ONLINE LEARNING

STRUCTURAL DESIGN OF FLEXIBLE PAVEMENT

Standard Design Procedure

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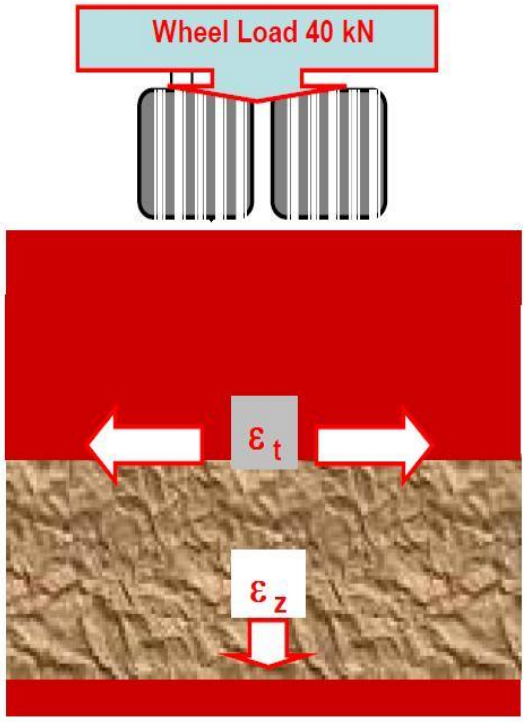
Structural design of flexible pavement

1. Elements of a Flexible Pavement Structure
2. Factors to be Considered in the Design
3. Methods of Design for New Pavements
4. Malaysian Design Methods

Introduction

Aim:

to design a structure that will ensure that the transmitted stresses are sufficiently reduced and do not exceed the capacity of the underlying subgrade



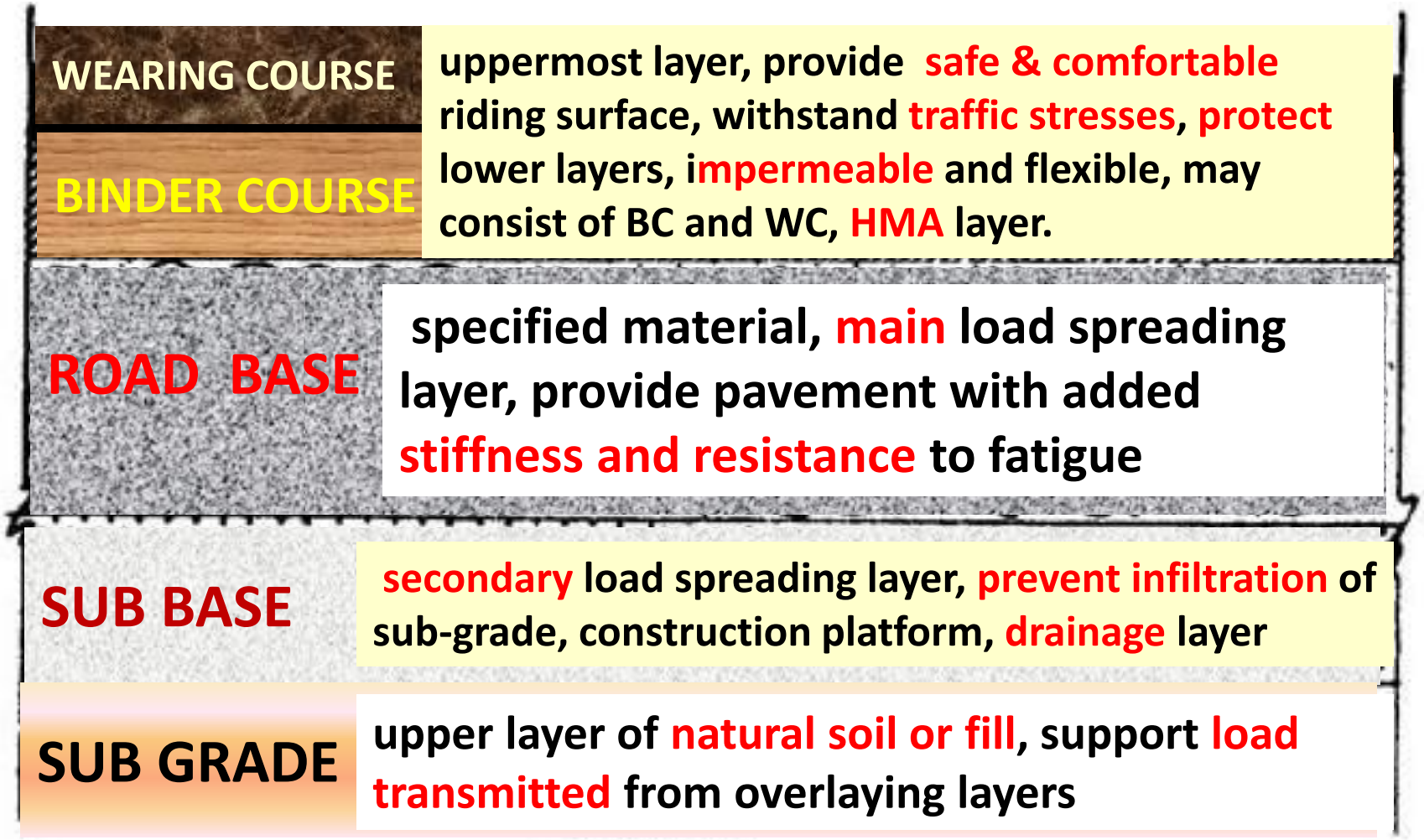
Bituminous Wearing Course
Durability, Safety (Skid Resistance, Smoothness), Strength

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

ELEMENTS OF A FLEXIBLE PAVEMENT



Factors to be Considered in The Design

1. Failure mechanism – two of concern are permanent deformation and cracking
   - rut (accumulation of permanent strain – water ponding)
   - crack (fracture failure under repeated or fluctuating stress – fatigue failure in the bituminous layer)

2. Traffic loading – pavement design must account for cumulative traffic loading during design life
   a. Tire loads & pressure – contact load and area
   b. Axle & wheel configuration – no of contact points
   c. Load repetition – cumulative
   d. Traffic distribution – lane, direction
   e. Speed – loading period (slow, climbing)……

Factors to be Considered in The Design

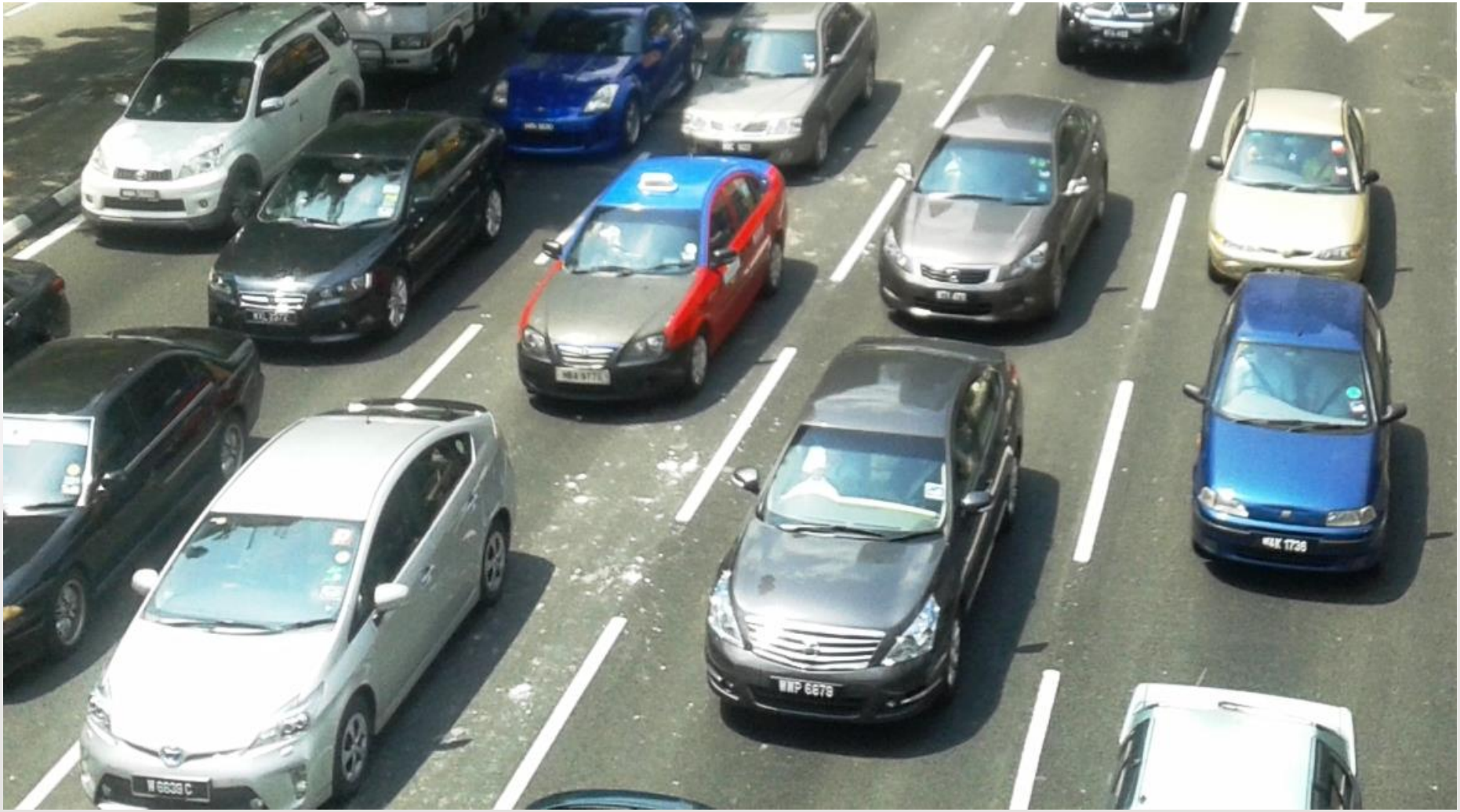
f. ESAL – convert wheel loads to standard loads
   std load = 80 kN, 8160 kg, or 18000 lb
   load equivalency factor, $e = (L/Ls)^n$
   consider only commercial vehicles,
   CV (BTM > 1.5 ton, 3 ton for RN31)

3. Environmental – temperature (asphalt – brittle/soft) and moisture (safety of users and pavement)

Classification of CV ATJ5/85 (2013)

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

Cars and Taxis – C (0.0)



Small Lorries and Van – CV1 (0.1)

Large Lorries (2-4 axles) - CV2 (4.0)

Articulated Lorries (3 or more axles) – CV3 (4.4)

Buses (2 or 3 axles) – CV4 (1.8)

Motorcycles – MC (0.0)

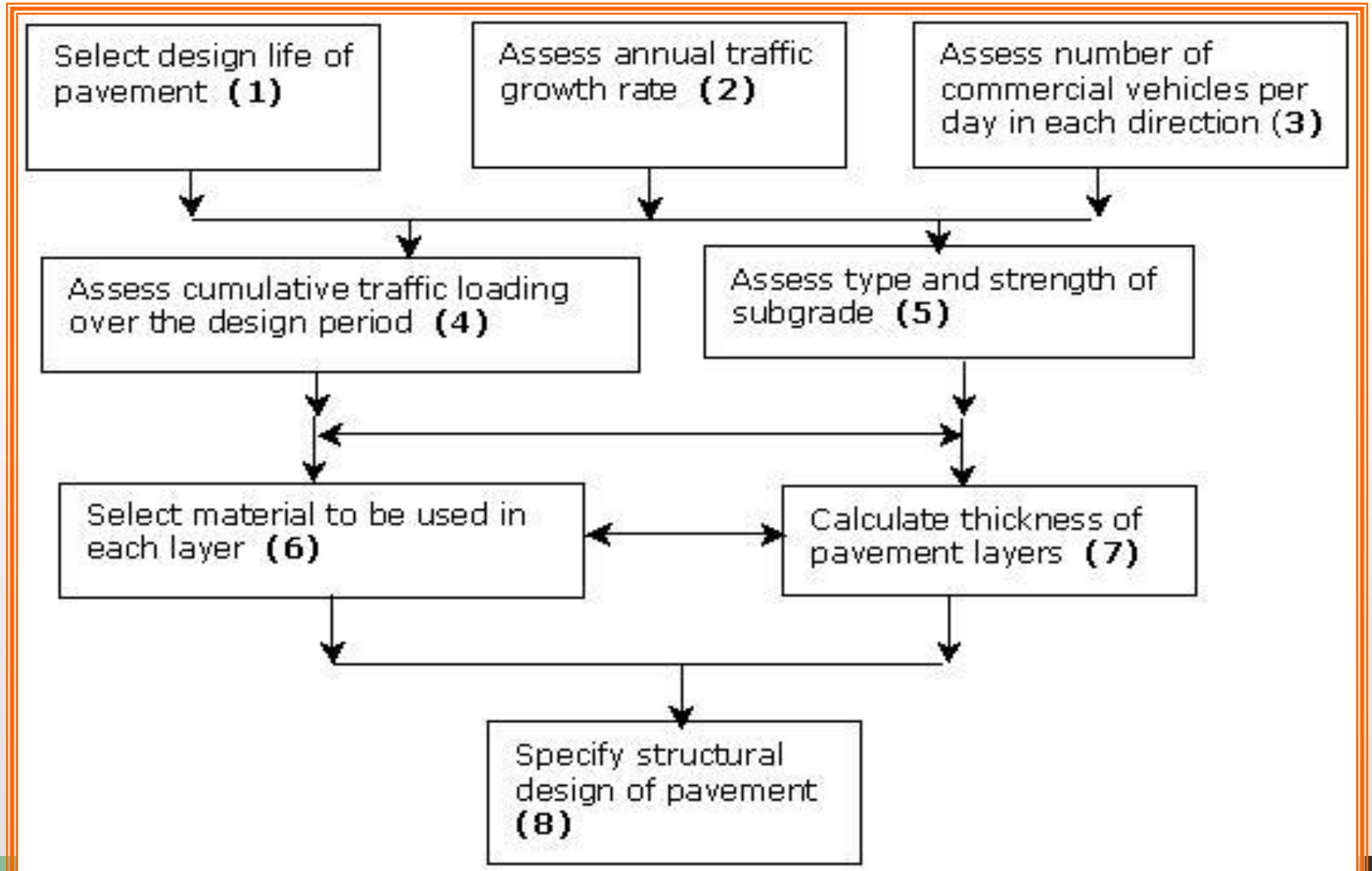
Methods of Design for New Pavements

Objective – to determine the number, material composition, and thickness of different layers that will be suitable in a specific environment and able to sustain the anticipated traffic loading

Three methods:

1. **Precedent – rule-of-thumb, std thickness for particular road classification**
2. **Empirical – soil classification or strength using experience, experimentation, or both**
3. **Theoretical/semi – mechanistic, based on mechanical model, relate pavement parameters (stress, strains, deflections) to physical causes (loads, material properties) using mathematical model**

Design Process



Malaysian Design Methods

Adopt design method based on AASHTO Guide, and catalogue of structure method:

1. Arahan Teknik Jalan 5/85 – based on AASHO road test, developed using multi-layered elastic theory. Suitable for major roads with heavy and medium traffic
2. Overseas Road Note 31 – based on research in tropical and sub-tropical countries. Design to cater traffic up to 30MSA in one direction
3. Arahan Teknik Jalan 5/85 (revision 2013) - later

PAVEMENT THICKNESS DESIGN

ATJ 5/85

Data required:

1. Design period, n – suggests 10 years
2. Class of roads
3. Initial Average Daily Traffic - ADT
4. Percentage of Commercial Vehicle - Pc
5. Average annual traffic growth - r
6. Sub-grade strength - CBR
7. Terrain condition

PAVEMENT THICKNESS DESIGN

ATJ 5/85

Design Procedure:

1. Calculate Vo = ADT x (1/2) x 365 x (Pc/100)
2. Calculate Vc= Vo $[(1 + r)^n - 1] / r$
3. Calculate cumulative ESA, ESA = Vc x e (Table 4.1 or e = 2.52)
4. Check daily capacity (Table 4.2, 4.3, 4.4)
5. Determine sub-grade CBR
6. Obtain equivalent thickness, TA' from nomograph
7. Calculate thickness for each layer (Table 4.5, 4.6, 4.7)

   $TA' = S_N = a_1D_1 + a_2 D_2 + ... + a_nD_n$
8. Sketch the designed thickness

Equivalence Factor

Percentage of selected heavy goods vehicles	0 - 15 %		16 - 50 %	51 - 100 %
Type of road	Local	Trunk		
Equivalence factor, e	1.2	2.0	3.0	3.7

Maximum Hourly capacity

Road type	Passenger vehicle unit per hour
Multilane	2000 per lane
2 lane (both ways)	2000 total for both ways
3 lane (both ways)	4000 total for both ways

Reduction Factor

Carriageway width (m)	Shoulder width (m)			
	2.00	1.50	1.25	1.00
7.5	1.00	0.97	0.94	0.90
7.0	0.88	0.86	0.83	0.79
6.0	0.81	0.78	0.76	0.73
5.0	0.72	0.70	0.67	0.64

Terrain Factor

Type of terrain	Factor
Flat	$T = 100/(100 + P_c)$
Rolling	$T = 100/(100 + 2P_c)$
Mountainous	$T = 100/(100 + 5P_c)$

Layer Coefficients

Component	Type of Layer	Property	Coefficients
Wearing and Binder Course	Asphaltic Concrete		1.00
Road Base	Dense Bituminous Macadam	Type 1: Stability > 400 kg	0.80
		Type 2: Stability > 300 kg	0.55
	Cement stabilized	Unconfined Compressive strength (7 days) 30 – 40 kg/cm^2	0.45
	Mechanically stabilized crushed aggregate	CBR $\geq$ 80 %	0.32
Sub-base	Sand, laterite, etc.	CBR $\geq$ 20 %	0.23
	Crushed aggregate	CBR $\geq$ 30 %	0.25
	Cement stabilized	CBR $\geq$ 60 %	0.28

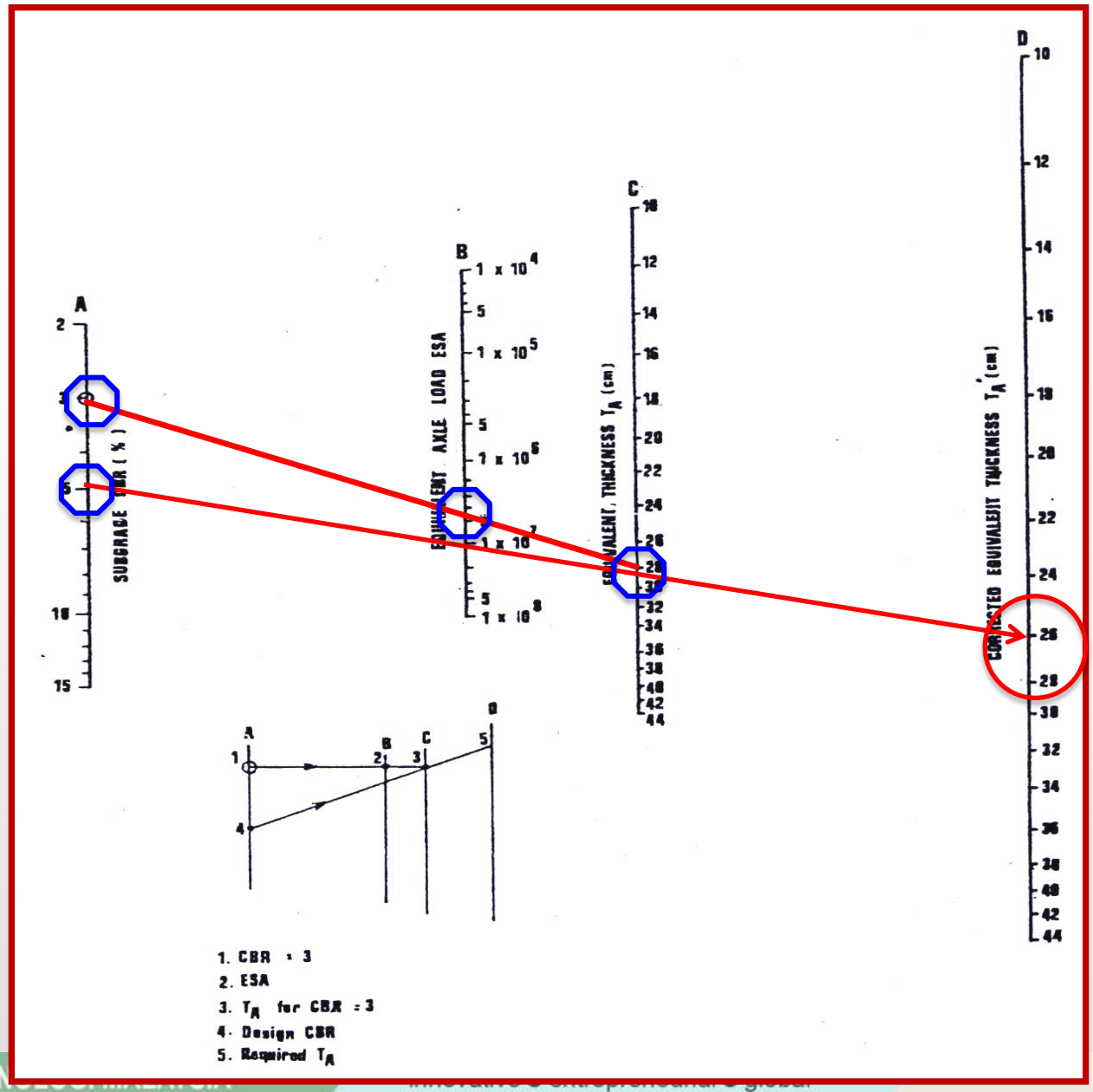
Standard and Construction thickness

Type of Layer		Standard Thickness (cm)	One Layer Lift (cm)
Wearing Course		4 - 5	4 - 5
Binder Course		5 - 10	5 - 10
Road Base	Bituminous	5 - 20	5 - 15
	Wet Mix	10 - 20	10 - 15
	Cement Stabilized	10 - 20	10 - 20
Sub-base	Granular	10 - 30	10 - 20
	Cement Stabilized	15 - 20	10 - 20

Minimum thickness of bituminous layer

TA' (cm)	Total Thickness of bituminous Layer (cm)
< 17.5	5.0
17.5 - 22.5	10.0
23.0 - 29.5	15.0
> 30.0	17.5

Nomograph


A
SUBGRADE CBR (%)
B
EQUIVALENT AXLE LOAD ESA
C
EQUIVALENT THICKNESS T_A (cm)
D
CORRECTED EQUIVALENT THICKNESS T_A' (cm)
1. CBR = 3
2. ESA
3. T_A for CBR = 3
4. Design CBR
5. Required T_A

PAVEMENT THICKNESS DESIGN
ATJ 5/85

In case of varying CBR for 1m depth of sub-grade, mean CBR is determined as follows:

$$CBR_m = [(h_1 CBR_1^{1/3} + h_2 CBR_2^{1/3} + \ldots + h_n CBR_n^{1/3}) / (1000)]^3$$

where:

CBR_m = mean CBR for that location

$CBR_1, CBR_2, \ldots CBR_n$ = CBR of soil strata

$h_1, h_2, \ldots h_n$ = thickness of soil strata (mm)

$h_1 + h_2 + \ldots + h_n$ = 1000 mm

PAVEMENT THICKNESS DESIGN
ATJ 5/85

Example:

Determine the mean CBR for this subgrade

CBR = 30 %	h = 350 mm
CBR = 8 %	h = 350 mm
CBR = 5 %	h = 300 mm

$$CBR_m = [(350 \times 30^{1/3} + 350 \times 8^{1/3} + 300 \times 5^{1/3}) / (1000)]^3$$

$$= 12\%$$

PAVEMENT THICKNESS DESIGN

ROAD NOTE 31

- Designed for tropical and sub-tropical countries to carry up to 30M CSA
- Heavy vehicle > 3 ton
- Equivalence: $e = (L/Ls)^{4.5}$

Design procedure:

1. Estimate CSA for design life >>> T (Table 3.8)
2. Assess sub-grade strength >>> S (Table 3.9, 3.10)
3. Select combination of material and thickness from structure catalogues based on T and S

Traffic Classes

Traffic classes	Range (10^6 ESA)
T1	< 0.3
T2	0.3 - 0.7
T3	0.7 - 1.5
T4	1.5 - 3.0
T5	3.0 - 6.0
T6	6.0 - 10
T7	10 - 17
T8	17 - 30

Sub-grade Classes

Class	Range (CBR %)
S1	2
S2	3 - 4
S3	5 - 7
S4	8 - 14
S5	15 - 29
S6	30+

Estimation of Sub-grade Classes

Depth of water table from formation (m)	Subgrade strength class				
	Non-plastic sand	Sandy clay PI = 10	Sandy clay PI = 20	Silty clay PI = 30	Heavy clay PI > 40
0.5	S4	S4	S2	S2	S1
1	S5	S4	S3	S2	S1
2	S5	S5	S4	S3	S2
3	S6	S5	S4	S3	S2

MATERIAL DEFINITION

	Double surface dressing, SD
	Flexible bituminous surfacing
	Bituminous surface (Wearing and binder course)
	Road base, RB
	Granular road base, GB1 – GB3
	Granular sub-base, GS
	Granular capping layer or selected subgrade fill, GC
	Cement or lime stabilized road base 1, CB1
	Cement or lime stabilized road base 2, CB2
	Cement or lime stabilized sub-base, CS

GRANULAR BASE, SURFACE DRESSING

	T1	T2	T3	T4	T5	T6	T7	T8
S1	SD	SD	SD	SD	SD	SD		
	150	150	200	200	200	225		
	175	225	200	250	300	325		
	300	300	300	300	300	300		
S2	SD	SD	SD	SD	SD	SD		
	150	150	200	200	200	225		
	150	200	175	225	275	300		
	200	200	200	200	200	200		
S3	SD	SD	SD	SD	SD	SD		
	150	150	200	200	200	225		
	200	250	225	275	325	350		
S4	SD	SD	SD	SD	SD	SD		
	150	150	200	200	200	225		
	125	175	150	200	250	275		
S5	SD	SD	SD	SD	SD	SD		
	150	150	175	200	225	250		
	100	100	100	125	150	175		
S6	SD	SD	SD	SD	SD	SD		
	150	150	175	200	225	250		

GRANULAR BASE, STRUCTURED SURFACE

	T1	T2	T3	T4	T5	T6	T7	T8
S1						100 200 225 350	125 225 225 350	150 250 250 350
S2						100 200 225 200	125 225 225 200	150 250 250 200
S3						100 200 250	125 225 250	150 250 275
S4						100 200 175	125 225 175	150 250 175
S5						100 200 100	125 225 100	150 250 100
S6						100 200	125 225	150 250

Thank you for your attention

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