23/24 SEM 1 SOLUTION
CV3014 TRANSPORTATION ENGINEERING
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Q1.

(a) PHF for 5pm to 6pm: $\frac{900+1000+1200+850}{4\times 1200} = 0.823 = 82.3\%$

PHF for 6pm to 7pm: $\frac{950+1000+1200+850}{4\times 1200} = 0.833 = 83.3\%$

(b) $q = vk$

$$q = 40v\ln\left(\frac{250}{k+0.01}\right)$$

When speed at capacity occurs, $\frac{dq}{dk} = 0$

$$\frac{dq}{dk} = 40\ln\left(\frac{250}{k+0.01}\right) - 40 = 0$$

$$40\ln\left(\frac{250}{k+0.01}\right) = 40$$

$$\ln\left(\frac{250}{k+0.01}\right) = 1$$

$$\frac{250}{k+0.01} = e$$

$$k + 0.01 = \frac{250}{e}$$

$k = \frac{250}{e} - 0.01 = 91.96\ veh/km$ (density at capacity)

Jam density, $v = 0$

$$40\ln\left(\frac{250}{k+0.01}\right) = 0$$

$$\ln\left(\frac{250}{k+0.01}\right) = 0$$

$$\frac{250}{k+0.01} = 1$$

$k = \frac{250}{1} - 0.01 = 249.99 veh/km$ (Jam density)

Speed at capacity, $k = 91.96$

$v = 40\ln\left(\frac{250}{91.96+0.01}\right) = 40 km/hr$ (Speed at capacity)

Maximum flow, $v = 40, k = 91.96$

$q = 40(40)\ln\left(\frac{250}{91.96+0.01}\right) = 1600 veh/hr$ (Maximum flow)

(c) $L = 400m$

$$y = y_0 + g_1x + \frac{1}{2}rx^2$$

$$y' = g_1 + rx$$

$$r = \frac{g_2 - g_1}{L} = \frac{-0.02 - 0.03}{400} = -\frac{1}{8000}$$

$$0.03 + \left(-\frac{1}{8000}\right)x = 0$$
$$\frac{1}{8000}x = 0.03$$
$$x = 240m$$
$$(160 + 30\ station) + (2 + 40\ station) = 162 + 70\ station$$

Q2.

(a) $x_1 + x_2 + x_3 = 15$ (1)
$x_1 + x_4 = 15$
$x_4 = 15 - x_1$ (2)
$t_1 = t_2 + t_4$
$28 + 2x_1 = 12 + 2x_2 + 8 + x_4$
$2x_1 - 2x_2 - (15 - x_1) = -8$
$3x_1 - 2x_2 = 7$ (3)
$t_1 = t_3 + t_4$
$28 + 2x_1 = 10 + x_3 + 8 + x_4$
$2x_1 - x_3 - (15 - x_1) = -10$
$3x_1 - x_3 = 5$ (4)
$$x_1 = \frac{47}{11}, x_2 = \frac{32}{11}, x_3 = \frac{86}{11}, x_4 = \frac{118}{11}$$

(b) $x_1 + x_2 + x_3 = 5$ (1)
$x_1 + x_4 = 15$
$x_4 = 15 - x_1$ (2)
$t_1 = t_2 + t_4$
$28 + 2x_1 = 12 + 2x_2 + 8 + x_4$
$2x_1 - 2x_2 - (15 - x_1) = -8$
$3x_1 - 2x_2 = 7$ (3)
$t_1 = t_3 + t_4$
$28 + 2x_1 = 10 + x_3 + 8 + x_4$
$2x_1 - x_3 - (15 - x_1) = -10$
$3x_1 - x_3 = 5$ (4)
$$x_1 = \frac{27}{11}, x_2 = \frac{2}{11}, x_3 = \frac{26}{11}, x_4 = \frac{138}{11}$$

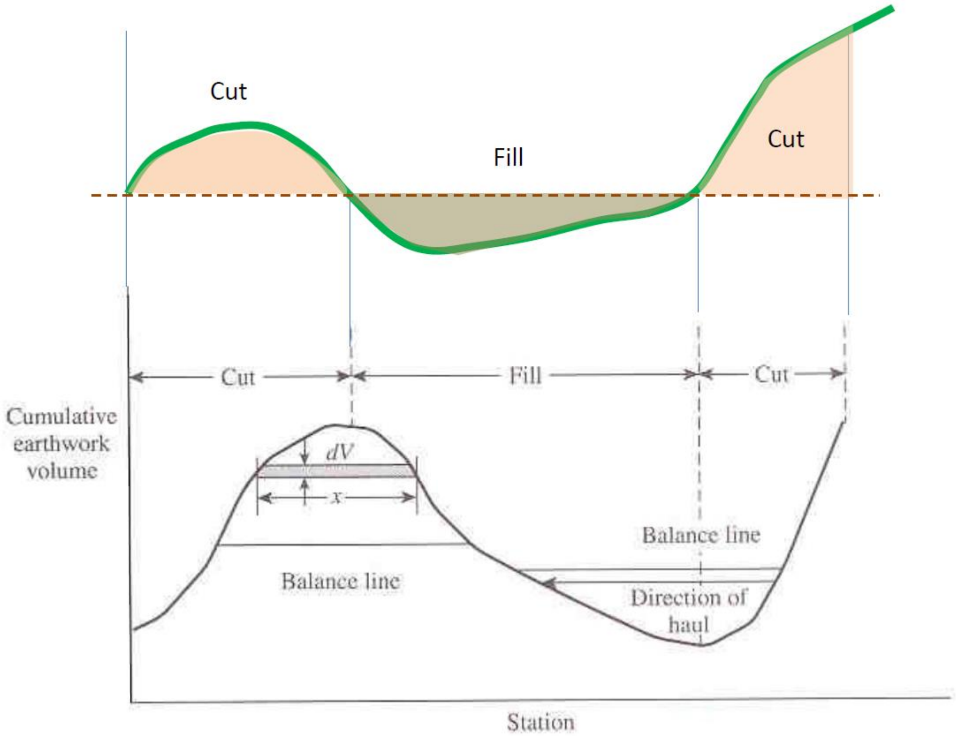
(c) $x_1 + x_2 + x_3 = 15$ (1)
$x_1 + x_4 = 10$
$x_4 = 10 - x_1$ (2)
$t_1 = t_2 + t_4$
$28 + 2x_1 = 12 + 2x_2 + 8 + x_4$
$2x_1 - 2x_2 - (10 - x_1) = -8$
$3x_1 - 2x_2 = 2$ (3)
$t_1 = t_3 + t_4$

$28 + 2x_1 = 10 + x_3 + 8 + x_4$
$2x_1 - x_3 - (10 - x_1) = -10$
$3x_1 - x_3 = 0$ (4)
$x_1 = \frac{32}{11}, x_2 = \frac{37}{11}, x_3 = \frac{96}{11}, x_4 = \frac{78}{11}$

(d) $x_1 + x_2 + x_3 = 20 - 0.5t_{AC}$
$x_1 + x_2 + x_3 + 0.5(28 + 2x_1) = 20$
$2x_1 + x_2 + x_3 = 6$ (1)
$x_1 + x_4 = 20 - 0.5t_{AC}$
$t_{AC} = t_1 = t_2 + t_4 = t_3 + t_4$
$x_1 + x_4 = 20 - 0.5(28 + 2x_1)$
$x_4 = 6 - 2x_1$ (2)
$28 + 2x_1 = 12 + 2x_2 + 8 + x_4$
$2x_1 - 2x_2 - (6 - 2x_1) = -8$
$4x_1 - 2x_2 = -2$ (3)
$28 + 2x_1 = 10 + x_3 + 8 + x_4$
$2x_1 - x_3 - (6 - 2x_1) = -10$
$4x_1 - x_3 = -4$ (4)
$x_1 = \frac{1}{8}, x_2 = \frac{5}{4}, x_3 = \frac{9}{2}, x_4 = \frac{23}{4}$

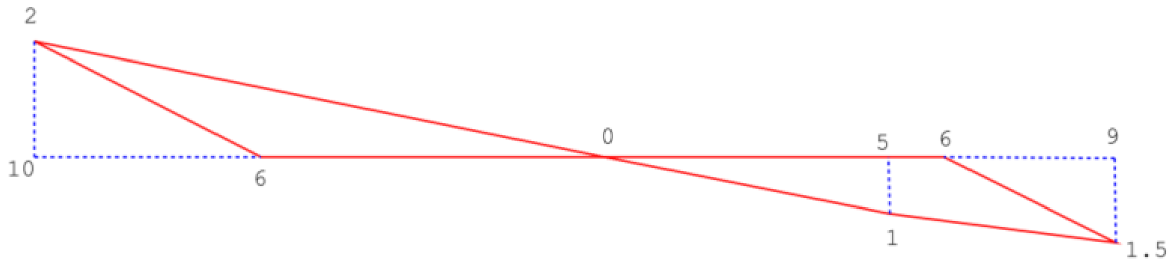
Q3.

(a) The principal function of a mass diagram that is used in earthwork application is for optimizing haul strategies and earthwork costs.



Cut treated as positive and fill as negative, with necessary corrections of shrinkage or swell. Haul is computed as area between two limits under the curve and the unit is in stn-m.

(b)

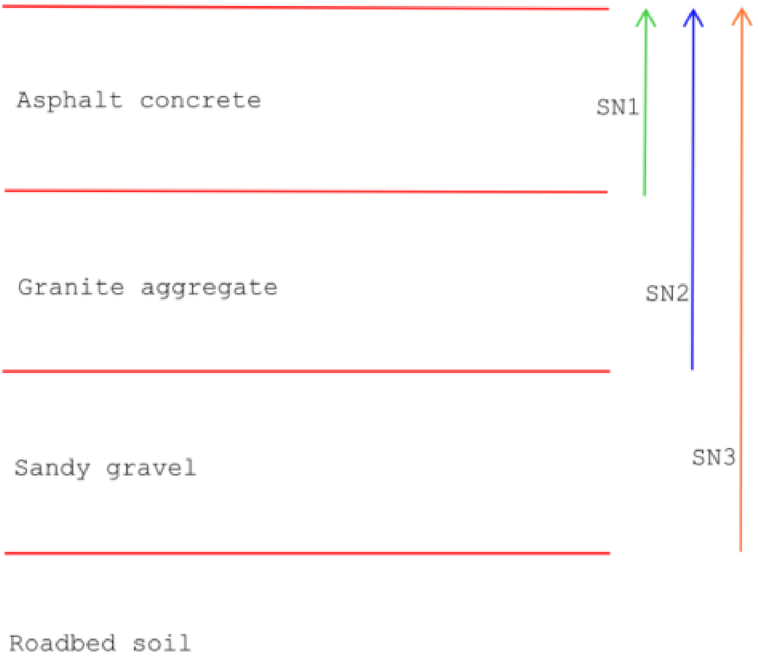


Cut: $\frac{1}{2} \times 6 \times 2 = 6m^2$

Fill: $\left(\frac{1}{2} \times 5 \times 1\right) + \left(\frac{(1+1.5)}{2} \times 4\right) - \left(\frac{1}{2} \times 3 \times 1.5\right) = 5.25m^2$

Q4.

(a)



$$SN_1 = a_1 D_1$$

$$D_1 = \frac{SN_1}{a_1} = \frac{2}{0.45} \times 25.4mm = 112.9mm$$

$$D_1^* = 120mm$$

$$SN_1^* = 0.45 \times \frac{120}{25.4} = \frac{270}{127}$$

$$SN_2 = SN_1^* + a_2 m_2 D_2$$

$$D_2 = \frac{3.3 - \frac{270}{127}}{0.2 \times 1.2} \times 25.4mm = 124.3mm$$

$$D_2^* = 130mm$$

$$SN_2^* = \frac{270}{127} + \left(0.2 \times 1.2 \times \frac{130}{25.4}\right) = \frac{426}{127}$$

$$SN_3 = SN_2^* + a_3 m_3 D_3$$

$$D_3 = \frac{4.3 - \frac{426}{127}}{0.15 \times 1.1} \times 25.4mm = 145.6mm$$

$$D_3^* = 150mm$$

(b) The 2 variables are effectiveness in handling water infiltration and higher value for good drainage material with low moisture condition.

(c) The concept of reliability is to account for chance variations in traffic or performance prediction which is a probabilistic approach. It is a pre-determined level of assurance, with application of 'z' variate from standard normal distribution. R is related to overall standard deviation which is indicator of uncertainty. The overall variance is the variation in traffic prediction, variation in material or construction and variation in pavement performance.

Q5.

(a) The type of stresses in the JRCP concrete slabs under in-service field conditions are curling stress from temperature differential, curling stress from moisture differences, wheel load stresses, temperature-friction stress, and moisture-friction stress.

Curling stress from temperature differential – the top of slab is at higher temperature during daytime thus there is tendency of slab to hog. Likewise, for nighttime, the top of slab tends to dish as it is at lower temperature. The weight of slab and load-transfer device or friction at joints impose restraints against curling thus it forms curling stress.

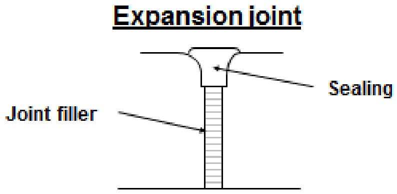
Curling stress from moisture differences – the concrete swells when moisture content increases. The bottom of slab is usually damper thus the edges or corners will curl upwards. Curling stress is form from restraints at joints and weight of slab. It is usually ignored in calculations for conservative approach.

Wheel load stresses – It is dependent upon position of application. The load can be at the edge, corner, or interior of the slab. Corner loading is the most critical for deflection. The magnitude dependent upon stiffness of supporting layer, flexural stiffness of slab.

Temperature-friction stress – It is the expansion or contraction of slab as temperature changes. The slab will blow-up if insufficient gap to expand and it will crack of insufficient joints during contraction. Compression stress is formed from friction between slab and layer below during slab expansion and tensile stress is formed during contraction.

Moisture-friction stress – it refers to the expansion or contraction of slab when moisture content changes. It works in the opposite direction with temperature. Frictional stresses is important for long slab and curling stresses is important for shorter slab.

(b)



Expansion joints are transverse joints for expansion. The full depth gap is around 20-25mm wide. It has non-protruding and compressible filler, capped by bituminous or rubberized sealant. It can also serves as contraction, construction and warping joints.