2018/19

1) a) $V = 40 - 0.2K$

$q = VK$

$q = (40 - 0.2K)K$

$q = 40K - 0.2K^2$

For q_{max},

$q' = 0$

$q' = 40 - 0.4K = 0$

$40 = 0.4K$

$K_o = 100$ veh/km

$V_o = 40 - 0.2(100)$

$= 20$ km/h

$q_{max} = V_o K_o$

$= 100(20)$

$= 2000$ veh/hr

$\frac{L}{2} + 70 = \frac{-g_1}{g_2 - g_1} \boxed{L}$

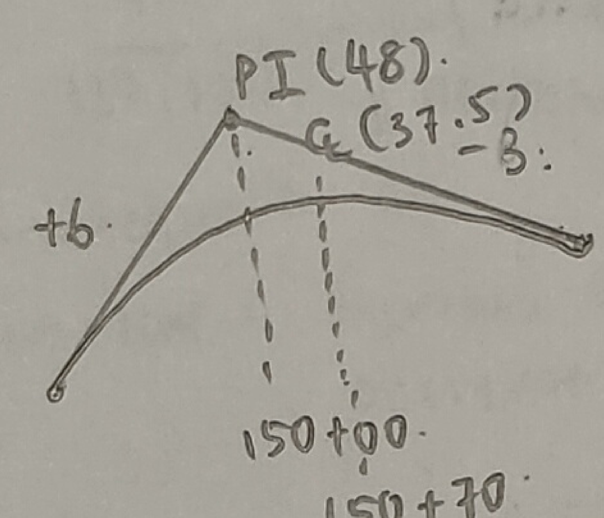
$x = 280$

48 -

$y = 150 \times 6\%$

b) -

2) a)



For highest pt,

$y' = 0$

$y = y_0 + g_1 x + \frac{1}{2} r x^2$

$y' = g_1 + rx = 0$

$g_1 + \frac{g_2 - g_1}{L} x = 0$

$x = \frac{-g_1}{g_2 - g_1} L$

For centerline, $x = \frac{L}{2} + 70$

$\frac{L}{2} + 70 = \frac{-g_1}{g_2 - g_1} L$

$\frac{L}{2} + 70 = \frac{-6}{-3-6} L$

$\frac{L}{2} + 70 = \frac{2}{3} L$

$70 = \frac{L}{6}$

$L = 420$ m //

b) For y_0

$\tan\theta = 6\%$

$\frac{48 - y_0}{420/2} = \frac{6}{100}$

$48 - y_0 = 12.6$

$y_0 = 35.4$ m

$y = 35.4 + 0.06x + \frac{1}{2}\left(\frac{-0.09}{420}\right)x^2$

$y = 35.4 + 0.06x - 1.0714 \times 10^{-4} x^2$

For centreline, $x = \frac{L}{2} + 70 = 280$ m

$y = 35.4 + 0.06(280) - 1.0714 \times 10^{-4}(280)^2$

$y = 43.8$ m

vertical clearance $= 43.8 - 37.5 = 6.3$ m //

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1) a)
b)
2) a)
b)

3) a) Zone A = 1000 hh
Zone B = 2000 hh

$P_A = \left(6 \times 1000 - \frac{1000}{20} x_A^2\right) = 6000 - 50x_A^2$

$P_B = \left(6 \times 2000 - \frac{2000}{20} x_B^2\right) = 12000 - 100x_B^2$

$x_A + x_B = 5 \qquad x_A = 5 - x_B$

$P = 6000 - 50x_A^2 + 12000 - 100x_B^2$

$= 18000 - 50(5-x_B)^2 - 100x_B^2$

$= 18000 - 50(25 - 10x_B + x_B^2) - 100x_B^2$

$= 18000 - 1250 + 500x_B - 50x_B^2 - 100x_B^2$

$P = 16750 + 500x_B - 150x_B^2$

$\frac{dP}{dx_B} = 500 - 300x_B = 0$ (max

$x_B = 1.67$ km

$x_A = 3.33$ km

b) In the middle

$P_A = 17133$
$P_B = 35096$

I	J	A_J	F_{IJ}	k_{IJ}	$A_J F_{IJ} k_{IJ}$	P_{IJ}	Q_{IJ}
A	S1	6	0.091	1	0.54	0.22	3769
	S2	12	0.16	1	1.92	0.78	13364
B	S1	6	0.359	1	2.154	0.529	18566
	S2	12	0.16	1	1.92	0.471	16530

16530 + 13364 = 29894.

$P_A =$

$\frac{1}{dC}$

BETTER

In same location

$P_A = 16891$
$P_B = 35442$

I	J	A_J	F_{IJ}	k_{IJ}	$A_J k_{IJ} k_{IJ}$	P_{IJ}	
A	S1	6	0.09	1	0.54	$\frac{1}{3}$	5630
	S2	12	0.09	1	1.08	$\frac{2}{3}$	11261
B	S1	6	0.359	1	2.154	$\frac{1}{3}$	11814
	S2	12	0.359	1	4.308	$\frac{2}{3}$	23628

11261 + 23628 = 34889

$x_1 + x_2 + x_3 = x_4 + x_1 \qquad x_2 + x_3 = x_4 = 5$

4) $t_1 = t_2 + t_4 + t_3 + t_4 \qquad x_3 = 5 - x_2$

a) $18 + 2x_1 = 12 + 2x_2 + 8 + x_4 = 10 + x_3 + 8 + x_4$

$18 + 2x_1 = 20 + 2x_2 + x_4 = 18 + x_3 + x_4$

$-2 + 2x_1 - 2x_2 = x_4 \qquad 2x_2 - x_3 = -2$

$x_3 = 2x_2 + 2$

$-2 + 2x_1 - 2x_2 = 5 \qquad 5 - x_2 = 2x_2 + 2$

$2x_1 - 2x_2 = 7 \qquad 3x_2 = 3$

$\boxed{x_2 = 1}$

$x_1 - x_2 = 3.5 \qquad \boxed{x_3 = 2(1) + 2 = 4}$

$x_1 = 3.5 + x_2$

$\boxed{x_1 = 4.5} \qquad \boxed{x_4 = 5}$

travel demand = 4.5 + 4 + 1
= 9.5

b) $B \to C \quad D = 7 - 0.5t$

$A \to C$
$B \to C \Rightarrow D = 7 - 0.5t$ at equilibrium,
$\Rightarrow D = 7 - 0.5t_4 \qquad x_4 = 4.$
$= 7 - 0.5(8 + x_4) \qquad t_4 = 8 + 4 = 12$
$D = 3 - 0.5x_4 \qquad D = 7 - 0.5(12)$
$x_4 = x_2 + x_3 + D \qquad = 7 - 6$
$x_4 = x_2 + x_3 + 3 - 0.5x_4 \qquad = 1$
$1.5x_4 = x_2 + x_3 + 3$

$x_1 + x_2 + x_3 = x_1 + x_4 - 1$

$t_1 = t_2 + t_4 = t_3 + t_4$
$t_3 = t_2$
$x_3 = 2 + 2x_2$
$1.5x_4 = x_2 + 2 + 2x_2 + 3$
$1.5x_4 = 3x_2 + 5$
$x_4 = 2x_2 + \frac{10}{3}$
$4 = 2x_2 + \frac{10}{3}$
$x_2 = \frac{1}{3}$
$x_3 = \frac{8}{3}$
$18 + 2x_1 = 12 + 2x_2 + 8 + x_4$
$18 + 2x_1 = 12 + \frac{2}{3} + 8 + 4$
$x_1 = \frac{10}{3}$
$D_{AC} = x_1 + x_2 + x_3$
$= {}^{19}/_{3} = 6.33$

$x_2 + x_3 = 3$

$\boxed{x_2 = 3 - x_3}$

$t_1 = t_2 + t_4 = t_3 + t_4$

$18 + 2x_1 = 20 + 2x_2 + x_4 = 18 + x_3 + x_4$

$A \to C \qquad B \to C$

$T_1 = 18 + 2x_1 \qquad T = 8 + x_4$

$T_2 = 20 + 2x_2 + x_4 + 1 = \qquad D = 7 - 0.5(8 + x_4)$

$= T_3 = 18 + x_3 + x_4 + 1 \qquad = 7 - 0.5(8+4)$

$= 7 - 6$

$= 1$

$\frac{7 \times 3}{2 \times 3} = \frac{21}{6} + \frac{2}{6}$

$\frac{23}{6}$

$18 + 2x_1 = 20 + 2x_2 + 4$

$18 + 2x_1 = 24 + 2x_2$

$\cancel{x_1 = \frac{7}{2} + x_2}$

$\cancel{9 + x_1 = 12 + x_2}$

$\cancel{x_1 = 3 + x_2}$

$\cancel{21 + 2x_2 + x_4 = 18 + x_3 + x_4}$

$\cancel{x_3 = 2x_2 + 3}$

$t_2 = t_3$
$12 + 2x_2 = 10 + x_3$
$x_3 = 2 + 2x_2$
$x_3 = 2 + 6 - 2x_3$
$3x_3 = 8$
$x_3 = \frac{8}{3}$

$x_2 + x_3 = x_4$

$\cancel{x_2 + 2x_2 + 3 = 4}$

$\cancel{3x_2 = 1}$

$\boxed{\cancel{D = x_1 + x_2 + x_3 = \frac{47}{6}}} \quad x_2 = \frac{1}{3}$

$x_1 = \frac{10}{3}$

$\boxed{\cancel{x_2 = \frac{1}{3} \quad x_1 = \frac{23}{6} \quad x_3 = \frac{11}{3}}}$

$D = x_1 + x_2 + x_3$
$= \frac{19}{3}$

$t_4 = t_2 + x_3 = 7 - 0.5t \quad (8 + x_2)$

$t_4 = t_2$

$t_4 = x_2 + x_3 + D_{BC}$

$x_2 + x_3 =$

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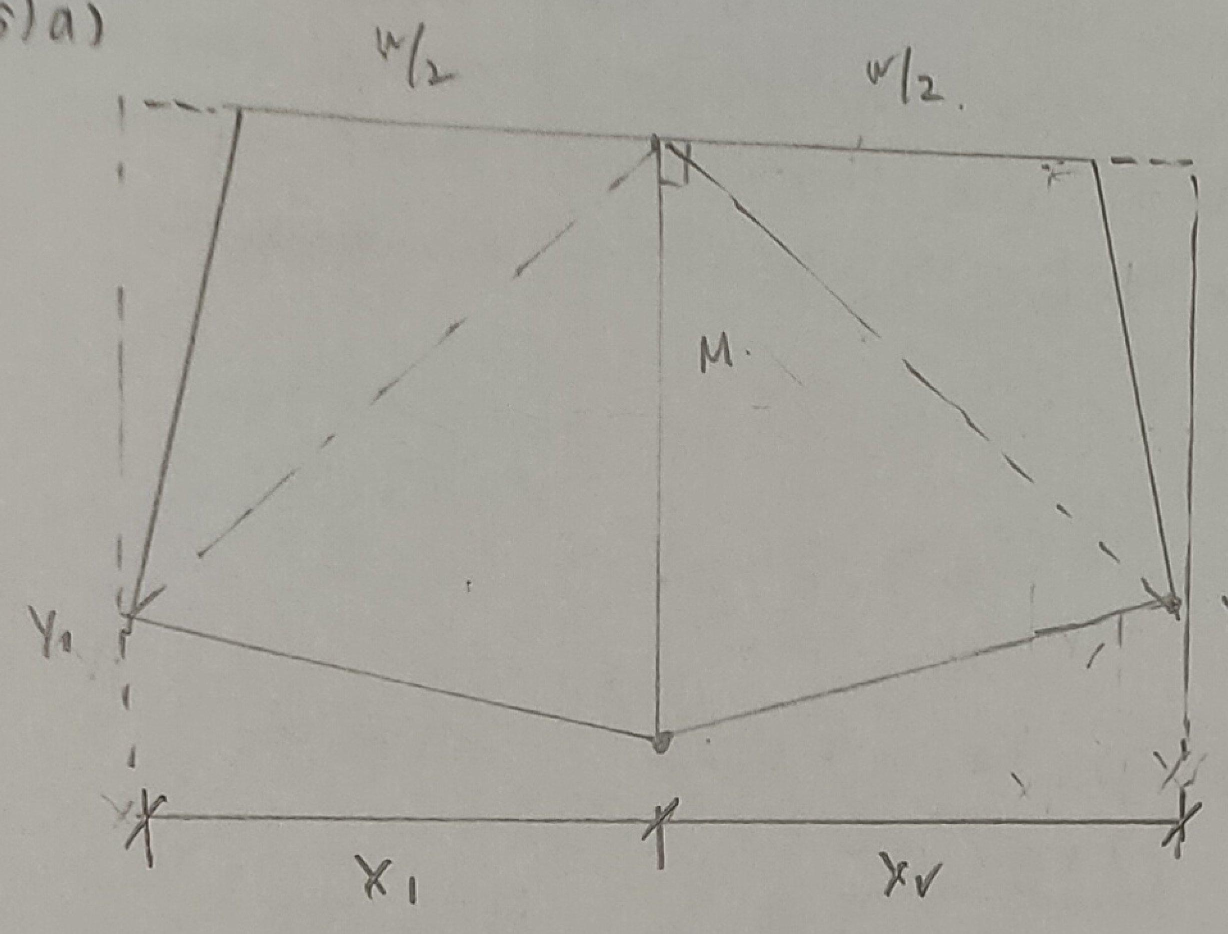
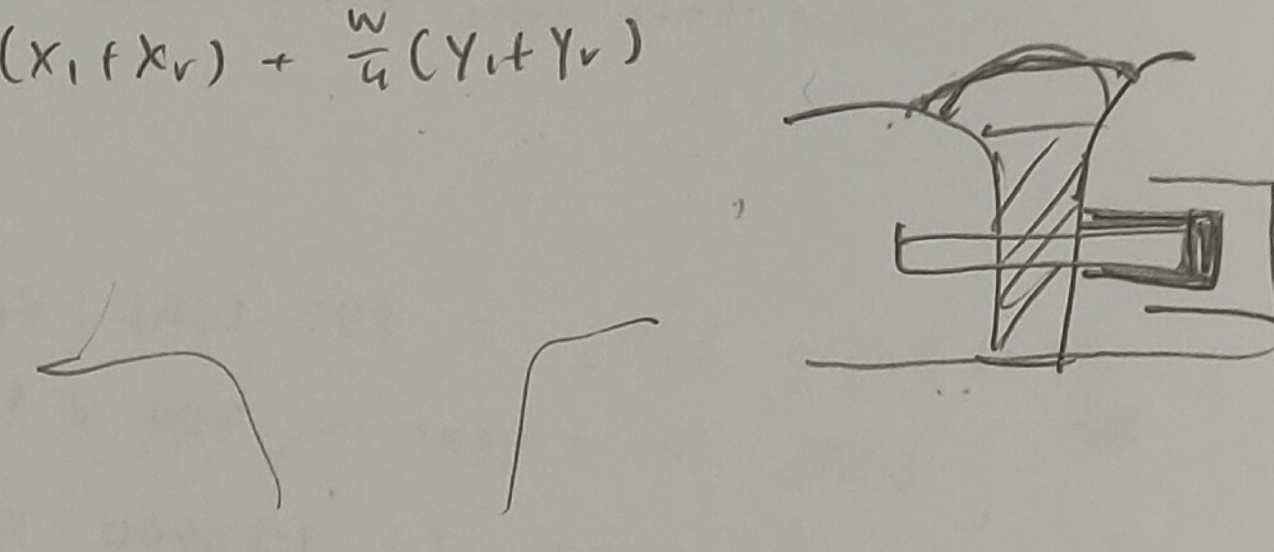
5) a)



$$A = \frac{1}{2}\cdot\frac{W}{2}\cdot Y_l + \frac{1}{2}M(X_l + X_r) + \frac{1}{2}\cdot\frac{W}{2}\cdot Y_r$$

$$= \frac{W}{4}(Y_l + Y_r) + \frac{M}{2}(X_l + X_r)$$

$$A = \frac{M}{2}(X_l + X_r) + \frac{W}{4}(Y_l + Y_r)$$



b)

Station	Calculation	Area	
150 + 50	$\left(\frac{1.5}{2}\right)(14.4 + 13.8) + \frac{12}{4}(3.6 + 2.3)$	38.85 m² cut	$\frac{38.85 + 53.6}{2}(50) = 2311.25\ m^3$
151 + 00	$\left(\frac{2.00}{2}\right)(16.8 + 16.7) + \frac{12}{4}(3.3 + 3.4)$	53.6 m² cut	$\frac{53.6 + 70.83}{2}(50) = 3110.75\ m^3$
151 + 50	$\left(\frac{2.2}{2}\right)(18 + 18.3) + \frac{12}{4}(4.3 + 6.0)$	70.83 m² cut	5422 m³

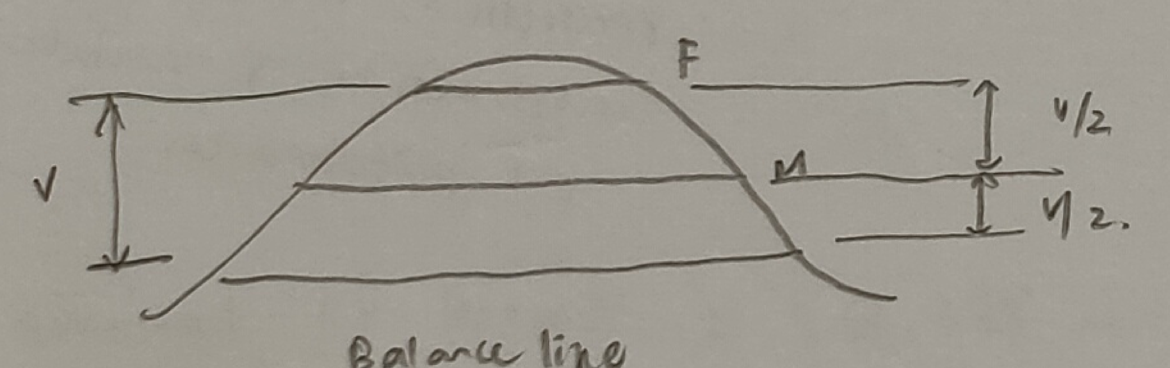
50
50

c) Overhaul is the cost to haul material beyond the free haul distance F and it is measured in terms of $/ stn - m³.

There are 2 methods to calculate overhaul on mass diagram. One is to use graphical calculation and the other is using median haul distance.

In median distance, OH = V(M − F).

$$\frac{\Delta V}{2}$$



$$\text{Balance line (LEH)} = \frac{C_B}{C_{OH}} + F$$

→ mark balance line and Free haul line on the mass diagram

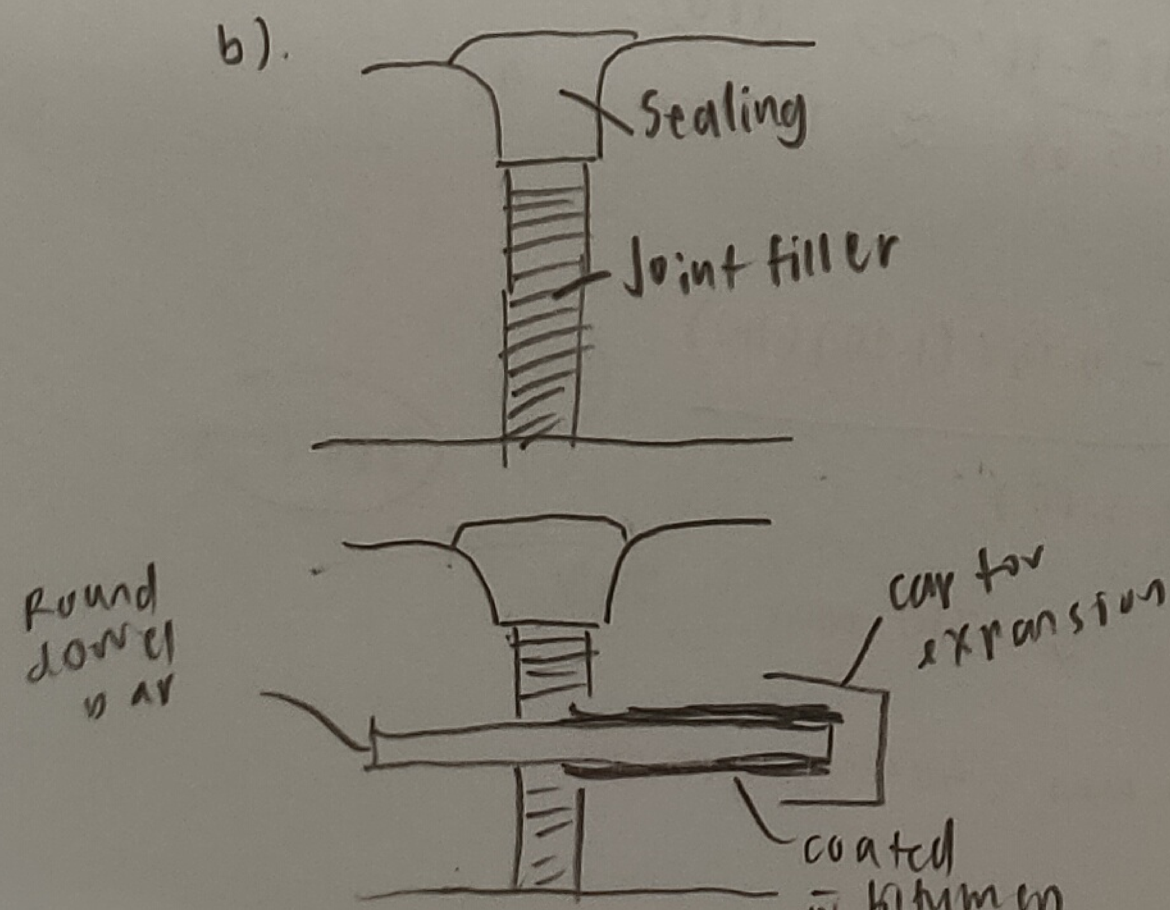
→ compute ΔV, the volume between the 2 lines

→ ΔV/2 → read from graph → get median line

→ measure median line (stn)

6) a) In rigid pvt structure, the S/B is used to remedy an unsatisfactory S/G condition. It controls S/G volume change as S/B holds down S/G & absorb some expansion. S/B also improves drainage of water from surface or variable WT. S/G also controls mud pumping which is caused by heavy load, water accumulation & unsuitable soil. S/G also controls frost damage & forms working surface.

b).



Expansion joints are transverse joint for expansion. It is a full depth gap of size 20-25 mm. It consists of a non-protruding & compressible filler capped by bituminous rubberised sealant (for waterproofing). Load transfer is done by dowel bars with one half debonded and installed parallel to each other on surface & pvt centreline. It also serve as contraction, construction & warping joints.

7) a) Equivalent single-axle load or ESAL represent the standard load unit for design, which is 8160 kg (18000 lb) → 80kN load on a single axle with pair of dual wheels on each side. Different axle loads can be converted to ESAL using equivalency factors (from table from AASHTO). The damage cause by the loadings can be calculated based on fourth power relationship where damage ∝ 4th power of axle load. The loads can also obtained from truck types using these equivalency factors.

b) i) Daily ESAL = 800 ESAL / day

ESAL in a year = 800 × 365 = 292000 ESAL / yr

In 20-year ⇒ $292000 \times f_g = 292000 \times \dfrac{(1+g)^n - 1}{g}$

$= 292000 \times \dfrac{(1+0.02)^{20}-1}{0.02}$

$= 7094831.98$ → 3547415.5

≈ 7 million ESALs ⇒ 3.55 mil ESALs

ii) Variance value.

So.

ii) R = 80%

S_0 = 0.45 (typical for flexible pavement)

W_{18} = 7 mil

ΔPSI = 4 - 2 = 2

variance = 0.3

S_0 = 0.55

iii) variance value represent the uncertainty of the pvt design. It is a function of many factors such as variation in traffic prediction, variation in materials or construction & variation in pvt performances.

SN_1, M_R = 30,000 psi

SN_2, M_R = 15,000 psi

SN_3, M_R = 6,000 psi

From nomograph

SN_1 = 2.7 (2.5)

SN_2 = 3.5 (3.3)

SN_3 = 5 (4.3)

layer coefficient

a_1 = 0.42

$a_2 = 0.249(\log_{10} M_{RBS}) - 0.977 = 0.249(\log_{10} 30{,}000) - 0.977 = 0.138$ 0.15

$a_3 = 0.227(\log_{10} M_{RSB}) - 0.839 = 0.227(\log_{10} 15{,}000) - 0.839 = 0.11$ 0.11

158.75 =

$D_1 = \dfrac{SN_1}{a_1} = \dfrac{2.7(25.4)}{0.42} = 163.286 \approx 170$ mm 160

110.11 ~> 110.

$D_2 = \dfrac{SN_2 - a_1 D_1^*}{a_2 m_2} = \dfrac{3.5(25.4) - 0.42(170)}{0.138(1.20)} = 105.68 \approx 110$ mm 90

$D_3 = \dfrac{SN_3 - a_1 D_1^* - a_2 m_2 D_2^*}{a_3 m_3} = \dfrac{5(25.4) - 0.42(170) - 0.138(1.20)(110)}{0.11(1.10)}$ 210

210 mm

$= 308.96$ mm ≈ 310 mm 240

170 mm asphalt concrete, 110 mm crushed stone & 310 mm sandy gravel