Geotechnical Engineering II / Foundation Engineering
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Lecture - 60
Summary

Good morning and now, I have reached at the end of this course and of course, I have discussed several topics now and I will summarize today that actually, what are the important points actually, you have to go through. There are several chapters we have done and each chapter we have discussed quite elaborately, but what are the highlights in each chapter. So, I will just mention here, so that you can give importance to those areas to prepare for exam.

And I have started with some introduction and then some review on soil mechanics and then I have started with shallow foundation bearing capacity, shallow foundation settlement, then I have done actually soil exploration and geotechnical investigation, then we have done perhaps deep foundation, then we have done earth retaining wall, then we have done some seat firewall, then we have done deep excavation a (Refer Time: 01:34), then we have done introduction to machine for (Refer Time: 01:37) These are the topics, we have completed as I have desired.

And now, I will just chapter wise, what are the important things one has know, you have to go now, you have to go through carefully for preparation of the exam I will just highlight one by one.

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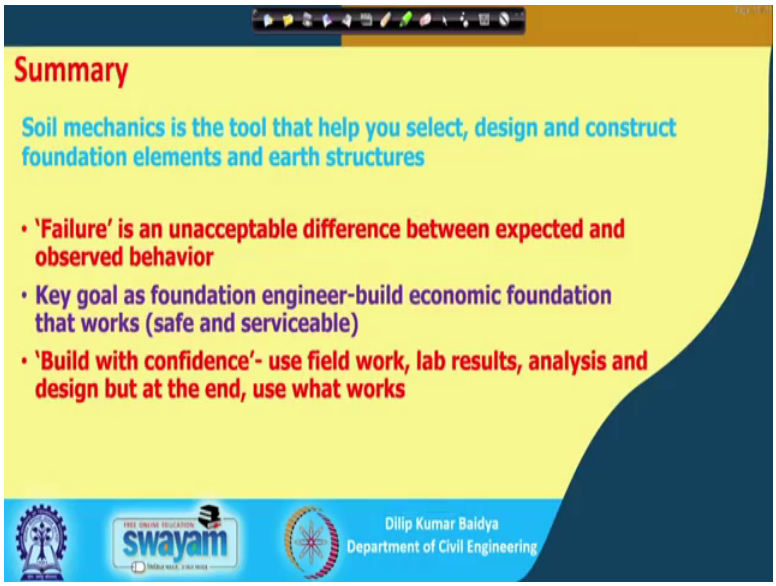

First of all, first slide I am showing here that some conclusion about the foundation engineering, that is repeatedly I say that soil mechanics is the tool that help you to select design and construct foundation elements and earth structure. So; that means, soil mechanics behind it will be there though it is not required, but without soil mechanics you cannot step into foundation engineering.

So, one has to be thorough in soil mechanics first and if you are not done soil mechanics do not jump into this course, it will be difficult. So, soil mechanics is the foundation for these foundation engineering that is what I say and another important thing from the foundation thing is I want to highlight that failure is an failure means what exactly ok. So, foundation fails when we say it is a failure occurs. So, failure is an unacceptable difference between expected and observed behavior.

That means what? I designed for a foundation settlement of 20 millimeter and if I observed that its a 40 millimeter; that means, it has to be considered as a failure, it is not acceptable. If your settlement is 15 millimeter which you have designed for 20 and if the settlement is 15; that means, your design is within the satisfactory and if you find instead of 20, if you find 40 50 or even more, then this can be treated as failure; that means, the failure is an unacceptable different with difference between expected and observe behavior.

So, expected behavior is 25 millimeter settlement, observed behavior is a 50 millimeter settlement. So, that difference is unacceptable, so that is called failure. Similar to that I can call, I can say same thing in terms of bearing capacity or any other things and key goal as a foundation engineer is a build economic foundation that works, that is actually, what actually; that means, what you have to design a foundation economic that you have to look for economic also, if you make a very massive structure definitely it will be workable, but if you make going to do that then it may be too expensive, that is also not a desirable.

So, you have to make economic foundation and that will be safe and serviceable. Safe means; it will stand and it will stand for expected life. So, that means, sometime we to carry out to different analysis, carry out different investigation, but finally, you have build something used to work that is what I want to, you may do some apply your judgment or experience.

And so that based on calculation it is coming something, but still you are giving something based on your experience, because otherwise it will not work. So, that is what one thing one has to learn through practicing foundation engineering. Built with confidence, use field work, lab results analysis design, but at the end use that works; that means, what actually I have already, I have mentioned that point; that means, built with confidence.

That means, you have to do several types of work field work, lab work, analysis, office work, but ultimately you have to build that has to that work actually that is a main objective actually. You may do anything, but and some time you may not finally, may not take, but whatever you have done based on that you gain some experience that to be use and design something, which will be that will work.

So, these are actually overall conclusion about foundation engineering that you have to do many things, but ultimately you have to do, your judgment or experience all those things to very-very important.

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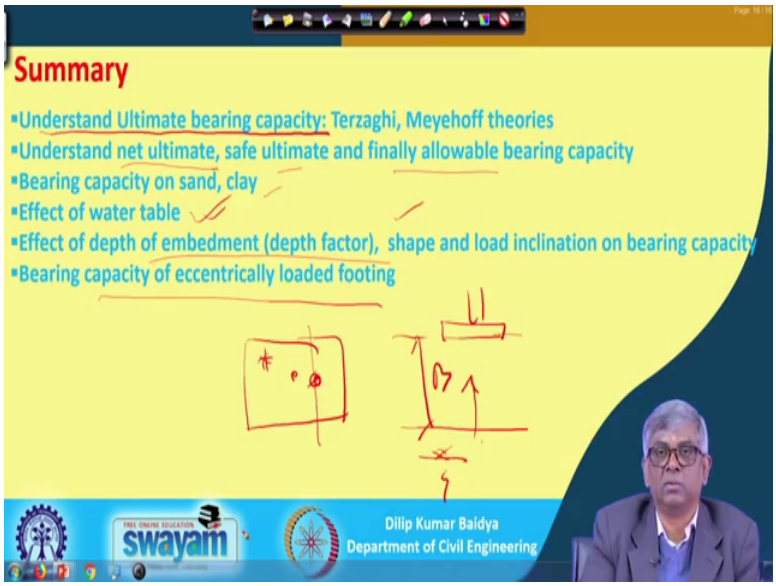

Now, will go look at, the chapter one that what we have done, bearing capacity and shallow foundation. We have to very carefully, you have to learn that ultimate bearing capacity, that bearing capacity theory by Terzaghi and Meyehoff how? What are the differences between these two theories and how bearing, ultimate bearing capacity is expressed and then that three component; one is the cohesion component, searchers competent and (Refer Time: 06:42) component that is cnc gamma nq gamma d n q and half gamma b n gamma; how they have derived that process; one has to learn.

Of course, detail derivation is not necessary, but understanding is required, what are the different failure? How is the failure takes place below the foundation, what different zones form? All those things to has to be one, one has to be familiar with once you are becoming foundation engineering. Then you have to understand different terminologies actually, it is net ultimate. Ultimate; that means, you apply pressure on the footing initially, low pressure is taking.

If you slowly increase at some time, it will fail. When it fail that is called ultimate bearing pressure and then there is a net ultimate, then safe ultimate then finally, allowable actually. So, these are the terminology, I have discussed. Ultimate minus gamma times (Refer Time: 07:39) is the net ultimate and if you provide a factor of safety to that then it become your safe ultimate and then finally, if you add there a finally,

gamma d that become allowable pressure that is actually, bearing capacity will be used as a for design.

Similarly, bearing capacity on sand and clay; so general bearing capacity will be derieved when finally, you have to modify it, when it is a sand, when it is a clay, what will be the bearing capacity? Again effect of water table; that means, while deriving the bearing capacity theory, we assume that water table will be below B, below from the base of the footing ok. So; that means, if your footing is here then you consider water table beyond that this is B; so water table somewhere here.

If water table goes here then how bearing capacity changes that the effect of water table, one has to land very carefully; then effect of depth and so once knowing the Terzaghi Meyehoff, then later on basic and other people what they have given. They have introduced a further different inclination different factors; depth factor, safe factor, inclination that has to be also learned carefully and bearing capacity eccentrically loaded footing.

That means, if the footing is there, then if I apply load here then it will be having a uniform pressure, but instead of here, if you load is applied somewhere here or load is applied somewhere here, is eccentrically loaded; then there are different ways to handle this one. So, that also we have discussed one has to learn that ok.

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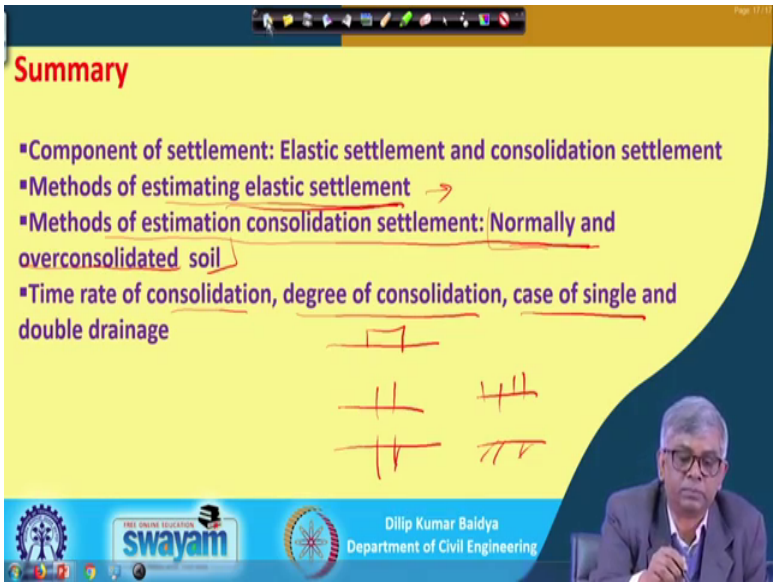

Then settlement chapter actually, if I consider the total settlement of foundation, that will consists of so many things actually; elastic settlement, then consolidation settlement, then secondary, settlement and we have discussed in detail about the elastic settlement. Again elastic settlement by different methods and then consolidation settlement and consolidation settlement and you can see that method of estimating elastic settlement, whatever we have discussed Markman method that has to be learned carefully.

Method of estimation consolidation settlement, when you do consolidation settlement, again a soil can be of normally consolidated or it can be of over consolidated. So, in that case two different types of formula, we have derived that has to be also learned carefully that application may be there during exam.

And consolidation settlement again elastic settlement is immediate you know, but consolidation settlement generally takes over a period of time and we have to find out also that how long the consolidation should take place. So, for that we need to understand that time consolidation, degree of consolidation and then using the degree of consolidation, you need to predict that time of achieving certain degree of consolidation.

And considering a single drain; that means, a soil comprisable layer here and foundation is here, that if it is a double drain analysis is something and if it is a single drain; that means, this is restricted only one side then time will be different; so that also one has to

learn careful. This is nothing, but application of soil mechanics here, purely application of soil mechanics this chapter.

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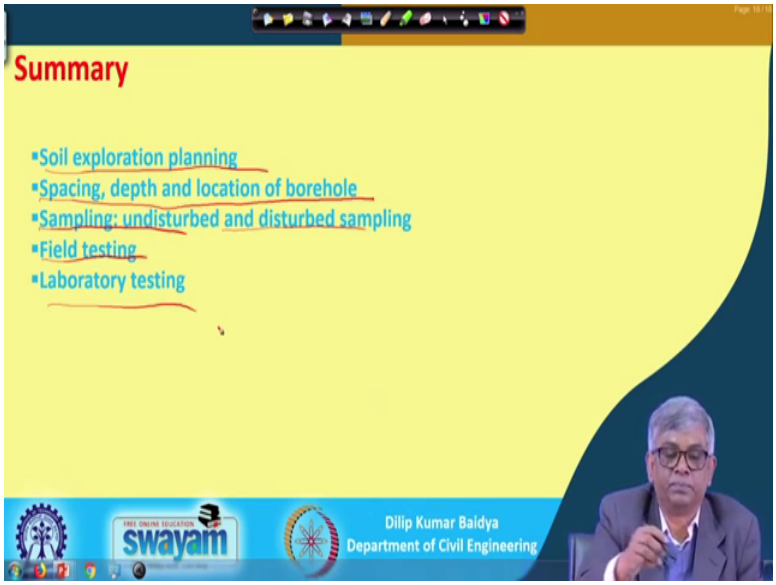

Then we have discussed about the soil investigation, the soil exploration planning; we have given how frequently, you have to do soil borehole, at what depth, what is the spacing, what is the location, all details we have done. So, those things to be has to be one has to go through carefully. Those are important and then borehole is one part that to see the stratification and the during borehole, making borehole, advancing borehole; what you do?

We collect sample and carry out also field test and when you carry out sample, sample can be of disturbed, sample can be undisturbed. How to collect disturbed sample? How to collect undisturbed sample? How to collect disturb sample? There are procedures, we discussed that has also has to, one has to learn carefully.

And then there are different field testing, we have discussed, there are different laboratory testing, also discussed that has to one has to go through in detail. So, particularly field test in foundation engineering, what are field test, we have discussed like a SPT CPT and your (Refer Time: 12:33) those things, one should go through for solving the problem.

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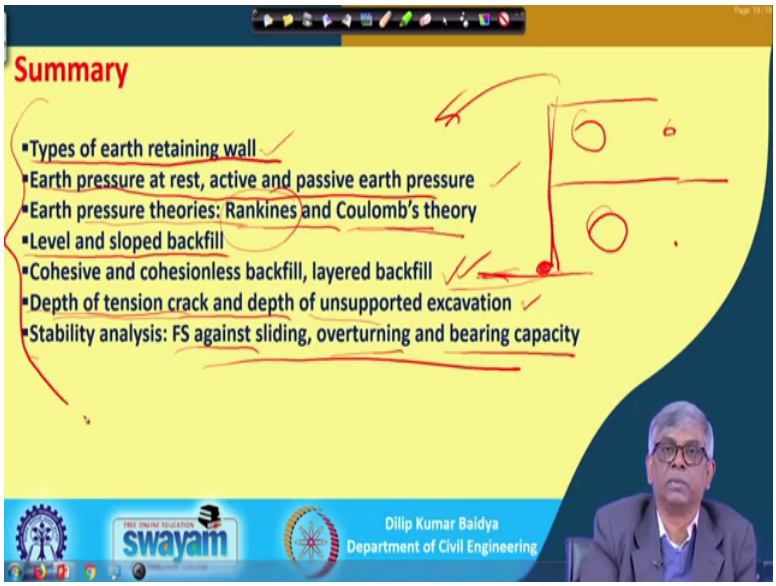

Then we have discussed earth pressures actually and while earth pressure actually; first, we have what is the use of determining earth pressure, because earth pressure is required to design the retaining wall, earth retaining wall and so at the beginning, we have discuss different types of earth retaining wall.

So, gravity wall, cantilever wall and then internally stabilized, externally stabilized, the gross definition, division and then afterwards, we have done again different types of retaining wall; one is cantilever, then gravity retaining wall (Refer Time: 13:25) wall then gabion wall and how they are actually we have discussed.

Then when you have a retaining earth retaining wall, what are the different types of pressure develop; one is earth pressure at rest that when there is a no moment of wall and then active; that means, when the wall moves away from the backfill, that then pressure will be released and when just before failure that what is the minimum pressure develop that is actually active pressure at, activate earth pressure.

So, that is actually one and then again if the wall moves towards the backfill, then pressure will be increasing and it will be increasing and just before the failing, it will be reaching to the maximum level and that maximum pressure is called a passive earth pressure. So, those things we have discussed; how to determine active pressure, how to determine earth pressure at rest, how to determine passive earth pressure.

Those procedures, we have discussed and in that we have discussed Rankine's and Coulombs theory, you need to know, what are the difference between Rankine's theory? What is the different and Coulombs theory. Actually, Coulombs though more versatile, because it has considered sloped backfill and sloped wall and then friction between the wall and soil, all those things that is considered, but because of the simplicity mostly, we use Rankines theory and I have also discussed in length about Rankines theory in this course and you should go through that.

Then initially, we have done most of the analysis for level backfill. If the backfill is sloped, then how to modify that we have also discussed; then the earth pressure again for cohesive soil, cohesion soil, that if there is a backfill mostly will be used to cohesion less soil, but sometimes it is a cohesive soil is there which is not desired most of the time, but if it is there then how will be the pressure diagram.

And sometime there may be two layers to; so, this is a retaining wall and backfill maybe this is one type of sand this is another type of sand two different sand layers maybe there or it may be sand here, clay here or clay here, sand here like the layered backfill also can be there. So, all those things we have discussed, you should must go through.

And then when there is a backfill is clay, then what is the depth for tension crack and what is the depth maximum depth of unsupported cart, there also we have discussed by following these earth pressure theories.

And then finally, after knowing all those things earth pressure theories and all, then we need to analyze stability analysis what the of the retaining wall have to, one has to do. And for stability analysis earth wall retaining wall means what? You have to find out the factor of safety against sliding, factor of safety against overturning, and factor of safety against bearing capacity. That means, if you want to design a retaining wall then what you have to do?

We can assume a dimension of retaining wall and then based on the dimension of retaining wall and backfill soil, you have to calculate all the forces and after knowing all the forces, then we can carry out that analysis whether it is stable; stable means what? The different different kinds of failure can occur for retaining wall.

One is overturning, that when this wall you can rotate along these and overturn or this wall can slide along this base, because if the pressure is excessive, it can slide or because of this loading the below the foundation pressure become more than the actual bearing capacity of the soil, in that case you have to modify; so, that analysis has to be done. So, these are the actually earth pressure theory. So, different things we have discussed, one has to go through these are the important parts of it.

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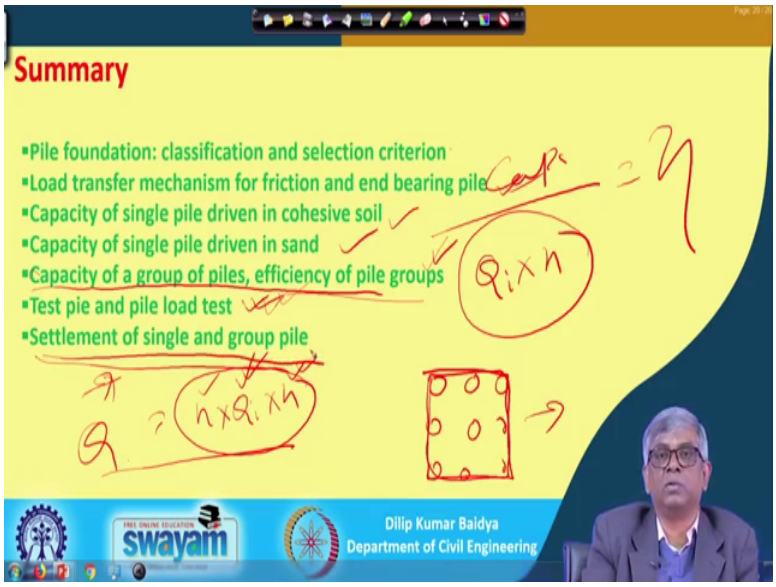

Next one actually was pile foundation and in the pile foundation you can see there are several topics we have discussed; first of all we have classified the piles. Different types of classification based on materials based on function, based on material, like concrete pile, wooden pile, steel pile. If it is a function that it is actually, whether the friction file or it is a end bearing pile.

So, like that there are several types of classification we have done and then we have done load transfer mechanism; that means, if I applied if there is a pile and if I apply a load here and then how that are load distributed over the depth of the pile and that has to be when is the friction pile distribution is something, when is end bearing pile distribution is different and when is a partially friction, partially end bearing that distribution again another type.

So, that load transfer mechanism one has to see that I have discussed, then after knowing all those things then we need to learn actually how to find out the capacity of each pile

and so, initially we will do for single pile and for single file when the driven in clay we can estimate the capacity. One single file driven in sand also you can find out estimation of the capacity.

So, these two cases; that means, pile driven in sand, pile driven in clay how to estimate the load that these are actually important this to, one has to learn. And we know that that pile foundation really will be used as a single piles, most of the time a group of pile will be used for supporting the structure.

So, because of that capacity of the group pile also essential and there actually efficiency of the group pile, also is there is the term that we have also discussed capacity of the group piles and efficiency of the pile; that means, that one has to learn.

So, if the capacity of the single pile is Qi and multiplied by n that become the suppose, to be the capacity of the group pile, but actual capacity the group pile maybe less than that. So, this that capacity divided by these actually, you are efficiency. So, that one has to learn and while calculating the capacity of the group that can be of two different ways, can we calculate, if the spacing is very close then suppose like this, spacing is very close, then the pile may fail as a entire as a block.

So, block of dimension these and length of pile equal to the length as a entire block can fail, based on that one can find out group capacity that is block capacity. And another actually calculating the efficiency of the pile depending of the spacing and all there are some efficiency formula we have given. So, efficiency multiplied by individual pile multiplied by n based on that that you will get another group capacity and that is also called based on individual pile failure, because we have calculated individual pile capacity multiplied by n and then multiplied by efficiency.

So, one is actually based on individual pile failure, then use this problem find out capacity and based on block failure find out another block capacity.. So, these two capacity we are getting for the group, but ultimate recommended capacity of the group will be lesser of this two. So, this one has to learn very carefully. So, I have done a number of problems also. So, so these things, so you have to do and then a test pile and pile load test.

Generally, based on site investigation whatever soil parameter we get, at based on that soil parameter, we generally access the capacity of the pile foundation and then some time there may be error in estimation in soil property or some other problem. So, because of that to make sure, that your capacity is the correct capacity, we have to do a test in the field. So, one of the pile actually can be tested or maybe one or more piles can be tested to assess the capacity of the pile.

So, there actually testing procedure, how to carry out the test; we have discussed that actually, if the capacity of the pile is 200 kilo Newton, then you have to apply, you have to go up to 400 double and load will be applied in 25 percent of that and then you have to go up to the maximum load and then you have to unload it by step and then this loading unloading based on loading and unloading time.

During loading and unloading time you have to observe settlement, then pressure versus settlement you can plot and using those actually you can predict the capacity of the pile. And that actually one has to do, test pile and by doing test file; what are the advantages we get? What are the information we get? What are the additional information we get?

One we have discovered that can be it is, one has to go through and finally, settlement of single and group pile again like cello foundation will undergo settlement, then group file also will undergo settlement, but pile foundation generally settlement range is less. And to reduce the settlement most of the time we go for pile foundation it will be less, but how less or sometime pile foundation this limiting settlement also less.

So, whether finally, you are reaching to that level or not that to be verified. So, there are different settlement calculation procedure also, we have discussed, one has to go through that also carefully.

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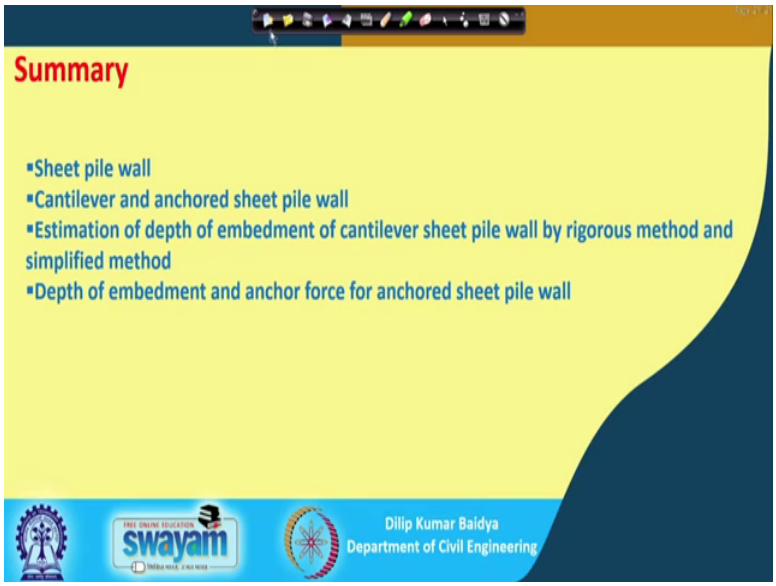

Next one was a sheet pile wall sheet pile wall again, it is a quite lengthy and rigorous thing and there are method of analysis, also rigorous method or single pair is there. Though, I have discussed rigorous method for one case, I have not discussed for other cases and finally, I have tried to adopt the modified, a simplified method and one has to go through that.

And retaining wall sheet pile wall can be of two types; cantilever sheet pile wall, when there is cantilever sheet pile wall, you have to do some analysis and then you have to find out depth of embedment required for stability purpose and that is another kind of sheet pile wall that is anchored sheet pile wall.

When anchored sheet pile wall, then two things to be obtained; one is a depth of embedment is required and the anchor force, these two things to be required. So, that actually we have discussed and one has to go through in detail.

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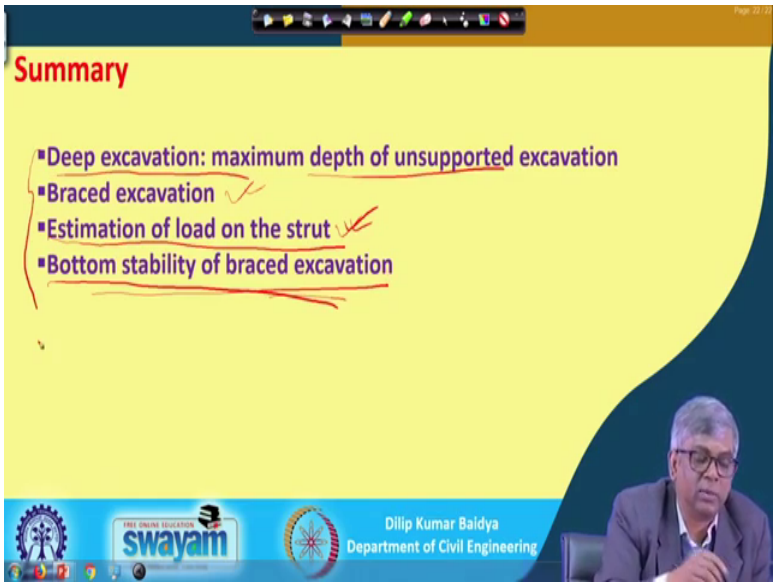

And next one is, actually deep excavation and there actually, while discussing earth pressure theories, while discussing earth pressure theory we have shown that depth of tension crack and what is the depth of unsupported cart and that is the limit actually.

We can excavate without any support, but there are various requirement, where we need to excavate much deeper. And in that case what you do you generally support it and then go for excavation and then if it is a; that means, braced; that means, supported excavation when you do then one has to design the support system.

So, for the support system there are some recommended pressure diagram is given for different soil type and using those pressure diagram and you can find out the, there are some model also, how to analyze. And it is if there are a number of supports are there it will be assumed like a beam supported or number of supports and if it is a continuous beam. Generally, it will be indeterminate, but to make it determinate we consider each support point is hinged and that simplified analysis we have discussed, because it is most of the time temporary. So, because of that that type of analysis maybe enough. So, we have done that and you should go through properly.

And same thing again, when you do deep excavation and, because and of some reason the bottom may become unstable. So, to mix that stability analogy one has to do; that means, how, at what level you have to give support and how much you can excavate that

stability analysis of the bottom also is done, one has to also go through. So, these are the important things under this chapter.

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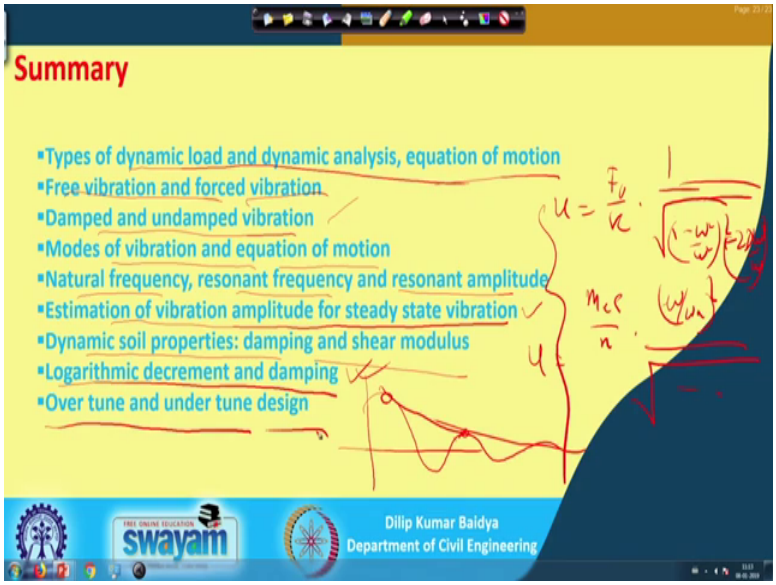

And last chapter, we have discussed actually that the machine foundation, I have introduced very deeply and you can see here that I have first types of dynamic load, a dynamic analysis, equation motion, I have discussed then free vibration, force vibration.

What is that I have discussed, that damped and un damped vibration, that when damping is considered that is called damped vibration and when damping is ignored undamped vibration that also we have discussed.

And modes of vibration and equation of motion that is actually only for understanding that., if it is a block then it can have of 6 degrees of freedom; that means, it can have vertical, it can horizontal and it can have rotation like these and it can have rotation like this. So, like that we have different degrees of modem, motion and if it is a different degree of motion, corresponding equation of motion also, I just for understanding I have given. It may not be important for exam, but it will be I have given.

And then what is natural frequency, resonant frequency, resonant amplitude, that also while discussing theory we have discussed. Estimation of vibration amplitude, for steady state vibration; that means, we have given that equation u equal to f naught by k and 1 by

under root 1 minus omega over omega n square whole square plus 2 d omega over omega n whole square.

So, this is actually equation for steady state vibration amplitude and another is me into e by m multiplied by omega over omega n whole square divided by same thing that is another equation. So, estimation of vibration amplitude for steady state vibration that is the one we have done and this one has to practice thoroughly. And dynamics soil properties damping and shear modulus how to determine that also I have discussed one has to go through.

And logarithm decrement and damping; that means, using logarithmic decrement, one can find out the damping; that if the response actually that way actually, this is called logarithmic decrement. So, ratio log of ratio of s successive peak is called logarithmic decrement and using that we can find out the damping of the soil that one has to learn properly.

And then what is overtune and what is under tune that also I have discussed. Overtune means what? Natural frequency will be more than the operating frequency. Under tune means; natural frequency will less than operating frequency; so these things also we have discussed. These are the basic minimum information required for machine foundation, that also I have discussed.

And with this actually, I just close and I hope for whatever way I have given you and I have solved the problem. While solving the problem, I have just problem, I have kept in the in the power point, but solving I have done by hand. I am not printed and given you the in the power point that is actually otherwise, if I keep printing you may not go through or listen the solutions step.

So, with that purpose actually, I have written the solution by hand instead of giving in the printed form. That is the way actually, if you follow me while, I am solving it will help you to understand the steps. So, and if you cannot understand in the ones then you can repeatedly see and then to understand; so I have not purposely actually, I have not given that.

Otherwise, I have taken a large number of problem for each topic and I hope it will be helpful to understand foundation engineering by this course and in between while, the

this one will be running; obviously, you have some procedure or provision to send question and queries, which I will be responding regularly.

And in addition to that I may arrange some online interaction one or two session I will make, where I will be present here directly, your question your question I will be receiving and replying immediately that also I may do that and I hope for with all those, it will be helpful and if it becomes helpful definitely, I will be very much happy. Thank you all, I will stop here and wish you all the best and for this course.

Thank you.