Transportation Engineering

Course Code –CE-422

Contact Hours -3+3

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Sight Distance

- Sight distance is the length of the highway visible ahead to the driver of the vehicle

- For operating a motor vehicle safely and efficiently, it is of utmost importance that drivers have the capability of seeing clearly ahead. Therefore, sight distance of sufficient length must be provided so that the drivers can operate and control their vehicles safely.

Aspects of Sight Distance

- The distances required by motor vehicles to stop.
- The distances needed for decisions at complex locations
- The distances required for passing and overtaking vehicles, applicable on two-lane highways
- The criteria for measuring these distances for use in design.

Stopping Sight Distance

- At every point on the roadway, the minimum sight distance provided should be sufficient to enable a vehicle traveling at the design speed to stop before reaching a stationary object in its path.
- Stopping sight distance is the aggregate of two distances:
  - – Brake Reaction Distance/ Brake Reaction Time
  - – Braking Distance

Brake Reaction Time

- Brake reaction time is the interval between the instant that the driver recognizes the existence of an object or hazard ahead and the instant that the brakes are actually applied.
- Extensive studies have been conducted to ascertain brake reaction time. Minimum reaction times can be as little as 1.64 seconds: 0.64 for alerted drivers plus 1 second for the unexpected signal.

Brake Reaction Time (cont'd)

- Some drivers may take over 3.5 seconds to respond under similar circumstances.
- For approximately 90% of drivers, including older drivers, a reaction time of 2.5 see is considered adequate.

Braking Distance

- The braking distance of a vehicle on a roadway may be determined by the formula

$$d = \frac{v^2}{2a}$$

d = braking distance (ft) or (m)

v = initial speed (ft/s) or (m/s)

a = deceleration rate, ft/s^2 (m/s^2)

Braking Distance

- Research studies revealed that most drivers decelerate at a rate greater than 4.5 m/s^2 (14.8 ft/s^2) when confronted with an urgent need to stop-for example, when seeing an unexpected object in the roadway.
- Approximately 90 percent of all drivers displayed deceleration rates of at least 3.4 m/s^2 (11.2 ft/s^2).
- Such deceleration rates are with-in a driver's capability while maintaining steering control and staying in a lane when braking on wet surfaces.

Braking Distance

- Most vehicle braking systems and tire-pavement friction levels are also capable of providing this level.
- Therefore, a deceleration rate of 3.4 m/s² (11.2 ft/s²) is recommended as a threshold for determining stopping sight distance (AASHTO, 2004).

Stopping Sight Distance

- The sum of the distance traversed during the brake reaction time and the distance to brake the vehicle to a stop is the stopping sight distance.
- The stopping sight distances for wet pavements and for various speeds are calculated using

$$S = \frac{v^2}{2a} + v t_r$$

Stopping Sight Distance

Metric	US Customary
$d = 0.278Vt + 0.039\frac{V^2}{a}$	$d = 1.47Vt + 1.075\frac{V^2}{a}$ (3-2)
where: t = brake reaction time, 2.5 s; V = design speed, km/h; a = deceleration rate, m/s^2	where: t = brake reaction time, 2.5 s; V = design speed, mph; a = deceleration rate, ft/s^2

- In computing and measuring stopping sight distances, the height of the driver's eye is estimated to be 1,080 mm [3.5 ft] and the height of the object to be seen by the driver is 600 mm [2.0 ft], equivalent to the tail-light height of a passenger car.

Stopping Sight Distance (cont’d)

Brake reaction time of 2.5 sec and deceleration rate of 11.2 ft/sec^2 (3.4 m/sec^2) is used in Table shown below for calculating SSD at various speed based on passenger car operation.

Metric					US Customary				
Design speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance		Design speed (mph)	Brake reaction distance (ft)	Braking distance on level (ft)	Stopping sight distance	
			Calculated (m)	Design (m)				Calculated (ft)	Design (ft)
20	13.9	4.6	18.5	20	15	55.1	21.6	76.7	80
30	20.9	10.3	31.2	35	20	73.5	38.4	111.9	115
40	27.8	18.4	46.2	50	25	91.9	60.0	151.9	155
50	34.8	28.7	63.5	65	30	110.3	86.4	196.7	200
60	41.7	41.3	83.0	85	35	128.6	117.6	246.2	250
70	48.7	56.2	104.9	105	40	147.0	153.6	300.6	305
80	55.6	73.4	129.0	130	45	165.4	194.4	359.8	360
90	62.6	92.9	155.5	160	50	183.8	240.0	423.8	425
100	69.5	114.7	184.2	185	55	202.1	290.3	492.4	495
110	76.5	138.8	215.3	220	60	220.5	345.5	566.0	570
120	83.4	165.2	248.6	250	65	238.9	405.5	644.4	645
130	90.4	193.8	284.2	285	70	257.3	470.3	727.6	730
					75	275.6	539.9	815.5	820
					80	294.0	614.3	908.3	910

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 3.4 m/s^2 [11.2 ft/s^2] used to determine calculated sight distance.

Stopping Sight Distance (cont'd)

- Truck stopping distances are usually longer, particularly for heavy trucks as compared to passenger cars. This is somewhat compensated by the truck driver's ability to see farther ahead over sight obstructions because of the higher placement of the seat in the vehicle.
- Generally in highway design separate stopping sight distances are therefore not used for trucks and passenger cars.

Effect of Grade on Stopping Sight Distance

- When a highway is on grade, the equation for stopping sight distance should be modified as follows:

$$S = \frac{v^2}{(2a \pm G)} + v t_r$$

Where G is grade or longitudinal slope of the highway divided by 100.

Metric	US Customary
$d = \frac{V^2}{254\left(\left(\frac{a}{9.81}\right) \pm G\right)}$	$d = \frac{V^2}{30\left(\left(\frac{a}{32.2}\right) \pm G\right)}$ (3-3)

Stopping Sight Distance on Grade

Metric						
Design speed (km/h)	Stopping sight distance (m)					
	Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%
20	20	20	20	19	18	18
30	32	35	35	31	30	29
40	50	50	53	45	44	43
50	66	70	74	61	59	58
60	87	92	97	80	77	75
70	110	116	124	100	97	93
80	136	144	154	123	118	114
90	164	174	187	148	141	136
100	194	207	223	174	167	160
110	227	243	262	203	194	186
120	263	281	304	234	223	214
130	302	323	350	267	254	243

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 on Grade

- However, at the end of long down- grades, where truck speeds approach or exceed passenger car speeds, it is desirable to provide distances greater than those recommended in Table or even those calculated using Equation

$$S = \frac{v^2}{(2a \pm G)} + v t_r$$

- It is easy to state that under these circumstances higher eye position of the truck driver can be of little advantage.

Problem

- An alert driver (with a reaction of 0.5 sec) is driving downhill on a 4% grade at 35 mph on a dry pavement when suddenly a person steps from behind a parked car in the path of the driver, at a distance of 125 ft.
  - Can the driver stop in time with emergency brake assuming a deceleration rate of 14.8 ft/sce^2
  - Can the driver stop in time on the rainy day with comfortable braking assuming a deceleration rate of 11.2 ft/sce^2

Solution

- The driver's reaction time, the condition of the road pavement, vehicle braking system and the prevailing weather all play a significant role in this problem.

Decision Sight Distance

- Stopping sight distances are generally sufficient to allow competent and alert drivers to stop their vehicles under ordinary circumstances, these distances are insufficient when information is difficult to perceive.

- When a driver is required to detect an unexpected or otherwise difficult-to-perceive information source, a decision sight distance should be provided.

Decision Sight Distance (cont'd)

- Interchanges and inter-sections, changes in cross-section such as toll plazas and lane drops, and areas with "visual noise" are examples where drivers need decision sight distances.
- Table provides values used by designers for appropriate decision sight distances with modified reaction time.

Decision Sight Distance (cont'd)

Metric						US Customary					
Design speed (km/h)	Decision sight distance (m)					Design speed (mph)	Decision sight distance (ft)				
	Avoidance maneuver						Avoidance maneuver				
	A	B	C	D	E		A	B	C	D	E
50	70	155	145	170	195	30	220	490	450	535	620
60	95	195	170	205	235	35	275	590	525	625	720
70	115	235	200	235	275	40	330	690	600	715	825
80	140	280	230	270	315	45	395	800	675	800	930
90	170	325	270	315	360	50	465	910	750	890	1030
100	200	370	315	355	400	55	535	1030	865	980	1135
110	235	420	330	380	430	60	610	1150	990	1125	1280
120	265	470	360	415	470	65	695	1275	1050	1220	1365
130	305	525	390	450	510	70	780	1410	1105	1275	1445
						75	875	1545	1180	1365	1545
						80	970	1685	1260	1455	1650

Avoidance Maneuver A: Stop on rural road—t = 3.0 s
Avoidance Maneuver B: Stop on urban road—t = 9.1 s
Avoidance Maneuver C: Speed/path/direction change on rural road—t varies between 10.2 and 11.2 s
Avoidance Maneuver D: Speed/path/direction change on suburban road—t varies between 12.1 and 12.9 s
Avoidance Maneuver E: Speed/path/direction change on urban road—t varies between 14.0 and 14.5 s

Decision Sight Distance (cont’d)

The decision sight distances for avoidance maneuvers A and B are determined as:

Metric	US Customary	
$d = 0.278Vt + 0.039\frac{V^2}{a}$	$d = 1.47Vt + 1.075\frac{V^2}{a}$	(3-4)

The decision sight distances for avoidance maneuvers C, D, and E are determined as:

Metric	US Customary	
$d = 0.278Vt$	$d = 1.47Vt$	(3-5)

Decision Sight Distance (cont'd)

- These values are applicable to most situations and have been developed from empirical data.
- Because of additional maneuvering space needed for safety, it is recommended that decision sight distances be provided at critical locations or critical decision points may be moved to where adequate distances are available.

Decision Sight Distance (cont'd)

- If it is not practical to provide decision sight distance because of horizontal or vertical curvature or if relocation of decision points is not practical, special attention should be given to the use of suitable traffic control devices for providing advance warning of the conditions that are likely to be encountered.

Passing Sight Distance for Two-Lane Highways

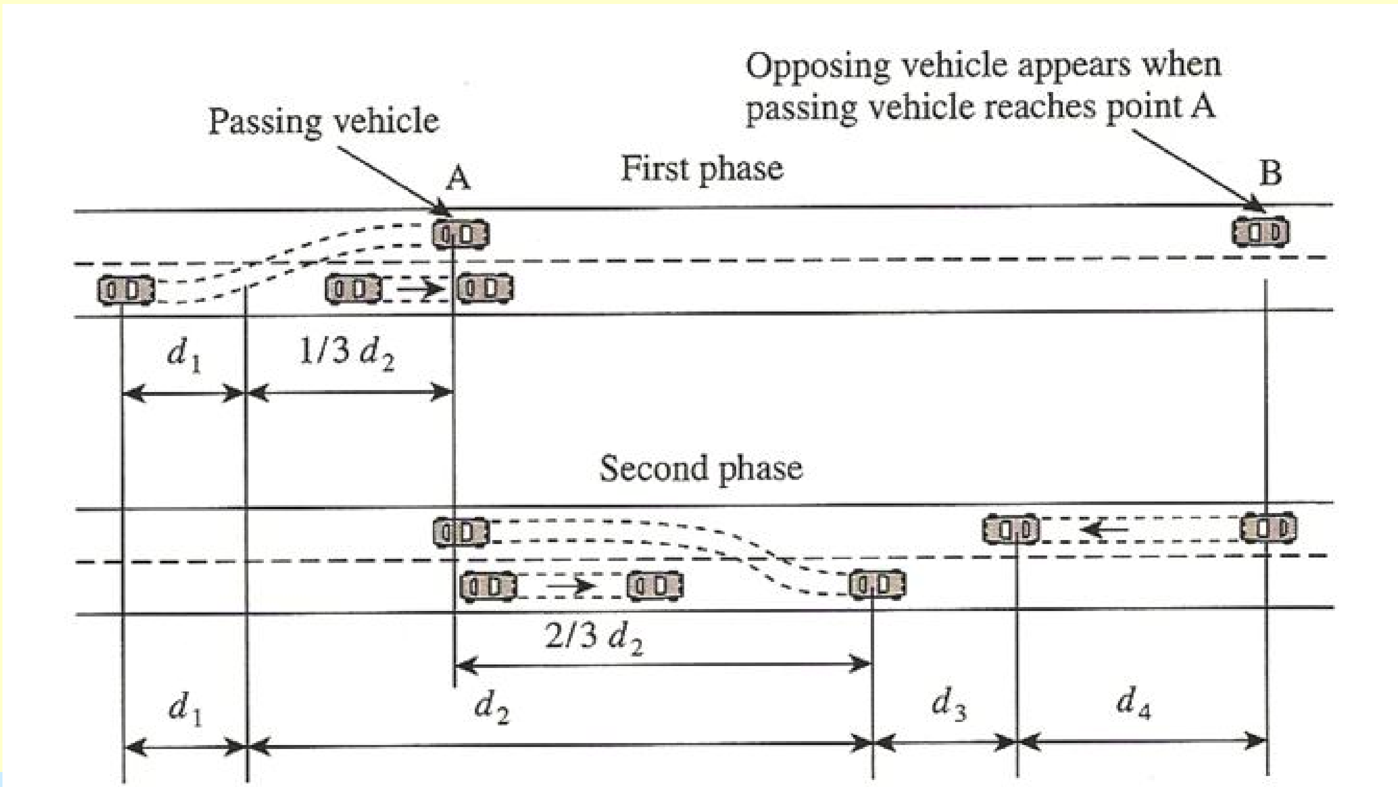
- On most two-lane, two-way highways, vehicles frequently overtake slower-moving vehicles by using the lane meant for the opposing traffic.
- To complete the passing maneuver safely, the driver should be able to see a sufficient distance ahead.
- Passing sight distance is determined on the basis that a driver wishes to pass a single vehicle, although multiple-vehicle passing is permissible.

Assumption for Passing Sight Distance for Two-Lane Highways based on Traffic behaviour

- The overtaken vehicle travels at a uniform speed.
- The passing vehicle trails the overtaken vehicle as it enters a passing section.
- The passing driver requires a short period of time to perceive the clear passing section, when reached and to start maneuvering.
- The passing vehicle accelerates during the maneuver, during the occupancy of the right lane, at about 15 km/h (10 mph) higher than the overtaken vehicle.
- There is a suitable clearance length between the passing vehicle and the oncoming vehicle upon completion of the maneuver.

Passing Sight Distance for Two-Lane Highways

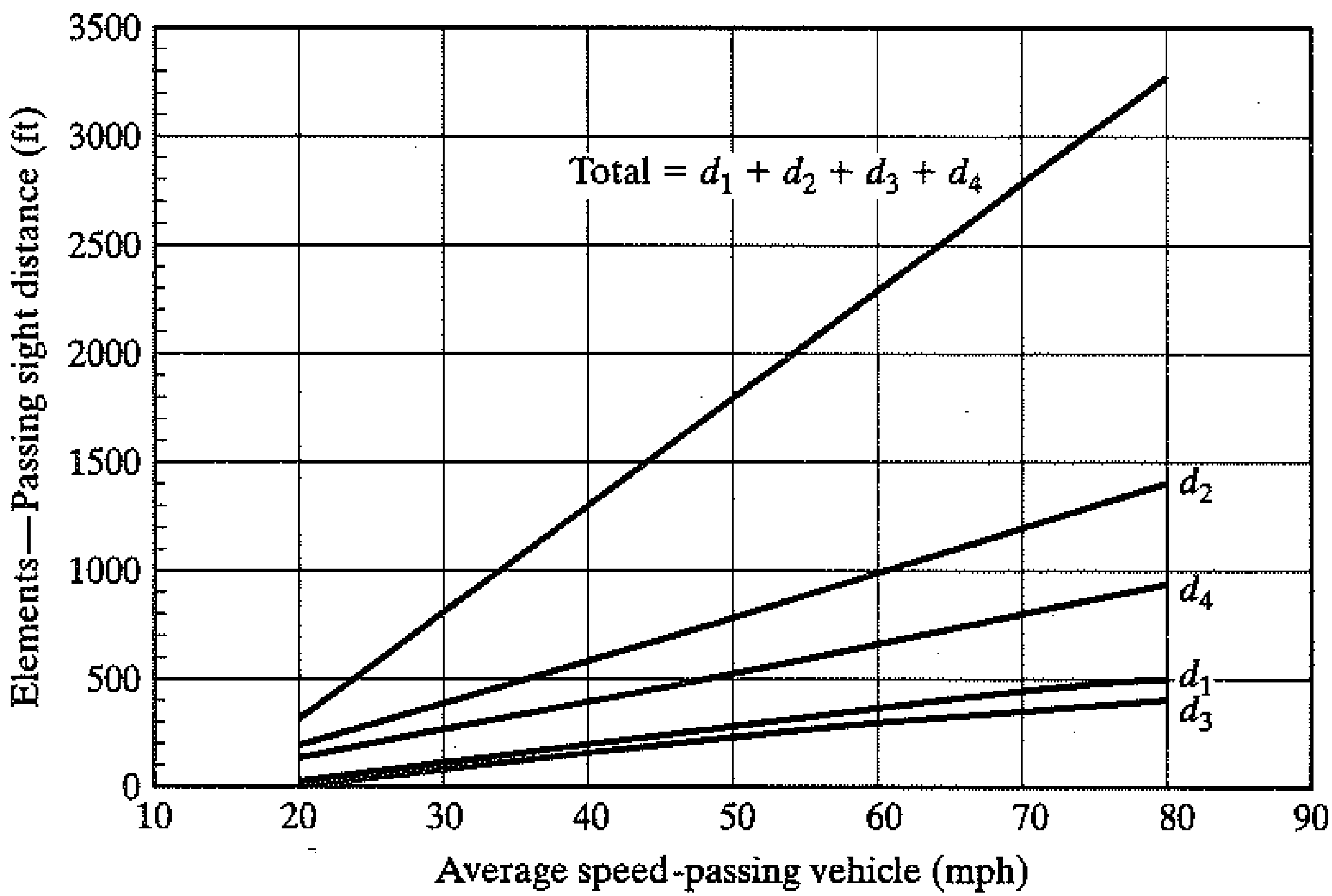
- The minimum passing sight distance for two-lane highways is determined as the sum of the four distances as shown in Figure



Passing Sight Distance for Two-Lane Highways

- d_1 – distance traveled during perception and reaction time and during initial acceleration to the point of encroachment on the left lane
- d_2 – distance travelled while the passing vehicle occupies on the left lane
- d_3 – distance between the passing vehicle at the end of its maneuver and the opposing vehicle
- d_4 – distance travelled by an opposing vehicle for two third of the time the passing vehicle occupies the left lane or two third of d_2

Passing Sight Distance for Two-Lane Highways



Initial maneuver distance d_1

- The distance d_1 traveled during the initial maneuver period is computed with the following equation:

Metric	US Customary
$$d_1 = 0.278\, t_i \left(v - m + \frac{a t_i}{2} \right)$$	$$d_1 = 1.47\, t_i \left(v - m + \frac{a t_i}{2} \right) \quad (3\text{-}6)$$
where: t_i = time of initial maneuver, s; a = average acceleration, km/h/s; v = average speed of passing vehicle, km/h; m = difference in speed of passed vehicle and passing vehicle, km/h	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

Distance while passing vehicle occupies left lane (d_2)

- Passing vehicles were found in the study to occupy the left lane from 9.3 to 10.4 s. The distance d_2 traveled in the left lane by the passing vehicle is computed with the following equation

Metric	US Customary
$d_2 = 0.278 v t_2$	$d_2 = 1.47 v t_2$ (3-7)
where: t_2 = time passing vehicle occupies the left lane, s; v = average speed of passing vehicle, km/h	where: t_2 = time passing vehicle occupies the left lane, s; v = average speed of passing vehicle, mph

Clearance length (d_3).

- The clearance length between the opposing and passing vehicles at the end of the passing maneuvers was found to vary from 30 to 75 m [100 to 250 ft].

Distance traversed by an opposing vehicle (d_4)

- The opposing vehicle is assumed to be traveling at the same speed as the passing vehicle

$$d_4 = \frac{2d_2}{3}$$

Estimation of Velocity of a Vehicle just Before it is Involved in an accident

Some times it is necessary to determine the velocity of a vehicle just before it is involved in an accident. Following steps are involved:

- Estimate length of skid marks for all the four tyres of the vehicle and take the average length. This is equal to braking distance.
- Find out "a" by performing trial runs under same environment /weather conditions and using a vehicle having similar conditions of tyres. Vehicle is driven at a known speed and braking distance is measured.

Estimation of Velocity of a Vehicle just Before it is Involved in an accident

- The unknown speed just before crash is than determined using the braking formula

$$V_u = \left[\frac{D_b}{D_t} V_t^{\,2} + V_i^{\,2} \right]^{1/2}$$

V_u- Unknown speed just before crash in mph or km/hr
D_b- Braking distance measured from skid marks in ft or m
D_t - Braking distance for trial run in ft or m
V_t - Speed of trial run in mph or km/hr
V_i - Speed when impact take place in mph or km/hr