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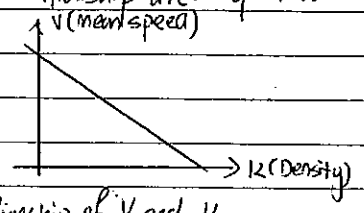
1(a)

Rate of flow (q) : Numbers of vehicles passing a point expressed as an equivalent hourly rate. (Veh/hr)

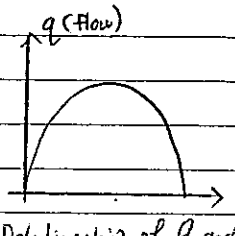
Density (k) : Numbers of vehicles occupying a given length of road way at a specified time. (veh/km)

Speed (v) : Space mean speed. (km/hr)

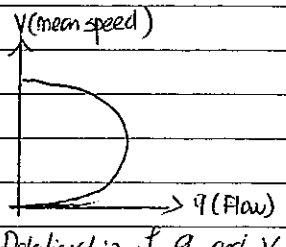
Their Relationship are: $q = kv$.



Relationship of V and K.



Relationship of q and K.



Relationship of q and V.

b) $V = 60 \ln \frac{100}{k}$

at $V=0$, $k = k_j$.

$0 = 60 \ln \frac{100}{k_j}$

$\therefore \ln \frac{100}{k_j} = 0$

$\therefore \frac{100}{k_j} = 1$

$\therefore k_j = 100$ veh/km

capacity => Maximum flow of the traffic.

$\therefore V = 60 \ln \frac{100}{k}$

$\therefore q = kv$

$= 60k(\ln \frac{100}{k})$

$q = 60k(\ln 100 - \ln k)$

$\frac{dq}{dk} = 60(\ln 100 - [k \cdot \frac{1}{k} + \ln k])$

when $\frac{dq}{dk} = 0$.

$1 + \ln k = \ln 100$

$\ln k = \ln 100 - 1$

$\ln k = 3.605$

$\therefore k = e^{3.605}$

$= 36.7879$.

$\therefore q = 60 \times 36.7879 (\ln \frac{100}{36.7879})$

$= 2207.27$ veh/hr.

Ans: The jam density is 100 veh/km and the maximum capacity is 2207.27 veh/hr.

c) Incremental Assignment:

I) Divide each OD entry into N portion.

II) Since $t = f$(OD loading), update t for each link.

III) Assign the loading to the link with the least travel time.

IV) Procedures stop when all loading have been assigned to the link.

Weakness of incremental assignment:

- The travel time of each link won't converge to one value ...e $t_1^* \neq t_3^* \neq t_5^*$.
- We assume that the drivers know exactly the travel time of each link. However, $t = f$(loading). Thus, it may not predict the driver behaviour exactly.

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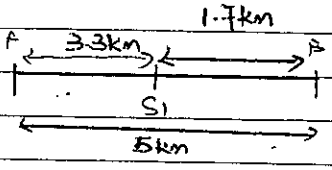
Q2. $P = \sum_j \left(A_j \times H_i - \frac{H_i}{20} x_{ij}^2 \right)$

a)



	H_i	A_j	x_{ij}	P_i
Zone A	1000	6	3.3	5455.5
Zone B	2000	6	1.7	11711

$\because Q_{ij} = P_{ij} P_i$ $\quad P_{ij} = \frac{A_j F_{ij}}{\sum A_j F_{ij}}$

Since, ____ and Zone B do not have other attractive zones.

$\therefore Q_{AS1} = 5455.5$

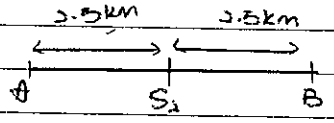
$Q_{BS1} = 11711$

$\therefore Q_{Total} = 5455.5 + 11711$

$= 17166.5$

Ans: There will be 17166.5 customers visit S1 per week.

b) First Option: Middle between A and B.



Since, production is a function of attractiveness.

∴ Production due to S2.

	H_i	A_j	x_{ij}	P_i
Zone A	1000	12	2.5	11687.5
Zone B	2000	12	2.5	23375

$\therefore P_A = 5455.5 + 11687.5 = 17143$

$P_B = 11711 + 23375 = 35086$

For Zone A.

$F_{ij} = \frac{1}{x_{ij}^2}$ $\quad Q_{ij} = P_{ij} P_i$.

$P_{ij} = \frac{A_j F_{ij}}{\sum A_j F_{ij}}$

	A_i	x_{ij}	F_{ij}	$A_i F_{ij}$	P_{ij}	Q_{ij}
S1	6	3.3	0.09182	0.55092	0.2229	3821.1747
S2	12	2.5	0.1600	1.92	0.7771	13321.8253
				$\sum$ 2.47092		

For Zone B.

	A_i	x_{ij}	F_{ij}	$A_i F_{ij}$	P_{ij}	Q_{ij}
S1	6	1.7	0.3406	2.0761	0.5195	18227.177
S2	12	2.5	0.16	1.92	0.4805	16858.823
				$\sum$ 3.9961		

$\therefore$ Total Flow to S2 = 13321.8253 + 16858.823 = 30180.6483 #

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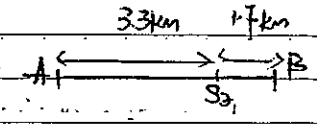
Second Option: Same place as S1.



Production due to S2.

	H_i	A_j	X_{ij}	P_i.
zone A	1000	12	3.3	11455.5
zone B	2000	12	1.7	23711

$\therefore P_A = 5455.5 + 11455.5 = 16911$

$P_B = 11711 + 23711 = 35422$

for Zone A.

	A_i	X_{ij}	F_{ij}	$A_i F_{ij}$	P_{ij}	Q_{ij}
S1	6	3.3	0.09182	0.55092	0.333	5631.363
S2	12	3.3	0.09182	1.10184	0.667	7640.8185
				1.65276		

for Zone B

	A_i	X_{ij}	F_{ij}	$A_i F_{ij}$	P_{ij}	Q_{ij}
S1	6	1.7	0.3406	2.0436	0.333	11795.526
S2	12	1.7	0.3406	4.0872	0.667	23626.474
				6.1308		

$\therefore$ Total Flow to S2 = 7640.8185 + 23626.474 = 31267.2925. (Option 2).

Total Flow to S2 = 30180.6483 (Option 1).

$\therefore$ The best option is to build S2 at the same location as S1.

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Q3. we can simplify the Network into 3 link.

d) link I: $t_I = 24 + 2x_1$ $t_2 = 12 + 2x_2$ $t_3 = 10 + x_3$ $t_4 = 8 + x_4$.

link II: $t_{II} = t_2 + t_4$

link III: $t_{III} = t_3 + t_4$

Thus. $x_4 = x_2 + x_3$.

$\therefore t_{II} = t_2 + t_4$ $t_{III} = t_3 + t_4$

$= 20 + 2x_2 + x_4$. $= 10 + x_3 + 8 + x_4$

$= 20 + 3x_2 + x_3$ $= 18 + x_3 + x_4$

$= 18 + 2x_3 + x_2$.

Since, these 3 links will be used.

$\therefore t_I = t_{II} = t_{III}$.

$x_1 + x_2 + x_3 = 5$.

$\therefore x_1 = 5 - x_2 - x_3$.

$t_1 = 24 + 2(5 - x_2 - x_3)$

$= 24 + 10 - 2x_2 - 2x_3$

$\boxed{t_I = 34 - 2x_2 - 2x_3}$

$t_I = t_{II}$ $t_I = t_{III}$

$34 - 2x_2 - 2x_3 = 20 + 3x_2 + x_3$ $34 - 2x_2 - 2x_3 = 18 + 2x_3 + x_2$

$14 = 5x_2 + 3x_3$ $16 = 4x_3 + 3x_2$

$5x_2 + 3x_3 = 14$ $3x_2 + 4x_3 = 16$

$3x_2 + 4x_3 = 16$

$\therefore x_2 = 0.7272$

$x_3 = 3.4545$

$x_1 = 0.8183$.

$x_4 = x_2 + x_3 = 4.1817$.

Ans: The Demand of each link is $x_1 = 0.8183$, $x_2 = 0.7272$, $x_3 = 3.4545$, $x_4 = 4.1817$.

3b) $\because x_4 = x_2 + x_3 = 3$

$\because t_{II} = t_{III}$.

$20 + 3x_2 + x_3 = 18 + x_2 + 2x_3$

$2x_2 - x_3 = -2$

$x_2 + x_3 = 3$

$\therefore x_2 = \frac{1}{3}$, $x_3 = \frac{8}{3}$

$\therefore t_{II} = 20 + 3x_2 + x_3$

$= 20 + 3(\frac{1}{3}) + \frac{8}{3}$

$= \frac{71}{3}$

$\because t_I = 24 + 2x_1 > 24$ For $(x_1 > 0)$ $\therefore x_1 = 0$, $x_2 = \frac{1}{3}$, $x_3 = \frac{8}{3}$.

$\therefore$ There is No flow in link 1.

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3c). Thus, in order for 4 links to be used:

t must be greater than 24.

From the equation, we know that t_{II} and t_{III} will be used when $t \leq 24$.

∴ At $t = 24$

$t_{II} = 20 + 3x_2 + x_3 = 24$ $\quad$ $t_{III} = 18 + x_2 + 2x_3 = 24$

$3x_2 + x_3 = 4$ $\quad$ $x_2 + 2x_3 = 6$

$x_2 + 2x_3 = 6$

$\therefore x_2 = 0.4, \quad x_3 = 2.8.$

$\therefore t = 24$

$t_1 = 24 + 2x_1$

$\therefore x_1 = 0.$

∴ Total Demand $= x_1 + x_2 + x_3$

$= 0 + 0.4 + 2.8$

$= 3.2.$

Ans: For $D > 3.2$, 4 links will be used.

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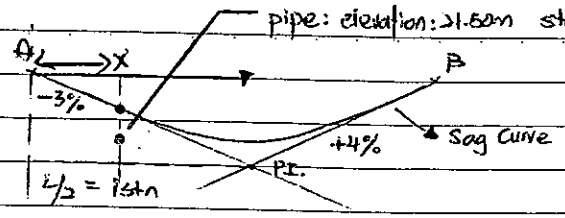
Q4

a)

I)



elevation: 24m station: 99+25 | elevation: 21m. station: 100+25 | elevation station: 101+25

$g_1 = -3\%$, $g_2 = +4\%$.

$\because y = y_0 + g_1 x + \frac{rx^2}{2}$ $\quad L = 200m = 2\,stn$

$r = \frac{g_2 - g_1}{L}$ m/stn²

$y_0 = 21m + 3\,m/stn \times 1\,stn$
$= 24m$

$= [+4\% - (-3\%)]/2$
$= [+7\%]/2$
$= +3.5\%/stn.$

The centreline of the roadway. $x = 99+50 - (99+25) = 25m = 0.25\,stn$

$\therefore y = y_0 + g_1 x + \frac{rx^2}{2}$
$= 24 - 3\,m/stn \times 0.25\,stn + \frac{3.5 \times 0.25^2}{2}\,m$
$= 23.359375\,m$

$\therefore \Delta height = y - elevation\ of\ pipe$
$= 23.359375 - 21.5$
$= 1.859375m > 1.5m$

Hence, the roadway can provide at least 1.859375m at the position of pipeline.

II)

There are

- appearance : long vertical curves give more pleasing appearance that short vertical curve.
- stopping sight distance : adequate sight distance for driver to react.
- Passing sight distance : adequate passing sight distance if it is a 2 way 2 lane road.
- Comfort critive ... : tolerable vertical acceleration.
- Clearance Critireon. : adequate clearance where ... under ... other facilities.

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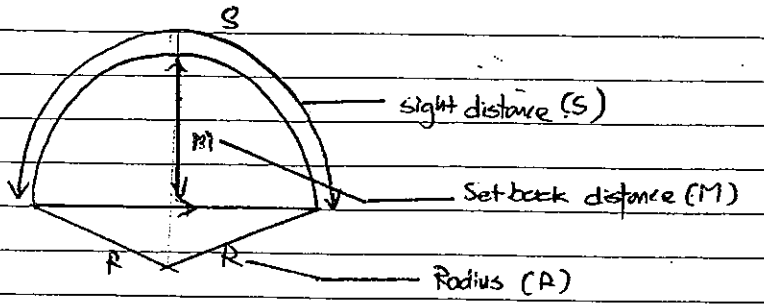
4b) I)



Circular Horizontal Curve

II)

$$M = R\left[1 - \cos\left(\frac{28.65}{R}\right)^{\circ}\right]$$

$M = 6m$, $R = 300m$

$$6 = 300\left[1 - \cos\theta\right]$$

$$0.02 = 1 - \cos\theta.$$

$$\therefore \cos\theta = 0.98$$

$$\frac{28.65}{300} = 11.4783$$

$\therefore S_{required} = 120.192\,m.$

$\because S < 140m.$

Hence, it is inadequate.

Thus, we can increase the radius of the circular horizontal curve, to increase the sight distance. or reduce the design speed of the horizontal circular curve.

III) There are.

a. Comfort Critirea: The curvature of the curve should not cause any discomfort when drive through.

b. Passing sight distance: Adequate passing sight distance should be provided if it is a 2 way 2 lane road.

c. Set back distance: Any blockage that may reduce sight distance should be taken into account.

d. Appearance critirea: long curve is preferred than short curve.

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4c)

Station	Area. Cut	Fill	
150+00		25.5	$V = \frac{(A_1+A_2)\times h}{2}$ (Trapezoidal)
h = 60m		$V = 1070m^3$	
150+50		17.3	
h = 20m		$V = 238m^3$	$V = \frac{A_3 \times h}{3}$ (pyramidal)
150+70	0	6.5	
h = 20m	$146.67m^3$	$V = 93m^3$	
150+90	22.00	0.8	
h = 50m	$1475m^3$	$V = 46.67m^3$	
151+40	45.00.	0	
	$V_{cut} = 1821.67m^3$	$V_{Fill} = 1447.67m^3$.	

$S = 0.05$

$$V_E = V_c(1+S)$$
$$= 1821.67(1-0.05)$$
$$= 1730.5865m^3$$

$\therefore$ Excess material $= 1730.5865 - 1447.67$

$= 282.9165m^3$ (in terms of fill material)

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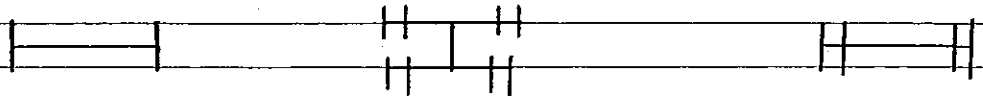
Q5

5a)



Single wheel.	Tandem axle	Dual wheel
load: 54kN	load: 145kN	load: 80kN.
	equivalance	

The above configuration are the single axle load. (ESAL).

In the pavement design, other type of loading are converted into ESAL by fourth power rule.

$$\text{loading unit} = \left[\frac{\text{loading}}{\text{ESAL}}\right]^4$$

By finding all of the loading, we can then design the pavement based on the the climate & environmental condition, S/G soil strength and pavement material properties & strength. Since ESAL is an indicator of 1 unit load to the pavement. The higher the traffic loading, the thicker the pavement for the same service life.

5b)

- Asphalt Concrete — $a_1 = 0.45$ — D_1
- Crushed Aggregate — $SN_1 = 2.2$ — $a_2 = 0.20$ $m_2 = 1.20$ — D_2
- Sandy Gravel — $SN_2 = 3.3$ — $a_3 = 0.12$ $m_3 = 1.10$ — D_3
- Roadbed Soil — $SN_3 = 4.0$
- → Design for the first 3 layer.

$\therefore SN_1 = 2.2 = a_1 D_1$ 1 inch = 25.4 mm

$25.4 \times 2.2 = 0.45 D_1$

$\therefore D_1 = 124.177$ mm

$\therefore D_1^* \geq 125$ mm $SN_1^* = 125 \times 0.45 = 56.25$

$\because SN_2 - SN_1^* = a_2 m_2 D_2$.

$3.3 \times 25.4 - 125 \times 0.45 = 0.2 \times 1.20 \times D_2$

$\therefore D_2 = 114.875$ mm

$D_2^* = 115$ mm $SN_2^* = 27.6$

$\because SN_3 - SN_1^* - SN_2^* = a_3 m_3 D_3$.

$4.0 \times 25.4 - 56.25 - 27.6 = 0.12 \times 1.10 \times D_3$

$D_3 = 134.469$ mm

$\therefore D_3^* = 135$ mm. $SN_3^* = 17.82$

$SN_1^* + SN_2^* + SN_3^* = 101.67$

$= 4.00 \geq SN_3$ (okay)

Ans: The required thickness are $D_1 = 125$mm, $D_2 = 115$mm, $D_3 = 135$mm.

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5c)

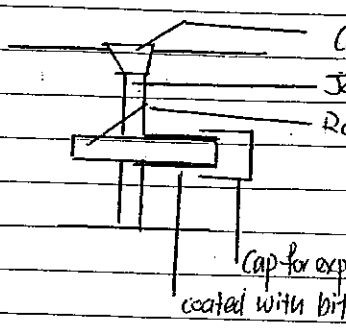
Major functional requirements of joints:

I. water proof at all times.

II. riding quality should not be impaired.

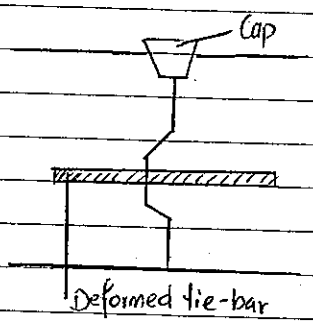
III. positioning of joints should not cause or encourage possible cracking or failure of pavement.

IV. should not interfere with placing of concrete.



Expansion Joints.

- Transverse joints for concrete expansion.
- It can relieve the compressive stresses that generated due to the restriction of concrete expansion.
- Compressibe joint filler can prevent mud pumping of joint.
- The round dowel bar can prevent cracks propagate.



Warping Joints

- longitudinal hinge joints.
- prevent angular movement between slab.