Geometric Design

Geometric design is intimately related to the capabilities and limitations of the roadway user and his vehicle, who will use the road and how often are also most important. Toward that end, traffic volume, speed, and composition are three major items to be considered in striving to provide safe, efficient, and economic traffic operations.

The geometric design of highways includes the visible elements of highway or street. It deals with the grade line or profile, horizontal alignment, the several components of the cross section, sight distances, & intersections.

In preparing the design of a new highway or the redesign of an old one, the highway engineer must give attention to the following basic considerations:

1. The design must be adequate for the estimated future traffic volume, both average daily traffic and design peak hour, for the character of vehicles and for the design speed.
2. The design must be safe for driving and should instill confidence in majority of drivers.
3. The design must be consistent, and must avoid surprise changes in alignment, grade, or sight distance.
4. The design must be complete. It must include the necessary roadside treatment & provide essential traffic control devices, such as markings & signs, and proper lighting.
5. The design must be as economical as possible relative to initial costs and maintenance costs.

Elements of Geometric Design

The design of highways necessitates the determination of specific design elements which include:

1. The number of lanes,

2. Lane width,

3. Median type (if any) and width,

4. Length of acceleration and deceleration lanes for on- and off-ramps,

5. Needing for truck climbing lanes for steep grades,

6. Curve radii required for vehicle turning,

7. The alignment required to provide adequate stopping and passing sight distance

The most of geometric features depends primarily on available sight distance.

Sight distance

It is the length of highway visible a head to the driver. It is important to consider to provide clear sight to enables the driver to see in both the horizontal and vertical planes. The available sight distance on a roadway should be sufficiently long to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object.

The components of the safer sight distance are three distances:

1. Stopping sight distance (SSD). it is provided for all types of highways

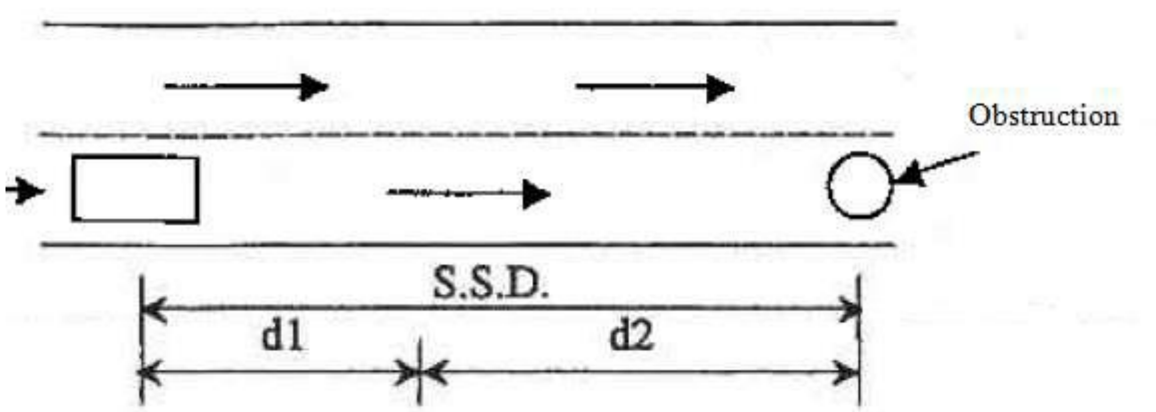
2. Decision sight distance. It is provided for complex location

3. Passing (overtaking) sight distance (PSD). It is provided for two-lane two-way highway to overtake slow vehicles.

1- ***Stopping Sight Distance (SSD)***: Minimum distance required for alerting driver to stop a vehicle traveling at the design speed, after seeing an object in the vehicle's bath without hitting that object. It is disaggregated into lag distance (Reaction distance) (d_1) and braking distance (d_2).

Thus:

SSD = d_1 (d lag) + d_2 (d breaking)



a. Lag distance (d_1): Lag distance. It is the distance traveled during perception & reaction time.

Perception = ½ sec. (Urban area)

= 1 ½ sec. (Rural area)

Break Reaction= 1 sec.

t= perception-reaction time = 1 ½ - 2 ½ sec.

The combined perception and reaction time, t, can vary widely depending on the driver. However, in Iraq, a value of 1.5 seconds is taken for urban area and 2.5 seconds for rural area. When the designated area is not specified, the value of 2.5 seconds will be used for safe and comfortable design.

d_1 (lag (m)) =V (m/sec) * t (sec)

1 (km/h) = 0.278 (m/sec)

$d_1 = 0.278\ V * t$

Where:

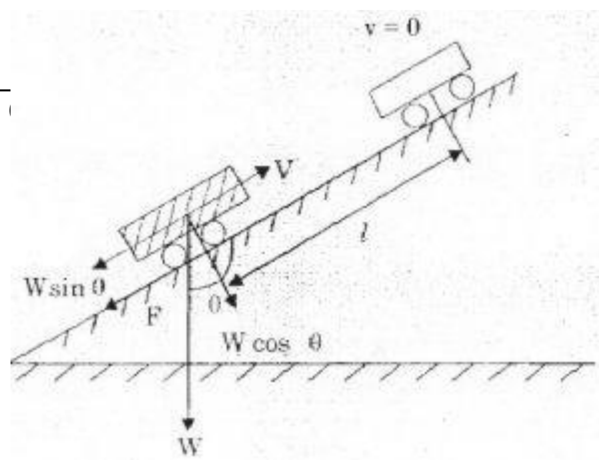
d_1 = lag distance (m)

V = speed (Km/hr)

t = perception-reaction time (sec)

b. Braking distance (d_2): it is the distance travelled after applying the brake.

$$d_{breaking} = \frac{}{254\,(}$$



Where:

V = initial speed in (Km/hr)

f_b = coefficient of friction due to braking

$$upgrade\ force = F + X$$

When ɵ is small

$$F = w.\cos\theta.f_b = w.f_b$$

$$x = w.\sin\theta = w.\tan\theta = w.g$$

 $upgrade\ force = w\ (f_b + g)$

$upgrade\ force = w\ (f + g)$

$Downgrade\ force = w\ (f_b - g)$

$In\ general\ force = w\ (f\ \mp g)$

Work = force * distance = change in kinetic energy

$= w\ (f_b + g).\, d_b = \frac{1}{2}\frac{w}{9.81}(v_o^2 - 0)$

$d_b = \frac{(0.278)^2\ v^2}{2*9.81\ (f_b + g)}$

$d_b = \frac{V^2}{254\ (f_b + g)}$

* f_b :-

= 0.55 - 0.62 (dry pavement condition)

= 0.28 - 0.4 (wet pavement condition)

= 0.1 (muddy)

= 0.05 (icy)

** g :- longitudinal grade (0 – 0.09)*

g ≤ 0.05 (high speed)

g ≤ 0.09 (low speed)

$$\boldsymbol{Min\ S\ (stopping) = 0.278\ Vt + \frac{V^2}{254\ (f_b + g)}}$$

Example 1: Find the clear spacing between a vehicle and an obstruction when the speed of a vehicle is 100 km/hr in the following cases:

1- Downgrade of -3%

2- Upgrade of 3%

Example 2: A driver with a perception-reaction time of 2.5 sec is driving at 65 mi/h when she observes that an accident has blocked the road ahead. Determine the distance the vehicle would move before the driver could activate the brakes. The vehicle will continue to move at 65 mi/h during the perception-reaction time of 2.5 sec.

Example 3: A student trying to test the braking ability of her car determined that she needed 18.5 ft more to stop her car when driving downhill on a road segment of 5% grade than when driving downhill at the same speed along another segment of 3% grade. Determine the speed at which the student conducted her test and the braking distance on the 5% grade if the student is traveling at the test speed in the uphill direction.

Example 4: The clear spacing between a vehicle and an obstruction ahead is 60m. The speed of a vehicle is 90 km/hr. Check whether this distance is satisfying the requirements of stopping distance for the following cases:

1- Level roadway

2- Downgrade of -3%

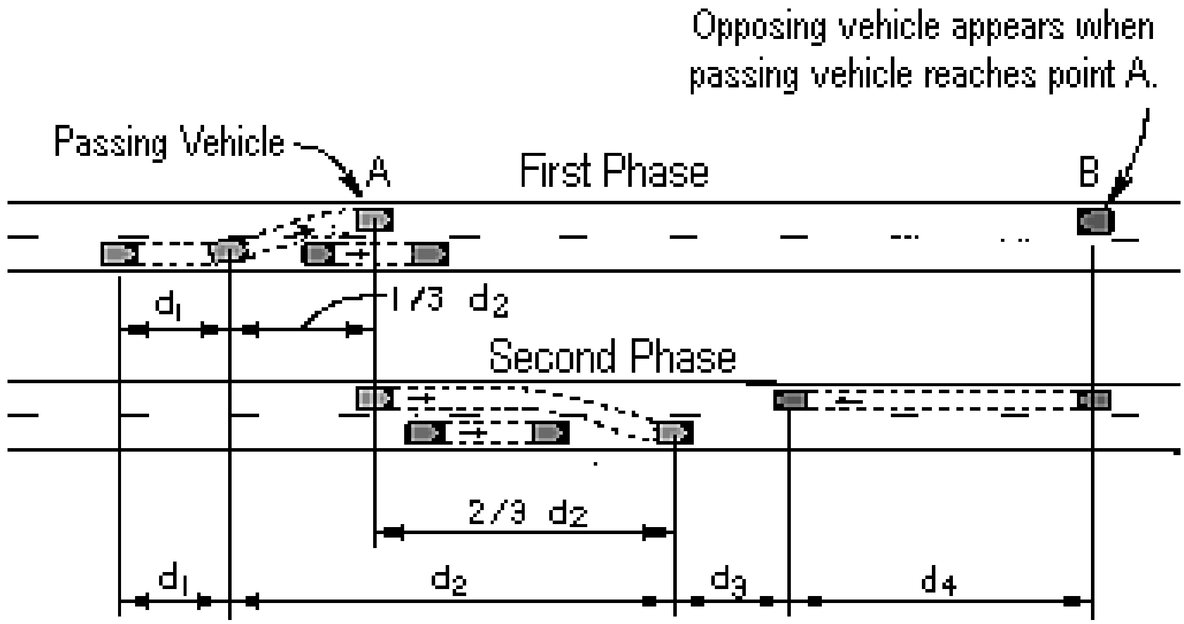
3- Upgrade of 3%

2. Decision Sight Distance (DSD)

It is the distance needed to avoid maneuver (stopping, speeding, or path change). It is considered in the design of roads at complex locations (visual noise area) like intersection, interchange or where there is a change in the cross section.

Maneuver	**Description**	**DSD (m) when speed=100kph**	**Time needed to pass the DSD (sec)**
A	Stopping in rural area	225	3
B	Stopping in urban area	415	9.1
C	Speed or path change in rural area	315	10
D	Speed or path change in suburban area	365	12
E	Speed or path change in urban area	405	14

3. *Passing Sight Distance (PSD)*: minimum distance required on two-way two-lane highways to give the opportunity to pass slow moving vehicles safely. It must be provided at intervals, otherwise capacity decreases and accidents may occur.



The PSD is determined as the sum of the following four distances:

PSD (Min S passing) = $d_1 + d_2 + d_3 + d_4$

1. d_1: distance traveled during perception and acceleration time (initial maneuver distance).

$d_1 = 0.278\, t_1\, [V + (a.t_1)/2]$

Where:

V: average speed of overtaking vehicle (Km/hr)

t_1: preliminary delay time (3.5-4.5) sec ≈ 4 sec

a: acceleration rate 0.5 - 1 Km/hr/sec for trucks
3-8 Km/hr/sec for ordinary car (passenger car)
16-24 Km/hr/sec for sport car

2. d_2: distance traveled in the opposite direction

$d_2 = 0.278\ V_2\ t_2$

Where:

d_2 = overtaking distance (m)

V_2= average speed of overtaking vehicle (Km/hr)

t_2: time of occupying opposing lane (9.5-11.5) sec ≈ 10 sec

3. d_3: safety distance(clearance distance) = 100m

   It is the distance between the passing vehicle at the end of its maneuver and the opposing vehicle.

4. d_4: It is the distance traversed by an opposing vehicle in the opposing lane (m). It is equal to the two-thirds of the time the passing vehicle occupies the left lane

   $d_4 = 2/3\ d_2$

Example: A driver is traveling on a two-lane highway (with speed of 90 km/hr) is trying to overtake a vehicle ahead (with speed of 65 km/hr). The acceleration rate of the passing vehicle is 3.1 km/hr/sec, and the vehicle spent 2.3 sec for the initial maneuver to the opposing lane and 8.1 sec traveling on it. If you know that the distance between the overtaking and the opposing vehicles before the beginning of the overtaking process is 450 meters. Is this distance adequate to complete the overtaking process? Assume that the required clearance length between the opposing and passing vehicle is 75m.

Solution:

P.S.D. = $d_1 + d_2 + d_3 + d_4$

d_1=0.278*2.3(90-(90-65)+3.1*2.3/2)= 43.84m

d_2=0.278*90*8.1=202.66m

d_3=75m

d_4 = (2/3)*d_2 = (2/3)*202.66 = 135.1m

P.S.D. = 43.84+202.66+75+135.1=456.6m <450 this means that it is not safe to pass the vehicle ahead.

Example: A driver is traveling on a two-lane highway (with speed of 90 km/hr) is trying to overtake a vehicle ahead (with speed of 75 km/hr). The acceleration rate of the passing vehicle is 3.1 km/hr/sec, and the vehicle spent 2.5 sec for the initial maneuvering to the opposing lane and 8.0 sec traveling on it. Find the required passing sight distance.