Introduction to Transportation Engineering
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Lecture - 9
Cross Section Elements

Module 3 geometric design of highways lesson 3.2 cross section elements.

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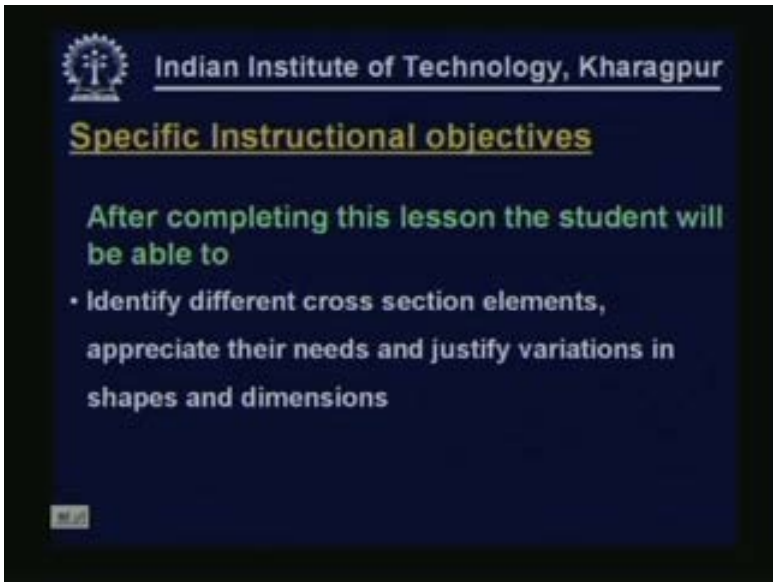

In the last lesson we discussed about functional classification of roads, design controls and the broad elements for geometric design. After today's lesson the student will be able to identify different cross sectional elements, appreciate their needs and justify variations in shapes and dimensions. Let us have a look at the elements we will cover under cross sectional elements.

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- Carriageway shoulder
- Roadway width
- Right of way
- Building line
- Control line
- Median
- Camber
- Side slope
- Lateral and vertical clearances
- Kerb
- Guard rail
- Side drain and also
- Other facilities

Carriage way: it is basically the traveled way which is used for movement of vehicles, it takes the vehicular loading and predominant vehicle loads is shared by this component which is called carriageway. It may be cement concrete road or it may be bituminous pavement. In case of bituminous pavement it is the black top portion which is the carriageway. The width of the carriage way depends on the number of traffic lane; minimum lane is a single lane road which is supposed to be used for movement of one vehicle at a time. the width of road or width of carriage way for single lane road is 3.75, for intermediate lane road 5.5 m, two lanes without raised kerb is 7 m, two lane with raised kerb is 7.5 m and for multi-lane road width per lane is 3.5 m.

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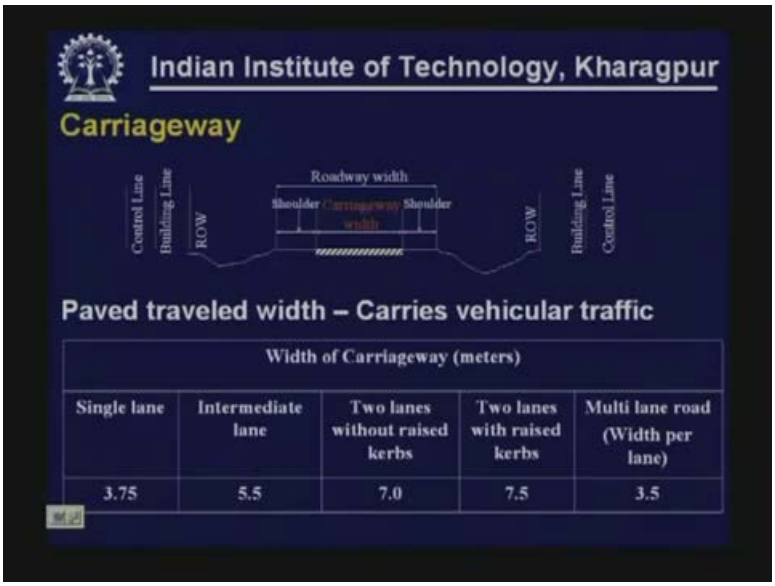

Intermediate lane road is used which is neither single lane nor width is more than single lane but lesser than standard two lane road. This is useful to keep some provision for essential maneuvers like overtaking or even a vehicle crossing that is when a vehicle is coming from the opposite direction, intermediate lane road is useful for completing the crossing maneuver. Now how these widths are decided? Let us look at the sketch.

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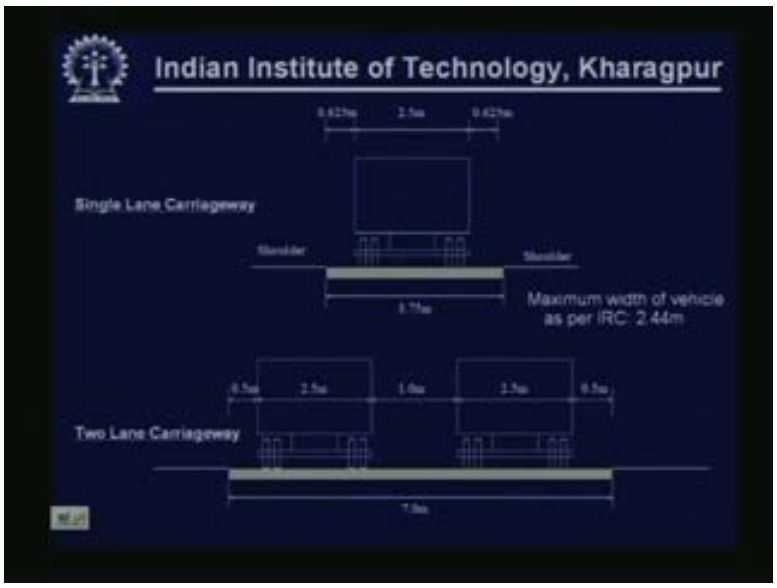

As per the standards of Indian Roads Congress the maximum width of vehicle is 2.44 m. So approximately if you take it as 2.5 m then 0.6 to 5 m clearance on each side is there making the

total width as 3.75 m for single lane road. for two lane roads it is suppose to be used for movement of two vehicle at a time so two vehicles must be placed so it is placed here each of which is 2.5 m wide, there is gap in between two vehicles which is assumed to be as 1 meter and the lateral clearance on each side is 0.5 m. So 0.5 m on each side, 1 m in between, 1 m, 2 m and 2.5 plus 2.5 so the total makes it 7 m. Thus, like that for different types of roads: single lane, two lane, multi-lane the width of carriage way is decided.

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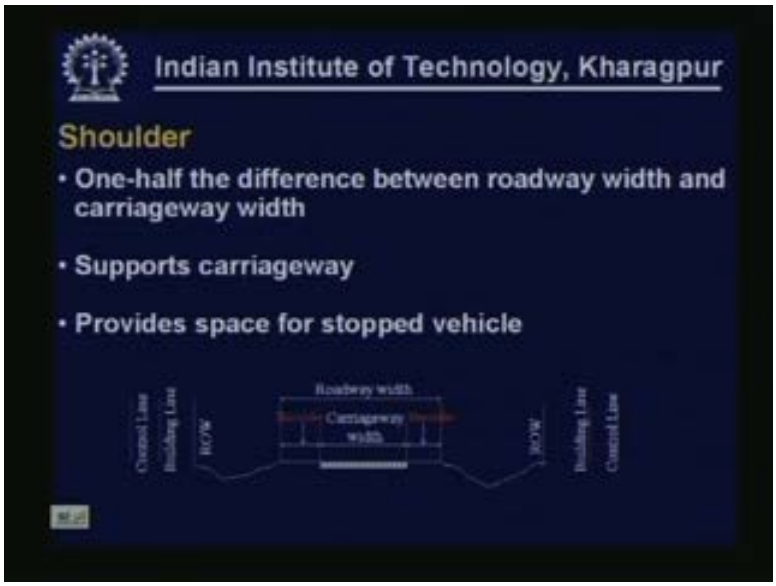

Next is shoulder. You might have seen a black top of surface and on each side some extra width or extra portion of the road which we call a shoulder. Basically it gives support to carriageway and provides a space for stop vehicle in case there is a necessity for a vehicle to stop, if there is no shoulder then it will stop right on the carriageway and it will block the entire carriageway. So, a shoulder is kept on each side of the carriage way which can be used by vehicle for stopping the vehicle and for parking. So it is basically one half the difference between the road way width and the carriageway width.

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The carriageway including separator or median, in case it is a divided road plus shoulders on both sides together is known as roadway width which is shown in the sketch. Carriageway width plus shoulder on both sides together is known as roadway width. This width of the roadway varies depending on the terrain condition. We are already familiar with the type of terrains, so, for difficult terrain that value is lesser and also it varies depending on the type of road namely NH national highways, state highways to major district road, other district road and the village road. Obviously the values are higher for higher category road namely national highway and state highway and the value reduces as we move from national highway state highway to MDR to ODR and for village road. Again the requirement for single lane and two lane are often different.

One can refer through suitable codes Indian Roads Congress codes for understanding the actual width which is required or prescribed for Indian conditions.

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For culverts up to 6 m span the normal roadway width is maintained and is measured from outside to outside of the parapet walls. In case of bridges where the span is greater than 6 m the clearway between kerbs depend on whether it is a single lane bridge or a two lane bridge or a multi-lane bridge. Again the prescribed or the recommended widths in each of these cases are available in Indian Roads Congress guideline. So you may refer to appropriate IRC code for obtaining the recommended values.

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Right of Way commonly known as ROW or land width: the area of land which is occupied or which is meant for development of road or for road purpose that area is known as right of way and the width of right of way is known as the land width. It is basically the land which is secured and preserved for road purposes, it should be adequate to accommodate all the cross section elements because carriageway shoulder and other elements are also kept within the odd place within this road width what is known as a land width or the right of way and it should also provide space for future upgradation.

Often it is necessary to upgrade the roads because of increase in traffic volume and increase in priority or the importance of the road. So it is very difficult to acquire more land in the future because the road development will definitely boost the land development so always the land or the development will take place along the side of the road and at a later date it is very difficult to acquire land for widening of roads. So right in the beginning sufficient land should be acquired for road purposes and the road still may be single lane road or may be an intermediate lane road but land width should be available so that future expansion of the road becomes easier.

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Again the width varies depending on the terrain so values are different for plane and rolling terrain and mountainous and steep terrain. For difficult terrain condition like mountainous and steep terrain the requirement of the recommended value is relatively lesser. Again it depends on whether the area is an open area or built up area because in built up area availability of land is difficult it is difficult to get free land for development of roads. so values are general lesser in built up areas and more in open areas.

Indian Road Congress guideline recommends values for different conditions. A normal value is recommended for each terrain and each type of road and it also gives a range. For example, national highway and state highway in plain and rolling terrain the range suggested in open areas is 30 to 60 meter and normally a typical value is 45 m. So again these recommended values will

be a lesser once we move from national highway and state highway to MDR Major District Road to ODR and also to village road so obviously the recommended values will be lesser.

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Next is building line and control line: Right of way is the portion which is acquired for road purpose. But as I mentioned it is often required to upgrade the road time to time because of increase in traffic volume priority and the importance of the road. So considering the future need building line and control line is kept or these two are suggested. Up to building line no building construction activity is allowed. Road is acquired up to right of way but beyond right of way up to the building line no building construction activity is allowed. This is done to make you know that the requirement of land in future is easy so that easily that land can be acquired. If there is no building, no permanent structure then acquiring land in the future will be easier.

Further to building line some exercise is controlled up to the control line. That means beyond building line building activities are allowed but still some exercise or some control is exercised on the type of building or the type of construction. Again it is basically for the same purpose keeping the option for the future so that even if buildings have come up and one has to acquire land if there is certain control on the type of development or the type of construction then it will become easy to acquire that land for road development purpose in the future. These are building line and control line. They are essentially considering the future need for the expansion or widening of the road which is being developed now.

Again to know what should be the building lines; what should be the width between the building lines and the control lines one can also understand it in terms of the set back distance IRC or Indian Roads Congress guideline the recommended values for all these conditions namely for different terrain conditions, plain and rolling terrain and also for mountainous and steep terrains. For each terrain type again values are different depending on whether it is in an open area or in built up areas and the recommended values vary depending on the type of road; requirements are

higher for national highway and state highway and slowly there is a reduction in the values once we move from national highway and state highway to major district road called MDR to further may be ODR and to VR so these values will be lesser.

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Median: Most of our highways and MDR, ODR they are basically two lanes road in most of the cases and two way traffic movements are allowed on these roads. two way traffic movement on undivided road is not desired from safety point of view because there is a great possibility for head-on collision where the fatal accidents may be the possibility of fatal accidents are much higher so medians are provided where adequate carriageway width is available. So median is essentially longitudinal space separating dual carriageways. So it essentially separates directional traffic stream for upstream and downstream, for different portions of the road so in between the median is kept.

The width of median should be more as far as possible because they are always advantageous if it is more if the width is more. However, the width of median is restricted by economic considerations because in a built up area or in a difficult terrain it may not be practically possible to have very wide median because may be it will invite land acquisition requirement or may be one as to demolish established structures so also the economy of construction should be considered and the width is restricted by economic consideration also.

The width of median should be uniform as far as possible. It is helpful in many ways. From traffic operation point of view and from safety point of view it is desirable to have uniform width as for as possible. However, it may not be practical possible to provide uniform width of median throughout the length of the road because of site condition, because of the availability of land and other practical considerations. So wherever there is a need to change the width of the median it should not be done abruptly rather a transition length should be provided for smooth change in the median width and it is easier for the driver to perceive the change and accordingly they can

also have better control on the movement of vehicles. So wherever there is a change in width it should be with adequate transition length.

The width of the median also depends on whether it is a road or whether it is a cross drainage structure depending on the type of facility and also depends on the availability of land as to what extend the land is available for road construction.

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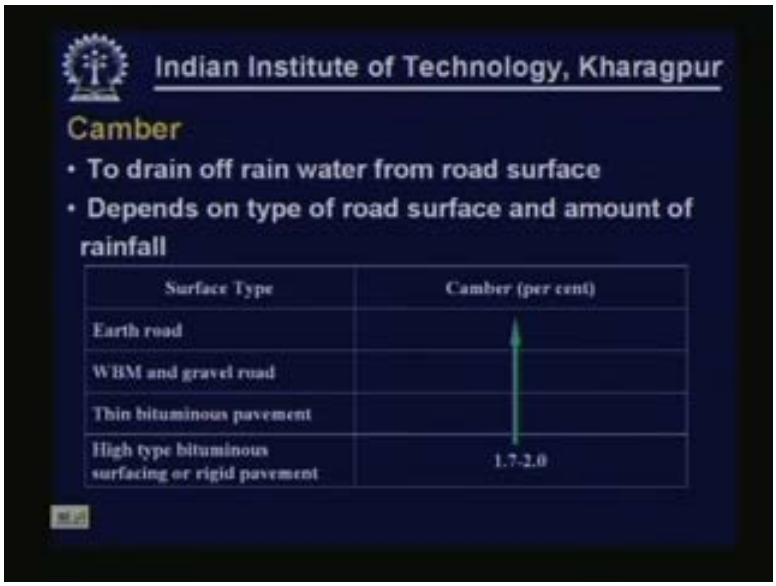

The next element is camber. You might have observed that the carriageway or the black top portion of the road is not really flat. There is a transfer slope which is provided and that transfer slope is known as camber. Why we provide this transfer slope or camber? The rain water during monsoons should be drained off immediately from the carriageway. it is essential to drain off the water from the road surface to keep the pavement in good condition. So, to drain of the water easily and reasonably in a faster manner there is a cross slope which is provided and it is known as camber.

What should be the amount of camber or amount of cross slope?
Certainly it depends on two major factors: what is the type of surface for the road under consideration. Obviously a flatter slope may be acceptable if the surface is highly impervious surface say for high type bituminous surfacing or may be cement concrete road and it should be more or it should be the slope should be steeper once you move slowly to pavement types where the surface is more and more pervious. So here we have shown four types of pavement surfaces namely: earth road, water bound macadam and gravel road, thin bituminous pavement and then finally high type bituminous surfacing or rigid pavement or cement concrete pavement. So obviously the requirements of cross slope or camber will be lesser for high type bituminous surfacing or rigid pavement and it will be more as we move towards thin bituminous pavement to water bound macadam and gravel road to earthen road so maximum value will be suggested for earthen road because the pavement surface is highly pervious.

It also depends on the amount of rainfall. So, given a type of pavement surface the requirement of cross slope will also depend on the amount of rainfall in that area. For areas where rainfall is heavy obviously the requirement of cross slope will be slightly higher. So again we may suggest for each type of pavement we may suggest different values depending on whether there is heavy rainfall in that area or rainfall is normally light to medium. So, for light rainfall area or medium rainfall area cross slope or the camber will be lesser but for heavy rainfall area the values will be higher.

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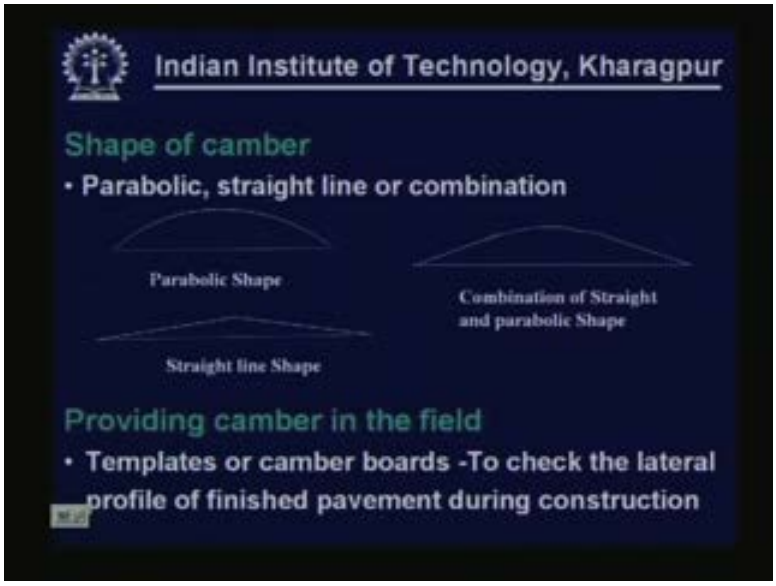

Now about the shape of camber: Different possible shapes are there which are also used like parabolic camber, straight line camber or it may be a combination of both parabolic and straight line. I have shown some sketches here. Parabolic camber is generally preferable for faster moving traffic particularly on two lane road because if we use straight line camber then it is not convenient for vehicles particularly faster moving vehicles on two lane roads to complete the overtaking maneuver. Because for overtaking on two lane road a faster vehicle has to occupy the lane which is supposed to be used for opposing traffic and then it completes the overtaking operation and comes back to its original lane. So it has to cross the central line of the carriageway which essentially will not be convenient if we provide straight line camber.

Therefore, for fast moving vehicles on two lane roads where overtaking is very common parabolic shape of camber is preferable because it keeps the shape, the carriageway will be flatter near the center of the road and it will be steeper towards the edges. However, when cement concrete road or high type pavement surface is used then the requirement of camber or the cross slope is generally lesser and we do not require really very a steep slope or the camber. in that case where it is a very flat slope one can also provide straight line camber because the actual difference a between the edge and the center will be negligible so even when there is a need for overtaking it will not be that uncomfortable for the faster moving vehicle. So where the

requirement is lesser particularly for high type pavement surface like cement concrete pavement one can also use straight line camber.

Sometimes a combination of straight and parabolic shape is also used because it is sometimes advantageous considering the traffic conditions and the requirements. Wherever the combination is used normally for the center portion a parabolic shape is used where this will help or this will result in to a flat or relatively smooth center portion and towards the edges straight line cambers are used. It is worthwhile to mention at this stage that non-motorized vehicles like bullock carts which steel wheel bullock carts may not carry heavy loads but because of the relatively lesser contact area between the steel wheel and the pavement surface the stress generated may be very very significant so there because of the shape of the camber it may happen that even full contact area for steel wheels may not be available. So if the contact area is reduced it will further increase the level of stress and needless to mention that it will invite damage for the pavement.

So one has apply judicious judgment that under what condition what type of or what shape of camber will be most suitable. We have options for parabolic camber, for straight line camber and a combination of both. So suitable shape should be suggested or recommended depending on the site condition, the traffic streams, the nature of traffic and their requirement. Now we provide camber because of smooth drainage of water so a slope is provided, what happens? If we really provide a much steeper slope obviously it will help the water to go away from the carriageway much early but there are also certain disadvantages associated with providing excessive cross slope or camber.

First of all it will cause a transverse tilt of the vehicle. normally if we consider a two lane road so the vehicle which is trying to keep himself in the lane where it is supposed to be obviously there will be a transverse tilt, it will not be comfortable for the passengers of the vehicle and also the distribution of load to two different wheels of an axel will also not be uniform so it will cause more wear or rather uneven damage of pavement and also uneven wear and tear of wheels of a vehicle.

Second: if we provide excessive slope then when there is heavy rain or places where rainfall is generally heavy cross ruts may be formed which is also a kind of damage for the pavement so cross ruts may be formed.

Third: the central seeking tendency of vehicles will increase. Because drivers, whenever there is a steep slope they try to keep their vehicles towards the center. In fact this is also another problem of straight line camber, central seeking tendency of vehicles will increase. So vehicles try to keep towards the centre so that there will not be any transverse tilt but this is again not desirable for two way traffic movement when there is two traffic movement because this will invite safety problem. Vehicles should be on their specified lanes and they should not try to use only the central portion of the carriageway for movements. So, from safety point of view also it is not desirable.

We need camber definitely adequate camber should be provided depending on the type of surface or the type of pavement and also depending on the rainfall in that area but at the same

time we must remember that excessive camber or excessive cross slope is also not desirable for the pavement and the traffic operation.

How to provide camber in the field?
When road constructions are happening cambers is to be provided at that time and one should be able to check whether adequate or the required camber is provided. To check that templates or camber boards are used and camber boards are used to check the lateral profile of finished pavement during construction. So, often camber boards are used to check whether adequate camber has been provided in the finished road and if there are any corrections to be done in the cross loop that also can be done during the construction stage.

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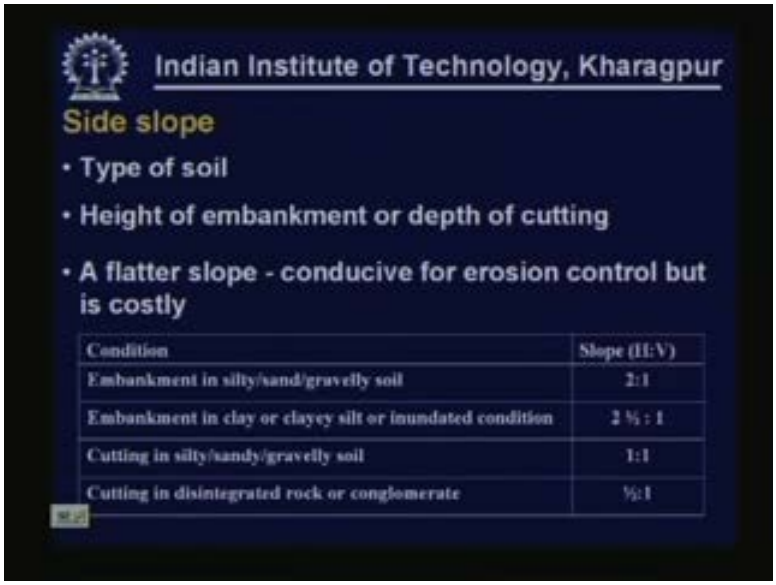

Next element is side slope: Often the roads are provided on embankment. You might have observed the roads where the level of road is generally higher as compared to the levels or the ground levels. So it is basically developed or kept on embankment. Often also there are situations whether roads are developing on cutting particularly in the hilly region. So whether it is on embankment or it is on cutting it is necessary to provide adequate slope for the embankment or cutting particularly to ensure the stability of slope.

What should be the side slope?
That will depend on what type of soil is there. So basically it depends on the type of soil and also it depends on the height of embankment or depth of cutting. It is needless to mention that obviously a flatter slope will be more stable and it is desirable. But at the same time if we try to provide a very flat slope it will no doubt be expensive or the cost incurred will be more. So there has to be a balance where it will be acceptable in terms of the stability and also it should not cause excessive amount for maintaining that slope so a balance is to be maintained.

Considering the type of soil, height of embankment or the depth of cutting different side slopes are recommended. Indian Roads Congress guideline again has prescribed different side slopes for different conditions. One can refer to those guidelines for getting the exact values under a given condition.

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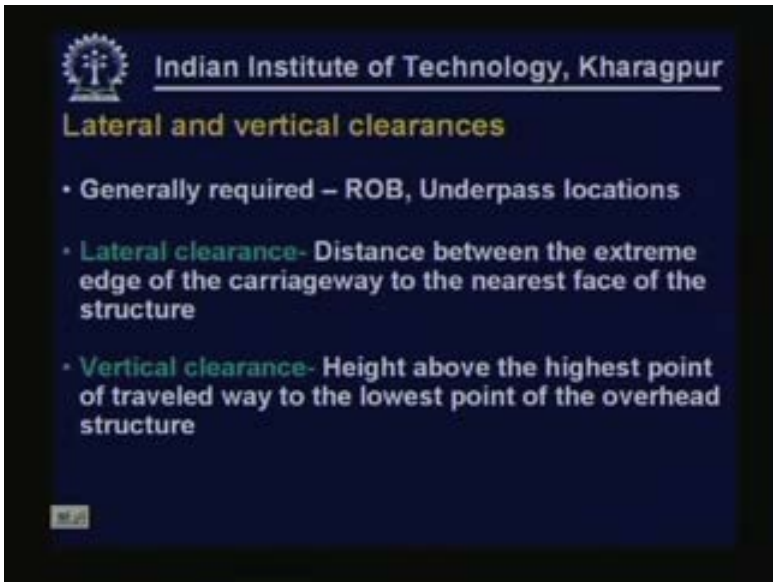

Lateral and vertical clearances: these are generally required at places where there is ROB or underpass locations. Often may be a railway line or the railway track is there and a road is crossing it at different rate may be below the railway track. So, in those cases it is necessary to ensure adequate lateral clearance as well as vertical clearance. Lateral clearance is measured or it is basically the distance between the extreme edge of the carriageway to the nearest face of the structure. So if there is a structure, often it is wall so from the edge of the carriageway to the nearest face of the wall of the structure what is the length or what is the distance that is known as lateral clearances.

Similarly, the vertical clearance is defined as the height above the highest point of the traveled way to the lowest point of the overhead structure; the highest point of travelled way or the carriageway to the lowest point of overhead structure. Now what is that distance that is known as vertical clearances. So, at ROB and underpass locations adequate lateral clearance as well as vertical clearance is to be given. Again what should be the lateral clearance minimum acceptable lateral clearance and minimum acceptable vertical clearance the values are given in Indian Roads Congress guideline. One can refer to the suitable guideline for getting the recommended values.

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Kerb is essentially a vertical or sloping member along the edge of a pavement or paved shoulder. Kerb is normally desirable for urban roads. It facilitates and controls drainage, it strengthens and protects pavement edge, it also helps to delineate pavement edge and presents a more finished appearance for the road. It also encourages orderly roadside development. So there are many functions for kerb. But it is a common feature for urban roads. Normally for non-urban situations or the rural environment kerb is not provided.

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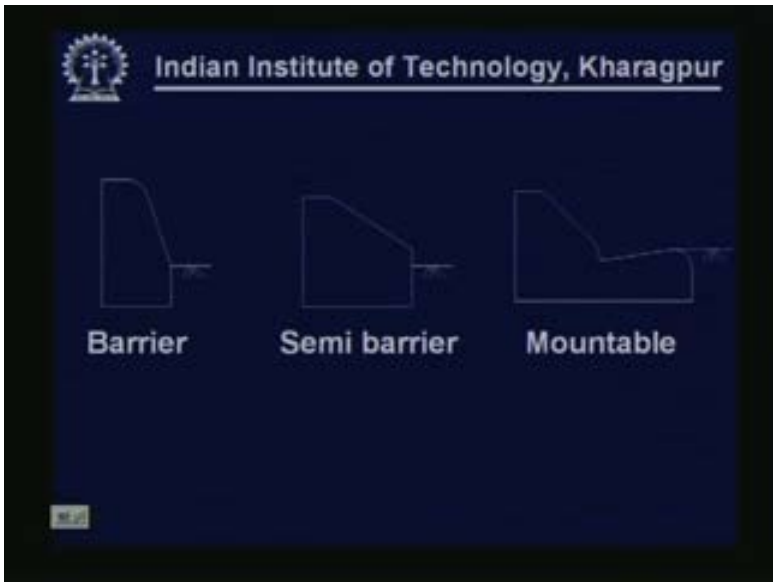

There are different shapes of kerb as shown here: barrier type kerb, semi-barrier type kerb and mountable kerb. Mountable kerbs are provided where we want the vehicle to cross the kerb with very minimum difficulty. Yes, there is kerb, there is a barrier but vehicle can easily cross that barrier. So wherever we feel that there should be provisions for vehicle to cross the barrier easily there we use mountable kerbs.

The other extreme is barrier type kerb which is very difficult for vehicle to cross. So wherever in urban environment we provide kerb to ensure the safety of pedestrians, there, often we provide barrier type kerb so that it cannot be crossed by vehicles so easily. Semi-barrier type kerb is in between which again can be crossed but with some difficulties.

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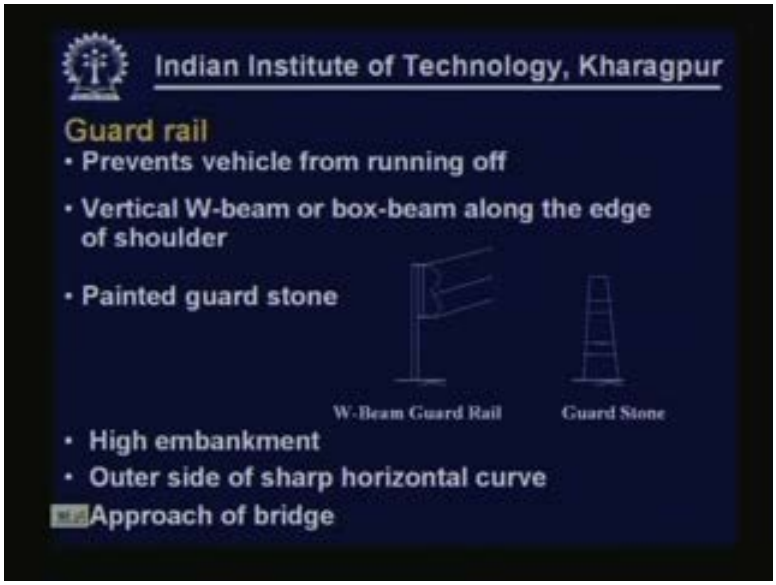

Guard rail: they prevent vehicle from running off. Wherever there is a possibility for vehicles to go away from the road there guard rails are provided. Vertical W-beam or box-beams are used and sometimes guard stones are also used. You might have seen isolated stones by the side of the road, they are basically guard stones painted in prescribed colors and guard rail is generally continuous. Earlier in most of the cases guard stones are used. Nowadays for almost all the modern road constructions W-beam guard rails are used. They are particularly suitable for high embankment or at outer side of sharp horizontal curve and approach of bridge where there is a possibility or there is high possibility that a vehicle may go out of the travelled way.

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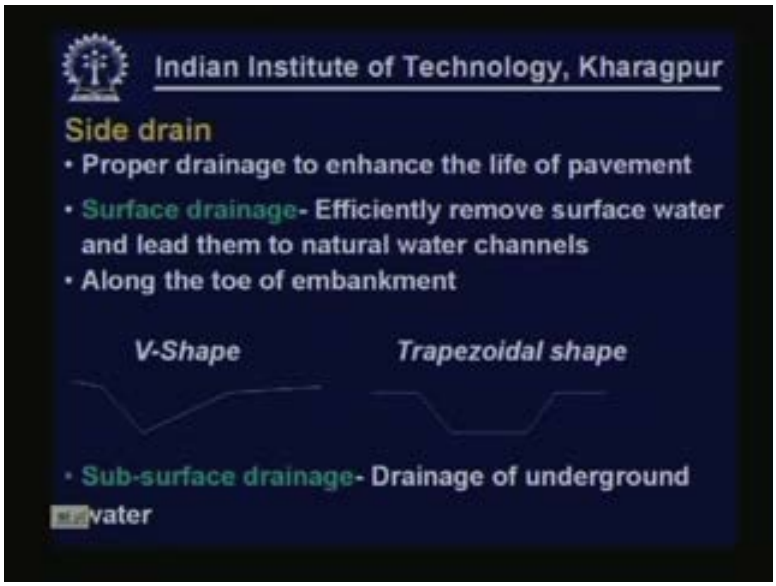

Side drain: Proper drainage of water is essential. We have talked about the camber but also one has to look into the need for surface drainage and sub-surface drainage. Surface drainage is required to efficiently move surface water and lead them to natural water channels. They are normally provided along the toe of embankment, they may be of V shape or trapezoidal shape. So the water which is coming out through camber should be channelized to natural water channels so we need to provide surface drainage.

Also, there is requirement for sub surface drainage particularly it is the drainage of underground water which is dealt separately under pavement design because this directly does not come under cross section elements.

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There are other facilities which are required like parking lanes. It is typical for urban roads. So some extra width is provided so that particularly cars can be parked by the side of the road but not encroaching that portion of carriageway which is supposed to be used for moving traffic. So it is typical for urban roads and for on street parking. So an extra width is provided so that parking can be done on that portion with minimum difficulties or minimum disturbance to the moving traffic stream.

Often parallel parking is done under parking lane. Of course other types of parking like angular or angular or may be perpendicular parking is also possible. The purpose or the process is generally same, again providing extra width but if it is provided for the trucks so that drivers can access to road side amenities and also the stop the vehicle for repair or maintenance purpose. Again an extra width is provided which is known as truck lay-bye. So at regular intervals truck lay-byes are provided so if the drivers have to stop they will stop their trucks there for repair, maintenance and also for accessing road side amenities.

Similarly, for bus bay again it is an extra widening but purpose is different. The purpose is to stop the buses at bus stops. But it should not be stopped right on the portion of carriageway which is predominately for through traffic movement. So it is a widening portion widened portion to avoid conflicts for other moving vehicles. Foot path is again provided on both sides of the road. Typical features are for urban roads considering the safety of pedestrians.

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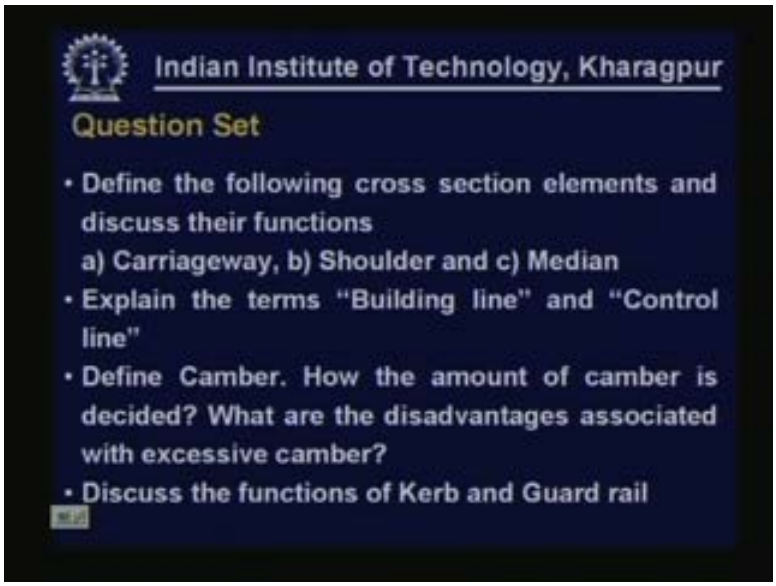

Now let me put some questions related to the topic what we have discussed. We have discussed about various cross sectional elements, their functions. Try to answer these questions.

Define the following cross section elements and discuss their functions: carriageway, shoulder and median.
Explain the terms building line and control line:
Define camber; how the amount of camber is decided what are the disadvantages associated with excessive camber?
Discuss the functions of kerb and guard rails:

The answers to these questions will be discussed during next lesson.

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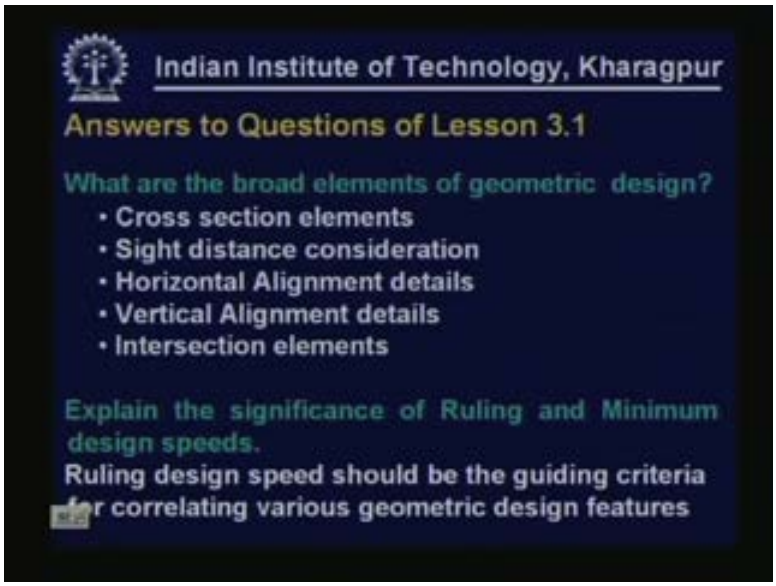

Now I shall quickly go through the answers of the questions we raised during lesson 3.1.
What are the broad elements of geometric design?
They are essentially cross section elements, sight distance consideration, horizontal alignment details, vertical alignment details and intersection elements.

Next question was; explain the significance of ruling and minimum design speeds:
Obviously we try to design the facilities based on ruling design speed only when due to sight conditions there are extreme difficulties we have another limit which is known as minimum design speed.

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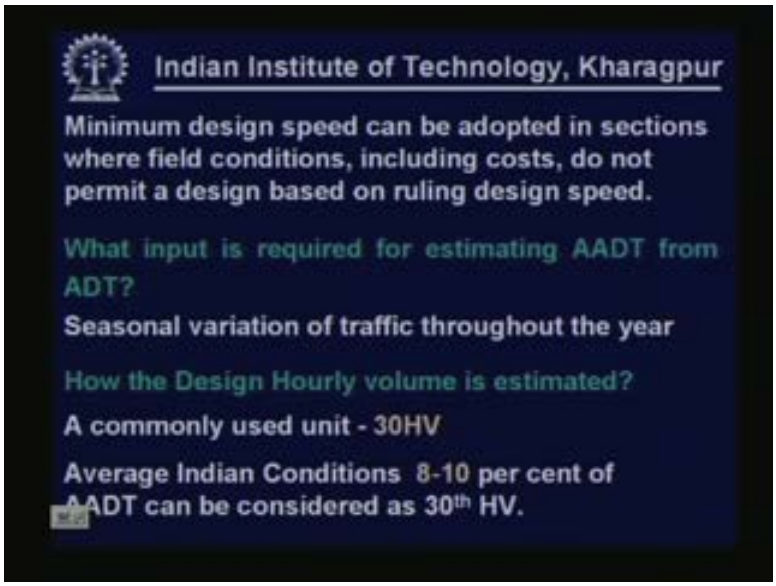

What input is required for estimating AADT from ADT?
The only difference is ADT does not consider seasonal variation, AADT considers seasonal variation. So to convert ADT to AADT we need seasonal variation of traffic data throughout the year.

How does design hourly traffic volume is estimated?
We have discussed the commonly used unit is thirtieth highest hourly volume which is 8 to 10 percent of the AADT in most of the cases in India.

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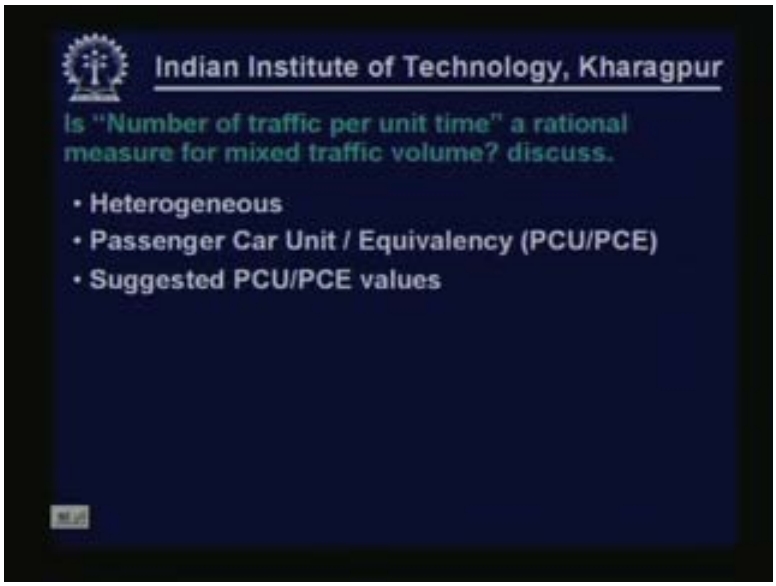

The last question was; is number of traffic per unit time a rational measure for mixed traffic volume?
The answer is no because they are different in size, dimensions, acceleration deceleration capability etc so, for heterogeneous traffic movement number of traffic is not a proper measure, for that one we use passenger car equivalency factor PCE or PCU and Indian Roads Congress guideline and other guidelines they suggest suitable PCU values which are to be used to convert heterogeneous traffic to a stream of homogenous traffic, thank you.