SIGHT DISTANCE (SD)

Sight distance is the length of the roadway ahead that is visible to the driver at any time.

Safe highways must be designed to give drivers a sufficient clear vision ahead so that they can:

- ✓ Avoid hitting unexpected obstacles in the road
- ✓ Can pass slower vehicles without danger

Types of sight distances

- Stopping Sight Distance (SSD)
- Passing Sight Distance (PSD)
- Decision Sight Distance (DSD)
- Intersection Sight Distance (ISD)

STOPPING SIGHT DISTANCE (SSD)

Defn.: ***Min dist reqr to stop a veh (traveling at or near the design speed) before it reaches a stationary obj in it's path. Applicable for all the rd way.***

- Sight distance at every point along a highway should be as long as possibl

Reaction Time/ PIEV Time and Distance:

Time interval between seeing, hearing or feeling the existence of an obj or hazard on or along the rd way and the instant of starting to do something in response. **PR dist = vt, where v vel in m/sec.**

Brake reaction time:

Time the object is sighted to the time the brakes are applied. For design a conservative value is used

Combined perception-reaction time and brake reaction time = 2.5 seconds

SSD = *Sum of Perception reaction dist and braking dist.* $= v \times t + D_b$

$$= vt + \frac{v^2}{2g(f \pm G)}, \qquad where\ v\ is\ in\ kmph$$

$$= 1.47vt + \frac{v^2}{32(f \pm G)}, \qquad where\ v\ is\ in\ mph\ and\ g = 32.2\ fps^2$$

STOPPING SIGHT DISTANCE (SSD)

The computation of sight distance depends on

- Perception Reaction (PR) time of the driver
- Break Reaction (BR) time of the driver
- Speed of the vehicle
- Efficiency of brakes, tyre, road surface
- Frictional resistance between the tyre and the road
- Gradient of the road, road alignment.
- Size, type of object
- Climate condition

Driver,
Vehicle,
Road,
Climate

Explain the effects of above factors. How they affect?

$$SSD = vt + \frac{v^2}{2g(f \pm G)} = 1.47vt + \frac{v^2}{32(f \pm G)}$$

STOPPING SIGHT DISTANCE (SSD)

Effect of friction/Climate

Wet condition

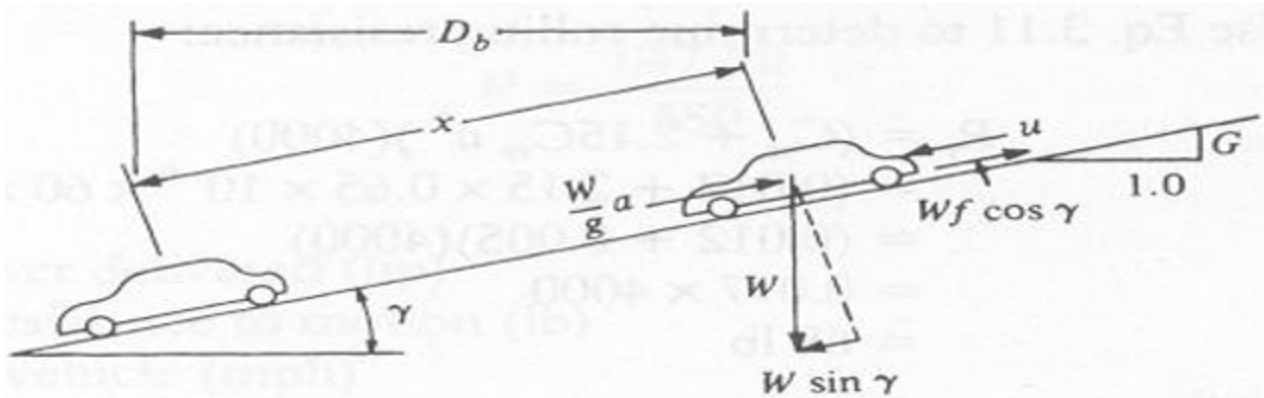
Dry Condition

Effect of Speed

Effect of Grade

Shorter along up grade

Longer along down grade



Will you design SSD for car or bus/trucks?

(for passenger cars. Truck drivers' eye heights are much higher and they can see further. Hence, SSDs for just trucks are not used.)

$$SSD = vt + \frac{v^2}{2g(f \pm G)} = 1.47vt + \frac{v^2}{32(f \pm G)}$$

STOPPING SIGHT DISTANCE (SSD)

SSD vs Speed

US Customary				
Design speed (mph)	Brake reaction distance (ft)	Braking distance on level (ft)	Stopping sight distance	
			Calculated (ft)	Design (ft)
15	55.1	21.6	76.7	80
20	73.5	38.4	111.9	115
25	91.9	60.0	151.9	155
30	110.3	86.4	196.7	200
35	128.6	117.6	246.2	250
40	147.0	153.6	300.6	305
45	165.4	194.4	359.8	360
50	183.8	240.0	423.8	425
55	202.1	290.3	492.4	495
60	220.5	345.5	566.0	570
65	238.9	405.5	644.4	645
70	257.3	470.3	727.6	730
75	275.6	539.9	815.5	820
80	294.0	614.3	908.3	910

celeration rate of 3.4 m/s^2 [11.2 ft/s^2] used to determine

SSD w.r.t. Grades

US Customary						
Design speed (mph)	Stopping sight distance (ft)					
	Downgrades			Upgrades		
	3 %	6 %	9 %	3 %	6 %	9 %
15	80	82	85	75	74	73
20	116	120	126	109	107	104
25	158	165	173	147	143	140
30	205	215	227	200	184	179
35	257	271	287	237	229	222
40	315	333	354	289	278	269
45	378	400	427	344	331	320
50	446	474	507	405	388	375
55	520	553	593	469	450	433
60	598	638	686	538	515	495
65	682	728	785	612	584	561
70	771	825	891	690	658	631
75	866	927	1003	772	736	704
80	965	1035	1121	859	817	782

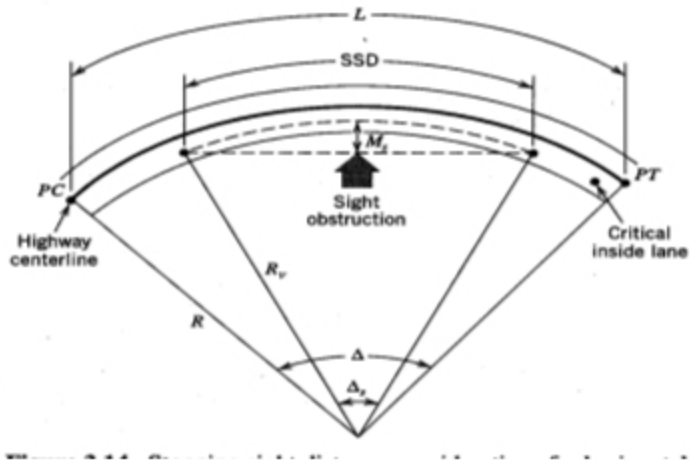
STOPPING SIGHT DISTANCE (SSD)

Low cost improvements for locations with inadequate sight distances

1. Installing reduced speed warning signs
2. Installing 'Limited Sight Distance' warning sign
3. Installing sight distance mirrors

Alternatives designs when SSD is not available due to object alongside of roadway

1. Increase offset to obstruction
2. Increase the radius
3. Reduce design speed



e. Horizontal curve (to see around obstruction):

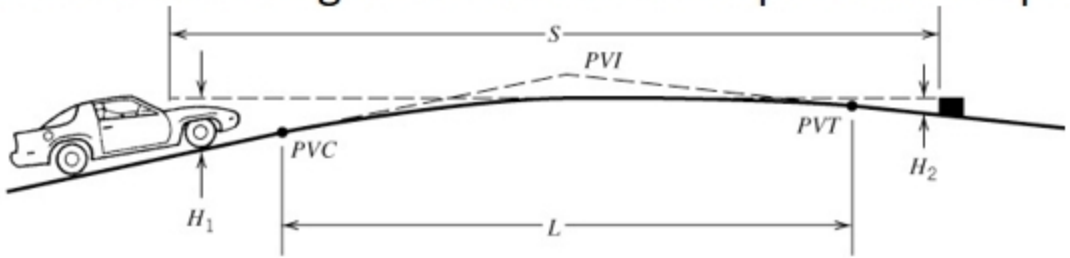
$$M = R\left[1 - \cos\left(\frac{28.65\,S}{R}\right)\right]$$

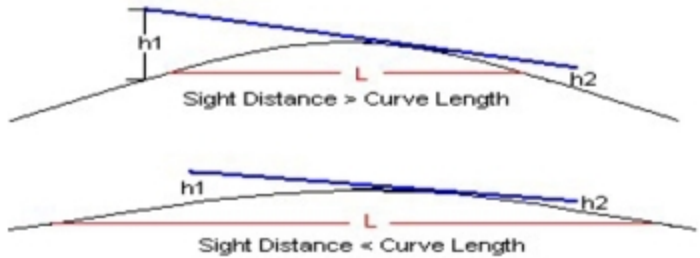
where

R = radius (ft or m)
M = middle ordinate (ft or m),
S = stopping sight distance (ft or m).

SSD for Crest Vertical Curve

- Based on driver eye height above roadway and height of object above roadway surface.
- Minimum length of curve that will provide adequate safety and minimum cost is desired.





$$S < L,\ L = \frac{AS^2}{100(\sqrt{2h_1}+\sqrt{2h_2})^2}$$

$$S > L,\ L = 2S - \frac{200(\sqrt{2h_1}+\sqrt{2h_2})^2}{A}$$

Using $h_1 = 3.5\ ft$ and $h_2 = 2ft$, the equations :

$$S > L,\ L = AS^2/2158$$

$$S < L,\ L = 2S - \frac{2158}{A}$$

L = length of vertical curve, in feet

S = sight distance, in feet

A = algebraic difference in percent grade, absolute value

h_1 = height of driver's eye in feet

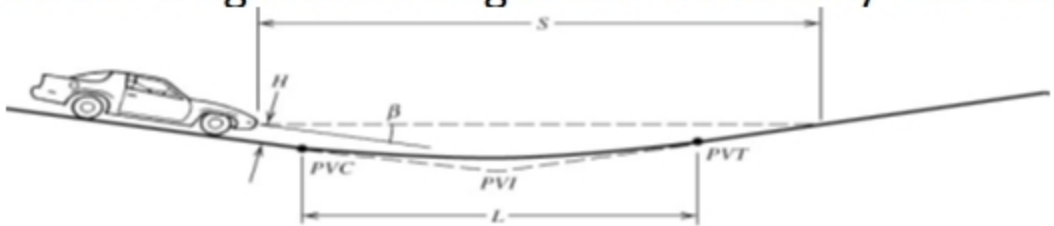
h_2 = height of object in feet

If the passing sight distance required for a vertical curve exceeds the stopping sight distance, to reduce cost, passing may be restricted along the curve

Minimum Curve Length would then = stopping sight distance

SSD for Sag Vertical Curve

- Sight distance is governed by night time conditions.
- Important - height of headlight above roadway and inclined angle of headlight beam.



where:
H = height of headlight above road surface
= inclined angle of headlight beam.

- For sag curves, SD is not physically constrained by the road surface during the day
- At night the SD is limited by the distance and angle of projection of a vehicle's headlights
- Headlights are mounted below a driver's eye height, at a height of 2 feet
- Headlight beam projects ≈1° upward along the vehicle's longitudinal axis

$$S < L,\ L = \frac{AS^2}{400+3.5S}$$

$$S > L,\ L = 2S - \frac{400+3.5S}{A}$$

Where:
L = length of curve, in feet
S = sight (light beam) distance, in feet
A = Algebraic difference in percent grade, absolute value
Using a headlight height of 2 feet and a headlight beam angle of 1°



Problem

A crest vertical curve is to be designed to join a +3% grade with a -3% grade at a section of a two-lane highway. The design speed of the highway is 60 mph. Determine: Minimum length of the curve.

A 1200 ft. equal tangent crest vertical curve is currently designed for 50 mi/hr. A civil engineering student contends that 60 mph is safe in a van because of the higher driver's eye height. If all other design inputs are standard, what must the driver's eye height inthe van be for the student's claim to be valid?

Problem: A sag vertical curve is to be designed to join a -3% grade to a +3% grade. Design speed is 40 mph. Determine: Minimum Length of the curve

A section of highway has vertical and horizontal curves with the same design speed. A vertical curve on this highway connects a +1% and a +3% grade and is 420 ft long. If a horizontal curve on this highway is on a two-lane section with 12-ft lanes, has a central angle of 37 degrees, and has a superelevation of 6%, what is the length of the horizontal curve?

EXAMPLE PROBLEM 4.2 Determine the minimum length of a crest vertical curve between a +0.5% grade and a −1.0% grade for a road with a 100-km/h design speed. The vertical curve must provide 190-m stopping sight distance and meet the California appearance criteria. Round up to the next greatest 20 m interval.

Stopping sight distance criterion:

Assume $S \leq L$

$$L = \frac{AS^2}{200(\sqrt{h_1} + \sqrt{h_2})^2} = \frac{[0.5 - (-1.0)](190^2)}{200(\sqrt{1.070} + \sqrt{0.150})^2} = 134.0 \text{ m}$$

$$134.0 \text{ m} < 190 \text{ m, so } S > L$$

$$L = 2S - \frac{200(\sqrt{h_1} + \sqrt{h_2})^2}{A} = 2(190) - \frac{200(\sqrt{1.070} + \sqrt{0.150})^2}{[0.5 - (-1.0)]}$$

$$= 380.0 - 269.5 = 110.5 \text{ m}$$

EXAMPLE PROBLEM 4.3 Determine the minimum length of a sag vertical curve between a −0.7% grade and a +0.5% grade for a road with a 110 km/h design speed. The vertical curve must provide 220 m stopping sight distance and meet the California appearance criteria and the AASHTO comfort standard. Round up to the next greatest 20 m interval.

Stopping sight distance criterion:

Assume $S \leq L$

$$L = \frac{AS^2}{120 + 3.5S} = \frac{[0.5 - (-0.7)](220^2)}{120 + 3.5(220)} = 65.3 \text{ m}$$

65.3 m < 220 m, so $S > L$

$$L = 2S - \frac{120 + 3.5S}{A} = 2(220) - \frac{120 + 3.5(220)}{[0.5 - (-0.7)]}$$

$$= 440 - 741.7 = -301.7 \text{ m}$$

Since $L < 0$, no vertical curve is needed to provide stopping sight distance.

Comfort criterion:

$$L = \frac{AV^2}{395} = \frac{[0.5 - (-0.7)](110^2)}{395} = 36.8 \text{ m}$$

An existing vertical curve on a highway connects a +3% grade with -4% grade. If the length of the curve is 250 ft, what is the maximum safe speed on this curve? Assume f = 0.4, PR time 3.0 sec and L> S.

If the speed as determined above is used to design a sag vertical curve, which will join a -3.5% grade to +3% grade, what will be the minimum length of the curve when f and PR time remain same. 5 +5

$$S < L,\ L = \frac{AS^2}{100(\sqrt{2h_1}+\sqrt{2h_2})^2} = \frac{7(76.22)^2}{200(\sqrt{1.07}+\sqrt{0.15})^2} = 100.6\ m$$

$$S < L,\ L = \frac{AS^2}{400+3.5S} = \frac{6.5(76.22)^2}{400+3.5(76.22)} = 56.6\ m, \text{not ok}$$

$$S > L,\ L = 2S - \frac{400+3.5S}{A} = 2(76.22) - \frac{400+3.5(76.22)}{6.5} = 49.86\ m, \text{ok}$$

An existing vertical curve on a highway connects a +3% grade with -4% grade. If the length of the curve is 250 ft, what is the maximum safe speed on this curve? Assume f = 0.4, PR time 3.0 sec and L> S.

If the speed as determined above is used to design a sag vertical curve, which will join a -3.5% grade to +3% grade, what will be the minimum length of the curve when f and PR time remain same. 5 +5

$$S < L,\ 250 = \frac{7(S)^2}{2158}, S = 277.6\ ft$$

$$SSD = vt + \frac{v^2}{2g(f \pm G)} = 1.47vt + \frac{v^2}{32(f \pm G)}$$

$$277.6 = 1.47x3v + \frac{v^2}{32(0.4 \pm G)}$$

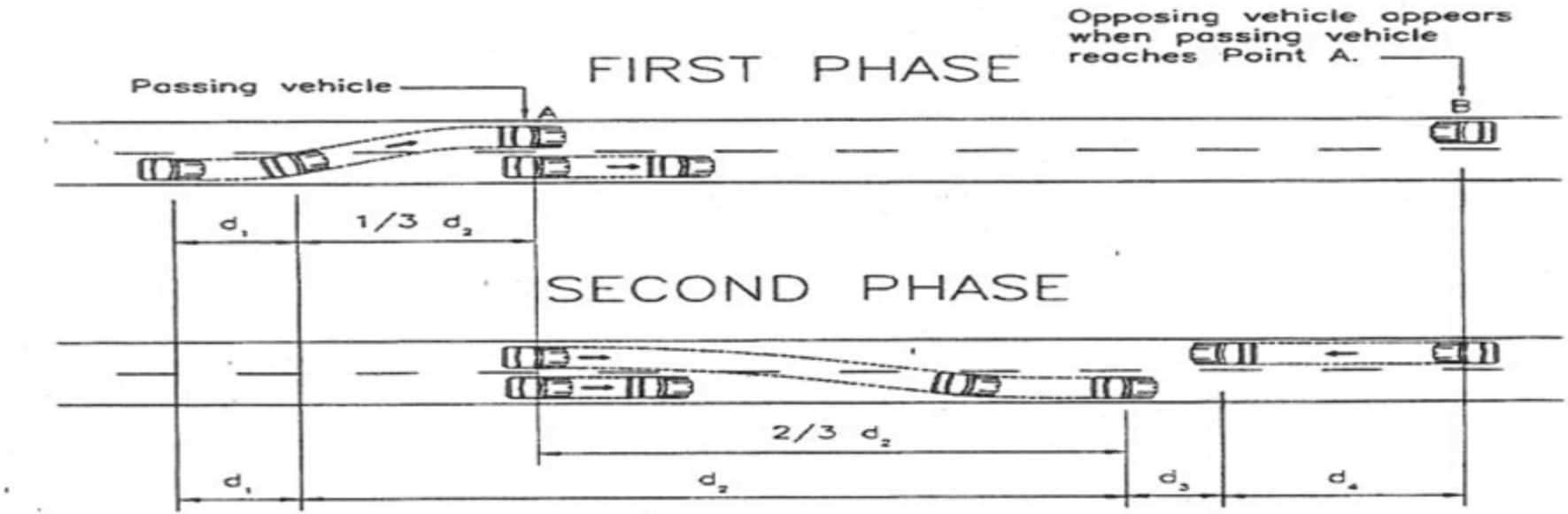
PASSIND SIGHT DISTANCE (PSD)

Defn. *Min dist which enable a veh (a dvr) to overtake and pass another veh on a two lane highway safely and efficiently without interfering the opposing veh. Applicable only on two lane highway.*

Assumptions:

1. PSD is determined for a single veh passing another single veh.
2. Overtaken veh op at uniform speed.
3. Overtaking veh has reduced speed and trails the overtaken veh as it enters a passing sec.
4. When passing sec is reached, dvr reqr a short period of time to perceive the clear passing sec and to react to start his maneuver.
5. Passing is accomplished under delayed start and hurried return in the face of opposing veh.
6. Passing veh accelerates during maneuver and its average speed during the occupancy of opposing lane is 10 mph higher than overtaken veh.
7. When return to own lane there is sufficient clearance dist between it and opposing veh.

Elements of PSD: $d_1+d_2+d_3+d_4$



d_1 = Initial maneuver distance

d_2 = Distance while passing vehicle occupies left lane

rance length = 110-300 ft

Elements of PSD

d_1 = Initial maneuver distance

US Customary

$$d_1 = 1.47 t_i \left(v - m + \frac{a t_i}{2} \right) \quad \text{(3-6)}$$

where:

- t_i = time of initial maneuver, s;
- a = average acceleration, mph/s;
- v = average speed of passing vehicle, mph;
- m = difference in speed of passed vehicle and passing vehicle, mph

d_2 = Distance while passing vehicle occupies left lane

US Customary

$$d_2 = 1.47 v t_2 \quad \text{(3-7)}$$

where:

- t_2 = time passing vehicle occupies the left lane, s;
- v = average speed of passing vehicle, mph

d_3 = Clearance length = 110-300 ft

d_4 = Distance traversed by an opposing vehicle = 2/3 of d_2

Elements of PSD

Component of passing maneuver	Metric				US Customary			
	Speed range (km/h)				Speed range (mph)			
	50–65	66–80	81–95	96–110	30–40	40–50	50–60	60–70
	Average passing speed (km/h)				Average passing speed (mph)			
	56.2	70.0	84.5	99.8	34.9	43.8	52.6	62.0
Initial maneuver:								
a = average acceleration[a]	2.25	2.30	2.37	2.41	1.40	1.43	1.47	1.50
t_1 = time (sec)[a]	3.6	4.0	4.3	4.5	3.6	4.0	4.3	4.5
d_1 = distance traveled	45	66	89	113	145	216	289	366
Occupation of left lane:								
t_2 = time (sec)[a]	9.3	10.0	10.7	11.3	9.3	10.0	10.7	11.3
d_2 = distance traveled	145	195	251	314	477	643	827	1030
Clearance length:								
d_3 = distance traveled[a]	30	55	75	90	100	180	250	300
Opposing vehicle:								
d_4 = distance traveled	97	130	168	209	318	429	552	687
Total distance, $d_1 + d_2 + d_3 + d_4$	317	446	583	726	1040	1468	1918	2383

[a] For consistent speed relation, observed values adjusted slightly.

Note: In the metric portion of the table, speed values are in km/h, acceleration rates in km/h/s, and distances are in meters. In the U.S. customary portion of the table, speed values are in mph, acceleration rates in mph/sec, and distances are in feet.

Exhibit 3-5. Elements of Safe Passing Sight Distance for Design of Two-Lane Highways

Estimate the total passing sight distance for a two-lane highway for average passing speed of 62 mph. The initial maneuver time is 4.5 sec and average acceleration is 1.50 mph/sec. Consider the time of passing vehicle occupying right lane as 11.3 sec and clearance length as 300 ft.

d_1 = Initial maneuver distance $= 1.47t_1\left(v - m + \frac{at_1}{2}\right)$

$= 1.47 \times 4.5\left(62 - 10 + \frac{1.5 \times 4.5}{2}\right) = 366.31\ ft = 367\ ft$

d_2 = Distance while passing vehicle occupies left lane

$= 1.47vt_2 = 1.47 \times 62 \times 11.3 = 1029.9 = 1030\ ft$

d_3 = Clearance length = 300 ft

d_4 = Distance traversed by opposing vehicle = 2/3 $d_2 = \frac{2}{3} \times 1030 = 686.6 = 687\ ft$

PSD

Effect of Grade:

- Up grade greater
- Down grade shorter