
UNIVERSITI SAINS MALAYSIA

First Semester Examination
2015/2016 Academic Session

December 2015 / January 2016

EAL334 – Highway Engineering
[Kejuruteraan Lebuh Raya]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of **TWENTY THREE (23)** pages of printed material including **TWO (2)** appendices before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi **DUA PULUH TIGA (23)** muka surat yang bercetak termasuk **DUA (2)** lampiran sebelum anda memulakan peperiksaan ini.]

Instructions : This paper contains **SIX (6)** questions. Answer **FIVE (5)** questions.

If you answer question **3(b)i** you have to submit the attachment together with the answer booklet.

[**Arahan** : Kertas ini mengandungi **ENAM(6)** soalan. Jawab **LIMA (5)** soalan.

jika anda menjawab soalan 3(b)i anda perlu kepilkan lampiran dan serah bersama dengan buku jawapan anda.]

You may answer the question either in Bahasa Malaysia or English.

[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

All questions **MUST BE** answered on a new page.

[Semua soalan **MESTILAH** dijawab pada muka surat baru.]

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

1. [a] Adequate drainage of the pavement structure is considered to be the most important element in the long-term pavement performance. There are several elements of water resources that often contribute to the pavement distress. Determine those elements with the aid of appropriate sketches.

Saliran pada struktur turapan yang lengkap dianggap sebagai satu elemen yang paling penting bagi prestasi jangka panjang turapan. Terdapat beberapa elemen sumber air yang sering menyumbang kepada kerosakan turapan jalan raya. Nyatakan elemen-elemen tersebut dengan bantuan lakaran yang bersesuaian.

[5 marks/markah]

- [b] John L. MacAdam was one of the first early pavement engineers to recognize the importance of drainage. He designed pavement drainage to protect the subgrade from moisture damage. State **FOUR (4)** effects of the improper drainage design or less maintained drainage to the pavement.

*John L. MacAdam merupakan salah seorang daripada jurutera turapan yang paling awal mengiktiraf kepentingan saliran. Beliau mereka bentuk saliran turapan untuk melindungi subgred daripada kerosakan kelembapan. Nyatakan **EMPAT (4)** kesan reka bentuk saliran yang tidak betul atau kurang diselenggara kepada turapan.*

[4 marks/markah]

- [c] Explain **FIVE (5)** functions of the subsurface drainage systems for a road structure.

*Terangkan **LIMA (5)** fungsi bagi sistem penyaliran air bawah permukaan untuk satu struktur jalan raya.*

[5 marks/markah]

- [d] As a road engineer, you need to ensure that the road design is safe, environmental friendly and convenient to be used by the road users. Based on your knowledge, state your opinion from the engineering perspective on how to tackle the pavement damage problems from the point of road design, road construction and road maintenance.

Sebagai seorang jurutera jalan raya, anda harus memastikan turapan yang direkabentuk adalah selamat, mesra alam sekitar dan selesa digunakan oleh pengguna jalan raya. Berdasarkan pengetahuan anda, nyatakan pendapat anda dari persektif kejuruteraan bagaimana untuk mengatasi masalah kerosakan turapan dari sudut reka bentuk jalan, pembinaan jalan dan penyenggaraan jalan.

[6 marks/markah]

2. [a] Aggregates are processed and produced in a quarry. With the aid of sketches, describe the following quarry activities:

Agregat diproses dan dihasilkan di dalam kuari. Berbantuan lakaran, terangkan aktiviti berikut yang dijalankan di dalam sebuah kuari:

- [i] steps taken to process aggregates beginning from blasting huge rock mass to building an aggregate stockpile of a desired size.

langkah yang diambil untuk memproses agregat dimulai dengan peletupan agregat batuan besar hingga membina timbunan stok yang diperbuat daripada agregat bersaiz yang dikehendaki.

- [ii] steps taken to minimize segregation when building an aggregate stockpile.

langkah yang diambil untuk meminimumkan pengasingan ketika membina timbunan stok.

- [iii] steps taken to minimize segregation when loading the trucks with aggregates from a segregated stockpile.

langkah yang diambil untuk meminimumkan pengasingan ketika memuatkan trak dengan agregat daripada timbunan stok mengandungi agregat yang terasing.

[10 marks/markah]

- [b] From sieve analysis, the aggregate grading of aggregates samples A, B and C are shown in **Table 1**.

*Daripada analisis ayak, pengredan agregat sampel A, B dan C ditunjukkan di dalam **Jadual 1**.*

Table 1/ Jadual 1

Sieve Size/ Saiz Ayak (mm)	Cumulative Percentage Passing/ <i>Peratusan Melempi Kumulatif</i>		
	Aggregate A/ <i>Agregat A</i>	Aggregate B/ <i>Agregat B</i>	Aggregate C/ <i>Agregat C</i>
37.5	100	100	100
28	100	100	100
20	100	83	100
14	87	77	92
10	72	63	65
5	67	51	48
3.35	51	38	21
1.18	21	22	11
0.075	7	5	6

From the above test results, report the following values for each aggregate sample according to the Superpave definition:

Daripada keputusan tersebut, laporkan nilai berikut untuk setiap sampel agregat menurut takrifan Superpave:

- [i] Maximum aggregate size
Saiz maksimum agregat

[ii] Nominal maximum aggregate size

Saiz maksimum nominal agregat

[4 marks/markah]

[c] Aggregates produced from a quarry must be able to resist abrasive forces. Name **ONE (1)** laboratory test that can simulate this aggregate property in the laboratory. Describe how this test simulate field behavior and describe the test principles to determine the aggregate Los Angeles Abrasion Value.

*Agregat yang dihasilkan di kuari mestilah berupaya merintanginya daya lelasan. Namakan **SATU (1)** ujian makmal yang boleh mensimulasikan ciri agregat ini di makmal. Terangkan bagaimanakah ujian ini mensimulasi keadaan di tapak dan terangkan prinsip ujian untuk menentukan Nilai Lelasan Los Angeles.*

[6 marks/markah]

3. [a] The following binder types are used for road construction:

- Tar
- Cutback
- Emulsions
- Blown bitumen
- Polymer modified binder

Jenis bahan pengikat berikut digunakan untuk membina jalan raya:

- *Tar*
- *Bitumen cecair*
- *Emulsi*
- *Bitumen tertiuap*
- *Bitumen berpinda polimer*

[i] Choose **ONE (1)** of the above binder types. Explain its production method.

*Pilih **SATU (1)** daripada pengikat tersebut di atas. Terangkan kaedah penghasilannya.*

[ii] Which **ONE (1)** of the above binder types would you select and recommend to solve the following scenarios (justify your answers):

- You need a tack coat material to bind the wearing course and binder course?
- You are awarded with a road project in Libya subjected to daily temperature fluctuating between 79°C during midday and 29°C at night time.
- As a petrol station operator, you insist on blacktop surfacing instead of concrete to pave the entire petrol station area.

Cadang SATU (1) jenis pengikat tersebut di atas untuk penyelesaian senario berikut (nyatakan justifikasi jawapan anda):

- *Anda memerlukan bahan lapisan semburan berbitumen untuk mengikat lapisan penghausan dan lapisan pengikat.*
- *Anda mendapat projek jalan raya di Libya yang terdedah kepada perubahan suhu harian di antara 79°C pada waktu tengah hari dan 29°C pada waktu malam.*
- *Sebagai pemilik stesen minyak, anda mahukan permukaan hitam dan tidak konkrit sebagai bahan turapan untuk seluruh kawasan stesen minyak anda.*

[8 marks/markah]

[b] **Table 2** shows the penetration tests results on bitumen A and B carried out at different temperatures.

Jadual 2 menunjukkan keputusan ujian penusukan ke atas bitumen A dan B yang dijalankan pada pelbagai suhu.

[i] Calculate the Penetration Index using the following methods:

- formula developed by Shell
- nomograph given in **APPENDIX A**
- graphical method

Use the nomograph provided in **APPENDIX A** and include this nomograph in your answer script

Kira Indeks Penusukan menggunakan kaedah berikut:

- rumus yang dibangunkan oleh Shell
- nomograf yang diberikan di dalam **LAMPIRAN A**
- kaedah bergraf

*Menggunakan nomograf yang diberikan di **LAMPIRAN A** dan sertakan nomograf ini di dalam skrip jawapan anda.*

[4 marks/markah]

Table 2 / Jadual 2

Bitumen Characteristics/ <i>Ciri Bitumen</i>	Bitumen Type/ <i>Jenis Bitumen</i>	
	A	B
Softening Point/ <i>Titik Lembut (°C)</i>	50	54
Penetration(dmm) at/ <i>Penusukan pada:</i>		
4	18	14
10	29	22
15	45	33
25	100	70
35	227	169

[ii] Compare between the two Penetration Indices that you obtained. Which value is the most accurate? Justify your answer.

Bandingkan nilai kedua-dua Indeks Penusukan. Nilai yang manakah yang lebih tepat? Nyatakan justifikasi jawapan anda.

[1 marks/markah]

- [iii] Name the bitumen which is more temperature susceptible. Justify your answer.

Namakan bitumen yang lebih sensitif terhadap suhu. Nyatakan justifikasi jawapan anda.

[1 marks/markah]

- [iv] From the penetration test results, identify the grade of both bitumen.

Daripada keputusan ujian penusukan, kenalpasti gred bitumen kedua-dua bitumen.

[1 marks/markah]

- [c] Bitumen is a visco-elastic material. Briefly explain the effects of temperature and time of loading on bitumen properties. With the aid of a sketch, show how does the bitumen respond when acted upon by an instantaneous load.

Bitumen adalah bahan likat-elastik. Terangkan secara ringkas kesan suhu dan tempoh pembebanan ke atas sifat bitumen. Berbantukan lakaran, tunjukkan bagaimanakah bitumen berindakbalas apabila ditindaki beban ketika.

[5 marks/markah]

4. [a] You are designing an asphalt mixture type AC14 for the wearing course for a JKR road surfacing project. The aggregate composition incorporating hydrated lime as filler is shown in **Table 3**. In the laboratory, mixes were compacted using a gyratory compactor and tested for volumetric properties and Marshall properties according to the JKR specifications. The laboratory test results are shown in **Table 4**, while **Table 5** shows the Malaysian Public Works Department specification limits.

From the results shown in **Table 3** and **Table 4**, calculate the specific gravity of aggregate mixture and plot the following relationships:

- Density versus bitumen content
- Air voids versus bitumen content
- Stability versus bitumen content
- Flow versus bitumen content
- Voids filled with bitumen versus bitumen content

In the laboratory, why was a gyratory compactor used to compact the Marshall specimens? From the graphs plotted, determine the optimum bitumen content. Compare the value obtained with the JKR specifications and evaluate their conformity to the specification requirements.

*Anda merencanakan campuran asfalt jenis AC14 untuk lapisan penghausan sebuah projek penurapan semula jalan JKR. Komposisi agregat yang mengandungi kapur terhidrat sebagai pengisi ditunjukkan di dalam **Jadual 3**. Di makmal, campuran dipadat menggunakan pemadat legaran dan diuji untuk mendapatkan ciri volumetrik dan Marshall menurut spesifikasi JKR. Keputusan ujian makmal ditunjukkan di dalam **Jadual 4**, manakala **Jadual 5** menunjukkan had spesifikasi Jabatan Kerja Raya Malaysia.*

*Daripada keputusan yang ditunjukkan di dalam **Jadual 3** dan **Jadual 4**, kira graviti tentu campuran agregat dan plot hubungan berikut:*

- *Ketumpatan campuran lawan kandungan bitumen*
- *Lompang udara campuran lawan kandungan bitumen*
- *Kestabilan campuran lawan kandungan bitumen*
- *Aliran lawan kandungan bitumen*
- *Lompang terisi bitumen campuran lawan kandungan bitumen*

Di makmal, kenapakah pemadat legaran digunakan untuk memadat specimen Marshall? Daripada graf yang diplot, tentukan kandungan bitumen optimum. Bandingkan nilai yang diperolehi dengan spesifikasi JKR dan nilai pematuhan campuran dengan kehendak spesifikasi.

[14 marks/markah]

Table 3/ Jadual 3

Material/ <i>Bahan</i>	Percentage/ <i>Peratusan</i> (%)	Specific Gravity/ <i>Graviti Tentu</i> (g/cm ³)
Coarse Aggregate/ <i>Agregat Kasar</i>	50	2.66
Fine Aggregate/ <i>Agregat Halus</i>	48	2.69
Filler (Hydrated Lime)/ <i>Pengisi (Kapur Terhidrat)</i>	2	2.76
Bitumen/ <i>Bitumen</i>	Variety/ <i>Pelbagai</i>	1.018

Table 4 / Jadual 4

Bitumen Content/ <i>Kandungan</i> <i>Bitumen</i> (%)	Mass in Air/ <i>Jisim di</i> <i>Udara</i> (g)	Mass in Water/ <i>Jisim di</i> <i>dalam Air</i> (g)	Mass Saturated Surface Dried/ <i>Jisim</i> <i>Permukaan</i> <i>Kering Tepu</i> (g)	Measured Stability/ <i>Kestabilan</i> <i>Terukur</i> (kN)*	Flow/ <i>Aliran</i> (mm)
4.5	1187.4	679.6	1191.3	8.8	1.8
5.0	1085.3	625.1	1089.2	14.8	2.3
5.5	1103.5	643.3	1107.6	12.5	3.5
6.0	1026.7	597.5	1032.4	10.3	5.1

*Assume all specimens are of heights equivalent to 63.5 mm/*Andaikan ketinggian semua spesimen adalah sama iaitu 63.5 mm.*

Table 5/Jadual 5

Property/ <i>Ciri</i>	Specification/ <i>Spesifikasi</i>
Stability/ <i>Kestabilan</i> , kN	> 8
Flow/ <i>Aliran</i> , mm	< 2 - 4
Air Voids/ <i>Lompang Udara</i> , %	3 - 5
Voids Filled With Bitumen/ <i>Lompang Terisi Bitumen</i> , %	70 - 80

- [b] [i] The asphalt batch mixing plant produced better quality asphalt mixes compared to asphalt mixes produced using the drum or continuous mixing plant. With the aid of sketches, explain how the batch asphalt mixing plant operates.

Loji campuran asphalt kelompok menghasilkan campuran asphalt yang lebih berkualiti berbanding campuran asphalt yang dihasilkan oleh loji campuran asphalt gelendong. Berbantukan lakaran, terangkan bagaimanakah loji campuran asphalt ini beroperasi.

- [ii] Explain the differences in the operating principles of this mixing plant compared with the continuous asphalt mixing plant.

Terangkan perbezaan prinsip operasi loji campuran ini berbanding loji campuran berterusan.

[6 marks/markah]

5. [a] A newly constructed road that was recently opened to traffic exhibits the following surfacing problems:

Terdapat masalah permukaan berikut pada sebatang jalan raya yang baru dibuka kepada lalu lintas:

- [i] surface waves are seen at frequent intervals along the road profile.

ombak permukaan dapat dilihat pada jarak berkala di sepanjang profil jalan raya.

- [ii] rutting or permanent deformation takes place along the wheel path.

ubah bentuk kekal berlaku disepanjang laluan tayar.

- [iii] from field extracted cores, the air voids is much lower than 4% and excessive bleeding takes place especially along the wheel path.

daripada teras yang diperolehi daripada tapak, lompong udara kurang daripada 4% dan penjujukan lumrah berlaku di sepanjang laluan tayar.

- [iv] the road surfacing is rough, riding quality is poor and many coarse aggregates are seen on the surfacing, some of which have cracked or disintegrated.

permukaan jalan raya kasar, mutu tunggangan tidak baik dan banyak agregat kasar kelihatan di atas permukaan, sebahagian daripadanya telah retak dan pecah.

For each of the scenario above, identify the probable sources of construction and materials problem and propose appropriate solutions.

Untuk setiap senario di atas, kenal pasti kemungkinan punca masalah pembinaan dan bahan dan cadangan penyelesaian yang sesuai.

[12 marks/markah]

- [b] Explain the meaning of “load transfer” in rigid pavement and state **THREE (3)** methods which can be used to achieve load transfer across transverse joints/cracks.

*Terangkan maksud “pemindahan beban” dalam turapan tegar dan nyatakan **TIGA (3)** kaedah yang boleh digunakan untuk memindahkan beban merentasi sambungan melintang atau retakan.*

[4 marks/markah]

- [c] In the thickness design of rigid pavement, based on Portland Cement Association (PCA) method, discuss the design criteria used.

Dalam reka bentuk ketebalan turapan tegar, menurut kaedah “Portland Cement Association (PCA)”, bincangkan kriteria reka bentuk yang digunakan.

[4 marks/markah]

6. [a] “ESAL” which stands for equivalent single axle load is an important factor in the design of pavement thickness. Explain the importance of ESAL in the design of pavement thickness. With the aid of sketches, explain the importance of wheel loading on the calculation of ESAL.

$$\text{Given: } F = \left(\frac{L}{L_s}\right)^4$$

where

F = Load equivalence factor

L = Axle load

L_s = Standard axle load

“ESAL” yang membawa maksud beban setara gandar tunggal merupakan factor yang penting dalam reka bentuk ketebalan turapan. Terangkan kepentingan ESAL dalam reka bentuk ketebalan turapan. Dengan berbantuan gambarajah, terangkan kepentingan beban gandar ke atas pengiraan ESAL.

$$\text{Diberi: } F = \left(\frac{L}{L_s}\right)^4$$

dimana

F = Faktor setara beban

L = Beban gandar

L_s = Beban gandar setara

[8 marks/markah]

- [b] Calculate the minimum and maximum average daily traffic (bothways) for a level two-way two-lane highway for traffic category T3 if the traffic growth rate is 4.5%, and the percentage of commercial vehicle is 14%. If the mean California Bearing Ratio (CBR) of the subgrade is 16%, design the flexible pavement for a typical design life period based on the JKR method.

If the highway is widen to four-lane with average daily traffic of 10,150 vehicles for bothways, determine the new pavement design. Refer and use the tables and chart given in **APPENDIX B**.

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

where

ESAL_{DES} = ESAL for the design period

ESAL_{Y1} = ESAL for base year

r = growth rate

n = number of years

Kira nilai purata lalu lintas harian minimum dan maksimum sebatang lebuh raya empat-lorong untuk kategori trafik T3 sekiranya kadar pertumbuhan lalu lintas ialah 4.0%, dan peratus kenderaan perdagangan ialah 14%. Jika purata Nisbah Galas California (CBR) subgred ialah 16%, reka bentuk sebuah turapan boleh lentur untuk jangka hayat lazim menurut tatacara JKR.

*Sekiranya lebuh raya tersebut dilebarkan menjadi empat-lorong dengan purata lalu lintas harian sebanyak 10,150 kenderaan dua hala, tentukan reka bentuk turapan yang baru. Rujuk dan gunakan jadual dan carta yang diberikan dalam **LAMPIRAN B**.*

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

dimana

$ESAL_{DES}$ = ESAL untuk tempoh reka bentuk

$ESAL_{Y1}$ = ESAL untuk tahun asas

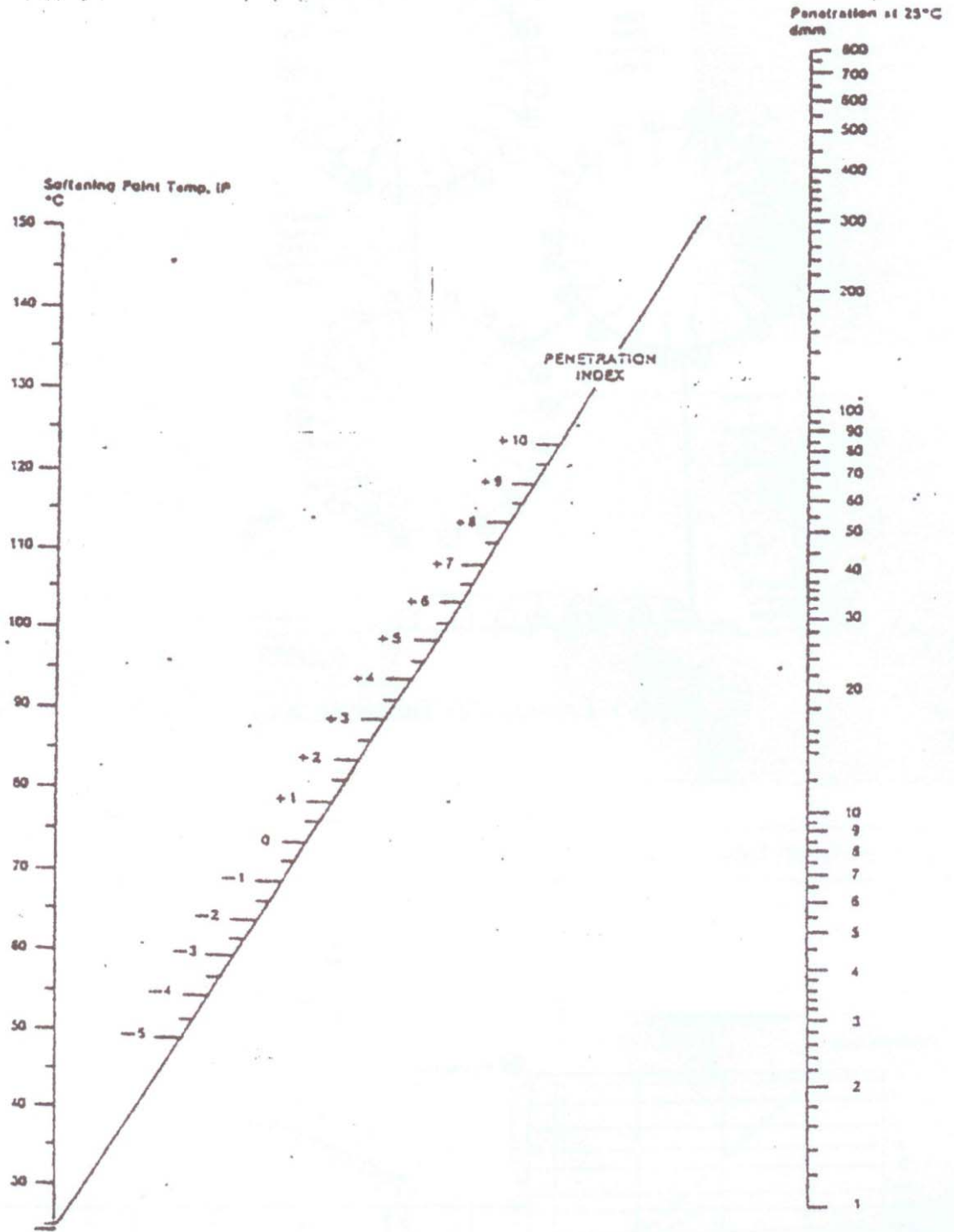
r = kadar pertumbuhan

n = bilangan tahun

[12 marks/markah]

ANGKA GILIRAN: _____

APPENDIX A / LAMPIRAN A



[Masukkan Lampiran Ini Dalam Buku Skrip Jawaban]

APPENDIX B / LAMPIRAN B

The following tables and figures are extracted from ATJ 5/85 (Pindaan 2013), "Manual for Structural Design of Flexible Pavement".

Jadual dan rajah berikut diambil daripada ATJ 5/85 (Pindaan 2013), "Manual for Structural Design of Flexible Pavement".

Table 1: Axle configuration and vehicle load factors (VLF) based on traffic categories

Vehicle		Load Equivalence Factor (LEF)
HPU class designation	Class	
Cars and taxis	C	0
Small trucks and vans (2 axles)	CV1	0.1
Large trucks (2 to 4 axles)	CV2	4.0
Articulated trucks (3 or more axles)	CV3	4.4
Buses (2 or 3 axles)	CV4	1.8
Motorcycles	MC	0
Commercial traffic (mixed)	CV%	3.7

Table 2: Lane distribution factor

Number of lanes (in one direction)	Lane distribution factor, L
One	1.0
Two	0.9
Three or more	0.7

Table 3: Terrain factor

Type of terrain	Terrain factor, T
Flat	1.0
Rolling	1.1
Mountainous/ steep	1.3

Table 4: Traffic Categories

Design period (years)	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

Table 5: Conceptual Outlines of Pavement Structures

Pavement Structure	Traffic Category (based on million ESALs @ 80 kN)					
	≤ 1	1 to 2	2.1 to 10	10.1 to 30	> 30	
	T1	T2	T3	T4	T5	
Combined Thickness of Bituminous Layers					24 cm	
			18 cm	20 cm		
	5 cm	10cm				
Crushed Aggregate Road Base + Sub-Base for Sub-grade CBR of:						
	• 5 to 12	25+15 cm	20+15 cm	20+20 cm	NR	NR
	• 12.1 to 20	20+15 cm	20+15 cm	20+20 cm	20+20 cm	20+20 cm
	• 20.1 to 30	20+10 cm	20+10 cm	20+15 cm	20+15 cm	20+15 cm
	• > 30	20 cm	20+10 cm	20+10 cm	20+10 cm	20+10 cm