UNIVERSITY OF JOHANNESBURG

PROGRAM	:	B TECH CIVIL ENGINEERING TECHNOLOGY
SUBJECT	:	**PAVEMENT TECHNOLOGY**
CODE	:	**PVT411**
DATE	:	WINTER SSA EXAMINATION 2015 22 JULY 2015
DURATION	:	(SESSION 1) 08:00 - 11:00
WEIGHT	:	40 : 60
TOTAL MARKS	:	100

ASSESSOR	:	DR H A QUAINOO
MODERATOR	:	MR I. ARIYO
NUMBER OF PAGES	:	10 PAGES

File Number

INSTRUCTIONS	:	QUESTION PAPERS MUST BE HANDED IN.
REQUIREMENTS	:	2 SHEETS OF DRAWING PAPER.

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INSTRUCTIONS TO STUDENTS:

PLEASE ANSWER ALL THE QUESTIONS.

QUESTION 1

(a) The Grading Modulus (GM) of an aggregate is given by the expression GM = P2.00mm +P0.425mm + P0.075mm / 100 (where P2.00mm, for example, denotes percentage retained on the 2.00mm sieve).

Briefly discuss the significance of the modulus above. **[5 marks]**

(b) The grading characteristics of two road construction materials as well as the grading limits are provided in Table 1.

Table 1: Grading test results and grading limits

% passing sieve size	*Fine Silty Clay (A)*	*Coarse material with insufficient fines (B)*	*Grading limits*
37 mm	100	95	85 – 100
19.0	100	80	60 – 100
4.75	90	50	30 – 65
2.00	59	40	20 – 50
1.18	49	36	16 – 43
0.425	32	27	10 – 30
0.30	29	25	9 – 27
0.075	15	4	5 – 15

(i) Using Rothfuch's graphical method of mechanical stabilisation (blending method), determine the optimum mix of the final material.

(ii) Plot the grading curve of the blended road material in (i)

(iii) Estimate the Grading Modulus of the optimum mix obtained in (i) and comment on its suitability as a road construction material.

[25 marks]

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QUESTION 2

Municipality X is planning to widen its existing 100 km freeway from six lanes to eight lanes in order to ease traffic congestion. There are two alternative designs for the project. The first design costs R12 million per kilometre (which includes drainage structures and a toll-gate). The annual maintenance would cost the Municipality R25 000 per kilometre in addition to an anticipated road accident cost of R700 000 per annum (on the entire 100 km length of road). It is envisaged that the Average Daily Traffic at the toll-gate would be 3500 vehicles per day at a toll-charge of R80 per vehicle. The design life of this alternative is 25 years.

The alternative design would cost R 10 million per kilometre over the 100 km length of road. However, the annual road maintenance is R35 000 per kilometre over the first 15 years and then R40 000 per kilometre over the remaining 5 years. The expected annual road accident cost is R800 000. The ADT and toll-gate charge remain the same.

(a) With interest rate at 12%, use ***Net Present Value (NPV)*** method of analysis to select one of the two alternative designs. **[20 marks]**

(b)In relation to the proposed road project above, briefly discuss how maintenance programme should be optimised. **[5 marks]**

(Hint: Important formulae: $F = P\ (1+i\ )^n$

$P = A\ [\ (1+i)^n - 1]\ /\ [i * (1+i)^n\ ]$

QUESTION 3

A four-lane express road is to be constructed in a dry region with an estimated present average daily traffic (ADT) of 5600 vehicles per day in both directions. The traffic growth rates are expected to be 4% until the road is opened to traffic in five years' time and thereafter 9% up to the end of its design life. Heavy vehicles, averaging 0.95E80s each, comprise 20% of the total traffic.

(i) Calculate the predicted design traffic at the end of the structural design period of 30 years and state the design traffic class.

(ii) If the design California Bearing Ratio of the subgrade averages 5% and 8%, propose a pavement design using the catalogue method over the full material depth for a structural design period stated above using a granular base.

[25 marks]

QUESTION 4

A 13.2 mm aggregate, single seal surfacing is to be used to reseal an existing road across a rolling terrain in a dry climate (i.e. Weinert N-value is greater than 5). Current traffic comprises 400 light vehicles per lane per day, with 80 heavy vehicles per lane per day. Texture depth is uniform and measured to be 0.5 mm; the corrected ball penetration test averaged 1.10 mm; ALD on the aggregate was 6 mm with a flakiness index of 10%.

Other details of the road are as follows:

- Terrain: Rolling with maximum gradients of 5% with slow-moving vehicles travelling at 35 km/h for which an adjustment of 10% is required for cold binder on uphill

- Policy:

  Aggregate spread rate: a dense shoulder-to-shoulder matrix is preferred
  Hot spray: 80/100 Penetration grade bitumen is to be used.

- Adjustment for climatic conditions:
  - Wet region: subtract 10% of the net cold binder
  - Dry region: add 10% to net cold binder
  - Moderate: No adjustment necessary

- Adjustment for aggregate spread rate:
  - Dense shoulder-to-shoulder matrix: no adjustment
  - Medium dense matrix: add 10% to net cold binder
  - Open shoulder-to-shoulder matrix: add 20% to net cold binder

- Practical spray rates for conventional binders:
  - Minimum hot spray: 0.7 litres per square metre
  - Maximum hot spray: 1.75 litres per square metre

Using the TRH3 catalogue, provide a full single seal design surfacing for the road.

[25 marks]

GRANULAR BASES (MODERATE OR DRY REGIONS)

DATE 1996

ROAD CAT.	ES0.003 < 3000	ES0.01 $0{,}3\text{-}1{,}0\times10^4$	ES0.03 $1{,}0\text{-}3{,}0\times10^4$	ES0.1 $3{,}0\text{-}10\times10^4$	ES0.3 $0{,}1\text{-}0{,}3\times10^6$	ES1 $0{,}3\text{-}1{,}0\times10^6$	ES3 $1{,}0\text{-}3{,}0\times10^6$	ES10 $3{,}0\text{-}10\times10^6$	ES30 $10\text{-}30\times10^6$	ES100 $30\text{-}100\times10^6$	Foundation
	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE)										
A							40A 125 G2 150 C3 40A 150 G2 150 G5	40A 150 G2 250 C3	50A 150 G1 250 C3	50A 150 G1 300 C3	
B						S 125 G4 150 C4 S 150 G4 150 G5	S*/30A 150 G3 150 C4 S*/30A 150 G3 150 G5	40A 150 G2 200 C4 30A 150 G2 200 G5			150 G7 150 G9 G10
C				S 100 G5 125 C4 S 125 G4 125 G6	S 125 G5 125 C4 S 125 G4 150 G6	S 125 G4 125 C4 S 125 G4 150 G5	S 150 G3 150 C4 S 150 G3 150 G5				
D	S1 100 G5 100 G7	S1 100 G5 125 G7	S1 100 G4 125 G7	S1 100 G4 125 G6 S1 100 G5 100 C4	S 125 G4 125 G6 S 100 G5 125 C4	S 125 G4 150 G6 S 125 G5 150 C4					150 G9 G10

Symbol A denotes AG, AC, OR AS. A0, AP may be recommended as a surfacing measure for improved skid resistance when wet or to reduce water spray.

S denotes Double Surface Treatment (seal or combinations of seal and slurry)

S1 denotes Single Surface Treatment

* If seal is used, increase C4 and G5 subbase thickness to 200mm.

EQUATIONS, FUNCTIONS, MISCELLANEOUS INFORMATION, & DESIGN CHARTS

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

Table 1: Properties of Road Construction materials

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

- Table 2: Subgrade design (TRH4 1996)

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

* If the in situ subgrade is in a wet region, an additional 150mm layer of G9 could be used.

- $E80 = (\text{axle load} / 80)^4$

  where the axle load is in kN

- $E80 \text{ total} = AADE_{initial} \times f_y$

- $f_y = 365 \times \frac{(1 + i/100) \times [(1 + i/100)^y - 1]}{i/100}$

  where i = growth rate in %
  y = structural design period in years
  AADE = annual average daily equivalent E80 traffic
  See attached catalogue of design.

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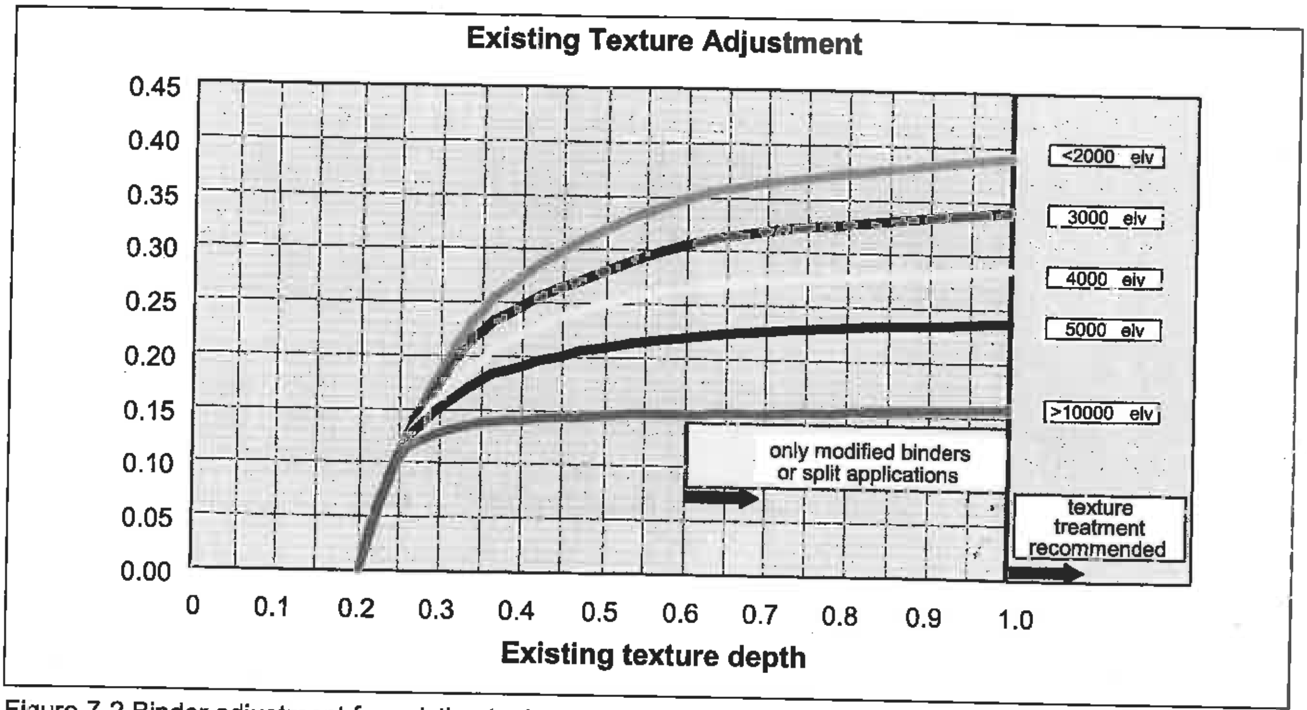


Figure 7-2 Binder adjustment for existing texture

7.6.3 Design process for double seals

7.6.3.1 Application rate

The steps are similar to those taken for the determination of application rates for single seals except for the following:

a) The design ALD of the double seal is calculated as follows:

Design ALD (double seal) = ALD of first layer + ALD of the second layer.

b) Use the relevant charts in APPENDIX E to determine the total binder application rate required for the double seal.

c) Binder distribution

Current practice differs from one road authority to the next with regard to the split in binder between the tack coat and penetration coat. However, it is generally agreed that this split is governed by the minimum application rates required for each layer to prevent whip-off or by the minimum rate that can be sprayed accurately (in the case of a fog spray).

The following guidelines may be used:

- Determine the total net cold binder required for the double seal.
- Subtract half of the binder required for the fog spray e.g. 0,33/2 = 0,17 ℓ/m^2 (if a fogspray will be applied). It is assumed that only half the binder will flow down - the remainder will stick to the top and sides of the aggregate, i.e. will be non-effective in terms of filling the voids.

The minimum quantity of net cold binder required for the penetration coat depends on the aggregate size of the second layer. (Table 7-4 may be used as a guideline.)

If traffic has to be accommodated on the first layer (this is not recommended), it is advisable to design the next layer separately as a second single seal.

The minimum quantity of residual binder required for the tack coat depends on the size of the aggregate used in the first layer. (See Table 7-5.)

The concepts of adjustment and sensitivity analysis of application rates, as used in the single seal design, should also be used in the design of double seal. They are not repeated here.

Concept of risk

Areas are indicated on the design graphs where the use of the curves constitutes a risk. Theoretically, in these areas the application rate is too low to prevent whip-off but is also too high to ensure the required texture depth. Therefore, the probability of the seal having a shorter life than normal is very high.

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

Note:

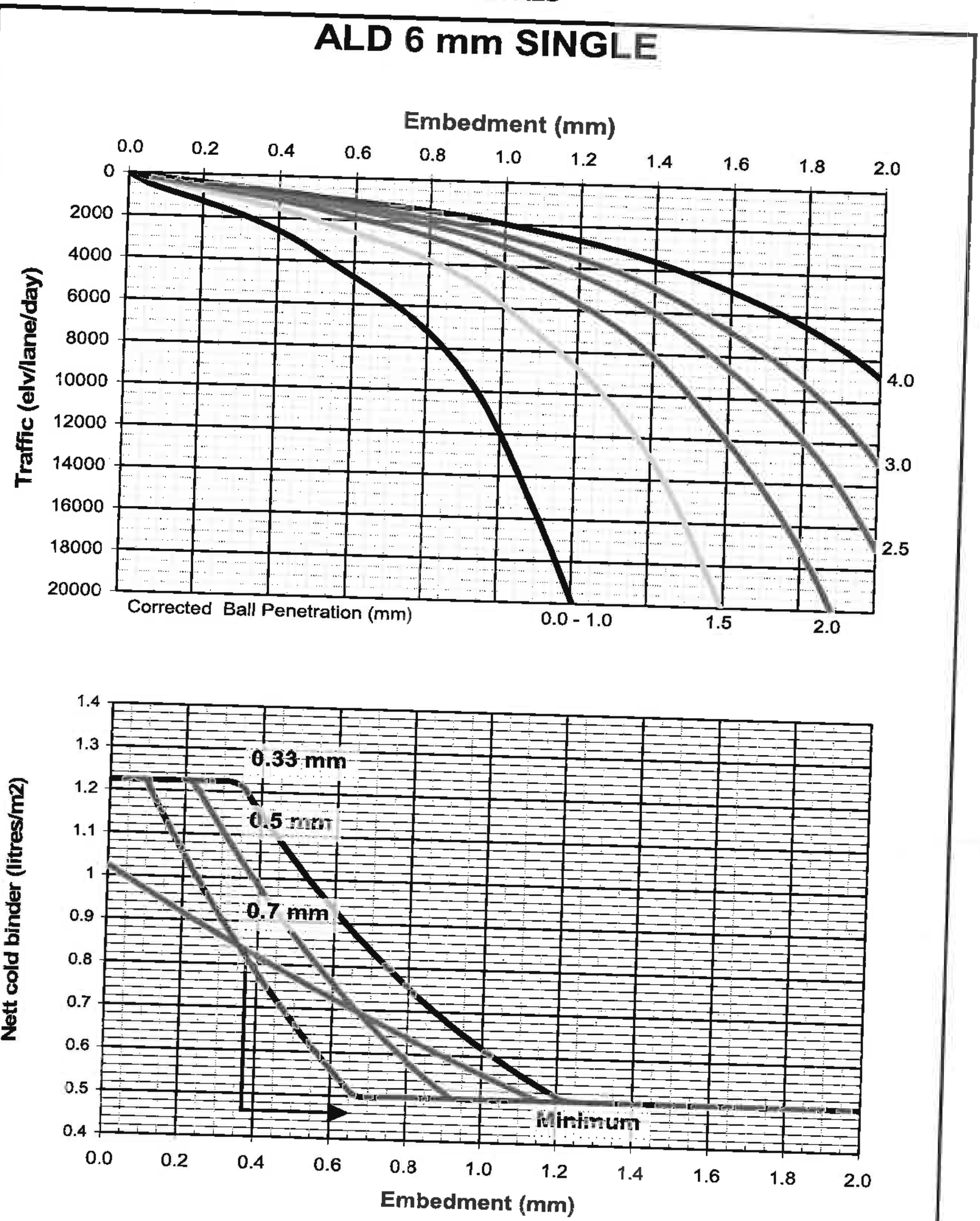
*** *Binders from different sources have different temperature conversion factors. The user should refer to the manufacturer.*

Table 7-4 - Minimum quantity of net cold binder required for penetration coat

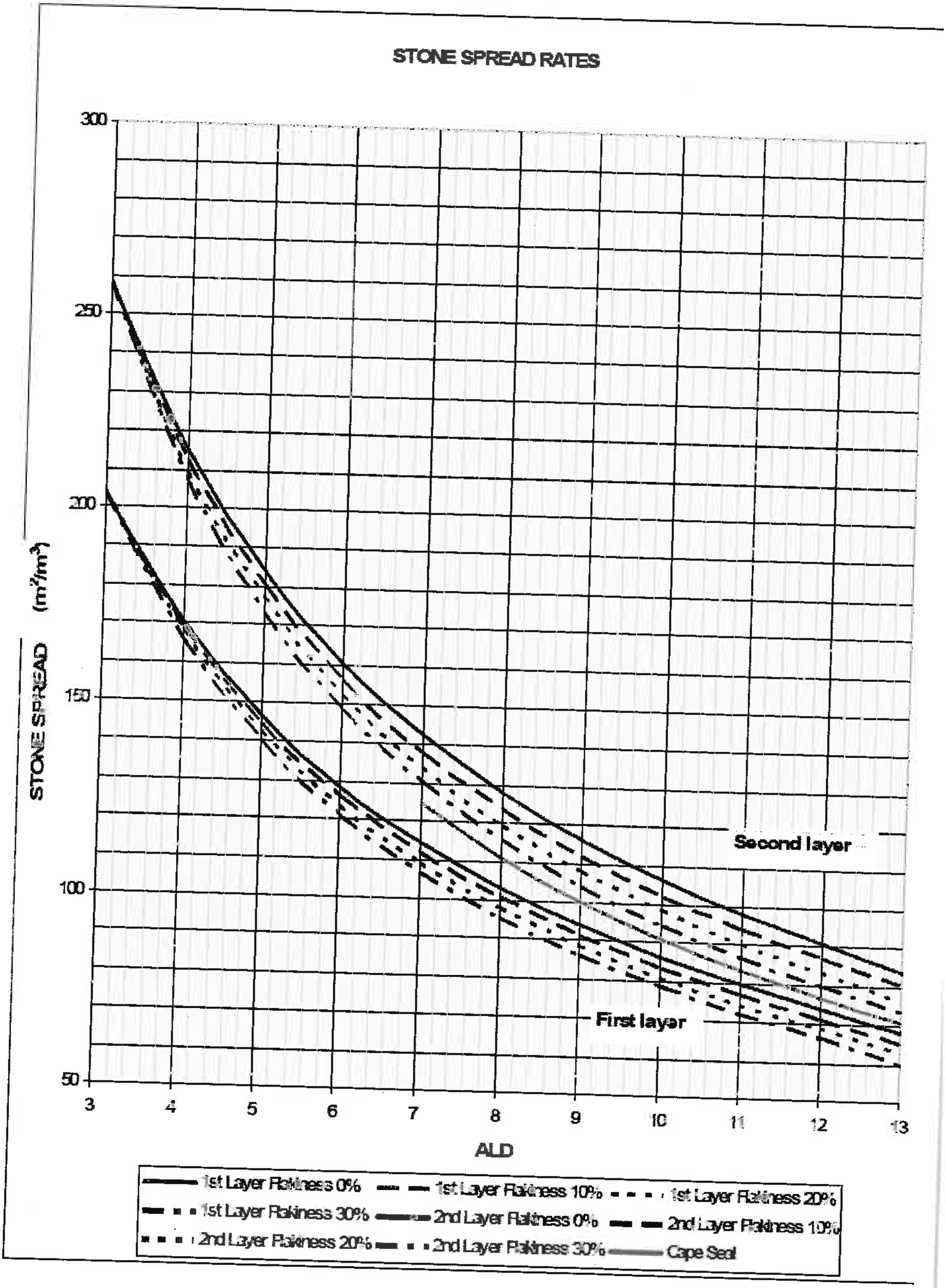
Aggregate size in top layer	4,75 mm or less	6,7 mm	9,5 mm
Minimum net binder required	0,3 ℓ/m^2	0,6 ℓ/m^2	0,7 ℓ/m^2

Table 7-5 - Minimum quantity of net cold binder required for tack coat

DESIGN CHART FOR SINGLE SEALS: 6mm ALD



Note: Risk - Too much binder for target texture, yet too little to prevent whip-off


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