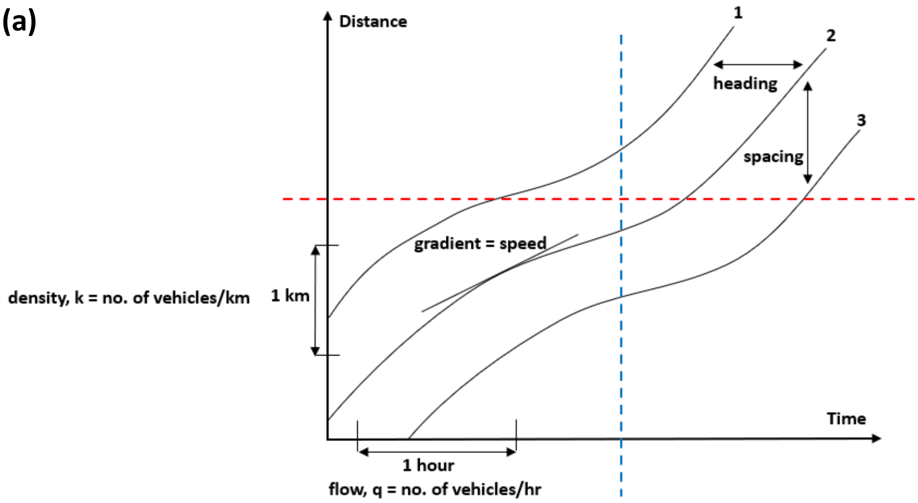
CV3014 TRANSPORTATION ENGINEERING AY21/22 SOLUTION

DONE BY: KEALEON LEE

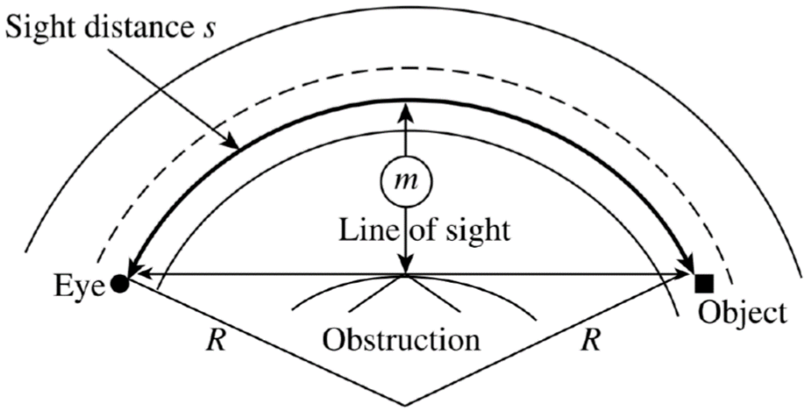
Q1.

(a)



Space mean speed (SMS) can also be obtained by taking the average of the vehicle graph gradients (which represents speed of a vehicle) at a specific time, i.e., at points intersecting the blue dashed line. Contrarily, time mean speed (TMS) can also be obtained by taking the average of the vehicle graph gradients (which represents speed of a vehicle) at a specific distance, i.e., at points intersecting the red dashed line.

(b)



(c) Superelevation is the difference in height between the two sides of the road is known as the superelevation. It is used in horizontal alignment problems and is important so that commuters can safely and comfortably manoeuvre the curve at safe speeds.

(d) $q = vk \rightarrow q = 120v - 2v^2$

$\frac{dq}{dv} = 120 - 4v, when \frac{dq}{dv} = 0, v_m = 30$

$q_{max} = (120)(30) - 2(30)^2 = 1800 veh/hr\ (capacity)$

$when\ q_{max} = 0, v = 60 m/s\ (free - flow\ speed)\ or\ 0\ m/s\ (rej)$

$k_m = \frac{q_{max}}{v_m} = \frac{1800}{30} = 60 veh/km\ (density\ at\ capacity)$

Q2.

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

$y' = g_1 + rx$

$at\ highest\ point, y' = 0,$

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

$6 + \frac{-3-6}{2}\left(\frac{L}{2} + 70\right) = 0 \rightarrow L = 420m$

(b) $at\ y_0,$

$\frac{48 - y_0}{420/2} = \frac{6}{100} \rightarrow y_0 = 35.4$

$y = 35.4 + 0.06x + \frac{1}{2}\frac{-0.03-0.06}{420}x^2 = 35.4 + 0.06x - 1.0714 \times 10^{-4} x^2$

$at\ x = \frac{L}{2} + 70 = 280\ m, y = 43.8m$

$clearance = 43.8 - 37.5 = 6.3m$

Q3.

(a) $x_1 + x_2 = 12 - ①$

$x_2 = x_3 - ②$

$t_1 = t_2 + t_3 \rightarrow 20 + x_1 = 10 + x_2 + 6 + 2x_3$

$x_1 - x_2 - 2x_3 = -4 - ③$

Solving ①, ②, and ③ gives:

$x_1 = 8, x_2 = 4, x_3 = 4$

(b) $x_3 = x_2 + 2 \rightarrow x_2 - x_3 = -2 - ①$

$x_1 + x_2 = 12 - ②$

$t_1 = t_2 + t_3 \rightarrow 20 + x_1 = 10 + x_2 + 6 + 2x_3$

$x_1 - x_2 - 2x_3 = -4 - ③$

Solving ①, ②, and ③ gives:

$x_1 = 9, x_2 = 3, x_3 = 5$

(c) $D = 20 - t_3 = 14 - 2x_3$

$x_3 = x_2 + D \rightarrow x_3 = x_2 + 14 - 2x_3$

$x_2 - 3x_3 = -14 - ①$

$x_1 + x_2 = 12 - ②$

$t_1 = t_2 + t_3 \rightarrow 20 + x_1 = 10 + x_2 + 6 + 2x_3$

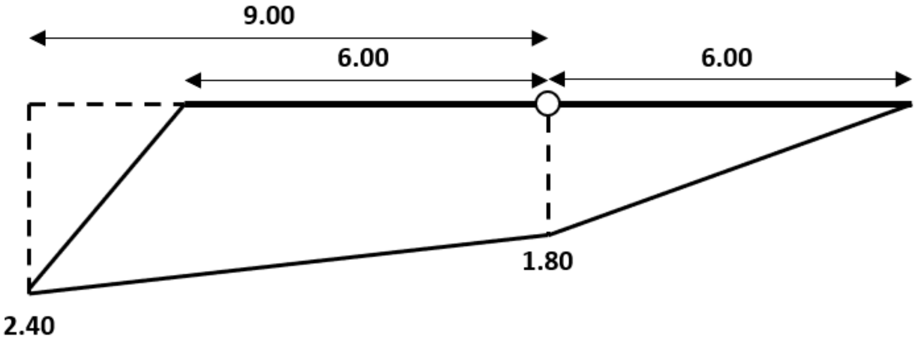
$x_1 - x_2 - 2x_3 = -4 - ③$

Solving ①, ②, and ③ gives:

$x_1 = 9.5, x_2 = 2.5, x_3 = 5.5$

Q4.

(a)



(b)

Station	Cross Sectional Areas (m^2)		Volume (m^3)	
	Fill	Cut	Fill	Cut
25+10	$\left(\frac{12}{4}\right)(0+2.40) + \left(\frac{1.80}{2}\right)(6.00 + 9.00) = 20.7$	---	$\left(\frac{20.7+4.8}{2}\right)(30) = 382.5$	$(\frac{5}{3})(30) = 50$
25+40	$\left(\frac{12}{4}\right)(0+1.60) = 4.8$	$\left(\frac{10}{4}\right)(0+2.00) = 5$		
25+80	---	$\left(\frac{10}{4}\right)(0+3.00) + \left(\frac{2.20}{2}\right)(5.00 + 9.00) = 22.9$	$\left(\frac{4.8}{3}\right)(40) = 64$	$\left(\frac{22.9+5}{2}\right)(40) = 558$
Sum of material volume (m^3)			446.5	608

Q5.

(a) Functions of sub-base layer in flexible pavement:

1. Sub-base helps to distribute the load into wider area so that the stress induced at the sub-grade is not overloaded, thus failure does not occur.

2. The subbase layer of a flexible pavement will usually be a higher quality, well-graded aggregate. The well gradation helps to provide a drainage function which is especially necessary in colder climates where frost heave may occur.

Functions of sub-base layer in rigid pavement:

1. Used as a remedy when the sub-grade is unsatisfactory.

2. Controls sub-grade volume change as the sub-base holds down sub-grade and absorbs some of the expansion.

3. Improves drainage of water from surface (cracks/joints) or variable water table.

4. Controls mud pumping which is dependent on 3 factors which are: heavy load, water accumulation, unsuitable soils.

5. Controls frost damage due to frost heave, where frost softens sub-grade.

6. Forms a working surface.

(b) Temperature variation affects the performance of rigid pavements in two ways:

1. Curling stress

In the daytime, the top of the slab would be hotter, as such the PCC slab would tend to hog. Due to restraint on curling by the self-weight of the slab, load transfer devices and friction at joints, there would be tensile stress at the bottom of the slab and compressive stress at the top of the slab.

Whereas in the nighttime, the top of the slab would be cooler, as such the PCC slab would tend to dish. Due to restraint on curling by the self-weight of the slab, load transfer devices and friction at joints, there would be tensile stress at the top of the slab and compressive stress at the bottom of the slab.

2. Temperature-friction stress

The slabs would expand or contract depending on the temperature. Due to friction between the slab and the layer below, there would be compressive stress when slab expands due to high temperatures. On the contrary, there would be tensile stress when slab contracts due to low temperatures.

Suitable measures to tackle both of these issues are to ensure sufficient gap between the slabs, and sufficient joints for slab contraction purposes. The usage of dowelled joints is the most critical as it allows horizontal movement, yet at the same time, prevents vertical displacement which often happens when curling stresses are induced.

Q6.

(a) From the design data,

$SN_1 = a_1 D_1 = \frac{(0.45)(33)}{25.4} = 0.5846$

$SN_2 = a_1 D_1 + a_2 D_2 m_2 = \frac{[(0.45)(33)+(0.25)(94)(1.30)]}{25.4} = 1.7874$

$SN_3 = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3 = \frac{[(0.45)(33)+(0.25)(94)(1.30)+((0.20)(152)(1.10)]}{25.4} = 3.1039$

Applying to satisfy construction requirements,

$SN_1 = a_1 D_1 \rightarrow 0.5846 \times 25.4 = (0.45)D_1$

$D_1 = 33\ mm \rightarrow D_1^* \approx 40mm$

$SN_2 = a_1 D_1 + a_2 D_2 m_2 \rightarrow 1.7874 \times 25.4 = (0.45)(40) + (0.25)D_2(1.30)$

$D_2 = 84.3\ mm \rightarrow D_2^* \approx 90mm$

$SN_3 = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$

$3.1039 \times 25.4 = (0.45)(40) + (0.25)(90)(1.30) + (0.20)D_3(1.10)$

$D_3 = 143.6mm \rightarrow D_3^* \approx 150mm$

(b) Pros:

1. Asphalt concrete is a relatively cheap and easily obtainable material given that it is recyclable. This would mean that a full-depth asphalt concrete pavement would be inexpensive to construct.

2. It is possible that the construction time of a full-depth asphalt concrete pavement would be very low. This is because much lesser compaction work would be required for the full-depth asphalt concrete pavement due to the lack of base and sub-base layer made up of aggregate. Moreso, the setting and curing time of asphalt concrete is known to be very minimal and reduces any form of delay for commuters. A full-depth asphalt concrete pavement would possibly be viable as a form of emergency roadway opening or even be used as a method to replace sections of current roadways. (based on my interpretation)

Cons:

1. When a whole full-depth layer of asphalt concrete is cast, it is impossible to compact the entire layer. This is because no amount of achievable force would be able to overcome the frictional forces of the asphalt and aggregate particles nearing the bottom sections of the asphalt concrete layer. This would subsequently lead to high porosity of the asphalt concrete in many areas. High porosity would then allow water and contaminants to infiltrate into the deeper portions of the asphalt concrete layer. Due to asphalt cement's susceptibility to moisture, the infiltration of water would lead to moisture damage in the form of stripping and softening, where stripping is the loss of adhesion between asphalt cement and aggregate, and softening is the loss in cohesion that results in a loss of strength, stiffness, and other engineering properties. All in all, resulting in a non-durable pavement, which requires regular and/or heavy maintenance, leading to heavy expenditure.

2. Full-depth asphalt concrete pavement may be more susceptible to temperature due to its increased thickness. In hot temperatures, the asphalt concrete layer would absorb and store heat and due to its thickness, it would have trouble dissipating heat. This would cause the "softening" of asphalt and rutting resistance would decrease, leading to higher possibility of rutting to occur. On the contrary, in cold climates, water which infiltrated into the asphalt concrete would freeze and subsequently cause cracking due to expansion of water volume. These would result in bad pavement quality with low durability.

(**NOTE:** The marks weightage is relatively low for this question. Capturing the main points with one line of solid elaboration would PROBABLY suffice. They are underlined for easier perusal.

The list of solutions to this question is non-exhaustive and there will be other advantages/disadvantages not being in this list. I believe that as long as the elaboration is theoretically sound, you would not be marked down for the point that you mentioned.)

(c) The two design parameters in the AASHTO design procedures which account for the probabilistic aspects are reliability of design, R and overall standard deviation, S_0.

The reliability concept helps to account for design uncertainties. It is the probability that a pavement section designed using the process will perform satisfactorily over the traffic and environmental conditions for the design period. A value of standard normal deviate, Z_R can be obtained from different reliability levels to be used in the AASHTO method for both flexible and rigid pavements.

For overall standard deviation, S_0, accounts for variation in traffic prediction, variation in material and construction, and variation in pavement performance. S_0 is usually 0.45 for flexible pavement and 0.35 for rigid pavement. It should be noted that S_0 is closely related to the reliability concept.

---END---

NOTE:

Do reach out to me at KEAL0001@e.ntu.edu.sg if you have any queries regarding any of my submitted workings. Feel free to leave an email to ask any questions covered in the curriculum, will be glad to help!