**Introduction to Transportation Engineering**
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**Lecture - 8**
**Functional Classification, Design Elements and Controls**

Module 3 geometric design of highways: this is the first lesson on functional classification, design elements and controls. After completing this lesson the student will be able to appreciate the need for geometric design, why it is necessary to carry out geometric design for the elements of highways, they will be able to classify road system basically the functional classification, identify broad elements of geometric design, also identify the design control and criteria.

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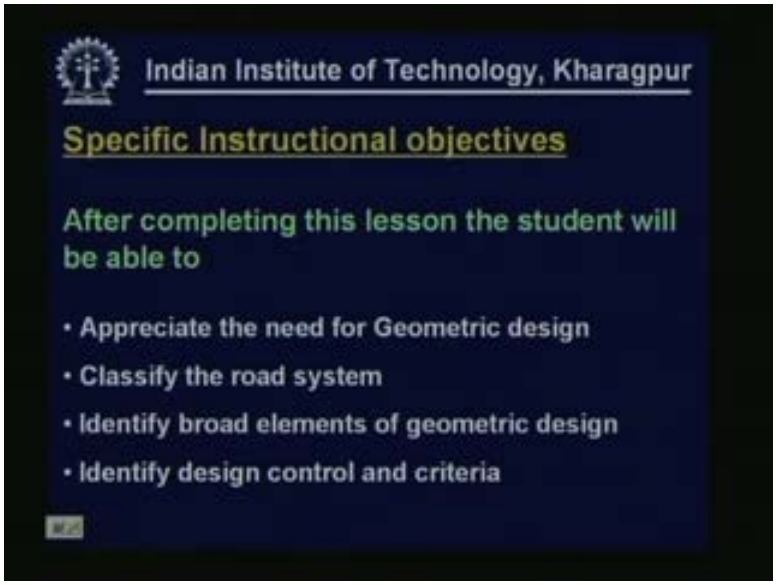

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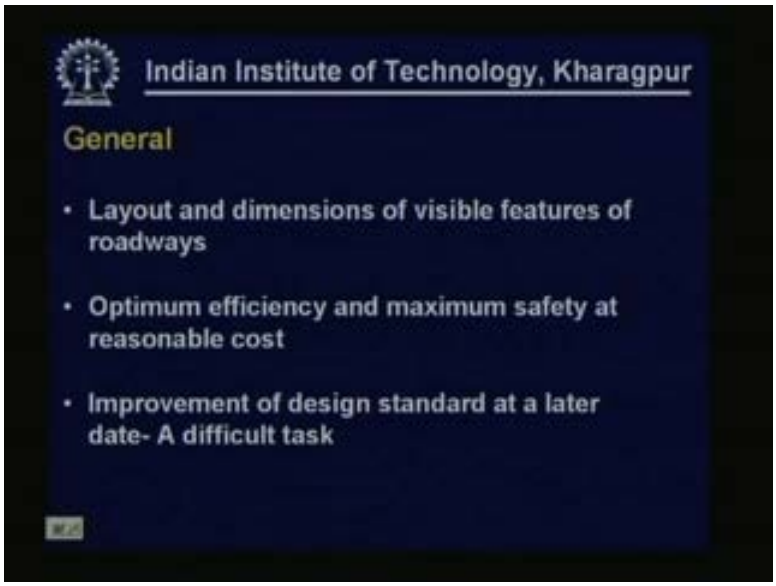


What we do with geometric design or why it is necessary to carry out geometric design. Layout and dimensions of visible features of roadway is what we deal with geometric design, all the layouts and visible features, what all are visible; their layouts and dimensions. It is aimed to provide optimum efficiency and maximum safety at reasonable cost. Given the investment how we can achieve optimum efficiency and also achieve maximum safety in terms of Traffic Corporation through adequate or suitable design.

We must keep in mind that improvement of geometric standards at a later date is a very very difficult task. So, right in the beginning it should be done in an accurate manner. The reason is, once a road is developed it has got an impact on the land development or land use interactions. So obviously it is found the moment the road is developed over a period of time the land development will take place predominately by the side of road. so due to the development at a later stage if it is felt that some corrections are necessary it is difficult to get the land for the required corrections because already establishments will be there, buildings will be there so acquiring land and correcting the geometric design standards is a very very difficult task. Also, the roads which is developed today, tomorrow due to the increase in traffic loading and also in the future it will be necessary to upgrade the road so that time it will be very difficult to correct the geometric design standards. So right in the beginning we must give due attention to the geometric design standards.

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Functional classification of roads:
First of all we must get convinced about the need for studying functional classification; why it is necessary and how it is relevant to the geometric design of roads. If you look at the roads around we can appreciate and very well get convinced that traffic volume is different on different roads, not that all road carries equal amount of traffic, it varies. similarly the type of traffic also varies while for some roads we can find may be commercial traffic is predominant whereas for some other roads may be it is mostly car in the residential area so obviously the traffic type as well as the mixer or the mix of traffic is different for different roads.

The purpose of the road itself may be different. While in a residential area the primary purpose of road may be to provide access give access to the buildings whereas for some other roads what we normally see may be wider roads higher category of road I am not trying to define it at this stage; the predominant function may be high speed movement of rates and also may be the passenger traffic again the function is not same.

The importance and the priority of the road is also different not that all roads have equal priority so prioritization is also done for different roads. Overall it is the economy that is to be looked into or that is to be considered. So it is not possible to have same standard neither it is necessary, we can also say it is not also economical or practical to have same kind of standards for all the types of road so that justifies the need why we need to classify road system based on their functions.

Once we are convinced about the need for functional classification the next issue is how to classify the road; we can classify it into say n-number classification n-categories of road but then how or what are the elements that should vary from one type of road to another type of road. Here are some of the points: We can define the expected speed for different types of roads; what is the expected speed that we are targeting, whether the road is predominantly to cater the

demand for long distance traffic or the short distance traffic that we are targeting, what type of access control is provided for the road access control is a very very important consideration. The performance of the road will be influenced by the type of access control, so, that may be different for different types of road, the traffic control at intersections: the way we are handling traffic or controlling traffic at intersections that may be different; obviously higher priority means we want to take measures so that the delay at the crossings or the intersections are minimized.

Similarly, we can also define whether parking is allowed, loading and unloading is allowed and what kind of gradients are permissible, what type of curves are permissible. Based on this criteria or element we can classify road system. Now let us look at the functional classification for urban roads as well as rural roads.

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Now, in natural classification is urban system and the rural system because they are predominantly different so a broad classification is urban roads and rural roads. Again, urban roads are classified as expressway the highest order of road which is predominantly for long distance traffic, higher speed is expected, greater access control is expected, no parking, waiting are allowed along the road. Similarly a slightly lower order road is arterial street, further little big lower order sub-arterial street, collector streets and local streets. Local streets essentially are the roads what we find in the residential area. So these are normally narrow roads; we do not expect very high speed so in most of the cases parking is also allowed, local streets they collect traffic and finally this traffic merges at collector streets so they are called as collector streets they are collecting from the local streets and then giving way to the traffic to go to a further higher category of road the sub-arterial street and arterial street.

Similarly, for the rural highways, national highways they are the highest category of road, then state highways, district roads; district roads are again classified as major district roads, minor

district roads and then finally village roads. So, again in this case village roads they basically connect different villages in the interior so they are essentially very low volume roads and the basic purpose is to give access to rural habitations. Then district roads normally cater to the demand at the district levels and obviously national highways and state highways they are higher category of roads so we expect better performance better speed for national highways and state highways.

A question comes; if we look at the road often we may not match the functions and the kind of control what is existing for that road often there could be a mismatch. May be road is actually a higher order road may be arterial streets but still we may find there are parking, there are pedestrian activities around and it may not match to our perception. The reason is that all the roads need upgradation or improvement over a period of time. The traffic volume will increase over time, activities also will increase over time so it will be necessary to upgrade road based on the demand and the other parameters that upgradation often does not take place at proper time. So we find that the importance of the road might have increased but yet the operating environment has not been upgraded.

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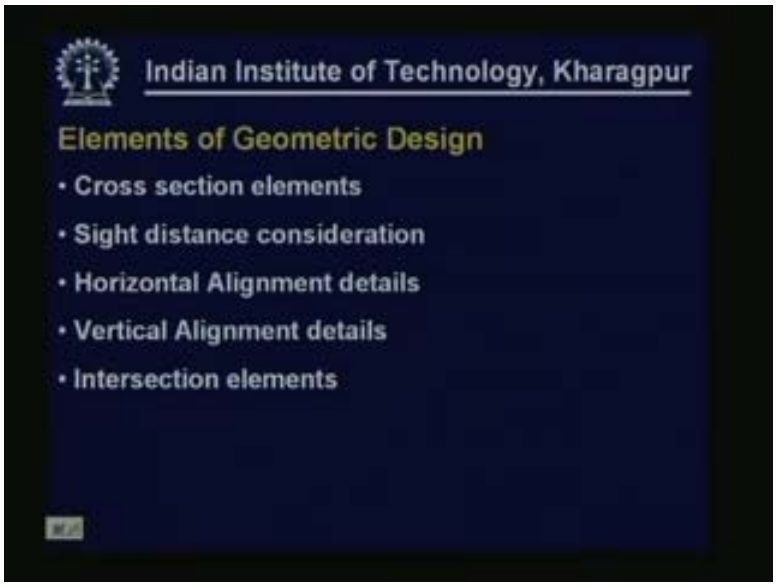


Let us look at the elements of geometric design. These are the broad elements. We will discuss in details about each of these elements in subsequent lectures. Here the purpose is just to have an idea about the broad elements that are addressed in the geometric design. Cross-section elements: Obviously what all we see; the ((13:37….blacked)) of surface and what are the other elements on both sides, sight distance consideration, visibility or the clear distance of the road ahead, adequate length of the road must be visible to the drivers so there is a sight distance consideration. We talk about the different design considerations in terms of the sight distance, we talk about the horizontal alignment details, curves are an integral part of the system so proper design of horizontal systems or horizontal alignment is necessary; similarly vertical alignment details and intersection elements. So we will discuss about different geometric components

different elements for cross-section, sight distance, horizontal alignment, vertical alignment and also intersection elements.

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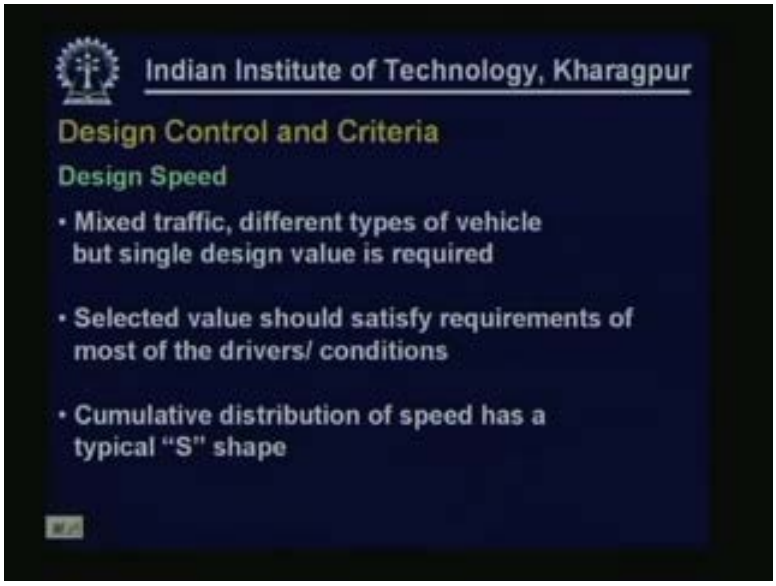


Design control and criteria for geometric design: The very first item is design speed. Now, in most of the developing countries the traffic system is heterogeneous in nature; we have cars, we have buses, we have commercial vehicles and they all share the same road space. Obviously the speed capabilities, acceleration and deceleration capability they are all different for different vehicle types but for design purpose we need a single value, we are designing a road so we need a particular design speed for which the particular road is to be designed. It is no doubt a complex task because predominantly the traffic is heterogeneous in nature.

So a single value is to be selected and that single value in most of the cases is selected on the basis that the selected value should satisfy requirements of most of the drivers and conditions; may be, it may not be adequate for some extreme conditions but the design values whatever will be taken that or they should satisfy the requirements of most of the drivers and operating conditions.

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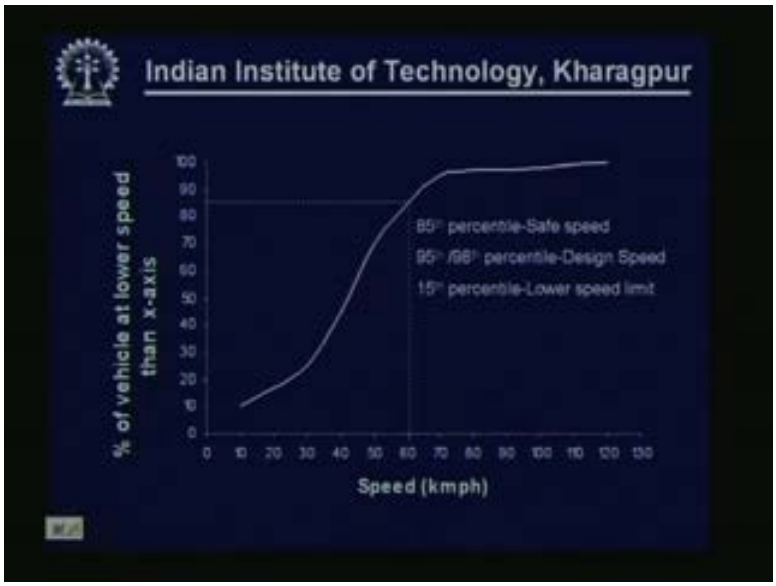


Let us look at the cumulative distribution of speed which is a typical S curve. This is the speed shown in x-axis and y-axis shows percentage of vehicle at lower speed than whatever is indicated in the x-axis. So this is a typical S curve what is normally obtained if we take spot speed distribution. From this curve often 85th percentile speed it is marked on the graph is normally taken as the safe speed limit for the road. The road system is designed with a speed which is 95th or sometimes 98th percentile speed. As I indicated a few minutes back that our traffic system is heterogeneous in nature so sometimes 15th percentile speed is used as the lower speed limit; this is basically to segregate the slow moving mostly non-motorized vehicle from the main traffic stream.

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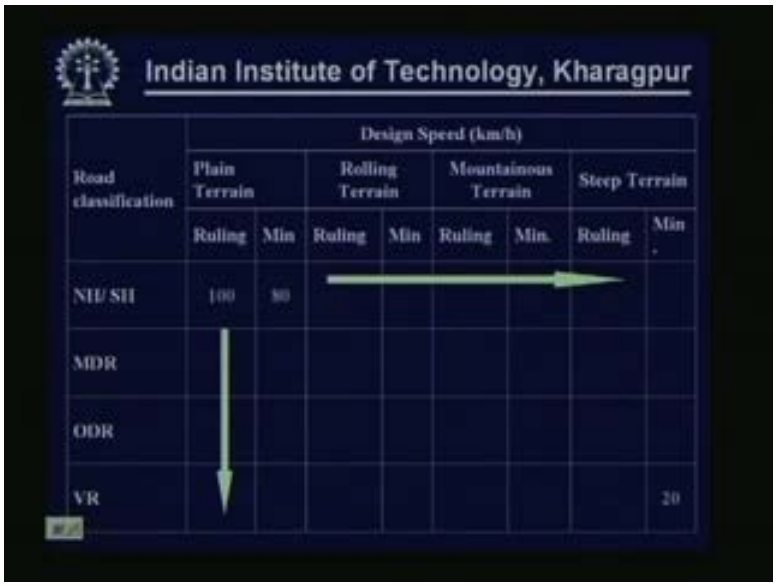


Design speed values are suggested; obviously we are convinced now that design speed will vary depending on the type of road. So a typical value for Indian condition is given here may be 100 kilometer per hour. There will be reduction in value of in terms of design speed as we move from national highway or state highway to major district road shown as MDR to further ODR other district road and to village road. So, one can expect a much lesser design speed for village road as compared to design speed for national highways and state highways. Similarly the speed will also depend on the type of terrain. Basically again the economy of construction should be given due weightage. It might be possible to create facilities where same or similar design speed can be maintained. But often it may not be economical and it does not make practical sense. So obviously once the terrain is difficult terrain from plain to as such in common term hilly terrain there is a compromise again in terms of the design speed.

I have not yet discussed the terrain classification so we will take up that component after our discussion about design speed. So here again terrain-wise as we move from plain terrain which is a smooth terrain to a difficult terrain again there is a reduction in the design speed. Now, for each terrain as you can observe from the table two columns are there: one is ruling and the other is minimum. Ruling design speed is the speed what we should target normally for the design of the roads. That means ideally for a particular category of road or under a particular terrain we must try to design the facility based on the ruling design speed, so that attempt should be made. But because of the terrain condition in the short stretch and also specific sight condition if it is felt that it is not really possible to achieve the speed or it is not economical to construct a facility with lot of investment to achieve that design speed then we have another limit available with us what is called as minimum design speed. So, attempt should be made to design the facility as far as possible based on the ruling design speed.

However, in a difficult condition where it is practically difficult to maintain or to achieve the ruling design speed one can go up to the minimum design speed. But nowhere, under no circumstances we should go below the speed specified under minimum design speed.

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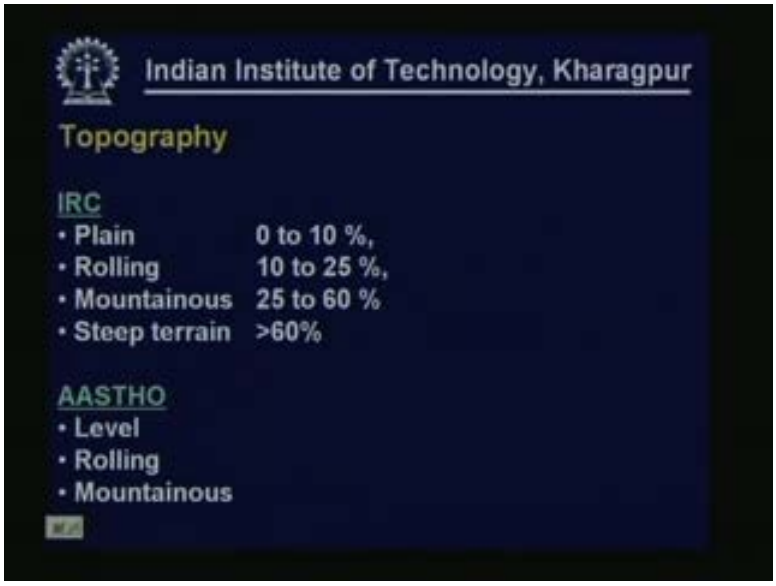


The topography is again not same. As I mentioned, the terrain condition varies so much from one corner to another corner. It may be possible even to construct a facility where the design speed will be as good as the design speed in plain and comfortable terrain condition but again it may not be economical to try do that or achieve that. May be in a very hilly region if we try to achieve a very high design speed may be it will be required to construct a number of bridges and tunnels which are very expensive. So the terrain is also classified As you have seen in that design speed table depending on the terrain also the design speed is specified.

Now the terrain is classified in many ways. Indian Roads Congress; most of the cases for our route design in India we follow the recommendations of Indian roads congress we call them IRC. So, in a number of places we may refer to IRC specifications, standards and their recommendations. So terrain is classified based on the cross slope of the country. Cross slope is the slope approximately perpendicular to the road.

What is the slope?
This is expressed normally in percentage. So according to this cross slope terrain is classified as under plain terrain, rolling terrain, mountainous and steep terrain. if the cross slope is between 0 to 10 percent it is called as plain terrain similarly 10 to 25 percent rolling terrain 25 to 60 percent mountainous terrain and more than 60 percent it is steep terrain. There are other ways also available for classifying terrain. Another possible alternative which is also followed in India classification of terrain based on average raise and fall and average curvature along the length of the road. So, if there is a road connecting two points a and b then along the length of the road total raise at different times, total falls of levels at different times along the center line we can

measure and we can measure the average raise and fall per kilometer length of the road. Similarly whenever there is a curve we can measure the angle in degree deflection angle in degree. Accordingly for the complete length of the road what is the average angle in degree per kilometer length of the road? Then average raise and fall is normally expressed in terms of meter per kilometer length and also average curvature degree per kilometer length of road. Based on these two points we can classify road system again under different terrains.

The American Association of state highway and transport officials they also classify terrains as level terrain, rolling terrain and mountainous terrain. So, in brief, actually there is a need to classify terrain system, the number of groups whatever is used that may vary from one place to another and also the way terrain is classified that also may vary from one place to another. But whatever way we take terrain is classified and accordingly most of the time different design speeds are specified for different terrain conditions.

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Traffic factors: under traffic factors we shall discuss different items. First item is traffic volume. Now the traffic volume is the major driving force for any road system development or any kind of transport infrastructure development. In most of the cases, except in a few cases like for rural roads it may be based on the accessibility, the primary consideration may be to give access to rural habitation. But in most of the cases national highways, state highways, arterials in urban area, sub-arterial is based on the demand. So, basic traffic volume is an essential consideration.

We measure the traffic volume in two ways: one is called Average Daily Traffic we call it ADT another is Annual Average Daily Traffic we call it AADT; one is ADT and another is AADT. Average Daily Traffic is the average of traffic volume counts more than one day. Often for Indian conditions Indian Roads Congress recommends that 7 day traffic volume count should be done for all the highway projects. So may be in most of the cases it is of average of 7 day traffic volume count. Traffic volume varies from one day to another day, in rural areas it is very

common may be on some days there is a local market some other day it is not so and during working day, week day or weekends the traffic volume varies.

So basically ADT is the Average Daily Traffic measured taking the traffic volume counts say for seven days and then calculating the average value. AADT is again average but where observation is available for all the 365 days in a year. That means the complete yearly traffic volume should be available and if we calculate the average daily traffic based on 365 day count then we get annual average daily traffic.

What is the difference?
The basic difference is the seasonal variation of traffic. Especially for non-urban scenario the traffic volume varies from once season to another season. For example, monsoons or the rainy season, during winter, during summer the traffic volume is not the same it varies; it varies due to various reasons because commercial traffic movement they carry some commodity, the commodity may be agricultural goods which are produced at specific time not throughout the year and similarly the other commodity movement the production or the availability or even sometimes the demand may be highly influenced by the seasonal variation.

So, in most of the cases the non-urban traffic is influenced by the seasonal factor. If we take a short traffic count short means in terms of number of days which is not really as large as 365 may be 7 day traffic volume count and if we calculate the average then that average does not consider the seasonal variability of traffic. So when we are talking about using the traffic volume for yearly representation that may give us under estimation or over estimation. So while it is practically impossible that for different projects we cannot really observe traffic for a very long period so what we get from the field in almost all the projects majority of the projects for that we calculate ADT but then this ADT must be converted to Annual Average Daily Traffic using the seasonal factors.

The question comes how we understand the seasonal variation?
Almost in all countries there are some permanent count stations along the major road network.
In permanent count stations traffic volume data is available automatically throughout the year. So, that traffic data may be utilized to understand the seasonal variation on a projects road or there are other ways to understand the seasonal factor based on secondary data may be the fuel sales detail in that locality and if there is a tollbooth somewhere then again data may be available. So the seasonal data normally is available from secondary source and which is used to upgrade the ADT to AADT.

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Then the next factor is traffic composition. In most of the cases in developing countries particularly the traffic is not homogeneous in nature; we do not expect homogeneous traffic so it is highly heterogeneous. now heterogeneous traffic if we say 100 buses, 100 2-wheelers or 100 cars do they completely convey the meaning, the answer is no because their speed capabilities are different, dimensions are different, acceleration deceleration characteristics are different, the turning radius they require at intersections they are different so it is incomplete. Therefore passenger car unit or passenger car equivalency factors are used to convert heterogeneous traffic stream to a stream of homogeneous traffic where it is suggested that a car is taken as a standard vehicle and all other vehicles are expressed in terms of equivalent number of cars, may be a bus is equivalent to three cars considering different aspects. So PCE or PCU values are suggested to convert heterogeneous traffic into a stream of homogeneous traffic.

There are suggested passenger car unit values for different road segments, different traffic conditions and those values are normally available in codes. There are also country specific values which are also available. So whatever is the recommended or suggested passenger car equivalence value for the particular type of facility I mean urban or rural and depending on the traffic type and mix accordingly suggested PCU values should be used to convert heterogeneous traffic into a stream of homogeneous traffic. So what I called earlier ADT and AADT normally the units are passenger car unit. So in terms of ADT it is PCE or PCU per day.

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Design vehicles:
For different vehicles their weights are different, dimensions are different, operating characteristics are different so it is understood that their requirements also will be different. Now the question is for which vehicle the road system should be designed. There the concept of design vehicle is useful. So design vehicle is selected motor vehicle; weight, dimensions and operating characteristics of a vehicle which is used to establish the design standard for the given road.

There are different types of vehicles that are considered as design vehicle. Say for Indian conditions single unit truck, semi-trailer, truck trailer combination all these vehicles can be used as design vehicles. Different other countries they have also specified design vehicles and for design vehicles the dimensions and all other features are established. So once the design vehicle is selected all the geometric features are to be designed making it compactable to the requirement of the design vehicle.

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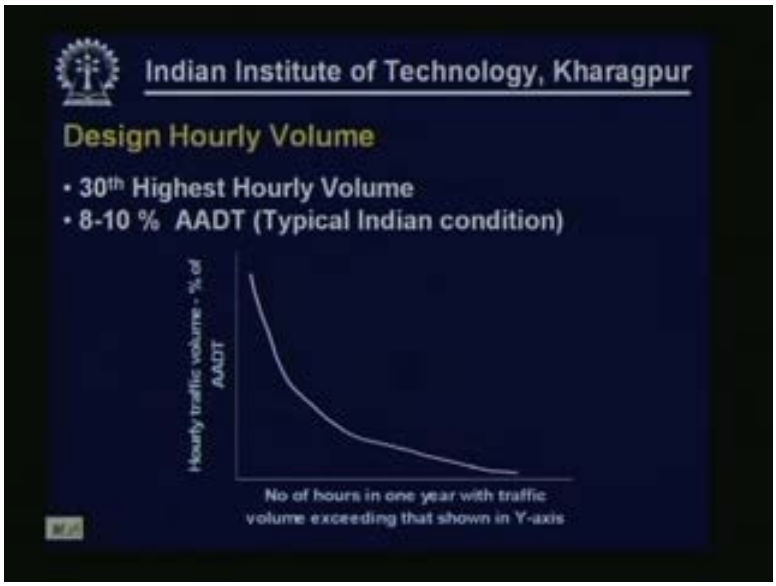


We talked about the Annual Average Daily Traffic, ADT Average Daily Traffic and then converting the same to Annual Average Daily Traffic. But normally normally not always the road capacity is defined in terms of number of vehicles that road can handle or passenger car unit the road can handle per hour. So it is expressed normally in terms of PCU or PCE per hour. So far we have discussed about the estimation of daily traffic but what is required is from the daily traffic or the AADT we must be able to estimate the design hourly volume.

Let us look at the graph. Here the X-axis shows number of hours in one year with traffic volume exceeding that shown in Y-axis. Y shows hourly traffic volume as percentage of AADT. Let us say we assume certain percentage of AADT so we get from the graph number of hours in a day. We can expect the traffic volume to be more than whatever we have assumed. So, if we assume a higher percentage obviously less number of hours in a year that traffic hourly traffic volume will exceed that value.

Let us assume theoretically, if we assume a very high percentage may be say 20 percent for example, 20 percent of the daily traffic as design hourly volume probably not even a single hour in a year the hourly traffic volume will be more than that. But again it may be may not be economical to take a very high percentage of AADT as design hourly volume because the infrastructure requirement also will be higher. on the other hand, if often the hourly volume increases the design hourly volume then there will be poorer level of service, there will be congestion, there will be unwanted reduction in speed, more delay so that is also again a difficult component.

Therefore what is done?
Normally the thirtieth highest hourly volume is suggested as design hourly volume in India. It means if we take thirtieth highest hourly volume we are accepting that for a maximum of twenty nine times in a year twenty nine times in a year the hourly volume may exceed the design hourly

volume what we are taking for design of the road system but it is only twenty nine times maximum and not more than that. So the thirtieth highest hourly volume is recommended for calculating the design hourly volume.

Now, it is in terms of percentage of AADT so it is how much? Wherever the yearly data is available, in India in a limited number of places this traffic volume data throughout the year is available. After analyzing that data it is found that normally for non-urban scenario in India the thirtieth highest hourly volume is normally 8 to 10 percent of the AADT or daily volume. So wherever it is possible and feasible to study or to have the data covering the complete traffic volume every hour throughout the year one can see the actual percentage of ADT which is indicating the thirtieth highest hourly volume.

In some cases it may happen that such data is not available there is no nearby permanent count station where the complete data is available and where for it is possible to actually calculate road specific percentage of ADT for representing the design hourly volume so in those cases it may be assumed as 8 to 10 percent of the AADT, design hourly volume can be estimated as 8 to 10 percent of the AADT.

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Environmental and other factors:
Road development or development activities in general should not be at the cost of environment, we must protect environment during the road development activities or when we are taking up road development activities. So it is necessary to give due considerations to the aspect environment. Often the demand of traffic and the resulting effect on environment is a major concern for developers or planners. The roads are congested so in most of the cases the pollution level will be very high; may be very high air pollution level, very high noise pollution levels which are more than the permissible standards so that itself is a major concern and road development activities normally should bring down the pollution level.

Therefore, if we widen the roads, enhance the capacity standards then it is expected that the service quality will improve, the speed will improve, the congestion will be lesser and also the pollution level around or surrounding the roadways or the traffic junction will be reduced. Similarly, while improvement in environment is also a driving force the road development activity also should give due consideration to all these attributes or environmental aspects particularly when the road development activity is taken up in terms of either developing a new road or may be improvement of an existing road then also it is necessary to concern or to give to due consideration to the environmental aspects.

There could be some sensitive areas, so, may be if we take the road the natural system may be hampered, may be disturbed so we must try to take the road alignment in such a way so that the impact on environment is minimized. So, for every stage of road construction we must give or ensure to take measure in terms of alignment and once the alignment is decided in terms of designing different elements in such a way that the impact on environment is minimized. How to consider these attributes or these aspects in selection of a particular alignment or feasible alignment will be discussed in a separate lecture.

In general, we must consider the aesthetics and the landscaping, we must consider the air pollution aspect again there are different constituents of air they me effected so effect on all those attributes, effect on noise pollution and also the local site condition. So we must not take roads through a place where the local site condition is not favorable or environmentally acceptable in general, that generally covers the design control and criteria.

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Let us try to summarize whatever we have discussed in this lesson. We have discussed about the need for geometric design, why we need to study this aspect geometric design of roads. Once we got convenience about the need and the scope we also discussed about the functional classification of roads and its relevance for geometric design, functional classification of roads

for urban, for rural, we also discussed why this classification or such classifications are necessary and on what basis this classification can be done, all the predominant factors which can affect or which can give the guideline for classification that we have discussed.

We have talked about broad elements of geometric design starting from cross section elements, sight distance considerations, horizontal alignment details, vertical alignment details and at intersections. So these are the broad elements we have identified. We have talked about the design control and criteria, under that we have basically talked about five major aspects: design speed, topography, design vehicle, design hourly volume and also environmental and other features. Under this design control the need for terrain classification, the mixed traffic condition, a way out to express heterogeneous traffic stream into a stream of homogenous traffic by using passenger car equivalence value and we have also talked about the ADT what we normally measure in the field, how to convert ADT to AADT Annual Average Daily Traffic then how to estimate design hourly volume from the ADT all those aspects we have discussed and covered. that essentially completes the discussion under lesson 1.

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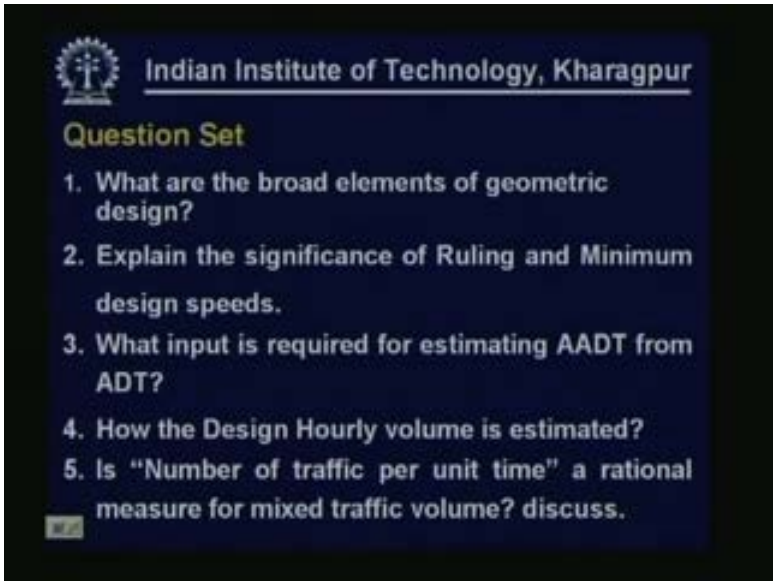


Now you can try to answer these questions:

1) What are the broad elements of geometric design?

You can try to answer what are the broad elements that are normally considered for geometric design process.

2) Explain the significance of ruling and minimum design speeds: Whenever design speed is specified two types of speeds or two values are available: ruling speed and minimum speed. You can try to explain the significance of that.

3) What input is required for estimating AADT from ADT Annual Average Daily Traffic from Average Daily Traffic what input is required?

4) How the design hourly volume is estimated? If you are given the task of estimating design hourly volume for a road how will you estimate the design hourly volume?

5) Is ‘number of traffic per unit time’ a rational measure for mix traffic volume? If you want to express mixed traffic volume is number of traffic per unit time is a rational measure, discuss:

The answers for these questions will be discussed in the next lesson. Thank you.