Transportation Depth Topics

School of PE

Refresher Solutions

Code: CITER-D **Spring 2015**

PROBLEM 27

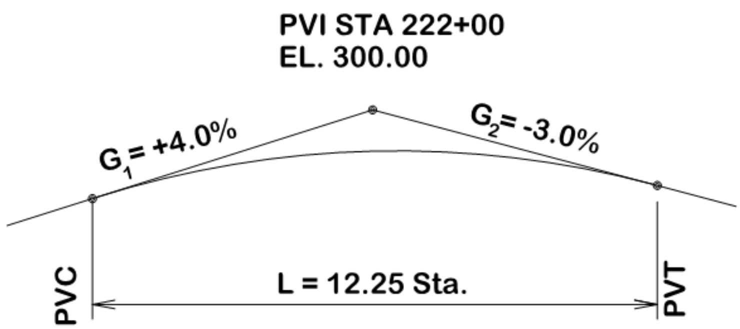
A +4.0% grade intersects a -3.0% percent grade at PVI Sta. 222+00 and Elev. 300.00 on a two-lane highway with a design speed of 45 mph. What is the turning point elevation for the curve that is designed to meet passing sight distance using K-value method?

SOLUTION 27

STEP 1: Compute the length of the curve based on Passing Sight Distance using K-value method?

Using AASHTO Table 3-35 included in this chapter in the previous pages, for V=45 mph …. K = 175;

L = K(A) = 175(7) = 1225’= 12.25 sta



STEP 2: Calculate the highpoint elevation

L=1225’

PVC Sta.= 22200 – 1225’/2 = 215+87.50

R = -7/12.25 = -0.571

$Elev_{PVC}$ = 300.00 – 12.25/2(4) = 275.50 ft

$x_{max} = -G_1/R = -4/-0.571 = \underline{7.005 \text{ sta.}}$

$Elev_{HP} = (R/2)\,(x^2_{max}) + x_{max}(G_1) + Elev_{PVC}$

$Elev_{HP} = (-0.571/2)(7.005^2) + 7.005(4) + 275.50'$

$Elev_{HP} = -14.01' + 28.02' + 275.50' = 289.51\underline{\text{ ft}}$

SOLUTION TABLE							
			Components of time gap, t_g			Total ISD (ft)	Reference
Turn	Design Vehicle	$1.47V_g$	Basic t_g	Adjustment for additional lanes crossed	Adjustment for approach grade		
1 Right	Passenger Car	88.2[	6.5 +	0 +	0.1(3.4)] =	603	AASHTO pg 664
	Single Unit Truck	88.2[	8.5 +	0 +	0.1(3.4)] =	780	
	Combination Truck	88.2[	10.5 +	0 +	0.1(3.4)] =	956	
2 Left	Passenger Car	88.2[	7.5 +	0.5(2.42) +	0.2(3.4)] =	828	AASHTO pg 660
	Single Unit Truck	88.2[	9.5 +	0.7(2.42) +	0.2(3.4)] =	1047	
	Combination Truck	88.2[	11.5 +	0.7(2.42) +	0.2(3.4)] =	1224	
3 Thru	Passenger Car	88.2[	6.5 +	0.5(2.42) +	0.1(3.4)] =	754	AASHTO pg 664
	Single Unit Truck	88.2[	8.5 +	0.7(3.42) +	0.1(3.4)] =	991	
	Combination Truck	88.2[	10.5 +	0.7(3.42) +	0.1(3.4)] =	1167	

10.2.1 Fratar Method

This is based on the following assumptions:

1. The distribution of future trips from an origin is proportional to the present trip distribution
2. The future distribution is modified by the growth factor of the zone to which these trips are attached.

This model has been used extensively in several metropolitan areas, particularly for estimating external trips coming from outside the study areas to zones located within the study area.

$$t_{ij}^f = t_{ij}^b \frac{O_i^f}{O_i^b} \frac{D_j^f}{D_j^b} \frac{\sum_{k=1}^{n} t_{ik}^b}{\sum_{k=1}^{n} D_k^f}$$

Where :

O_i^f and O_i^b = future and base year origin trips from zone i

D_j^f and D_j^b = future and base year destination trips to zone j

t_{ij}^f and t_{ij}^b = future and base year trips from zone i to zone j

PROBLEM 44

An origin zone *i* with 20 base-year trips going to *j*, *k*, and *l* numbering 4, 6, and 10, respectively. Growth rates for *i*, *j*, *k*, and *l* are 2, 3, 4, and 6 respectively in 25 years. Determine the future trips from i to *j*, *k*, and *l* in the future year.

SOLUTION 44

$t_{ij}^b = 4;\ t_{ik}^b = 6;\ t_{il}^b = 10$

$O_i^b = 20;\ O_i^f = 20 \times 2 = 40$

$D_j^b = 4;\ D_k^b = 6;\ D_l^b = 10$

$D_j^f = 4 \times 3 = 12$

$D_k^f = 6 \times 4 = 24$

$D_l^f = 10 \times 6 = 60$

$\sum D^f = 96$

$$t_{ij}^{f} = \left(4 \times \frac{40}{20} \times \frac{12}{4}\right)\left(\frac{4+6+10}{96}\right) = 24 \times \frac{20}{96} \quad = 5$$

$$t_{ik}^{f} = \left(6 \times \frac{40}{20} \times \frac{24}{6}\right)\left(\frac{4+6+10}{96}\right) = 48 \times \frac{20}{96} \quad = 10$$

$$t_{il}^{f} = \left(10 \times \frac{40}{20} \times \frac{60}{10}\right)\left(\frac{4+6+10}{96}\right) = 120 \times \frac{20}{96} \quad = 25$$

$$Total \; = 40$$

PROBLEM 45

A 6-lane (3 lanes in each direction) freeway passes through level terrain in an urban area. The freeway is constructed with 11 ft lanes and concrete barriers 3 ft from the outer pavement edges of both outer lanes. The one-direction peak hourly volume during the weekday commute is 2200 vph. Traffic includes 4% buses, 6% trucks, and 2% recreational vehicles (RVs). There is one ramp per mile on average. The peak hour factor is 0.92. The posted speed limit is 55 mph.

(a) What is the passenger car equivalent flow rate per lane?
(b) What is the free flow speed?
(c) What is the density?
(d) What is the weekday peak-hour level of service?

SOLUTION 45

(a) $$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

Where: V=2200 vph; PHF=0.92; N = 3; f_{HV} = ?; f_p = ?

Trucks and buses have the same passenger car equivalents, so the "truck" fraction is 10% (4% + 6%). The traffic includes 2% RVs. From Exhibit 11-10 of HCM, for level terrain, E_T = 1.5 , and E_R = 1.2 ;Using Eq. 11-3
The commuter population knows the route, so f_P = 1.0

$$f_{HV} = \frac{1}{1+P_T(E_T-1)+P_R(E_R-1)} = \frac{1}{1+0.10(1.5-1)+0.02(1.2-1)} = 0.9488$$

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p} = \frac{2200}{0.92 \times 3 \times 0.95 \times 1.0} = \frac{2200}{2.622} = 839 \text{ pcphpl}$$

(b)

FFS = 75.4 – f_{LW} – f_{LC} – 3.22 $TRD^{0.84}$ = 75.4 - 1.9 - 1.2 - 3.22$(1)^{0.84}$
= 69.08 mph

(c) Density

$$D = \frac{v_p}{S} = \frac{839\ veh/h}{69.08} = 12.15\ pcpmpl$$

(d) Using LOS Criteria table, 11 < 12.15 < 18;
Therefore the roadway is operating at LOS B

SOLUTION 50

$W_E = 14.0 - 1.5 - 2.0 = 10.50$ ft

$$v_p = \frac{v_{15}}{15 * W_E} = \frac{1250}{15 * 10.5} = 7.9\ p/min/ft$$

LOS for Average Flow (using Exhibit 23-1) = C

LOS for Platoon Adjusted Flow (using Exhibit 23-2) = D

11.4 Signalized Intersections

Cycle length – the time required for one complete sequence of all signal indications

Phase – the right-of-way (green), change (yellow), and clearance (all red) intervals in a cycle that are assigned to an independent traffic movement or combination of movements

Green interval – the right-of-way interval during which the signal indication is green

Yellow Change interval – the first interval following the green interval or which the signal indication is yellow

Clearance interval – an interval that follows a yellow change interval and precedes the next conflicting green interval

11.4.1 Change Interval

Reference – Any Traffic Engineering Book

- Also known as "Yellow Interval"

$$y = t + \frac{v}{2a + 2Gg}$$

Where:
y = length of yellow interval (sec)
t = driver perception/reaction time (1.0 sec generally used)
v = velocity of approaching vehicle (fps)
a = deceleration rate (10 fps^2 generally used)

PROBLEM 51
Estimate change intervals for grades -2%, 0%, and +2% for an approach speed of 30 mph.

SOLUTION 51

- For -2% grade,

$$y = 1.0 + \frac{30\ \text{miles/hour} * \frac{5280\ \text{ft/mile}}{3600\ \text{sec/hour}}}{2 * 10 + 2 * 32.2(-2/100)} = 3.4\ \text{sec}$$

- For 0% grade, y = 3.2 sec
- For +2% grade, y = 3.1 sec

11.4.3 Cycle Length, Phases, Green Interval

Reference - Chapter 18 of HCM

Using Equation 18-17 (modified) from HCM, required Cycle Length for an intersection can be computed as follows:

$$C = \frac{L * X_c}{X_c - \sum y_i}$$

Where,

$$\sum y_i = (v/s)_1 + (v/s)_2 + (v/s)_3 + \ldots(v/s)_n$$

PROBLEM 52
The traffic volumes for a two phase signal at the intersection of High Street and Broad Street are summarized below.

Street	Flow Rate	Max Saturation Flow
High St.	500 vph	1500 vph
Broad St.	600 vph	1200 vph

Given the following facts, answer parts ‘a’ through ‘e’

- lost time/ phase: 4 sec; desired intersection v/c (X_c) = 0.90

SOLUTION 52

a.) What is the actual volume-to-saturation flow ratio for High St.?

v/s = 500/1500 = **0.33**

b.) What is the actual volume-to-saturation flow ratio for Broad St.?

v/s = 600/1200 = **0.50**

c.) What cycle length, C, should be used?

Total Lost time: L = 2 x 4 = 8 sec/cycle.

$$C = \frac{L \times X_c}{[X_c - (v/s)_1 - (v/s)_2]} = \frac{8 \times 0.90}{[0.90 - 0.33 - 0.50]} = 103\ sec$$

d.) What is the optimum (effective) green time that will maintain the optimum v/c ratio on each street?

$$g_{High\ St} = \left(\frac{v}{s}\right)\left(\frac{C}{X_i}\right) = 0.33\left(\frac{103}{0.9}\right) = 38\ sec$$

$$g_{Broad\ St} = \left(\frac{v}{s}\right)\left(\frac{C}{X_i}\right) = 0.50\left(\frac{103}{0.9}\right) = 57\ sec$$

e.) What is the phase length for each street?

Phase length = Effective Green Time of the Phase + Lost Time of the Phase

Phase length for High Street = 38 sec + 4 sec = 42 sec
Phase length for Broad Street = 57 sec + 4 sec = 61 sec

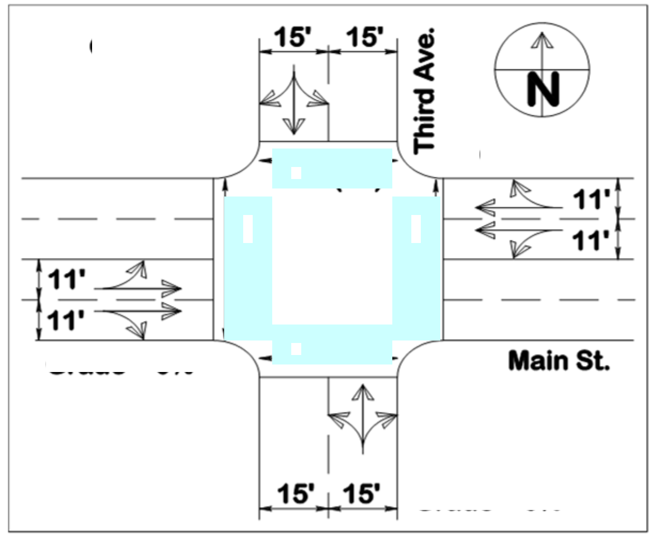
Clue: When we add all phase lengths, it should equal to Cycle length. In this example, 42 sec plus 61 sec = 103 sec which is the Cycle Length.

f.) What is the minimum cycle length, C, should be used? (Use $X_c = 1.00$)

$$C = \frac{L \times X_c}{[X_c - (v/s)_1 - (v/s)_2]} = \frac{8 \times 1.0}{[1.0 - 0.33 - 0.50]} = 47\ sec$$

PROBLEM 54

The intersection of Third Avenue (NB/SB) and Main Street (EB/WB) is located in the Central Business District (CBD) of a small urban area. Intersection geometry is shown. What is the minimum green time required for pedestrian crossings?



The Facts:

- Cycle Length = 60 sec
- Two phase signal
- Crosswalk width = 10'; Pedestrian Volume = 120 p/h at each approach

SOLUTION 54

Minimum effective green time required for pedestrians can be calculated using the following equation (Equation 18-66 of HCM): $3.2 + \frac{L}{S_p} + 0.27 N_{ped}$

Using Eqn 18-54,

Pedestrians per cycle (N_{ped}) = $\frac{v}{3600} \times C = \frac{120}{3600} \times 60$ = 2 ped/cycle

- to cross Third Ave. = $3.2 + \frac{L}{S_p} + 0.27 N_{ped}$

  $= 3.2 + \frac{30}{4.0} + 0.27 \times 2 \qquad = 11.24\ sec$

- to cross Main Street = $3.2 + \frac{L}{S_p} + 0.27 N_{ped}$

  $= 3.2 + \frac{44}{4.0} + 0.27 \times 2 \ = 14.74\ sec$

PROBLEM 55

Given the following information by approach, what is the intersection LOS?

- EB – Flow rate 800 veh/h; Approach Control Delay 59.4 sec/veh
- WB – Flow rate 833 veh/h; Approach Control Delay 31 sec/veh
- NB – Flow rate 466 veh/h; Approach Control Delay 14.4 sec/veh
- SB – Flow rate 667 veh/h; Approach Control Delay 21.9 sec/veh

SOLUTION 55

Intersection Delay as per equation 18-48 of HCM ,

$$d_I = \frac{\sum d_A v_A}{\sum v_A} = \frac{59.4 \times 800 + 31 \times 833 + 14.4 \times 466 + 21.9 \times 667}{800 + 833 + 466 + 667}$$

$$= 34.2\ sec/veh$$

From Exhibit 18-4 of HCM, LOS = C

PROBLEM 56

Consider a one-way arterial as shown in the following figure with the indicated spacing between four signals. Assuming there are no vehicles queued at the signals, determine the offsets between the signals if the desired platoon speed is 50 fps and cycle length 60 seconds.

SOLUTION 56

Signal (Downstream)	Relative to Signal (Upstream)	Ideal Offset
2	1	1000/50 = 20 sec
3	2	2000/50 = 40 sec
4	3	1500/50 = 30 sec

PROBLEM 57

Consider a one-way arterial as shown in the following figure with the indicated spacing between five signals. Assuming there are no vehicles queued at the signals, at what speed a vehicle should be travelling to avoid stopping at signal 2 after leaving signal 3. Given the following parameters:

Offset between Signals 3 and 2 = 60 sec
Cycle length = 90 sec

SOLUTION 57

Desired speed = Spacing/Offset = 1800 ft/ 60 sec = 30 fps

SOLUTION 60

Minimum Vehicle Warrant Criteria		
Major Street		Minor Street
• At least 500 vph • Both directions Combined • 8 of the hours in the day	And	• At least 150 vph • Either direction • 8 of the hours in day
o Same 8 hours for major and minor street		

Major Street Volumes									
Hour Begins	**EB**	**WB**	**Total**		**Hour Begins**	**EB**	**WB**	**Total**	
6: a.m	390	100	490		12:pm	500	500	1000	
7: a.m	400	90	490		1:pm	345	400	745	
8: a.m	600	400	1000		2:pm	300	350	650	
9: a.m	500	350	850		3:pm	350	600	950	
10: a.m	400	400	800		4:pm	400	700	1100	
11: a.m	450	500	950		5:pm	300	600	900	
The major street meets the criteria during 10 hours; 10>8 , therefore the major street meets the signal warrant criteria.									

Minor Street Volumes							
Hour Begins	**NB**	**SB**		**Hour Begins**	**NB**	**SB**	
6: a.m	35	60		12:pm	175	150	◄
7: a.m	100	170	◄	1:pm	125	160	◄
8: a.m	100	190	◄	2:pm	80	140	
9: a.m	80	90		3:pm	135	105	
10: a.m	90	110		4:pm	200	175	◄
11: a.m	80	120		5:pm	180	195	◄
The minor road has 150 vph in only 6 hours, 6 <8, Therefore it does not meet the minor road criteria, and a signal is **NOT warranted** at this intersection (based on traffic data)							

Hours met for both Major and Minor Streets – 5 hours (8 am; 12 pm, 1 pm, 4 pm, and 5 pm)