

**Course Name – Pavement Construction Technology**  
**Professor Name – Dr. Rajan Choudhary**  
**Department Name – Civil Engineering**  
**Institute Name – Indian Institute of Technology Guwahati**

**Week – 01**

**Lecture – 01**

A very warm welcome to all of you. Myself Rajan Chaudhary, professor in the Department of Civil Engineering, Indian Institute of Technology, Guwahati, course instructor for the NPTEL MOOC course, Pavement Construction and Technology, funded by Ministry of Education, Government of India. In today's lecture, we will discuss about the salient features and importance of transportation sector, the different modes of transportation, We will discuss the development of roads, the traditional methods which are used for road construction. We will also go through the discussion over the Indian road infrastructure. We will be discussing about the classification of the different types of roads which we have in India. So, beginning with today's lecture, let us first, in the very beginning, I would like to acknowledge the use of text, information, graphs, and images sourced from various test books, code standards, general articles, reports, newsletters, and public domain searches.

When we come to the transportation sector, this sector forms one of the vital sector in the development of any country. And not only India, throughout the globe, this is a recognized fact, the transportation sector plays a very, very important role in the overall growth of the country. It contributes to the economic, industrial, social and cultural development of country. You might have seen various cities even in India also and abroad also which have picked up as industrial centers as well as centers for social and cultural development because of good transportation facilities available in those regions or in those cities.

In addition to this particular one, it plays a very important role in the tourism of a country also. As in our country, we have certain regions like location. Leh is a place which is located in Jammu and Kashmir. It is a tourist center and a place of attraction as it offers a good transportation facility also. It has a good connectivity also by road also, by air also.

So, transportation plays an important role in the development of tourism of any country. It plays an important role in the defense and security of a country and is essential for a strategic movement during an emergency. We as India share our international borders with many other countries. So, from the strategic point of view also, the development of transportation sectors or the development of transportation facilities along the international borders also forms an important part of the country's development. Improved transportation facilities help us to maintain the population concentration between urban and rural areas.

Now, this is again a matter of concern. You can see for any state, any city, what's the population density you have in Mumbai compared to the whole population density of Maharashtra state. What is the population density of Patna compared to the population density of the entire Bihar state? The cities which have good transportation facilities get overcrowded, or we can say the population density increases there. So, there is a migration of population from the rural areas, especially to the centers which have good transportation facilities. So, if we need to keep a balance between it, we have to provide good transportation facilities in throughout the entire region of our country.

Now, when it comes to the different types of or we say the different modes of transportation, the one popular mode of transportation is air transport. Now, this particular mode of transportation is the fastest mode of transportation, but along with the fastest speed of transportation, which is available, it is also the costliest mode of transportation. The second most popular or the common mode of transportation is through land which is either through roadways or through the railways. This mode of transport is very popular throughout the globe and specifically in India, we have a very good facilities, especially in terms of road and rail transport facilities. Then, the third one comes the water transport, this is again an important mode of transport, where you have waterways, sea routes between harbours and ports, where the travel is made by ships and boats, inland water transportation along rivers, canals and lakes by boats and ferries.

Certain countries like Germany is there, Belgium is there, Netherlands is there, they have very good water inland transportation. So, in India also, we are developing the inland water transportation facilities along certain sections, and this comparatively is a slower mode of transportation compared, but the cost of transportation is quite less compared to the air transportation. The some other modes of transportation may be in terms of pipeline transport or cable transport like you have ropeway. So, these are the major modes of transportation. Now, let us look to the development of roads.

Even if you go back to the Roman period, the earliest large-scale highway road construction is attributed to Romans, who constructed an extensive system of roads radiating in many directions from Rome around 312 BC. Now, at the peak of the Roman Empire, there has been more than 4 lakh kilometers of roads, out of which 80,000 were stone paved. So, this shows even in that old period, there was a significant importance of the road transport. They during that particular time, they used to build up the sections, or we can call the roads, especially without any gradients, and the total thickness used to range from 0.75 to 1.2 meter.

Now, the pictorial representation which have been created in this particular slide may not be exactly to the scale, but just to give an idea explanation, how the roads were constructed in those periods. You can see large stone pieces are placed at the foundation

level, and then smaller stone sizes are placed over it, and again, on the top, you have large stone slabs, and the thickness used to range from 0.75 to 1.2 meter.

Now, this particular gives you a very strong foundation compared to the type of the amount of load which used to come in those days, especially, mostly the animal-drawn vehicles used to be there. But they and they were constructed straight, but this forms a strong foundation for the on the left hand side you see a picture which has been taken to depict the type of roads which were there during the Roman Empire. Even in Indian subcontinent also, we have a very old history with the development of road. Indian civilization which is one of the oldest in the world had evidence of road construction dating back to around 2800 BC. Excavations, you can see one of the excavation from the Mohenjodaro civilization, have been shown on the right-hand side.

Excavation of Mohenjodaro and Harappa revealed that existence of roads during the period of 2500 to 3500 BC, which shows how the roads were present in that particular moment of time also. Ancient scriptures mentioned the existence of roads during the Aryan period also, 400 BC. Between 200 and 400 BC, the Mauryan kings were known for building well-maintained roads that enhanced trade and transportation through their empire. So, even those old civilizations were knowing the importance of transportation, good road network, so as to grow in terms of their trade. Further, if some of us might be familiar with the Grand Trunk Road of the Indian subcontinent, which was an important road running from the modern-day Bangladesh through what is now India, Pakistan, and Afghanistan.

You can see the right-hand side shows a pic of the Grand Trunk Road. For at least 2500 years, it has linked Central Asia to the Indian subcontinent. Over the centuries, the road has acted as one of the major trade routes in the region and facilitated both travel and postal communication. So, these road sectors, which are still existing, played a very very important role even in the earlier periods, and currently also, we realize what is the importance, in coming slides also, I will be able to explain you, highlight, what is the road, importance of road transportation or the transportation sector. Now, the left-hand side shows a picture of a village road in Bengal in 1860s.

The right-hand side shows a picture of Grand Trunk road. Now, what were the traditional methods which were used for road construction? Just to feel an idea, how the roads were constructed, what type of combinations were considered, how they used to build up those surfaces for the movement of people, for the movement of the animal-drawn vehicles. So, one of the popular traditional method is the Tresaguet method, and Pierce Mary Jerome Tresaguet was the inspector general of roads in France. He suggested the thickness of construction to be around 30 centimeter with proper site drainage. Now, again, this particular picture has been drawn to explain some of the features of it, not to the scale, not very exactly to the scale.

You can see here, large foundation stones are placed at the top of the subgrade soil. And then over that particular one, broken stone pieces are there, and finally again, a smaller pieces are there on the top, and with a camber of around 1 in 45. So, this is around a camber in between 2.2 to 2.5. Normally, we nowadays also construct roads with a camber of around 2 percent. See the top layer wearing course was constructed using small-size broken stones or hard angular gravel. They didn't incorporated any binding material. Nowadays, the surface, says which we construct we call them as paved roads, are making use of some binding materials. The common binding materials are cement and bitumen fly ash.

Those are the common binding materials, but that time, they were not using any binding material such as bitumen or cement, instead, they relied solely on mechanical interlock between these aggregate pieces and compaction through the traffic to achieve the stability. Provision of camber was there. This was felt so as to remove the surface water. The construction involved the excavation of the soil, followed by laying of large stone pieces. The use of curved stones was there also found reported in some of the studies.

Furthermore, broken stones gravels were used. The shoulders were constructed at a steeper slope compared to the main surface. Now, the another traditional road construction method, popular road construction method, is the one through the Thomas Telford, which was who was the founder of the institution of civil engineers at London. Now, in this particular course also again, a pic has been shown. You can see this particular picture where larger foundation stones are placed at the bottom, and having a thickness of around 17 to 22 centimeter.

Now, the thickness varied from one edge to the other edge. So, it used to in the larger foundation stones itself they are able to create a camber there. And, then the surface was followed by smaller size of aggregate pieces, and they occasionally used sand to lock these aggregates. So, this particular one shows a picture of Telford method of paving from Pennsylvania in the year 1908. Now, the another very popular method of road construction is the McAdam method.

So, John Mcadam is being surveyor general of roads in England who was the founder for this particular method. There he felt in his method the importance of the subgrade. He said subgrade need to have adequate density and kept drained. So, therefore the subgrade was therefore compacted and prepared with a cross slope of 1 in 36. So, you can see, compared to the other two methods here from the beginning part, the subgrade itself is compacted and maintained at a cross slope of 1 in 36.

He recommended that instead of placing large foundation stones small size broken stones shall be spread over the prepared soil subgrade and compacted. So, this is again a pictorial representation which have been created to explain the methodology which was

conventionally suggested under the Macadam method. The pavement surface was constructed with small broken stones and also prepared with a cross slope in 1 and 36 for drainage of surface water. So, this shows how from very old periods, how the things were getting developed, how the technology was improving, how the understanding over this particular, the road construction methodology was developing. So, these are some of the traditional road construction methods.

Now, as we can see, from very old civilization point of view compared to what we have currently, everybody has felt the importance of road transportation. So, why there is so much demand of road transportation, we have seen that it contributes to every sector, it contributes to the social development, industrial development, tourist development, it is important from the strategic point of view also. And, what from a user perspective is required, everybody for any mode of transport, we require a comfortable and a safe movement from one place to other. Whatever mode of transportation we are using, our one main requirement is that the movement should be comfortable and it should be safe. So these are, I think, two main requirements from any user perspective.

Now, in this surface transport, especially the roads and railways, and I will be more focusing on road transport here in this particular course. So, surface transportation is the most widely used mode of transportation, not only in India, throughout the globe. And, a country's development is often measured in terms of its total road, paved road mileage. Even fortunately, India is having the second largest road network. So, even a country's progress or the development is measured in terms of how much length of road it has.

Especially this surface transportation, or road transportation, why it is so important, you can see. It has easy accessibility, flexibility of operations, door-to-door service, and reliability, have earned road transport as an increasingly higher share of both passenger and freight traffic. This is the beauty, advantage of road transportation. And, the surfaces I have discussed in the traditional methods of road construction, and what we now have are the engineered roads. Those time also, they were engineered roads, but the surfaces has evolved with the more and more development of the technology of the construction.

So, these nowadays, we call these surfaces as engineered surfaces. Many times you call them as paved surfaces also. The paved surfaces means when the surface is built up strong enough to serve under different conditions of traffic and environment, mainly using any binding material like cement or bitumen. So, these engineered surfaces forms an essential part of our life and are used, we use them as roads, we use them as runways, parking lots. So, all these are constructed as engineered surfaces.

Now, a very common quote which have been there by US President John F. Kennedy, who says American roads are good not because America is rich, but America is rich because American roads are good. Now, let us come to the current state of Indian road

infrastructure. Most of the information have been derived from the ministry of road transport and highways and the Indian brand equity foundation, where these informations have been extracted and shared with you. So, if you look to the Indian road infrastructure.

Here you can see we have a total length of around 66.71 lakh kilometer, which is a figure of 2024. Now, under this particular one, you can see the again some classification have been there, in terms of NH which represents national highways, in terms of SH which represents state highways, and all other categories are kept under the category of other roads. Now, so India has about 66.71 lakh kilometers of road network, which is the second largest in the world.

This comprises of national highways, expressways, state highways, major district roads, other district roads, village roads, urban roads. So, all these are different categories of roads. I will discuss these different categories of roads when I will be discussing about the classification of the roads. Now, this bar chart on the right hand side shows that how much length of national highways were constructed in different financial years. Now, the interesting fact to note here is, in the financial year 2021, which is the period of COVID pandemic.

That time also, the length of national highway which was constructed in the country was around 13000 kilometres. So, from this, you can get an idea that even when some difficult times are there, every government or every country, focus on the development to boost up the economy of a country. One major focus always goes on the development of infrastructure and where road infrastructure plays a vital role. So this gives an idea how the infrastructure or the road infrastructure is important for the development of any country. Now, this will further highlight, what is the significance of road infrastructure currently under the Indian scenario.

In India, we have over 64.5% of all goods in the country are transported through roads, while 90% of the total passenger traffic uses road network to commute. So, this shows the importance of road infrastructure. The focus of a country, why a country is specially focused on the development of road infrastructure. National Highway Authorities of India, a body which looks into the construction of national highways, spent a record-breaking 2,07,000 crores on the construction of national highways in the financial year 2023-24. In the financial year 2020-21, the construction of highways has paced to 36.5 km per day, which is the highest ever construction speed of national highways in the country. So, see again this was a COVID pandemic period. We were not only India, throughout the globe, there was an economic crisis was there. So these are the focus areas where all governments try to focus to boost the economy of any country. Along with that, how advanced we have moved it, an example is given here, a world record has been

created by India by constructing 2.5 kilometres four lane concrete road in just a duration of 24 hours and a 26 kilometres single lane bituminous road in just 24 hours of time.

So how much advancement have been made in the construction technology and how much focus is coming upon the road infrastructure. This again shows an idea about how the government's focus is there through the budget allocation, which is made for Ministry of Road, Transport and Highways. This gives us an idea how the focus of the government is there towards the road infrastructure development. This road transportation emerges as a dominant segment in India's transportation sector with a share of around 4-5% in the GDP of India.

In 2025-26 also, the union budget has allocated around 2,87,333 crores to the ministry of road transport and highways. So, this you can see how from 2020-21, 22, 23, 24, how the allocation of the fund, already we allocated budget is very high but then also year by year it is increasing. Now, the second thing as I said when we discussed the total road length, we mentioned that the different categories of roads are there. So what are those different categories how the classification is done? Two broad classifications which are done are on the basis of urban roads and non-urban roads. So, under non-urban roads, many a times a term is referred as rural roads in rural regions or rural roads, but those are non-urban roads.

And, where the categories which are considered are expressways, national highways, state highways, district roads and village roads. When it comes to urban sections, urban regions, the classifications are urban expressways. Majorly expressways passes through urban sections also, rural sections also. Then, we have arterial roads, sub-arterial roads, collector streets, and local streets. The other part of classification which we will discuss in coming lectures will be on the basis of their composition.

I am just mentioning the two main classification systems flexible pavements and rigid pavements. Along with it, I am referring the Indian Roads Congress specifications, like we have IRC 73, which is the geometric design standards for urban roads. Then, we have IRC 86-2018 division, which is the geometric design standard for urban roads and streets. So, further information. which have been derived here, discussed refers to this particular course.

Now, the first category under the non-urban roads comes up as the expressway. Many of us might have used some of the expressway at any moment of travel. So, like this is the bottom most picture shows for the Delhi Gurgaon expressway, Delhi Mumbai expressway. We have Indian Roads Congress codal specification also, IRC special publication SP 99-2023, which is manual of specifications and standards for expressways.

So it specifically deals with the expressways. And, what are expressways are class of highway with a superior facilities. We can call them high speed corridors but national highways are also considered high speed corridors but this forms a special class of highways with superior facilities and design standards are meant as a through route catering to a high volume of traffic. The design the geometric design standards are to be as per IRC 73-2023 and using IRC SP 99. They provide more lanes. We have these Gurgaon expressways or the other expressways, 6 lane, 8 lane, even 12 lanes are also there.

They provide more lanes, a better surface, a divided carriageway is there, controlled access, this is very important part, controlled access, grid separations are there at crossroads and even fencing is also there. So, expressways permit only they are especially meant for say fast moving vehicles and the design speed in plane terrains is 120 kilometer per hour whereas for rolling terrain it is 100 kilometer per hour. When it comes to terrain, the classification is on the basis of cross slope. When the cross slope is from 0 to 10%, we call them as plain terrain. When the cross slope varies from 10 to 25%, we call it as rolling terrain.

Now, the second most popular category of roads in India is the national highways. We keep on traveling. We are moving from one place to other. We say we have traveled on NH 27. NH 27, a highway, which passes through the state of Assam. So, they form an important category of roads and highways running through the length and breadth of the country, connecting major ports, foreign highways, state capitals, large industrial and tourist centres, etc., including roads required for strategic movements for the defence of country. So, this is the important category of roads under the non-urban roads. It is constructed and managed by National Highway Authority of India, the National Highways and Infrastructure Development Corporation Limited (NHIDCL) and in some cases by the public works department, where it passes through some states, some of the part of it may be managed by public works department of a particular state. The national highway network, you can see has grown by 60 percent, rising from a length of around 91,000 kilometer in 2014 to around 1 lakh 50 lakh kilometer by the end of 2024.

So, major development has taken place in the development of national highways because these are high speed corridors. Now, this can be some of you might be aware of one very famous Road Development Scheme which is the NHDP program, National Highways Development Program which is there, NHDP program which is there. A project which was taken up or ongoing to upgrade, rehabilitate and widen major highways in India to a higher standard. The project was launched in 1998 and this project was managed by the National Highway Authority of India under the aegis of Ministry of Road Transport and Highways. One major part of it under this particular scheme was the development of golden quadrilateral which connects Delhi to Mumbai to Chennai and Kolkata.

This forms the golden quadrilateral. Then we have the north-south corridor which connects Srinagar to Kanyakumari. We have east-west corridor which connects Porbandar to Silchar. So, these are some of the We have many more popular schemes ongoing, the so these schemes show how the government is taking up the different schemes and projects for the development of these high speed corridors throughout the country. Now, the other important category of roads is the state highways. When the definition comes, these definitions are as per IRC codal provision IRC 73.

When it comes up it says state highways is an arterial route of a state linking district headquarters and important cities within the state and connecting with them to the national highways or highways of the neighbouring states. So this is what state highways are. The national highways and state highways usually have same design standards in terms of geometry, in terms of their speed also, design speed also. It is mainly constructed. These national highways are mainly constructed by the public works department of states or and they are constructed under different schemes.

Now, you can see. This is state highway 5A in the state of Uttar Pradesh, this is a state highway 25 in the state of Gujarat, this is a state highway 78 in the state of Bihar. So, these are pictures of different state highways. Now, the other category of classification of roads is the district roads, which consists of two categories. One is major district roads and second is your other district roads. Major district roads are important roads within a district, serves as serving areas of production and markets, and connecting these with each other and with the main highways.

The main highway may be a state highway most probably or a national highway. The major district roads has lower speed and geometric design specifications as compared to your state highways and national highways. The other district roads are roads serving rural areas of production and providing them with an outlet to market centres, talukas, tehsil headquarters, block development headquarters or other main roads. So, this is what the categories which comes under your major district roads and the other district roads. Then comes another major classification which is your village roads. Now, this village road connects villages or group of villages with each other and to the nearest road of a higher category.

This forms a major important segment of the Indian road infrastructure. This serves as a feeder roads as well as the road for inter-village movements, and some of you might be aware of the very popular scheme which is Pradhan Mantri Gram Sadak Yojana abbreviated as PMGSY. Which was launched in the year 2000, 25th December 2000, to provide connectivity to unconnected rural habitations. This is a 100 percent centrally funded scheme and it has played a very important and significant role in the development of villages, rural areas throughout the country. So it is a marvelous piece of example.

So how to bring the development to the rural areas through road connectivity. Now just whenever you travel on this particular roads you might see a different kind of kilometer stones which are there. So these from the kilometer stones you get an idea whether it is a national highway, a state highway, a major district road or a village road is there. And, all these kilometre stones need to be constructed as per IRC codal guidelines only. IRC 8 is there which gives the details about the type designs for highway kilometre stones.

An example is there. What should where the place name should be placed, what should be the font size for the place name, how the kilometre has to be placed, what has to be the font size for it, route number is to be placed, how that has to be placed. So all this information are as per codal specifications, which gives you an idea about the type of road which it is having, it gives you an idea about the distance from different places. Now the second classification of roads comes under the urban roads, where you have the four different major roads which are there arterial roads, sub arterial roads, collector streets, and local streets. Now, you can see this right hand side example is there from here you can just get a feel what these individual are going to reflect.

You can see there is an arterial road. This appears to be a major road. Then, there are sub arterial roads, which are there, which gives an access, which picks up the traffic from further interior regions through the collector streets, which comes to the sub arterial roads, and then it goes to the major your arterial roads. And, these are the local streets which passes nearby our residences or the developments which are there. So, the local roads feeds to the collector streets, collector streets feeds to the sub arterial roads, sub arterial roads feeds to the arterials and these all are the distribution in the urban regions. So, railroad street primary for through traffic usually as a continuous route is an arterial considered as an arterial roads. And, the IRC codal specification, which gives information about it, is your IRC 86-2018, which gives geometric design standards for urban roads and streets, and for the space-related information, we have the IRC 69 1977 space standards for roads in urban areas.

So arterial roads facilitate mobility across the city and connects to the long distance destinations within and outside the city. On street parking is prohibited or restricted except when there is a space available for some service road for parking. The design speed of vehicles on arterial roads is 60 kilometer per hour in planes, it is 50 kilometer per hour in rolling and 40 kilometer per hour in mountainous and steep terrain. I mentioned that plain are where the cross slope is from 0 to 10.

When the cross slope is for a country, is in the range of 10 to 25, it is rolling terrain. When we say mountainous terrain, it is 25 to 60 percent and when it is more than 60 percent, it comes under the steep terrains. Recommended land width for arterial roads in plain terrain is around 50 to 60 meters. So, this is a general requirement for arterial roads which comes under the urban roads category. Then the other one as I mentioned in the

earlier slide about the sub arterial roads. A general term denoting a street primarily for through traffic usually on a continuous route but offering a somewhat lower level of traffic mobility than the arterial roads.

So, their spacing may vary, the spacing between two sub arterial roads may vary from 0.5 kilometer in the central business district to 3 to 5 kilometer in the suburban fringes. The design speed of vehicles in sub arterial roads is same as that as of arterial roads. Recommended land width for sub arterial roads in plain terrain is 30 to 45 meters. So, again, the space is standard for this particular sub-arterial roads or arterial roads have to be referred through the IRC 69-1977.

Then the other category, which comes under the urban sections, is the collector street. Why this term mentions it is a street or a road which is used for collecting and distributing traffic from and to local streets. So, you have these local streets here, so it collects traffic from here or it distributes the traffic which it gets from the sub arterial roads. So, a street for collecting and distributing traffic from and to local streets and also for providing access to the arterial streets, the function of collector streets is to collect traffic from local streets and feed it to the arterial and sub-arterial streets or vice versa. These may be located in residential neighborhoods, business areas, and industrial areas. Normally, full access is allowed on these streets from abutting properties, except in some cases when peak hour flows are there.

Recommended length width for collector roads in plain terrains is 20 to 30 meter. More details are to be referred through IRC 69 because this gives the complete details. In general, this is what a collector street refers under the urban roads. Now then you have the local street, which is a street primarily for access to directly one residence.

From how he will access. He will access through the local street. You move out through your residence and what you access is a local street. Access to residences, businesses, or any other abutting property which is there. These are intended primarily to provide access to abutting property and normally do not carry any large volumes of traffic. Small volume of traffic for residences and small developments. Majority of trips in urban areas either originate or terminate to these streets because finally you go out for some work come back so most of the trips originate and terminate to these local streets.

May be residential, commercial or industrial depending upon the predominant use of the adjoining land where it is lying it may be in a industrial zone, residential zone or a commercial zone. They allow unrestricted parking. Here parking restrictions are normally not there in case of your local streets and pedestrian movements are also unrestricted. Recommended land width for collector streets in plain terrain is 10 to 20 meters.

So, this gives us a broad classification of the different type of your urban sections which we have. So, in today's discussion, we have gone through the importance of transportation sector, different modes of transportation, the development of roads which were there, the traditional methods which were used in the road construction. We discussed about the Indian road infrastructure, what is the current state, what is the focus of the government, what schemes are ongoing. Then, we discussed about the classification of the different type of roads under two main categories. One is urban roads and second is non-urban roads. Where you have, under the non-urban roads, you have expressways, national highways, state highways, major district roads, other district roads, and village roads.

When it comes to the urban sections, it is normally your arterial streets, sub-arterial streets, collector streets and your local streets. Now, this last slide gives you an example: what is the state? This is an information which is picked up for the year 2020. So, and which was published total surface road length, which was published in the annual report of 24, 25. Which further classifies into different categories of roads. How much national highways were there, how much state highways, district roads, rural roads, as section of urban sections also, where it says around 8.6 percent share is there with the urban roads also. As on 31st March 2020, the percentage of surfaced roads to total road length is 64.9%. So 65% is the surfaced roads.

So still 35% needs a major improvement. Major improvement in terms of good surface for the movement. National highways are fully surfaced around 99.4%, state highways again around 96% are fully surfaced, and 99.4 percent is there with state highways, and then around 96 percent is there for district roads. So, the main focus have to be again in terms of the surfacing is to be on other district roads and village roads. When we call off surfaces, as I mentioned normally the paved surfaces is a term which is conventional very conventionally used, and the paved surfaces means when you have a surface either a bituminous paved surface or a cement concrete paved surface.

So, these things we will discuss in coming lectures also. So, this is this is all for today's this lecture. Thank you all of you.