Traction Engineering
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Lecture 10
Tutorial 2 - Measurement of Shear Strength, Modulus of Sinkage and Cone Index

Hi everyone, this is Professor H Raheman from Agriculture and Food Engineering Department, IIT Kharagpur. I welcome you to this NPTEL course on Traction Engineering. This is lecture 10, where I will try to take a tutorial which will be related to measure of, Measurement of Shear Strength, Modulus of Sinkage and Cone Index, which we discussed in my previous classes.

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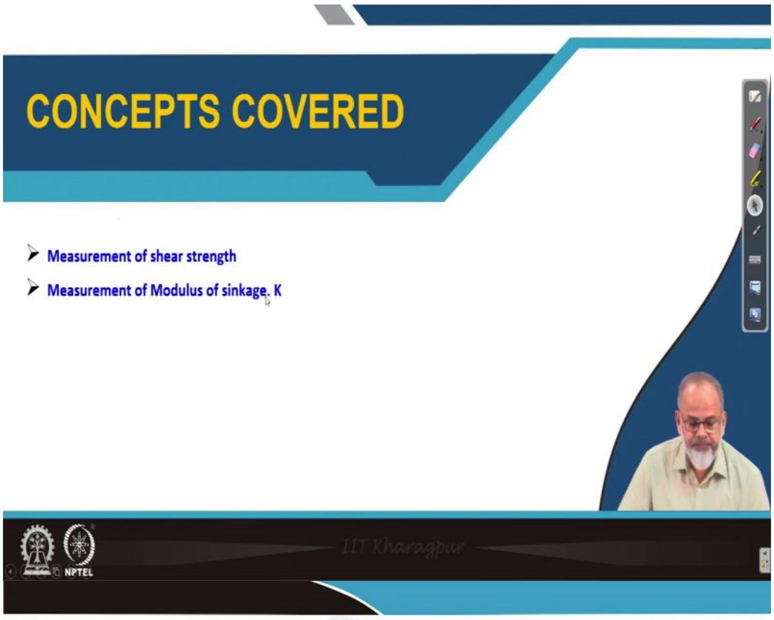

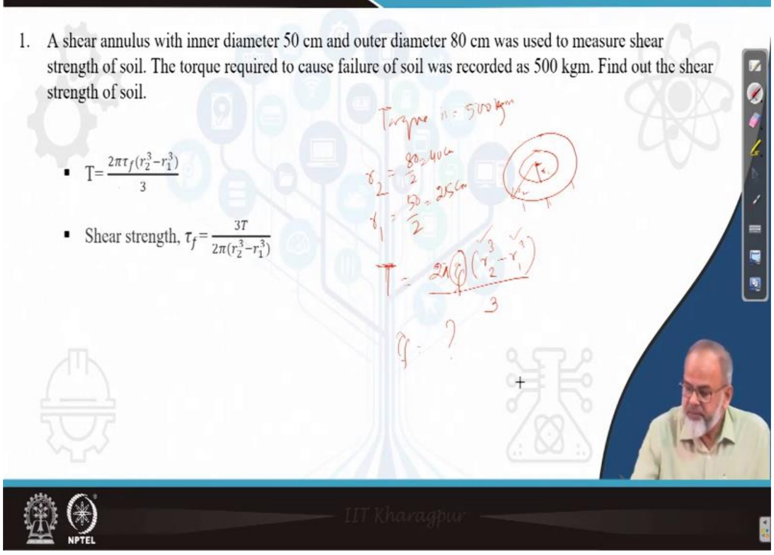

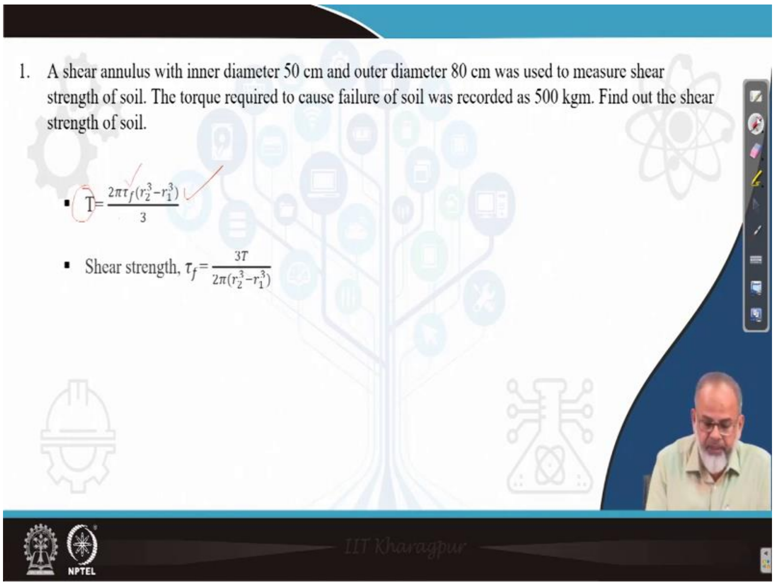

So, measurement of shear strength then measurement of modulus of sinkage. These are the two parameters, then in the third we are going to take the cone index value, how to measure cone index of a given area. So, to start with, first, I will give you a problem like a shear annulus with inner diameter 50 centimeter, outer diameter 80 centimeter. This was used to measure shear strength of soil and the torque required to cause failure of soil was recorded as 500 kg meter, now how to find out the shear strength of soil.

As I said shear annulus, so immediately you can draw the shear annulus. So, now here we are interested in finding out the shear strength of soil using this shear annulus. So, what we have to measure is the torque. So torque is given, so it is 500 kg meter and outer radius is given which is r_2 and inner radius is r_1, inner radius of the annulus.

So r_2 is the outer radius which is given as 80 by 2, 40 centimeter and r_1 is the inner radius which is equal to 50 by 2 that means 25 centimeter. And we know that torque relationship which is given on the left side,

$$Torque = \frac{2\pi\tau_f \times (r_2^3 - r_1^3)}{3}$$

So r, is r_1 you have found out, r_2 you have found out, then T is known. So, τ_f is to be calculated, so now we substitute these one and find out τ_f.

This is question number 1, how to find out shear strength of soil using shear annulus or in other words you can do like this. If shear strength of soil is known then you can find out how much torque is required to cause the soil to fail, so the same equation shear strength is given then you can find out how much is the torque on the same equation can be utilized so shear strength is given, so you can find out what is the value of T.

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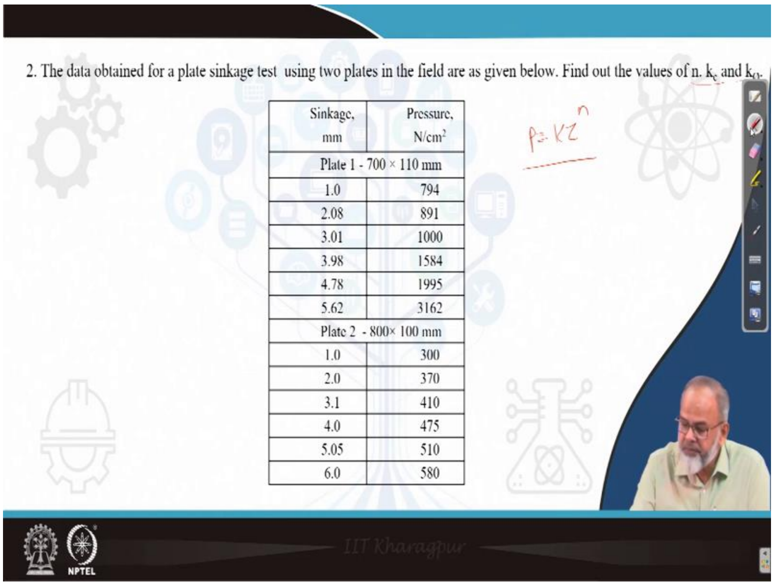

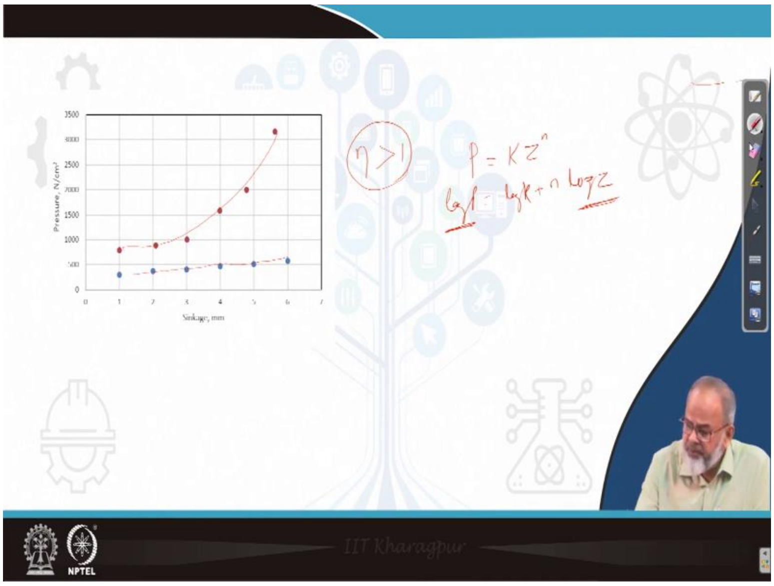

The second question is the data obtained for a plate sinkage tests using two plates in the field are as given below. So, you are asked to find out the values of exponent of sinkage n, k_c cohesive modulus of sinkage and k_φ frictional modulus of sinkage. So, the data which are given is sinkage for a plate size of 700 by 110 millimeter and for a plate 2 it is given as 800 by 100 millimeter and sinkage values are given and corresponding pressure values are given 794, this is a Newton per centimeter square, same is the case with for plate 2.

Now how to proceed to find out these values n, k_c and k_φ. So, if you remember the Bekker's pressure sinkage relationship, where we have taken that

$$p = kz^n$$

This is the relationship given by pressure, given by Bekker. So if we try to plot the pressure versus sinkage that means p versus z value then you will get a kind of, a set of curves because there are two plates so you will get a set of curves which is shown as in this slide.

So this is the nature of the curve which will be obtaining, one is, the plate 1 is this, plate 2 is this, so that means, this shows that n is, n has a value greater than 1. But what is the exact value? To do that we have to take the help of that Bekker's pressure sinkage relationship where

$$p = kz^n$$

And,

$logp = logk + nlogz$

Now if you plot log P versus log z then it will be a straight line. So what we have done is we try to find out the log P and log z value then you try to plot it and then see the nature of the curve.

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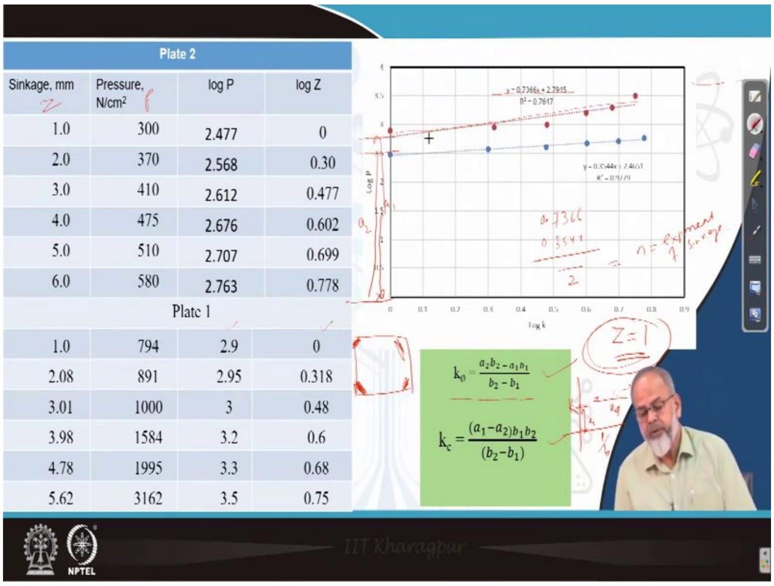

For plate 2, I first calculated, you can do either way plate 1 or plate 2, does not matter. So log, sinkage value which is nothing but your z value and pressure value is p so logp and logz value, I have calculated then I tried to plot it. So, this will be the your plate 2 and similarly for plate one I have calculated, logp value, logz value, then I plotted.

So what we observed here is two, these are all points which are observed now I have best fitted those points with a straight line relationship which is given as y is equal to this much

$$y = 0.7366x + 2.7945$$

Now the plate 2 is given as

$$y = 0.3544\, x + 2.4651$$

So, these are two straight lines so but the slopes are not uniform, they are not same.

So how to find out n, if the slopes are not uniform then as suggested by Bekker, you have to take the average value, so slope here is in the first case slope is 0.736 plate 1, 6 and in the second class it is 0.3544 and take the average so whatever comes that has to be divided by 2 to find out the a slope, average slope which is equal to your exponent of sinkage, n.

Now next thing is how to find out k_c and k_φ. So each one of this curve they are getting an intercept which is equal to or we can denote it as a_2 this is a_1. Now in my previous classes where I have dealt with the pressure sinkage test that I have derived the expression for k_c and k_φ but these expressions are valid when z is equal to 1. When sinkage is equal to 1 then only these equations are valid otherwise you cannot calculate.

So if that is the case so z, take z is equal to 1 so then with the help of this equation that means the intercept and the plate size which is given by b_2 and b_1 so taking those values we can calculate directly the k_c and k_φ values. If you want to get rid of this limitation that z is equal to 1 then what you have to do is you have to take at least three plates of different dimensions, you can take square plate, you can take circular plate, does not matter but width of the rectangular plate should be equal to radius of the circular plate and circular plates are better in the sense, the application of pressure is uniform. So, when you apply load, it is uniformly distributed, whereas in case of a square plate at the corner points are dead pockets actually. These points are dead pockets so it is better to go for circular plate so that pressure is more or less uniform.

So you have to take three plates so you will get three k values because for three circular plates you have three relationships and if you take logarithm then you will find out three relationships from which you can find out what are the values of K and if you try to plot the K versus 1/b and then you can find out a relationship.

This is on the y-axis you take K, on the x axis you take 1/b then you will get some points like this then you try to best fit that one and then the intercept will give you k_φ and the slope will give you k_c. So, this is how we calculated if you apply this limitation z is equal to 1 then you can utilize the method which we described or if you do not want to do that if you are interested in finding out for all other values of z then you take at least three plates so that you can easily calculate k_c and k_φ.

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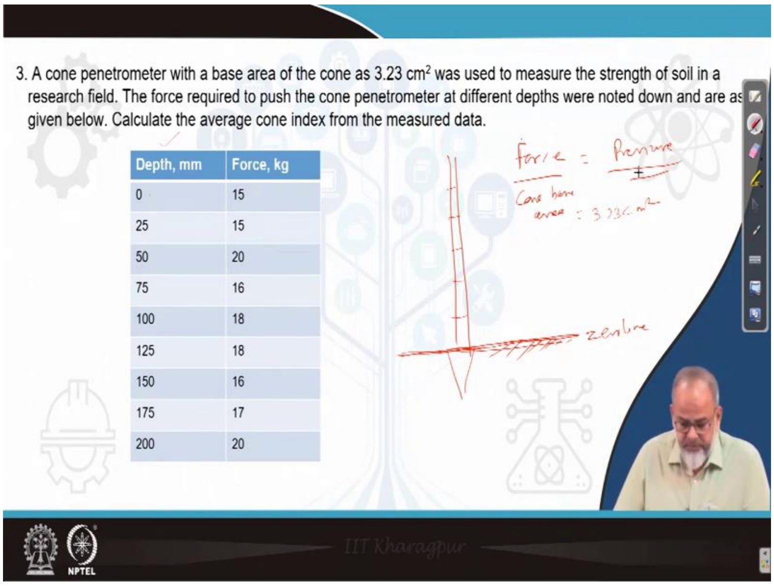

Then the next question is, a cone penetrometer with a base area of a cone 3.23 square centimeter was used to measure the strength of soil in a research field. So, the force required to push the cone penetrometer at different depths were noted down and the values are given in a tabular form below. Then the question which is asked is how to find out the average cone index because the cone index is given for different depth.

And the force which is experience has been given for different depths that’s why I ask you to calculate - what is the average cone index for the measured data. So what data are given, depth data at 0, 0 means if you take a cone penetrometer with a probe at the bottom, so zero lines refers to this which is just flushing, when the soil surface is just flushing the top surface of the cone so that becomes a zero line. So, zero reading starts from here.

Now at every 25 millimeter interval, I have taken the reading and these readings are given here, so what readings are given, force, then how to calculate pressure so force divided by the cone base area so that will give you pressure which is applied. So, what is the cone base area, it is giving us 3.23 centimeter square, okay.Now we have to find out first the pressure, so in the next slide I will show you, what is the pressure corresponding to the force which is applied at different depth.

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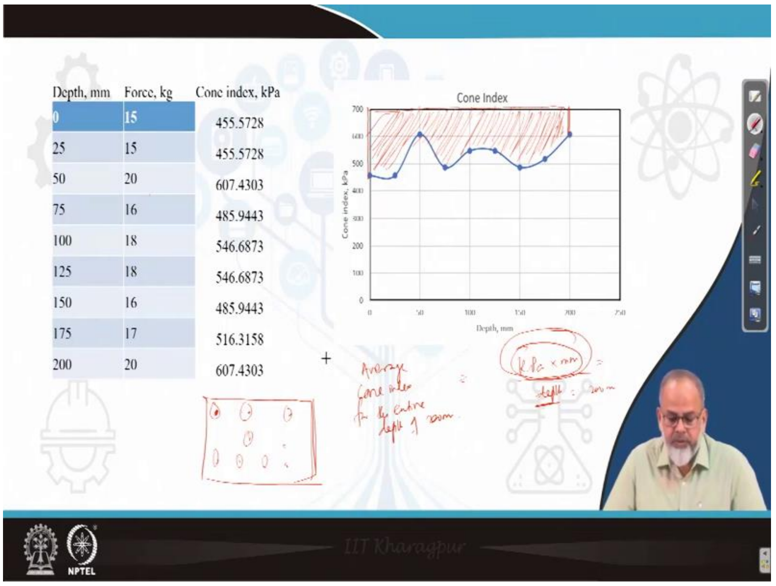

After knowing the force then we have to calculate the pressure which is applied which I have indicated as cone index, so cone index at each depth I have calculated and when I tried to plot it on a XY sheet, graph sheet you can see, depth is taken in the x axis and on the y axis you have taken the cone index value then these are the points which will refer to different observations which you took in the field.

Now after getting this plot what next, how to find out the cone index for the entire depth for which the penetrometer has been pushed into the soil. So, what you have to do is, we have to connect this, connect this then this is the area which is to be considered, so area of this curve is nothing but kilo Pascal into millimeter.

Now if you divide by depth so in your case depth is 200 millimeter so that will give you what is the average cone index for the entire depths of 200 millimeter. So depth and the area which is computed either you can manually compute or you can take a planimeter or you can take the help of AutoCAD to find out this area, you take the image of this one, take the help of AutoCAD and then find out what is the area.

If you do not want to do this then take a simple graph sheet and then try to calculate the area which is if you know the scale of x axis and y axis then you can find out how much area is bounded by this curve so that becomes your the numerator and then you divide by depth that becomes your denominator to find out what will be the cone index, average cone index for the data which you obtained.

This is referred to a particular place, now if you are interested to find out the average cone index of the entire plot which I have drawn now. I have only given data for one point so you have to take similar data for different points, randomly you can select different points in the field and then you will have a set of data.

So for each point or each test points you have to calculate the cone index value and then take the average and find out the standard deviation and coefficient of variance, so that will give you the average cone index of that particular plot. So I have only given the procedure for finding out the cone index at a particular point up to a particular depth so similar exercise has to be done for several points in a field so that it can give you a better average.

So while you mention the average score index you have to mention the standard deviation and the coefficient of variance so that is a complete specification of average cone index in a field. I hope, I have clarified how to calculate cone index, how to calculate the shear strength of soil then how to find out the parameters related to plate sinkage test that is exponent of sinkage, cohesive modulus of sinkage and frictional modulus of sinkage. So this will help you in further enhancing your concepts which are covered in my lecture class.

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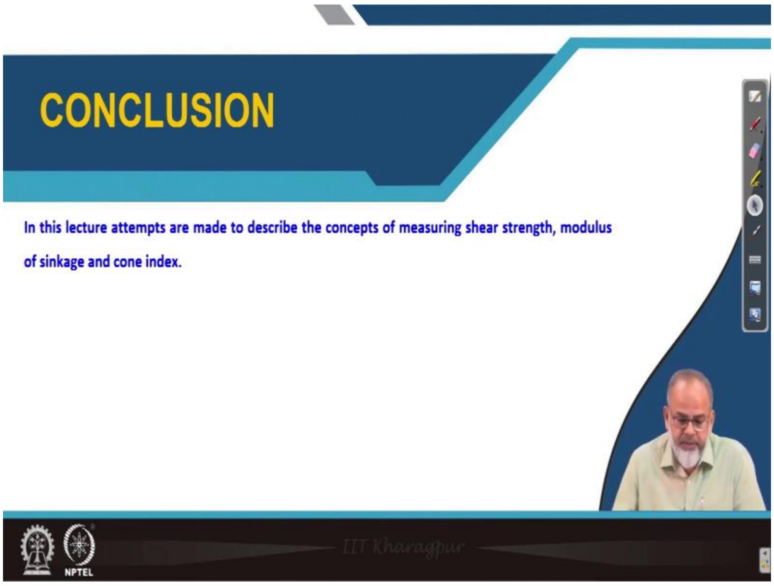

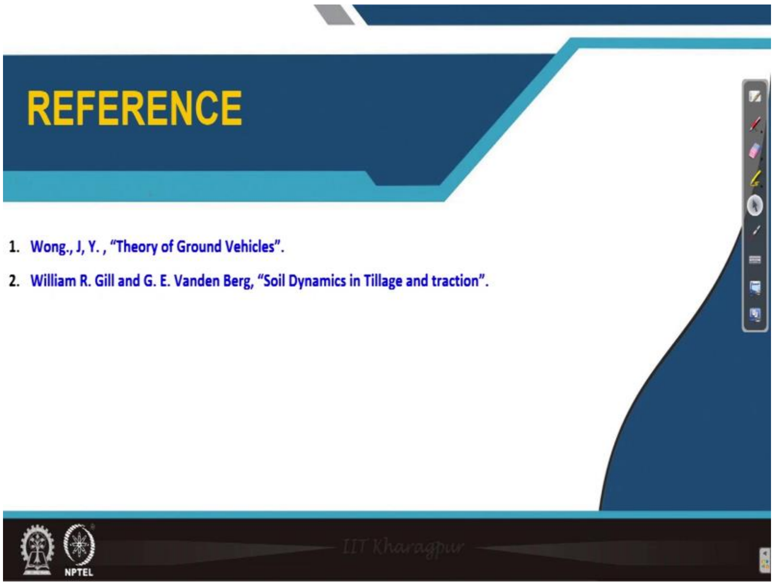

So in brief I can say I can conclude that the attempts are made to describe the concepts of measuring shear strength, measuring modulus of sinkage and cone index, thank you. The reference can be Theory of Ground Vehicles, Soil Dynamics Tillage and Traction by Gill and Vandenberg, that is all.