UNIVERSITY OF JOHANNESBURG

PROGRAM	:	Baccalaureus Ingeneriae (BIng)
SUBJECT	:	**TRANSPORTATION ENGINEERING**
CODE	:	**VVI3A11**
DATE	:	JUNE EXAMINATION - 2019
DURATION	:	THREE (3) HOURS
WEIGHT	:	50 : 50
TOTAL MARKS	:	100

EXAMINER	:	DR HA QUAINOO
MODERATOR	:	PROF FN OKONTA
NUMBER OF PAGES	:	15 PAGES

INSTRUCTIONS	:	PLEASE ANSWER ALL THE QUESTIONS.
REQUIREMENTS	:	NONE

UNIVERSITY OF JOHANNESBURG
DEPARTMENT OF CIVIL ENGINEERING SCIENCE
VVI3A11/VVICIA3: TRANSPORTATION ENGINEERING 3A11
EXAMINATION – JUNE 2019

Answer All Questions **Time Allowance: 3 Hours**

Question 1

In a road sag curve, a downgrade of 4% meets a rising grade of 5%. At the start of the curve the level is 123.06 m at chainage 3420 m, whilst at chainage 3620 m there is an overpass with an underside level of 127.06 m. If the designed curve is to afford a clearance of 5 m at this point as illustrated in Figure 1.1, calculate the:

(i) required length of the curve
(ii) chainage at the lowest point from the start of the curve
(iii) offsets and curve levels at intervals of 50 m (i.e. 0, 50, 100m, etc.) from VPC (i.e. T_1) to VPT (i.e. T_2)

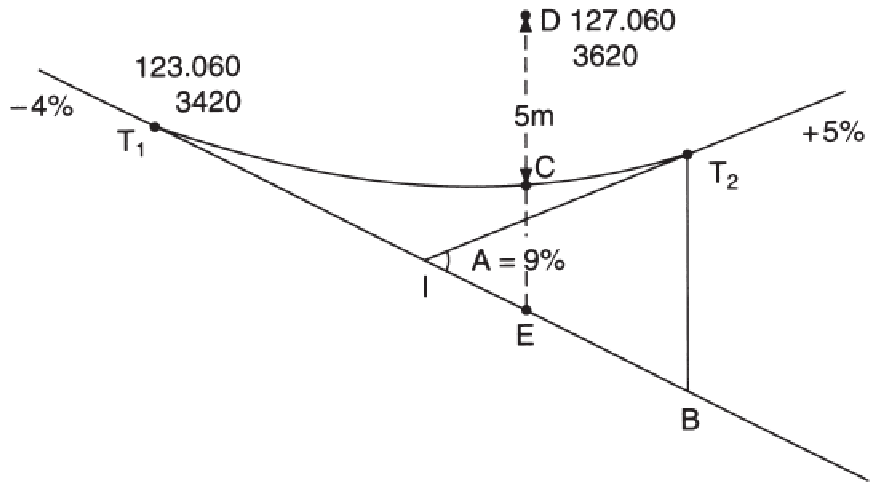


Figure 1.1

[25 marks]

Question 2

(a) On a specific westbound section of highway, studies show that the speed–density relationship is $U = U_f \ [1 - (K/K_j)^{3.5}]$

The capacity of the highway is 3800 veh/h and the jam density is 140 vehicles per kilometre per lane.

(i) Determine the space-mean-speed of the traffic at capacity
(ii) Hence calculate the free-flow speed

[13 marks]

(b) A six-lane two–way urban freeway is on a level terrain with 3,5 m lanes, obstructions 0,9 m from the right edge of the travelled pavement, and 1,1 interchanges per kilometre. The traffic stream consists primarily of commuters. A directional weekday peak-hour volume of 1800 vehicles is observed, with 500 vehicles arriving in the most congested 15-min period. If the traffic stream has 15% large trucks and buses and 2% recreational vehicles, determine the LOS. (Assume the BFFS for urban freeway = 120 km/h; driver population adjustment factor for commuters, f_p = 1,0)

[12 marks]

Question 3

(a) Traffic data for a proposed 6-lane, 2-way road construction in a wet region is as follows:

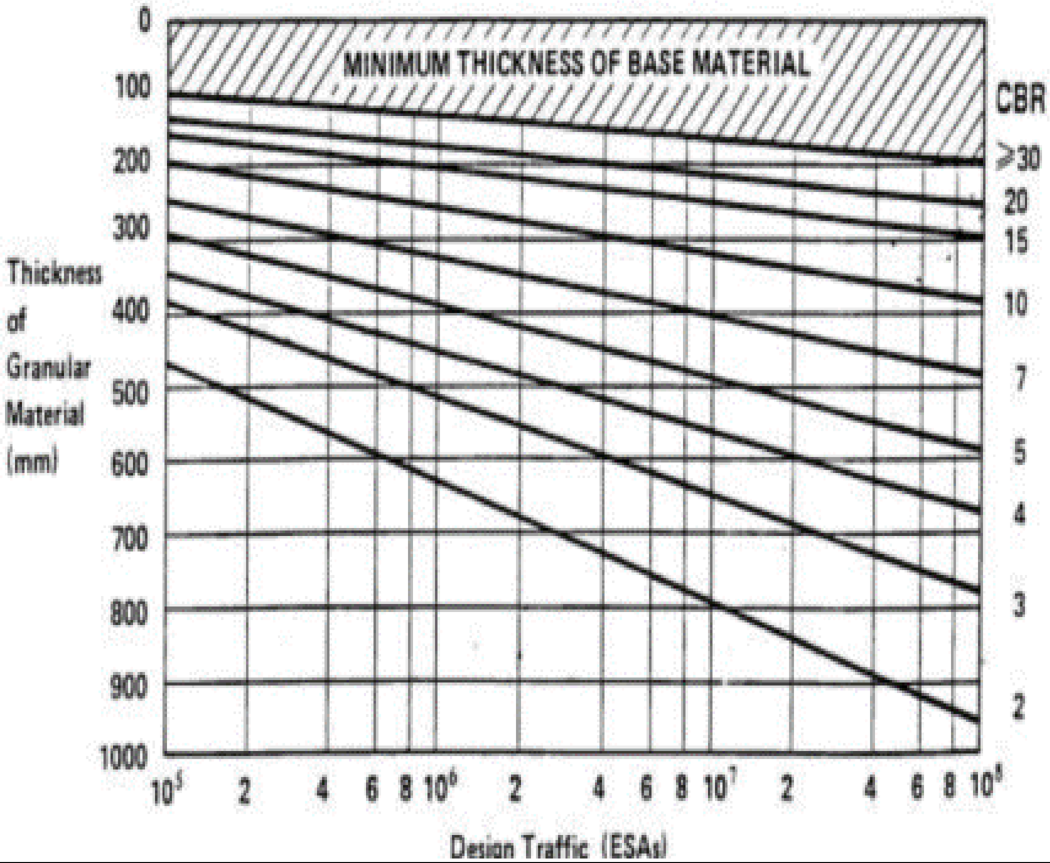
- Initial estimated vehicles per day in both directions is 4 000
- 14% are overloaded heavy vehicles at 3,5 E80s each
- 20% are buses at 1,75 E80s each
- 5% are empty heavy vehicles at 1,2E80 each
- Structural Design Period = 25 years
- Period of planning, design & construction = 5 years
- Traffic growth before opening road to traffic = 2,5% p.a.
- Traffic growth after opening road to traffic = 5,5% p.a.

●	Lane distribution factor, Be	=	0,97
●	In situ subgrade CBR over its total length	=	2.5
●	CBR of selected subgrade	=	12
●	CBR of Sub-base layer	=	45
●	CBR of base-course	=	80

(i) Calculate the equivalent E80s for the pavement for a 25 year design life.

(ii) Hence estimate the thicknesses of each layer of the proposed pavement and assign materials codes (Hint: use Figure 3.1, TRH4 and miscellaneous information provided).

Figure 3.1 Pavement thickness design chart (Austroads,



[18 marks]

(b) Briefly discuss how you would use the DCP to estimate the remaining life of an existing road. **[7 marks]**

Question 4

A new road is to be surfaced using 150/200 Penetration Grade Bitumen. Aggregates for the double seal surfacing are 13.2 mm and 6.7 mm respectively. The predicted traffic volume for the road comprises 2400 light vehicles per lane per day and 215 heavy vehicles per lane per day. Climate is wet (and requires an adjustment of 10%). Aggregate properties are: 13.2 mm stone: ALD = 8.2 mm, flakiness is 10%; 6.7 mm stone: ALD = 4.3 mm, flakiness is 15%. Ball penetration values (corrected) averaged 1.5 mm, gradients are greater than 4% (and requires an adjustment by 10%), and base texture depth is 0.5 mm.

Use TRH 3 to design a double seal of 13.2 mm stone and 6.7 mm stone, using a 150/200 Penetration Grade Bitumen for a new road work.

Other details of the road are as follows:

●Policy:

Aggregate spread rate: open shoulder-to-shoulder matrix is preferred (requires correction of 10%)

No pre-coating of aggregates (i.e. Tack Coat = 35%; Penetration Coat = 35%; Fog Spray = 30 %)

[25 marks]

EQUATIONS, FUNCTIONS, MISCELLANEOUS INFORMATION

FFS = BFFS – BFFS – f_{LW} – f_{LC} – f_N – f_{ID} Eqn. 1

$$V_p = \frac{V}{PHF * N * f_{HV} * f_P}$$ Eqn. 2

PHF = V / (V_{15} *4) Eqn. 3

$f_{HV} = 1 / [1 + P_T (E_T - 1) + P_R (E_R - 1)]$ Eqn. 4

Density = (flow rate, V_p) / (average passenger car speed) Eqn. 5

EXHIBIT 23-4. ADJUSTMENTS FOR LANE WIDTH

Lane Width (m)	Reduction in Free-Flow Speed, f_{LW} (km/h)
3.6	0.0
3.5	1.0
3.4	2.1
3.3	3.1
3.2	5.6
3.1	8.1
3.0	10.6

EXHIBIT 23-5. ADJUSTMENTS FOR RIGHT-SHOULDER LATERAL CLEARANCE

Right-Shoulder Lateral Clearance (m)	Reduction in Free-Flow Speed, f_{LC} (km/h)			
	Lanes in One Direction			
	2	3	4	≥ 5
≥ 1.8	0.0	0.0	0.0	0.0
1.5	1.0	0.7	0.3	0.2
1.2	1.9	1.3	0.7	0.4
0.9	2.9	1.9	1.0	0.6
0.6	3.9	2.6	1.3	0.8
0.3	4.8	3.2	1.6	1.1
0.0	5.8	3.9	1.9	1.3

EXHIBIT 23-6. ADJUSTMENTS FOR NUMBER OF LANES

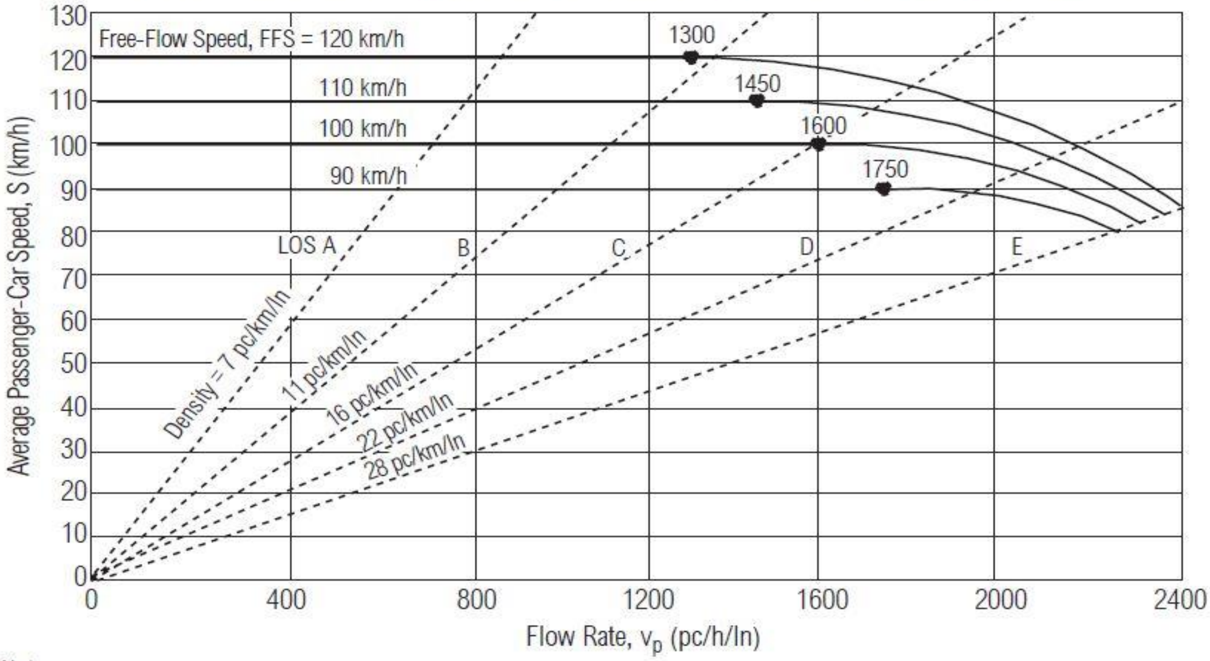
Number of Lanes (One Direction)	Reduction in Free-Flow Speed, f_N (km/h)
≥ 5	0.0
4	2.4
3	4.8
2	7.3

Note: For all rural freeway segments, f_N is 0.0.

EXHIBIT 23-7. ADJUSTMENTS FOR INTERCHANGE DENSITY

Interchanges per Kilometer	Reduction in Free-Flow Speed, f_{ID} (km/h)
≤ 0.3	0.0
0.4	1.1
0.5	2.1
0.6	3.9
0.7	5.0
0.8	6.0
0.9	8.1
1.0	9.2
1.1	10.2
1.2	12.1

EXHIBIT 23-3. SPEED-FLOW CURVES AND LOS FOR BASIC FREEWAY SEGMENTS



Note:

Capacity varies by free-flow speed. Capacity is 2400, 2350, 2300, and 2250 pc/h/ln at free-flow speeds of 120, 110, 100, and 90 km/h, respectively.

For $90 \leq FFS \leq 120$ and for flow rate (v_p)

$(3100 - 15FFS) < v_p \leq (1800 + 5FFS)$,

$$S = FFS - \left[\frac{1}{28}(23FFS - 1800)\left(\frac{v_p + 15FFS - 3100}{20FFS - 1300} \right)^{2.6} \right]$$

For $90 \leq FFS \leq 120$ and

$v_p \leq (3100 - 15FFS)$,

$S = FFS$

Table 2: Subgrade design (TRH4 1996)

CBR values for various layers are given in the table below:

Material Code	Minimum CBR	Layer
G4	80	Gravel base
G5	45	Subbase
G6	25	Subbase / selected
G7	15	Selected
G8	10	Subgrade
G9	7	Subgrade
G10	3	Subgrade

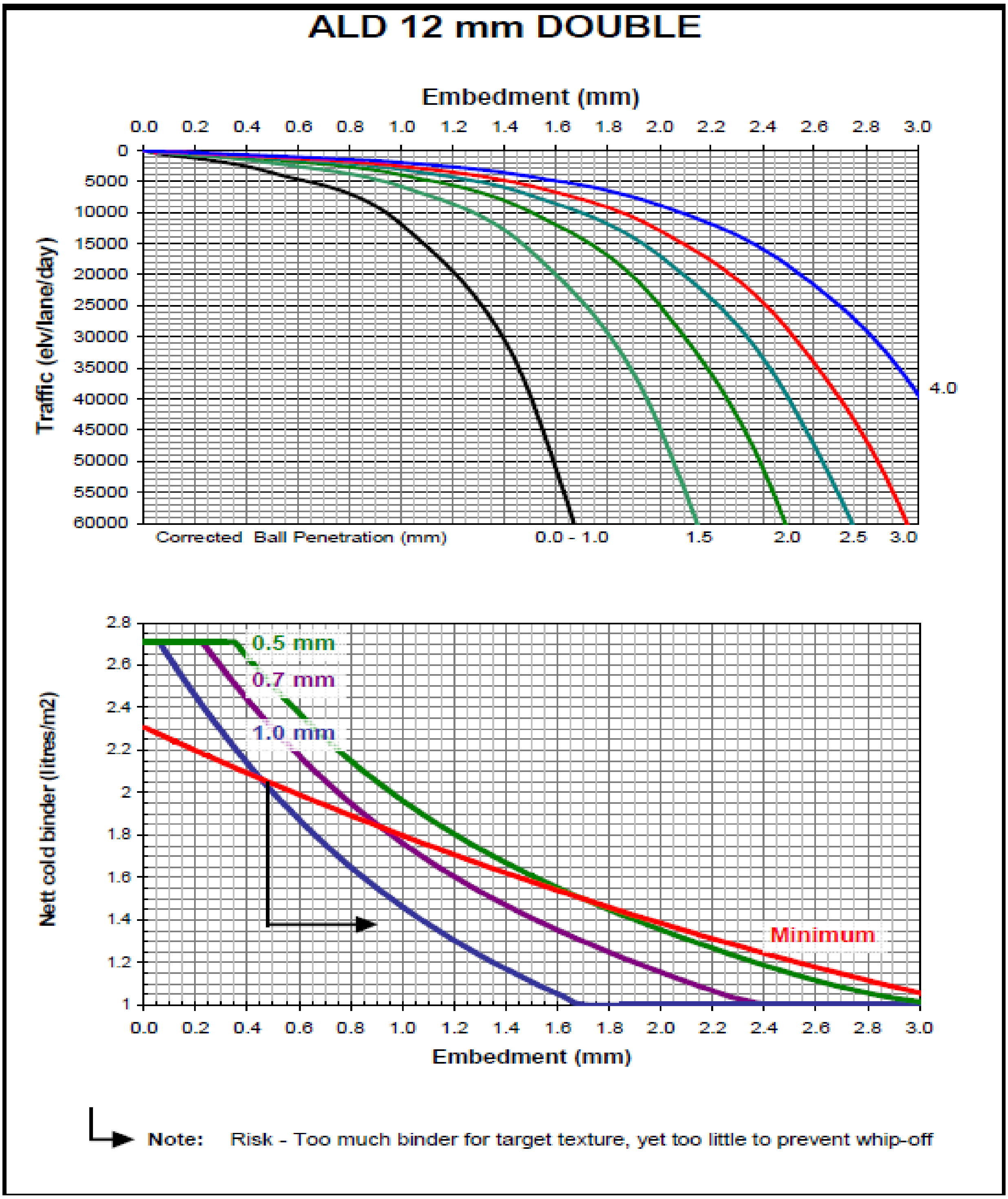
Design CBR of subgrade	< 3	3 to 7	7 to 15	> 15
Layerwork	Special treatment essential	150 mm G7 150 mm G9	150 mm G7 --	-- --
Roadbed		R + R; 150mm G10	R + R; 150mm G9	R + R; 150mm G7

TABLE 12

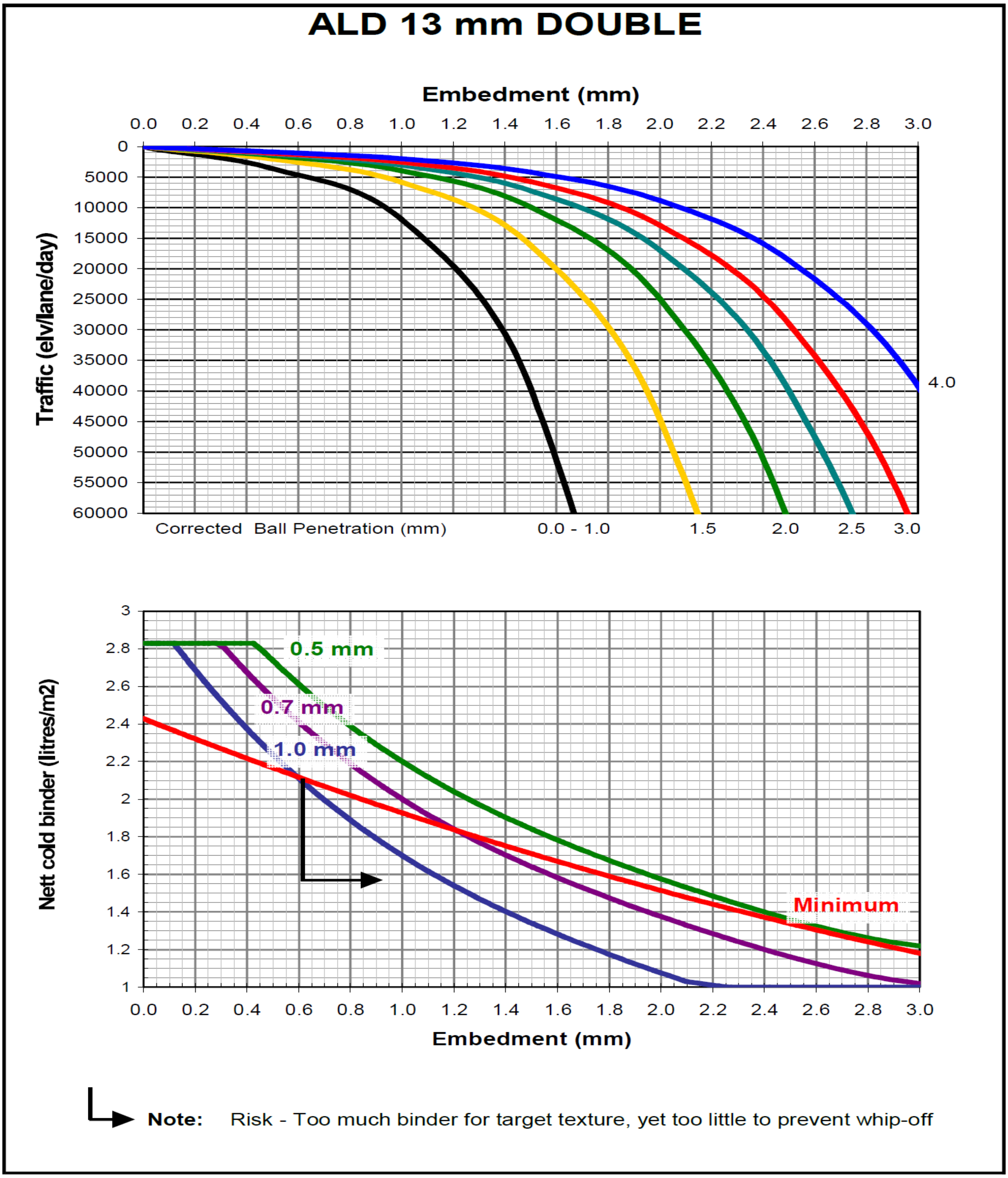
Traffic growth factor (f_y) for calculation of cumulative traffic over prediction period from initial (daily) traffic

Prediction period, y (years)	f_y* for traffic increase, I (% per annum)									
	2	4	6	8	10	12	14	16	18	20
4	1 534	1 611	1 692	1 776	1 863	1 953	2 047	2 145	2 246	2 351
5	1 937	2 056	2 180	2 312	2 451	2 597	2 750	2 911	3 081	3 259
6	2 348	2 517	2 698	2 891	3 097	3 317	3 551	3 801	4 066	4 349
7	2 767	2 998	3 247	3 517	3 809	4 124	4 464	4 832	5 229	5 657
8	3 195	3 497	3 829	4 192	4 591	5 028	5 506	6 029	6 601	7 226
9	3 631	4 017	4 445	4 922	5 452	6 040	6 693	7 417	8 220	9 109
10	4 076	4 557	5 099	5 710	6 398	7 173	8 046	9 027	10 130	11 369
11	4 530	5 119	5 792	6 561	7 440	8 443	9 588	10 895	12 384	14 081
12	4 993	5 703	6 526	7 480	8 585	9 865	11 347	13 061	15 044	17 336
13	5 465	6 311	7 305	8 473	9 845	11 458	13 352	15 575	18 183	21 241
14	5 947	6 943	8 130	9 545	11 231	13 242	15 637	18 490	21 887	25 927
15	6 438	7 600	9 005	10 703	12 756	15 239	18 242	21 872	26 257	31 551
16	6 939	8 284	9 932	11 953	14 433	17 477	21 212	25 795	31 414	38 299
17	7 450	8 995	10 915	13 304	16 278	19 983	24 598	30 346	37 500	46 397
18	7 971	9 734	11 957	14 762	18 308	22 790	28 458	35 625	44 680	56 115
19	8 503	10 503	13 061	16 338	20 540	25 934	32 859	41 748	53 154	67 776
20	9 045	11 303	14 232	18 039	22 995	29 455	37 875	48 851	63 152	81 769
25	11 924	15 808	21 227	28 818	39 486	54 506	75 676	105 517	147 559	206 727
30	15 103	21 289	30 587	44 656	66 044	98 656	148 459	224 533	340 661	517 664
35	18 612	27 958	43 114	67 927	108 816	176 464	288 595	474 509	782 431	1 291 373
40	22 487	36 071	59 877	102 120	177 700	313 586	558 416	999 544	1 793 095	3 216 609

DESIGN CHART FOR DOUBLE SEALS: Design ALD = 12mm



DESIGN CHART FOR DOUBLE SEALS: Design ALD = 13mm



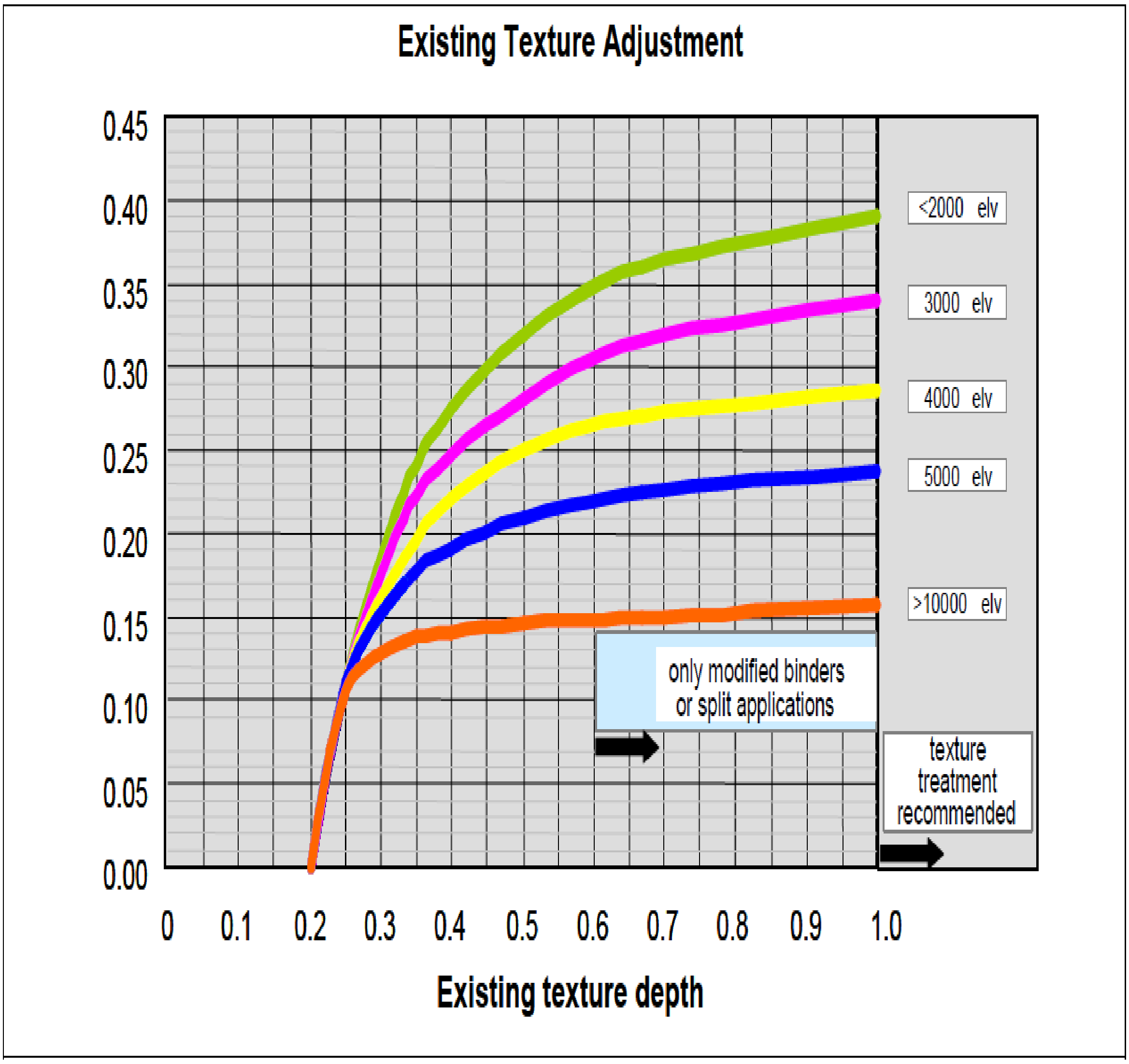
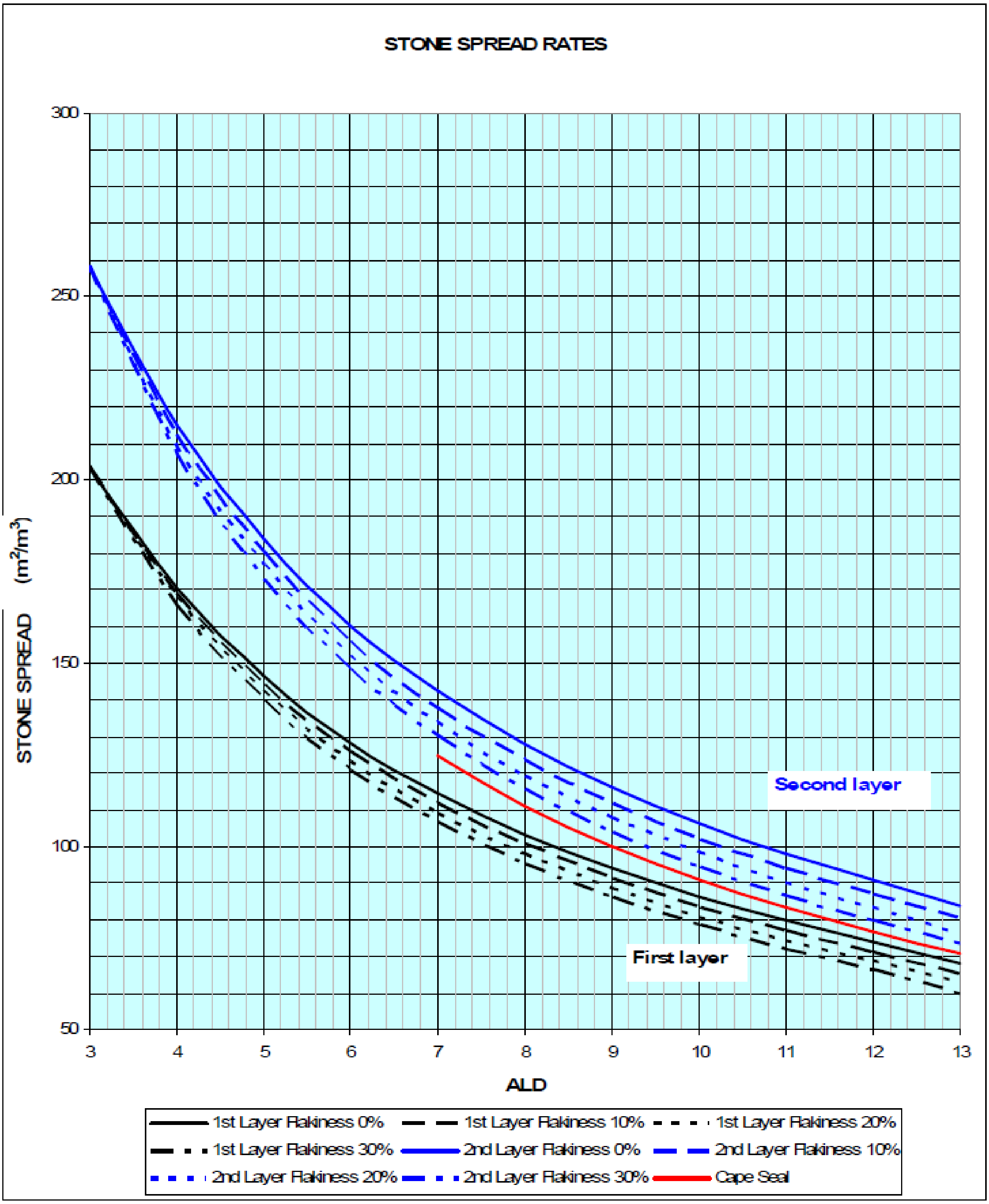

Existing Texture Adjustment
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Existing texture depth
<2000 elv
3000 elv
4000 elv
5000 elv
>10000 elv
only modified binders or split applications
texture treatment recommended

Table 7-3 - Factors for converting net cold residual binder to hot spray rates and storage and spraying temperatures

Type of binder	Conversion *** factor	Spray temperature (℃)	Max. storage temperature (℃)
Cutback bitumen			
MC 3000	1.19 – 1.27	130 - 155	100
MC 70	1.63 – 1.72	60 - 80	Ambient
MC 30	1.88 – 1.99	45 - 65	Ambient
Penetration grade bitumen			
150/200 pen	1.09	145 - 185	115
80/100 pen	1.09	160 - 200	125
Polymer modified bitumen			
S-E1	1.08	165 - 190	150
S-E2	1.06	165 - 190	150
Bitumen rubber (S-R1)	1.07	195 - 205	-
Bitumen emulsions			
60% emulsion	1.68	60	Ambient
65% emulsion	1.55	60	Ambient
70% emulsion	1.44	70	Ambient


STONE SPREAD RATES
300
250
200
150
100
50
STONE SPREAD (m²/m³)
3
4
5
6
7
8
9
10
11
12
13
ALD
Second layer
First layer
1st Layer Flakiness 0%
1st Layer Flakiness 10%
1st Layer Flakiness 20%
1st Layer Flakiness 30%
2nd Layer Flakiness 0%
2nd Layer Flakiness 10%
2nd Layer Flakiness 20%
2nd Layer Flakiness 30%
Cape Seal