Introduction to Transportation Engineering
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Lecture - 14
Horizontal Alignment - 1

Horizontal alignment part I.

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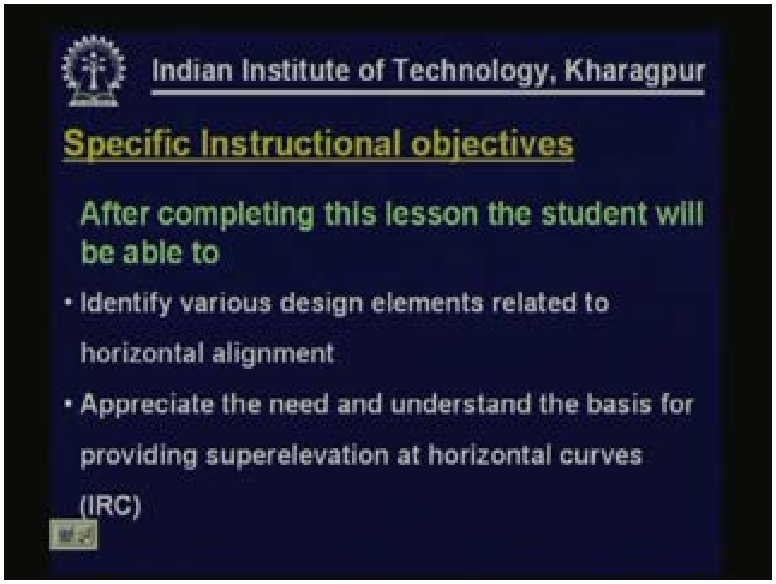

After completing this lesson the student will be able to identify various designed elements related to horizontal alignment. The student will be able to appreciate the need and also understand the basis for providing Superelevation at horizontal curves and particularly the student will be able to understand the approach which is normally followed in India that is the IRC approach.

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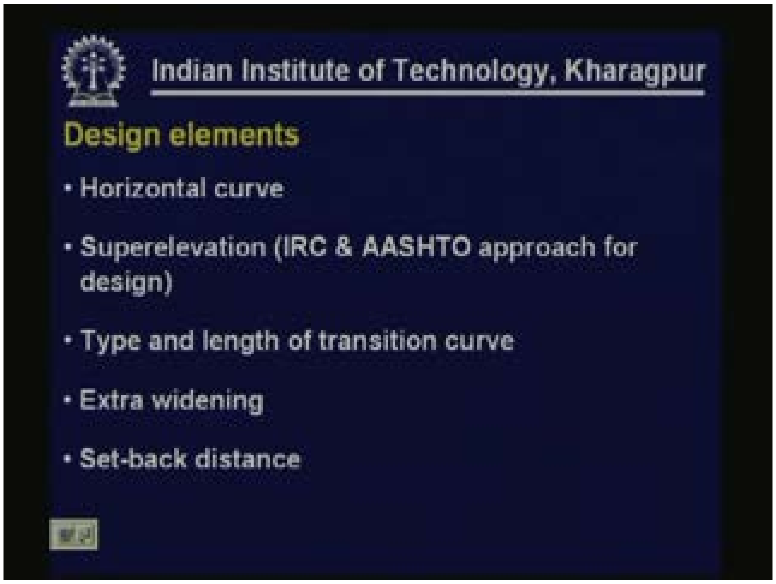

Let us look at various designed elements related to horizontal alignment. They are horizontal curve because a road can never be perfectly straight. A straight road is also not preferable from safety point of view. So, a road essentially consists of a number of tangents and curves or the curves are essential components of road way.

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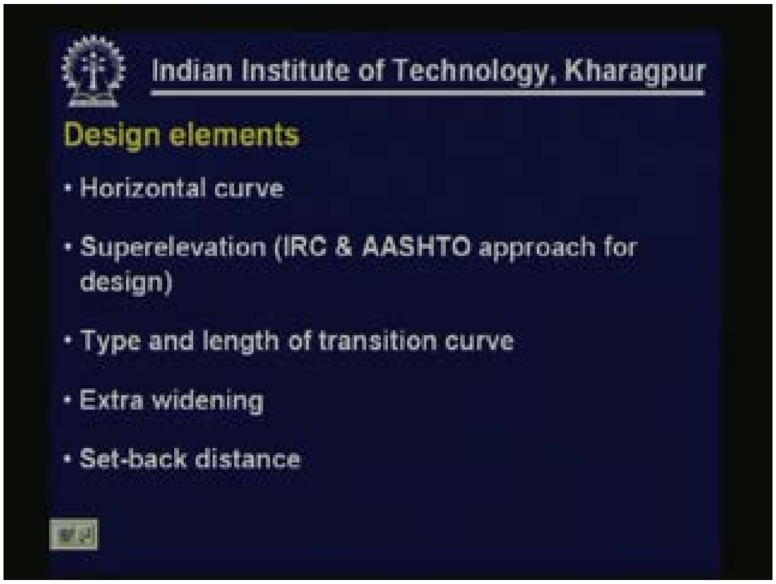

With curves one should also understand the concept of Superelevation and understand the basis for providing Superelevation. So Superelevation is another designed element. Then in most of the cases whenever there is a horizontal curve at both ends of horizontal curves there are transition curves in most of the cases.

So one should also understand why transition curves are necessary and understand the design basis that means how the length of the transition curve should be decided. Then on horizontal curves the rear axle and front axle or the rear wheels and the front wheels rather they do not follow the same track. So often it is necessary to widen the road considering various aspects; mechanical requirement, psychological requirement etc. So one should also understand the extra widening why it is necessary and how one can calculate the required extra widening for a given road.

Then on the horizontal curves sight distance is a major consideration. Particularly the inner sight of the curve should be free from all sorts of encroachment. There should not be any obstruction that may cause difficulty in terms of available sight distance. So up to certain distance inside the horizontal curve it should be free from obstruction that's how we try to calculate how much portion or how much length should be free from obstruction. So there actually the set back distance is meaningful. So altogether horizontal curves, Superelevation, transition curve, extra widening and set back distance these are the five major designed elements when we are talking about the horizontal alignment.

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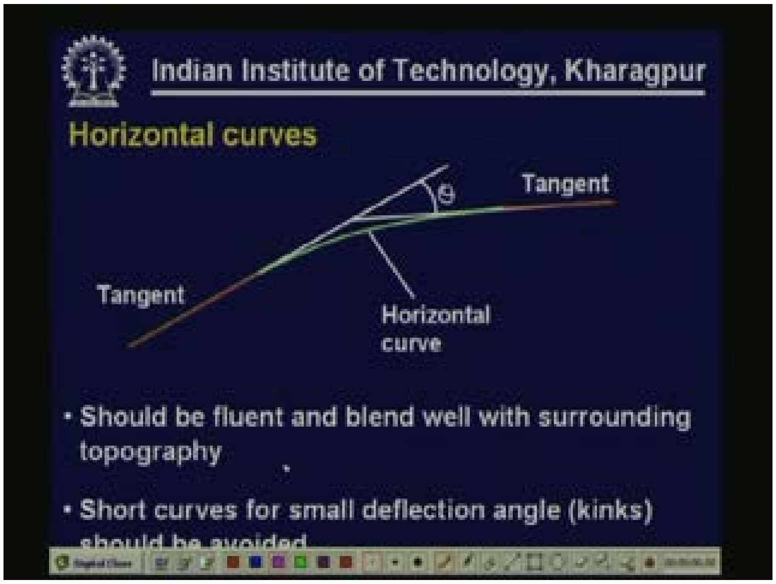

Now as I mentioned that a road can never be perfectly straight even if it is possible to have a road which is perfectly straight it is not desirable to have a perfectly straight road for a longer length from safety point of view. So ideally a road should consist of a number of tangents and horizontal curves. That's what is shown here in the sketch.

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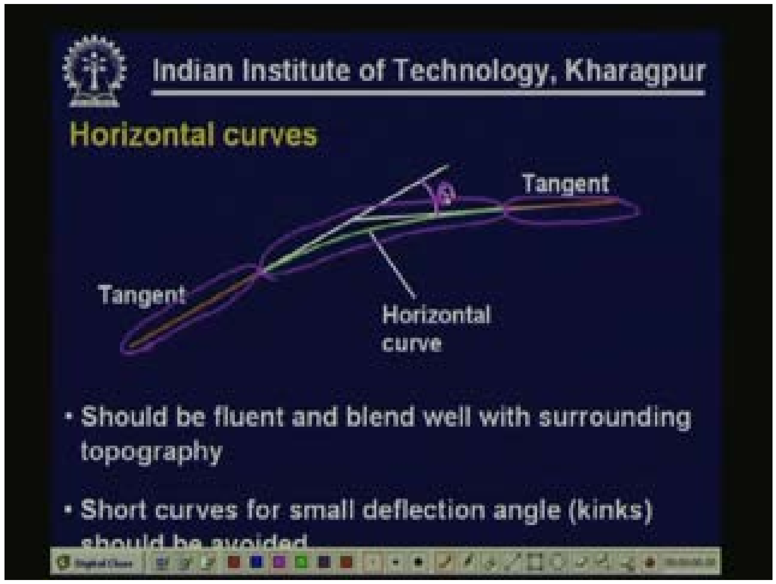

This is the tangent portion of the road. This is also another tangent and in between a horizontal curve is inserted which is shown as green lights. So this is the horizontal curve. So we have tangent at both ends and in-between a horizontal curve is inserted. In most of the cases are for in fact for designed purpose always we use circular curve for this purpose or this stretch. As shown here this is the tangent and here there is another tangent so this angle we call it as deflection angle denoted here as theta.

Now some of the dos and don'ts in fact some of the don'ts say here in this case are:
Should be fluent and blend with surrounding topography. Short curves for small deflection angles should be avoided. Curves in same direction separated by short tangents should again be avoided and replaced by a large single curve. Sharp curves should not be introduced at the end of long tangents. Compound curves should be avoided when unavoidable limiting value of ratio of flatter curve radius and sharper curve radius is 1.5:1; this is as per the recommendations of Indian Roads Congress.

So what essentially I am trying to indicate is that horizontal curves are essential components of road way. Basically from one tangent to another tangent in between we provide horizontal curve which is mostly circular curve. But these are some of the aspects which we should keep in mind particularly some of the don'ts for we should not do when we are putting a circular curve in between two tangents.

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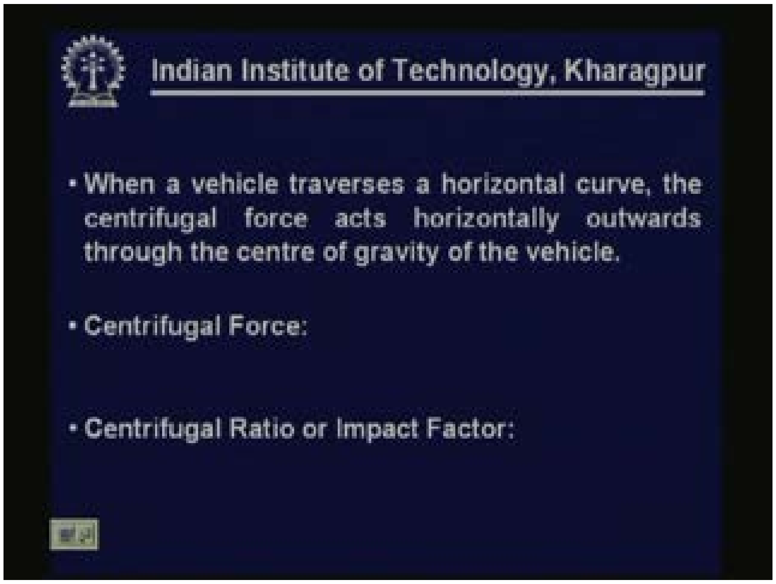

Now with this background let us try to see what happens to a vehicle when the vehicle is trying to negotiate a horizontal curve. When a vehicle negotiates a horizontal curve the centrifugal force acts outwards and this centrifugal force acts outward through the center of gravity of the vehicle cg of the vehicle and the centrifugal force we can write it like this.

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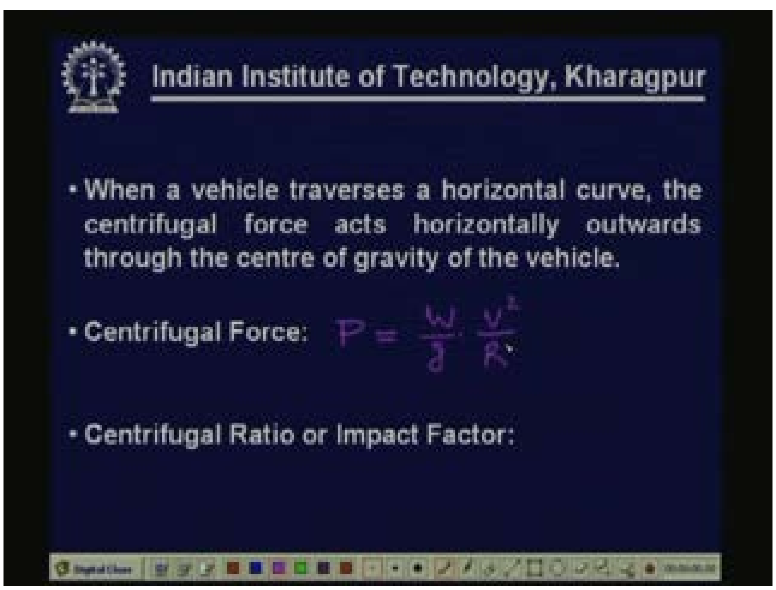

If 'P' is the centrifugal force then P = W/g V square/r popularly mV square/r if m is the mass. So w/g V square/r this ‘P’ is the centrifugal force so if a vehicle suppose is negotiating this horizontal curve then this force is acting outward in the outward direction. Here w is the weight of vehicle, g is acceleration due to gravity, V is the speed of the vehicle and r is the radius.

Now you can see from this equation P/W = V square/gR. This P/W this term it is known as centrifugal ratio or it is also known as impact factor. So what we understand centrifugal force which is acting outward is w/g into V square/r as shown here. Now this ratio P/W it is known as centrifugal ratio or impact factor and this impact factor equals to V square/gR where V is the speed of the vehicle, g is acceleration due to gravity and r is the radius of circular curve.

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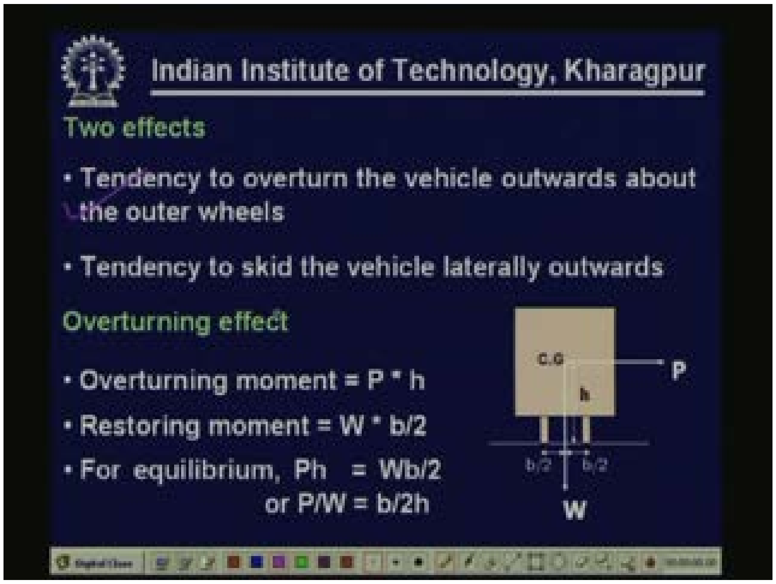

Now when a vehicle is negotiating a horizontal curve this centrifugal force has two distinct effects. One is it tries to push the vehicle outward and another effect is it tries to overturn the vehicle above the outer wheel. So both effects may have unwanted consequence in terms of the safety aspects.

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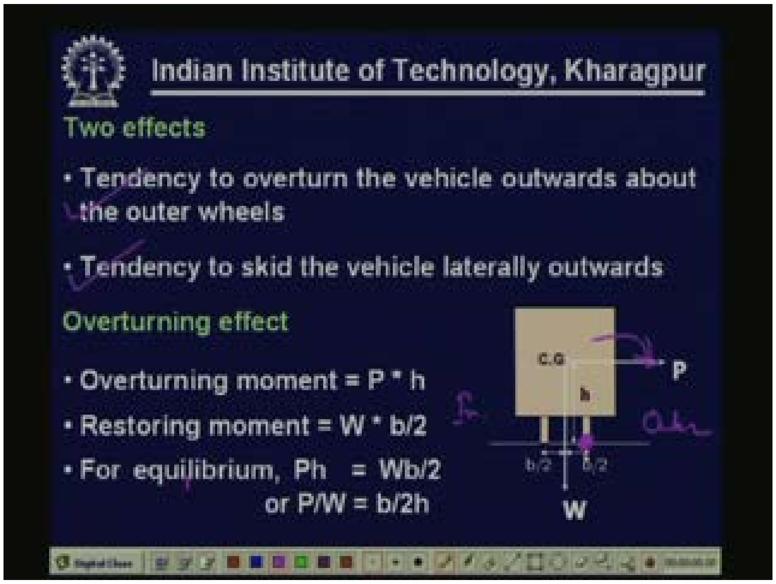

So let us see, the effects are tendency to overturn the vehicle outwards about the outer wheel this is one effect and then the other effect is tendency to skid vehicle laterally outwards, these are the two effects. Now let us see try to understand the overturning effect. Let us consider that this is a vehicle with the cg of the vehicle located at this point so the centrifugal force 'P' is acting outward. Obviously this is the outer edge and this is the inner edge of the curve. So centrifugal force is acting outwards this is 'P', weight of the vehicle is acting like this 'W', now if it take the moment about this outer wheel that means about this point then the overturning moment is 'P' multiplied by h where h is the height of center of gravity of vehicle about the road surface so 'P' into h is the overturning moment so this has the tendency to shift or to turn the vehicle about the outer wheel.

Now this tendency is restored by a restoring moment which is nothing but this weight of the vehicle into b/2. If b is the distance between these two wheels or the total width the width of the wheel base then the restoring moment is w multiplied by this distance. So this moment p into h is trying to turn the vehicle towards the outer side and this tendency is registered by the restoring moment w into b/2.

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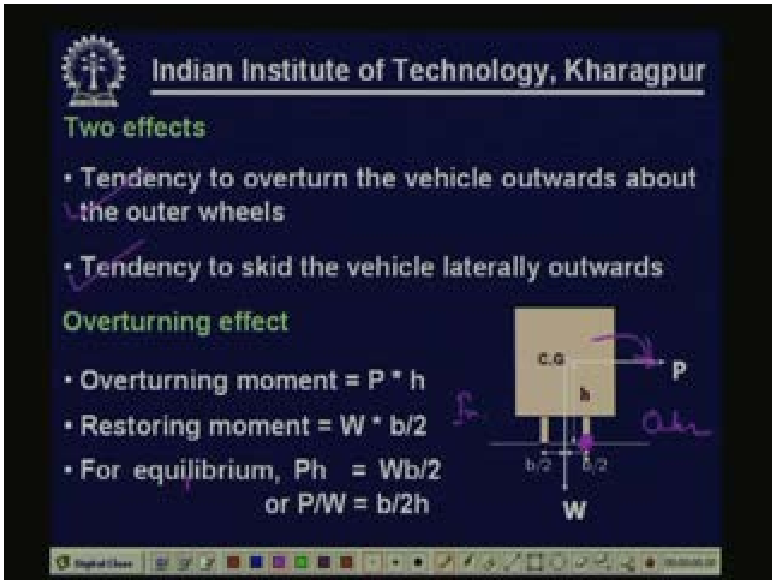

So in limiting case or under equilibrium p into h should be equal to w into b/2 that means overturning moment equal to restoring moment. So in that case P/W the centrifugal ratio or the impact factor is b/2h so this is one equilibrium limiting condition.

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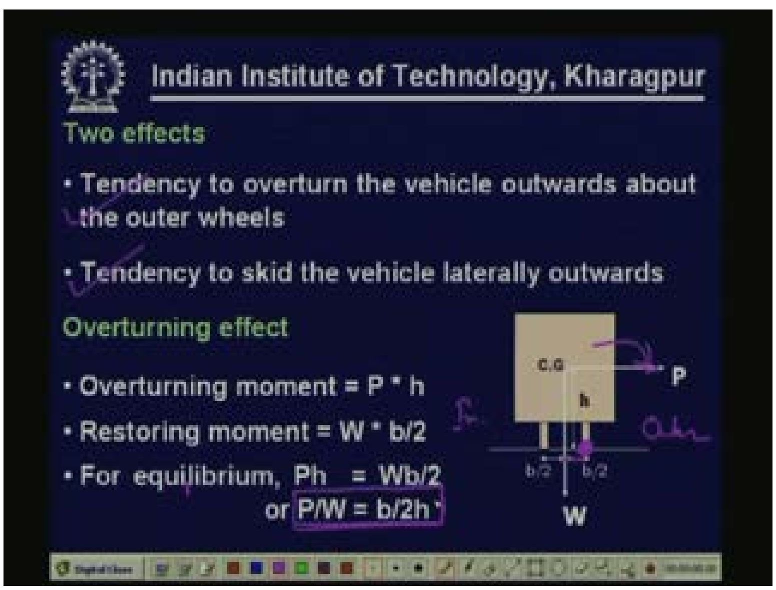

That means if P/W is more than b/2h then the over turning moment will be more than the restoring moment and the vehicle will overturn about the outer wheel. So for safe moment the centrifugal ratio or the impact factor must be less than equal to b/2h. In fact equal to is the limiting condition.

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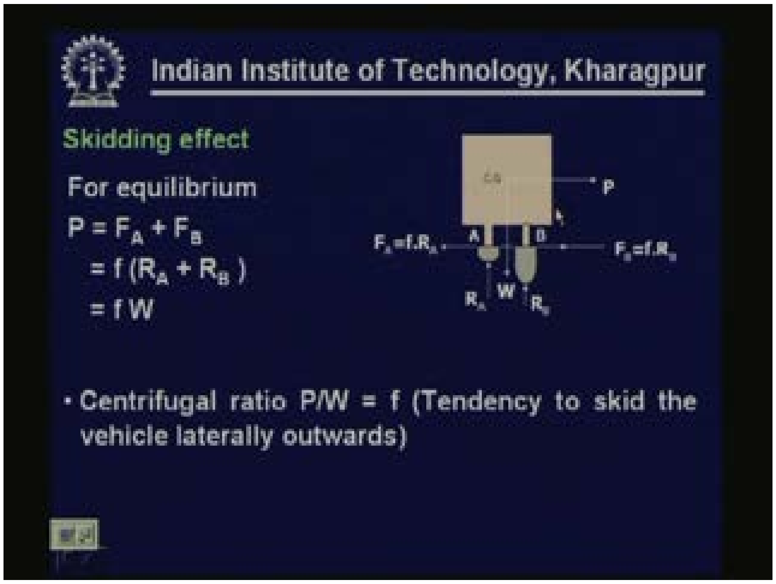

Now let us see the skidding effect. Again a free diagram is shown. The centrifugal force 'P' is acting outward. Now in the transverse direction if we consider the equilibrium then this ‘P’ force is resisted by skidding resistance which is shown here as F_A and F_B.

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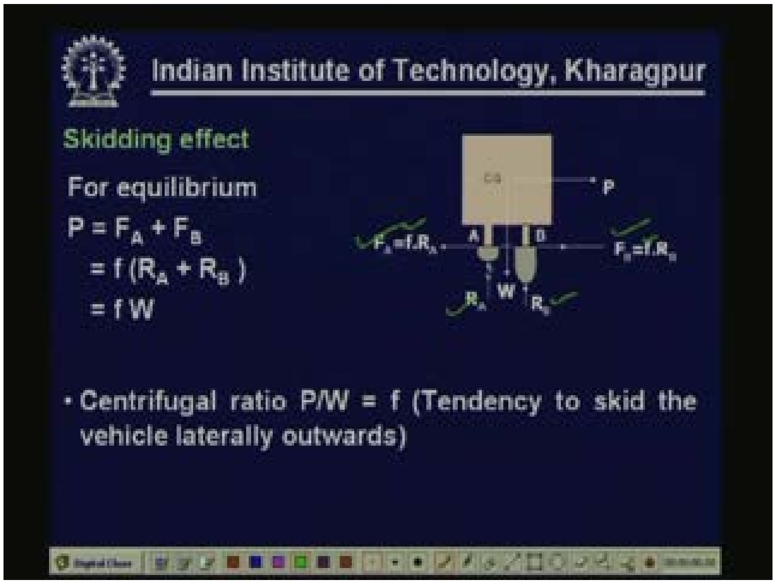

Now F_A and F_B is nothing but coefficient of friction this is in lateral direction that is f multiplied by reaction R_A as indicated here and R_B correspondingly. So R_A and R_B in fact together is nothing but the weight of the vehicle which is acting downwards because this weight is balanced by R_A and R_B reaction at wheel a and reaction at wheel b respectively.

So if we consider now the equilibrium then this $P = F_A + F_B$. Now F_A and F_B is nothing but coefficient of lateral friction f into $R_A + R_B$ reaction so that means it is f into W. So in this case impact factor or the centrifugal ratio limiting value P/W = f. So, if the impact factor or the centrifugal ratio is more than the coefficient of friction f then the vehicle will be skidding because the centrifugal force will be more than the skidding resistance so vehicle will laterally skid outward. Therefore in order to have safe movement this centrifugal ratio must be lesser than the coefficient of friction.

In fact it is equal to coefficient of friction just that limiting condition so preferably it should be lesser than the coefficient of friction. So if you want the vehicle to remain stable and safe then the vehicle should not overturn should not laterally move outward also. Therefore P/W or the impact factor or the centrifugal ratio should be less than b/2h and the centrifugal ratio should also be less than the coefficient of friction. But this coefficient of friction is in the transverse direction For a flat road in the transverse direction the centrifugal force of the impact factor should be less than f and it should also be less than b/2h.

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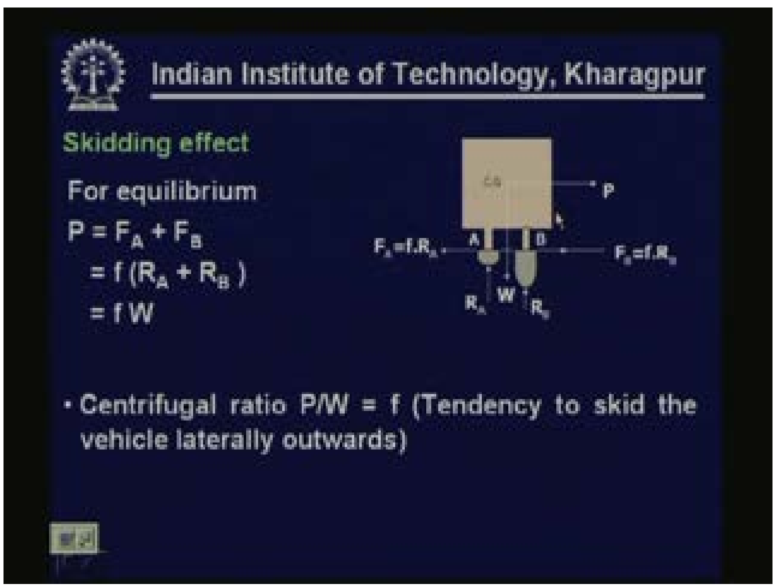

Now to counteract the effect of centrifugal force and to reduce the tendency of the vehicle to overturn or skid, the outer edge of the pavement is raised with respect to the inner edge, and this transverse inclination of the pavement surface is known as Superelevation or Cant. That means earlier we considered a vehicle like this.

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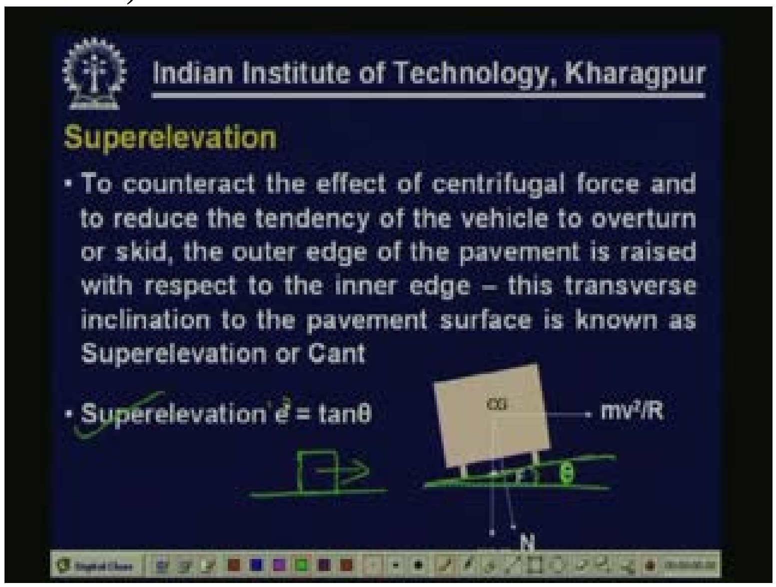

Now we have made an inclination of road surface in the transverse direction like this at angle theta so a slope is provided to counteract the effect of centrifugal force and also to reduce the tendency of vehicle to overturn or skid then this transverse inclination is known as Superelevation. So Superelevation we denote it normally by e and it is equal to tan theta where theta is this angle. Therefore Superelevation is equal to tan theta. Now let us see the analysis.

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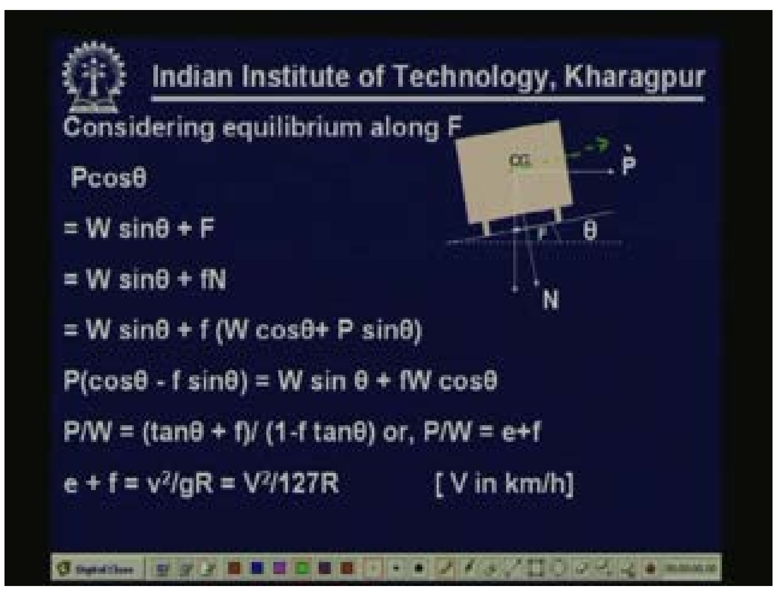

Let us consider the same vehicle again where we have to provide a slope in the transverse direction with an amount theta so that the Superelevation is actually tan theta. Now this 'P' or the centrifugal force is acting outward or in the outward direction. So if we now take component of this 'P', observe it carefully, along that inclined surface along f then we can actually take it like this.

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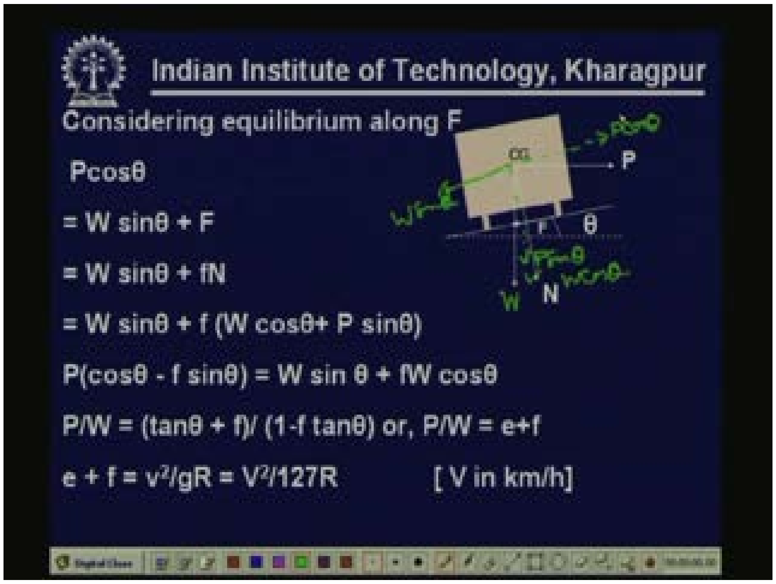

Now this component is actually P cos theta and perpendicular to the surface this component is actually P sin theta. Similarly the weight of the vehicle is acting vertically downward. If we take the component parallel and perpendicular to the inclined surface then this component is again added W cos theta and in this direction the component is W sin theta. So now if we consider that equilibrium then this P cos theta should be counteracted or should be equal to W cos theta + the f the force what we mentioned earlier the skidding resistance. Now this f is nothing but coefficient of friction f multiplied by the total normal force.

Now what is the total normal force?
Normal force here in this case is nothing but W cost theta as we have indicated this is acting vertically downward so perpendicular to the surface this component is W cos theta + this is the centrifugal force so this component of the centrifugal force is P sin theta.

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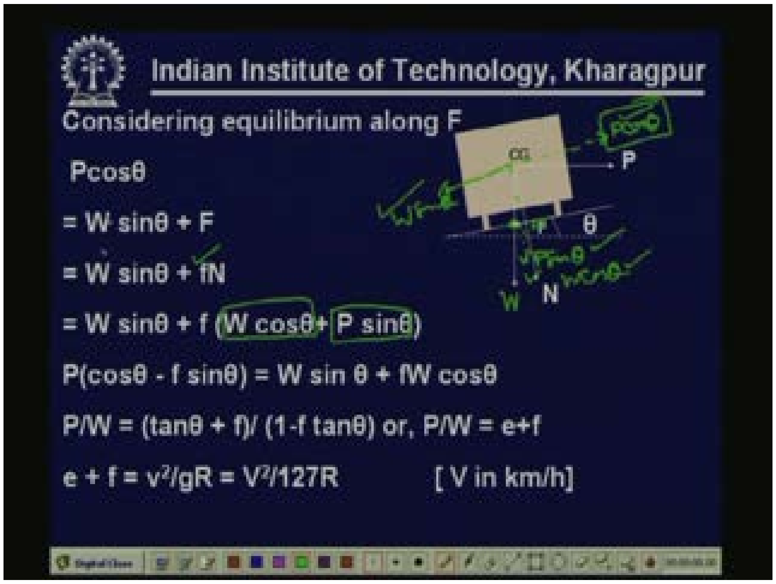

So what is the total force acting in the normal direction is W cos theta this component + P sin theta. Now this total force multiplied by f is the total resistance. So this f which is nothing but f into W cos theta + P sin theta + W sin theta that is this component together should balance this P cos theta component. So equilibrium equation we can write it like this; P cos theta = W sin theta + f coefficient of friction into P sin theta + W cos theta. Now if we take this P sin theta component to the left hand side then what we find is P into this cos theta – this f sin theta equal to W sin theta this component + fW cos theta and that's what remain.

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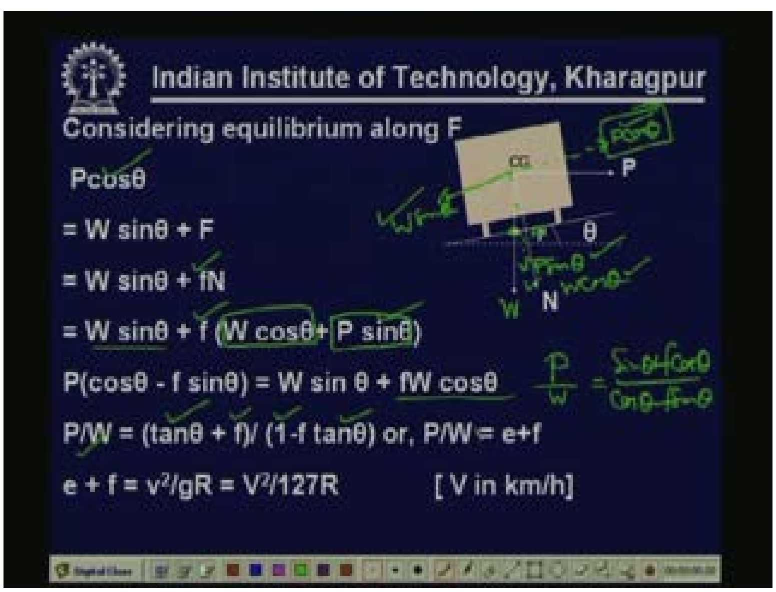

Now if I divide both sides, and P/W if you want to calculate then P/W is nothing but sin theta + f cos theta/cos theta – f sin theta. So P/W equal to sin theta + f cos theta/cos theta – f sin theta.

Now if we divide both denominator and numerator by cos theta then P/W becomes tan theta sin theta/cos theta so it becomes tan theta + f/cos theta/cos theta so 1 – f again sin theta/cos theta so f tan theta. Now because normally this transverse slope which is provided is not very high, it is a very small angle theta. Therefore this sin theta and tan theta multiplied by f 1 – f tan theta this is practically 1 – f tan theta = 1 or unity because f tan theta is a very negligible quantity because tan theta is small so tan theta itself is a very small quantity multiplied by the coefficient of friction which is again a small value so 1 – f tan theta is almost equivalent to 1. Therefore what we get P/W = tan theta + f. But tan theta is again nothing but the Superelevation what we normally denote as e so P/W = e + f.

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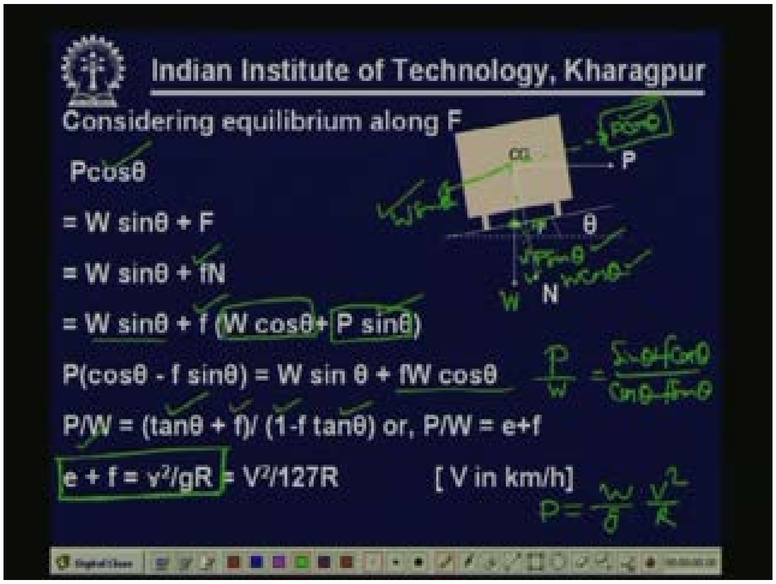

Now if you remember that P/W or the impact factor is nothing but V square/gR because basic equation was the force was W/gV square/R so WP/W = V square/gR so if we replace P/W/V square/gR then this becomes e + f = V square/gR. This is the very basic equilibrium equation we shall use frequently in the subsequent discussion. So V square/gR = e + f. Superelevation + coefficient of friction together should be equal to V square/gR. But in this case this V is normally expressed as meter per second.

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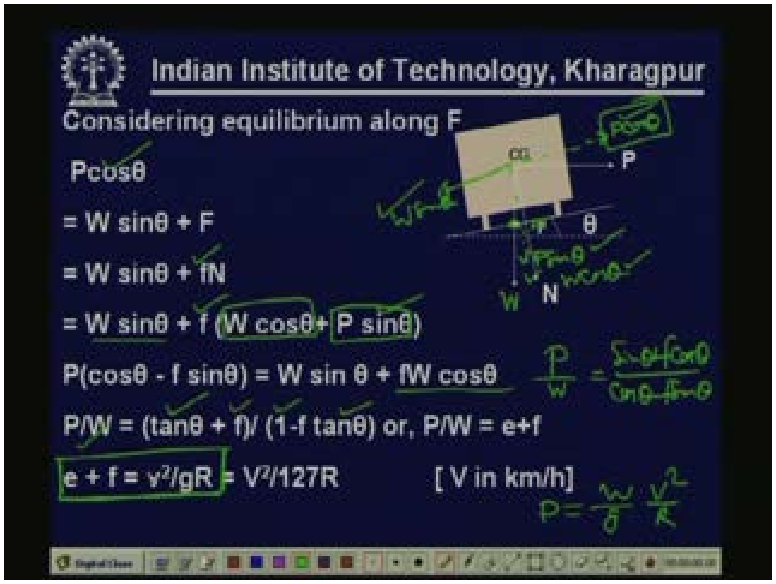

If we express this speed in kilometer per hour and use the value of g acceleration due to gravity then it becomes V square/127R.

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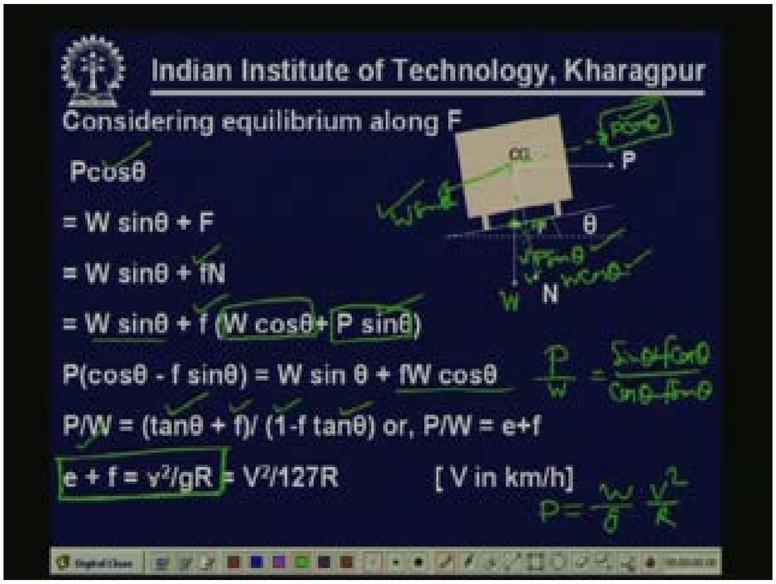

Basically it is the same equation the unit of V is different, here in this case it is kilometer per hour and we have already put the value of g inside the equation. Then it becomes e + f equal to V square by 127R so this becomes the equilibrium equation. Thus one can use either e + f = V square to gR where V is in meter per second or e + f equal to V square/127R where V is in kilometer per hour and in both cases 'R' is in meter. Therefore this is the basic equilibrium equation which will be used subsequently for Superelevation design also.

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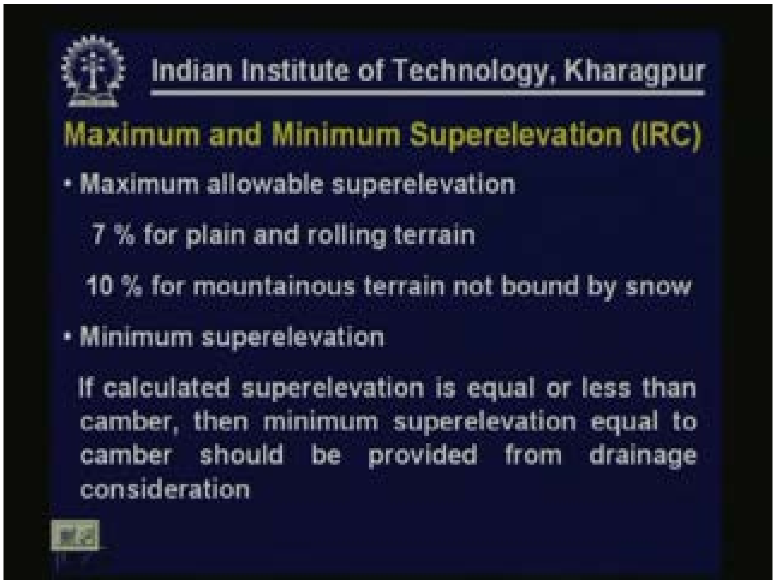

Now let us try to understand the provisions for maximum and minimum Superelevation. Maximum allowable Superelevation is decided based on several practical considerations. What we are studying now or discussing now is the recommendations which is followed in India or the recommendations of the Indian Roads Congress. As per the recommendations maximum allowable Superelevation is 7% for plain and rolling terrain and one can also allow Superelevation up to 10% for mountainous terrain not bounded by snow.

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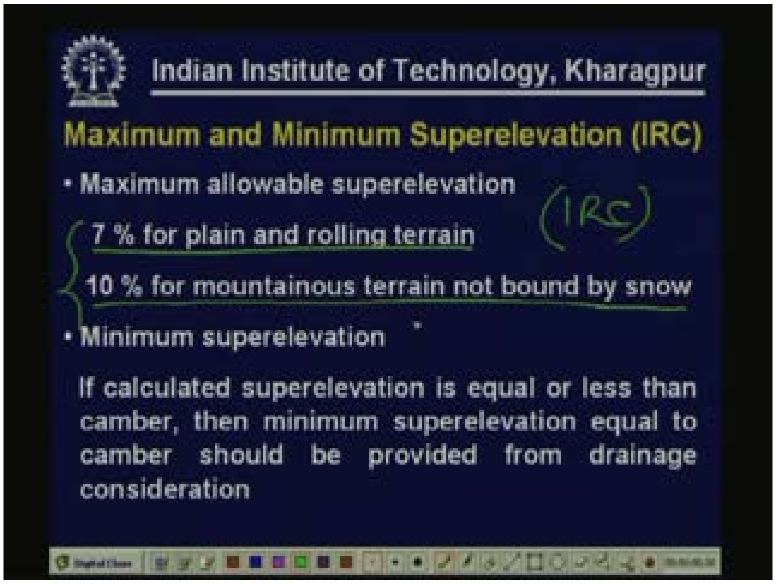

So normally it is 7% for plain and rolling terrain and it can go up to 10% for mountainous terrain not bounded by snow. If it is bounded by snow obviously it will be again 7%. But this is the provision as per the Indian conditions, these are the recommendations as per IRC or the Indian conditions. We shall study later the recommendation of AASHTO or the American Association of State Highway and Transport Officials.

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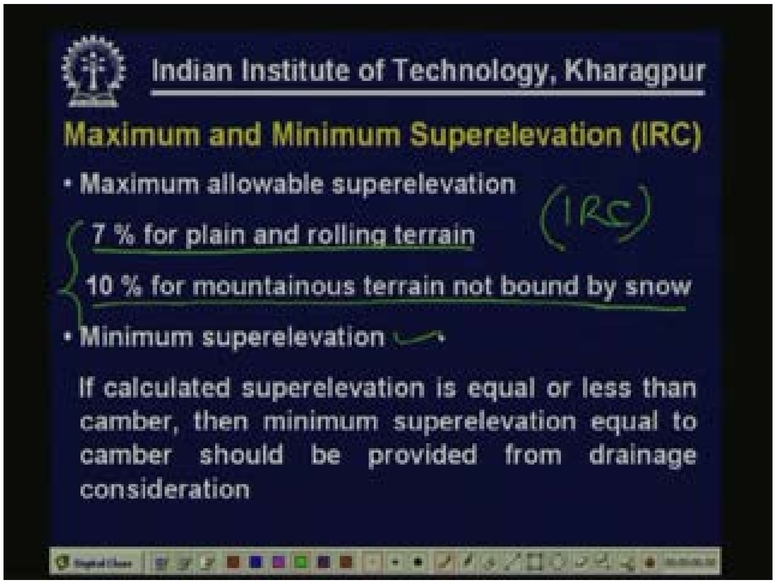

There is a minimum Superelevation, one may be surprised why there is a need for minimum Superelevation. But one can recall the discussions from the earlier lessons about the camber. Camber is also a cross slope, Superelevation is also a cross slope so both are basically cross slopes. The purpose of camber was the drainage consideration. From drainage considerations we discussed the need about the camber. For Superelevation the purpose is something else, the purpose is to counteract the centrifugal force in a meaningful way.

So if we find that the required Superelevation is very insignificant in fact it is lesser than the required camber then actually the camber should be the minimum or the lower limit of the cross slope. Because if we provide a cross slope even milder than the required camber then there will be drainage problem and pavement will be damage in due course of time due to several other reasons. We have discussed these earlier.

So there is a limiting value even on the lower side. Yes there is a maximum value which is seven percent it may go up to ten percent for hilly region not bounded by snow and on the other hand there is a lower limit the cross slope should never be lesser than the required camber. Again for camber what should be the actual value? That will again depend on the rainfall whether it is a heavy rainfall area or medium rainfall area and what is the type of surface that is used for the road whether it is impervious surface or it is other type of surface say earthen roads or gravel roads. Obviously the requirement of camber will depend on all these considerations. But camber should be the minimum acceptable slope and also there is a prescribed limit for the maximum slope or the Superelevation.

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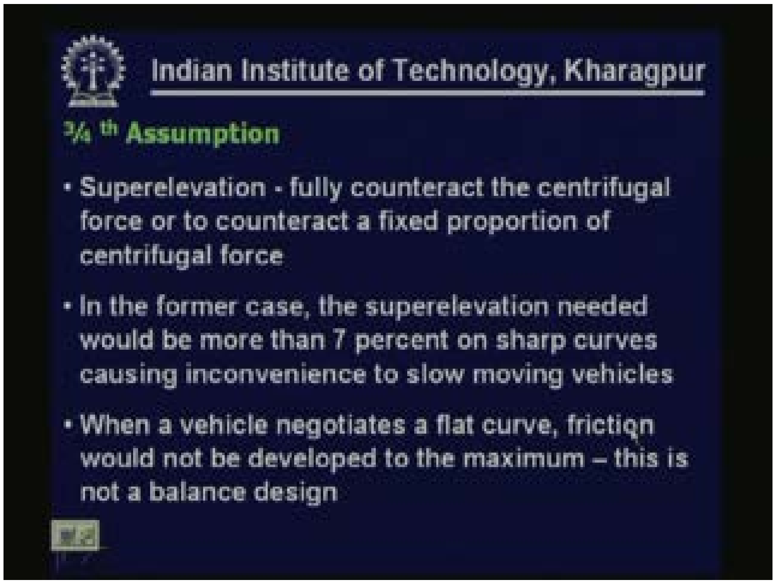

Now there is a 3/4th assumption. This is again typical to Indian conditions. In most of the cases if we consider Indian traffic scenario it is a highly heterogeneous traffic. Fast moving vehicles, new technology cars, old technology cars, other passengers vehicles, commercial vehicles and even the non-motorized animal drawn vehicle or hand driven vehicles are also used using the same road space. So what happens is if we provide Superelevation considering the design speed then it will be convenient and safe for vehicles which are traveling at or near the design speed. Basically they are traveling at very high speed close to the design speed of the road. So for them the Superelevation will be absolutely fine and it will be convenient also for those kinds of vehicles. But the same road space is also used by the slow moving vehicles.

So if we provide camber or if provide Superelevation considering the full design speed then for slow moving vehicle it will not be convenient. So now the question comes should we design the road for the fast moving vehicle for the design speed?
The answer is yes because a road is designed for designed speed so a vehicle traveling at design speed also must be safe. On the other hand a vehicle should also be safe or the movement of vehicle should also be safe even if the vehicle is not traveling at the design speed.

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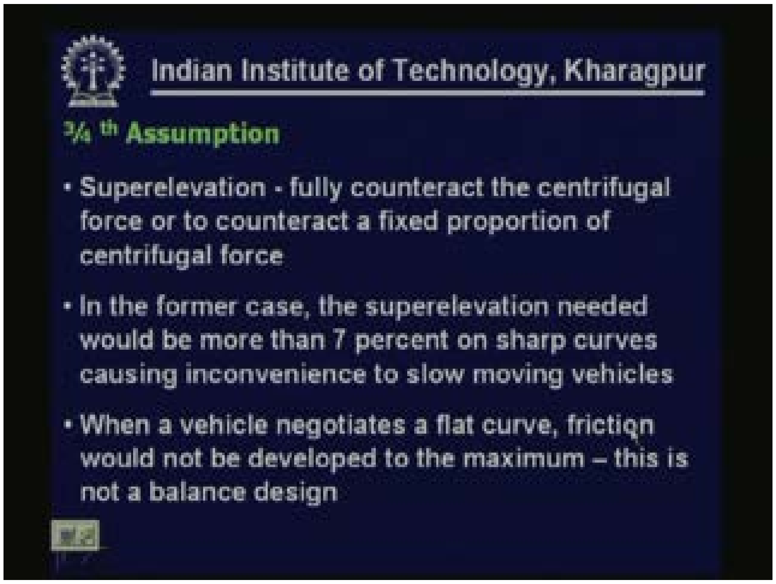

So considering both this requirements the question then comes whether the Superelevation should fully counteract the centrifugal force or to counteract a fixed proportion of centrifugal force. Now in the former case the Superelevation needed may be substantial and it may not be very convenient for the slow moving vehicles and that's what is indicated. Even when a vehicle negotiates a flat curve friction would not be developed to the maximum so this is again not a balanced design.

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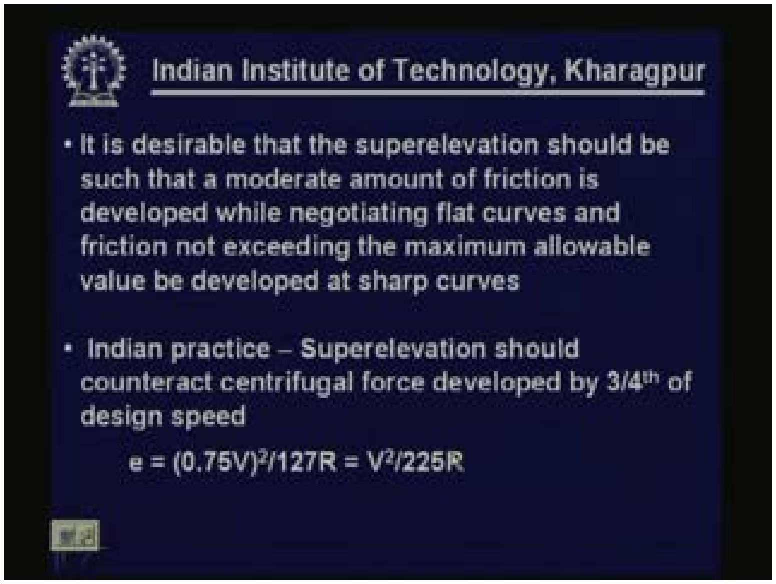

Therefore it is desirable that the Superelevation should be such that a moderate amount of friction is developed while negotiating flat curves and friction not exceeding the maximum allowable value be developed at sharper curves.
For flatter curves allow some friction or consider the friction value into design aspects. Now with all this background considering all these aspects by IRC or in the Indian scenario the practice is to consider 3/4th of the design speed and provide Superelevation rather try to provide Superelevation based on the 3/4ths of the design speed. So instead of designing Superelevation for the complete design speed an attempt is made to design Superelevation with 3/4th of the design speed.

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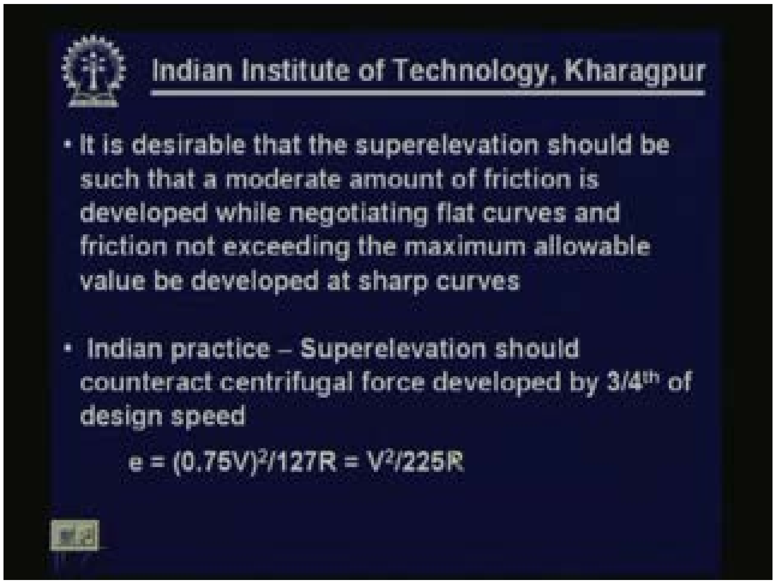

Therefore whatever we have got earlier that equilibrium equation e + f = V square/127R. Now we design Superelevation e considering 7% of the design speed so it is 0.75 V whole square divided by 127R which becomes close to V square/225R so that's what we try.

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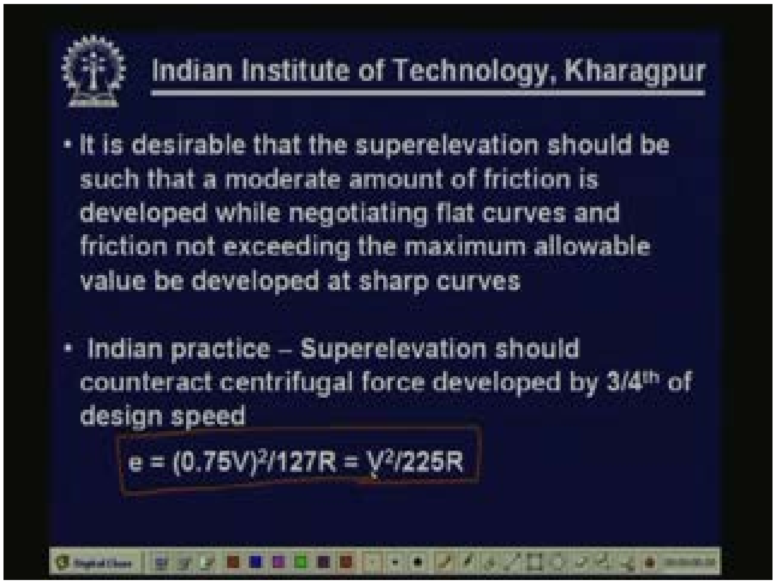

So we try to design Superelevation considering 7% of the design speed. Now we shall come back to this part again.

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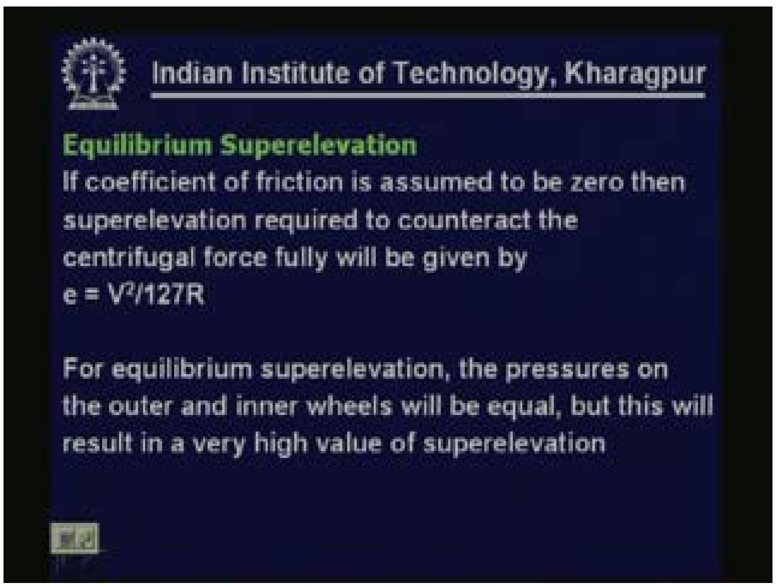

Let us try to understand the concept of equilibrium Superelevation. If we neglect the coefficient of friction that means if coefficient of friction is assumed to be 0 then whatever Superelevation is required to counteract the centrifugal force fully can be given or expressed as V square/127R because in that case f is assumed as 0 so the basic equation e + f = V square/127R if we put f as 0 then e becomes V square/127R. So this Superelevation is known as equilibrium Superelevation.

Now for equilibrium Superelevation the pressure on inner and outer wheels will be equal because of the effect of Superelevation. But this will result in a very high value of Superelevation. So normally we try to counteract the centrifugal force with the help of both Superelevation as well as coefficient of friction.

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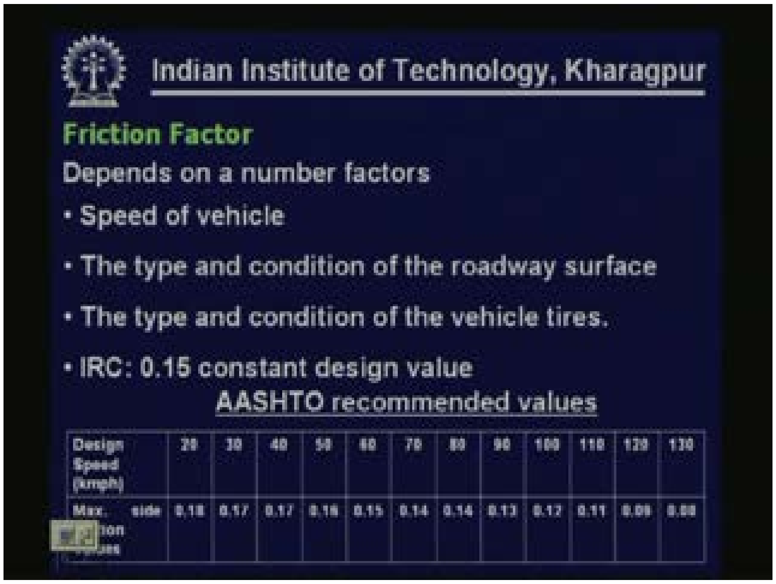

Since we are talking about the coefficient of friction what should be the design value. Actually the friction factor or the coefficient of friction depends on a number of factors. For example, speed of vehicle, the type and condition of the roadway surface, type and condition of the vehicle tires etc.

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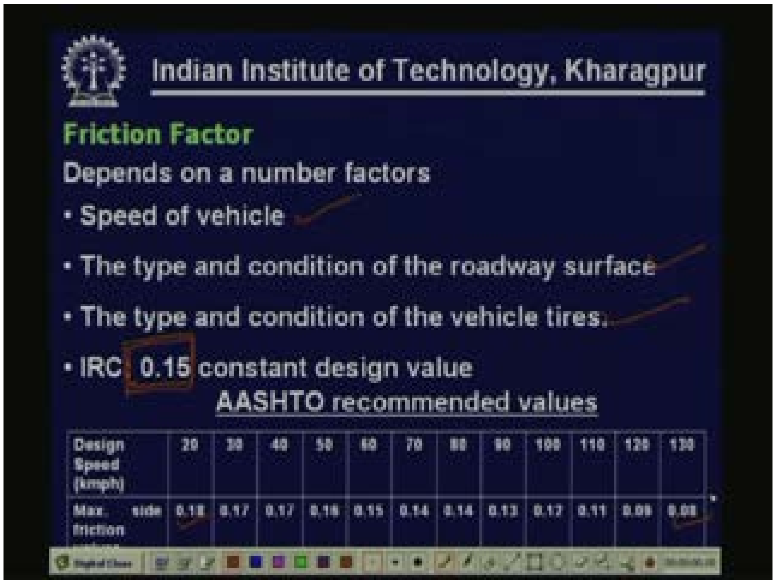

However, for design purpose IRC recommends a value of 0.15 so this is the value 0.15 we should use for design purpose. Now AASHTO recommends the value in a range depending on the design speed so design speed from 20 to 130 the value of side friction varies from 0.18 to 0.08. So this table is given in AASHTO so depending on the design speed one can provide or take the acceptable coefficient of friction. Anyhow for today our primary discussion is the approach which is followed in India so mostly it is the IRC one.

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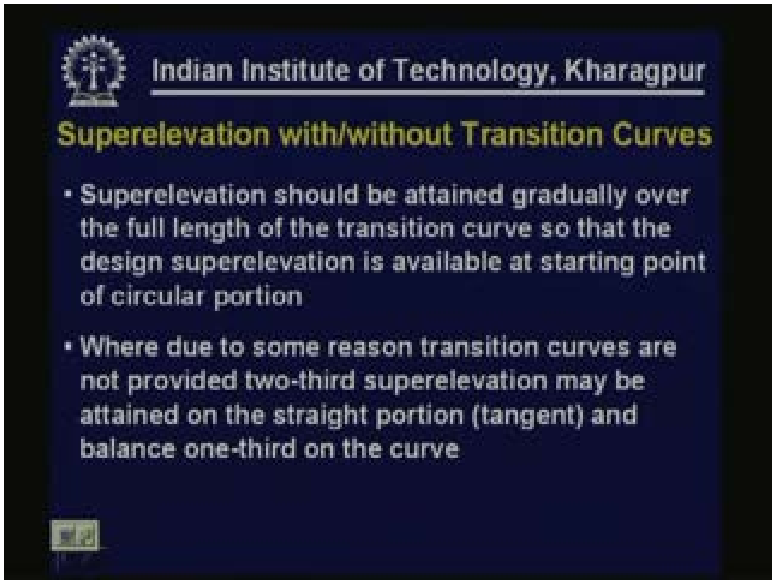

Superelevation is required basically when the vehicle has entered in the horizontal curve portion. But in most of the cases wherever it's possible wherever it is practically feasible for smooth movement we provide transition curves at both ends of horizontal curve. Therefore when there are transition curves at both ends then Superelevation is introduced gradually over the length of transition curves. That means at the end of tangent Superelevation is 0 then it is gradually introduced over the length of the transition curve so at the end of the transition curve or the beginning of circular curve full Superelevation is available. Then the same Superelevation is maintained throughout the length of the circular curve.

Again at the beginning of the transition curve to the point up to the tangent portion it is again reduced. And right on the beginning of the tangent it is brought back to 0. That means essentially the full Superelevation is available right at the beginning of circular curve and that is introduced gradually over the length of the transition curve.

Now if transition curve is not provided in that case 2/3rd of the Superelevation is attained at the beginning of circular curve. That means even if there is no transition curve on the straight portion itself Superelevation is introduced partially and at the beginning of circular curve 2/3rd of the required Superelevation is attained and the remaining 1/3rd is developed over the length of the circular curve. The primary consideration, the primary basis for this is, even if we do not provide transition curve the natural path of driving also follows a particular pattern a transition pattern in that way. Because driver suddenly do not rotate the wheels to match to the radius of the circular curve this is done gradually.

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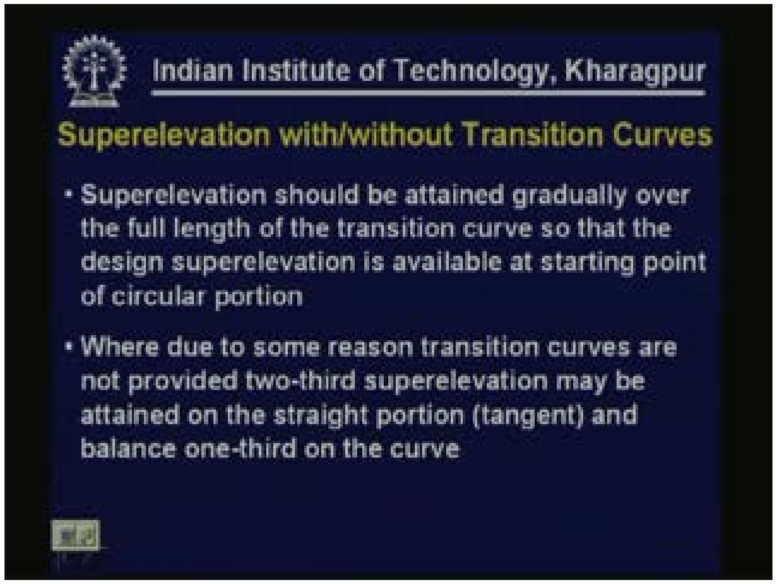

That means right from the tangent portion when the vehicle is on the tangent itself the driver starts steering the vehicle and it follows a natural transition. Therefore 2/3rd of the Superelevation is attained on the straight portion and 1/3rd is on the curve.

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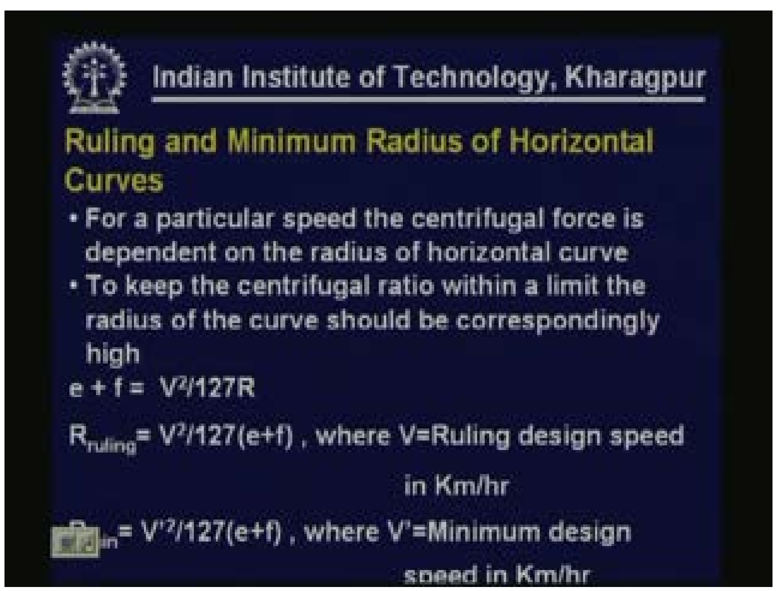

Now, for ruling and minimum radius of horizontal curve you know the basic equation which is e + f = V square/gR. So if we know the speed if know the allowable Superelevation designed coefficient of the friction we can find out what should be the minimum radius of the circular curve, that's what is shown here; e + f = V square/127R so 'R' is nothing but V square/127 into e/f. So if our 'R' is more than this value then we can provide required Superelevation without any problem or restriction on the speed. But there are two types of speed; ruling speed and the minimum speed. So the radius corresponding to ruling speed is known as ruling minimum radius and the radius corresponding to minimum design speed is known as minimum radius.

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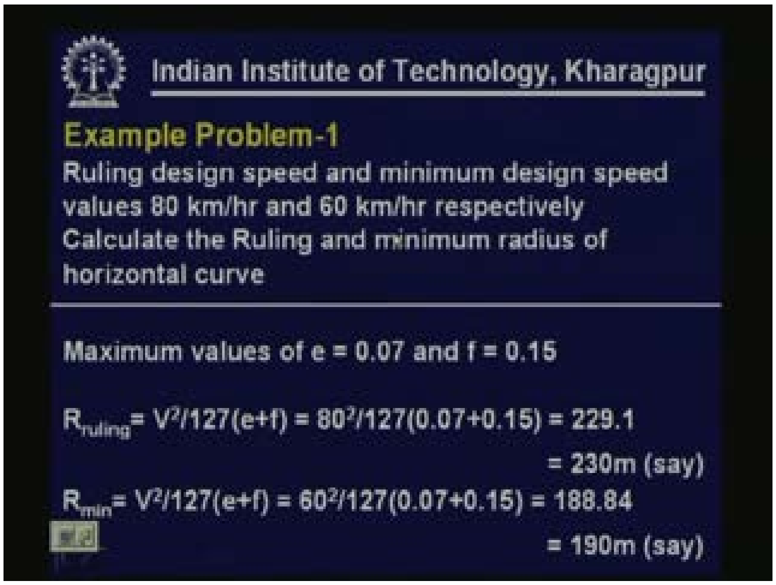

Now let us take an example, say for ruling design speed and the minimum design speed values are 80 Km/h and 60 Km/h so calculate the ruling and minimum radius.

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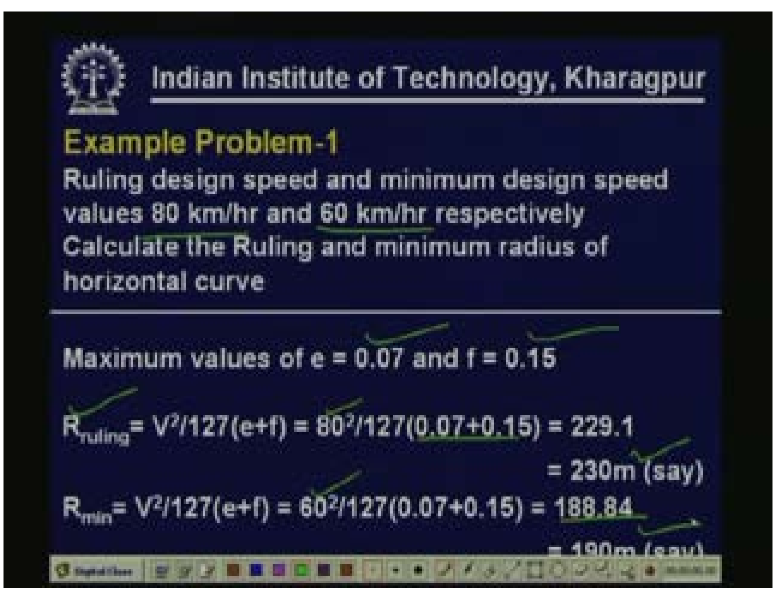

Therefore we know that e is 7% if it is 0.15 so ruling is V ruling which is 80/127 into e + f where e is 0.07 and f is 0.15 so accordingly we can calculate the ruling radius and taking the minimum design speed in the same way we can calculate the minimum radius.

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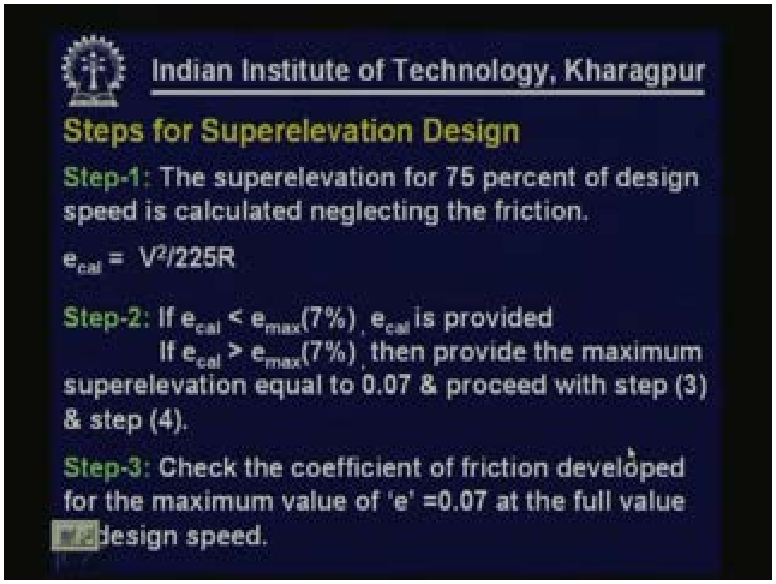

Steps for design of Superelevation in the mixed traffic condition:
I have already mentioned that we try to develop Superelevation considering 75% of the designed speed. So if we take that then e calculated is actually V square/225R so we calculate e using this formula or assuming 7% of the design speed.

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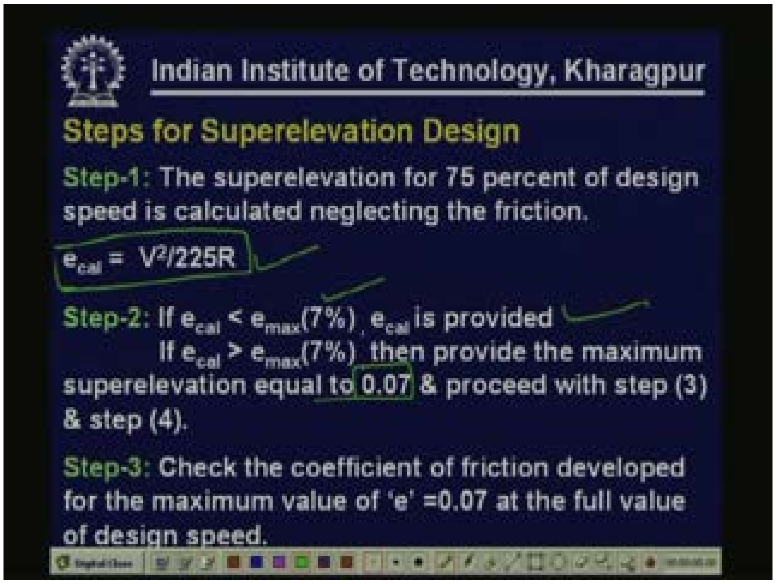

If the calculated e is less than the permissible value say which is 7% per plain and rolling terrain then whatever e we have calculated we provide that value if not then we provide only the maximum allowable value which is for plain and rolling terrain let's say it is 7% but then we proceed with step 3 and step 4.

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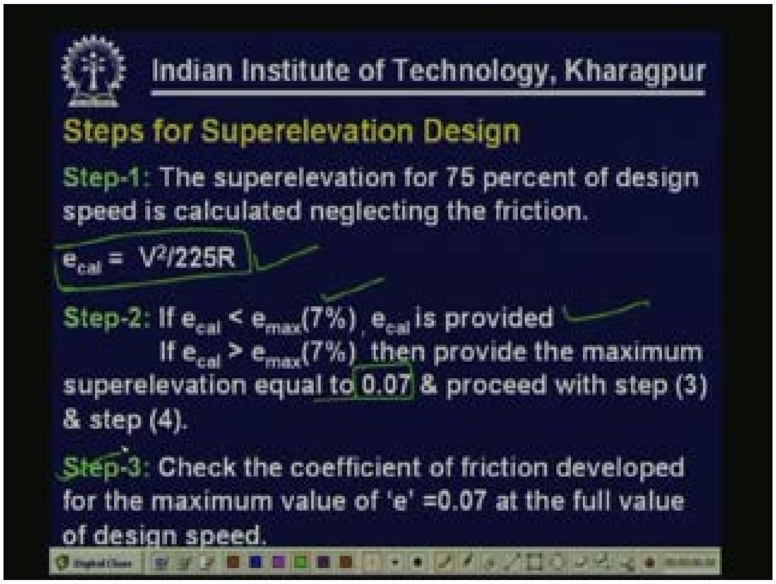

Now what is step 3?
In that case we have to check for the side friction whether the side friction is adequate. Now what we do is check for the coefficient of friction developed for the maximum value of e as 0.07.

That means assuming Superelevation as 7% we check whether the coefficient of friction which is required to counteract the balance centrifugal force is adequate.

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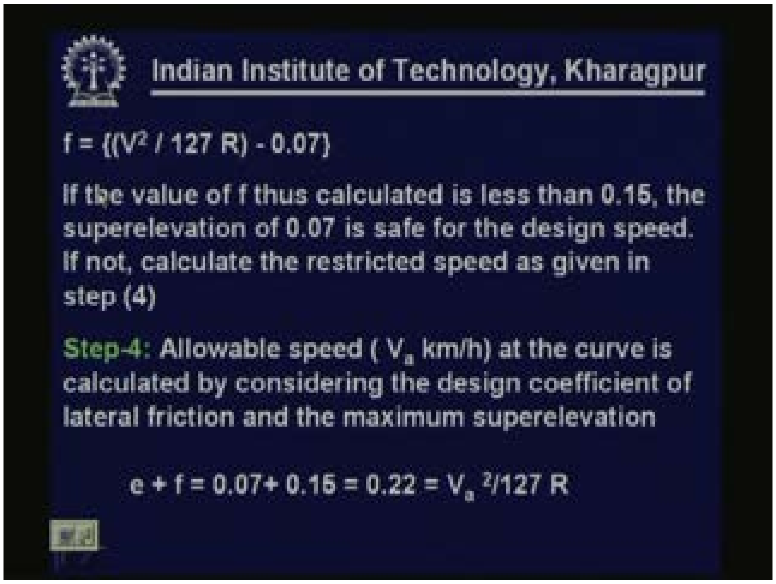

So here we again do this formula; V square/127R because this is the total force which is to be encountered, e is already 0.07 so we check the value f = V square/127R – 0.07. Now if this e value or the f value is less the permissible value which is 0.15 then overall design is safe with seven percent Superelevation also the overall design is safe because the Superelevation and side friction together can very well counteract the centrifugal force.

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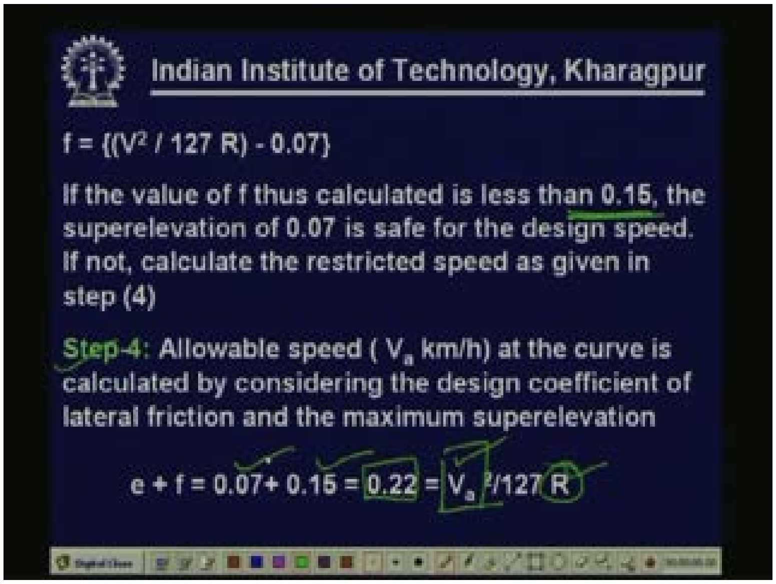

Now if we find that this is even more than the permissible value of 0.15 in that case we had to go for the speed restrictions, there is no other way normally or may be change the alignment and have a different radius. So in that case e + f = V square/127R put the limiting value of e put the limiting value of r so total is 0.022 for plain and rolling terrain and this equal to V square/127R. So if we know the r value that for a given situation this is the r we can easily calculate the permissible speed that will be safe on that stretch of the road where we are providing maximum Superelevation up to 7% or the allowable Superelevation. So, either in that case we have to neither go for speed restriction nor realign the road with a different radius.

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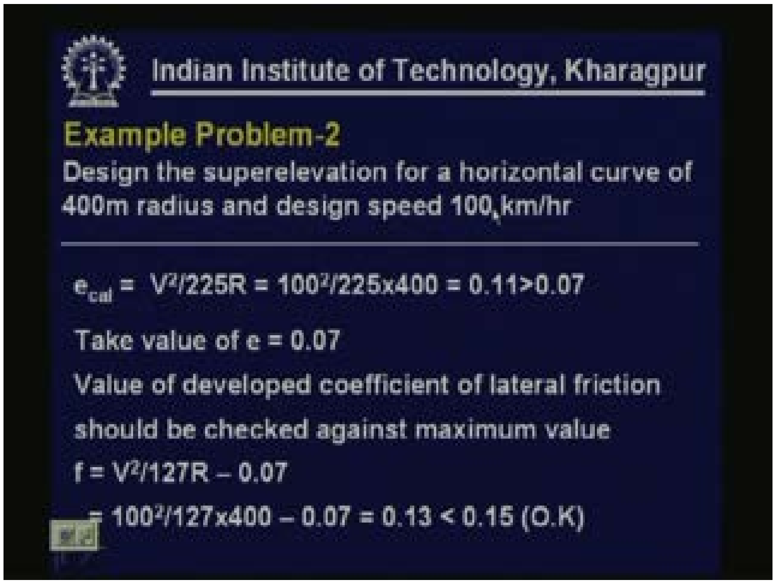

Now let us see this example problem for a horizontal curve with four hundred meters radius and design speed of 100 Km/h. So we calculate e as V square/225R it is 0.011 so it is more than 7% for plain and rolling terrain.

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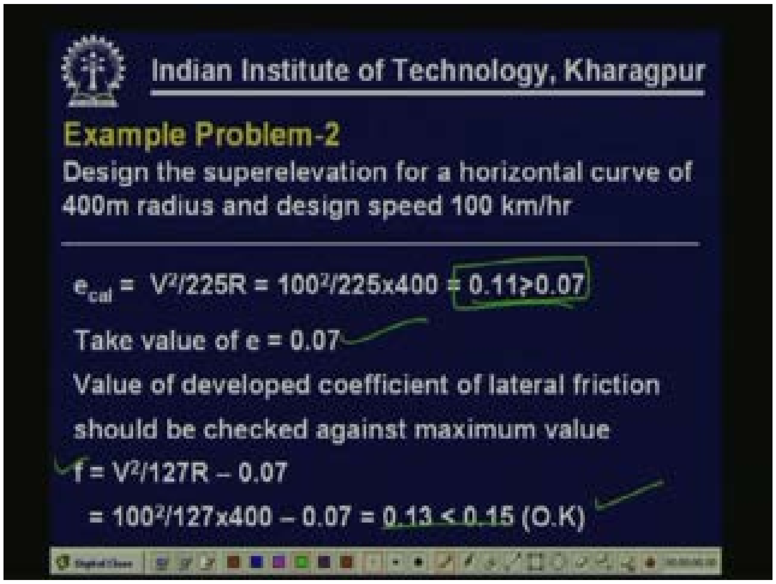

So it takes the value of e which check the value for f and we find f is 0.13 which is less than 0.15 so overall the design is okay. So it provides Superelevation of seven percent and overall e + f it can counteract the force so the design is safe.

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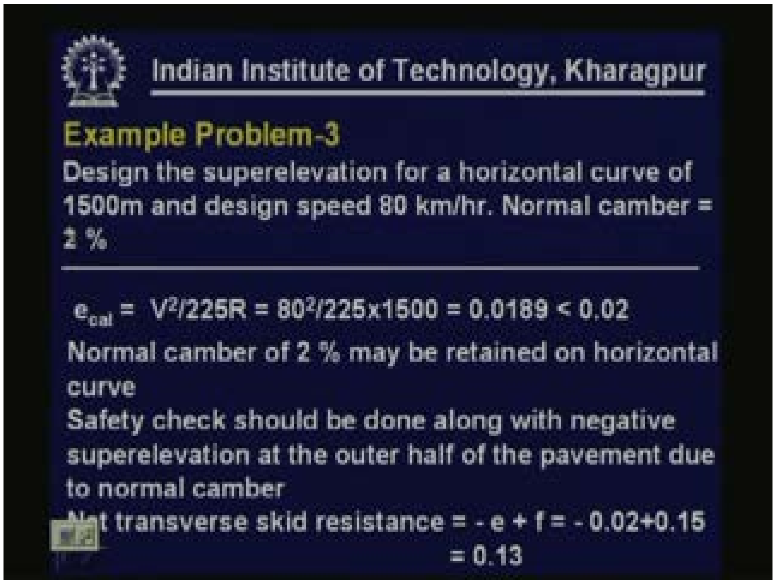

Now let us consider another example problem. Design the Superelevation for a horizontal curve 1500 m and 80 Km speed. In this case also with 75% designed speed we calculate e but this e is lesser than 7% but it is also lesser than the camber the camber value is 0.02. So what we try to do we try to provide the slope equal to camber and check whether the normal camber section can be retained. Normal cambered section can be retained means in that case e is actually negative. So e is – 0.02 + f the permissible value 0.15 that means equivalent thing is 0.13. Now we check what the requirement for the given situation is.

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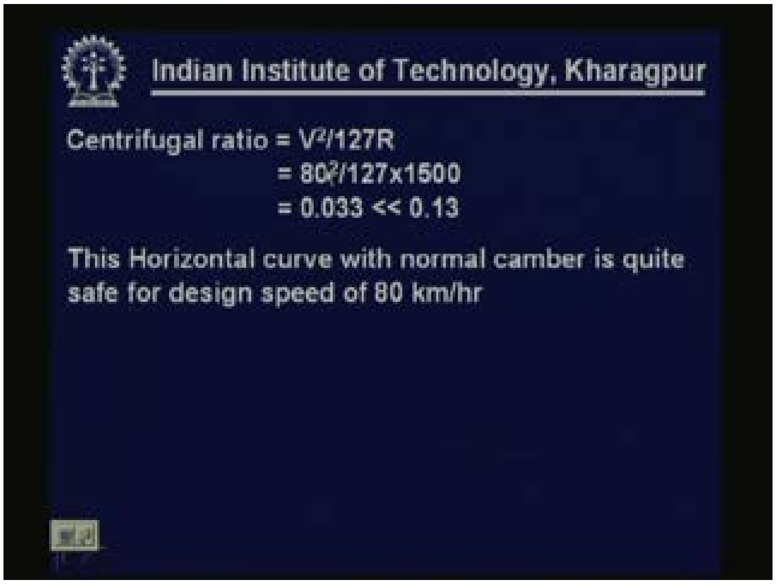

The centrifugal ratio V square/127R we calculate it as 0.033 so it is certainly lesser than 0.013 so again the normal camber section can be written and still the design will be safe in this condition.

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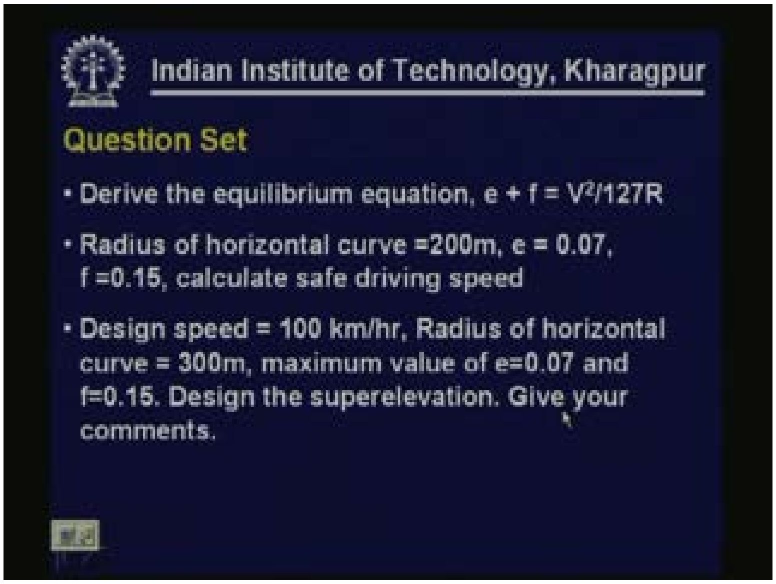

Now try to answer some of these questions:
Derive the equilibrium equation e + f = 127R

Question 2) For radius 200 m permissible e as seven percent f is 0.15 calculate the safe driving speed. Then for a road where the design speed is 100 Km/h radius is 300 m maximum value of e is 0.7 and f as 0.5 design the Superelevation and give your comments.

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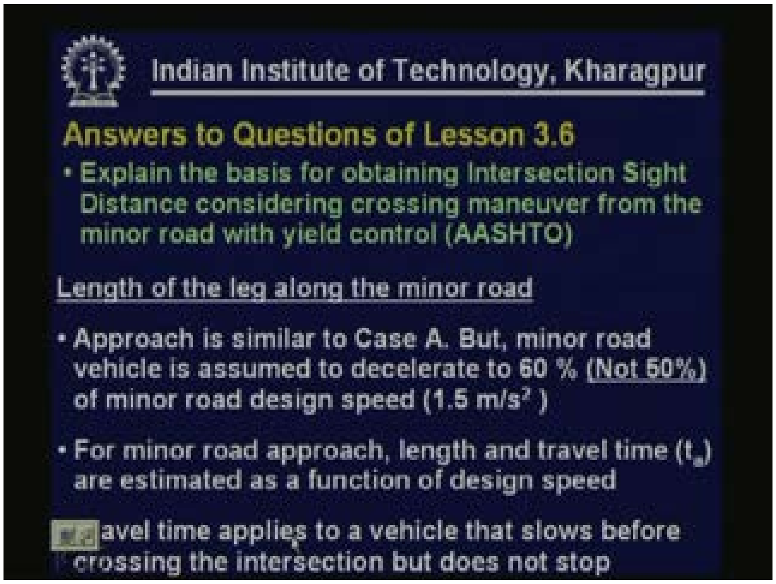

Let me quickly try to answer some of these questions raised in the last lesson. Explain the basis for obtaining intersection sight distance considering crossing maneuver from the minor road with yield control. Now two things we have to do, length of the lane along the minor road, this is an approach similar to case A that means no control but minor road vehicle is assumed to decelerate to 60% of the speed not 50% so accordingly the ta value or the time for to approach the major road is decided and here assumption is that the travel time applies for a vehicle that slows before crossing the intersection but the vehicle does not stop.

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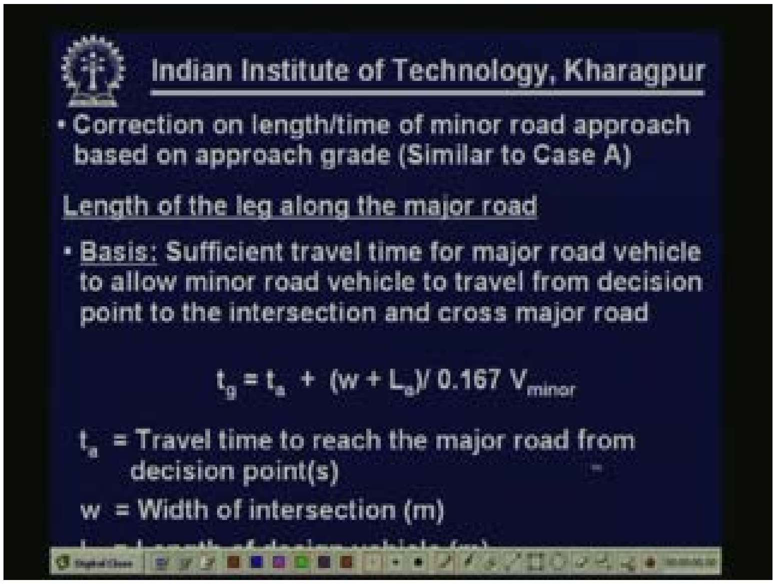

And length of the leg along the major road is decided based on the basis that sufficient travel time for major road vehicles to alarm minor road vehicle to travel from decision point to the intersection and then cross the road safely. Now where this ta is known as the travel time to reach the major road so this component is understood, w is the width of the intersection and la is the width of the approach so this is to be covered like how much time is required divided by the speed but speed normal used is 0.278 V minor but here the speed is reduced to 60% so 60% of 0.278 so that is why it is 0.167.

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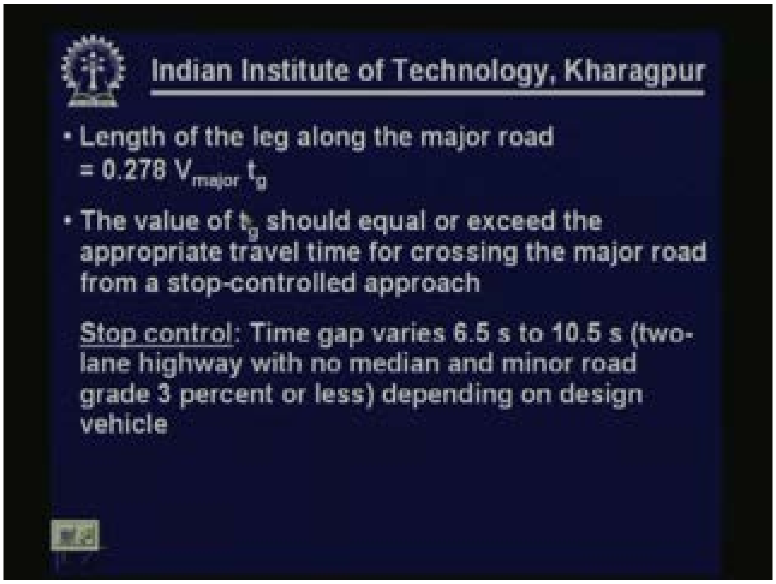

Length of the leg along the major road can be calculated as 0.278 into V major into this time.

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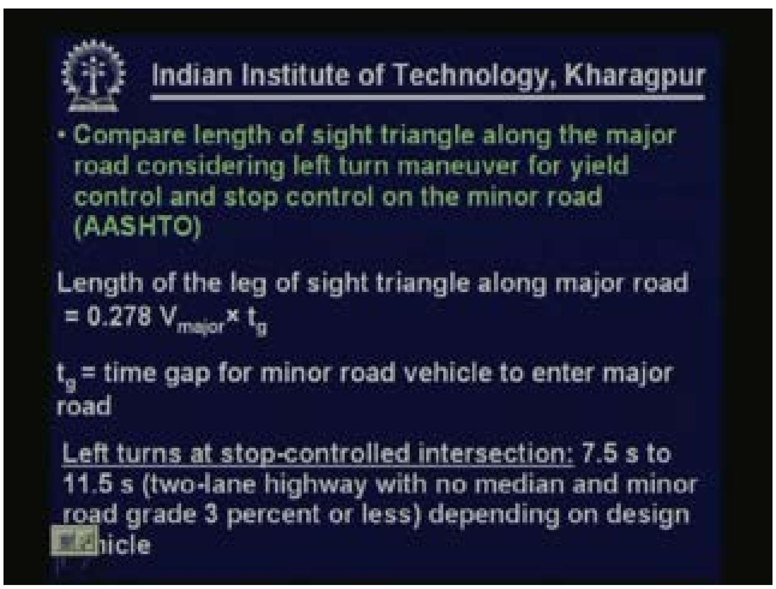

Now compare length of the sight triangle along the major road considering left turn maneuver for yield control. Basically both approaches is same it is 0.278 V major multiplied by time gap for minor road vehicle to enter the major road. In one case for stop control case it is 7.5 seconds to 11.5 seconds depending on the design vehicle but in other case it is 8 seconds to 12 seconds which is 1/2 second more. And why it is half a second more? It is because minor road vehicle needs 3 1/2 seconds to travel from the decision point to the intersection. This is not required for stop control intersection so this is the additional time for yield control. However, for yield control the acceleration time is 3 seconds because the vehicle do not stop, it is the turning speed of 16 Km/h. So this is 3 seconds less altogether half a second more is required, that's why instead of 7 to 11.5 it is 8 to 12 seconds.

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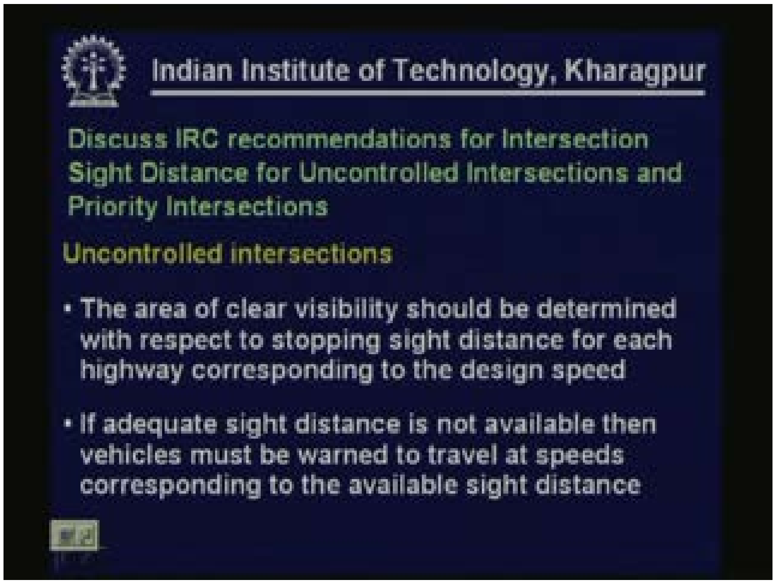

The last question was discussed, the IRC recommendation for intersection sight distance for uncontrolled intersections and priority intersections. For uncontrolled intersection the area of clear visibility should be determined with respect to SSD stopping side distance. If inadequate sight distance is not available then the vehicles must be warned with appropriate speed restriction. So stopping sight distance is the major criteria.

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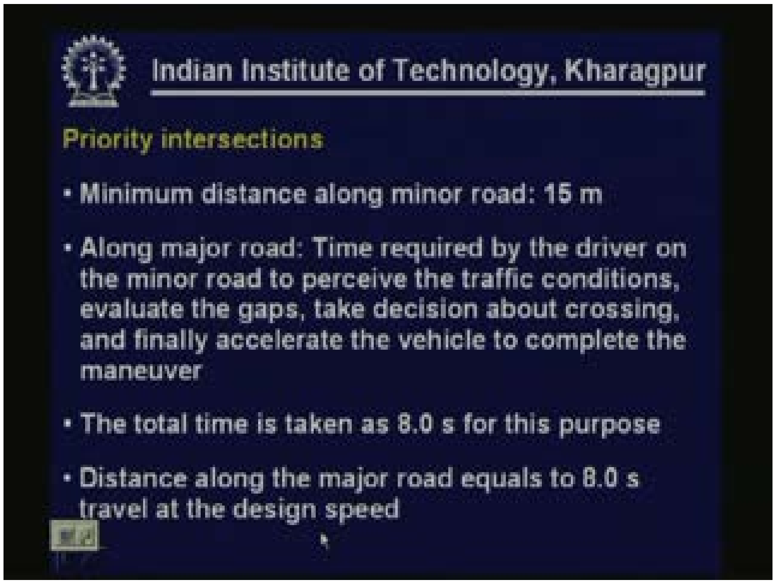

And for priority intersection minimum distance along the minor road is 15 m along the major road time required by the driver on the minor road to perceive the gap and then complete the operation. So total time taken is 8 seconds for this purpose so distance along the major road is 8 seconds travel at design, speed that way one can calculate it.