Sudan University of
Science & Technology
College of Engineering
CIVIL ENGINEERING

A Supplementary Research To Obtain a Bachelor's Technology Degree In Civil Engineering

# Comparative Design of Rigid and Flexible Pavement

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# الإستهلال

قَالَ تَعَالَىٰ:

﴿ وَقُل رَّبِّ زِدْنِي عِلْمًا ﴿١١٤﴾ ﴾

صدق الله العظيم

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# الإهداء

نهدي هذا العمل إلى:

كل الآباء والأمهات

نقول لهم بكل خضوع هذا ثمار ما زرعتم

وأمد الله في أعماركم على طاعته

إلى كل من علمنا حرفاً وأنار لنا سبيل العلم والمعرفة

إلى اخواننا وأخواتنا الذين غمرونا بصدق مشاعرهم ودعوتهم

إلى كل من قدم لنا الدعم والتشجيع وكلمة صادقة

إلى هؤلاء جميعاً نهدي هذا الجهد

سائلين الله أن يكتب للجميع التوفيق والسداد في الدنيا والآخرة.

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# Abstract

Flexible and rigid pavements design methods in Sudan is depend on study of soil and paving materials, to carry loads under climatic conditions. There are several methods of flexible pavement design for implemental and rigid pavement is not implemental.

The Study aims at investigating and comparing between rigid and flexible pavements designs, as applied to Highway pavement designs, they were included the following methods: for flexible; American Association of State Highway and Transportation Official (AASHTO), Asphalt Institute(AI). For rigid the design methods are; Portland Cement Association (PCA) and American Association of State Highway and Transportation Official (AASHTO).

Relevant design data were obtained from side and lap to Elmadina Alridiea. The discussion of the comparison follow the thickness design and the cost of pavements. The conclusion and recommendation of the case Study focused on the appropriate method to implement and commitment of the properties of the concrete pavement to be used.

## المستخلص

أساليب تصميم الرصف المرن والجامد تعتمد على دراسة التربة ومواد الرصف وتختمل الأحمال في ظل الظروف المناخية المختلفة.

هنالك عدة طرق لتصميم وتنفيذ الرصف المرن وعدة طرق لتصميم الرصف الجامد. وتهدف الدراسة إلى التحقق والمقارنة بين تصميم الرصف الجامد والمرن كما هو منطبق على تصميم الطرق. وتشمل هذه الأساليب للرصف المرن : AASHTO Asphalt Institute – ، أما بالنسبة للرصف الجامد فهنالك طريقتي : Portland Cement Association (PCA) – (AASHTO). وقد تم الحصول على البيانات ذات الصلة بالمشروع من قبل الحصر المروري في الموقع والاختبارات من شركة أداء العالمية للطرق والجسور وذلك لتصميم شارع المدينة الرياضية جامعة السودان، ومن المناقشة والمقارنة تم التوصل للسمك التصميمي.

الاستنتاجات والتوصيات لدراسة الطريق المعني ركزت على طريقة الأسلوب المناسبة لتصميم الرصف المرن والجامد والالتزام بالخواص المحددة للرصف الخرساني والاسفلت.

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## SYMBOLS & ABBREVEATIONS

| | |
|---|---|
| AASHTO | American Association Of State Highway and Transportation Official |
| PCA | Portland Cement Association |
| CBR | California Bearing Ratio |
| AI | Asphalt Institute |
| HMA | Hot Mix Asphalt |
| EAB | Emulsified Asphalt Base |
| Mr | Resilient Modulus |
| ESG | Elastic Modulus of Sub-grade |
| Esb | Elastic Modulus of Sub-base |
| EbS | Elastic Modulus of Base |
| R | Reliability |
| SN | Structure Number |
| PCC | Portland Cement Concrete |
| HMAC | Hot Mix Asphalt Concrete |
| JPOP | Jointed Plain Concrete Pavement |
| JRCP | Jointed Reinforced Concrete Pavement |
| CRCP | Continuously Reinforced Concrete Pavement |
| fc | Compressive Strength of Concrete |
| EC | Elastic Modulus of Concrete |
| CD | Drainage Coefficient |
| J | Load Transfer Coefficient |
| D | Cumulative Damage |
| ESAL | Equivalent Single Axle Load |
| ELAF | Equivalent Load Axle Factor |
| ADT | Average Daily Traffic |
| Nt | Number of Truck |
| Pt | Percent of Trucks in AJD |
| N | Growth Rate |

# CHAPTER ONE
# INTRODUCTION

## 1.1 General Introduction:

With the importance, growing of road networks and their high cost necessitated the development of several methods for the design and characteristics of the methods taking into account the behavior of soil and pavement materials under the influence of large loads and effects of climate and environmental effects.

In United State there are about 4 million miles of paved roads of which of 94% are asphalt surfaced and about 75000 miles of rigid pavements, representing 6%. In Sudan the total paved roads is 2271 miles all of it asphalt Surfacing and there is no concrete pavement except some place in road way that suffer from heavy loading and this part is not designing and consider as concept rigid pavement.

## 1.2 Problem Statement and Significance:

Why not to use the rigid pavement in Sudan with the knowledge that it is used internationally?

## 1.3 Causes of the problem:

Environmental factors (Sudan tropical climate).

Economic factors (as Sudan is a developing country).

## 1.4 Objectives:

In this project, we want to compare between the pavements design Methods in Flexible and Rigid:

1-Flexible: - Asphalt Institute - Burmister two layer method – TRL – AASHTO .

2- Rigid – PCA – AASHTO.

#### 1.4.1 General Objectives:

Capability to replace rigid pavement alternative to flexible. Problems, obstacles and solutions if the proposal were accepted, include economic and engineering aspects.

#### 1.4.2 Specific Objectives:

(AI, AASHTO) and rigid (PCA, AASHTO) pavements design methods and knowing the differences in the thickness, cost and performance, by Appling in Road (Madeena Riyadiea Collage street), and find the best alternative.

# CHAPTER TWO:
# BACKGROUND AND LITERATURE REVIEW

## 2.1 Pavement Definition.

Pavement is the actual travel surface especially more durable and serviceable to with stand the traffic load in earlier times before the vehicles traffic become most regular, cobblestone paths were much familiar pavements are primarily to be used by vehicles and pedestrians.

## 2.2 Pavement Types:

### 2.2.1 Flexible Pavement:

#### *2.2.1.1 Introduction:*

Flexible pavement is composed of wearing material surface course and lower layers are base and sub-base course, the bituminous material is more of the asphalt which viscous nature allows significant plastic deformation, most asphalt surfaces are paved on gravel base, although some “full depth” asphalt surface are paved directly on the sub grade. Depending on the temperature at which it is applied asphalt is categorized as hot mix asphalt (HMA), warm mix asphalt, or cold mix asphalt flexible pavement is so named as the pavement surface reflects the total deflection of all subsequent layers due to the traffic load applied on it .

### *2.2.1.2 Flexible Pavement Types:*

### *2.2.1.3 Flexible Pavements*

Flexible pavements are layered systems with better materials on top where the intensity of stress is high and interior materials at the bottom where the

Intensity is low. Adherence to this design principle makes possible the use of local materials and usually results in a most economical design. This is particularly true in regions where high-quality materials are expensive but local materials of interior quality are readily available.

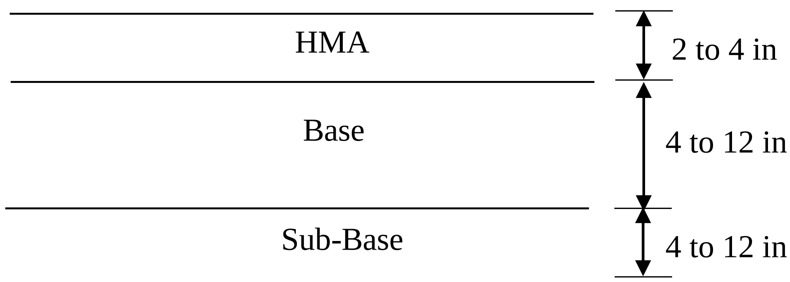



**Figure 2-1 : Typical cross section of a flexible pavement**

### *2.2.1.4 Full-Depth Asphalt Pavements*

Full-depth asphalt pavements are constructed by placing one or more layers of HMA directly on the sub-grade or improved sub-grade. This type of construction is quite popular in areas which local materials are not available. It is more convenient to purchase only one material, i.e., HMA, rather than several materials from different sources, thus minimizing the equipment cost of construction and time.

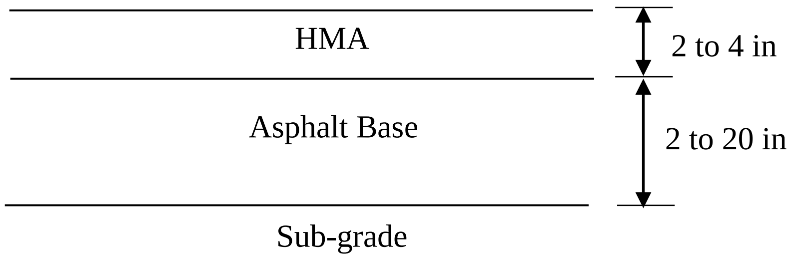



**Figure 2-2 : Typical cross-section of a full-depth asphalt pavement**

### 2.2.2 Rigid Pavements:

#### *2.2.2.1 Introduction:*

Rigid pavement is constructed of Portland cement concrete and should be analyzed by the plate theory, instead of the layered theory. Plate theory is a simplified version of the layered theory that assumes the concrete slab to be a medium thick plate with a plane before bending which remains a plane after bending. Rigid pavements are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material. Because there is only one layer of material under the concrete and above the sub-grade, some call it a base course, others a sub-base. Figure 2.3 shows a typical cross section for rigid pavements.

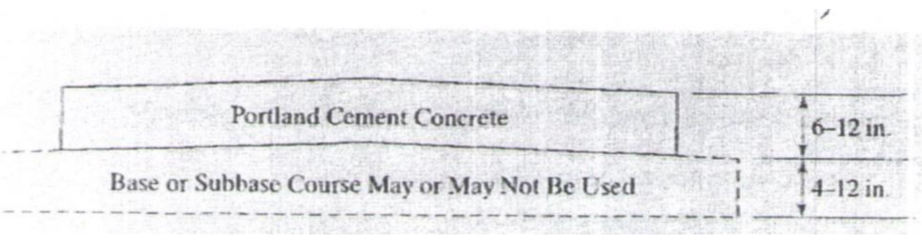



**Figure 2-3 : Typical cross section of a rigid pavement**

### *2.2.2.2 Rigid Pavement Types:*

**Concrete pavements can be classified into four types:**

Jointed Plain Concrete Pavements (JPCP)

All plain concrete pavements should be constructed with closely spaced contraction joints. Dowels or aggregate interlocks may be used for load transfer across the joints. The practice of using or not using dowels varies among the States Dowels are used most frequently in the southeastern states, and both are used in other areas. Depending on the type of aggregate, climate, and prior experience,

joints spacing between 15 and 30 ft (4.6 and 9.1 m) have been used. However, as the joint spacing increases, the aggregate interlock decreases, and there is also an increased risk of cracking Based on the results of a performance survey

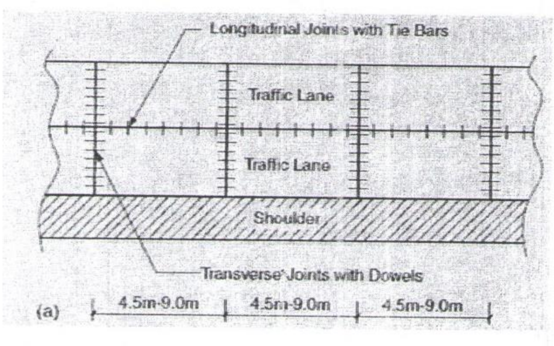



**Figure 2-4 : Jointed plain concrete pavement**

### *2.2.2.3 Jointed Reinforced Concrete Pavements (JPRCP)*

Steel reinforcements in the form of wire mesh or deformed bars do not increase the Structural capacity of pavements but allow the use of longer joints spacing. Joints spacing vary from

30 to 100 ft (9.1 to 30 m). Because of the longer panel length, dowels are required for load transfer across the joints. The number of joints and dowel costs decrease with the increase in joint spacing.

Based on the unit costs of sawing, mesh, dowels, and joint sealants.

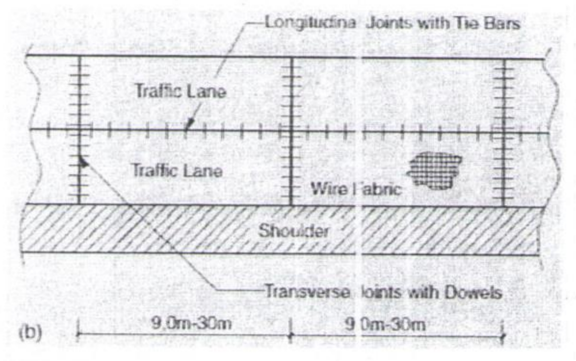



**Figure 2-5 : Jointed Reinforced Concrete Pavements**

### *2.2.2.4 Continuous Reinforced Concrete Pavements (CRCP)*

It was originally reasoned that joints were the weak spots in rigid pavements and that the elimination of joints would decrease the thickness of pavement required. As a result, the thickness of CRCP has been empirically reduced by 1 to 2 in (25to 50 mm) or arbitrarily taken as 70 to 80% of the conventional pavement.

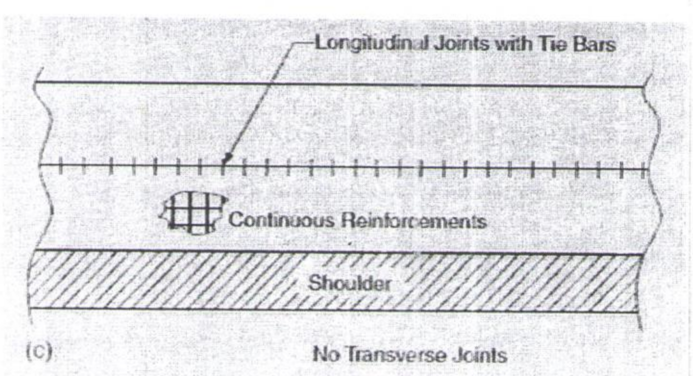



**Figure 2-6 : Continuous Reinforced Concrete Pavements**

#### *2.2.2.5 Pre-stressed Concrete Pavements Concrete (PCP)*

is weak in tension but strong in compression . The thickness of concrete pavement required is governed by its modulus of rupture, which varies with the tensile strength of the concrete. The pre-application of a compressive stress to the concrete greatly reduces the tensile stress caused by the traffic loads and thus decreases the thickness of concrete required. The pre-stressed concrete pavements have less probability of cracking and fewer transverse joints and therefore result in less maintenance and longer pavement life.

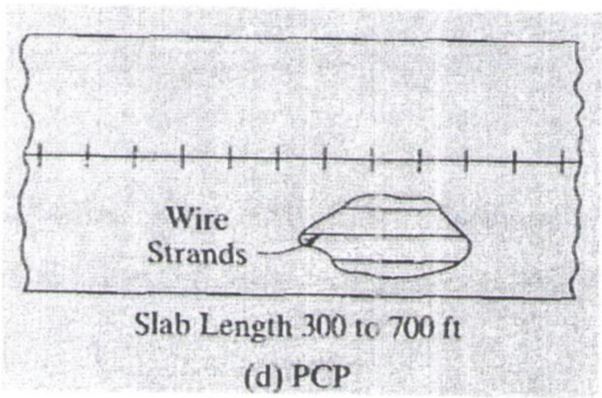



**Figure 2-7 : Pre-stressed Concrete Pavements Concrete**

### 2.2.3 Composite Pavement:

Composite pavement is combination of HMA and PCC pavements.

Occasionally, they are initially constructed as composite pavement rehabilitation.

## 2.3 Pavement Design Methods:

**Flexible Pavement:**

### 2.3.1 Empirical Methods:

The empirical methods are based on past experience and may include laboratory or filed tests of the sub-grade and pavement materials.

Empirical methods of pavement design have played an important role in determining the thickness of pavement structure for many years, the major advantage of the empirical method is that the design procedure is relatively easy and fast to perform.

### A. TRL Method:

For designing a new road pavement : estimating the amount of traffic and the cumulative number of equivalent standard axle load assessing the strength of Sub-grade soil and selecting the most economical combination of pavement materials and layer thickness.

### B. CBR Method:

This pavement design method is presented as design curves relating CBR, wheel load and thickness.

### 2. Asphalt Institute Method:

1. This method applies elastic layered theory to pavement design.

2. Layer materials are characterized by modulus of elasticity and position ratio .
3. laws of mechanics are applied to predict critical stressed and strain.
4. Temperature effects is represented by annual air temperature.
5. Traffic is expressed in terms of equivalent single axle load
6. Determined CBR design and MR design.
7. Uses design charts to get a full depth thickness.

**3. AASHTO Design Method:**

The purpose of the AASHTO model in the pavement thickness design process is to calculate the required structural number (SN).

**The Procedure :**

1. The strength (Mr) of sub-grade or determined layer.
2. The number of equivalent" daily 18000 Ib single axle load.
3. Given the reliability R, traffic and performance prediction stand error (So) sum ESAL (W18), layer Mr and PSI the structural number is determined from the design chart or from equation.
4. Determined the combinations of pavement base and sub-base thickness that will develop the required structural number (SN ) this is obtained the equation.

$$SN = a1D1+a2D2m1+a3D3m2 \ldots\ldots\ldots (2.1)$$

Where :

al, a2, a3 are layer coefficients

m1, m2 are drainage factors

D D2, D3 the thickness of AC surface, base course and sub-base course.

**4, Mechanistic Methods :**

The theoretical approach for designing flexible pavement , which is called mechanistic method or analytical method. This method uses fundamental physical properties and theoretical model of each

pavement material to predict the stresses, strain and deflection due to load on the pavement material.

**A. Layered System Method:**

In 1943, Burmister provided analytical expression for stresses and displacement in tow and three layers elastic systems due to static loads. Burmister first developed solution for two layer system and the extended them to three layer systems, with advent of computers.

**B. Shell Pavement Design Method SPDM:**

The Windows program (SPDM) contains modules for thickness design, rutting calculation and asphalt overlay design.

### 2.3.2 Rigid Pavement:

## 1. Mechanistic Method:

## A. Portland Cement Association:

The Portland Cement Association (PCA) thickness -design procedure for concrete pavement was published in 1984, superseding that of 1966. The method can be applied to jointed plain concrete pavement (JPCP) jointed reinforced concrete pavement (JRCP) and continuously reinforced concrete pavement (CROP).

## B. AASHTO Method:

The design procedure based on the empirical obtained from the AASHTO Road Test, with further modification based on theory and experience.

### 2.3.3 Pavement Design Guide 2002(AASHTO):

The 2002 Guide for Design of New and Rehabilitated Pavement Structures will constitute a significant revision to the pavement design and analysis procedure currently used throughout the world. Some general features of the Guide are Summarized below :

i. The Guide presents procedures for the design and analysis of all commonly used new and rehabilitated pavement systems. Particular emphasis is placed on pavement rehabilitation including procedures for life-cycle cost analysis (LCCA) evaluations of existing pavements, as well as recommendations on rehabilitation treatments, sub-drainage, and foundation improvements for problem soils.

2. The Guide uses the calibrated mechanistic design procedure that allows the full integration of material characterization, climate condition, and traffic loading into pavement design.

3. The Guide integrates the design methodologies for the various types of pavements whenever feasible. The same design parameters, such as material and soil characterization, climate factors, traffic analysis, arid reliability, will be used across all pavement types. This integration of input parameters puts all types of pavements on an equitable basis and allows the use of alternate pavement types for comparison.

4. The Guide uses a hierarchical approach for determining the design inputs.

5. The Guide eliminates the equivalent single axle load (ESAL) approach and use the full spectra of axle loads applied to a pavement structure by the prevailing or projected traffic stream.

# CHAPTER THREE
# DESIGN OF FLEXBLE HIGHWAY PAVEMENT

## 3.1 Flexible Pavement Components:

### 3.1.1 Introduction

A typical flexible (or asphalt) pavement consists of surface, base course, and sub-base built over compacted sub-grade (natural soil) as shown in Figure 3.1. In Some cases, the sub-base layer is not used, whereas in a small number of cases both base and sub-base are omitted The surface layer is made of hot-nix asphalt (HMA) (also called asphalt concrete). The material for the base course is typically unstabilized aggregates.

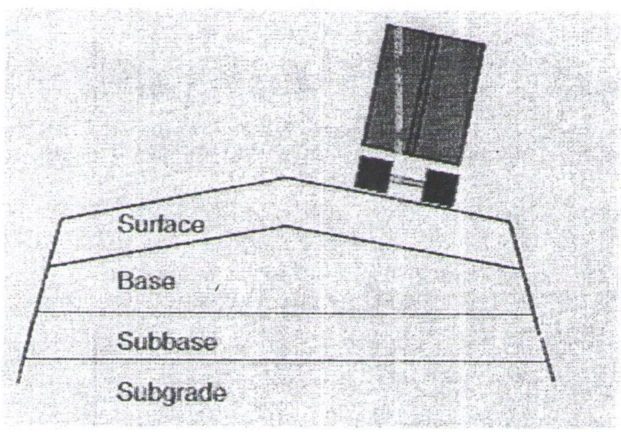



**Figure 3-1 : Typical layers of flexible pavement**

### 3.1.2 Base and Sub-base Materials:

There are several underlying layers that play a critical role in the performance of a pavement. This includes bases, sub-bases, and sub-grades. These layers consist primarily of treated and untreated aggregates. The base course is the layer of material immediately beneath the surface or binder course. It can be composed of crushed Stone crushed slag, or other untreated or stabilized materials. The sub-base course is the layer of material beneath the base course . The reason that two different granular materials are used is for economy. Instead of using the more expensive base course material for the entire layer, local materials can be used as a sub-base course on top of the sub-grade. If the base course is open graded, the sub-base course with more fines can serve as a filter between the sub-grade and the base course . The top 6 in . (152 mm) of sub-grade should be scarified and compacted to the desirable density near the optimum moisture content. This compacted sub-grade may be the in-situ soil

or a layer of selected material.

### 3.1.3 Aggregate :

Mineral aggregates make up 90 to 95% of a HMA mix by weight or approximately 75 to 85% by volume. Their physical characteristics are responsible for providing a strong aggregate structure to resist deformation due to repeated load applications.

Aggregate is defined as "a granular material of mineral composition such as sand, gravel, shell, slag, or crushed stone, used with cementing medium to form mortars or concrete or alone as in base courses, railroad ballasts, etc. Natural aggregates are mined from river or glacial deposits. Gravel and sand are examples of natural aggregates.

Gravel is normally defined as aggregates passing the 3 in. (75 mm) sieve and retained on the No. 4 (4.75 mm) sieve. Sand is usually defined as aggregate passing the No. 4 sieve with the silt and clay fraction passing the No. 200 (0.075 mm) sieve. These aggregates in their natural form tend to be smooth and round. Aggregate mineralogical and chemical makeup are important in evaluating characteristics such as hardness (toughness), soundness (durability), shape, and Stripping potential.

### 3.1.4 Hot-Mix Asphalt Concrete HMAC:

HMAC consists primarily of mineral aggregates, asphalt cement for binder), and air. It is important to have suitable proportions of asphalt cement and aggregate in HMAC so as to develop mixtures that have desirable properties associated with good performance. These performance measures include the resistance to the three primary HMAC distresses: permanent deformation, fatigue cracking, and low temperature cracking.

The road industry in Sudan costs relatively high compared to several other countries mainly due to using hot mix asphalt (HMA) for flexible pavement surface layer.

All asphalt materials used in road construction are imported costing the country excessive foreign currency ... the high cost of importing bitumen amounting to one thousand US dollars perton, and lack of paved roads for most parts of the largest country in Africa led to spending huge sums of scarce resources of foreign currency.

### 3.2 Design Factor:

Design factor can be divided into four categories:

1. Traffic loading and volume.
2. Material
3. Environment
4. Failure criteria

#### 3.2.1 Traffic Loading and Volume:

Traffic is the most important factor in pavement design. The consideration of traffic should include both the loading magnitude and configuration and the number of load repetitions.

**Equivalent Single Axle Load:**

An equivalent axle load factor (EALF) defines the damage per pass to pavement by the axle in question relative to the damage per pass of standard axle load usually the 18-Kip (80-Kn) single – axle load. The design based on the total number of passes of Standard axle load during the design period, defines at the equivalent single axle load (ESAL) and computed by

$$ESAL = \sum Fi * Ni \text{ ……………………..(3.1)}$$

Where, (Fi) is the EALF for the ith-axle load group and (Ni) is the number of basses of each axle load group during the design period.

### 3.2.2 Traffic Analysis:

To design a highway pavement, it is necessary to predict the number of repetitions of each axle load group during the design period. The initial daily traffic is in two directions overall traffic lanes and must be multiplied by the directional and lane distribution factors to obtain the initial traffic on the design lane. The traffic to be used for design is the average traffic during the design period, so the initial traffic must be multiplied by a growth factor.

If ni, is the total number of load repetitions to be used in design for the ith load group. The following formulas are used do obtain the design ESAL:

Daily ESAL= $\{\sum(\mathrm{NA} * \mathrm{EALF}) / \mathrm{ADT} * (\frac{\mathrm{D}}{100\left(\frac{\mathrm{PT}}{100}\right)}\}$ .........(3.2)

where:

| | |
|---|---|
| NA | = number of axles in each axle group |
| EALF | =equivalent axle load factor |
| ADT | =average daily traffic at the start of the design |
| NT | =number of trucks surveyed by day |
| D | = directional split of traffic |
| PT | =% trucks in ADT |
| Design ESAL | = Daily ESAL*365*Growth Factor |

Where:

Growth Factor = ((1+r)^n-1) ………………(3.3)

Where:

n = the design period

r = the growth rate.

## 3.3 Design Methodologies:

### 3.3.1 AASHTO Method:

#### *3.3.1.1 Introduction:*

The design procedure recommended by the American Association of State Highway and Transportation Officials (AASHTO) is based on the results of the extensive AASHO Road Test. The empirical performance equations obtained from the AASHO Road Test are still being used as the basic models in the current guide, but were modified and extended to make them applicable in different regions and climates. The original equations were developed under a gives climatic setting With a specific set of pavement materials and sub-grade soils. The climate at the test site is temperate with an average annual precipitation of about 34 in . (864 min). The average depth of frost penetration is about 28 in . (711 mm. The subgrade soils consists of A-6 and A-7-6 that are poorly drained, with CBR values ranging from 2 to 4.

#### *3.3.1.2 Design variables:*

### Time Constraints

To achieve the best use of available funds, the AASHTO design guide encourages the use of a longer analysis period for high-volume facilities, including at least one rehabilitation period. Thus, the analysis period should be equal to or greater than the performance period, as described below.

### Performance Period:

The performance period refers to the time that an initial pavement structure will last before it needs rehabilitation or the performance time between rehabilitation operations.

### The analysis period

The analysis period is the period of time that any design strategy must cover. It may be identical to the selected performance period.

**Table 3-1 : Length of Analysis Period**

| **Highway conditions** | **Analysis period ( years)** |
|---|---|
| High-volume urban | 30-50 |
| High-volume rural | 20-50 |
| Low-volume paved | 15-25 |
| Low-volume aggregate surface | 10-20 |

**Traffic:**

The design procedures are based on cumulative expected 18-lip (80kN) equivalent single-axle load (ESAL).

**Reliability:**

Reliability is a means of incorporating some degree of certainty into the design process to ensure that the various design alternatives will last the analysis period. The level of reliability to be used for design should increase as the volume of traffic, difficulty of diverting traffic, and public expectation of availability increase.

Application of the reliability concept requires the selection of a standard deviation that is representative of local conditions. It is suggested that standard deviations of 0.49 be used for flexible pavements and 0.39 for rigid pavements.

These correspond to variance of 0.2401 and 0.1521.

**Table 3-2 : Levels of Reliability for Various Functional Classification**

| Functional classification | Recommended level of reliability | |
|---|---|---|
| | Urban | Rural |
| Interstate and other freeways | 85-99.9 | 80-99.9 |
| Principal arterials | 80-99 | 75-95 |
| Collectors | 80-95 | 75-95 |
| Local | 50-80 | 50-80 |

## Environmental Effects:

The AASHTO design equations were based on the results of traffic tests over a two-year period. The long-term effects of temperature and moisture on the reduction of serviceability were not included. If problems of swell clay and frost leave are significant in a given region and have not been properly corrected, the loss of serviceability over the analysis period should be estimated and added to that due to cumulative traffic loads.

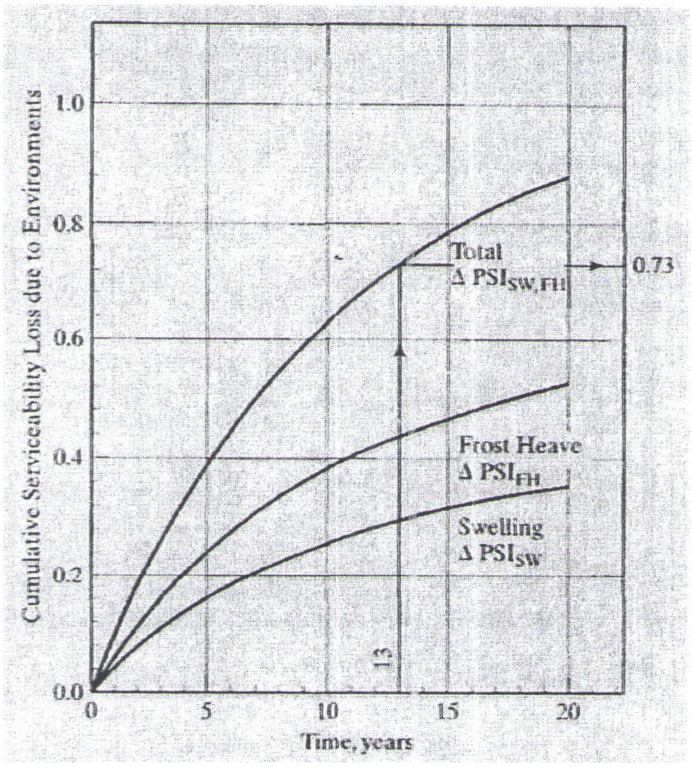



**Figure 3-2 : Environmental serviceability loss versus time**

Figure 3.2 shows the serviceability loss versus time curves for a specific location. The environmental loss is a summation of losses from both swelling and frost heave . The chart may be used to estimate the serviceability loss at any intermediate period.

**Serviceability:**

Initial and terminal serviceability indexes must be established to compute the change in serviceability PSI, to be used in the design equations. The initial Serviceability index is a function of pavement type and construction quality . Typical values from the AASHO Road Test were 42 for flexible pavement and4.5 for rigid pavement. An index ofn2.5 or higher is suggested for design of major highways and 2.0 for highways with lower traffic. For relatively minor high ways where economics dictate a minimum initial capital outlay, it is suggested that this be accomplished by reducing the design period or total traffic volume, rather than by designing a terminal serviceability index less than 2.0.

**Design Equation :**

The original equations were based purely on the results of the AASHO Road Test but were modified later by theory and experience to take care of sub-grade and climatic conditions other than those encountered in the Road Test.

$$SN = a1*D1+a2*D2*m1+a3*D3*m2 \quad \text{………………}(3.4)$$

Where:

a1,a2,.a3 : layer coefficient for the surface base sub-base respectively

$a2= 0.249 (\log E2)-0.2977$………………(3.5)

$a3=0.277 (\log E3 )-0.839$ ………………(3.6)

D1, D2, D3: thickness of the surface base sub-base respectively

m1 m2 drainage coefficient for base, sub-base respectively.

**7. Design Procedure:**

Using E2 as MR, determine from monograph the structural number SN1 required to protect the base, and compute the thickness of lay

$$D1 \geq \frac{SN1}{a1} \ldots\ldots\ldots\ldots\ldots\ldots (3.7)$$

2. Using E3 as MR, determine from monograph, the structural number SN2required to protect the sub-base, and compute the thickness of layer 2 from:

$$D1 \geq \frac{SN2-a1D1}{a2m2} \ldots\ldots\ldots\ldots\ldots\ldots (3.8)$$

3. Based on the roadbed soil resilient modulus MR, determine from monograph the total structural number SN3 required, and compute the thickness of layer 3 from:

$$D3 \geq \frac{SN3-a1D1-a3D3}{a3m3} \ldots\ldots\ldots\ldots\ldots\ldots (3.9)$$

Or determining (SN) from equation:

$$\text{Log } W_{1s} = Z_R S_0 + 9.36 \text{ Log } (SN + 1) - 0.20 + \frac{Log\{\frac{\Delta PSI}{4.2} - 1.5)\}}{0.4 + 1094/(SN+1)^{5.19}}$$

$$+ 2.32 \text{ Log } M_R - 8.07 \ldots\ldots\ldots\ldots\ldots\ldots (3.10)$$

Where:

W18 = predicted number of 80 Kn (18000 Lb)

ZR = Standard normal deviation.

SO = combined standard error of traffic prediction and performance prediction.

A PS1 = difference between the initial design serviceability. Index, p0, and the design terminal serviceability index, Pt.

MR = Sub-grade resilient modulus (in psi).

### 3.3.2 Asphalt Institute Method:

## I. Introduction:

This method is used to determine thickness from a computer program and design chart, it depends on traffic (ESAL) and strength (Mr) only.

## 2. Design alternatives:

## A. Full-Depth HMA:

Figure is the design chart for full-depth asphalt pavements. Given the sub-grade resilient modulus MR and the equivalent 18-kip single-axle load, ESAL, the total HMA thickness, including both surface and base courses, can be read directly from the chart.

## B. AC over Emulsified Asphalt Base:

There are three types of mixes specified :

Type I: mixes with processed dense graded aggregates, which should be mixed in a plant and have properties similar to HMA.

Type II: mixes with semi processed, crusher run pit run, or bank run aggregates.

Type III: mixes with sands or Silty sands

The minimum thickness for HMA over the emulsified asphalt layer varies with the traffic level, as shown in table 2.3.

**Table 3-3 : Minimum Thickness for HMA Over Emulsified**

| Traffic level ESAL | HMA thickness for type I mix (in.) | HMA thickness for type II and type III mixes (in.) |
|---|---|---|
| $10^4$ | 1 | 2 |
| $10^5$ | 1.5 | 2 |
| $10^6$ | 2 | 3 |
| $10^7$ | 2 | 4 |
| $>10^7$ | 2 | 5 |

**C. AC over Untreated Aggregate Base:**

The designer must first determine the thickness of aggregate base to be used and Select the design chart to find HMA thickness.

**D. HMA and Emulsified Asphalt Mix over Untreated Aggregate Base:**

Design charts for pavements consisting of a HMA Surface, an emulsified asphalt base, and an untreated base are currently not available. The following method has been recommended by the Asphalt Institute .

1. Design a full-depth HMA pavement for the appropriate traffic and sub-grade conditions . Assume a 2-in . (51-mm) surface course, and calculate the corresponding base thickness.
2. Design a pavement for the same traffic and sub-grade conditions, using the Selected emulsified mix type. Assume a 2-in. (51-mm) surface course, and calculate the corresponding base thickness.
3. Divide the thickness of the emulsified asphalt base in step 2 by the thickness of the HMA base in step 1 to obtain a substitution ratio.
4. Design a pavement for the same traffic and sub-grade conditions, using HMA and untreated base.
5. Select a portion of the HMA thickness to be replaced by the emulsified asphalt mix, based on the minimum HMA thickness.
6. Multiply the above thickness by the substitution ratio determined in step 3to obtain the thickness of emulsified asphalt mix required.

#### 3.3.3 Layered System Method :

The method depend on Burmister's layered system theory. The theory developed solution for two layer system and then extended to deal with three layer system and now the theory using computer software.

**The basic assumptions to be satisfied are:**

1. Each layer is homogeneous, isotropic, and linearly elastic with an elastic modulus E and a Poisson ratio v.
2. The material is weightless and infinite in areal extent.
3. Each layer has a finite thickness h, except that the lowest layer is infinite in thickness.
4. A uniform pressure q is applied on the surface over a circular area of radius
5. Continuity conditions are satisfied at the layer interfaces, as indicated by the Same vertical stress, shear stress, vertical displacement, and radial displacement.

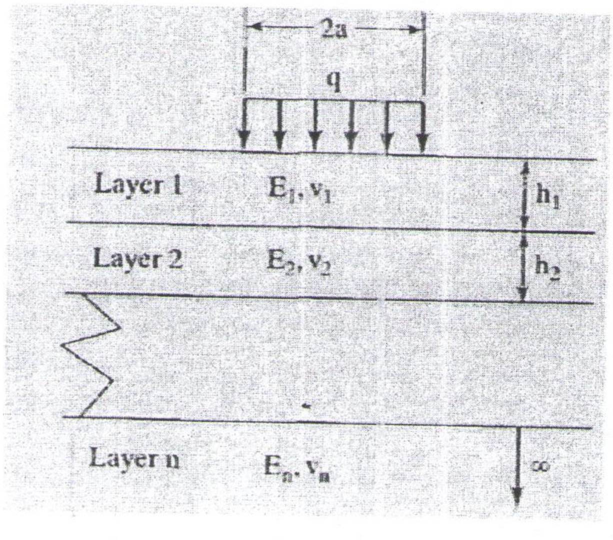



**Figure 3-3 : Multi-layer System Subjected to a Circular Load**

## 1. Two-Layer Systems:

The exact case of a two-layer system is the full-depth construction in which at hick layer of HMA is placed directly on the sub-grade. If a pavement is composed of three layers . It is necessary to combine the base course and the sub-grade into a single layer for computing the stresses and strains in the asphalt layer or to combine the asphalt surface course and base course for computing the stresses and Strains in the sub-grade

# CHAPTER FOUR

# DESIGN OF RIGID HIGHWAY PAVEMENT

The concrete pavements have been used for highways, airport, streets, local roads, parking lots, industrial facilities, and other types of infrastructure .when properly designed and built out of durable material, concrete pavements can provide many decades of service with little or no maintenance. Concrete generally has a higher initial cost than asphalt but lasts longer and has lower maintenance costs.

## 4.1 Rigid Pavement Components:

### 4.1.1 Sub-Grade Soil:

A wide range of materials can be used as unbound road-bases including crushed quarried rock, crushed and screened, mechanically stabilized, modified or naturally occurring as dug gravels. Their suitability for use depends primarily on the design traffic level of the pavement and climate but all road-base materials mist have a particle size distribution and particle shape which provide high mechanical stability and should contain sufficient fines (amount of material passing the 0.425 mm sieve) to produce a dense material when compacted.

### 4.1.2 Base Course:

Early concrete pavements were constructed directly on the sub-grade without a base course. As the weight and volume of traffic increased, pumping began to occur, and the use of a granular base course became quite popular . When pavements are subject to a large number of very heavy wheel loads with free water on top of the base course, even granular materials can be eroded by the positive action of water . For heavily traveled pavements, the use of a cement-treated or asphalt treated base course has now become a common practice.

### 4.1.3 Surface Course :

#### *4.1.3.1 .Introduction:*

Typical concrete is composed of coarse aggregate (crushed Stone and gravel),fine aggregate such as sand port land cement and water. The concrete can be modified in a number of ways , including the addition of cementations material other than Portland cement, or through the use of admixture, which are material that are added to mixture to enhance the properties of the fresh or hardened concrete PC pavement are subject to challenging environments and load over their lifetimes so the concrete must be strong and durable , yet cost effective and Workable The surface course can vary in thickness but is usually between 150 mm for light loading and 300 mm for heavy loads.

#### *4.1.3.2 . Joints:*

- **Expansion Joints:**

Expansion joints are full-depth transverse or longitudinal joints designed to allow for concrete slab expansion, thereby relieving compressive stresses due to temperature rise, and avoiding blowups on hot summer days. Expansion joints should be spaced at 60 m intervals for slabs thicker than 200 mm, and 40 m for thinner slabs. The gap width of the expansion joint is usually of the order of 20 to 25 mm (3/4 to 1 in.). The width required depends on the difference between the temperature at which the concrete is laid and the maximum service temperature, the coefficient of thermal expansion of the concrete, the frictional restraint provided by the sub-grade or Sub-base, and the compressibility of the joint filling material.

- **Contraction joints:**

Contraction joints are transverse or longitudinal joints constructed to reduce slab length or width as a means to decrease temperature induced stresses (warping stresses as well as tensile stress caused by slab movements), control spacing and width of cracks caused by thermal forces or moisture changes, and to allow for thermal contraction of the concrete slabs. The maximum acceptable spacing of contraction joints is a function of slab thickness, amount of steel reinforcement provided, tensile strength of the concrete, thermal coefficient of thermal expansion of the concrete, magnitude of temperature change in the area, aid frictional resistance at the bottom face of the pavement. Higher values of the first two factors will allow the joint spacing to increase, while any increase in the latter three factors will call for smaller joint spacing. The required amounts of steel reinforcement for joints spacing of 35 m, 21 m and 10 m are 555, 3.41 and 1.73 kg per m3 of slab volume, respectively.

**Figure 4-1 : Rigid Pavement in Khartoum (Soba)**

## 4.2 Design Factor :

The design thickness is governed by the following four major design factor:

### 4.2.1 Traffic Loading:

Traffic loading is used as an input in the design of rigid pavements in the form of axle load distribution. To be able to compare flexible and rigid pavements, they should be designed for the same traffic loading. Therefore, the same traffic loadings that were used in the design of flexible pavements were converted into ALD for their use in the design of rigid pavements

ESAL Equation:

1. ESAL= (NA*EALF*NT)*ADT*D/100*PT/100……(4.1)
2. ∑ ESAL= ESAL*365*((1+i)**n)-1)+i………………(4.2)

**Where:**

NA = number of axle group

EALF= load equivalent axle load factor.

NT = number of trucks surveyed per day

ADT = average daily traffic during first year (vpd)

D = direction split of traffic flow.

PT = percent of trucks in ADT.

### 4.2.2 Sub-Grade and Sub-Base Support:

Sub-grade and sub-base support is defined by the modulus of sub-grade reaction, k. Methods for determining the modulus of sub-grade reaction The contention is that the reduced sub-grade support during thaw periods has very little or no effect on the required thickness of concrete pavements, as evidenced by the results of AASHO Road Test.

### 4.2.3 Concrete Modulus of Rupture:

The modulus of rupture is determined by the same beam test, but with a steadily increasing static load, as specified by ASTM (1989a) in "C78-84 Standard Test Method for Flexural

Strength of Concrete Using Simple Beam with Third Point Loading. The 28-day flexural strength is used as the design strength.

### 4.2.4 Elastic Modulus of Concrete:

The Ec can also be estimated from the compressive strength by the following expression.

Ec = $4730\sqrt{(fc)}$ (Ec and fe in MPa) ………………(4.3)

Fic = $57000\sqrt{(fc)}$ (Ec and fe in psi) ………………(4.4)

### 4.2.5 Design Period :

The "design period" should not be confused with the term "pavement life." which is not subject to precise definition "Design period" is more nearly synonymous with the term "traffic analysis period ." Because traffic probably cannot be predicted with much accuracy for a longer period, a design period of 20years has commonly been used in pavement design.

# CHAPTER FIVE
# CASE STUDY AND RESULTS

## 5.1 Road Information

Road Name : Madeena Riyadiea College Street

Location : Khartoum – Sudan

Length : 0.517Km

- Traffic Analysis
- Statistic Analysis

## 5.2 Traffic

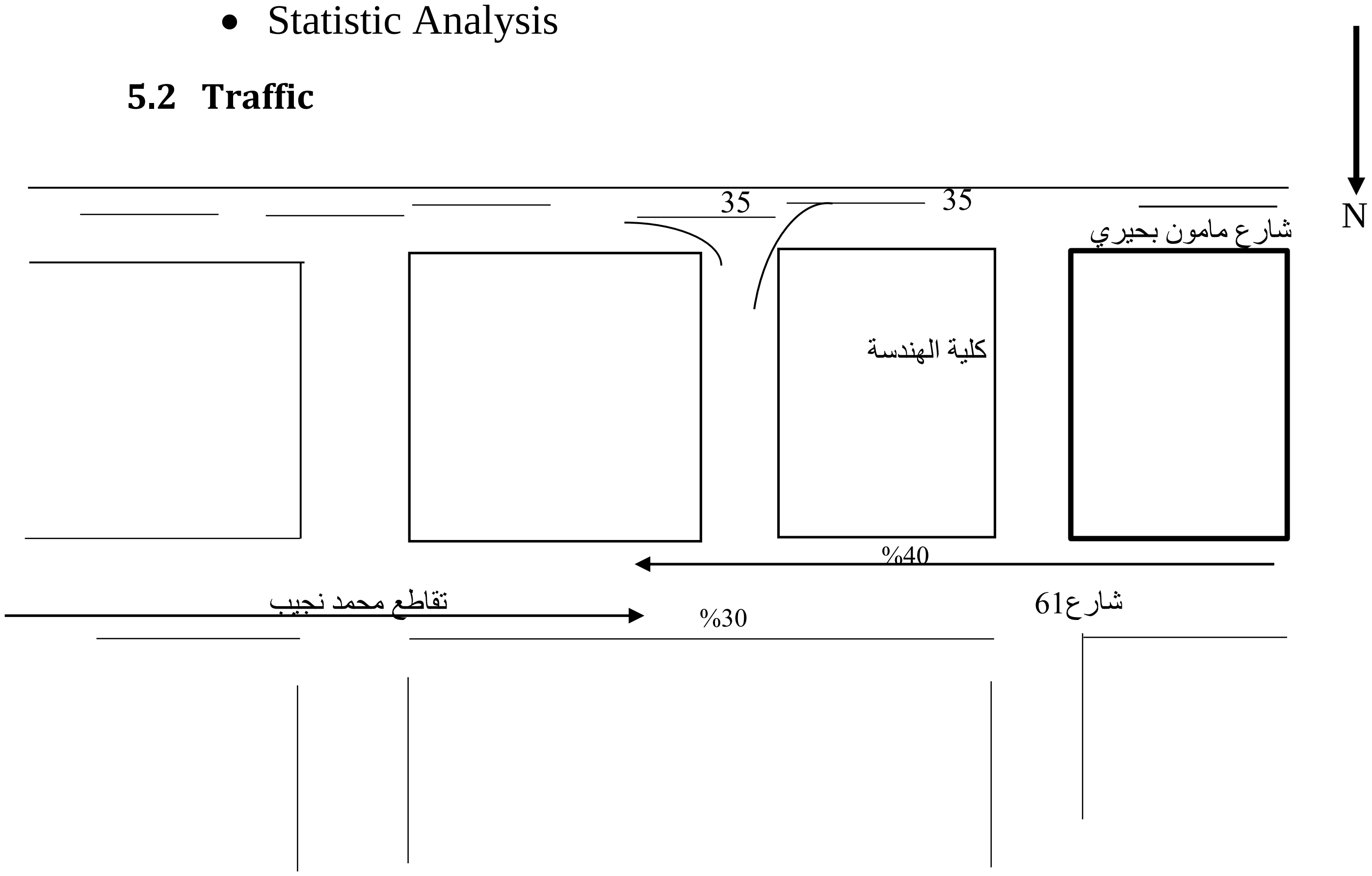



Figure 5-1 : Plan for Case Study to Estimate Travel

**Determine The ADT:**

This Road will contain anew travel from the Roads

Mamon behair 35%

Mamon behair × alshargi 35%

## Summary

**Table 5-1 : Summary for Presented Traffic**

| from | to | D% |
|---|---|---|
| 61 zalat | 61 sharg | 40% |
| 61 sharg | 61 zalat | 30% |
| Mamon bhairy zalat | Mamon bhairy sharg | 35% |
| Mamon bhairy shareg | Mamon bhairy zalat | 35% |

## Traffic:

## Site data :

**Table 5-2 : Street 61 Cross with Mohamed Najeeb Street**

| time | Cars | | Track | | bicycle | |
|---|---|---|---|---|---|---|
| Sunday 2/4/2017 | Left | right | Left | right | Left | right |
| 8-10 | 512 | 720 | 8 | 24 | 43 | 31 |
| 10-12 | 634 | 701 | 30 | 60 | 51 | 40 |
| 12-2 | 643 | 687 | 44 | 82 | 45 | 58 |
| 2-4 | 812 | 514 | 72 | 46 | 71 | 56 |
| 4-6 | 735 | 496 | 44 | 60 | 65 | 47 |
| Tuesday 4/4/2017 8-10 | 603 | 712 | 20 | 14 | 56 | 55 |
| 10-12 | 647 | 761 | 22 | 36 | 53 | 6 |
| 12-2 | 654 | 601 | 44 | 62 | 82 | 61 |
| 2-4 | 791 | 616 | 40 | 74 | 100 | 71 |
| 4-6 | 811 | 515 | 66 | 80 | 85 | 88 |
| | | | | | | |
| Thursday 6/4/2017 8-10 | 517 | 612 | 80 | 24 | 106 | 88 |
| 10-12 | 431 | 571 | 61 | 61 | 56 | 94 |
| 12-2 | 718 | 912 | 36 | 56 | 94 | 101 |
| 2-4 | 642 | 731 | 50 | 74 | 94 | 88 |
| 4-6 | 812 | 797 | 88 | 82 | 102 | 84 |
| | | | | | | |

**Table 5-3 : Street 61 Cross With Mamon Bhairy Street**

| time | cars | | track | | Bicycle | |
|---|---|---|---|---|---|---|
| Sunday 2/4/2017 | Left | right | Left | right | Left | right |
| 8-10 | 712 | 827 | 80 | 64 | 101 | 88 |
| 10-12 | 807 | 912 | 48 | 60 | 75 | 81 |
| 12-2 | 824 | 605 | 50 | 84 | 90 | 102 |
| 2-4 | 726 | 618 | 66 | 102 | 74 | 90 |
| 4-6 | 817 | 412 | 160 | 126 | 141 | 132 |
| Tuesday 4/4/2017 8-10 | 614 | 727 | 24 | 82 | 96 | 19 |
| 10-12 | 781 | 875 | 66 | 114 | 91 | 96 |
| 12-2 | 810 | 711 | 120 | 86 | 121 | 123 |
| 2-4 | 914 | 547 | 142 | 24 | 145 | 158 |
| 4-6 | 712 | 910 | 24 | 116 | 71 | 78 |
| | | | | | | |
| Thursday 6/4/2017 8-10 | 801 | 809 | 36 | 40 | 106 | 81 |
| 10-12 | 827 | 914 | 80 | 62 | 115 | 106 |
| 12-2 | 786 | 615 | 92 | 102 | 90 | 81 |
| 2-4 | 949 | 786 | 132 | 88 | 115 | 97 |
| 4-6 | 1110 | 817 | 30 | 62 | 142 | 53 |
| | | | | | | |

We need to determine the average for two hours assuming that (Friday and Saturday) are having 0.5 daily traffic

Left ratio is 0.3

Average two hours = 9962/15 = 665

P. cars = 665 * 617 * 0.3 = 121

Average truck = 717/15 * 0.3 * 6/7 = 42

Right ratio is 0.4

P. cars = 9940/15 =664

664 * 0.4 *6/7 = 228 cars

Truck= 835/15 = 56*7 = 4.2

M = 70 * 6/7 * 0.4 = 24

## Summary

**Table 5-4 : Summary for Street 61 Cross with Mohamed Najeeb Street**

| Passenger cars | Trucks | Bicycle and motors |
|---|---|---|
| 399 | 33 | 41 |

## Mamon bhairy * (zalat and sharig)

- left ratio = 0.35
- passenger cars = 12190/15 = 813 * 6/7 * 0.35 = 246
- T = 28
- M = 32

Right ratio = 0.35

Passenger cars = 223

T =25

M =28

**Summary**

**Table 5-5 : Summary for Street 61 Cross with Mamon Bhairy Street**

| Passenger cars | T | M |
|---|---|---|
| 460 | 49 | 62 |

**Summary ADT:**

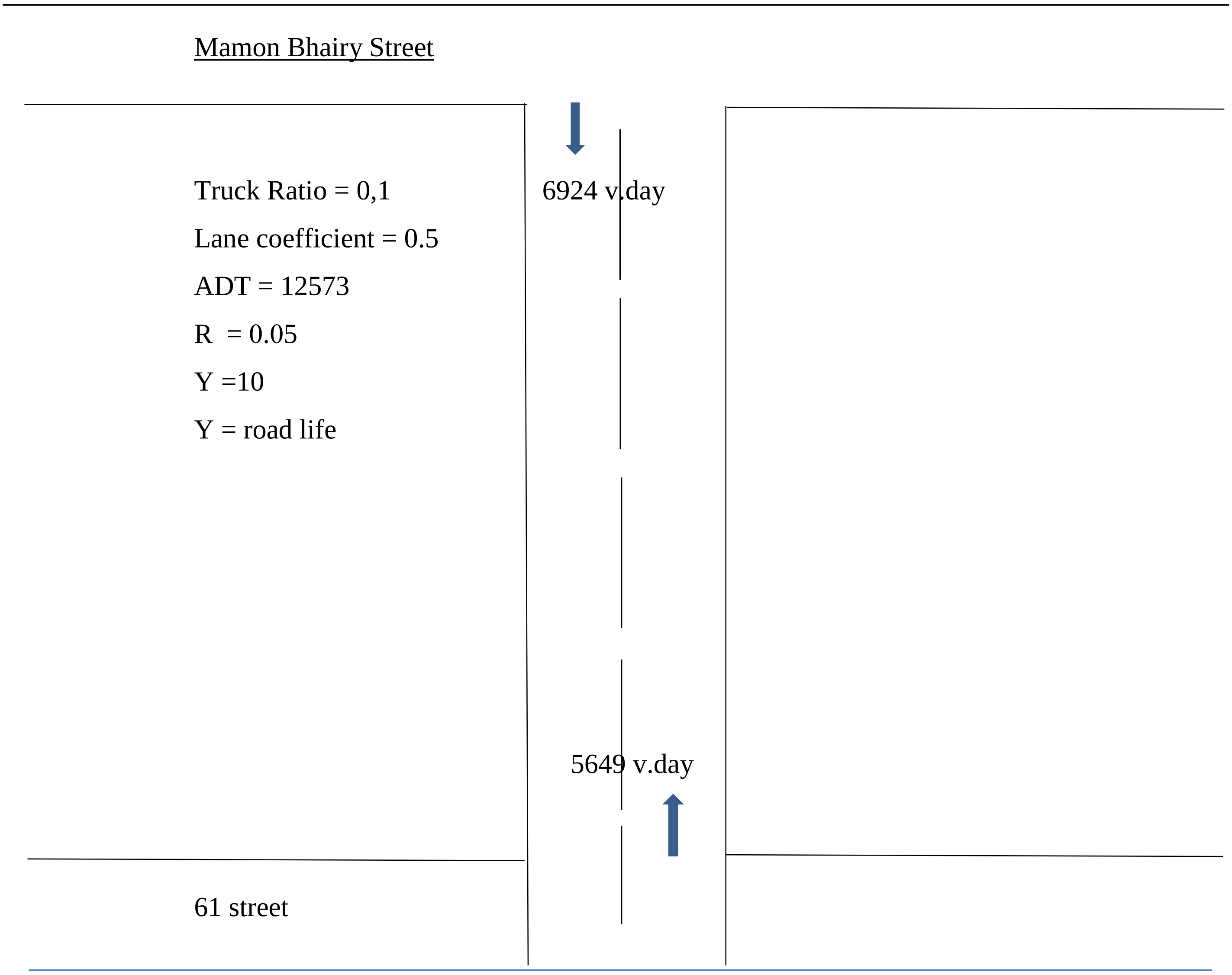



**Figure 5-2 : Plan to Explain the Estimated ADT for Case Study**

**Table 5-6 : Traffic Analysis Output**

| | |
|---|---|
| Analysis period = | 10 years |
| AADT | 12573 |
| Track percent | 10% |
| Track Equivalent Factor | 1 |
| Annual growth factor | 0.05 |
| Total Equivalent 18000 pound single axles per 100 track (table: A1) | 61.98 |
| Lane Direction Factor | 0.5 |

Daily ESAL = (Na * ESALF) * NT/100 * Dire/100 * pt/100

= 6/099/100 * 12573 * 0.5 * 0.10

= 389.7

$\sum ESAL$ = Daily ESAL * 365 * $\frac{\{(1+r)^n-1\}}{r}$

= 389.7 * 365 * $\frac{\{(1+1.05)^{10}-1\}}{0.05}$ = $1.7 \times 10^6$

## 5.3 Material Characteristic

Road name: Madeena Riyadiea  Collage street

Length: 0.517 Kilo

Location: Khartoum state

Soil characteristic

**Table 5-7 : Design Percentile for Sub Grade CBR**

| Sample No | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| CBR | 15 | 16 | 17 | 18 | 20 | 22 |
| CBR value % | 100% | 83% | 66.3% | 49.6% | 33.2% | 16.36% |

## 5.4 Design CBR:

Asphalt institute Criteria Method

**Table 5-8 : Design sub-Grade Resilient Modulus**

| Traffic level ESAL | Low $10^4$ | Media $10^4 - 10^6$ | Height > $10^6$ |
|---|---|---|---|
| Design Percent | 60 | 75 | 87.5 |

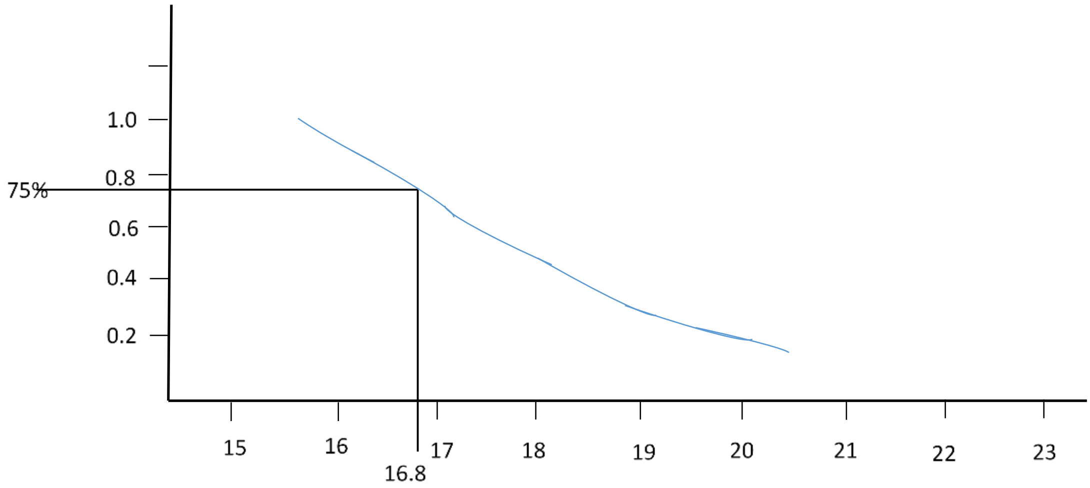



Figure 5-3 : CBR Value

Design CBR = 16.8

Use design

Asphalt institute < 20 CBR

**Table 5-9 : Finding MR Using CBR Value**

| | |
|---|---|
| MR psi | = 1500 × CBR |
| MRMPa | 10.342 × CBR |

$MR = 16.85 * 1500 = 2.5 \times 10^4$ PSI

## Subgrade Evaluation

The design CBR Percentile = 16.8

MR = 16.8 * 1500 = 25200 PSI = $2.4 \times 10^4$

### 5.5 Design Method

#### 5.5.1 Flexible Pavement

##### *5.5.1.1 Case Study Designed By Asphalt Institute Method*

Full Depth Ac

from figure (A-1)

= 7.5 IN = 190.5

**Emulsified Asphalt Base:**

from table A-2

Asphalt Type 2 = 3 in → (67.2m)

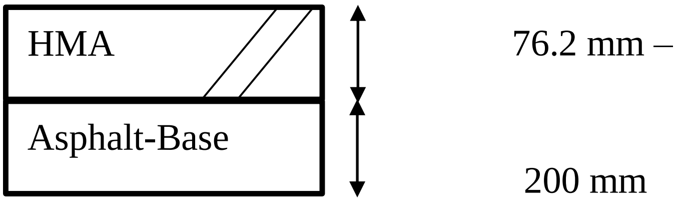



Figure 5-4 : Design Details Using Full Depth Institute Method

10.9 – 3 = 7.9

Untreated aggregate base 6 in granular Sub base

Figure 5.3 type II

Sub base ratio = 152/200 = 0.76

Total thickness 12 in

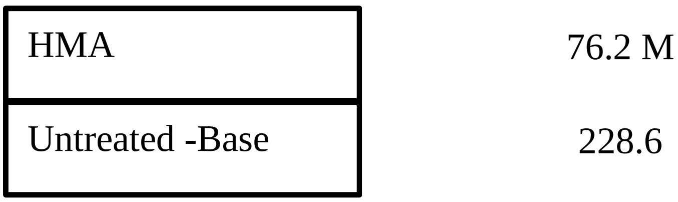



Figure 5-5 : Design Details Using Asphalt Institute Method

Use this optional with emulsified asphalt type II

The ratio between H.M.A and emulsified asphalt sub satiation ratio = 200.6/228.6 = 0.88

Minimum H.M.A = 76.2 mm

Emulsified Asphalt Base = 228.6 – 76.2 = 152.4 mm

152.4 * 0.88 = 134 mm

| | |
|---|---|
| HMA | 76.2 mm |
| EAB | 134 mm |
| Untreated aggrade | 152.5 mm |

**Figure 5-6 : Final Design Details Using Asphalt Institute Method**

### *5.5.1.2 Case Study Designed By AASHTO method:*

Design Input

R = 85%

$S_0$ = 35

Δ PSI = 4.2 – 2.0 = 2.2

DRANAGE Coefficient:

$M_1 = M_2 = 1$

$E_2$sb = 15.000 from AASHTO

$E_{3bs}$ = 30.000

**<u>Layer coefficient:</u>**

$a_1$ = 0.44 from figure

$a_2$ = 0.249 (log 30,000) – 0.977 = 0.871

$a_3$ = 0.227 log 15000 – 0.839 = 0.108

From figure A5

$SN_1 = 3.9$

$SN_2 = 2.7$

$SN_3 = 5.5$

$D_1 = SN_1/a_1$

$= 3.9/0.44 = 8.8$ in

$$D_2 = \frac{sn_2 - a_1 * D_1}{a_2 M_2} = \frac{2.7-(0.44*8.8)}{0.87}$$

1.3 in = 33 MM

$D_3 = SN_3 – a_1D_1M_1 – a_2D_2M_2 / a_3$

$$= \frac{5.5-(0.44*8.8)-(0.87*1.3)}{0.108} = 4.6 \rightarrow 116$$

| | |
|---|---|
| HMA | 23.5 mm |
| Granular Base | 33 mm |
| Granular Sub Base | 116 mm |

**Figure 5-7 : Design Details Using AASHTO Method**

### 5.5.2 Rigid pavement

#### *5.5.2.1 Case Study Designed By ASHTO Method*

## Design Traffic

**Table 5-10 : Design Input**

| Type | Passenger car | Light trucks | Median | Coach | Bus | Heavy tracks |
|---|---|---|---|---|---|---|
| ADT | 6924 | 15 | 13 | 60 | 80 | 2 |
| ELAF | 0.0003 | 0.28 | 0.55 | 0.02 | 0.48 | 8.35 |
| Na * F | 2.07 | 4.2 | 7.15 | 1.2 | 38.1 | 16.7 |

$\sum F \times N = 69.72$

ADT = 12,573

ESAL = $1.7 \times 10^6$

**<u>Design input:</u>**

Reliability (R) = 85%

MR = $2.4 \times 10^4$

Stander Deviation = 0.35

Service ability Δ PSI = 4.5 – 2 = 2.5

Sc = 650 PSI

Mean concrete modules of rupture (Sc) = 650 PSI

Ec = $5 \times 10^6$ PSI

K from figure A7 using 6 in Sub-Base

K = 110 PCI

J = 2.8

Drainage coefficient cd = 1.1

W18 = $1\times 10^6$

From AASHTOO Design chart for Rigid pavement

A10 →

7.5 inch

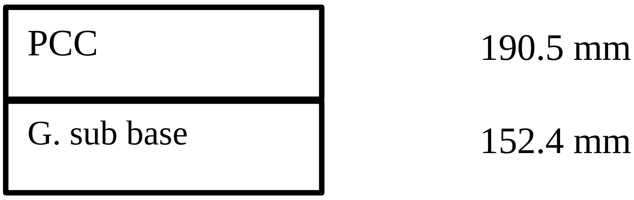



Figure 5-8 : Design Details Using AASHTO Method for Rigid

### *5.5.2.2 Case Study Designed By (PCA) Method*

***Given:***

***ADT=12573***
***Truck Per Day =2924***
***ADTT =2500***
***Modulus of Rupture = 650 Pci (4.5 MPa)***
***Untreated Granular Subbase =6-in (153mm)***
***MR = 2.5x10$^4$ (25 MN/m$^3$ ) = (92.2 Pci)***

Both ADT and ADTT fit well with axle-load category **4**. From **Table A5,** the ***k*** value of the subgrade and subbase combined is about 110 pci (29 .8 MN/m*3*), so the subgrade—subbase support is classified as **low** according to **Table A6**. From **Table A7,** a 9-in . (229-mm) slab gives an allowable ADTT of 5900; a 8.5-in . (216.75-mm) slab gives only 1500 . The predicted ADTT is 2500, so the use of 8.5- in. (216.75-mm) is adequate

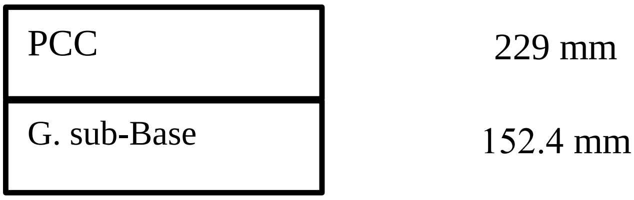



Figure 5-9 : Design Details Using PCA Rigid Method

## 5.6 RESULTS AND DISCUSSIONS

In this chapter the analysis has been done on both flexible and rigid pavement, according to AASHTO 93 design guide to road.

## 5.7 Comparison Between flexible and Rigid Pavement

The pavement thickness are calculated with the parameters above and the results obtain from different method for both pavements.

### 5.7.1 Comparison Between flexible Pavement Design:

The design thickness calculated from the average obtain from al, AASHTO, Elastic layer method for Elmading ELriyadia Road.

**Table 5-11 : Comparison Between Flexible Pavement Design**

| Layer | Surface (mm) | Base (mm) | Sub-base (mm) |
|---|---|---|---|
| - Al method<br>- Full depth | 76.2 | 134 | 152.5 |
| AASHTO method | 23.5 | 33 | 116 |
| % | 30.8 | 24.6 | 76.0% |

### 6.2.2 Comparison Between Rigid Pavement Design:

The design thickness calculated from the average thickness obtain from table below

**Table 5-12 : Comparison Between Rigid Pavement Design**

| Layer | PCC Per (mm) | Sub-Base |
|---|---|---|
| AASHTO (mm) | 190.5 | 152.4 |
| PCA (mm) | 229 | 152.4 |
| % | 83.1% | 100% |

# CHAPTER SIX

# SUMMARY, CONCLUSION AND RECOMMENDATION

## 6.1 SUMMARY

The study provides Asphalt institute, AASHTO for design of flexible pavement for one road study cases, while the AASHTO and PCA adopted for rigid pavement. The comparison had been made for construction cost via AASHTO design method for flexible and concrete pavement of the case Street. The comparing study include the design parameter, design method. By using the average design thickness for both pavements, the flexible pavement cost greater than jointed-plain concrete.

## 6.2 CONCLUSION:

1. This study was conducted to characterize and compare currently available used pavement types, flexible and rigid pavement design methods with pavement total depth and performance is generally the major factor in deciding the type of pavement to be constructed.
2. Selected as a case study for this research Madeena Riyadiea Road represent the state road.
3. The results show advantage of applying concrete in favor of flexible pavement

### 6.3 RECOMMENDATION:

The following recommendation for using rigid pavement

1. Using rigid pavement because of the existence of the initial material from naturalness concrete sand and powder.

2. Using rigid pavement because the surface must be totally plain without transience lean, which fits highways.

3. Dragging resistance immensely few in rigid pavement.

4. Using rigid pavements does not cause sliding of vehicles when surfaces are wet. for example when RAIN happens. -

5. The concrete less effected with heat than flexible roads.

6. Designing age is immensely big more than 20 year.

7. Maintenance cost is insignificant.

8. Light colour of the surface gives better vision for the driver at night.

9. Erosion of the surface is insignificant without undulation and twist.

10. Specialized government factories to produce and provide concrete for use in roads instead of import asphalt.

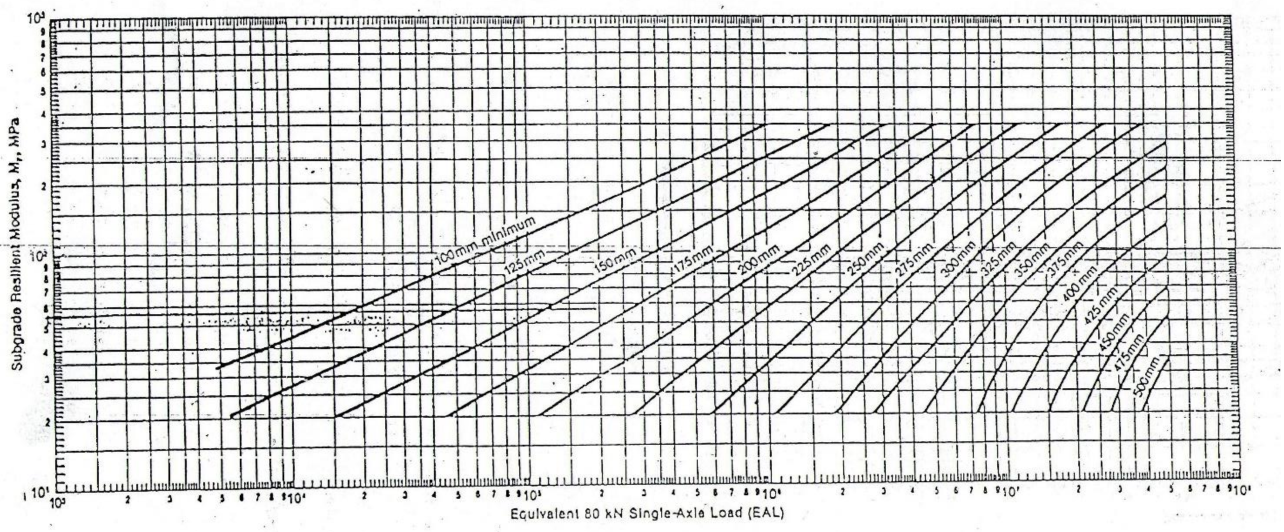
11. Usage of computer software in the design process.

## REFERENCES:


1. American Association of State Highway and Transportation Officials, "AASHTO Guide for Design of Pavement Structure ", 1993.
2. Akakin, T, Engin, Y, Ucar, S "Initia1 Cost Comparison of Rigid and Flexible Pavements: Under Different Traffic and Soil Conditions", Turkish Ready Mix Concrete Association, Turkey, 2009.
3. Ali, G, El Niema, A, El Obied, H "Feasibility of Using Concrete Pavement in Developing Hot Climate Countries: Case Study for Conditions of Khartoum State in Sudan", 9"' International Concrete Conference, Bahrain, 2013. '
4. Bautista, F, Basheer, I "Guide for Design and Construction of New Jointed Plain Concrete Pavements" 2008 Office of Pavement Design, Pavement Design and Analysis Branch.
5. Bezabih, AG & Chandra, S "Comparative Study OF Flexible and Rigid Pavements for Different Soil and Traffic Conditions", Journal of Indian Roads Congress, Paper No. 554, pp. 153-162, 2009.
6. F wa, T. F " The Civil Engineering Handbook", 2°d Edition, CRC Press LLC, 2003
7. Garber, N.J & Hoel, L.A "Traffic and Highway Engineering", West Publishers, 1988.
8. Huang, Y.H "Pavement Analysis and Design", 31" Edition, Pearson Prentice, 2011.

**APPENDIX**

# Figure A1: Full – Depth asphalt Concrete




Design Chart VI-1.

Table A1: equivalent axle load computation
(P = 2.0 and S = 4)

| Axle Load (kips) | Single Axles per 100 Trucks | | | Tandem Axles per 100 Trucks | | |
|---|---|---|---|---|---|---|
| | Number | F | N × F | Number | F | N × F |
| Under 3000 | 75.3 | 0.0002 | 0.02 | | | |
| 3–5 | 29.9 | 0.002 | 0.06 | | | |
| 5–7 | 10.5 | 0.01 | 0.11 | | | |
| 7–9 | 3.4 | 0.03 | 0.10 | | | |
| 9–11 | 4.2 | 0.08 | 0.34 | | | |
| 11–13 | 3.0 | 0.18 | 0.54 | | | |
| 13–15 | 4.1 | 0.35 | 1.43 | 0.1 | 0.03 | 0.01 |
| 15–17 | 9.3 | 0.61 | 5.78 | 0.5 | 0.05 | 0.03 |
| 17–19 | 11.0 | 1.00 | 11.00 | 1.5 | 0.08 | 0.12 |
| 19–21 | 8.0 | 1.55 | 12.40 | 2.0 | 0.12 | 0.24 |
| 21–23 | 5.0 | 2.31 | 1.55 | 3.6 | 0.17 | 0.61 |
| 23–25 | 1.1 | 3.33 | 3.66 | 4.2 | 0.25 | 0.11 |
| 25–27 | | | | 8.4 | 0.35 | 2.94 |
| 27–29 | | | | 9.2 | 0.48 | 4.41 |
| 29–31 | | | | 5.0 | 0.64 | 3.20 |
| 31–33 | | | | 1.2 | 0.84 | 1.00 |
| 33–35 | | | | 0.8 | 1.08 | 0.86 |
| 35–37 | | | | 0.4 | 1.38 | 0.65 |
| 37–39 | | | | 0.2 | 1.72 | 0.34 |
| 39–41 | | | | 0.1 | 2.13 | 0.21 |
| 41–43 | | | | 0.1 | 2.62 | 0.26 |
| Totals[a] | | | 46.99 | | | 14.99 |

[a] Total equivalent 18,000-pound single axles per 100 trucks on road: 46.99 + 14.99 = 61.98

Table A2

| Traffic level ESAL | HMA Thckness For type I | HMA thickness For type II , III |
|---|---|---|
| 10000 | 1 | 2 |
| 100000 | 1.5 | 2 |
| 1000000 | 2 | 3 |
| 10000000 | 2 | 4 |
| > 10000000 | 2 | 5 |

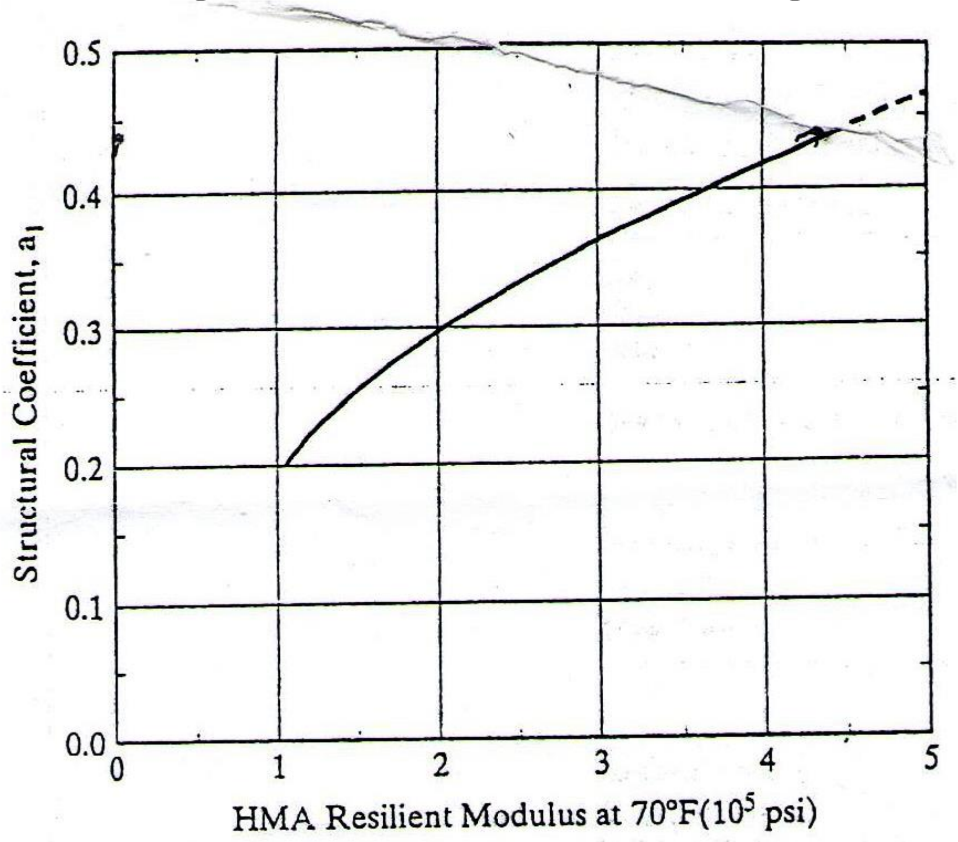
**Minimum thickness**

**Table A3: Suggested Levels Of Reliability For Various Function Classification**

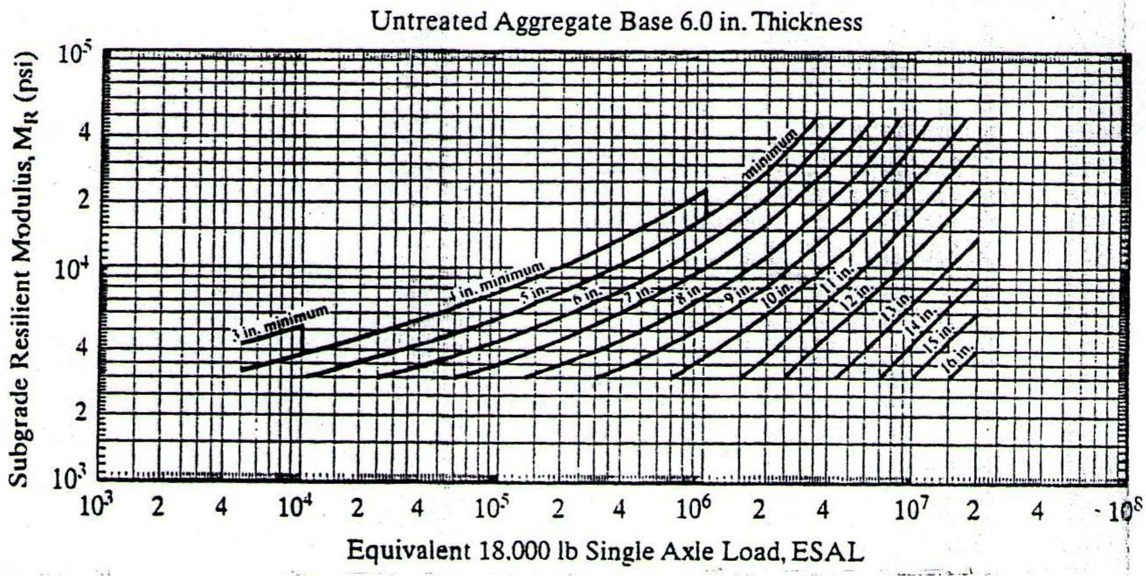
| Functional classification | Recommended level of reliability | |
|---|---|---|
| | Urban | Rural |
| Interstate and other freeways | 85–99.9 | 80–99.9 |
| Principal arterials | 80–99 | 75–95 |
| Collectors | 80–95 | 75–95 |
| Local | 50–80 | 50–80 |

*Note.* Results based on a survey of AASHTO Pavement Design Task Force.
*Source.* After AASHTO (1986).

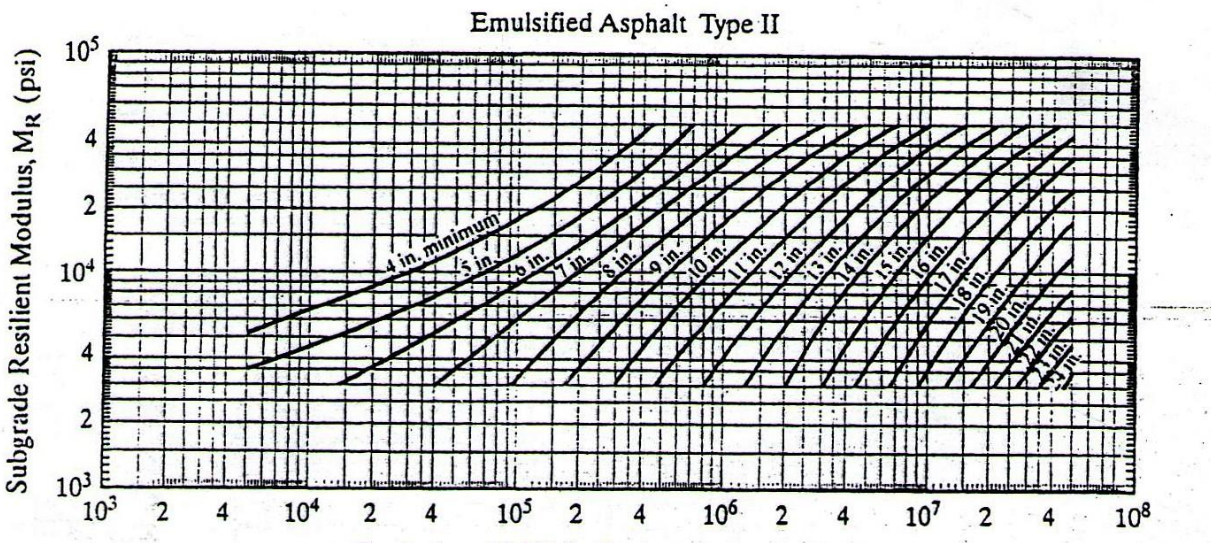
## Figure A4: Flexible Pavement Design




## Figure A3: Untreated Aggregate Base 6 in. Thickness



# Figure A2: Emulsified asphalt Type II



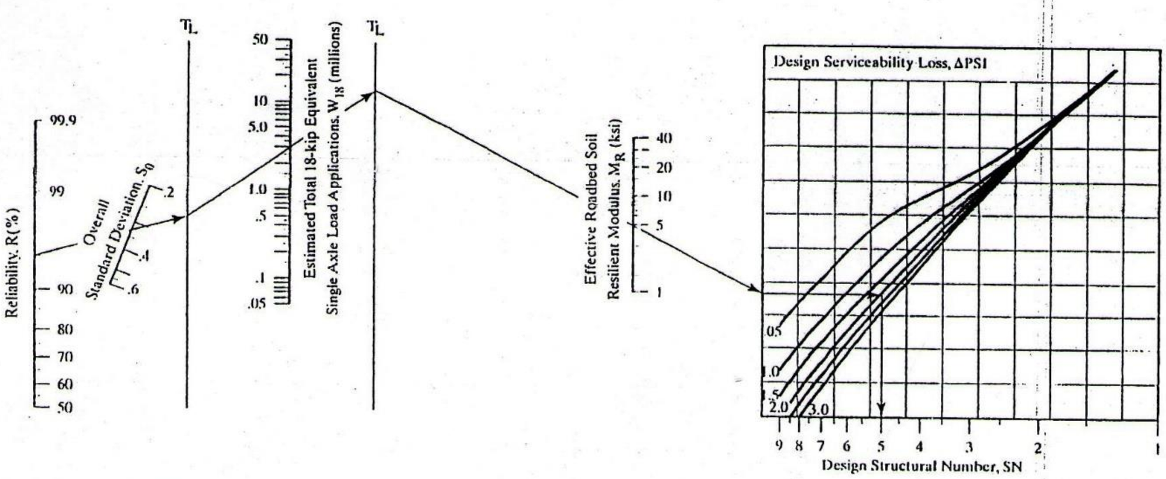



FIGURE A-5

Design chart for flexible pavements based on mean values for each input (1 ksi = 6.9 MPa). (From the *AASHTO Guide for Design of Pavement Structures*. Copyright 1986. American Association of State Highway and Tranportation Officials, Washington, DC. Used by permission.)

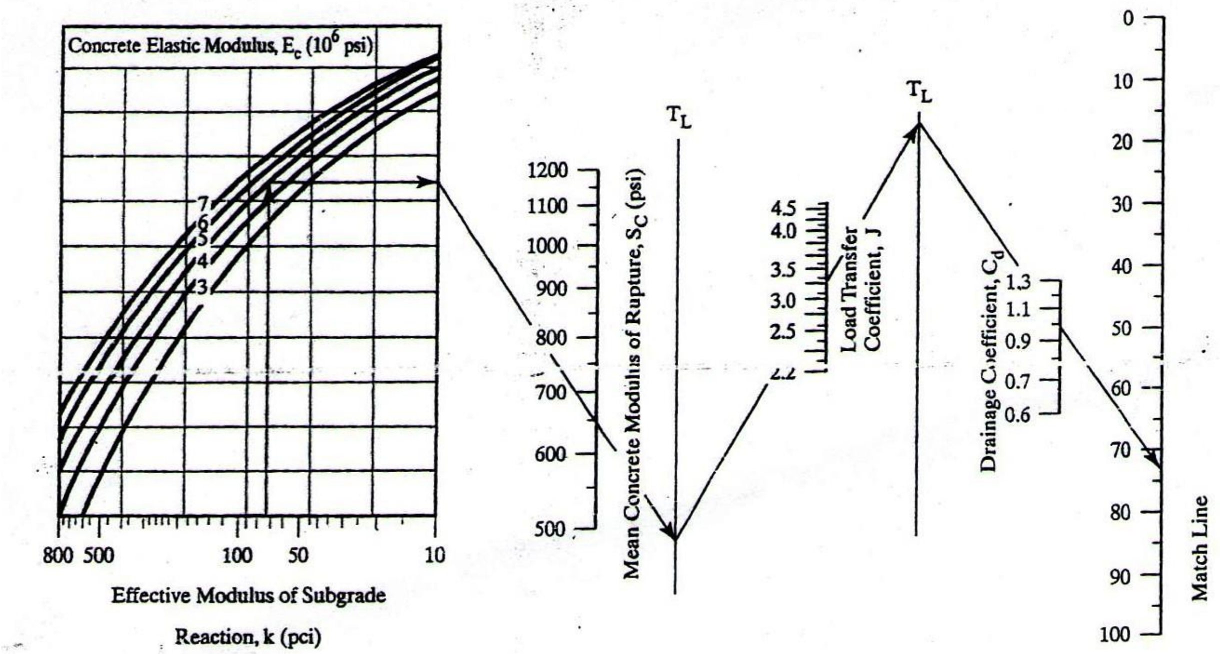



FIGURE A6

Design chart for rigid pavements based on mean values (1 in. = 25.4 mm, 1 psi = 6.9 kPa, 1 pci = 271.3 kN/m$^3$). (From the *AASHTO Guide for Design of Pavement Structures*. Copyright 1986. American Association of State Highway and Transportation Officials, Washington, DC. Used by permission.)

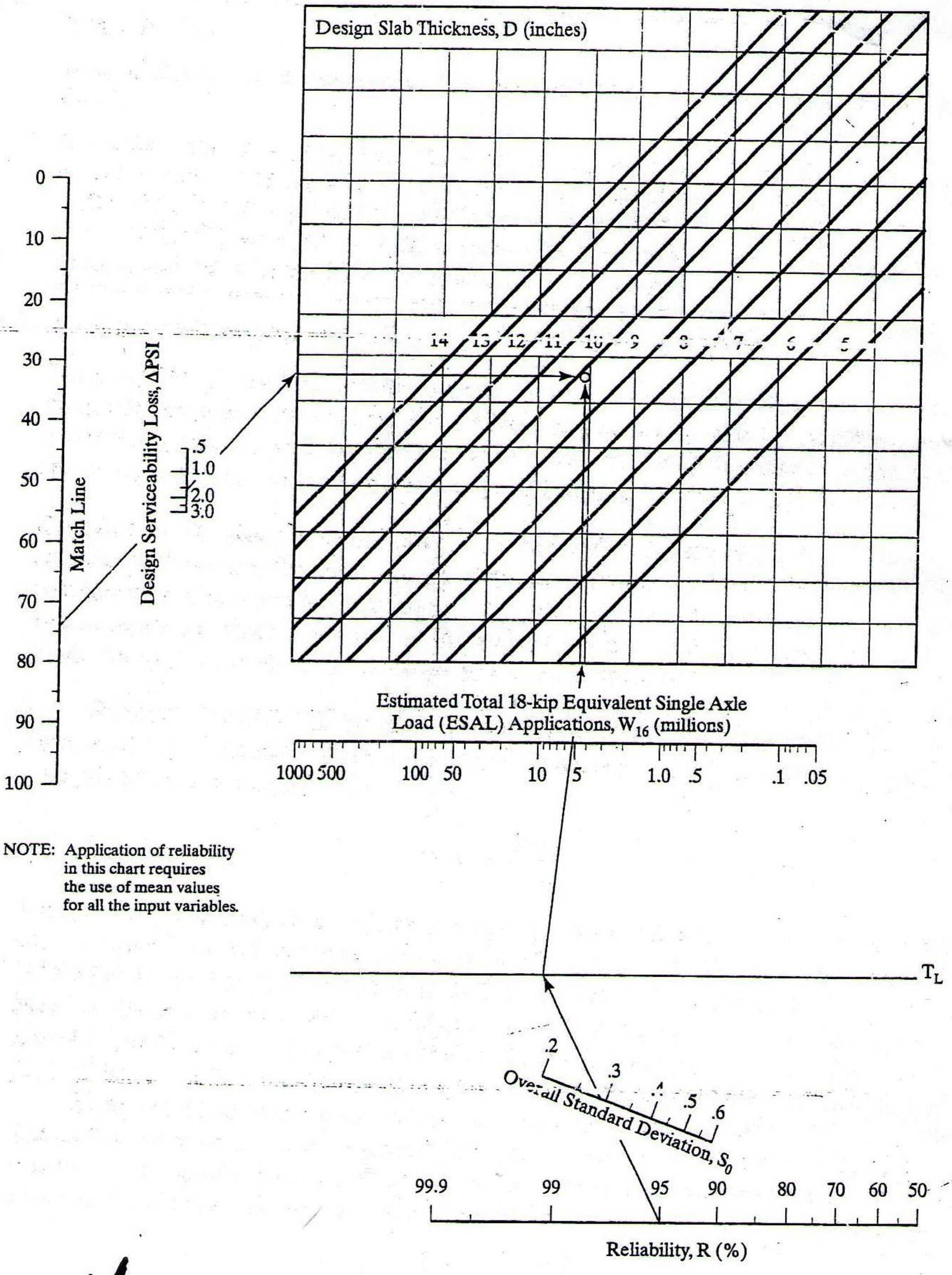



FIGURE A6 (Continued)

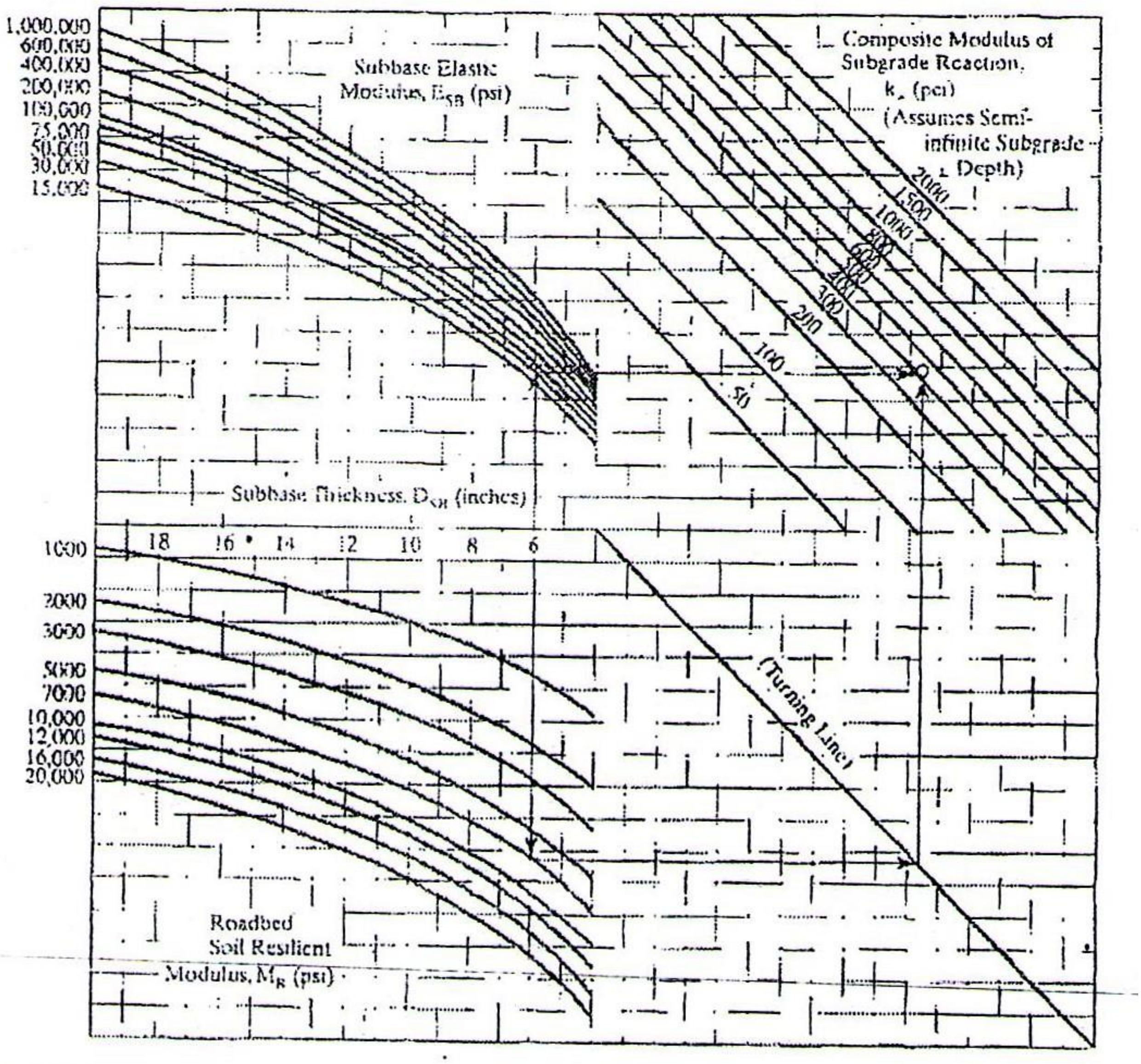



**figure (A7) Chart for modifying modulus of sub-grade reaction (from the AAHTO for design pavement structure copyright 1986**

**(from the AAHTO for design pavement structure copyright 1986.)**

**Source after AASHTO (1986)**

**Table: A5 Axle Load Distribution for Traffic Categories**

| Axle load (kips) | Axles per 1000 trucks | | | |
|---|---|---|---|---|
| | Category 1 | Category 2 | Category 3 | Category 4 |
| Single axles | | | | |
| 4 | 1693.31 | | | |
| 6 | 732.28 | | | |
| 8 | 483.10 | 233.60 | | |
| 10 | 204.96 | 142.70 | | |
| 12 | 124.00 | 116.76 | 182.02 | |
| 14 | 56.11 | 47.76 | 47.73 | |
| 16 | 38.02 | 23.88 | 31.82 | 57.07 |
| 18 | 15.81 | 16.61 | 25.15 | 68.27 |
| 20 | 4.23 | 6.63 | 16.33 | 41.82 |
| 22 | 0.96 | 2.60 | 7.85 | 9.69 |
| 24 | | 1.60 | 5.21 | 4.16 |
| 26 | | 0.07 | 1.78 | 3.52 |
| 28 | | | 0.85 | 1.78 |
| 30 | | | 0.45 | 0.63 |
| 32 | | | | 0.54 |
| 34 | | | | 0.19 |
| Tandem axles | | | | |
| 4 | 31.90 | | | |
| 8 | 85.59 | 47.01 | | |
| 12 | 139.30 | 91.15 | | |
| 16 | 75.02 | 59.25 | 99.34 | |
| 20 | 57.10 | 45.00 | 85.94 | |
| 24 | 39.18 | 30.74 | 72.54 | 71.16 |
| 28 | 68.48 | 44.43 | 121.22 | 95.79 |
| 32 | 69.59 | 54.76 | 103.63 | 109.54 |
| 36 | 4.19 | 38.79 | 56.25 | 78.19 |
| 40 | | 7.76 | 21.31 | 20.31 |
| 44 | | 1.16 | 8.01 | 3.52 |
| 48 | | | 2.91 | 3.03 |
| 52 | | | 1.19 | 1.79 |
| 56 | | | | 1.07 |
| 60 | | | | 0.57 |

*Note*. 1 kip = 4.45 kN; all two-axle, four-tire trucks are excluded.
*Source*. After PCA (1984).

## Table: A6 Subgrade Soil Types and Approximate K Values

| Type of soil | Support | $k$ Values (pci) |
|---|---|---|
| Fine-grained soils in which silt and clay-size particles predominate | Low | 75–120 |
| Sands and sand-gravel mixtures with moderate amounts of silt and clay | Medium | 130–170 |
| Sands and sand-gravel mixtures relatively free of plastic fines | High | 180–220 |
| Cement-treated subbases | Very high | 250–400 |

*Note.* 1 pci = 271.3 $kN/m^3$.
*Source.* After PCA (1984).

## Table: A7 Allowable ADTT, * Axle-Load Category 4 – Pavement with Doweled Joints:

| | No Concrete Shoulder or Curb | | | | | Concrete Shoulder or Curb | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Slab thickness, in. | Subgrade-subbase support | | | | Slab thickness, in. | Subgrade-subbase support | | | |
| | | Low | Medium | High | Very high | | Low | Medium | High | Very high |
| MR = 650 psi | 8 | | | | 270 | 7 | | | | 400 |
| | 8.5 | | 120 | 340 | 1,300 | 7.5 | | 240 | 620 | 2,100 |
| | 9 | 140 | 580 | 1,500 | 5,600 | 8 | 330 | 1,200 | 3,000 | 9,800 |
| | 9.5 | 570 | 2,300 | 5,900 | 14,700** | 8.5 | 1,500 | 5,300 | 12,700 | 41,100** |
| | 10 | 2,000 | 8,200 | 18,700** | 25,900** | 9 | 5,900 | 21,400 | 44,900** | |
| | 10.5 | 6,700 | 24,100** | 31,800** | 45,800** | 9.5 | 22,500 | 52,000** | | |
| | 11 | 21,600 | 39,600** | | | 10 | 45,200** | | | |
| | 11.5 | 39,700** | | | | | | | | |
| MR = 600 psi | 8.5 | | | | 300 | 7.5 | | | 130 | 490 |
| | 9 | | 120 | 340 | 1,300 | 8 | | 270 | 690 | 2,300 |
| | 9.5 | 120 | 530 | 1,400 | 5,200 | 8.5 | 340 | 1,300 | 3,000 | 9,900 |
| | 10 | 480 | 1,900 | 5,100 | 19,300 | 9 | 1,400 | 5,000 | 12,000 | 40,200 |
| | 10.5 | 1,600 | 6,500 | 17,500 | 45,900** | 9.5 | 5,200 | 18,800 | 45,900 | |
| | 11 | 4,900 | 21,400 | 53,800** | | 10 | 18,400 | | | |
| | 11.5 | 14,500 | 65,000** | | | | | | | |
| | 12 | 44,000 | | | | | | | | |
| MR = 550 psi | 9 | | | | 260 | 8 | | | 130 | 480 |
| | 9.5 | | | 280 | 1,100 | 8.5 | | 250 | 620 | 2,100 |
| | 10 | | 390 | 1,100 | 4,000 | 9 | 280 | 1,000 | 2,500 | 8,200 |
| | 10.5 | 320 | 1,400 | 3,600 | 13,800 | 9.5 | 1,100 | 3,900 | 9,300 | 30,700 |
| | 11 | 1,000 | 4,300 | 11,600 | 46,600 | 10 | 3,800 | 13,600 | 32,900 | |
| | 11.5 | 3,000 | 13,100 | 37,200 | | 10.5 | 12,400 | 46,200 | | |
| | 12 | 8,200 | 40,000 | | | 11 | 40,400 | | | |

*ADTT excludes two-axle, four-tire trucks; total number of trucks allowed will be greater—see text.
**Erosion analysis controls the design; otherwise fatigue analysis controls.