Analysis and Design of Bituminous Pavements

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Lecture - 11

KENLAYER – 3

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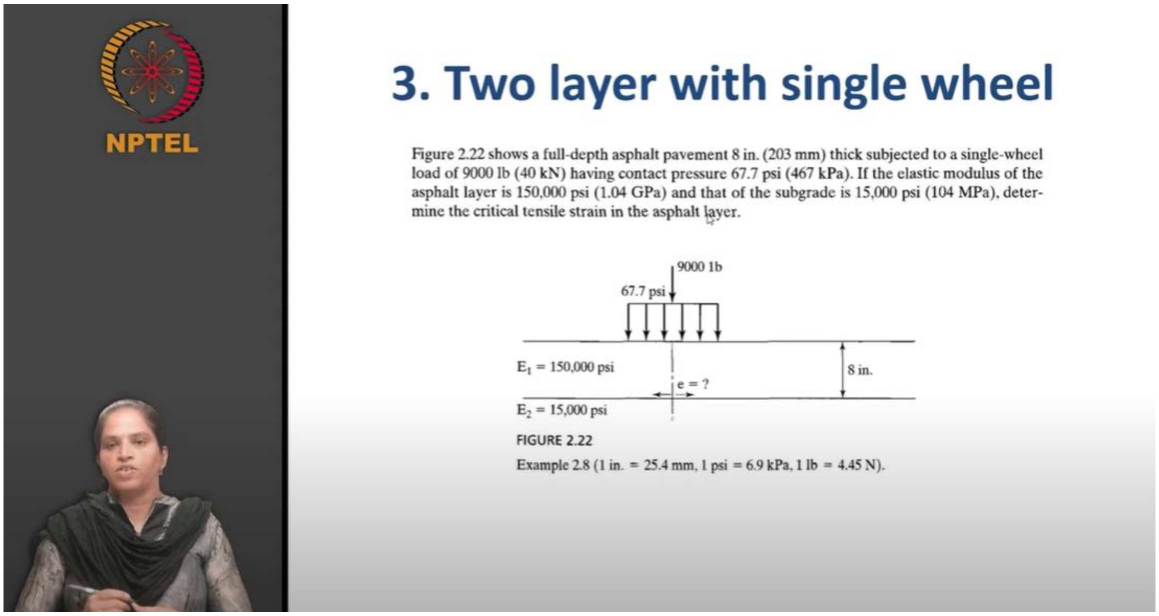

In the last lecture, we focused on determining vertical stress, strain and deformation at the top of a subgrade layer. We know that there are at least two critical locations in the bituminous pavement. One is at the top of the subgrade layer where the critical stress induces rutting in the subgrade layer. The second one is at the bottom of the asphalt layer where the critical stress and strain at the bottom of an asphalt layer induce fatigue damage. So, our last lecture we focused on determining critical stresses and strain at the subgrade layer. Now, we will focus on determining tensile stress, tensile strain at the bottom of the asphalt layer. We will also see how the tensile stress is influenced by various axle configurations.

We will directly start with a numerical now. This is going to be the first numerical. The figure below shows a full depth asphalt pavement. The thickness of the asphalt pavement is 203 mm and this is subjected to single wheel load of load intensity 40 kN. This has a contact pressure of 467 kPa and the elastic modulus of the asphalt layer is 1.04 GPa. This layer is resting on a subgrade that has a modulus of 104 MPa. So, what we need to do now is we have a two layered structure that is subjected to a single wheel load. We need to determine the critical tensile strain at the bottom of the asphalt layer.

So, this critical tensile strain at the bottom of an asphalt layer is something that induces fatigue damage in the asphalt layer. Now, let us see what inputs we have to give in the KENPAVE software. So, to start with, when you open a new file, these are the general information which you have to give in a KENPAVE software. We are going to do a linear analysis with the no damage analysis. Number of period-it is only one modulus here. Load group-it is a single axle single wheel and the tolerance for numerical integration is default value. Number of layers is 2 here. Z coordinate is the point which is at the bottom of the asphalt layer. So, other values we will keep it as default values and we will use SI system of unit type.

So, once you give this input, the next input will be your z coordinate. So, we have given only one z coordinate here. So, you will have only one column and we need to give the point which is the bottom of an asphalt layer. The thickness of a top layer in centimeter is 20.3. So, we will find out what is the critical strain at the bottom of the asphalt layer.

So, once you complete with the z coordinate, we have to give the layer thickness in the KENPAVE. The top layer is 20.3 cm, bottom layer is infinite thickness. Now let us use a Poisson's ratio of the asphalt layer to be 0.35 and the soil layer to be 0.5. If you want you can try it with a different Poisson's ratio and check how the stresses and strain vary.

Once you complete the layer thickness, now we will go for the next, load information. When you open the load file, you will get this information. You need to assign the type of load. We assign 0 for single axle single wheel and the contact radius here is 15.2 cm. We have a contact load of 40 kN and this contact load has a pressure intensity of 467 kPa. So, pressure intensity is 467 kPa. This is pressure intensity is CP. Now, we need to find out what is the contact radius from this. So, we know that the contact area is going to be load (40×10^3 kN) divided by its pressure intensity in MN/mm^2. So, if you use this you will get the contact area to be in mm^2. When you keep the contact area to be circular (πr^2), you will get the contact radius which is 15.2 centimeters. So, we will have a contact radius to be 15.2 centimeters. Contact pressure is 467 kPa and this being a single axle single wheel, you have YW to be 0 and XW to be 0. So, the number of points at which we need to find out stresses and strain is 1 and it is exactly at the center of loading that is at 0 point. So, you have a load here exactly at the center of loading at which we have the critical stress value. So, RC here is going to be 0.

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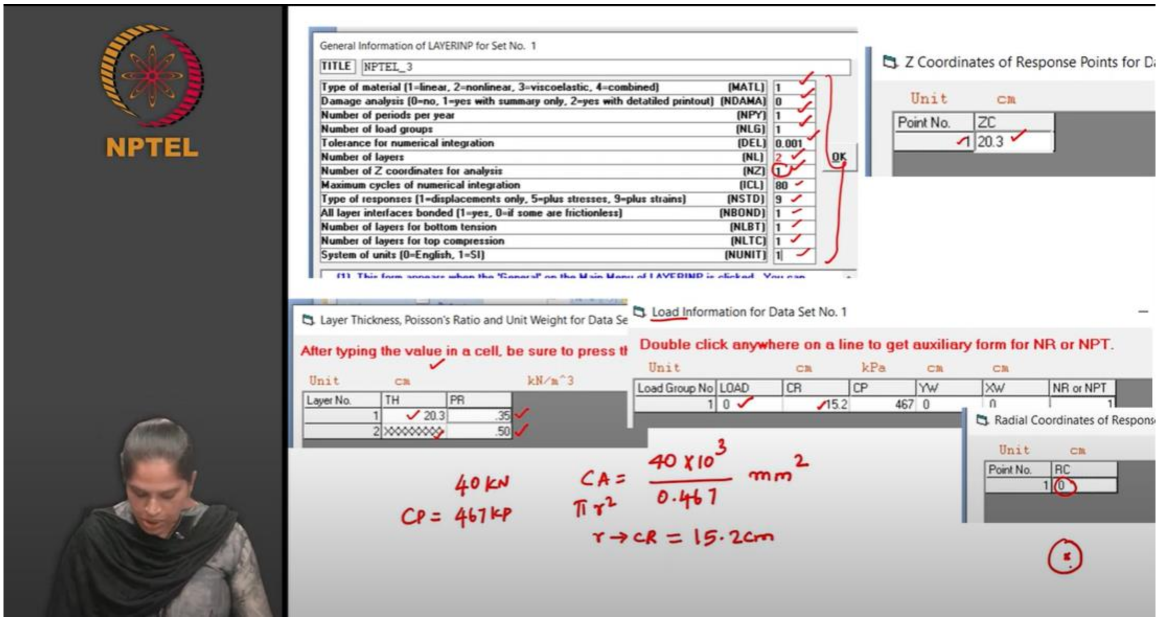

So, once you give all this input you will get the results. When you compile it, you will get the results. So, at a radial distance of 0 and at a vertical coordinate of 8 inch or 20.3 centimeter below the surface you will get the vertical displacement, vertical stress and the corresponding strain, radial stress and the corresponding strain, tensile stress and the corresponding strain, shear stress and the corresponding strain. So, what is that we are interested in is the tensile strain at the bottom of the asphalt layer. The tensile strain at the bottom of an asphalt layer can be radial stress or tangential stress. So, for this condition, the radial stress and the tangential stress is the same. You can see that the intensity here is -3.530E-4. The negative sign indicates the tensile nature and the magnitude is 3.53E-4. So, the critical tensile strain at the bottom of the asphalt layer is 3.53E-4.

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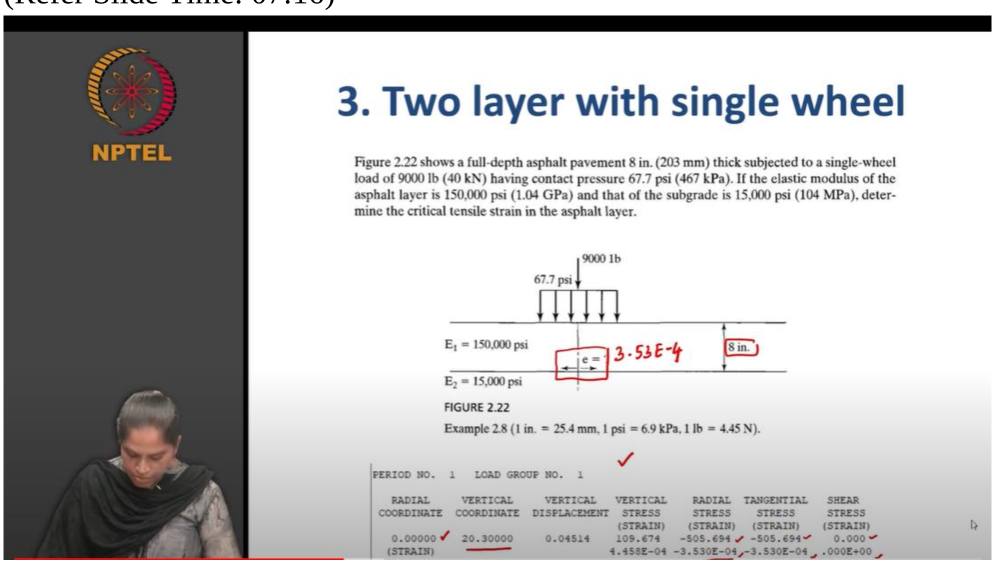

Now we will just replace the single axle single wheel by single axle dual wheel. So, at the top of the pavement you have a dual wheel. Now, if that is the case, we will see what is the tensile strain at the bottom of the asphalt layer. You have the same structure, asphalt layer with 8-inch thickness and it has the same modulus as we used in the previous case which is 1.04 GPa and this layer is resting on a soil that has a modulus of 104 MPa. Now this structure is subjected to a dual wheel. When you see a dual wheel in plan, you will have something like this. Now, if that is the case what is the magnitude of tensile strain at the bottom of an asphalt layer? Imagine you have a standard axle load something like this or any axle load with the total load from the axle as 80 kN. So, this 80 kN will be divided equally on both sides. So, total on one side will be 40 kN. So, each wheel will be having an intensity of 20 kN. So, this is 20 kN. So, the load from this axle will be 20 kN. In a previous case, the total of 40 kN is distributed in one contact area. This is the case which we solved in the previous third example. So, the total load is 40 kN. Here, this 40 kN is divided into two, 20 and 20. You have the same pressure. So, for the same pressure of 467 kPa, we expect the contact radius to be different.

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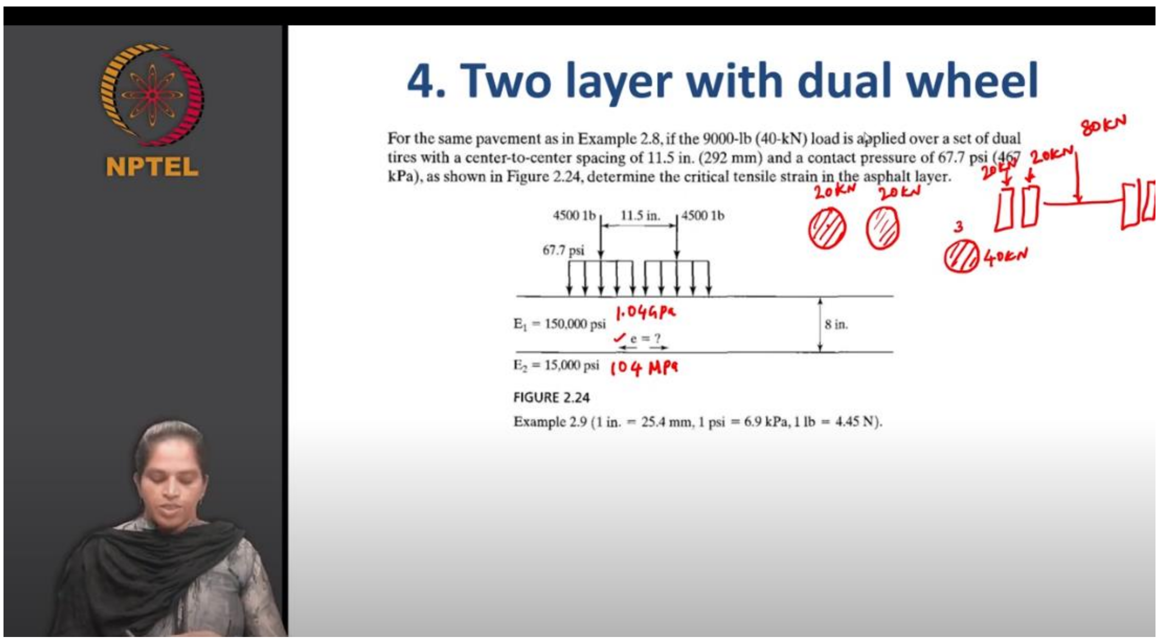

Now, we will see what input we have to give in the KENLAYER software to get the tensile strain at the bottom of the asphalt layer. So, these are the inputs. You can see that the general information which are listed here is same as that of the previous problem and the thickness of the layer also remains the same which is 20.3 cm and we will keep the same Poisson's ratio. So, this is also an identical input that we did in the previous numerical. Since we need the tensile strain at the bottom of the asphalt layer of 20.3 cm thickness, we have the z coordinate to be 20.3 cm. The only difference here, is this load information.

Here, we are going to use dual wheel. So, we need to assign 1 for dual wheel and contact radius is also different from our previous numerical. We have a load intensity here of intensity 20 kN and the contact pressure to be 467 kPa. So, the corresponding contact area is going to be 20×10^3 Newton divided by 0.467 MPa pressure. So, you get this area in mm^2. When you solve this, you will get the contact radius to be 11.68 cm. So, the contact radius is 11.68 cm and the contact pressure is 467 kPa. So, here, we have a dual wheel and each wheel has a radius of 11.68 cm and separated by a center-to-center distance of 29.2 cm which is YW and XW is 0 because there is only one axle. Now, let us focus on giving different radial points and understand how these stresses and strain vary at different radial locations. So, we will give three points here. The point 1 is exactly at the center of one loading. So, x and y values are 0. Point 2 is at the same axis where x is equal to 0 and y is considered at the radial point, exactly at the periphery. So, point 2 is 0 and 11.68 cm. Point 3 is middle of the loading. So, x is 0 and y is half of YW which is 14.6 cm.

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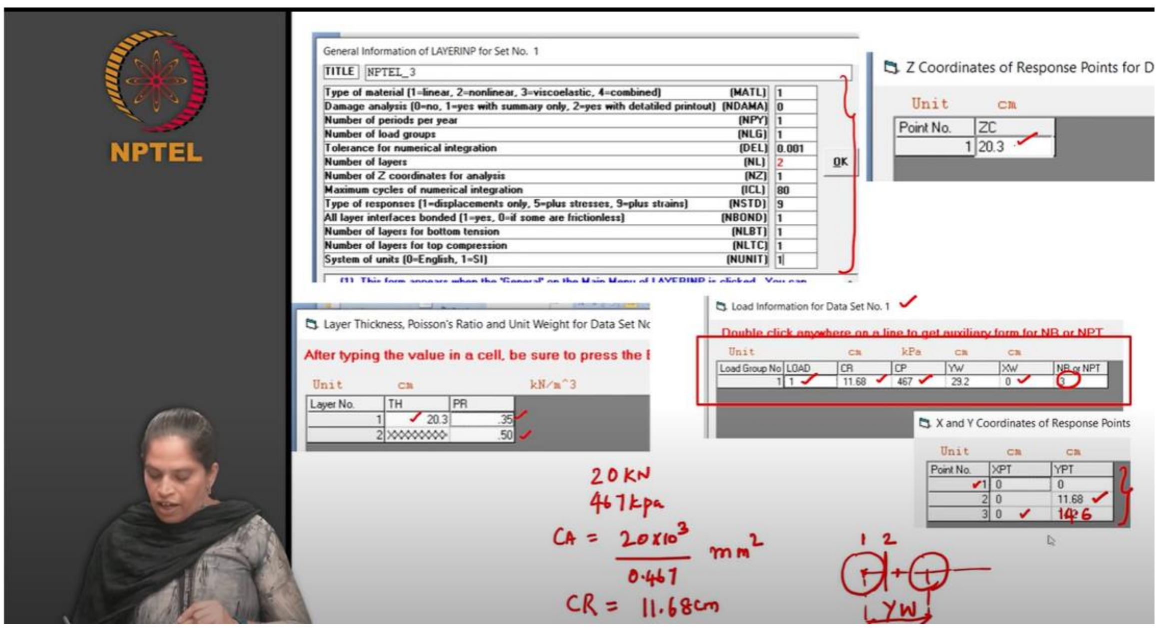

Now, once you give this input and compile it, this is the result you are going to get. So, for three different points and only one vertical coordinate that is exactly at the bottom of the asphalt layer, you have vertical displacement, vertical stresses and strain. Here, you have major principal stress, minor principal stress and intermediate principal stress and the corresponding strain value. Now, let us focus on the tensile strain at the bottom of the asphalt layer. So, we have minor principal stress and major principal stress and strains to be equal. So, let us focus on tensile strain at the bottom of the asphalt layer. Negative sign indicates the tensile nature. The critical value here is 3.367E-4 which corresponds to the point 3 which is exactly at the middle of two loadings. Now, let us compare the magnitude of what we get here from the magnitude of the column, the previous one. Now, you can see that previous case it is 3.53E-4 and in this case, it is 3.36E-4. So, this corresponds to single axle single wheel and this corresponds to single axle dual wheel. For the same load intensity, instead of a single axle if you use a dual wheel, you can see that the strain value reduces, it is a marginal reduction but this reduction magnitude depends on what is the thickness of the asphalt layer we are providing. That you will understand at the end of the KENPAVE demo.

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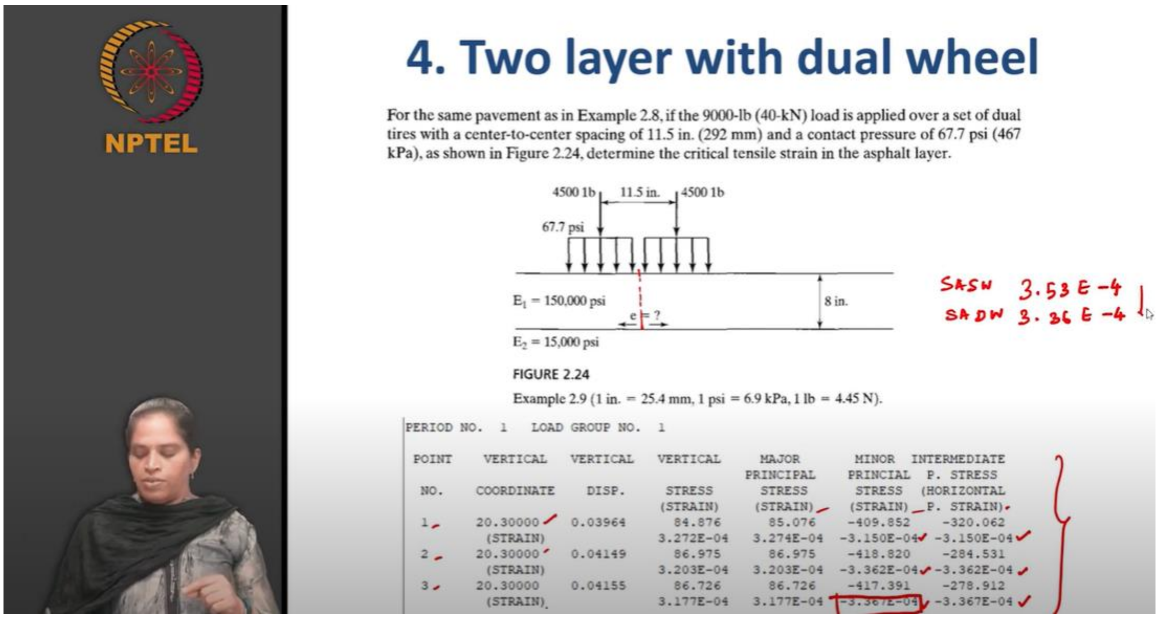

Now, let us see how the tensile strain at the bottom of the asphalt layer varies if we use tandem axle. Tandem axle will have four wheels on one side. So, the same structure here, the two-layered structure is subjected to a tandem axle. The load intensity of each beam here is 20 kN and if you want to configure this tandem axle in the KENLAYER software, you need contact radius which is going to be same as the previous case because we are subjecting the wheels to 20 kN each. Contact pressure remains the same as that of the previous case and you need distance between two beams which is nothing but YW which is same as our previous case and you need distance between two axles which is XW here. The value of XW is 1.25 m. So, these are the four data you need to give for the tandem axle configurations in the KENPAVE software. So, this two-layered system is subjected to a tandem axle loading as shown here. Now what is the tensile strain at the bottom of the asphalt layer?

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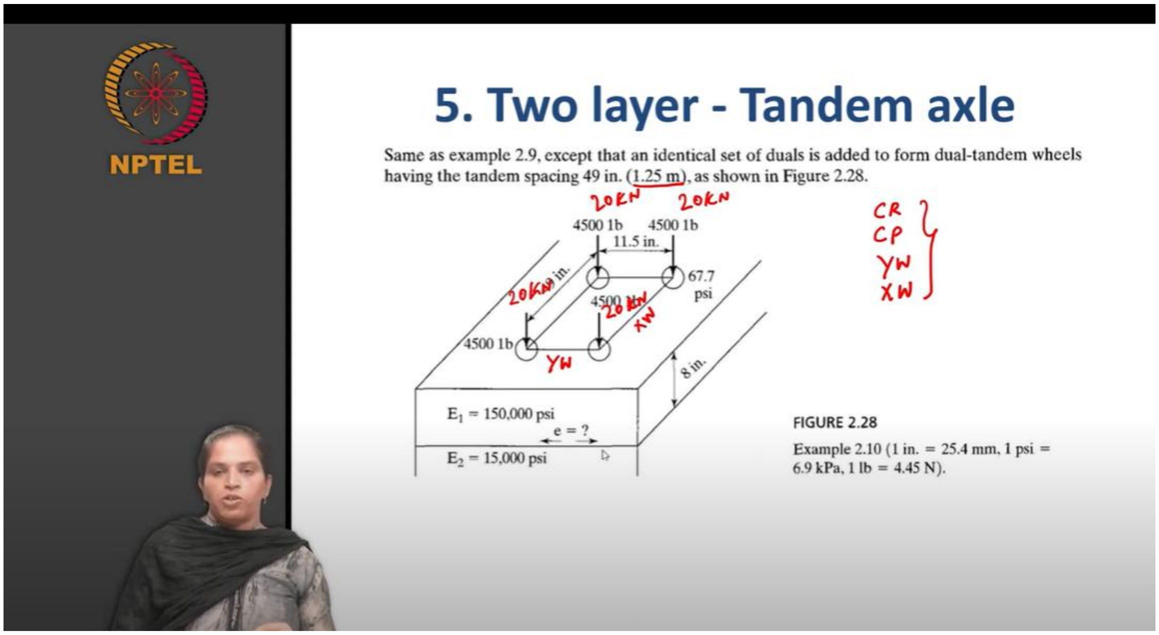

So, first we need to also find out at which locations the tensile strain is critical. All the input other than load input are same as that of the previous numerical. So, now we will see what load input we need to give to find out the critical tensile strain at the bottom of the asphalt layer. So, we need to assign 2 for tandem axle. Our contact radius is 11.68 same as previous numerical, 467 kPa is our contact pressure. This is also same as the previous numerical. YW is same as our previous one which is 29.2 cm, XW is 1.25 m or 125 cm. Now, you have two wheels and two axles separated by some distance. You have so many numbers of lateral points to determine. We will use 9 points here to determine stresses and strain. I will explain you what are those 9 points I have considered here for the analysis. So 1 is exactly at the center of one loading. Before I name numbers here, this is our YW and this is our XW, YW is 29.2 cm, XW is 125 cm. First point is exactly at the center of loading. So, let us put number 1 here. So here, exactly X is 0 and Y is 0. Second point, it will fall in the periphery of the loading. So, this is point 2, X is 0, radius is 11.68, so, Y is 11.68 for the second point. Third point is exactly at the center of loading. So, X is 0, Y is half of YW, which is 14.6. Now, fourth point is at the periphery of one loading. So here X is 11.68 and Y is 0 here. Fifth point, X is also the radius and Y is also a radius here. So, 11.68 and 11.68. Sixth point is at the center. So, with the same X 11.68 and Y is 14.6. Seventh point is at the middle of XW which is half of XW which is 62.5 and Y is 0. And eighth point is at half of XW and projection of the periphery point. So, it is 62.5, 11.68. Ninth point is exactly at the center of the system which is 62.5, that is half of XW and 14.6 which is half of YW. So, these are the 9 points we are going to find the response of the structure.

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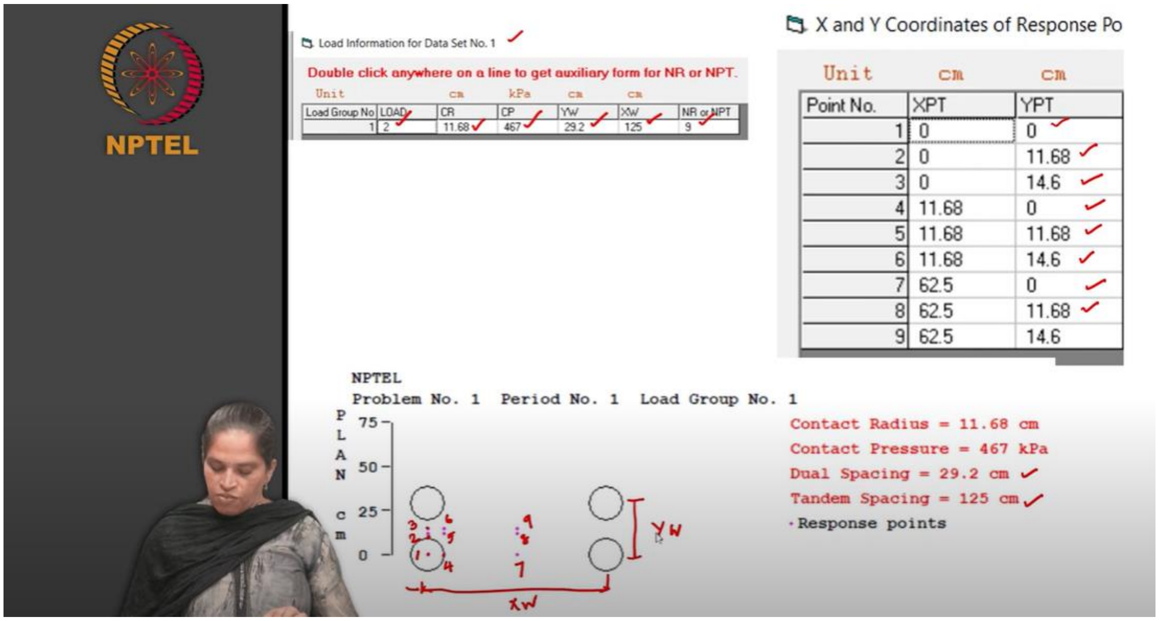

So, after giving the input when you compile it, this is the result that you will get. So, you have 9 different points. We know what are these 9 points now. We have only one vertical coordinate which is exactly at the interface of two layers. You will get vertical displacement, vertical stress, major principal stress, minor principal stress and intermediate principal stress. We are interested now in tensile strain. So, it will be either minor principal stress or intermediate principal stress. So, now if you see the tensile strain of all 9 points here, you will see that the maximum value occurs exactly this value which is 3.230 and this is the third point here. Our third point is this and the magnitude of this is 3.230 E-4. Now, let us compare this number with the previous one. So, this is the value we got for a tandem axle. So, we can see that the axle configuration influences the tensile strain at the bottom of the asphalt layer, but the amount of influence also depends on the thickness of different layers.

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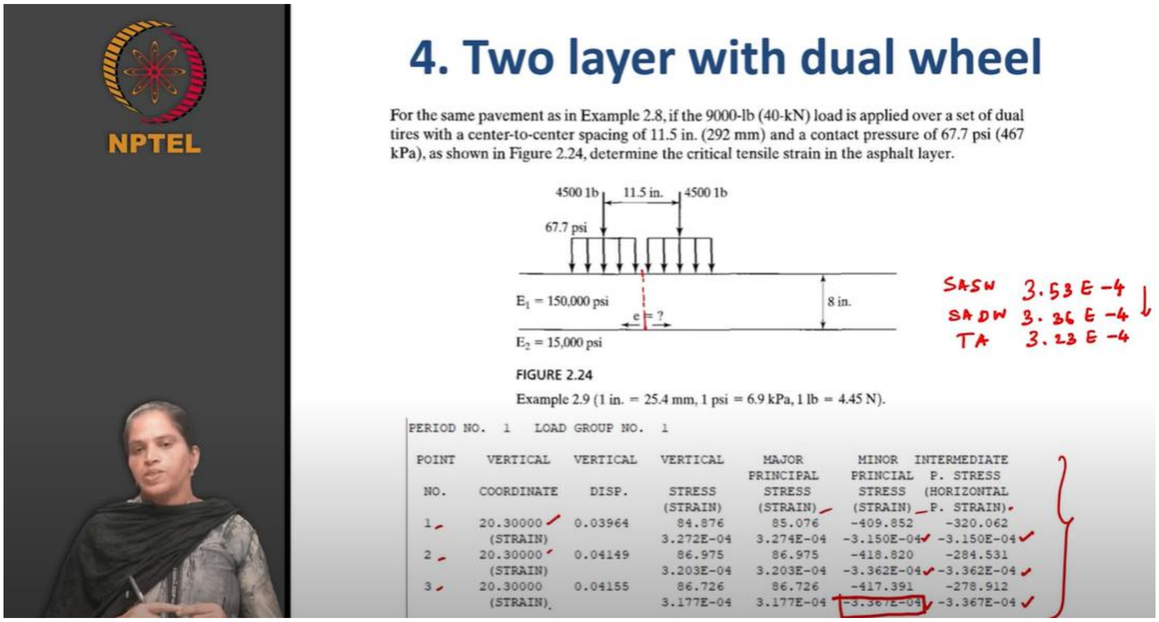

So, the influence of different layer thickness we will see it in the next lecture.