1.2.5 Cross-section of highway

Cross-section elements of a roadway include principal elements such as travel lanes, shoulders, and medians and marginal elements such as gutters, sidewalks, cross slopes, side slopes, back slopes, guard-rails. However, the availability of these elements depends of whether the road is in urban or rural areas. The element of cross-section will discussed later in detail. Figure 1.5 shows a typical cross-section of highway.

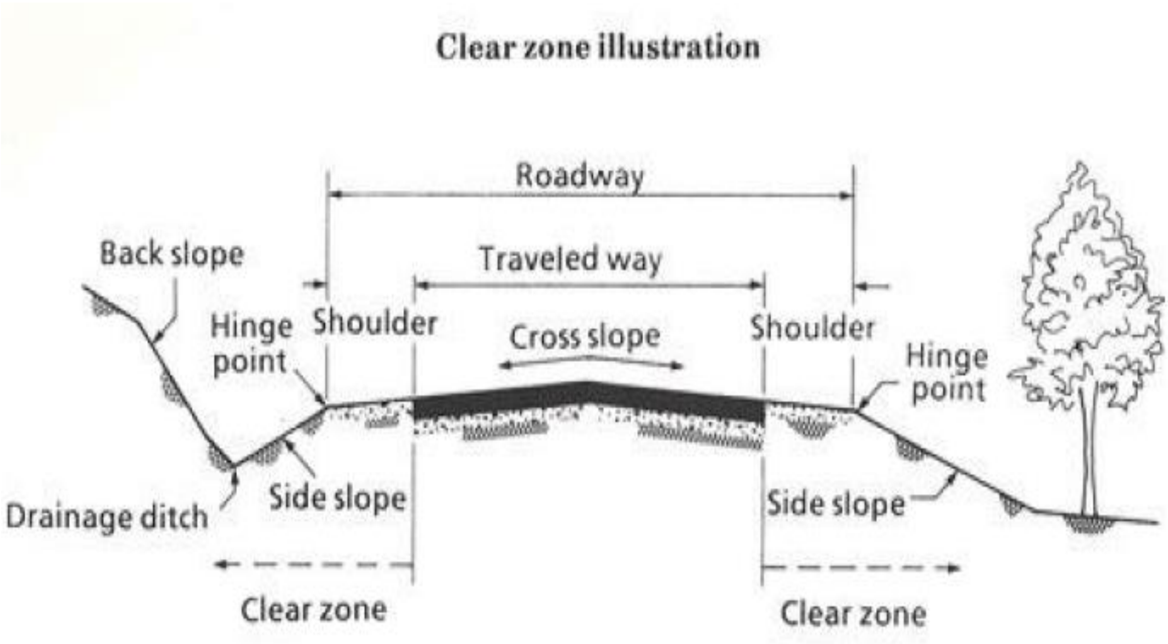

Figure 1.5: Typical cross-section of road

1.2.6 Presence of heavy vehicles on steep grades

The presence of heavy vehicles affects the required geometric design of road. This point is mostly related to next point.

1.2.7 Topography and environmental

For highway design, topography is generally classified into three groups:

1. Level terrain: this is relatively flat. Horizontal and vertical alignments are generally long or can be achieved without much construction difficulty or major expense. In addition, these horizontal and vertical alignments permitting heavy vehicles to maintain approximately the same speed as passenger cars. Grades are generally limited to 1 or 2 percent.

2. Rolling terrain: this type has natural slopes that often rise above and fall below the highway grade with occasional steep slopes that restrict the normal vertical and horizontal alignments. This terrain causing heavy vehicles to reduce their speeds substantially below those of passenger cars, but not to operate at crawl speeds.

3. Mountainous (hilly) terrain: it has sudden changes in ground elevation in both the longitudinal and transverse directions, thereby requiring frequent hillside excavations to achieve acceptable horizontal and vertical alignments. Furthermore, this type of terrain causing heavy vehicles to operate at crawl speed. Heavy vehicles are defined as any vehicle having a weight (Pounds) to horsepower ratio of 200 or greater. Crawl speed is defined as the maximum sustained speed that heavy vehicles can maintain on an extended upgrade

1.2.8 Level of service

1.2.9 Safety

1.2.10 Funds

1.2.11 Restrictions

1.3 Cross-section elements

As mentioned previously, the principal elements of a highway cross section consist of the travel lanes, shoulders, and medians (for some multilane highways). Marginal elements include and roadside barriers, kerbs, gutters, guard rails, sidewalks, and side slopes. Figure 1.6 shows a typical cross section for a two-lane highway, while Figure 1.7 shows that for a multilane highway. The features of the cross-section of the pavement influence the life of the pavement as well as the riding comfort and safety. Camber, kerbs, and geometry of various cross-sectional elements are important aspects to be considered in this regard. They are explained briefly in this lecture.

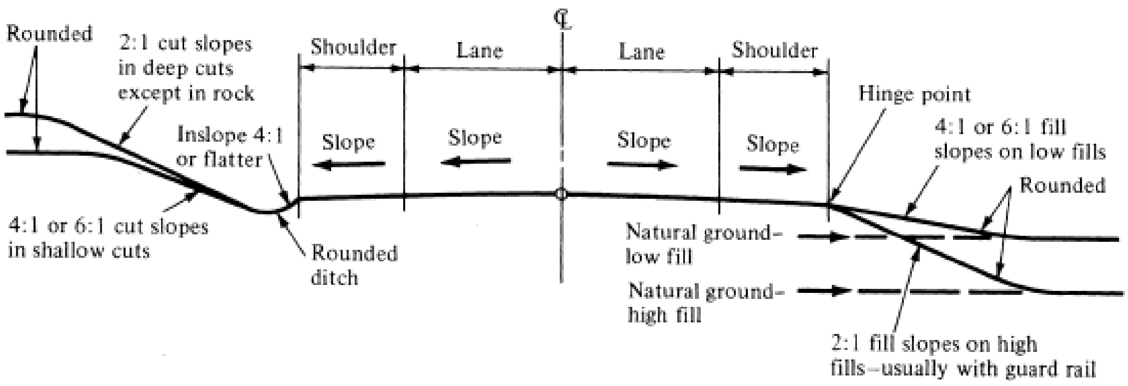

Figure 1.6: Typical cross-section for two-lane highway

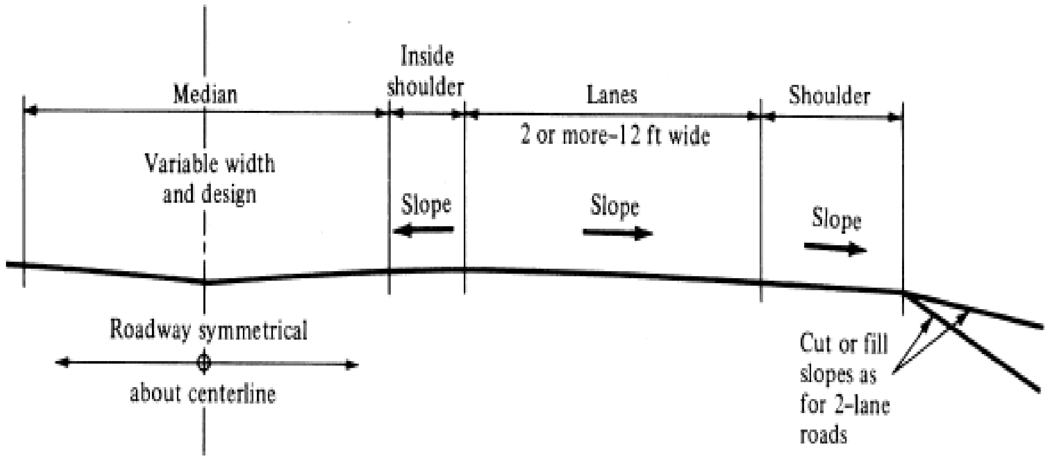

Figure 1.7: Typical cross-section for multilane highway

1.3.1 Pavement Surface Characteristics

For safe and comfortable driving four aspects of the pavement surface are important; the friction between the wheels and the pavement surface, smoothness of the road surface, the light refection characteristics of the top of pavement surface, and drainage to water

1.3.1.1 Friction

Friction between the wheel and the pavement surface is a crucial factor in the design of horizontal curves and thus the safe operating speed. Further, it also affect the acceleration and deceleration ability of vehicles. Lack of adequate friction can cause skidding or slipping of vehicles.

- ❖ Skidding happens when the path travelled along the road surface is more than the circumferential movement of the wheels due to friction
- ❖ Slip occurs when the wheel revolves more than the corresponding longitudinal movement along the road.

Various factors that affect friction are:

- ✓ Type of the pavement (like bituminous, concrete, or gravel),
- ✓ Condition of the pavement (dry or wet, hot or cold, etc),
- ✓ Condition of the tyre (new or old), and
- ✓ Speed and load of the vehicle.

The frictional force that develops between the wheel and the pavement is the load acting multiplied by a factor called the coefficient of friction and denoted as *f*. The choice of the value of f is a very complicated issue since it depends on many variables. It is typically suggested that the coefficient of longitudinal friction as 0.35-0.4 depending on the speed and coefficient of lateral friction as 0.15. The former is useful in sight distance calculation and the latter in horizontal curve design.

1.3.1.2 Unevenness

It is always desirable to have an even surface, but it is seldom possible to have such a one. Even if a road is constructed with high quality pavers, it is possible to develop unevenness due to pavement failures. Unevenness affect the vehicle operating cost, speed, riding comfort, safety, fuel consumption and wear and tear of tyres. Unevenness index is a measure of unevenness which is the cumulative measure of vertical undulations of the pavement surface recorded per unit horizontal length of the road. An unevenness index value less than 1500 mm/km is considered as good, a value less than 2500 mm/km is satisfactory up to speed of 100 km/h and values greater than 3200 mm/km is considered as uncomfortable even for 55 km/h.

1.3.1.3 Light of reflection

- ✓ White roads have good visibility at night, but caused glare during daytime.
- ✓ Black roads has no glare during day, but has poor visibility at night
- ✓ Concrete roads has better visibility and less glare

It is necessary that the road surface should be visible at night and reflection of light is the factor that answers it.

1.3.1.4 Drainage

The pavement surface should be absolutely impermeable to prevent seepage of water into the pavement layers. Further, both the geometry and texture of pavement surface should help in draining out the water from the surface in less time. ***Please Remember, the main enemy for pavement is water and water and water.***

1.3.2 Camber (Cross-slope)

Camber or cant is the cross slope provided to raise middle of the road surface in the transverse direction to drain off water from road surface. The objectives of providing camber are:

- ✓ Surface protection especially for gravel and bituminous roads
- ✓ Sub-grade protection by proper drainage
- ✓ Quick drying of pavement which in turn increases safety

Too steep slope is undesirable for it will erode the surface. Pavements on straight sections of two-lane and multilane highways without medians are slope from the middle downward to both sides of the highway, resulting in a transverse or cross slope, with a cross section shape that can be curved, plane or a combination of the two. A parabola is generally used for curved cross sections, and the highest point of the pavement (called the crown) is slightly rounded, with the cross slope increasing toward the pavement edge. Plane cross slopes consist of uniform slopes at both sides of the crown. Travelled-way cross slope should be adequate to provide proper drainage. Normally, cross slopes range from 1.5% to 2% for paved surfaces and 2% to 6% for unpaved surfaces. For unpaved surfaces, such as stabilized or loose gravel, and for stabilized earth surfaces, a 3% cross slope is desirable. Figure 1.8 shows different types of camber (cross-slope).

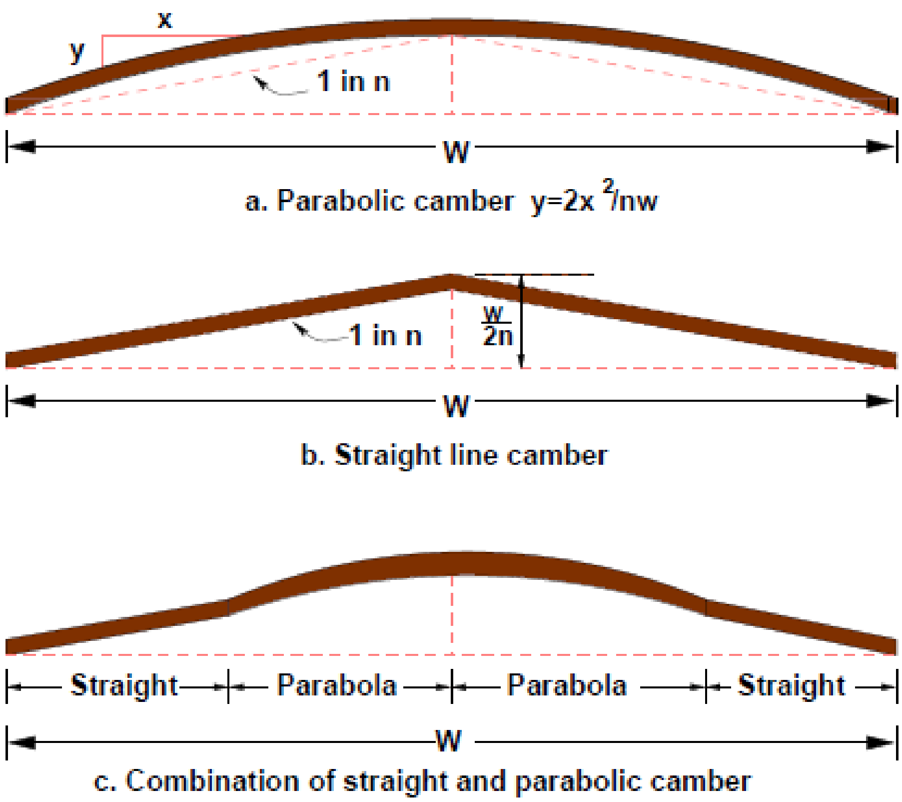

Figure 1.8: Different types of camber (cross-slope)

1.3.3 Width of Travel Lanes

Width of the carriageway or the width of the pavement depends on the width of the traffic lane and number of lanes. Width of a traffic lane (one lane width) depends on the width of the vehicle and the clearance. Side clearance improves operating speed and safety. In general, travel lane widths usually vary from 2.75m to 3.75m. Most arterials have 3.75 travel lanes since the extra cost for constructing 3.75m lanes over 3m lanes is usually offset by the lower maintenance cost for shoulders and pavement surface, resulting in a reduction of wheel concentrations at the pavement edges. On two lane, two-way rural roads, lane widths of 3m or 3.65m may be used, but two factors must be considered when selecting a lane width less than 3.65m wide. When pavement surfaces are less than 6.75m, the crash rates for large trucks tend to increase and, as the lane width is reduced from 3.65m, the capacity of a highway significantly decreases.

Lane widths of 3m are therefore used only on low-speed facilities. Lanes that are 3m wide are used occasionally in urban areas if traffic volume is low and there are extreme right-of-way constraints. It should be noted that the maximum permissible width of a vehicle is 2.44m and the desirable side clearance for single lane traffic is 0.68 m. This require minimum of lane width of 3.75 m for a single lane road. However, the side clearance required is about 0.53 m, on either side or 1.06 m in the centre. Therefore, a two-lane road require minimum of 3.5m for each lane.

In Iraq, a lane width of 3.75m is generally used for multilane highways while standard lane width is 3.60m. Table 1.2 represents the lane width as recommended by AASHTO Green book

1.3.4 Shoulders

The shoulder of a pavement cross section is always contiguous with the travelled lane to provide an area along the highway for vehicles to stop when necessary. Shoulder surfaces range in width from 0.6m on minor roads to 3.65m on major arterials. Shoulders are also used to laterally support the pavement structure. The shoulder width is known as either *graded* or *usable*, depending on the section of the shoulder being considered. The graded shoulder width is the whole width of the shoulder measured from the edge of the travelled pavement to the intersection of the shoulder slope and the plane of the side slope. The usable shoulder width is that part of the graded shoulder that can be used to accommodate parked vehicles. The usable width is the same as the graded width when the side slope is equal to or flatter than 4%. Minimum shoulder width of 1.80-2.40m may be considered for low- volume highways.

Asphalt and concrete – surfaced shoulders should be sloped from 2% to 6%, aggregate and untreated granular shoulders from 4% to 6%. In other words, slope of shoulder depends on the type of constructed materials.

Table 1.2 lane width as recommended by AASHTO

Metric					U.S. Customary				
Design Speed (km/h)	Minimum Width of Traveled Way (m) for Specified Design Volume (veh/day[a])				Design Speed (mph)	Minimum Width of Traveled Way (ft) for Specified Design Volume (veh/day[a])			
	under 400	400 to 1500	1500 to 2000	over 2000		under 400	400 to 1500	1500 to 2000	over 2000
30	6.0[b]	6.0	6.6	7.2	20	20[b]	20	22	24
40	6.0[b]	6.0	6.6	7.2	25	20[b]	20	22	24
50	6.0[b]	6.0	6.6	7.2	30	20[b]	20	22	24
60	6.0[b]	6.6	6.6	7.2	35	20[b]	22	22	24
70	6.0	6.6	6.6	7.2	40	20[b]	22	22	24
80	6.0	6.6	6.6	7.2	45	20	22	22	24
90	6.6	6.6	7.2	7.2	50	20	22	22	24
100	6.6	6.6	7.2	7.2	55	22	22	24	24
					60	22	22	24	24
					65	22	22	24	24
	Width of Shoulder on Each Side of Road (m)					Width of Shoulder on Each Side of Road (ft)			
All Speeds	0.6	1.5[c]	1.8	2.4	All Speeds	2.0	5.0[c]	6.0	8.0

[a] On roadways to be reconstructed, a 6.6-m [22-ft] traveled way may be retained where the alignment is satisfactory and there is no crash pattern suggesting the need for widening.

[b] A 5.4-m [18-ft] minimum width may be used for roadways with design volumes under 250 veh/day.

[c] Shoulder width may be reduced for design speeds greater than 50 km/h [30 mph] provided that a minimum roadway width of 9 m [30 ft] is maintained.

1.3.5 Medians

A median is the section of a divided highway that separates the lanes in opposing directions. The width of a median is the distance between the edges of the inside lanes, including the median shoulders. The functions of a median include:

- ✓ Providing a recovery area for out-of-control vehicles
- ✓ Separating opposing traffic
- ✓ Providing stopping areas during emergencies
- ✓ Providing storage areas for left-turning and U-turning vehicles
- ✓ Providing refuge for pedestrians
- ✓ Reducing the effect of headlight glare

Medians can either be raised, flush, or depressed as follows:

- Raised medians are frequently used in urban arterial streets because they facilitate the control of left-turn traffic at intersections by using part of the median width for left-turn-only lanes. Some disadvantages associated with raised medians include possible loss of control of the vehicle by the driver if the median is accidentally struck, and they cast a shadow from oncoming headlights, which results in drivers finding it difficult to see the curb.
- Flush medians are commonly used on urban arterials. They can also be used on freeways, but with a median barrier. To facilitate drainage of surface water, the flush median should be crowned. The practice in urban areas of converting flush medians into two-way left-turn lanes is common, since the capacity of the urban highway is increased while maintaining some features of a median.
- Depressed medians are generally used on freeways and are more effective in draining surface water. A side slope of 6% is suggested for depressed medians, although a slope of 4% may be adequate.

In general, median widths are in the range from 1.2m to 24m or even more at some cases. Median widths should be as wide as possible but should be balanced with other elements of the cross section and the cost involved. In general, the wider the median, the more effective it is in providing safe operating conditions and a recovery area for out-of-control vehicles. Figure 1.9 shows median cross-slope illustrations at different roads.

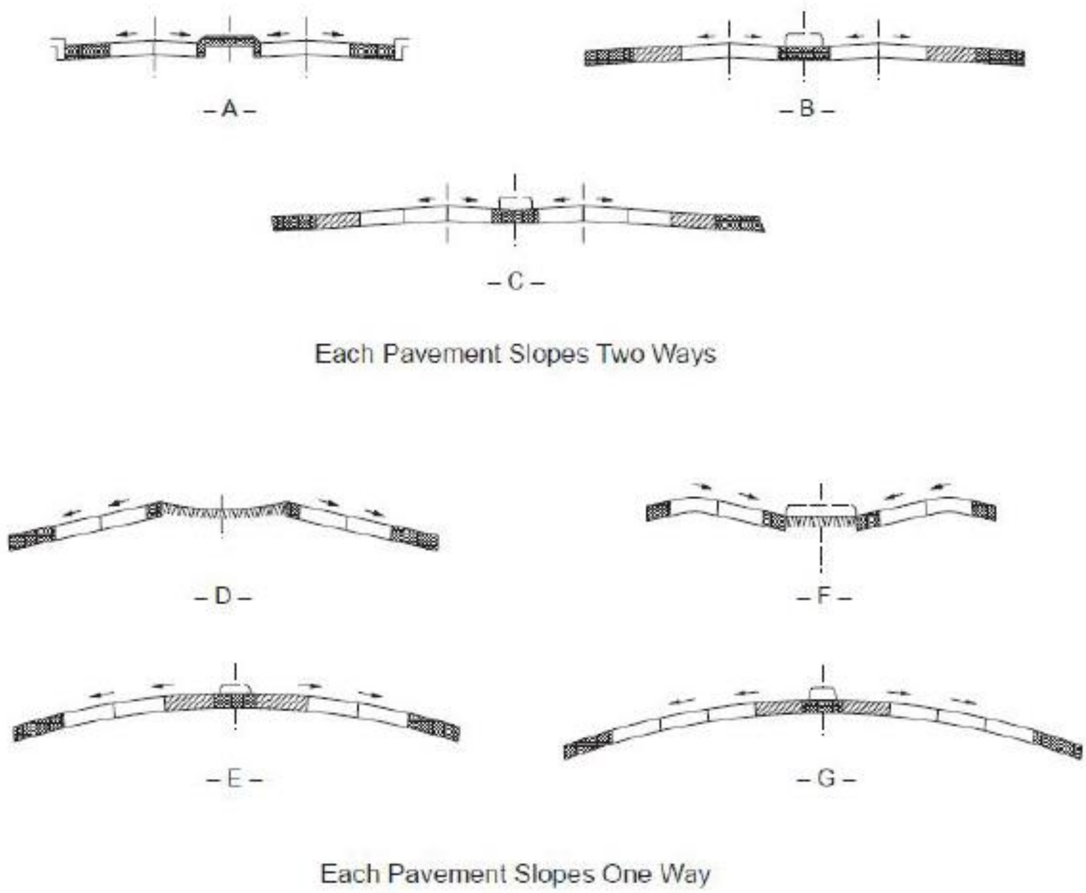

Figure 1.10: Median cross-slope illustrations at different roads

1.3.5 Kerbs

Kerbs are raised structures made of either Portland cement concrete or bituminous concrete (rolled asphalt kerb) that are used mainly on urban highways to delineate pavement edges and pedestrian walkways. kerb are also used to control drainage, improve aesthetics, and reduce right of way. They can be generally classified as either vertical or sloping Kerbs indicate the boundary between the carriage way and the shoulder or islands or footpaths.

Different types of kerbs are shown in Figure 1.11

- ✓ Low or mountable kerbs: This type of kerbs are provided such that they encourage the traffic to remain in the through traffic lanes and allow the driver to enter the shoulder area with little deficiency. The height of this kerb is about 10cm above the pavement edge with a slope, which allows vehicles to climb easily. This is usually provided at medians and channelization schemes and also helps in longitudinal drainage.

- ✓ Semi-barrier kerbs: when the pedestrian traffic is high, these kerbs are provided. Their height is 15cm above the pavement edge. This type of kerb prevents encroachment of parking vehicles, but at acute emergency it is possible to drive over this kerb with some difficulty.
- ✓ Barrier kerbs: they are designed to discourage vehicles from leaving the pavement. They are provided when there is considerable amount of pedestrian traffic. They are generally placed at a height of 20cm above the pavement edge with a steep batter
- ✓ Submerged kerbs: They are used in rural roads. The kerbs are provided at pavement edges between the pavement edge and shoulders. They provide lateral confinement and stability to the pavement.

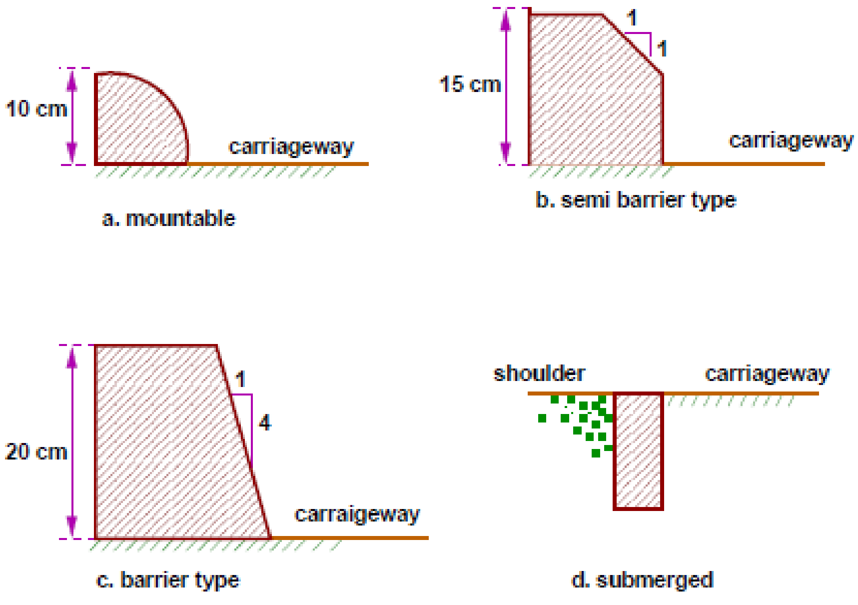

Figure 1.11: Different types of kerbs