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So, a very warm welcome to all of you. I am Rajan Chaudhary, Professor in the Department of Civil Engineering at the Indian Institute of Technology, Guwahati, and instructor for the NPTEL MOOC course, Pavement Construction and Technology, funded by the Ministry of Education, Government of India. Today, we will be having a discussion on lecture two of module one, the second part of lecture two, which is on pavement types and their cross-sectional elements. We were discussing the key factors of the different pavement structures; especially, we discussed the carriageway in the previous lecture. So, going ahead with this particular one, today we will have a discussion about the median. Now you can see this picture shows a typical example of an existing road.

Now, here on the left-hand side, you can see the carriageway. This is the carriageway where traffic moves in one direction. Then there is some structure; a raised structure is there, and on this particular side, the other direction of traffic is moving. What this is provided, this is what we call a median. So, it is the portion of a divided highway separating the traveled ways for traffic in opposite directions. So, there is one traffic going in this direction and another traffic going in this direction; we separate out those two through the help of these medians. Now, the median width is the distance between the inside edges of the individual carriageways. So, it can be from here to here, and here you can see that these median shines are there or kerb shyness is there because this marking shows that it gives you an indication and creates a space. So that your vehicle does not get brushed against your medians and these raised concrete structures are kerbs.

So, the width of the median depends on the available right of way. So, the greater the width of the median, the more beneficial it is because whenever you drive at night, if there is a good amount of width in the median, you do not feel a glare from the opposing vehicles. Whenever a median is placed, you turf that particular surface or plant some shrubs over it to provide anti-glare options, and this particular one separates the traffic traveling in different directions. Urban roads with four lanes or more should be provided with medians. The provisions of medians should be judicious, taking into account such considerations as safety; as I said, if one vehicle is moving in this direction, especially during lights, glare is experienced by the vehicles in the other direction. And later on, there is another beautiful advantage: if you need to widen this particular one, then if you have a good amount of width already incorporated in your median, you can use it later on during the widening of the project as well. So, a judicious decision has to be made regarding how much slow-moving traffic, road-side development, and the quality of surfaces are there. I will show you that these are the two typical types of medians you can construct; one I showed is the raised one,

and here you can see there is a depressed median. These are two depressed medians. All multi-lane highways shall be provided with depressed or flush medians depending on the availability of land.

As I said, the wider it is, the more wonderful this land is, always available to me because it is in my right of way. So, if any widening is to be carried out at a later stage, I can use this particular one. Another part is that if any vehicle goes out of control, it gets sufficient time to regain control before it collides with vehicles traveling in the opposite direction. So, it gives you a good amount of ample scope for safety as well. Now, this much amount of land may not be available to you in certain cases every time.

So, because of emergencies, if it needs to be traversed, then flushed medians are also provided in some cases. The minimum width of the depressed median shall be 7 meters in the case of plain and rolling terrain and 2.5 meters or less in mountainous and steep terrain. As far as possible, the median shall have a uniform width. This is very important because all of a sudden the width should not vary, as that creates many challenging situations for the vehicles that are moving.

If you suddenly reduce and then suddenly increase, it creates discomfort for the people who are using that particular item. And if at some location you still have to do it, there should be a transition from 1 in 50 to 1 in 20. That should be there if you are reducing the width of a median or increasing the width of a median. I will again show a picture that was taken from the IRC 86. Now, here you can see that this particular part shows that there is an 8-meter median; this is a 6-lane road.

It is a 6-lane road, so you can see that on this particular side there are these 6 lanes. 3.75 into 3, approximately 11 meters, is constructed on this side. 11 meters are constructed, and as mentioned, a small kerb shyness is always there. A 0.5 meter wide kerb shyness is there to protect against any brushing along the median curves. So, then there is again this green belt that has come, and then you can also have the service roads. This is a typical feature of a median, which is there for a raised median. Then you can see that this particular one is a 6-lane depressed median. Here again, this is a depressed part; the curve shines are there, this is a carriageway, and there are side access roads.

In any case, the median width should not be less than 1.2 meters. So, it states that the absolute minimum width of the median in urban areas is necessary because it is very difficult to obtain a good amount of right of way in those areas. So, you have to restrict it if you need to provide a median; the width has to be reduced. So, in that case, it should not be less than 1.2 meters; desirable is always said to be 5 meters. A smaller-width flush median is allowable in mountainous and steep terrain with a crash barrier and anti-glare measures. If a flush median is present, then you have to take other measures to implement the anti-glare restrictions so that you do not get glare from the vehicles at the opposite end. Now, one more feature is that camber is the slope which you have. So, camber or cross slope is the slope provided to the road surface in the transverse direction to drain rainwater from the road surface.

This is a two-lane road without any median; you can see here that this is the slope in this direction, and if this is the center line, then this is the slope in this direction. So, any rainwater that comes over the surface flows in this direction; half of it flows in this direction, this is drained, and then there should be adequate openings where it is taken to the side trenches. This should be the conventional practice. Now, how does it help? It serves three important purposes. First of all, if the water enters through any measure, any crack, any depression, or any site, and it enters into the pavement crust, it damages it.

The granular layers, the bounded layers, the unbound layers, and the subgrade all get damaged in the presence of or lose their strength in the presence of water. That is avoided if I quickly remove the surface water; I collect it through drains and take it away. So, this is one important aspect; the second is for these flexible pavements, which have this bituminous binder: the bond between the aggregate and bitumen gets damaged in the presence of water because aggregates have more affinity for water compared to bitumen. So, that is why this bond gets damaged, you might have heard. This term many times there have been potholes created on the roads because when water stands on the road surface, it damages the bond, and this layer loses its strength or integrity, resulting in the formation of potholes.

So, this is another thing we do not want to lose, and third is the challenge with respect to the safety aspect. If water is present on the surface and you do not have a good amount of camber, it will stand for a good amount of time on the surface itself, and the surface will appear flooded. If it flooded, anyway, this is shown in a real picture; if it moves over this particular area, a lot of splash and spray is generated, and the vehicle loses control because there is a film of water on the surface. So, there is a loss of friction, is there? This phenomenon is called hydroplaning, because of which it loses control and there is a chance of skidding. So, that is another major concern; if you do not have a proper camber, these kinds of safety concerns arise.

Higher values of camber should be adopted in regions with high rainfall intensity. But yes, the upper is also a restriction; you cannot have a camber of a very high percentage; otherwise, it will lead to issues because the balance of the vehicle will get disturbed if you raise this particular camber to a very high level. So, there is a restriction on this particular one as well. Overturning of the vehicles may happen if a very high amount of camber is provided. At certain places, you might have seen the earlier picture, which I showed was having a camber or a slope in both directions, but if there is a curve like this, then there is a slope in one direction.

This is the water that has to move because it cannot give in. So, now the entire water has to pass through this carriageway; then there is a median, some median drains may be there where the water comes inside, the median drains are taken to culverts, or it crosses the medians, goes on the other carriageway, and then goes to the side drains. The standard requirements we should be aware of for it are that you can notice a visual effect, and you can say the camber is not properly maintained. Why is there water on the surface? Because camber is not properly maintained, it can lead to uneven tire wear. That is an important

aspect while constructing any pavement structure that proper camber should be present.

If proper camber is not present, then we cannot blame the surface for the loss of bond; the loss of bond was due to the improper camber, which damaged the bond. So, the Kodal specifications have already given us wonderful guidelines; it states that if you have thin surfacings that are not suitable, especially for low-density traffic, you can maintain a camber of 2 percent, and if it is a heavy rainfall region, it recommends a camber of 2.5 percent. For most of the higher categories of roads, it says a camber of around 1.7 to 2 percent is good enough, and if it is a heavy rainfall region, it is 2.5 percent of slope. If you provide a 2.5 percent slope in any of the open areas near your house, it can quickly drain away the rainwater. Now, in addition to this particular one here, you can say there is a shoulder as well. So if there is a shoulder, then the shoulder may be earthen shoulders or paved shoulders. So water from the carriageway will flow to the shoulders and then go to the trenches.

So in those cases, we always prefer to give the shoulders a higher amount of slope so that shoulders may not be strong enough or constructed to the same structural strength as what you are or the same dense material as the main carriageway. So, you want that water to move more quickly from the shoulders. So, here it says that for 2, 4, 6, and 8 lane highways, the cross fall for earthen shoulders, especially earthen soil, gets more damaged in the presence of water, and their strength decreases. So, at least 0.5 percent more, and ideally 1 percent steeper. So, if I give a camber slope of 2 percent for the main carriageway, I will give it 3 percent for my shoulders, which are earthen shoulders. In the case of expressways, the cross fall for earthen and granular shoulders will be discussed when I come to explain what earthen shoulders and granular shoulders are, along with their key features. So, when the earthen or granular shoulders are present, we prefer to give a cross slope that is 1 percent steeper than what you have in the main carriageways. Now I talked about the term kerbs; there was a kerb shyness, and the other was the median. So, a kerb is a line of raised concrete forming an edge between the carriageway and the footpath or median.

So, it is a raised concrete section specifically constructed to separate. So, either we want to separate out the median, we want to separate out the footpath, the movement, or we want to separate out railing; those particular ones are separated out with a raised concrete structure which we call a kerb. Now, curbs at different locations may serve different purposes. I will only mention three different types of kerbs here: one is a mountable kerb, the second is a semi-barrier kerb, and the third is a barrier kerb. Now, one of the most common types of kerbs is made of concrete; it can also be made of stone or any desirable material, but the most common is made of concrete mixes.

Now, as it says, you can see that there is a mountable kerb; here, the height is 200 mm and the width is 250 mm. So, this particular one now has slanting edges again. So, in case it says "within the roadway" at channelization schemes, medians, outer separators, and raised medians on bridges. In some cases, any vehicle that goes out of control or is in an emergency can move over the kerbs, so these are mountable kerbs. Now, when we want to

separate out that there is some pedestrian movement on the sides, we want to determine how much the intensity is and how much the movement of pedestrians is, so then we can have a different design of curves, which is a semi-barrier type.

It is a barrier; the word itself says it barriers. It gives control so that the vehicles do not come on this particular side. So, the semi-barrier design becomes different; the width here is 1, while there it is 150, and the height is 275. These designs are all typical designs given by IRC 86. It is located on the periphery of the roadway where pedestrian traffic is light. Now, there is again concern that when you give the curbs, there is also a concern with traffic capacity because people or vehicles will try to move away from the curbs. So, the effective width is reduced. So, you have to judiciously plan here based on the amount of pedestrian traffic to determine how much you provide. The barrier kerbs; this is the full barrier type kerb, and here you can say the height is 325 mm. So, there are no chances that any vehicle can climb over it and move to the other side, except in some exceptional cases.

So, it is a type of barrier. We keep built-up areas adjacent to footpaths with considerable pedestrian traffic. So, these are different designs. So, there are a few more designs that have been mentioned here. So, these kerbs are also concrete structures designed in different manners. We are often placing it on the edges of the carriageways when we need to separate the footpaths, or always towards the median if there is one; those medians are also edges with these particular cement concrete kerbs.

Now, the other key feature of any pavement structure is its shoulder. This is a very important structure; it has to be constructed in a good manner and maintained in a good manner as well. So, shoulders are provided along the edge of the road. You can also see here that this picture shows a marking which clearly indicates that this is the main carriageway and these are your paved shoulders. Now, from the paved shoulders, you can get an idea from the top; if you see both surfaces, there is no difference in them.

Only through the pavement markings are you able to work out that this is a continuous marking and that this is a paved shoulder. Now there is a paved shoulder that serves as an emergency lane; if there is a breakdown, the vehicle can stand on the side. This particular vehicle is also standing here. So, lanes for vehicles compelled to be taken off the pavement or roadway, in case of an emergency or vehicle breakdown, can be used for this particular purpose, or even if it is good enough.

So, many times if an emergency ambulance etc. requires some additional space, this should always be kept free. This is a short emergency escape route for any vehicle in case of an emergency, allowing it to escape with the help of your pivot shoulders. Shoulders also act as service lanes for vehicles that have broken down. If you do not have service roads that also give this. Paved and earthen shoulders are preferred on both sides.

It should not be on one side on both carriageways; it should be provided if it is divided on both sides. Both sides of the shoulder should be provided undivided, and both are provided. When paved shoulders are provided on both sides, earthen shoulders are provided on both

sides. Paid shoulders should be constructed in layers, each matching the thickness of the adjacent pavement layer.

The work is to be carried out according to the clause. Now this particular clause states how the median shoulders are to be constructed; Clause 408 of the Ministry of Road Transport and Highways specifications, which we call the orange book. So that specification gives you details on how the different types of shoulders have to be constructed. Now, for example, if an unpaved shoulder or earthen shoulder is to be constructed, what type of material can be used? So, that information is given in your MoRTH specifications section 300, which says that this should be the material to be used for an earthen shoulder. When it comes to, say, your paved shoulders and earthen shoulders, there are many cases where they say earthen shoulders if constructed from soil, and earthen shoulders if constructed from granular materials. Then it should follow up on your clause 401 of the MoRTH specifications, and the material should meet certain requirements of strength as well.

Here it is mentioned that for granular materials as per clause 401 of MoRTH specification, it needs to have a soaked CBR value of not less than 30 percent. This time, when we discuss the subgrade course, we will discuss the CBR requirements. And for granular courses, also the CBR (California Bearing Ratio). This is a penetration test that gives you an idea of the strength of the soil. So, for any granular material, it says that the strength of that material should be at least this much value.

So, when I discuss the California bearing ratio part in the shoulder, I will again discuss the CBR value part. Now, as I said, the carriageway should have a camber, and then the water from the carriageway should flow to the shoulders, which may be a paved shoulder or an earthen shoulder, and for paved and earthen shoulders, we prefer to have a camber that is greater than that of the main carriageway. So, the composition of the paved shoulder is mainly kept the same as that of the main carriageway; as I mentioned at the beginning, you cannot figure out where the paved shoulder is and where the main carriageway is. The pavement markings help you work out where the main carriageway is and where the paved shoulder is. The earthen shoulder is preferably considered to be constructed with non-erodible granular material.

So, as mentioned on the last slide, the strength should be more than 30 percent, and the CBR value should be more than 30 percent. An important aspect is that the camber and the integrity of the shoulder are to be maintained in a proper manner. If this is not maintained, and the shoulder is not maintained in a proper manner, then there is no escape available for the vehicles in case of a breakdown; it has to stand on the carriageway itself. If it stands on the carriageway, your effective width of the carriageway gets disturbed, and overall, the complete movement of the traffic gets interrupted as a result. So, an important thing is that we should get an idea that all this information is well stated and these codal specifications keep on revising with time; you can see this is one that was revised in 2023.

So, a very recent one. So we have the Indian Roads Congress, which keeps revising and coming up with new specifications depending on any new material, new technology, and

new construction practices. So new specifications also come up, and on the basis of the experience developed over the number of years, the specifications also get revised with time. So, we have very good information available through our Indian Roads Congress specifications. So, the width of shoulders in plain and rolling terrains for 4- and 6-lane, height 8 highways. It says that if there is a certain type of section, and if it is an open country with isolated built-up areas, you can have a paved shoulder of 2 meters in width on both sides, or a shoulder of 1.5 meters. So, you need 3.5 meters and 3.5 meters.

So, when you compute the roadway width, you will include the carriageway, the paved shoulder, the earthen shoulder, and the median, so that will give you the roadway width, and then the margins are considered, and finally, you come up with your right of way. If built-up areas are present, you can avoid earthen shoulders. Approaches to grade-separated structures that are separated at different grades should have only a paved shoulder. Approaches to bridges are there; we are mentioning that 2 meters is the paved shoulder and 1.5 meters is the earthen shoulder. Now, as I mentioned earlier, the important aspect is that whenever a new road has to come up, we need to acquire the right amount of right of way, because if the right amount of right of way is acquired, you will have scope for your drains, you will have scope for your utility corridors, and you will have scope for the proper width of medians.

So, this will give you, as I said, nowadays there are two concerns: one concern is that you get a smooth ride, so if the surface is smooth, you can travel fast; the second important concept is that it should be a safe travel. Now, for safety, you need a space for it and a space for different purposes, so if I have acquired the right amount of land in terms of right of way, I can provide a good amount of features or create a good amount of features that make my travel safe. So, here you can see there is a depressed median, and see how much the recommended width is; it is a typical cross-section for six lanes. Since it is a dual one, with three lanes on one side and three lanes on the other side, that is why 3.75 times 3 equals 11.25. So, the width of the carriageway is this: this is for an expressway in plain or rolling terrain with a depressed median for future widening inside.

So, what they have done is acquire the land, and later on, even if you want to go for more than that, I may want to go for an even 12-lane highway after 10 years or 15 years, then I will use this much land that is available to me in the median. So, I do not need to acquire more land; I already have whatever I am expected to have in the coming years; this is 22.5 meters of median that is there. So, you have the median edge strip, which is mentioned here; this is your side slopes, and expressways are, as we discussed in the first lecture, controlled access; access control through traffic is present.

So, here you can see they even provide fencing so that animals cannot enter your carriageways. So, all these utility corridors and facilities, considering the safety aspects, can be made possible when you have a good amount of ROW, and this ROW should remain with you. It should be noted that once you have acquired it, it can get encroached upon at a later stage. Now this is another picture; this shows the sections I am presenting that are

recommended by the Indian IRC guidelines. Here it says a 6-lane divided highway with service roads and a raised median.

Earlier, the one I showed had a depressed median; this is a raised median. Here, as I said, a preferable width of a raised median is 5 meters; this is what is provided here. So, this raised part is 4 meters, and then there are curb shines of 0.5 meters; effectively, you have given 5 meters for your medians. Then, you have given 10.5, considering 3.5 meters for 1 lane. So, for 3 lanes, you have given 10.5. Then, there is a paved shoulder that is 2.5 meters wide, and there is an earthen shoulder that is 1.5 meters wide. So, finally, my roadway width is 34 meters, which includes my carriageway, median, and shoulders.

And then what I want to acquire, I have these drains that are there; I will have earthen shoulders, and I will also have a service road, a 7-meter service road, a 2-lane 7-meter service road. Then, again, earthen shoulders and a 2-meter space are there for my utility corridors. So, it's like when you purchase a mobile, you need all the features on it. So, I need to have a road surface that includes all the features: a service road, a utility corridor, and a sufficient width of median to avoid glare and ensure safety from vehicles traveling in the opposite direction. It should have enough space for the drains to carry away the water because these are void pavements. See how much void there is; 11 and 12, 13, and 14.5 meters width of water will come up here and has to move through these drains to the culverts or the nearby outlets. So, this is the structure that needs to be seen, and this is how this road looks.

Here you can see these are yours; this is a main carriageway. This is a three-lane road; this is again a main carriageway; this is a service road on this side; this is a service road on this side. You can feel from this particular one that the people traveling on this kind of surface will be safe enough and will be able to complete their journey in a shorter period of time with a good amount of safety. Now, state highways are not for national highways and expressways; even for state highways, the example given mentions that you can have it for your two-lane undivided highway in open country, plain, and rolling terrain. So, I can have one lane on this side, and the other lane can be on this side. And these lane markings give me an idea of whether I can overtake the vehicles or not, and in which zone I can overtake.

When we discuss the pavement markings, I will mention what these individual markings refer to. So, here I can have a camber in this direction, there is no median here, the width is 7 meters, I will provide paved shoulders, the paved shoulder is provided here, and 2 meters of earthen shoulder is also to be provided. An earthen shoulder should be maintained; it should not be that the existing soil alone makes your earthen shoulder; a prepared soil that is properly constructed and compacted forms your earthen shoulders. So, then the carriageway, paved shoulder, earthen shoulder, 7, 7 plus 3, 10, 10 plus 4, 14; this is your roadway width.

And then you have the side slopes. Fill areas may be there, side slopes have to be gentle, finally, your drains have to be there, and your utilities have to be 2 meters on both sides. Otherwise, what happens is that the utility electric post comes next to your carriageway; it

is a safety hazard. If any vehicles go out of control, they hit the electric post. So, all these things need to be moved under this utility corridor part. So, this shows, this gives you an example of what you expect from a pavement structure, what the key components and features are, how it looks, what the right of way is, what a carriageway is, and what a median is. These are basic terms that all of us who need to learn about road construction should know, such as what a kerb is, what a median is, what a carriageway is, what a shoulder is, what a paved shoulder is, and what an earthen shoulder is. What is the requirement for a paved shoulder? What is a camber and cross slope? So, what is one lane, what is two lanes, what is a dual carriageway, where the two directions of traffic are separated? So, these are some of the key features; these are the common terminologies. So, this is a beginning part, this is an informative one, where we discuss what the general features of any road surface are, specifically as the focus will be on flexible pavements. So, this is all for this particular lecture. Thank you so much.