Port and Harbor Structures
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Module-06 Lecture-31
Soil Structure Interaction

So soil structure interaction is important in the analysis. Many structures, civil engineering structures as well ocean engineering structures, we have to assume the support given by the soil.

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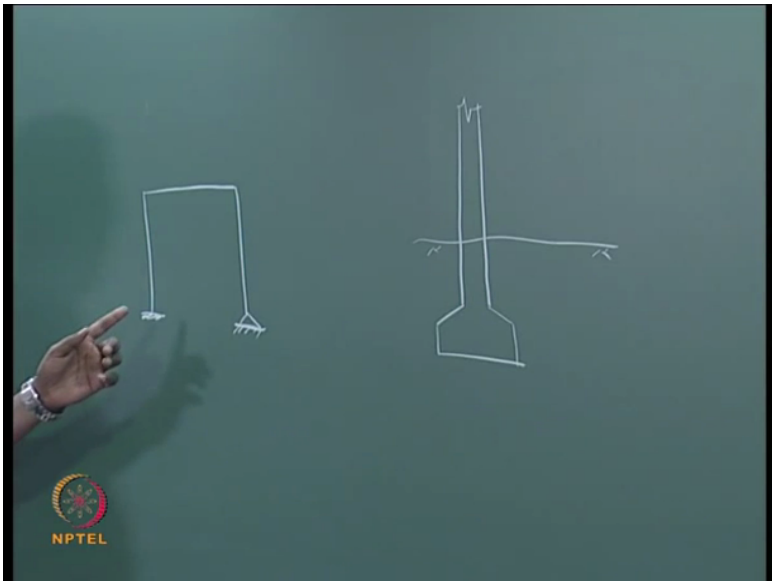

So if you take a residential building, what we will be having is, you may have isolated footing most commonly used. So what you will assume is a boundary condition for this isolated footing. You have to assume boundary condition for analysis. All of you know that there is a problem like this, you know a portal frame.

"Professor-student conversation starts."

Professor: How many of you have studied analysis of a portal frame? Raise your hands. Okay. What is this boundary condition means? What is this boundary condition?

Student: Fixed and hinged.

Professor: Thank you. What is the difference between fixed and hinged?

Student: Moment is (())(1:19)

Professor: Moment is….

Student: Restrained.

Professor: What is it?

Student: Restrained.

Professor: Moment is restrained. What is the boundary condition? You know what is meant by boundary condition? What is boundary condition?

Student: Displacement.

Professor: Displacement, then? What else?

Student: Rotation.

Professor: How many displacement and how many rotation?

Student: 3 rotation and 3 displacement.

Professor: 3 rotation and 3 displacement. For fixed condition, boundary condition, what happens to the displacement and rotation?

Student: 0

Professor: For hinged?

Student: Displacement is 0 and rotation.

Professor: Displacement is 0. Rotation is not 0. That is what we give. So there is isolated footing here, multi-story building. What is the boundary condition? How many of you have given and seen the foundation for new hostel blocks being built, ladies hostel and gents hostel? You want to raise your hand or not? I am not going to ask question because I have not gone there. You have also seen? Why not others? Why you are not going and seeing? Simply go and see. Always better to go and see these structures and they are being built.

So these, some people use hinged, some people use this as fixed, this all depends on how much depth this goes into below the sea, below the ground level and what is the type of soil here. If you have a very good weathered rock, what type of rock is there near gents hostel? You have visited both gents hostel and ladies hostel?

Student: Only gents hostel.

Professor: Only gents hostel. What type of soil is there? Soil also has gone. And gents hostel or ladies hostel?

Student: Gents.

Professor: Uhh….?

Student: Gents.

Professor: What type of soil is there?

Student: Clay such.

Professor: It cannot be clay. Gents hostel it is highly weathered rock or sometimes it is very good rock also. Ladies hostel, you go and see. Most probably it must be clay. So if it is a clay soil, then we may have to use it as hinged and if it is rocky strata, we may have to use it as fixed. All the four boys hostel what we have built, we have taken into rock. Top surface there is clay and as you go deeper and deeper, we get rock.

“Professor-student conversation ends.”

One of the hostel the rock is at about 2 meter below the ground level. Another hostel the rock is at about 4 or 5 meters below the ground level. We excavated up to that and then put it into the rock. Ladies hostel we have lot of problems, both Sharavati as well as, I do not know about the new hostel, there we have very soft clay for a very deep excavation because we have the lake. All of you might have seen the lake. From the lake there is extension of, that clay particles is there. That is why it is coming.

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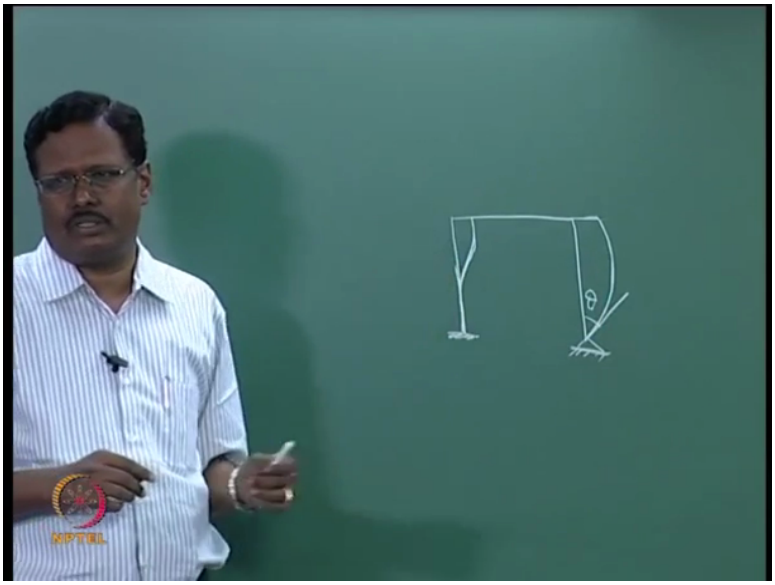

If it is fixed, the displacement will be more. There is a displacement here, right? Suppose you draw the displacement diagram for this, should be like this, should be like this.

“Professor-student conversation starts.”

Professor: Any mechanical engineer, what is the difference between this curve and this curve? Is there any difference?

Student: Displacement, point displacement is mentioned.

Professor: What is the difference? Next, you are also mechanical, uhh, what is the difference? This is the displacement diagram. This is another displacement diagram. What is the difference in the displacement diagram? Next?

Student: In fixed boundary condition we have restricted that rotation also. The rotation is 0 at that point. In hinged point, that rotation is (())(05:39).

Professor: So whatever she is telling is correct. I am able to understand. Most of you may not understand. See, this is the slope. What is the slope of the curve here? What is the slope?

Student: 0.

Professor: 0. What is the slope here? The slope is not 0. That is the difference. And if you see the deflection between this point and this point, deflection may be more here compared to this point. This is for a building.

“Professor-student conversation ends.”

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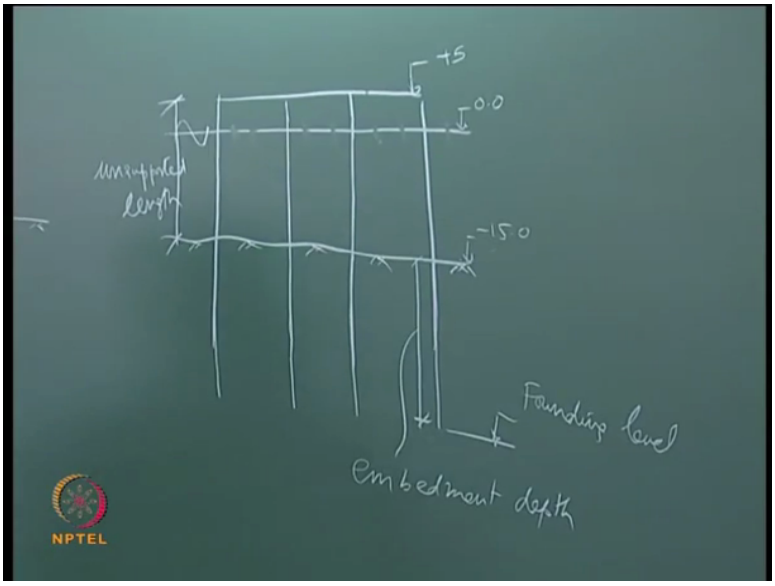

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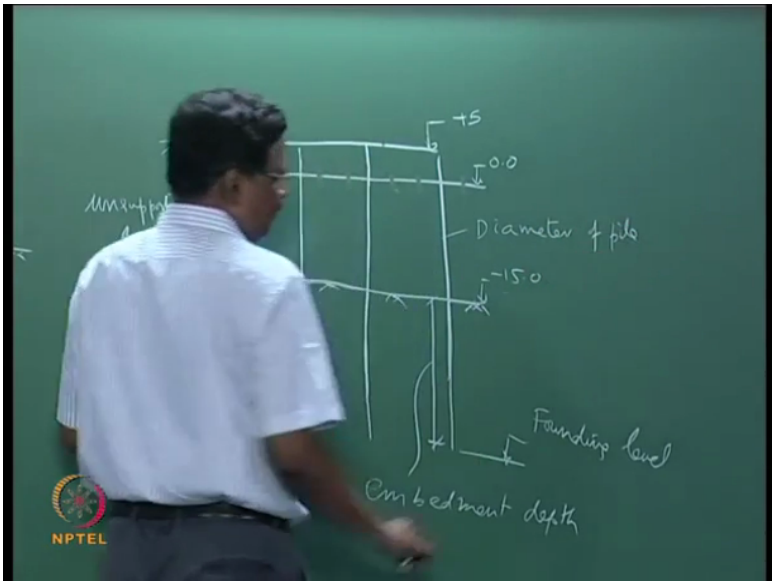

So in harbor structures what we are having is we may have piles and we may have deck on top of it. And we may have the seabed here and we have a water level here. This is the top level of the

structure. Let us assume that is plus 5. And this is a charged atom, we will take it as 0.0. We assume the bed level as minus 15.0. This we will call it as founding level. This depth we will call it as embedment depth. So this is the top level of the structure where we have the beam. That beam central line I am taking it as plus 5, this is a charged atom which is 0.0. This is the dredge level that I am taking it as minus 15. And this is the founding level.

"Professor-student conversation starts."

Professor: Now you tell me how much should be the founding level? How much should be the embedment depth? What it should relate to?

Student: Bearing capacity.

Professor: It should relate to one of the dimensions here.

Student: Height above.

Professor: Height above the ground level. So this we will call it as unsupported length. It should relate to another dimension, what should be that? What is the dimension?

Student: Diameter of the pile.

Professor: Diameter of the pile. So embedment depth is equal to how many times the diameter of the pile?

Student: Three times.

Professor: Three times means the structure will fail. Unless if it is rock, okay, unless it is rock, you see, let us assume that this is the pile which I have marked, okay.

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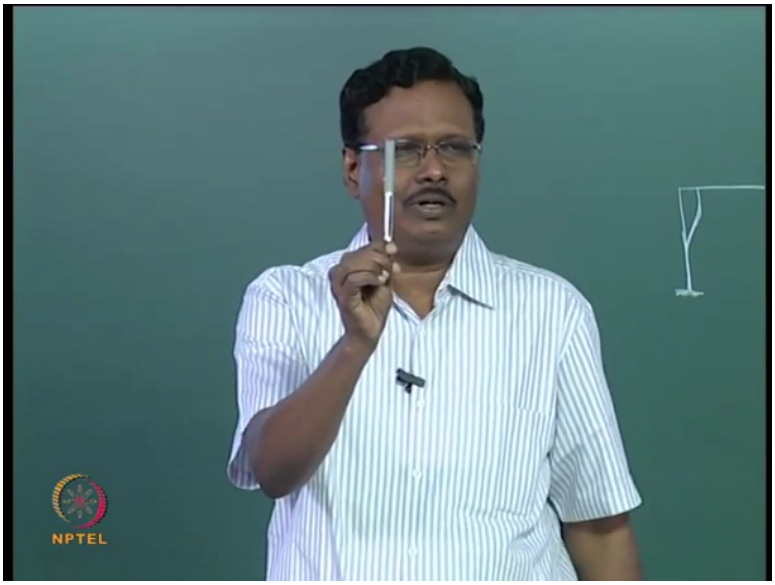

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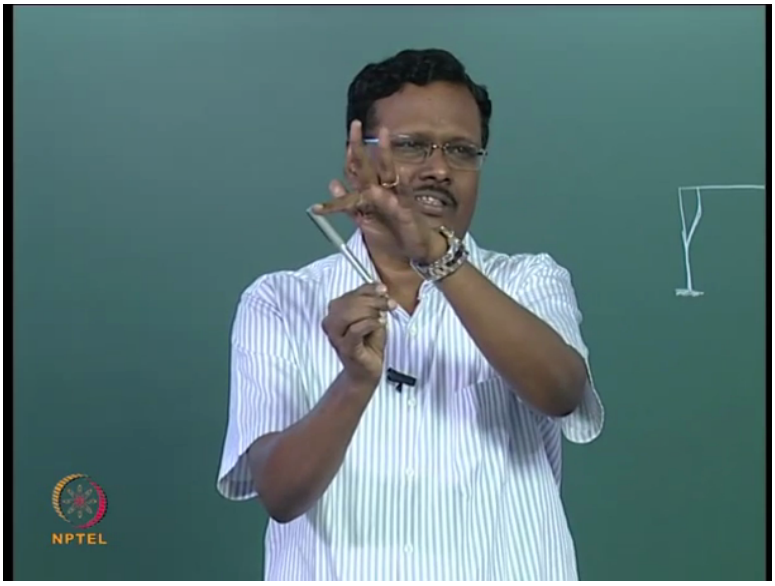

Suppose this portion only is the embedment depth, I hold it like this and apply a load like this. What happens? It will fall.

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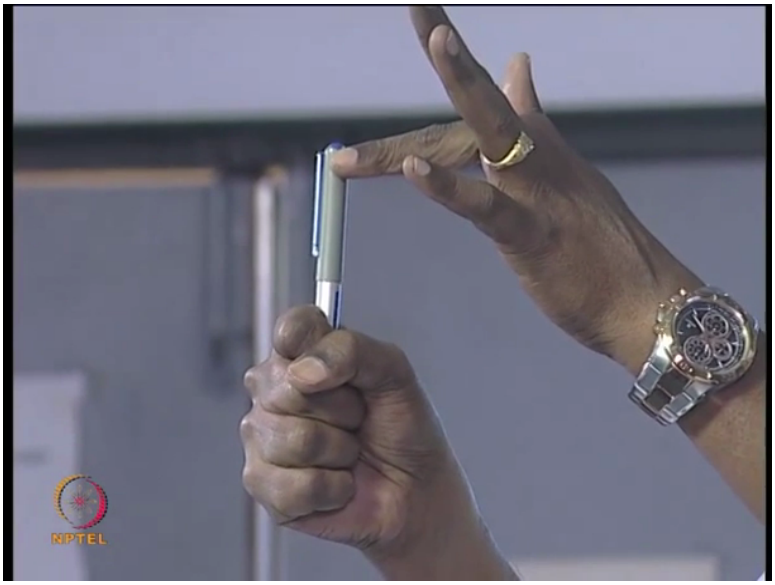

Suppose I hold it like this and then push it, pen may break but it will not fall down. Okay, so 3D is not sufficient, then how many Ds it should be?

Student: 30.

Professor: 30, 30 means you will become a (())(9:43) in the structure. It depends on the type of soil. Okay. The other parameter is type of soil.

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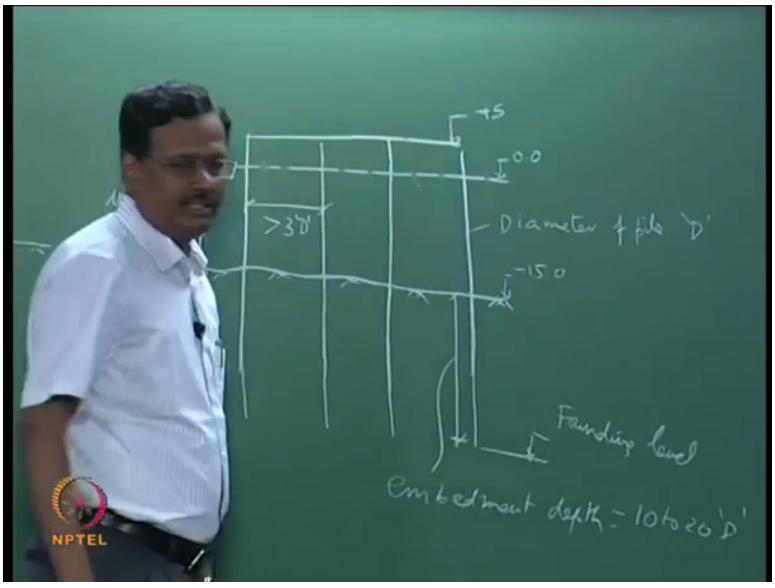

Generally it is between 10 times to 20 times diameter of the pile. If it is a soil, soil means it is a sand or clay. Sometimes we have very hard rock, rock means granite and things like that. If you have that type of rock, you will not have any possibility of going up to 10 times the diameter of the pile.

Okay. What should be the diameter of the pile? Because and this problem we have not given the diameter of the pile. What should be the diameter of the pile? It should relate to some dimension, what dimension?

Student: Axial load.

Professor: Uhh….?

Student: Axial load.

Professor: Finally it depends on the axial load and bending moment, okay, finally it depends on that. But based on the dimension what is given here, you should be in position to find out the diameter of the pile.

Student: Spacing.

Professor: Uhh….?

Student: Spacing.

Professor: Spacing between the pile also is important but we will see later. Spacing depends on diameter. Generally this spacing between the pile, it should be greater than 3D where D is the diameter of the pile. Why it should be greater than D, 3D?

Student: (())(11:19)

Professor: Uhh, Should not interfere the….

Student: Pressure bulbs.

Professor: Pressure bulb. Pressure bulb, I am not going to draw. Answer is correct but I cannot explain it at this level.

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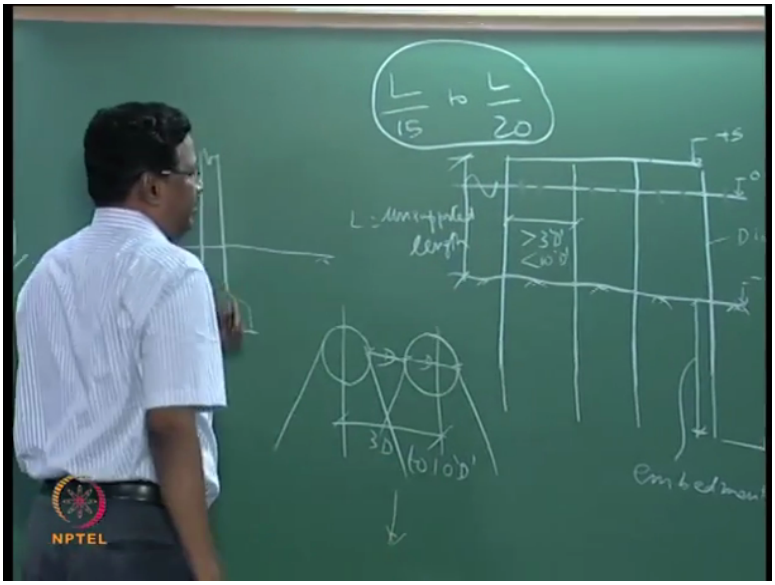

So this is the center to center distance, we are asking. Okay, this is 3D. This is your D. Minimum gap between these two should be diameter. That means center to center distance should be minimum two times the diameter of the pile. Okay, the piles are very close, then it will hit one another and it may not be able to give the resistance to the soil. Soil is supporting the structure.

Suppose there is a force which is acting on this direction. This pile will support the soil like this. This pile will support the soil like this. So it should come and hit. So if it is 3D, the capacity of the pile, foundation capacity will be the same as single pile. Otherwise if it is group of pile, if it is very close, then it becomes a difficult. But minimum should be either clear gap of D. There should be some physical gap between one pile and another pile, that should be equal to the diameter of the pile. There are diameter of the piles are different. It should be equal to the larger diameter of the pile. Okay. The maximum normally they use is about 10 times the diameter of the pile.

So it should be between, should be less than about 10D. That is a spacing between the pile. But after fixing the diameter of the pile, you have to fix the spacing. Okay, but how to fix the diameter of the pile? It should relate to some dimension. What dimension? There are only few dimensions here.

Student: Unsupported length.

Professor: Unsupported length, suppose this unsupported length is L. It should be equal to L by 15 to L by 20. This is the range. This is based on experience but there is a provision in IS456 where we have to check for serviceability of deflection.

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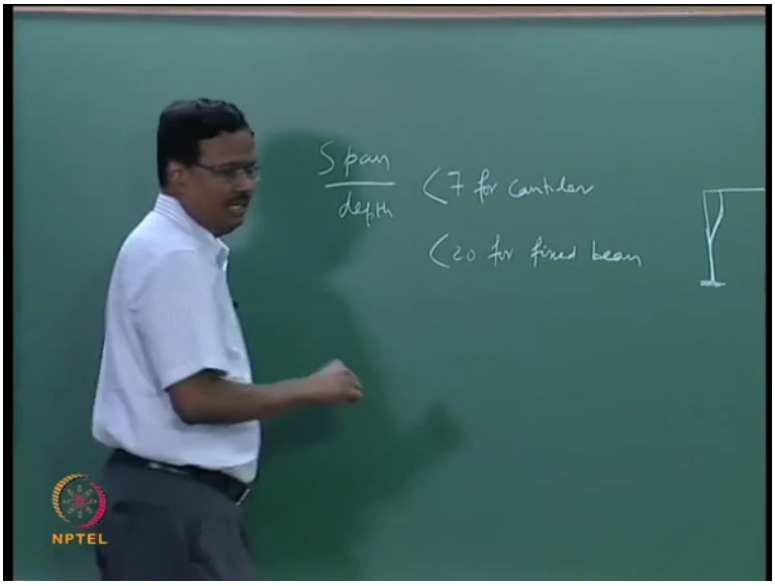

There they have given the span by depth ratio should be less than 7 for cantilever and less than 20 for fixed beam. How many of you have seen this provision? I think it is 28 or so for simply supported. Any of you have seen this in IS456? Raise your hand. You have seen, really you have seen? Okay. This pile, is it a cantilever or fixed?

Student: Cantilever.

Professor: On cantilever, what else it is? See, today's class what we want to do is we want to find out a depth.

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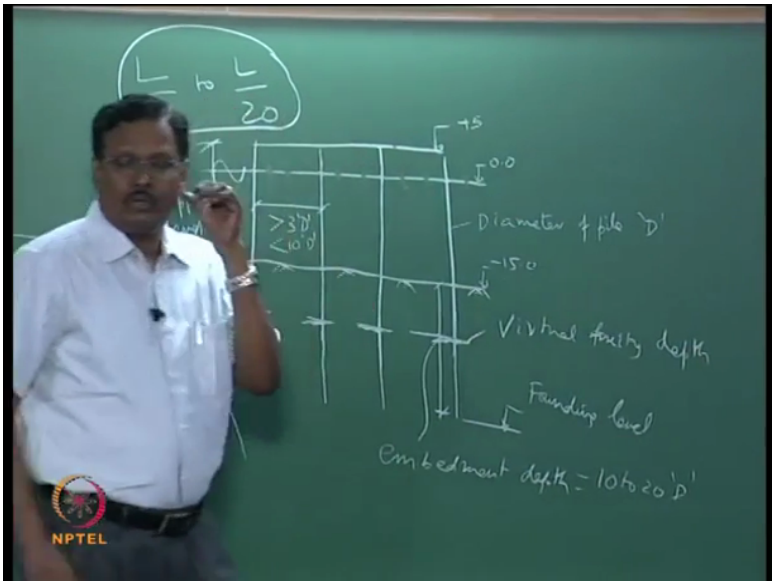

This is called as virtual fixity. What is a meaning of virtual? Virtual memory we are talking. Virtual fixity depth we are talking. What is the meaning of virtual fixity depth?

Student: We are assuming imaginary.

Professor: What is it?

Student: Imaginary.

Professor: What you are telling is correct only. Go back, what is it?

Student: Sir, we are assuming that is, that will be presenting, we are assuming.

Professor: Now you said one thing.

Student: Imaginary.

Professor: Uhh?

Student: Imaginary.

Professor: Imaginary. So imaginary thing, it is not a real. Real means it does not exist in a practical sense. It is imaginary point which is called as fixity depth.

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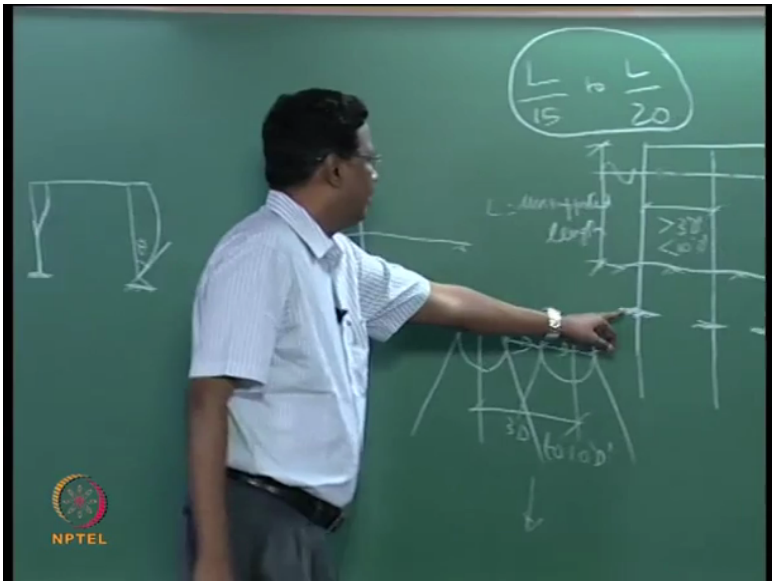

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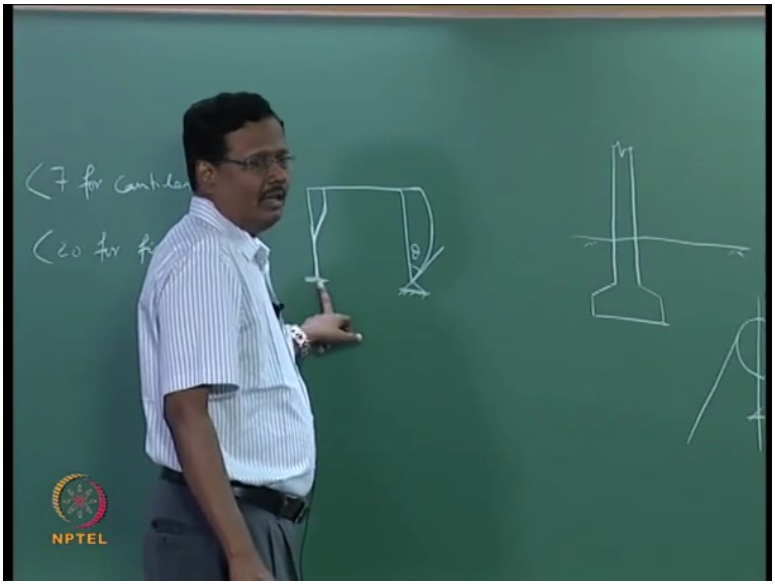

That means this is fixed. Fixed like this here. Okay.

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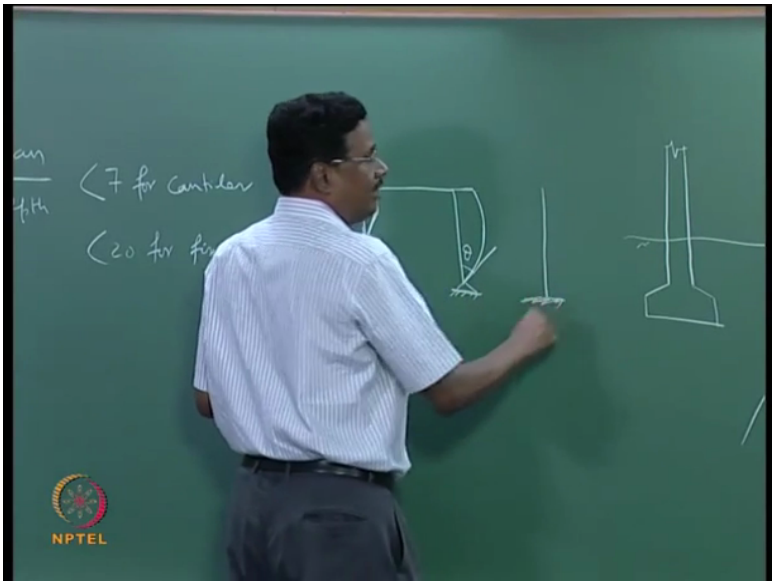

All of you told cantilever, cantilever means what? This is cantilever. Okay.

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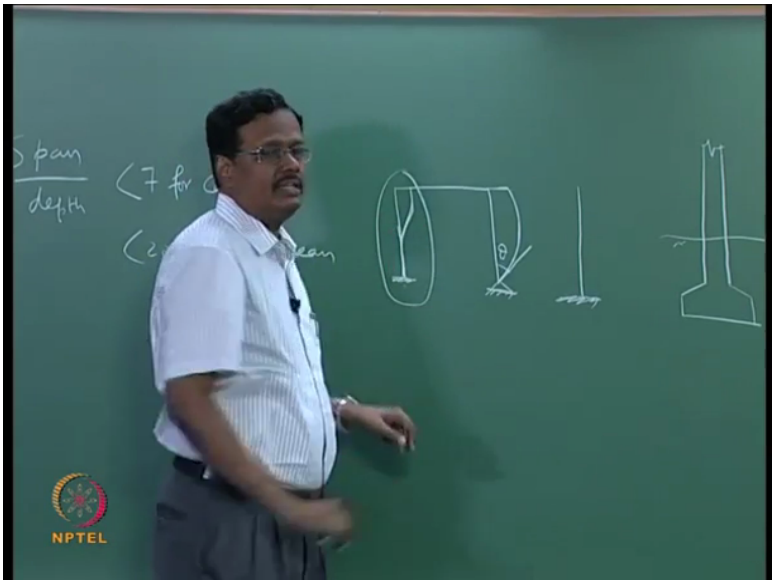

When you fix it here and put it here for this, can you say that this is cantilever? Is it cantilever or not cantilever? And what is it?

Student: Propped.

Professor: What is it?

Student: Propped cantilever.

Professor: Propped cantilever. You are coming for class. [Regional language; 16:14 to 16:17] coming directly from Holi.

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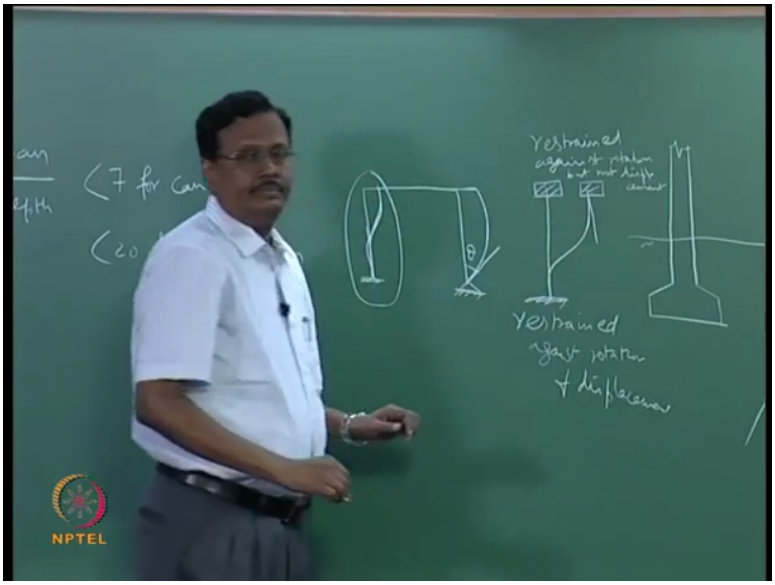

So this is restrained against rotation and displacement. What about this here? You see this is the figure I am drawing it there. The same figure only I am drawing. Is it restrained against rotation? Yes or no? Is restrained or not restrained? Restrained means this slope should be 0. Slope is 0 against rotation but not displacement. So this is a boundary condition. All of you know effective length? Effective length you know. What is effective length?

Student: 0 bending (())(17:41)

Professor: Uhh?

Student: Distance between the 0 bending moments.

Professor: 0 bending moment. What is the effective length for this?

Student: 0.78.

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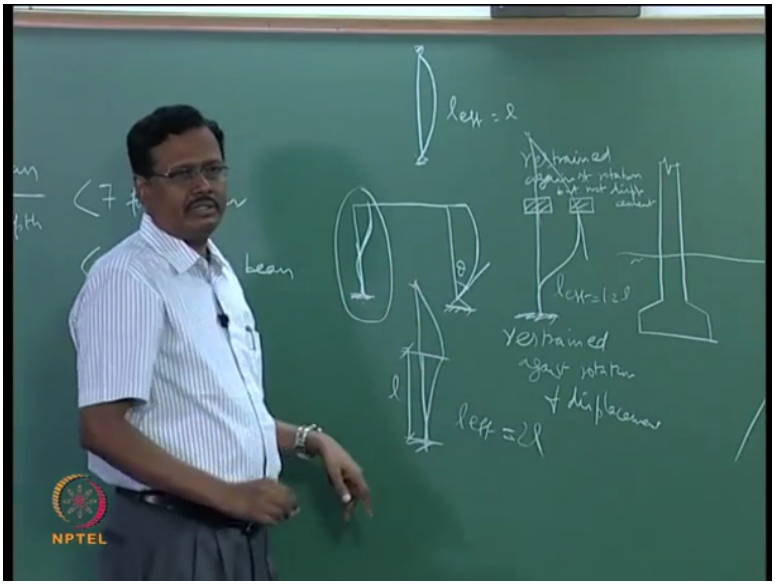

For a cantilever, what is the effective length?

Student: 2L

Professor: You come to consensus, 2L only. What is the effective length for this to bend like this? What is the effective length? Whether you are civil mechanical, all of you should know this. Okay. What is the effective length for this?

Student: 0.8

Professor: Uhh?

Student: 0.7L sir.

Professor: Uhh?

Student: 0.7L

Student: 0.87

Student: 0.8

Professor: You told it is distance between 0 deflection.

Student: 1.29

Professor: See, it will bend and go and meet here at 0 deflection. This length is the corrective length. So between this it will meet at the same point, same. But this deflection is like this. If you plot like this, it will go and meet here. This is your effective length.

“Professor-student conversation ends.”

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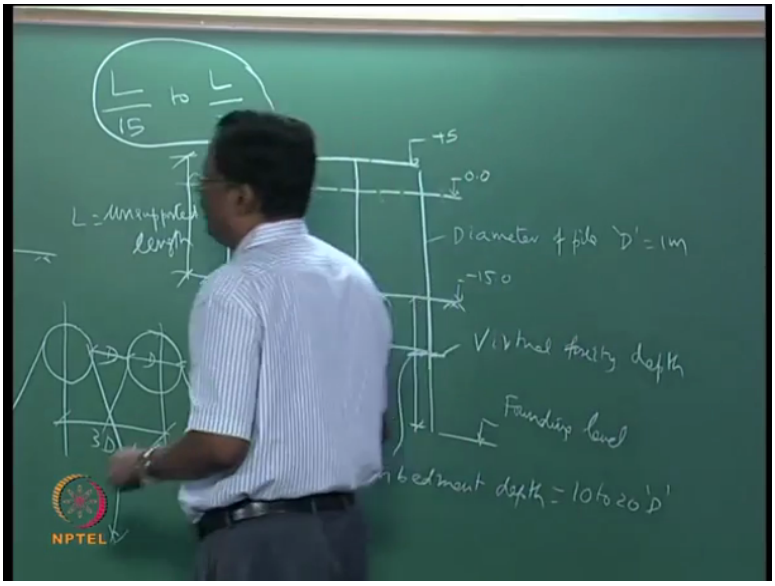

Now suppose this is about 20 meters, minus 15 to plus 5. If you take L by 20, this is equal to 1 meter.

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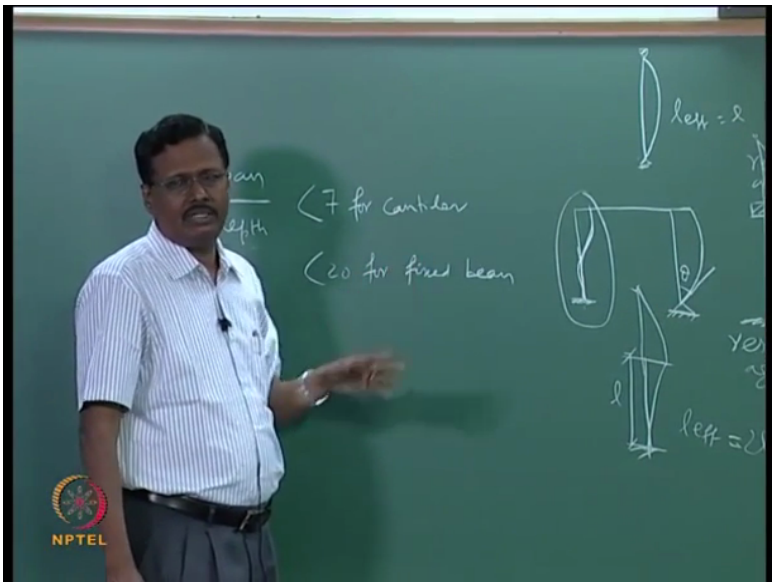

Here what I was telling is span by depth is equal to less than 7 for cantilever. That is for this type of condition. It should be less than 20 for fixed beam. Fixed beam means both the ends restrained, right? But we can take, that is why I said L by 15 to L by 20 because this boundary condition is not same as fixed. So it should be between the cantilever and fixed beam. Is it clear? That is why we get L by 15 to L by 20. But this is an approximation. Do not take too much weightage for this particular case. But approximations are always better. You should know the value initially very close to the real value, then you do the analysis and then go on improving the diameter.

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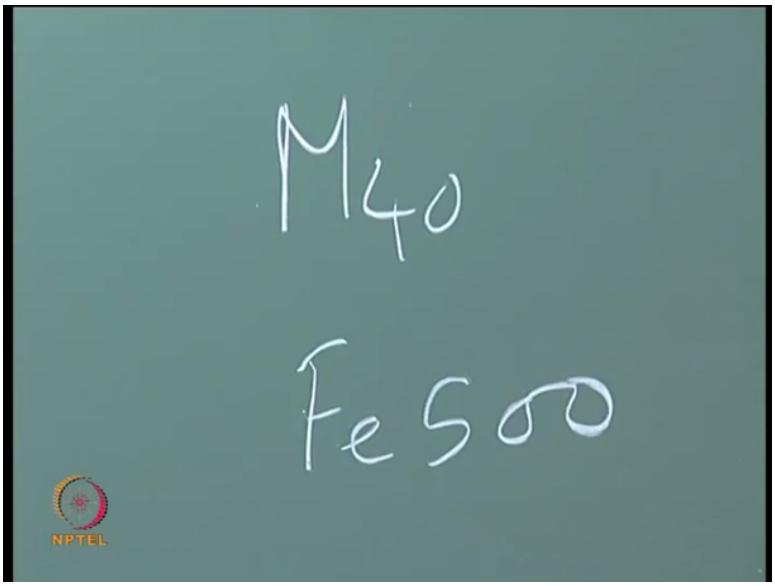

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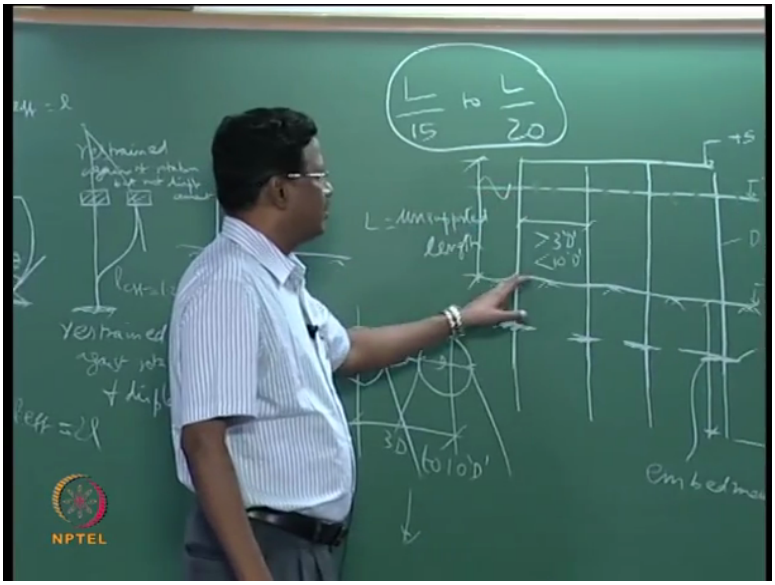

Okay, diameter of the pile depends on some more parameters, that is what is the grade of concrete to be used and what is the steel we are using. So it also depends on this. Suppose we use lower grade, we have to go in for L by 15. But actually speaking we should take the length from here to here, not this unsupported length. But based on experience we have taken this as L by 15 to L by 20 is sufficient of unsupported length. Actually you have to take the total length. This is an approximation which we use it for calculating.

“Professor-student conversation starts.”

Professor: So this embedment depth should be equal to 10 to 20 times diameter of the pile. That is one consideration. What is the other one? Some of you told it should be a function of unsupported length. How much it should be embedment depth? Embedment depth is equal to some factor of unsupported length. How much it could be? Two times unsupported length or one time unsupported length or 0.5 times unsupported length? Uhh? 1, 0.5.

Student: 0.5.

Professor: Any other answer?

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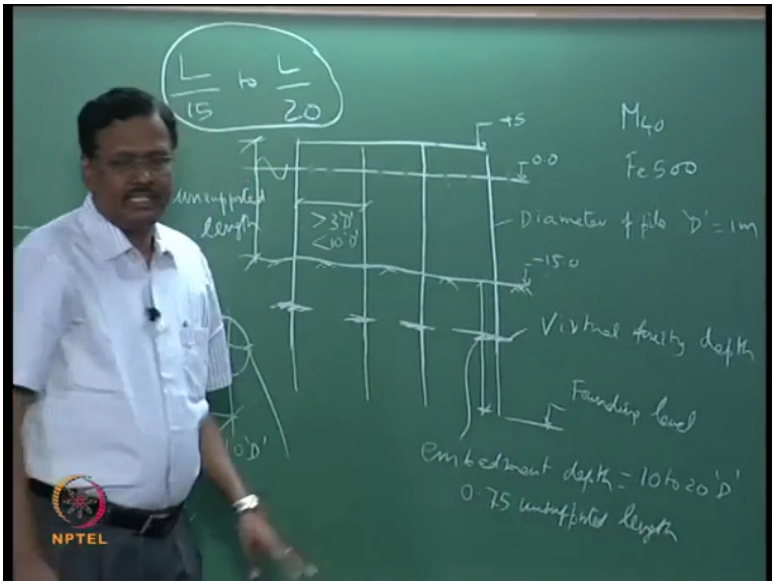

It is very difficult to say but generally we take it as 0.75 times unsupported length. But this is not always true. In Cochin we have very soft clay where the embedment depth may be even equal to two times the unsupported length. In Jaigad which is near Ratnagiri, anybody knows where is Ratnagiri? No one knows Ratnagiri. You please go to the Google map and find out because these are locations where we have very good harbor facilities, it is in Maharashtra.

In Maharashtra, Bombay and Goa it is there. There we have a very particular problem. We have soft clay deposits up to about 30 meter water depth. Below 30 meter we have only rock, granite. Do not know that is granite, is not granite.

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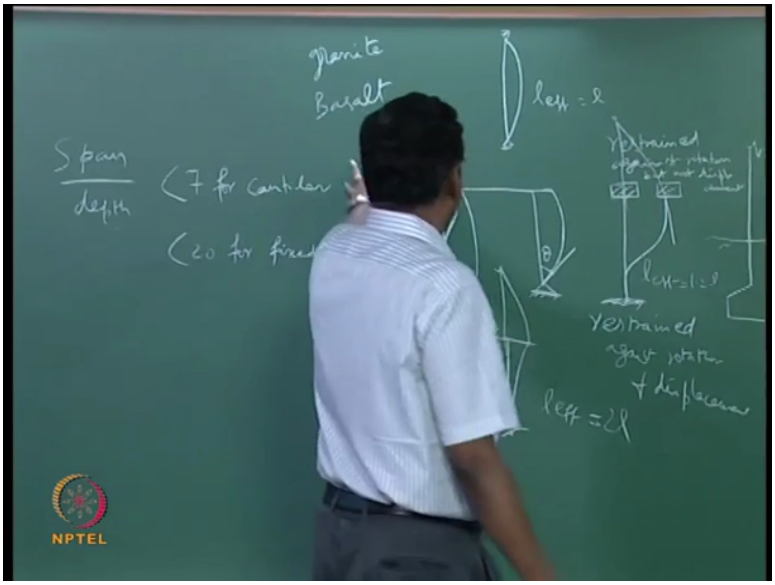

We have different types of rock. One is granite, what is other type of rock? Granite is one type of rock, what is other names of rock?

Student: Basalt.

Professor: Basalt. And which is stronger? Basalt or granite? This fellow is answering, you are mechanical engineer? Civil?

Student: Mechanical.

Professor: How do you know basalt and granite? How do you know? You heard granite and basalt. Civil engineering students you have studied Geology? Which is stronger, granite or basalt? Basalt is stronger than this. Basalt will be equal to M60 or something like that. But you may have granites of higher strength but in general basalt is stronger than granite. So in Jaigad we have basalt and that is there only above, just below the seabed. We cannot chisel out the rock. So there they have given embedment depth is equal to only three times the diameter of the pile.

"Professor-student conversation ends."

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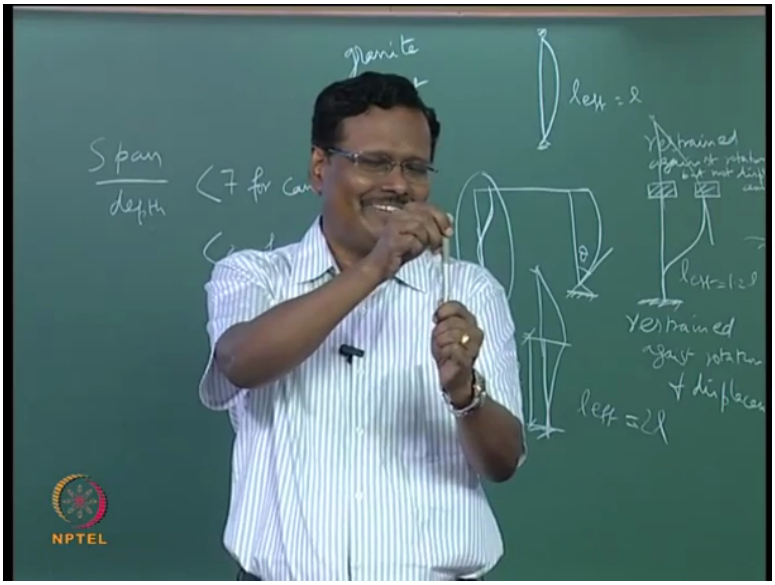

This condition I was telling. Only this much penetration it was holding it like this, basalt. But this basalt is very strong. So a strong person hold this pen, it will not rotate. I am not very strong. It will not rotate, so there we have used. So this is what we are doing. So there is so many points that we have to discuss to find out the fixity depth. The point is how much should be the fixity depth.

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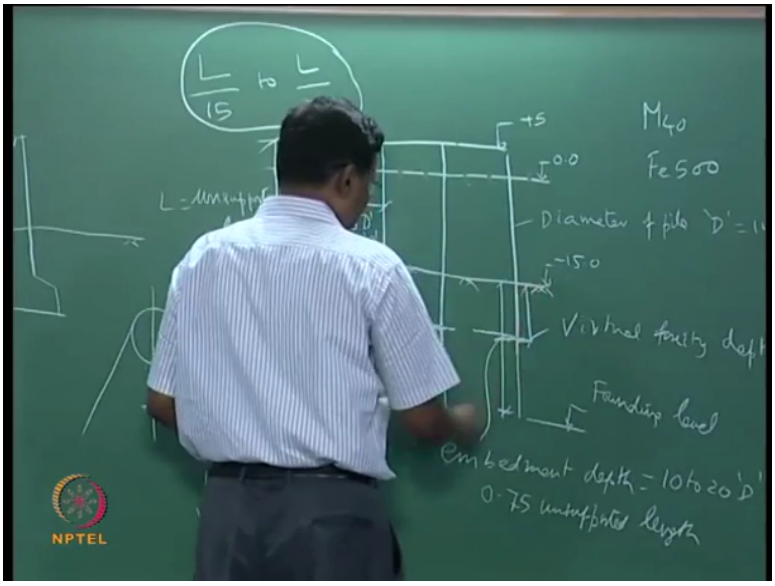

Fixity depth should be, this is embedment depth and this is your fixity depth. Fixity depth should be less than the embedment depth. It is generally 50 percent of the embedment depth.

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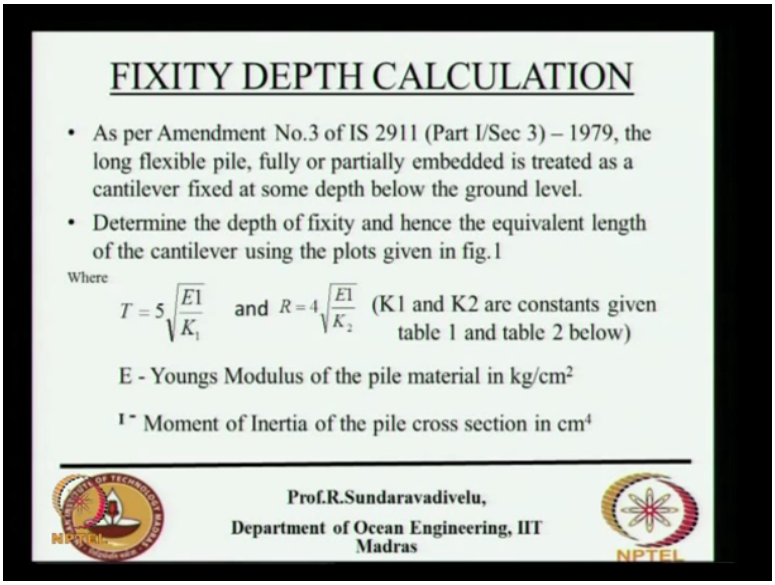

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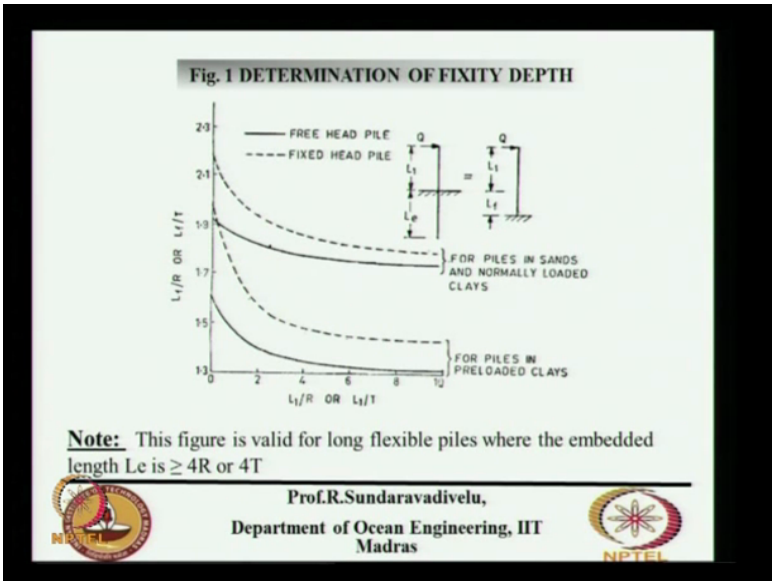

How to find out this fixity depth, that is what we want to discuss. So we have to find out, this formula is given here. From this we have to find out the value of T and R. Value of T and R is, this T is some kind of length, unit is length. It is a function of, this is a mistake here I think, it should be EI. Young's modulus of pile and moment of inertia of pile and it also depends on K1 and K2. These are the constants related to soil.

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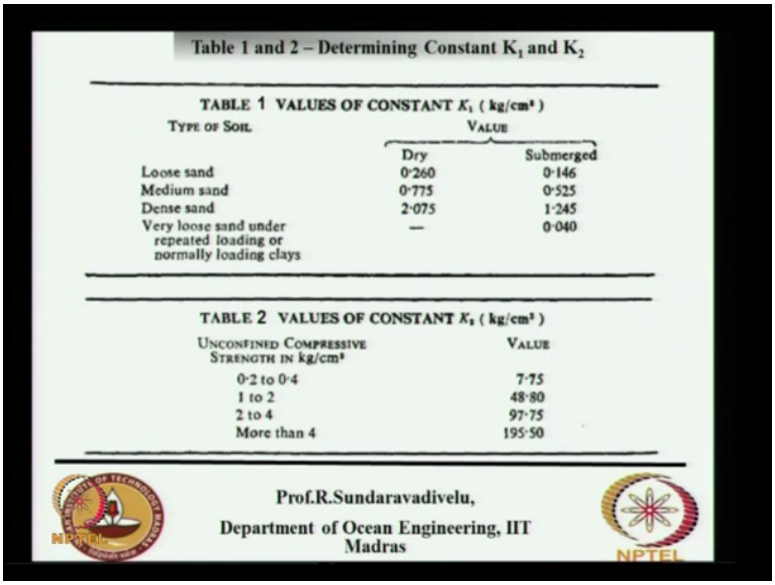

This K1 and K2 is given in this table. This is equal to horizontal subgrade modulus. These values are different for type of soil. K1 is for sandy soil, K2 is for clay soil. The sandy soil is defined as loose sand, medium sand or dense sand. And this is some, this you do not have to consider now. This is very loose sand under repeated loading. There are two cases. One is dry, another is submerged. Dry is when there is no water table in the foundation. But our case we should take only submerged. This is a value which you have to take because it is under water. So if it is a loose sand, value is 0.146. It is a dense sand, it is 1.245.

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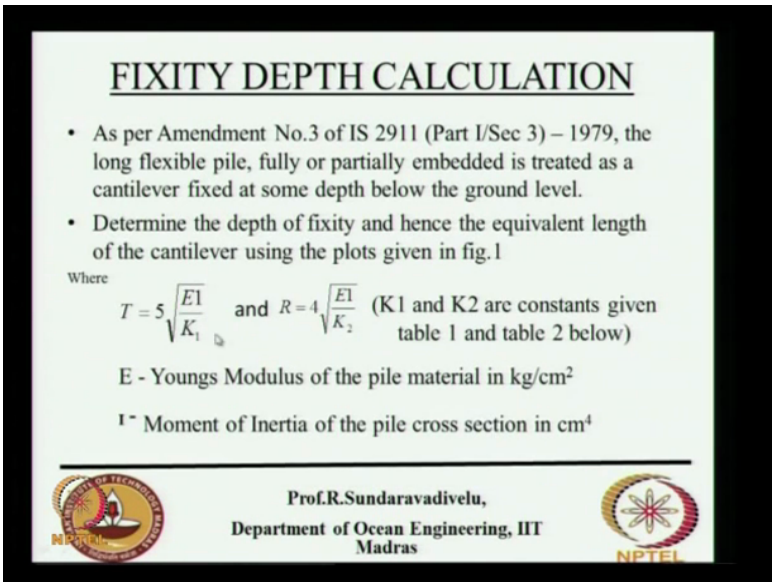

And that you have to substitute in this formula. K1, for this we have to get the value of T which is equal to fifth root of EI by K1. E is the Young's modulus of concrete, I is the moment of inertia of the pile, pi d power 4 by 64. R is the equivalent length, that is the fourth root of EI by K2. This is for clay soil.

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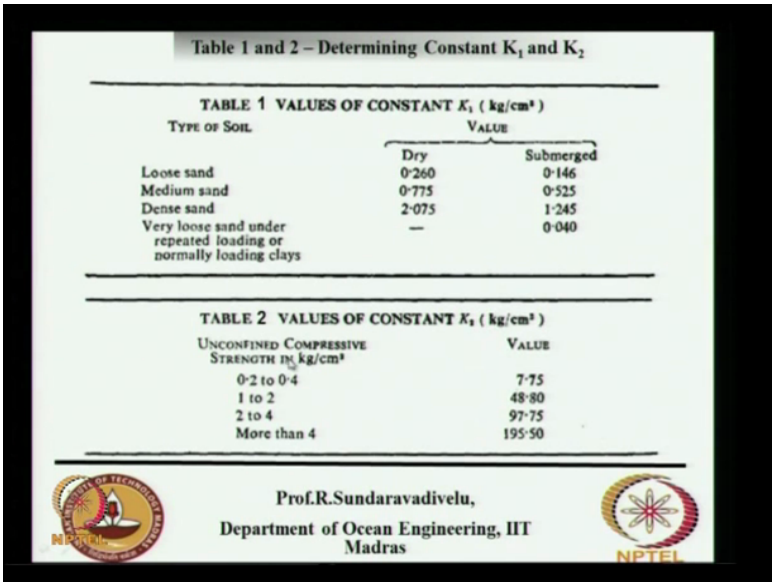

So clay soil is defined by unconfined compressive strength varying from 0.2 to 0.4, is very soft clay, medium stiff clay, stiff clay and very stiff clay for which the values are given here, K2 values. So you have to find out what is unconfined compressive strength of the soil and find out these values. What is the type of sand and find out this value.

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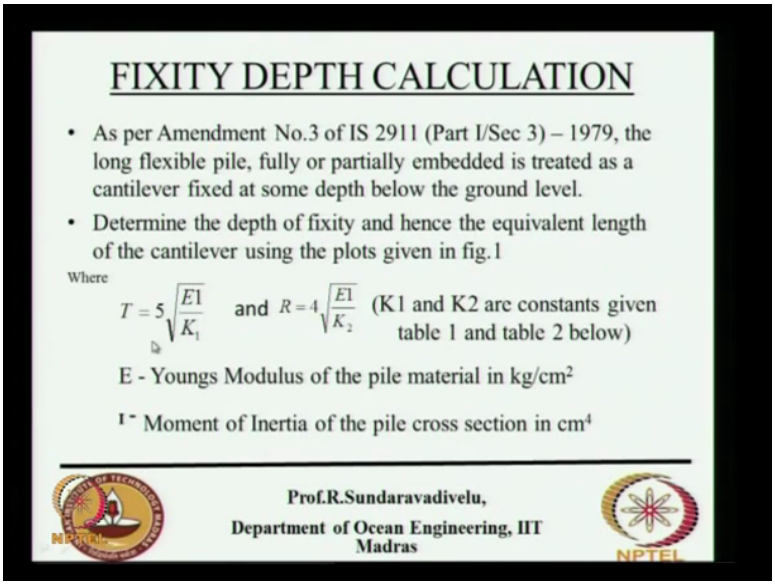

And you have to substitute in this formula to get T and R. Any doubt in this? You should know the diameter of the pile to calculate moment of inertia. You should know the grade of concrete to get the Young's modulus. You should know the type of soil to get the K1. This is the fifth root of EI by K1. This is fourth root of EI by K2. This is some equivalent length. This depends on the rigidity of the pile as well as stiffness of the soil. It is a relative pile length or so, we can call it. It depends on the relative stiffness. The K1 and K2, the units are kg per centimeter square. EI will become kg per centimeter square.

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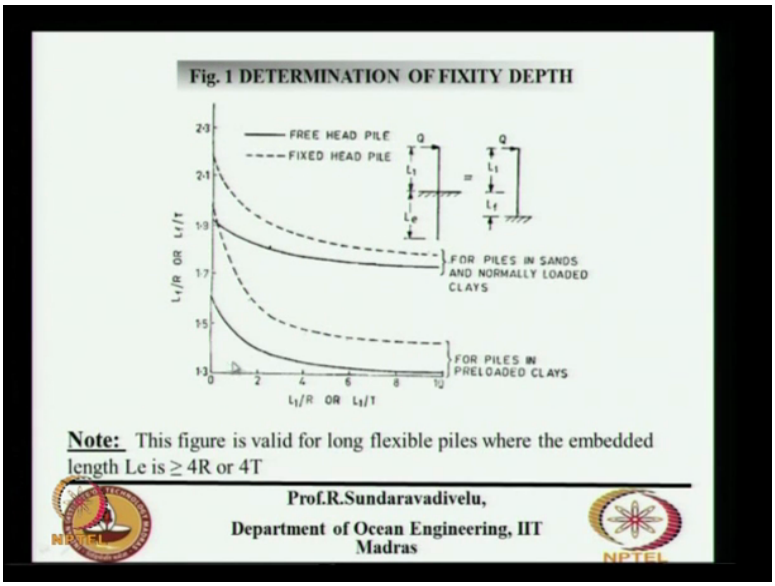

Then there are two figures which are given. One is this continuous line, that is for free head pile. Another one is a dotted line which is for fixed head pile. This is for sands and normally loaded clays. And this is for piles in preloaded clays. Preloaded clays means already there is some weight on top of this. So we have two sets of curves. The one set of curve is for sand and normally loaded clays. Another set of curve is for preloaded clays.

And in each set we have two curves. One curve is for fixed head, that is this is a fixed head, that is for free head. Fixed head means what I have drawn here, this is for fixed head. Free head is just like a cantilever. So the beam depth is very small what is connecting the pile, then you can call it as free head. Then the x axis is L1 by R or L1 by T. Y axis is Lf by R, Lf by T. So the figure is given here. L1 is the unsupported length. Le is the founding length and Lf is the virtual fixity. This is your seabed. So L1 is your unsupported length.

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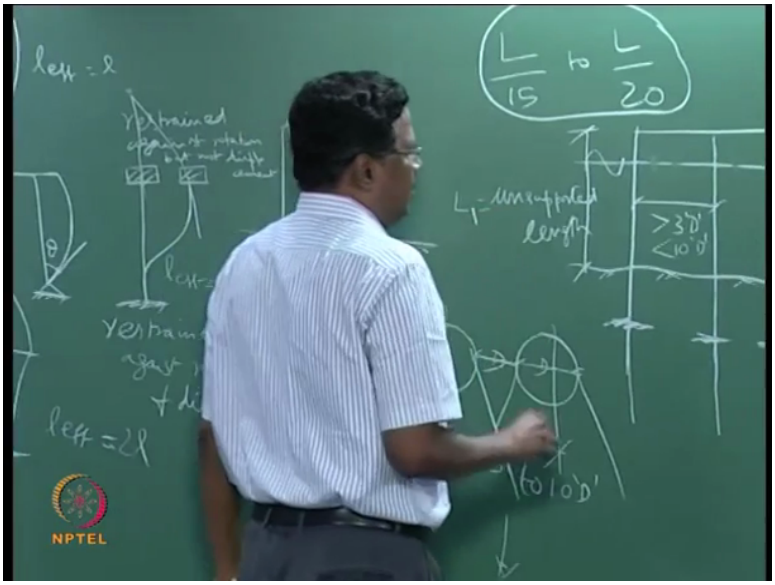

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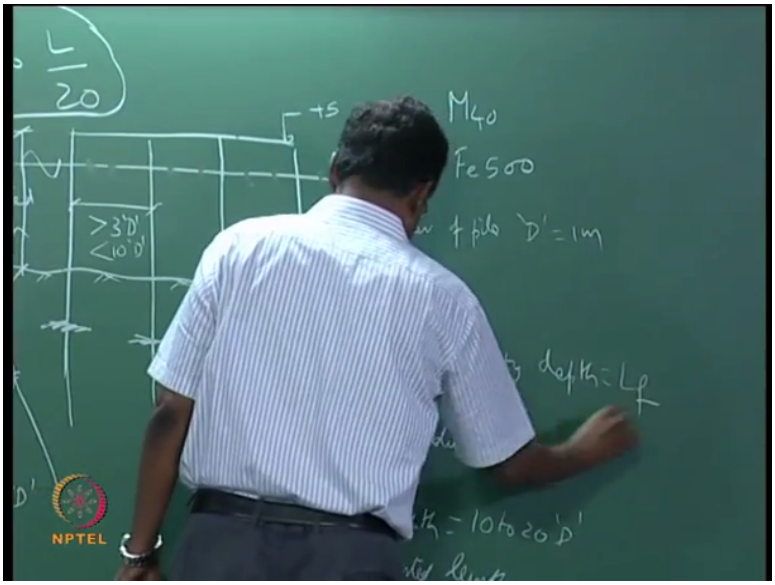

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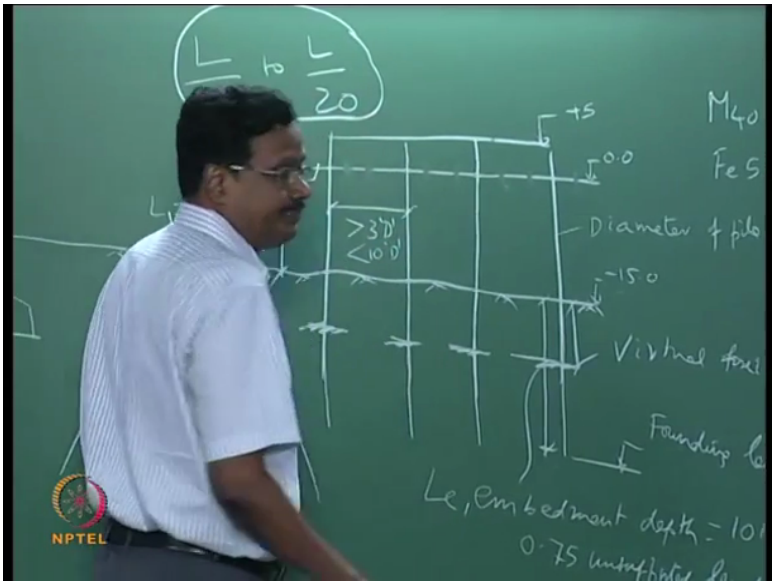

This is L1, this is Lf. This is Le.

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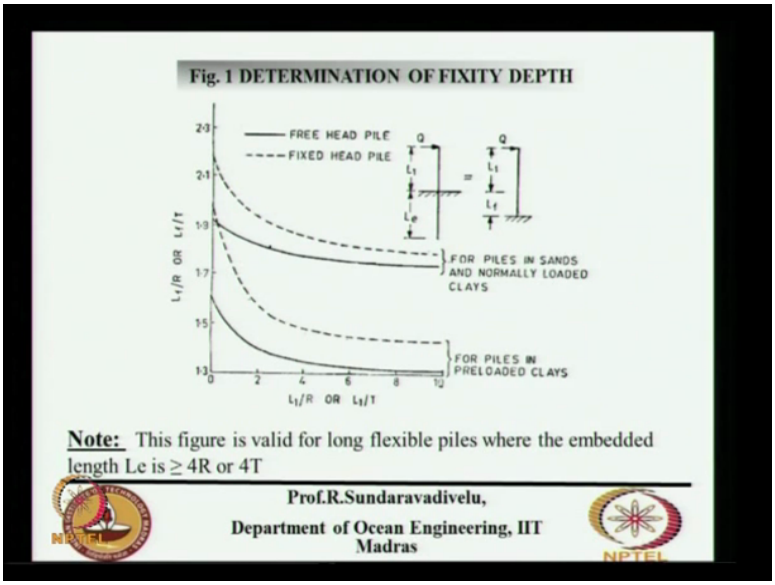

So whatever factor you are calculating R or T, from this what is that you know in this curve? X axis, L1 by R or L1 by T. Y axis, Lf by R or Lf by T.

"Professor-student conversation starts."

Professor: What is known and what is unknown in this? Everything is unknown? What is known?

Student: R and T value.

Professor: One by one and tell, what, there are about 1, 2, 3, 4, 5. Uhh, 1, 2, 3, 4 factors are there. 4 variables are there: L1, R, T and Lf. Out of these four how many of the things you know?

Student: Lf is unknown.

Professor: Lf is the only unknown. L1 you know, that is unsupported length. R and T, you can calculate. R and T you can calculate once you know the soil parameter and the pile diameter.

"Professor-student conversation ends."

So suppose you calculate L1 by R is equal to 4. Let us say L1 by T is equal to 4. Then you have to go to this curve and if it is a fixed head pile, L1 by R is equal to 4, Lf by R is equal to very close to 1.9. Lf by T, so Lf will be 1.9 times T. Okay. Is it clear? Once you know this T and L1,

let us say L1 by T is equal to 4, then you go here, go to the fixed head pile and corresponding to this you find out what is your Lf by T. That is equal to slightly more than 1.9.

So this figure is valid for long flexible piles where the embedded length Le is greater than 4R or 4T. So this embedment length if it is greater than 4R or 4T, then only this figure is valid. Otherwise it is not valid. Okay. So let us see one problem.

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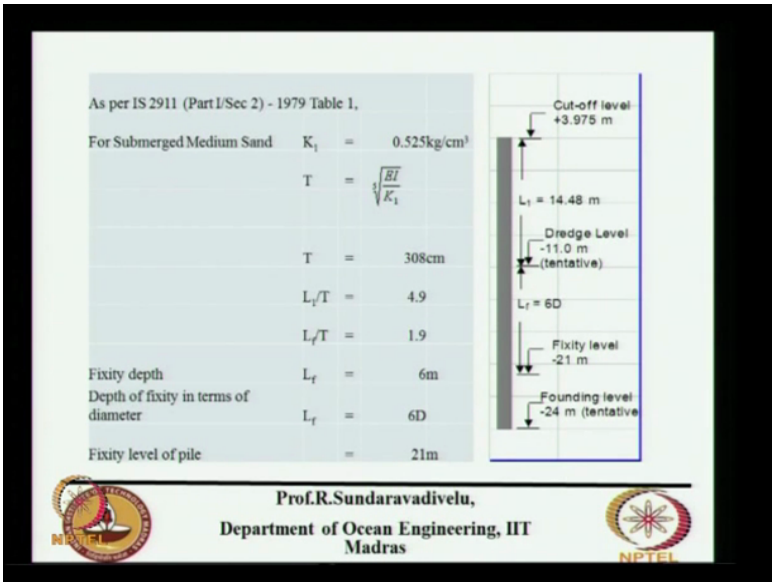

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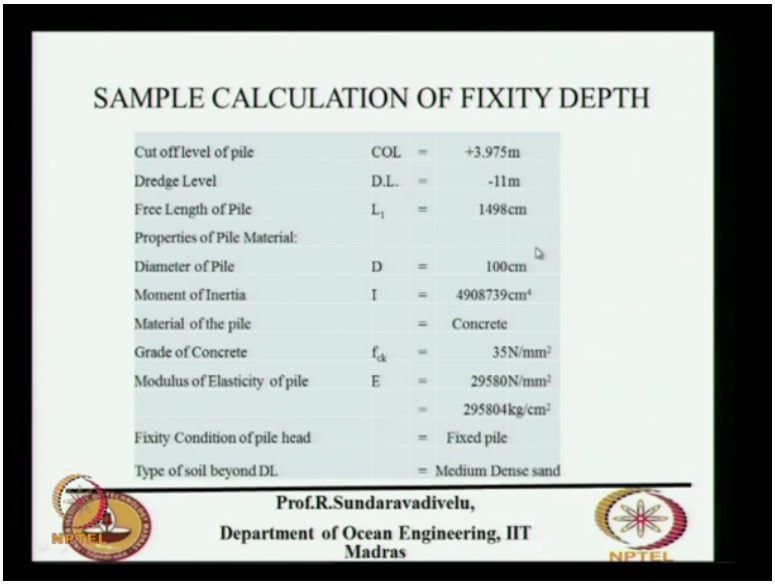

The T is coming about 3 meters for this problem. Diameter of the pile is 1 meter. So we will discuss about this tomorrow's class but for example I am telling for a diameter of pile 1 meter, T is coming 3.08 meter. L1 by T is 4.9. Lf by T is coming 1.9. So 1.9 times 3.08 becomes 6 meter. So depth of fixity in terms of diameter of the pile comes to 6D. That is what we are giving. So here the cut-off level of the pile is 3.975. Dredge level is minus 11. So this is your unsupported length. The founding level is minus 24. 11, 24 means 13 meter is your embedment length.

You calculate the fixity depth using this formula. It becomes, what is the diameter? 6D is, something wrong here. 6D means it is 6 meter. 6D means it should become minus 17 only. That is a mistake here. This should be minus 17. So this is the virtual fixity depth. This we will see in the next class.