FINAL ASSIGNMENT

STUDY THE DIFFERENCE BETWEEN FLEXIBLE PAVEMENT AND RIGID PAVEMENT CONSTRUCTION

Submitted to fulfill the requirements of undergraduate education in Civil Engineering Department, Faculty of Engineering Universitas Islam Sultan Agung (UNISSULA) Semarang

Wahyu Wardani
30.2017.00.183

Yusia Nanda Agustanti
30.2017.00.188

DEPARTMENT OF CIVIL ENGINEERING
FACULTY OF ENGINEERING
UNIVERSITAS ISLAM SULTAN AGUNG SEMARANG

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STUDY THE DIFFERENCE BETWEEN FLEXIBLE PAVEMENT AND RIGID PAVEMENT CONSTRUCTION

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Supervisor, Co-Supervisor,

Ir. Gatot Rusbintardjo, M.R.Eng.Sc.,Ph.D **Eko Muliawan Satrio, S.T., M.T.**

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BERITA ACARA BIMBINGAN TUGAS AKHIR
No. / A.2 / SA-T / VII / 2021

Pada hari ini Senin, 5 Juli 2021 berdasarkan Surat Keputusan Kepala Program Studi Teknik Sipil Fakultas Teknik Universitas Islam Sultan Agung (UNISSULA) Semarang Nomor: 25/A.2/SA-T/III/2021 tanggal 17 Januari 2021 Hal penunjukan Dosen Pembimbing I dan Dosen Pembimbing II.

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telah menyelesaikan Tugas Akhir dengan judul STUDY THE DIFFERENCE BETWEEN FLEXIBLE PAVEMENT AND RIGID PAVEMENT CONSTRUCTION dengan tahapan sebagai berikut:

No.	Tahapan	Tanggal	Keterangan
1	Penunjukan Dosen Pembimbing	17 Januari 2021	√
2	Proposal	25 Januari 2021	√
3	Pengumpulan Data	Januari s.d Maret 2021	√
4	Penyusunan Laporan	April s.d. Juni 2021	√
5	Seminar Tugas Akhir	14 Juli 2021	√

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Dosen Pembimbing 1 Dosen Pembimbing 2

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PLAGIARISM FREE STATEMENT

The undersigned below

Name : Wahyu Wardani
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Name : Yusia Nanda Agustanti
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declare that our Final Assignment entitled:

"STUDY THE DIFFERENCE BETWEEN FLEXIBLE PAVEMENT AND RIGID PAVEMENT CONSTRUCTION".

is free from plagiarism. If our statement turns out to be untrue, then we are willing to accept sanctions in accordance with applicable regulations of Universitas Islam Sultan Agung (UNISSULA) Semarang.

This statement is made in : Semarang
On the date of : 5 July 2021

Signed,

Wahyu Wardani
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Yusia Nanda Agustanti
NIM: 30.2017.00.188

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STATEMENT ORIGINALITY

The undersigned below:

Name / NIM : Wahyu Wardani / 30.2017.00.183

Name / NIM : Yusia Nanda Agustanti / 30.2017.00.188

From Department of Civil Engineering, Faculty of Engineering, Universitas Islam Sultan Agung (UNISSULA) Semarang, hereby declare that:

The Final Assignment entitled **"STUDY THE DIFFERENCE BETWEEN FLEXIBLE PAVEMENT AND RIGID PAVEMENT CONSTRUCTION"** is really the original result of our research, our thoughts that we compiled with the guidance of our supervisor and co-supervisor.

If our statement turns out to be untrue, then we are willing to accept sanctions in accordance with applicable regulations of Universitas Islam Sultan Agung (UNISSULA) Semarang.

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On the date of : 5 July 2021

Signed,

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NIM: 30.2017.00.188

MOTTO

"Dan janganlah kau berputus asa dari rahmat Allah. Sesungguhnya tidaklah seseorang berputus asa kecuali orang – orang yang kafir"

(QS. Yusuf : 87)

"Behold along with the difficulty there is relief. Therefore when you're done (do something else). And hope to the Lord.

(QS. Al Insyirah : 6-8)

`

DEDICATION

"I dedicated this Final Assignment to the knowledge of Civil Engineering in general and Highway Engineering in special and as my worship to Allah Subhana Wa Ta'AlaSWT"

`

ACKNOWLEDGEMENT

Bismillahirrahmanirrahim,

I realize that this Final Assignment can be completed because of the Grace of Allah Subhana wa Ta'ala, the prayers of my Father and Mother, with approval of the Dean of Engineering Faculty of UNISSULA Semarang, the guidance of my supervisors and the help of friends especially Yusia Nanda Agustanti. For that I would like to thank to:

1. Dean of the Engineering Faculty of UNISSULA Bapak Ir. H. Rachmat Mudiyono, MT., Ph.D.,
2. Head of Civil Engineering Department, Faculty of Engineering of UNISSULA Bapak M. Rusli Ahyar, ST., MT., for his facilities that he gives, so that I can carry out this Final Assignment.
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4. My co-supervisor Bapak Eko Muliawan Satrio, S.T., M.T. Thank for his encouragement, guidance, criticsm, friendship, advice, and motivation. Without his continued support and interest, this Final Assignment reportwould not able to be completed.
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Thus my gratitude, I hope my Final Assignment is useful, for myself in particular and for the knowledge of Civil Engineering in general.

Semarang, 5 July 2021

Wahyu Wardani

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Semarang, 5 July 2021

Yusia Nanda Agustanti

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ABSTRACT

Road is defined as infrastructure of land transportation that have important role for economic growth, social culture, development of tourism areas, and defense as well as security to support national development. While pavement is defined as a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute theapplied vehicle loads to the sub-grade. In its development, pavements structure can be broadly classified into two types, flexible and rigid pavement. In Indonesia, rigid pavement most used than flexible pavement. In contrast different with average developed country that mostly using flexible pavement than rigid pavement. From the comparison of flexible pavement that used more than rigid pavement, so performed design of road pavements are between flexible and rigid pavement. the objective of this design is to examine the differences between Flexible and Rigid pavements and to find out why flexible pavement is more used than rigid pavement in countries around the world. the examination includes: The subgrade and base/subbase layer strength; Distribution of traffic loads to subgrade; The design life of the pavement construction; Determination of Traffic Loading; Damage and maintenance of Flexible Pavement and Rigid Pavement; and Skid resistance of the surface layers. This methodology use literature review then followed by design calculation of flexible and rigid pavement. After getting pavement design of both pavement, the study continued with comparize of design life, materials used, initial cost, and subgrade strength. From the calculation,getting a result that the thickness of rigid pavement more than the thickness of flexible pavement are for structure of rigid pavement is 43.18 cm or 17 inches for plate slab concrete, 15.21 cm or 6 inches for base/subbase course layers, and unlimited for subgrade course layer and structure of flexible pavement is 17.50 cm or 7 inches for surface course layer, 12.50 cm or 5 inches for base course layerand 40 cm or 16.50 inches for subbase course layer. Finally, the conclusion from the difference of pavement are based on the literature review, design of both pavement thickness, and from discussion many aspect, conclusions can be drawn as follows: flexible pavement has more positive aspects than rigid pavement; rigidpavement is not safe to be used for vehicle with high speed, since has no skid resistance; repairing damage on rigid pavement is more difficult than on flexible pavement because if there is damage, it must dismantle the hard concrete slab, andthe repair or maintenance costs are also expensive. From those conclusions above,are the reason why in many countries around the world, flexible pavements are used more than rigid pavements.

Keywords: Roads, Flexible, Rigid, Pavement, The differences.

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ABSTRAK

Jalan didefinisikan sebagai infrastruktur dari transportasi darat yang memiliki peran penting untuk pertumbuhan ekonimi, sosial budaya, perkembangan dari area pariwisata, dan pertahanan sebagai keamanan untuk mendukung perkembangan nasional. Sementara perkerasan itu didefinisikan sebagai struktur yang terdiri dari lapisan yng ditumpangkan bahan material diatas tanah dasar alami, yang fungsi utama untuk mendistribusikan beban kendaraan yang di aplikasikan ke tanah dasar. Dalam perkembangannya, struktur perkerasan dapat diklasifikasikan secara luas kedalam 2 tipe, perkerasan lentur danperkerasan kaku. Di Indonesia, perkerasan kaku lebih banyak digunakan dari padaperkerasan lentur. Sebaliknya berbeda dengan negara maju yang rata-rata lebih banyak menggunakan perkerasan lentur dari pada perkerasan kaku. Dari perbandingan perkerasan lentur yang digunakan lebih banyak dibandingkan perkerasan kaku, maka dilakukan perencanaan perkerasan jalan antara perkerasan lentur dan perkerasan kaku. Tujuan dari perencanaan ini adalah untuk menguji perbedaan antara perkerasan lentur dan perkerasan kaku dan untuk mengetahui mengapa perkerasan lentur lebih banyak digunakan daripada perkerasan kaku di negara-negara di seluruh dunia. Pemeriksaan tersebut meliputi: Kekuatan lapisan tanah dasar dan pondasi/dasar; Distribusi beban lalu lintas ke tanah dasar; Umur rencana konstruksi perkerasan jalan; Penetapan Beban Lalu Lintas; Kerusakan dan pemeliharaan Perkerasan Fleksibel dan Perkerasan Kaku; serta Ketahanan selip dari lapisan permukaan. Metodologi ini menggunakan literature review kemudian dilanjutkan dengan perhitungan desain perkerasan lentur dan kaku mengacu pada peraturan metode di AASHTO 1993 dan ketentuan dari Manual DesainPerkerasan Jalan 2017 yang diterbitkan oleh Direktorat Jendral Bina Marga. Setelah mendapatkan desain perkerasan dari kedua perkerasan tersebut, penelitian dilanjutkan dengan membandingkan umur rencana, material yang digunakan, biaya awal, dan kekuatan tanah dasar. Dari perhitungan didapatkan hasil bahwa tebal perkerasan kaku lebih besar dari tebal perkerasan lentur dimana struktur dari perkerasan kaku yaitu 43.18 cm atau 17 inci untukk plat beton, 15.21 cm atau 6 inci untuk lapisan pondasi/lapisan pondasi bawah , dan tidak terbatas untuk tanah dasar dan struktur pada perkerasan lentur yaitu 17.50 cm atau 7 inci untuk lapisan permukaan, 12.50 cm atau 5 inci untuk lapisan pondasi and 40 cm atau 16.50 inci untuk lapisan pondasi bawah. Akhirnya, kesimpulan perbedaan perkerasan didasarkan pada tinjauan literatur, desain kedua ketebalan perkerasan, dan dari diskusi beberapa aspek, kesimpulan dapat di gambarkan sebagai berikut:perkerasan lentur memiliki aspek positif lebih dari pada perkerasan kaku; perkerasan kaku tidak aman digunakan untuk kendaraan dengan kecepatan tinggi, sejak tidak memiliki ketahanan selip; perbaikan kerusakan di perkerasan kaku lebih susah dari pada perkerasan lentur karena jika terjadi kerusakan, kerusakan harus membongkar pelat beton keras dan biaya perbaikan atau perawatan juga mahal. Dari kesimpulan diatas, alasan kenapa di banyak negara seluruh dunia, perkerasan lentur digunakan lebih banyak dari pada perkerasan kaku.

Kata Kunci: Jalan, Perkerasan, Lentur, Kaku, Perbedaannya.

`

ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials 1993
ADT	Average Daily Traffic
AADT	Annual Average Daily Traffic
B.C.	Before Christ
CBR	California Bearing Ratio
CMA	Cold Mix Asphalt
CRCP	Continuously Reinforced Concrete Pavements
CTB	Cement Treated Base
D_D	Directional Distribution Factor
D_L	Lane Distribution Factor
E	The Number of Equivalency
HMA	Hot Mix Asphalt
JDRCPs	Jointed Dowel-Reinforced Concrete Pavements
JPCPs	Jointed Plain Concrete Pavements
m	Meter
MR	Resilient Modulus
Psi	pounds per square inch
ft	Feet
in	Inch
lbs	pounds
MPa	Mega Pascal
MPa.m	Mega Pacal . meter
p_t	A Terminal Serviceability
p_o	The Initial Serviceability
PCC	Portland Cement Concrete
PQC	Performance Quality Control
R	Reliability
SN	Structural Number
S_0	Standard Deviation

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VDF	Value Damage Factor
WMA	Warm Mix Asphalt
ΔPSI	Serviceability loss

CHAPTER I

INTRODUCTION

1.1 Background

Roads are defined as land transportation infrastructure that has an important role for economic growth, socio-culture, tourism area development, and defense and security to support national development. [1]. Meanwhile, the definition of pavement is an arrangement of layers that function to transmit the load of the vehicle wheel to the subgrade consisting of (from top to bottom), cover layer or often referred to as wear layer, top foundation layer, and bottom foundation layer. The three layers, known as pavement, are placed on the subgrade. Therefore, apart from being able to withstand wheel loads, the pavement structure must also be safe and comfortable for vehicles to pass, including having adequate skid resistance. Then the stress caused by the wheel load will be reduced enough, so it will not exceed the bearing capacity of the subgrade [2].

Beginning in 2600 to 1150 BC in the Minoian period, road pavements were built on the Greek island of Crete. In the days of the Roman Empire, road pavements were designed with excellent engineering. Pavement technology then continues to develop until the composition of the pavement layers we know today. The development of the road pavement layer is marked by the use of increasingly strong pavement materials, namely the use of asphalt as a surface layer material. In terms of the materials used, it is known that there are flexible pavements and rigid pavements. Flexible road pavement is pavement using hot asphalt mixture as the surface layer, while rigid road pavement uses cement concrete as the surface layer, as can be seen in Figures 1.1a to 1.2b.

In most countries in the world, including Indonesia, the use of flexible pavement is more than that of rigid pavement. In Indonesia, which has a total length of roads, both National Roads, Provincial Roads and Regency Roads 542,310 km, 61% or 329,926 km are roads with flexible pavement. [4].

Malaysia, which have 91.620 kilometers length of their road network is 87.626 kilometers or 95.64% are flexible pavement, and the remaining 343 kilometers or 0.37% are rigid pavement.

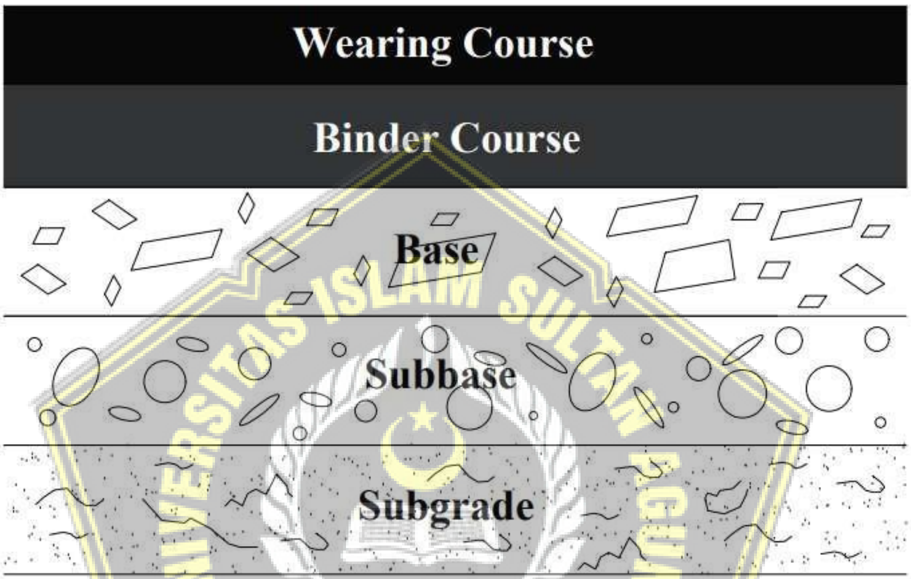


Figure 1.1a. Flexible Pavement Structure.

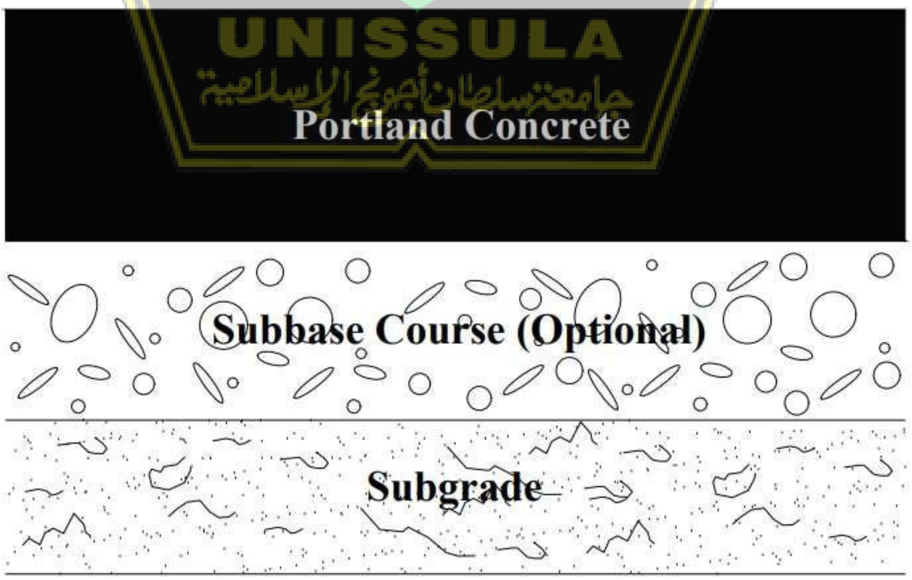


Figure 1.1b. Rigid Pavement Structure.

Figure 1.2a. Photograph of Flexible Pavement.

Figure 1.2b. Photograph of Rigid Pavement.

Japan, one of the developed country, have road network 1,21 million kilometres consist of 973.000 kilometers paved road and 237.000 kilometers unpaved road. From 973.000 kilometers of paved road, 632.450 kilometers or 65% are flexible pavement and 340.550 kilometers or 35% are rigid pavement. The other country that have flexible pavement much more than rigid pavement is USA which have a length of roads more than 6,58 million kilometers become the country with the longest road in the world [5], 4.3 million kilometres are paved roads which consist of 4.04 million kilometers or 93.99% are flexible pavement and 0.26 million kilometers or 6.01% are rigid pavement [6].

Become question why flexible pavement is used more than rigid pavement. It is also a question why Indonesia has recently been using more rigid pavements, especially for toll road construction.

1.2 Problem Statement and Problem Limitations

There are many aspects that differentiate between Flexible and Rigid Pavement. Beside the surface layer, these differences include the subgrade, the base layer, the implementation of its construction, its maintenance etc. These differences will be studied in this Final Assignment, but due to time constraints, not all differences will be studied.

1.3 Objective of the Final Assignment

From the problem limitations given in sub section 1.2 above, the objective of this Final Assignment is to study the differences between Flexible and Rigid pavements. The study includes:

1) The subgrade and base/subbase layer strength;
2) Distribution of traffic loads to subgrade;
3) The design life of the pavement construction;
4) Determination of Traffic Loading;
5) Damage and maintenance of Flexible Pavement and Rigid Pavement;
6) Skid resistance of the surface layers.

1.4 Scope of the Study

To be able to achieve this goal, the study began by conducting a literature review related to the difference between flexible and rigid pavement covers what has been mentioned in subsection 1.3 above. Literature are review then continued with methodology which will be given in Chapter III, followed with Chapter IV calculation of the flexible pavement thickness Chapter V calculation of the rigid pavement thickness. Chapter VI discussion, and finally conclusion will be given in Chapter VII.

CHAPTER II

LITERATURE REVIEW

2.1. Introduction

Available papers and books that discuss about Flexible and Rigid pavement, their construction, subgrade, how to calculate pavement thickness, will be reviewed. Beside those papers and books, subgrade, design life, and loading system on flexible and rigid pavements also will be reviewed. The review begins by looking for the differences between flexible and rigid pavement.

2.2. Differences between Flexible and Rigid Pavement

2.2.1. Difference between Flexible Pavement and Rigid Pavement based on hhttps://allabouteng.com/different-betwen-flxible-pavement-and-rigid-pavement/ [7], explained as follows:

Flexible Pavement

Flexible pavement is the pavement which uses asphalt concrete as the surface layer. This pavement usualy consist of three layers and laid over the strenght soil called subgrade soil. Those three layers are, from the top to the bottom, surface layer which function as wearing course layer, base course layer, and the bottom layer is subbase course layer.

Rigid Pavement

Rigid pavement is the pavement which uses slab cement concrete as the surface layer. The concrete slab layer placed directly on the subgrade. Base or subbase course layer in rigid pavement have no structural value and optionally use.

Therefore the layers of rigid pavement are: concrete slab as surface layer, subbase or base layer (optional), and laid over the subgrade soil.

Table 2.1 below give the 20 differences between flexible pavement and rigid pavement.

Table 2.1. Twenty differences of Flexible and Rigid Pavement [7]

No.	Flexible Pavement	Rigid Pavement
1.	Have low initial construction cost.	Have high initial construction cost.
2.	Have a short design life.	Have a long design life.
3.	Total pavement layer are thickest	Total pavementlayer are thinner.
4.	In flexible pavements joints are not required	In rigid pavements, joints are required.
5.	Less durability	More durable
6.	Does not require a good subgrade.	A good subgrade is required
7.	Easy to repair the damage.	Difficult to repair the damage
8.	Required normal skill but less supervision.	Requaires a high skill and more supervision.
9.	Locating and repairing underground pipes is simple.	Locating and repairing underground pipes is a difficult.
10.	Road can be opened for traffic as soon as the overlay of surface layer finish.	Take a long time (28 days) to be opend for traffic.
11.	Have more strenght to traffic load.	Less strenght to traffic load..
12.	Can be adjusts the subgrade distortion without fracturing or cracking.	Does not adjust the subgrade distortion, and crack will occur.
13.	Have more adhesion resistance or friction.	Have no adhesion resistance or friction.
14.	Acceptable for all types of traffic.	Not acceptable for all types of traffic.
15.	Possible to be constructed in two or three stages.	Difficult to make stage construction.
16.	Rehabilitation and mantainance are easy and relatively low cost.	Rehabilitation and mantainance are difficult and high cost.
17.	Is made up of several layers.	Concrete slab lies directly to subgrade
18.	Vertical and compressive stresses are transferred to the lower layers.	The stress occour is tensile stress.
19.	The flexural strength is low.	The flexural strenght is high
20.	The strees are not depend on the temperature	Temperature rises and tensile stress rises.

2.2.2. Lance Bradshaw [8], explain the advantages and disadvantages of flexible and rigid pavement as follows:

Flexible Pavement

This pavement is made of bituminous or asphalt aggregates. The pavement's structure is designed to flex and deflect in response to external influences such as traffic loads and weather. Flexible pavement, in essence, is more adaptable to the factors to which it is exposed.

Flexible pavement has a low initial cost of mixing and spreading it, and it has a lifespan of roughly 10-15 years with good regular maintenance. Flexible pavement is applied in exceptionally thick layers, allowing it to endure large and frequent traffic flows, making it an excellent choice for major highways and roads.

Because this type of pavement necessitates regular maintenance, repair work is fairly easy. Because of the high volume of traffic, many pavement maintenance companies prefer to work on these roads at night or during off-peak hours.

Layers are used to flexible pavement. To ensure the structural integrity and adaptability of the entire structure, the weakest materials are laid at the bottom and the more durable materials are laid at the top. Flexible pavement is more structurally sound and less likely to collapse under heavy loads because the top layer isn't entirely load-bearing. Every layer carries a share of the load, especially as more traffic goes through.

Advantages of Flexible Pavement

- It may be used during the pre-construction stage
- It is easy to repair and can be opened and patched
- Materials are affordable
- Frost heave and settlement are easily fixed
- Ice glazing development is prevented
- Quick curation equals fewer traffic and business interruptions.

- During installation, no joints are required.

Disadvantages of Flexible Pavement

- Has a shorter lifespan than rigid pavement
- Requires more frequent maintenance, which raises the cost
- Susceptible to oil stains and other chemical effects
- Because edges are brittle, they require curbing or edging.

Rigid Pavement

Rigid pavements are more expensive to build and maintain than soft pavements. They're composed of cement concrete and have a subbase and base. Rigid pavements, in contrast to flexible pavement, have a high flexural strength, making each layer practically impervious to bending under pressure.

There is no load transmission from grain to grain, which means that the top layer of concrete absorbs the majority of the pressure and weight from traffic and other external forces. Permanent or semi-permanent oil and grease stains are also less probable on rigid pavements.

One disadvantages of rigid pavement instillation is the high cos of installation, but the cost of maintenance is acceptable. Given the fact that you will be obtained a long-lasting product, this is unquestionably a wise purchase.

Advantages of Rigid Pavement

- A longer life expectancy
- Low-cost maintenance
- Allows for future asphalt resurfacing
- Allows for wider load distribution with fewer base and sub base requirements
- Can be placed on low- and high-quality soils
- Strong edges that don’t require additional edging work or curbs
- Oil spills and pollutants have no effect on it.

Disadvantages of Rigid Pavement

- The cost of the first installation is high.
- Repair costs are exorbitant.
- Riding quality is poor to extremely poor.
- In various situations, support joints are necessary for concrete contraction and expansion.

2.2.3. V. Sutharsan [9], make comparisson between Flexible and Rigid pavement as follows:

Flexible pavement

Bituminous or asphalt-surfaced flexible pavements are those with a flexible surface. It's flexible because traffic loads cause the entire pavement structure to bend or deflect. Every 10 to 15 years, this type of pavement should be maintained or restored.

Typically, a flexible pavement structure is made up of several layers of material. Where the intensity of stress from traffic loads is high, higher quality materials will be placed on top, while lower quality materials will be placed at the bottom. Under loading, flexible pavements can be modeled as a multilayer system. The surface course, as well as the underlying base and sub base courses, make up a typical flexible pavement structure. Each of these layers helps to support and drain the structure.

It is the stiffest and may contribute the most to pavement strength when hot mix asphalt is used as the surface course. Although the underlying layers are less rigid, they are still necessary for pavement strength, drainage, and frost protection. When a seal coat is used as the surface course, the base layer is usually the one that contributes the most to stiffness. A typical structural design produces a series of layers with progressively lower material quality as depth is increased.

Rigid pavement

A rigid pavement structure is made up of a surface course made of hydraulic cement concrete and concealed base and sub base courses. The rigid layer, the surface course, provides the majority of the strength. The base or sub base layers are much less rigid than the PCC surface, but they still help with pavement drainage and frost protection, as well as providing a working platform for construction equipment.

Due to the high modulus of elasticity of the PCC – Plain Cement Concrete material, rigid pavements are significantly harder than flexible pavements, resulting in very low deflections under load. The plate theory can be used to analyze rigid pavements. Reinforcing steel can be used in rigid pavements to handle thermal stresses, reducing or eliminating joints and maintaining tight crack widths.

In short, Lance Bradshaw gives the difference between flexible and rigid pavement in Table 2.2. below.

Table 2.2. Comparison of rigid and flexible pavement based on reference no.[9]

Flexible pavement	**Rigid pavement**
Subgrade deformation is transferred to the upper layers.	Subsequence layers are affected by deformation in the subgrade.
Flexural strength is low	Flexural strength is high
Grain-to-grain contact was transferred as a result of the load.	There is no such thing as grain to grain load transfer.
Have a low completion rate but a high cost of repair	Have a low cost of repair but a high cost of completion
Oil and chemicals have harmed it.	There is no damage from oil or Greece.
Based on the load distribution factor, create a design.	Design based on slab action or flexural strength.

2.2.4. Gopal Mishra, Flexible Pavement and Rigid Pavement [10], gives they other difference between flexible and rigid pavement as shown in Table 2.3.

Table 2.3. Difference between Flexible and Rigid Pavement according to the reference no.[10]

No	Flexible Pavement	Rigid Pavement
1	It consists of a series of layers with the highest quality materials at or near the surface of pavement	It consists of one layer Portland cement concrete slab or relatively high flexural strength
2.	It reflects the surface deformations caused by subgrade deformations and subsequent layers.	It has the ability to span localized failures and areas with insufficient support.
3.	The aggregate interlock, particle friction, and cohesion all play a role in its stability.	The pavement slab's beam action provides structural strength.
4.	The strength of the subgrade has a big impact on pavement design.	Concrete's flexural strength is an important consideration in design.
5.	It works by distributing load throughout the component layers.	Because of its rigidity and high modulus of elasticity, it disperses load over a large area of subgrade.
6.	Variations in temperature caused by changes in atmospheric conditions do not cause stress in flexible pavements.	Rigid pavements are subjected to significant stresses as a result of temperature changes.
7.	Because heavier wheel loads are recoverable to some extent, flexible pavements have self-healing properties.	Excessive deformations caused by heavier wheel loads are irreversible, resulting in permanent settlements.

2.3. Design Life Flexible Pavement and Rigid Pavement

Road Pavement Design Manual [14] provides guidelines for determining the design life of the pavement. From the Table 2.4. (Table 2.1. in the reference no. 14) the design life for Flexible Pavement is 20 years, while for Rigid Pavement is 40 years.

Table 2.4. Design Life for New Pavement

Type of Pavement	Pavement Element	Design Life (years)
Flexible Pavement	Asphalt layer and Aggregate layer	20
	Base	40
	All pavement for area is not possible for overlay, like urban road, underpass, bridge, and channel	
	Cement Treated Base (CTB)	
Rigid Pavement	Base course, Subbase course, Cement concrete layer	
Road Without Surface	All element (Including Base)	Minimum 10

2.4. Subgrade on Flexible Pavement and Rigid Pavement

Mallick Rajib. B and El-Korchi Tahar (2009) in their book Pavement Engineering Principles and Practice [11], described about flexible pavement structural design construction is carried out to determine the thickness of the various layers in order to avoid problems or distresses in the pavement caused by traffic and the environment. The stiffness/resistance to deformation properties of the soil layers are used to determine the desired thickness of the layers (such as with the use of test property CBR). The imposed stress (weight of layers above them and vehicle load) and the thickness of the layers above them determine the stress in the subgrade/subbase. If the subgrade, subbase, or base is known to be relatively weak, proper binder/surface mix selection and layer thickness should be used to protect it. As a result, the pavement structure design process is an iterative process that balances the availability of materials with the overall cost of the pavement structure.

A rigid pavement, on the other hand, is essentially a slab resting on a base or subgrade. The slab carries a significant portion of the induced stresses because it is much stiffer than the supporting base or foundation material. Although a concrete slab is much wider than a beam and should be regarded as a plate, the load-carrying mechanism is similar to that of a beam. The concept of rigid pavement structural design is based on limiting stresses to prevent excessive pavement damage and deterioration. Stresses in rigid pavements result in distress. Wheel loads, temperature and moisture variations (causing warping, expansion and shrinkage stresses), and volume changes in the base and subbase are all factors that contribute to these stresses.

Papagiannnakis, A.T and Masad E.A (2007) in their book Pavement Design and Materials [12], Flexible Pavement is described as a layered elastic system with infinite lateral dimensions. These layers rest on the subgrade, which is frequently modeled as an infinite-depth elastic layer. All of the pavement layers and the subgrade can be described by their elastic properties. Their Poisson's ratio and Young's modulus E. The layers are also thought to be homogeneous and isotropic. Equation 2.1 is used to model tire loads as either point loads or circular loads of uniform pressure.

$$a = \sqrt{\frac{P}{i\,\pi}} \quad \text{.......... eq. 2.1}$$

where: The vertical load carried by the tire is denoted by P, and the inflation/contact pressure is denoted by i.

The stress state is axis-symmetric under these conditions, meaning it has rotational symmetry around the load's center axis, making it easier to describe using a radial coordinate system. The responses of the pavement (i.e., stress, strains, and deflections) are calculated using elasticity relationships. According to D'Alembert's superposition principle, the responses from multiple loads are calculated by superimposing the stresses from individual tires.

Solutions for single-layer, two-layer, and multilayer flexible pavement systems are discussed in the following section. The granular layers are treated as linear elastic and nonlinear elastic (i.e., stress-independent and stress-dependent moduli, respectively), while the asphalt concrete is treated as linear elastic or linear visco-elastic.

Rigid Pavements are made up of Portland cement concrete slabs resting on a base course or directly on the subgrade, according to the definition. The modulus of Portland concrete, which is in the range of 28,000 MPa, is significantly higher than the moduli of the underlying layers, which typically range from 80 to 600 MPa.

As a result, rigid pavements derive much of their load-carrying capacity from plate action (i.e., two-directional slab bending on the x-y plane), while the lower layers provide support.

When thermally induced tensile stresses exceed the concrete's tensile strength, unreinforced slabs tend to crack transversely. As a result, either transverse joints or tensile reinforcement are required. Aggregate interlock or dowel bars provide vertical load transfer between adjacent slabs in joined pavements. Jointed plain concrete pavements (JPCPs) and jointed dowel-reinforced concrete pavements (JDRCPs) are the terms used to describe them. The slab's integrity is maintained by continuous reinforcement, which keeps the tension cracks in the Portland concrete closed. Continuously reinforced concrete pavements are the name for these types of pavements (CRCP). Concrete pavement stresses are the result of the interaction of several factors that can be divided into three categories:

1. Environmetal (n.d.) (n.d.) (n (i.e., effect of temperature and moisture changes in the slab)
2. The volume of traffic
3. Support for the slab's base/subgrade (i.e., slab curling and volume changes or erosion of the subgrade)

The subgrade and how it supports the slab is one of the most common simplifications used in analyzing concrete pavements. The subgrade is either modeled as a series of non-interacting linear springs or as an infinitely deep homogeneous and isotropic continuum.

The elastic constant of the springs, known as the modulus of subgrade reaction, is denoted by k in the first foundation model. In equation 2.2, it's defined as the ratio of stress to deflection, and it's measured in MPa.m through plate-loading tests.

$$k = \frac{\sigma}{\delta} \quad \text{eq. 2.2}$$

where: k = the modulus of subgrade reaction (MPa.m)

σ = contact stress (MPa)

δ = Circular plate deformation (m)

This foundation, known as Winkler or "liquid," implies that load at a specific point only causes subgrade deflection directly beneath that point. The elastic modulus and Poisson's ratio of the subgrade, denoted b Es and s, respectively, characterize the second foundation model (this is to distinguish them from the slab's elastic constants, denoted by E and μ). Triaxial laboratory testing or back-calculation based on in-situ surface deflection measurements are used to determine these subgrade properties. This foundation, known as Boussinesq, or "solid," implies that load at a specific point causes subgrade deflections all around it. Figure 2.1 depicts the relationship between load and deflection, with rij denoting the distance between the load application I and the deflection location j.

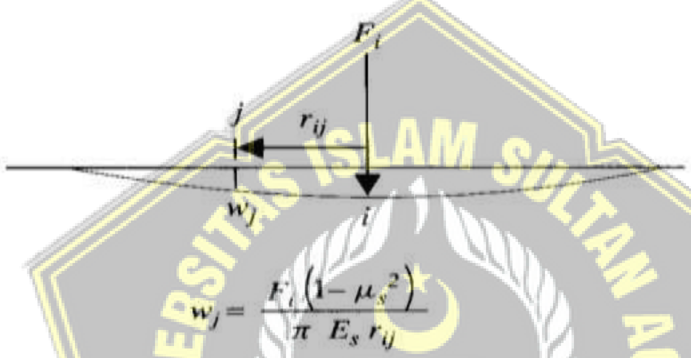


Figure 2.1 Solid Concrete Pavement Foundation Model [12]

The solid foundation model is unquestionably more realistic than the liquid foundation model. The bellow is the most common expression for the relationship between k and Es:

$$k = \left(\frac{E_s}{E}\right)^{1/3} \frac{E_s}{(1-\mu_s^2)h} \quad \text{eq. 2.3}$$

where:

k = the modulus of subgrade reaction (MPa.m)

E_s = the elastic modulus of subgrade

E = the elastic modulus

μ_s = the Poisson’s ratio of the subgrade

h = the thickness of the PCC slab.

It should be noted right away that closed-form solutions for structural analysis of concrete pavements are only available for a small number of simple loading scenarios, which will be discussed next. Numerical methods, such as the Finite Element Method (FEM), which is discussed later in this chapter, are required for more complex problems. The FEM can easily analyze load and moment transfer across joints under a variety of environmental and traffic-loading inputs and can model the slab and subgrade as a whole. It's especially good at analyzing complex boundary conditions, like those caused by shifting base/subgrade support beneath a slab. Following that, a detailed structural analysis of concrete slabs in response to each of the three groups of factors previously mentioned is presented. This discussion begins with a review of elasticity theory applied to pure plate bending.

Nick, Tom (2008) in their book Principles of Pavement Engineering [13], describes basically, a rigid pavement is one with PQC slab as the main structural layer and a flexible pavement consist entirely of unbound materials and asphalt. In pavement layers, there are many layers. First the subgrade is uneconomic to place high-value materials straight into a weak soil. Moving on top, the surface course (not present as a separate layers in concrete pavements) is a high-quality (and therefore expensive) materials, though enough to withstand direct loading and with surface properties designed to achieve adequate skid resistance thick layer 20-50 mm.

Somewhere in he middle of the structure, the base is the layer which given the pavement most of its strength. It is usually relatively thick (often 200 mm or more) and therefore has to be as inexpensive as possible within the constrain of required mechanical properties.

Finally, the subbase is much more than just a fill in layer. The performance of an asphalt or concrete base is critically dependent on the stiffness of the layer immediately beneath, because of its influence on the flexure of the base under traffic load. A typical thickness is 150 mm.

2.5. Loading System in Flexible Pavement and Rigid Pavement

The stiffness of each layer or lift in the flexible pavement was greater than that of the layer below and less than that of the layer above. This can be seen in the load distributions in Figures 2.2 and 2.3 for flexible and rigid pavements, respectively, where the stress at the surface layer was higher than the stress at the layer below. The surface layer must be able to withstand the greatest amount of stress while also adapting to changing environmental conditions. As a result, this top layer is usually made up of the "best" and most expensive materials. Unless it is an open graded friction course, this layer is always ‘bound,' that is, mixed with a ‘binder’, in this case asphalt cement or bitumen binder, to prevent raveling materials under traffic and to provide a dense surface to prevent water ingress. As a result, the surface layer is made up of two main elements: bitumen binder and aggregates.

From the description below, the thickness of the flexible pavement layer depends on the strenght of the subgrade, or in other words, the stronger the subgrade bearing capacity, thinner of the thickness of the pavement layer and vice versa.

Different with flexible pavement, in the rigid pavement, tire load distribute evenly from the slab to the subgrade. Therefore, subgrade in rigid pavement should be strong.

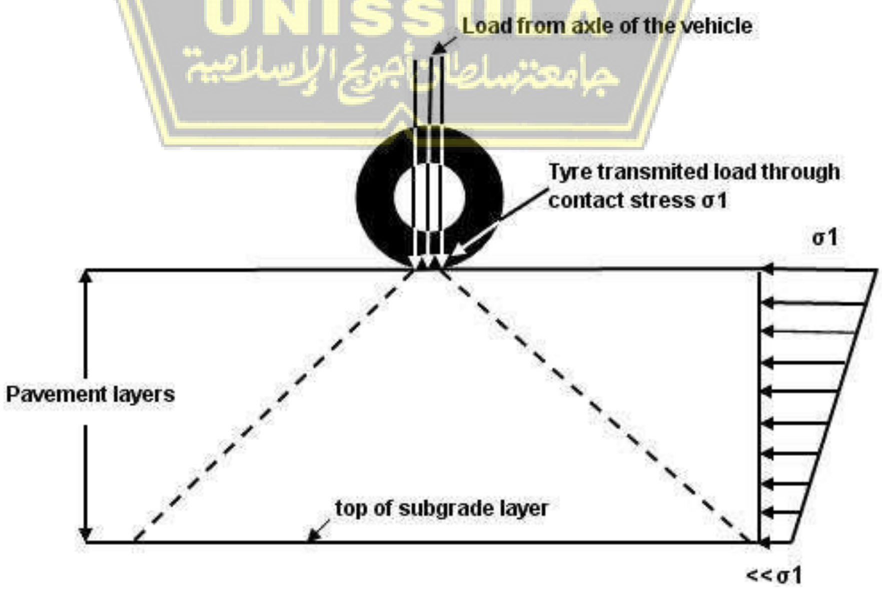


Figure 2.2. Load Distributions on Flexible Pavement

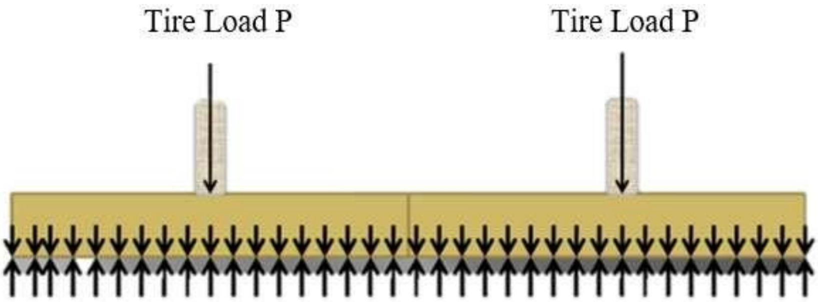


Figure 2.3. Load Distributions on Rigid Pavement

2.6. Summary of The Literature Review

From the literatures about the difference between flexible and rigid pavements, and from the URL https://allabouteng.com gives the most complete difference which is 20 items. However, the study of the differences between flexible and rigid pavements will be discussed in detail in chapter VI.

CHAPTER III

METHODOLOGY

3.1. Introduction

This methodology chapter was written to explain the steps in studying the diffeences between flexible pavement and rigid pavement. The Flowchart of methodological was given in Figure 3.1. As shown in the Flowchart, the study begins with conducting a literature review, namely reviewing some difference between flexible and rigid pavement, and design parameters of flexible and rigid pavement. The literature was review then followed by design calculation of flexible and rigid pavement. After getting pavement design of both pavement, the study continued with comparize of design life, materials used, initial cost, and subgrade strength. Discussion on the comparison results will be carried out, and as the end of the study.

3.2. Design calculations

Design calculation of flexible and rigid pavement will be done using AASHTO 1993 design method and based on the provision in the Bina Marga's Road Pavement Design Manual Method 2017.

The purpose of this method is for the implementation of the road construction that can provide optimal service to traffic in accordance with the design life.

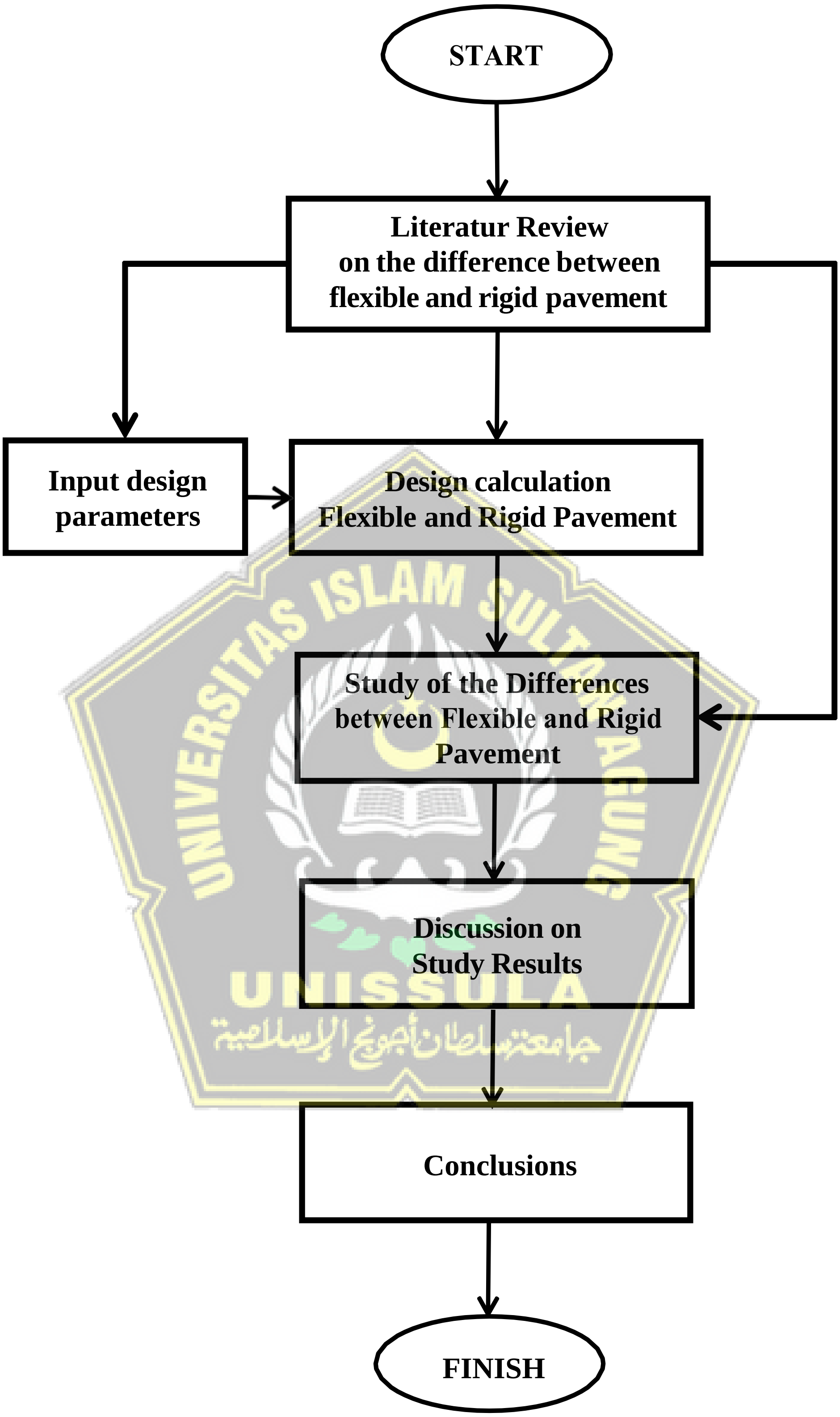


Figure 3.1. Flowchart of methodologi

3.3. Provisions pavement design from Bina Marga's Pavement Design Manual 2017 [13]

3.3.1 Design Life

Bina Marga's Pavement Design Manual 2017 give the design life for flexible and rigid pavement as shown in Table 3.1.

Table 3.1 Design Life for New Pavement [14]

Type of Pavement	Pavement Element	Design Life (years)
Flexible Pavement	Asphalt layer and Aggregate layer	20
	Base	40
	All pavement for area is not possible for overlay, like urban road, underpass, bridge, and channel	
	Cement Treated Base (CTB)	
Rigid Pavement	Base course, Subbase course, Cement concrete layer	
Road Without Surface	All element (Including Base)	Minimum 10

3.3.2 Traffic

1) Traffic volume analysis

The main element of traffic loading on pavement design were:

- Axle load commercial vehicle
- Traffic volume in standart axle.

Traffic volume analysis was conducted base on the survey results that found from:

1. By conducting traffic survey with minimum duration 7 x 24 hours. Survey can be conducted manually according to guidance in "Pedoman Survei Pencacahan Lalu Lintas" (Pd T-19-2004-B) or using tools with the same guidance.

2. From the results of previous traffic survey.
3. Estimate traffic volume from point 4-10 or the road with low traffic volume.

On analuzing Traffic, determination traffic volume on the peak hour and Yearly Average Daily Traffic (Y-ADT) refers to the Indonesian Road Capacity Manual Determination of Y-ADT based on traffic volume survey by considering ‘k’-factor [14].

2) Traffic Data

Accuracy of traffic data is important to get an effective pavement design which can well perform during the design life. Therefore, the calculation of traffic data have to include all types of commercial vehicles. Classification of vehicles based on the type given in Table 3.2.

Table 3.2 Vehicle Clasification based on Type [14]

Group	Transportation Type
1	Motorcycle
2,3,4	Private car/ Angkot/ Pickup/ Station W
5A	Small bus
5B	Big bus
6A	2 axis truck - light cargo
6B	2 axis truck - heavy cargo
7A	3 axis truck
7B	2 axis truck & 2 axle towing trailer (Articulated Truck)
7C	4 Axis Truck- Trailer

3) Traffic Growth Factor

Traffic growth factor set based on series traffic growth data (historical growth data) or the formulation of correlation with other prevailing traffic growth factor [14]. If the traffic data were not available, then can be used the Table 3.3. below which lasting for 2015 to 2035.

Table 3.3 Traffic Growth Rate Factor *(i)* (%) [14]

	Jawa	Sumatera	Kalimantan	Average Indonesia
Arterial and Urban	4,80	4,83	5,14	4,75
Rural Collectors	3,50	3,50	3,50	3,50
Village Roads	1,00	1,00	1,00	1,00

Traffic growth during the design life is calculated by using the *Cumulative Growth Factor* :

$$R = \frac{(1+0{,}01\ i)^{UR} - 1}{0{,}01\ i} \quad \text{.................... eq. 3.1}$$

where: *R* = cross cumulative growth multiplying factor

i = annual traffic growth rate (%)

UR = plan age (year)

If it is estimated that there will be a difference in the annual growth rate over the total design life (UR), with i 1% during the initial period (UR1 year) and i 2% during the remainder of the next period (UR - UR1), the cumulative traffic growth multiplier can be calculated from the following formula:

$$R = \frac{(1+0.01\ i_1)^{UR1} - 1}{0.01\ i_1} + (1 + 0.01\ i_1)^{(UR1-1)}(1 + 0.01\ i_2)\left\{\frac{(1+0.01\ i_2)^{(UR-UR1)} - 1}{0.01\ i_2}\right\} \quad \text{.................... eq. 3.2}$$

where: *R* = cross cumulative growth multiplying factor

i_1 = annual traffic growth rate for period 1 (%)

i_2 = annual traffic growth rate for period 2 (%)

UR_1 = total plan age (year)

UR_1 = plan age period 1 (year)

If the traffic capacity is estimated were reached in year 'Q' of the design life, the multiplier factor of the cumulative traffic growth was calculated as follows:

$$\boldsymbol{R} = \frac{(1+0.01\,i)^{Q}-1}{0.01\,i} + (\boldsymbol{UR} - \boldsymbol{Q})(\boldsymbol{1} + \boldsymbol{0.01}\,\boldsymbol{i})^{(\boldsymbol{Q}-\boldsymbol{1})} \quad \text{eq. 3.3}$$

where for R, UR already given in equation (3.1) and equation (3.2), while Q is the year when traffic growth were calculated.

4) Traffic on the design lane

The design lane is one of the traffic lanes of a road that accommodates the largest commercial vehicle traffic (truck and bus). The traffic load on the design lane was expressed in cumulative standard axle load (ESA) by taking into account the direction of distribution factor (D_D) and the lane distribution factor for commercial vehicles (D_L). Traffic on the design lane were calculated by two factors, namely:

i. For two way direction, distribution factor (D_D), generally take 0.50.

ii. The lane distribution factor (D_L), was used for adjusts the cummulative equivalent single axle load (ESAL) on the road with two-lane or more in one direction. On such roads eventhough most commercial vehicles will use outside lanes, some will use inner lanes. The value of the lane distribution factor is given in Table 3.4.

Table 3.4 Lane Distribution Factor (D_L)

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

5) Cummulative Equivalent Single Axle Load (Cummulative ESAL)

The cumulative standard single axle load or cummulative ESAL was the cumulative total axle load of design traffic on the design lane over the design life, which was determined using the Vehicle Damage Factor (VDF) of each commercial vehicle.

$ESA_{TH-1} = (\Sigma LHR_{JK} \times VDF_{JK}) \times 365 \times DD \times DL \times R$ .... eq. 3.4

where:

ESA_{TH-1} = Cumulative single axle (equivalent standard axle) in the first year

ΣLHR_{JK} = daily traffic average of each type of commercial vehicle (unit vehicles per day)

VDF_{JK} = Load Equivalent Factor (Vehicle Damage Factor) of each type commercial vehicles Table 3.5 and Table 3.6

DD = Direction distribution factor

DL = Lane distribution factor

CESAL = The cumulative standard axle load is equivalent over the design life

R = Multiplier factor for cumulative traffic growth

3.3.3 Determination of Subgrade Strength

In designing the road foundation, it will depend heavily on the bearing capacity of the subgrade. Therefore, determining the bearing capacity of the subgrade accurately and the design of the pavement foundation are important requirements to produce a good road foundation so that it can support pavement performance optimally. If the carrying capacity of the subgrade is insufficient, it is necessary to improve the subgrade, add layers of support and various other measures.

In the design of the road foundation includes several aspects that must be considered, namely:

- **CBR Subgrade Design**

Roads that are designed must be grouped based on similarity in segments representing subgrade conditions that can be considered uniform (without significant differences). Initial grouping can be done based on the results of table studies and field investigations on the basis of similarities in geology, pedology, drainage and topography conditions, and geotechnical characteristics (such as gradation and plasticity). It is generally recommended to avoid selecting uniform segments that are too short. If the CBR value obtained varies widely, the designer must compare the benefits and costs between the options making a short uniform segment based variations in the CBR value, or create a longer segment based on a more conservative CBR value. Another important thing that must be considered is the need to distinguish the low carrying capacity that is local (local) from the carrying capacity of the more general subgrade (representing a location). Local subgrade with low bearing capacity is usually removed and replaced with better materials or specially handled.

The three most important factors in pavement design are traffic, subgrade and water influences. In addition, in the case of pavement that must be built in areas with problematic soils such as peat and soft soil, the characteristics of the relevant soil are a very important factor because ordinary subgrade analysis cannot produce pavements with the expected performance.

For design, the carrying capacity of subgrade plans is obtained from the CBR value of 4 days immersion at 95% of the maximum standard dry density. Design chart - 1 shows the bearing capacity of different types of soil. The values shown are used as initial references only. The bearing capacity test must be carried out to obtain the true CBR value. The chart indicates that local conditions affect the bearing capacity of the subgrade.

In the 1993 AASHTO resilient modulus is used to express subgrade strength. Resilient modulus is a measure that expresses the elasticity property of subgrade soils. The use of MR subgrade in the 1993 AASHTO design which was later adopted into the Pt T-01-2002-B Bina Marga Guidelines was chosen to replace the use of subgrade bearing capacity in the previous method.

In its implementation in the field, if the implementer does not have the equipment to carry out the MR value-taking test, several factors and equations can be used to determine the MR value from the CBR value, R-Value, and the results of the soil index test. Equation (3.1) relates the value of MR to CBR

$M_R = 1500 \times \text{CBR}$ .... eq. 3.5

where:

M_R = Modulus Resilien tanah dasar (psi)

CBR = *California Bearing Ratio*

- **Subgrade Improvement or Adding Layers of Support (Capping Layers)**

Inadequate subgrade bearing capacity needs special handling so that the subgrade becomes capable of supporting the pavement structure effectively. One way to improve the subgrade is by adding a layer of support. Determination of the thickness of the supporting layer can be seen in Table 3.5.

Table 3.5. Design Chart 1- Indication of the CBR Value Estimate

Design Chart 1- Indication of the CBR Value Estimate

	Groundwater Surface Position	**Under the minimum standard (not recommended)**	**According to standard design**	**≥1200 mm under subgrade**
	Implementation	All excavation except as indicated for case - 3 and fill without proper drainage and LAP * <1000 mm above original ground level		Excavation in climate zone 1 ** and all stockpiles well drained (m ≥1) and LAP> 1000 mm above original soil surface
Type of soil	PI case	1	2	3
Clay	50-70	2	2	2,5
Silty Clay	40	2,5	3	3,5
	30	3	4	4
Sandy Clay	20	4	4	5
	10	4	4	5
Sit		1	1	2

3.4. AASTHO 1993 Design Method

3.4.1. Flexible Pavement

The design is based on identyfying a flexible pavement structural number (SN) to withstand the projected level of axle load traffic.

- Determine Required Structural Number

Figure 3.2 presents the nomograph recommended for determining the design structural number (SN) required for specific conditions, including:

(1) the estimated future traffic, W_{18} , for the performance period,
(2) the reliability, R, which assumes all input is at average value,
(3) the overall standard deviation, S_o,
(4) the effective resilient modulus of roadbed material, M_R, and
(5) the design serviceability loss, $\Delta PSI = p_o - p_t$

- **Stage Construction**

Experience in some states has shown that regardless of the strength (or load-carrying capacity) of a flexible pavement, there may be a maximum performance period associated with a given initial structure which is subjected to some significant level of truck traffic. Obviously, if the analysis period is 20 years (or more) and this practical maximum performance period is less than 20 years, there may be a need to consider stage construction (i e, planned rehabilitation) in the design analysis. This is especially true if life-cycle economic analysis are to be performed, where the trade-offs between the thickness designs of the initial pavements structure and any subsequent overlays can be evaluated. In such instances, where stage conctruction alternatives are to be considered, it is important to check the constraint on minimum performance period within the various candidate strategies. It is also important to recognize the need to compound the reliability for each individual stage of the strategy.

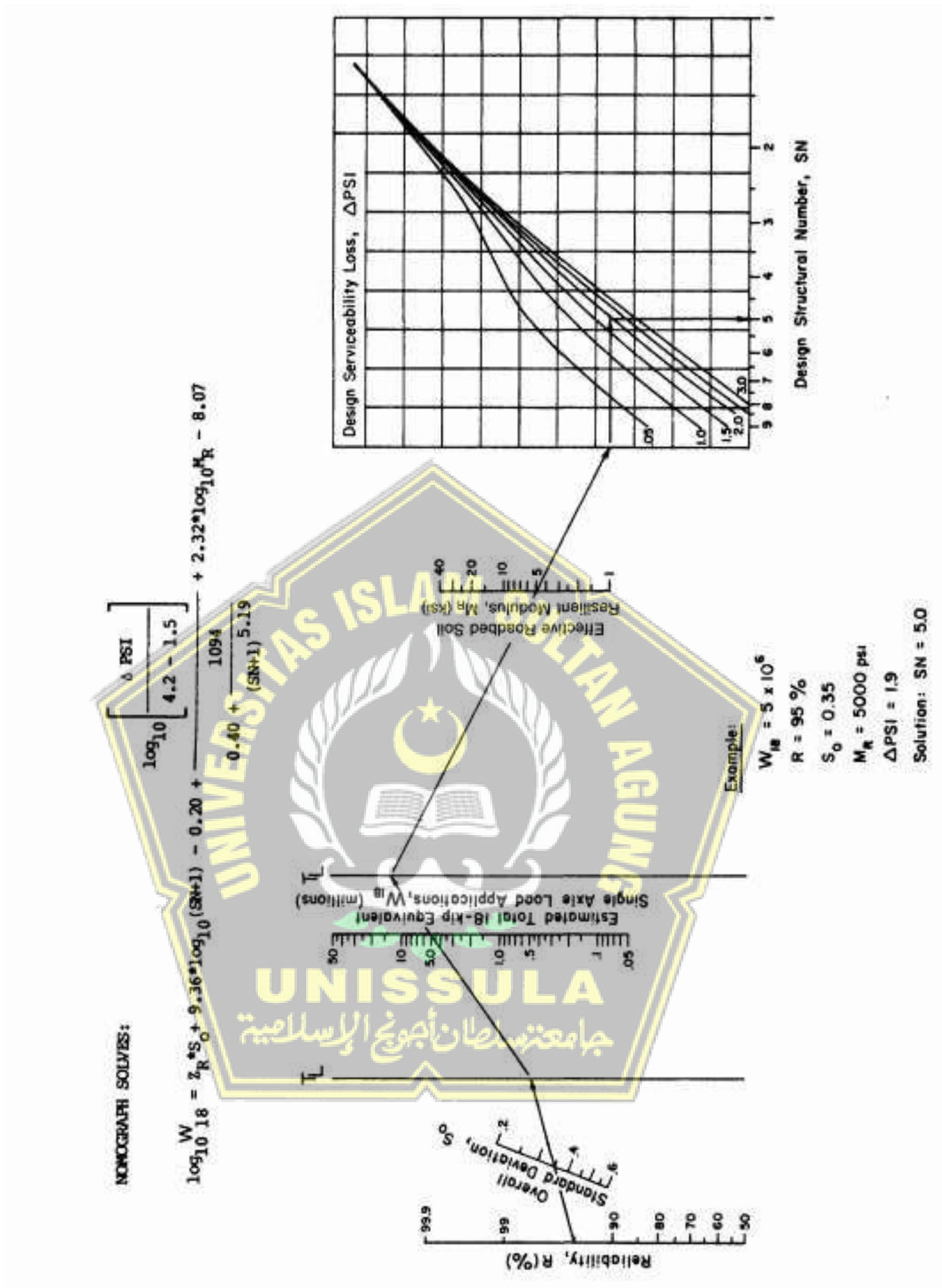


Figure 3.2. Design Chart for Flexible Pavements Based on Using Mean Values for Each Input

For example, if each stage of 3-stage strategy (an initial pavement with two overlays) has a 90-percent reliability, the overall reliability of the design strategy is 0.9 x 0.9 x 0.9 or 72.9 percent. Conversely, if an overall reliability of 95 percent is desired, the individual reliability for each stage must be $(0.95)^{1/3}$ or 98.3 percent. It is important to recognize compounding of reliability may be severe for stage construction, and later opportunities to correct problems areas may be considered.

- **Roadbed Swelling**

Roadbed swelling and or frost heave are both important environmental considerations because of their potential effect on the rate of serviceability loss. Swelling refers to the localized volume changes that occur in expansive roadbed soils as they absorb moisture. A drainage system can be effective in minimizing roadbed swelling if it reduces the availability of moisture for absorption.

If either swelling or frost heave are to be considered in terms of their effects on serviceability loass and the need for future overlays, then the following procedure should be applied. It does require the plot of serviceability loss versus time.

The procedure for considering environmental serviceability loss is similar to the treatment of stage construction strategies because of the planned future need for rehabilitation. In the stage construction approach, the structural number of the initial pavement is selected and its corresponding performance period (service life) determined. An overlay (or series of overlays) which will extend the combined performance periods past the desired analysis period is the identified. The difference in the stage construction approach when swelling and or frost heave are considered is that an iterative process is required to determine the length of the performance period for each stage of the strategy. The objective of this iterative process is to determine when the combined serviceability loss due to traffic and environment reaches the terminal level.

- **Selection of Layer Thickness**

Once the design structural number (SN) for an initial pavement structure is determined, it is necessary to identify a set of pavement layer thicknesses which, when combined, will provide the load-carrying capacity coreesponding to the design SN. The following equation provides the basis for converting SN into actual thicknesses of surfacing, base and subbase :

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3 \qquad \text{eq. 3.6}$$

where :

SN = Structural Number

a_1, a_2, a_3 = layer coefficients representative of surface, base, and subbase course, respectively

D_1, D_2, D_3 = actual thicknesses (in inches) of surface, base, and subbase courses, respectively, and

D_1, D_2 = drainage coefficients for base and subbase layers, respectively

The SN equation does not have a single unique solution; i e, there are many combinations of layer thicknesses that are satisfactory solutions. The thickness of the flexible pavements layer should be rounded to the nearest $^1/_2$ inch.

When selecting appropriate values for the layer thicknesses, it is necessary to consider their cost effectiveness along with the construction and maintenance constraints in order to avoid the possibility of producing an impractical design. From a cost-effective view, if the ratio of costs for layer 1 to layer 2 is less than the corresponding ratio of costs layer coefficient times the drainage coefficient, then the optimum economical design is one where the minimum base thickness is used. Since it is generally impractical and uneconomical to place surface, base, or subbase courses of less than some minimum thickness, the following are provide as minimum practical thicknesses for each pavement course.

Because such minimums depend somewhat on local practices and conditions, individual design agencies may find it desirable to modify the above minimum thicknesses for their own use.

Table 3.6 Minimum Thickness (inches) [14]

Traffic, ESAL'S	Asphalt Concrete	Aggregate Base
Less than 50,000	1 0 (or surface treatment)	4
50,001-150,000	2 0	4
150,001-500,000	2 5	4
500,001-2,000,000	3 0	6
2,000,001-7,000,000	3 5	6
Greater than 7,000,000	4 0	6

Individual agencies should also establish the effective thicknesses and layer coefficients of both single and double surface treatments. The thickness of the surface treatment layer may be neglectibe in computing SN, but its effect on the base and subbase properties may be karge due to reductions in surface water entry.

- **Layered Design Analysis**

It should be recognized that, for flexible pavements, the structure is a layered system and shoul be designed accordingly. First, the structural number required over the roadbed soil should be computed. In the same way, the structural number required over the subbase layer and the base layer should also be computed, using the applicable strength values for each. By working with differences between the computed structural numbers required over each layer, the maximum allowable thickness of any given layer can be computed. For example, the maximum allowable structural number for the subbase material would be equal to the structural number required over the subbase substracted from the structural number required over the roadbed soil. In a like manner, the structural numbers of the other layers may be computed.

It should be recognized that this procedure should not be applied to determine the SN required above subbase or base materials having a modulus greater than 40,000 psi. For such cases, layer thicknesses of materials above the “high” modulus layer should be established based on cost effectiveness and minimum practical thickness consideration.

3.4.2 Rigid Pavement

This section describes the design for portland cement concrete pavements, including plain jointed (JCP), jointed reinforced (JRCP), and continuosly reinforced (CRCP). As in the design for flexible pavements, it is assumed that these pavements will carry traffic levels in excess of 50,000 8,16-kip ESAL over the performance period.

The AASTHO design procedure is based on the AASTHO Road Test pavement performance algorithm. In herent in the use of the procedure is the use of dowels at transverse joints. Hence, joint faulting was not a distress manifestationat the Road Test. If the designer wishes to consider nondowelled joints, he may develop an appropriate J-factor.

- **Develop Effective Modulus of Subgrade Reaction**

Before the design chart for determining design slab thickness can be applied, is is necessary to estimate the possible levels of slab support that can be provided. This is accomplished using Table 3.7 and Figures 3.3, 3.4, 3.5, and 3.6 to develop an effective modulus of subgrade reaction, k.

Since the effective k-value is dependent upon several different factors besides the roadbed soil resilient modulus, the first step is to indentify the combinations (or levels) that are to be considered.

(1) Subbase types – Different types of subbase have different strengths or modulus values. The consideration of a subbase type in estimating an effective k-value provides a basis for evaluating its cost-effectiveness as part of the design process.

(2) Subbase thicknesses (inches) – Potential design thicknesses for each subbase type should also be identified, so that its cost-effectiveness may be consideres.

(3) Loss of support, LS – Is used to correct the effective k-value based on potential erosion of the subbase material.

(4) Depth to rigid foundation (feet) – If bedrock lies within 10 feet of the surface of the subgrade for any significant length along the project, its effect on the

overall k-value and the design slab thickness for that segment should be considered.

For each combination of these factors that is to be evaluated, it is necessary to prepare a separate table and develop a corresponding effective modulus of subgrade reaction.

The second step of the process is to identify the seasonal roadbed soil resilient modulus values and enter them in Column 2 of each table. As before, if the length of the smallest season is one-half month, then all seasons must be defined in terms of consecutive half-month time intervals.

The third step in estimating the effective k-value is to assign subbase elastic (resilient) modulus (E_{SB}) values for each season. These values, which were discussed in Section 2 3 3, should be entered in Column 3 of Table 3.2 and should correspond to those for the seasosns used to develop the roadbed soil resilient modulus values. For those types of subbase material which are insensitive to season (e g, cement-treated material), a constant value of subbase modulus may beassigned for each season. For those unbound materials which are sensitive to seasonbut were not tested for the extreme conditions, values for E_{SB} of 50,000 psi and 15,000 psi may be used for the frozen and spring thaw periods, respectively. For unbound materials, the ratio of the subbase to the roadbed soil resilient modulus should not exceed 4 to prevent an artificial condition.

Table 3.7 Table for Estimating Effective Modulus of Subgrade Reaction

Trial Subbase: Type ________________

Thickness (inches) __________

Loss of Support, LS ________

Depth to Rigid Foundation (feet) ________

Projected Slab Thickness (inches) ________

(1) Month	(2) Roadbed Modulus, M_R (psi)	(3) Subbase Modulus, E_{SB} (psi)	(4) Composite k-Value (pci) (Fig. 3.3)	(5) k-Value (pci) on Rigid Foundation (Fig. 3.4)	(6) Relative Damage, u_r (Fig. 3.5)
Jan					
Feb					
Mar					
Apr					
May					
June					
July					
Aug					
Sept					
Oct					
Nov					
Dec					
				Summation Σu_r =	

Average: $\bar{u}_r = \frac{\Sigma u_r}{n} =$ ______

Effective Modulus of Subgrade Reaction, k (pci) = ______

Corrected for Loss of Support k (pci) = ______

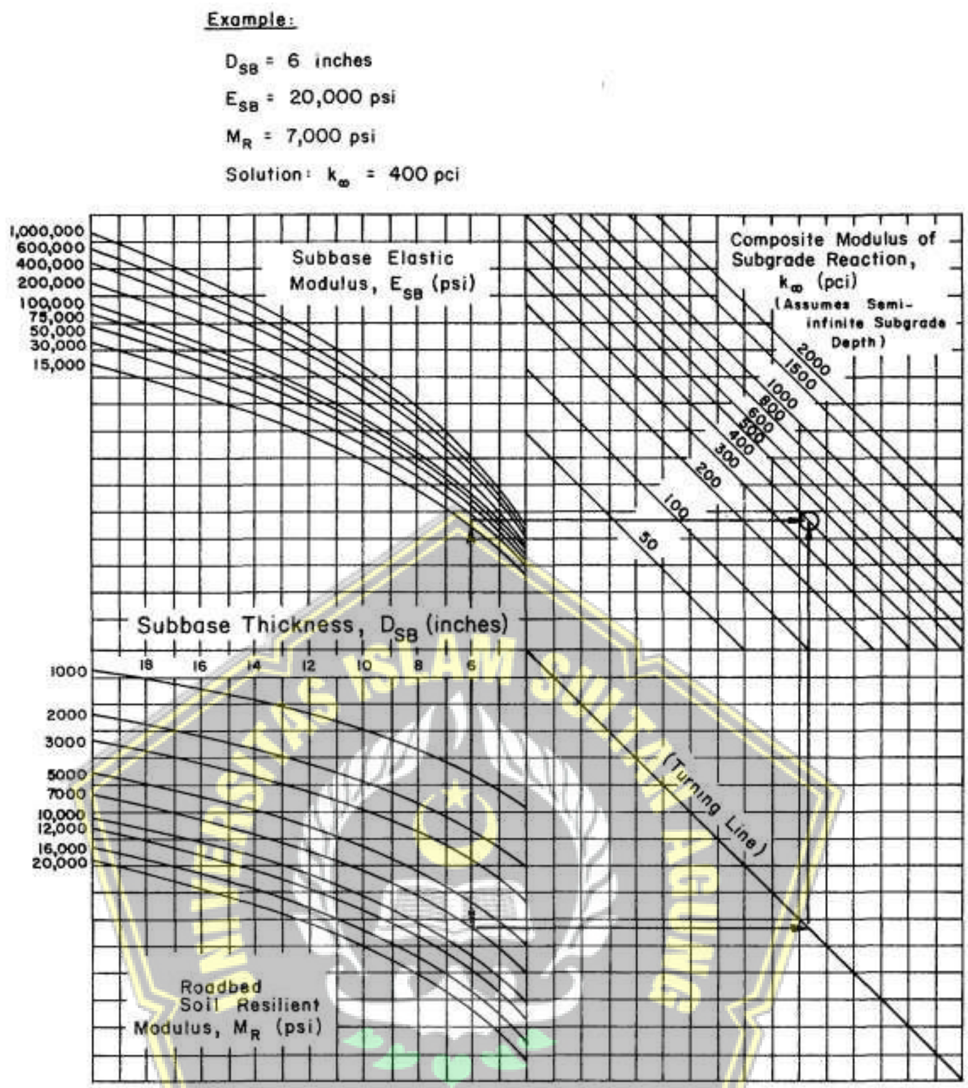


Figure 3.3 Chart for Estimating Composite Modulus of Subgrade Reaction, k_{∞}, Assuming a Semi-Infinite Subgrade Depth. (For practical purpose, a semi-infinite depth is considered to be greater than 10 feet below the surface of the subgrade.)

The fourth step is to estimate the composite modulus of subgrade reaction for each season,assuming a semi-infinite subgrade depth (i e, depth to bedrock grater that 10 feet) and enter in Column 4. This is accomplished with the aid of Figure 3.3. Note that the starting point in this chart is subbase thickness, D_{SB}. If the slab is placed directly on the subgrade (i e, no subbase), the composite modulus of subgrade reaction is defined using the following theoretical relationship between k-values from a plate bearing test and elastic modulus of the roadbed soil.

$k = M_R/19,4$ .... eq. 3.7

where:

k = Modulus of Subgrade Reaction (pci)

M_R = Resilient Modulus (psi)

The fifth step is to develop a k-value which includes the effect of a rigid foundation near the surface. This step should be disregarded if the depth to a rigid foundation is greater than 10 feet. Figure 3.4 provides the chart that may be used to estimate this modified k-value for each season. It considers roadbed soil resilient modulus and composite modulus of subgrade reaction, as well as the depth to the rigid foundation. The values for each modified k-value should subsequently be recorded in Column 5 of Table 3.7

The sixth step in the process is to estimate the thickness of the slab that will be required, and then use Figure 3.5 to determine the relative damage, u_r , in each season and enter them in Column 6 of Table 3.7

The seventh step is to add all the u_r values (Column 6) and divided the total by the number of seasonal increments (12 or 24) to determine the average relative damage, u_r. The effective modulus of subgrade reaction, then, is the value corresponding to the average relative damage (and projected slab thickness) in Figure 3.5.

The eight and final step in the process is to adjust the effective modulus of subgrade reaction to account for the potential loss of support arising from subbase erosion. Figure 3.6 provides the chart for correcting the effective modulus of subgrade reaction based on the loss of support factor, LS.. Space is provided in Table 3.7 to record this final design k-value.

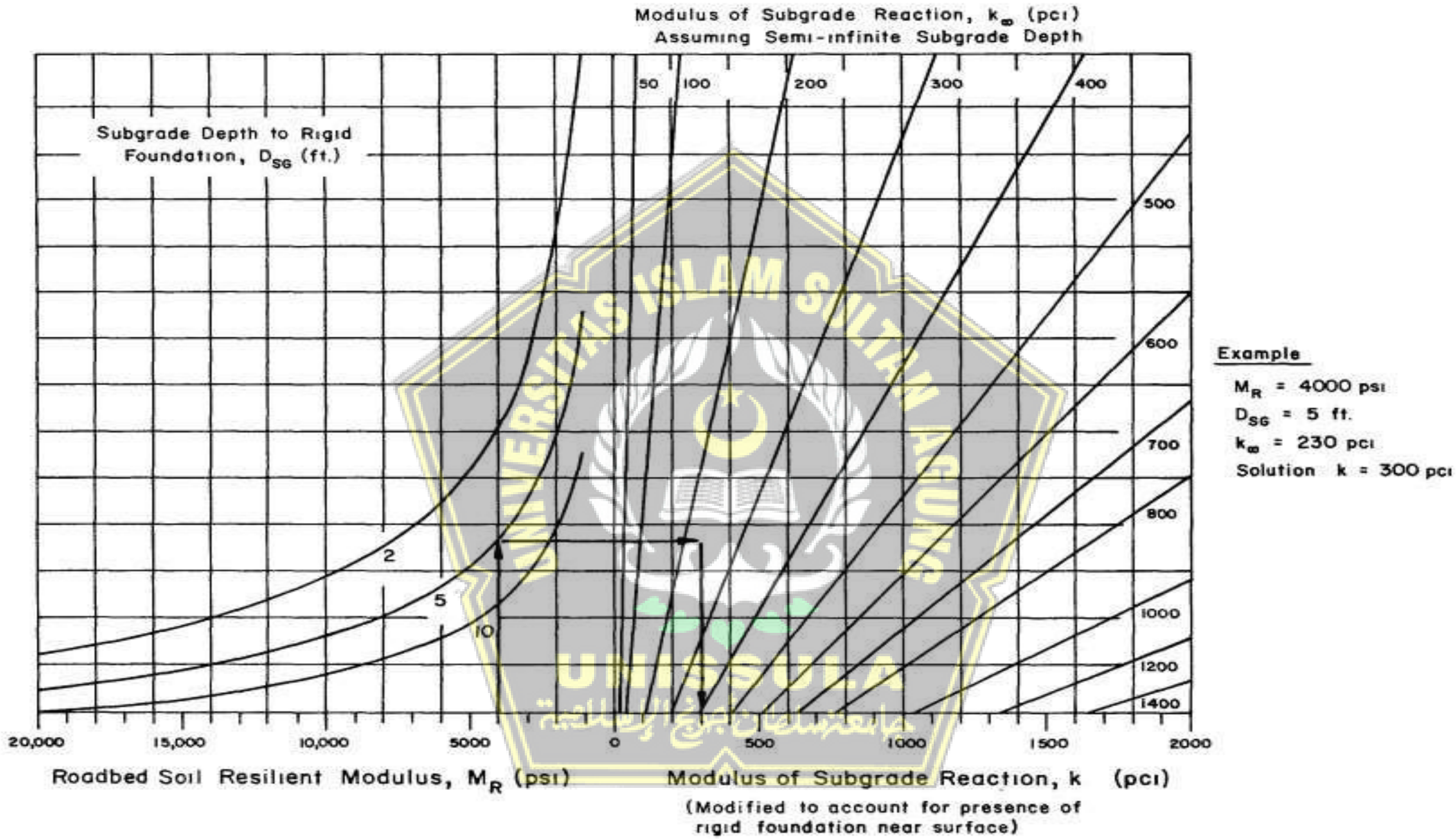


Figure 3.4 Chart to Modify Modulus of Subgrade Reaction to Consider Effects of Rigid Foundation Near Surface (Within 10 feet)

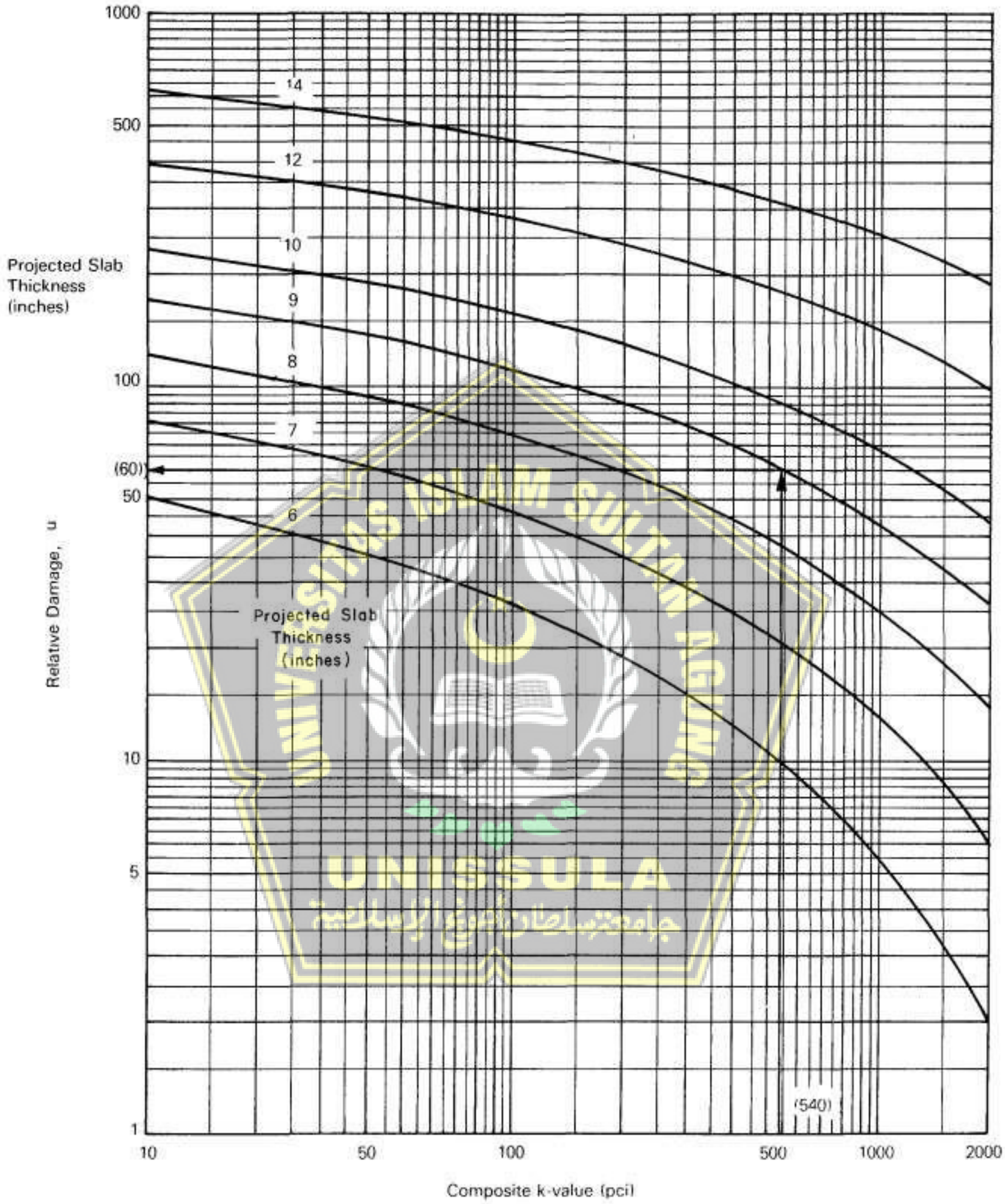


Figure 3.5 Chart for Estimating Relative Damage to Rigid Pavement Based on Slab Thickness and Underlying Support

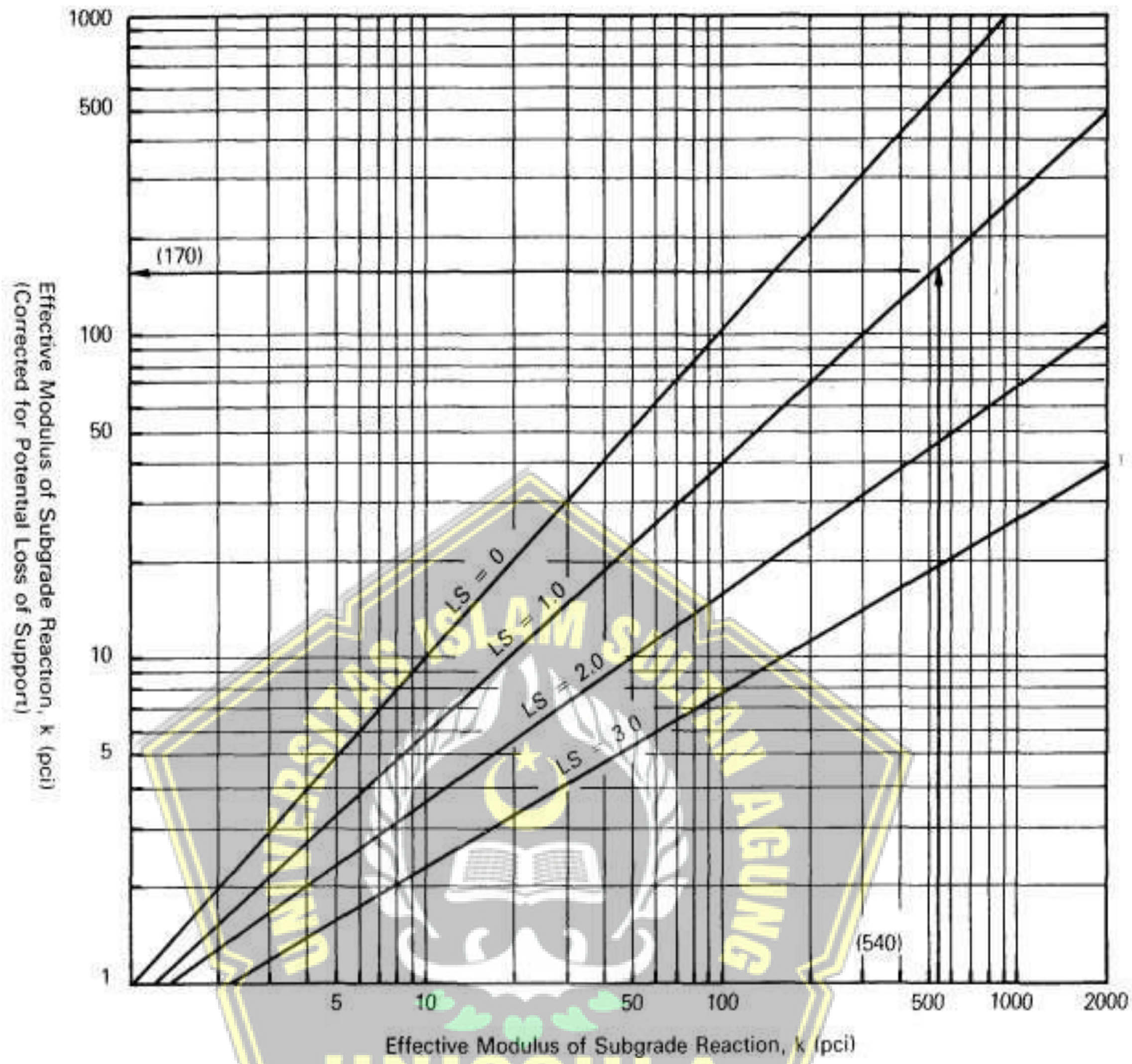


Figure 3.6 Correction of Effective Modulus od Subgrade Reaction for Potential Loss of Subbase Support

- **Determine Required Slab Thickness**

Figure 3.7 (in 2 segements) presents the nomograph used for determining the slab thickness for each effective k-value identified in the previous section. The designer may then select the optimum combination of slab and subbase thicknesses based on economics and other agency policy requirements. Generally, the layer thickness is rounded to the nearest inch, but the use of increments. In addition to the design k-value, other inputs required by this rigid pavement design nomograph include :

(1) The estimated future traffic, W_{18}, for the performance period,

(2) The reliability, R,

(3) The overall standard deviation, S_O

(4) Design serviceability loss, $\Delta PSI = p_i - p_t$

(5) Concrete elastic modulus, E_C

(6) Concrete modulus of rupture, S'_c

(7) Load transfer coefficient, J

(8) Drainager coefficient

- **Stage Construction**

Experience in some states has shown that there may be a practical maximum performance period associated with a given rigid pavement which is subjected to some significant level of truck traffic. To consider analysis periods which are longer than this maximum expected performance period or to more rigorously consider the life-cycle costs of rigid pavement designs which are initially thinner, it is necessary to consider the stage construction (planned rehabilitation) approach in the design process. It is also important to recognize the need to compound the reliability for each individual stage of the strategy. For example, if both stages of a two-stage strategy (an initial PCC pavement with one overlay) have a 90-percent reliability, the overall reliability of the design strategy would be 0.9 x 0.9 or 81 percent. Conversely, if an overall reliability of 95 percent is desired, the individual reliability for each stage must be $(0.95)^{1/2}$ or 97.5 percent.

- **Roadbed Swelling**

The approach to considering the effects of swelling in rigid pavement design is almost identical to that for flexible pavements. Thus, some of the discussion is repeated here.Roadbed swelling are important environmental considerations because of their potential effect on the rate of serviceability loss. Swelling refers to the localized volume changes that occur in expansive roadbed soils as they absorb moisture. A drainage system can be effective in minimizing roadbed swelling if it reduces the avalability of moisture for absorption.

If swelling is to be considered in terms of their effects on serviceability loss and the need for future overlays, then the following procedure should be applied.The procedure for considering environmental serviceability loss is similar to the treatment of stage construction strategies because of the planned future need for rehabilitation, in the stage construction approach, an initial PCC slab thickness is selected and the coresponding performance period (service life) determine.

An overlay (or series of overlays) which will extend the combined performance periods past the desired analysis period is then identified. The difference in the stage construction approach when swelling are considered is that an iterative process is required to determine the length of the performance period for each stage of the strategy. The objective of this iterative process is to determine when the combined serviceability loss due to traffic and environment reacges the terminal level.

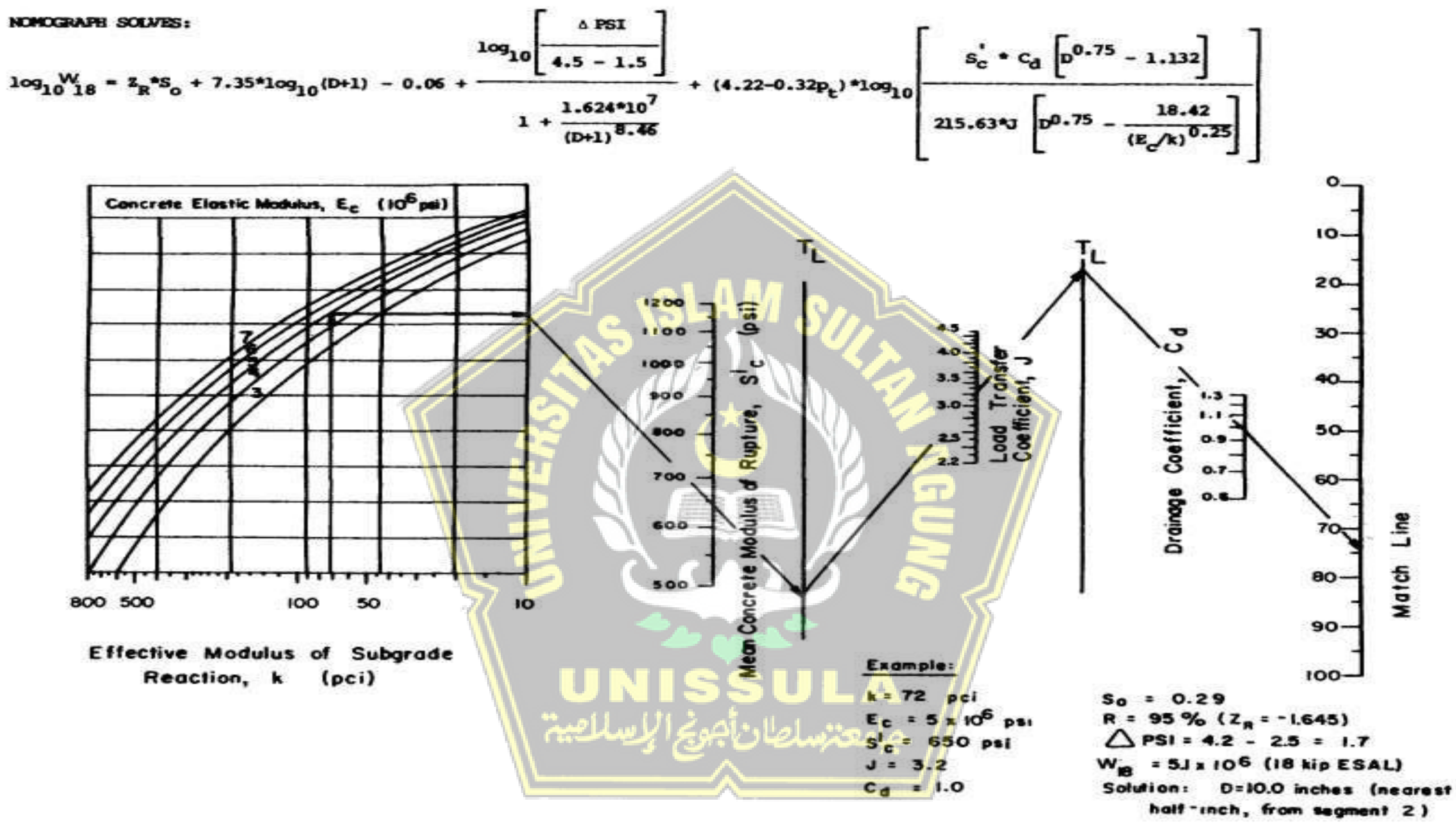


Figure 3.7 Design Chart for Rigid Pavement Based on Using Mean Values for Each Input Variable (Segment

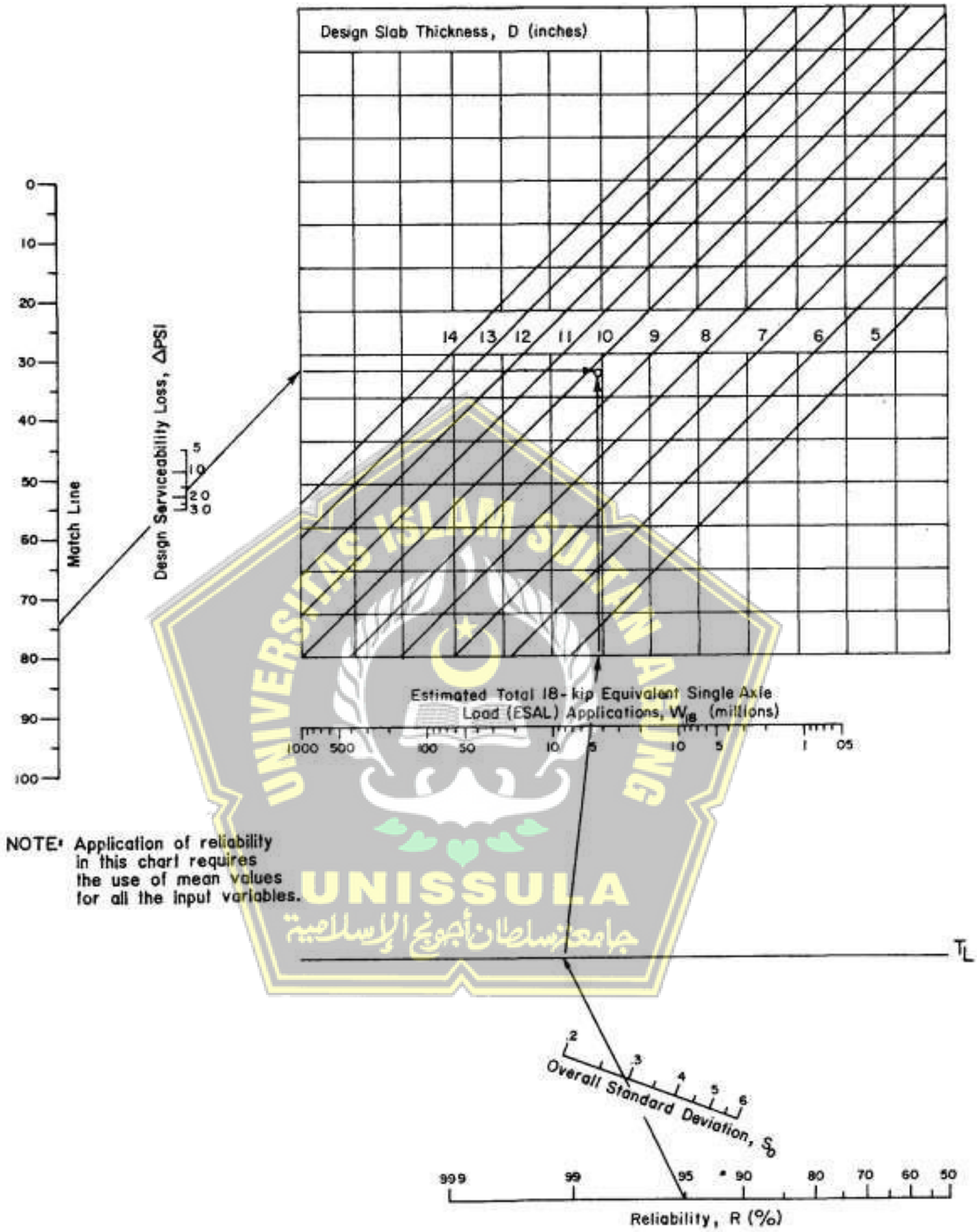


Figure 3.8 Continued- Design Chart for Rigid Pavements Based on Using Mean Values for Each Input Variable (Segment 2)

CHAPTER IV

FLEXIBLE PAVEMENT THICKNESS DESIGN

4.1. Introduction

In this chapter the pavement thickness design and calculation of flexible pavement will be conducted. The purpose of pavement design is to determine the difference in construction between flexible and rigid pavement. AASHTO 1993 design method will be used with several exceptions such as design life, traffic growth factors, will be used the provisions from the Road Pavement Design Manual 2017 published by the Directorate General of Highways [14]. In addition, to make a good comparison, the design parameters for the both pavements are made the same. The case study is the collector road Semarang – Purwodadi. The traffic used in the calculation is the average daily traffic (ADT) of the year 2020 with the growth of traffic per year based on [14] for collector roads is 3.5% per year. Materials for the base course and subbase course layer, as well as subgrade soil are taken equally for either Flexible or Rigid pavement.

4.2. Time Constrains

The analysis period selected for flexible pavement design, according to the 2017 Road Design Manual issued by the Directorate General of Highways [14] for collector road is selected 20 years (see Table 3.1. of Chapter III). For design life 20 years, AASHTO 1993 Method provides an guidence that the maximum pavement performance period which can be reached is only 15 years, and the design life is started from the year 2021. In order to achieve a design life of 20 years, a stage construction by making overlay is required. However, overlay calculations will not be carried out in this chapter.

4.3. Traffic

Detail of the Annual Average Daily Traffic (AADT) of Semarang – Purwodadi road for the year 2020 is given in Attachment A and the summary is as follows:

1. Small bus = 417 vehicles/day
2. Bus = 587 vehicles/day
3. Light truck = 5.194 vehicles/day
4. Medium truck = 3,064 vehicles/day
5. Three axle truck = 1.036 vehicles/day
6. Semi trailer = 241 vehicles/day
7. Trailer = 40 vehcles/day

Total AADT = 10.579 vehicles/day

Estimate of two-way 8.16 ton equivalent single axle load (ESAL) applications during the first year of the pavement's life will be calculated using the above AADT, and directional distribution factor (D_D) and the lane distribution (D_L) based on [14] are taken 50% and 80% respectively.

Calculation of 8.16 ton – ESAL

To calculate the number of 8.16 ton – ESAL that must be carried out by the pavement, Table 4.1 shows the number of equivalency (E) of axle load (ESAL), and Table 4.2 shows load configuration for ESAL - 8.16 ton are used.

Based on those two tables, the number of equivalency for heavy vehicle (passenger car is neglected) are as follows:

1. Light bus (8ton) = 3ton (single) + 5ton (single) = 0.0110 + 0.0940 = 0.10502.

Bus (13ton) = 5ton (single) + 8ton (single/2) = 0.0940 + 0.3365 = 0,4305

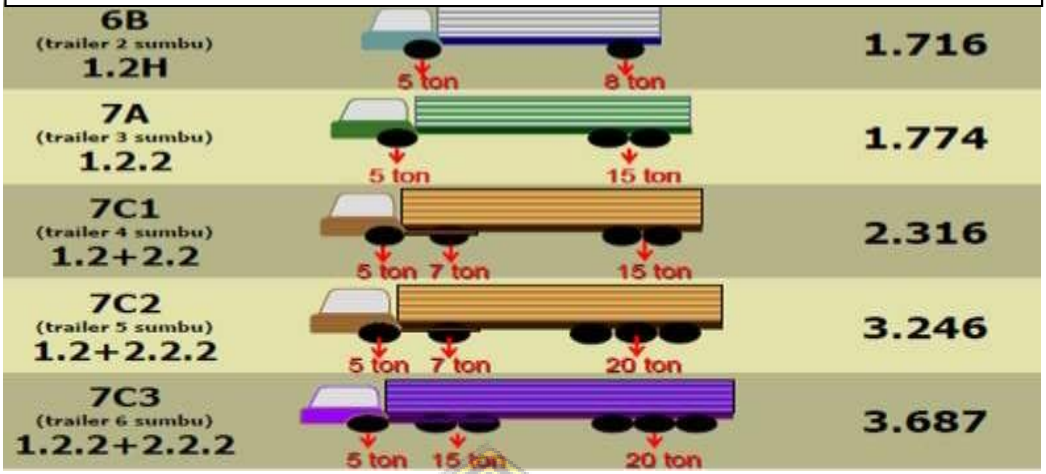
3. Light Truck (13ton) = 5ton (single) + 8ton (single/2) = 0.0940 + 0.3365= 0.4305

4. Medium Light Truck (13ton) = 5ton (single) + 8ton (single/2) = 0.0940 + 0.3365 = 0.4305
5. Three Axle Truck (20ton) = 5ton (single) + 15ton(tandem/2) = 0,0940 + 0,3537 = 0.4477
6. Semi Trailer (27ton) = 5ton (single) + 7ton (single/2) + 15ton (tandem/2) = 0,0940 + 0,193 + 0,3537 = 0.6407
7. Trailer (32ton) = 5ton (single) + 7ton (single/2) + 20ton (triple/2) = 0,0940 + 0,1930 + 0.2602 = 0.5472

Table 4.1. Axle Load Equivalency Factor for Flexible Pavement with pt = 2.0. and estimate SN = 4 [15]

Axle Load		**Equivalency Factor (E)**		
(kips)	(ton)	single	tandem	triple
2	1	0.0002	0.00	
4	2	0.002	0.0002	
6	3	0.011	0.0011	
8	4	0.036	0.0033	
10	5	0.094	0.0077	
12	6	0.202	0.0154	
14	7	0.386	0.0286	
16	8	0.673	0.0506	
18	9	1.10	0.0858	
20	10	1.705	0.1287	0.0286
22	11		0.1914	0.0418
24	12		0.2772	0.0605
26	13		0.3883	0.0847
28	14		0.5291	0.1166
30	15		0.7073	0.154
32	16		0.9262	0.2024
34	17		1,188	0.2618
36	18		1,518	0.3333
38	19		1,892	0.4191
40	20		2,343	0.5203

Table 4.2. Load Configuration for 8.16 Ton ESAL [16]



CATEGORY	LOAD CONFIGURATION	VDF
6B (trailer 2 sumbu) 1.2H	5 ton, 8 ton	1.716
7A (trailer 3 sumbu) 1.2.2	5 ton, 15 ton	1.774
7C1 (trailer 4 sumbu) 1.2+2.2	5 ton, 7 ton, 15 ton	2.316
7C2 (trailer 5 sumbu) 1.2+2.2.2	5 ton, 7 ton, 20 ton	3.246
7C3 (trailer 6 sumbu) 1.2.2+2.2.2	5 ton, 15 ton, 20 ton	3.687

Note: VDF = Value Damage Factor

Table 4.3 worksheets for calculating 8,16 ton ESAL applications for a 15-year analysis period.

Table 4.3. Calculating 8,16 ton (ESAL) Applications Worksheet

Analysis Period = 15 years

Vehicle Types	Current Traffic (A)	Growth Factors (B)	Design Traffic (C) $(x10^6)$	E.S.A.L Factor (D)	Design E.S.A.L $(x\ 10^6)$
Light Bus	432	19,3	3.00	0.1050	0.315
Bus	608	19,3	4.28	0.4305	1.843
Light Truck	5.376	19,3	37.87	0.4305	16.303
Medium Light Truck	3.171	19,3	22.34	0.4305	9.617
Three Axle Truck	1.072	19,3	7.55	0.4477	3.380
Semi Trailer	41	19,3	0.29	0.6407	0.186
Trailer	249	19,3	1.75	0.5472	0.958
Number of Vehicles	10.949			**Design E.S.A.L**	**32.602**

The formula for calculating traffic during the first year is as follows::

$W_{8,16} = D_D \times D_L \times$ Design ESAL .... eq. 4.1

where:

D_D = a directional distribution factor = 50%

D_L = a lane distribution factor = 80%

$\hat{W}_{8.16}$ = during the analysis period, the total two-directional 8.16 ton - ESAL units predicted for a specific section of highway

Using Equation 4.1. the traffic during the first year is:

$W_{8,16}$ = 0,5 x 0,8 x 32.602 x 10^6 = 13.041 x 10^6 - 8,16 ton ESAL applications

As mentioned in section 4.1. above, traffic growth rate of Semarang – Purwodadi road which the the function is collectore road is 3.5% per year. By using equation

$$G_r = \frac{W8{,}16(1+r)^n - 1}{r} \quad \text{eq. 4.2.}$$

The chart for plot of cummulative 8,16 ton – ESAL traffic versus time can be drawn, and show in Figure 4.1.

4.4. Reliability

AASHTO 1993 were introduced Reliability concept. Basically, it is a means of incorporating some degrees of certainty into th design process to ensure that the various design alternatives will last the analysis period. Th reliability design factor accounts for chance variations in both traffic prediction ($w_{8,16}$) and the performance preiction ($W_{8,16}$), and therefore, provides a predetermined level of assurance (R) that pevement sections will survive the period for which they were designed.

Application of the reliability concept requires the following steps:

(1) Define the functional calssification of the facility and determine wheter a rual or urban condition exists.

(2) Select a reliability level from the range given in Table 2.2. of AASHTO 1993 Guide Design of Pavement structure. The greater the value of reliability, the more pavement structure required.

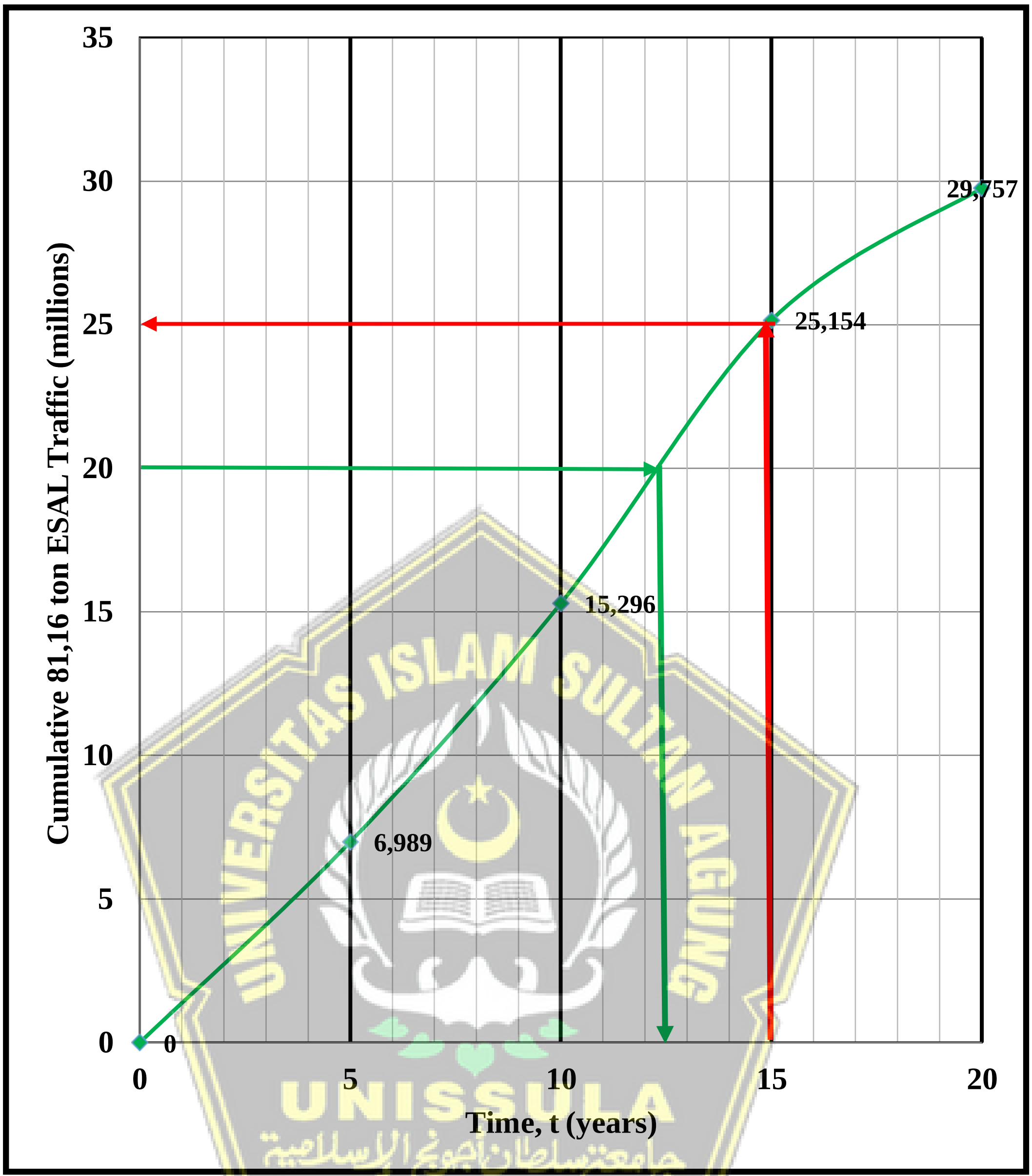


Figure 4.1. Plot of Cumulative 8.16 ton – ESAL Traffic vs Time

(3) Standard deviation (S_0) should be selected that is representative of local conditions.

In this flexible pavement design calculation, reliability (R) is taken 85 for rural – collector road as is functions and status of Semarang – Purwodadi road, and Standard deviation S_0 is taken 0.35 for flexible pavement. However, since the construction have to be done in two stages, the design reliability for each stage must be $0.85^{1/2}$ or 92%.

4.5. Determined the Serviceability Loss, ΔPSI

Based on the traffic volume and functional classification of the facility (2 lane state highway), a terminal serviceability (p_t) is 2,0 and the initial serviceability (p_o) normally achieved for flexible pavements is 4,2 (refers from AASTH0 1993 page II-12).

The equation to calculate this is:

$\Delta PSI = p_o - p_t$ .... eq. 4.2

where:

ΔPSI = Serviceability loss

p_t = a terminal serviceability

p_o = the initial serviceability

Thus, the overall design serviceability loss for this pavement calculation is:

$\Delta PSI = 4{,}2 - 2{,}0 = 2{,}2$.

4.6. Determined The Modulus of Resilient

According to the Bina Marga Pavement Design 2017, minimum CBR *(California Bearing Ratio)* for subgrade of collector road is 2,5%. AASHTO 1993 used Modulus of Resilient M_R instead of CBR in calculating of subgrade soil strength, and the value of M_R is equal to 1500 x CBR. Therefore, the value of M_R is = 1500 x 2,5 = 3.750 psi.

4.7. Determine of Determined the Pavement Layer Materials Characterization and Layers Coefficients

4.7.1. Asphalt Concrete Surface Course

Figure 4.2. provides a chart that may be used to estimate that structural layer coefficient a_1 of a dense-graded asphalt concrete surface course based on its elastic (resilient) modulus (E_{AC}) at 60^0F. Caution is recommended for modulus values

above 450,000 psi. Although higher modulus asphalt concrete are stiffer and more resistant to bendingm they are also more susceptible to thermal and fatigue cracking. In this flexible pavement design the resilient modulus for asphalt concrete surface course E_{AC} is taken 500,000 psi, and structural layer coefficient is 0.46.

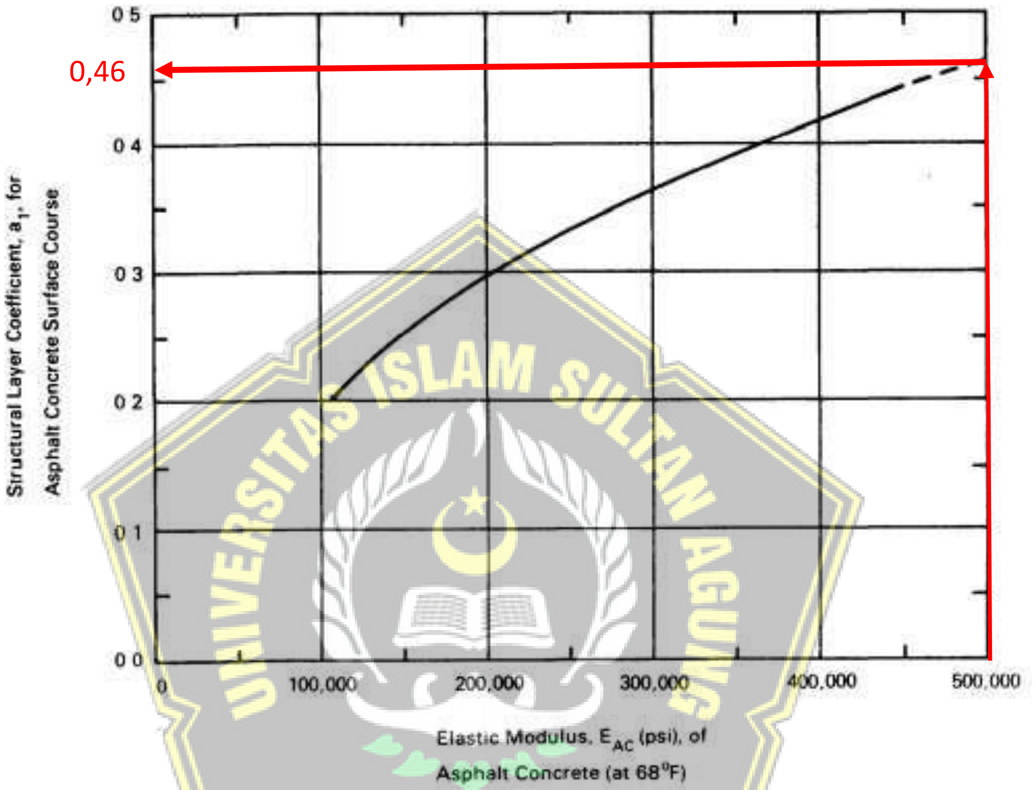


Figure 4.2. Chart for Estimating Structural Layer Coefficient of Dense-Graded Asphalt Concrete Based on the Elastic (Resilient) Modulus (a_1)

4.7.2. Granular Base Layers

Figure 4.3. provides a chart that may be used to estimate that structural layer coefficient a_2 from one of four different laboratory tst results on a granular base material, including base resilient modulus E_{BS}. The AASHTO Road Test basis for these correlation is:

a_2 = 0.14
E_{BS} = 30,000 psi
CBR = 100 (approximate)

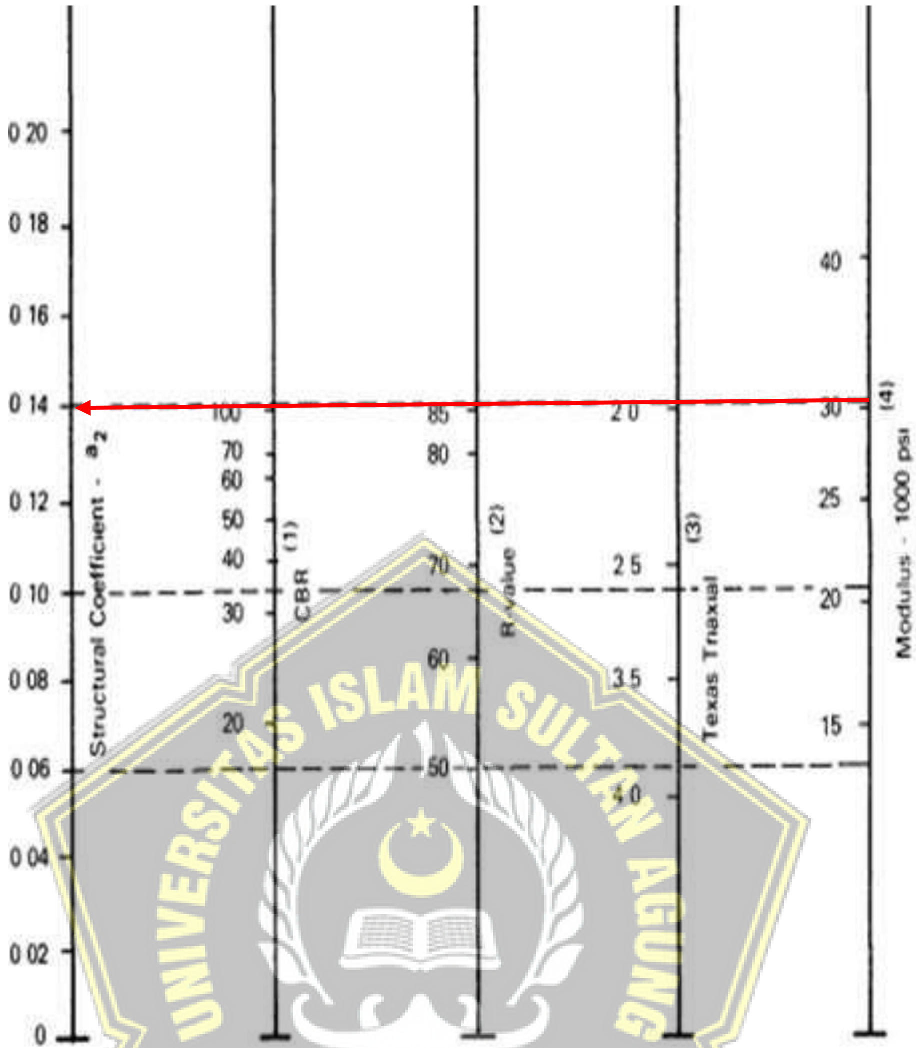


Figure 4.3. Variation in Granular Base Layer Coefficient (a_2) with Various Base Strength Parameters

4.7.3. Granular Subbase Layers

Figure 4.4. provides a chart that may be used to estimate that structural layer coefficient a_3 from one of four different laboratory tst results on a granular subbase material, including base resilient modulus E_{SB}. The AASHTO Road Test basis for these correlation is:

a_3 = 0.11
E_{BS} = 15,000 psi
CBR = 30 (approximate)

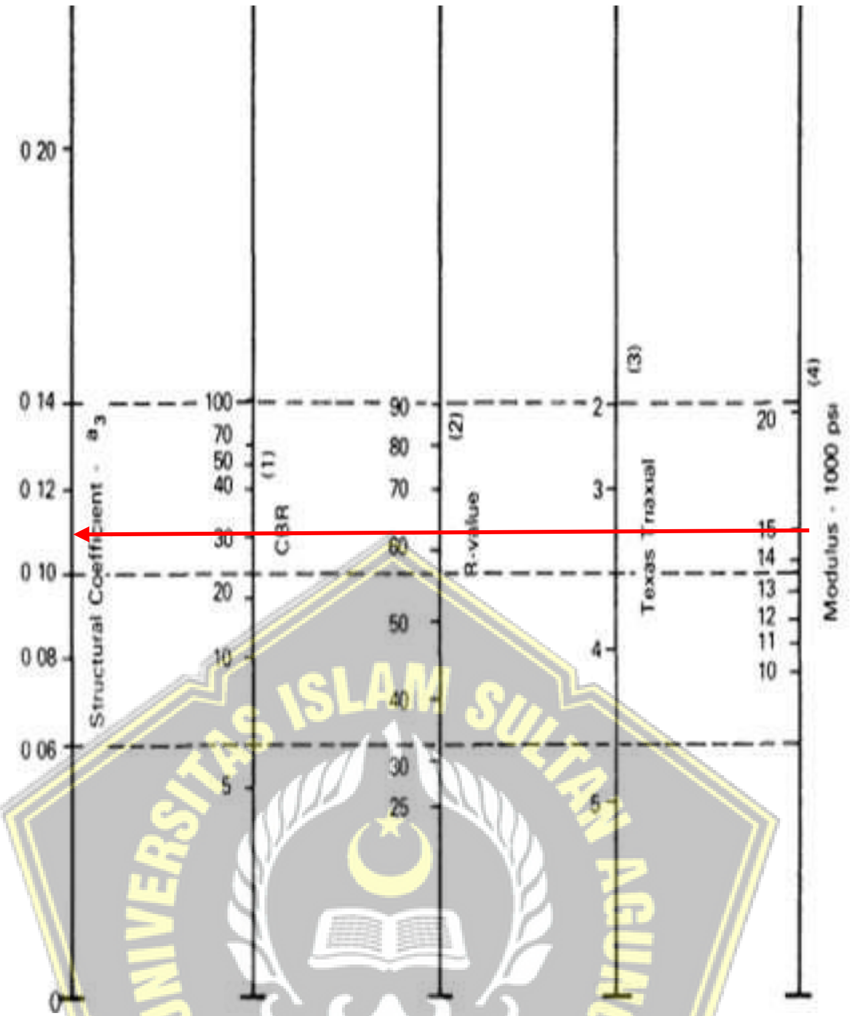


Figure 4.4. Variation in Granular Subbase Layer Coefficient (a_3) with Various Subbase Strength Parameters

4.8. Determined Coefficient of Drainage (m)

There are five drainage levels from the pavement structure given by AASHTO namely:

Quality of drainage	Water removed within
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very poor	Water will not drain

Drainage level of Semarang – Purwodadi road included in the quality level 'good', and the percent of time the pavement structure is exposed by water is 1 to 5%. With these conditions, the coefficient of drainage is taken 1.25 both for base 'm_1' as well 'm_2' subbase layer.

4.9. Determination of Structural Layer Thickness for Initial Structure

- **Determined Required Structural Number (SN) for intial structure**

Referes to Figure 3.1. Chapter III page II-31 from AASHTO 1993 determining the design structural number (SN) required for specific conditions, including the data:

R = 92 %

So = 0,35

Traffic for 15 years = 25.154 x 10^6 – 8.16ton ESAL

M_R = 3750 psi

ΔPSI= 2.2

SN_3 = 6.4

- **Determined the structural number SN_1 for surface layer**

To get the structural number for surface layer (SN_1) process to predict the performance period of an initial pavement structure considering swelling is used. Table 4.4. show the process. The first iteration is the trial performance period 13 years. Using Figure 4.5. Graph of environmental serviceability loss versus time for swelling conditions, is obtained the serviceability loss due to swelling ΔPSI_{SW} is 0.21. By deducting ΔPSI = 2.2 with ΔPSI_{SW}, the corresponding serviceability loss due to raffic ΔPSI_{TR} 1.99 is found. Using this ΔPSI_{TR} = 1.99 and applying the chart in reverse will get the traffic 20 x 10^6 – 8.16 ton ESAL. From the Figure 4.1. Plot of cumulative 8.16 ton – ESAL traffic vs time, is found that the traffci 20 x 10^6 reach in the year 12.5. Since the different between trial performance period and corresponding performance period is less than 1, the iteration is stop. Now using traffic 20 x 10^6 and appltying the chart, SN_1 can be determined. The magnitude of SN_1 is 3.1.

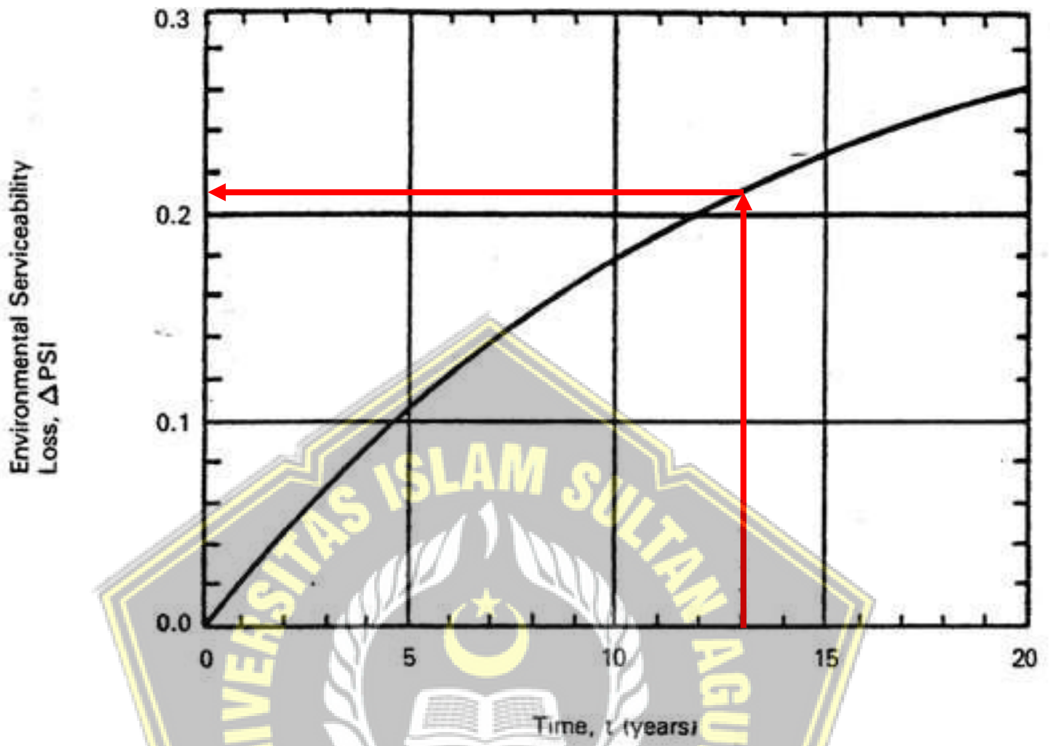


Figure 4.5. Graph of Environmental Serviceability Loss versus Time for Swelling Conditions

Table 4.4. Process to Predict The Performance Period of An Initial Pavement Structure Considering Swelling.

Initial SN = 6.4
Maximum Possible Performance Period (years) = 15
Design Serviceability Loss, ΔPSI = $p_o - p_t$ = 4.2 – 2.0 = 2.2

(1)	(2)	(3)	(4)	(5)	(6)
Iteration No.	Trial Performance Period (Years)	Serviceability Loss Due to Roadbed Swelling ΔPSIsw	Corresponding Serviceability Loss Due to Traffic ΔPSItr	Allowable Cummulative Traffic (18-kip ESAL)	Corresponding Performance Period (years)
1	13	0,21	1,99	20x10^6	12,5

The process stop only 1 iteration since the different between trial performance and corresponding performance is less than 1.

- **Determined structurtal number for base layer SN2**

Similar on determing structural number for surface layer SN_1, using the subbase modulus of 15.000 psi as the effective road bed soil resilient modulus, SN_2 is equal to 4.0. Chart in Figure 4.10 show the process to get SN_2.

- **Determine the thickness of pavement layers.**

1) Surface layer D_1

$D^*_1 = SN / a_1 = 3.1/0.46 = 6.74$ inches ≈ 7 inches = 17.5 cm

$SN^*_1 = a_1 D^*_1 = 0.46. \times 7 = 3.22$

2) Base layer D_2

$D^*_2 = (SN_2 - SN^*_1) / (a_2.m_2)$

$= (4.0 - 3.22) / (0.14 \times 1.5) = 0.78 / 0.175$

= 4.46 inches or 5 inches.= 12.5 cm

$SN^*_2 = 5 \times 0.14 \times 1.25 = 0.875$

3) Subbase layer D_3

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

$= (6.4 - (3.22 + 0.875)) / (0.11 \times 1.25)$

= 2.31 / 0.14 = 16.5 inches = 41.25.cm or 40 cm

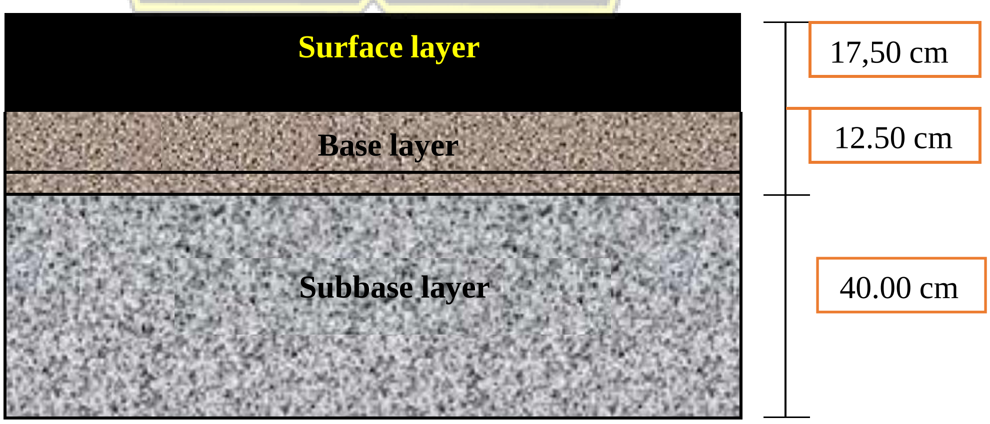


Figure 4.6 Structure of Flexible Pavement.

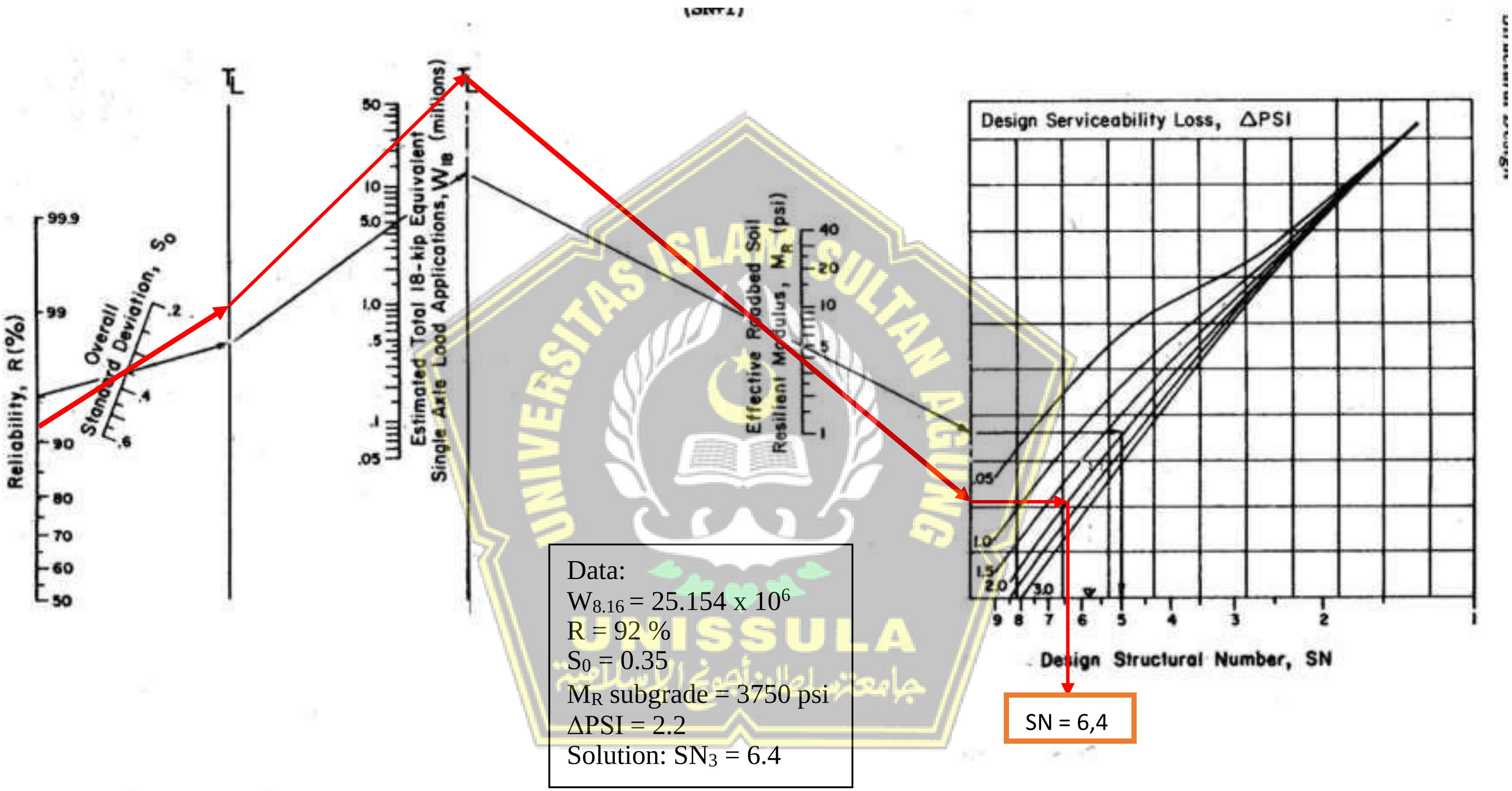


Figure 4.7. Chart Calculating Intial Structural Number SN for all pavement layers.

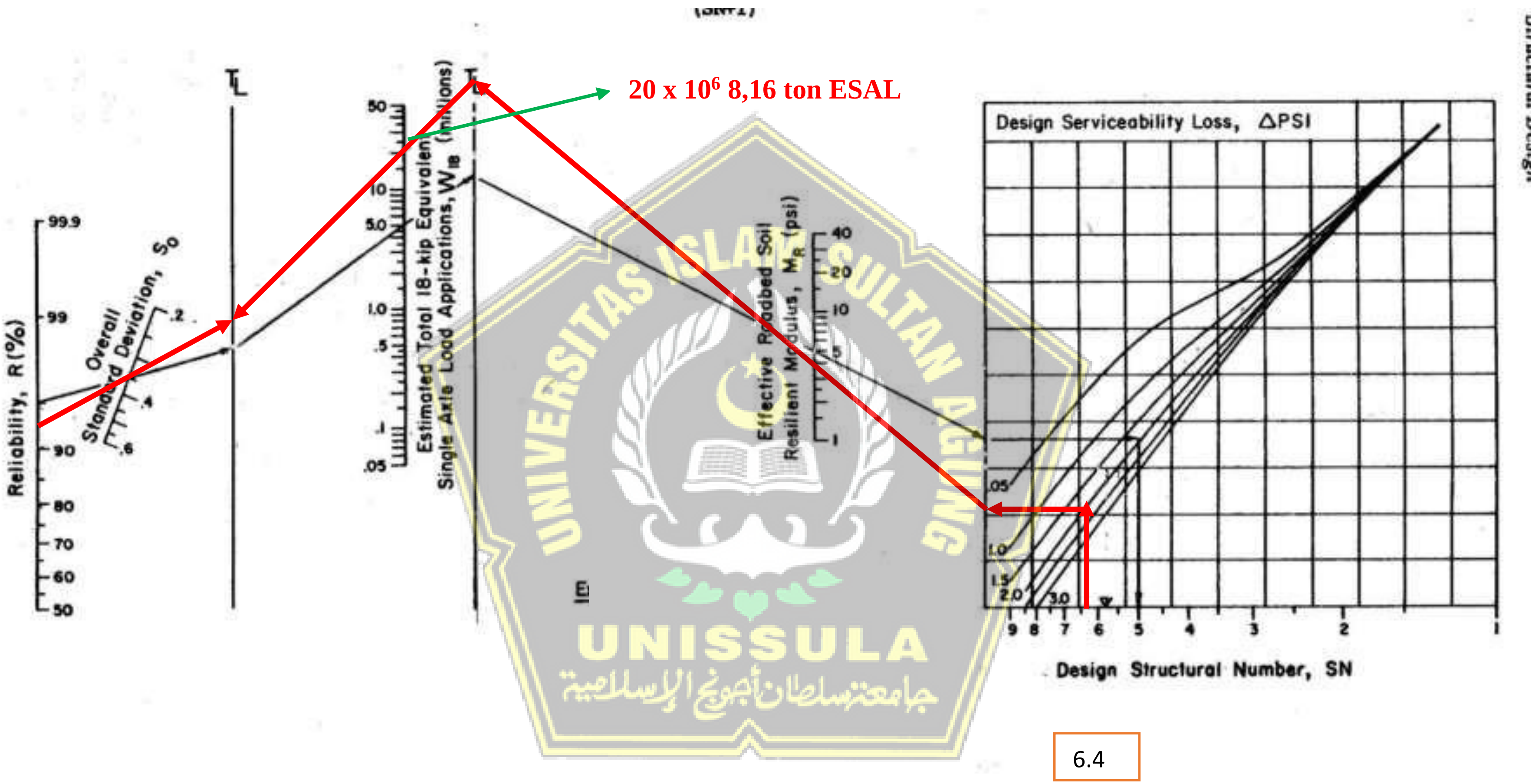


Figure 4.8. Chart to Determine Traffic in Iteration Process

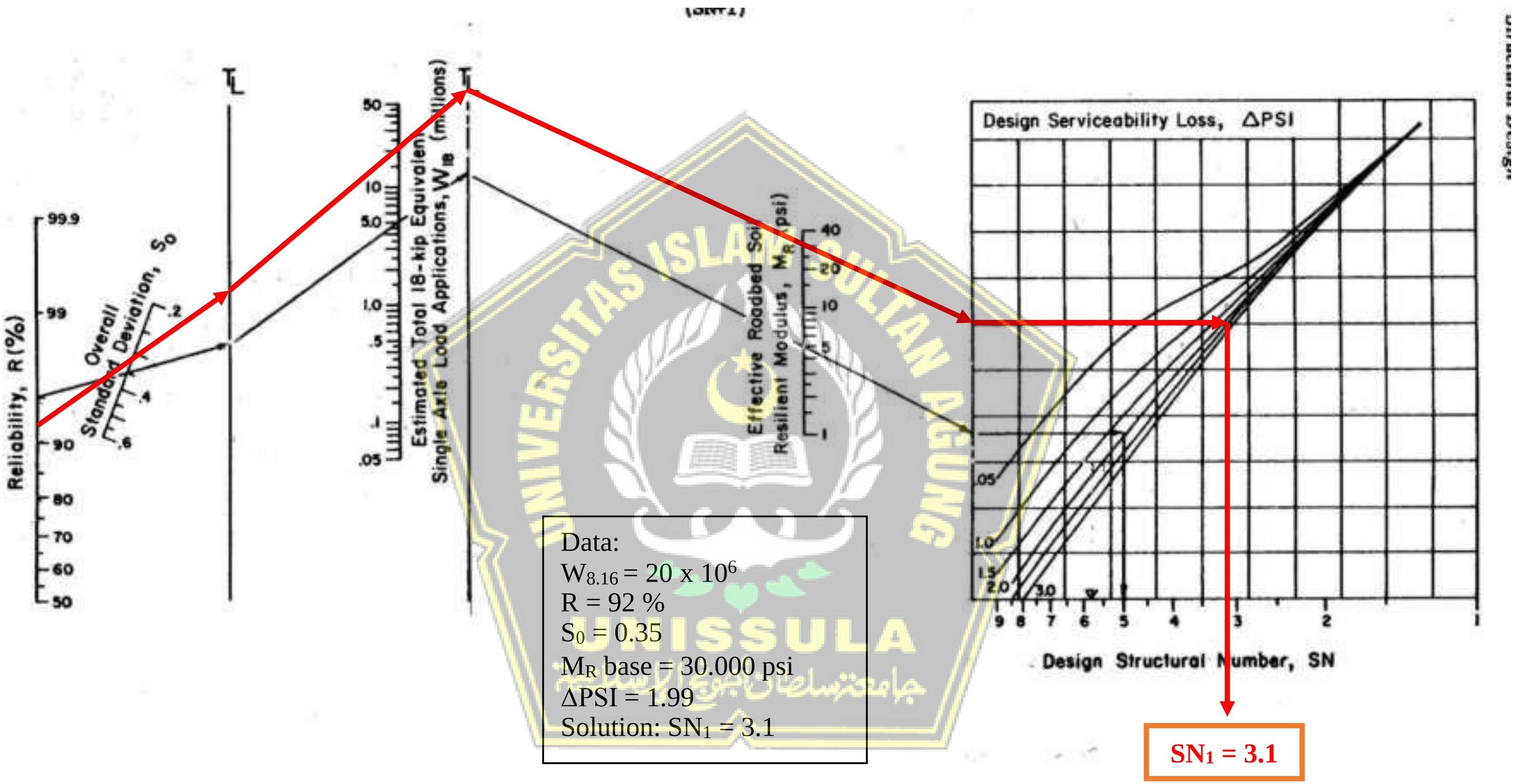


Figure 4.9. Chart to Determine Structural Number SN_1 for Surface Layer

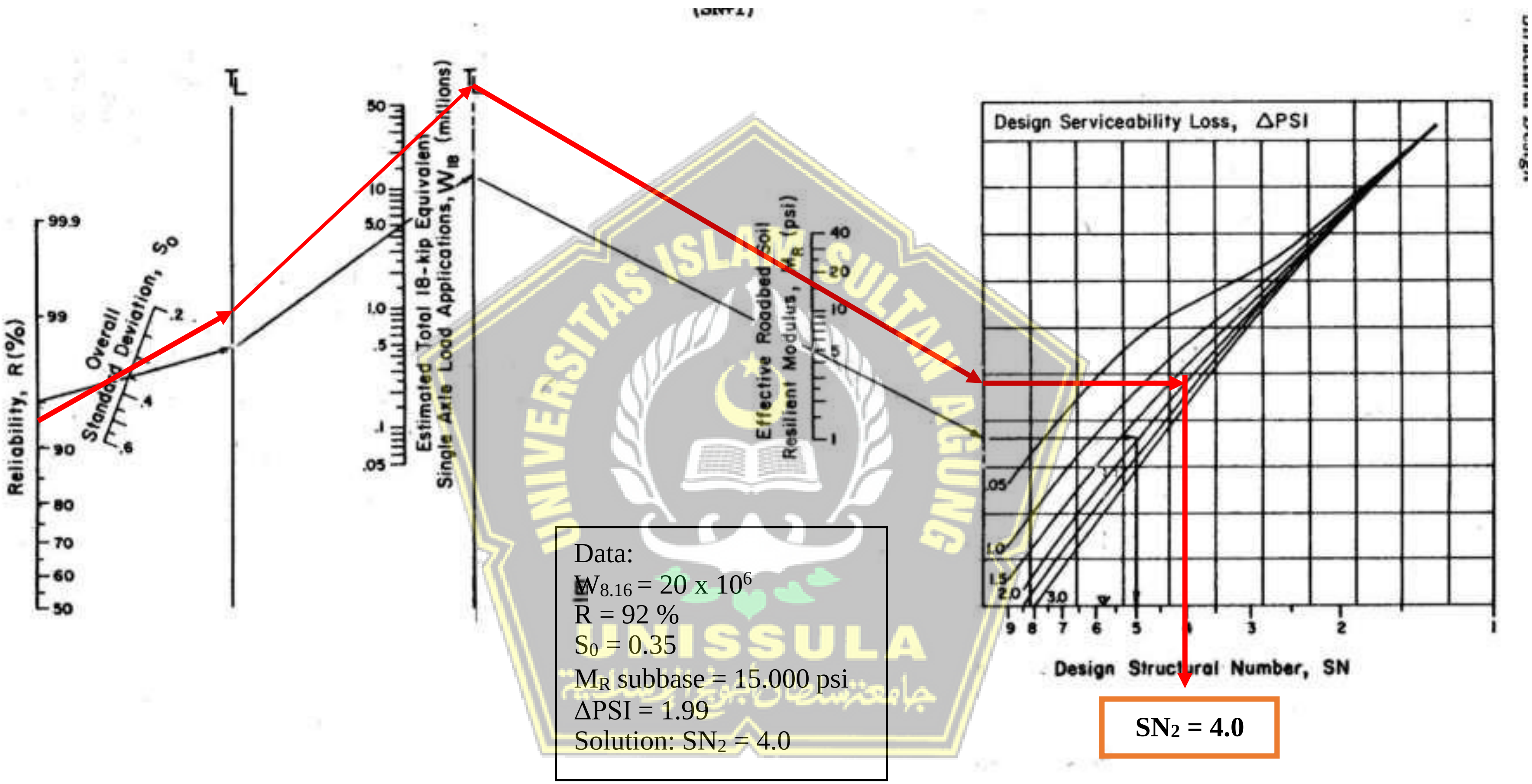


Figure 4.10. Chart to Determine Structural Number SN_2 for Base Layer

CHAPTER V

RIGID PAVEMENT THICKNESS DESIGN

5.1 Introduction

In this chapter the pavement thickness design and calculation of rigid pavement will be conducted. As have been mentioned in Chapter IV the purpose of pavement calculations is to determine the difference in construction with flexible pavement. Similar to the flexible pavement design AASHTO 1993 design method will be used with several exceptions such as design life, traffic growth factors, will be used the provisions from the Road Pavement Design Manual 2017 published by the Directorate General of Highways [14]. In addition, to make a good comparison, the design parameters for the both pavements are made the same. The case study is also the collector road Semarang – Purwodadi. The traffic used in the calculation is the average daily traffic (ADT) of the year 2020 with the growth of traffic per year based on [14] for collector roads is 3.5% per year. Materials for the base course and subbase course layer, as well as subgrade soil are also taken equally with Flexible pavement.

5.2 Time Constrains

The analysis period selected for rigid pavement design, according to the 2017 Road Design Manual issued by the Directorate General of Highways [14] for collector road is selected 40 years (see Table 3.1. of Chapter III). For design life 40 years, AASHTO 1993 Method provides an guidence that the maximum pavement performance period which can be reached is only 30 years, and the design life is started from the year 2021. In order to achieve a design life of 40 years, a stage construction by making overlay is required. However, overlay calculations will not be carried out in this chapter.

5.3 Traffic

Similar to flexible pavement design, the total AADT 10.579 vehicles per day, with Direction distribution and lane distribution factor also are taken 50 % and 80 %t respectively.

Table 5.1. Axle load equivalency factor for rigid pavement
with p_t = 2.0. and estimate D = 9 inch [14]

Axle Load		Equivalency Factor (E)		
(kips)	(ton)	single	tandem	triple
2	1	0.0002	0.0001	
4	2	0.002	0.0005	
6	3	0.011	0.0022	
8	4	0.035	0.0055	
10	5	0.089	0.0132	
12	6	0.193	0.0275	
14	7	0.372	0.0517	
16	8	0.661	0.0891	
18	9	1.10	0.1482	
20	10	1.738	0.2244	0.0726
22	11		0.3355	0.1078
24	12		0.4851	0.1529
26	13		0.682	0.2134
28	14		0.935	0.2893
30	15		1.254	0.3861
32	16		1.650	0.506
34	17		2.145	0.6534
36	18		2.739	0.8316
38	19		3.443	1.045
40	20		4.279	1.298

The following are the equivalency numbers for heavy vehicles (passenger cars are not included):

1. Light bus (8ton) = 3ton (single) + 5ton (single) = 0.0110 + 0.0890 = 0.1000
2. Bus (13ton) = 5ton (single) + 8ton (single/2) = 0.0890 + 0.3305 = 0.4195

3. Light Truck (13ton) = 5ton (single) + 8ton (single/2) = 0.0890 + 0.3305= 0.4195
4. Medium Light Truck (13ton) = 5ton (single) + 8ton (single/2) = 0.0890 + 0.3305 = 0.4195
5. Three Axle Truck (20ton) = 5ton (single) + 15ton(tandem/2) = 0.0890 + 0.6270 = 0.7160
6. Semi Trailer (27ton) = 5ton (single) + 7ton (single/2) + 15ton (tandem/2) = 0.0890 + 0,1860 + 0.6270 = 0.9020
7. Trailer (32ton) = 5ton (single) + 7ton (single/2) + 20ton (triple/2) = 0,0890 + 0,1860 + 0.6490 = 0.9240

Table 5.2. shows the worksheets for calculating 8,16 ton ESAL applications for analysis period 25 years.

Table 5.2. Calculating 8,16 ton (ESAL) applications worksheet

Analysis Period = 25 years

Vehicle Types	Current Traffic (A)	Growth Factors (B)	Design Traffic (C) ($x10^6$)	E.S.A.L Factor (D)	Design E.S.A.L (E) ($x10^6$)
Light Bus	432	38,95	6,14	0,1000	0,614
Bus	608	38,95	8,64	0,4195	3,624
Light Truck	5376	38,95	76,43	0,4195	32,062
Medium Light Truck	3171	38,95	45,08	0,4195	18,911
Three Axle Truck	1072	38,95	15,24	0,7160	10,912
Semi Trailer	41	38,95	0,59	0,9020	0,532
Trailer	249	38,95	3,55	0,9240	3,280
Number of Vehicles	10949			Design E.S.A.L	69,936

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

$W_{8,16} = D_D \times D_L \times$ Design ESAL .... eq. 4.1

where:

D_D = a directional distribution factor = 50%

D_L = a lane distribution factor = 80%

$\hat{W}_{8.16}$ = during the analysis period, the total two-directional 8.16 ton - ESAL units predicted for a specific section of highway

Using Equation 4.1. the traffic during the first year is:

$W_{8,16}$ = 0.5 x 0.8 x 69,9362 x 10^6 = 27,974 x 10^6 - 8,16 ton ESAL applications.

As mentioned in section 4.1. above, traffic growth rate of Semarang – Purwodadi road which the the function is collectore road is 3.5% per year. By using equation

$$w_{8.16} = 1^{st}\ year\ ESAL\ [\frac{(1+r)^t - 1}{r}]$$ ....eq. 4.2.

where:

$w_{8,16}$ = 8.16ton-ESAL per year

1^{st} year ESAL = 27,974 x 10^6 8.16ton-ESAL

r = Traffic growth per year

t = Year

By equation 4.2. the chart for plot of cummulative 8,16 ton – ESAL traffic versus time can be drawn, and is shown in Figure 4.1.

5.4 Reliability

AASHTO 1993 were introduced Reliability concept. Basically, it is a means of incorporating some degrees of certainty into th design process to ensure that the various design alternatives will last the analysis period. Th reliability design factor accounts for chance variations in both traffic prediction ($w_{8,16}$) and the performance preiction ($W_{8,16}$), and therefore, provides a predetermined level of assurance (R) that pevement sections will survive the period for which they were designed.

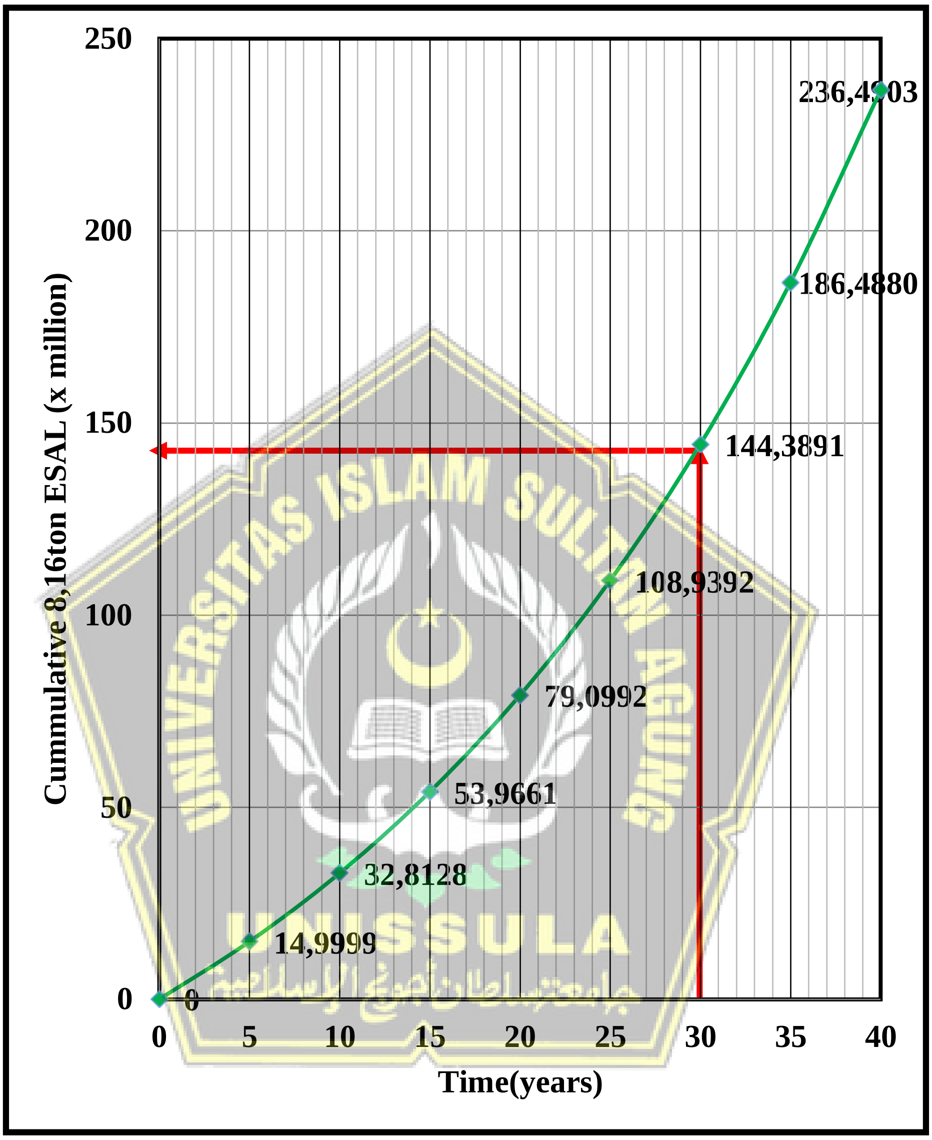


Figure 5.1. Plot of cummulative 8.16ton ESAL traffic versus time

Application of the reliability concept requires the following steps:

(1) Define the functional calssification of the facility and determine wheter a rual or urban condition exists.

(2) Select a reliability level from the range given in Table 2.2. of AASHTO 1993 Guide Design of Pavement structure. The greater the value of reliability, the more pavement structure required.

(3) Standard deviation (S_0) should be selected that is representative of local conditions. For rural – collector road as is functions and status of Semarang – Purwodadi road, and Standard deviation S_0 is taken 0.35 for rigid pavement. However, since the construction have to be done in two stages, the design reliability for each stage must be $0.85^{1/2}$ or 92%.

5.5 Determined the Serviceability Loss, ΔPSI

Based on the traffic volume and functional classification of the a highway, a terminal serviceability (p_t) is 2.0 and the initial serviceability (p_o) normally achieved for rigid pavements is 4,5 [AASHTO]

The equation to calculate this is:

$\Delta PSI = p_o - p_t$ .... eq. 4.3.

where:

ΔPSI = Serviceability loss

p_t = a terminal serviceability

p_o = the initial serviceability

Thus, the overall design serviceability loss for this pavement calculation is:

$\Delta PSI = 4{,}5 - 2{,}0 = 2.5$

5.6 Determined the Modulus of Subgrade Reaction Based on CBR Value

Similar to the flexible pavement, the resilient modulus (M_R) of subgrade for rigid pavement is 3750 psi. In rigid pavement subgrade strength is calculated based on modulus of subgrade reaction 'k' instead of resileint modolus or CBR. From equation 3.7 of Chapter III, the value of 'k' is:

$k = \frac{M_R}{19.4} = \frac{3750}{19.4} = 193.30$ psi.

The value of modulus of subgrade reaction k = 193.30 psi above must be corected due to potential loss of subbase support. Correction is conducted using chart of Figure 5.1. (Taken from Figure 3.6 of AASHTO 1993 Guide for Design of Pavement Structure), with Loss of Support factor (LS) equal 1.0. Loss of support is included in the design of rigod pavements to account for the potential loss of support arising from subbase erosion and/or differential vertical soil movement. By using chart in Figure 5.1. below and with the value of LS = 1.0, modulus of subgrade reaction 193.30 psi become 70.00 psi.

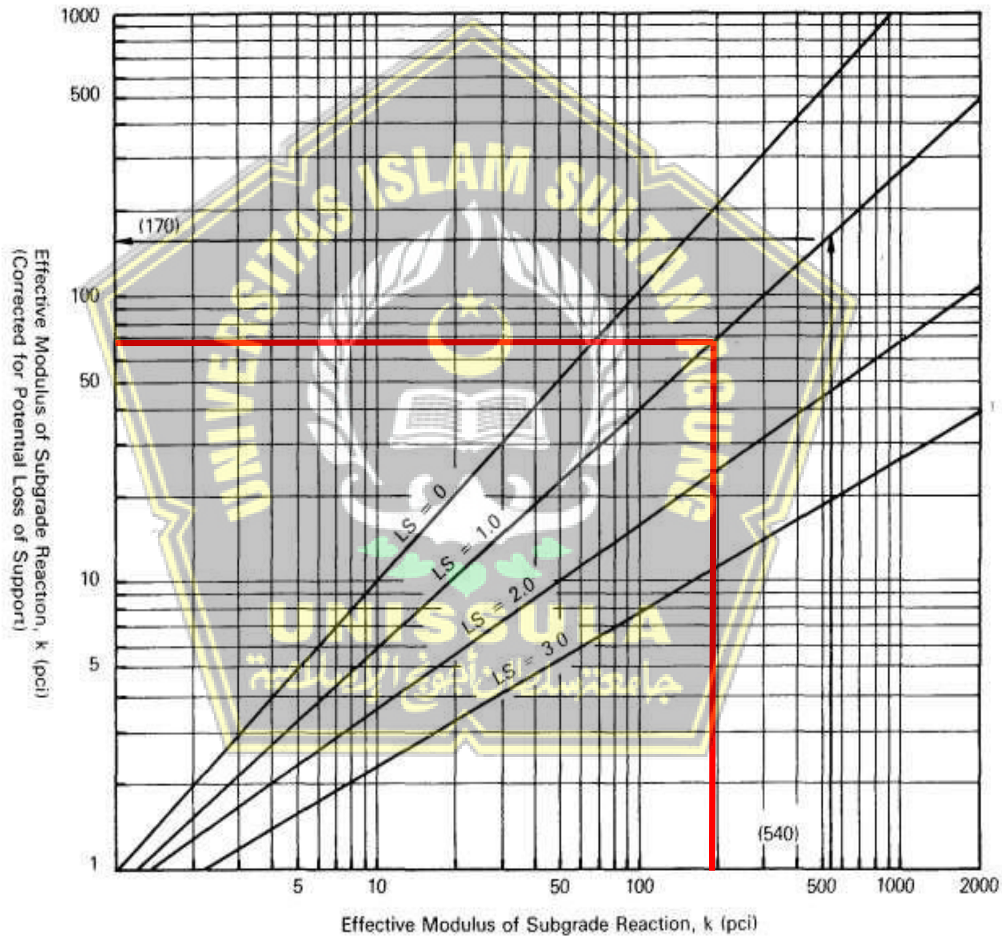


Figure 5.2 Chart to make correction the effective of modulus of subgrade reaction [14]

5.7 Determined the Modulus of Elasticity of Concrete

Portland Cement Concrete (PCC) cement pavement is generally placed directly on the subgrade or on top of the foundation layer (subbase). In this design, PCC is placed on top of the granular subbase. It is known that the PCC modulus and granular subbase are as follows:

Modulus of PCC : $E_C = 4.2 \times 10^6\ psi$

Modulus of Subbase, $E_{SB} = 15000\ psi$ (for wet conditions)

$E_{SB} = 25000\ psi$ (for dry conditions)

and in this design is taken 20.000 psi.

Modulus of Rupture (Flexural Strength) PCC, $S_C' = 578\ psi$ which the strength of concrete age 28 days.

5.8 Determined the Drainage Coefficient (C_d)

For this design the quality of drainage level of Semarang – Purwodadi road included in the quality level 'good', the water on the pavement can disappear within 1 day, and the percentage of wet pavement time is 5 to 25 percent, therefore the coeficient of drainage C_d was taken 1.05 (see Table 5.3 [14]).

Table 5.3. Recommended values of drainage coeficient, C_d for rigid pavement design [14]

Quality of Drainage	Percent of Time Pavement Structure is Exposed to Moisture Levels Approaching Saturation: Less Than 1%	1–5%	5–25%	Greater Than 25%
Excellent	1 25–1 20	1 20–1 15	1 15–1 10	1 10
Good	1 20–1 15	1 15–1 10	1 10–1 00	1 00
Fair	1 15–1 10	1 10–1 00	1 00–0 90	0 90
Poor	1 10–1 00	1 00–0 90	0 90–0 80	0 80
Very poor	1 00–0 90	0 90–0 80	0 80–0 70	0 70

5.9 Determined the coefficient Load Transfer (J)

The load transfer coeficient, J, is a factor used in rigid pavement design to account for the ability of a concrete pavement structure to tansfer (distribute) load across discontinuities, such as joints or crackes. Table 5.4., was taken from Table 2.6. of AASHTO [14], establishes ranges of load transfer coeficients for different conditions developed from experince and mechanistic stress analysis. In this rigid pavement design, shoulder use asphalt and pavement type is plain jointed reinforced, therefore load of transfer, J, is taken 3.2.

Table 5.4. Recommended Load Transfer Coeficient for various pavement types and design conditions [14]

Shoulder	Asphalt		Tied P.C.C.	
Load Transfer Devices	Yes	No	Yes	No
Pavement Type				
1 Plain jointed and jointed reinforced	3 2	3 8–4 4	2 5–3 1	3 6–4 2
2 CRCP	2 9–3 2	N/A	2 3–2 9	N/A

5.10 Calculation of The Concrete Slab Thickness

By using chart in figure 5.2 and cumulative 8.16ton ESAL in 30 years are 144,3891 and other parameters that has been determined above, the results obtained are plate thickness of 17 inch or 43,18 cm. Based on [14] the subbase thickness are 6” or 15,24 cm for high quality granular subbase.

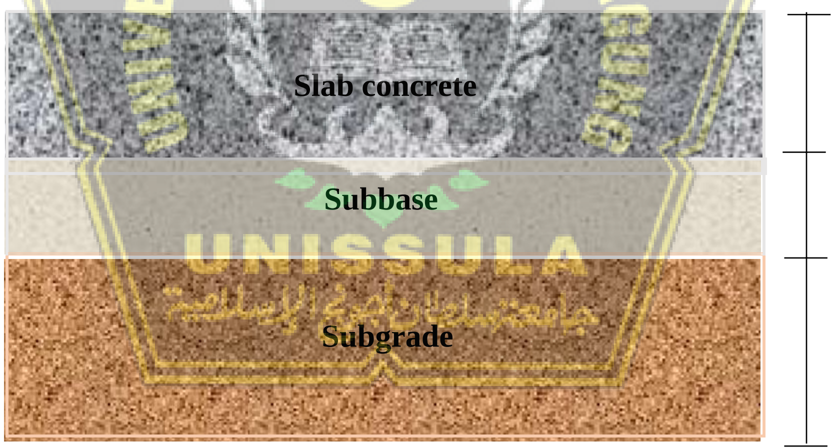


Figure 5.3 Structure of Rigid Pavement.

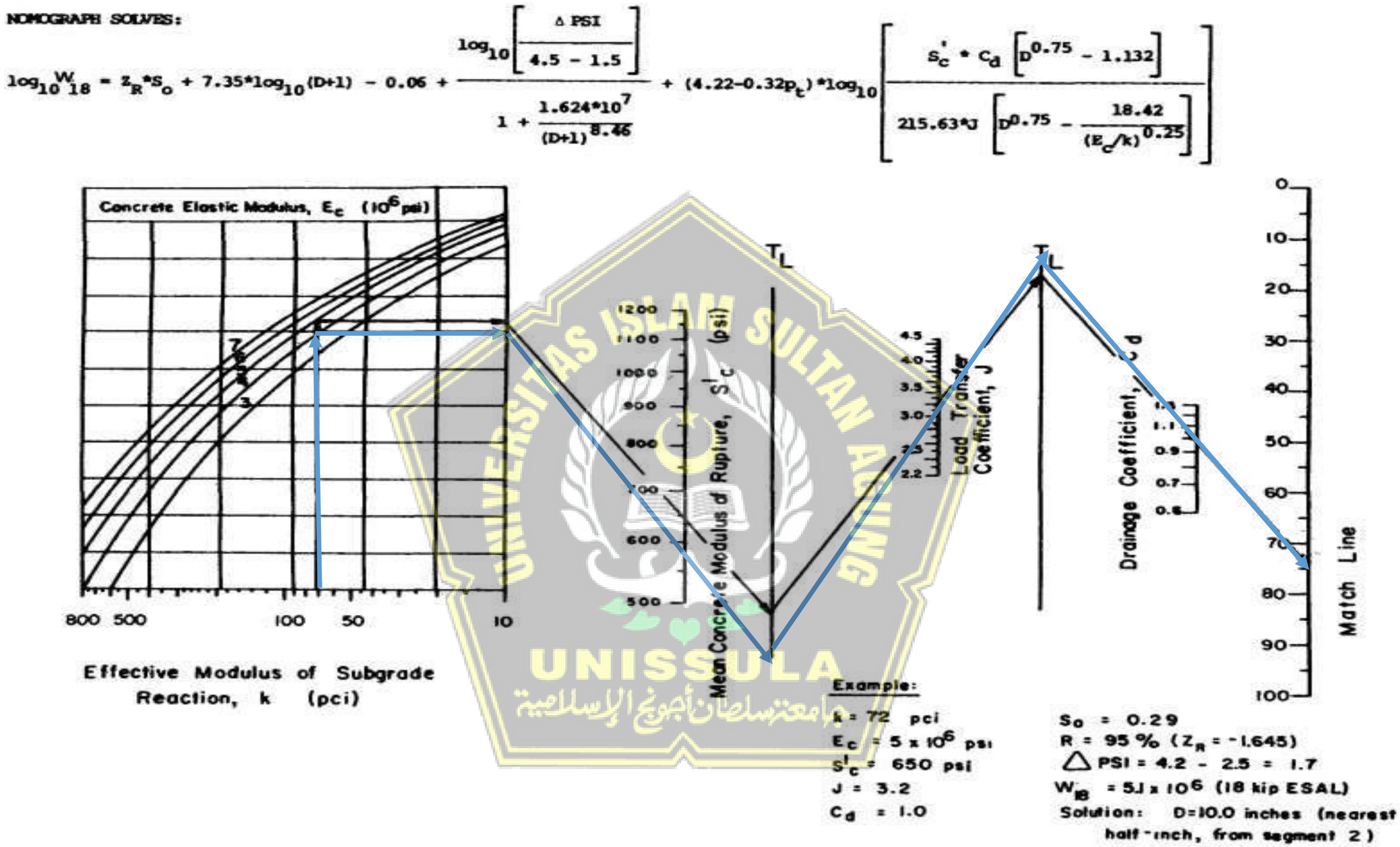


Figure 5.4 Chart for determine slab thickness Rigid Pavement (Segment 1)

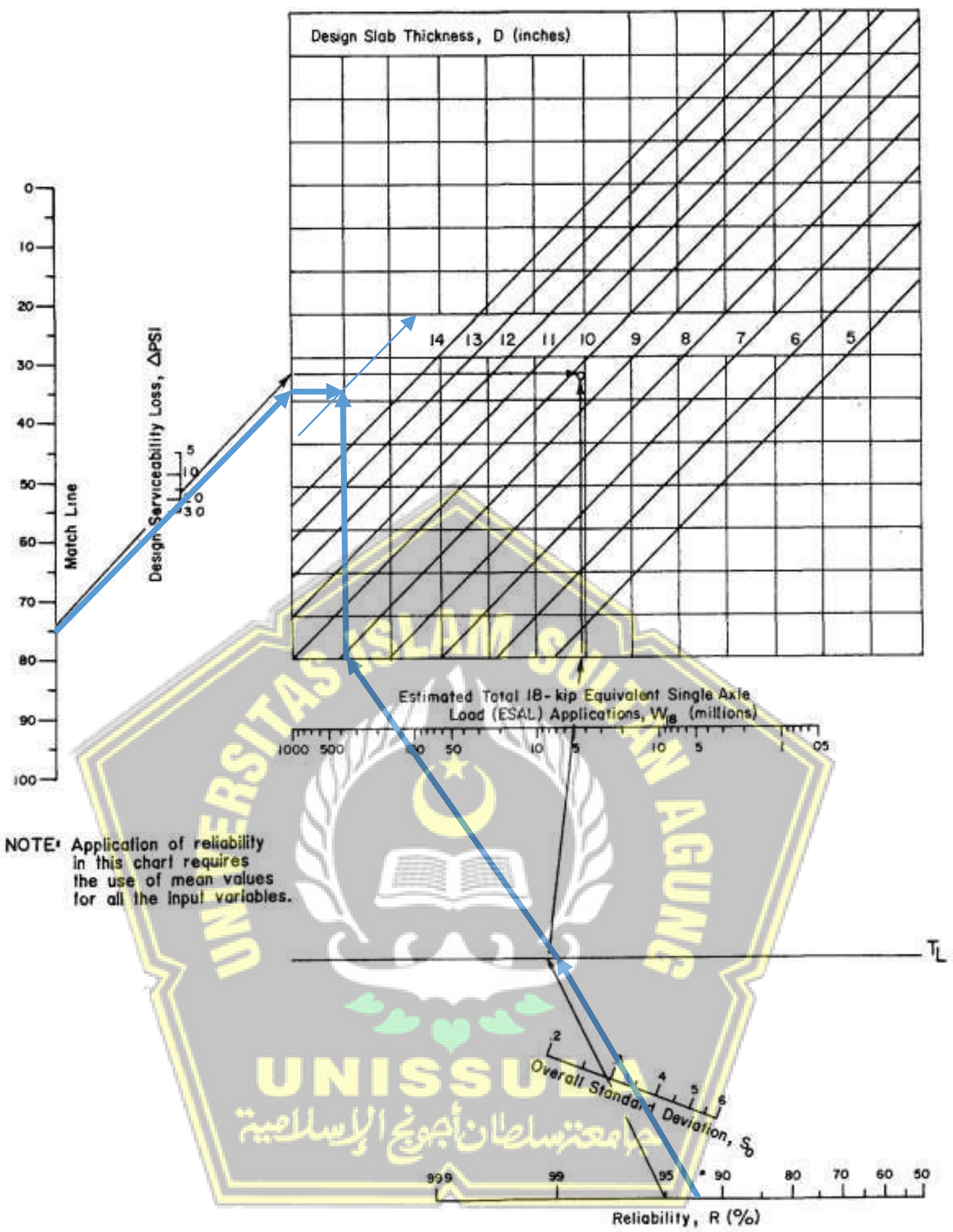


Figure 5.5 Continued- Chart for determine slab thickness
Rigid Pavements (Segment 2)

CHAPTER VI

DISCUSSION

6.1. Introduction

As has been mentioned in Chapter I, the objectives of this final asignment are to study the differences of between flexible and rigid pavement in case of their subgrade and base/sub-base layer strength, distribution of traffic load to subgrade, the design life of the pavement construction, determination of traffic loading, and damage and rehabilitation as well as skid resistance of the surface layer. These differences will be discussed in the next subsections.

6.2. Subgrade Strength

6.2.1. Flexible Pavement

Refer to the Figure 2.2. of Chapter II, in flexible pavement subgrade is not directly burdened by traffic, but the traffic load is distributed through the surface layer, base layer, subbase layer and then to the subgrade. Therefore, the traffic load that must be carried out by the subgrade on flexible pavement is small depending on the thickness of the base and subbase layers above it. Or in other words, the thickness of the pavement layer on flexible pavement depends on the strength of the subgrade. Good soil to be used as subgrade is soil that has a bearing capacity of 5 to 10% when measured by CBR, or 10.000psi to 20.000psi if measured by modulus of resilient M_R.

6.2.2. Rigid Pavement

Westergaard is considered the pioneer in providing the rational treatment of the rigid pavement analysis. He considered the rigid pavement slab as a thin elastic plate resting on sub-grade soil, which is assumed as a dense liquid. The upward reaction is assumed to be proportional to the deflection. Base on this assumption, Westergaard defined a *modulus of sub-grade reaction K* in kg/cm^3. Therefore, different with flexible pavement, in the rigid pavement, tire load distribute evenly from the slab to the subgrade, as shown in Figure 2.3. Chapter II, the sub-grade deformation is same as the slab deflection. Hence the slab deflection is direct measurement of the magnitude of the sub-grade pressure.

6.3. Base and Subbase Course Layer

6.3.1. Flexible Pavement

On flexible pavement base and subbase course layer have function to distribute traffic load to the subgrade. As mention above, the thickness of base and subbase course layer are depend on the strnght of the subgrade soil. For that reason, base and subbase must be made from the strnght materials, usually crushed stone have 90 to 100% of CBR value for base, and 60 to 70% for subbase.

In addition, the base and subbase also function as a drainage layer so that water does not collect in the base and subbase layers which can weaken the pavement. The subbase layer also functions as a filter so that fine materials in the subgrade do not enter the pavement layers.

6.3.2. Rigid Pavemnt

On rigid pavement base or subbase have no structural value or do not share the traffic load. The use of base or subbase in rigid pavement is also optional, that is, it can be used or not used. The function of the base or subbase in rigid pavement merely as a layer to prevent pumping. Pumping is up and down movement of the edges of the slab of rigid pavement caused by weak subgrade which can cause the rigid pavement slab to crack. The base or subbase layer on rigid pavement is usually used on roads with heavy traffic only, and its thickness is usually only around 15cm.

6.4. Pavement Design

Although using the same design method and guidelines, several things such as design life, application of traffic loads, are different for flexible and rigid pavements.

6.4.1. Design Life

Design life is the pavement life during which the pavement will carry the traffic loading. For flexible and rigid pavement according to reference no. [13] is 20 years and 40 years respectively. Design life on flexible pavement is taken 20 years because take the structural condition when rutting of 10mm in the wheel paths or cracking in the wheel paths occurs, into account.

Meanwhile, on rigid pavement is aken 40 years, since the load carrying capacity is mainly due to the rigidity and high modulus of elasticity of the slab (slab action).

6.4.2. Determination of Pavement Thickness in Flexible Pavement

Determine of pavement thickness in flexible pavement is determine required structural number (SN). There are seven steps to determine SN, those are:

1) Estimate the future traffic, $w_{8,16}$ for the performance period.
2) Set the reliability R which assume all input is at average value,
3) Set the overall standard deviation S_0,
4) Set the effective resilient modulus of subgrade material, M_R,
5) Set the elastic modulus of asphalt concrete, base, and subbase materials.
6) Set the design serviceability loss, $\Delta PSI = p_0 - p_t$
7) Set drainage coefficient, C_d

6.4.3. Determination of Slab Thickness in Rigid Pavement

Meanwhile in rigid pavement there are nine steps in determining required slab thickness, those are:

1) Estimate the future traffic, $w_{8,16}$ for the performance period.

2) Set the reliability R which assume all input is at average value,
3) Set the overall standard deviation S_0,
4) Set the coefficient of subgrade reaction, k
5) Set the design serviceability loss, $\Delta PSI = p_0 - p_t$
6) Set the concrete elastic modulus, E_c
7) Set concrete modulus of rupture, S'_c
8) Set the load transfer coefficient, J, and
9) Set drainage coefficient, C_d

The difference between the procedure to determine the pavement thickness in flexible and rigid pavemen are in setting the modulous of rupture and load transfer coefficient in rigid pavement because stiffness properties in concrete slab.

6.5. Damage and Rehabilitation of Pavement

There are different types of damage in flexible and rigid pavement, and of course also different methode of repairing them. The following are the types of damage to both road pavements and how to repair them.

6.5.1. Damages in Flexible Pavements

There are four main damages in flexible pavement and will be described the cause of damages and method to repair it. All of flexible pavement distresses describes below are taken from reference no. [17].

Alligator Cracking of Flexible Pavements

Map cracking is another name for alligator cracks. This is the result of a fatigue failure in the asphalt concrete. As a result of the disturbance, a series of interconnecting cracks may be seen. The asphalt surface has the highest tensile stress (base). This is where the cracks appear, i.e. the location with the highest tensile stress. With the passage of time, a parallel of longitudinal cracks will propagate to the surface. Individual cracks will be helped to join by repeated loading and stress concentration. They'll resemble chicken wire or alligator skin in appearance. The alligator cracking is what this is known as. The crocodile cracking is also a name for it. Crocodile cracking is another name for it. Only in locations where there is a lot of traffic can you see cracking like this. One of the most serious structural problems is alligator cracking. This dissatisfaction is followed by rutting. Alligator cracks have formed in the pavement, as seen in Figure 6.1.

Figure 6.1. Crocodile crack occur in flexible pavement surface layer

Depressions in Flexible Pavements

There are certain parts of the pavement that are isolated and have a lower height than the rest of the pavement. These depressions in the pavement are known as lowerings. Only after they are filled with water do they become noticeable (after rain). Depressions in flexible pavements are a typical occurrence in both parking lot and overlay construction. These depressions can be created by foundation soil settling as a result of ongoing loads, or they might occur during construction. For the depression in the flexible pavement that is created for airport reasons, there are several severity levels that are considered. The dipressions in flexible pavement are seen in Figure 6.2.

Figure 6.2. Depression Distress

Shoving

Shoving distress is a type of plastic movement that appears in the form of a wave. These can also be seen while the traffic is moving in the perpendicular direction. Figure 6.3 shows an example of pushing distress.

Figure 6.3. Shoving

Potholes

Cause a disturbance by producing a pothole in road surfaces where a piece of the same has broken away. This is also known as a kettle. Chuckhole is a term used in the Western United States to describe this. The development of potholes is mostly caused by pavement fatigue. Fatigue cracking will start to interlock, becoming alligator cracking. Under constant pressure and strains, these pieces between the cracks in the pavement will become loose and will be plucked out. This will result in a pothole in the road. The water trapped in the pothole will freeze and thaw in low conditions, causing further strains and fracture development. Once a pothole has formed, the discomfort increases, leading in the removal of pavement pieces on a regular basis. This rate of distress growth will be accelerated by trapped water. A pothole can grow to be many feet wide. They don't go into great detail. Large potholes had ruined the car tires.

Figure 6.4. Potholes

Permanent Deformation or Rutting

Rutting is the term for the depression that forms in the surface. This is formed on the surface of the wheel path. As shown in Figure 6, this depression causes uplift on the other sides of the wheel. Shearing is another name for this type of pavement uplift. After rain, these ruts appear as depressions. Water would be placed into these depressions. Pavement rutting and subgrade rutting are the two types of rutting that can occur.

Figure 6.5 depicts ruts in real time, while Figure 6.6 depicts ruts over time. Rutting Formation in the under of Vehicular Load.

Figure 6. 5 Real-Time Formation of Ruts

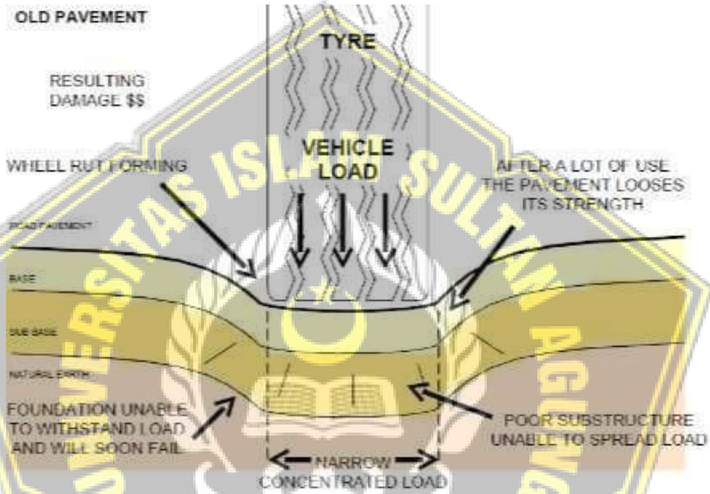


Figure 6.6. Rutting Formation under Vehicular Load

Swelling of Flexible Pavements

These are the distress of the long, gradual wave. These can reach a length of ten feet. The upward bulge in the pavement surface is a sign of swelling distress. Following swelling, surface cracking is the next stage of suffering. The main cause of flexible pavement swelling is frost action in the subgrade. The soil swells as a result of the icing. Figure 6.7. shows swelling in flexible pavement.

Figure 6. 7. Swelling in Flexible Pavement

Raveling or Fretting

The dislodgement of aggregate particles will cause the hot mixed asphalt to disintegrate starting at the surface in a downward direction. Raveling is the technical term for this type of failure. The aggregate particles and the asphalt binder lose their bonding, which causes dislodgement. Dust particles can cover aggregates, causing lack bonding problems. The aggregate will bind with the dust rather than the binder as a result of this. Figure 6.8 shows a description of the damage in the form of reveling or fretting.

Figure 6.8. Reveling or Freeting in the Surface of Flexible Pavement

Rehabilitation of road surface damage in the form of reveling is by using surface dressing. Surface dressing is the repair of the surface layer by covering the asphalt surface with medium-sized aggregate (chips) with diameter 0.5 to 1.0 cm. Figure 6.9 shows the photograph activity of surfac dressing after the surface has been sprayed with asphalt and the aggregate has been spread and then compacted, and Figure 6.10. shows the photograph activity of surfac dressing.

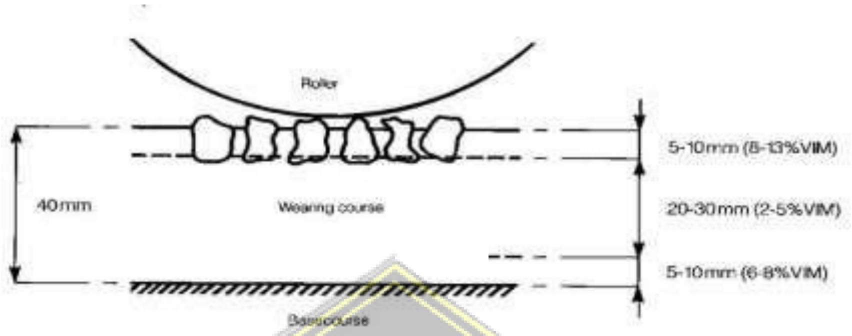


Figure 6.9. Illustration of surface dressing

Figure 6.10. Photograph of Activity of Surface Dressing

To repair crack and potholes on the surface pavement where cracks or holes occur are dug as deep as the surface layer thickness or up to the base layer if the hole has reached the base layer. The area of the excavated part is made wider than the area of the damaged part, usually the width of the excavation is made a minimum of 20 cm wider to anticipate if the damage occurs is widespread. After excavation reaches the desired depth, the bottom of the excavation is then primed and covered with the same material as the existing surface layer material and then be compacted. The compactor used is a lightweight compactor, namely a 2-ton stamper, but can pound so that the compaction effect is more than 2 tons. The thickness of the new material is made 1cm thicker than the existing thickness so that the layer does not fall down in the event of compaction by vehicular traffic. The sequence of repairing the crack or hole process is shown in Figure 6.11.

Figure 6.11. The Process of Repairing Cracks or Potholes on the Surface Pavement
Top left: Illustration of exacavation. Top right: Digging the damaged part
Bottom left; Prime coating. Bottom right: Compaction

6.5.2. Damages in Rigid Pavement

Cracking, joints, disintegration, distortion, and loss of skid resistance are the most common types of damage in rigid pavement. Other Distresses The following presentation of PCC (Portland Concrete Cement) pavement distresses was developed using the following information: American Society for Testing and Materials D5340 and D6433, 2011; Pavement Interactive website, 2014; Federal

Aviation Administration – Operational of Airport Pavements 2004 and Distress Identification Manual for the Long-Term Pavement Performance Project - Strategic Highway Research Program 1993; Federal Aviation Administration - Advisory Circular, 2007 and also their website. All of these can be found in reference [18] and can be used to describe the rigid pavement distress described below.

Cracking

Cracks in rigid pavements are frequently caused by stresses caused by the pavement's expansion and contraction or warping. Overloading, a loss of subgrade support, and insufficient and/or improperly cut joints, acting singly or in combination, are all possibilities. There are several types of cracking that can occur:

1) **Longitudinal, Transverse and Diagonal Cracking**

Cracks that divide the slab into two or three pieces characterize longitudinal, transverse, and diagonal cracking. A combination of repeated loads, curling and shrinkage stresses, poor construction techniques, underlying pavement layers that are structurally inadequate for the applied load, or pavement overloads are the most common causes of cracking. Figure 6.12. show example of longitudinal and diagonal cracks in rigid pavement.

Rehabilitation: Crack sealing (FAA, 2007 a) can be used to repair slabs with a single, narrow crack, as discussed in more detail in Chapter 4. A full-depth patch is usually required when there are multiple cracks.

Figure 6.12. Examples of Longitudinal and Diagonal Cracks on the Left and on the Right Transverse and Diagonal Cracks [18]

2) Durability "D" Cracking

Closely spaced, crescent-shaped cracks running in the vicinity of and parallel to a joint, linear crack, or free edges are typical of "D" cracking. Because concrete becomes saturated near joints and cracks, a dark colored deposit is common around this type of cracking, which can eventually lead to concrete disintegration within 30 to 60 cm of the joint or crack.

The concrete's inability to withstand environmental factors, such as freeze-thaw cycles due to the expansion of the large aggregate within the PCC slab, is one possible cause of this type of distress. Figure 6.13 depicts an example of this disterss.

Figure 6.13**.** Examples of Durability Crack in a Slab [18]

Rehabilitation: A full-depth or partial-depth patch, as described in Chapter 4, can repair the affected area, but it does not address the root problem and, of course, will not prevent "D" cracking elsewhere (Pavement Interactive, 2014 b). Remove the immediate surface and apply a thin bonded overlay for temporary repairs. (Federal Aviation Administration Advisory Circular, 2007 or FAA, 2007a)

3) Corner Breaks

A crack that intersects the joints at a distance less than or equal to one-half of the slab, describing approximately a 450 angle with the direction of traffic, measured from the slab's corner, characterizes this type of break. Figure 6.14 show the corner breaks damages.

Load repetition, in combination with a loss of support and curling stresses, is a common cause of slab corner cracks. Pumping or a loss of load transfer at the joint could cause a lack of support.

Figure 6.14**.** Examples of Corner Breaks at a High Volume Traffic Road

Rehabilitation: Full-depth patch

4) Shrinkage Cracking

Shrinkage cracks are small hairline cracks that do not extend across the entire slab and are usually only a few cm long. They form during the concrete's setting and curing process, and they usually don't go all the way through the slab's depth. Shrinkage cracks usually don't go deeper than 6.4 mm from the slab surface, and they're mostly found in the finished surface paste. Figure 6.15 show shrinkage crack in rigid pavement.

Possible Causes: Because all PCC shrinks as it sets and cures, shrinkage cracks are to be expected in rigid pavement, and provisions are made to control them. Uncontrolled shrinkage cracking, on the other hand, can indicate:

- Sawed-too-late contraction joints: In JPCP, if contraction joints are sawed too late, the PCC may have already cracked in an unfavorable location.
- Inadequate reinforcing steel design: Proper reinforcing steel design in CRCP should result in shrinkage cracks every 1.2 to 3 m.

- Improper curing technique: Allowing the slab surface to dry too quickly causes it to shrink and crack.
- High early strength PCC: High early-strength PCC may be used to quickly open a newly constructed or rehabilitated section to traffic. This type of PCC has a high heat of hydration and shrinks faster and to a greater extent than standard PCC.

Figure 6.15. Example of Shrinkage Cracking on New Slabs on the Left and Severe Shrinkage Cracking on the Right

Rehabilitation: Non-structural and non-propagating shrinkage cracks exist. Cracks of this nature should be treated as cosmetic rather than structural (FAA, 2007a). The slab and epoxy cement should work well together. The entire slab may need to be replaced in severe cases.

5) Joint Distresses

5.a. Joint Seal Damage

Any condition that allows incompressible materials (soil or rocks) to accumulate in the joints or allows water infiltration is considered joint seal damage. An accumulation of materials that prevents the slabs from expanding, resulting in buckling, shattering, or spalling, is one possible cause of joint seal damage. Pumping or sub-base deterioration can result from water infiltration caused by damaged joint seals. Stripping of joint sealant, extrusion of joint sealant, hardening of the filler (oxidation), loss of bond to the slab edges, and lack of sealant in the joint are all examples of typical joint seal damage. Improper joint width, incorrect sealant type, incorrect application, and/or not properly cleaning the joint before sealing cause joint seal damage. Example of joint seal damage is shown in Figure 6.16.

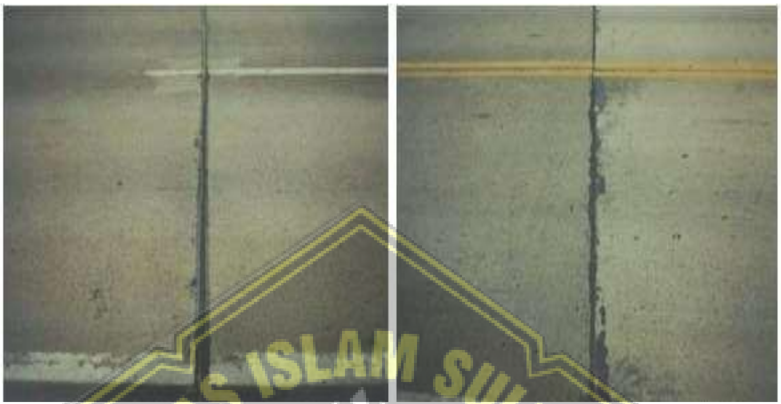


Figure 6.16. Example of Low Severity Joint on the Left and on the Right a Moderate Severity Joint

Rehabilitation: Depending on the condition of the joint, it may be necessary to replace existing preformed sealant with new preformed sealant when addressing joint seal damage. Preformed sealant can be used if the joint can be resawn straight and uniformly wide, even if the new joint width is greater than the old joint width. The repair area must extend from one joint intersection to the next joint intersection in this case. Partially replacing something isn't an option.

5.b. Joint Load Transfer System Deterioration

As a result of the joint dowels, a transverse crack or corner break developed. The failure of load transfer dowel bars can be caused by two main factors:

- Corrosion. Dowel bars can corrode if they aren't adequately protected. Corrosion products take up space, causing tensile stresses to form around the dowel bars. A severely corroded dowel bar is weaker and more likely to fail after repeated loading.
- Misalignment. Dowel bars that are inserted incorrectly or too close to the slab edge can cause localized stresses that can cause the slab to break. Misalignment can happen during the construction process or during dowel bar replacement.

Example of joint load transfer system deterioration is given in Figure 6.17.

Rehabilitation of this danage is by removing and replacing followed by a full-depth patch for the affected area of the affected joint load transfer system.

Figur 6.17. Example of a Dowel Bar Corrosion on the Left and on the Right a Patch Over an Area of Dowel Bar Failure

6) Disintegration

The breaking up of a pavement into small, loose particles, which includes the dislodging of aggregate particles, is known as disintegration. This distress can be caused by poor concrete curing and finishing, the use of inappropriate aggregates, and poor concrete mixing. There are several types of disintegration:

6.a. Scaling, Map Cracking or Crazi

A network of shallow, fine, or hair-like cracks that only extend through the upper surface of the concrete is referred to as this distress. Delamination or disintegration of the slab surface to the depth of the defect, usually 6 to 13 mm, is a common symptom of scaling. Map cracking or crazing is caused by improper concrete curing and/or finishing, and it can result in surface scaling. With little or no surface deterioration, this distress is often noticeable. Scaling, map cracking, and crazing can result in a significant amount of foreign object debris (FOD), which can damage propellers and jet engines.

Possible causes of this type of damage is construction defects, material defects and environmental factors.

- Over-finishing, adding water to the pavement surface during finishing, lack of curing, and attempts to repair fresh concrete surfaces with mortar are all examples of construction defects. This usually happens over a small area of a slab.
- Inadequate air entrainment for the climate is one of the material flaws. This usually happens over a number of slabs that were impacted by the concrete batches.
- Environmental factors such as freezing of concrete before it reaches sufficient strength or thermal cycles from certain aircraft, which occur over a large area for freezing and isolated areas for thermal effects. Sweeping usually removes the FOD from scaling, but the concrete will continue to scale until the affected depth is removed or exhausted.

Example of scaling is shown in Figure 6.18. below.

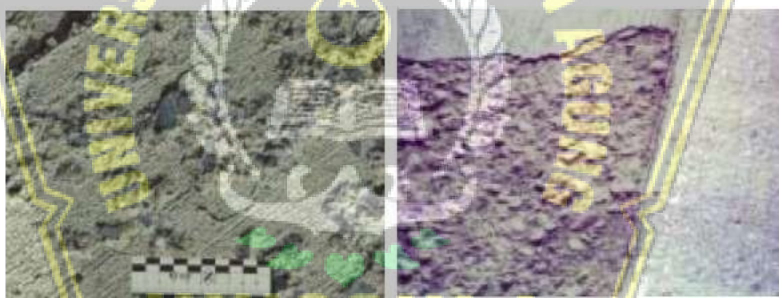


Figure 6.18. Example of Scaling [18]

Rehabilitation: If the distress is severe and produces FOD, the immediate surface should be removed and a thin bonded overlay applied.

6.b. Alkali- Silica Reaction

The expansive reaction between alkali (contained in the cement paste) and elements within an aggregate (certain reactive silica minerals) in Portland concrete cement (PCC) forms a gel that is usually white, brown, or gray, with staining present at the crack surface. If severe enough, this reaction, which occurs to some extent in most PCC, can result in map or pattern cracking, surface popouts, concrete volume increase, and spalling.

The following are some of the possible causes of this type of damage:

- Reactive silica dissolution and initial alkaline depolymerization. Non-crystalline silica's solubility and rate of dissolution can be improved by cement (a high-alkali substance). Furthermore, the cement will raise the pH of the surrounding medium, causing crystalline silica to be affected.
- • A hydrous alkali silicate gel is formed. After the reactive silica dissolves, the aggregate pore structure opens up, allowing more silica to dissolve into solution. The final product is an alkali-silica gel that forms on the spot. This gel formation is not expansive in and of itself, but it does compromise the aggregate particle's integrity.
- • Water is attracted to the gel. The gel absorbs a lot of water and expands as a result. The resulting stress will crack the now weakened aggregate and surrounding cement paste if the expansion is large enough.
- The formation of a colloid gel. The water takes over after the gel has ingested enough water, and the substance becomes an alkali-silica gel dispersed in a water fluid. This fluid then escapes into nearby cracks and voids, where it may cause secondary reactions.

Damage of alkali –silica reaction is shown in Figure 6.19.

Figure 6.19. Examples of Map Cracking Resulting from Alkali-aggregate Reaction [18]

Rehabilitation (how to control it) are:

- Avoiding susceptible aggregates. Certain types of rock may contain reactive silica, according to local knowledge. Siliceous limestone, chert, shale, volcanic glass, synthetic glass, sandstone, opaline rocks, and quartzite are all examples of susceptible rock types. River rock is also prone.

- Pozzolanic admixture is a type of admixture that occurs naturally in some rocks. A pozzolan can lower the pH of the pore solution by reacting with the calcium hydroxide found in cement paste. A pozzolan's silica may also react with the cement's alkali. Because it bypasses the expansive water attraction step, this reaction is not harmful.
- Cement with a low alkali content. Gel formation will be limited if there is less alkali available for reaction.
- The water-to-cement ratio is low. The less permeable the concrete is, the lower the water-cement ratio. The alkali-silica gel's water supply will be limited by its low permeability.

In conclusion, alkali-silica reactions are widespread in nature and can be found in almost all PCC. If the reaction is severe enough, it can cause cracking, popouts, and spalling in the aggregates and surrounding paste. There are a number of ways to avoid this reaction, the most basic of which is to avoid susceptible aggregate. Otherwise, a full-depth patch is required once alkali-silica is detected.

6.c. Spalling

The cracking, breaking, or chipping of joint/crack edges is known as spaling. On airports, it usually happens within 0.6 m of the joint/crack edge, while on roadways, it usually occurs within 0.5 m of the joint/crack edge and generally angles downward to intersect the joint.

The following are examples of possible causes of this type of damage:

- Excessive strains at the joint/crack due to infiltration and subsequent expansion of incompressible materials (can also cause blowups).
- Freeze-thaw action or "D" cracking causes the PCC to disintegrate.
- Weak PCC at a joint as a result of poor construction consolidation. If low quality PCC is used to fill in the last bit of slab volume or dowels are improperly inserted, this might happen at a construction joint.

- Corroded dowel or misalignment
- High volume of traffic.

Figure 6.20. below shows the spalling.

Figure 6.20. Examples of Spalling Along a Linear Crack on the Left and a Joint and Corner Spalling on the Right [18]

Rehabilitation: Spalling less than 75 mm wide from the crack surface can usually be repaired with joint seal repair or repaired with a partial-depth patch. Spalling that extends beyond 75 mm from the fracture face may indicate joint bottom spalling and should be treated with a full-depth patch.

6.d. Blowups

Blowups are most common in thin pavement sections, but they can also occur at drainage structures (manholes, inlets, etc.). They are more common occur in hot weather due to the concrete's increased thermal expansion. Blowups usually happen when a transverse crack or joint isn't wide enough to allow the concrete slabs to expand. Infiltration of incompressible materials into the joint space or gradual closure of the joint due to concrete expansion due to ASR can be caused insufficient width. When expansive pressure cannot be relieved, the slab edges will buckle or shatter in the vicinity of the joint.

Blowups can occur when PCC slabs contract during cold weather (winter), resulting in wider joint openings. If incompressible material (such as rocks or soil) is filled into these openings, subsequent PCC slab expansion during hot periods (spring, summer) may result in high compressive stresses. The slabs may buckle and shatter to relieve the stresses if the stresses are great enough. Blowup can be accelerated by:

- Joint spalling (reduces slab contact area and supplies incompressible material to fill the joint/crack);
- Durability "D" cracking (weakens the slab at the joint/crack area);
- Freeze-thaw damage (the slab weakens near the joint/crack area)

Example of blowups distress is given in Figire 6.21.

Figure 6.21. Examples of Blowup Distress

Full-depth patching was used for rehabilitation. It means that one plate block must be removed and replaced with a new concrete slab.

6.e. Shattered Slab/Divided Slabs

A shattered slab is one that has been broken up into four or more fragments by intersecting fractures.

Overloading due to traffic and/or poor foundation support are the most common causes of this discomfort.

Photograph of shattered is shown in Figure 6.22.

Figure 6.22. Examples of a Shattered Slab Distress [18]

To repair a fractured slab, the entire slab must be replaced. Remove unstable subgrade materials and replace with chosen material using the same techniques as for blowup repairs (full-depth patch). Install drains to remove extra water to improve poor drainage conditions.

6.f. Punchout

This distress is a condition that commonly occurs in CRCP between two cracks that are closely spaced or between a crack and a 1.5 m wide joint. A crack and a joint characterize the Punchout, although it may assume many other shapes and forms. Heavy repeated loads, insufficient slab thickness, loss of foundation support, or a localized concrete construction deficiency, such as honeycombing, are all possible causes of this distress.
Figure 6.23 shows the distress of punchout.

Figure 6.23. Examples of Punchout Distress

Rehabilitation: Full depth-patch, mean all parts of distress must be dismantled.

6.g. Popouts

A popout distress is a small crack in the concrete surface caused by a small piece of pavement breaking loose. Popouts typically have a diameter of 25 to 100 mm and a depth of 13 to 50 mm. A popout can also be a single large aggregate piece that breaks free from the concrete surface or clay balls in the concrete mix.

Freeze-thaw action in combination with poor aggregates are possible causes of distress. Poor durability can be caused by a variety of factors, including:

- Poor freeze-thaw resistance in the aggregate
- Aggregates with a lot of space
- Aggregate-Alkali Reactions

Figure 6.24 show the example of popouts.

Figure 6.24. Examples of Popouts Distress

It's possible that the rehabilitation method of isolating low-severity popouts isn't warranted. Larger popouts or groups of popouts can usually be repaired with a partial depth patch or by filling them with the same materials that are used to repair cracks and joints in PCC pavements.

6.h. Patching

A patch is an area where the original pavement has been removed and a filler material has been fitted in its place. Patching is typically classified into two categories:

- Small: A small patch is one that is smaller than 0.5 m2 in size.
- Utility and Large Cuts A huge patch is one that is larger than 0.5 m2. A utility cut is a patch that has replaced the original pavement as a result of the installation of subsurface utilities.

Distress can be caused by a loss of support, heavy load repetitions, wetness, and heat gradients, among other things are possible causes of this distress.

Patching distress is shown in Figure 6.25.

Figure 6.25. Examples of Slab Patching

Rehabilitation: Patching minor, large, or utility cuts usually necessitates removing and replacing the patch. The slab should be removed and replaced if there are numerous big spots.

6.i. Distortion

Distortion is a change in the original position of the pavement surface caused by foundation settlement, expansive soils, frost-susceptible soils, or fines loss due to poorly designed subdrains or drainage systems. There are two types of distortion that commonly occur:

6.i.1. Pumping

Pumping is defined as the ejection of water and underlying material through joints or cracks in a pavement due to the deflection of the slab when loaded. When water is ejected, it carries gravel, sand, clay, or silt with it, causing a gradual loss of pavement support that can lead to cracking. Surface staining and base or subgrade material on the pavement near joints or cracks are signs of pumping. Pumping near joints indicates a poor joint seal, poor joint load transfer, and/or the presence of ground water.

Possible causes of pumping is water accumulation underneath the slab. This can be caused by such things as: a high water table, poor drainage, and panel cracks or poor joint seals that allow water to infiltrate the underlying material.
Figure 6.26 shows the distress of pumping.

Figure 6.26. On the Left it's an Example of Pumping in Action and on the Right is an Example of Pumping Distress

Method of rehabilitation:

- First, to remove any deteriorated slab areas, the pumping area should be patched with a full-depth patch.
- Second, if there are any significant transverse joints created by the repair, dowel bars should be considered.
- Third, because the pumping may have removed significant amounts of the underlying base, subbase, or subgrade, any slabs adjacent to the pumping area should be stabilized. Finally, the water source or the cause of poor drainage must be addressed.

6.i.2. Settlement or Faulting

Pumping, the most common faulting mechanism, causes a difference in elevation at a joint or crack, with the approach slab typically being higher than the leave slab. Undoweled JPCP is often linked to this type of distress.

Swelling soils, soft foundation, pumping or eroding of material from below the slab, and slab edge curling due to temperature and moisture changes are all possible causes.

Rehabilitation: Any faulting heights on airport runways must be repaired; however, in roads, faulting heights of less than 3 mm do not need to be repaired. Faulting in an undoweled JPCP (jointed plain concrete pavement) greater than 6 mm in the case of airport runways, and between 10 and 20 mm in the case of roads, is a candidate for a dowel bar retrofit.

Example of settlement is shown in Figure 6.27.

Figure 6.27. – Example of Faulting Distress at the Left and a Close-up on the Right

6.6 Skid Resistance

The force developed when a tire that is unable to rotate slides along the pavement surface is known as skid resistance (Highway Research Board, 1972).

Because insufficient skid resistance leads to more skid-related incidents, skid resistance is an important pavement parameter metric.

The ability of a pavement to provide a surface with the desired friction characteristics under all weather conditions is also referred to as skid resistance. It is a result of the texture of the surface. The loss of skid resistance is caused by the textured surface wearing down due to normal wear and tear or the accumulation of contaminants.

Friction, also known as skid resistance, is an important safety factor for highway pavement and airport runways that must be considered during material selection, design, and construction. Friction is a measure of pavement serviceability in pavement management. The cost of restoring friction is usually considered in a life cycle cost analysis. The term "friction" is defined as (ASTM, 2011).

$$SN = F/W \times 100$$

where SN = skid number; F = traffic force (horizontal force applied to the test tire at the tire–pavement contact patch, Newton or lb; W = dynamic vertical load on the test wheel, Newton or lb.

Surface mixes that must provide enough resistance to sliding to allow normal turning and braking movements are only required to have friction. For skid resistance, aggregate texture, shape, size, and polish resistance are all required. Also, the asphalt cement content of the mix should not be so high that bleeding occurs, resulting in a slick surface. The ASTM E 274: Standard Test Method for Skid Resistance of Paved Surfaces specifies a number of methods for determining friction, including the locked trailer method. Using a Full-Scale Tire and portable friction measurement devices that can be used in the lab and on the road (eg, British Portable Tester, California Skid Tester). Blast furnace and steel slag aggregates have rough microtextures that differ from natural aggregates like limestone, sandstone, and gravel, resulting in vastly different friction qualities.

Loss of Skid Resistance in Rigid Pavement

In rigid pavement, even when the surface of the rigid pavement is made rough, after a few days of passing by vehicles, the surface of the rigid pavement becomes slippery. Some aggregates polish quickly when exposed to traffic. If natural polished aggregates are used in the pavement without being crushed, they can cause skid hazards.

Possible causes: traffic applications on a regular basis The protruding rough, angular particles on a pavement usually become polished as it ages. If the aggregate is prone to abrasion or is subjected to excessive studded tire wear, this can happen more quickly.

Loss of skid resistance causes the rigid pavement surface to be slippery, there is almost no friction between the pavement surface and the tire. This causes many accidents on rigid pavements especially when the vehicle speed is high.

Rehabilitation: Natural polished aggregates are crushed to create rough angular faces that provide good skid resistance (FAA, 2007 a). Consider milling, grooving, or diamond grinding the entire pavement surface because polished aggregate distress usually occurs over a large area. Loss of skid resistance almost not occurance in flexible pavement.

CHAPTER VII

CONCLUSION AND RECOMMENDATION

7.1. Conclusion

Based on the literature review, design of pavement thickness in Chapter V and VI and discussions in Chapter VII, conclusions can be drawn as follows:

1. Flexible pavement has more positive aspects than rigid pavement.
2. Rigid pavement is not safe to be used for vehicle with high speed more than 100 km/hour, since has no skid resistance.
3. Repairing damage on rigid pavement is more difficult than on flexible pavement because if there is damage, it must dismantle the hard concrete slab, and the repair or maintenance costs are also expensive.

From those conclusions above, are the reason why in many countries around the world, flexible pavements are used more than rigid pavements

7.2. Recommendation

A longer time is needed in order to analyze the differences between Flexible pavement and Rigid pavement more thoroughly, including conducting a traffic accident survey in both type of pavement so that the results will be clearer. and more accurate.

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DINAS PEKERJAAN UMUM BINA MARGA DAN CIPTA KARYA
PROVINSI JAWA TENGAH

STUDI PERHITUNGAN LALU LINTAS HARIAN
TAHUN 2020

NO. URUT	RUAS NO RUAS	RUAS STATUS	RUAS SUB RUAS	KLAS 2019	NAMA RUAS	BPJ	AADT MBT	AADT Total	Car %	Bus %	LTr %	HTr %	CEK	Gol 1 Sepeda Motor, Sekuter & Kend Roda Tiga	Gol 2 Sedan, Jeep & Station Wagon	Gol 3 Opelet, Pick Up, Suburban, Combi & Mini Bus	Gol 4 Pick Up, Mikro Truk & Mobil Hantaran	Gol 5a Bus Kecil	Gol 5b Bus Besar	Gol 6a Truk Ringan 2 Sumbu	Gol 6b Truk Sedang 2 Sumbu	Gol 7a Truk 3 Sumbu	Gol 7b Truk Gandengan	Gol 7c Truk Semi Trailer	Gol 8 Kendaraan Tidak Bermotor	WAKTU SURVEI
1	025	P	0	A	SIDOHARJO - GEMOLONG	PURWODADI	11.176	36.770	67,50	2,46	23,31	6,73	100	25168	5750	75	1719	152	123	1845	760	723	20	9	426	2 - 3 Juni 2020
2	050	P	0	A	KUTOARJO - KETAWANG	MAGELANG	7.276	40.824	80,09	2,31	17,26	0,34	100	32761	4649	99	1079	96	72	59	1197	23			787	15 - 16 Juni 2020
3	098	P	K 11	A	JL. KENDIL WESI (CILACAP)	CILACAP	1.535	6.268	33,22	0,20	5,02	61,56	100	4378	432	3	75	3	0	30	47	938	7	0	355	6 - 8 Juli 2020
4	098	P	K 12	A	JL. VETERAN (CILACAP)	CILACAP	2.603	23.395	52,32	0,08	5,07	42,53	100	19687	1161	2	199	0	2	25	107	1103	4	0	1105	6 - 8 Juli 2020
5	098	P	K 13	A	JL. KOL SUGIONO (CILACAP)	CILACAP	2.383	27.140	91,78	0,13	5,46	2,64	100	23970	1809	2	376	3	0	64	66	63	0	0	787	6 - 8 Juli 2020
6	098	P	K 14	A	JL. KARANG (CILACAP)	CILACAP	2.085	14.775	67,19	0,58	11,08	21,15	100	12014	1034	13	354	7	5	54	177	435	3	3	676	6 - 8 Juli 2020
7	102	P	0	A	WIRADESA - KALIBENING Bts.Kab.BANJARNEGARA	PEKALONGAN	10.150	64.604	87,13	0,84	11,20	0,83	100	53814	7007	108	1729	49	36	654	483	82	0	2	640	2 -3 Juli 2020
8	103	P	0	A	WANAYASA - KALIBENING Bts.Kab.PEKALONGAN	WONOSOBO	5.956	28.883	79,99	3,29	16,67	0,05	100	22274	1983	64	2717	196	0	735	258	3	0	0	653	14 - 15 Mei 2020
9	104	P	0	B	WANAYASA - BATUR	WONOSOBO	2.117	8.196	78,51	0,71	20,60	0,19	100	6077	577	3	1082	15	0	134	302	4	0	0	2	14 - 15 Mei 2020
10	105	P	0	B	BATUR - DIENG	WONOSOBO	4.185	13.352	70,94	6,59	22,44	0,02	100	9162	1375	209	1385	275	1	87	852	1	0	0	5	14 - 15 Mei 2020
11	106	P	0	A	DIENG - KEJAJAR	WONOSOBO	5.389	16.038	66,91	9,50	22,88	0,71	100	10621	2052	16	1538	508	4	156	1077	36	0	2	28	13 - 14 Mei 2020
12	107	P	0	A	WONOSOBO - KEJAJAR	WONOSOBO	6.947	26.100	77,36	7,74	14,19	0,71	100	19139	3160	24	2190	536	2	108	878	48	1	0	14	13 - 14 Mei 2020
13	108	P	0	A	PURWOKERTO - PEGALONGAN	CILACAP	10.500	44.280	84,76	1,18	13,68	0,38	100	33492	7469	101	1330	63	61	33	1403	40	0	0	288	9 - 10 Juli 2020
14	112	P	0	A	KETANGGUNGAN - KERSANA - BANTARSARI	TEGAL	15.322	73.842	83,83	1,47	14,38	0,31	100	58058	10342	260	2243	109	116	78	2126	46	0	2	462	30 Juni - 1 Juli 2020
15	113	P	0	A	SIDAREJA - KARANGPUCUNG	CILACAP	4.488	19.168	81,51	2,79	15,31	0,40	100	14464	2919	68	67	40	85	79	608	18	0	0	216	6 - 8 Juli 2020
16	114	P	0	A	JATIBARANG - KETANGGUNGAN	TEGAL	10.166	46.473	83,08	1,50	15,00	0,42	100	36172	6787	162	1497	75	77	56	1469	43	0	0	135	30 Juni - 1 Juli 2020
17	115	P	0	A	SLAWI - JATIBARANG / Bts.Kab.BREBES	TEGAL	9.445	41.643	68,79	3,04	27,49	0,69	100	31904	5014	113	1370	83	204	274	2322	65	0	0	294	30 Juni - 1 Juli 2020
18	116	P	0	A	JATINEGARA - SLAWI	TEGAL	3.860	17.405	82,75	1,40	15,75	0,10	100	13510	2018	83	1093	42	12	556	52	4	0	0	35	2 -3 Juli 2020
19	117	P	0	A	RANDUDONGKAL - JATINEGARA Bts.Kab.TEGAL	PEKALONGAN	4.120	16.390	82,65	0,10	17,04	0,22	100	12162	2314	130	961	0	4	139	563	9	0	0	108	29 - 30 Juni 2020
20	118	P	0	B	BANTARBOLANG - KESESI / Bts.Kab.PEKALONGAN	PEKALONGAN	1.712	8.107	75,88	2,45	21,32	0,35	100	6395	944	19	336	18	24	52	313	6	0	0	0	2 -3 Juli 2020
21	119	P	0	A	KESESI / Bts.Kab.PEMALANG - KEBONAGUNG	PEKALONGAN	1.889	13.300	67,44	0,11	31,45	1,01	100	11307	967	9	298	2	0	32	562	19	0	0	104	29 - 30 Juni 2020
22	120	P	0	A	KEBONAGUNG - Bts.Kab.BATANG	PEKALONGAN	6.305	31.662	96,02	0,21	3,68	0,10	100	25061	5273	13	768	8	5	85	147	6	0	0	296	29 - 30 Juni 2020
23	121	P	0	A	WONOTUNGGAL - Bts.Kab.PEKALONGAN	PEKALONGAN	5.593	29.777	80,53	2,43	16,52	0,52	100	24109	2850	27	1627	133	3	266	658	29	0	0	75	2 -3 Juli 2020
24	122	P	0	A	BATANG - WONOTUNGGAL - SURJO	PEKALONGAN	6.581	52.404	88,45	0,77	10,48	0,29	100	45782	4182	31	1608	40	1	131	559	14	0	5	41	29 - 30 Juni 2020
25	124	P	0	A	PLANTUNGAN - SUKOREJO / BLIMBING	SEMARANG	3.502	17.494	78,16	0,54	21,22	0,09	100	13988	1520	8	1209	14	5	134	609	2	1	0	4	13 - 14 Mei 2020
26	125	P	0	A	SUKOREJO - BOJA - CANGKIRAN	SEMARANG	5.087	30.873	71,63	0,43	27,09	0,85	100	25710	2317	16	1311	22	0	482	896	43	0	0	76	13 - 14 Mei 2020
27	126	P	0	A	CANGKIRAN - UNGARAN Bts.Kodya SEMARANG	SEMARANG	6.804	29.891	68,80	2,94	27,43	0,84	100	23039	3010	1	1670	191	9	272	1594	57	0	0	48	13 - 14 Mei 2020
28	127	P	0	A	SEMARANG – GODONG	SEMARANG	34.668	129.406	74,03	2,21	20,18	3,58	100	94334	20222	833	4611	187	578	4953	2042	961	40	241	404	21 -22 Mei 2020
29	127	P	K 15	A	JL. BRIJEND SUDIARTO (SEMARANG)	SEMARANG	62.089	244.040	76,76	2,13	17,88	3,24	100	180647	39385	1094	7181	241	1080	7286	3813	1683	41	285	1304	5 - 6 Agustus 2020
30	128	P	0	A	GODONG - PURWODADI	PURWODADI	8.975	38.711	82,43	2,66	14,07	0,84	100	29638	4675	49	2674	230	9	241	1022	75	0	0	98	21 -22 Mei 2020
31	128	P	K 11	A	JL.A.YANI (PURWODADI)	PURWODADI	20.818	105.180	74,10	2,22	19,87	3,81	100	82969	13439	163	1824	305	157	885	3252	743	20	30	1393	18 -19 Mei 2020
32	129	P	0	A	PURWODADI - WIROSARI	PURWODADI	20.695	75.707	60,18	4,46	30,82	4,53	100	54541	9899	157	2398	624	300	1176	5203	860	0	78	471	18 -19 Mei 2020
33	130	P	0	A	WIROSARI - KUNDURAN	PURWODADI	6.584	19.097	53,87	1,34	33,96	10,83	100	12031	2093	195	1259	1	87	193	2043	713	0	0	482	19 - 20 Mei 2020
34	131	P	0	A	KUNDURAN - NGAWEN - BLORA	PURWODADI	9.346	39.014	64,74	1,42	26,71	7,13	100	29486	4498	201	1352	48	85	528	1968	666	0	0	182	19 - 20 Mei 2020
35	132	P	0	A	WIROSARI - SULURSARI - SINGGET/Bts.Kab.BLORA	PURWODADI	7.293	27.942	54,18	3,83	37,34	4,66	100	20500	2610	149	1192	197	82	290	2433	340	0	0	149	19 - 20 Mei 2020
36	133	P	0	A	SINGGET - DOPLANG - CEPU	PURWODADI	11.669	35.195	55,79	1,21	41,40	1,60	100	23429	4213	195	2102	66	75	962	3869	187	0	0	97	19 - 20 Mei 2020
37	134	P	0	A	LINGKAR UTARA PURWODADI	PURWODADI	11.829	37.902	67,08	1,90	24,81	6,21	100	25545	6087	79	1769	80	145	2194	741	713	21	0	528	21 -22 Mei 2020
38	135	P	0	A	LINGKAR SELATAN PURWODADI	PURWODADI	12.283	40.119	67,82	1,94	23,20	7,04	100	27235	6366	80	1884	93	145	2580	270	844	21	0	601	18 -19 Mei 2020
39	136	P	0	A	KERSANA - BANDUNGSARI	TEGAL	7.259	44.620	69,24	3,18	25,86	1,72	100	36888	3791	40	1195	212	19	722	1155	112	6	7	473	30 Juni - 1 Juli 2020
40	137	P	0	B	BANDUNGSARI - PENANGGAPAN	TEGAL	1.313	9.730	94,44	0,00	5,56	0,00	100	8356	750	27	463	0	0	18	55	0	0	0	61	30 Juni - 1 Juli 2020
41	138	P	0	C	BANDUNGSARI - SALEM Bts.Kab.BREBES	TEGAL	906	6.867	88,52	0,00	11,48	0,00	100	5926	455	25	322	0	0	33	71	0	0	0	35	30 Juni - 1 Juli 2020
42	139	P	0	A	BUMIAYU - SALEM Bts.Kab.BREBES	TEGAL	2.130	10.978	82,25	1,50	15,92	0,33	100	8665	1360	16	376	17	15	6	333	7	0	0	183	30 Juni - 1 Juli 2020
43	140	P	0	B	CILOPODANG - SALEM	CILACAP	1.869	9.948	83,52	1,12	14,98	0,37	100	8055	1038	37	486	17	4	8	272	7	0	0	24	30 Juni - 1 Juli 2020
44	141	P	0	A	BUMIAYU - SIRAMPOK	TEGAL	3.909	12.825	71,04	6,32	22,64	0,00	100	8913	1292	209	1276	246	1	91	794	0	0	0	3	2 -3 Juli 2020
45	142	P	0	A	MORONGSO - TUWEL - SIRAMPOK	TEGAL	2.065	8.064	78,84	0,68	20,29	0,19	100	5997	566	3	1059	14	0	133	286	4	0	0	2	29 - 30 Juni 2020
46	143	P	0	A	MOGA - MORONGSO BTS.KAB.TEGAL	PEKALONGAN	6.846	26.038	88,93	0,03	10,14	0,91	100	19191	4549	234	1305	0	2	162	532	62	0	0	1	2 -3 Juli 2020
47	144	P	0	A	RANDUDONGKAL - MOGA	PEKALONGAN	6.448	44.177	87,28	1,10	11,45	0,17	100	37695	4176	92	1360	11	60	207	531	11	0	0	34	29 - 30 Juni 2020
48	145	P	0	A	RANDUDONGKAL - BELIK Bts.Kab.PURBALINGGA	PEKALONGAN	8.025	41.268	80,26	2,45	16,72	0,56	100	33087	4177	56	2208	153	44	354	988	45	0	0	156	2 -3 Juli 2020
49	146	P	0	A	BOBOTSARI - BELIK Bts.Kab.PURBALINGGA	CILACAP	9.015	38.564	84,71	2,03	12,79	0,47	100	29442	6190	139	1308	98	85	52	1101	42	0	0	107	9 - 10 Juli 2020
50	147	P	0	A	PURBALINGGA - BOBOTSARI	CILACAP	8.824	30.451	79,79	4,57	14,14	1,50	100	21603	5434	73	1534	280	123	244	1004	132	0	0	24	5 - 6 Juli 2020
51	148	P	0	A	SOKARAJA - KALIMANAH Bts.Kab.BANYUMAS	CILACAP	13.977	58.985	81,71	2,85	14,16	1,29	100	44558	9488	148	1784	231	167	44	1935	170	5	5	450	9 - 10 Juli 2020
52	149	P	0	A	KALIMANAH - PURBALINGGA (BMU)	CILACAP	20.977	84.563	82,88	2,14	12,60	2,38	100	63120	13390	678	3318	145	303	586	2057	497	1	2	466	5 - 6 Juli 2020
53	149	P	K 13	A	JL. SUNGKONO (PURBALINGGA)	CILACAP	11.686	57.706	73,23	2,79	19,78	4,19	100	45294	6547	90	1921	179	147	1770	542	452	21	17	726	9 - 10 Juli 2020
54	150	P	0	A	KLAMPOK - PURBALINGGA	CILACAP	17.733	71.667	67,08	3,64	27,65	1,62	100	53664	9268	186	2442	157	489	569	4335	286	1	0	270	5 - 6 Juli 2020
55	151	P	0	A	KALIORI – PATIKRAJA	CILACAP	9.796	35.921	71,06	2,50	24,06	2,38	100	25886	5274	206	1481	86	159	293	2064	233	0	0	239	5 - 6 Juli 2020
56	152	P	0	A	PURWOKERTO - BATURADEN	CILACAP	7.354	38.607	93,95	0,00	6,00	0,05	100	31124	6115	10	784	0	0	158	283	4	0	0	129	5 - 6 Juli 2020
57	153	P	0	A	SIDAREJA - CUKANGLEULEUS	CILACAP	4.984	25.643	82,83	0,98	15,75	0,44	100	20293	3258	70	800	26	23	225	560	22	0	0	366	6 - 8 Juli 2020
58	154	P	0	A	MENGANTI - KESUGIHAN	CILACAP	6.760	26.525	70,50	1,58	22,77	5,15	100	19142	2546	146	2074	59	48	525	1014	329	0	19	623	9 - 10 Juli 2020
59	155	P	0	A	BUNTU - KROYA - SLARANG	CILACAP	9.734	42.394	78,10	1,62	18,37	1,91	100	32468	5714	42	1846	108	50	394	1394	185	1	0	192	6 - 8 Juli 2020
60	156	P	0	A	GOMBONG-SEMPOR-KETILENG/Bts.Banjarnegara	MAGELANG	3.188	13.072	81,62	0,47	17,75	0,16	100	9868	1829	27	746	15	0	77	489	5	0	0	16	5 - 6 Juli 2020
61	157	P	0	A	MANDIRAJA - KETILENG BTS.KEBUMEN	WONOSOBO	2.709	12.004	73,39	0,78	24,88	0,96	100	9250	1303	20	665	21	0	174	500	16	0	10	45	9 - 10 Juli 2020
62	158	P	0	A	PEMALANG - RANDUDONGKAL	PEKALONGAN	10.619	32.778	76,60	3,85	17,79	1,76	100	22152	6223	35	1876	318	91	231	1658	172	0	15	7	29 - 30 Juni 2020
63	159	P	0	A	BANJARNEGARA - WANAYASA	WONOSOBO	6.468	31.337	80,53	3,00	16,42	0,05	100	24199	2224	84	2901	194	0	902	160	3	0	0	670	14 - 15 Mei 2020
64	159	P	K 13	A	JL. SUNAN GRIPIT (BANJARNEGARA)	WONOSOBO	8.595	38.166	84,41	2,78	12,41	0,40	100	29488	4464	38	2753	239	0	222	845	34	0	0	83	14 - 15 Mei 2020
65	160	P	0	A	PREMBUN - WADASLINTANG Bts.Kab.Wonosobo	MAGELANG	1.347	6.546	72,83	0,00	26,73	0,45	100	5159	529	5	447	0	0	334	26	6	0	0	40	13 - 14 Mei 2020
66	161	P	0	A	WADASLINTANG - SELOKROMO	WONOSOBO	2.009	9.134	74,17	1,44	24,24	0,15	100	7095	850	19	621	29	0	216	271	3	0	0	30	13 - 14 Mei 2020
67	162	P	0	A	KUTOARJO - BRUNO Bts.Kab.WONOSOBO	MAGELANG	2.837	20.367	94,01	0,00	5,85	0,14	100	17229	1914	113	640	0	0	45	121	4	0	0	301	18 -19 Juni 2020
68	163	P	0	B	Bts.Kab / BRUNO - KEPIL	WONOSOBO	736	5.416	65,35	0,27	34,38	0,00	100	4676	263	11	207	2	0	4	249	0	0	0	4	15 - 16 Juni 2020
69	164	P	0	A	KERTEK - KEPIL	WONOSOBO	9.681	41.021	74,23	3,18	20,93	1,66	100	31252	4704	84	2398	291	17	275	1751	149	0	12	88	16 - 17 Juni 2020

LEMBAR ASISTENSI

Nama : Wahyu Wardani (30201700183)

Yusia Nanda Agustanti (30201700188)

Tugas : Laporan Tugas Akhir

Dosen Pembimbing 1 : Ir. Gatot Rusbintardjo, M.R.Eng.Sc.,Ph.D

Dosen Pembimbing 2 : Eko Muliawan Satrio, ST., MT

NO	TANGGAL	KETERANGAN	PARAF
1	26/12/'20 Sabtu.	Judul T.A: The Comparison of Flexible and Rigid Pavement. Tulis Bab I Introduction: 1.1 Background · Aplikasi jalan umum & C.U.R.T. Tanah jalan 2. Pegerasan 3. Tipe jalan + gambar. 4. objectives 5. Scope of the study. 6. design construction. Bab II.	[signature]

NO	TANGGAL	KETERANGAN	PARAF
2	SECARA 29/12-20	Mulai mengecam tabel perbedaan lintas, sambil menulis bab 1, 2 & 3 lalu yang di [illegible]: [illegible] [illegible] [illegible] [illegible] s. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] lalu lintas: LHR [illegible] 2010, [illegible] UR = 2014. R = 90 % Jalan Kolektor	[signature] 29/12 '20

* [illegible] ([illegible]) = 1500 × CBR } CATATAN
Hal I-14 AASHTO } PENTING

LEMBAR ASISTENSI

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Dosen Pembimbing 2 : Eko Muliawan Satrio, ST., MT

NO	TANGGAL	KETERANGAN	PARAF
2.	Selasa 17, 2021	Hitung Perkerasan jalan lebih dr. data LHR (CTRR) 2018 & 2019 ε (traffic growth) = 1.98 CBR tanah dasar (lihat buku pdk) [illegible] = [illegible] x CBR UR = 20 th. A = 90% Z0. S0 = 0.35. CTRR coba ditambah Gordon-Duval;	

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Dosen Pembimbing 2 : Eko Muliawan Satrio, ST., MT

NO	TANGGAL	KETERANGAN	PARAF
4	12/01-'21	- Perbaiki perencanaan tebal lentur [illegible] AASHTO. CBR th 2019 dengan SL pertumbuhan i.l = (3,5%) Periode 20 th [illegible] = [illegible] th - Hitung kebutuhan pelapisan ulang (overlay) agar dapat mencapai UR 20 th.	[paraf]

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Dosen Pembimbing 2 : Eko Muliawan Satrio, ST., MT

NO	TANGGAL	KETERANGAN	PARAF
J.	Senin 25/01 '21.	- Perbaiki bab 1 dan bab 2. Bab 2 mereview buku2 yg ada. - Tulis bab per-hitungan Flex-Pav dengan dibandingkan dgn buku Inggris. - Asistensi setiap hari Selasa (kecuali ada acara lain/libur)	[signature]

LEMBAR ASISTENSI

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Dosen Pembimbing 2 : Eko Muliawan Satrio, ST., MT

NO	TANGGAL	KETERANGAN	PARAF
6	16/2-'21 Selasa	- Perbaiki bab 1 - bab 2 [illegible] tabel data - Perbaiki bab 3	[signature]
7.	2/3 '2021	- Perbaiki bab 1 dan bab 2 kirim lewat email	[signature]
8	23/3 '2021	- Cari data kecelakaan B.L. di jalan perkotaan luar maupun kota. - data kecelakaan jalan. - tambahkan di bab 2.	[signature]

NO	TANGGAL	KETERANGAN	PARAF
8	23/3 '21 (lanjutan)	- Bab 3: Buat bagan alir (disesuaikan dengan bab 2)	[signature]
9.	Senin 5/4 '21	- Bab 1: Batasan: Perbaiki ujar kontrol. - Kerangka pemikiran - ... - Bab 2: - Ambil dari buku. - Bab 3: Disusun sesuai bab 2.	[signature]

NO	TANGGAL	KETERANGAN	PARAF
12	Kamis 15/4 2021	Bab 2. ~~[illegible]~~ - [illegible] [illegible] - kan = [illegible] & [illegible]² di [illegible] foto. - Bab 3 metode [illegible] perhitungan [illegible] [illegible] [illegible] dengan [illegible] [illegible] th 2017.	[signature]
13	Senin 19/4 '21.	- Judul diganti "ANALISIS OF F.P X R.P". - Bab I s/d 3 disesuaikan. - Lakukan perhitungan ~~[illegible]~~ tebal perkerasan dengan manual B.M 2017	[signature]

LEMBAR ASISTENSI

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Dosen Pembimbing 2 : Eko Muliawan Satrio, ST., MT

NO	TANGGAL	KETERANGAN	PARAF
14	Sabtu 24/11 21	- Bab 2 ok. - Bab 3 perlu diganti pembahasan hitung perencanaan dgn metode BM 2017	[illegible]
15	Kamis 29/11 21.	- Bab 1 ok - Bab 2 ok - Bab 3 → ada perbaikan. - hitung perkerasan jalan dgn metode AASHTO 1993 dgn pedoman ketentuan Manual B.M 2017	[illegible]

NO	TANGGAL	KETERANGAN	PARAF
6	Jumat 3/5 2021	- Bab 1&2 ACC - Bab 3 ACC perlu di edit. - Ketik prakti- kum perbeda- [illegible] [illegible] & [illegible] asisten [illegible]- [illegible] Kamis 6/5,	[illegible]
7	Kamis 6/5 '21	- Bab 3 keterangan [illegible] supaya di [illegible] [illegible]. - Bab 3: Di perbaiki susunannya & keterang- an gambar dari [illegible] 10 asisten 5 praktikum (sudah di ketik).	[illegible]

LEMBAR ASISTENSI

Nama	: Wahyu Wardani	(30201700183)
	Yusia Nanda Agustanti	(30201700188)
Tugas	: Laporan Tugas Akhir	
Dosen Pembimbing 1	: Ir. Gatot Rusbintardjo, M.R.Eng.Sc.,Ph.D	
Dosen Pembimbing 2	: Eko Muliawan Satrio, ST., MT	

NO	TANGGAL	KETERANGAN	PARAF
18	Sabtu 8/5 '21.	- selesaikan perhitungan perkerasan - Tulis bab 4 ANALISIS.	[illegible]
19	Senin 10/5 '21.	Perbaiki perhitungan Flexible pav. - Hindari langkah-langkah AASHTO. - Kerjakan juga Rigid Pave - asistensi besuk 17/5 '21	[illegible]

NO	TANGGAL	KETERANGAN	PARAF
20	Kamis 20/5 '21.	- Perhitungan Rigid menggunakan L.L yg sama dengan Flex. Pav.	[illegible]
21	Senin 24/5 '21.	- lanjutkan perhitungan Rigid Pav. periksa. - Cc modulus of RPtve - Load transfer - Mass support - Tulangan tidak perlu dihitung.	[illegible]
22	Rabu 26/5 '21.	- Edit perhitungan F.P. - Hitung ulang R.P.	[illegible]

LEMBAR ASISTENSI

Nama : Wahyu Wardani (30201700183)

Yusia Nanda Agustanti (30201700188)

Tugas : Laporan Tugas Akhir

Dosen Pembimbing 1 : Ir. Gatot Rusbintardjo, M.R.Eng.Sc.,Ph.D

Dosen Pembimbing 2 : Eko Muliawan Satrio, ST., MT

NO	TANGGAL	KETERANGAN	PARAF
23	Kamis 2/6/21.	- Check kekakuan [illegible] pada rigid pav. Perbaiki gambar lagi [illegible] baku. - Ke bab 4.	[signature]
24	Jum'at 4/6/'21	- Jadikan [illegible] "DIFFERENCES BETWEEN FP & RP". - Sesuaikan bab 1 – 3 dengan judul baru. - Kerjakan bab 5.	[signature]

NO	TANGGAL	KETERANGAN	PARAF
24	Rabu 23/6/21	Bab Pelengkap: - Huruf & font disesuaikan pedoman penulisan - diketik sesuai pedoman.	[paraf]
25	Rabu 30/6/21	- Halaman belakang harus ditambahkan sesuai konten	[paraf]

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Nama : Wahyu Wardani (30201700183)

Yusia Nanda Agustanti (30201700188)

Tugas : Laporan Tugas Akhir

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Dosen Pembimbing 2 : Eko Muliawan Satrio, ST., MT

NO	TANGGAL	KETERANGAN	PARAF
1	29 - 12 . 2020	- Coba pergunakan penilaian kuantitatif dgn skala penilaian - Saran : pakai metode penilaian AHP. - Buat variabel pembanding antara Flexible Pavement & Rigid Pavement. - Diskusikan dgn Dosbing 1 misal : Aspek Keselamatan Aspek Ekonomi dsb.	(paraf)
2.	12 Juli 2021	Jika sudah dapat ACC dari Dosbing 1 maka lanjut ke Seminar. Saya ACC (paraf)	(paraf)

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Nomor : 25 / A.2 / SA - T / III / 2021
Lampiran : - -
Perihal : *Bimbingan Tugas Akhir*

Kepada : Yth. :
1 Ir. Gatot Rusbintardjo,MSc,Ph.D (Dosen Pembimbing I Tugas Akhir)
2 Eko Muliawan Satrio,ST,MT (Dosen Pembimbing II Tugas Akhir)
Dosen Fakultas Teknik Prodi Teknik Sipil UNISSULA

Assalamu'alaikum Wr Wb.
Bersama Surat ini kami menghadapkan mahasiswa Fakultas Teknik Program Studi Teknik Sipil UNISSULA yang telah memenuhi syarat untuk mengerjakan Tugas Akhir (TA) :

No	Nama	NIM
1	Wahyu Wardani	30201700183
2	Yusia Nanda Agustanti	30201700188

Maka dengan ini kami mohon kepada Bapak / Ibu untuk memberikan Bimbingan Tugas Akhir (TA) kepada mahasiswa tersebut diatas.
Wassalamu'alaikum Wr Wb.

Semarang, 17 Januari 2021
Ketua Program Studi Teknik Sipil

M.Rusli Ahyar,ST,M.Eng
NIK. 210216089

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Nomor : 03 / A.2 / SA - T / VII / 2021

Pada hari ini, Rabu Tanggal 14 Juli 2021 telah dilaksanakan

Seminar Tugas Akhir, dengan peserta sebagai berikut :

1	Nama	Wahyu Wardani	30201700183
2	Nama	Yusia nanda Agustanti	30201700188

Judul TA : Study The Difference Between Flexible Pavement And Rigid Pavement Construction

0

0

Dengan Hasil : ada beberapa hal yang harus diperbaiki sesuai koreksi penguji.

Demikian Berita Acara Seminar Tugas Akhir ini dibuat untuk diketahui dan pergunakan seperlunya.

Dosen Pembimbing I	Dosen Pembimbing II	Dosen Pembanding
Ir. Gatot Rusbintardjo,MSc,Ph.D	Eko Muliawan Satrio,ST,MT	Selvia Agustina,ST,M.Eng

Mengetahui ,
Ketua Program Studi Teknik Sipil

M Rusli Ahyar,ST,M.Eng

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DOSEN PENGUJI
SEMINAR TUGAS AKHIR

Hari	Rabu
Tanggal	14 Juli 2021
Jam	13.00 WIB

Judul Tugas Akhir

Study The Difference Between Flexible Pavement And Rigid Pavement Construction

1	Wahyu Wardani	30201700183	1
2	Yusia nanda Agustanti	30201700188	2

NO	NAMA	TANDA TANGAN	
1	Ir. Gatot Rusbintardjo,MSc,Ph.D	1	
2	Eko Muliawan Satrio,ST,MT		2
3	Selvia Agustina,ST,M.Eng	3	

Semarang, 14 Juli 2021
Ketua Program Studi Teknik Sipil

M Rusli Ahyar,ST,M.Eng
NIK. 210216089

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FAKULTAS TEKNIK Bismillah Membangun Generasi Khaira Ummah

JUDUL TUGAS AKHIR
DALAM BAHASA ~~INGGRIS~~ INDONESIA

Hari	Rabu
Tanggal	14 Juli 2021
Jam	13.00 WIB

Judul Tugas Akhir

Study The Difference Between Flexible Pavement And Rigid Pavement Construction
0
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JUDUL TUGAS AKHIR DALAM BAHASA ~~INGGRIS~~ INDONESIA

MENGKAJI PERBEDAAN ANTARA PERKERASAN JALAN LENTUR DAN PERKERASAN JALAN KAKU.

1	Wahyu Wardani	30201700183	1
2	Yusia nanda Agustanti	30201700188	2

Pembimbing Tugas Akhir

NO	NAMA	TANDA TANGAN	
1	Ir. Gatot Rusbintardjo,MSc,Ph.D	1	
2	Eko Muliawan Satrio,ST,MT		2

Semarang, 14 Juli 2021
Ketua Program Studi Teknik Sipil

M Rusli Ahyar,ST,M.Eng
NIK. 210216089

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SEMINAR TUGAS AKHIR

Nama Mahasiswa / NIM : Wahyu Wardani (30201700183) / Yusia Nanda A (30201700188)
Hari / Tanggal : Rabu / 14 Juli 2021
Judul TA : Study The Difference Between Flexible Pavement and Rigid Pavement Construction

NO	
1	Point penting pada diskusi lebih dijabarkan lagi
2	Rumus ditambahkan pada desain perkerasan yang lebih jelas, misalnya So / Standar Deviation untuk apa
3	Salah ketik pada daftar isi dibenarkan, terutama pada bagian abstrak
4	Pada daftar pustaka Chapter II bagian website dibenarkan yaitu dengan menuliskan point yang dibahas pada web tersebut
5	

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Hari / Tanggal : ....
Judul TA : ....
: ....

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1	- Mohon y/ ditambah mengenai kesimpulan dari Laporan TA nya tentang kelebihan flexible pavement thd pemakaian kendaraan kecepatan tinggi.
2	- Dalam recomendasi perlu ditambahkan aspek maintenance & operation.
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Tanggal : 14-07-2021
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by Wahyu Wardani Yusia Nanda Agustanti

Telah diperiksa tanggal 03/08/2021 oleh Ari Sentani, ST., M.Sc

Submission date: 03-Aug-2021 09:00AM (UTC+0800)
Submission ID: 1627150534
File name: Tugas_Akhir_Wahyu_Wardani_dan_Yusia_Nanda_2.pdf (4.45M)
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