Traction Engineering
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Lecture 27
Pressure Sinkage Relationship in a Sandy Clay Loam Soil

Hi everyone, this is professor H. Raheman from Agricultural and Food Engineering Department, IIT Kharagpur. I welcome you all to this NPTEL course on Traction Engineering. Today I will try to cover Pressure sinkage relationship. For this I will take, I will demonstrate a set experimental setup.

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Where I will try to clear the concepts like what is the setup which is used for measuring plates sinkage, and then we will try to find out what is the Cohesive modulus of sinkage, frictional modulus of sinkage, exponent of sinkage. And these parameters are important related to and they are related to bearing strength of soil. So, that is why, we are interested in measuring these, these parameters.

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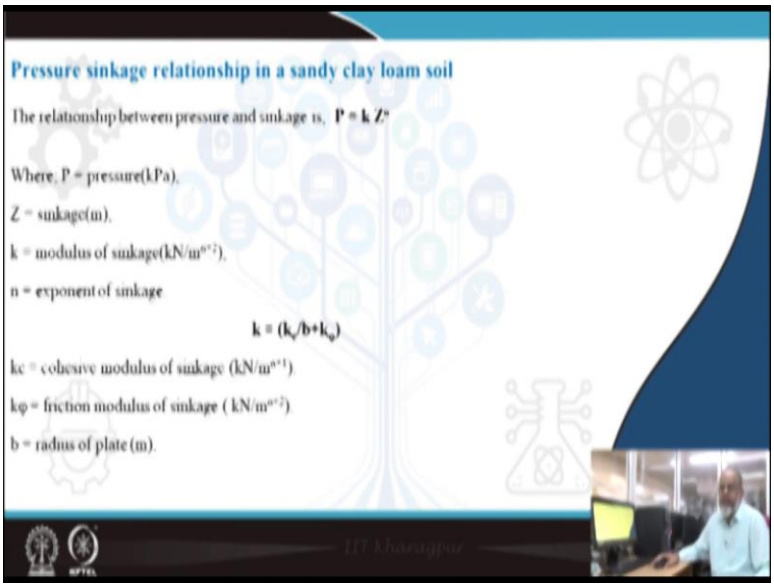

In a pressure sinkage test what we are measuring is, how much pressure we required to force a plate. Plate could be a rectangular plate, plate could be circular plate, and that should simulate the contact area of a tyre. Now, it is better to take a circular plate because when you apply a load, it becomes uniformly distributed, if you take a rectangular plate, the corners are dead points. So, that is why pressure is not uniformly distributed.

So, what we have done is, we have taken 3 different circular plates of diameters 25 centimeter, 30 centimeter and 35 centimeter. Now, these plates are put on the soil and then we tried to apply a force using a hydraulic cylinder and the force which is applied that is measured with a loadcell and the force data and the corresponding sinkage data, which is this sinkage is measure using a potentiometer, so, these data are recorded in the computer.

And now I will try to show those data and how they will be utilized to find out the modulus of sinkage, and exponent of sinkage. So, pressure which can be calculated by dividing force with the corresponding area, area in this case will be area of plate 1, plate 2, plate 3 like that. So, there will be 3 different plates you have taken. So, P will be calculated, then P is related to Z, by an exponential relationship.

So, that means $P = kZ^n$, where k becomes your modulus of sinkage and n is the exponent of sinkage. Now, modulus of sinkage is again divided into 2 parts. The first part is your cohesive

modulus of sinkage which is kc and the second part is your frictional modulus of sinkage. This cohesive modulus of sinkage is dependent on the plates dimension and k_ϕ is independent of the plate dimension that means loading area the n represents the soil characteristics, whereas k represents both soil as well as the loading area characteristics.

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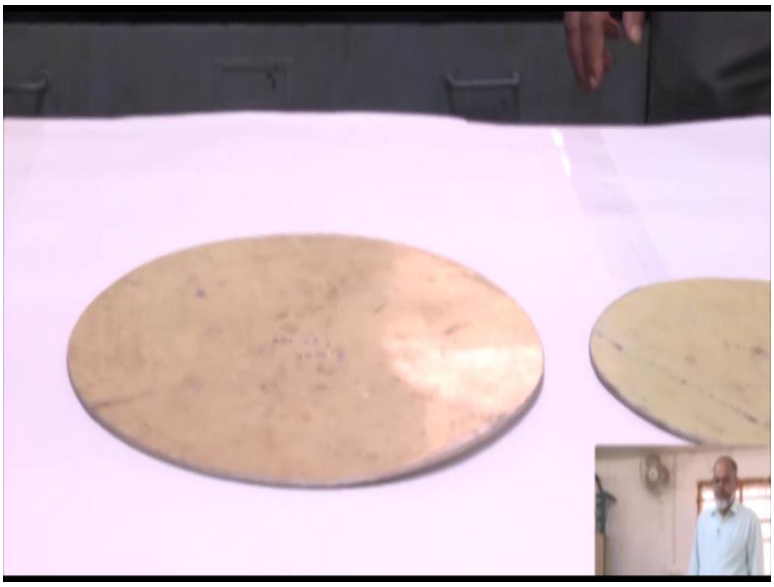

It is a rectangular plate or a circular plate which simulates the contact area of a tyre and that has to be forced to enter into the soil. So, what you are going to measure is the force which is required to press it and what is the corresponding sinkage. So, once you know the force, force

divided by the area, area of the plate that will give you pressure. So, and the corresponding sinkage will try to measure, so, I will try today with the 3 plates of different diameter.

This is of 25 centimeter or the other one is 30 centimeter, the third one is 35 centimeter, the each has its own weight like the 25 centimeter plate has a weight of 431.95 gram, 30 centimeter plate has a weight of 620.51 gram and 35 centimeter plate has a weight of 851.18 gram. So, these are to be pressed into the soil and with the help of a hydraulic arrangement, so I will give you the details of the setup, then I will show you how a plate is pushed into the soil to find out the pressure and sinkage parameters.

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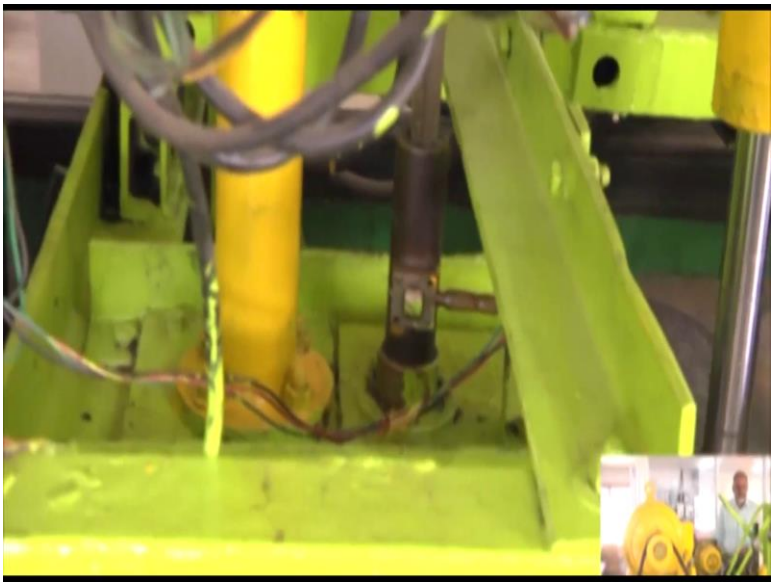

I will now show you the setup which is used for measuring the pressure of a pressure required to place a plate into the soil. The setup comprises of a plate which is kept over the soil surface is the plate which has a diameter of 30 centimeter. Then this has to be pressed using a shaft, this shaft is connected to the hydraulic cylinder, this the hydraulic cylinder. So, in between the shaft and the hydraulic cylinder, there is a load cell that is going to measure how much force you are applying.

So, the corresponding sinkage has to be measured. So, we have an arrangement like potentiometer which is shown here, this potentiometer will be used to measure the sinkage that means when there is a sinkage there will be a change in resistance and that has been already calibrated by which you can know how much depth it has the plate has entered. So now I will show you.

So, this shaft is now in contact. There is a crossbar provided, so that will apply more or less a uniform pressure. So, I have applied some force and the plate has now entered into the soil. Now I will remove the shaft. So, similar exercise I have to carry out for 3 different plates and the data which are record which are acquired using this loadcell and the potentiometer that will be stored in a computer using a data acquisition system.

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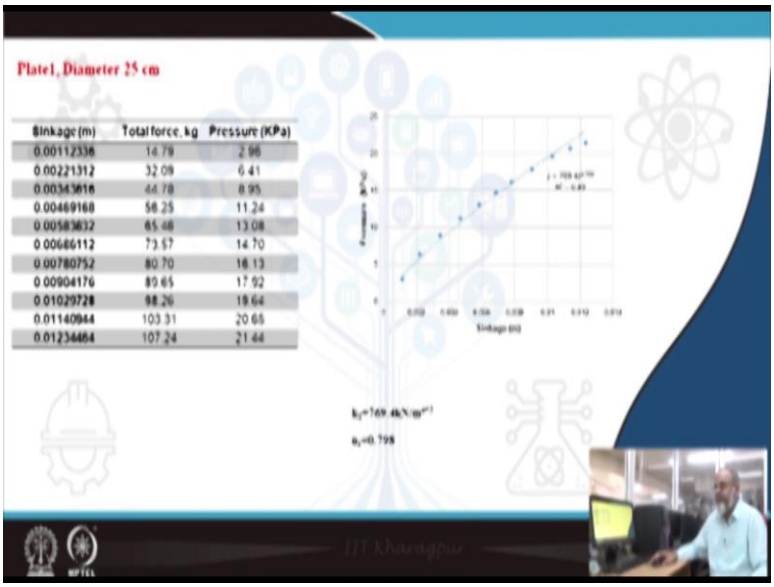

Now, the data which you obtain related to plate 1, that is diameter 25 centimeter, this is the sinkage values, these are the corresponding force values and then force are converted to pressure by dividing its area (πr^2). So, these are the pressure data which you got. Now, you try to plot these pressure data against the sinkage data. So, sinkage we have taken on the x axis and pressure you have taken y axis.

Now, what we observe here is, this is fitted to a power equation which can be given as pressure is equal to 769.4 kN/m^{n+2} and into x, x is your sinkage, sinkage raised to the power 0.798. So, here we got 2 values, one is k value, the other one is n value and we have denoted these as k1 and n1 corresponding to plate one.

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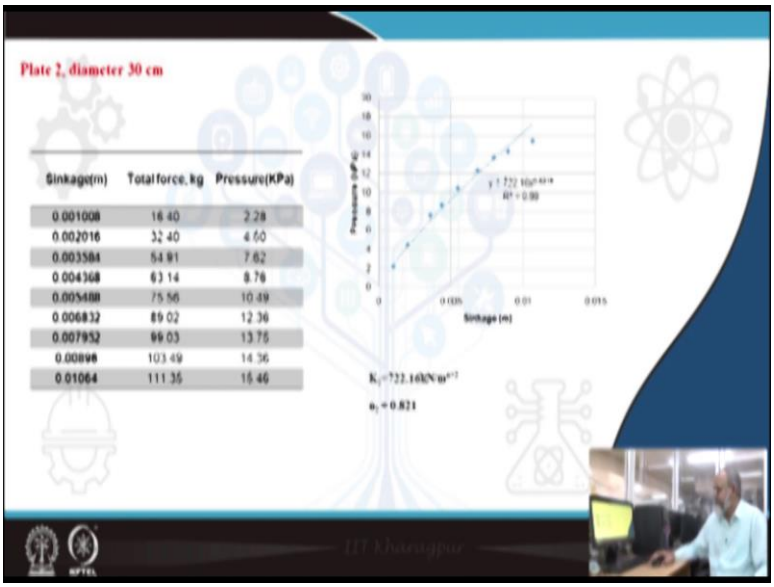

So, similarly, we got data for third diameter 30 centimeter. So, these are the sinkage data, these are the force data which you got then we convert it into pressure data. So, this pressure data is plotted against the sinkage data and again we saw that this is best fitted to by a power equation. Where pressure equal to $722.16 \times \text{sinkage}^{0.8219}$, that means, the modulus of sinkage value, which is denoted as k2 and the exponent of sinkage value which is denoted as n2 they are found out from this equation.

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Again, we try with another diameter plate which is 35 centimeter we got the sinkage data here, we got the force data and then force divided by the area of the plate, so, that will give you the pressure data. So, now, we try to plot pressure versus sinkage. So, what we observe here is, again a power equation which will be a best fitting the observed data points. So, the pressure is equal to $684.89 \times \text{sinkage}^{0.7661}$.

So, we got modulus of sinkage value 684.89 kN/m^{n+2}. And then exponent of sinkage value, we got 0.766.

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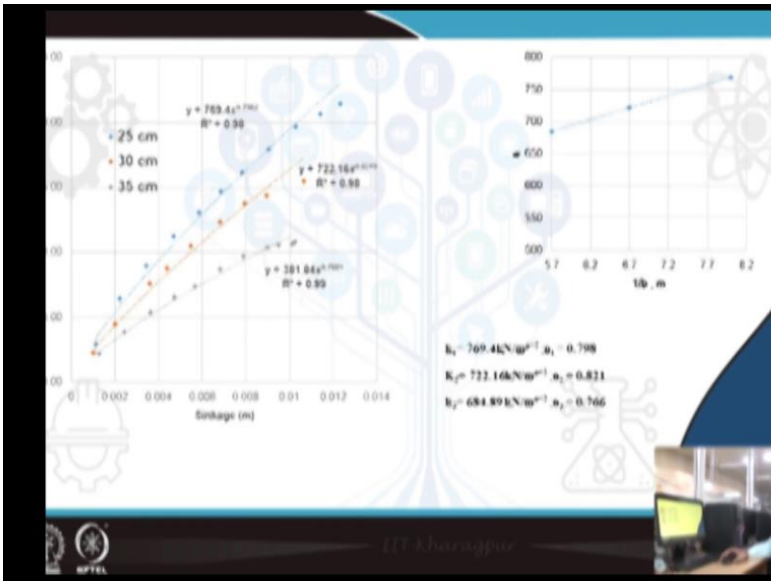

So, now, all the 3 sets of values which we obtain for 3 different plates for the same soil condition, we try to plot in 1 graph. So, these are the results that you can see the blue line indicates the data related to 25 centimeter, the orange line indicates the, orange dots are indicating the data related to 30 centimeter plate radius diameter plate and the gray ones representing the 35 centimeter diameter plate.

So, what we observe here is, these 3 lines they are not parallel they are having a slope, each slope is different. Now, question arises, for the same soil condition we have utilized 3 different plates and we are getting 3 different slopes which is possible, because since we are doing experimental measurements, so, the soil condition may not be that much uniform so, that is why you are getting 3 different slopes.

So, Bekker has suggested because the equation which is given that $p = kZ^n$, that has been proposed by Bekker. So, now, he has suggested that if you are getting different slopes, then the best way is to take the average which will be representing the average exponent of sinkage of that soil. So, we found out the slopes n1, n2 and n3, then to the average of n1 plus n2 and n3 so, that becomes the your, the exponent of sinkage for the soil for which we carried out the test. Now, comes how to find out the frictional modulus of sinkage, the cohesive modulus of sinkage because we have got data related to modulus of sinkage.

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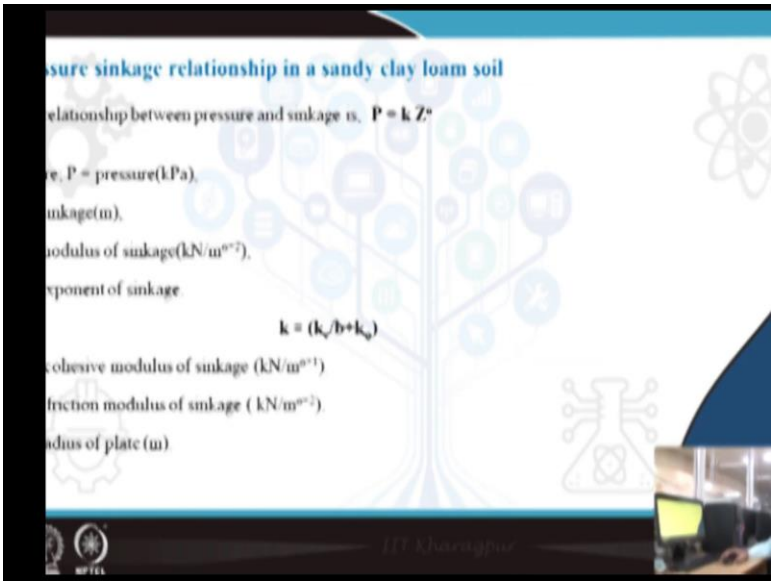

Now, we know that modulus of sinkage is related to this frictional modulus of sinkage, k_ϕ and k_c by a straight line relationship that means $k = (k_c/b)+k_\phi$. So, if you are plotting k versus 1/b, then the slope will give you k_c value and the intercept will give you k_ϕ value.

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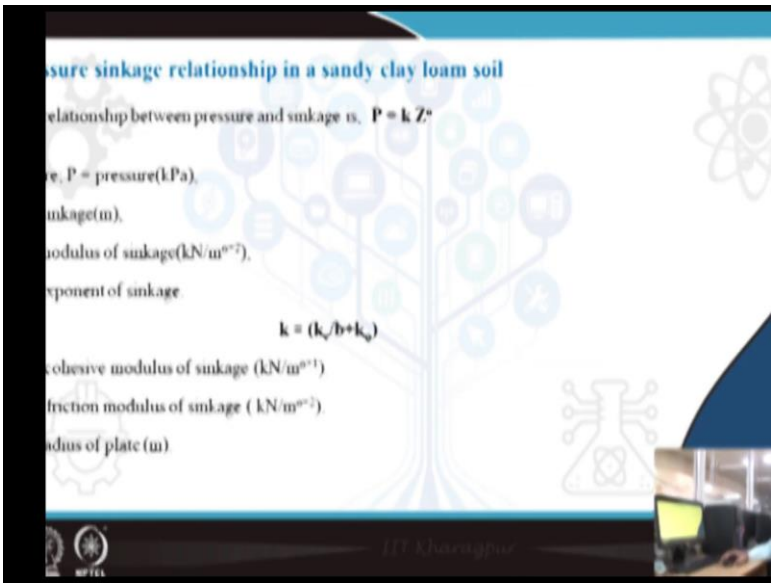

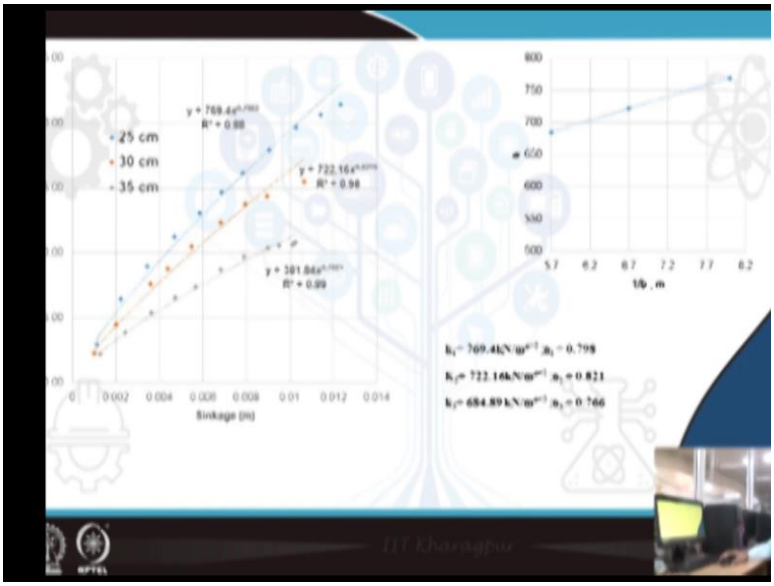

So, the k value which we got for 3 different plates in terms of k1, k2 and k3, we tried to plot against 1/b. So, you got 3 points, then we try to best fit these 3 observed points. So, what we observed is there is a straight line which can very well predict these values.

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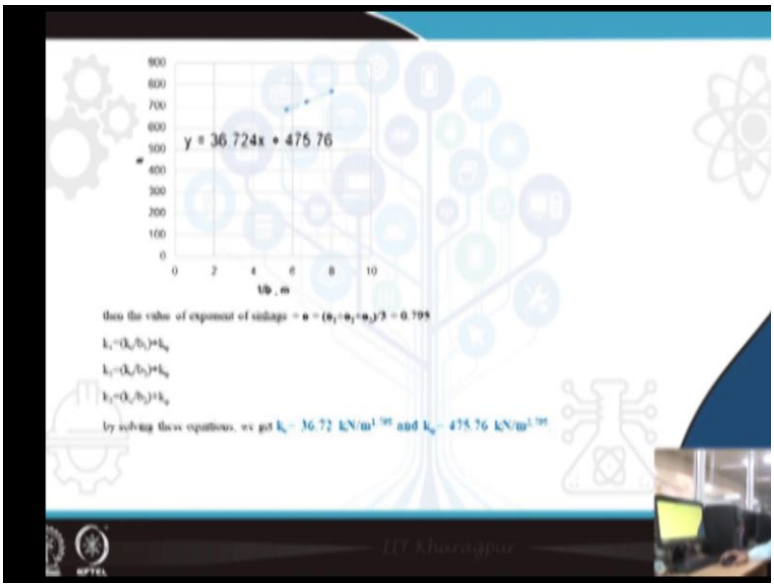

So, the straight line is 36.724×1/b + 475.76. That means, the intercept is 475.76 which is nothing but your frictional modulus of sinkage and the slope is nothing but k_c which is equal to 36.724 and we also calculated the average exponent of sinkage which is summation of these 3, and we took the average so that we got around a value of 0.795.

So, finally, what we have derived is, k_c is equal to 36.72 kN/m$^{1.795}$ and k_ϕ is equal to 475.76 kN/m$^{2.795}$. This k_c unit and unit of k_ϕ they are not same as we know that they are dependent on exponent of sinkage. So, that is why there is a variation. So, in one case, we are getting 1.795 meter raised to 1.795. In the other case, we are getting meter raised to the power 2.795.

Now, these are the values for a sandy clay loam soil which is around the moisture content is around 10 percent at dry basis. So, the plate sinkage test, as I said in the beginning, which indirectly give you the response of the terrain, terrain means the soil how it is behaving when it is loaded with a tyre. So, these parameters are required and this is one of the techniques which is used for measuring this response of the terrain.

There are 2 methods basically, which is called the bevameter technique and out of this bevameter technique, the 2 methods are one is plate sinkage test the other one is shear annulus test. So, shear annulus test will give you the shear stress, which is causing the failure of the soil, maximum shear stress, which is causing the failure of the soil.

So, and the plate penetration test is going in the, is going to give you the bearing strength of soil. So, we have utilized this plate penetration test and then we try to find out the exponent of sinkage and modulus of sinkage. Again, modulus of sinkage is nothing but your cohesive modulus of sinkage and frictional modulus of sinkage. So, these are the 3 values which you obtained by carrying out the plate sinkage test.

So, the values which you got, that is valid for a sandy clay loam soil. The moment you change the soil, then these values may change. So, it is a, these parameters are dependent on type of soil and also the moisture content that is important. So, whenever we try to mention these values, this we have to mention that okay. These are the values which you obtained at moisture content of this that has to be mentioned. So, this is how we carry out the plate sinkage test, and I hope you will understand how to calculate k_c, k_ϕ and n for a given soil condition.