)------------=  1

Length and displacement in cm, stress and modulus in kPa
unit weight in kN/m^3, and temperature in C

THICKNESSES OF LAYERS (TH) ARE : 4  6  14.5  30
POISSON'S RATIOS OF LAYERS (PR) ARE : 0.4  0.4  0.4  0.35  0.45
VERTICAL COORDINATES OF POINTS (ZC) ARE:  0  24.4995  24.5005  54.4995
 54.5005
ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE :    1  1.100E+06   2  1.200E+06
   3  1.600E+06   4  1.500E+05   5  1.500E+05

LOAD GROUP NO. 1  HAS 2  CONTACT AREAS
CONTACT RADIUS (CR)--------------- =  11
CONTACT PRESSURE (CP)------------- =  550
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- =  3
WHEEL SPACING ALONG X-AXIS (XW)------------------- =  0
WHEEL SPACING ALONG Y-AXIS (YW)------------------- =  33

RESPONSE PT. NO. AND (XPT, YPT) ARE:  1   0.000   0.000  2   0.000  10.000
  3   0.000  16.500

PERIOD NO.  1   LOAD GROUP NO.  1

 POINT    VERTICAL   VERTICAL   VERTICAL    MAJOR       MINOR  INTERMEDIATE
                                           PRINCIPAL   PRINCIAL  P. STRESS
  NO.    COORDINATE    DISP.     STRESS     STRESS      STRESS  (HORIZONTAL
                                (STRAIN)   (STRAIN)    (STRAIN)  P. STRAIN)
  1       0.00000    0.03001    550.000    668.553     587.212     649.087
          (STRAIN)             5.469E-05  1.582E-04   5.469E-05   1.334E-04
  1      24.49950    0.02557     65.794     66.039    -352.507    -284.594
          (STRAIN)             2.003E-04  2.005E-04  -1.657E-04  -1.657E-04
  1      24.50050    0.02557     65.792     67.227       0.760       5.950
          (STRAIN)             4.196E-04  4.325E-04  -1.657E-04  -1.657E-04
  1      54.49950    0.01714     29.282     29.903      -1.972      -0.608
          (STRAIN)             1.998E-04  2.054E-04  -8.150E-05  -8.150E-05
  1      54.50050    0.01714     29.281     30.025       3.242       4.346
          (STRAIN)             1.702E-04  1.774E-04  -8.150E-05  -8.150E-05
  2       0.00000    0.02909    550.000    484.619     346.869     456.635
          (STRAIN)            -2.694E-05  1.484E-04  -2.694E-05   1.128E-04
  2      24.49950    0.02654     66.511     66.517    -353.670    -254.768
          (STRAIN)             1.937E-04  1.937E-04  -1.740E-04  -1.740E-04
```

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2	24.50050	0.02654	66.508	66.541	0.839	10.424
	(STRAIN)		4.170E-04	4.173E-04	-1.740E-04	-1.740E-04
2	54.49950	0.01763	31.140	31.239	-2.103	-0.666
	(STRAIN)		2.138E-04	2.147E-04	-8.536E-05	-8.536E-05
2	54.50050	0.01763	31.140	31.258	3.369	4.680
	(STRAIN)		1.831E-04	1.842E-04	-8.536E-05	-8.536E-05
3	0.00000	0.02848	0.000	410.682	252.729	379.970
	(STRAIN)		-5.776E-05	1.433E-04	-5.776E-05	1.042E-04
3	24.49950	0.02666	65.371	65.371	-345.757	-233.224
	(STRAIN)		1.856E-04	1.856E-04	-1.741E-04	-1.741E-04
3	24.50050	0.02666	65.370	65.370	0.904	11.845
	(STRAIN)		4.061E-04	4.061E-04	-1.741E-04	-1.741E-04
3	54.49950	0.01772	31.486	31.486	-2.128	-0.672
	(STRAIN)		2.164E-04	2.164E-04	-8.609E-05	-8.609E-05
3	54.50050	0.01772	31.486	31.486	3.392	4.747
	(STRAIN)		1.855E-04	1.855E-04	-8.609E-05	-8.609E-05

Appendix 7 Analysis Result of Alternative Pavement 2 using KENPAVE Program with Viscoelastic Model

```
INPUT FILE NAME  -C:\KENPAVE\REDESIGN VISCOELASTIC ALT-2_4.DAT

NUMBER OF PROBLEMS TO BE SOLVED =  1

TITLE -REDESIGN VISCOELASTIC ALT.2

MATL = 3 FOR VISCOELASTIC LAYERED SYSTEM
NDAMA = 0, SO DAMAGE ANALYSIS WILL NOT BE PERFORMED
NUMBER OF PERIODS PER YEAR (NPY) =  1
NUMBER OF LOAD GROUPS (NLG) =  1
TOLERANCE FOR INTEGRATION (DEL) -- =  0.001
NUMBER OF LAYERS (NL)------------- =  6
NUMBER OF Z COORDINATES (NZ)------ =  7
LIMIT OF INTEGRATION CYCLES (ICL)- =  80
COMPUTING CODE (NSTD)------------- =  9
SYSTEM OF UNITS (NUNIT)------------=  1

Length and displacement in cm, stress and modulus in kPa
unit weight in kN/m^3, and temperature in C

THICKNESSES OF LAYERS (TH) ARE : 4  6  7.5  15  15
POISSON'S RATIOS OF LAYERS (PR) ARE : 0.4  0.4  0.4  0.35  0.35  0.45
VERTICAL COORDINATES OF POINTS (ZC) ARE:  0  17.4995  17.5005  32.4995
 32.5005  47.4995  47.5005
ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE :    1  1.100E+06   2  1.200E+06
   3  1.600E+06   4  5.000E+05   5  2.500E+05   6  1.500E+05

LOAD GROUP NO. 1  HAS 2  CONTACT AREAS
CONTACT RADIUS (CR)--------------- =  11
CONTACT PRESSURE (CP)------------- =  550
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- =  3
WHEEL SPACING ALONG X-AXIS (XW)------------------- =  0
WHEEL SPACING ALONG Y-AXIS (YW)------------------- =  33

RESPONSE PT. NO. AND (XPT, YPT) ARE:  1   0.000   0.000  2   0.000  10.000
  3   0.000  16.500

DURATION OF MOVING LOAD (DUR) =  0.1
NUMBER OF VISCOELASTIC LAYER (NVL)         =  3
LAYER NUMBERS WHICH ARE VISCOELASTIC (LNV) =  1  2  3
CREEP TIMES (TYME) ARE: 0.001  0.003  0.01  0.03  0.1  0.3  1  3  10  30  100

FOR LAYER 1  TIME TEMPERATURE SHIFT FACTOR (BETA) =  0.113
REFERENCE TEMPERATURE (TEMREF) =  25

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 25  ARE:
  9.162E-07  9.303E-07  9.778E-07  1.098E-06  1.393E-06  1.746E-06  2.152E-06
  2.599E-02  3.276E-06  5.095E-06  1.146E-05

FOR LAYER 2  TIME TEMPERATURE SHIFT FACTOR (BETA) =  0.113
REFERENCE TEMPERATURE (TEMREF) =  25

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 25  ARE:
  9.162E-07  9.303E-07  9.778E-07  1.098E-06  1.393E-06  1.746E-06  2.430E-05
  2.599E-06  3.276E-06  5.059E-06  1.146E-05

FOR LAYER 3  TIME TEMPERATURE SHIFT FACTOR (BETA) =  0.113
```

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REFERENCE TEMPERATURE (TEMREF) = 25

CREEP COMPLIANCES (CREEP) AT REFERENCE TEMP. (TEMREF) OF 25 ARE:
9.162E-07 9.303E-07 9.778E-07 1.098E-06 1.393E-06 1.746E-06 2.152E-06
2.599E-06 3.276E-06 5.095E-06 1.146E-05

LAYER NO. 1 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 25 ARE:
1.372E-02 -3.534E-02 4.063E-02 -4.924E-02 5.031E-02 -2.093E-02 1.888E-03

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 25 ARE:
5.357E-04 -2.166E-04 -1.031E-03 1.143E-03 -2.230E-05 -4.460E-03 9.060E-03
1.777E-02 5.400E-03 -3.305E-03 1.143E-03

LAYER NO. 2 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 25 ARE:
-1.152E-05 2.708E-05 -2.357E-05 -9.569E-06 3.787E-05 -3.391E-05 1.360E-05

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 25 ARE:
4.403E-07 1.116E-06 1.906E-06 1.285E-07 9.385E-07 8.522E-06 1.155E-05
1.050E-05 3.239E-06 3.016E-06 1.240E-05

LAYER NO. 3 DIRICHLET SERIES AT REFERENCE TEMPERATURE (TEMREF) OF 25 ARE:
4.399E-07 -1.133E-06 6.852E-07 -2.827E-06 9.932E-06 -1.801E-05 1.186E-05

COMPUTED COMPLIANCES (CREEP) AT REFERENCE TEMP.(TEMREF) OF 25 ARE:
9.334E-07 9.233E-07 9.445E-07 1.135E-06 1.392E-06 1.603E-06 2.383E-06
2.777E-06 2.606E-06 5.728E-06 1.122E-05

FOR PERIOD NO. 1 LAYER NO. AND TEMPERATURE ARE: 1 25 2 25 3 25

CREEP COMPLIANCES (CREEP) OF LAYER 1 AT TEMPERATURE (TEMP) OF 25 ARE:
5.357E-04 -2.166E-04 -1.031E-03 1.143E-03 -2.230E-05 -4.460E-03 9.060E-03
1.777E-02 5.400E-03 -3.305E-03 1.143E-03

CREEP COMPLIANCES (CREEP) OF LAYER 2 AT TEMPERATURE (TEMP) OF 25 ARE:
4.403E-07 1.116E-06 1.906E-06 1.285E-07 9.385E-07 8.522E-06 1.155E-05
1.050E-05 3.239E-06 3.016E-06 1.240E-05

CREEP COMPLIANCES (CREEP) OF LAYER 3 AT TEMPERATURE (TEMP) OF 25 ARE:
9.334E-07 9.233E-07 9.445E-07 1.135E-06 1.392E-06 1.603E-06 2.383E-06
2.777E-06 2.606E-06 5.728E-06 1.122E-05

PERIOD NO. 1 LOAD GROUP NO. 1

POINT NO.	VERTICAL COORDINATE	VERTICAL DISP.	VERTICAL STRESS (STRAIN)	MAJOR PRINCIPAL STRESS (STRAIN)	MINOR PRINCIAL STRESS (STRAIN)	INTERMEDIATE P. STRESS (HORIZONTAL P. STRAIN)
1	0.00000	0.65557	550.000	613.301	356.650	357.365
	(STRAIN)		1.751E-01	1.751E-01	-1.349E-02	-1.370E-02
1	17.49950	0.02558	175.885	178.363	-89.428	-57.848
	(STRAIN)		2.491E-04	2.529E-04	-1.459E-04	-1.459E-04
1	17.50050	0.02558	175.876	179.269	-7.428	8.007
	(STRAIN)		3.490E-04	3.581E-04	-1.460E-04	-1.460E-04
1	32.49950	0.02188	67.502	69.800	-51.987	-37.184
	(STRAIN)		1.958E-04	2.020E-04	-1.268E-04	-1.268E-04
1	32.50050	0.02188	67.498	70.621	-16.655	-9.518
	(STRAIN)		2.519E-04	2.659E-04	-1.268E-04	-1.268E-04
1	47.49950	0.01877	37.187	37.884	-30.872	-23.862
	(STRAIN)		1.870E-04	1.901E-04	-1.193E-04	-1.193E-04
1	47.50050	0.01877	37.186	38.437	0.833	3.169

	(STRAIN)		2.321E-04	2.442E-04	-1.193E-04	-1.193E-04
2	0.00000	0.35476	550.000	349.853	198.957	232.166
	(STRAIN)		8.304E-02	8.304E-02	-1.662E-02	-2.510E-02
2	17.49950	0.02626	147.943	149.123	-76.327	0.863
	(STRAIN)		1.911E-04	1.931E-04	-1.455E-04	-1.449E-04
2	17.50050	0.02626	147.936	149.475	-8.922	32.106
	(STRAIN)		2.786E-04	2.827E-04	-1.449E-04	-1.449E-04
2	32.49950	0.02279	70.927	71.150	-55.438	-35.846
	(STRAIN)		2.056E-04	2.062E-04	-1.356E-04	-1.356E-04
2	32.50050	0.02279	70.925	71.233	-17.988	-6.408
	(STRAIN)		2.645E-04	2.659E-04	-1.356E-04	-1.356E-04
2	47.49950	0.01944	40.041	40.145	-33.276	-26.630
	(STRAIN)		2.032E-04	2.037E-04	-1.267E-04	-1.267E-04
2	47.50050	0.01944	40.040	40.230	0.780	3.732
	(STRAIN)		2.528E-04	2.547E-04	-1.267E-04	-1.267E-04
3	0.00000	-0.04946	0.000	71.563	-9.650	4.667
	(STRAIN)		-2.347E-02	3.682E-02	-2.312E-02	-2.976E-02
3	17.49950	0.02622	129.863	129.863	-67.181	31.744
	(STRAIN)		1.563E-04	1.563E-04	-1.405E-04	-1.405E-04
3	17.50050	0.02622	129.860	129.860	-9.287	44.290
	(STRAIN)		2.352E-04	2.352E-04	-1.405E-04	-1.405E-04
3	32.49950	0.02294	70.823	70.823	-55.788	-34.657
	(STRAIN)		2.050E-04	2.050E-04	-1.369E-04	-1.369E-04
3	32.50050	0.02294	70.820	70.820	-18.221	-5.543
	(STRAIN)		2.638E-04	2.638E-04	-1.369E-04	-1.369E-04
3	47.49950	0.01957	40.540	40.540	-33.705	-27.071
	(STRAIN)		2.060E-04	2.060E-04	-1.281E-04	-1.281E-04
3	47.50050	0.01957	40.539	40.539	0.769	3.857
	(STRAIN)		2.464E-04	2.564E-04	-1.281E-04	-1.281E-04

Appendix 8 Analysis Result of Alternative Pavement 2 using KENPAVE Program with Linear Elastic Model

```
INPUT FILE NAME  -C:\KENPAVE\REDESIGN LINEAR ELASTIC ALT-2_1.DAT

NUMBER OF PROBLEMS TO BE SOLVED =  1

TITLE -REDESIGN LINEAR ELASTIC ALT.2

MATL = 1 FOR LINEAR ELASTIC LAYERED SYSTEM
NDAMA = 0, SO DAMAGE ANALYSIS WILL NOT BE PERFORMED
NUMBER OF PERIODS PER YEAR (NPY) =  1
NUMBER OF LOAD GROUPS (NLG) =  1
TOLERANCE FOR INTEGRATION (DEL) -- =  0.001
NUMBER OF LAYERS (NL)------------- =  6
NUMBER OF Z COORDINATES (NZ)------ =  7
LIMIT OF INTEGRATION CYCLES (ICL)- =  80
COMPUTING CODE (NSTD)------------- =  9
SYSTEM OF UNITS (NUNIT)------------=  1

Length and displacement in cm, stress and modulus in kPa
unit weight in kN/m^3, and temperature in C

THICKNESSES OF LAYERS (TH) ARE : 4  6  7.5  15  15
POISSON'S RATIOS OF LAYERS (PR) ARE : 0.4  0.4  0.4  0.35  0.35  0.45
VERTICAL COORDINATES OF POINTS (ZC) ARE:  0  17.4995  17.5005  32.4995
 32.5005  47.4995  47.5005
ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE :    1  1.100E+06   2  1.200E+06
   3  1.600E+06   4  5.000E+05   5  2.500E+05   6  1.500E+05

LOAD GROUP NO. 1  HAS 2  CONTACT AREAS
CONTACT RADIUS (CR)--------------- =  11
CONTACT PRESSURE (CP)------------- =  550
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT)-- =  3
WHEEL SPACING ALONG X-AXIS (XW)------------------- =  0
WHEEL SPACING ALONG Y-AXIS (YW)------------------- =  33

RESPONSE PT. NO. AND (XPT, YPT) ARE:  1   0.000   0.000  2   0.000  10.000
  3   0.000  16.500

PERIOD NO.  1   LOAD GROUP NO.  1
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POINT NO.	VERTICAL COORDINATE	VERTICAL DISP.	VERTICAL STRESS (STRAIN)	MAJOR PRINCIPAL STRESS (STRAIN)	MINOR PRINCIAL STRESS (STRAIN)	INTERMEDIATE P. STRESS (HORIZONTAL P. STRAIN)
1	0.00000	0.02918	550.000	851.587	808.813	834.647
	(STRAIN)		1.220E-04	1.765E-04	1.221E-04	1.553E-04
1	17.49950	0.02430	158.406	159.851	-231.690	-178.721
	(STRAIN)		2.012E-04	2.025E-04	-1.401E-04	-1.401E-04
1	17.50050	0.02430	158.398	161.506	-12.983	1.546
	(STRAIN)		3.226E-04	3.310E-04	-1.401E-04	-1.401E-04
1	32.49950	0.02091	60.882	62.896	-48.085	-35.140
	(STRAIN)		1.786E-04	1.841E-04	-1.156E-04	-1.156E-04
1	32.50050	0.02091	60.879	63.627	-15.739	-9.512
	(STRAIN)		2.292E-04	2.415E-04	-1.156E-04	-1.156E-04
1	47.49950	0.01807	34.200	34.809	-28.065	-22.016
	(STRAIN)		1.717E-04	1.745E-04	-1.085E-04	-1.085E-04
1	47.50050	0.01806	34.199	35.295	0.933	2.937
	(STRAIN)		2.131E-04	2.237E-04	-1.085E-04	-1.085E-04

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2	0.00000	0.02683	550.000	467.413	346.870	438.307
	(STRAIN)		-1.402E-05	1.394E-04	-1.402E-05	1.024E-04
2	17.49950	0.02490	132.512	132.979	-201.214	-79.921
	(STRAIN)		1.530E-04	1.534E-04	-1.390E-04	-1.390E-04
2	17.50050	0.02490	132.506	133.419	-14.349	24.197
	(STRAIN)		2.575E-04	2.599E-04	-1.390E-04	-1.390E-04
2	32.49950	0.02172	63.806	64.002	-51.193	-34.187
	(STRAIN)		1.872E-04	1.878E-04	-1.233E-04	-1.233E-04
2	32.50050	0.02172	63.803	64.075	-16.974	-6.926
	(STRAIN)		2.402E-04	2.415E-04	-1.233E-04	-1.233E-04
2	47.49950	0.01867	36.675	36.766	-30.166	-24.486
	(STRAIN)		1.859E-04	1.863E-04	-1.149E-04	-1.149E-04
2	47.50050	0.01867	36.674	36.841	0.874	3.393
	(STRAIN)		2.312E-04	2.328E-04	-1.149E-04	-1.149E-04
3	0.00000	0.02614	0.000	387.434	252.730	354.973
	(STRAIN)		-4.021E-05	1.312E-04	-4.021E-05	8.992E-05
3	17.49950	0.02486	116.108	116.108	-180.245	-27.219
	(STRAIN)		1.244E-04	1.244E-04	-1.349E-04	-1.349E-04
3	17.50050	0.02486	116.105	116.105	-14.534	35.058
	(STRAIN)		2.178E-04	2.178E-04	-1.349E-04	-1.349E-04
3	32.49950	0.02185	63.698	63.698	-51.508	-33.174
	(STRAIN)		1.867E-04	1.867E-04	-1.244E-04	-1.244E-04
3	32.50050	0.02185	63.696	63.696	-17.187	-6.187
	(STRAIN)		2.396E-04	2.396E-04	-1.244E-04	-1.244E-04
3	47.49950	0.01878	37.108	37.108	-30.541	-24.881
	(STRAIN)		1.884E-04	1.884E-04	-1.161E-04	-1.161E-04
3	47.50050	0.01878	37.107	37.107	0.861	3.496
	(STRAIN)		2.343E-04	2.343E-04	-1.161E-04	-1.161E-04

Appendix 9 Pavement Structure Thickness

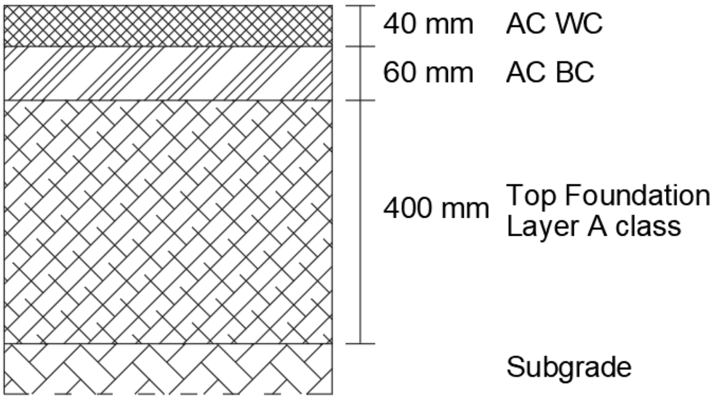

Figure A-9.3 Existing Pavement

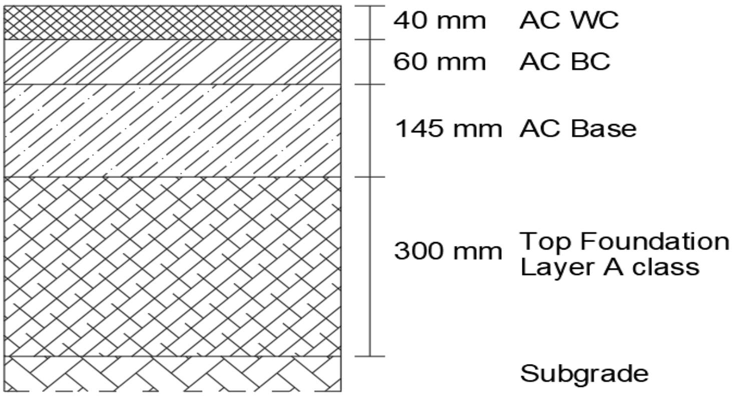

Figure A-9.2 Alternative Pavement 1

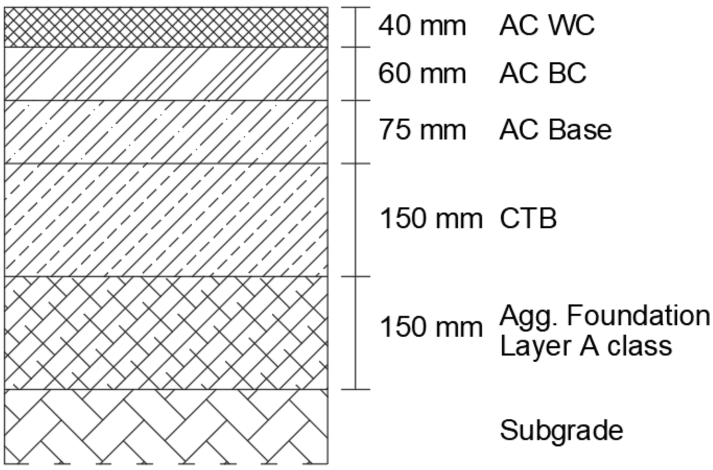

Figure A-9.2 Alternative Pavement 2