University Of Technology
Building and Construction Eng. Dept.
Final Exam 2014/2015

Subject: Highway Eng.
Branch: Building & Const. Manage. Eng.
Examiner: *Munther Ali*

Class: 3rd
Time : 3 Hours
Date : 8/6/2015

Note: Attempt Four questions only

Q1:

(a) A vertical curve joining a (-5%) and (+3%) grades in a rural highway has a design speed of 100kph. The tangents intersect at a station (225+71.35) at an elevation of 290m. Calculate the elevations of intermediate points on the curve each 50m, and determine the stations and elevations of PVC, PVT. It is important to know that the driver acceleration rate is $3 m/sec^2$ and the perception & reaction time is 2.5 seconds. **(15 marks)**

(b) Two types of aggregate (A and B) have a gradation out of specification limit of producing an asphalt concrete mixture. Show how you can mix these two types of aggregate to meet the required specification limit of gradation shown below: **(10 marks)**

Sieve Size (inch)	Sieve Size (mm)	% Passing by weight		
		Specification limit	Agg. (A)	Agg. (B)
1½	37.5	100	100	100
1	25.0	90-100	90	95
¾	19.0	76-90	60	95
½	12.5	56-80	20	85
⅜	9.5	48-74	15	78
No. 4	4.75	29-59	9.5	69
No. 8	2.36	19-45	5	55
No. 50	300μm	5-17	2.3	22
No. 200	75μm	2-8	-	12

Q2:

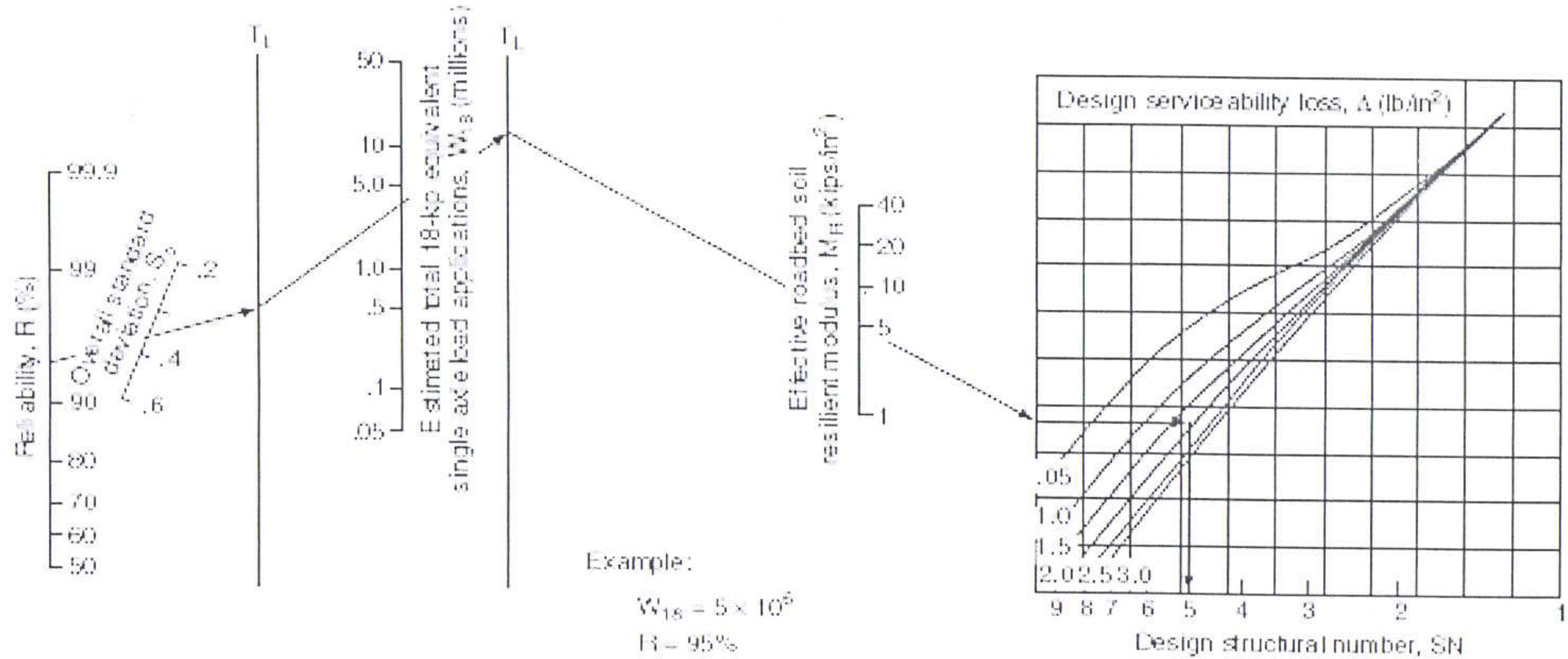
(a) On a section of an existing rural highway, a vertical alignment is used. The two grades (-4% and +2%) are joined with a symmetrical parabolic curve of 300m length. Determine the vertical clearance (in meters) required between the pavement surface (within the vertical curve) and a structure above it if you know that the design speed is 100kph and the vehicles acceleration rate is $2.8 m/sec^2$ and the perception & reaction time is 2.5 seconds. **(10 marks)**

(b) According to the AASHTO1993 guide for design of flexible pavements, show if the designed thicknesses of the different structural layers are adequate to accommodate the ESAL of 5500000 applications using the available materials shown below and assuming that the drainage adjustment factor (m)=0.8, reliability level (R)=90%, standard deviation (So)=0.4, and Initial serviceability=4.5, Terminal serviceability=2.0, California Bearing Ratio of subgrade =6 %: **(15 marks)**

Layer	Layer Coefficient (a)	Resilient Modulus (Mr) (Psi)	Thickness (inch)
Surface	0.44	450000	4
Base Course	0.14	30000	6
Subbase Course	0.10	14800	6

Nomograph solves:

$$\log_{10} W_{18} = Z_R \cdot S_o + 9.36 \cdot \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta \text{ (lb/in}^2\text{)}}{4.2 - 1.5}\right)}{0.40 + \frac{1094}{(SN + 1)^{5.19}}} + 2.32 \cdot \log_{10} M_R - 8.07$$



Example:

$W_{18} = 5 \times 10^6$

$R = 95\%$

$S_o = 0.35$

$M_R = 5000$ lb/in^2

Δ (lb/in^2) 1.9

Solution: SN = 5.0

FIGURE 3.17 Design chart for flexible pavements based on using mean values for each variable. (From Guide for Design of Pavement Structures, *American Association of State Highway and Transportation Officials*, *Washington, D.C., 1993, with permission.*)

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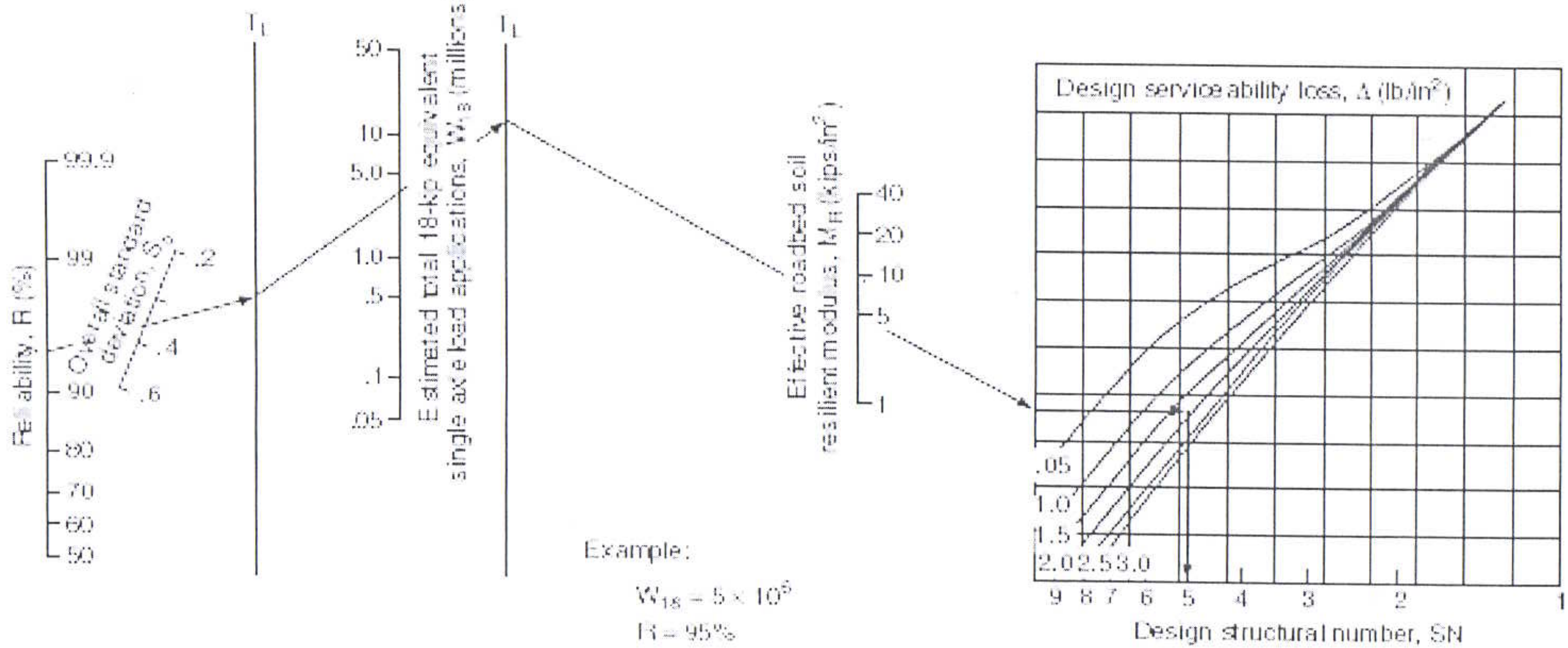

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Q1:(a)

$$S = 0.278 * V * t + \frac{V^2}{254\left(\frac{a}{9.81} \pm g\right)} = 0.278 * 100 * 2.5 + \frac{100^2}{254\left(\frac{3}{9.81} - 0.05\right)} = 223.4m$$

$$When\ (S < L): L = \frac{A * S^2}{120 + (3.5 * S)} = \frac{|+3 - (-5)| * 223.4^2}{120 + (3.5 * 223.4)} = 442.7m > 223.4m\ ok$$

$$Sta.PVC = Sta.PVI - \frac{L}{2} = (225 + 71.35) - \frac{4 + 42.7}{2} = 223 + 50$$

$$Sta.PVT = Sta.PVI + \frac{L}{2} = (225 + 71.35) + \frac{4 + 42.7}{2} = 227 + 92.7$$

$$Elev.PVC = Elev.PVI + \left(\frac{L}{2} * 0.05\right) = 290 + (\frac{442.7}{2} * 0.05) = 301.07m$$

$$Elev.PVT = Elev.PVI + \left(\frac{L}{2} * 0.03\right) = 290 + (\frac{442.7}{2} * 0.03) = 296.64m$$

$$a = \frac{g2 - g1}{2L} = \frac{+0.03 - (-0.05)}{2 * 442.7} = 0.00009035464$$

Station	x	$a*x^2$	g_1*x	Elev.
22350	0	0	0	301.070
22400	50	0.225887	-2.5	298.796
22450	100	0.903546	-5	296.974
22500	150	2.032979	-7.5	295.603
22550	200	3.614186	-10	294.684
22600	250	5.647165	-12.5	294.217
22650	300	8.131918	-15	294.202
22700	350	11.06844	-17.5	294.638
22750	400	14.45674	-20	295.527
22792.7	442.7	17.708	-22.135	296.643

Q1:(b)

$$b = \frac{P - A}{B - A} = \frac{44 - 9.5}{69 - 9.5} = 0.58$$

a = 1-b = 0.42

Sieve Size (inch)	Sieve Size (mm)	% Passing by weight Specification limit	Agg. (A)	Agg. (B)	4/4 Agg. (A)	Agg. (B)	Total Agg. (A) + Agg. (B)	
1½	37.5	100	100	100	42	58	100	ok
1	25	90-100	90	95	37.8	55.1	92.9	ok
¾	19	76-90	60	95	25.2	55.1	80.3	ok
½	12.5	56-80	20	85	8.4	49.3	57.7	ok
⅜	9.5	48-74	15	78	6.3	45.24	51.54	ok
No. 4	**4.75**	**29-59**	**9.5**	**69**	3.99	40.02	44.01	ok
No. 8	2.36	19-45	5	55	2.1	31.9	34	ok
No. 50	300mm	5-17	2.3	22	0.966	12.76	13.726	ok
No. 200	75mm	2-8	0	12	0	6.96	6.96	ok

Q2:(a)

$$Sight\ Distance = (0.278 * V * t) + \frac{V^2}{254\left(\frac{a}{9.81} \pm g\right)}$$

$$= (0.278 * 100 * 2.5) + \frac{100^2}{254\left(\frac{2.8}{9.81} - 0.04\right)} = 230m < 300(L) \rightarrow S < L$$

$$\therefore L = \frac{A * S^2}{800(C - 1.5)} \rightarrow 300 = \frac{|+2 - (-4)| * 230^2}{800(C - 1.5)} \rightarrow C = 2.82m$$

Q2:(b)

SN3 = 3.82, SN2 = 3.25, SN1 = 2.55

$SN1 = a1 * d1 \rightarrow 4 = 0.44 * D1 \rightarrow D1 = 5.8\ inch,$ $use \quad \boldsymbol{D1 = 6\ inch}$

$\therefore SN1' = 0.44 * 6 = 2.64$

$SN2 = SN1' + (a2 * m2 * d2) \rightarrow 3.25 = 2.64 + (0.14 * 0.80 * D2) \rightarrow D2 = 5.5\ inch$

$use \quad \boldsymbol{D2 = 6\ inch}$

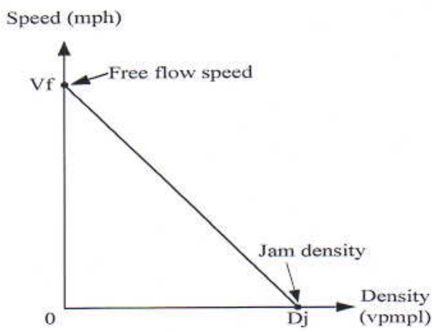
$\therefore SN2' = 3.312$

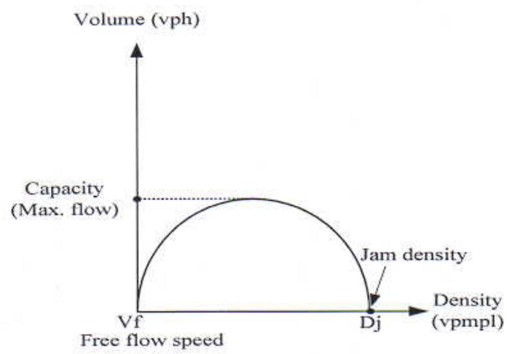
$SN3 = SN2 + (a3 * m3 * D3) \rightarrow 3.82 = 3.312 + (0.11 * 0.80 * D3) \rightarrow D3 = 6.4\ inch,$

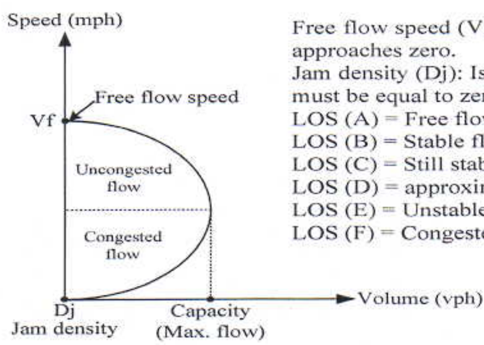
$use \quad \boldsymbol{D3 = 8\ inch}$

∴ **The design is not adequate in surface layer and subbase layer.**

<u>Q3:</u>(a)

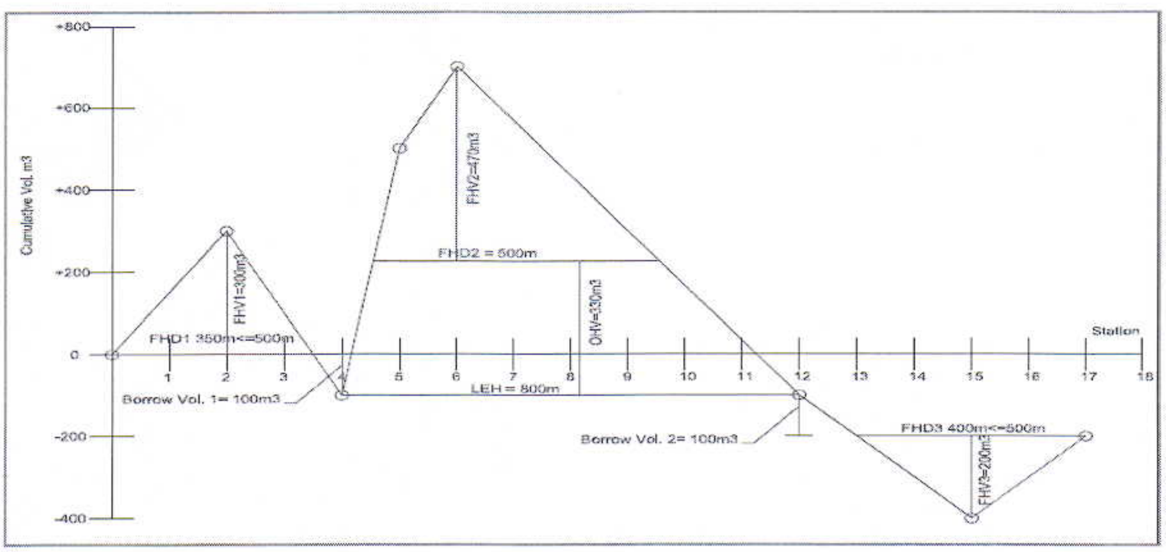






Free flow speed (Vf): Is the theoretical speed of traffic as density approaches zero.
Jam density (Dj): Is the maximum value of density when the flow must be equal to zero.
LOS (A) = Free flow.
LOS (B) = Stable flow.
LOS (C) = Still stable flow.
LOS (D) = approximate unstable.
LOS (E) = Unstable flow.
LOS (F) = Congested or forced flow.

<u>Q3:</u>(b)



FHV = 300+470+200 = 970 m3
OHV = 330 m3
LEH = 500 + 300 = 800 m
Borrow Vol. = 100 + 100 = 200 m3
Waste Vol. = zero

<u>Q4:</u>

(a)
- Structural performance, (load carrying capacity & distresses)
- Functional performance, (riding comfort)
- Safety, (sliding (skid) resistance)

(b)

1- Asphalt viscosity.
2- Asphalt film asphalt.
3- Nature of aggregate.
4- Applied stresses.
5- Environmental & drainage conditions.
6- Mineral filler, anti-stripping additives

(c) R1 = 550m, R2 = 350m, R3 = 700m

$\Delta 1 = 22°50'32$=22.842°, Δ2=19°36'45 $= 19.6125°, \Delta 3 = 30°25'00" = 30.4167°$

$T1 = R1tan\frac{\Delta 1}{2} = 550tan\frac{22°50'32"}{2} = 111.11m, L1 = \frac{\Delta 1 R1}{57.3} = 219.25m$

$T2 = 60.50m, L2 = 119.80m$

$T3 = 190.30m, L3 = 371.58m$

$\frac{Z1}{sin\Delta 2} = \frac{T1+T2}{sin\,(180-(\Delta 1 + \Delta 2))} \rightarrow Z1 = 85.33m$

$\frac{Z2}{sin\Delta 1} = \frac{Z1}{sin\,(\Delta 2)} \rightarrow Z2 = 98.68m$

$\frac{Z3}{sin\Delta 3} = \frac{T2+T3+Z2}{sin\,(180-(\Delta 1 + \Delta 2 + \Delta 3))} \rightarrow Z3 = 185.15m$

Ta=T1+Z1+Z3=381.60m

Sta. PC=(50+00)-(3+81.60)=46+18.40

Sta. PCC1= Sta. PC2= (46+18.40)+(2+19.25) = 48+37.65

Sta. PCC2=Sta. PC3= (48+37.65)+(1+19.80) = 49+57.45

Sta. PT = (49+57.45)+(3+71.58) = 53+29.03

Q5:

$- dbulk = \frac{Wd}{Wd - Ww}$

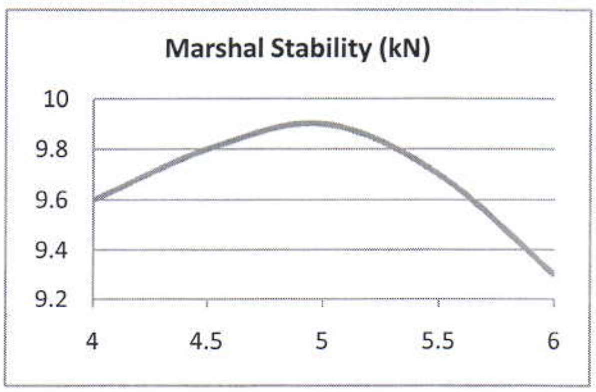
- bulk Ga = $\frac{43+51+6}{\frac{43}{2.60}+\frac{51}{2.71}+\frac{6}{2.69}} = 2.66$

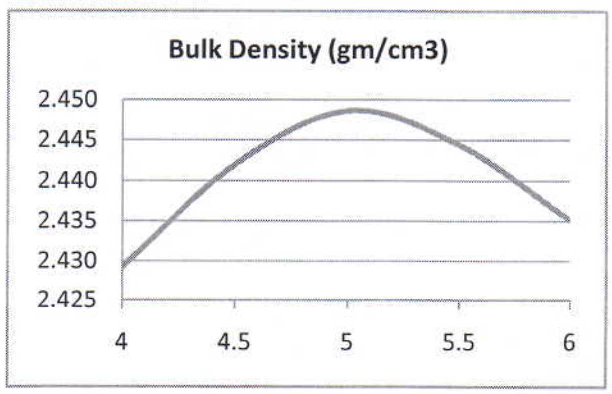
- VMA = $100 - \frac{dbulk * Pa}{BulkGa}$

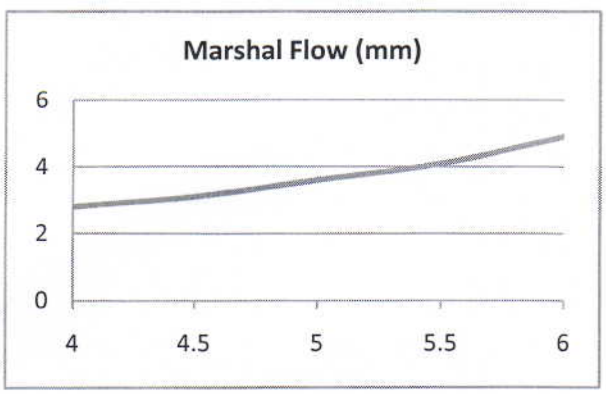
% Air voids = $\frac{Gm-dbulk}{Gm} * 100$

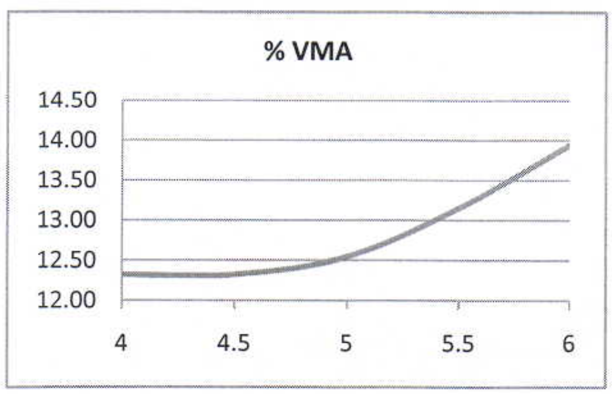
d_{bulk}	Bulk Density (gm/cm³)	%VMA	%Air voids
2.429	2.429	12.32	5.47
2.442	2.442	12.33	4.23
2.449	2.449	12.55	3.22
2.444	2.444	13.16	2.61
2.435	2.435	13.95	2.20

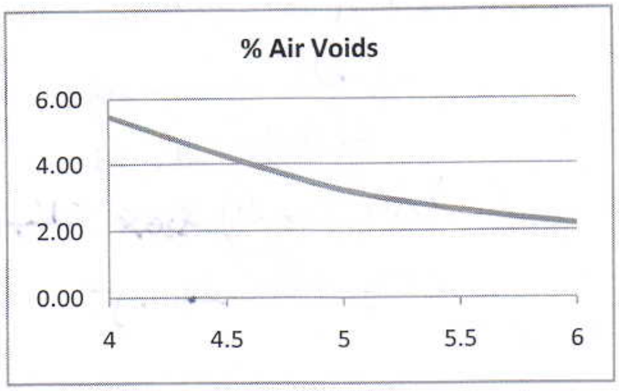
Plotting the % asphalt content by weight of total mix against (bulk density, stability, flow, % air voids, & %VMA)











- The asphalt content at the max. bulk density = 5.5%.
- The asphalt content at the max. stability = 5.5%.
- The asphalt content at 4% of air voids = 4.3%

The optimum asphalt content is determined as the average.
Therefore the optimum asphalt content = **5.1%**
The properties of the paving mixture containing the optimum asphalt (5.1%) content should now be determined and compared with the given specifications:

@ 5.1%of asphalt content the stability = 9.87 > 8	**OK**
@ 5.1%of asphalt content the flow = 3.6 (between 2-4mm)	**OK**
@ 5.1%of asphalt content the % Air voids = 3.1% (between 3-5%)	**OK**
@ 5.1%of asphalt content the %VMA = 12.6 > 10.0	**OK**

فرع هندسة البناء
هندسة الطرق
المرحلة الثالثة
حل أسئلة (الدور الأول)
م. منذر علي