Transportation Depth Topics

School of PE

Workshop Solutions
Set 1

Code: CITES-D **Spring** **2015**

PROBLEM 1

A local survey crew measures a distance of 2,500 ft for a new road construction. The beginning point for the road is located at station 5+00. What is the station of the end point of the road?

A) 30.00 Sta B) Sta 3+00 C) 3.00 Sta D) Sta 30+00

SOLUTION 1

End point station = (Sta 5+00) + 2,500' = 500' + 2,500' = 3,000' = Sta 30+00

Answer D

PROBLEM 2

A vehicle is traveling at 60 mph on a level roadway when the driver notices traffic stopped in its path. If the driver's perception reaction time is 2.5 seconds, approximately how much distance does the driver take to perceive, decide, react, and stop the vehicle at a deceleration rate of 11.2 ft/sec^2 after noticing the stopped traffic?

A) 220 ft B) 345 ft C) 570 ft D) 645 ft

SOLUTION 2

v = 60 mph; t_p = 2.5 sec; a = 11.2 ft/sec^2; G = 0

$$S = 1.47 \times 2.5 \times 60 + \frac{60^2}{30\left(\frac{11.2}{32.2} + 0\right)} = 566 \text{ ft}$$

(OR) From CERM Table 79.2, SSD=570ft

Answer C

PROBLEM 3

Two vehicles are traveling in the same direction at different speeds on a two-lane rural highway. The lead vehicle is traveling at 40 mph speed. The following is traveling at 50 mph and intends to overtake and pass the lead vehicle. What is the approximate passing sight distance required in this situation.

A) 600 ft B) 700 ft C) 800 ft D) 900 ft

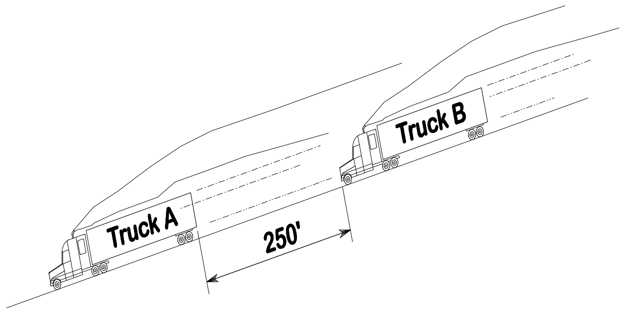
SOLUTION 3

See Table 3-4 in AASHTO GB, Use the row that has 38 mph for passed vehicle and 50 mph for passing vehicle. Then, PSD = 800 ft

Answer C

PROBLEM 4

Two semitrailers are traveling down a 5.5% grade at 40 mph on a two lane highway in the same lane. Truck A has new tires. Truck B has worn tires. The roadway is paved with Portland cement concrete.



Driver A suddenly slams on the brakes to make a panic stop. Assume it takes Driver B 1.5 seconds to react to Driver A.

Friction factors for New Tires = 0.76; Friction factors for Worn Tires = 0.33

(a) What is the new distance between Trucks A & B?

(b) Repeat the problem assuming Truck A has worn tires and Truck B has new tires.

(c) Repeat the original problem assuming the trucks are going <u>up</u> the 5.5% grade, Truck B following Truck A.

(d) Repeat case (b) with both trucks heading up the 5.5% grade.

SOLUTION 4

Case	Truck A	Truck B	New Distance
(a)	$s_{bA} = 1.47 t_p V_{mph} + \frac{V_{mph}^2}{30(f+G)} \Rightarrow$ *CERM eqn.*79.43(*b*) $s_{bA} = 1.47 \times 0 \times 40 + \frac{40^2}{30(0.76\text{-}0.055)} = 75.65'$ $s_{bA} \sim 76'$	$s_{bB} = 1.47 t_p V_{mph} + \frac{V_{mph}^2}{30(f+G)}$; $s_{bB} = 1.47 \times 1.50 \times 40 + \frac{40^2}{30(0.33\text{-}0.055)}$ $s_{bB} = 88.2' + 193.94' = 282.14' \sim 283'$	76'+250'-283'=43'
(b)	$S_{bA} = \frac{40^2}{30(0.33 - 0.055)} = 193.94' \sim 194'$	$S_{bB} = 88.2' + \frac{40^2}{30(0.76 - 0.055)} = 163.87' \sim 164'$	194'+250'-164'=280'
(c)	$S_{bA} = \frac{40^2}{30(0.76+0.055)} = 65.44' \sim 66'$	$S_{bB} = 88.2' + \frac{40^2}{30(0.33 + 0.055)} = 226.73' \sim 227'$	66'+250'-227'=89'
(d)	$S_{bA} = \frac{40^2}{30(0.33 + 0.055)} = 138.53' \sim 139'$	$S_{bB} = 88.2' + \frac{40^2}{30(0.76 + 0.055)} = 153.64' \sim 154'$	139'+250'-154'=235'

PROBLEM 5

For a circular curve, what is its degree of curve for the following:

i) A Roadway curve with 800 feet radius

A) $7^0 9'43''$ B) $8^0 51'18''$ C) $8^0 55'55''$ D) $7^0 51'18''$

ii) A Railroad curve with 800 feet radius

A) $6^0 50'55''$ B) $7^0 10'00''$ C) $8^0 55'55''$ D) $7^0 51'18''$

SOLUTION 5

i) For Roadway Curve: $D_a = \dfrac{5729.578'}{800 \text{ ft}} = 7^{\circ}9'43.1''$ (Answer A)

ii) For Railroad Curve: $D_c = 2(\sin^{-1})\left(\dfrac{50}{800 \text{ ft}}\right) = 7^{\circ}9'59.92''$

$= 7^{\circ}10'00''$ (Answer B)

PROBLEM 6

A running race track consists of two semicircles and two tangents, and is exactly five miles long as measured along its centerline of the perimeter. The two semicircular curves constitute exactly one-half its totally length.

i) What is the length of each curve?

A) 26,400 ft B) 13,200 ft C) 6,600 ft D) 3,300 ft

ii) What is the radius of each curve?

A) 4,000 ft B) 3,204 ft C) 1,208 ft D) 2,101 ft

iii) What is the degree of curvature of each curve?

A) $2^0 43'37''$ B) $2^0 20'27''$ C) $3^0 43'42''$ D) $3^0 20'27''$

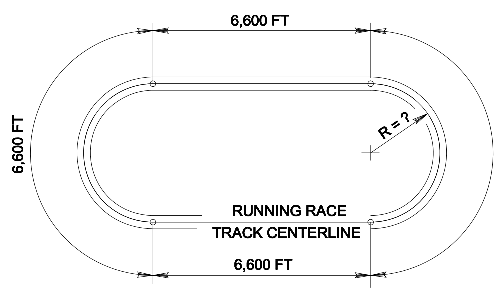
SOLUTION 6

i) Length

$5 \text{ miles } \times 5{,}280 \text{ ft/mi} = 26{,}400 \text{ ft}$

$L = \dfrac{1}{2}\left(\dfrac{26{,}400}{2}\right) = 6{,}600 \text{ ft}$ (Answer C)

5 MILE RUNNING RACE TRACK



RUNNING RACE TRACK CENTERLINE

ii) Radius

$\text{Circumference } = 2\pi R = \dfrac{1}{2} \times 26{,}400 \text{ ft}$

$= 13{,}200 \text{ ft}$

$$R = \frac{13{,}200}{2\pi} = 2{,}101 \text{ ft} \qquad \text{(Answer D)}$$

iii) Degree of Curve

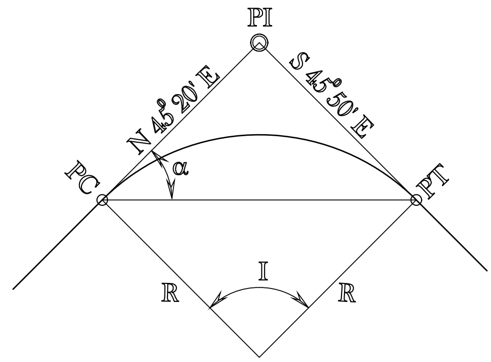
$$D_a = \frac{5{,}729.578}{2{,}101} = 2^{\circ}43'37'' \qquad \text{(Answer A)}$$

PROBLEM 7

Determine angle ‘α’ for the following circular curve:

A) $44^{0}40'$ B) 44’25” C) $88^{0}50'$ D) $44^{0}25'$

SOLUTION 7



$$\alpha = \frac{I}{2}$$

$$\text{Where } I = 180^{\circ} - 45^{\circ}20' - 45^{\circ}50' = 88^{\circ}50'$$

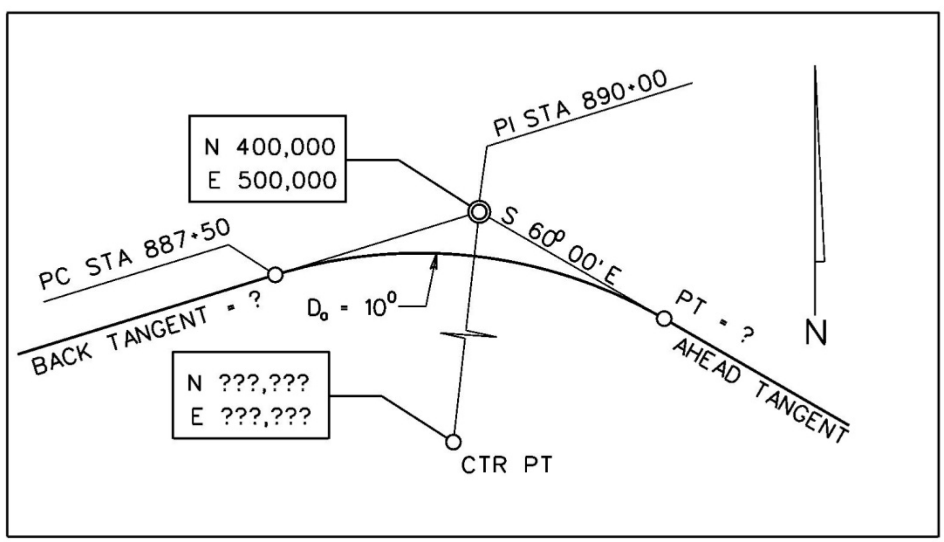
$$\alpha = \frac{88^{\circ}50'}{2} = 44^{\circ}25'$$

Answer D

PROBLEM 8

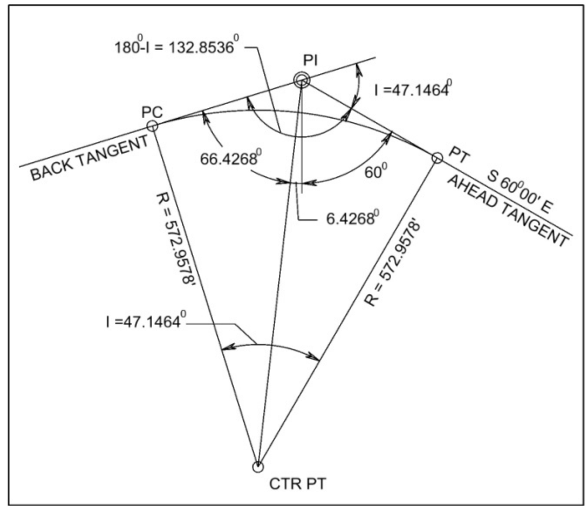
A horizontal curve is shown in the figure below. Using the information provided, determine the following:

i) the back tangent bearing
ii) the PT Station
iii) PT Coordinate
iv) the coordinates of the Center Point.



SOLUTION 8

Basic Approach –



- Draw a rough sketch of the curve, paying careful attention to the Ahead Tangent Bearing. It should resemble CERM Figure 79.1
- Use CERM Equation 79.1 to solve for R.
- Find the tangent length, T.
- Use CERM Equation 79.4 to solve for I.
- Use CERM Equation 79.3 to solve for L.
- Determine the bearing of the back tangent
- Determine the PT Station
- Use the above values and trigonometry to find the coordinates of the PT, Center Point.
- Use CERM Equation 79.5 to solve for E.
- Check the Center Point coordinates using trigonometry and working from the PI.

$R = 5729.578 / D_a$	=	$5729.578 / 10^0$	= 572.9578 ft.
T = PI Sta. – PC Sta.	=	89000.00 – 88750.00	= 250.00 ft.
$I = 2 \tan^{-1}(T/R)$	=	$2 \tan^{-1}(250.00/572.9578)$	= 47.1464^0
$L = 2\pi RI/360^0$	=	$2\pi 572.9578(47.1464^0)/360^0$	= 471.464 ft

i) Back Tangent Bearing – see sketch

$180^0 - 47.1464^0 - 60^0\ 00' = 72.8535^0 =$

N 72.8535⁰ E

ii) PT Station = PC Station + L =

Sta. 887+50.00 + 471.464 =

PT Sta. 892+21.464

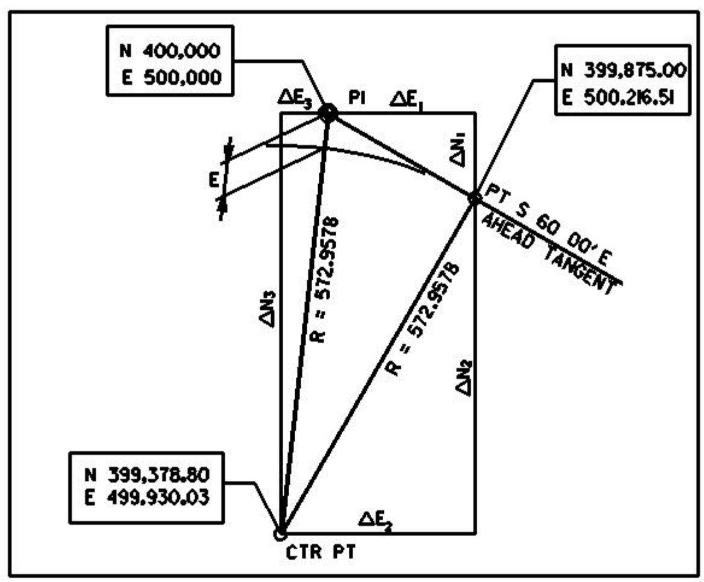
iii) **PT Coordinates** – see sketch

Departure = 250 sin 60^0 = 216.51ft

E_{PT} = 500,000 + 216.51 = 500,216.51

Latitude = - 250 cos 60^0 = -125.00 ft

N_{PT} = 400,000 - 125 = 399,875.00



iv) **Center Point Coordinates** – see sketch

Departure = - 572.9578 sin 30^0 = -286.479 ft
E_{CC} = 500,216.50635 - 286.479 = **<u>499,930.0274</u>**

Latitude = - 572.9578 cos 30^0 = -496.1960 ft
N_{CC} = 399,875.0000 - 496.1960 = **<u>399,378.804</u>**

PROBLEM 9

A four-lane undivided highway has a design speed of 40 mph. The lanes are 12 ft wide. The centerline Degree of Curvature, D is 10^o 45' Determine the required clearance (or in other words HSO) from the center of the curve's inside lane (or in other words center line of the lane with the shortest radius) based on Stopping Sight Distance criteria.

A) 22.41 ft B) 21.67 ft C) 305 ft D) 533 ft

SOLUTION 9

From CERM Table 79.2, for V = 40 mph, S = 305 ft.

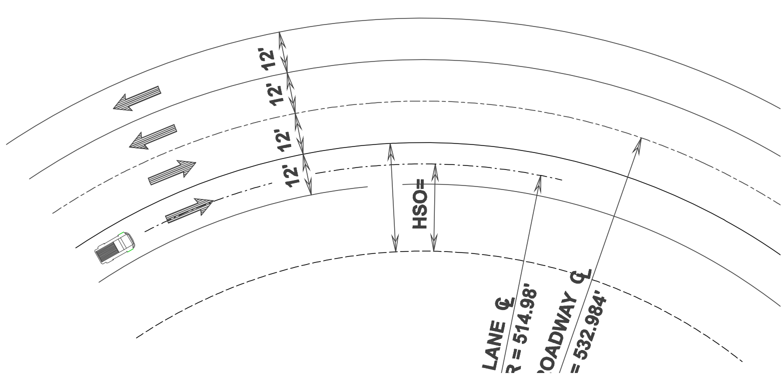
D = 10^o 45' = 10.75 ^{o} $R = \frac{5729.578'}{10.75^0} = 532.98$ ft

The centerline of the inside lane is offset 18 ft (12 ft + 6 ft) from the roadway centerline. Therefore, $R_{\text{lane centerline}}$ = 532.98 ft – 18 ft = 514.98 ft

Using CERM equation 79.45,

$$HSO = R\left(1 - \cos\left(\frac{28.65S}{R}\right)\right) = 514.98 \times \left(1 - \cos\left(\frac{28.65 \times 305}{514.98}\right)\right) = 22.41 \text{ ft}$$

Answer A



PROBLEM 10

You are travelling on a two-lane highway in eastbound direction that curves to the right. The following curve data describes the centerline: $D_a = 9^o30'$; PI Sta. 16+00. The lanes are 12-feet wide and a continuous hedge of 8-foot high trees is located along the right side of the highway in your travel direction, exactly 29.32 ft from the highway centerline. Based on this data, what should be the maximum safe design speed of this highway?

SOLUTION 10

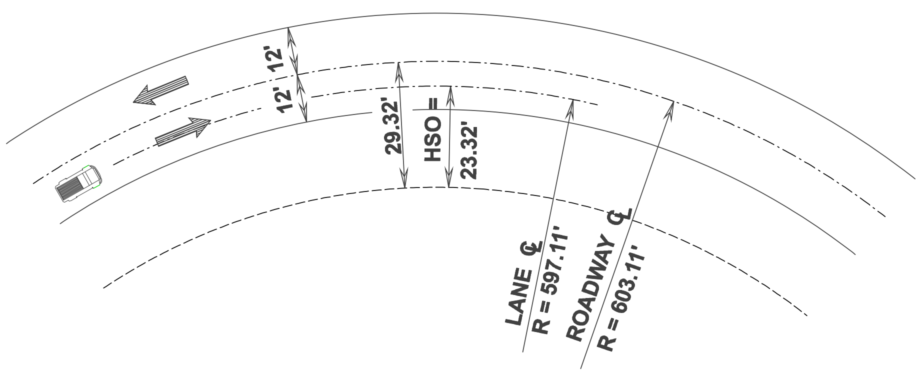
Use the following solution procedure:

- Convert $D_a = 9^o30'$ to R = 5729.578 / 9.5 = 603.11' (radius of roadway centerline).
- Determine the radius of the centerline of the inside lane (603.11' – 6' = 597.11')
- Find the actual HSO distance: 29.32'- 6' = 23.32'
- Plug the above values of R and HSO values into CERM Eq. 79-44 and solve for S.

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

$$S = \frac{597.11}{28.65}\left[cos^{-1}\left(\frac{597.11 - 23.32}{597.11}\right)\right]$$

- Your calculation should result in S = 335'.
- Comparing this S value to CERM Table 79-2, 335' falls between 40 mph and 45 mph. Take the lower of the two speeds which is 40 mph



PROBLEM 11

A rural highway curve has a radius of 150 m (500 ft.) and a superelevation of six percent. If the posted speed limit is 55 mph, what is the MOST appropriate advisory speed for this curve?

A) 50 mph B) 45 mph C) 40 mph D) 35 mph

SOLUTION 11

Refer to Table 3-7 in the AASHTO Green Book:

For given e = 6%, 500 feet radius falls between 485 with associated speed of 40 mph and 643 ft with the associated speed of 45 mph. Take the lower of the two speeds which is 40 mph.

Answer C

PROBLEM 12

A two lane highway curves to the right. The lanes are each 12-ft wide. The following information is provided:

Design Speed	55 mph
Normal cross slope	2.0%
Superelevation	6.2%
PC Station	Sta. 657+50.00
PT Station	Sta. 668+90.00
Superelevation runoff rate	1:213

The superelevation is to be developed by rotating the pavement about the roadway centerline and using the 2/3 and 1/3 rule. Use the above information to determine:

i) Superelevation runoff

A) 76 ft B) 158 ft C) 67 ft D) 327 ft

ii) Tangent runout

A) 51 ft B) 237 ft C) 67 ft D) 327 ft

iii) The station where normal crown ends (approaching the curve)

A) Sta 655+92 B) Sta 655+94 C) Sta 657+50 D) Sta 668+90

iv) The station where superelevation runoff begins (approaching the curve)

A) Sta 655+92 B) Sta 656+45 C) Sta 657+50 D) Sta 668+90

v) The station where full superelevation ends (leaving the curve)
A) Sta 668+90 B) Sta 670+48 C) Sta 668+37 D) Sta 657+50

vi) The station where superelevation runoff ends (leaving the curve)
A) Sta 668+90 B) Sta 669+95 C) Sta 668+11 D) Sta 657+50

SOLUTION 12
See CERM Figure 79.8

i) Superelevation runoff, L = we/SRR (CERM Equation 79.41)
= 12(0.062)/(1/213) = 158.47 say **158 ft** **(Answer B)**

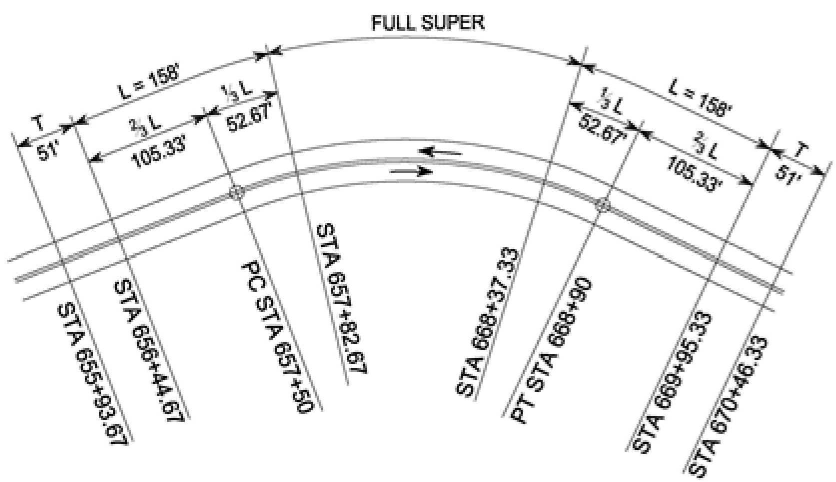
ii) Tangent runout, T_R = wp/SRR (CERM Equation 79.40)
= 12(0.02)/(1/213) = 51.12 say **51 ft** **(Answer A)**

iii) The station where normal crown ends (approaching the curve)
PC Sta. – 2/3L - T_R = 657+50.00 – 2/3(158) – 51 = **Sta 655+94** **(Answer B)**

iv) The station where superelevation runoff begins (approaching the curve)
PC Sta. – 2/3L = 657+50.00 – 2/3(158) = **Sta 656+45** **(Answer B)**

v) The station where full superelevation ends (leaving the curve)
PT Sta. – 1/3L = 668+90.00 – 1/3(158) = **Sta 668+37** **(Answer C)**

vi) The station where superelevation runoff ends (leaving the curve)
PT Sta. + 2/3L = 668+90.00 + 2/3(158) = **Sta 669+95** **(Answer B)**



PROBLEM 13

A new rural highway is to be designed with a design speed of 70 mph and a max rate of superelevation, e_{max} = 0.08 ft/ft. The highway will have a curve of degree of curvature 3^0. A design criterion requires that this curve be spiraled.

i) What is the length of spiral curve given the rate of increase of lateral acceleration is 2 ft/sec^3?

A) 1910 ft B) 5729 ft C) 179 ft D) 283 ft

ii) What is the rate of change in degree of curvature (in degrees per station) along the spiral?

A) 3^0 B) 2.87^0 C) 1.50^0 D) 1.06^0

SOLUTION 13

i)

$$L_s = \text{Length of Spiral Curve} = \frac{3.15 v^3_{mph}}{R_{ft} C_{ft/sec^3}} \text{ (CERM Eqn 79.62b)}$$

$$R = \frac{5729.578}{3^\circ} = 1909.86 \text{ ft}$$

$$L_s = \frac{3.15 \times 70^3}{1910 \times 2} = 282.84 \text{ ft}$$

L_s = 282.84 ft = 2.8284 stations **(Answer D)**

ii)

The rate of change of curvature = D_C / L_S = 3^0 / 2.8284 stations = <u>1.0607^0 / station</u>.

Answer D

PROBLEM 14

The horizontal alignment of an interchange exit ramp consists of a series of three consecutive and progressively sharper circular curves that form a single compound circular curve. Proceeding in the direction of traffic, if the first curve has degree of curvature, $D_a = 2^0$, what is the <u>minimum</u> radius of the third curve?

A) 2865 ft B) 1432 ft C) 716 ft D) 358 ft

SOLUTION 14

As per AASHTO Greens Book page 3-84, for compound curves at intersections where drivers accept more rapid changes in direction and speed, the radius of the flatter arc can be as much as 100 percent greater than the radius of the sharper arc, a ratio of 2:1

$R_{(1)} = \frac{5729.578}{D_a} = \frac{5729.578}{2^\circ} = \underline{2864.79\text{ ft}}$

$R_{min(2)} = \frac{R_{(1)}}{2} = 1432.40\text{ ft};\ R_{min(3)} = \frac{R_{(2)}}{2} = 716.20\text{ ft}$

Answer C

PROBLEM 15

A +5.00 % grade intersects a -2.75% grade at Sta. 21+75, and elevation 1682.20 ft. A 400-ft vertical curve connects the two grades. Determine:

i) the turning point station

A) Sta 19+75 B) Sta 21+75 C) Sta 22+33 D) Sta 23+75

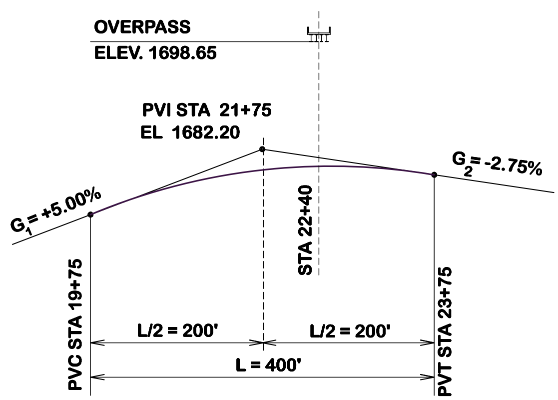
ii) the turning point elevation

A) 1698.65 ft B) 1678.65 ft C) 1682.20 ft D) 1700.00 ft

iii) clearance available at the overpass point above the vertical curve (Overpass is located at Sta 22+40 with bottom of beam elevation 1698.65 ft)

A) 1698.65 ft B) 1678.65 ft C) 20.00 ft D) 26.45 ft

SOLUTION 15



i) Using CERM equation 79.46 on page 79-12,

R = (-2.75-5.00)/4= -1.9375

$x = -G_1/R = 2.5806$ sta

Sta. = PVC Sta. + x = 1975 + 258.06 = **Sta 22+33.06**

Answer C

ii) Elevation at PVC = 1682.20 - 2(5) = 1672.20'

Elev. = $(R/2)x^2+G_1(x)$+PVC Elev. = **1678.65 ft**

Answer B

iii) First find out the elevation of vertical curve at Sta. 22+40 -> x=2.65

Elev. = $(R/2)x^2+G_1(x)$+PVC Elev. = **1678.65 ft**

Vertical clearance = 1698.65 – 1678.65 = 20 ft **(Answer C)**

PROBLEM 16

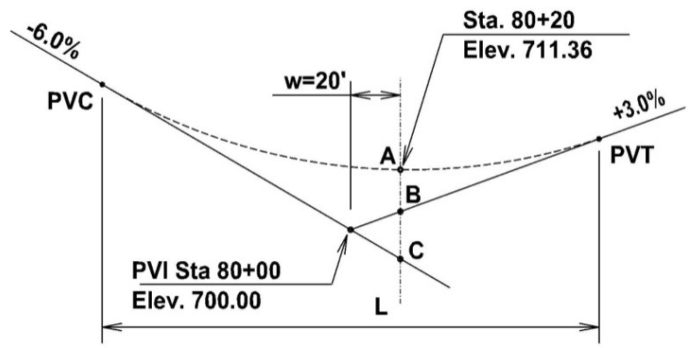
A -6.0% grade intersects a +3.0% grade at PVI Sta. 80+00 and Elev. 700.00. The vertical curve connecting the grades passes through a fixed point located at Sta. 80+20, and elevation 711.36. What is the length of the vertical curve?

A) 698 ft B) 711 ft C) 1035 ft D) 1200 ft

SOLUTION 16

Step 1. Calculate the elevations of points A, B, and C.

Point	Calculation	Elevation
A	Given	711.36
B	700 + 0.2'(3) =	700.60
C	700 + 0.2'(-6) =	698.80



Step 2. Calculate the constant z.

$$z = \sqrt{\frac{\text{ElevA} - \text{ElevC}}{\text{ElevA} - \text{ElevB}}} = \sqrt{\frac{711.36 - 698.80}{711.36 - 700.60}} = 1.0804$$

Step 3. Solve the following equation for L.

$$L = \frac{2w(z+1)}{z-1} = \frac{2(0.2)(1.0804+1)}{1.0804-1} = 10.35 \text{ sta} = 1035 \text{ ft}$$

Answer C

PROBLEM 17

A -6.0% grade intersects a +3.0% grade at PVI Sta. 80+00 and Elev. 700.00. The vertical curve connecting the grades passes through a turning point at elevation 711.36. What is the length of the vertical curve?

A) 700 ft B) 1136 ft C) 1200 ft D) None of the above

SOLUTION 17

Using CERM equation 79.52,

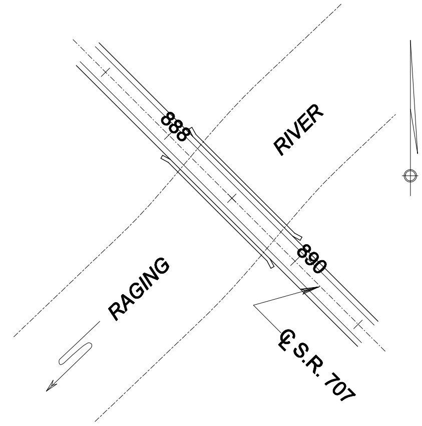
$$L = \frac{2(G_2 - G_1)(\text{elev}_{PVI} - \text{elev}_{TP})}{G_1 G_2} = \frac{2(3+6)(700-711.36)}{-6 * 3} = 11.36 \text{ sta} = 1136 \text{ ft}$$

Answer B

PROBLEM 18

State Route (S.R.) 707 crosses the Raging River in a narrow mountain valley. After a heavy storm the river overtops the bridge and crests at elevation 560.00. Given the vertical alignment data, determine:

S.R. 707 Vertical Alignment	
PVI Station	889+50
PVI Elev	545.00
L =	500 ft
G_1 **=**	-4.0%
G_2 **=**	+3.0%

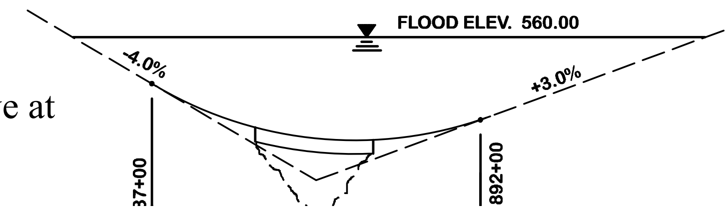


i) How deep the water is at Station 890+50 at the roadway centerline?

A) 10.42 ft B) 15.00 ft C) 0 ft D) 10.71 ft

ii) How deep is the water at the low point in the profile?

A) 10.42 ft B) 15.00 ft C) 0 ft D) 10.71 ft



SOLUTION 18

i) First, find the elevation on the vertical curve at Sta. 890+50.

$$R = \frac{G_2 - G_1}{L} = \frac{+3-(-4)}{5} = \frac{7}{5} = 1.4;$$

$$\text{BVC Elev} = 545 + \frac{5}{2}(4.0) = 555.00;$$

$$\text{BVC sta} = 88950 - \frac{500}{2} = 88700 = \text{Sta } 887+00;$$

$$x = 89050 - 88700 = 350' = 3.5 \text{ sta's}$$

Elev at Sta. 890 + 50:

$$\frac{R}{2}x^2 + G_1(x) + \text{BVC Elev} = \frac{1.4}{2}(3.5)^2 \pm 4.0(3.5) + 555.00 = 549.58$$

$$\text{Depth at Sta. } 890+50 = 560 - 549.58 = \underline{\underline{10.42 \text{ ft}}}.$$

Answer A

ii) First, find the elevation on the vertical curve at the lowest point on the curve.

Low point (turning point)location: $x_t = \frac{-G_1}{R} = \frac{-(-4)}{1.4} = 2.857 \text{ sta's}$

Low Point Station: BVC Sta + $x_t = 88700 + 285.7 = 88985.70 = \text{Sta } 889 + 85.70$

Elev. at Sta 889 + 85.70 :

$$\frac{R}{2}x^2 + G_1(x) + \text{BVC Elev} = \frac{1.4}{2}(2.857)^2 + (-4.0)(2.857) + 555.00 = 549.29$$

Depth at Sta 889 + 85.70 = 560.00 − 549.29 = 10.71 ft.

Answer D

PROBLEM 19

An unlighted roadway is on a vertical curve with the following parameters:
G_1 = -4.5%, G_2 = +2.0%, L = 600 ft. Based on AASHTO criteria, determine:

i) the actual head light sight distance (HLSD) of the curve

A) 413 ft B) 851 ft C) 0 ft D) 500 ft

ii) the maximum design speed (based on HLSD)

A) 40 mph B) 45 mph C) 55 mph D) 60 mph

SOLUTION 19

i) Using CERM Table 79.4, Assume S < L;

$$L = \frac{AS^2}{400 + 3.5S}; \qquad 600 = \frac{6.5 \times S^2}{400 + 3.5S}$$

S = 412.57 ~ 413 ft. This value of S agrees with the assumption: S < L

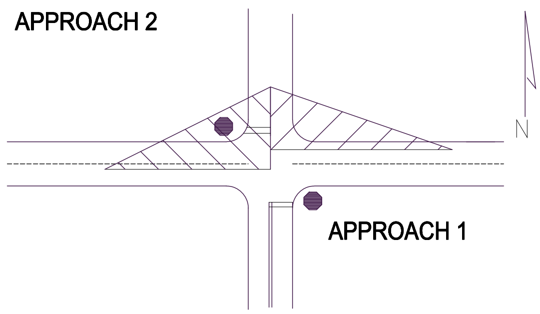
Answer A

ii)

Compare S = 413 to the values of S listed in CERM Table 79.2. This value falls in between the S required for 45 mph (360’) and 50 mph (425). Take the lower side of the speed which is 45 mph even though 413’ is closer to 425’than 360’. (**Answer B)**

PROBLEM 20

You are the city engineer and recently you have been asked to evaluate the stop sign controlled intersection described in the figure below. In this intersection the major road is a two-lane east-west highway with a speed limit of 55 mph. The minor road is a two-lane north-south highway with a speed limit of 35 mph. Compute the following items for approach 1 with 4% uphill for single unit truck design vehicle. You may assume a lane width on the minor road as 11 feet and a lane width on the major road as 12 feet.



i) Determine the maximum length of the "a_1" leg of the intersection sight triangle for a RIGHT turn at Approach 1.

ii) Determine the lengths of the "b" leg of the intersection sight triangle for a RIGHT turn at Approach 1.

iii) Determine the maximum lengths of the "a_2" leg of the intersection sight triangle for a LEFT turn at Approach 1.

A) 36 ft B) 76 ft C) 687 ft D) 606 ft

iv) Determine the lengths of the "b" leg of the intersection sight triangle for a LEFT turn at Approach 1.

A) 768 ft B) 868 ft C) 832 ft D) 606 ft

SOLUTION 20

Reference: AASHTO Green Book pages 9-28 to 9-41

A right turn is expressed by Case B2 per AASHTO for i) and ii)

i) a_1 = 18 ft which is the max per page 9-36 + ½ LW = 18 + 6 = 24 ft

ii) b = ISD = 1.47 V_{major} t_g = 1.47 x 55 (8.5+0.1x4) = 719.6 ft

NOTE: For t_g value, see Table 9-6 in AASHTO Green Book

A left turn is expressed by Case B1 per AASHTO Green Book for iii) and iv)

iii) a_2 = 18 ft which is the max +LW+ ½ LW = 18 + 12 + 6 = 36 ft
Answer A

iv) b = ISD = 1.47 V_{major} t_g = 1.47 x 55 (9.5+0.2x4) = 832.8 ft

NOTE: For t_g value, see Table 9-5 in AASHTO Green Book

Answer C

NOTE: See AASHTO Green Book Figure 9-15 for the a1, a2, and b items

PROBLEM 21

A new interchange will be located on a north-south highway with a design speed of 70 mph. The northbound exit will have a -2.0% grade and an exit curve with a design speed of 40 mph. Ramp is a taper type.

i) What is the minimum deceleration length, L, on the northbound exit ramp?
A) 490 ft B) 440 ft C) 550 ft D) 340 ft

ii) What is the average running speed, V'_a, on the northbound exit ramp exit curve?
A) 30 mph B) 40 mph C) 38 mph D) 36 mph

SOLUTION 21

Referring to the table below, i) L = 440 ft **(Answer B)** **ii)** V'_a = 36 mph **(Answer D)**

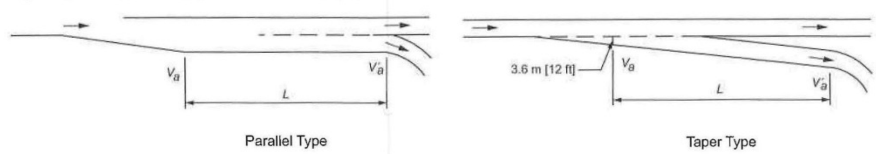
U.S. Customary										
		Deceleration Length, L (ft) for Design Speed of Exit Curve V' (mph)								
Highway Design Speed, V (mph)	Speed Reached, V_a (mph)	Stop Condition	15	20	25	30	35	40	45	50
		For Average Running Speed on Exit Curve, V'_a (mph)								
		0	14	18	22	26	30	36	40	44
30	28	235	200	170	140	—	—	—	—	—
35	32	280	250	210	185	150	—	—	—	—
40	36	320	295	265	235	185	155	—	—	—
45	40	385	350	325	295	250	220	—	—	—
50	44	435	405	385	355	315	285	225	175	—
55	48	480	455	440	410	380	350	285	235	—
60	52	530	500	480	460	430	405	350	300	240
65	55	570	540	520	500	470	440	390	340	280
70	58	615	590	570	550	520	490	440	390	340
75	61	660	635	620	600	575	535	490	440	390

V = design speed of highway (mph)

V_a = average running speed on highway (mph)

V' = design speed of exit curve (mph)

V'_a = average running speed on exit curve (mph)



AASHTO Green Book Table 10-5. Minimum Deceleration Lengths for Exit Terminals with Flat Grades of Two Percent or Less.

PROBLEM 22

A traffic study of an urban freeway corridor identified the locations with the highest incidence of crashes. The corridor includes three freeway segments and three interchanges. Using the crash data and traffic volumes tabulated below,

a. Rank the interchanges by number of crashes per year per million vehicles for each interchange from highest to lowest.

b. Rank the highway segments by number of crashes per year per million vehicle miles.

Inchg Exit	ADT	Crashes per yr
48	28500	73
55	11250	49
58	23150	68

Highway Segment	ADT	Crashes per yr	Segment Length
48 to 55	68000	890	7.18
55 to 58	72000	490	3.12
58 to 61	63000	478	2.96

SOLUTION 22

a. Interchanges Ranking

$$R\,(\text{Inchg}_{48}) = \frac{(73\ \text{crashes/yr})(10^6)}{(28{,}500\ \text{veh/day})(365\ \text{days/yr})} = 7.02\ \text{crashes/MEV} \qquad (3)$$

$$R\,(\text{Inchg}_{55}) = \frac{(49\ \text{crashes/yr})(10^6)}{(11{,}250\ \text{veh/day})(365\ \text{days/yr})} = 11.93\ \text{crashes/MEV} \qquad (1)$$

$$R\,(\text{Inchg}_{58}) = \frac{(68\ \text{crashes/yr})(10^6)}{(23{,}150\ \text{veh/day})(365\ \text{days/yr})} = 8.05\ \text{crashes/MEV} \qquad (2)$$

b. Highway segments. Use 10^6 instead of 10^8 because the ranking is per million vehicle miles, not 100 million.

$$R\,(\text{Inchg}_{48\text{ to }55}) = \frac{(890\ \text{crashes/yr})(10^6)}{(68{,}000\ \text{veh/day})(365\ \text{days/yr})(7.18\ \text{mi})} = 4.99\ \text{crashes/MVM} \qquad (3)$$

$$R\,(\text{Inchg}_{55\text{ to }58}) = \frac{(490\ \text{crashes/yr})(10^6)}{(72{,}000\ \text{veh/day})(365\ \text{days/yr})(3.12\ \text{mi})} = 5.98\ \text{crashes/MVM} \qquad (2)$$

$$R\,(\text{Inchg}_{58\text{ to }61}) = \frac{(478\ \text{crashes/yr})(10^6)}{(63{,}000\ \text{veh/day})(365\ \text{days/yr})(2.96\ \text{mi})} = 7.02\ \text{crashes/MVM} \qquad (1)$$

PROBLEM 23

On a four lane undivided highway in north-south direction, right most lane in the northbound direction needs some repairs for one mile long. The 85^{th} percentile speed on this highway is 45 MPH. All lanes are 12 feet wide and the shoulders are 6 feet wide. What is the most appropriate merge taper length to place cones for this work zone inside the northbound right most lane?

A) 203 ft B) 270 ft C) 405 ft D) 540 ft

SOLUTION 23

Refer to Figure 6C-2 and Tables 6C-3 and 6C-4 in MUTCD

L = WS = 12 x 45 = 540 ft

Taper length = L = 540 ft **(Answer D)**

PROBLEM 24

Shoulder work needs to be completed on an urban two-lane low speed highway. The 85th percentile speed is 25 MPH and the offset required is 12 ft. How far in advance of the shoulder work area should the very first sign be placed that drivers will see notifying them of the road work?

A) 125 ft B) 200 ft C) 242 ft D) 42 ft

SOLUTION 24

See Tables 6H-3, 6H-4, and Figure 6H-3 in MUTCD.

$L = WS^2/60 = (12)\ (25^2)/60 = 125$ ft

Distance to first sign from the shoulder work area = 1/3 L + A + B
= 1/3*125+100+100 = 242 ft

Answer C

PROBLEM 25

Shoulder work needs to be completed on a freeway. The 85th percentile speed is 65 MPH and the offset required is 18 ft. How far in advance of the first cone should a driver see the first "Right Side Shoulder Closed" sign?

A) 1000 ft B) 1500 ft C) 1890 ft D) 2890 ft

SOLUTION 25

See Tables 6H-3, 6H-4, and Figure 6H-5 in MUTCD.

Distance from work area to the first "Right Side Shoulder Closed" sign = A
= 1,000 ft

Answer A