

Highway ENGINEERING

FOR DIPLOMA STUDENTS



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Highway Engineering For Diploma Students

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We hereby declare that this module is our original work. To the best of our knowledge it contains no materials previously written or published by another person. However, if there is any, due acknowledgement and credit are mentioned accordingly in the e-book.

Preface

This book is designed to provide diploma students with a fundamental understanding of Highway Engineering and its various components. As a significant field within Civil Engineering, Highway Engineering offers a plethora of opportunities for aspiring professionals like you! Throughout this book, we aim to impart as much knowledge as possible to help you grasp the essential concepts and develop a genuine passion for this subject, just like we have. So, dive in, explore the world of Highway Engineering, and let this guide be your companion on your learning journey

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Highway ENGINEERING

FOR DIPLOMA STUDENTS

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HIGHWAY : A BRIEF HISTORY

An Introduction of Highway Engineering and how it began.

1.1 Introduction to Highway Engineering

According to The Oxford Dictionary, “**Highway**” is defined as a main road for traveling long distances, especially **one connecting and going through cities and towns**. Highways are a major feature of any industrialized country, and modern economies depend on them.



According to Mc-Graw-Hill, “**Highway engineering**” is an engineering discipline branching from civil engineering that involves the **planning, design, construction, operation, and maintenance of roads, bridges, and tunnels to ensure safe and effective transportation of people and goods**.

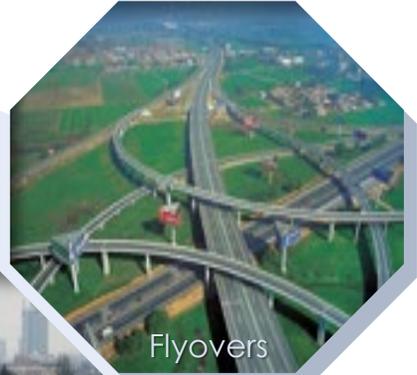
Highway engineers study traffic volumes and patterns to determine the **best strategies for minimising traffic volumes, avoiding collisions, and limiting damage** to highway structures caused by vehicular traffic. Highway engineers also design highway systems with the goal of **optimising traffic flow and safety** for all vehicles that pass through them.



1.1 Introduction to Highway Engineering

HIGHWAY STRUCTURES

Structures in Highway Engineering are as follows:



1.2 History of Highways

The ancient roads, found in what is now known as Iraq, specifically in the former region of Mesopotamia, hold the distinction of being the oldest known man-made pathways ever unearthed. These streets, crafted from stone, can be traced back to approximately 4000 B.C. and were originally laid in the cities of Ur and Babylon in Mesopotamia

ANCIENT ROADS

ROMAN ROADS

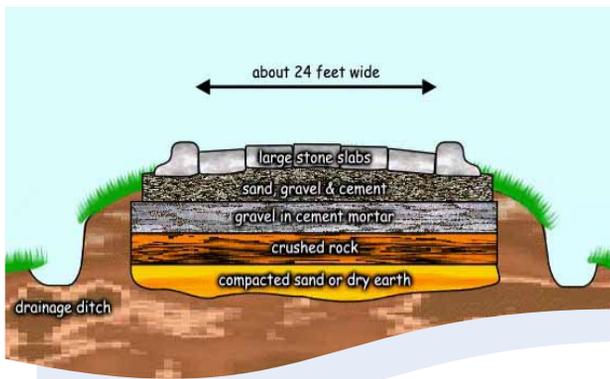
Roman roads were physical infrastructure which was the main symbol of development of the Roman state. They were built around 500 BC through the expansion and consolidation of the Roman Republic and Roman Empire. The main purpose of roads back then was for the movement of armies, officials and civilians. Other uses of roadways were for inland and carriage of communication and trade goods.

The Roman road system spanned more than **400,000 km** of a network of roads, including over **80,500 km** of paved roads. When Rome reached the height of its power, no fewer than 29 great military highways radiated from the city. Hills were cut through and deep ravines filled in

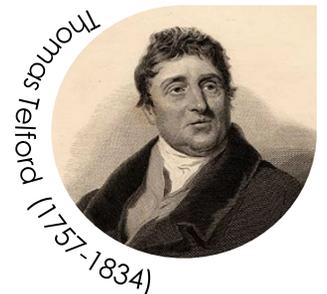


1.2 History of Highways

In the construction of Roman roads, it was customary to incorporate four distinct layers. The initial layer, known as the statumen, comprised large stones. Above the statumen, the next layer called the rudus consisted of gravel mixed with concrete. Finally, on top of the rudus, the nucleus was laid, which consisted of sand and smaller gravel mixed with concrete.



ROMAN ROADS



MODERN ROADS

After the Romans introduced Road layers, the technique was introduced through the FOUR road Engineers.

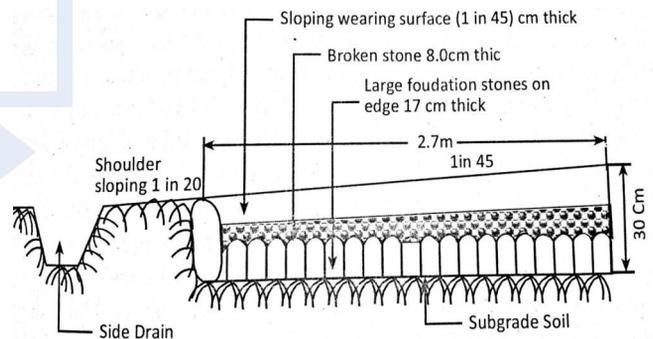
- John Metcalf
- Pierre-Marie-Jerome Tresaguet
- Thomas Telford
- John McAdam

1.2 History of Highways

John Metcalf, also known as Blind Jack of Knaresborough, was an 18th-century English civil engineer who played a significant role in the construction of various roads in England. He was renowned for his expertise in road building and is credited with constructing numerous important roadways during his lifetime.

Metcalf emphasized the importance of **properly preparing the roadbed** by **creating a solid foundation through excavation and leveling**. Metcalf would then add layers of large stones, gravel, and **compacted earth to ensure stability and longevity**.

METCALF ROADS



A Typical Cross Section of Metcalf's Construction by "Dreamcivil".

One of Metcalf's innovative contributions was the use of "macadamization," a method **involving the careful placement and compaction of crushed stones to create a smooth and durable road surface**. This technique greatly improved road quality and enhanced the overall travel experience. Metcalf's road construction projects often involved overcoming challenging terrains, including hilly and marshy areas. He was known for his ability to navigate difficult landscapes, constructing roads with winding paths, embankments, and drainage systems to ensure safe and efficient travel.

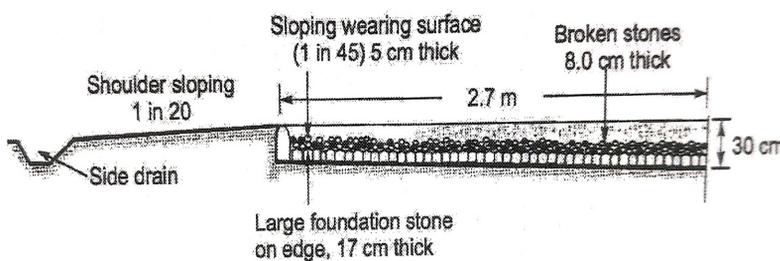
1.2 History of Highways

TRESAGUET ROADS

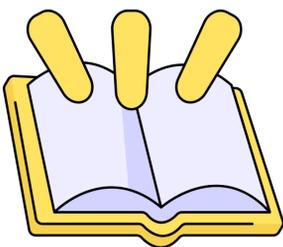
Firstly, **an earth foundation that ran parallel to the new road's surface is excavated**, positioned approximately ten inches below the eventual finished level. This foundation had a convex shape in its cross section, designed to promote water drainage from the surface.

Next, **large stones are positioned on the edges**, ensuring any protruding pieces along their upper edges are removed to create a smooth surface. On this stone foundation, a second layer consisting of smaller, rounded stones is added.

Lastly, **a third layer composed of hard, broken stones was spread** using shovels to create the topmost surface layer. This construction method remained in continuous use in France from 1775 until 1820, when the country transitioned to the more cost-effective Macadam approach.



Can you differentiate the technologies developed by Tresaguet and Metcalf

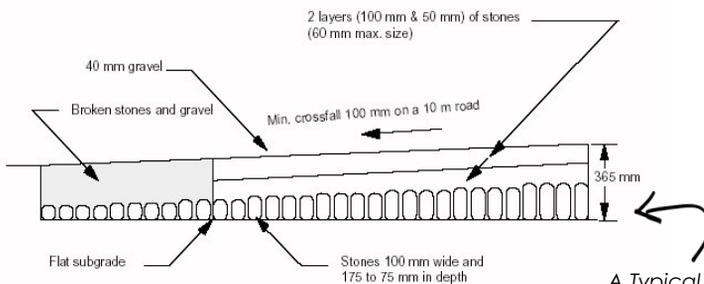


A Typical Cross Section of Tresaguet's Construction by "The Civil Engineering Education".

1.2 History of Highways

TELFORD ROADS

Thomas Telford (1757-1834) made substantial advances in the engineering of new roads and the construction of bridges. His method of road building involved **excavating a large trench in which a foundation of heavy rock** is set. Additionally, he engineered his roads with a **deliberate slope away from the center**, facilitating effective drainage—a significant enhancement compared to Trésaguet's methods.



A Typical Cross Section of Telford's Construction by "Pavementinteractive".

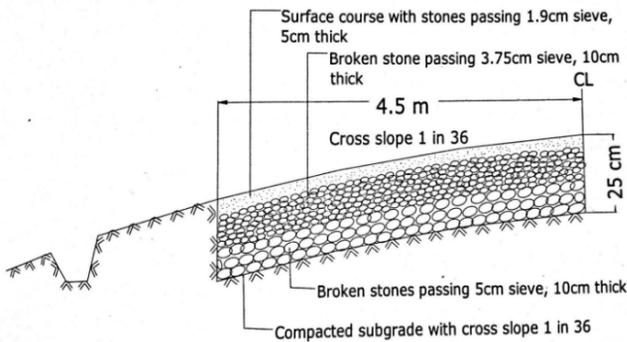
Telford also emphasized **the importance of regular maintenance and upkeep of roads**. He advocated for proper inspection and timely repair of any damages to ensure the longevity and functionality of the roadways.



Telford's approach focused on durability, proper drainage, and meticulous construction, leading to the development of reliable road networks that greatly improved transportation infrastructure during his time and continue to have a lasting impact today.

1.2 History of Highways

MACADAM ROADS



A Typical Cross Section of McAdam's Construction by "Dreamcivil".

Macadam roads, named after Scottish engineer John Loudon McAdam, were a significant advancement in road construction during the 19th century. McAdam's approach aimed to **create durable and cost-effective roads that could withstand heavy traffic and adverse weather conditions.**

One of the key innovations of macadam roads was **the use of angular stones that interlocked** with each other, **creating stability and reducing the risk of displacement under traffic.** The compacted stones formed a solid and durable road surface that was resistant to wear and erosion.

McAdam also emphasized the **importance of proper drainage. He incorporated ditches and side slopes to allow rainwater to drain off the road,** preventing water damage and prolonging the lifespan of the road surface.

Improved comfort for travellers

Smoother rides for vehicles

More efficient transportation



1.3 Concept of Highways in Malaysia

Road construction in Malaysia has traditionally been carried out by both the Federal Government and State Government. However, since the mid-1980s, the construction of toll roads has been initiated by private companies. These companies are subsequently granted permission by the government to levy toll fees on road users. These toll roads serve as alternatives to the existing road network and are equipped with various amenities and services for the convenience of users.

The categories of roads and highways in Malaysia can be divided into:

01 FEDERAL ROADS

02 STATE ROADS



Find out what each of these Road categories represent.



1.3 Concept of Highways in Malaysia

FEDERAL HIGHWAYS



Federal roads are all roads declared under the Federal Roads Ordinance (1959) and the major interurban roads joining the state capitals and roads leading to points of entry to and exit from the country.

Road Category	General Description	Authority
Toll Expressways	Inter-urban toll expressways	MHA
National Highways	Inter-urban linking Federal Capitals	PWD
Regional Road Schemes	Roads forming Network in RDA	PWD (Regional)
Minor Roads	Access to federal government institutions	PWD (state)

MHA: Malaysian Highway Authority
 PWD: Public Works Department

1.3 Concept of Highways in Malaysia

STATE HIGHWAYS

State roads generally comprises of the primary roads providing intra-state travel between the district administrative centres. Other roads included in this category are the urban collector roads under the municipalities and other minor roads within the villages and the rural inhabited areas under the Districts Offices..

Road Category	General Description	Authority
Roads Within Federal Territories	Roads other than the designated Federal Roads	City Hall / Municipal Council.
Primary Roads	Major roads forming the basic network within a state, linking state capitals and major towns.	PWD (State)
Secondary Roads	Roads forming the network within a district	PWD (State)
Minor Roads	Minor roads within a village or rural inhabited area.	District Officers
Local Roads	Basic road network within an urban neighbourhood serving primarily to offer direct access to abutting land.	Local Authorities



Try to answer the following questions

1. Define Highway in the terms of Engineering.
2. Name and briefly describe FIVE (5) structures in Highway Engineering.
3. With the help of diagrams, explain the history of road construction from Roman Roads to Macadam Roads.
4. Using a table, explain the highway and road categories in Malaysia.
5. Explain the roles of FIVE (5) government agencies in Malaysian Transportation.
6. Identify the importance of the introduction of acts related to roads.
7. Explain the relationship of the RTA 1986 and EQA 1974 to traffic and transportation in Malaysia.

CHAPTER 02



PAVEMENT MATERIALS & TESTING

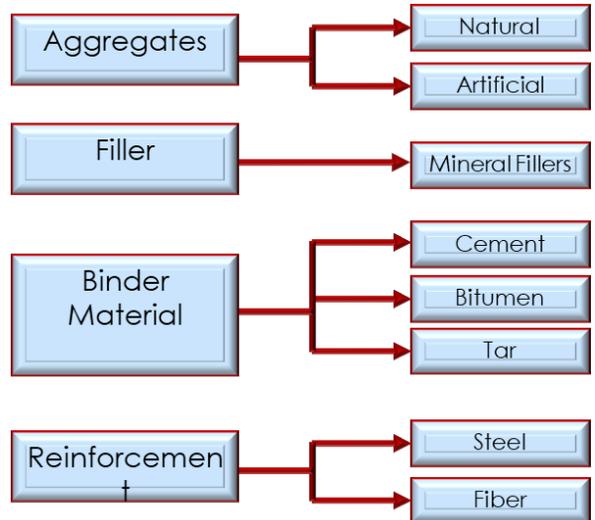
Materials used in Highway Construction and Quality Testing.

2.1 Pavement Materials

Road surface or pavement is the **durable surface material laid down** on an area intended **to sustain vehicular or foot traffic**, such as a road or walkway. In the past cobblestones and granite setts were extensively used, but these surfaces have mostly been replaced **by asphalt (bitumen) or concrete**.

Traffic subjects pavement to wear and damage. The **amount of wear depends on the weight and number of vehicles** using the pavement over a given period of time. Road engineers estimate the pavement damage from the axle loads of the various vehicles expected to use the pavement over its designed life, usually 20 years. As a general principle, **the heavier and more numerous the vehicles using the road, the thicker the pavement** needed to support them.

Materials Used in Highway Construction



Bitumen is the most common binder used in Road Construction



2.1 Pavement Materials

Aggregates

Aggregates are **coarse particulate material** used in construction, including **sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates.**

Aggregates are a component of composite materials such as concrete and asphalt concrete.

Aggregates **serves as reinforcement to add strength** to the overall composite material.



Aggregates are divided into two sources:



Naturally formed aggregates are generally extracted from larger rock formation through an open excavation (quarry).

Usually, the rock is blasted or dug from the quarry wall then reduce in size using a series of screens and crushers.

Examples: Crushed rocks, gravel and sand.

Man-made aggregate is usually made of the mixture of fly ash, binders, admixtures and water. It consists of blast-furnace slag, which is a co-product of the iron and steelmaking process which undergoes conditioning, screening, crushing and washing.

Important Properties of Aggregates

Strength – to withstand crushing and impact during construction, and also from traffic load.

Durability– resistance to disintegration, under weathering.

Shape & surface texture – helps in interlocking, which increases resistance to sliding which affect the strength.

Affinity – to be properly coated by binder.

Relative density and absorption – appropriate stripping, drying time, mix design.

Hardness – polished under traffic, skid resistance.

Gradation – quality & pavement strength.

2.1 Pavement Materials

Fillers

Mineral filler consists of very fine, inert mineral matter that is added to the hot mix asphalt to improve the density and strength of the mixture. Mineral fillers consist of finely divided mineral matter such as rock dust, slag dust, hydrated lime, hydraulic cement, fly ash, loess, or other suitable mineral matter. The portion of the mineral filler that is finer than the thickness of the asphalt film and the asphalt cement binder form a mortar or mastic that contributes to improved stiffening of the mix.



Sieved aggregates (<14mm) is also often used as pavement fillers.

Mineral fillers make up less than 6 percent of the hot mix asphalt concrete by mass, and generally less than about 3 percent.

A typical mineral filler completely passes a 0.060 mm (No. 30) sieve, with at least 65 percent of the particles passing the 0.075 mm (No. 200) sieve. The particles larger than the thickness of the asphalt film behave as mineral aggregate and hence contribute to the contact points between individual aggregate particles. The gradation, shape, and texture of the mineral filler significantly influence the performance of hot mix asphalt.

Importance of Mineral Fillers in HMA

- Fill voids between aggregates, enhance compaction and stability.
- Modify the gradation of the asphalt mix to achieve the desired properties.
- Absorb a portion of the asphalt to reduce binder content requirement.
- Helps the mix flow to improve its workability during construction.
- Providing better internal support and reducing binder drainage.
- Aids in reducing thermal stresses and preventing the formation of cracks.

2.1 Pavement Materials

Binder Material

A binder or binding agent is any material or substance that holds or draws other materials together to form a cohesive whole mechanically, chemically, by adhesion or cohesion. In pavement construction, rigid pavements (concrete) use cement as a binder whereas flexible pavement uses bitumen (asphalt) or tar.

Difference between Bitumen and tar

Properties	Bitumen / Asphalt	Tar
Colour	Dark Black	Deep Black
Existing State	Usually solid at normal temperature	Soild as a viscous liquid
Adhesive Power	Good	Very Good
Effect on Heating	Becomes liquid on heating	Less viscous on heating
Carbon Content	Less	Most

Bitumen

Bitumen (UK), also known as asphalt (US), is an important material used in flexible road construction. It is a sticky, black, semi-solid form of petroleum and is derived from the refining of crude oil. Bitumen plays a vital role in creating durable and resilient road surfaces.

In road construction, bitumen is used as a binding agent to hold the aggregates together and form bituminous or asphaltic concrete. Bitumen is available in different grades based on its properties and performance characteristics. The selection of the appropriate bitumen grade depends on factors like traffic loads, climate conditions, and road design.

Common bitumen grading systems:

Penetration Grade Bitumen (ASTM D946 / AASHTO M20)

Viscosity Grade Bitumen (ASTM D3381 / AASHTO M226)

Performance Grade Bitumen (AASHTO M320)

2.1 Pavement Materials

Reinforcements

Reinforcements in road construction refer to materials that are added to the road pavement to improve its mechanical properties, enhance durability, and extend its service life. These reinforcements are used in various types of road construction, including flexible pavements (asphalt) and rigid pavements (concrete).

Types of Reinforcements

Geogrids

Geogrids are strong, open-weave polymer materials used in road construction to boost strength, spread loads better, and increase road durability. They are placed within the base or subbase layers to improve their tensile strength and distribute loads more efficiently reduce cracks in asphalt and enhance road performance.

Geotextiles

Geotextiles are permeable fabrics made from synthetic or natural fibers. In road construction, geotextiles are primarily used for separation and filtration purposes. They prevent the mixing of different soil layers, preventing the subgrade soil from contaminating the base course materials. Geotextiles also aid in draining water away from the road structure, reducing the risk of moisture-related damage.

Steel Reinforcement

For concrete roads, which are considered rigid pavements, steel reinforcement is commonly employed to manage and reduce cracking resulting from temperature fluctuations and the weight of traffic. Steel bars or mesh are incorporated into the concrete to enhance its ability to resist tension, thereby averting the development of extensive cracks and enhancing the pavement's overall lifespan.

Polyester Fiber

These synthetic fibers are sometimes added to the asphalt mix to enhance its mechanical properties. They help control and reduce cracking, improve the mix's resistance to rutting, and provide better resistance to fatigue and thermal stresses.

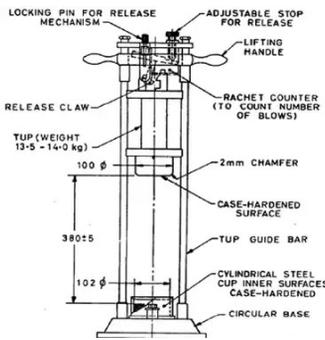
Paving Fabric

Paving fabric is a composite material placed between the existing pavement and the new overlay. It functions as a waterproofing layer and minimizes the transmission of existing pavement cracks to the new overlay, reducing reflective cracking.

2.2 Pavement Material Tests

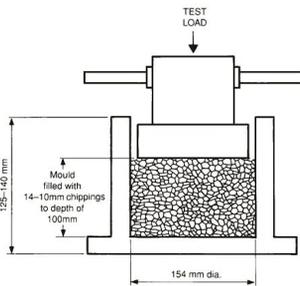
Aggregate

Aggregate Impact Value Test (AIV) BS 812: Part 112:1990

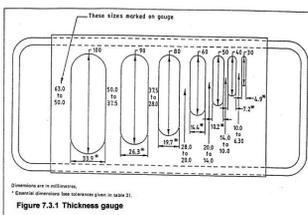


AIV test is performed to determine Aggregate resistance due to impact. The size of aggregates for this test: passing sieve 14mm and retained at sieve 10mm. Aggregates are filled into a mold in ONE layer and will be hit by a rod for 25 times. The aggregate mass is recorded. A hammer weighing between 13.5kg to 14kg will be released from the height of 380mm 15 times on the sample. The sample is sieved through a 2.36mm sieve and weighed to obtain the AIV value.

Aggregate Crushing Value Test (ACV) BS 812: Part 110:1990



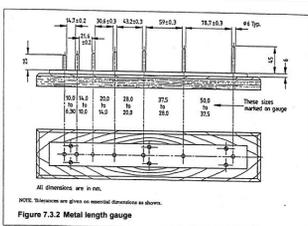
ACV Test is performed to determine the strength of aggregates to resist crushing under applied compressive load. Similar to AIV test, the aggregate sample must pass 14mm sieve and retained at 10mm. The aggregate sample is filled into a mold in 3 layers, each layer to be hit 25 times using a rod. The sample is inserted into a compression machine for 10 minutes and compressed by a 400kN load.



Aggregate Shape Test BS 812

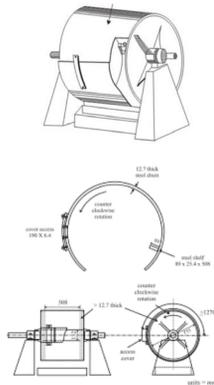
Shape test are performed on an aggregate sample with size between 63µm to 63mm.

1. Flakiness Index Test (BS 812: Section 105.1 : 1989)
To determine percentage of flat aggregates in a sample (flat, when thickness < 0.6 of average size).
2. Elongation Index Test (BS812: Part 1:1975)
To determine the percentage of long aggregates in a sample (long, when the longest dimension is more than 1.8 times from the average size).



2.2 Pavement Material Tests

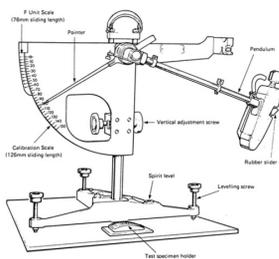
Aggregate



LA Abrasion Test
ASTM C131 or AASHTO T96

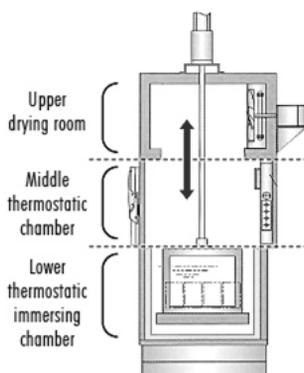
The aggregate abrasion test is a standard method used to determine the resistance of coarse aggregates to abrasion and wear. The test involves subjecting the aggregates to abrasion in a rotating steel drum along with steel spheres or steel rods. The abrasion simulates the wear and tear that aggregates experience under traffic loads in the pavement. The test measures the "loss of mass" of the aggregates due to abrasion.

Polished Stone Value Test (Skid Resistance) ASTM E303



This test is only conducted on aggregates used at wearing course. Polishing value of aggregates show the aggregates resistance due to the friction from vehicle tyres. Polishing level affects the skid resistance of pavement.

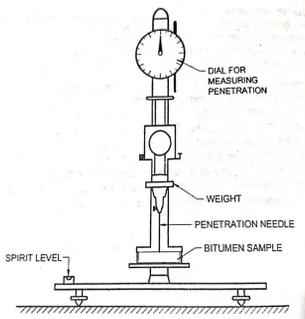
Soundness test
ASTM C88 or AASHTO T104



The aggregate soundness test, also known as the "soundness test" or "weathering test," is a standard laboratory test used to evaluate the ability of aggregates to resist disintegration and degradation caused by weathering effects, such as freezing and thawing cycles. The test helps determine the durability of aggregates when exposed to moisture and environmental changes, which is critical in ensuring the long-term performance of asphalt and concrete pavements.

2.2 Pavement Material Tests

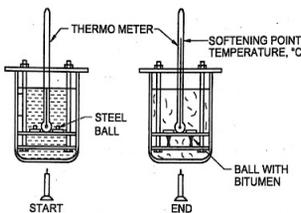
Bitumen



Penetration Test
AASHTO T49-84

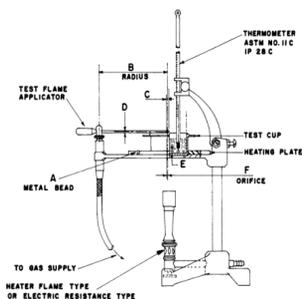
In order to determine the stiffness of the material, a test is conducted using a standard needle under a load of 100g for 5 seconds at a temperature of 20°C. The defined length (in 1/10) is achieved using a standard needle puncture, where the time, load, and temperature are pre-determined. The outcome of this test is indicated by the penetration value, where a high value suggests that the material is soft.

Softening Test (Ring and Ball method)
AASHTO T53



This test is used to determine the temperature at which a sample of bitumen softens under specific conditions. In this test, a bituminous sample is heated and a steel ball is gradually applied on its surface. The temperature at which the bitumen softens enough for the ball to sink a specific distance into the sample is recorded as the softening point. This test helps in evaluating the temperature susceptibility and performance characteristics of bituminous materials, which are commonly used in road construction.

Flash and Fire Point Test (Cleveland Open Cup)
ASTM D92-18



The flash point and fire point tests for bitumen are methods used to determine the temperatures at which bituminous materials emit flammable vapors and sustain combustion, respectively.

Flash Point Test: This test heats a bitumen sample and checks for the lowest temperature at which it gives off flammable vapors that can briefly catch fire when exposed to a spark or flame.

Fire Point Test: This test checks for the temperature at which bitumen vapors can continue to burn after catching fire. It's a bit higher than the flash point and shows when bitumen could sustain a fire.



Try to answer the following questions

1. Describe the material used in highway construction:
 - a. Aggregate
 - b. Fillers
 - c. Binder (Bitumen, tar and cement)
 - d. Reinforcement
2. Explain the properties and characteristics of aggregates.
3. Explain the properties and characteristics of bitumen.
4. Name FOUR (4) types of bitumen in road construction.
5. Discuss the objectives of tests on road construction materials:
 - a. Aggregate impact Value Test
 - b. Polished Stone Value Test
 - c. Aggregate Crushing Value Test
 - d. Flakiness Index Test
 - e. Elongation Test
 - f. Penetration Test



FLEXIBLE PAVEMENT DESIGN

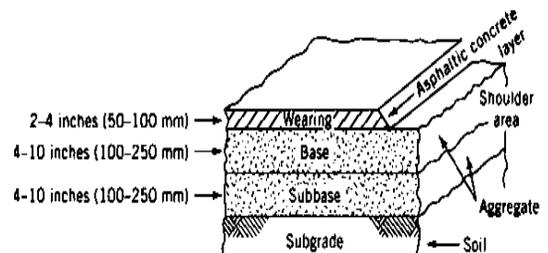
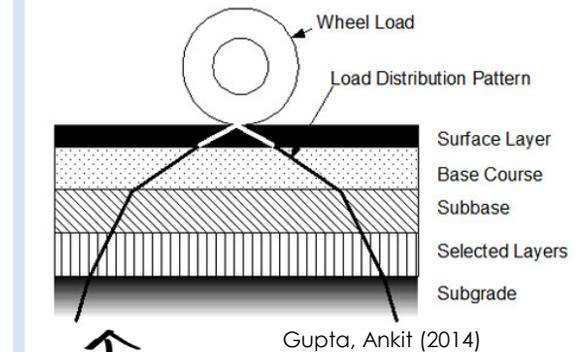
Construction and Design of the Flexible Pavement as referred to JKR Flexible Pavement Design (JKR ATJ 5/85 Pindaan 2013)

3.1 The Flexible Pavement

Flexible pavement can be defined as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade.

Flexible pavement has very low flexural strength and are flexible in their structural behavior when under a load.

The surface layer absorbs traffic load and distribute it to the layers below until it reaches the subgrade. The subgrade supports most of the load.



Functions of Flexible Pavement

- To provide a level/flat surface for a comfortable and safe journey.
- To receive and distribute the load of the vehicle to the ground layers.
- To protect the sub-grade layers from damage due to exposure of climate change.
- To prevent seepage of water into the roadbed.
- To reduce noise from the wheels of vehicles.
- To provide high resistance to traction/skid.
- To reduce splashing water from the wheels of the vehicle during raining season

Characteristics of Flexible Pavement

- Flexible Pavements are “elastic” which means they are allowed to contract and expand upon loading.
- Flexible pavements commonly use bitumen/asphalt or tar as binder material.
- Maintenance work are easily done on the surface for minor deformation.
- Does not require joints.

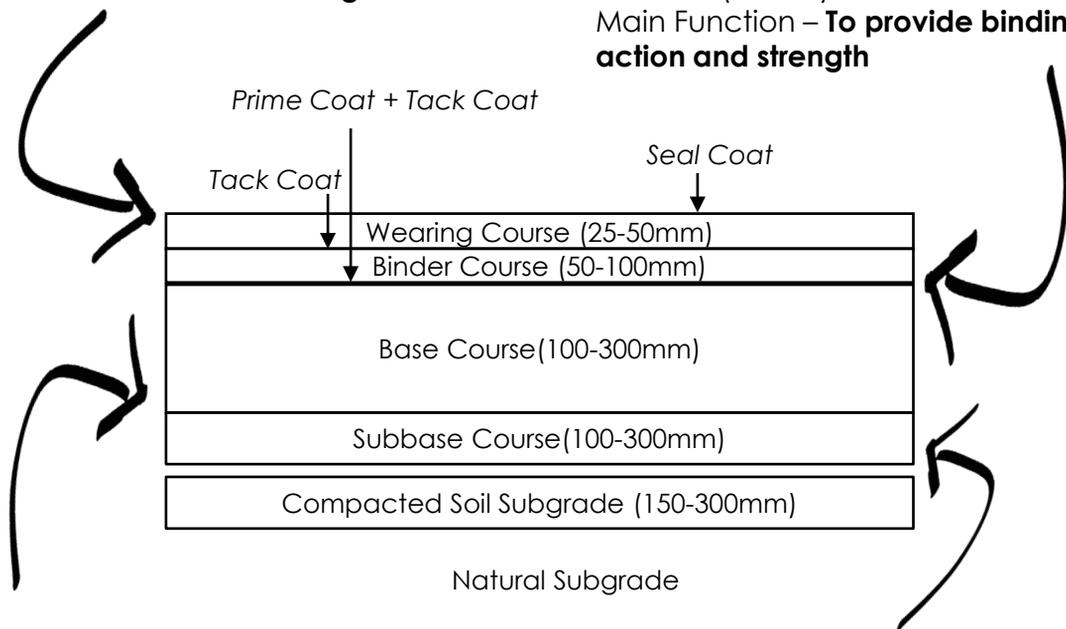
3.1 The Flexible Pavement

Bituminous Concrete

It contains graded smaller aggregates and bitumen (5.2-5.4%)
Main Function – **as a wearing Course**

Dense Bituminous Macadam (DBM)

It contains graded aggregates and bitumen (4-4.5%).
Main Function – **To provide binding action and strength**



Wet Mix Macadam (WMM)

It consists of laying and compacting clean, crushed, graded aggregate and granular material, premixed with water to a dense mass.

Main Function – **to provide structural support**

Granular Subbase (GSB)

It contains natural sand, moorum, gravel, crushed stone or its combination and the materials should be well graded.

Main functions: **To improve drainage and structural support**

Prime coat: a low viscous bituminous material / bitumen emulsion, density 7.3 to 14.6 kg/m²
Tack Coat: a high viscous bituminous material / bitumen emulsion, density 4.9 to 9.8kg/m²
Seal Coat: to waterproof the surface and to provide skid resistance, density 6.8kg to 9.8kg/m²

3.2 Construction of The Flexible Pavement



Subgrade

Materials : Selected soil, Moorum, Gravel, Small Aggregates (<50mm)

Machineries: Excavator, Roller Compactor, Wheel loader

Method: After determining the maximum structural support by CBR tests, The subgrade is constructed by spreading the loose soil and compacting the same soil at an optimum moisture content of the soil in subgrade layer. If not adequately compacted, the subgrade will continue to compress, deform or erode after construction, causing pavement cracks and deformation.



Subbase

Materials : Crushed Stone Aggregates, Gravel, Coarse Sand, Selected soil (low plasticity).

Machineries: Roller Compactor, Crawler Excavator, Semi Truck

Method: Subbase is constructed on the compacted subgrade. The subbase material is spread to uniform thickness and specific cross-slope. The moisture content of the material is checked, and additional quantity of water required to bring up the optimum moisture content of the material is sprinkled uniformly. The layer is then, compacted.

3.2 Construction of The Flexible Pavement



Base

Materials: Hand crushed aggregates, adequate proportion of water

Machineries: Tandem Roller, Roller Compactor, Vibrator roller, Asphalt Paver

Method: Wet Mixed Macadam is prepared in a mixing plant. The mix is transported to the site and spread using self propelled type paver finisher machine. Wet Mixed Macadam is compacted using a vibratory roller of minimum static weight of 10 tones and compacted thickness in less than 200mm. The laid mix is dried for at least 24 hours under the sun.



Surface

Materials : Bituminous Macadam

Machineries: Roller Compactor

Pavement surface construction is divided into two steps:

Prime Coat

The graded subgrade or the top granular base layer can be prepared with a prime coat. A prime coat is a sprayed application of a cutback or asphalt emulsion applied to the surface of untreated subgrade or base layers in order to:

- Fill the surface voids and protect the base from weather.
- Stabilize the fines and preserve the base material.
- Promote bonding to the subsequent pavement layers.

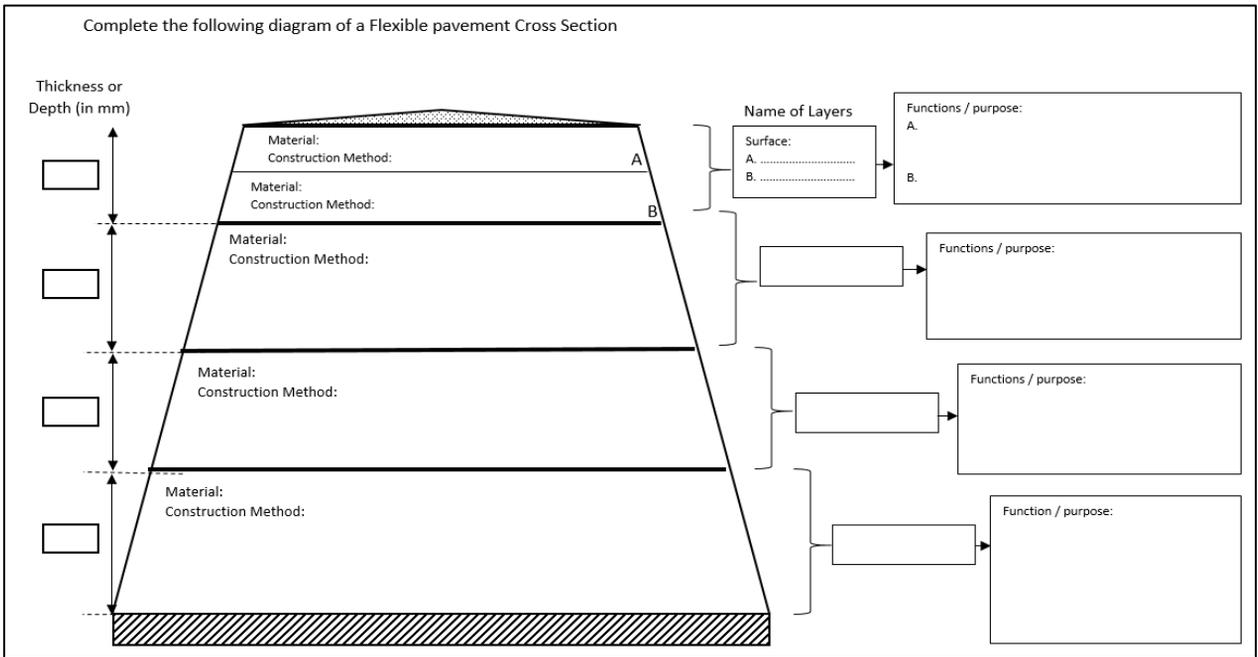
Tack Coat

A tack coat is a thin bituminous liquid asphalt, emulsion or cutback coating applied between HMA pavement lifts to promote bonding. Adequate bonding between construction lifts and especially between the existing road surface and an overlay is critical in order for the completed pavement structure to behave as a single unit and provide adequate strength. Inadequate bonding between layers can result in delamination (debonding) followed by longitudinal wheel path cracking, fatigue cracking, potholes, and other distresses such as rutting that greatly reduce pavement life.

3.2 Construction of The Flexible Pavement



Complete The Diagram below!



Answer the following questions!

1. In your own words, describe the functions of each layer of the Flexible Pavement.
2. Name **FOUR (4)** road construction machines used in the Construction of a Flexible Pavement.
3. Name the materials used in each layer of the flexible pavement.
4. Describe in detail, the construction work of the flexible pavement.

3.3 The Flexible Pavement Design

The method of Flexible Design for this book refers to JKR Flexible Pavement Design (JKR ATJ 5/85 Pindaan 2013)

Flexible pavements are surfaced with bituminous (or asphalt) materials and are called "flexible" because the entire pavement structure bends or deflects under traffic loads. It consists of multiple layers of materials that can accommodate this flexing. Flexible pavements make up over 90 percent of our paved roads.

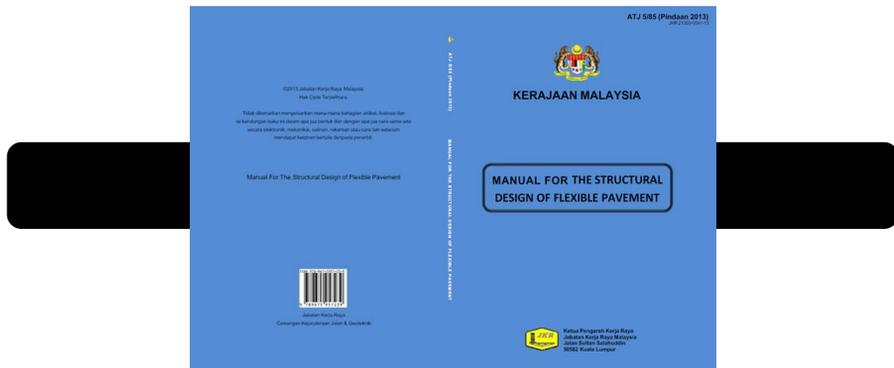
Factors of Design Thickness

Failure criteria

Traffic Loading

Traffic Decaying power

Environmental Effect



Key Elements of Pavement Design

INPUT 1

- Design Traffic;
- Traffic Volume (CV)
 - Axle Load spectrum
 - Traffic Speed

INPUT 2

- Material Properties;
- Sub Grade Strength
 - Paving Materials

INPUT 3

- Environmental Effects;
- Temperature
 - Water Drainage

Select Reliability & Structural Model

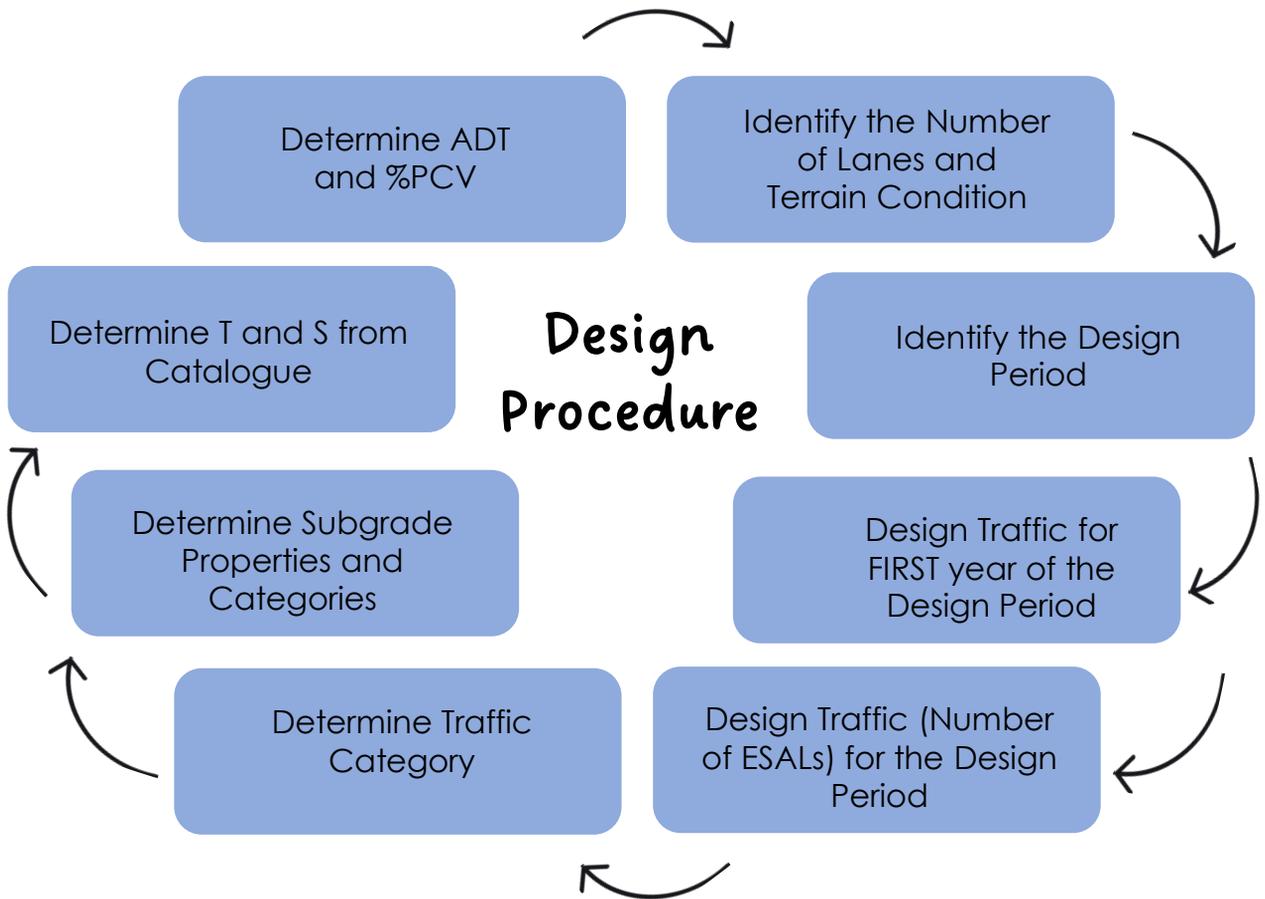
Calculate Stresses and Strains and resulting distress for Trial Pavement Structures

Check Predicted Pavement performance against Design Standard and Evaluate Alternative designs

3.3 The Flexible Pavement Design

Required Data for the Design

- 1 Number of commercial vehicles during Year 1 of Design Period, which is the expected year of completion of construction.
- 2 Vehicle Class and axle load distribution
- 3 Directional lane and distribution factors
- 1 Traffic Growth Factors



3.3 The Flexible Pavement Design

Design Procedure

Step 1 Determine Annual Daily Traffic (ADT) and Percentage of Commercial Vehicles (%PCV)

From Traffic count, determine:

- ADT (24 hours per day, If traffic count covers time period of 0600 to 2200 hours, multiply the count with 1.2)
- % PCV with un-laden weight > 1.5 tons (PCV) and break down into vehicle categories.
- Traffic Growth Factor, TGF from (r) for CV

Step 2 Identify the Number of Lanes and Terrain Condition

From geometric design – number of lanes and terrain condition

Step 3 Identify the Design Period

(10 years for low volume and rural road)

(20 years for high volume and urban road)

3.3 The Flexible Pavement Design

Design Procedure

Step 4 Design Traffic for FIRST year of the Design Period

- $ESAL_{Y1}$ = $ADT \times 365 \times P_{CV} \times LEF \times L \times T$
- $ESAL_{Y1}$ = number of ESALs for base year (design lane)
- ADT = Average Daily Traffic (one way)
- PCV = Percentage of CV (un-laden weight > 1.5 tons)
- LEF = Vehicle Load Equivalent Factor (including Tire Factor, or use 3.7)
- L = Lane Distribution Factor (refer table)
- T = Terrain Factor (refer table)

Number of lanes (in ONE direction)	Lane Distribution Factor, L
One	1.0
Two	0.9
Three or more	0.7

Type of Terrain	Terrain Factor, T
Flat	1.0
Rolling	1.1
Mountainous / Steep	1.3

If traffic distribution by vehicle type is available:

$$ESAL_{Y1} = [ADT_{CV1} \times LEF_{CV1} + ADT_{CV2} \times LEF_{CV2} + \dots + ADT_{CV3} \times LEF_{CV3}] \times 365 \times L \times T$$

Step 5 Design Traffic (Number of ESALs) for the Design Period

$$ESAL_{DES} = ESAL_{Y1} \times [(1 + r)^n - 1] / r$$

$ESAL_{DES}$ = design traffic for the design lane
in One Direction

r = annual traffic growth rate factor for design period

n = number of years in design period

Vehicle		Load Equivalent Factor (LEF)
HPU Class Designation	Class	
Cars and Taxis	C	0
Small Lorries and Vans (2 Axles)	CV1	0.1
Large Lorries (2-4 Axles)	CV2	4.0
Articulated Lorries (>3 Axles)	CV3	4.4
Buses (2-3 Axles)	CV4	1.8
Motorcycles	MC	0
Commercial Vehicle Mixed	CV%	3.7

3.3 The Flexible Pavement Design

Design Procedure

Step 6 Determine Traffic Category

Traffic Category	Design Traffic (ESAL x 10 ⁶)	Probability (Percentile) applied to properties of Sub Grade
T1	<1.0	≥60%
T2	1.1 to 2.0	≥70%
T3	2.1 to 10.0	≥85%
T4	10.1 to 30.0	≥85%
T5	>30.0	≥85%

Normal distribution with single tailed analysis, the following

normal deviate values shall apply:

- 60% Probability: Mean – 0.253 x STD
- 70% Probability: Mean – 0.525 x STD
- 85% Probability: Mean – 1.000 x STD

Step 7 Determine Subgrade (SG) properties and categories

Subgrade Category	CBR (%)	Elastic Modulus (MPa)	
		Range	Design Input Value
SG1	5 to 12	50 to 120	60
SG2	12.1 to 20	80 to 140	120
SG3	20.1 to 30	100 to 160	140
SG4	>30	120 to 180	180

Min 5% CBR for T1- T5

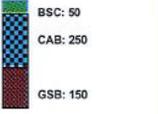
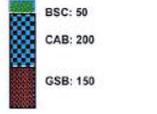
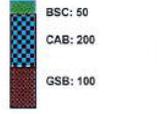
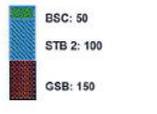
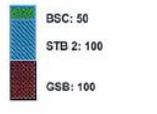
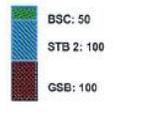
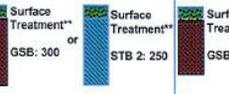
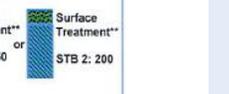
If not, at least 0.3 meter of SG shall be replaced or stabilized to ensure the minimum value is met.

Large volume traffic T4 and T5, min CBR 12%

3.3 The Flexible Pavement Design Design Procedure

Step 8 Determine T and S, choose from catalogue

T1 < 1 million ESALs

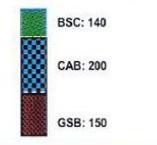
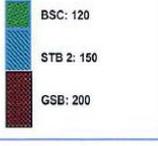
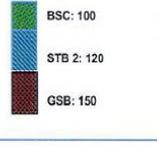
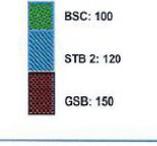
Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	 BSC: 50 CAB: 250 GSB: 150	 BSC: 50 CAB: 200 GSB: 150	 BSC: 50 CAB: 200 GSB: 100	 BSC: 50 CAB: 100 GSB: 100
Deep Strength: Stabilised Base	 BSC: 50 STB 2: 100 GSB: 200	 BSC: 50 STB 2: 100 GSB: 150	 BSC: 50 STB 2: 100 GSB: 100	 BSC: 50 STB 2: 100 GSB: 100
Stabilised Base with Surface Treatment*	 Surface Treatment** or GSB: 300 or STB 2: 250	 Surface Treatment** or GSB: 300 or STB 2: 250	 Surface Treatment** or GSB: 250 or STB 2: 200	 Surface Treatment** or GSB: 250 or STB 2: 200

Notes:

* Full Depth Asphalt Concrete Pavement is not recommended for this Traffic Category.

** Single or Double Layer Chip Seal or Micro-Surfacing.

T2 = 1-2 million ESALs

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	 BSC: 140 CAB: 200 GSB: 150	 BSC: 140 CAB: 200 GSB: 150	 BSC: 120 CAB: 200 GSB: 100	 BSC: 100 CAB: 200 GSB: 100
Deep Strength: Stabilised Base	 BSC: 120 STB 2: 150 GSB: 200	 BSC: 120 STB 2: 150 GSB: 150	 BSC: 100 STB 2: 120 GSB: 150	 BSC: 100 STB 2: 120 GSB: 150
Full Depth: Asphalt Concrete Base	 BSC: 50 BB: 100 GSB: 250	 BSC: 50 BB: 100 GSB: 200	 BSC: 50 BB: 100 GSB: 150	 BSC: 50 BB: 80 GSB: 150



3.3 The Flexible Pavement Design

Design Procedure

Step 8 Determine T and S, choose from catalogue

T3 = 2-10 million ESALs

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	 <p>BSC: 50 BC: 130 CAB: 200 GSB: 200</p>	 <p>BSC: 50 BC: 130 CAB: 200 GSB: 200</p>	 <p>BSC: 50 BC: 130 CAB: 200 GSB: 150</p>	 <p>BSC: 50 BC: 130 CAB: 200 GSB: 100</p>
Deep Strength: Stabilised Base	 <p>BSC: 50 BC: 100 STB 1: 150 GSB: 200</p>	 <p>BSC: 50 BC: 100 STB 1: 150 GSB: 150</p>	 <p>BSC: 50 BC: 100 STB 1: 100 GSB: 150</p>	 <p>BSC: 50 BC: 100 STB 1: 100 GSB: 100</p>
Full Depth: Asphalt Concrete Base	 <p>BSC: 50 BC/BB: 160 GSB: 200</p>	 <p>BSC: 50 BC/BB: 150 GSB: 150</p>	 <p>BSC: 50 BC/BB: 130 GSB: 150</p>	 <p>BSC: 50 BC/BB: 130 GSB: 100</p>

T4 = 10-30 million ESALs

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	 <p>Sub-Grade Improvement is Recommended</p>	 <p>BSC: 50 BC/BB: 150 CAB: 200 GSB: 200</p>	 <p>BSC: 50 BC/BB: 150 CAB: 200 GSB: 150</p>	 <p>BSC: 50 BC/BB: 150 CAB: 200 GSB: 100</p>
Deep Strength: Stabilised Base		 <p>BSC: 50 BC/BB: 150 STB1: 120 GSB: 200</p>	 <p>BSC: 50 BC/BB: 140 STB1: 100 GSB: 150</p>	 <p>BSC: 50 BC/BB: 130 STB1: 100 GSB: 100</p>
Full Depth: Asphalt Concrete Base		 <p>BSC: 50 BC/BB: 200 GSB: 200</p>	 <p>BSC: 50 BC/BB: 180 GSB: 150</p>	 <p>BSC: 50 BC/BB: 150 GSB: 100</p>



PAVEMENT THICKNESS CATALOGUE

3.3 The Flexible Pavement Design

Design Procedure

Step 8 Determine T and S, choose from catalogue

T5 : > 30 million ESALs

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	 <p>BSC: 50 BC: 130 CAB: 200 GSB: 200</p>	 <p>BSC: 50 BC: 130 CAB: 200 GSB: 200</p>	 <p>BSC: 50 BC: 130 CAB: 200 GSB: 150</p>	 <p>BSC: 50 BC: 130 CAB: 200 GSB: 100</p>
Deep Strength: Stabilised Base	 <p>BSC: 50 BC: 100 STB 1: 150 GSB: 200</p>	 <p>BSC: 50 BC: 100 STB 1: 150 GSB: 150</p>	 <p>BSC: 50 BC: 100 STB 1: 100 GSB: 150</p>	 <p>BSC: 50 BC: 100 STB 1: 100 GSB: 100</p>
Full Depth: Asphalt Concrete Base	 <p>BSC: 50 BC/BB: 160 GSB: 200</p>	 <p>BSC: 50 BC/BB: 150 GSB: 150</p>	 <p>BSC: 50 BC/BB: 130 GSB: 150</p>	 <p>BSC: 50 BC/BB: 130 GSB: 100</p>



PAVEMENT THICKNESS CATALOGUE

3.3 The Flexible Pavement Design

Example

A road for 2-lane is to be built as a main road in a rolling terrain. It has an average daily traffic of 1500; the percentage of commercial vehicles is 15% with an un-laden weight >1.5 tons. The rate of traffic growth is 4.5%. The road design life is 20 years.

CBR mean = 18.5%

CBR Standard Deviation = 4.4%

Probability 85% (Normal Deviate=1.282)

- i. Estimate the flexible pavement thickness and subgrade strength by employing the JKR Malaysia Design Method for the road.
- ii. Choose a suitable flexible pavement structure.

Solution

Step 1 : Determine ADT and %PCV

- | | |
|------------------------|-------------------|
| - ADT (from question) | = 1500 |
| - %PCV (from question) | = 15% (>1.5 tons) |

Step 2 : Identify the Number of Lanes and Terrain Condition

- | | |
|-------------------------------------|-----------|
| - Number of Lanes (from question) | = 2 Lanes |
| - Terrain Condition (from question) | = Rolling |

Step 3 : Identify the Design Period

- | | |
|---------------------------------|-----------|
| - Design Period (From question) | =20 years |
|---------------------------------|-----------|

3.3 The Flexible Pavement Design

Solution

Step 4 : Design Traffic for FIRST year of the Design Period

$$\begin{aligned}
 ESAL_{y_1(\text{base Year})} &= ADT \times 365 \times PCV \times LEF \times L \times T \\
 \text{From question, } r &= 4.5\% = 0.045 \\
 \text{From Tables,} & \\
 LEF (CV) &= 3.7 \\
 L_{one} &= 1.0 \\
 T_{Rolling} &= 1.1 \\
 ESAL_{y_1} &= 1500 \times 365 \times 15/100 \times 3.7 \times 1.0 \times 1.1 \\
 &= 334\,249 \text{ or } 0.334 \text{ million.}
 \end{aligned}$$

Step 5 : Design Traffic (Number of ESALs) for the Design Period

$$ESAL_{DES} = ESAL_{y_1} \times [(1 + r)^n - 1]/r$$

$$ESAL_{DES} = \text{design traffic for the design lane in One Direction}$$

$$TGF = \text{annual traffic growth rate factor for design period}$$

$$n = \text{number of years in design period}$$

$$r = \text{Traffic growth (from question is } 4.5\% \text{ or } 0.045)$$

$$TGF = \frac{[(1+r)^n]-1}{r}$$

$$\begin{aligned}
 TGF &= \frac{[(1+0.045)^{20}]-1}{0.045} \\
 &= 31.37
 \end{aligned}$$

$$\begin{aligned}
 ESAL_{DES} &= ESAL_{y_1} \times TGF \\
 &= 0.334 \times 31.37 \\
 &= 10.48 \text{ million}
 \end{aligned}$$

3.3 The Flexible Pavement Design

Solution

Step 6 : Determine Traffic Category

From Table, Traffic Category is T4

Traffic Category	Design Traffic (ESAL x 10 ⁶)
T1	<1.0
T2	1.1 to 2.0
T3	2.1 to 10.0
T4	10.1 to 30.0
T5	>30.0

Step 7 : Determine Subgrade (SG) properties and categories

Subgrade Category	CBR (%)	Elastic Modulus (MPa)	
		Range	Design Input Value
SG1	5 to 12	50 to 120	60
SG2	12.1 to 20	80 to 140	120
SG3	20.1 to 30	100 to 160	140
SG4	>30	120 to 180	180

Subgrade Strength,

Design Input Value

Characteristic CBR value used for design:

$$= \text{Mean} - (\text{Normal Deviate} \times \text{Standard Deviation})$$

$$= 18.5\% - (1.282 \times 4.4\%)$$

$$= 18.5 - 5.6\%$$

$$= 12.9\%$$

From Table, Subgrade (CBR 12.1 to 20%) is Category SG2.

3.3 The Flexible Pavement Design Solution

Step 8 : Determine T and S, choose from catalogue

Appendix: Pavement Structures for Traffic Category T4: 10.0 to 30.0 million ESALs

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base				
Deep Strength: Stabilised Base				
Full Depth: Asphalt Concrete Base				

3 pavement types considered for T4 SG2,

1. Conventional flexible pavement with granular base
2. Deep strength flexible (composite) pavement with bituminous surface course and a base stabilized with Portland Cement, Bituminous Emulsion or a combination of both.
3. Full depth asphalt pavement with bituminous base course



INTRODUCTION TO RIGID PAVEMENT

Rigid pavement, often referred to as concrete pavement, is a type of road or surface construction that is characterized by its stiff structure.

4.1 Introduction

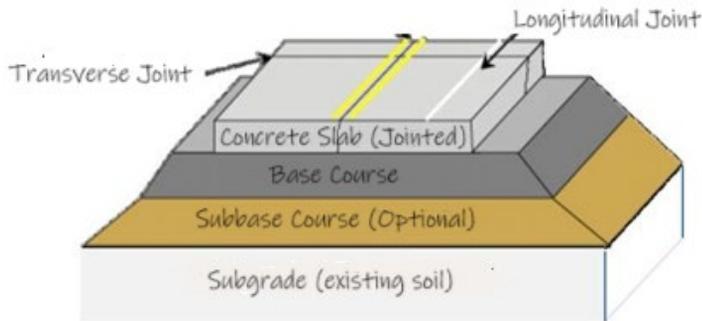
Rigid pavement, often referred to as concrete pavement, is a type of road or surface construction that is characterized by its stiff and unyielding structure. Unlike flexible pavement, which can bend under pressure, rigid pavement consists of a firm and unbroken layer of concrete. Rigid Pavements are typically used in highways, airports, and other areas where durability and load-bearing capacity are paramount.

Differences between Rigid and Flexible Pavements

The differences between Rigid and Flexible Pavements are described in the table below:

	Rigid Pavement	Flexible Pavement
Material	Applies Cement as Binder material	Applies Bitumen or Tar as Binder material
Layers	Constructed in 3 layers: <ul style="list-style-type: none"> - Subgrade - Base - Surface 	Constructed in 4 layers: <ul style="list-style-type: none"> - Sub grade - Subbase - Base - Surface
Deflection	Concrete deflects forces outward	Bitumen deflects forces downward
Strength	Dependent on the flexural strength of concrete.	Reliant on subgrade strength
Deformation	Deformations pose permanent settlements	have self-healing properties that can recover from heavier wheel loads.

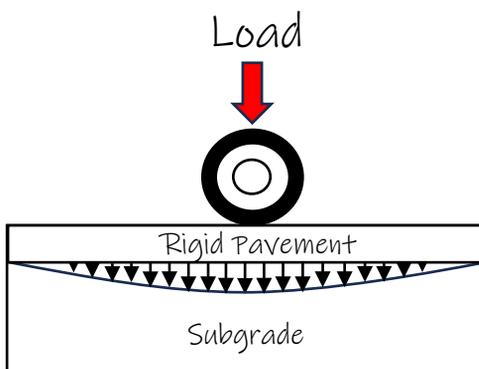
4.1 Introduction



A typical cross section of a rigid pavement (Asfoor, 2015)

Elements of a Rigid Pavement

Just like the Flexible Pavement, a Rigid pavement consist of the existing soil (subgrade), base and surface (concrete slab). Subgrades are optional for rigid pavements. The surface is constructed using (pre-designed) concrete mix in the form of slabs and are connected using joints. These are the important elements in a rigid pavement which is different than the common flexible pavement.



How do Rigid Pavements bear loading?

When a vehicle tire applies a load to the surface of a rigid pavement, the load is distributed over a relatively large area of the concrete slab. The rigidity of concrete allows it to distribute the load efficiently, reducing the pressure or stress on any particular point on the pavement surface.

4.2 Types of Rigid Pavement

Rigid pavements, also known as concrete pavements, come in various types, each with specific design and construction characteristics. The choice of rigid pavement type depends on factors such as traffic volume, load-bearing capacity requirements, climate conditions, and budget considerations. Here are some common types of rigid pavements:

Jointed Plain Concrete Pavement (Mass Concrete) (JPCP)

JPCP is the most basic and commonly used type of rigid pavement. It consists of individual concrete slabs separated by transverse and longitudinal joints.

Transverse joints are typically spaced at regular intervals to control cracking and allow for thermal expansion and contraction.

Longitudinal joints are used to separate adjacent lanes.

Jointed Reinforced Concrete Pavement (JRCP)

JRCP includes reinforcing steel bars (rebar) within the concrete slabs.

The reinforcement helps control cracking and improve the pavement's load-carrying capacity. JRCP is often used in areas with heavy traffic or where additional strength is required.

Continuously Reinforced Concrete Pavement (CRCP)

CRCP is a type of rigid pavement that has continuous reinforcement throughout the entire length of the slab.

This type of pavement is designed to resist cracking and maintain structural integrity under heavy loads.

CRCP is commonly used on high-traffic highways and roads.

Prestressed Concrete Pavement (PCP)

PCP uses prestressed strands or wires in the concrete slabs to create compressive forces that counteract the tensile stresses experienced by the pavement.

Prestressing enhances the load-bearing capacity and minimizes cracking.

PCP is often used in airport runways and industrial pavements.

Other types of Rigid Pavements are Roller-Compacted Concrete, Post-Tensioned Concrete Pavement and Prestressed Precast Concrete Pavement.

4.3 Joints in Rigid Pavement

Concrete is a material which is strong in compression, but relatively weak when placed in tension. Tensile stresses may build up in concrete pavements because of shrinkage during the hydration process, temperature and moisture changes, and/or traffic loadings. When the tensile stresses are great enough, cracks occur. The main type of joints, **Expansion Joints** allow for expansion of the pavement due to temperature changes whereas **Contraction Joints** provide crack control by relieving tensile stresses in the pavement slab.

Joints are often used as a means of:

- To control cracking
- To protect adjacent structures
- To accommodate paving operations

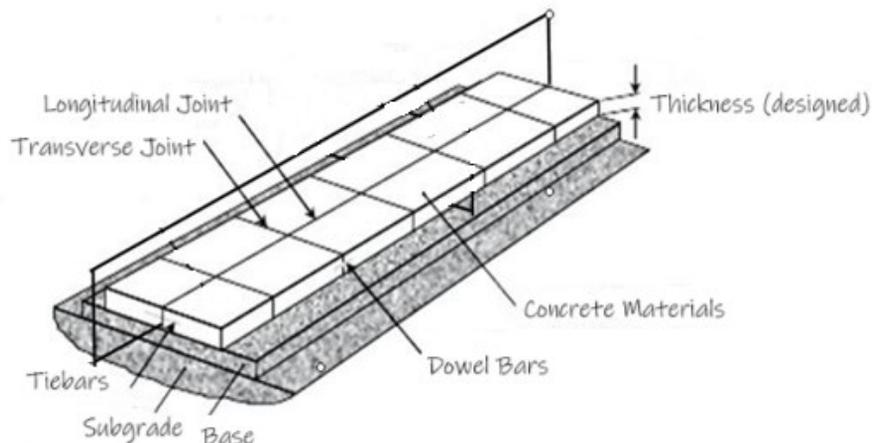
Types of Joints:

(1) Crossed Joint @ Transverse Joint

- Expansion joint
- Contraction joint
- Construction joint
- Isolation Joint

(2) Logitudinal Joints

- Expansion joint
- Isolation Joint



4.3 Joints in Rigid Pavement

Expansion Joints

Expansion joints are used to separate slabs and concrete from other parts of the structure.

An expansion joint is placed at a specific location to allow the pavement to expand without damaging adjacent structures. However, expansion joints are not typically used today because their progressive closure tends to cause contraction joints to progressively open. Expansion joints allow independent movement between adjoining structural members, minimizing cracking when such movements are restrained.

Contraction Joints

Contraction joints are planes, usually a vertical separating concrete in a structure or a pavement placed at a designed location.

Contraction joints are placed in such a way that they interfere least with the performance of the structure as well as prevent formation of objectionable shrinkage cracks elsewhere in concrete.

Concrete is subjected to shrinkage due to loss of moisture in it at the time of drying, which results in the formation of cracks in the structure. The interval of these joints is from 5m to 10m.

Isolation Joints

An isolation joint is a separation of an existing concrete slab from a new concrete slab or wall.

Isolation joints allow for anticipated differential horizontal and vertical movements between pavements and structures. Their purpose is to allow movement without damaging adjacent structures.

Isolation joints should be constructed with a preformed joint filler material to prevent infiltration of incompressible material—typically sand, dirt, or other debris.

Construction Joints

A construction joint is a type of concrete joint that is used when a new section of concrete is poured adjacent to another concrete section that has already set.

The purpose of a construction joint is to allow for some horizontal movement, while being rigid against rotational and vertical movement.

Construction joints prevent the premature failure of the concrete structure.

An alternative method to join a concrete slab that is already set with another concrete slab is to place a tie bar through each, thus connecting them together.

4.4 The Construction of Rigid Pavement

Equipment

- Three wheeled or vibratory roller for compaction purpose.
- Shovels, spades and sieving screens.
- Concrete mixer for mixing concrete.
- Formwork and iron stakes.
- Watering devices.
- Wooden hand tampers for concrete compaction.
- Cycle pump / pneumatic air blower for cleaning of joint.
- Mild steel sections and blocks for making joint grooves for finishing purposes.

Method

- Construction by Slip Form Paver.
- Construction by Fixed form Paver.
- Construction by Fixed Form and labor-oriented method of paving

Operation

- Spreading prepared concrete mix to desired thickness, grade and cross profiles.
- Compacting.
- Finishing the surface to desired surface profile.
- Texturing.
- Curing.
- Cutting of construction joints and longitudinal joints.

4.4 The Construction of Rigid Pavement

Site Preparation

Before construction begins, the site must be carefully prepared – this includes preparing the subgrade, sub-base (if needed) and road base. Firstly, the site is graded into cut high points and fill low areas to the desired roadway profile elevation. (The cut material can be used as fill material / embankment). An aggregate course is layered on the subgrade to improve drainage and stability. A course of fairly rigid material (treated cement or asphalt) is placed on the subgrade to provide a stable platform.

Construction by Slipform Paver

Depending on the type of slip-form paver used, it can do the finish grading; spread the concrete over the subgrade; vibrate, tamp, strike-off and shape the concrete to the desired thickness and surface conformation. Concrete used in slip-form paving is the same as that used in conventional form paving. The concrete should have a uniform consistency, a slump of about 2 inches. It is deposited directly in front of the paving machine or into a hopper box. The slip-form paver then goes into action. It spreads the concrete by means of a paddle. This is followed by vibrators, tampers, and oscillating bars in various configurations. After the consolidation, a extrusion meter extending the complete pavement width creates the correct surface conformation for the slab. There is little hand finishing required. A pigmented membrane curing compound is applied immediately.

Construction by Fixed-form Paver

Fixed form paving uses a series of preset molds (or “forms”) to shape a rigid pavement. These forms are placed on the graded base or subgrade in the desired shape of the final rigid pavement. They can be made of anything from welded steel sections to simple lumber. Typically, larger jobs use 3m.



HIGHWAY DEFECTS & MAINTENANCE

Defects and Deformation of highway and
Methods of Highway Rehabilitation and Repair.

5.1 Highway Maintenance

Highway maintenance refers to the ongoing effort of fixing issues on established roads. This process commences once road construction concludes, aiming to manage potential hazards and guarantee the safety of pedestrians and other users. It encompasses various tasks aimed at upholding the road's condition and safety following its initial construction.

“ Maintenance works are done to control the defect and ensure the road service stays in good condition. ”

Objectives of Highway Maintenance

The overall purpose of highway maintenance is to fix defects and preserve the pavement's structure and serviceability. The three (3) objectives of highway maintenance are:

- Repair functional pavement defects **to ensure the durability** of the road.
- **Extend the functional and structural service life** of the pavement to maintain the road for traffic use.
- Keep road reserve in acceptable condition to **smoothen the traffic system**.

The overall purpose of highway maintenance is to fix defects and preserve the pavement's structure and serviceability. The three (3) objectives of highway maintenance are:

- Maintaining the pavement and road furniture after construction.
- Controlling the rate of damage by conducting immediate remediation.
- Reducing higher costs due to late repair works.
- Continuous improvement of the traffic flow.
- Ensuring the safety of all road users.
- Providing a comfortable pavement for long distance travels.

5.1 Highway Maintenance

Types of highway maintenance in Malaysia

Emergency

Which are difficult to predict or beyond control, but which have an immediate effect on serviceability of the road and need to be dealt with without delay.

Present / Routine

Which is not subjected to detailed planning but can be assessed on the basics of acceptable level of service and is performed throughout the year.

Periodic

Which can be predicted and planned, generally are cyclic in nature and carried out after certain periods of time.

Emergency Maintenance

- Avalanches
- Soil or Pavement Erosion
- Floods
- Roadkill
- Malfunctioned Traffic Lights
- Road accidents

Routine Maintenance

- Rebuild road surface with Premix.
- Surface dressing.
- Grading and rebroadcast shoulder roads stone.
- Paint the center road line.

Routine Maintenance

- Grass cutting.
- Drainage cleaning
- Puddle patch/tile.
- Road shoulder maintenance.
- Bridge and culvert cleaning.
- Sign board cleaning.
- Bridge maintenance.
- Traffic light and Intersection checking.

5.2 Road Defects

5.2.1 Cracking

Distress	Causes & Details
Fatigue cracking	Commonly called alligator cracking, this type of defect can progress to potholes. This is a series of interconnected cracks creating small, irregular shaped pieces of pavement. It is caused by failure of the surface layer or base due to repeated traffic loading.
Block cracking and thermal cracking	Block cracking is an interconnected series of cracks that divides the pavement into irregular pieces. This is sometimes the result of transverse and longitudinal cracks intersecting. They can also be due to lack of compaction during construction.
Longitudinal cracking	Longitudinal cracks are long cracks that run parallel to the center line of the roadway. These may be caused by frost heaving or joint failures, or they may be load induced.
Transverse Cracking	Transverse cracks form at approximately right angles to the centreline of the roadway. They are regularly spaced and have some of the same causes as longitudinal cracks.
Slippage cracking	Poor bond between the surface layer and underlying layer Slippage cracking occurs in areas where vehicles brake and turn.
Edge Cracking	Edge cracks typically start as crescent shapes at the edge of the pavement. They will expand from the edge until they begin to resemble alligator cracking. This type of cracking results from lack of support of the shoulder due to weak material or excess moisture.
Reflective Cracking	Reflective cracking occurs when a pavement is overlaid with hot mix asphalt concrete and cracks reflect up through the new surface. It is called reflective cracking because it reflects the crack pattern of the pavement structure below.

5.2 Road Defects

5.2.2 Surface Deformation

Distress	Causes & Details
Rutting	Rutting is the displacement of pavement material that creates channels in the wheel path. Very severe rutting will actually hold water in the rut. Rutting is usually a failure in one or more layers in the pavement.
Corrugation	Corrugation is referred to as wash boarding because the pavement surface has become distorted like a washboard. Corrugations usually occur at places where vehicles accelerate or decelerate.
Shoving	Shoving is also a form of plastic movement in the asphalt concrete surface layer that creates a localized bulging of the pavement. Locations and causes of shoving are similar to those for corrugations.
Depressions	Depressions are small, localized bowl-shaped areas that may include cracking. Depressions cause roughness, are a hazard to motorists, and allow water to collect. Depressions are typically caused by localized consolidation or movement of the supporting layers beneath the surface course due to instability.
Swelling	A swell is a localized upward bulge on the pavement surface. Swells are caused by an expansion of the supporting layers beneath the surface course or the subgrade.

5.2 Road Defects

5.2.2 Disintegration

Distress	Causes & Details
Potholes	Potholes are bowl-shaped holes similar to depressions. They are a progressive failure. Potholes are often located in areas of poor drainage, formed when the pavement disintegrates under traffic loading, due to inadequate strength in one or more layers of the pavement, usually accompanied by the presence of water.
Patches	A patch is defined as a portion of the pavement that has been removed and replaced. Patches are usually used to repair defects in a pavement or to cover a utility trench.

5.2.3 Surface Defects

Raveling and weathering	It is a result of insufficient adhesion between the asphalt cement and the aggregate. Initially, fine aggregate breaks loose and leaves small, rough patches in the surface of the pavement. As the disintegration continues, larger aggregate breaks loose, leaving rougher surfaces.
Bleeding	Bleeding is defined as the presence of excess asphalt on the road surface which creates patches of asphalt cement. Excessive asphalt cement reduces the skid-resistance of a pavement, and it can become very slippery when wet, creating a safety hazard. This is caused by an excessively high asphalt cement content in the mix, using an asphalt cement with too low a viscosity (too flowable), too heavy a prime or tack coat, or an improperly applied seal coat.
Polishing	Polishing is the wearing of aggregate on the pavement surface due to traffic. It can result in a dangerous low friction surface.

5.3 Highway Maintenance Techniques

5.3.1 Cracking

Distress	Recommended Maintenance Technique
Fatigue cracking	- Small areas may be fixed with a patch or area repair. Larger areas require reclamation or reconstruction.
Block cracking and thermal cracking	- Narrow cracks in unreinforced slabs and medium cracks in all slabs will need to be sealed; or - Stitched crack repair - Wide cracks will necessitate either a bay replacement repair or a full depth repair
Longitudinal cracking	- Narrow cracks in reinforced slabs require no immediate action - Narrow cracks in unreinforced slabs and medium cracks in slabs of all types should be remedied by means of a stitched crack repair - Wide cracks in all slabs should be remedied either by a longitudinal full depth repair or by means of a bay replacement repair
Transverse Cracking	- Medium width cracks – form a groove and seal - Wide cracks – transverse full depth repair - Full bay reconstruction
Slippage cracking	- Repair requires removal of the slipped area and repaving, applying new tack coat in the new pavement
Edge Cracking	- Corner or transverse full depth repair
Reflective Cracking	- They can be repaired in similar techniques to the other cracking noted above. Before placing any overlays or wearing courses, cracks should be properly repaired.

5.3 Highway Maintenance Techniques

5.3.2 Surface Deformation

Distress	Recommended Maintenance Technique
Rutting	<ul style="list-style-type: none"> - Minor surface rutting can be filled with micro paving or paver-placed surface treatments - Deeper ruts may be shimmed with a truing and levelling course, with an overlay placed over the shim. If the surface asphalt is unstable, recycling of the surface may be the best option. If the problem is in the subgrade layer, reclamation or reconstruction may be needed.
Corrugation	<ul style="list-style-type: none"> - Minor corrugations can be repaired with an overlay or surface milling. - Severe corrugations require a deeper milling before resurfacing.
Shoving	<ul style="list-style-type: none"> - Repair minor shoving by removing and replacing. For large areas, milling the surface may be required, followed by an overlay.
Depressions	<ul style="list-style-type: none"> - Repair by excavating and rebuilding the localized depressions. Reconstruction is required for extensive depressions.
Swelling	<ul style="list-style-type: none"> - Repair swells by excavating the inferior subgrade material and rebuilding the removed area. - Reconstruction may be required for extensive swelling

5.3 Highway Maintenance Techniques

5.3.3 Disintegration

Distress	Recommended Maintenance Technique
Potholes	<ul style="list-style-type: none"> - Repair by excavating and rebuilding. - Area repairs or reconstruction may be required for extensive potholes.
Patches	<ul style="list-style-type: none"> - To repair a patch, a semi-permanent patch should be placed. - Extensive potholes may lead to area repairs or reclamation. Reconstruction is only needed if base problems are the root source of the potholes
Shoving	<ul style="list-style-type: none"> - Repair minor shoving by removing and replacing. For large areas, milling the surface may be required, followed by an overlay.

5.3 Highway Maintenance Techniques

5.3.4 Surface Defects

Distress	Recommended Maintenance Technique
Raveling and weathering	- Repair the problem with a wearing course or an overlay
Bleeding	- Remedies include: - Cold mill and resurface - Square patching - Hot-in-place recycling
Polishing	- Cold mill and resurface with standard bituminous wearing course or textured - wearing course if high skidding resistance is essential - Hot-in-place recycling
Depressions	- Repair by excavating and rebuilding the localized depressions. Reconstruction is required for extensive depressions.
Swelling	- Repair swells by excavating the inferior subgrade material and rebuilding the removed area. - Reconstruction may be required for extensive swelling

The End

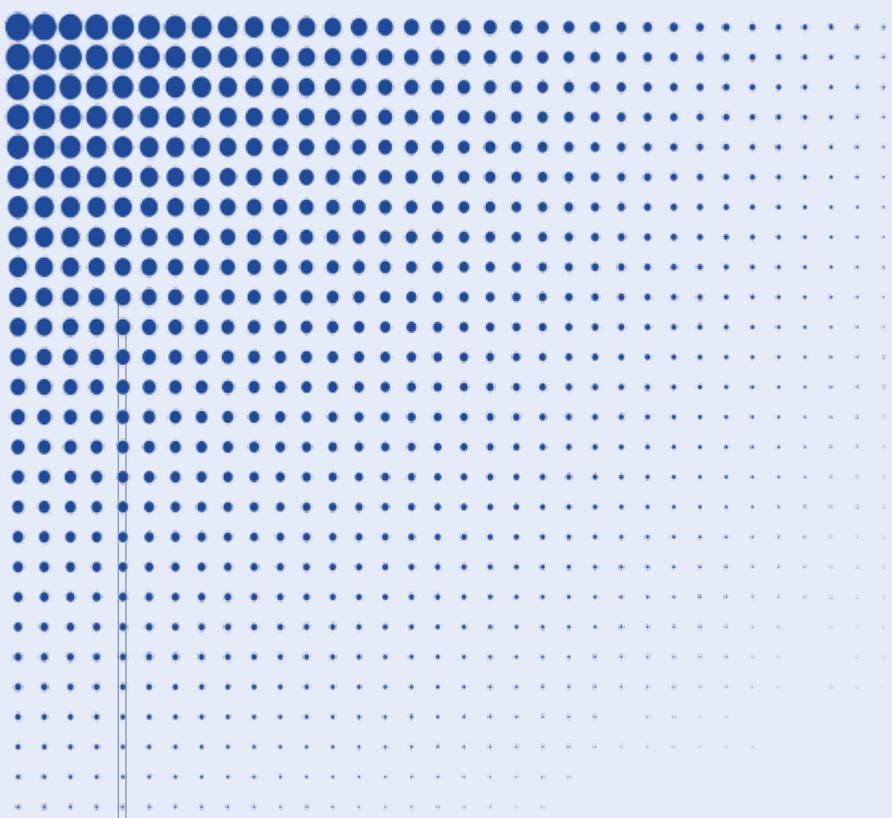
That is all for this book!

'The pursuit of knowledge is an unending journey, and each study is but a steppingstone on the path to greater understanding.'

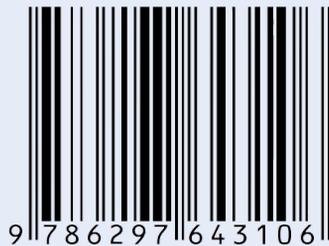
Indeed, our work here is just one of many steppingstones in the ongoing quest to deepen our comprehension of Highway Engineering especially for Diploma Students!

See you next time!

**NOR HANIZA BINTI MUSTAFAR KAMAR
DAZLYNA BINTI ZAINAL ABIDIN**



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