Kursus Rekabentuk Turapan Jalan
(Flexible Pavement)
7 - 9 Ogos 2019

Rekabentuk Pavemen (Jajaran Baru)

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Cawangan Jalan

KANDUNGAN

1. Pengenalan kepada rekabentuk turapan anjal (fleksibel)
2. Kaedah rekabentuk
    2.1 Empirical
    2.2 Mekanistik Empirical
3. Kaedah Rekabentuk Empirical
4. Kaedah Rekabentuk Mekanistik Empirical
5. Hands On

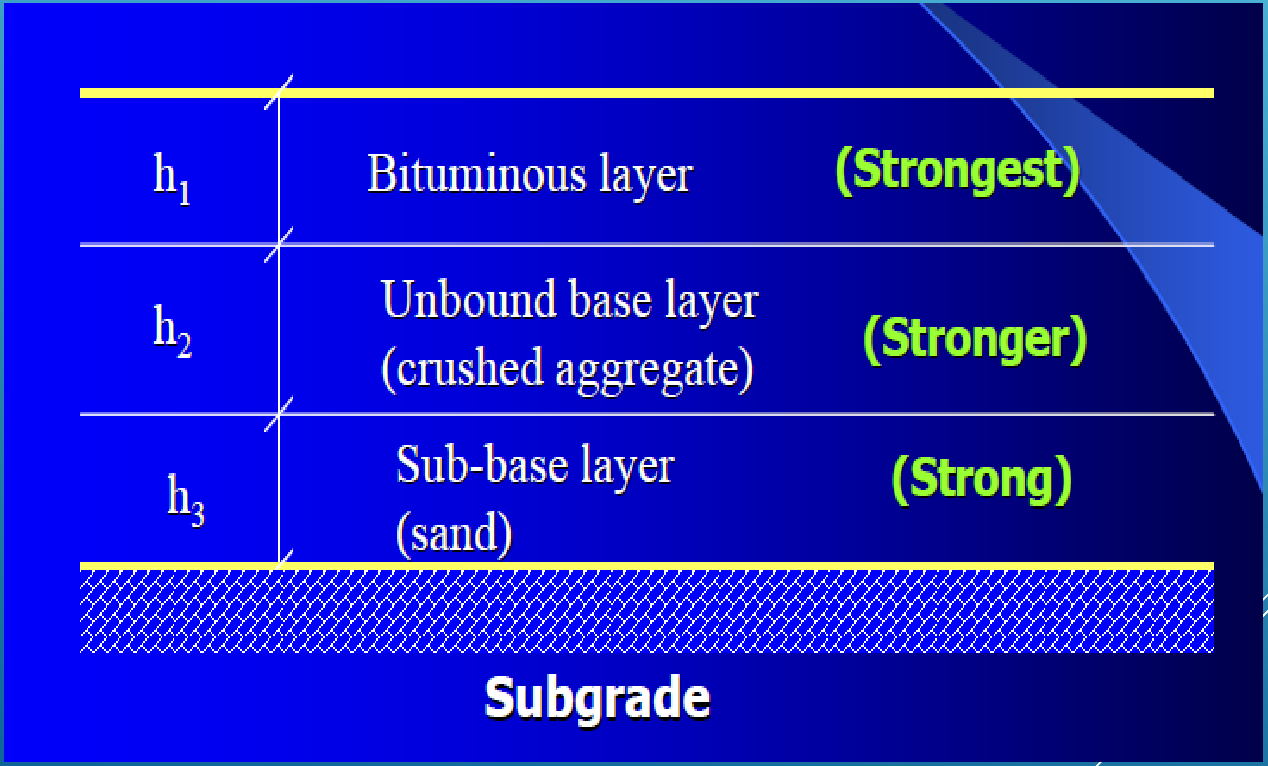
REKABENTUK TURAPAN ANJAL

Proses sistematik untuk mengenalpasti kombinasi ketebalan lapisan pavemen yang ekonomik berdasarkan : -

- keadaan tanah (subgred)
- unjuran beban trafik (ESAL)

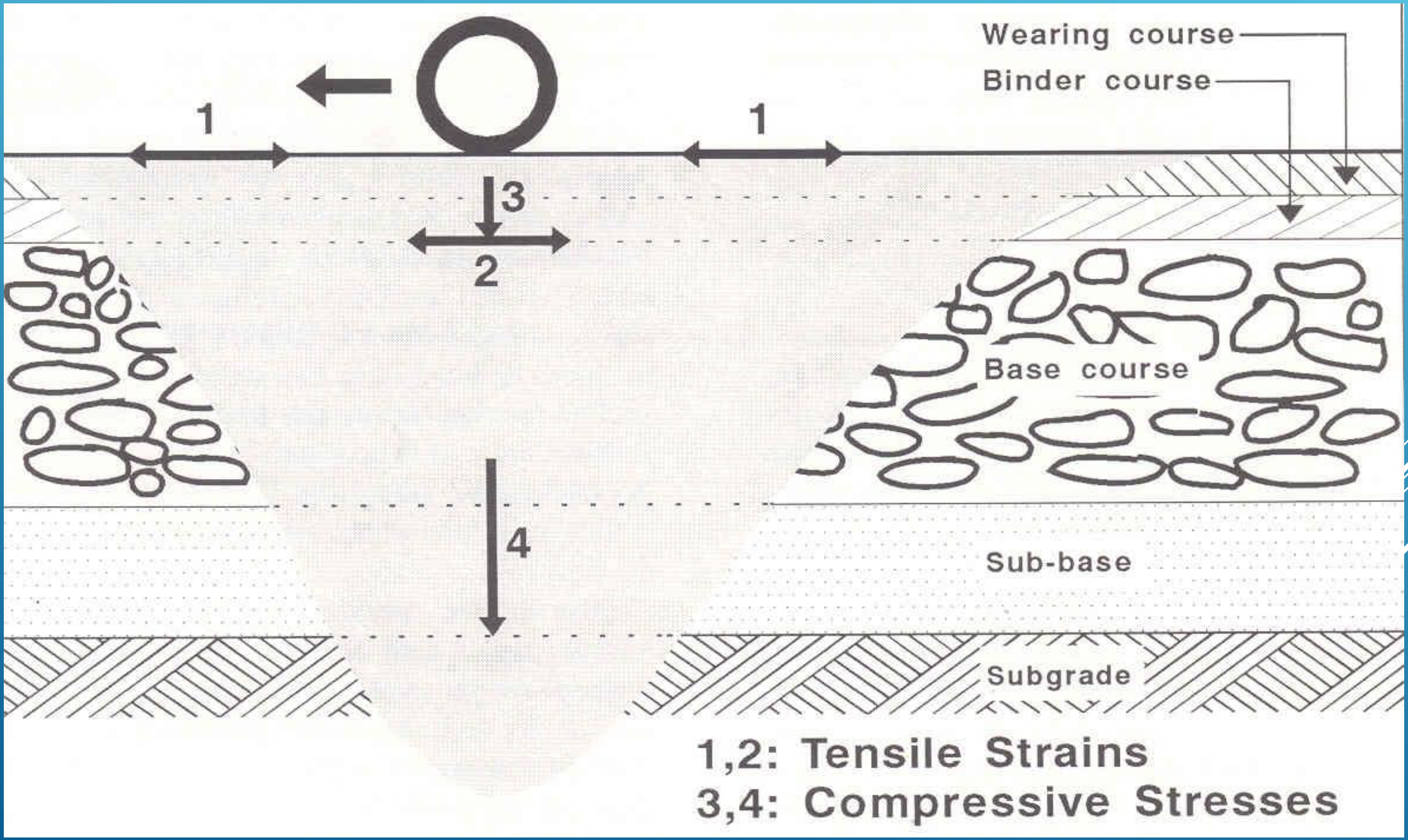
REKABENTUK TURAPAN ANJAL

Untuk memenuhi keperluan agihan bebanan (stress) secara seragam ke atas subgred, lapisan yang berbeza kekuatan dari atas ke lapisan subgred digunakan



REKABENTUK TURAPAN ANJAL

Konsep bebanan kepada pavemen



KAEDAH REKABENTUK TURAPAN

- kaedah empirikal
- kaedah mekanistik empirikal

KAEDAH EMPIRIKAL

- Empirical = based on, concerned with, or verifiable by observation or experience rather than theory or pure logic.
- Dibangunkan sejak tahun 1940an
- pemerhatian kepada prestasi jalan di bawah keadaan tertentu
- menggunakan carta, katalog, nomograph
- contoh : -
  - AASHTO (1984)
  - ATJ 5/85 Manual on Pavement Design

ATJ 5/85 Manual on Pavement Design

- Kaedah empirikal
- Guna nomograph
- Guna analisis komponen struktur


FOR INTERNAL USE ONLY
Arahan Teknik(Jalan) 5/85

JABATAN KERJA RAYA

JKR

MANUAL ON PAVEMENT DESIGN

CAWANGAN JALAN
IBU PEJABAT JKR MALAYSIA
JALAN SULTAN SALAHUDDIN
50582 KUALA LUMPUR

Cawangan Jalan, Ibu Pejabat JKR, K.L
Page 1

ARAHAN TEKNIK 5/85

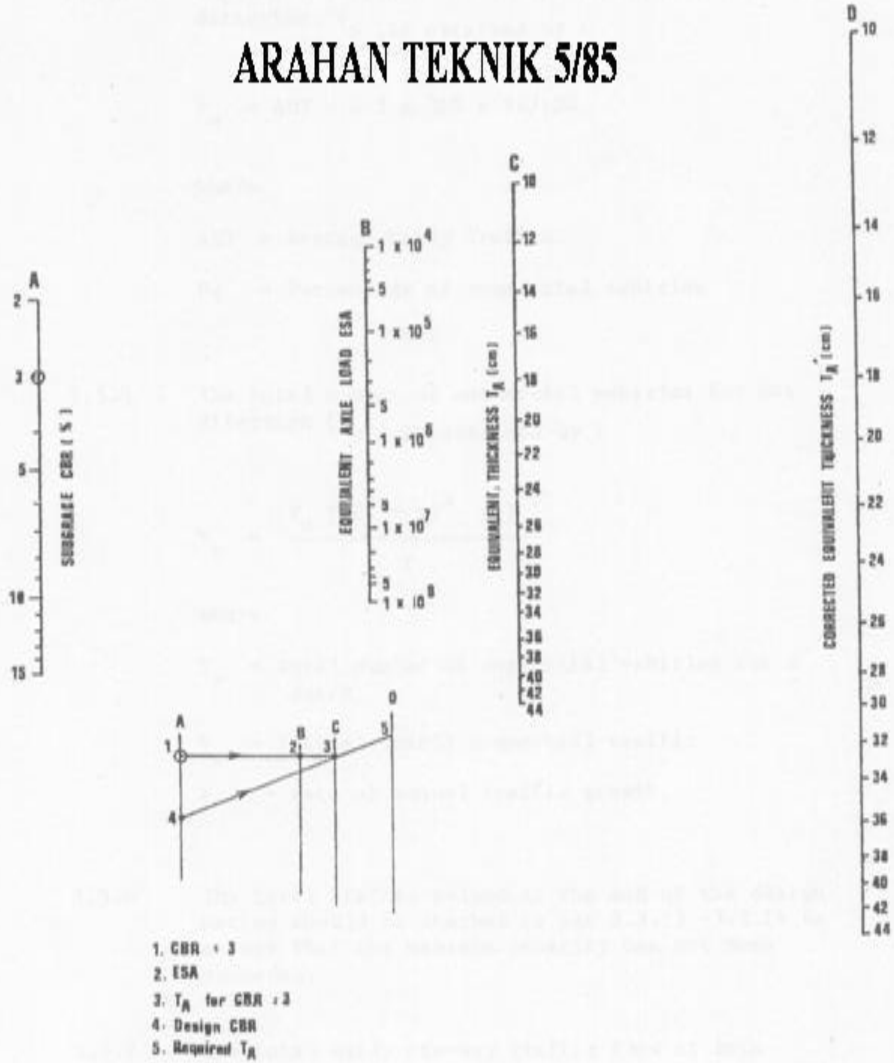


FIG-2 THICKNESS DESIGN NOMOGRAPH

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- jangkahayat rekabentuk untuk 10 tahun
- anggaran faktor setaraan seperti jadual 3.1

3.3.8 Estimate the Equivalence Factor (e)
In the absence of an axle load survey, Table 3.1 below shall be used as a guide.

Table 3.1 Guide for Equivalence Factor

Percentage of selected heavy goods vehicles*	**0-15%**		**16-50%**	**51-100%**
Type of road Equivalence Factor	local 1.2	trunk 2.0	3.0	3.7

* Selected heavy goods vehicles refer to those conveying timber and quarry materials.

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Table 3.5 Structural Layer Coefficients

Component	Type of Layer	Property	Coefficient
Wearing and Binder Course	Asphalt Concrete		1.00
Base Course	Dense Bituminous Macadam	Type 1:Stability > 400 kg	0.80
		Type 2:Stability > 300 kg	0.55
	Cement Stabilized Mechanically Stabilized crushed aggregate	Unconfined Compressive strength(7 days) 30-40 kg/cm2	0.45
		CBR? 80%	0.32
Subbase	Sand, laterite etc.	CBR ? 20%	0.23
	Crushed aggregate	CBR ? 30%	0.25
	Cement Stabilized	CBR ? 60%	0.28

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Table 3.6 Minimum Layer Thickness

Type of Layer		Minimum Thickness
Wearing Course		4 cm
Binder Course		5 cm
Base Course	Bituminous	5 cm
	Wet Mix	10 cm
	Cement treated*	10 cm
Subbase Course	Granular	10 cm
	Cement treated	15 cm

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Table 3.7 Standard & Construction Layer Thickness

Type of layer		Standardard thickness	One layer lift
Wearing course		4-5 cm	4-5 cm
Binder course		5-10 cm	5-10 cm
	Bituminous	5-20 cm	5-15 cm
Base	Wet mix	10-20 cm	10-15 cm
Course	Cement treated	10-20 cm	10-20 cm
Subbase	Granular	10-30 cm	10-20 cm
Course	Cement treated	15-20 cm	10-20 cm

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Table 3.8 Minimum Thickness of Bituminous Layer

T_A	Total thickness of bituminous layer
< 17.5 cm	5.0 cm
17.5 - 22.5 cm	10.0 cm
23.0 - 29.5 cm	15.0 cm
> 30.0 cm	17.5 cm

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New Pavement Design : Steps

(i) Determine subgrade support using CBR or DCP test.

(ii) Calculate traffic design loading.

(iii) Use nomograph to determine equivalent thickness, T_A

(iv) Determine thickness of each pavement layer by trial and error using:

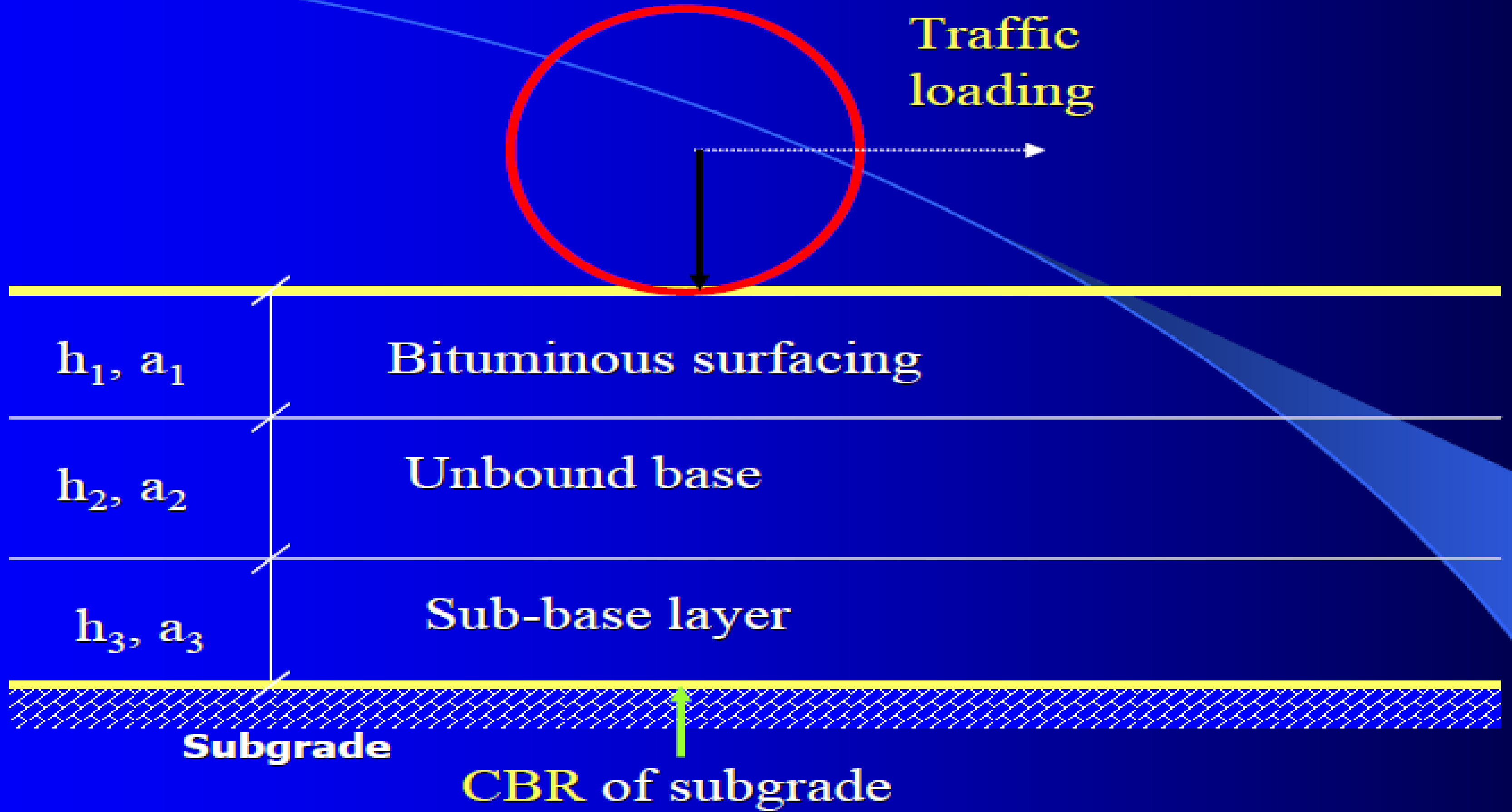
$$T_A = h_1a_1 + h_2a_2 + h_3a_3 \ldots h_na_n$$

where,

$h_1 \ldots h_n$ = layer thickness

$a_1 \ldots a_n$ = structural layer coefficient

(v) Check minimum thickness and other practical aspects of construction.



h_1 = thickeness of bituminous layer
a_1 = structural coefficient of layer

h_2 = thickeness of unbound base
a_2 = structural coefficient of unbound base

h_3 = thickeness of subbase
a_3 = structural coefficient of subbase

EXAMPLE OF PAVEMENT DESIGN

Conditions of road (Design Parameter)

Class of road	R5
Average Daily Traffic (ADT)	10,000 (Both way)
Percentage of Commercial Vehicles	15%
Annual Growth rate (r)	5%
Design Life (n)	10 Years
Equivalence Factor (E.F)	2.0
Subgrade CBR	5%

Calculation of Design Loading

First year traffic = $V_0 = 10{,}000 * 0.15 * 0.5 * 365$

(one way) = 273,750

Total Traffic (10 years) = $V_c = V_0 [(1+r)^n - 1] / r$

= $273{,}750 [(1 + 0.05)^{10} - 1] / 0.05$

= 3,443,198

Total Design Loading = V_c * E.F.

= 3,443,198 * 2.0

= 6.9 million standard axles

= 6.9 msa

Design Calculation

Design subgrade **CBR** = **5%**

Design **Loading** = 6.9 msa

From Arahan Teknik 5/85, **Thickness Design Normograph**,

The required pavement thickness T_A = 270mm

Desgin Caluculation (cont'd)

$T_A = 270mm$

Layer Thickness	Structural Coefficient	Minimum Thickness
Asphaltic Concrete, h_1	$a_1 = 1.0$	90mm
Wet-Mix, Macadam base, h_2	$a_2 = 0.32$	100mm
Sand Sub-base, h_3	$a_3 = 0.23$	100mm

First Trial :

Use

$h_1 = 100mm$

$h_2 = 150mm$

$h_3 = 300mm$

Then

$T_A = 1.0 * 100 + 0.32 * 150 + 0.23 * 300$

$= 217 \text{ mm} < 270mm$

NOT ADEQUATE

Second Trial :

Use

$h_1 = 110mm$

$h_2 = 300mm$

$h_3 = 300mm$

Then

$T_A = 1.0 * 110 + 0.32 * 300 + 0.23 * 300$

$= 275 \text{ mm} > 270mm$

O.K

Proposed Pavement Thickness

Asphaltic Concrete Wearing Course (ACWC)	=	50mm
Asphaltic Concrete Binder Course (ACBC)	=	60mm
Wet mix macadam	=	300mm
Sand	=	300mm

KAEDAH MEKANISTIK - EMPIRIKAL

- berdasarkan model responsif dan parameter asas kejuruteraan pavemen
- menggunakan teori multi-layer linear elastic
- boleh digunakan merentasi perubahan keadaan geografi dan iklim
- masih guna analisis komponen struktur
- contoh AASHTO (1993), TRL LR1132 (1984), Shell (1985), ATJ 5/85 - 2013

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- merupakan mekanistik empirikal
- menggunakan katalog
- katalog dibangunkan berdasarkan analisis struktur bersama kaedah mekanistik
- disemak berdasarkan beberapa kaedah mekanistik yang berada di pasaran (perisian)

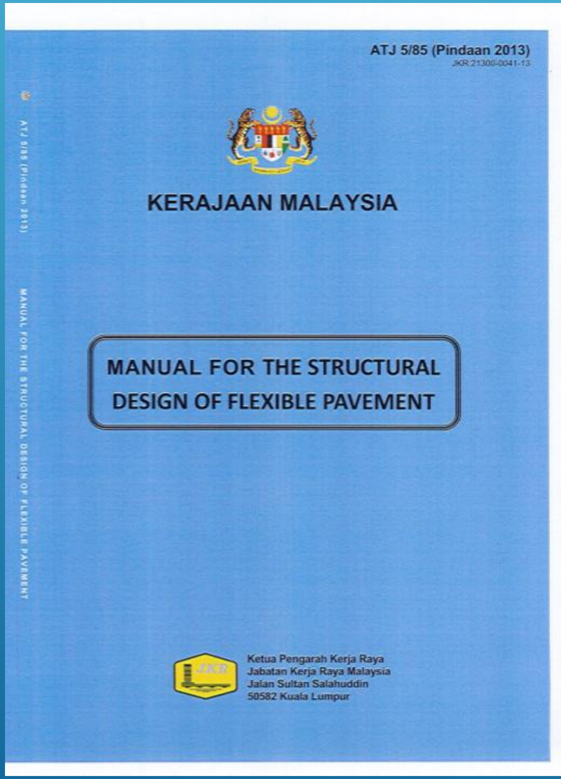

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FIGURE 3.1: Pavement Structures for Traffic Category T 1: < 1.0 million ESALs (80 kN)

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** GSB: 300 or Surface Treatment** STB 2: 250	Surface Treatment** GSB: 300 or Surface Treatment** STB 2: 250	Surface Treatment** GSB: 250 or Surface Treatment** STB 2: 200	Surface Treatment** GSB: 250 or Surface Treatment** 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.*

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- jangkahayat rekabentuk untuk 20 tahun untuk trafik kategori T4 & T5

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TABLE 2.1: Axle Configuration and Load Equivalence Factors (LEF) based on Traffic Categories used by HPU

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

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TABLE 2.4: Total Growth Factors (TGF)

Design Period (Years)	Annual Growth Rate (%)					
	2	3	4	5	6	7
10	10.95	11.46	12.01	12.58	13.18	13.82
15	17.29	18.60	20.02	21.58	23.28	25.13
20	24.30	26.87	29.78	33.06	36.79	41.00
25	32.03	36.46	41.65	47.73	54.86	63.25
30	40.57	47.58	56.08	66.44	79.06	94.46

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TABLE 2.5: Traffic Categories used in this Manual (ESAL = 80 kN)

Traffic Category	Design Traffic (ESAL x 10^6)	Probability (Percentile) Applied to Properties of Sub-Grade Materials
▪ T 1	**≤ 1.0**	≥ 60%
▪ T 2	**1.1 to 2.0**	≥ 70%
▪ T 3	**2.1 to 10.0**	≥ 85%
▪ T 4	**10.1 to 30.0**	≥ 85%
▪ T 5	**> 30.0**	≥ 85%

Note: *Whenever feasible, statistical analysis shall be used to evaluate laboratory or field test results for use as input for pavement design (sub-grade, sub-base, road base and bituminous courses). The above probability values shall be applied to material strength and stiffness values as follows: -*

Design Input Value = Mean – (Normal Deviate x Standard Deviation)

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TABLE 2.6: Classes of Sub-Grade Strength (based on CBR) used as Input in the Pavement Catalogue of this Manual

Sub-Grade Category	CBR (%)	Elastic Modulus (MPa)	
		Range	Design Input Value
▪ SG 1	**5 to 12**	50 to 120	**60**
▪ SG 2	**12.1 to 20**	80 to 140	**120**
▪ SG 3	**20.1 to 30.0**	100 to 160	**140**
▪ SG 4	**> 30.0**	120 to 180	**180**

The correlation between sub-grade stiffness and CBR values shown in **Table 2.6** above is based on the following criteria: -

- For cohesive soils, a relationship similar to that shown in *TRRL LR 1132: "The Structural Design of Bituminous Roads"* is used.
- For primarily granular materials, information contained in the 1993 edition of the *AASHTO Pavement Design Manual and in Appendices CC and DD of Mechanistic-Empirical Design of New & Rehabilitated Pavement Structures ("AASHTO 2002")* is used as primary guideline.

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The design used to develop the catalogue of pavement structures shown in this Manual is based on default values (**Table 2.7** and **2.8** below). If mechanistic design is carried out in lieu of adopting one of the pavement structures offered in this Manual, material input parameters similar to those shown below or developed on the basis of mechanistic laboratory tests (elastic modulus) shall be used. The use of design input values that differ by more than 50% from the design values shown below is discouraged.

TABLE 2.7: Elastic Properties of Unmodified Bituminous Mixtures

Bituminous Mixture based on **PEN 80/100 Bitumen**	Elastic Modulus (MPa)		Poisson's Ratio	
	25°C	35°C	25°C	35°C
▪ Wearing Course AC 10 and AC 14	----	1200	0.35	0.40
▪ Wearing Course SMA 14 and SMA 20	----	1200	0.35	0.40
▪ Binder Course AC 28	2000	1600	0.35	0.40
▪ Road Base AC 28	2000	---	0.35	---

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TABLE 2.8: Elastic Properties of Polymer Modified Bituminous Mixtures

Bituminous Mixture based on **PMB**	Elastic Modulus (MPa)		Poisson's Ratio	
	25°C	35°C	25°C	35°C
▪ Wearing Course AC 10 and AC 14	----	1400	0.35	0.40
▪ Wearing Course SMA 14 and SMA 20	----	1400	0.35	0.40
▪ Binder Course AC 28	2500	2000	0.35	0.40
▪ Road Base AC 28	2500	---	0.35	---

Notes :

1. *The elastic modulus values shown above are based on the bituminous binders as shown in the tables, on average mixture air voids of 5.0%, and on a loading time of 0.1 second (corresponding to a traffic speed of about 60 km/hour at a depth of 10 cm below pavement surface).*
2. *If PEN 60/70 bitumen is used instead of PEN 80/100, increase the elastic stiffness values shown in* **Table 2.7** *by 20%.*
3. *When polymer modified asphalt is specified, use type and grade of PMB in accordance with JKR Standard Specification for* Road Works JKR/SPJ/2008 – Section 4.

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TABLE 3.1: Conceptual Outline of Pavement Structures used in this Manual

Pavement Structure	Traffic Category (based on million ESALs @ 80 kN)				
	≤ 1	1 to 2	2.1 to 10	10.1 to 30	> 30
	T 1	T 2	T 3	T 4	T 5
▪ Combined Thickness of Bituminous Layers	5 cm	10 cm	18 cm	20 cm	24 cm
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

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item penting Table 2.1 : Axle Configuration & Equivalent Load Factor

Vehicle		Load Equivalence Factor (LEF)
Class Designation	**Class**	
Cars and Taxis	C	0
Rigid Vehicle (1+1) incl. Buses (2 Axle)	CV1	3.9
Rigid Vehicle (1+2) incl. Buses (3 Axle)	CV2	2.8
Rigid Vehicle (2+2) (4 Axle)	CV3	2.6
Articulated Vehicle (1+1+1) (3 Axle)	CV4	7.1
Articulated Vehicle (1+1+2) (4 Axle)	CV5	6.1
Articulated Vehicle (1+1+3) (5 Axle)	CV6	4.7
Articulated Vehicle (1+2+2) (5 Axle)	CV7	4.2
Articulated Vehicle (1+2+3) (6 Axle)	CV8	3.5
Articulated Vehicle (1+2+4) (7 Axle)	CV9	3.6
Motorcycles	MC	0

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5.1 Traditional Pavement with Granular Base

Design a road pavement for a 2-lane highway with an average daily traffic of 1350 vehicles, 16% of which are commercial vehicles with an un-laden weight > 1.5 tons.

ATJ 5/85 Manual on Pavement Design Semakan 2013 - kaedah pengiraan

Step 1: Development of Design Input

Traffic count data indicate a total of 2700 vehicles in both directions; pavement design is then based on 1350 vehicles (one direction, 24 hour period). If the design is based on traffic data from an HPU survey, the result based on a 16- hour survey (usually 06:00 to 22:00 hours) should be multiplied with 1.2.

The following additional project related information is available: -

PCV = 16 % (no detailed break-down by vehicle type)

Lane Distribution Factor, L = 1.0 (one lane in one direction)

Terrain Factor, T = 1.1 (rolling)

Design Life = 20 years

Annual Traffic Growth = 4.0%

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<u>Step 2</u>: Determine Design Traffic (Traffic Category)

$ESAL_{Y1}$ (Base Year) = ADT x 365 x P_{CV} x LEF x L x T

= 1350 x 365 x 16/100 x 3.5 x 1.0 x 1.1

= 0.304 million

Design Traffic over 20 Years; $ESAL_{DES}$ = $ESAL_{Y1}$ x TGF

= 0.304 x 29.78

= **9.05 million**

= **Traffic Category T 3**

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Step 3: Determine Sub-Grade Strength (Sub-Grade Category)

Results from Sub-Grade testing: -

CBR Mean	=18.5%
CBR Standard Deviation	= 4.4%
Probability 85% (Normal Deviate	= 1.282)

Characteristic CBR value used for design;

= 18.5% – 1.282 x 4.4%

= 18.5% – 5.6%

= 12.9%

= **Sub-Grade Category SG 2**

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Step 4: Select one of the pavement structures from **Figure 3.3** (T 3, SG 2)

- Conventional flexible with unmodified bitumen;
  - Bituminous Surface Course (AC 10 or AC 14): 50 mm
  - Bituminous Binder Course/Road Base (AC 28): 130 mm
  - Crushed Aggregate RoadBase: 200mm
  - Granular Sub-Base: 200 mm

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5.2 <u>Full-Depth Asphalt Pavement</u>

Design a road pavement for a 4-lane freeway (concession toll-road) with an average daily traffic of 7286 vehicles, of which 20% are commercial vehicles with an un-laden weight > 1.5 tons.

<u>Step 1</u>: Development of Design Input

ADT based on HPU survey (from 06:00 to 22:00 hours);

- CV 1 = 624 x 1.2 = 749 vehicles per 24-hour period
- CV 2 = 456 x 1.2 = 547 vehicles per 24-hour period
- CV 3 = 316 x 1.2 = 379 vehicles per 24-hour period
- CV 4 = 102 x 1.2 = 121 vehicles per 24-hour period

ATJ 5/85 Manual on Pavement Design Semakan 2013 - kaedah pengiraan

Step 1: Development of Design Input

ADT based on HPU survey (from 06:00 to 22:00 hours);

- CV 1 = 624 x 1.2 = 749 vehicles per 24-hour period
- CV 2 = 456 x 1.2 = 547 vehicles per 24-hour period
- CV 3 = 316 x 1.2 = 379 vehicles per 24-hour period
- CV 4 = 102 x 1.2 = 121 vehicles per 24-hour period

Lane Distribution Factor, L = 0.9 (two lanes in one direction)

Terrain Factor, T = 1.0 (flat)

Design Life, n = 20 years

Assumed Annual Traffic Growth Rate, r = 4.5%

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Step 2: Determine Design Traffic (Traffic Category)

$ESAL_{Y1}$ (Base Year) = $(ADT_{CV1} \times LEF_1) + (ADT_{CV2} \times LEF_2) +$

$(ADT_{CV3} \times LEF_3) + (ADT_{CV4} \times LEF_4) \times 365 \times L \times T$

$= (749 \times 0.1) + (547 \times 4.0) + (379 \times 4.4) + (121 \times 1.8) \times 365 \times 0.9 \times 1.0$

= 1.363 million

Design Traffic over 20 Years;

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

= 1.363 million x 31.37 = **42.7 million**

= **Traffic Category T 5**

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<u>Step 3</u>: Determine Sub-Grade Strength (Sub-Grade Category)

Results from Sub-Grade testing: -

Mean Modulus (H-FWD) = 165 MPa

Standard Deviation (H-FWD) = 28 MPa

Reliability 95% (Normal Deviate = 1.645)

Characteristic Sub-Grade Modulus value used for design:

= 165 MPa – (1.645 x 28 MPa)

= 165 MPa – 46 MPa

= **119 MPa**

= **Sub-Grade Category SG 3**

Note: Use design input value from Table 2.6 equal to:

(119 + 165)/2 ~ 140)

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- **OPTION 1: Conventional flexible pavement with unmodified bitumen and granular base:**
  - Bituminous Surface Course (AC 10 or AC 14): 50 mm
  - Bituminous Binder Course/Road Base (AC 28): 190 mm
  - Crushed Aggregate Road Base: 200 mm
  - Granular Sub-Base: 150 mm

- **OPTION 2: Full-Depth Asphalt Pavement with unmodified bitumen:**
  - Bituminous Surface Course (AC 10 or AC 14): 50 mm
  - Bituminous Binder Course and Road Base: 200 mm
    - Bituminous Binder Course (AC 28): 60 mm
    - Bituminous Road Base (AC 28): 140 mm
  - Granular Sub-Base: 150 mm

Note: *If asphalt binder and base course mixtures are based on the same type of binder and aggregate gradation, the thickness of binder and base course are interchangeable, that is, instead of 6 cm binder course and 14 cm base course, 10 cm binder course and 10 cm base course can be selected.*

- **OPTION 3: Use 40 mm polymer modified SMA 14 instead of 50 mm unmodified AC 10 or AC 14**

TERIMA KASIH