Geotechnical Engineering II / Foundation Engineering
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Lecture - 08
Foundation Engineering Introduction (Contd.)

Once again, let me continue to your previous lecture what we are discussing, that was basically steps in foundation design these are of course, qualitative steps, actual step you have not discussed yet these are all qualitative. What we have to do that I am giving you some idea and we have examined most of the steps and now I will last steps actually perhaps left and that I will discuss let me go to the next slide.

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And, you can see that I have listed right from beginning actually from 6th lecture onwards and I have discussed one by one these these these all those things I have discussed. Now, this is the one monitor design construction and performance. And, basically based on so, so many observation, and inspection, from report will be submitted and then based on that report actual design will be there. So, while designing also one has to have some monitoring and also during construction also should have monitoring, also after construction also when it will be in the opened for service and their also you have to have some monitoring.

Why the monitoring is necessary? Because, we have design with some expectation that this will a perform like this, but it may not perform accordingly. In that case actually a may not perform. So, may or may so, that to make sure that you have to have some monitoring arrangement and you have to see that; that it is performing properly and if it does not perform then; obviously, you have to do some corrective measure even after construction also. So, these are all finally, in the form of summary I will of these whatever we have discussed I will see in the next two slides.

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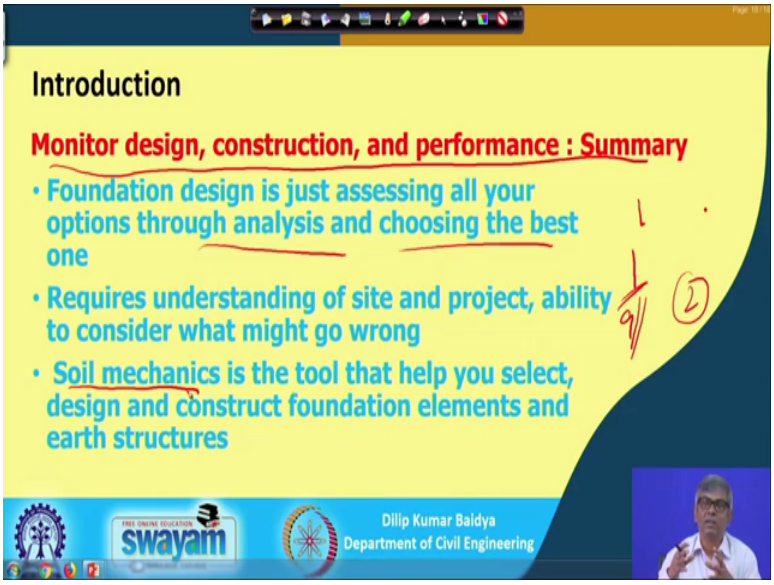

You can see under this monitor design constructional performance in the and together I can say the summary of this entire 2 3 lecture I will just put together. And, that foundation design it just accessing all your options through analysis and choosing the best one is it not. So, as I have mentioned that you may have different site condition, you may have different soil properties, you may have different loading condition. And you may have different contractors, it depends material availability, all those things to be considered and then finally, you may have a several options and finally, you have to choose the best one.

So, that is what foundation is a just assessing all your option through analysis and finally, choosing the best one. And, for these actually you request to understand the site and project and ability to consider what might go wrong; that means, while doing all those things and while taking the several option you need to know that if I do what is the benefit and if I do what is the harmful or difficulties. So, in that like that for each or options you know to know that you need to know that. Sometime some option you may have 9 or 10 positive points and 2 negative points. And there may be some aspect alternative there maybe 50 50. So, we have to then you have to choose accordingly which one give you best benefit. So, that is a one you have to understand until you will understand entire site and project then it will be notable do judge this one.

So, you have to what might go wrong based on certain selection that also you have to visualize so, this is another point. And, this also I have told again and again that soil mechanics is the tool, that will help to select, design, construct foundation elements and art structure; that means, whatever a foundation design; that means, whether it is a art structure art pressure art (Refer Time: 04:27) structure, whether it is a pile foundation, whether it is a shallow foundational, whether it is a some other type of foundation wherever you do ultimately you have to apply soil mechanics.

So, that is what the soil mechanics first of all you have to digest properly until always you do that then you will not be able to become a successful foundation engineers. So, these are the things to be noted.

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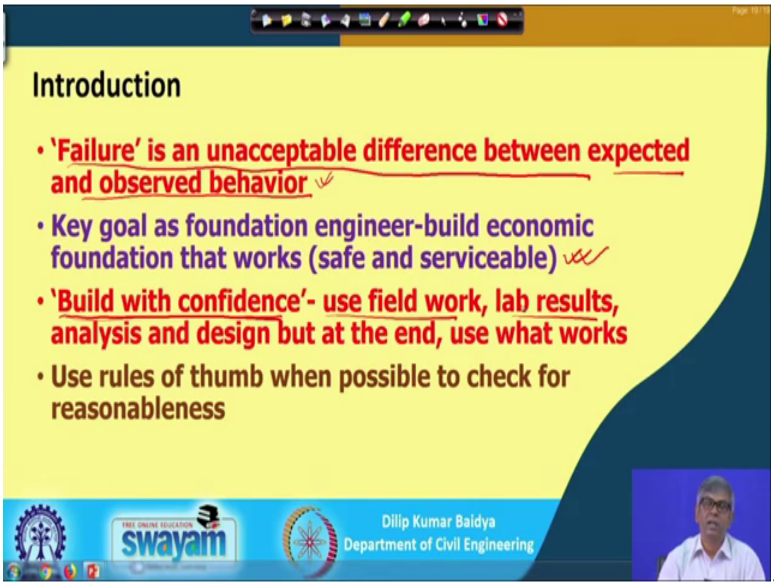

Next part is that this is very very important, you can see the failure is an unacceptable difference between expected and observed behavior; that means, we have designed something we expect something it will perform this way. And, after construction whatever observe the difference, whatever expected and whatever observed if they are saying that is a successful design, but whatever expected and whatever you are observing they differ too much; that means, a failure.

And, this is the; that means, it did not always is failure and that difference become unacceptable; that means, if settlement is kept suppose 25 millimeter at settlement after 50 millimeter it is not stopping; that means, it is beyond our acceptable limit, that mean that consider as a failure. That is what failure is an unacceptable difference between expected and observed behavior and this failure should not occur actually.

Once you construct something facility for some purpose then that should not fail. So, that is our expectation. So, if it is fails actually you have to know the un consequences of that and should because of that you have to take extra precaution to make sure that foundation is sound and serviceable the.

So, that is a one part to be kept in mind. Key goal as foundation engineer build economic foundation that works, that is what I have mentioned few minutes back also or in the let us last lecture in fact, that you have to do several analysis and you have to do several investigation, but finally, you have to design or built something which will work; that means, if the design comes 1 meter, but I adopt something 1.5 meter. There may be some inside I have that 1 meter may not work thought it is giving you from the design that is giving 1 meter, but still I will adopt 1.5 meter or 1.25 meter while inside actually I will not permit 1 meter.

So, these are the things actually; that means, with experience you will gain this that key goal as foundation engineer build economic foundation that was; that means, safe and serviceable. That means, sometime best or design etcetera you may create a value, but you may adopt something else, because considering the safety of the system, you from the from your experience, you are feel that is not correct though you are getting from the analysis, but we that may be something else to be adopted that is also to be developed over time not by 1 day.

Build with confidence that is what; that means, use field work lab result analysis and design, but at the end use what works that is what whatever I have told you that you do analysis investigation ultimately so, many things, but finally, you have to adopt something which will work. And, sometime use rules of thumb when possible to check for reasonableness; that means, what is the meaning of it? That there are thumb rules in the particularly in civil engineering the if the field people actually know, what should be the minimum size or a minimum number this is known very well.

So, though it based on calculation you are getting certain values. So, by thumb rule actually you have to cross check that whatever it is there it is workable. For example, this reasonableness is very very important most of the time while teaching we have seen that, because of the some software many people are nowadays using the software for design purposes and that software actually adopt certain units. And, our pile parameter or material parameters also have a definite unit. Ultimately, if you do not give the input comfortable to the what software is taking, then your a result will be something and sometime it is 200 millimeter or 200 centimeter or 200 meter sometime most of the many time many a time students are not able to judge.

And, it happens many a time that the depth of the foundations some students are coming support 2 meter or 2.5 meter or 3 even 3 meter or 4 meter, but they do not know whether this 4 meter depth of the beam is generally not possible for the building.

Because, building height is maximum 2.5 to 3 meter 3 meter around 10 feets. So, that may that reasonableness; that means, you have to judge by some means, that whatever results you have got this is reasonable. That is somehow some may by some means you have to check and that is in the in the field actually particularly in civil engineering these are many thumb rules available by which one can make sure that whatever you are constructing there acceptable.

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Next actually I will enter slowly now foundation engineering really. So, far we have given introduction actually; that means, what are the steps and the out steps really is not a design step, they are all qualitative safe what you have to how will proceed that I have mentioned. Now, really I will I am entering to foundation engineering and this foundation engineering when we enter the first thing I need to classify the foundation type, one that one actually at the when you brought the classified it will come 2 groups. One is shallow foundation and another is deep foundation.

Then this is already in the introduction time a partly I have covered and shallow foundation general less expensive, and better for lighter structure or less problematic soil and that means, if the problematic soil will not be able do that. That is what that shallow foundation is applicable only less problematic soil, or even no problematic soil and your cost is; obviously, less and foundation is generally at shallow depth. And, typical types spread footings and raft mat that also I have given example in the previous lecture I have shown (Refer Time: 11:25) a sketch also.

And, deep foundation actually; obviously, it is I have also mention already that is a more expensive. And, typically used for heavy and stall structure; heavy and stall structure. So, maybe at end at a heavy and tall structure on more problematic soil not only that heavy and tall and even when there is a soil is problematic sometime pile foundation is the soil or deep foundation is the solution so, (Refer Time: 11:51).

And, typical type of deep foundation is ‘driven’ piles, ‘drilled’ piers and sometime castle and well foundation also comes under deep foundation.

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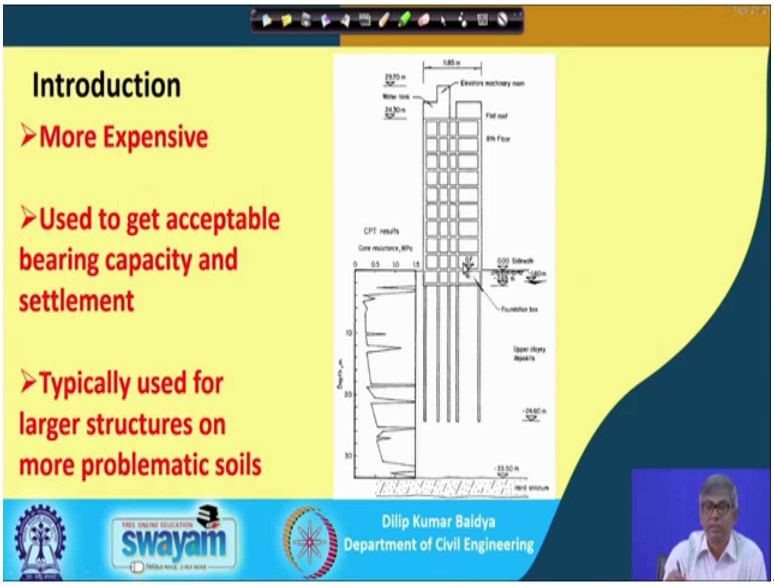

Now, this is deep foundation already I have shown once actually is more expensive and used to get acceptable bearing capacity and settlement; that means, if I built a shallow foundation for this building, then whatever a presser comes to the soil, that may exceed the bearing capacity of the actual soil. So, because of that that is one thing that two as two achieve acceptable bearing capacity; that means, you have to the long structure like this you have to drive, inside the soil. And when you will drive these structure, then it will have friction along the surface then maybe the tip there may be the resistance all those together. And, if it is a large number of them are there, then whatever capacity it gets the it may be the enough to support the entire building load.

So, that is why the used to get accepted bearing capacity another reason why you go for deep foundation sometime, if I adopt the shallow foundations such as building then you may see that the settlement of this building may be significantly high which is not permit permissible, in that case by adopting deep foundation we can restrict those settlement also. And a typical used for larger structure or more problematic soil I will already have mentioned.

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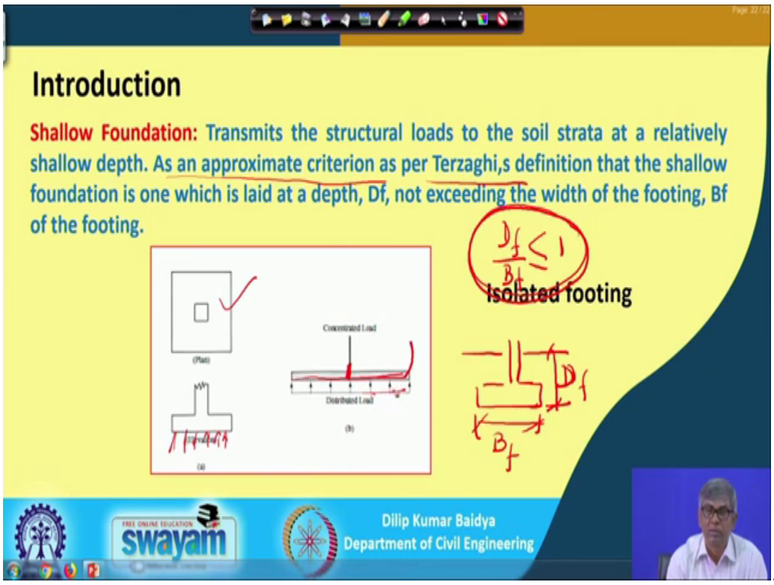

And, you can see shallow foundation the definition it is not a qualitative definite definition only a shallow foundation transmits the structural loads to the soil strata at a relatively shallow depth. And, most of the shallow foundation will be within 0.22 meter even less than 1 meter also possible. And, as Terzaghi gave and in a guideline as an approximate criteria as for Terzaghi definition that shallow foundation is one which is laid at a depth Df, that is if this is the foundation. If this is the foundation and this is the ground surface, that this is called depth of foundation D f. If the foundation is left laid at a depth D f and which will not exceed the width of the footing; that means, if this is B this is B f. So, D f over B f it will be less than equal to 1.

So, according to Terzaghi given definition that the shallow foundation; that means, your foundation will be laid at his depth D f in such a way that, it will not exceed the width of the footing. Then, that soil that one will be treated as shallow foundation and if it is exceeds around 15, then that is called deep foundation in between called moderate depth foundation. And, most of the foundation whatever I have mentioned that isolated footing, steep footing, rafts footing, combined footing, all are actually depth varying between 1 to 2 meter absolute depth you can say and really that is shallow depth. And, if I give a general guideline, that is actually D f by B less than equal to 1.

And, you can see that that isolated footing this is a planned view, this is the; this is the elevation; that means, this is the footing and this is the column. And when you do the analysis, then what will happen when footing will be there below the footing there will be earth pressure there will be pressure given by the soil. Because of the load in the column the soil will be registered load, that pressure will be there and it for the analysis purpose, we will take this foundation like this it will be a 1 point and there will be 2 this is the member like a you can assume that the beam is hold here at this portion in a cantilever with a loading downward.

So, accordingly this member can be designed. So, this is the footing plan and elevation and this is the idolization for analysis. And, this is called isolated footing, sometimes it is called spread footing, sometimes it is called pad footing as I have told before.

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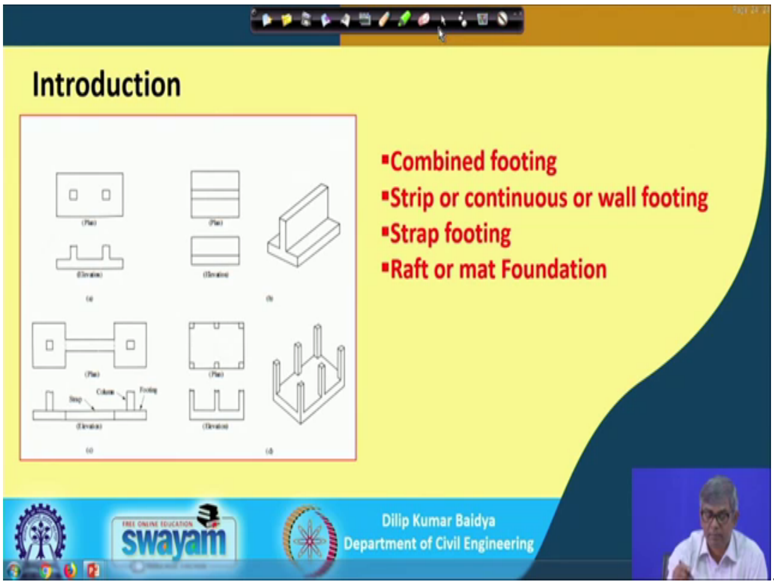

And, these are all other type of foundation you can see that this is the one as I have told you combine footing this is the elevation. And, this is the top view and this sometime the if your because of various reason, if the column does not carry equal load that mean then sometime your foundation may be something like this also trapezoidal also.

So, combine footing not only that it will be rectangle it can be of other size or shape also. And, this is the one that is strip footing that is of elevation and this is the front planned view; that means, this is the wall thickness and this is the width of the footing. And this is actually thickness of the footing and this is the wall continuation the elevation you are seeing and this is the side view; that means, from the side if you see from this side, we will say footing like this. And, then there is a this is called sometime called strap footing.

Strap footing is actually basically this two footing are isolated, but because of some reason unequal load and many other reason this two also will be connected by a beam like structure. So, that some load some balancing of load will be there. So, that is actually called strap footing, this is also a special type of combined footing. And as I have mentioned before that when many of the footings are connected by a single foundation that is like this, you can see these are the foundation plan and there maybe another footing here also column here.

So, all will have a common foundation that is like if you see the side view isometric view you see like this and elevation and planned is like this. So, that is called raft or mat foundation. So, this is combined footing this one both are combined footing strip or continuous footing this one, strap footing this one a raft or mat foundation this one.

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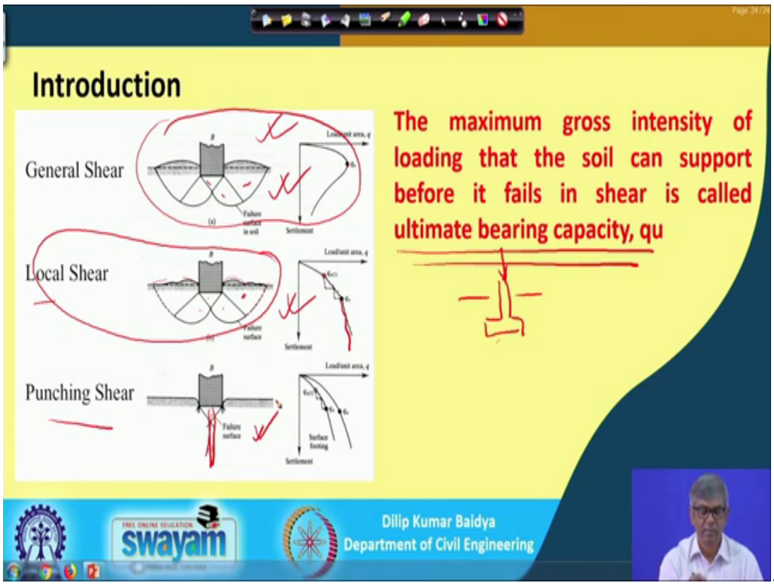

And, now actually when you will apply a load through a footing suppose there is a footing. And, if you apply load through these on the soil suppose if I apply load, then if I observe load versus settlement then you will see load versus settlement will get a plot like this. Not always there are different types of plots are available.

And, if the soil is having general shear; that means, the footing is loaded here, then it is also experimentally shown that the below the footing soil will be having like this 3 distinct zone 1 2 and 3 and there will be some little bit of heaving at the surface. And, so, and with the increase of the load, the within the soil this will happen and if you record load corresponding to settlement and if you plot then you will get like this. And what will happen that it will reach to a peak.

And, then it will be suddenly will give you large settlement without increase any load that mean that is failed soil failed. This type of failure is called general shear failure. And, the load at which that shear failure occur that is called actually ultimate load and the if it is converted into pressure that is ultimate pressure. The maximum gross intensity of loading that the soil can support before it fails in shear is called the ultimate bearing capacity or q u ok. So; that means, if I when the soil just fail just before the failure whatever the pressure is here that is actually ultimate bearing capacity.

Now, if this is the when loading load versus settlement if you see like this then that is called general shear that is mentioned by Terzaghi. Then, similarly in some soil if I load and then below the foundation you may have like this; that means, this two zone will be distinct, but this zone somehow it will not be distinct this will this failure surface will not reach up to the ground surface and this is heaving also at the surface will be broken. And when you will be record the load versus settlement then, we will see that it will go almost straight line. Suddenly reach a peak and again it will change the slope another; that means, there are number of failures will happen.

So, like that we will get then again it will be broken line it will continue like this. So, number of you will get a curve like this you will not you will not get a typical curve like this instead of that you will reach a peak one point. Then suddenly it will be reducing it will load will increase, but not at the same rate it will be lesser rate with settlement or more settlement with the less load.

So, that way will happen then finally, will be happening. So, this type of phenomena when we will observe, then that is called local shear. And, another type of soil when it will be actually overloading when there will be 3 zone like this it will not form and suddenly it will punch to the soil that is called punching shear and when you will find out the load settlement curve. Then, we will not get any peak no such peak we will get continuously it will settle and that is called punching shear. So; that means, when a the soil is loaded through a footing then soil can failed in different ways. One it can be failed by general shear, it can fail by local shear, it can fail by punching.

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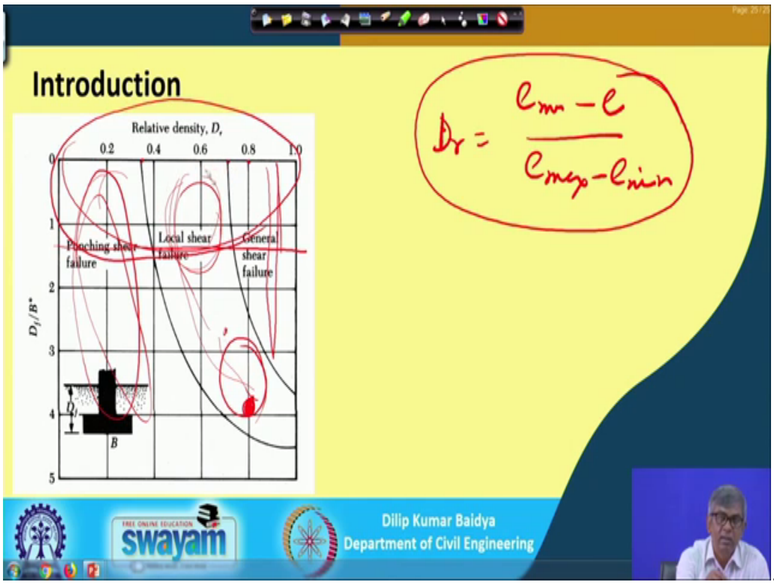

And, again this depends on some of the factors like what soil will fail in general shear, what soil will fail in local shear, what soil will fail in punching shear, there are some guidelines actually there are some investigation are carried out. And through the relative density of the soil this is actually clarified the relative density again is a part of soil mechanics, we have discussed the relative density D r actually relative density D r actually e max minus e divided by e max minus e minimum. That means, void ratio maximum or minimum void ratio and in situ void ratio if you know, then by doing this calculation we get a number that is actually relative density in percent.

And, you can see relative density plotted in this axis 0.2 0.4 0.6 0.8 1 means it is 20 percent, 40 percent, 60 percent, 80 percent, 100 percent and this side actually D f by B. And, you can see that the if the soil relative density become more than 35 percent, this one soil relative density is less than 30 percent it is expected that punching shear will punch because the entire zone is punching shear. And, if it is 35 to up to suppose 70 the soil with shallow depth may have local shear, but when depth is increasing then they may have of course, this is this is the zone actually where actually depth D f by B and relative density if vary in such a way this is the zone, if the soil come then that soil will have local shear.

And, if the relative density is more than 70 percent and D f by b in such that it vary between this, then entire zone will have the entire ah; that means, D f by B you have set in such a way and relative density is more than 70 percent then you will have the all soil will have undergo general shear failure. So; that means, you are though your relative density is 80 percent and D f by B suppose 4 though very dense soil, but still because of the that depth that soil may undergo failure by local shear.

Most of the time good soil good dense soil will have general shear failure, but it has of some relationship with depth also. If the depth by B suppose is very high like 4 or 3 then there is a chance of local shear failure also. So, these are actually otherwise you can see the relative density up to these means it is all punching shear from here to here this is actually and if it is a shallow depth one most of the time your; most of the time your shallow foundation is D f by B is one or in between.

So, if it; that means, if it I put like this then when relative density is less than 30 35, then you will have local shear if relative density is 35 to 70, then we will have local shear and 35 to 100 percent we will have general shear failure.

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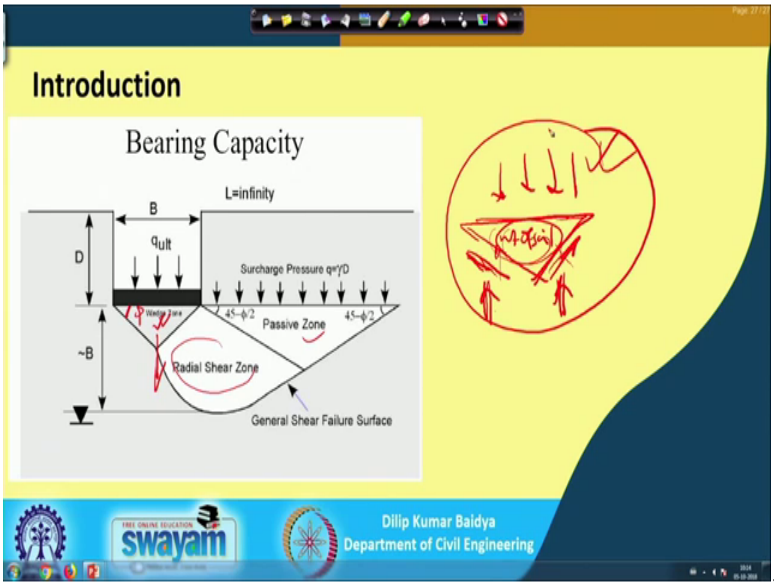

Now, this is actually finally, it is observed general shear failure is considered and it is modelled and then bearing capacity theory can be developed that is actually given by Terzaghi, that he has assumed certain thing the soil is homogenous isotropic and all and then several other assumption like water table is at a great depth.

And, based on that assumption he has given this model and if you see that there are sorry there are 3 distinct zones that is this is called wedge zone, or static elastic equilibrium zone, and this is called radial shear zone, and this is called Rankine Rankine passive zone. And, here actually as per Terzaghi suggested that this angle suppose to be phi and this angle suppose to be 45 minus phi by 2 and when will apply the load and then ultimately until unless this wedge goes downward then soil will not fail.

So, that is the one actually main thing this become actually part of the foundation. This wedge become part of the foundation and if I consider equilibrium of the wedge.

Finally, then before failure there will be a cohesion suppose there will be reaction from here suppose and there will be loading suppose here and there will be weight of the soil, there will be weight of the soil, weight of the soil, these are the things will be there and if I consider the equilibrium vertical equilibrium. Then this component I will take in this direction, this component I will take in this direction plus, this into this this plus this plus vertical component of this vertical component of this, all summation minus wedge should be equal to this.

And, if do this then finally, we will be able to express bearing capacity into 3 components and that 3 components one is called cohesion contest component, another is called surcharge component, another called density component. And, those 3 components will have 3 factors and they are called bearing capacity factor and one cohesion factor.

Cohesion related factor actually nc; that means, a bearing capacity factor for cohesion is nc. Similarly, that surcharge factor n q; that means, bearing capacity factor for surcharge that is n q and 3rd one n gamma, which is actually bearing capacity factor for density. So, those things can be so, like that I will continue in the next class with this that I will take this wedge. And finally, I will consider the equilibrium of this wedge and I will calculate this force, I will calculate this force, I will calculate this force.

And, then I have find out the weight of the soil here and then I will consider the vertical equilibrium of this entire system and from there I will express the bearing capacity equation in terms of nc n q n gamma. And, that is the thing which you have to finally, used in the design and perhaps I will I can discuss this one elaborately in the next class with this I will close here.

Thank you.