ONLINE LEARNING

PAVEMENT THICKNESS DESIGN

ATJ 5/85 (revision 2013)

(Manual for the Structural Design of Flexible Pavement)

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Manual For The Structural Design of Flexible Pavement

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Jabatan Kerja Raya
Cawangan Kejuruteraan Jalan & Geoteknik

ATJ 5/85 (Pindaan 2013) MANUAL FOR THE STRUCTURAL DESIGN OF FLEXIBLE PAVEMENT

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KERAJAAN MALAYSIA

MANUAL FOR THE STRUCTURAL DESIGN OF FLEXIBLE PAVEMENT

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50582 Kuala Lumpur

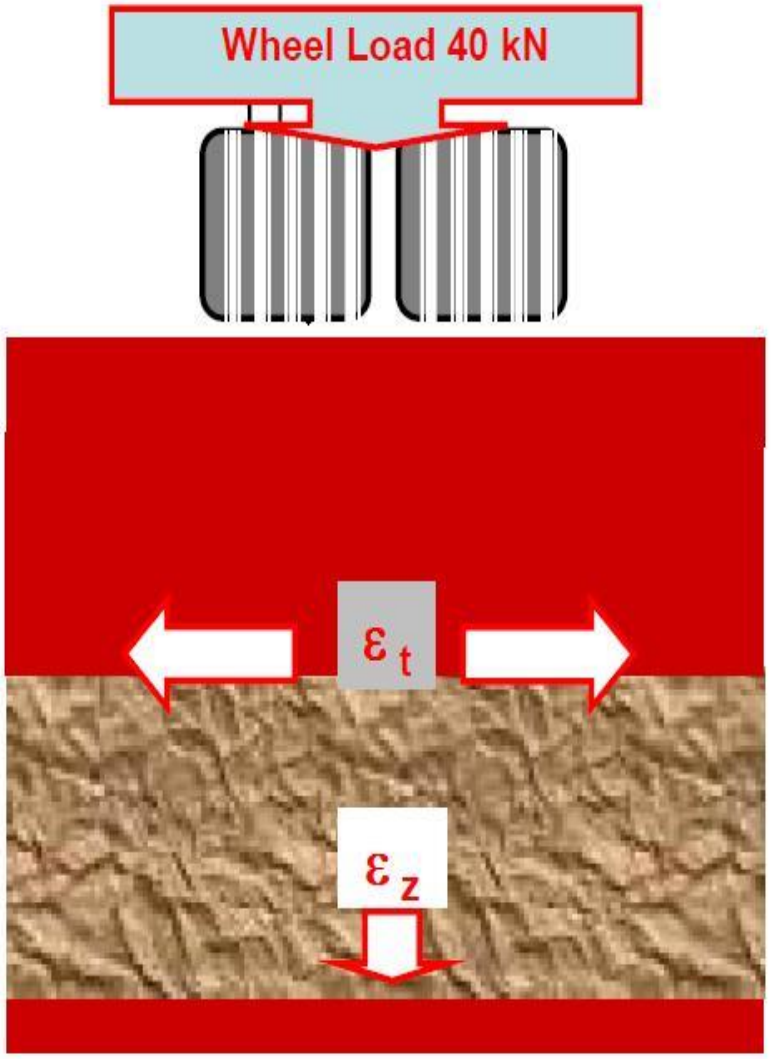
Procedure can be used to design:

1. New flexible for low volume roads, consisting of unbound or new cement stabilized granular materials
2. New flexible and semi flexible pavements containing one or more bound layers
3. New flexible and semi-flexible heavy duty pavements for severe loading conditions

Data required:

1. Type and volume of commercial vehicles
2. Design life
3. Sub-grade type and strength
4. Type and properties of paving materials
5. Environment which pavement will be exposed to

Criteria



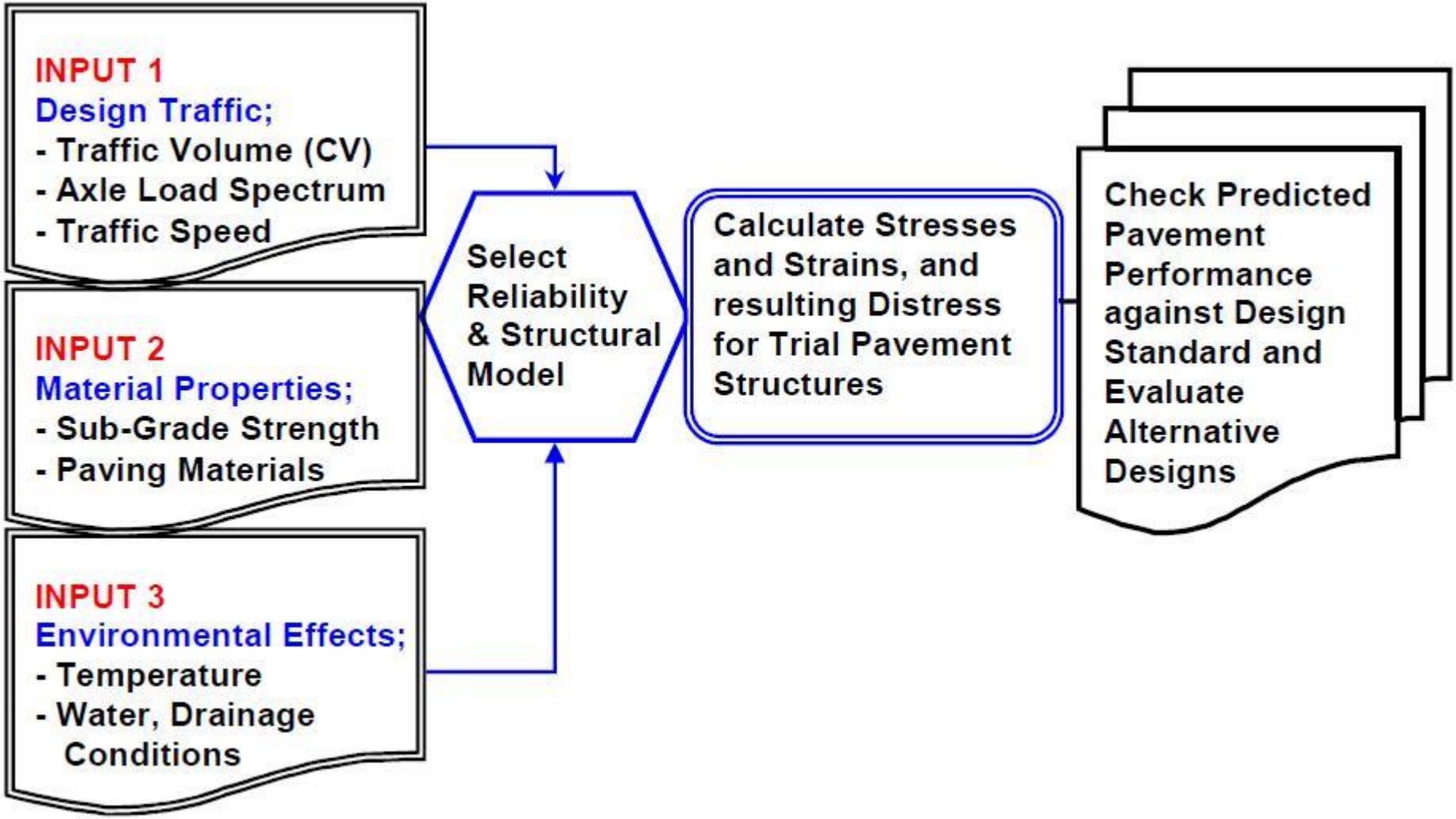
Bituminous Wearing Course
Durability, Safety (Skid Resistance, Smoothness), Strength

Bituminous Binder/Base Course
Stiffness (Load Bearing), Fatigue
Horizontal Tensile Strain at Bottom of Bound Layer

Granular Base and Sub-Base
(Additional Load Distribution)

Vertical Compressive Strain on Sub-Grade

Key elements of a systematic pavement design procedure



Required Traffic Data

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 and lane distribution factors.
4. Traffic growth factors.

Design Procedure

1. 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)
   - % P_{CV} with un-laden weight > 1.5 tons (P_{CV}) and break down into vehicle categories.
   - Traffic Growth factor (r) for CV
2. From geometric design – number of lanes and terrain condition (*L and T factors*)

3. Design Period

- 10 years for low volume and rural road
- 20 years for high volume and urban road

4. Design traffic (1st year of 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)
P_{CV} = 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
T = Terrain Factor

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:

$ESAL_{Y1}$ = [ADTcv1 x LEFcv1 + ADTcv2 x LEFcv2 +…+ ADTcv3 x LEFcv3] x 365 x L x T

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

LEF for various vehicle class

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

6. Determine traffic category

Traffic Category	Design Traffic (ESAL x 10^6)	Probability (Percentile) Applied to Properties of Sub-Grade
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%

Normal distribution with single tailed analysis, the following normal deviate values shall apply:

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

7. SG properties and categories

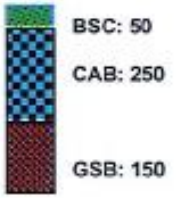
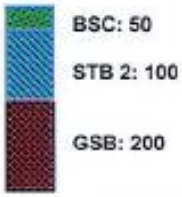
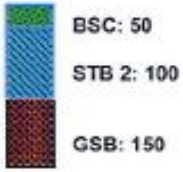
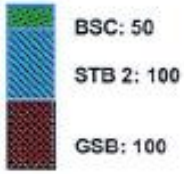
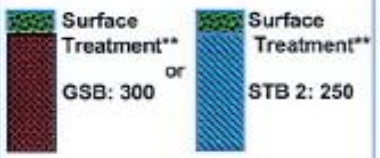
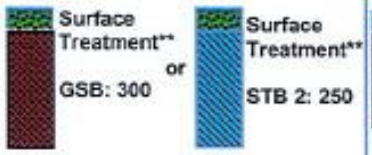
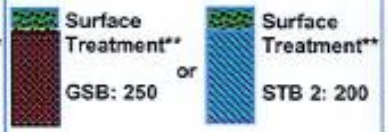
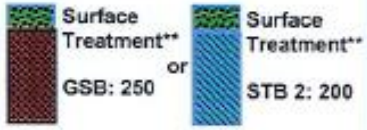
- Min 5% CBR for T1- T5
- If not, at least 0.3 meter of SG shall be replaced or stabilized to ensure the minimum value is met.
- Large volume traffic T4 and T5, min CBR 12%

Sub-Grade 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

8. Determine T and S, choose from catalogue

- 3 types of pavement considered:
  1. Conventional flexible pavement with granular base.
  2. Deep-strength flexible (composite) pavement with bituminous surface course(s) and a base stabilized with Portland cement, bituminous emulsion, or a combination of both.
  3. Full-depth asphalt pavement with bituminous base course

T1 : < 1 million ESALs

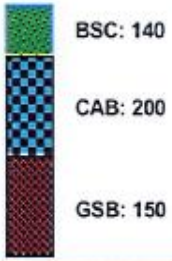
Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base				
Deep Strength: Stabilised Base				
Stabilised Base with Surface Treatment*				

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

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	 BSC: 50 BC: 130 CAB: 200 GSB: 200	 BSC: 50 BC: 130 CAB: 200 GSB: 200	 BSC: 50 BC: 130 CAB: 200 GSB: 150	 BSC: 50 BC: 130 CAB: 200 GSB: 100
Deep Strength: Stabilised Base	 BSC: 50 BC: 100 STB 1: 150 GSB: 200	 BSC: 50 BC: 100 STB 1: 150 GSB: 150	 BSC: 50 BC: 100 STB 1: 100 GSB: 150	 BSC: 50 BC: 100 STB 1: 100 GSB: 100
Full Depth: Asphalt Concrete Base	 BSC: 50 BC/BB: 160 GSB: 200	 BSC: 50 BC/BB: 150 GSB: 150	 BSC: 50 BC/BB: 130 GSB: 150	 BSC: 50 BC/BB: 130 GSB: 100

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	Sub-Grade Improvement is Recommended	BSC: 50 BC/BB: 150 CAB: 200 GSB: 200	BSC: 50 BC/BB: 150 CAB: 200 GSB: 150	BSC: 50 BC/BB: 150 CAB: 200 GSB: 100
Deep Strength: Stabilised Base		BSC: 50 BC/BB: 150 STB1: 120 GSB: 200	BSC: 50 BC/BB: 140 STB1: 100 GSB: 150	BSC: 50 BC/BB: 130 STB1: 100 GSB: 100
Full Depth: Asphalt Concrete Base		BSC: 50 BC/BB: 200 GSB: 200	BSC: 50 BC/BB: 180 GSB: 150	BSC: 50 BC/BB: 150 GSB: 100

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	Sub-Grade Improvement is Recommended	BSC: 50 BC/BB: 190 CAB: 200 GSB: 200	BSC: 50 BC/BB: 190 CAB: 200 GSB: 150	BSC: 50 BC/BB: 190 CAB: 200 GSB: 100
Deep Strength: Stabilized Base		BSC: 50 BC/BB: 160 STB1: 150 GSB: 200	BSC: 50 BC/BB: 140 STB1: 150 GSB: 150	BSC: 50 BC/BB: 140 STB 1: 150 GSB: 100
Full Depth: Asphalt Concrete Base		BSC: 50 BC/BB: 210 GSB: 200	BSC: 50 BC/BB: 200 GSB: 150	BSC: 50 BC/BB: 180 GSB: 100

T5 : > 30 million ESALs
(Polymer Modified Asphalt)

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
Special Purpose Surface Course	Sub-Grade Improvement is Recommended	SMA, PA, FC or PMA: 50 BC/BB : 170 OR PMA : 140 CAB: 200 GSB: 200	SMA, PA, FC or PMA: 50 BC/BB: 160 OR PMA : 130 CAB: 150 GSB: 150	SMA, PA, FC or PMA: 50 BC/BB: 150 OR PMA : 120 CAB: 100 GSB: 100
Deep Strength High-Modulus Base Course		BSC: 50 PMA Base: 250 GSB: 200	BSC: 5 PMA Base: 220 GSB: 15	BSC: 50 PMA Base: 200 GSB: 100

Conceptual outline of Pavement Structure

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 layer	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
201. to 30	20+10 cm	20+10 cm	20+15 cm	20+15 cm	20+15 cm
> 30	10+10 cm	20+10 cm	20+10 cm	20+10 cm	20+10 cm

Other options for Low Volume Roads

Sub-Grade (CBR %)	ESALs (x 1000) over Design Period		
	≤ 100	100 to 500	500 to 1000
▪ 5 to 12	40 mm BSC 200 mm CAB 150 mm GSB	50 mm BSC 200 mm CAB 150 mm GSB	50 mm BSC 250 mm CAB 150 mm GSB
▪ 12.1 to 20	40 mm BSC 200 mm CAB 100 mm GSB	50 mm BSC 200 mm CAB 100 mm GSB	50 mm BSC 200 mm CAB 150 mm GSB
▪ ≥ 20	40 mm BSC 200 mm CAB 100 mm GSB	50 mm BSC 200 mm CAB 100 mm GSB	50 mm BSC 200 mm CAB 100 mm GSB

WORKED EXAMPLE

Design a road pavement for a 2-lane highway with an average daily traffic of 2700 vehicles, 16% of which are commercial vehicles with an un-laden weight > 1.5 tons, traffic growth rate 4% per annum and rolling terrain.

Subgrade CBR: Mean =18.5% with Standard Deviation of 4.4%

WORKED EXAMPLE

Step 1: Design Input

- Traffic 1350 one way
- P_{CV} = 16 % (assume LEF = 3.7 since no break-down of vehicle type)
- Lane Distribution Factor, L = 1.0 (one lane in one direction)
- Terrain Factor, T = 1.1 (rolling)
- Design Life, n = 20 years
- Annual Traffic Growth, r = 4.0%

WORKED EXAMPLE

Step 2: Determine Traffic Category

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

  = 1350 x 365 x 0.16 x 3.7 x 1.0 x 1.1

  = 0.321 million

- Design Traffic over 20 Years;

  $ESAL_{DES} = ESAL_{Y1} \times [(1 + 0.04)^{20} - 1)]/0.04$

  = 0.321 x 29.78

  = 9.56 million (Traffic Category T3)

WORKED EXAMPLE

Step 3: Determine Sub-Grade Category

- CBR Mean =18.5%
- CBR Standard Deviation = 4.4%
- Since T3; Probability 85% (Normal Deviate = 1.00)
- Characteristic CBR value used for design;

  = 18.5% – 1.00 x 4.4%

  = 18.5% – 4.4%

  = 14.1% (Sub-Grade Category SG2)

WORKED EXAMPLE

Step 4: Select pavement structures from Catalogues (T3, SG2)

Conventional Flexible: Granular Base	
Deep Strength: Stabilized Base	
Full Depth: Asphalt Concrete Base	

Thank you for your attention

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