**Introduction to Transportation Engineering**
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**Lecture - 11**
**Overtaking, Intermediate and Headlight Sight Distances**

In the last lesson we discussed about stopping sight distance and also decision sight distance. Today we shall talk about three other types of sight distance: overtaking sight distance, intermediate sight distance and headlight sight distance.

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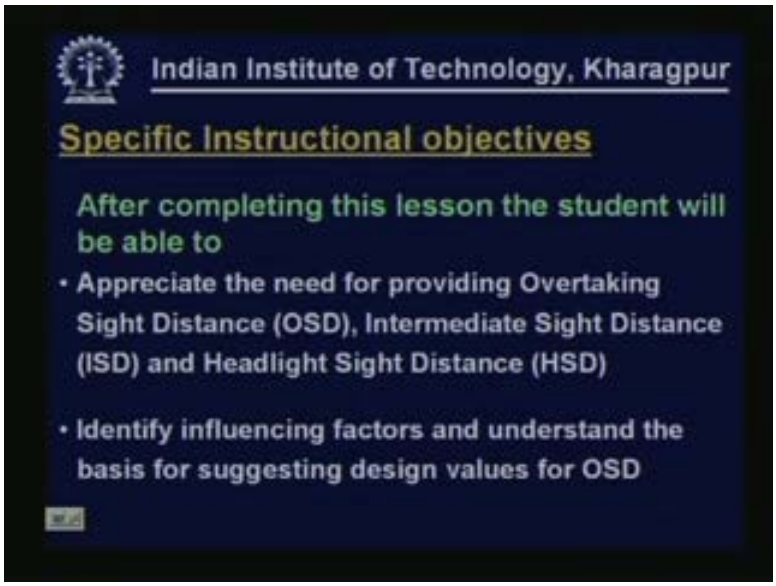


After completing this lesson the student will be able to appreciate the need for providing Overtaking Sight Distance (OSD), Intermediate Sight Distance (ISD) and Headlight Sight Distance (HSD), why they are necessary and where we should apply them. Student will also be able to identify influencing factors and understand the basis for suggesting design values for overtaking sight distance.

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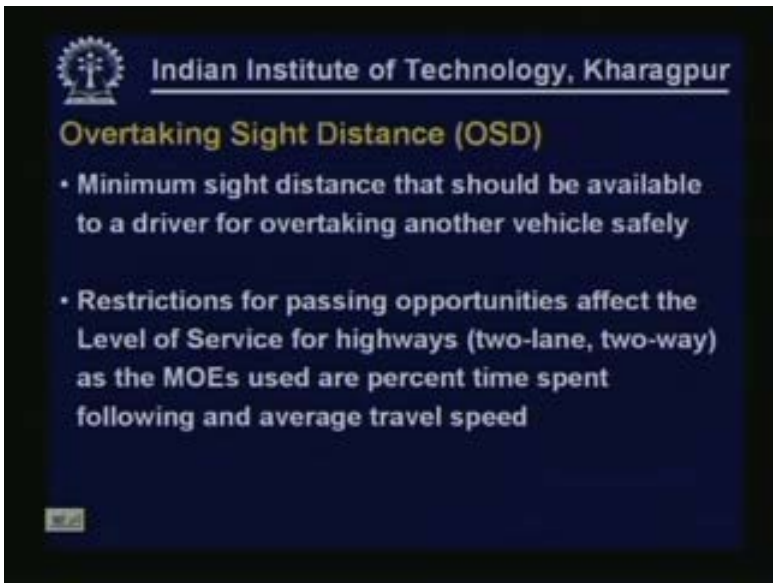


Why it is necessary to provide overtaking sight distance?
Wherever there are two lane roads with two-way traffic movement often vehicles moving at higher speed they are required to overtake slow moving vehicles. This requirement is more when

the traffic is heterogeneous in nature. The slow moving vehicle, fast moving vehicle they all share the same road space. Therefore often fast moving vehicles they require to overtake slow moving vehicles. Therefore adequate sight distance should be available so that faster moving vehicles can overtake slow moving vehicles without hitting another vehicle which is coming from the opposite direction. So normally if we see, the minimum sight distance that should be available to a driver for overtaking another vehicle safely. It is worthwhile to mention that restrictions for passing opportunities affect the level of service for highways particularly two-lane two-way roads as the measure of effectiveness for defining level of service for such facilities include percent time spent following and average travel speed.

Once there are adequate passing opportunities obviously lesser time a vehicle has to spend following slow moving vehicles and also the average travel speed will be different. Once more passing opportunities are provided average travel speed will be higher. So therefore if we provide adequate passing opportunities or overtaking opportunities then the level of service are expected to be better.

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Now how the overtaking maneuver takes place?
Overtaking vehicle follows the slow vehicle for sometime. Initially faster moving vehicles they have to follow slow moving vehicles. Subsequently a faster moving vehicle finds a favorable condition for overtaking, available sight distance and he also looks at opposing vehicles whether there is any vehicle which is coming from opposite direction, he finds a favorable condition then pulls out the vehicle, overtakes and returns back to original lane before meeting an oncoming vehicle from the opposite direction. That is what is the process for overtaking.

While estimating the design requirement or design value certain assumptions are made like: number 1: a single vehicle overtaking a single vehicle. It may be possible that in some situations or there are occasions when multiple overtaking are happening but for design purpose we do not consider multiple overtaking because simple reason is then the required values will be much

higher. Also, the design values require minimum values therefore if we consider multiple overtaking operations then the minimum requirement itself will be higher. It is not desirable, it is not necessary. So therefore a single vehicle overtaking another single vehicle and the required overtaking sight distance for that condition is what is our subject for discussion.

The overtaking vehicle travels at uniform speed. This is another design assumption that the overtaken vehicle traveling at uniform speed applies no acceleration or deceleration, so no acceleration or deceleration is applied by the overtaken vehicle.

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Third: overtaking vehicle follows the vehicle ahead for a short while then overtaking vehicle accelerates rapidly, pulls out, occupies the opposing lane, overtakes slower vehicle and returns to original lane. That is the way overtaking normally takes place. Then vehicle travels from opposite direction at the same speed as the overtaking vehicle because remember that we are taking about two-lane roads with two-way traffic movement so obviously there is a possibility that a vehicle is also approaching from the opposite direction and the required sight distance also will depend on the speed of the vehicle from opposite direction. So it is assumed that the vehicle from the opposite direction is also traveling at the same speed as the overtaking or passing vehicle.

Difference between average speed of overtaking and overtaken vehicle is 15 kilometer per hour. This is again a design consideration considered by AASHTO or in formulating their recommendations. That difference between average speed of overtaking and overtaken vehicle is 15 kilometer per hour. In reality it may vary, it may be different than 15 kilometers but for design purpose this difference is taken as 15 kilometer per hour.

Similarly, speed of overtaken vehicle is assumed to be 16 kilometer per hour lesser than the designs speed of the road. You are already familiar with the term design speed. This is the assumption based on or this is the assumption considered by Indian Roads Congress while

recommending the design values for OSD. So IRC or Indian Roads Congress assumes that speed of overtaken vehicle is 16 kilometer per hour lesser than the designed speed of the road but AASHTO assumes that the difference between average speeds of overtaking this average speed is not the designed speed so the difference between average speed of overtaking and overtaken vehicle is 15 kilometer per hour.

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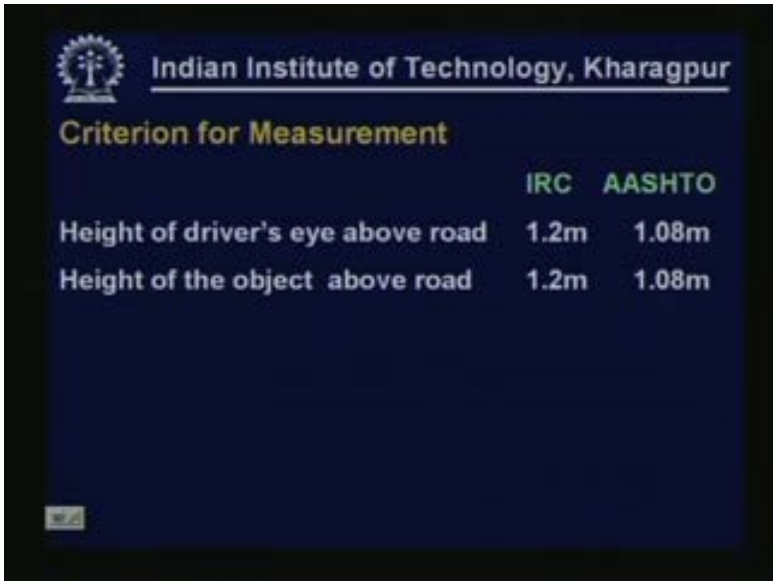


Like stopping sight distance for overtaking sight distance also it is necessary to specify the height of driver's eye above road level and also the height of object above road surface. In this condition for overtaking or passing the opposing object is also an opposing vehicle so therefore the height of driver's eye above road surface and height of object they are the same. As per Indian Roads Congress recommendations it is 1.2 m and as per AASHTO recommendations it is 1.08 m. 1.2 and 1.08 were used while estimating the required stopping sight distance as per IRC and AASHTO respectively so it is the same value.

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Now how the overtaking sight distance can be estimated?
There are different approaches for estimating the overtaking sight distance. We shall discuss about three different approaches. Approach 1 is shown here: there are three vehicles which are involved in the overtaking operation: vehicle A, vehicle B and vehicle C. Vehicle A is the overtaking vehicle, vehicle B is the overtaken vehicle and vehicle C is vehicle which is coming from opposite direction. Initially vehicle A follows vehicle B and looks for an opportunity a suitable opportunity for overtaking so by the time it changes its position from A 1 to A 2 then it completes the overtaking operation as shown in the sketch. It encroaches the lane which is supposed to be used by vehicles from opposite direction, completes the overtaking operation and then comes back to its original lane. So in the complete process the vehicle changes its position from A 2 to A 3.

When vehicle A is overtaking slow moving vehicle B then vehicle B is also moving. So let us look at the sketch: vehicle B is changing its position from B 1 to B 2 and during this overtaking operation another vehicle is assumed from opposite direction which is vehicle C and when vehicle A is overtaking vehicle B vehicle C is changing its position from C 1 to C 2. Now the speed of overtaking and opposing vehicle is assumed to be the same so it is taken as say v meter per second and the overtaken vehicle or the slow moving vehicle speed let us assume it as v b meter per second.

Now the total required overtaking distance is d 1 plus d 2 plus d 3 so that much sight distance should be available to the driver of vehicle A when it is starting the overtaking operation. So let us see how we can calculate each and every component that is d 1, d 2 and d 3. Now d 1 is the distance traveled by vehicle A during the perception reaction time. You are already familiar with this component perception reaction time; we used perception reaction time when we calculated the stopping sight distance; here also the same component is applicable but the design value is taken as 2 seconds. I repeat; the design value of perception reaction time is taken as 2 seconds.

So during this perception reaction time vehicle A or the overtaking vehicle is forced to follow the slow moving vehicle in front that is vehicle B therefore the distance d 1 equal to v b multiplied by t; it is v b not v because the slow moving vehicle is in front and the faster moving vehicle is forced to follow the slow moving vehicle during this time period.

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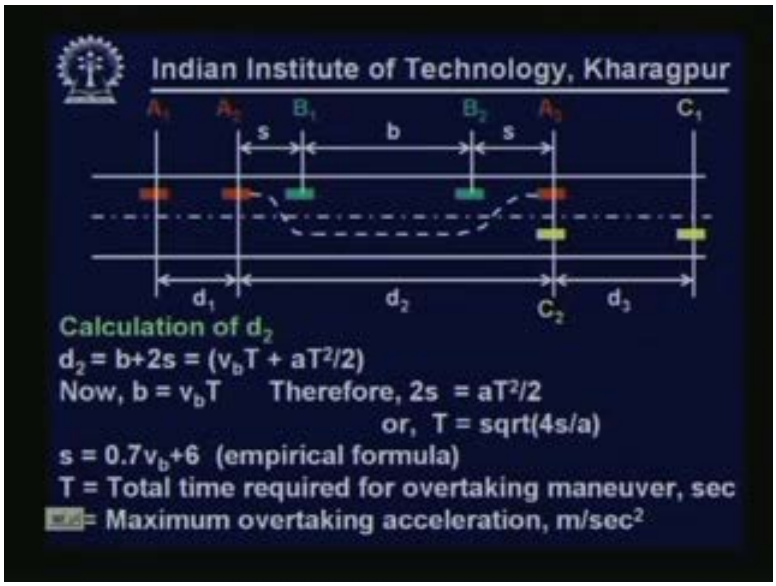


Now let us see how we can calculate component d 2.
d 2 from the sketch it is clear that d 2 is equal to b plus 2s; b is actually the distance traveled by the slow moving vehicle B during this overtaking time t and s is the minimum required spacing between two vehicles. So just before overtaking and after overtaking s gap or s distance is skipped between vehicle A and vehicle B. So therefore the distance d 2 is b plus 2s. Also, if we consider a fast moving vehicle then this distance d 2 can also be estimated as v b into T where v b is the initial speed of vehicle A plus half aT square where a is the acceleration applied by vehicle A and T is the total time required for overtaking maneuver expressed in seconds. So therefore d is equal to b plus 2s and again d 2 is equal to v b multiplied by T plus half of aT square.

Now b is again v b multiplied by T because the slow moving vehicle during the complete time capital T is covering this distance and the slow moving vehicle is traveling at uniform speed therefore b is v b into T. As a result we find that 2s is equal to half aT square or T is square root of 4s by a. Now s is the minimum spacing between two moving vehicles which is also often taken as 0.7 v b plus 6this is an empirical formula where v b is expressed in meter per second and s the spacing is also expressed in this empirical formula in meter.

Therefore once the speed is known once the v b is known one can calculate the ‘s’ and also another input required is ‘a’ in order to calculate the total overtaking time T. The ‘a’ value is also recommended depending on the speed. For higher speed the acceleration is lesser and reverse thing that means for lesser speed maximum acceleration values are relatively higher. Therefore,

with the value of a and s one calculate the total time required for overtaking and then accordingly this distance d 2 can be calculated.

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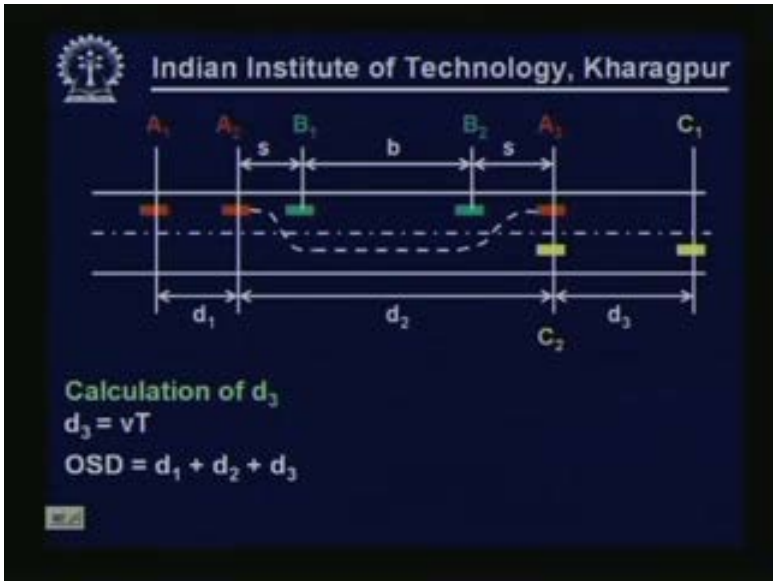


Now let us see how the component d 3 can be calculated. d 3 is the distance traveled by the opposing vehicle C during the time capital T overtaking time. So it is v multiplied by T where v is the speed of the overtaking vehicle. Therefore the total overtaking sight distance required d 1 plus d 2 plus d 3.

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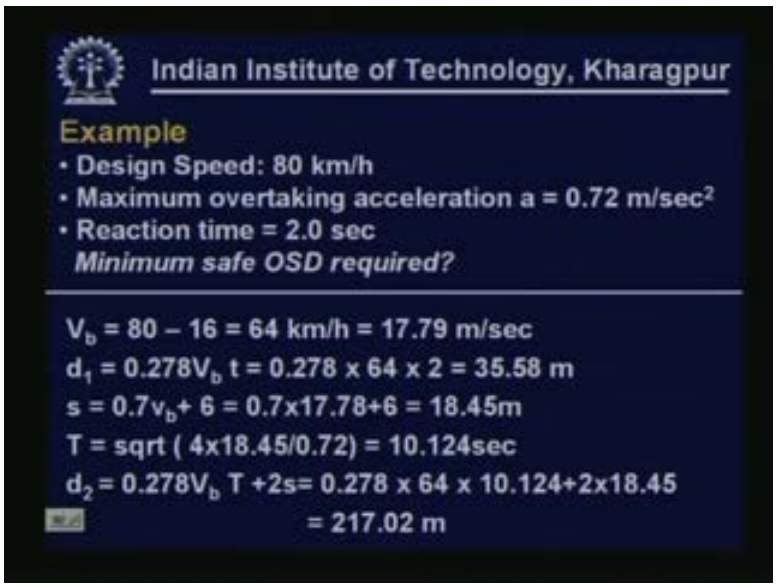

Now let us take an example: if the design speed is say 80 kilometer per hour maximum acceleration is 0.72 m per second square, reaction time is 2 seconds then what is the minimum required overtaking sight distance. You know that as per Indian Roads Congress recommendations the slower moving vehicle is assumed to travel at a speed 16 kilometer lesser than the designed speed of the road. So, when the design speed is 80 the slow moving vehicle speed is 80 minus 16 that is 64 kilometer per hour. If you convert it into meter per second it is 17.79 m per second. Therefore d 1 is V into t we use 17.79 m or it is 0.278 V b into t if V b is expressed or the speed is expressed in kilometer per hour so you get the distance d 1.

One can also calculate the spacing between two vehicles with the help of the empirical formula 0.7 V b plus 6 so 0.7 into 17.78 or 79 m plus 6 m then once s is known acceleration is known therefore the T value can be calculated as square root of 4 into s by a which is 10.12 second so the distance d 2 can be calculated and d 3 also with the original speed 80 kilometer per hour and overtaking time 10.12 seconds the distance traveled by the opposing vehicle can also be calculated. Therefore the required overtaking sight distance is d 1 plus d 2 plus d 3 in this case the total is 477.76 m so that is the required overtaking sight distance for this case.

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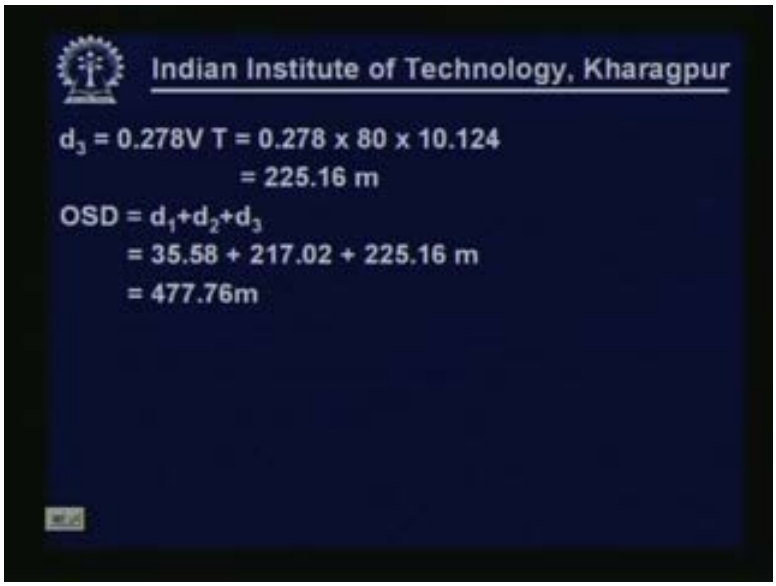

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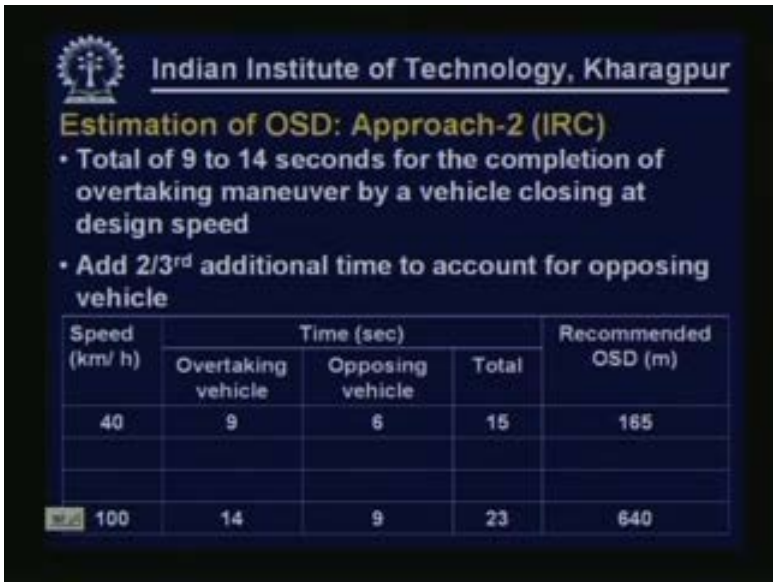


Now let us see another approach for estimating overtaking sight distance. This approach is recommended by Indian Roads Congress. It is assumed that the complete overtaking operation takes a time in between 9 seconds to 14 seconds. So 9 seconds to 14 seconds is the total time required for overtaking depending on the speed. IRC suggests two-third of this time to account for vehicle from opposite direction. Ideally it should be that complete time not two-third time but if we take the complete time then the design requirement or the minimum required value will be higher.

It is felt that up to certain time when the faster moving vehicle is trying to overtake a slow moving vehicle even when it is on the opposing lane still it can come back to its original position up to certain time. Therefore it is not necessary to consider the complete time while calculating the distance covered by the vehicle from opposite direction. So a practical value is taken as based on the two-third of this total overtaking time. Therefore look at this table for different design speed the OSD value can be calculated. The overtaking time varies from 9 to 14 seconds at lower speed say 40 kilometer per hour it is 9 seconds and as the design speed is higher the required time for the overtaking is also more, say for 100 kilometer per hour speed the overtaking time is 14 seconds.

Therefore, in each case two-third of this time is added to account for the vehicle from the opposite direction so the total time is calculated. In case of 40 kilometer per hour speed say it is 15 seconds. So what is the distance if the speed is 40 kilometer per hour and time is 15 seconds that is what is the recommended value and the only thing is that the values are rounded.

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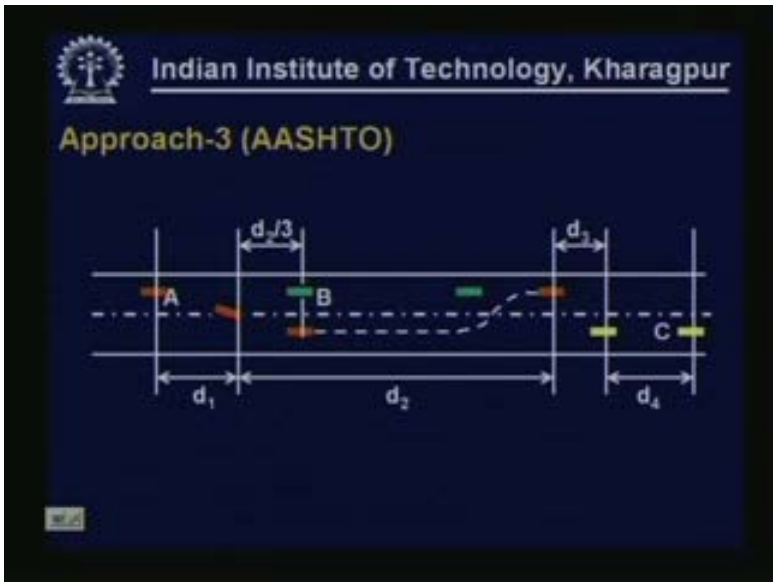


Now let us see also another approach the approach taken by AASHTO American Association of State Highway and Transport Officials how they calculate the required overtaking sight distance value. Let us look at the sketch. Here also we have components like d 1, d 2, d 3 and d 4. d 1 is the distance traveled by the overtaking vehicle during the initial perception reaction time and also during the initial acceleration up to the encroachment of opposing lane. It is shown accordingly in the sketch, the vehicle position for vehicle A and the distance covered during this time is d 1, d 2 is the time for overtaking when the overtaking vehicle is actually overtaking vehicle B encroaching or staying in opposing lane and then it is coming back to its original position that is distance d 2 and d 3 is the clearance time. After completion of overtaking a gap is assumed between the overtaking vehicle which has just completed the overtaking operation and a vehicle which is coming from the opposite direction.

If you remember the sketch which I have shown you when I was talking about the fast approach it was assumed that after overtaking when the overtaking vehicle is back to its original lane the opposing vehicle is just by the side of this overtaking vehicle but in a different lane so they were placed side by side. In this case there is a clearance which is assumed and called as d 3; d 4 is the distance covered by opposing vehicles during this overtaking maneuver. So it is a vehicle C which is coming from opposite direction. Now let us see how each component say d 1, d 2, d 3 and d 4 can be calculated.

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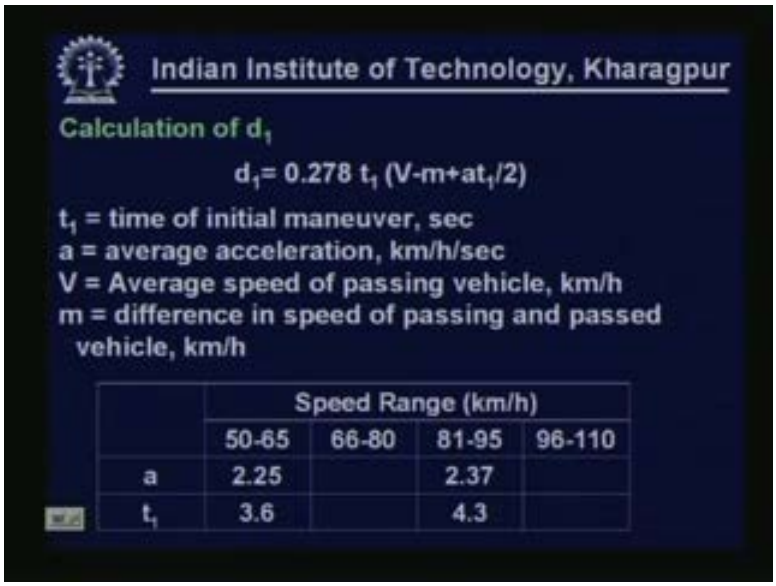


| | Speed Range (km/h) | | | |
|---|---|---|---|---|
| | 50-65 | 66-80 | 81-95 | 96-110 |
| a | 2.25 | | 2.37 | |
| $t_1$ | 3.6 | | 4.3 | |

d 1 as I told is the distance covered by the overtaking vehicle during the initial perception reaction time and also during initial acceleration. So this is expressed as 0.278 t 1 if that time required is t 1 multiplied by (V minus m plus half into a into t 1. It is nothing but distance into speed multiplied by time plus half of acceleration into time square, the same basic equation. Why it is taken as V minus m? It is because here also before overtaking the fast moving vehicle or the overtaking vehicle is forced to follow the slow moving vehicle in front. Now the difference is that the slow moving vehicle is struggling at a speed 15 kilometer per hour lesser than the average speed of the overtaking vehicle so this component is taken as V minus m instead of V.

Now, experiments have been carried out for passing maneuver and suitable values are found out in terms of say acceleration and also the time taken based on different speed range. Say one speed clause is considered as in between 50 to 65 kilometer per hour, the second one 66 to 80 kilometer per hour, third one is 81 to 95 kilometer per hour and the last one is 96 to 110 kilometer per hour. Field observations are made for the first three clauses to find out the average acceleration and average time required for initial clause for each of the first three speed range or speed clause.

The values are extrapolated to get a suitable value of acceleration and time taken for the speed range between 96 kilometer to 110 kilometer. So these values are available: values of a values of t for different speed range and using those values one can calculate that length d 1.

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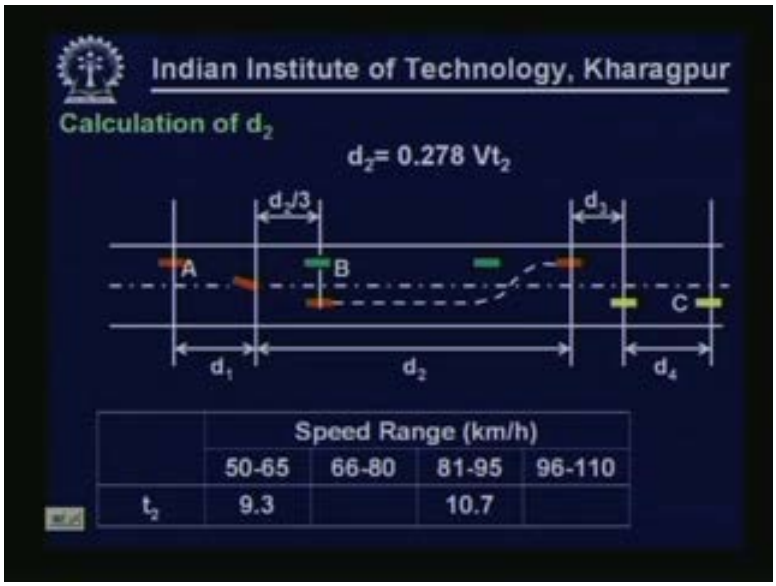


Similarly, for calculating the distance d 2 from field observations the required time t 2 for overtaking maneuver is found out for three different speed ranges and again values are extrapolated for the speed range between 96 and 110 kilometer per hour. Say for example, for speed range between 50 and 65 kilometer per hour it is found that average time taken is 9.3 seconds. So actually the average speed of overtaking vehicle multiplied by this time t 1 for overtaking maneuver can give us the value for distance d 2.

Now, since V is expressed in kilometer per hour so 0.278 multiplier is used therefore d 2 is 0.278 multiplied by V into t 2 and t 2 values are obtained from experimental observations and it is available in design code.

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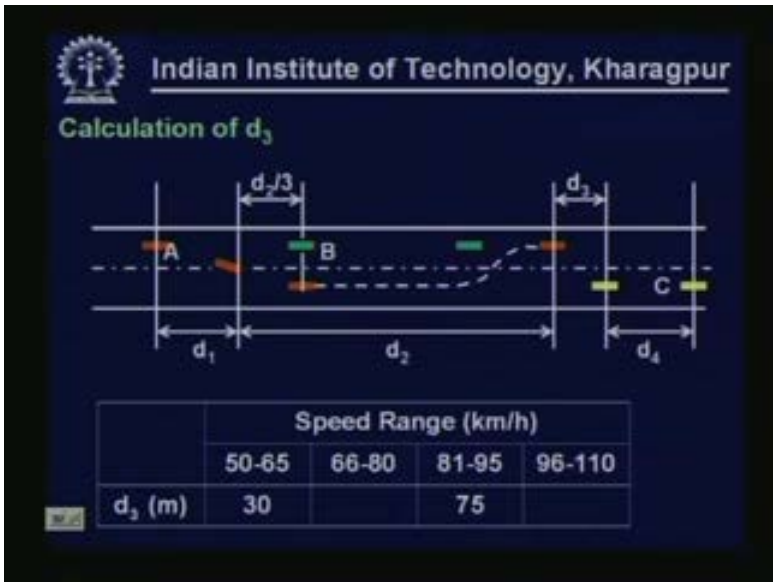


Now d 3 is the clearance between two vehicles so it is assumed that clearance is maintained. This value is again obtained from experimental observations for different speed ranges. Say for example for the speed range between 50 and 65 kilometer per hour this clearance is suggested as 30 m. Similarly, suitable values are suggested for different speed ranges.

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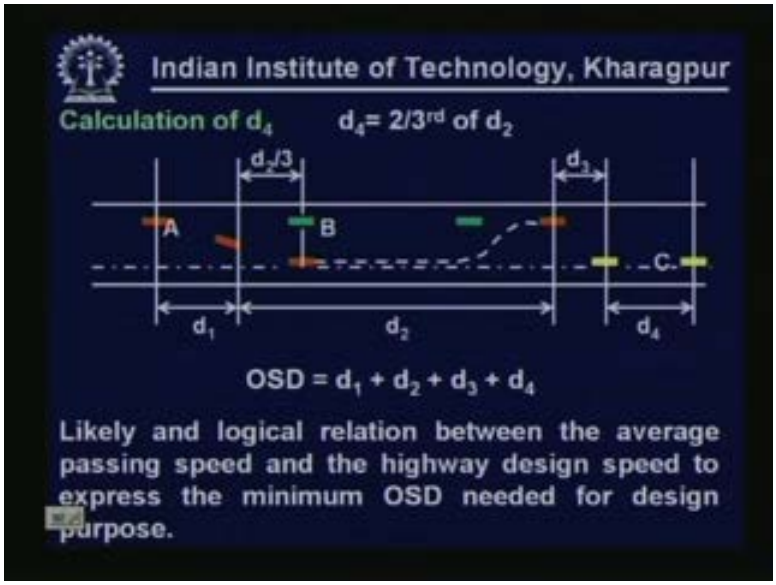


d 4 is the distance covered by opposing vehicle. Here also it is taken as two-third of the distance d 2 not the complete distance d 2 for the same reason as we have discussed earlier. You can see also from the sketch approximately up to one-third of the distance to d 2 vehicle B is actually placed just by the side of vehicle B in the other direction so it is assumed that even up to this

position the vehicle A can comfortably go back to its original lane if it detects any vehicle from the opposite direction. So it is basically taken as two-third of d 2. So therefore in the same way here the total OSD is calculated as summation of d 1, d 2, d 3 and d 4.

I have mentioned that here all these distances are calculated considering the average speed of overtaking or passing vehicle and not the designed speed. But finally for different or design of highways we need to relate this required OSD with the relate it to the design speed and that is only possible when we find out a likely and logical relation between the average passing speed or overtaking speed and the highway design speed then only we can express OSD in terms of the design speed.

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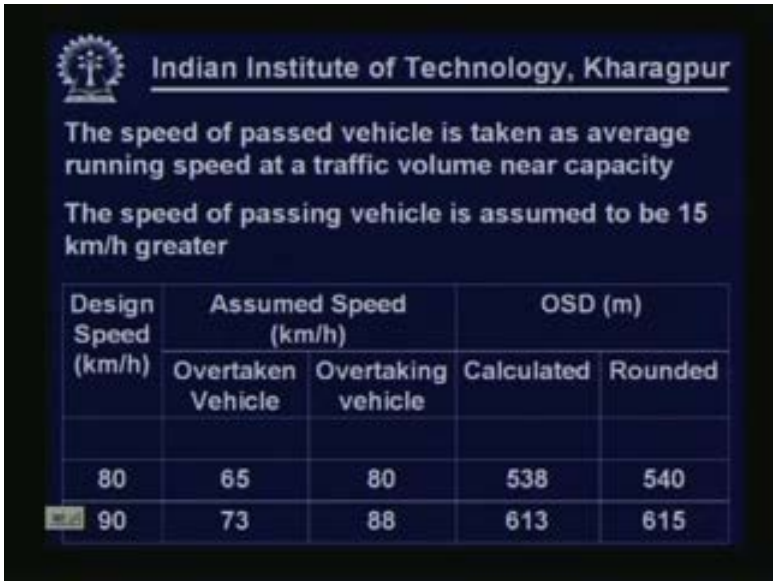


| Design Speed (km/h) | Assumed Speed (km/h) | | OSD (m) | |
|---|---|---|---|---|
| | Overtaken Vehicle | Overtaking vehicle | Calculated | Rounded |
| 80 | 65 | 80 | 538 | 540 |
| 90 | 73 | 88 | 613 | 615 |

To do that it is assumed that the speed of passed vehicle is the speed of the traffic stream at or near capacity volume. That means when the volume of the traffic stream is at or near capacity then what is the speed of the traffic stream that is taken as the speed of the passed vehicle. So a relation is established then the speed of passing or overtaking vehicle is assumed 15 kilometer per hour higher than the speed of the passed vehicle. Considering that as shown in this table the OSD requirements are found out and for designing different design speed the assumed speed for overtaken vehicle and overtaking vehicle are mentioned.

Say for example, design speed of 80 kilometer per hour it is assumed that overtaken vehicle speed is 65 kilometer. This is assumed to be the average stream speed when the volume is approaching capacity then the overtaking vehicle is assumed to travel 15 kilometer higher that that so 65 plus 15 so it is 80 kilometer per hour. Accordingly once this average speed of overtaking vehicle is known all the components d 1, d 2, d 3, d 4 can be calculated because all of them are related to average speed of overtaking vehicle similarly these values are calculated. Say in this case is 538 for design purpose AASHTO recommends the value 540 after rounding this value. Similarly, for different other design speeds the recommended OSD values have been calculated and are available in AASHTO guidelines.

Now, is there any effect of grade on required overtaking sight distance?
We have explored this same issue when we discussed about the stopping sight distance. Let us see what happens when the vehicle is in downgrades. Here overtaking vehicle can accelerate rapidly because of the grade so there is expected to be lesser time required for overtaking but this factor is compensated by the fact that overtaken vehicle can also accelerate. On the level you assume uniform speed of overtaking vehicle but when it is a downgrade overtaken vehicle may also accelerate so therefore they may compensate each other to some extent.

Similarly, for upgrades more sight distance is required due to reduced acceleration of the overtaking vehicle and likely speeding up of opposing vehicles. So you expect that probably we require higher overtaking sight distance. But here also there is a compensating factor that is in the speed of overtaken vehicle there is a loss in speed for the overtaken vehicle which is frequently a heavy truck, a heavy commercial vehicle so therefore these factors they try to compensate each other in some way and generally no correction is applied for grade.

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We shall talk about another type of sight distance now which is called as intermediate sight distance. So we have discussed about stopping sight distance, decision sight distance and in this lesson we have already studied overtaking sight distance, now we shall talk about intermediate sight distance. This design recommendation is only given by the Indian Roads Congress guideline not by AASHTO. AASHTO does not recommend anything called intermediate sight distance but it is a recommendation given Indian Roads Congress.

Sections where providing overtaking sight distance is impractical for practical reasons or otherwise. That means where it is not possible to have required sight distance at least equal to overtaking sight distance then the intermediate sight distance is recommended which is twice the stopping sight distance. So what is that stopping sight distance requirement? We already have studied the stopping sight distance so the double of that value is intermediate sight distance and it is recommended that wherever due to sight condition or other practical difficulties it is not

possible to provide a sight distance at least equal to overtaking sight distance so in those locations are in those situations try to provide sight distance which is equal to the intermediate sight distance. The idea is if intermediate sight distance is available then that will provide a facility for overtaking at least in a limited manner not fully, but in a limited manner it will provide opportunities for faster vehicles to overtake slow moving vehicles.

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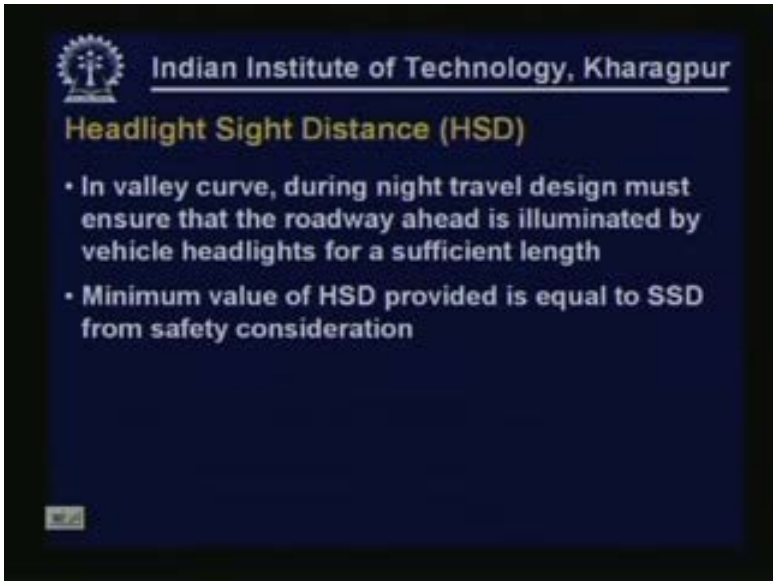


Then we have another type of ah sight distance which is called Headlight Sight Distance (HSD). When there is a valley curve, valley curve is generally concave, it looks like you know concavity upward so when there is a valley curve then during night time vehicles can see only that portion of the road which is illuminated by the headlight of vehicles. Therefore there is a necessity to consider this sight distance for this special situation which is called as headlight sight distance. That means the distance available by the illumination of headlights.

This headlight sight distance should be at least equal to the stopping sight distance so that under emergency conditions during night time driving on valley curves the vehicle can also stop. So the available sight distance or the headlight sight distance should be equal to the stopping sight distance for design purpose. We shall come back to this topic headlight sight distance and discuss in details about its application when we talk about the vertical curve design particularly the valley curve design. So we will come back to this topic later.

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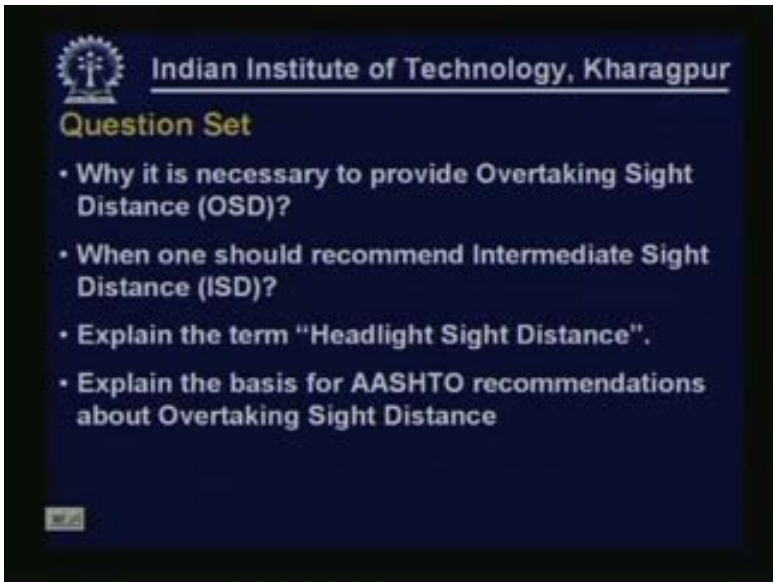


Some of the questions for you from this lesson. Try to answer to these questions.
Why it is necessary to provide overtaking sight distance?
You have studied what is side sight distance so why it is required to provide overtaking sight distance that is under which conditions or under which type of facilities, for which type of facilities.
Then second question: when one should recommend intermediate sight distance? When one should recommend intermediate sight distance?
Number 3: Explain the term headlight sight distance:
Number 4: Explain the basis for AASHTO recommendations about overtaking sight distance;
How the design values are calculated in AASHTO recommendations, what is the basis for that; discuss the same:

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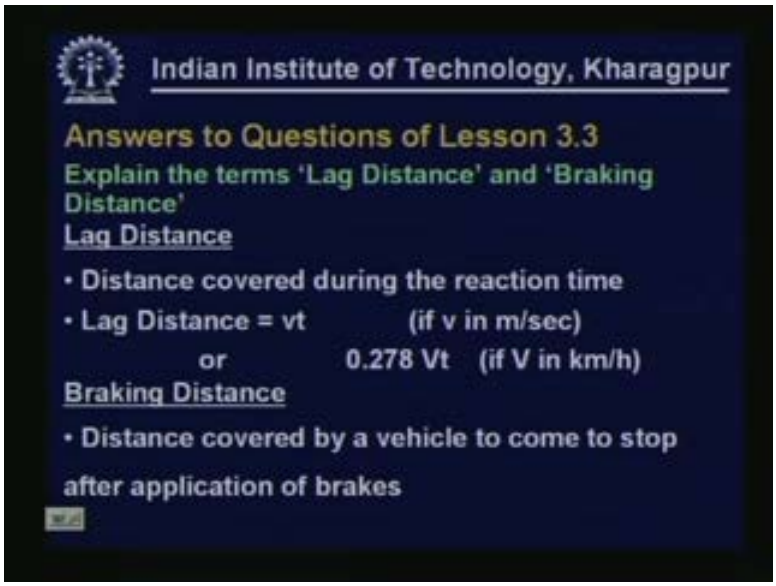


Now I shall try to answer the questions which were raised during lesson 3.3.
The first question was: Explain the terms lag distance and braking distance.
You know, lag distance is the distance traveled by a vehicle during the perception reaction time of the driver. So when an object is visible there is a perception reaction component before the brakes are applied effectively which is at a distance traveled during the time known as the lag distance while the braking distance is the distance covered by vehicle after effective application of brakes. That means when the brakes are applied effectively after that one how much distance the vehicle takes before it comes to a stop.

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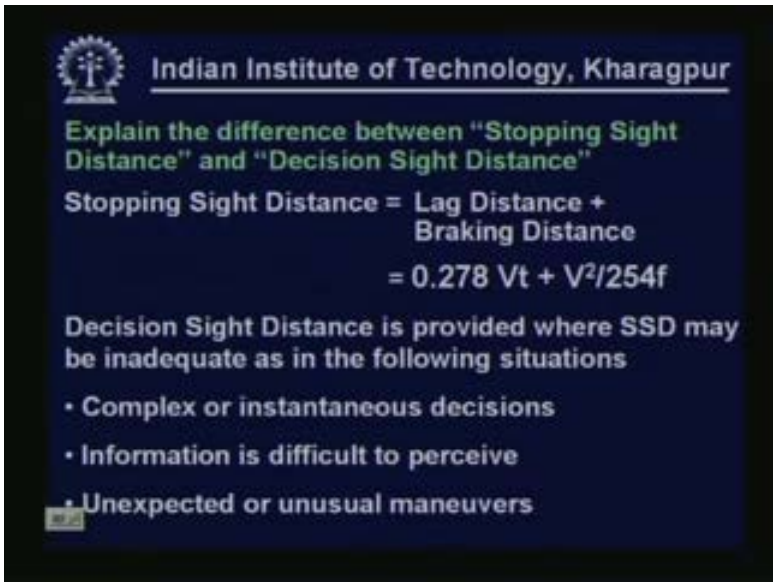

Second question was: Explain the difference between stopping sight distance and decision sight distance:
Now, in stopping sight distance the reaction time considered is applicable for general condition.
But there a certain special conditions where drivers have to make complex or instantaneous decision, where information is difficult to perceive, where unexpected or unusual maneuvers are expected so under those conditions the stopping sight distance and the reaction time perception reaction time assumed for SSD stopping sight distance calculation is not adequate there one has to go for decision sight distance.

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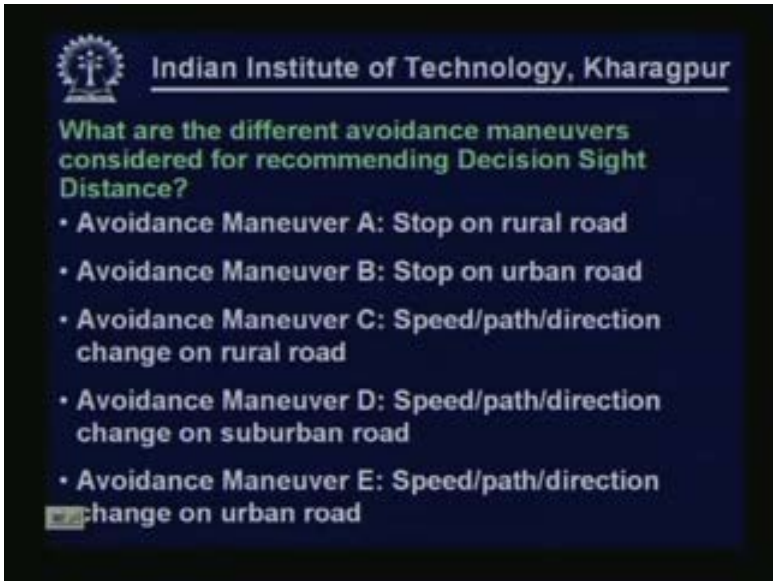


What are the different avoidance maneuvers considered for recommending decision sight distance?
Five different avoidance maneuvers are considered: maneuver A stop on rural road, B stop on urban road, A and B are essentially stop maneuver but then there are C, D and E which are not stop maneuvers but they are speed, path, direction change; C is for rural road, D is for suburban road and E is for urban situation so all the values are different for different maneuvers.

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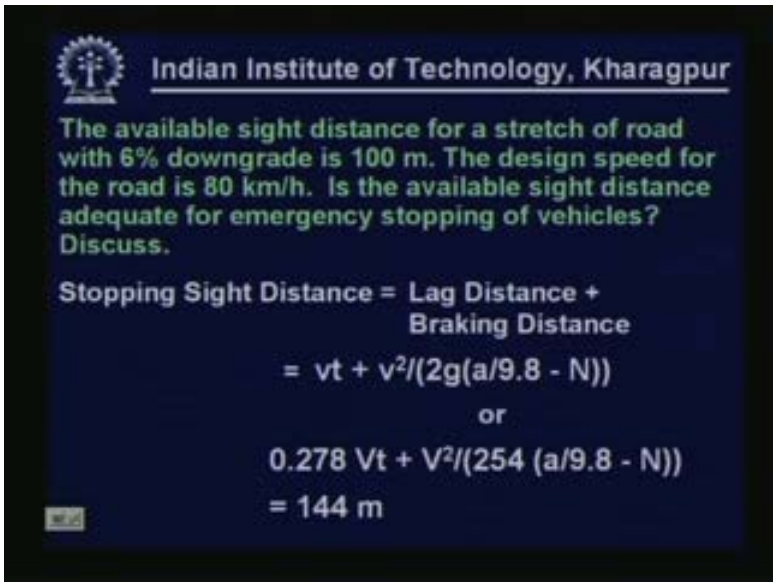


This is the last one: there is a problem: The available sight distance for a stretch of road with 6 percent downgrade is 100 m, the design speed for the road is 80 kilometer per hour, is the available sight distance adequate for emergency stopping of vehicle. The problem is fairly simple. You know that if we take AASHTO recommendations the stopping sight distance can be calculated as shown here, lag distance plus braking distance. So one can apply a comfortable or the design value for deceleration. Here the end value is negative, downward slope so it is minus N written as minus N hence you can calculate the value it is 144 m which is more than the available sight distance which is 100 m.

So what are the options?
Basically one can try to have a different grade so that the available sight distance is sufficient for the stopping or the other option is the restriction of speed. So, one has to go for speed restriction but with proper sign marking so that drivers know that for this particular stretch of road there is a speed restriction so one has to go for speed restriction under such situations.