**Foundation of Offshore Structures**
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**Module 1**
**Lecture 8**
**Bearing Capacity of Foundations 1**

Ok, so let's recap of the idea behind the bearing capacity, I think I mentioned the other day with lower bound and upper bound equilibrium versus mechanism.

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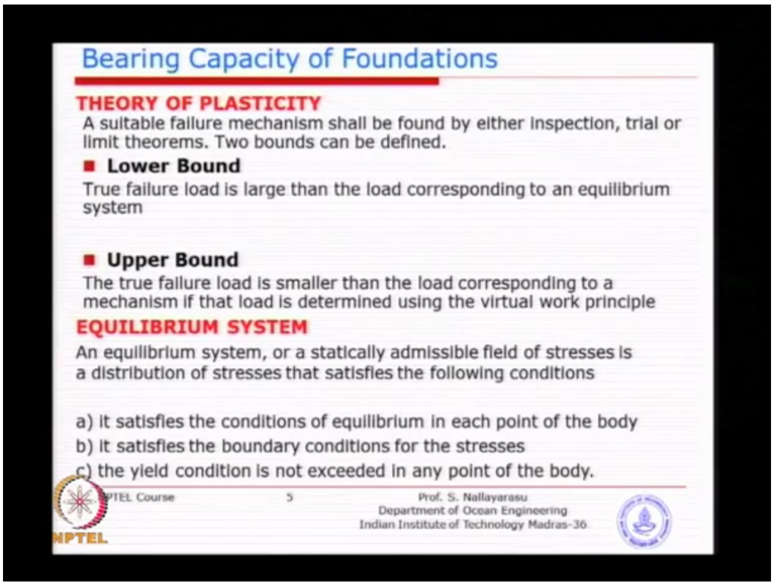


So the equilibrium is just equilibrium of forces which we saw one case the mechanism is basically a rotation or displacement case where u know the equilibrium you know the condition of ultimate strength is achieved after failure.

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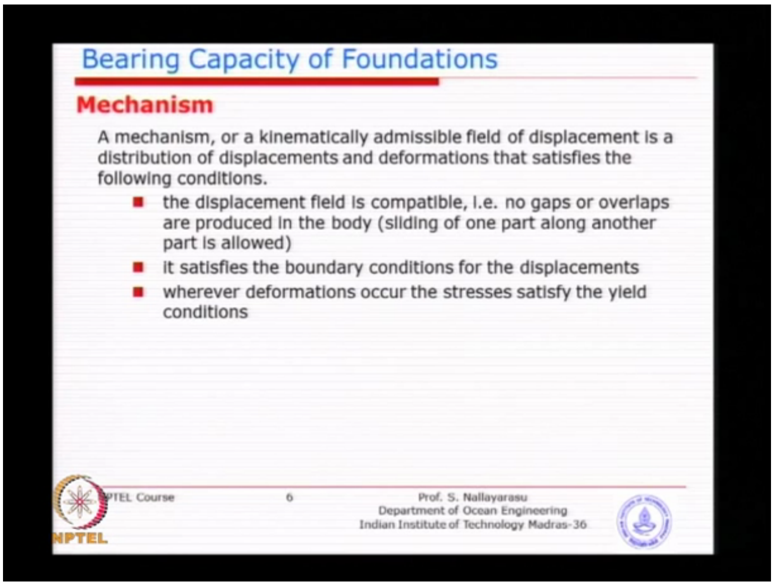


So if you look at the case that we are going to look at, is the second case.

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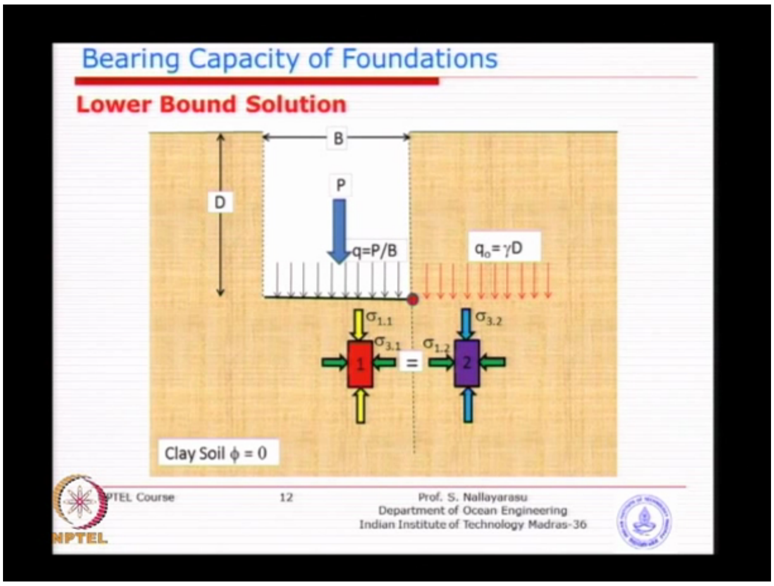


First case we have already seen this we just equated the horizontal pressures and active pressure versus the overburden pressure on the right hand side and then trying to equate and we derived a simple formula.

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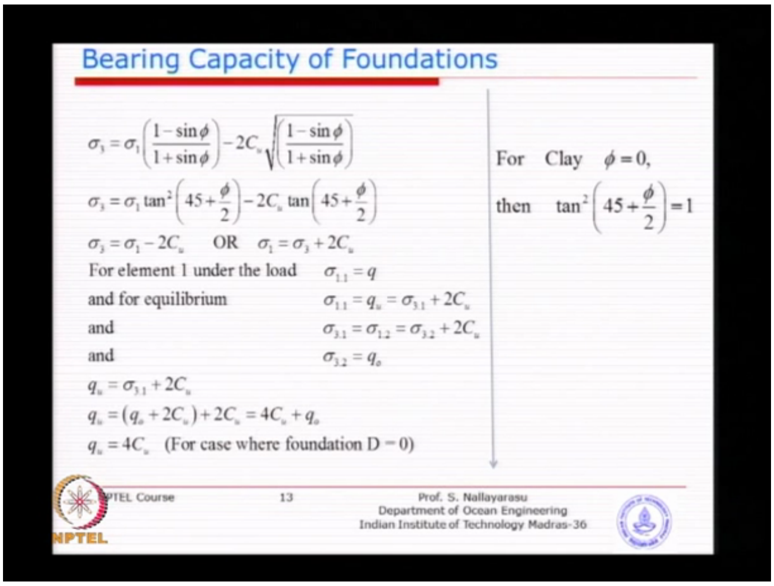


Which is giving the relationship between undrain shear strength of soil with respect to the load at which the soil will fail because of the equilibrium case.

And we have us reduced case where if the foundation is at the surface level just like of our off floor mud matts you where we just placed it on top we have reduced the equation to quite a simple four times the undrain shear strength now this 4 is a numerical coefficient depending on the failure mode we apply it maybe different it maybe 5 it maybe 6 now this is for the simple case where 5 is equal to 0 that means is purely clay type of soil now let’s go back to one more simplified case.

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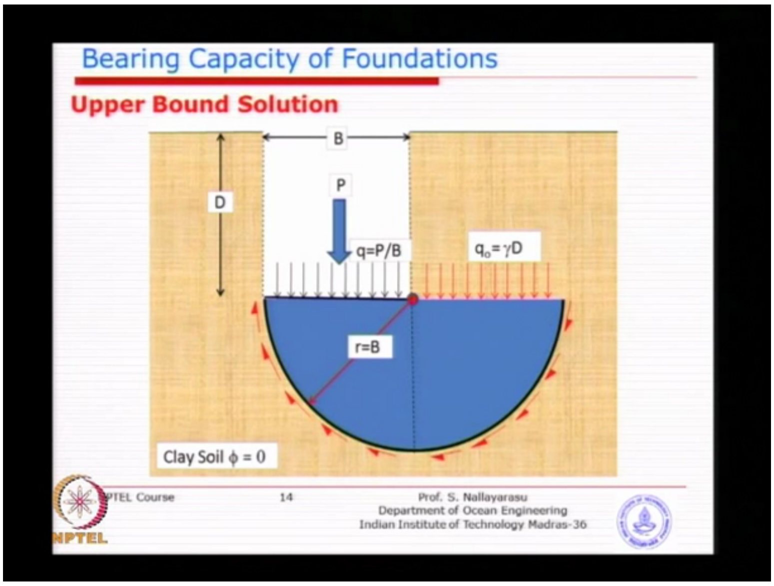

Where the failure is not by means of equilibrium it is going to be a mechanism that is means is a rotational failure so you can here from this picture easily that the pressure applied on the bottom of the foundation excavated foundation to a depth of D and it is trying to fail by means of a failure along the lines of circular shape.

What I have just noted down there. So the mechanism is about the point of rotation is this and the resistance is going to come from the shear strength of the profile of their. So if you equate the moment at that particular point and you can find out the equation that's what is trying to do we do here and the overburden pressure is same Q knot is the depth times the and you know the density of soil in this case will take gamma dash because we will be having the submerged condition.

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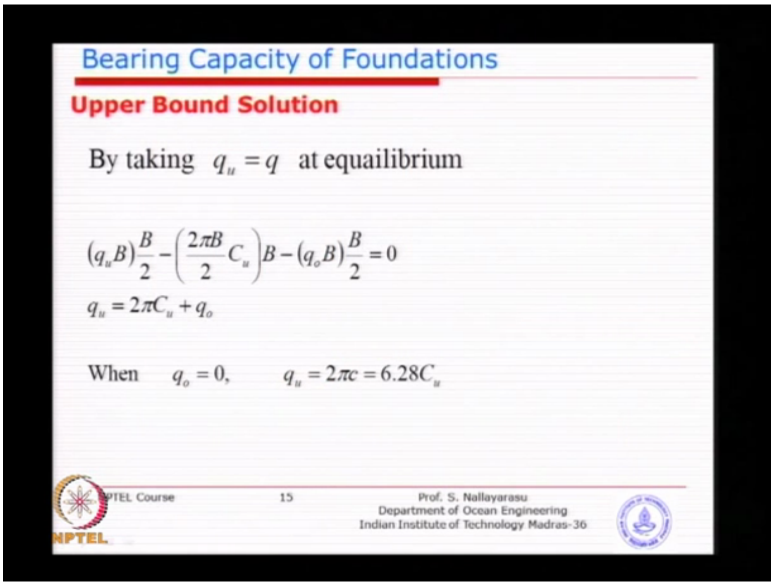


So you see here we just write the equilibrium equation for the moment you will get Q U is equal to 2 phi C U which is basically the arc length multiplied by the undrain shear strength which is going to create the resistance against the rotation plus your Q knot which is nothing but the overburden pressure

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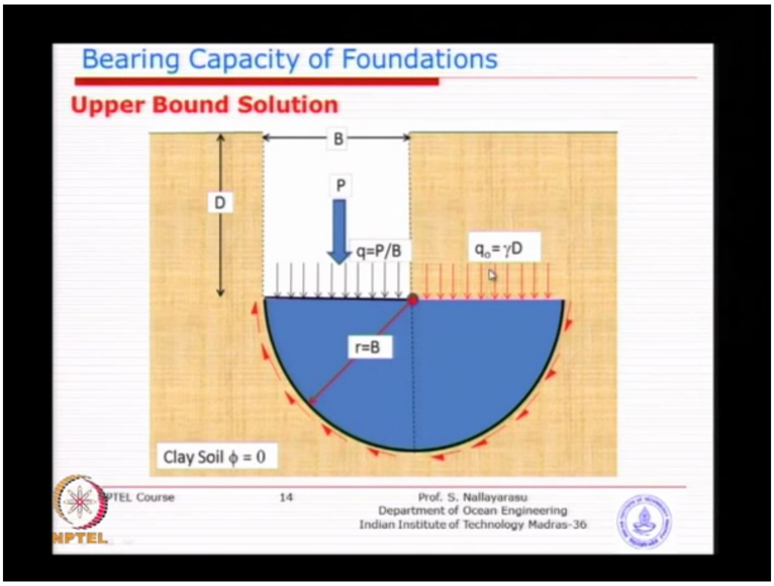


So the resistance is coming from the friction path as well as from the overburden path which is just, imagine if this whole thing is under surface then you will not have the Q knot there because there is no overburden, and the acting movement is basically the movement due to the pressure multiplied by half the distance just taking the U D L to the point of center from this point of rotation that is what we have done here.

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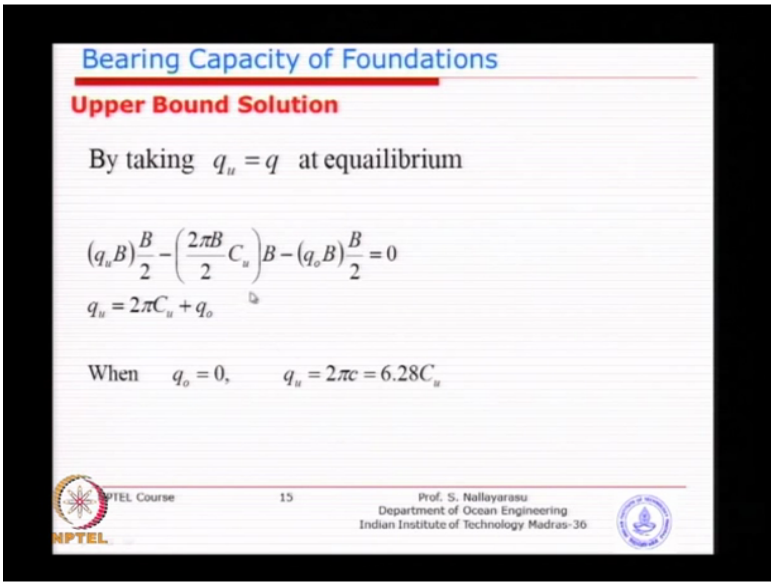


You know the active path and the resisting path, resisting path is the shear friction or the shear strength and basically the overburden time and this is the acting moment due to applied load which is Q times, B times half the you know basically this is acting at this point at the middle point and nekated by or opposed by the friction plus.

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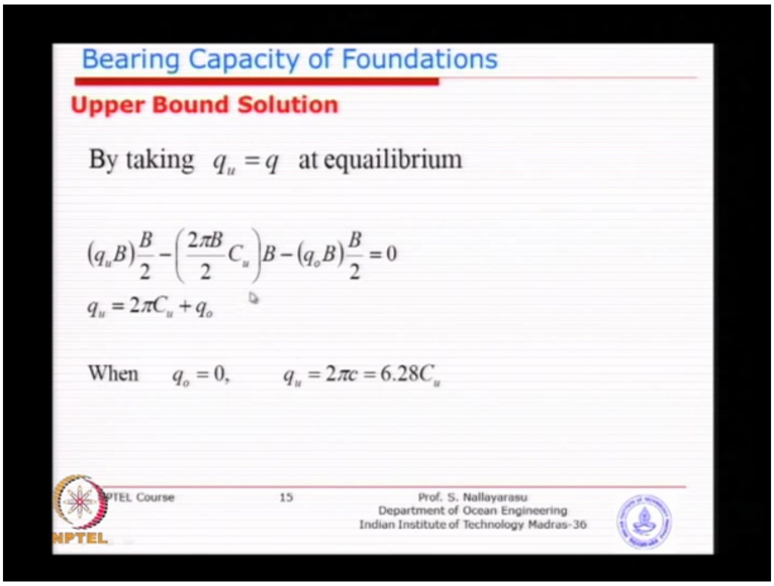


So it is a simple mechanism by which we are trying to equate the, again this type of soil is basically purely clay type of soil phi is not there. Based on this we got a you know basically if you take Q not equals to 0 bring the foundation to the surface you get 6 point 2 eight times C U. Now the previous one we saw four times U this one we are seeing, so this is, that is the lower bound is the upper bound solution. So we can see soil can fail either way but what we don’t know is which one to select. And basically that’s one of the idea that the solution is bound by this much from 4 to 6 it can wary and it can be anywhere depending on the nature of soil even if it is pure clay

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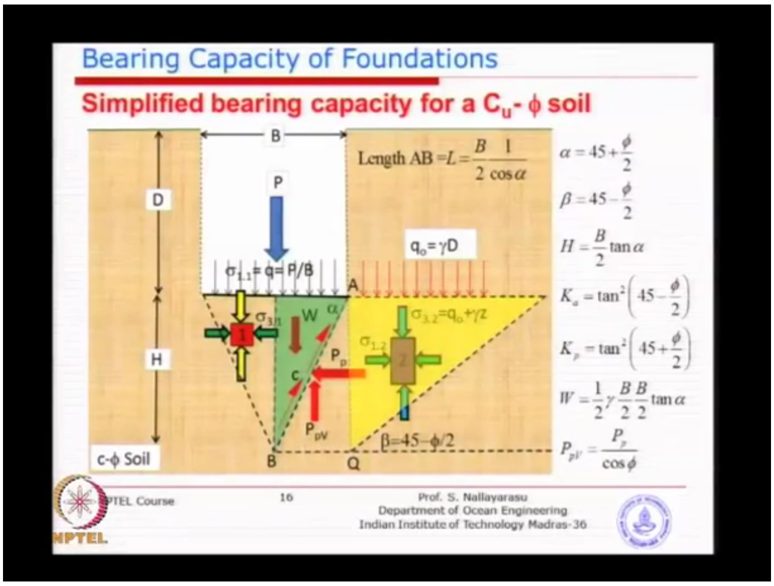

Now what we are going to just see the next one is a generic soil where you will have shear strength as well as the angle of internal friction, which is a generalized soil we called it C phi soil which in many cases you will find in real nature in, when you are designing foundation you are not going to get a pure sand because it is not under your control so if you see this picture slightly complicated of course this picture goes back to us as early as 1950's where Terzaghi first initially assumed certain configuration like what I am deriving but later it become quite complex ,because this is not going to be a so nice straight line you know several researches have come up with different profile and different bearing capacity coefficients and that's the history.

But the starting point is something like this where integration can be done very easily. So what he has assumed is basically a triangle just below the foundation path which going to become part of foundation itself that's the idea behind that. So you see the triangle drawn in light, light green color down there is just half of it I have drawn just for clarity. Actually the other side also will be filled with the similar. So this soil below the foundation with certain height which you could calculate and the width is same as the foundation , this soil becomes the part of the foundation load itself.

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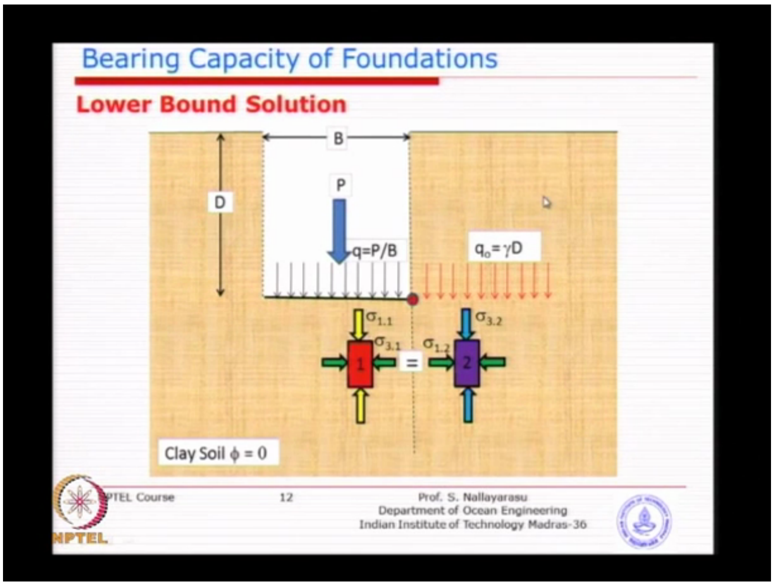


So it is just going to go down together so that is the first assumption and instead of failure at the interface see if you go back to the first one we were looking at failure along the vertical line, the line just coming down form the excavated surface. So that is the place where we are equating the left pressure is equal to right pressure so that is the equilibrium line we were looking at instead what Terzaghi was looking at is basically a incline d surface joining A and B which is something slightly different from what was our assumption.

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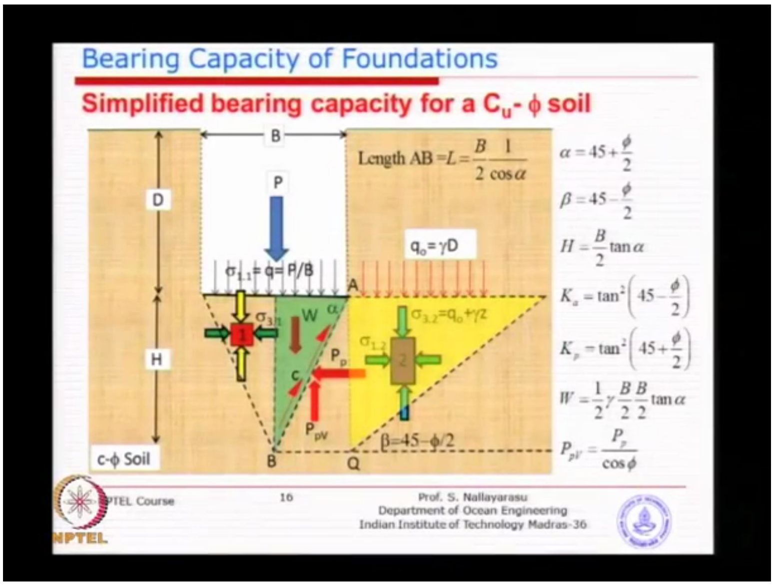


It all depends on, imagine if all this is water the vertical line assumption is correct if it is a very soft clay it is going to go down like this but if it is a C5 soil with good amount of sand and clay probably the assumption made by Terzaghi is very correct because it is going to take a inclines failure surface and that's why this is actually a reasonable assumption. So the failure line is assumed from A to B. Now we need to find the equilibrium, of vertical forces which will make them stable. The vertical force equilibrium is applied force is this P, you can calculate the unit pressure P by width.

Because what we are looking at is an infinite or a very long footing. So we are not looking at three dimensional effect it just the two dimensional effect and the load applied plus the weight of the soil itself which is going to become part of the wedge, the green wedge which you can find out the vertical component both them as vertical what we need to find out is the resisting component coming from the soil surrounding the foundation.

So which we can find out from a horizontal earth pressure which we have learned about lateral earth pressure, you know active and passive, so we need to find out what is P from which we can find out a component which is resisting this movement of the foundation plus the wedge, which is going to go down. In order to do that several things needs to be taken care for example when the foundation load is applied this way this is going to be a, the surface is going to active pressure wedge, whereas with is pressure this side this angle this soil is going to go passive because it is going to be pushed away.

And basically from the previous cases the passive angle of failure is 45 minus phi by 2, and active failure is 45 plus phi by 2. So that is what I have just summarized the parameters what we have learned over last few classes, so that you will just take it and substitute, so from this picture if you tale a elemental soil we could actually equate the vertical pressure which is nothing but your overburden pressure, gamma times whatever the depth and if you are able to find out the horizontal pressure which is 1, sigma 1 of the element 2 , based on the lateral earth pressure theory for passive pressure basically we will use our previous equations that we had.

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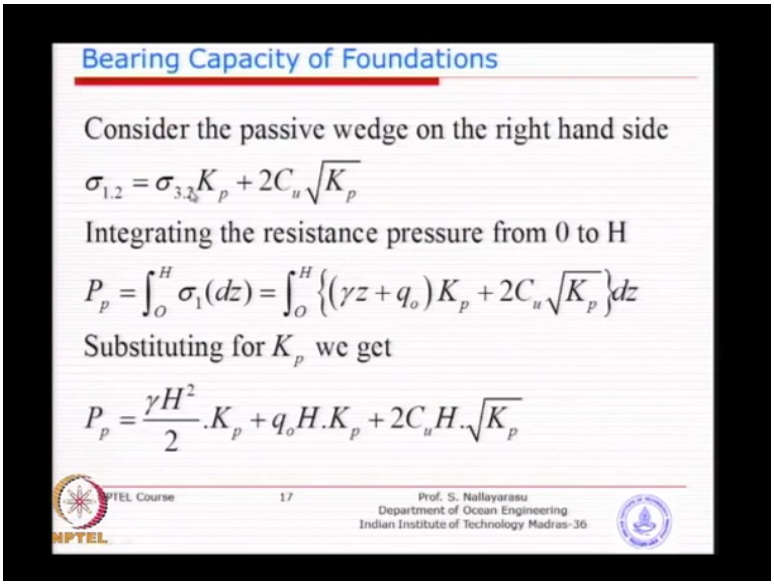


You simply substitute sigma 1 will be equal to sigma 3 into K P plus two times C, because this not pure sandy or clayey soil so you will have a both components, so you can substitute and arrived at this. This equation we have derived earlier and then integrate with this for full depth of from here to here, because that is what is happening here. This is a dot place what you are going to do is integrate that , and that what we have done ultimately you will get the total passive pressure from the triangular wedge on the right hand side based on the equation for what we derived from sigma 3 to sigma 1

Which we have just got the approximate equation there, once we know the PP then it is a matter of geometric calculation to find out the vertical force. So in this interface between A and B we have got two components one is the resistance coming from the earth pressure the second one is coming from the pure friction along the surface, very similar to what you just now did.

In here we have got a frictional the soil is trying to rotate this way but the frictional resistance along the surface is trying to resist it.

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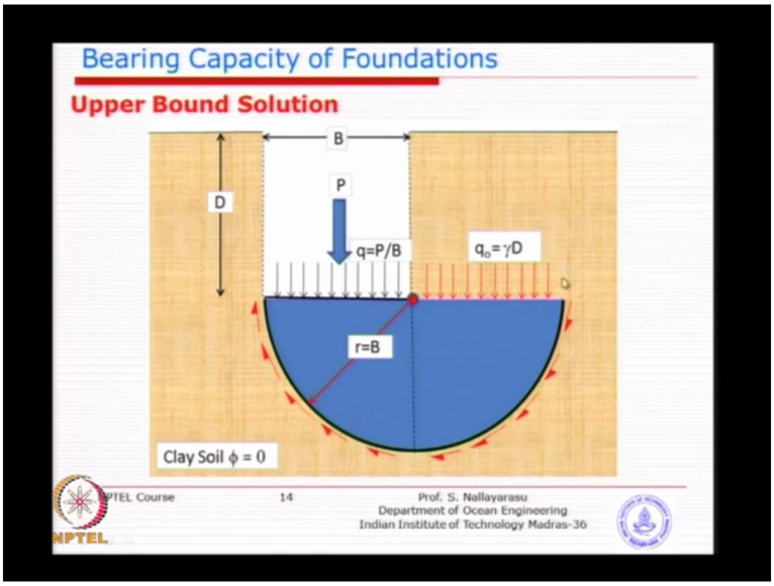


Exactly same way if you go back to this picture we have got a frictional interface between A and B and is trying to push the soil up because its unable to break the shear strength of the soil, so basically two component of resisting two component of acting basically the P plus W is acting downwards and a friction plus the vertical component of the, the earth pressure is going to be acting opposing resisting the failure. So what we need is just computation of that components and which we have already got PP from geometry which I have drawn at this interface.

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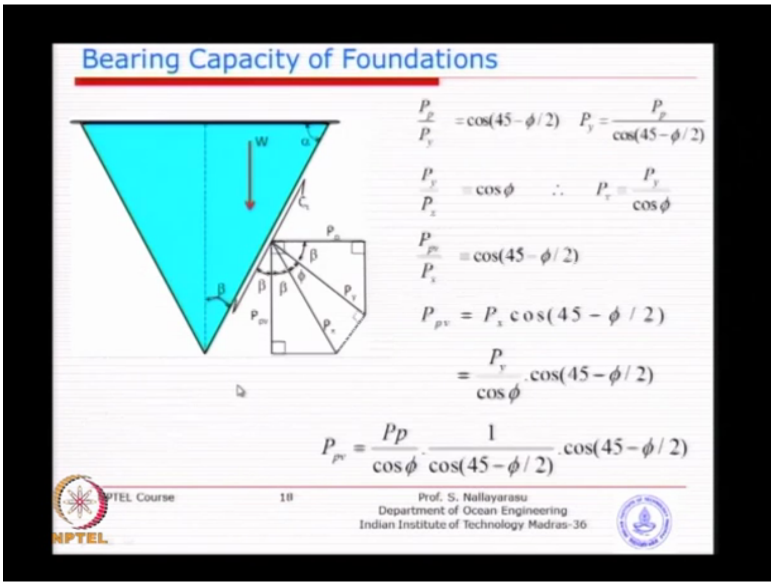


You could easily derive just a geometric arrangements .Finally you will you will come with a equation relationship between PP and PP vertical, which is just I have summarized in this at the last term here the relationship between PP V and PP is basically cos phi and that is what I am just giving you, you can go through simple geometric calculation of shifting from one to other and basically here the beta and phi is used because you see here this is beta and this is alpha and you got to draw both the triangles super impose 90 degree shift

So that's the idea behind. So basically this is the diagram that we will derive relationship between PP and PP V. Once you have this relationship then you can simply substitute.

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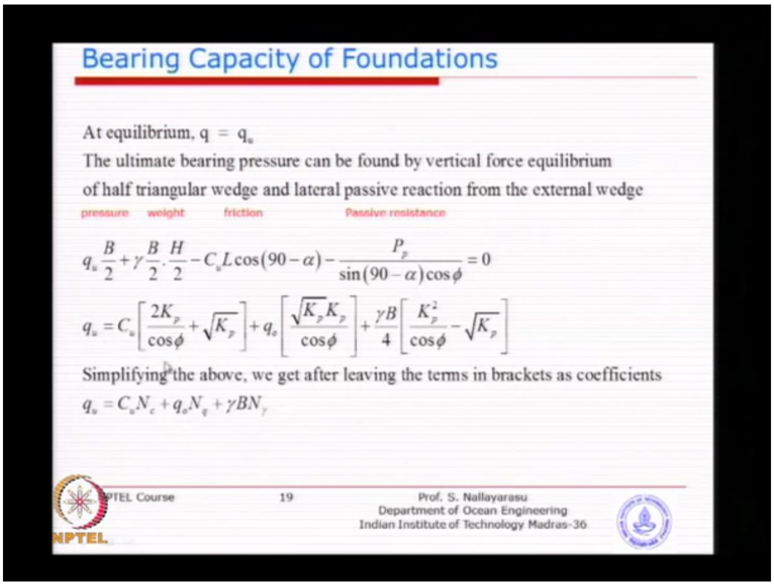

This is the applied pressure from the foundation load which is just load divided by the B by 2. I have taken half because of cemetery purpose you can take this half you can just leave it the other side or else you have to multiply by 2 so am just taking applied load at failure state , it is become Q becomes Q U , so that's the idea.

And the W will be calculated by the height of you know the triangle and width half and gamma is the density so that is the acting and the resisting is the friction , the length is calculated in that particular inclined length from A to B has to be calculated multiplied by the shear strength and basically the passive resistance the relationship coming from PP , and once you have this equation you simplify this in terms of KP you go back to geometric identities substitute, expand this sin 90 minus alpha and all that re substitution.

You will get something like this, so first stamp is combining CU with all this replacement you will get certain things inside, which is basically a substitution you get KP and the second term is Q knot which is your, your overburden pressure effect and the third term is the self-height of wedge itself so the , from here you have to do a lot of substitution to get replacement like this, so what we have is one is the pressure, applied pressure weight , the friction between the right side and left side or inclined failure surface and the last one is the passive resistance coming from the overburden effect

Now you see here Terzaghi has simplified this equation in terms of CU multiplied by a term just denoted by NC, which is basically a bearing capacity factor and NQ and N gamma, so what he that, what he was doing is just removing this complex equations and noting down by such simple you know, notations so that you can later calculate each one of them.

See NC, NQ and N gamma are called bearing capacity factors for different purposes. So could actually plot these equations in terms of chart for different characteristic of soil you can go and pickup and that is what you will see from some of the graphs.

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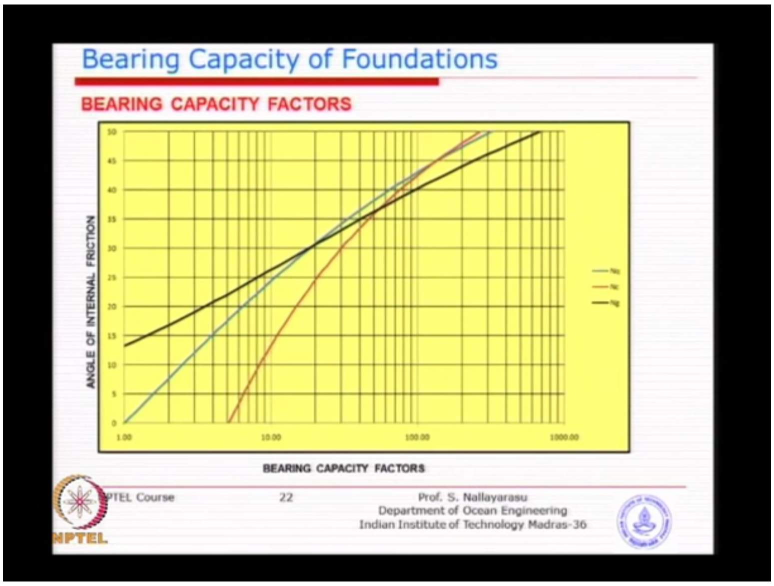


Something like this so what I have done is just plotted in excel. So given angle of internal friction for any sandy type of material you can see her is taking this kind of variations.

So you can calculate and then substitute so the idea behind this original equation is basically the passive earth pressure coefficient is known then you can straight away calculate everyone of them and for that if it is pure sandy soil, the sea component will go away then it becomes even simpler. So that's the first equation derived by Terzaghi as a basic form of bearing capacity of a spread footing in two dimension that means the third or the length is very long that the effect is negligible.

So that is the idea behind this, so what we have now got slightly complex shape of the triangle or the wedge which is resisting and this work was done by several people you know you started with Mayor Horf, bridge (())(15.00) and then several other researches they found based on testing you know the shape is slightly complex and have lot of mathematical expressions. ultimately instead of looking at this you could actually get some of them proposed numerical coefficients of varying nature base and testing then comparison, and you know if you look at several course you go to other Indian course of British course you will find these equations are plotted against either a SPT values.

Sometime you have relationship directly with this SPT values or with angle of internal friction which is your phi angle or with shear strength, so you can find many ways of finding this coefficients which can be used with this bearing capacity equation basically. Now in fact final form of equation for NQ is given like this

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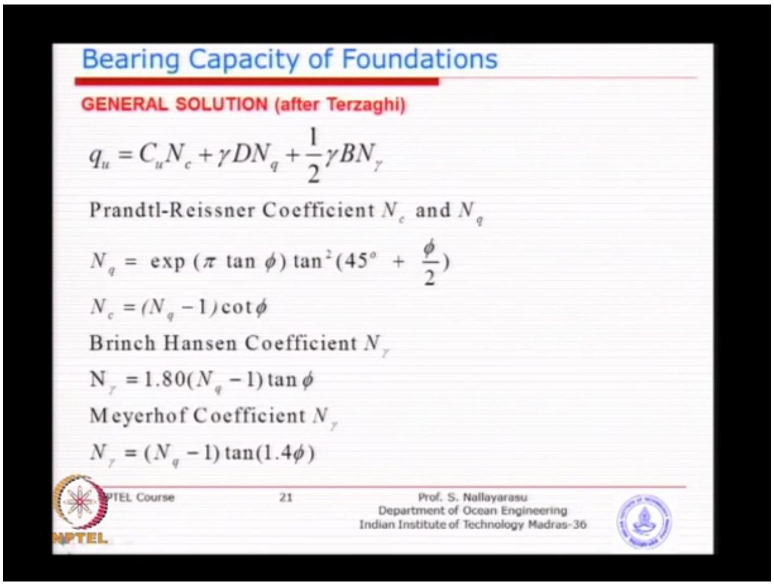


If you back and compare this NQ in here you simplified this equation in in terms of something like this and NC something like this and N gamma so is all final form of equations, but if look at later part of the you know like 70's and 80's even this equations got modified slight difference but the numbers are not very big difference.

Still may times we continue use the work done by Terzaghi for simple spread footing foundations even. So for all practical purposes we will use this equations to calculate if it is you know sandy type of soil or C phi type of soil where NC is related is with NQ and you can find out NC from there.

That is the chart which I was just discussing about we could use it without ant problem. So you have to little bit careful h use of this chart here only angle of internal friction is given, but though you can even get the NC values if you look at the NC is red color 2,3,4,5 I think it is about 5.14 if you calculate using this equation you will get 5.14..So remember we derived two cases for a clay type of soil we got four for lower bound 6.28 for upper bound, so this 5.14 is somewhere in between. So that's the idea behind.

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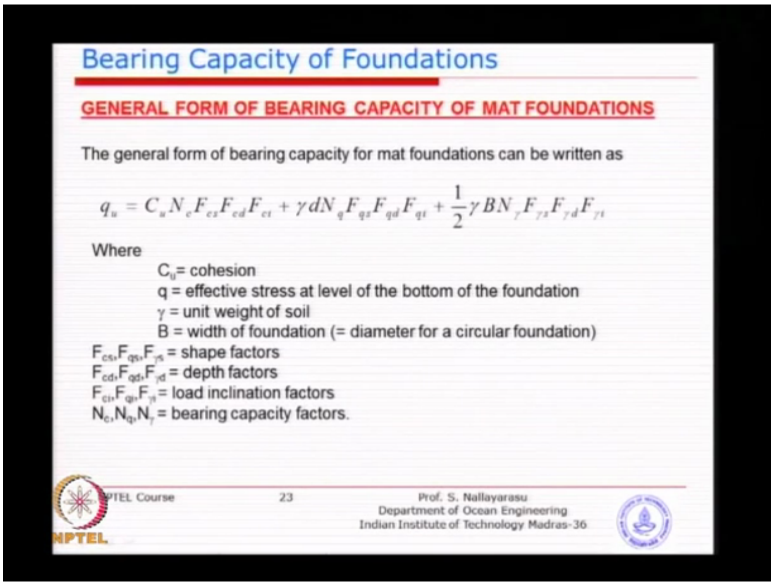


Now the general form of bearing capacity equation, so we have we have been looking at vertical loading, pure vertical loading, which is and a rectangular footing.

Instead we could generalize a bearing capacity evaluation in terms of load directions slightly inclined or maybe sometimes you get horizontal loads and then you will have non-rectangular shapes so we have a effect of shape coming into picture and depth .It could be at the surface it could be going to down load inclination factors which is just I was mentioning about and basically these three will be very common in ant type of foundation except maybe you know primarily gravity type of loading from buildings.

You may have a very little wind effect but for optional structures you know even if it is temporary you will see that a lot of wave and current loads will be coming so you have to take into account. So this you can easily understand the first one very-very simple, for example you take a circular shape of foundation when you apply loading to a circular shape foundation the foundation tries to settle down because of applied pressure, so the settle down means the soil around the circular footing is trying to squeeze out, isn't it?

Very simple idea, because you are pressing down what will happen? The squeezing out effect is going to be uniform throughout the periphery of the circle. instead of that if you actually take a rectangular shape for example just like a rectangular shape the squeezing out effect will be more on the width side rather than length side, because the length is more. Very similar to our you know the slab design, I think if you have learned about RC slap design.

Two way action versus one way action for circular it is multiple directions you know everywhere you have a similar effect so that mean which is better? Which is better is circulars definitely going to be better because the effect of overburden all around is going to be effective, you know. So circular shape is always better but, construction wise not preferred because it’s quite difficult. That’s why most of the time this spread footings will be either rectangle or a combined rectangle something like this.

So shape factor is very simple depending on the type and the shape of the foundation you will be able to get the factor its greater than one or not basically circular shape to rectangular, rectangular to strip some very rare cases we have triangular foundation but what normally we do is we convert the triangular foundation into an equivalent circular shape because it is very hard to find out the shape factor and then find out the capacity in off shore applications we have many-many cases circular non circular shapes like triangular and rectangular circular very-very few cases we have used.

So you will have definitely the effect of shape from the bearing capacity calculated based on a simple, simple you know long rectangle I would say strip footing to a various shapes needs to be taken into account by means of these factors. Depth factors is very straight forward because the more that you go you get a better soil and you get more overburden pressure. Load inclination factor basically is very important because the more- more horizontal load the frictional effect will come into picture.

And failure will be earlier than actual vertical load, so that is one of the important thing we need to remember. So all these things can be found from textbooks I will cover only what is relevant for the cases that we are looking at.

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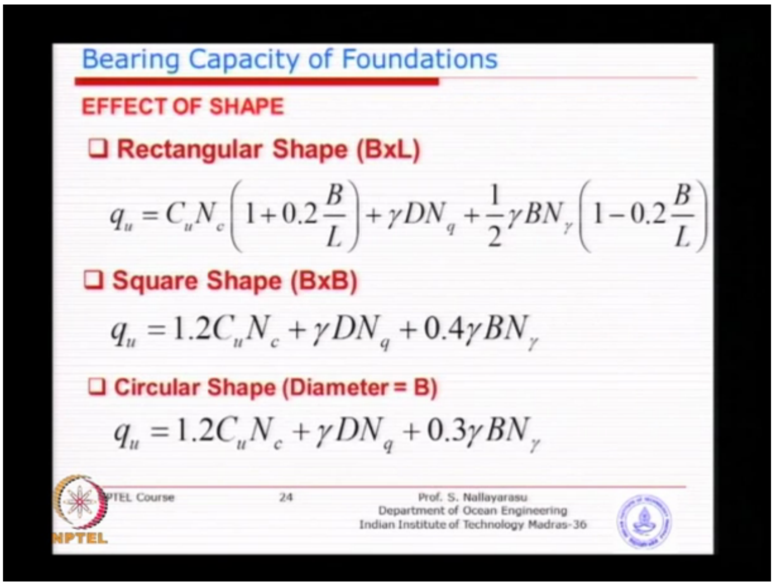


Some somebody of you know the three cases rectangular shape from strip footing to a square shape to a circular shape. So basically you can see here circular shape is just substitution of B and L equal to same. So will get 1.2 times both are same you know breath for circular shape is similar and for square shape basically 1.2

All other factors not getting so much affected basically the last one is the effect of the shape itself so can substitute from rectangular shape to square, square to circle. So you have to remember this formulas, what are the coefficients from this to this, only shear factor is applied here, off course inclination factor we have to calculate and multiply for each component separately.

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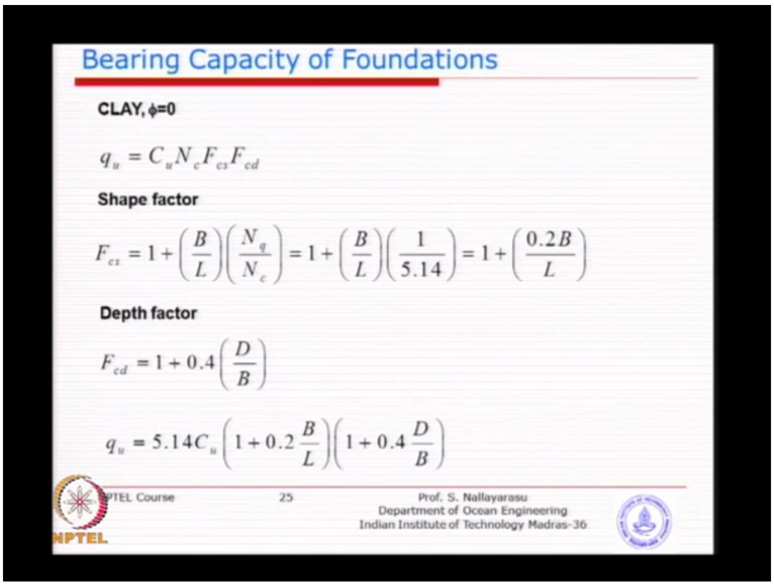

I think that that is the derivation that is looking at various factors shear factors that depth factors. You can use these formulas for phi is equal to zero type like clay type of soil.

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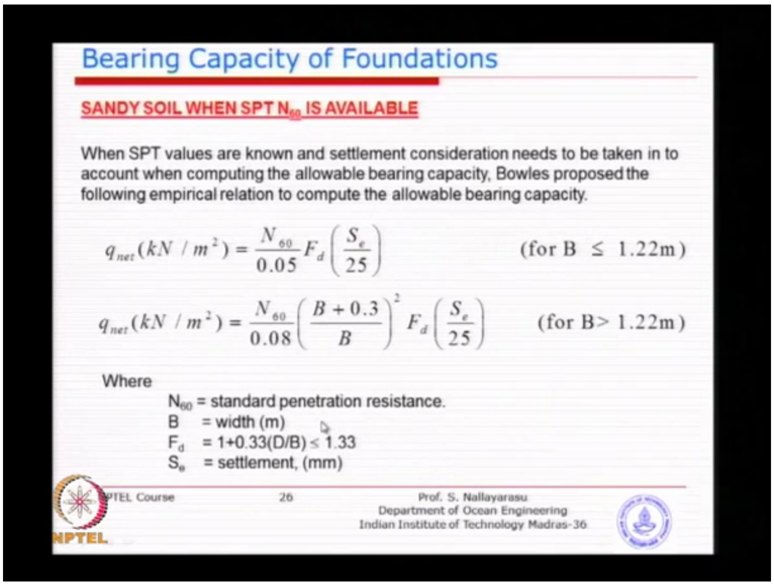


Now when you have SPT values are given directly calculation of bearing capacity I have just referred to several textbooks you could not find actually this is one of the application where you will be very useful instead of converting from SPT values to say angle of internal friction or CU basically in this particular reference they have given a I think I have forgotten to put the in fact its given in Bowl's book but work is done by somebody else.

You know basically numerical relationship is given directly can be used. One of the advantage of this particular method is, he has tried to relate the foundation capacity with respect to a given settlement. If you look at this equations what we have derived so far

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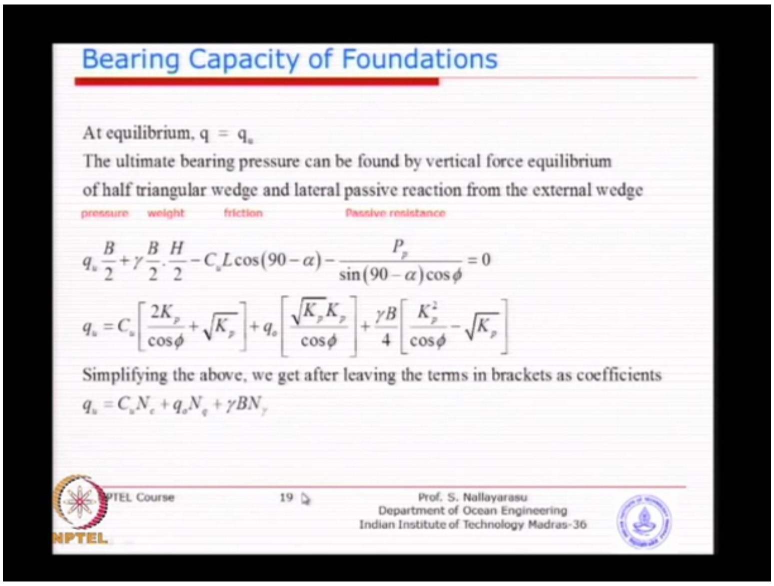


if you look at the whole equation it does not tell at this time of failure or at this type of equilibrium what could be the potential settlement of the soil so that means the bearing capacity is delinked from the settlement, what is going to happen.

So that is why later using the same load you calculate the settlement of the foundation and try to see what can be achieved or what you can actually allow a settlement then you have to come and correct the bearing capacity according. So that means you got to do some extra work whereas in this particular case he has given relationship which actually given for 25mm the settlement basically normalized with respect to 25mm. only thing is this is numerical formula sometime you have to be little bit careful not very straight forward.

Depending on the situation you have to correct it so basic idea is this is one formula where you will find use of N60. So from SPT you calculate the N60 and then apply that. Typically we need to just remember some you know basically the bearing capacity what could be the range? So if you look at very soft material at the bottom is about 75 know basically soft and silt clay less than 75 kilo newton per square meters. So if you convert into ton seven, seven and a half ton per square meters, which is reasonably a good load.

But if you go to a very soft clay you will find even less than that like 5,10,15 such type of soil even if you apply a slight pressure will be settling down. So the bearing capacity magnitude we need to remember is just keep in mind that when you are doing computation this is not come up with some large numbers. So if you go back all the way to a very large number like

600 kilonewton per square meter. So what is means is nearly 60 ton per square meter for a dense gravel or dense sand.

So that means you can play 60 ton load within one square meter of, so you can imagine to get the 60 ton load how much of, how many concrete blocks you have to stack up, several probably more than 10,15. So that is the idea behind you can understand the capacities of good sand is so much compare to soft clay, so in between you will have several cases where you can keep the numbers as a reference values but not exactly you're not you're not suppose to use this numbers.

Because even after defining medium dense sand you will have a very large you know the range of values, so have to be little bit careful but just for information I have taken from the BS codes, quite reasonable when you will calculate you will get somewhere around here.

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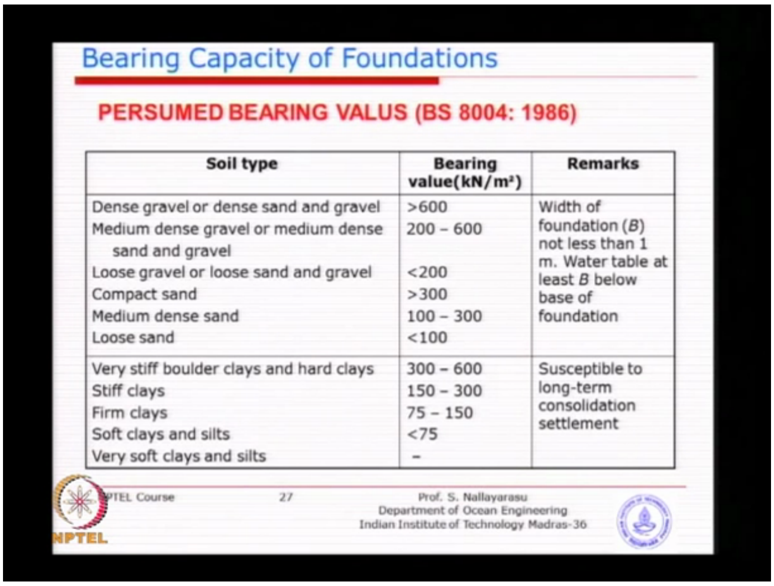


These are bearing capacity fact is given by API, slightly different from what Terzaghi has given, this is bases on works by I think mayor Horf, and when we are designing mudmatts for offshore foundation we should use this.

That is why I have reproduced that from the, for easy and convenience they also have given numbers, so that you don't need to read for given soil friction angle you can straight away read it. But if you're not comfortable you can use this numbers. This are given for every five degrees them you can just interpolate in between them. So for examination point I will give you this table so that you can just interpolate wherever you require.

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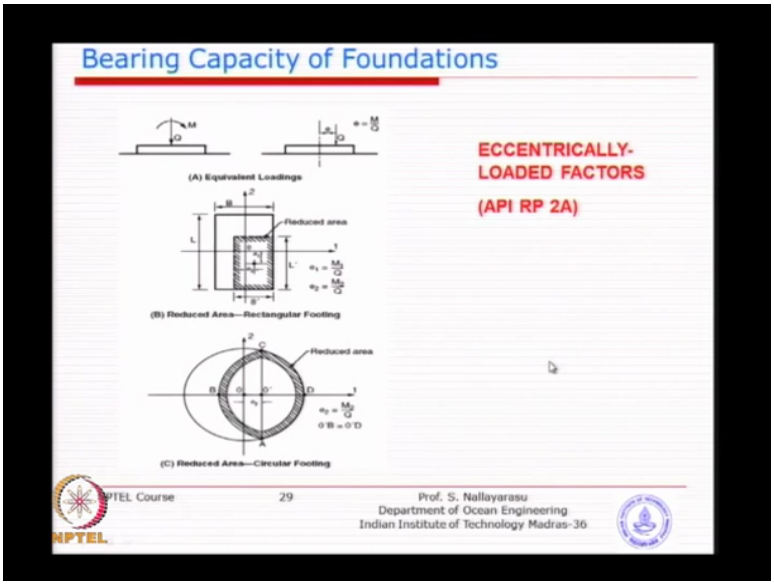


So this, the second thing is instead of applying basically the inclination factor API recommends use the method of effective bearing area. For example if you have only a vertical load what will happen? The whole contact surface between the foundation and soil will be positive compression pressure, isn't it? Pure vertical load but if the vertical load is shifted by say few meters to one side, what will happen, there will be a there will be a non-uniform pressure on one side is higher one side is lower.

So what you will you happen, whenever the pressure on one side becomes negative that means the extensity is on too much so what will happen is the foundation is trying to tilt. But since there is no you know basically tensile stress can be taken by soil what will happen, the foundation will start lifting off and that area will not have a contact surface. Now what will happen when the, when this is trying to happen when the foundation load is very far and foundation is trying to readjust itself.

It is basically the contact pressure will start increasing in the area where the contact pressure is, contact surface is there. So that means this load is same only the location of load is shifting and it is a continuous equilibrium it will achieve its equilibrium as long is able to take it. if it is not able to take it, what will happen? The whole structure is going to overturn.

And that is not very easy defined. Even today they have no solution for this. so that is why API recommends an approximate method simple approximation you could use it because to find out that the contact surface after achieve equilibrium is very difficult because the soil settlement also happens, you know simultaneous with the rotational behavior of the foundation. So as the soil settles as the foundation goes down the soil gets better.

Bearing capacity is increasing which we cannot model it unless you can carry out a finite element analysis or a complex or carry out an experiment, you are not able to find out what settlement, or what contact surface area because is a iterative process. So at the equilibrium there will be a reduced surface area and there will be some settlement and basically the foundation will, will be stable if is able to achieve the required overturning moment from the, the resisting pressure.

Otherwise the foundation will, or the whole system will just rotate and fail by overturning. So this you see from this picture there is a length and width of the foundation and the load is applied off course, load is applied eccentrically or load is applied with some movement, which both the cases are same. So you can see here in this case the extensity is that applies movement divided by the normal load or the other way around.

If you have just load applied at eccentrically at the point here then the moment is basically the load times the distance which will give you the movement so because of that the contact surface is only shown in that you know the hatch color area and that is the area effective so after this what you will do is the vertical load divided by the effective area. That means the increased bearing pressure. But what difference we are making? For example this you are going to do total load divided by that reduced the area but uniform pressure.

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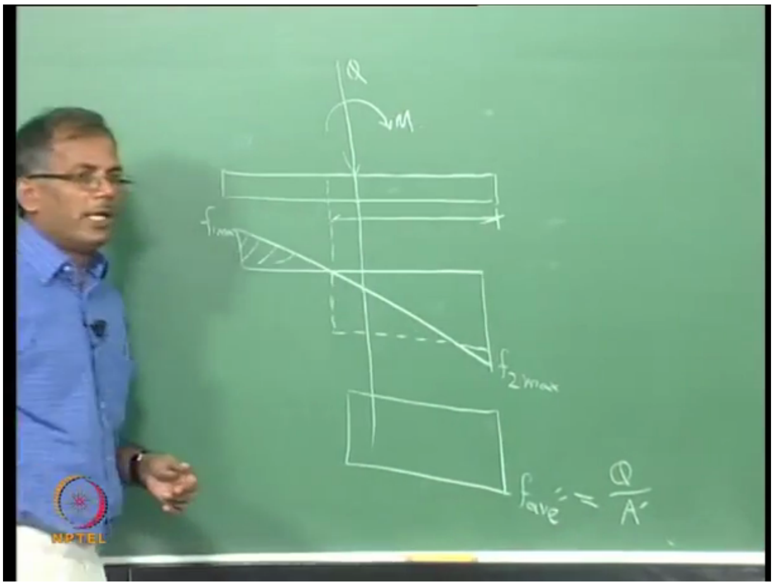

But if you actually draw a pressure diagram basically if you just look at the base of the foundation originally so that is the area where negative pressure because this is your foundation and probably that is your Q applied with movement, something like this increased pressure negative pressure but now this maybe say f2 max this is F1 max this is negative, now reduced the area probably you will be taking something like this or you adjust it that is the width finally available.

What you are trying to do is or I can draw it something like this. Now what we are ignoring is this slightly increased pressure because we are going to take a this is the average not the peak pressure because we are to find out this by Q divided by A dash. A dash is nothing but the effective area after re-distribution which may actually not hundred percent correct but that is going to be a quite small difference so we are just going to use that method.

Otherwise finding out the actual re-distribution pressure is going to be quite troublesome. The reason why we need to do this in comparison to building design, building design we don't encounter this problem because the horizontal loads are very-very small compared to the vertical loads. The vertical loads are predominant the magnitude is so huge that even horizontal loads are there its negligible effect will be under foundation.

Whereas in offshore structures especially in the temporary phase when the jacket is placed is very light structure and the horizontal loads are predominant, because the design why we make it light because we make it buoyant remember all the jacket members are made buoyant so that when you place the jacket on water it should float number one and we make it vertical by just (())(32:54)little bit of water and we place it.

So at that time the jacket is not going to be very heavy it is going to be very light structure now vertical load is small horizontal load is going to be subsequently larger and that is where we encounter this problem compared to on shore structures we have a serious problem to resolve that's why we have to learn little bit more about eccentrically loaded foundation but we cannot apply the conventional method of foundation design thats why API has given this method and it has suggested that this error in taking average pressure is not going to be that too much.

But some of the times the method proposed by API has also has been challenged because the difference between the average pressure and the peak pressure what we have here is more than 10 to 15%. There are several other methods proposed by different course which we may discuss in the later part of the tutorial time.

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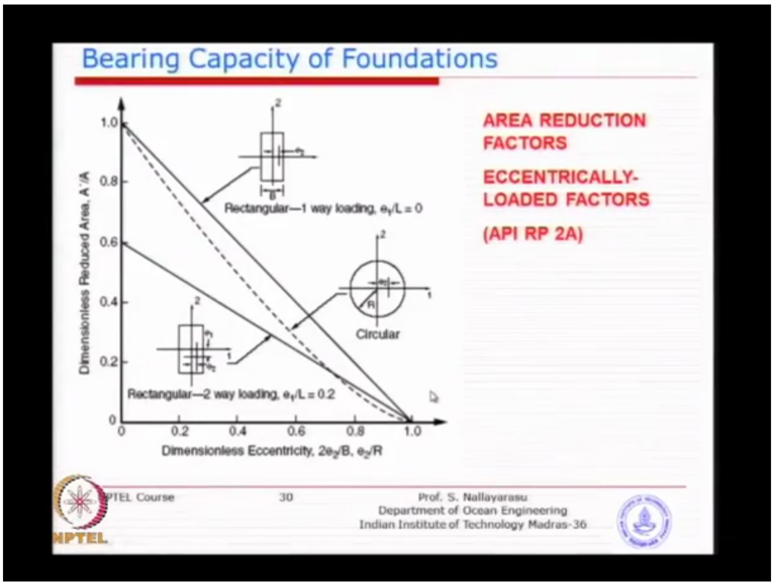


Basically this is the chart given by API for one side or two side eccentricities. So you could read the factors varying from zero to one depending on the eccentricities factors. So basically the eccentricity is E2 or E1, E1 is, so for circular one is basically in this because in any direction eccentricity is going to be same so you read that or if it is a single side even you read this or double one you read this and basically the reduction in area is given as A dash by A, A is your original area, A dash is the reduced area.

And basic idea is if E2 is zero you will see that full area you will be getting so either you go by this line or go by this line depending on whether E1 and E2 are present. So you can read the chart and get the reduced area if it is a square one is very easy if it is a rectangular one you have to proportionate to the length and the width of the foundation. According to the multiplication factor what you are going to get.

So this chart is quite useful in terms of trying to find out a simplified solution slightly approximative but still practically very easy to do the problem basic idea is we will apply this method.

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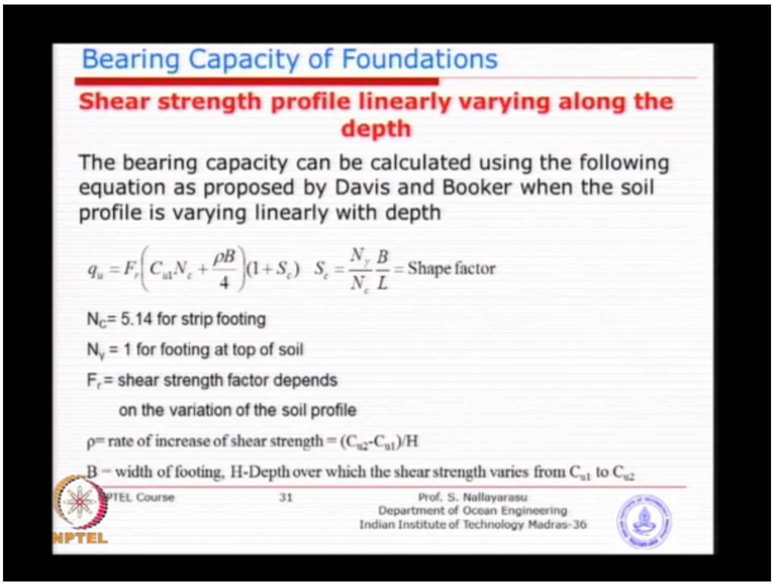


The next one is slightly a different problem and also done by this researcher basically Davidson Booker several years back I think 1976 this this is predominantly interesting problem in off shore as I mentioned into the first few classes these marine deposits for most of the you know the island has deposited areas.

The younger clay keeps depositing sediment particles and it just keep growing over the last hundred years or two hundred years you will see that as the new layer get deposited the previous layer gets you know compressed consolidated and the strength increased so when we do the bore hole we normally find that first 30 to 40 meters of clay you see a very low shear strength at the top and then the shear strength keeps increasing in a linear fashion.

Some places we have seen almost like 30 to 40 meters from 5kpi it goes to 40kpi something like this. Now how do we use the knowledge that we have developed on bearing capacity equations. Because what we have derived three three types of equations is just a uniform soil either a clay type of soil with a constant shear strength to infinite or a very large depth or C phi soil with a characteristic same whereas here we have a soil where strength is low at the top and strength keep on increasing but then we could do one thing we can an average characteristic and do it.

But whether it is true or not it is not very clear. So he has done experiments on this type of soil and come up with a numerical coefficient basically slightly improved. Imagine if you take the lower shear strength for example the top soil and just finish your foundation design you will get a bearing capacity of some amount which is going to be very conservative because you are only considering the lower strength.

Actually the strength increasing means is going to boost the capacity by some amount and that's what is going to be taken advantage of that. So he has proposed this method we called it Davidson Booker method is nothing but we got back to the original bearing capacity equation multiplied by the effect due to increase in shear strength by means of so called strength factor because of the variations and also he added a component called the rate of increase of shear strength.

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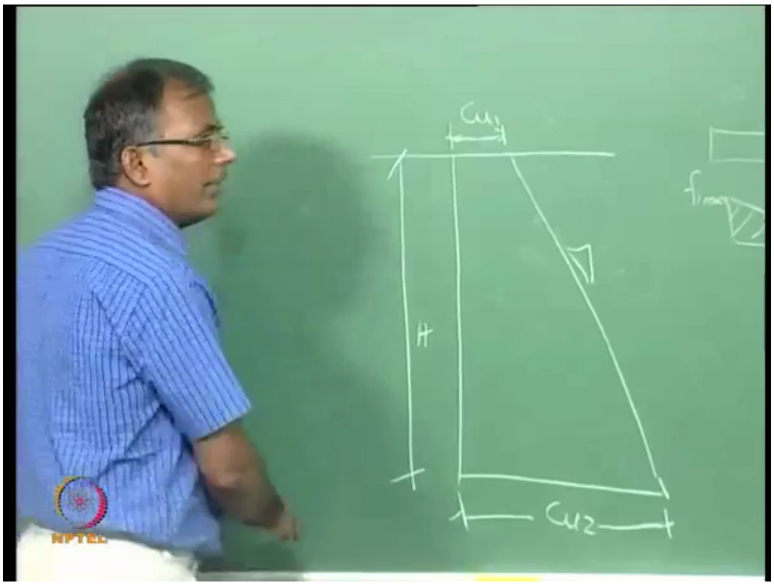

So if you draw a picture it will be something like this you know basic profile that is your seabed so this is the shear strength at the top and the shear strength at bottom. So this is the slope is the rate of increase and that is what the total height is H something like this so that's the formula that you can use that. So C times NC is the same basic form of equation for a clay type of soil because the reminder will go away and one plus SC is the shape coefficient.

Which I think we have derived for several shape cases so one plus SC, SC is calculated by the ratio N gamma by NC as per the Terzaghi equation and B by L will come into picture for circular foundation it will become one square foundation becomes one and N gamma by NC will become 1.2 when you go and calculate and basic idea is the calculation of Fr is given by a chart.

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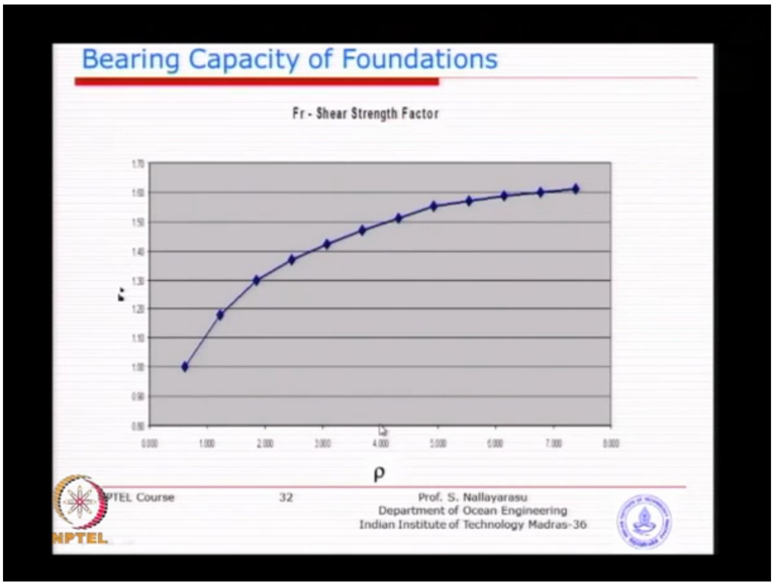


I have tried to reproduce because it was a 1976 paper basically to be used for calculations so just took the values and re-plotted with respect to rate of increase and the fr value can be taken from this chart.

So for calculation purpose there is a equation given by this particular paper I think that can also be used in one of the references I, the original paper was not giving but the later researches have came up with a equation for this particular graph which I think for examination point of view I will try to give that equation so that you can you don't have to read the charts from here. So this method is very useful for many-many occasions where practical applications you will find this type of strength increase in several sights.