Analysis and Design of Bituminous Pavements

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Lecture - 10
KENLAYER – 2

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In this lecture, we will solve two numericals using the KENLAYER software and understand how the vertical stress on the subgrade is influenced by the thickness above the subgrade layer. So, we will move to the numerical here.

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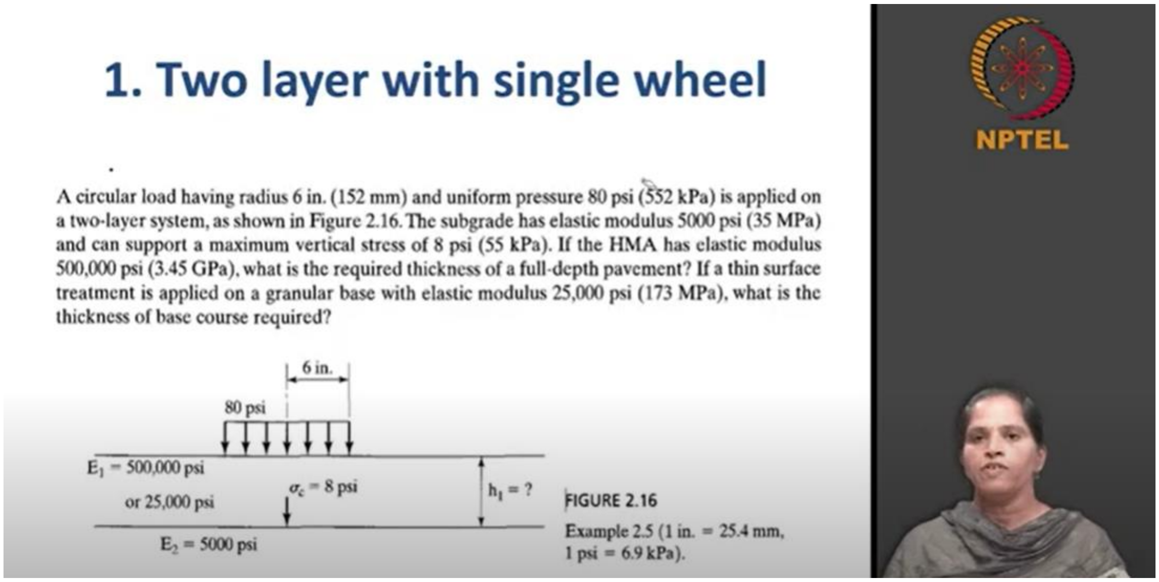

The first one is using a two-layered system with a single wheel. So, first let us understand the problem here. You have a circular load having a radius of 152 millimeter. Let us focus here, the SI system of units. So, circular load having a radius of 152 millimeter and a uniform pressure of 552 kPa is applied on a two-layered system. The subgrade has an elastic modulus of 35 MPa and it can support a maximum vertical stress of 55 kPa. So, the catch here is the stress on the subgrade is limited to 55 kPa, it cannot exceed beyond that. If HMA has an elastic modulus of 3.45 GPa, what is the required thickness of a full depth pavement? This is the first part of the question. So, above the subgrade you have a HMA layer. So, HMA layer has a modulus of 3.45 GPa. Now, what is the thickness of the top layer required? So, now, in the next part of the question you have, if a thin surface treatment is applied on a granular base with an elastic modulus of 173 MPa, what is the thickness of base course required? So, the question is like you have a subgrade layer above a subgrade instead of a hot mix asphalt layer, you have a base layer and the base layer is a granular layer. So, the modulus of this base layer is 173 MPa. Now, you have a difference here if you use HMA, the modulus is going to be 3.45 GPa, but this is 173 MPa, which is much less than the HMA layer. So, above the base layer, you have a thin HMA surface. So, this is the structure here. Now, what is the thickness of the base course required? See, if the surface is too thin, we do not consider it as a structural layer. So, the top surface is not considered as a structural layer. So, again, you can do analysis assuming that this is also a two-layer system.

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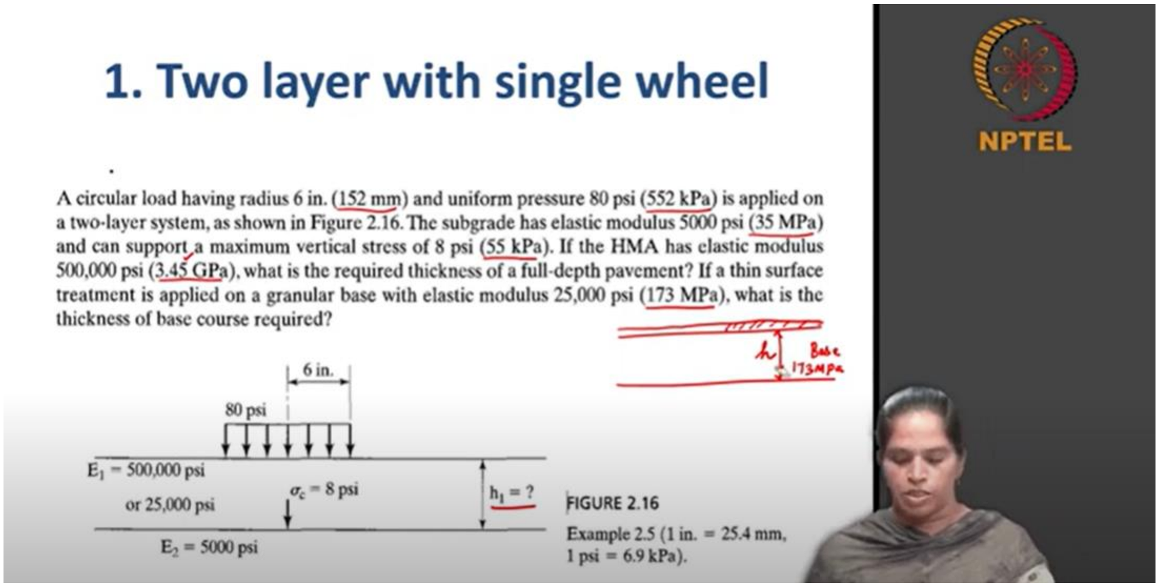

So, first we will see this one. So, you can go to KENPAVE, open the KENPAVE software and go to layer input and start with a new file here. When you give a new file, it will be named as ‘untitled’. Open the ‘general’ input. So, these are the general inputs you have to define. So, first give title, type of material is linear, no damage analysis, number of periods, we are going to use only one because you have only one modulus, number of load group, it is going to be single axle single wheel as per numerical. You know what is number of integrations and tolerance for integrations Number of layers, it is a two-layer system and number of z coordinate, it is only one and we need it exactly at the top of the subgrade layer. Maximum cycle of numerical integration, leave it as a default value. Now, everything has default, only thing is you just go and change the system of unit to SI and click OK.

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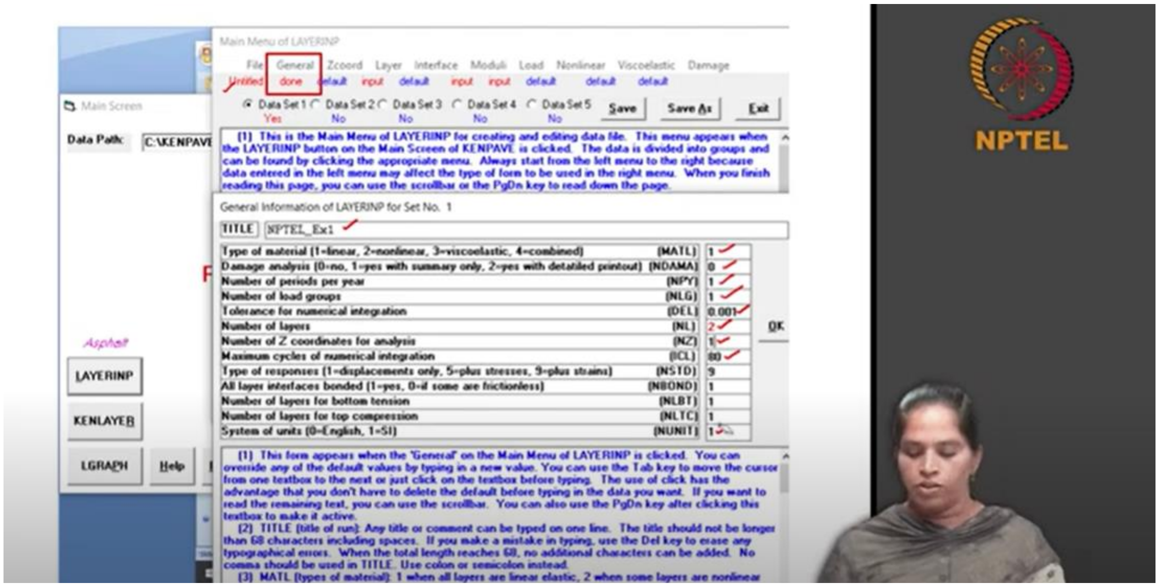

So, once the general input is done, now next is z coordinate. So, this is a thickness here, this is our layer. Now, where exactly you need to determine stresses and strain is at this point (below layer 1). So, this is the point we need to determine stresses and strain. We need to give z coordinate to be this, that is distance from the top to this point. So, it is the thickness, we need the thickness of a top layer, but that is what we need to determine, we will do it based on the trial-and-error basis. So, we will assume the thickness and find out what is the stresses here and we will check whether that is within the allowable limit. We let us assume to be 13 centimeters or 130 millimeters. So, your z coordinate you have to give it as 13 centimeters. So, if you do that your z coordinate input is done.

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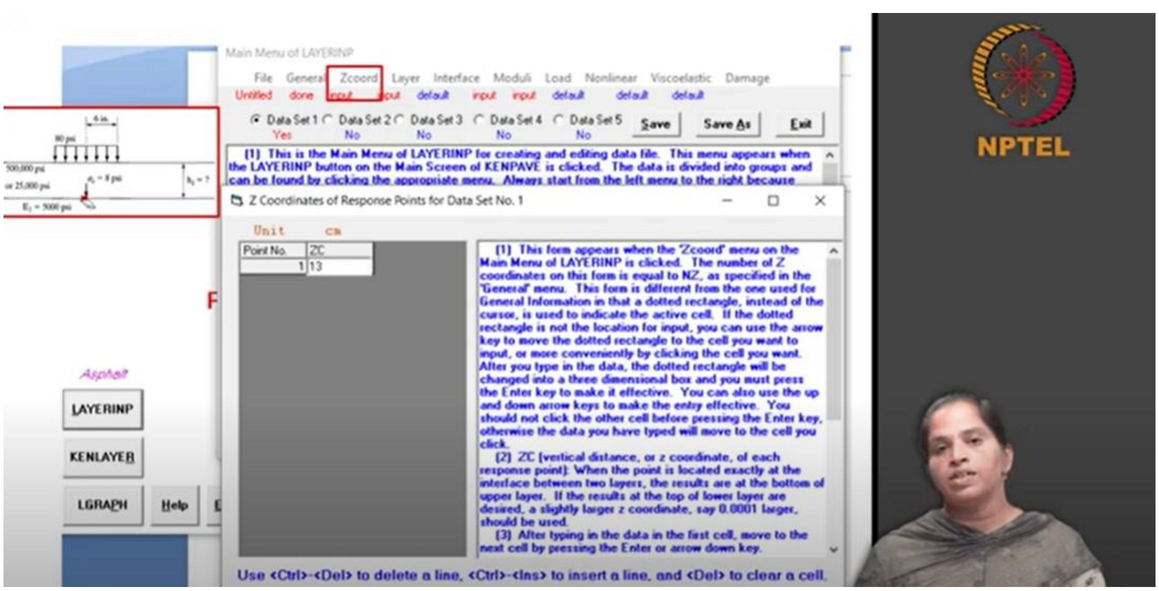

Next one is the layer input. So, layer input you need to define a structure here, thickness of first layer is 13 centimeters, second layer is infinite, you cannot change anything. Poisson's ratio, let us assume the Poisson's ratio to be 0.5 and 0.5. If you want, you can go change the Poisson's ratio of asphalt layer to be 0.35 and try, but as of now I will keep the Poisson's ratio to be 0.5 and 0.5.

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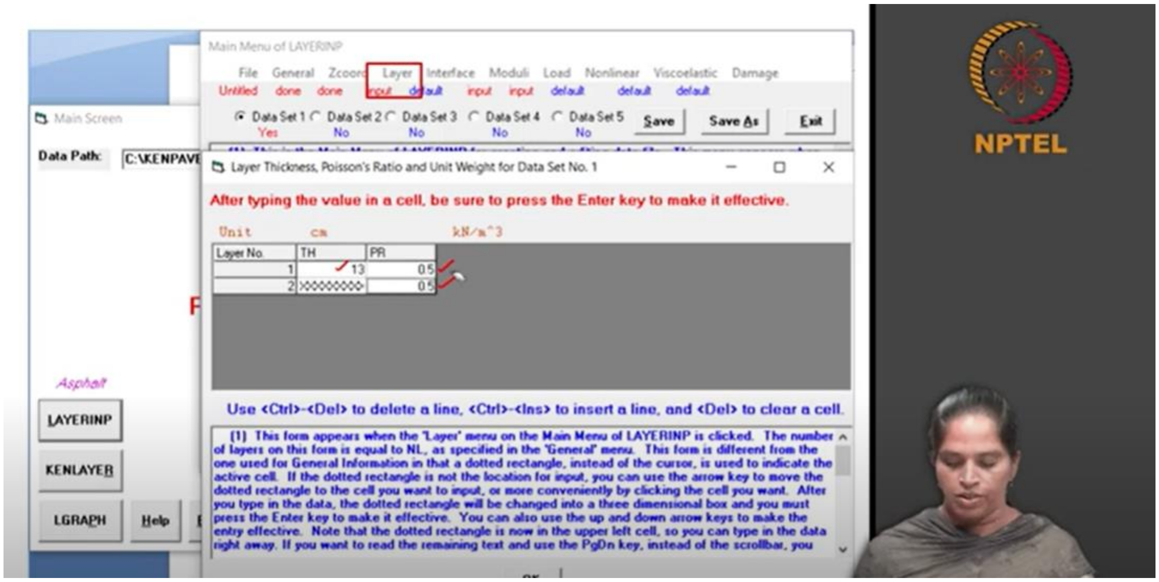

So, once this is done, next input is the moduli input. So, when you click the moduli, you will get one period, when you click on this, you need to specify the modulus for the two layers. So, as per our numerical, modulus of the first layer is 3.45 GPa and modulus of soil layer is 35 MPa. So, you have to convert it into kPa and give here. So, once you do this, the modulus input is done.

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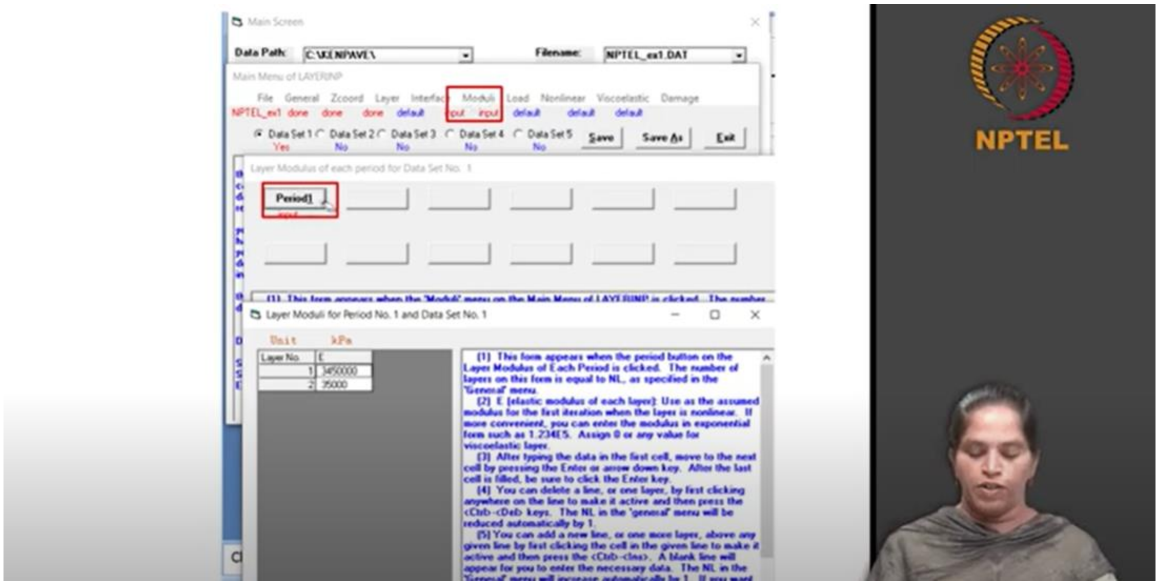

Now, next is load. So, load here it is a single axle single wheel. So, we assign 0 for defining single axle single wheel. So, the contact radius is 152 millimeters, contact pressure is 552 kPa as per numerical. We do not have YW and XW here, this is because, it is a single axle single wheel. So, once this input is given, now you need to give where exactly you need the stress, whether you need it at the center of loading or at the periphery of loading. So, it is the critical stress what we are interested in and in the numerical, it is given exactly at the center of loading. So, we will give only one point and you just double click on this (NR or NPT cell) you will get a window. In this window, you can define RC here, RC is exactly at the center, so it is 0. So, by defining these 5 parameters, our input for load is done.

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So, once you complete all the information, all the input in the layer input category, you can just give ‘save as’, you can save it using any file name and then come out of a layer input by clicking exit. So, after you give all the input, you can compile using the KENLAYER button and when you compile using the KENLAYER button, you will see the results. And in the results given as a tabular column, you can see that you have radial coordinates to be 0. So, you have radial coordinates and vertical coordinates. We can see 2 vertical coordinates, as I have given 2 vertical coordinates. One is at the surface and other is at the interface of 2 layers. You have vertical stress and strain, radial stress and strain, tangential stress and strain and shear stress and strain. The negative sign indicates the tensile nature and the positive sign indicates the compressive nature. So, what exactly we need? We need stress on the top of a subgrade layer. Exactly at 0 point (radial distance), 13 centimeter below the surface layer, we need to find out the vertical stress. So, the vertical stress at the top of a subgrade layer is 58.509 kPa. So, our constraint here is, we need to restrict the stress on the subgrade layer, top of a subgrade layer to be 55 kPa. This is what our need is. But, as per our analysis, we have 58.509 kPa. So, this clearly says that stress is more than the allowable value. So, this thickness, 130 millimeter above the subgrade layer is not sufficient to restrict the stress above the subgrade layer to 55 kPa.

Now, what you can do is, you can increase the thickness to 135 millimeter and proceed in the same way as you did and you can check what is the stress above the subgrade layer for 135 millimeter thickness. So, you can see that the stress above the subgrade layer is 54.965 kPa, which is well within the allowable stress of 55 kPa. So, you need a minimum of 135 millimeter to restrict the stress on the subgrade layer to be within 55 kPa. This is what the numerical says. So, when you increase the top layer thickness, the stresses and strain on the subgrade layer will be reduced.

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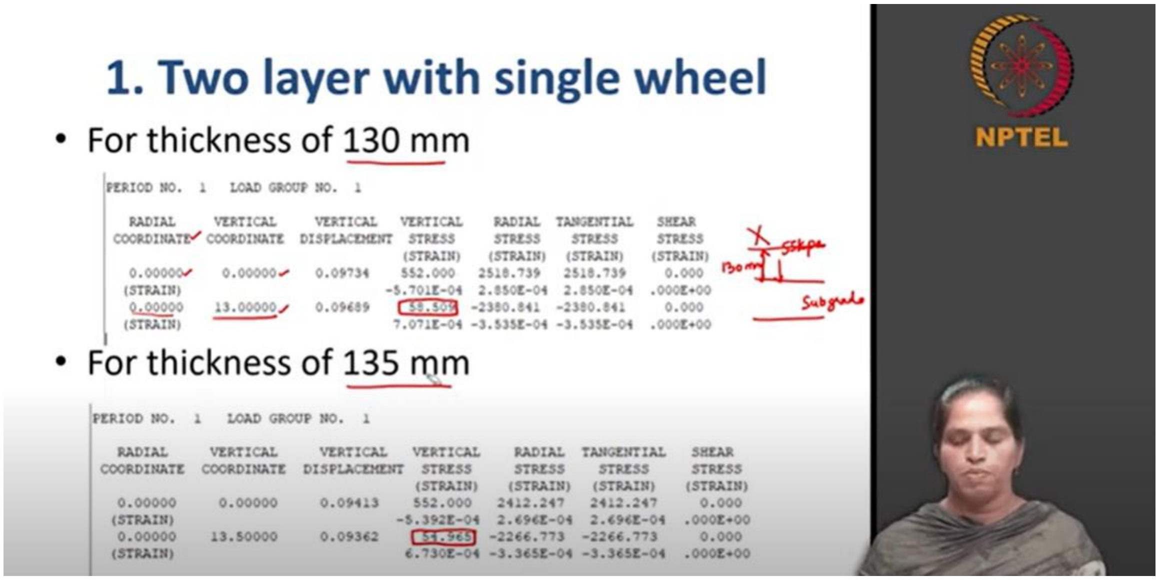

In the second part of a numerical, instead of a surface layer, if we use a base layer of 173 MPa, then what is the thickness of the base course? The modulus is less compared to the previous problem, so we will try and change the parameters. The parameter you need to change is the modulus value. So, the modulus value of the first layer is 173 MPa and the modulus of the second layer is same, 35 MPa. So, one input which you need to change is the modulus. You need to find out stresses and strain exactly at the layer interface. If you are going to vary the thickness, the location is also going to vary. Let us assume some number and find it out. Now, I will assume it to be 38.5 centimeters, this is based on trial and error. You can just increase the thickness and find out at what exact thickness you get the allowable stress value. I am going to use 38.5 centimeters. So, thickness of the layer, first layer is going to be 38.5 centimeters, thickness of second layer is infinite, you cannot change it, Poisson's ratio is 0.5 and 0.5. What we are interested in is the vertical stress at the center of loading and at a depth of 38.5 centimeters. So, at the top of a subgrade, the critical vertical stress if you provide 38.5 centimeters is 54.613 kPa. So, you have a stress well within the allowable limit, that is 55 kPa. So, you need a minimum thickness of 38.5 centimeters.

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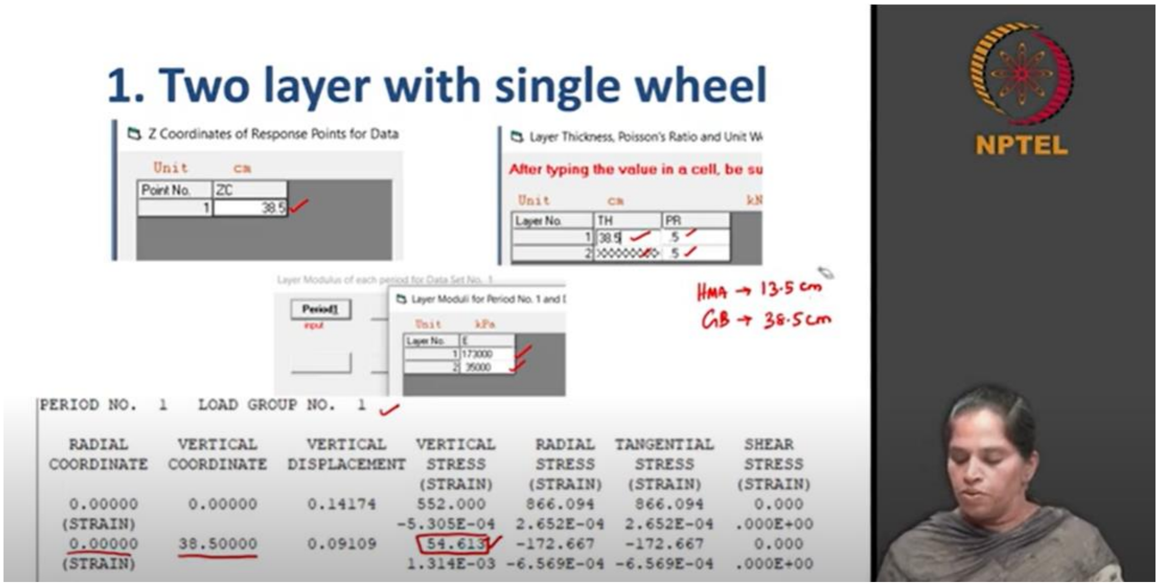

So, if you provide a granular base, your thickness requirement is 38.5 centimeters. If you provide an asphalt layer or a HMA layer that has a higher modulus, you need a thickness of 135 millimeters or 13.5 centimeters. So, the value of thickness varies with the modulus. If you increase the thickness, you can reduce the stresses and strain on the subgrade layer.

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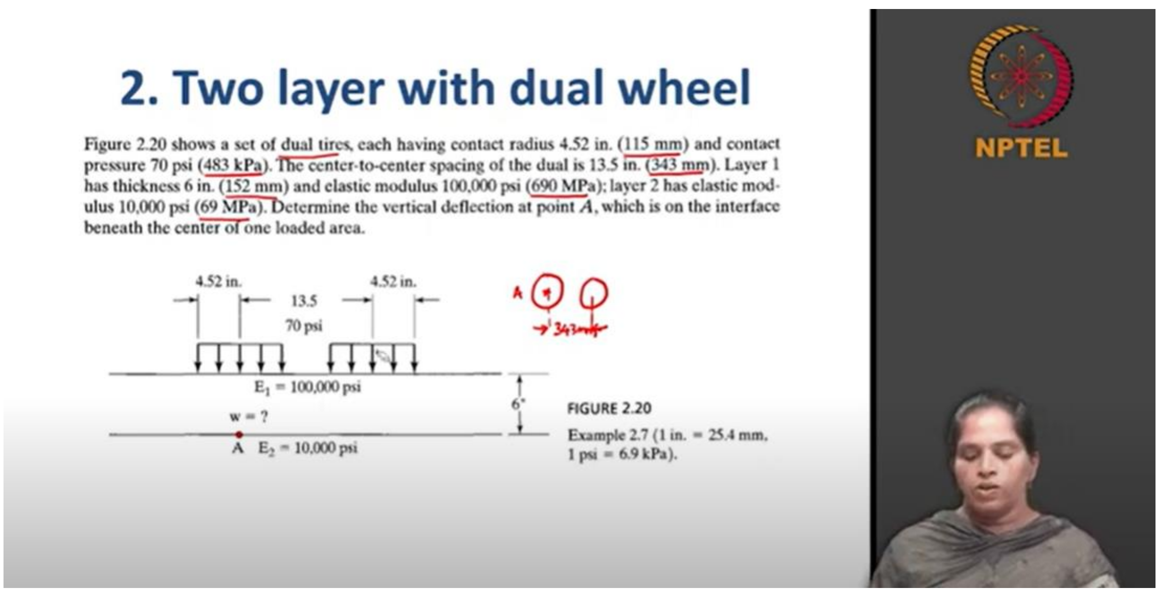

So, the next problem, what we will look into is a two-layered system, but instead of a single wheel load, we will use a single axle dual wheel. So, we are going to use a dual wheel here to find out stresses and strains. So, let us understand the problem here. You have a two layered system and it is subjected to dual tires and each has a contact radius of 115 millimeters and a contact pressure of 583 kPa.

The center to center spacing between the dual wheel loads is 343 millimeters. Layer 1 has a thickness of 152 millimeters and has a modulus of 690 MPa. Layer 2 has an elastic modulus of 69 MPa. Now, determine the vertical deflection at the point A. So, A is at a depth of 6 inches, that is, 152 millimeters and it is beneath the center of one loading area. So, when you sketch the plan of the load, it looks like this, two circular loads with the center to center spacing of each load as 343 millimeters. You need exactly at this point the value of vertical deflection. This is the point A in plan, this is the point A in elevation.

So, now let us see how to give the input. All input here remains the same and the only difference here from the previous problem is we are going to use dual wheels and change all the numbers as per this problem. Now we will see only the dual wheel input here. So, you need to assign 1 for dual wheel. The contact radius is 11.5 centimeters, contact pressure is 483 kPa. You need to define YW, which is nothing but center to center spacing between two wheels. It is 34.3 centimeters. XW is 0 as you do not have another axle. Number of radial points, if you give 1 and double click on this, you do not get RC here like in the previous case, you have XPT and YPT. So, this is x coordinate and y coordinate. x coordinate is defined along the movement direction and y coordinate is defined perpendicular to the movement direction. So, this point is exactly where x is 0, y is 0. So, you have x as 0 and y as 0.

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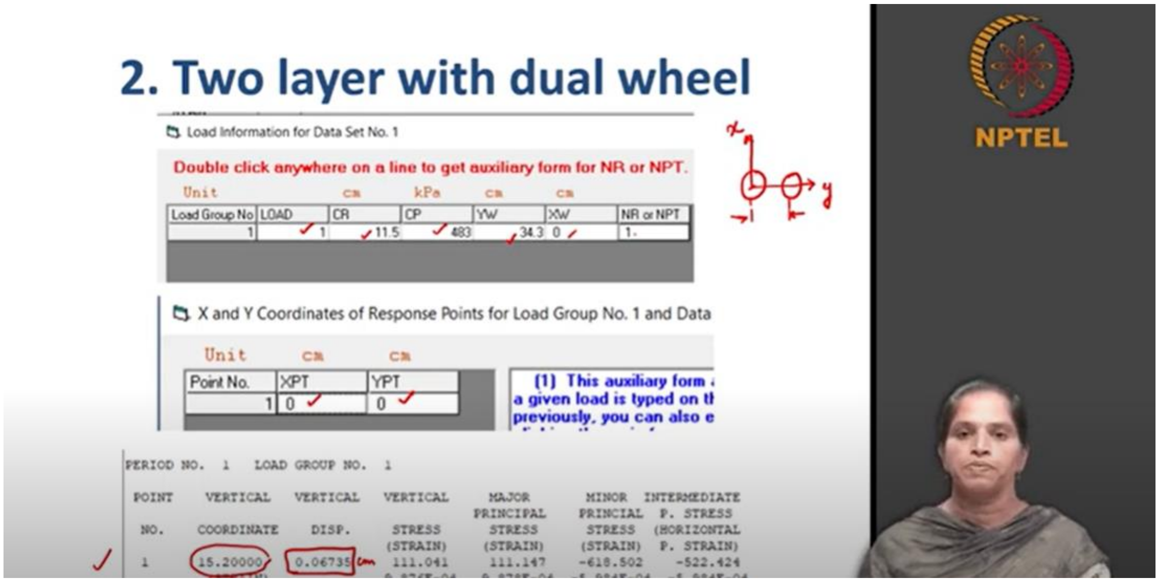

So, once you give all this input and compile it, this is the result you will get. At a vertical distance of 15.2 cm, that is at the interface between two layers, your vertical displacement is 0.06735 centimeters. Now you can also check by changing the z coordinates and check where the vertical displacement is critical.

So, in this lecture, we were focusing on a two-layered system and we used the KENLAYER software to determine vertical stress and deflection at the top of the subgrade layer. And we have seen that the modulus of the top layer influences the stresses at the subgrade layer. So, in the next lecture, we will focus on the tensile strain and we will see how the axle configuration influences the tensile strain at the interface of the two layers.