Advanced Foundation Engineering

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Lecture - 16
Deep Foundation - Introduction

In last session I have discussed about shallow foundation or different type of shallow foundation, how to design the dimension of the shallow foundation based on the settlement and the bearing capacity calculation. Now, in this session I will discuss about the deep foundation. Now, as I have discussed the shallow foundation mean the depth of the foundation is very shallow; now in the deep foundation if the load is amount of load which is coming in the foundation is very high and the soil is not capable to take that load if I provide or if we provide a shallow foundation. Then we have to go for the deep foundation, where the load carrying capacity of the foundation that will increase if we use the deep foundation. And definitely the depth of the foundation is much high as compared to the width of the foundation.

So, with the in shallow foundation we assumed that the depth and width of the foundation are more or less equal then or within the, if the depth of the foundation is less than the width of the foundation then we talk about the shallow that is the shallow foundation, but if it is more than its deep foundation in its that is guideline. So, that so why in deep foundation that depth of the foundation is very high. So, basically first I will discuss about the pile foundation then in the next module I will discuss about the well foundation or the... So, these are the different types of deep foundation.

Now, this introductory class of the deep foundation I will discuss about different types of deep foundation basically in the pile foundation in this session, and then what are the construction methods then how to calculate the load carrying capacity and what are the different types of foundation pile foundation based on the load load loading patterns.

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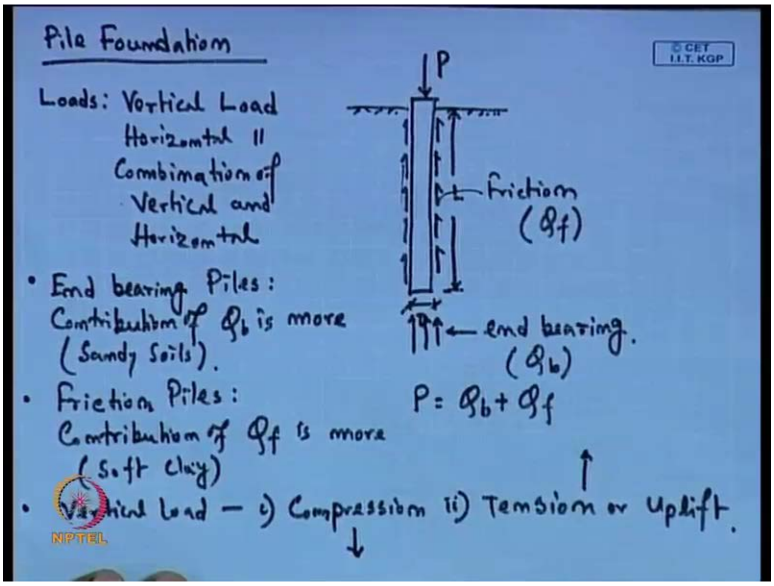

So, first I will go for the pile foundation. So, that is our first. So, this deep foundation first we explain this pile foundation. Now this pile foundation that is we can draw, if this is the a typical pile and we can write this say this is the ground surface or here we can provide the pile cap and then this is the width of the or the if it is the circular pile this is the diameter of the pile and this is the length of the pile. So, here we can see that the length of the pile is very high as compared to the depth of the or this width of the pile or diameter of the pile. So, here the load carrying capacity I will explain for different types of loading and the how to calculate the load carrying capacity of the pile and here also there are two types of criteria one is load carrying capacity and another is again settlement criteria.

So, we will consider all this aspect when design this pile foundation. So, what are the load? First we will talk about the load. So, there are first we can say this is the vertical load then one type of load is horizontal load horizontal load. And the third one is the combination of vertical and horizontal. So, these are the different types of load that is acting on a pile foundation. So, now, this vertical load and that can be upward or downward directions.

Now, if this pile, so different types of piles based on their performance we can write when first one is end bearing pile. So, this is basically for the, suppose here when we suppose this is the vertical load we are applying here. So, that the resistance this pile is getting from the soil is one is the bearing that is the resistance at the bottom of the pile tip and another resistance from the friction between the pile surface and the soil. So, the load carrying capacity this p, if this is p this is acting here. So, this is due to the friction and this is end bearing. So, if I write the contribution from the friction is Q f and contribution from the bearing is Q b. So, we can write the total load that this is taking by form the contribution of bearing plus contribution of the friction.

So, we can say that end bearing piles now if the contribution of the bearing part Q b is very high as compared to the Q f then these type of pile is called the end bearing piles so; that means, the contribution is Q b is more so; that means, the contribution Q b is more which is generally can observe that sandy soil and next one is the friction pile. So, sandy soil or the pore soil, so that type of contribution is more the bearing.

In friction pile if the contribution of Q f is more. So, this is the soft soil or soft clay we will get this type of pile. So, now, if the contribution from the bearing is more that is the end bearing pile that most of the loading is taken by this point resistance of the bearing that is end bearing piles and is the modes of the loads is taken by this friction resistance that is for the friction pile.

Now, depending upon the different type of loading and as I was discussing about the vertical loading, horizontal loading and combination of vertical and horizontal loading we can write pile in different types. One is generally pile is used to resist the compression load. So, now this type of pile one is your compression pile. So, vertical load that can be two types one is compression another is tension or uplift. Now this compression type of pile which is very common for any structure generally this piles are used to against the compression load, but in the tension load; that means, the vertical load its can be compression means the downward direction and tension means in the upward direction loaded here, but both are vertical loads.

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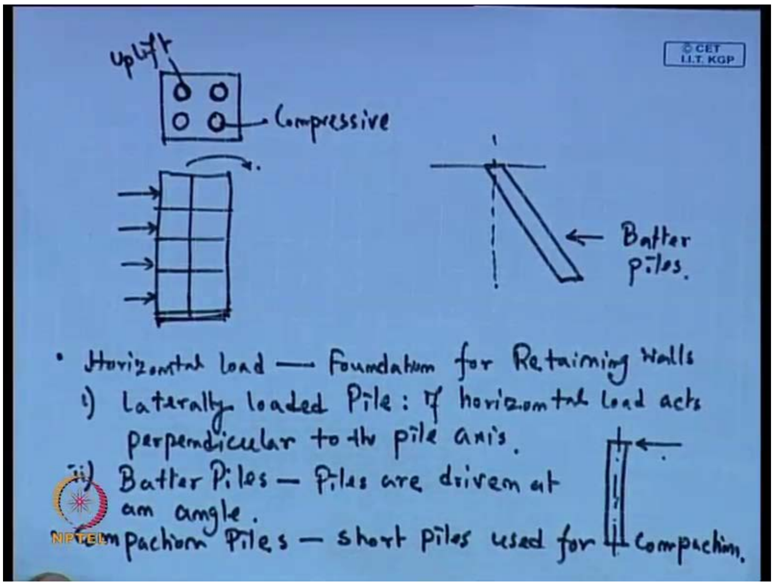

Now, now this tension load or the uplift load that is basically supposed is applied for a tall billing or any suppose this is the we can write the different combination of the pile suppose this is our one pile or one billing pattern. So, this is the these are the different types of piles and here this is the very tall building and we can write the this is the plan and suppose this is the plan of this tall building, so now if the load laterals load or the in pressure which is acting in lateral direction. So, in direction this total system will go in this side. So, here we can say the, these pile these will be subjected is a compressive load and these piles we subjected by tension load or this is the uplift load and this is under compressive load. So, these piles are called the... So, here we have to design this piles against this uplift load which is the tension pile; this similar case can be happened for the foundation pile foundation a below tall chimney where also we have to design this piles for both compressive load as well as for the uplift load.

Now, this direction of this vertical load this can be perfectly vertical or it can be inclined also depending upon the type of structure or the type of loading it is acting that can be inclined also that inclined compressive load or inclined tension load. So, now this is the vertical load if we are talking about the horizontal load. So, that is used for the foundation for retaining wall. So, there we can. So, this is the again the two types one is your laterally loaded pile. Now, this laterally loaded piles the definition we can write that if horizontal load acts perpendicular to the pile axis that means, suppose we can if we draw this pile and this is the pile axis.

Now, if the load is this horizontal load is perfectly perpendicular to the horizontal axis of the pile then this is called the lateral loaded pile. Now another one we can say that is the batter pile. So, here piles are driven at an angle. So, we can write say suppose this is the batter pile where piles are driven with an angle which is depending upon suppose these are the called the batter piles or inclined piles to resist the inclined load that is acting. So, here this load is inclined. So, that is not perfectly perpendicular to the axis which is somehow inclined load. So, so to resist against this inclined load you can sometimes use this pile which is called the batter pile or the inclined pile. The next one is the compression or the next one is the compaction pile. So, these are the short piles used for compaction. So, sometimes for compacting the soil similarly the sandy soil we can use the pile short piles, these types of piles are the compaction piles.

Now, the different loading condition this uplift load that is used for the tall structure or the chimney structure compressive pile which is common for any type of structure now this lateral load that is used for suppose we provide the foundation for retaining wall or the lateral load is coming or for any offshore structure where the loading form the this sea water or that load is lateral types there we can use the lateral load we can load can come. So, there we can use the lateral loaded piles or the batter piles. So, these are the different types of loading and the different types of structures.

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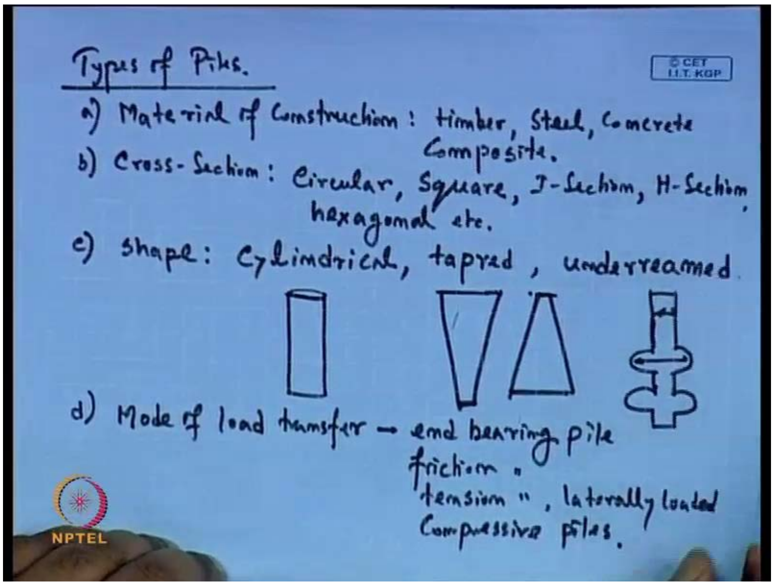

So, against you can draw design for different types of pile that is compressive design against compressive load design against uplift load and design is again lateral load. So, those things we will discuss in this section.

So, next types of piles or further if I classify this piles one is based on the material suppose based on the material of construction. So, pile can be one is timber pile, pile can be made of steel, concrete and then composite type of material also. Now, the next one the based on the cross section, this pile can be circular that is can be square that is can be I section if it is a steel pile that can be h section that can be hexagonal etcetera. Now, based on the shape this pile can be cylindrical which is very common then this can be tapred pile. So, cylindrical means suppose this is the diameter this diameter of the pile throughout constant and tapred it can be suppose this is the tapred type of piles where the diameter is not constant or it can be either type also depending upon the type of soil. So, this is the tapred piles then this is the under reamed piles under reamed piles.

So, here this is the tapred piles this is the cylindrical piles and under reamed piles, suppose here some bulb is constructed this can be single bulb or double bulb. So, these are the tapred pile where this diameter is higher compared to this diameter. So, here specific shape of the piles and where the different type of soil we can use a different types of piles this is the common and cylindrical shape this is the tapred shape because here if we need the more bearing tip resistance; that means, end bearing piles here we can use this enlarge space and this is the under reamed piles where we can get the additional bearing capacity for this under reamed bulb or we can provide this one for the this is the negative skin friction also we will discuss these things while later on what is this negative skin friction and how we can design this under reamed piles etcetera.

So, next one is this mode of load transfer. So, again we can say this is the end bearing pile or friction pile or we can say this is tension pile that can be lateral loaded pile or compressive pile. So, different types of load, these are different types of piles.

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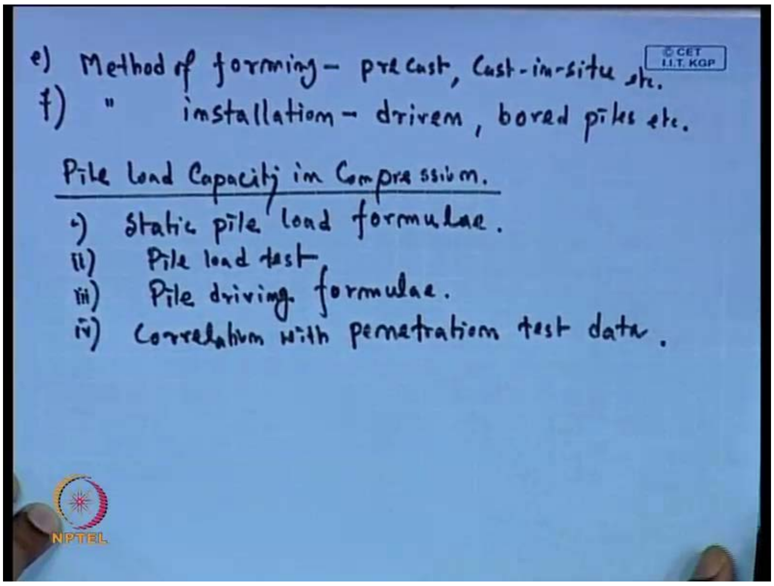

The next one by this e type that is based on the mode of method of formation forming that can be precast; that means, cast in situ and pist is also etcetera, and based on the method of installation that can be driven or bored piles etcetera. So, these are the different types of piles that I have explained. Now, next one is the for the timber piles that we are talking about this different types of pile suppose first when we go for the timber piles this timber piles is generally used up to say 30 meter long and which can carry a load from 100 to 250 kilo Newton per pile.

Now, steel piles these are the small displacement piles and used to carry a heavy loads and up to 40 meter of length and it can carry 1800 around kilo Newton per pile load. Under driven picas piles usually a driven picas concrete piles this is driven picas concrete pile. So, these piles are usually in a state of compression. So, now, this is or in cast in situ concrete piles these are the different types of piles are used.

Now, next one I will discuss about the different type of load bearing capacity, how to calculate the load bearing capacity of the pile or different piles? First we will go for the pile load carrying capacity in compression. So, the first we will. So, these are the different types of load carrying capacity one is compression one is tension another is lateral load carrying capacity.

So, first I will discuss about the compressive piles against the compressive load then later I will discuss the other cases also. So, this one first I will discuss this load carrying capacity of the pile. So, expression that we will use that is static pile load formulae formulae next one is the pile load test, by pile load test also we can calculate the pile load carrying capacity; third one the pile driven or driving formulae; next one is the correlation with penetration test data. So, these are the different method by which or we can determine the pile load capacity in under compression.

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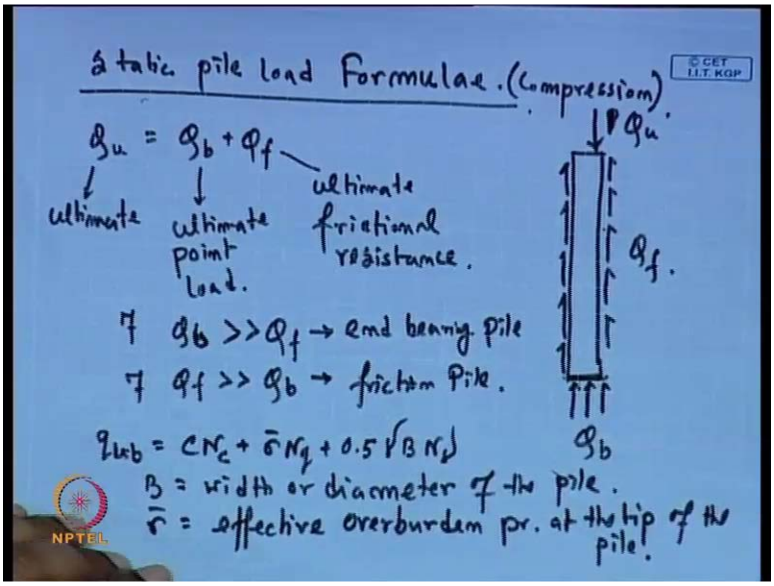

Now, first we will calculate the static load carrying capacity of the pile. So, by by the static load expressions these are we are talking about compressive load compression under or compressive load. Now, when we are talking about these if this is the pile, so as I have mentioned that we will get the resistance from here that is Q b and this is set of total load is acting and this is the friction resistance this is Q f. So, the ultimate load carrying capacity of the pile Q u that is equal to Q b plus Q f or here we can write in place of p this is Q u. So, ultimate load carrying capacity of the pile, so this Q u is summation of the Q f plus Q b where coming from the resistance from the tip or from the friction.

So, this is the ultimate load and this contribution from the ultimate frictional resistance and Q b is the ultimate point load. So, this is the total ultimate load is ultimate point load plus ultimate frictional resistance. So, here when we apply the load first this frictional resistance give the support when this and then the load bearing capacity of the end bearing that will be the. So, pulp friction resistance that will mobilized and then this is mobilized, then the next one next the end bearing capacity that will give the support when we apply the load then first is frictional resistance that will give the support then the end bearing will give the support.

Now, as we have mentioned that if Q u is much or Q b is much greater than Q f that pile is called end bearing pile and now if Q f is much much greater than Q b and this is called the friction pile. Now, here we will calculate the pile load carrying capacity. So, first we can write that Q u or Q u b; that means, the ultimate load carrying capacity of any foundation here we can say this is the ultimate stress of the base soil or the base of the pile; that means, the bearing resistance that we are getting from these two that expression you can write that C N c plus sigma bar N Q plus 0.5 gamma B N gamma. So, this is common as the shallow foundation bearing capacity expression. So, that same expression we are using here to determine this bearing end bearing capacity of the pile. So, this is the only the Q b part. So, that this is the stress carrying capacity or b is the width or diameter of the pile and sigma bar is effective overburden pressure at the tip of the pile.

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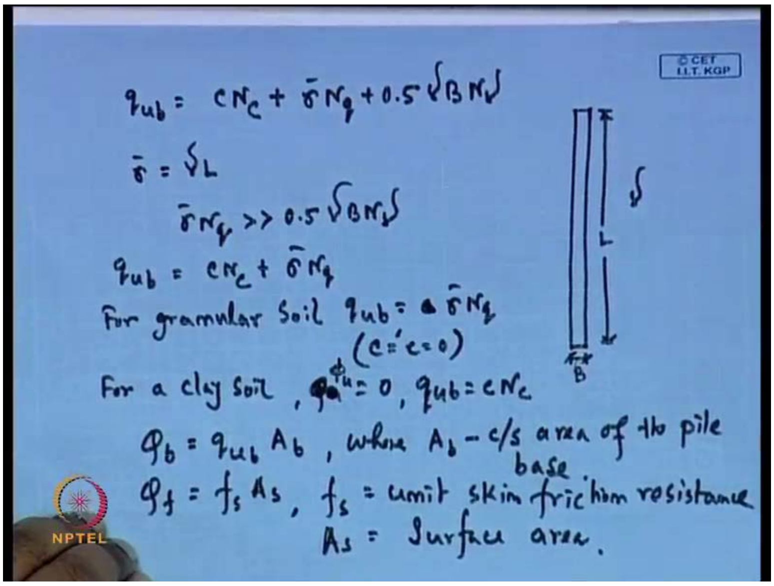

So, now we will calculate this expression suppose if we calculate the general expression that here we can write that Q u b that is equal to C N c plus sigma v is sigma bar N Q plus 0.5 gamma B N gamma where again this C N c N Q N gamma are the bearing capacity factor and gamma is the unit weight of the soil and c is the cohesion of the soil.

And now here we can see that suppose this is the pile we are talking about and this is the total length of the pile and this is the b or D of the diameter of the pile. So, the contribution we can see that here. So, the contribution sigma v we can write the sigma bar is gamma into L. So, this is if this is the gamma or unit weight of the soil at this region this is gamma and if I talking of the same soil so this is also gamma otherwise we can consider this is the layer soil at different layer intensity we have to consider.

Now this is our Q L and the contribution from here that means, this second contribution is the contribution that is we are getting because of this overburden pressure of the soil and the third one we are getting because of this only this region. So, that this contribution is very, very small compared to the contribution from this overburden pressure that means, the second part we can say that sigma bar N Q is much higher than the 0.5 gamma B into N gamma for the third part. So, we can write that Q u b is equal to C N c plus sigma bar N q, so neglecting the third part.

So, now for the granular soil we can write Q u b is equal to sigma bar N Q as for the granular soil purely sandy soil c c dash equal to c equal to 0. Now, for a clay soil a clay soil we can write that phi u is equal to 0. So, Q u b will be C N c where c is the coefficient. So, finally, when this is the phi u value phi u is zero.

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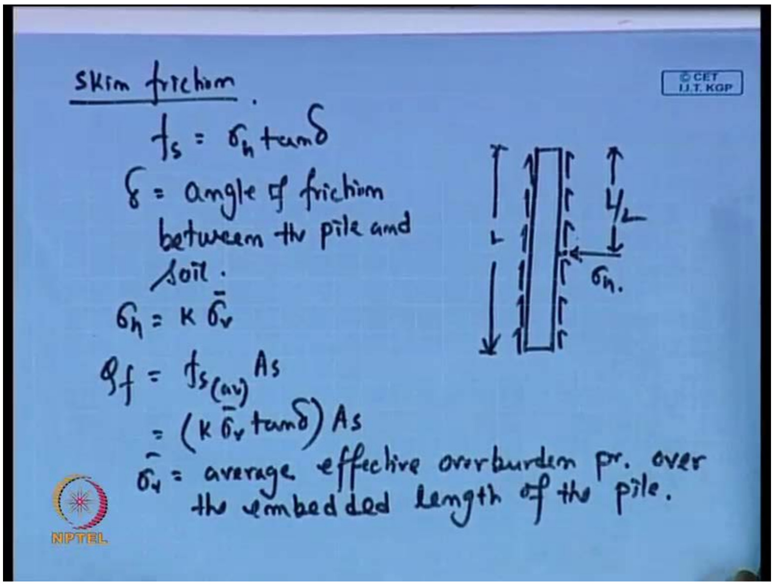

So, the u u b is C N c. So, when you calculate this total Q b that is equal to Q u b into A b where A b is the cross section area of the pile base. So, well Q f we will get that frictional resistance f s into A s where f s equal to unit in friction resistance and A s equal to surface area. So, now we will calculate the other parts, how to calculate this skin friction area. So, now we have to calculate. So, we know how to calculate the tip bearing resistance now we will go for the skin friction with the f s we can write this is sigma h into tan delta now what is sigma h. Suppose this is the pile that we are talking about and this is the resistance friction resistance is acting here. So, suppose this is the at the center point we are talking about sigma h that is the distance at L by 2 and this is the total length of the pile L and delta is the frictional angle between the soil and the pile that means, the frictional resistance that will be sigma h lateral force acting in this direction and the tan delta.

So, here delta is the angle of friction between the pile and soil and sigma h we can calculate that is k into sigma v. So, sigma v is the vertical load acting k is the coefficient of lateral earth pressure. So, the Q f we can write that is sigma s average into A s and sigma A is average it is we can write that is k into sigma v bar into tan delta into A s.

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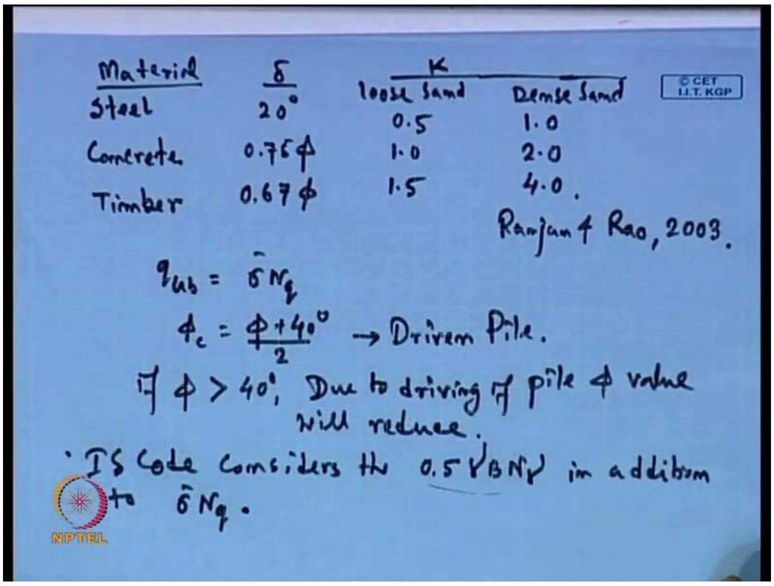

So, here sigma v bar is the average effective overburden pressure over the embedded length of the pile. So, here this sigma average is calculated at the center or the middle of the pile length so; that means, if the length is L we will calculate sigma h at the center. So, that is the average sigma v we will calculate and based on we will multiply this by k we will get the sigma h and then we multiplied the tan delta we will get the average friction resistance and then we have to multiply the total thing as the as the area of the surface area. So, then we will get the, this friction resistance of the soil.

Now, in the next one that how to get this k value for the different pile material suppose that the pile material if we consider the steel then then delta value this is suppose the material and this is the delta value that we are getting suppose this is 20 degree and the k value that we are getting therefore, the loose sand and this is for the dense sand this is 0.5 and this is 1; for the concrete this is 0.75 phi this is 1 this is 2; for timber that is 0.67 phi this is 1.5 this is 4. So, this is values we are taking from this Ranjan and Rao book this is 2003 this reference.

Now, one thing that we are talking about this pile in cohesion less soil or the granular soil so this frictional resistance we are calculating. So, this frictional resistance that we are calculating this is for the granular soil like sand or granular. So, this frictional is that you are calculating this friction you are getting that is basically for the sandy soil or granular soil. Here we will calculate this total sigma v into tan delta and then multiply this friction resistance we will get this value and this is the k value we will getting so if this we are talking about the granular soil sand there that is why we are talking about the loose sand and the dense sand and different material steel concreting, but here delta we will consider 20 if this concrete will consider 0.75 phi and for the timber we will consider 0.67 phi.

Now, the thing that when we are driving a pile into the soil and then we have to calculate this effective overburden pressure because here for the granular soil we use this calculation N Q and sigma bar or sigma bar that is the effective overburden pressure. So, N Q we will calculate from the table and this N Q bar this N Q we will calculate from the table that is few tables are available. So, that charts from this chart we will calculate the N Q and sigma bar we will calculate by the calculation.

So, when we calculate the sigma bar for the Q u b so that is sigma v N Q and then we will calculate this phi c is phi plus 40 degree plus 2. So, this is for the driven pile. So, if the granular soil, if the soil is phi less than 40 degree, so because of this driving of the pile the pile the soil will get compacted. So, that the phi value of the soil that will increase because of this driving of the pile in a loose type of pile so; that means, the average value or the phi value that will increase.

So, that is why we are taking this expression if this phi plus 40 degree plus 2 now if this phi is greater than 40 degree then the pile driving shell have the effect of reducing the angle now if the phi value is 40 degree greater than 40 degree and due to driving of a pile the phi value will reduce because of the dilatancy effect because there is the size 40 degree then is become a very dense type of soil now if there will apply the driving pile then the phi value reduce due to the dilatancy effect.

So, that is why here phi will calculate phi plus phi 0 plus 2 when you calculate this N Q this N Q there we will use this suppose if it is less than 40 degree phi value then instead of using that phi we will multiply we will add this phi with 40 degree and then we will take the average because here the actual pile will increase because of this driving of the pile in the loose soil and then based on that phi c we will calculate the N q.

But if the phi is greater than 40 degree then because of this dilatancy effect the pile may is phi value will reduce, but another thing here we are considering that Q b is equal to sigma v into N Q, but IS code IS code recommends that considers the 0.5 gamma B and N gamma in addition to sigma v N Q so; that means, here in IS code recommend that we have to consider this third part that we have neglected in the this expression in addition to this one. So, they will get the contribution from this one also.

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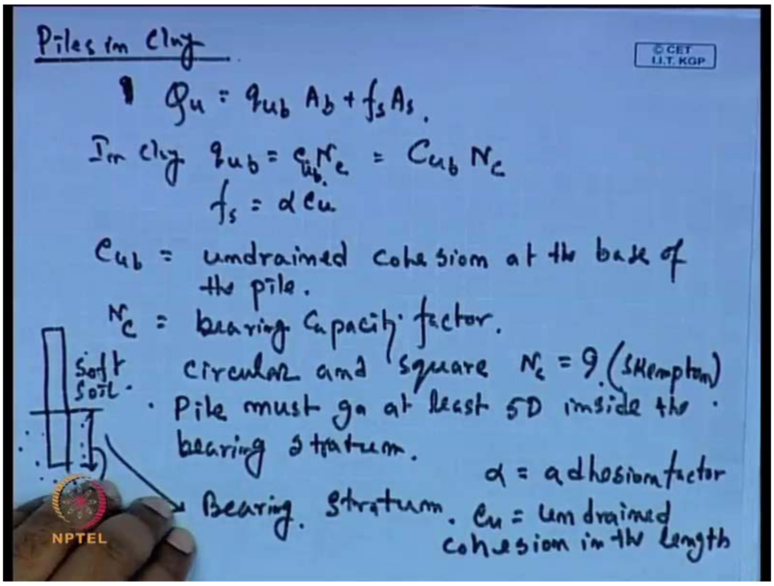

But actually this contribution is this is very less compared to this one we can neglect this one, but according to the IS code we have to consider this part also and we consider calculate this Q u b.

So, now now this is the pile for the friction granular type of soil. Now in the next one we will get the piles in clay. So, piles clay we will take this Q total Q ultimate load is again q u b into A b plus f s into A s same as. So, here in clay q u b at the c N c where considering and f s that we are taking that alpha into c u that is c u b and this is alpha into c u or we can write this is c u b into N c and this is alpha into c u where c u b is the undrained cohesion at the base of the pile and N c is the bearing capacity factor.

Now, for circular and square is N c is equal to 9 as proposed by the Skempton. So, here condition is that the pile must go at least 5 D inside the bearing stratum. Suppose if this is in bearing stratum and this is the pile so this is the bearing stratum here this distance that should be greater than 5 D. So, this is the soft stratum and this is the bearing stratum and this one is the bearing stratum. So, here we calculate this N c and we will get the Q u b and for the other part we calculate that alpha is equal to adhesion factor and c u is the average cohesion in the embedded length of the pile this is the undrained cohesion into the or through the length of the pile. So, this is the undrained cohesion into the embedded length of the pile. This way we can calculate the phi value now.

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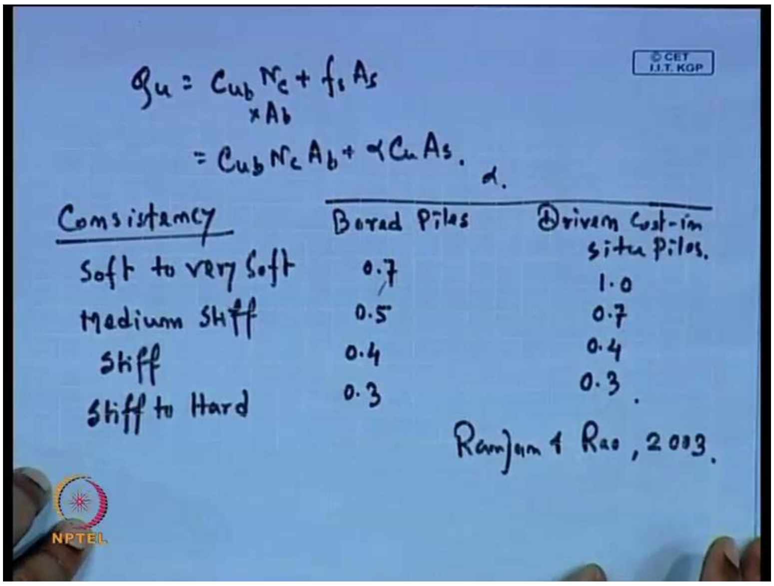

So, now, in the pile in the clay soil that we will get this expression, now here this is total this c u b into N c plus f s into A s this is into A b. So, the expression c u b into N c into A b plus f s is alpha into c u into A s. So, c u is the undrained cohesion throughout the length of the embedded pile, c u b is the cohesion at the base of the pile N c if it is circular and square we will get the 9, A b is the base area A s is the surface area. So, you all know this things, so in this alpha value we have to calculate this adhesion value we have to calculate.

Now, for different types of soil so suppose based on the consistency and we will get the alpha value, this is for the bored pile and driven pile. So, here as I have mentioned that the two types of piles one is bored piles and another is driven piles. So, this driven piles is cost in situ driven piles or this can be precast driven piles also and this is another one is the bored piles and now here different types of pile this is the soft soil soft to very soft for the bored piles this alpha value is 0.7 we can take and for the driven cost in situ piles it is 1.

For medium stiff this value both pile value we can take 0.5 and this is 0.7, for very stiff soil we consider this is 0.4 and this is also 0.4, must stiff to hard consider this is 0.3 this is also 0.3. So, this values also is taken. So, these are the value alpha value for the adhesion factor value we will get for different types of piles from this table.

Now, in this section I have discussed about the different types of the piles that we are getting for and how to calculate the bearing capacity of the pile. So, there we are talking about the single piles now actually in the field the piles are used as a group. So, now we have to calculate the group efficiency or group calculation of the piles because these are the piles I have discussed this is the load carrying capacity of the single pile it is not a group pile. So, load carrying capacity of the single piles in cohesive soil or cohesion less soil. So, then this is the resistance that we are getting that is from the base and from the friction then how to calculate the friction resistance for the cohesive soil and the granular soil then how to calculate the end bearing capacity for the cohesive soil and the granular soil those things I have discussed for this all things for the single pile.

But actually when you use these piles in a group, so then we have to calculate the group load carrying capacity of the piles. Now the condition is this, this piles depending upon the spacing in the group I this piles can be either fill individually if spacing is very high if the spacing is more or it will fill like a block as a group if the spacing is very small

And then so that means, we have to check whether these things fill as a block as a group or as a individual. So, both things we have to check and then the minimum one we have to provide as the group carrying capacity of the pile and the depending upon the spacing the efficiency of the pile that will I will we can calculate the efficiency of the piles. So, whether how much efficiency we will get, if we use a single pile in a group. How much efficiency we will increase the efficiency of the piles or it will decrease that thing you can also calculate.

So, those things I will discuss in the next class how to calculate the load bearing capacity of the pile in a group, and then I will discuss about the pile load test, because here the static expression that we are using to calculate the load bearing capacity of the this time will single pile next class we will discuss about the group piles. Then we will discuss of the next method then by the pile load test, how we will calculate the ultimate load carrying capacity of the piles, and then we will discuss the other methods also.

So, thank you.