Illumination Engineering and Electric Utility Services
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Lecture No. # 17
Road Lighting

Welcome to this course on illumination engineering and electric utility services.

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Today we take up lesson 17. Lesson 17 looks into the road lighting recommendations is titled road lighting. Continuing with what we discussed in lesson 16 on exterior lighting, we could say another important aspect of exterior lighting is the road lighting and this lesson addresses road lighting.

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So, hence the instructional objectives for this lesson could be listed as, the list factors affecting the road lighting scheme, one. Two, state the conditions provided by the road lighting, three, list the categories of road and appropriate recommended light levels. Understand zones in a tunnel lighting, the door lighting invariably also includes lighting for tunnels, tunnels are integral part of the roads and lastly what are post top lanterns. So, this is the aim of today's lesson. We are looking into the second most important aspect of exterior lighting, the road lighting.

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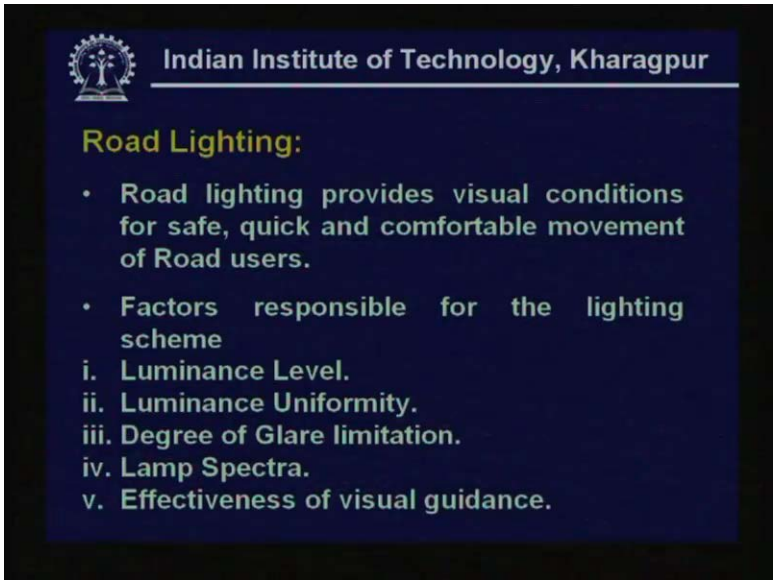

The road lighting actually aims at providing good visual conditions for a safe, quick and comfortable movement of road users. Road users consist of vehicular movement and depending

on the nature of the road, it could be combination of light vehicles, heavy vehicles, pedestrians. It could be a combination and hence the roads are categorized according to the type of load it has to carry or type of uses it has to carry. So, the aim is to provide quick, safe and comfortable movement of road users. And road users could be pedestrians, light vehicles and heavy vehicles. And therefore depending on the time of the day and the speed of the vehicular movement and the density, one has to provide the conditions so that you are able to recognize the obstacles. Therefore, if you look at the factors responsible for the lighting schemes are luminance level, luminance uniformity in fact uniformity of luminance is very important.

We saw that even in case for sports lighting where certain uniformity indices were developed which were used to take care of a conditions required for the sport on hand. Thirdly, a degree of glare limitation, as all of us are aware glare is the one of the causes of a bad design of lighting schemes and is the source of discomfort, it could if allowed to occur in large quantities can even impair the vision. The lamp spectra which is to be used and the visual guidance, it's believed the lighting is to guide the road user to go along the path in an appropriate manner. Incidentally the roads in urban metros are of dual purpose apart from enabling the road user to understand the obstacles that are there, it also needs to illuminate the surroundings. So, these are some of the five factors that are taken into account when we look at the road lighting.

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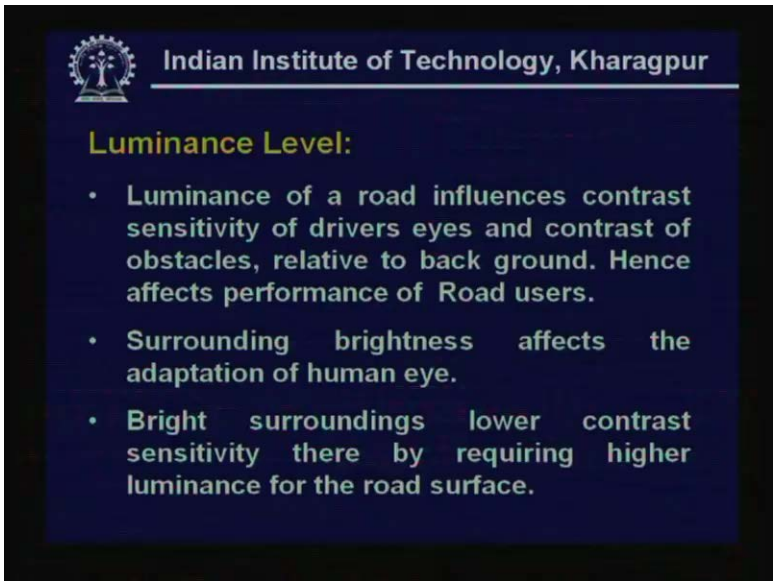

Considering the first one luminance level, the luminance of a road influences the contrast of driver's eye and obstacles. It depends on the background and therefore this has high impact on the performance of the road users. Now predominantly we find two categories of roads, one which are made of rccr cement concrete which are essentially good reflectors of light. On the other hand you have black top roads which are predominant absorbers of the light and the ability of human eye to adapt to the conditions and able to discriminate the obstacles very much depends on the relative brightness, therefore surrounding brightness also makes an impact. Bright surroundings with lower contrast sensitivity therefore require higher luminance for the road surface.

So bright surroundings if you have you need higher luminance for the road surface so that you are able to really take care whereas darker surroundings, it is possible with lesser luminance for the road, the driver is able to adapt to the road.

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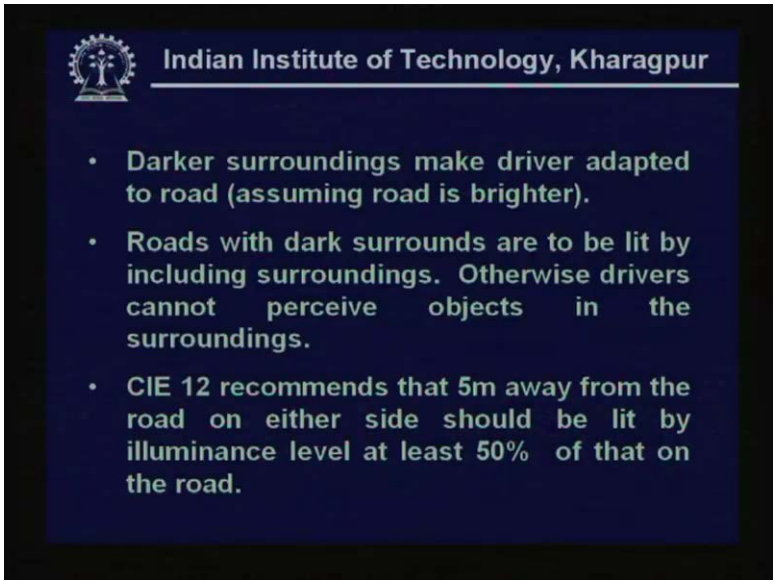

Roads with dark surroundings are to be lit sometimes to include the surroundings because this could be the situation typically in a high way which is passing through uninhabited area and it is necessary specially in our time if there is any wild animal in the surrounding. So there is some amount of surrounding lighting included with the part of the road or street lighting. This is what we call road lighting or street lighting, the roads could be simple, small streets within the residential areas or urban roads then express ways or high ways linking various towns and cities.

The international commission CIE 12 recommends that about 5 meters on either side of the road should have illuminance level at least 50% of that on the road. If we say that we need about certain amount of illuminance on the roads then 50% to that 50%, at least 50% of that is expected to be available up to 5 meters on either side of the edge of the road that enables some amount of surrounding lighting. As already mentioned in case of an urban street, this light itself helps in as a part of illuminating buildings stretching along the road.

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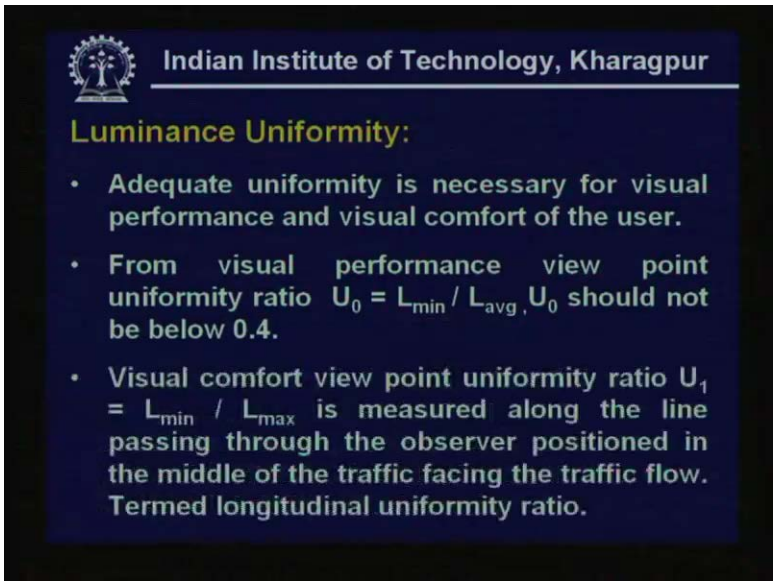

Next comes the uniformity in fact uniform illumination or uniformity of a condition of visual conditions enables good performance and requires less changes in adaptations. So, it is necessary both from the visual performance and visual comfort of the user. From the visual performance view point, the uniformity is specified by the index U sub o or U sub naught defined by the ratio of the luminance, minimum luminance to the average luminance. That is L min over L average and this is said to be U_0 and U_0 is recommended never to be below 0.4. So, visual performance index is talked about in terms of uniformity ratio U_0 which should be never less than 0.4. The other aspect from the uniformity point of view is the visual comforts which again actually, why do you have this comfort coming into picture.

If there were abrupt changes in the light levels, the eyes need to adapt and that is where the performance of the human eye come into picture and comfort also. So this is where these indices come of use. So, the visual comfort view point uniformity ratio is defined as U_1 is the ratio L min to L max that is luminance minimum to the luminance maximum and it is measured along a line passing through the observer facing the traffic flow in the middle of the road and this is called also longitudinal uniformity ratio. So, the luminance uniformity is taken care to have good visual performance and we shall comfort and it's specified by two indices, one U sub naught another U sub 1. And one being specified not to be below 0.4 and the other based on the, based on the measurement along a line passing through the observer facing the traffic in the middle of the road and is termed longitudinal uniformity ratio.

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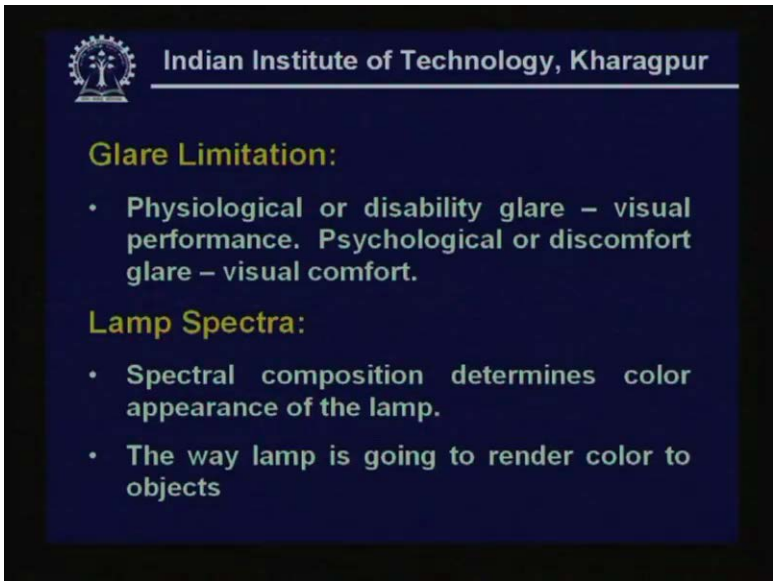

Then the question of glare limitation comes. Glare limitation is addressed from two angles, one is physiological. Physiologically increase glare would mean producing disability glare altogether impairing the vision or affecting the visual performance whereas psychological aspect comes in or discomfort glare which affect the visual comfort. So, glare again is an issue which comes from the point of view of visual performance. The lamp spectra actually looks at how the colour appearance comes into picture and this is to be taken from two aspects, one how the radiation per say appears from the lamp that is because of the spectrum that it radiates like we know that the sodium vapour lamp has a tendency to give yellowish, orangish radiation. And the other issue is the way lamp is going to render colour to the objects which we call colour rendering.

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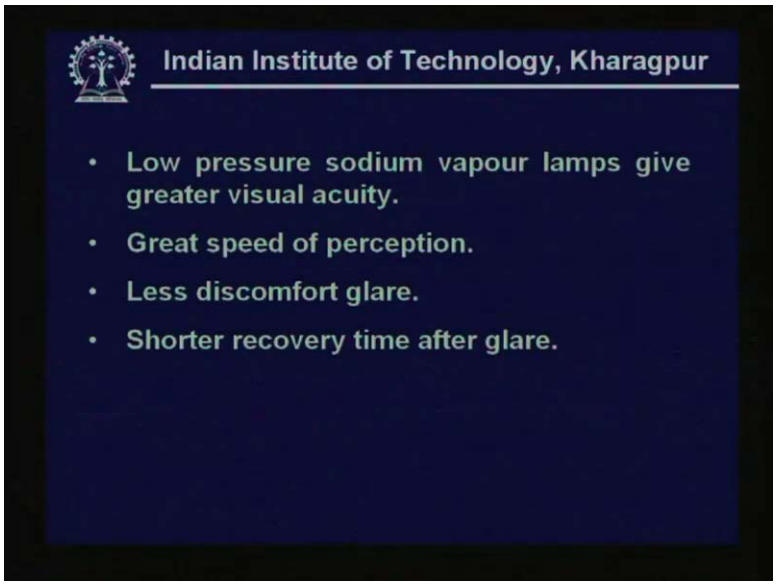

But we find that from the usual utilization point of view, we have already seen the sodium pressure lamps give good performance and is in fact extensively used road lighting lamps. They are known to give greater visual acuity with greater speed of perception and less discomfort glare. The other issue is that subsequent to the discomfort due to a glare, the recovery time for the eyes to become comfortable it's observed that they have shorter recovery time after glare.

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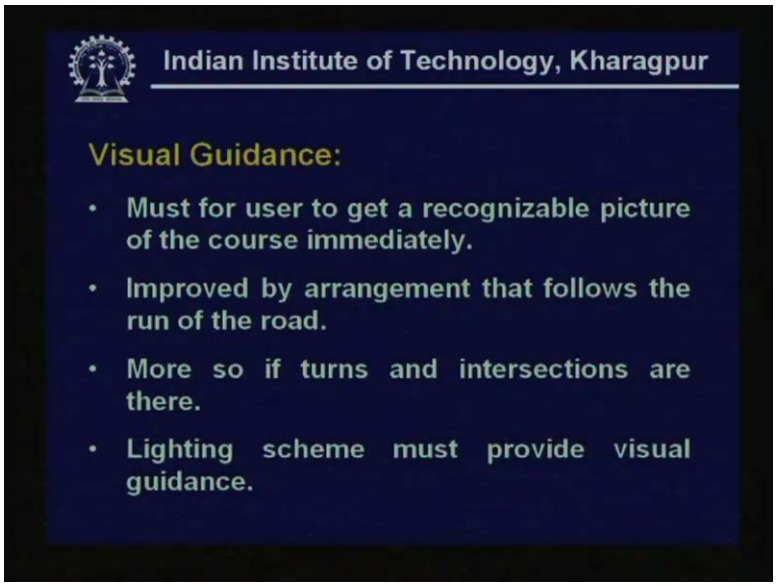

We said visual guidance is a must. Yes, visual guidance is a very very important issue, in fact this tells us the way the road leads to where you need to go. This is very important for the driver to get a recognizable picture of the course immediately. Mind you, if it is a high speed vehicle he has to observe the obstacles and remember that there is a certain minimum time or minimum distance necessary for it come to a halt even if we sees a obstacles and tries to apply breaks. So this is improved by taking or locating the lamps which follow the run of the road. Especially this has to be taken care, obviously we cannot be having long straight roads all through and if roads have to serve our purpose, there should be turns, curves, bends and intersections without which they will not serve the purpose which we require. So the scheme or the location must provide all these aspects.

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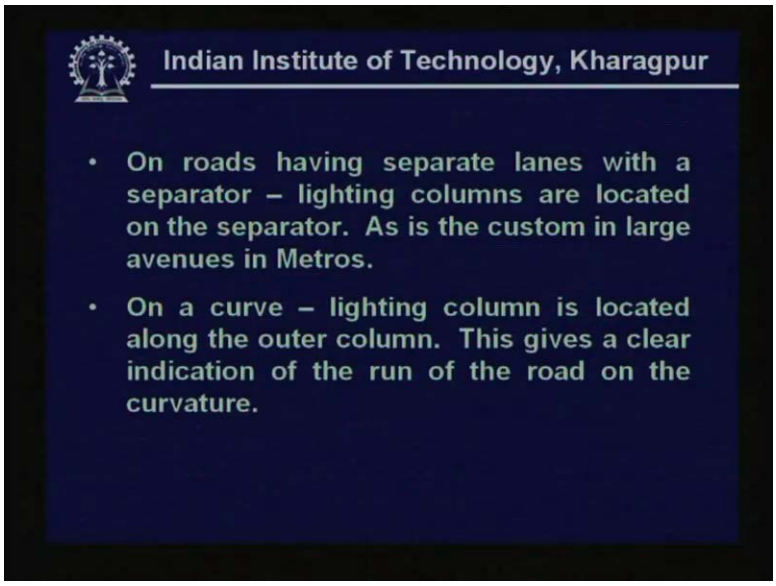

Now in case when we find where the traffic density is high especially in large metros and even in high ways, one does have separate lanes. And quite often there are separators separating the two lanes in such situations the lighting column are located on the separator, as all of us have noted such things in large avenues in metros. When locating on a curve, it's preferable that we locate it along the outer column so that the user is very clear, the curvature nature of the curvature and how the road is getting along because it is believed that visual guidance enables the user to know.

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And in fact in order to have branching of, as I told you that it can be curves, intersections, junctions all these are necessary. It may so happen at a particular point a road may branch off into three different directions lead into three different towns. So this is where the lamps of different colors could be used to really pilot the traffic into the direction it is desired. Often, it's taken care to see that exits to branch roads from the main roads are differently lit and as already told sodium vapour lamps are extensively used for the road lighting. One could possibly be using sodium vapour lamps for the main roads and the exit roads or the branch roads could be having mercury lights.

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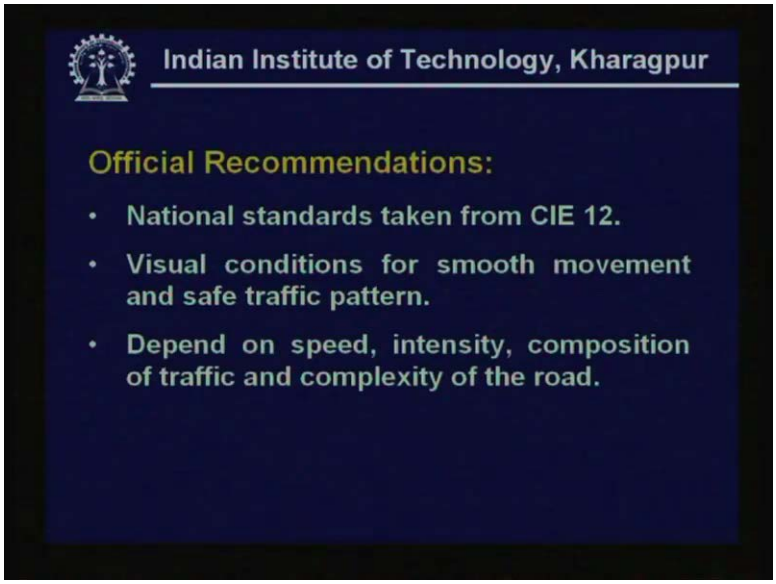

Look at the official recommendations. Official recommendations are contained in several national standards which are again adapted from the international recommendation CIE 12. The aim of these recommendations is essentially to have smooth and continuous safe traffic movement and enable the users of the road to be able to observe the obstacles and the lighting provides the necessary visual conditions. Therefore these recommendations depend on the speed of the traffic, intensity of the traffic composition, composition meaning light traffic, heavy traffic could be two wheeled, four wheeled and pedestrians whether it is an express way or a small road, large road, road with lanes, road without lanes.

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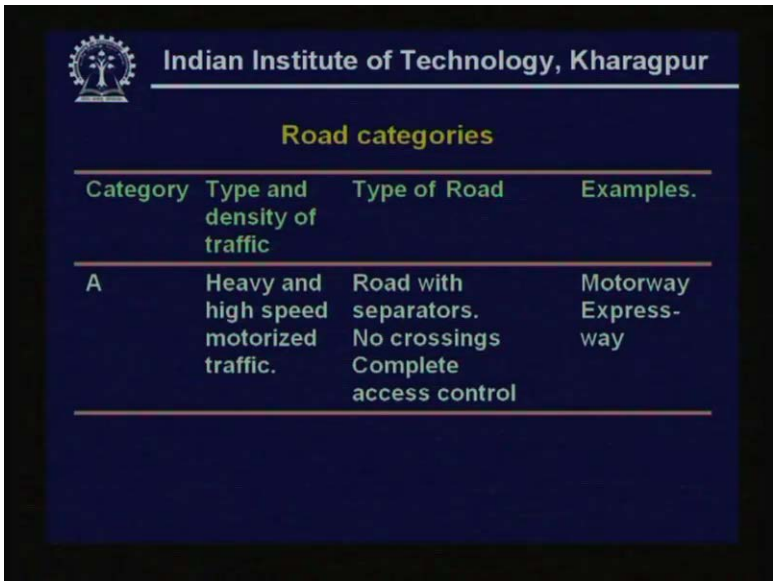

This brings in the concept of categories of roads. We can see the table here we have a listed, what is known as category A. The category A consists of essentially heavy vehicular traffic says heavy and high speed motorized traffic that is heavy vehicular traffic moving with high speed and normally such roads are either national highways or state highways or called interstate highways and if and often times called express ways or motor ways, they are usually having no crossings for very long distance. There is a complete control of access to these roads and usually have lanes with fixed separators. So the lighting columns could be located on the separators.

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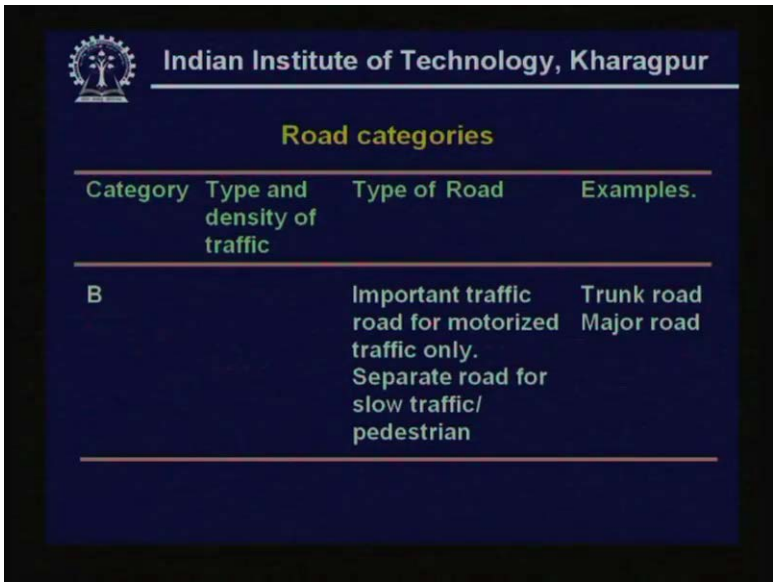

As opposed to this, we have slightly lower density and lower speed traffic termed as category B. This could be a trunk road or major road in a city and here the main roads are essentially for we have a main road which is made for vehicular traffic with adjoining streets for slow traffic and pedestrians as we find in metros.

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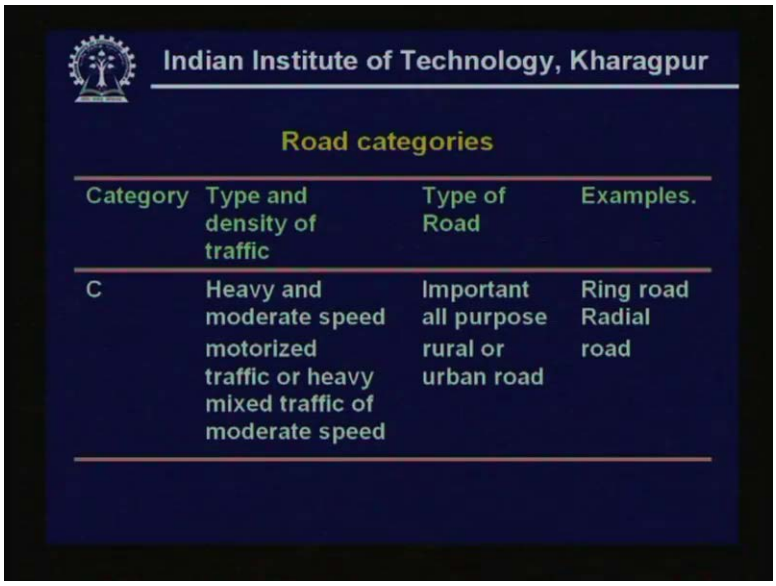

Then we have a composite category or C where you have both moderate speed traffic and mixed traffic of moderate speed that is all categories. These could be important urban roads or rural roads and in fact these come under the category of what we call as ring roads, we do have ring roads in all cities so that they do not interfere with the local traffic within the town which basically connects the major points within them.

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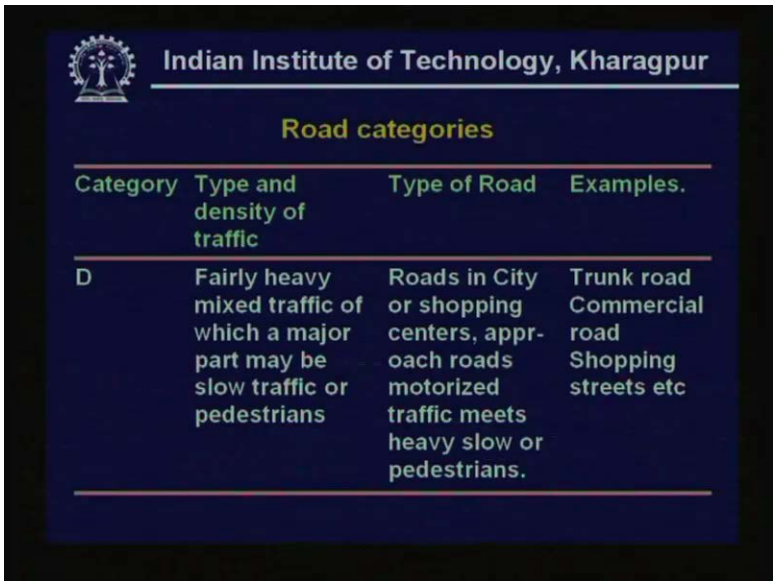

Then when the mixer of the traffic keeps increasing where the slow traffic content goes higher we call that D, this is a city centers these are linking to shopping areas and invariably the pedestrians density starts increasing in these roads, they are called category D. Now why are we looking at this? When we look at any of the standards for the official recommendation levels, the two issues which will be coming up is the luminance levels and the visual uniformity indices and they depend on the category of the road.

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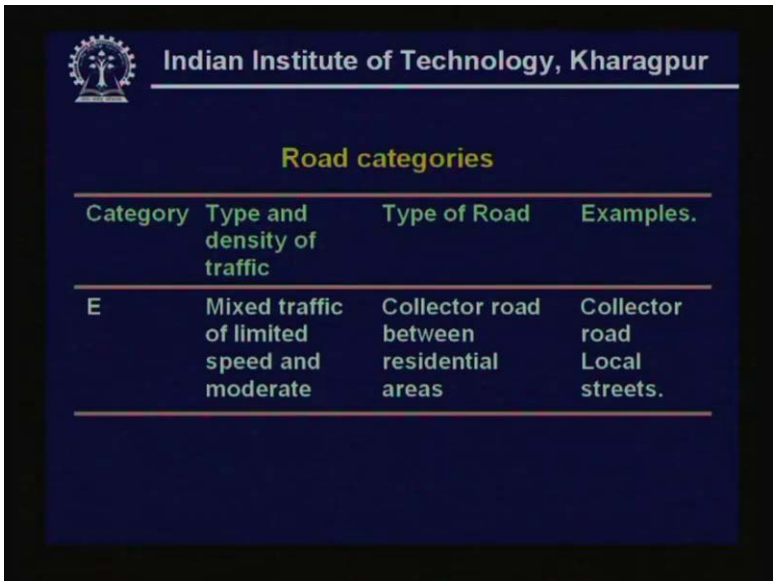

Lastly you have highly mixed traffic predominantly pedestrians, this could be in the highly residential area where only slow traffic will be there, this will be the local streets and they are

also called collectors road. So what do we find, depending on the composition and the mix of the traffic and the nature of the roads we have five categories. So we have recommendations accordingly.

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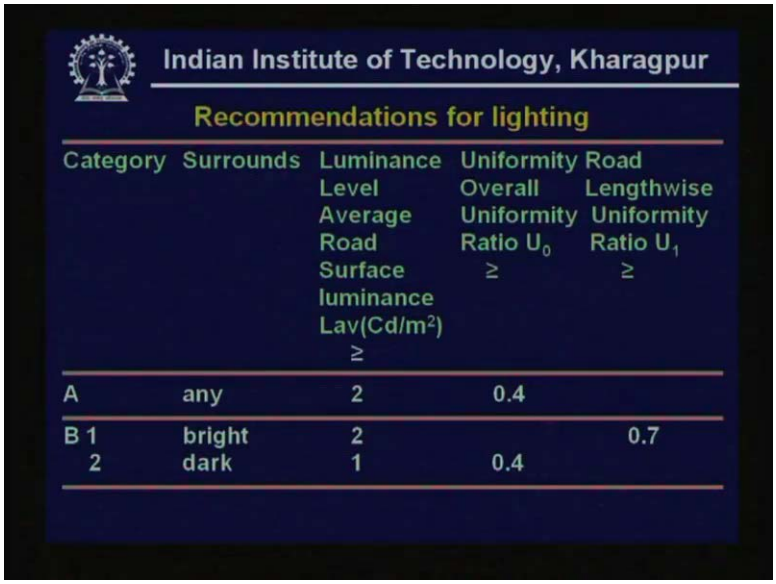

If you see the table for recommendation for lighting, the first column talks about category. Second one is surrounds then average road surface luminance level is mentioned and you have the two uniformity indices which we talked about L min by L average or U naught, L min by L max along a line where the observer faces the traffic flow called the longitudinal uniformity ratio U_1. These levels also take into account what we call surroundings. Observe that for the category A no matter what is a surroundings, remember category A is essentially express ways which have complete access control to the roads. One must say that there are hardly any slow speed traffic, its high heavy traffic and would come under the category of national highways or state highways.

It's recommended to be around 2 CD per meter square and uniformity ratio, I told you it can never be below 0.4, it's kept around 0.4 and U_1 remains around 0.7. As opposed to when we move to category B there are two roads, one corresponding to bright surroundings other corresponding to dark surroundings, as you can see the surroundings are dark one could do with lower level of luminance, surface luminance is recommended to be 2 CD per meter square bright surrounding and about 1 CD per meter square for dark surroundings. U_0 still remains at 0.4 and U_1 is expected to be around 0.7.

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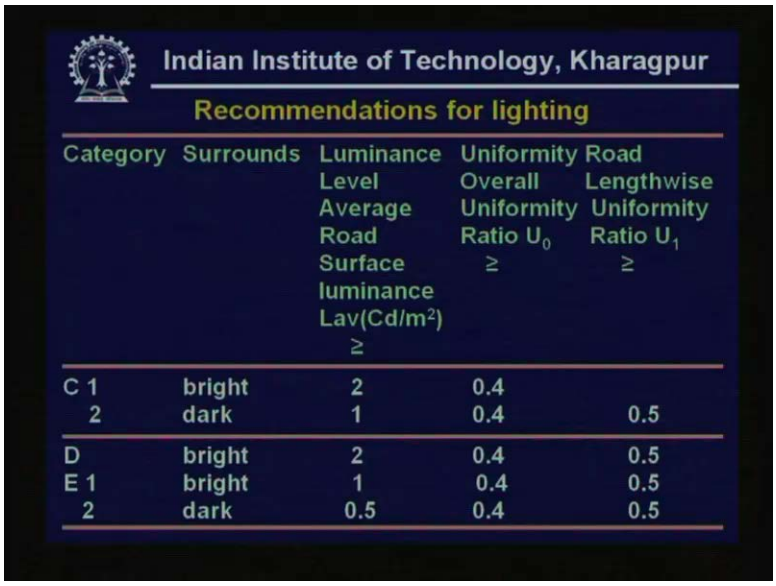

Category	Surrounds	Luminance Level Average Road Surface luminance Lav(Cd/m²) ≥	Uniformity Ratio Overall Uniformity U_0 ≥	Road Lengthwise Uniformity Ratio U_1 ≥
C 1	bright	2	0.4	
2	dark	1	0.4	0.5
D	bright	2	0.4	0.5
E 1	bright	1	0.4	0.5
2	dark	0.5	0.4	0.5

When we move to the category C where we do encounter some slow speed traffic, we find it remains, for bright surroundings we have around 2 cd per meter square whereas with dark surroundings it reduces to 1 and uniformity indices U_0 is more or less recommended for all categories of roads to be around 0.4 which U_1 which was expected to be around 0.7 for category A and B is allowed to be around 0.5 for category C D and E. One may see that the level required under the category E has come down to 1 and 0.5, essentially because it's predominantly slow speed traffic with pedestrians included. So, as already said the requirement of luminance levels goes higher with the speed we saw that the heavy traffic was categorized as A.

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Now looking at the arrangements, the arrangements can be looked at this way. Consider the situation where there are two way traffic roads, two way traffic roads means you have the, in fact we do find in order to control the traffic in cities we do have one way roads. There are four arrangements, the first one is single sided, you locate on one side and this is done by considering if the width of the road is less than the mounting height so that luminance at the opposite remote end will be lower than that under the lamp. So we have the first arrangement which is single sided, we locate on one side. The second arrangement is staggered, we locate on either side of the road in zig zag fashion, this is resorted when it is 1 - 1.5 times the mounting height so that along the road dark patches are provided. Only disadvantage with having a staggered thing is that from an electrical point of view, one may need to have two separate circuits for each sort.

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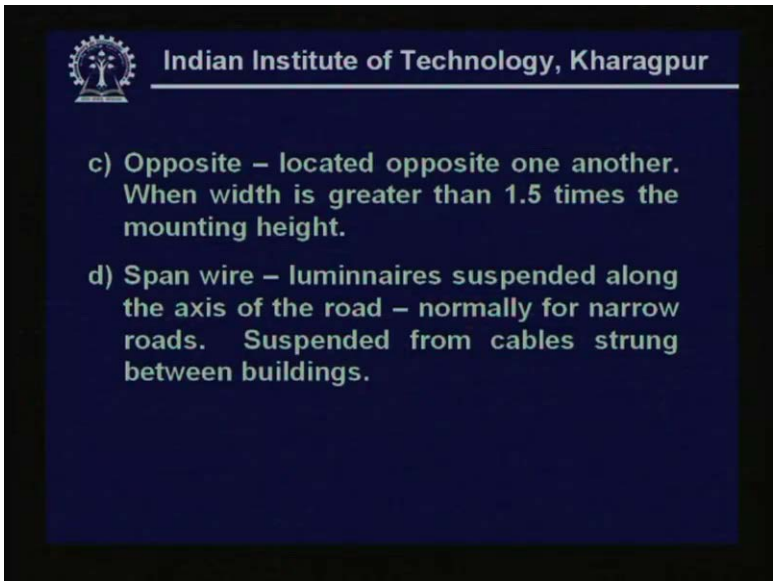

Opposite, located opposite to one another in the wider roads like a venues, when width is greater than 1.5 times the mounting height, we locate lamps on the opposite sides or a fourth arrangement is the what we call as a span wire arrangements basically suspended, luminaires are suspended along the access of the road and this practice is only for small narrow roads where the lamps are suspended on cables or strings strung between the buildings.

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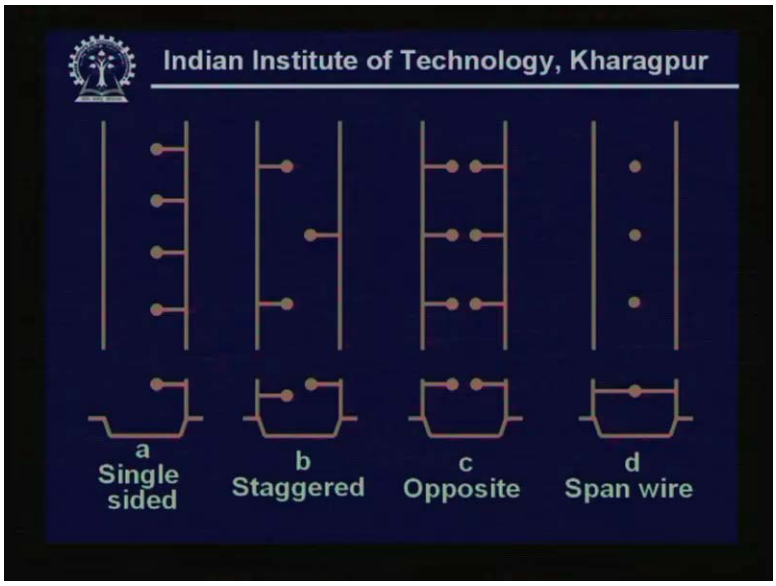

Let's look at these picture, these pictures show the various arrangements. The figure a shows all the lamps in fact the two views are there, one top view along the road, the other the perpendicular sectional view. So you can see when the lamps are mounted on single sided as shown in a, in staggered you locate alternatively on either side. However remember this keeps in mind the width of the road, when the road becomes wider we tend to have the arrangement shown in C which is the opposite arrangement. There are two lamps one opposite to the other. For very narrow roads I said the span wire arrangement is taken resorted where the lamps are suspended the center of the road as shown in figure D. These are the four arrangements.

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As against this in high speed ways and dual lanes where separators are available, the lamps are located on the separator. So, in very high speed ways and multi-lane roads where separators are there, they are located on the separator. This arrangement is known as central twin bracket arrangement.

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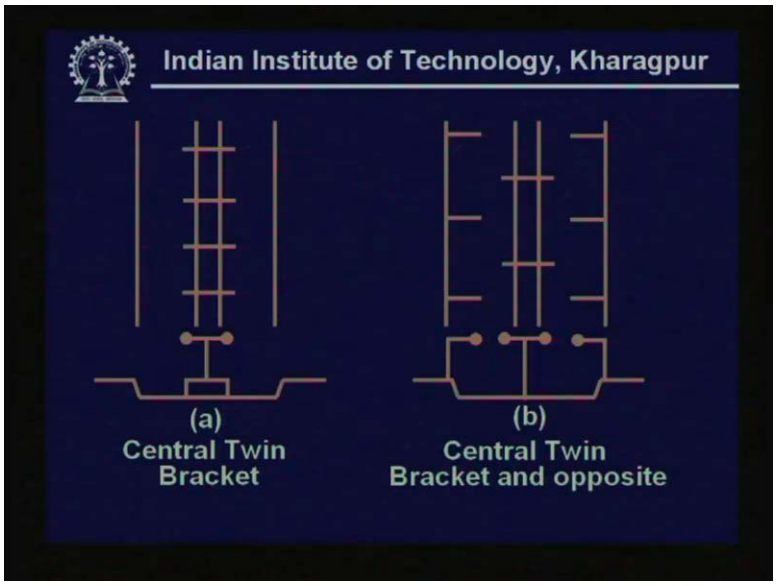

This can be seen in this figure. Here again you have two categories, one where each lane is narrow you may just have lamps twin brackets located on the separator alone. On the other hand there the lanes themselves are high I mean wide, you have central twin bracket and opposite. There are number of, here it shows a kind of a staggered arrangement in the figure B with opposite central twin bracket and opposite arrangement. So we saw that there are four arrangements for the roads without separators either by providing only on one side zig zag fashion I said zig zag fashion, the problem would be you will have to have cabling on either side of the road. Third was opposite when the road is very wide or span wire when narrow roads but for the roads with multi lanes and separators, they can be located on the separator with what we call as central twin bracket. Here again depending on the lane size, lane width there could be just lamps located on the separators or with the opposite, though we have shown separator with staggered arrangement for opposite lamps it could be similar to the single lane kind of a thing.

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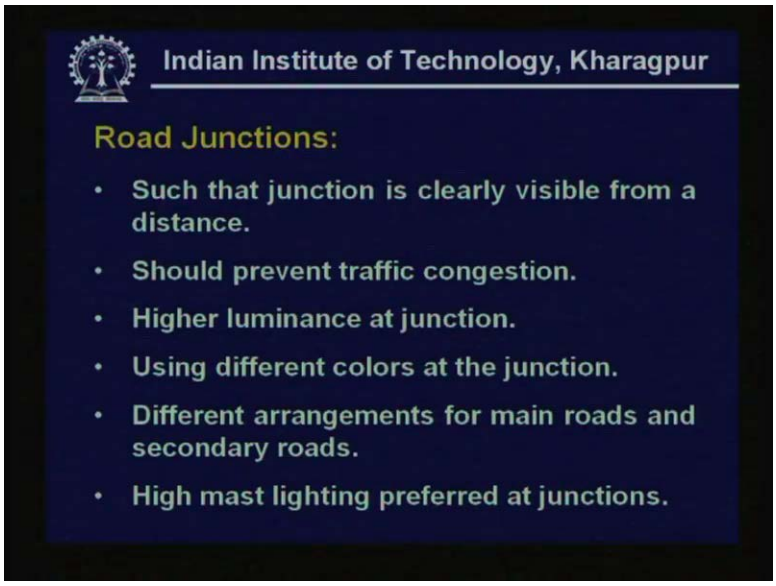

Road junctions are need to be taken care and they need to be visible from a distance in fact that is why they are in fact linked with a different colour often times because if not done because that is where the traffic gets deviated diverted into various directions and could cause traffic conjunction otherwise, therefore the first thing that is done is the luminance at the junction is increased, number one. Number two it's made of a different colour. These two enable the ability of smooth traffic movement and diversion junctions and therefore care is also taken that in main roads or secondary roads are having different arrangements. And in fact typically at a junction the mounting height is further increased or what we call as high mast lighting is resorted. Therefore this statement says high mast lighting is preferred at junction.

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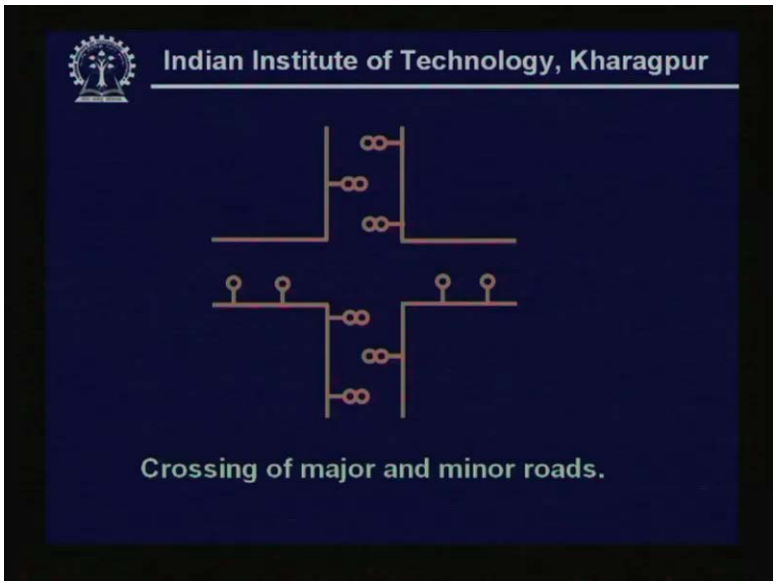

Then in fact this shows, picture shows an arrangement where there is a major road and a minor road and a crossing. As can be seen to distinguish between the two arrangements, the lamps on the major roads which is perpendicular from top to bottom of the figure, the arrangement taken is staggered. The double circles indicate they are possibly the lamps of higher flux levels and in the minor road we find that they are arranged only on one side there by making at a little lower level. Remember that the minor road needs to carry lower traffic density.

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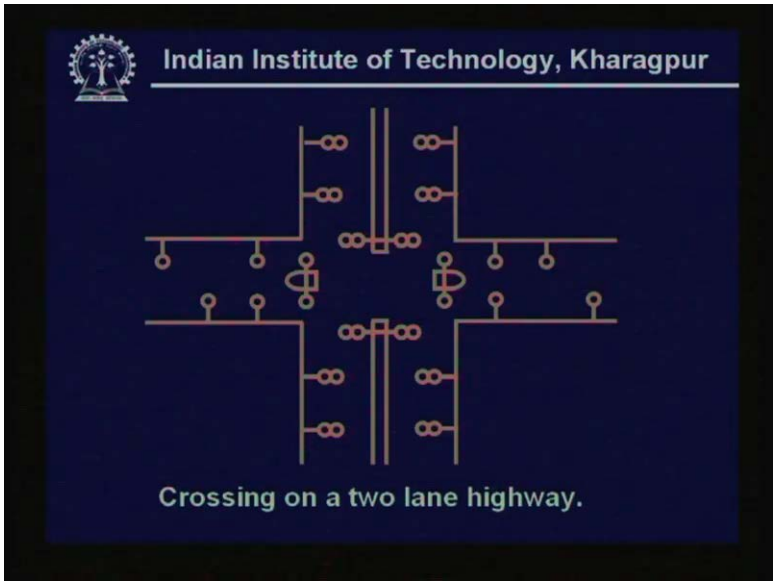

This again shows a junction with crossing a two lane highway with a single lane road. And as you can see the, both the two lane highway as well as the single lane highway are lit using what are called as the staggered arrangement of lamps in case of a single lane highway and opposite arrangement for the major highway but observe around the junctions, number of lamps have increased, as already pointed out junctions intend to increase the illuminance levels. This is what has been done. So, as you approach the junction the illuminance levels are increased.

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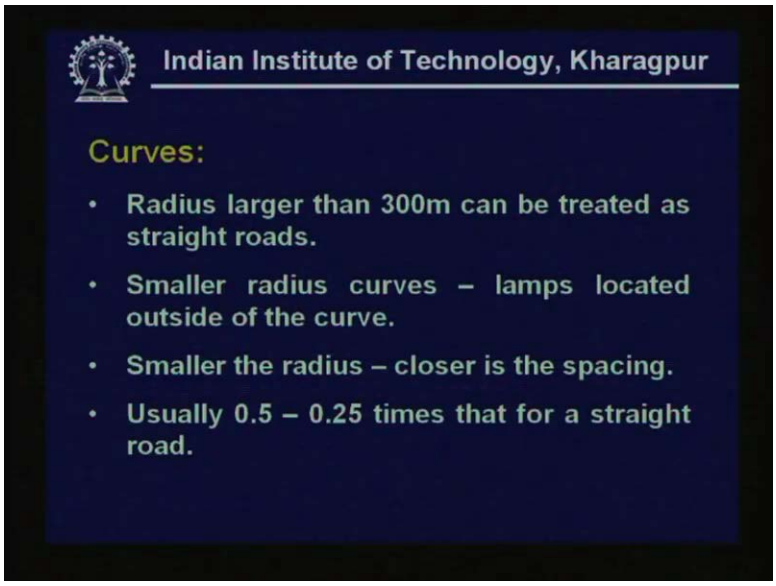

Curves have to be taken care as I said outer end of the curve is lit so that you are really guided. Now when the curve radius is larger than 300 meters, one could adapt the same techniques which are adapted in the straight roads but smaller radius curves you have to locate lamps on the outside curves so that you know the and in order to accentuate the curve, the spacing between the lamps which is larger on straight roads is reduced. So, this is another area just as we try to increase the luminance at a junction, we also try to increase at the curve. See, in fact the spacing is reduced to as low as 0.25, 0.5 to 0.25 times that for a straight road.

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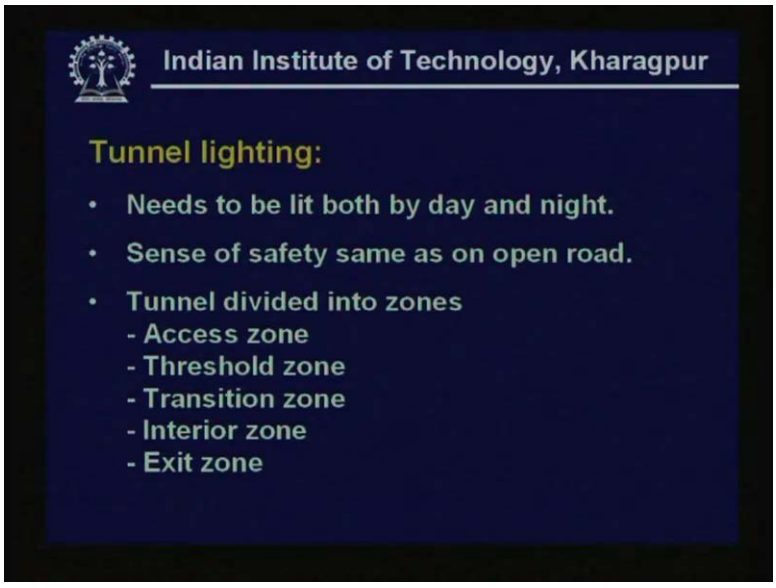

Tunnel lighting is another important thing because in long roads one has to in fact does encounter tunnels and depending on the length of the tunnel they may need to be lit both by day and night, so that one feels as safe inside the tunnel as on the open road. Therefore in trying to do this, tunnel is divided into zones. The zones are access zone or just little outside the tunnel, threshold zone entered of the zone inter tunnel, transition zone from outside environment into the tunnel, the interior the tunnel proper and the exit zone.

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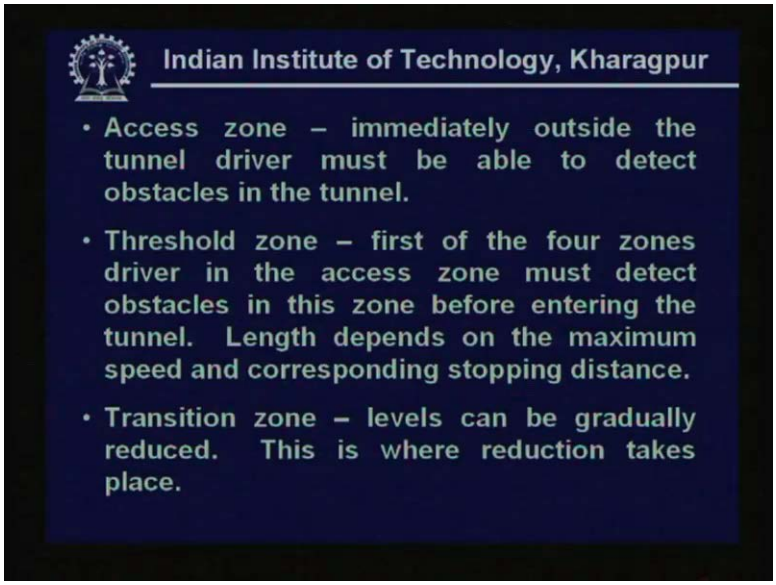

You see the zone immediately outside the tunnel is what we call access zone. This should right away when the driver in this zone he should be able to detect obstacles in the tunnel so that it has not entered that. The threshold zone is the first of the four zones where before entering the tunnel, if there are any obstacles the driver should be able to find out. This definition depends on the maximum speed and the stopping distance involved and that varies from road to road. Now transition zone is one where the levels can be gradually reduced illumination levels. Obviously inside the tunnel illumination is lower much lower than outside, we are talking about say day time, so it can be gradually reduced so that one can get adapt even at the high speed to the darkness in the tunnel.

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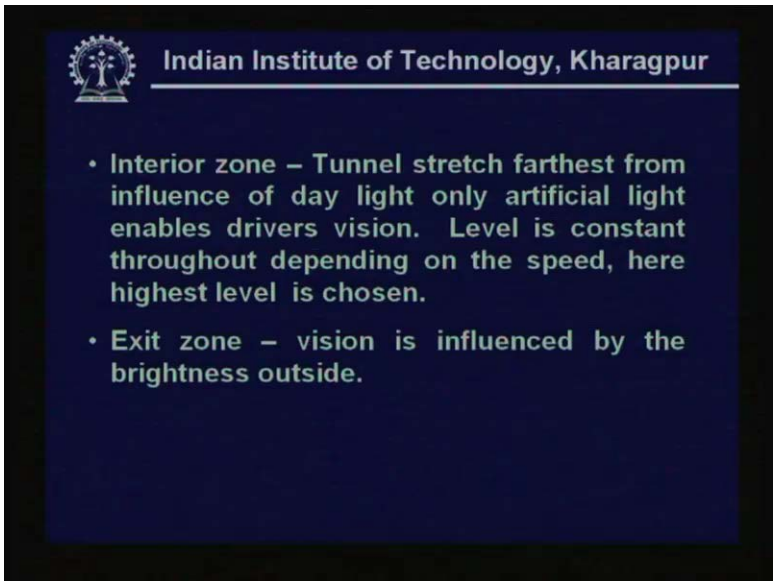

This is the tunnel stretch what we call interior zone which is the farthest from the influence of day light and entirely by the artificial light driver is guided and it is kept constant and usually the highest level is chosen here. Again this is a zone where influence of the brightness from outside begins to appear because he is about to come out.

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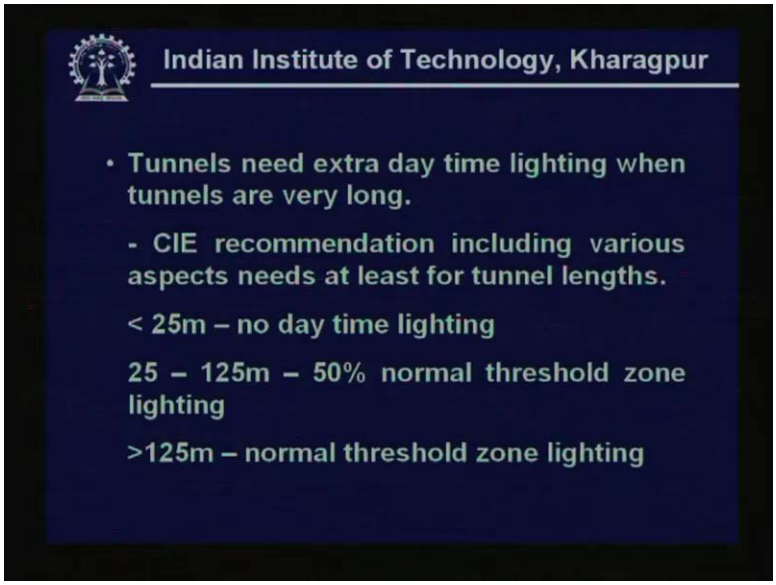
e 

So this is the four zones which are there in tunnels and it must be mentioned that in view of bright light during the day time outside, tunnels need extra day time lighting more so when the tunnel stretch is very long.

CIE recommendations consider depending on the tunnel lengths, if the tunnel length is less than 25 meters there is no day time lighting required, 25 to 125 time meters 50% of the normal threshold zone lighting is required and anything more than that as much as normal threshold zone lighting, threshold is threshold zone is just at the entry.

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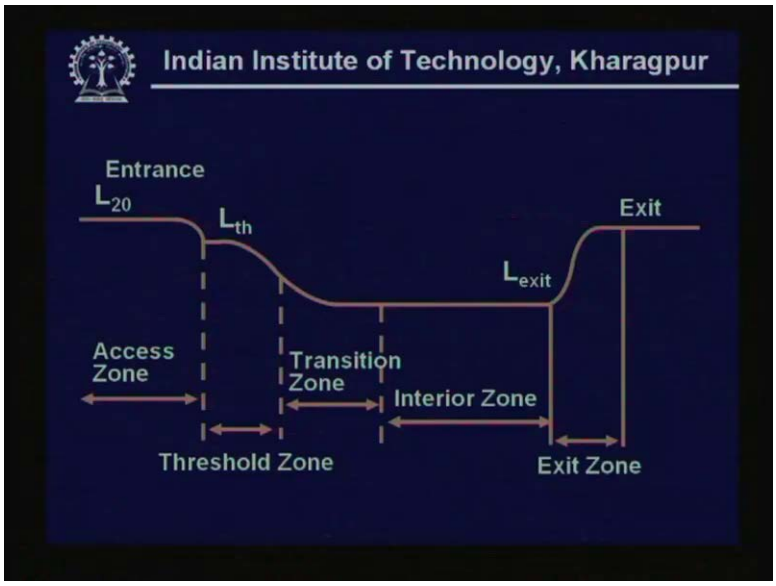

And this is shown in the form a picture, what you are seeing at the entrance is the luminance due to a broad day light and this is a threshold zone and transition zone, interior zone what we are calling is the stretch, the longest stretch or stretch of the tunnel which is very important.

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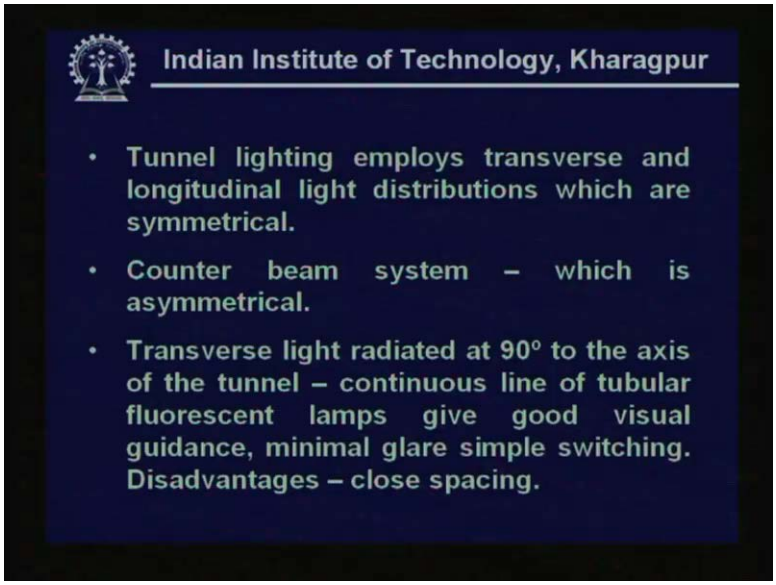

So if that is the case the, what are the types of arrangements they use? The tunnel lighting employs transverse and longitudinal light distributions which are symmetrical, transverse is perpendicular to the road or longitudinal along the axis of the road. Counter beam system also is used but that produces what we call as an asymmetrical lighting. Transverse light is radiated at the 90 degrees to the axis of the tunnel. So you have continuous line of fluorescent lamps and they can, they are spaced close by and if proper diffusing luminaire is used, they produce minimal glare and becomes ease of control by way of simple switching. This is the first scheme transverse light.

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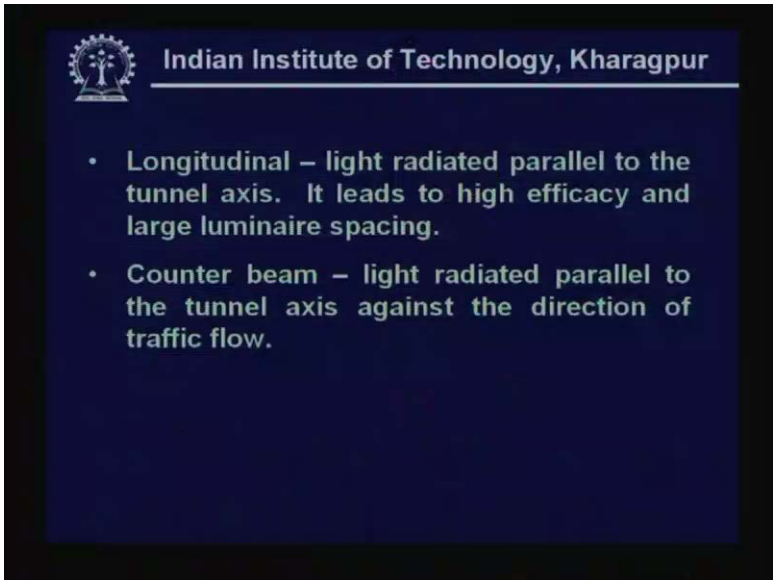

As opposed to this you have a longitudinal scheme, light is radiated parallel to the tunnel axis. The advantage of such a thing is if you are using again fluorescent lamps, you are able to provide with larger luminaire spacing, as if you put transverse spacing between luminaires has to be shorter. Counter beam light is again radiated parallel with tunnel axis but it is against the direction of traffic flow. This presupposes that the traffic is going to flow only in one direction in the tunnel; it cannot flow in both the directions. That's the thing.

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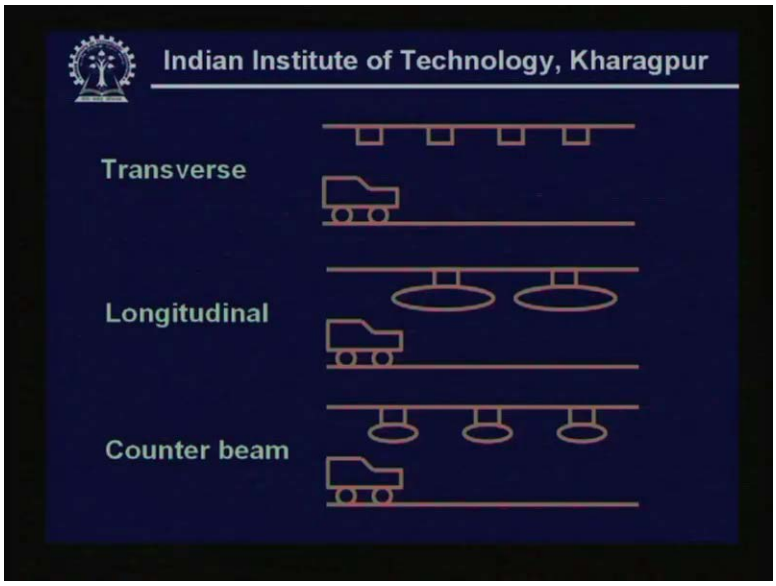

So the picture here shows transverse perpendicular to the plane of paper, the fluorescent lamps are located that's what in the top picture. Longitudinal, they are located along the axis, the spacing can be larger. Counter beam opposite to the traffic flow, so the traffic is flowing from left to right and therefore this presupposes traffic is flowing only in one direction.

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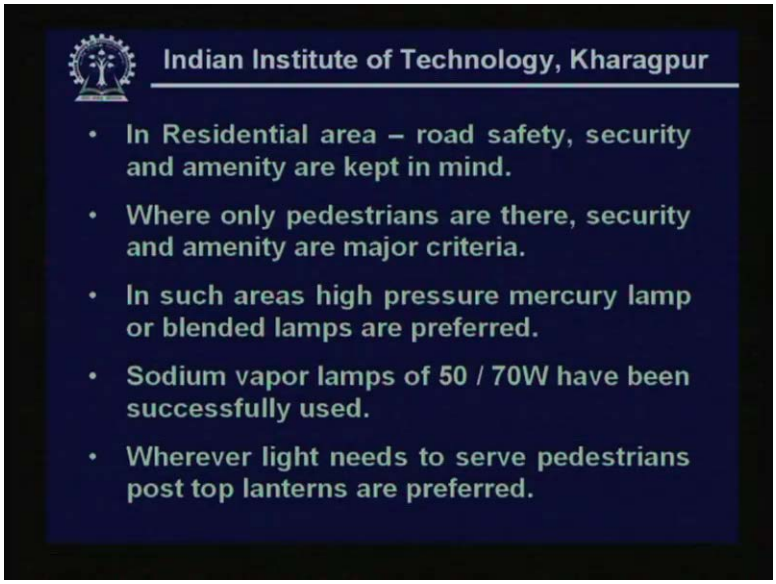

In residential area road safety, security and amenity are kept in mind. Now here in residential areas, the major issue would be the pedestrians are there and security and comfort of the pedestrians becomes very important.

In such areas high pressure mercury lamps or blended lamps as already said in sports lighting, the to improve the current colour rendering metal halides which are nothing but high pressure mercury vapour lamps with halides included give good colour rendering. Sodium vapour lamps of 50 and 70 watts are successfully used. Wherever lighting needs to serve pedestrians we do use post of lanterns, in fact this is one thing which is also used in garden lighting which is another form of exterior lighting though does not fall on the category of road lighting but this is what is done.

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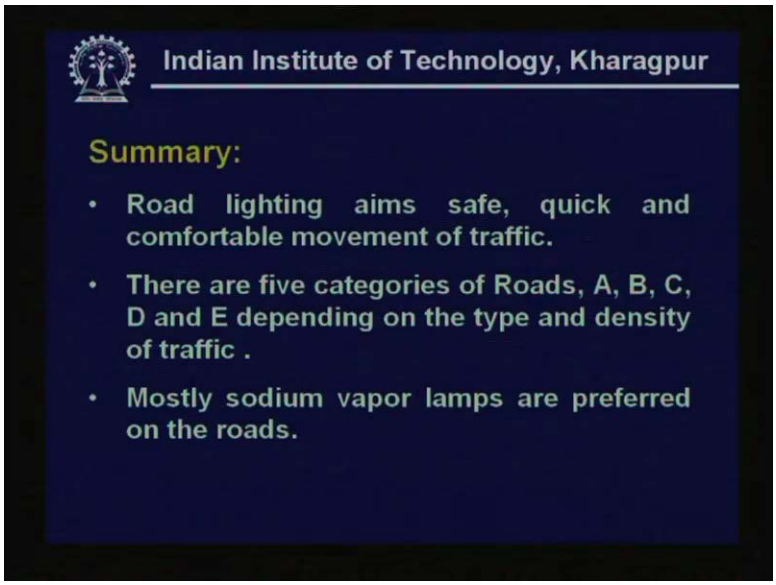

And in total the summary of this lecture, lesson may be road lighting aims safe, quick and comfortable movement of traffic which may include heavy traffic, light traffic, pedestrians depending on the nature of the road. The categories of the roads are A B C D and E depending on the type, density and mixture of the traffic that is if pedestrians are there, pedestrians are there or not there and most road lighting preferred category of lamps are sodium vapour lamps.

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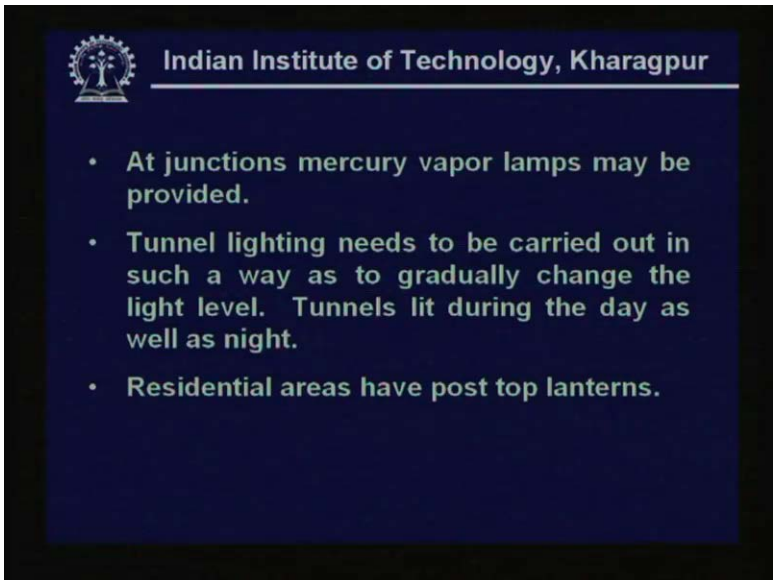

However care is taken at junctions, curves where the intensity levels are increased, mercury vapour lamps are provided. Tunnel lighting is one area which needs special care, it should gradually change the light level and they need to be lit during night as well as day. The post top lanterns which are also ornamental are useful in the residential areas because they do serve the pedestrians.

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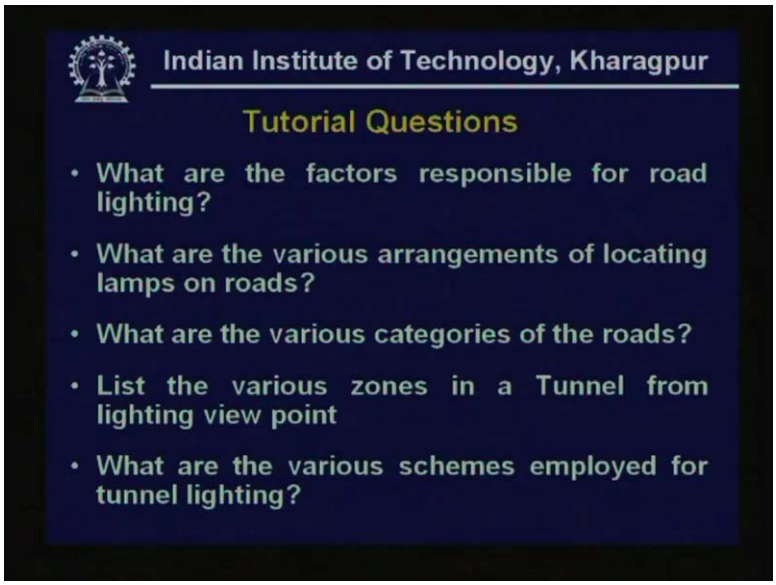

The tutorial questions that may be addressed. What are factors responsible for road lighting? What are the various arrangements of location, locating lamps on roads, what are various

categories of the roads? List the various zones in a tunnel from lighting view point? What are the various schemes employed for tunnel lighting?

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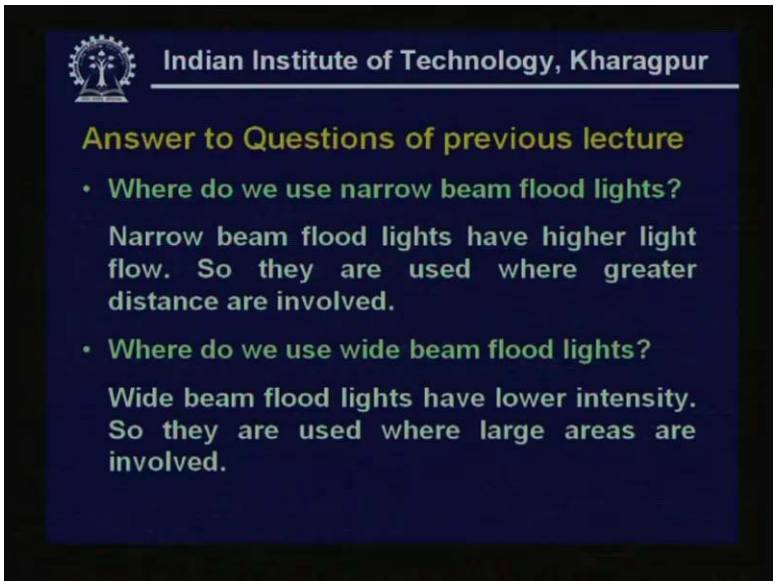

Now taking answers to some of the questions addressed in the previous. Where do we use narrow beam flood lights? Narrow beam flood lights have higher light flows, so they are used where great distances are involved where the mounting height is high. Where do we use wide beam flood lights? The wide beam flood sights have lower intensity; they are used where large areas are involved.

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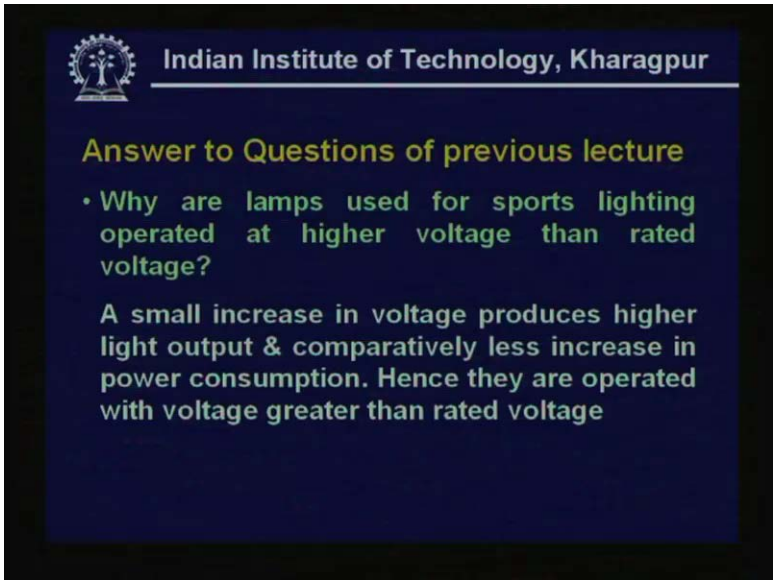

Why are lamps used for sports lighting operated at higher voltage than rated voltage? A small increase in voltage produces higher light output and comparative less increase in power consumption. Hence they are operated with voltage slightly greater than the rated voltage for sports applications. Thank you.