

Course Name – Pavement Construction Technology
Professor Name – Dr. Rajan Choudhary
Department Name – Civil Engineering
Institute Name – Indian Institute of Technology Guwahati
Week – 10
Lecture – 35

A very warm welcome to all of you. I am Rajan Choudhary, Professor in the Department of Civil Engineering at the Indian Institute of Technology, Guwahati, and Course Instructor for the NPTEL MOOC course, Pavement Construction and Technology, funded by the Ministry of Education, Government of India. Today's lecture will be under Module 10 and will be a continuation of our discussion on the structural evaluation of flexible or bituminous pavements. We discussed the Benkelman beam; today, we will discuss the structure evaluation using the falling weight deflectometer. At the very beginning, I would like to acknowledge the use of text, information, graphs, and images sourced from various textbooks, codal standards, journal articles, reports, newsletters, and public domain searches. Now, in this discussion, I will cover some of the key aspects that are involved in the structural evaluation of flexible pavement using a falling weight deflectometer.

Now, what is a falling weight deflectometer? A falling weight deflectometer is an impulse loading device that closely simulates the duration and amplitude of the load pulses produced by moving loads. So, there in the Benkelman beam, we worked out the deflections using a static load, but here we will be applying impulse loading through the following deflectometer, which is able to represent the actual loading that comes on a pavement surface in terms of the duration and amplitude of the load. The falling weight deflectometer and impulse loading equipment are widely used for the structural evaluation of pavements, and the one we are going to discuss is IRC 115, which provides guidelines for the structural evaluation and strengthening of flexible road pavements using the falling weight deflectometer technique. This is a widely used technique for the structural evaluation of in-service flexible pavements using what we get; we obtain deflection data from this falling weight deflectometer, along with other pavement parameters.

Now, the specific inputs are required here, and from this particular one, the moduli of the payment layers are computed, or we can call them back-calculated. Here, in taking care of the deflections obtained through the falling weight deflectometer and other input parameters, we are able to back calculate using a back calculation model. We are able to determine the elastic moduli of different pavement layers, and then these elastic moduli are used to work out the residual life of an existing pavement, or we can work out the overlay required for a flexible pavement for a given duration of time or for a given design traffic. So, these guidelines are used for two important purposes: one is to determine the residual life of existing pavement. So, we can use this as a tool for our quality control or assurance, and to determine the required overlay thickness over the existing flexible pavements.

This is how a falling weight deflectometer works; it is a vehicle-towed one. Now, as we did in the case of the Benkelman beam, we are going to apply a load that should be more representative of how traffic loads are, and then we are going to record the response of the pavement in terms of elastic deflections at various locations, which will then be analyzed. Taking care of input parameters such as subgrade strength, thickness and quality of pavement layers, drainage conditions, and pavement surface temperatures. So, these, along with the deflection, are the key important factors that will be required. So, among the various equipment used for structural evaluation, the falling bed deflectometer, as I said, is a widely preferred one because the loading pattern closely simulates the actual traffic loading.

So how does it work? When a moving load is present, it generates a load pulse that rises from a 0 level to a peak stress and then returns to 0. So I can call it a pulse duration. So it says the normal stresses at a pavement rise from 0 to a peak value and then fall back to 0. So, this cycle can be called a pulse duration. Now, for pavement evaluation, the peak load and the corresponding pavement responses are important.

So, with the help of this falling deflectometer, we can work out both the load and the duration of the application of the load. So, the pulse duration, as well as the amplitude, can be worked out with this falling weight deflectometer. So, how this particular one here works is that an impulse load is applied by dropping a mass on a system of springs. You can see this is a standard mass that may vary from 50 kg to 700 kg, depending on the kind of structure we are evaluating and how strong the structure is. So, this standard weight is allowed to fall from a standard height, and it is over a system, with this particular one going through a system of springs over a circular loading plate.

So, as you can see, there is a system of springs which is there, and finally it comes over a load cell. So, through that particular circular loading plate, it is applied to the pavement surface. Then, in the direction of travel or longitudinal directions, various sensors or velocity transducers are present to capture the deflection at the peak load. So, the resulting pavement surface deflections are measured using or monitored with displacement sensors placed at various rear-deer distances from the load center. Now, we have both the vehicle towed one, which is the trailer-mounted one, and the vehicle-mounted one.

Nowadays, a lot of advancements have also been made in falling weight deflectometer equipment. So, a good variety of them is available. And as I mentioned, a predetermined mass is dropped to generate a load pulse, and the corresponding peak load and peak surface deflections at various radial distances are recorded in that particular one. Now, the circular load plate over which this load comes is typically of a diameter of around 30 centimeters or up to 45 centimeters; the one that is typically used is of 300 mm diameter. Now, this particular one, as I mentioned, a load can vary from 30 to 350 kg, and it may go up to 700

kg for heavier versions, specifically when dropped from a typical height of 100 to 600 mm to generate a controlled load pulse with the required peak and duration.

So, how much peak do you want in terms of that, and that is how much maximum load you want to come over that particular plate, and what is the duration of that particular? Now, for flexible pavements, the target peak load is 40 kilonewtons because we considered a standard axle of 80 kN. So, that is why it is considered that 40 kN is the target for this particular falling weight deflectometer when the load is applied. So, for bituminous flexible pavements, the target load is 40 kN, equivalent to the load from one dual wheel of a standard 80 kN axle. If the central deflection under this load exceeds the central limits, that is why, because in that particular case, the load may be reduced. This is because if we find that when you apply a 40-kilonewton load and the sensors show the deflections going beyond the limits, then we can reduce it.

And typically, another factor is that at least a capturable amount of deflection should be present. So, it mentions that if we monitor, we should at least have a load that can give us at least 10 micrometers of deflection at 1.2 meters of radial distance, because we will place these velocity transducers at different radial distances. Now, if in that particular case it may not be the target of 40 kilo Newtons, it may vary from this particular one. So, the major deflections are linearly normalized to a standard load.

So, if you are doing it at 45 kilonewtons, whatever deflections we get can be linearly normalized and brought back to 40 kilonewton deflections corresponding to 40 kilonewtons because that is what is required in this particular evaluation. And as I mentioned, the impulse load, what should be the pulse duration, is to approximate the time taken from a wheel to traverse a tire imprint at a speed of 60 kilometers per hour, and that normally is a period from 20 to 30 milliseconds. So, we want to apply a load pulse that goes from 0 peak to 0 in the range of 20 to 30 milliseconds. So, most of these typically have a range from 15 to 50 milliseconds. These falling weight deflectometers can generate load pulses in this particular range.

So, we have options for varying the load, and we have an option for varying the pulse duration as well. So, both the amplitude and the duration can be varied, and this can be controlled because we can apply different levels of load for different durations. Now, to capture these deflections at different radial distances, the velocity transducers, geophones, or seismometers are placed, and they are positioned at radial distances aligned along the longitudinal direction, with various combinations typically used. Like, one is when we use 7 sensors placed at a radial distance of 0, 300, 600, 900, 1200, 1500, and 1800. So, seven sensors are placed.

You can see that these 7 sensors are placed in a longitudinal direction. These 7 sensors can also be in this particular manner, and there may also be 6 sensors. These two are also

arranged in two different manners. So, these are widely used by different agencies to work. Now, this particular exercise of evaluation through a falling weight deflectometer involves certain important steps, or key steps, that can be identified.

The first is the collection of historical data on pavement because whatever pavement you are going to evaluate requires some historical information in terms of its composition, material, layer thickness, and the modulus of the bituminous layers, so that information needs to be collected in this one. Second is a condition survey to identify uniform performance sections; then, the survey has to be done so that we can identify how many measurements need to be taken in one particular section. So, for this particular exercise, we will first divide the sections into uniform sections, and then we will proceed with the deflection measurement exercise using the falling weight deflectometer. And along with it, we will require the determination of layer thickness, composition, and subgrade characteristics so that we can proceed with the temperature and seasonal corrections. So, then we can work out, through back calculation, the modulus of the different layers, and through this, we can determine the residual strength or the residual life of the pavement.

Additionally, if an overlay is required, we can calculate the overlay thickness for strengthening the pavement. So, these are some of the steps; first, we will discuss them. So, historical data helps us identify the causes because there may be certain causes that are not directly related to the structural part; in that case, if stripping is present in that particular case, we can obtain some information from the historical data itself about the pavement structure. So, we can identify certain causes through this historical data; design deficiencies are present. Poor material selection, improper construction, a high water table, and inadequate drainage are present.

So, many times it is difficult to get this particular data, but still an attempt has to be made to collect this historical data about the pavement that is under consideration. Then we go for a pavement condition survey. So, this is conducted before deflection testing, consisting mainly of visual inspection supplemented by measurements of cracking, which can be done by rutting, and other distresses can be identified in this visual condition survey. On the basis of this visual condition survey, the sections can be classified into uniform pavement performance sections. And for this particular condition, surveys, again, we can divide the lanes and shoulders.

In each lane, it has to be done for each lane, so a length of 50 meters into 3.5 meters can be used as a block. So, one of these different blocks can be considered, and we will have a visual inspection for the different stresses over this particular one, especially cracking and rutting. So, based on the survey data, the road is then segmented into uniform performance sections, and we preferably require a uniform section of at least 1 kilometer in that case. So, you can see that as per IRC 115, it states a uniform section can be classified as good if

there are isolated cracks of less than 3 mm in width, and if they are less than 5 percent of the total paved area, and the average depth is less than 10 mm.

So, if this is there, then that particular section can be classified as a good section. So, a fair isolated or interconnected crack of less than 3 mm in width in 5 to 20 percent of the area of the total paved average layer depth between 10 and 20 mm. If this exceeds, then this particular section can be classified as a poor section. So, this classification has to be discussed later. Now, after this particular one, we need to work out what our sample size is, so how many samples have to be taken in that particular uniform section?

So the sample size or the interval at which deflection measurements in that particular uniform section are to be taken is based on some statistical principles, and it is taken into account that we can increase the sample size depending on when a large variation in measured deflection is expected. This is another instance where we want it to be a newly constructed one, and we want to have a smaller margin of error between the estimated mean deflection and the true mean deflection. So, this can decide on the basis of it we can increase our the increase and decrease our sample sizes. So, this is one of the common expressions given by IRC 115 to work out the sample size, which is n here. Now, in this particular case, Z is our standard normal deviation, which can be computed from the standard statistical tables.

This is the other one: the coefficient of variation of our deflection, which is the standard deviation divided by the mean, expressed as a percentage, and ME is the acceptable margin of your error. Now, for our study, according to IRC 115, it states that this acceptable margin of error should be 10%, whereas the confidence interval, which we require for the determination of Z , is to be 90%. And then this coefficient of variation, which is there again, states that this is 15 percent for a good section, 30 percent for a fair section, and 45 percent for a poor section. So, on the basis of this, using a 90 percent confidence interval and a margin of error of 10 percent, we can work out the sample size for good, fair, and poor sections as 4, 15, and 33, respectively.

So, this is what is mentioned. So, this is how the sample size can be calculated. Now, in addition to this particular one, the scheme for the measurement of the deflections is very important for determining where these deflections are to be measured. So, it may be along the most distressed wheel path of the carriageways. So, this is because all these measurements will always be focused on the wheel path. So, it says that most distressed wheel paths are along the inner and outer wheel paths of the lane; both can be present along both wheel paths of only the outermost lane, because normally we expect heavy vehicles to be moving in the outermost lane.

So, that may be the more distressed one in that case, along with the more distressed path of each lane, because if there is no lane discipline, the heavy vehicles may be moving in

the middle lane. So, these different methodologies can be used. Schemes can be picked up for doing these measurements. So, IRC 115 provides guidelines for selecting deflection measurement schemes for different carriageway types and states that if you have, for example, this particular one. Here, it says the type of carriageway recommended measurement scheme.

So, it is a two-lane, two-way single carriageway. So, there is no median; it is a two-lane, two-way single carriageway. So, there are two lanes measured along both outer ends; it says both outer wheel paths. So, since there are two lanes on both sides of the outer wheel paths, it is to be mentioned, and then it states that on the basis of maximum spacing for test points along the selected wheel path for pavements of different classifications, it works out that okay. The maximum spacing can be 60; for the fair one, the maximum spacing can be 130; and for the good one, the maximum spacing can be 500.

So, as this action is becoming good, the spacing is obvious to increase in this case. So, this is then we have similarly the guideline for four-lane single carriageway measures along the outer wheel paths of the outer lanes. This is again a single carriageway, but with four lanes measured along the outer wheel path of the more distressed inner lane. This is already given, and now this number for the maximum specifying spacing is typically given, considering a uniform section of 1 kilometer. So, if the uniform section is more than that particular one, it has to be multiplied by that section's uniform length to get this particular spacing.

Along with it, it is also said that we can go for these deflection measurements along the hard shoulders because, in that particular case, they are proposed to form a part of a new lane in widening projects. So, these hard shoulders can also be for that particular one; again, we can go for these deflection measurements if they are considered to be a part of a widening project. Now, in addition to this particular one, you can work out the wheel paths on your own by having a visual inspection or not. There are certain typical guidelines that are said to determine what the wheel path is where the actual measurement has to be taken. So, the outer wheel path positions are preferably identified by visual inspection of the surface condition; you can work out where the typical wheel path is followed.

If that is not possible, we go with the IRC 115 guidelines and what it says. For the outer wheel path of outer lanes, it gives an "so," and if we need to for outer lanes, at what location do you have to make this deflection measurement? So, it says for a single-lane two-way carriageway at 0.6 meters from the outer edge. So, from the outer edge, we go 0.6 meters for the deflection measurement. For a 2-lane, 2-way carriageway, this is without any median; for a multi-lane, single carriageway, again without any median, at 1 meter from the outer edge of the outer lane. So, the outermost layer from its edge at 1 meter EV is going to make the deflection measurements, and similarly, when it refers to a divided carriageway with 2 or more lanes in each direction. So, we can call it a two-lane dual

carriageway when there are two lanes on one side or two lanes on the other side; it says 0.75 meters from the outer edge of the outer lane. Now, this is the case when we are talking about the outer lanes, or there may be a case when inner lanes are also there, but we will always prefer to go for the outer wheel paths.

So, it says for a multi-lane single carriageway. It is when we are looking for an inner lane at 4 meters from the outer edge of the outer lane. So, if we are looking for inner lanes, then we go for the measurements, which are, say, for divided carriageways with 2 lanes in each direction, 4.2 meters from the outer edge of the outer lane. So, this is when we are looking for the inner lanes because the inner lanes are more distressed compared to your outer lanes, as the previous table shows where you make the measurements. So, the following steps are represented here together: first, we need to mark where we have to make these measurements, and then the FWD has to be brought up; it has to be centered over that particular location where the measurement has to be taken; it has to be lowered down.

The loading plate on this pavement point, where deflection measurements are taken, lowers the frame holding the geophones; then, where you have these velocity transducers, they are also lowered down, and the standard mass is raised to produce a target load of 40 kilonewtons. Initially, we give a sitting load, which is not considered for the deflection measurements; raise the mass and drop it. So, if we are from this particular one, if we are able to work out that we have the deflections more than the capacity of our transducers, or if it is less, we can increase the load, also considering those particular factors, but our target load will be 40 kilonewtons. Recording air and pavement surface temperatures simultaneously at half-hour intervals will allow us to measure the pavement temperatures, and we can then proceed in a similar fashion: we can dig a hole to a depth of around 45 mm, and with the help of glycerol and a thermometer, we can determine the pavement surface temperature. Normally, we do not go for these exercises of falling with a deflectometer when the temperatures are above 45 degrees centigrade.

So, we typically target temperatures of 35 degrees centigrade. Then, once the measurements are done, we usually go for three measurements. We raise the geofoam frames and load the plate, and then we move to the next location. So this is a typical table that has been taken from IRC 115, which states how the information has to be recorded: the lane position, the chainage (which is the distance from the carriageway edge), air temperature, pavement temperature, load drop number (which indicates how much peak load you are going), and the peak deflection obtained at the different deflection transducers. So, here you can see these are the seven transducers that are mentioned, and any specific remarks that are there can also be put up.

So, well-recorded information has to be there, and it is not recommended when the pavement temperature is typically, as I mentioned, more than 45 degrees centigrade. In addition to this particular one, as you have historical data, you need to ensure the thickness

of the individual pavement layers. So, for this particular reason, that is what is required for the back calculation of the moduli for estimating the remaining life, as well as the overlay thickness. So what is being done? We normally go for test picks of sizes 0.6 meters to 0.6 meters, which are at the pavement edges and preferably at 1-kilometer intervals, and this is the one. So, near the southern shoulders, it has to be dug down, and during this particular exercise, simultaneously, cores have to be taken up. Cores can be taken up from the intact sections. Cores may also be taken from the distressed sections. So, from this particular examination of what we need, we require the thickness of the individual layers, and in addition to these cores, we will work out the modulus of the existing materials that will be used for comparison when calculating the back-calculated moduli.

So, test peaks should coincide with the falling weight; this is important, at least for this particular one, because this will be done at an interval of 1 kilometer. So, it should coincide with where one measurement of your falling weight deflectometer has to be taken. So, major deflections now, as I mentioned, the deflections—once you have the deflections, you have the layer thickness. From this particular one, for a given load and the target load, if it is 40 kilonewtons, and if it is varying, we have to normalize it and bring it to 40 kilonewtons. Now, with these inputs, what is your target load, what is your layer thickness, and what are the deflections at the different transducers? As inputs, what are the inputs? These are the deflection transducer measurements, which include layer thickness, Poisson's ratio—typically Poisson's ratio for the different kinds of materials used—and the applied load, which is specifically normalized to 40 kilonewtons.

Plate radius sizes, as I mentioned, are typically 30 centimeters, which helps to use the back calculation to determine the elastic moduli of pavement layers. IRC 115 recommends the use of a KGPBACK version of software developed at IIT Kharagpur for this purpose, and this particular one is to analyze/back calculate the moduli because this is a regression exercise done using this software, allowing us to attain the modulus for the different layers. So, this is already a software program provided by IIT Kharagpur and incorporated with our IRC 115 to compute the elastic back or back-calculate the moduli of the different pavement layers. Now, as I mentioned, this definitely affects the back-calculated moduli, which are affected by the pavement temperatures. So, one needs to make some corrections specifically for pavement temperatures because the binders are stiff at lower temperatures and become soft at higher temperatures.

So, we need to target a standard temperature, and as I mentioned, the modulus which is targeted or the temperature which is targeted at 35 degrees centigrade. So, in the field, when you are measuring these moduli at some other temperatures, they need to be corrected for the variation in temperature, or a temperature correction factor has to be applied. So, for this particular one, again the IRC 115 gives an expression to compute if we are measuring the deflection surface, say exercise, at a temperature T_2 ; then it can be corrected to estimate the modulus corresponding to a temperature T_1 , which is our 35 degrees

centigrade. So, here it can be seen that this is the modulus for our standard temperature, and this is where the actual measurements were done, and this is what the temperature correction factor is, which is worked out through this particular expression. Now, this is possible specifically in certain regions when altitudes are very high and the temperatures are preferably less than 20 degrees centigrade for more than, say, 4 months of the year.

In this particular case, you may not be able to do this exercise at 35 degrees centigrade. So deflection measurements are preferably done when temperatures are above 20 degrees centigrade, and no correction is considered in that particular case. So, similar to what we considered in the case of the Benkelmann beam study as well. Now, the moisture or the seasonal variation is another important factor. So, it influences the moisture because the seasonal variation of the subgrade and granular layers is quite important.

So, this affects the pavement layer moduli, and when do we prefer to determine when it is in the weakest condition during the monsoon period? So, in that particular case, whatever back-calculated moduli are there need to be corrected again for this seasonal factor, and they have to be the ones that are under the weakest condition. So, again, we have some standard expressions to estimate the subgrade modulus values from the back-calculated ones using the reflections measured in winter and summer, respectively. So, what it says is that you have the expression for subgrade modulus, which is there in the monsoon period, and that can be worked out through what you have measured during the winter period. So, here you can see the subgrade modulus in the monsoon, and this is so; these expressions, if you have the modulus for winter, can help you work out the subgrade modulus specifically, but these are typically when the monsoon subgrade modulus is more than 20 MPa. So, this is what is usually expected; this much amount of strength is expected from the subgrade.

So, this is when the expressions mentioned by IRC 115 are typically applicable when the monsoon modulus of subgrade is more than 20 MPa. So, similarly, if it is measured in summer, it can be worked out for the monsoon period. The same is true for the granular courses, where we want to work out the modulus during the monsoon period. Here again, a requirement is that it should be at least 60 MPa for the monsoon granular modulus, or we can say the minimum winter modulus is 80 megapascals, and the minimum summer modulus is 800 megapascals. Then we can work out the modulus of the granular courses for the monsoon period.

So, what back-calculated modulus we obtain, we have to correct it for the temperature; we also need to correct it for the seasonal part. Now, in addition, if we are looking for the overlay design, we also have to work out the design traffic, as we did in the case of the Benkelmann beam study. And this has to be done as per the IRC 37-2018 guidelines, where you work. Your design traffic, which is in terms of the cumulative number of standard axles to be catered for during the design period, is typically considered for at least 10 years.

r is your growth rate of commercial vehicles, N is your design life, which can be taken as 10 years or more.

The vehicle damage factor, F, is the vehicle damage factor, D, is your lane distribution, and A is your initial traffic at the completion of the construction. So, if that is not there during the construction period, there will also be a growth of traffic. So, that also needs to be taken care of. So, this design traffic is required when you are calculating the overlay thickness. Now, if the key steps are clubbed in this particular one, what are the key steps that get involved in this one? First of all, we will measure the surface deflections of homogeneous sections of pavement using a falling weight deflectometer.

So, we have already worked out the uniform sections, the number of samples that has to be taken, the location where it has to be taken, in which lane, and at what distance from the edges it has to be taken. So, the first deflection measurements are there, and these deflection measurements are normalized to bring them to the standard load. So, this is the second step, which is an important step that is involved. Then, the collection of information about the layer type and layer thickness is conducted. So, how much is the thickness of the granular courses, and how much is the thickness of the bituminous courses that need to be worked out? So, for this, we dug pits at least at a location of 1 kilometer, and we collected this particular information.

As I mentioned, simultaneously, you can do the coring; you can work out. So, the bituminous samples can be taken out, their modulus can be determined in the laboratory, and that modulus can be compared with the back-calculated moduli as well. So, that gives you better confidence in this evaluation exercise. Now, back calculation is performed using the back-calculated software provided by IIT Kharagpur. So, with this IRC 115 that will be used for the back calculation of pavement layer moduli from the normalized deflections, considering this 40 kilonewton load and using the back calculation software that is available. And then this particular step is necessary since it is dependent upon the temperature; therefore, these are to be corrected for the temperature, considering a standard temperature of 35 degrees centigrade.

So, that will be followed once you have these back-calculated elastic moduli. And when it is there for the subgrade and granular courses, this again has to be corrected, considering the weakest period, which is during the monsoon. So, again, we go for the modulus of subgrade and the granular courses, which are corrected for the season to have the modulus for our monsoon period. Now, we have the corrected modulus for our bituminous courses, for our granular courses, and for our subgrade courses as well. Now, out of this, we normally pick the selection of the 15th percentile modulus, considering that 15% of the values will be less than this particular one. So, this is the one again to have a safeguard that only 15% of values will be lesser than this particular one.

So, those modulus values are considered for our computations. Now, with this particular instance, you have the exact layer thickness and the back-calculated modulus that you are going to input in your flexible pavement design software as per IRC 37 to work out what you will determine because that incorporates the elastic three-layer theory, where you will have the bituminous bound courses, granular courses, and your subgrade. So, you will work out the modulus for subgrade; you will input the modulus for subgrade for granule courses and bituminous-bound courses, and you will work out the strains. So, considering the basis of the strains obtained, two critical strains are identified: one is the tensile strain at the bottom of the bituminous layers, and the second is the vertical compressive strain at the top of the subgrade. So, using those two strain values, you work out the remaining fatigue life and the remaining rutting life.

So, that can give you the residual life of your flexible pavement. So, then you can compare what it is, and this can also give you quality control. So, at a period of, if you do say after 5 years, you have designed a structure for a period of 20 years. So, after 5 years, when you do this FWD exercise, you should be able to get the strength that gives you 15 more years of design life; if it is less than this, then you can say the structure was deficient or an inadequate structure because of some distress. So, this is one way you can work out the residual life this particular structure will last for this many more design traffic. This is one part of the determination of residual life; the second is that I want to strengthen it, so in that particular case, you will work out an overlay type and its thickness, and you will provide the modulus of that particular overlay as input.

So, the first is the estimation of the remaining life of the pavement using the criteria for fatigue and rutting. So, we calculate the strains at the bituminous courses at the bottom of the bituminous layers for our fatigue criteria, and for rutting, we assess the vertical compressive strain at the top of the subgrade, and then we determine how much life is remaining. So that gives us the residual life. The other way, when strengthening is required, is that we will work out some trial overlay thickness and use that trial overlay thickness along with the modulus of that particular overlay. We will again compute the strains, the tensile strains, and the compressive strains, and then we will work to ensure that these are well within limits, considering our expected design traffic.

So, this is the next step when some overlay needs to be designed. So, in the final steps of bituminous overlay, thickness is selected by trial such that the calculated critical strains remain. So, I can work out the other way around; I have the design traffic with me. So, to have my rutting and my cracking within a permissible strain, I can work out what the permissible tensile strain and compressive strain should be, and then I can check with this excessive thickness. If it is less than this, my design is okay for that particular traffic. So, this is another way of working out within permissible limits as specified by the design traffic.

So, the modulus should be determined following the guidelines; the modulus that is to be obtained is to be considered as per IRC 37. So, it can also be worked out by the laboratory determinations, and some guidelines are given in IRC 37. So, it is a combination that involves conducting the structural evaluation with the falling weight deflectometer assessment while simultaneously determining the residual life using IRC 37, and we are also trying to calculate the required overlay thickness for a given design traffic. So, these are the two ways in which the structural evaluation of flexible pavements is carried out. Thank you so much.