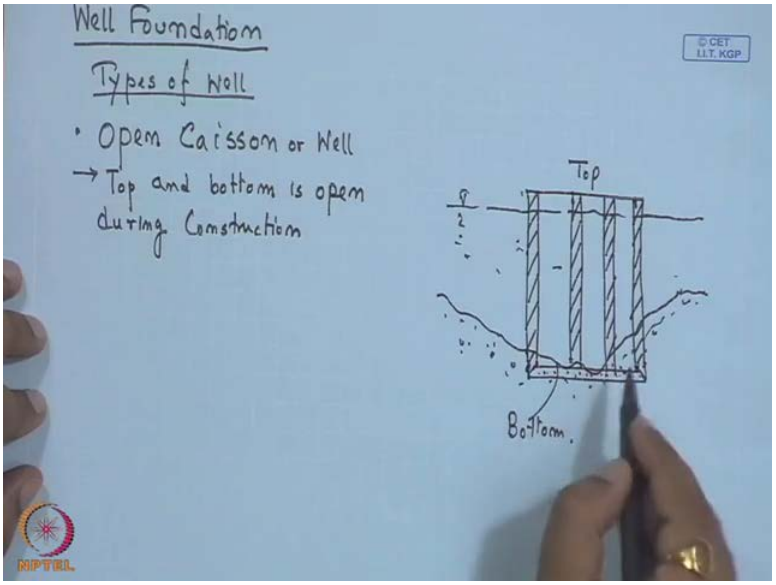
Advanced Foundation Engineering
Prof. Kousik Deb
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture - 21
Well Foundation

So, last class I have discussed about the tension pile and the pile subjected to lateral loads now, when the structure which heavily loaded then we have to go for another type of de-foundation that is called foundation. So, that is useful for heavily loaded structural line bridge foundation where we generally use this well foundation. So, today's class I will discuss about various components of well foundation and then how to determine the depth of well foundation. So, now, first what are the different types of well foundation? As I mentioned that this is used for, for heavily loaded structures so and then what are the different types of well foundation? So, depending upon that construction methodology they are the different types of type of well foundation. So, first will go so, for that is well foundation.

(Refer Slide Time: 01:16)



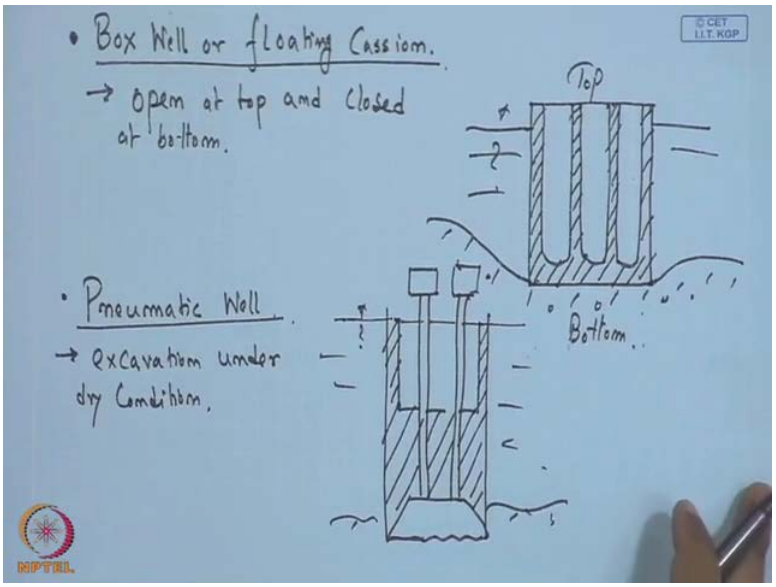
The first types of well; now, first type that is called open caisson or open well. Now, in this type that this is existing mid-level below in a river now here is shown is the water level. So, this is water level this is the existing these of the water body or the river. And then open well the top and bottom is open during construction so that means here opal open well is allowed to sink into the water this is another. And then this portion is filled

with concrete so that shown it is the open type of well that here top. And bottom portion is open during construction that mean during construction this top portion this is the top and this is the bottom portion. So, these two portion open during construction. And then this can be circular type and this can be rectangular type also and the possess of sinking is continue till reach the required depths. So, that means these possess when it is sink, sink into the water.

So, it is continue till the required depth is reach now once the required depth is reached then the bottom portion is sealed with concrete. So, this one required depth is reached is bottom portion is sealed with concrete. And then the shipped this is over the portion in a sapped which are filled with sand now once that means during the construction this top portion. And the bottom portion are open once the it is reach at the ground surface or the required depth. The bottom portion is sealed with concrete and the shaft is filled with sand. Now, advantage of these type of open well, well that the, it can become stuck trade of up to inhale depth the, of the up to the required depth and with a credibly low-cost condition.

So and the limitation or disadvantage of this open well is the, if the bolded deposit is there. If the, this ground surface or this bottom of the water body is there well bolded deposit represent. Then it is maybe difficult to in possess or progress the construction of this type of well. And then very slow at may this if deposit this is very slow construction and a concrete sealed is done under the water. So, that means one it is reached in the bottom then the concrete sealing is done under the water which is not very effective. And that is the advantage and the disadvantage of this open well or open caisson. So, next type of the well is that is called box well of floating caisson.

(Refer Slide Time: 06:15)



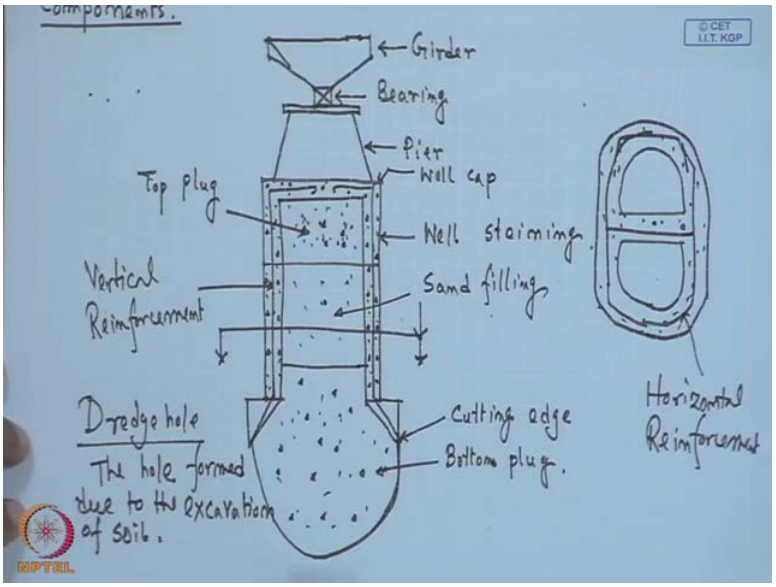
So, this is second type of well foundation so here again if this is water surface and this is the well and this is the ground of the water body; this is top bottom. So, in case of first case with the top and bottom both are remain open during the construction, but in this type of well top is open but the bottom is close during construction. So, this is the closed bottom and this is the open top so that means this type of well the top open at top and closed at bottom. So, this is cast in land so that means before this is this is as it is closed. So, during the first case the bottom was sealed after it is reached up to the desired depth. So, that means the casting was done under the water which was non so effective for the first case top well. But in case of bottom box well floating caisson the construction cost is done in the land because as this is the sealed or the bottom is closed condition.

And can be used when land is not very, that means this can be used when the load is not very heavy. And we are in strata is up to a shallow depth that means a up to shallow depth. This can be done and the advantage of this type of well is that that foundation when has to be prepared before and so that advantage this advantage then this is the construction is done in the land. So, it is effective and the disadvantage is the before the it is placed into the ground. The land has to be prepared so and the bearing capacity of the base has to be properly calculated so that otherwise it, it is be difficult to construct this type of well into the soil. So, that means when we calculate the this prepare the and then the calculate the bearing capacity all this case factor. Then the, this covering on the foundation action has to be a a incorporated during the calculation.

So, next type of well that is first one is the open caisson then the box well and the second one is the pneumatic well. So, this pneumatic well is another type of well foundation so, that is in this is water surface and this is ground surface. So, this is constructed in an dry condition so in this well the, this is and excavation is done under the dry condition. The when once the tip required depth is achieve the working chamber is filled with the concrete and the advantage of this type of well that the better control during the sinking. And the suspension can be done the bottom of the chamber can be sealed effectively with concrete under dry condition. So, that means is here the first case the concrete bottom of the concrete was sealed under the below the water so which is not so effective. But here the concrete heating is done the bottom of the concrete it is sealed under the dry condition which is so effective. And the disadvantage is the, the cost of this type of well is very high. And the limit of the depth of the penetration below the well is around the 30 to 35 meter.

So, that means if we compare the 3 type of well that the first one is a top well where the concrete is done below the water the width condition which is not so effective. And the second one is concrete is done costing is done in land, but the second one which is applicable if the bearing strata is, are the shallow depth. And during so and the bearing capacity calculation has to be properly done. And the third one is it is also done up to the required depth, but the advantage is that the concreting is done under dry condition which is very effective and the disadvantage. And all the advantages explain for the different types of this well in the first case a cost is not high, but concrete is being done in well width condition in the last case it is so high cost is high. So, these are the limitation and the advantages of different types of well and depending upon the cost of the project and the type of the land or the, the base condition. And we have to use the different types of well foundation now next part is that the components of the well foundation. So, what are the different types of components of the well foundation?

(Refer Slide Time: 14:16)



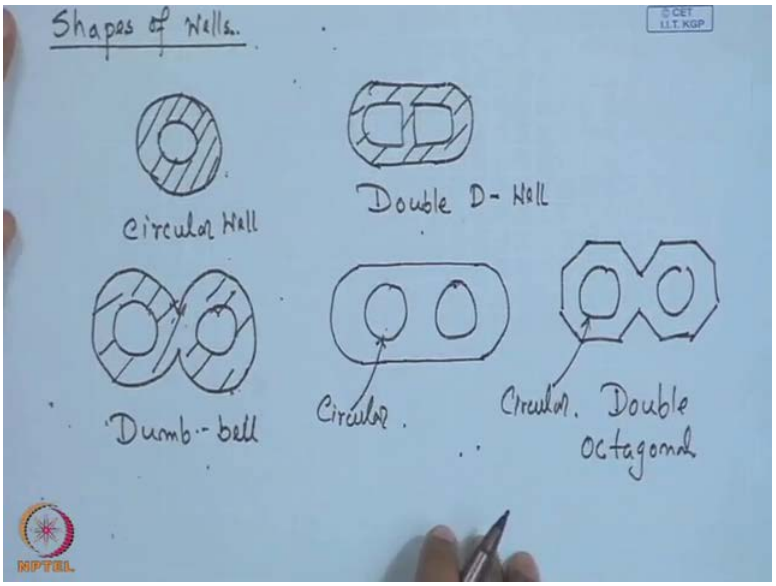
So, first for the different types of component has to be if we draw. The first this is the pile or that above that pile will we have to place this in order that is the, that is placed above of bearing. So, this one is the girder this one is the bearing. So, first this is bridge girder then this is bearing then which is placed in a pier this is top portion then this is pier. Then this various components of this well that will start then this is our different components. And this is what we called in first meant of the pier this portion is it is a concrete in this shown is the bottom plug. So, when this is the top plug where again the concrete in is done sealed with top plug in this is the bottom plug and here this is sand fielding.

Now, these are the various components of the pier. So, these are this is the well so, this is pier then this one is called as the top plug then this one is bottom plug. Then this is cutting edge and this is sand fielding then this one is well cap then this is the body of the well main body of the well that will well staining. Now, these are the various components of the well and now the pier which was the section of the same well. Then we can draw like this these are the horizontal; this is vertical reinforcement; this is horizontal reinforcement so these are the various components. So, now the purpose of this various type of components so in this top filling the, this provides context between the well cap and the sand filling. And this helps to transfer the load which is coming from this structure to the sand filling. So, from here pier caps it will transfer the load from pile to the sand filling that is the purpose of these top plug.

Now, the well cap which is made up R R C slab so that is a cast with the staining. And the well staining that is the main body of this well and the bottom plug after the well is sync up to the desired level. Then in the, this is plugged with concrete and this concrete is done for this different types of well it is done in different condition. Now, this is the cutting edge the purpose of this cutting edge is so cuts the soil during the sinking now and this the various components of this well and the purpose of this components are expects. Now, secondly that during the construction of the excavation of the hole the, a dredge hole is formed. Now, the definition of this dredge hole is that is that this is the hole form during the excavation of the soil and which is filled with sand later on.

So, that means during the excavation this hole is form and this hole is called the dredge hole which is filled sand later on. So, that means this is the definition of this one is the hole which is form due to the excavation of soil during the construction. So, later on it is filled with sand so these are the various components. So, this is the section and these are the horizontal reinforcement and this is the vertical reinforcement which is shown here. So, next part is that, what are the various type of shape of the well? So, now, the different types of the well that I have been explained then the components of the well in other shape of the well.

(Refer Slide Time: 23:20)



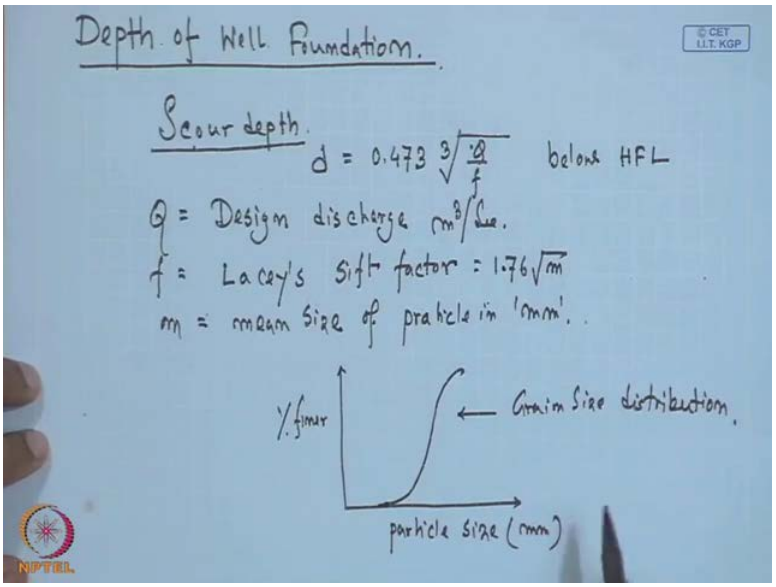
Now, first that one is call the circular shape of the shape of the well or circular well. So, this is type of well that is circular well. So, next one well can be in this form. So, this is

double D well now will can be in this form also, this is dumb bell dumb well form of well now will can be in this form also where this is the circular dredge whole. Now, it can be in this form also these are the circular dredge hole and this is octagonal shape. So, this is also circular dredge hole and this is octagonal or double octagonal shape. So, these are the variation in shape of the well. So, depending upon the recumbent we have to go for different types of well now the when we construct well you have to deep in mind that the staining thickness should be sufficient. So, that it can be easily sink into the well and then the dredge hole should be large enough to permit the dredging.

So, when another condition is the when you construct the dredge hole that should be large enough and the base of the structure should be sufficiently stable and the size is sufficient to transfers the load. So, these conditions we have to taken care when we construct the well. So, next one that will go for that how we have, we have to calculate the depth of the well now this if you summarize the other parts then, then you are different types of well foundation. And this types are in the open well then the box type of well. And in the third one is the pneumatic well so when you construct this type of well foundation. So, you have 2 very careful then this, the base the base that you have to construct there should be sufficiently rigid. And then that should sufficiently transfer the load from the superstructures to the foundation soil.

And then depending upon the different types of well then you have 2 construct the, for various different form and various purpose. And when these other weights various components that will also be designed during the construction of the well the next we have 2, determine the, what would be the required depth of the well foundation? And how we calculate the depth of the well foundation because the well foundation when you construct in a, for a river way. Then you have 2 very careful for the scoring effect because that will play a very important role. Then what would be the grip plane below the foundation, below the score level than what with the minimum thickness of the, of the minimum depth of the foundation that you have to be very carefully design now, the next part that is the depth of the foundation.

(Refer Slide Time: 28:48)



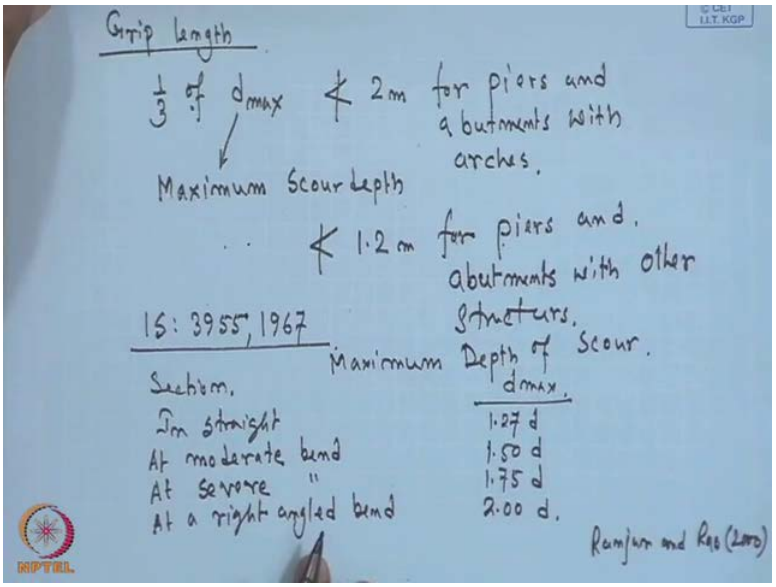
So, in any construct the depth of the foundation as I mentioned the scoring depth in a play very important role. So, that then this scour depth, how we calculate this scour depth? Because this scour depth means that during this flow of the water some soil will be taken out by the flow. Then you have the, consider this covering during our design. So, this scour depth you can calculate that d is scour depth is equal to 0.473 root 3 q y f know where the the, this is b; this scour depth is below H F L l I high flag level. Now, here q is equal to design discharge that is meter cube per second and f is called as lacey's sift factor that is 1.76 root to the power m where m is equal to mean size of particles in mille meter now this when. So, how will calculate the design discharge? So design discharge will calculate so, that is given parameters so that you have to first determine over from the P V S history of the site that is you have to give input to calculate the scour depth.

So, that maximum discharge oh maximum design discharge that you have to consider. And then this is less sealed function you will calculate then how will calculate the m? So, that means the particle size of that area so that means soil you have to collect the soil sample for the required depth. And then form this soil sample you have to go for particle distribution analysis. So, that you can soil distribution analysis that depending upon which type of soil it is soil will go for the analysis or have to go for the analysis. So, we have the gain stain distribution curves so once you have the gain stain distribution scour then form that gain stain distribution scour we can determine. What would be the n value

that once you get that gain size distribution curve than we have the gain size distribution. So, that means here if I draw the gain size distribution scour.

So, this is the particle size which is mille meter so that is in the large scale and this is the person y fimer. So, we have this type of curve will get so that is the gain size distribution curve and form this gain size distribution curve. We have calculate the mean size of particles in what is the mean size of this particle and we can take weighted average of this particle size. So, there will be basically particle size and from there we calculate what is the, of the particle size of these that area? And from that particular size that will be use as the n value. And then form using that n value we can calculate what could be the field factor f? So, this, these design picture as a input f we can calculate this on the particular distribution curve or that we have to done by in the particular distribution analysis. And from that is we can determine the m value and then from that m value will determine the f and from there he will get the scour depth scour depth is the required. Now, once we get the scour depth then another line that is the required is that.

(Refer Slide Time: 33:48)



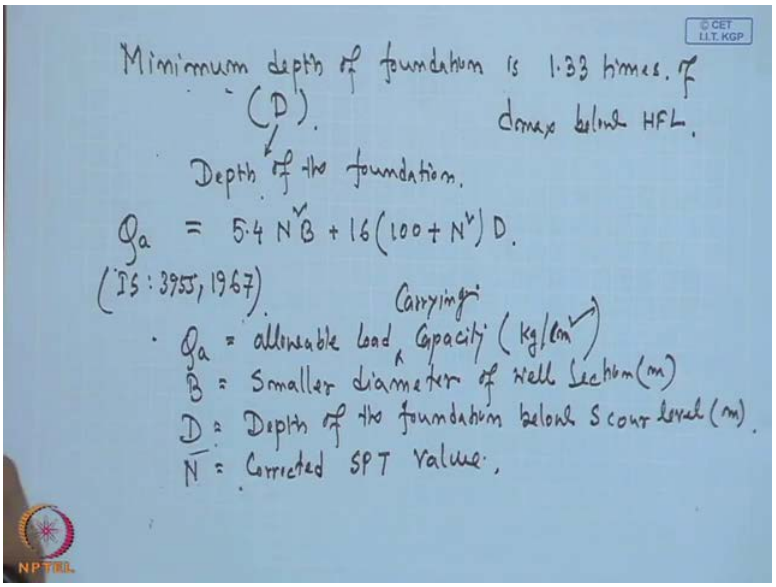
The grip length and now grip length is generally given by one third of d max, d max means maximum scour depth. Now, could into the highest score that, that this d max should not be less than 2 meter for piers and abutment with arches? Or I mean this grip plane that should not be less than 2 meter for piers and abutments with arches. And that should not be less than 1.2 meter for and abutment with other structures. Now, this d max

is the maximum scour depth were what will be the maximum score depth that high score also recommends some values. That means that the grip line that we have to provide additional that is one third of the d max. Now for the d max I score that I s 3955, 1967 that recommends some maximum scour depth of the scour value. And that depends on the different types of the section of the river in straight section that this maximum d max is given the 1.27 of d. So d given that is the scour depth that we have calculate and this is d max.

Similarly, for a moderate bend is values given by the 1.5 d. So, first severe bend this is 1.75 d for right angle bend that is given 2 d. So, depending upon the C P C state section then this will be. So, that the source that is taking is Ranjan and Rao 2000 book. So, now in the state portion if the section state then we have to provide d max value is 1.27 d and the for the moderate bend we have to provide d max is 0.5 d and for severe bend so that which 1.75 d and right angle bend 2 d. So, depending upon the section of the rivyar how much t you have to consider? So, that we can calculate so from this one, we can calculate that the d max. And then we have 2 d we have to collect the scour depth and the seal factor does mentioned. So, for depending once we can one process we can determine the f value from the laboratory test.

So, what would be the f value that we can determine from the laboratory test as I explain? Then distribution analysis you can determine the f value where you can determine the n value. And from that m you can determine the f value another option that for different tables available tables are available for different types of soil, what would be the f value? So, that we can also use at better is we can test the soil from that the area from the sight. And from that testing data, we can determine the, what would be the m value, based on that we can determine the f value. So, f value we can determine and from there we can determine d value and from this difference type of section we can determine the d max value. And then d max is generally various 1.27 times to 1.2.75. And then from there we can determine the grip line that the grip plane will be one third of the d max now, what is the minimum depth of the foundation? So, that it is recommend again highest recommend that when the minimum.

(Refer Slide Time: 39:39)



Depth of foundation is 1.33 times of d max below H F L. So, once we have the d maximum, what will be the mix minimum depths of the foundation that we have to add with the foundation with the depth of the foundation? So, that means the minimum depth of the foundation will be has one third is a grip line. So, that will be a 1.33 times of d max so below the high flag level. So, once we get the d max or depth of the foundation so depth in a minimum depth of the foundation is the D so that is or depth of the foundation. So, this is D is the depth of the foundation of the well then at depth, what would be the load carrying allowable load carrying capacity of the soil? So, for these highest 3955, 1976 they proposed that this will be the depth of the foundation. So, that is at 5.4 N squares B plus 1600 plus N squire into D so by which we can determine, what is the allowable load carrying capacity of the soil at depth of the foundation D? Now wave this Q a is the allowable load carrying capacity so which is given in kg per meters kg per meter square; this is kg per meter squire. And then the B is given that the smallest diameter of the well meter of well section in meters. And D is the depth of the foundation, foundation below scour level so that is in meter an here a in is corrected S P T value.

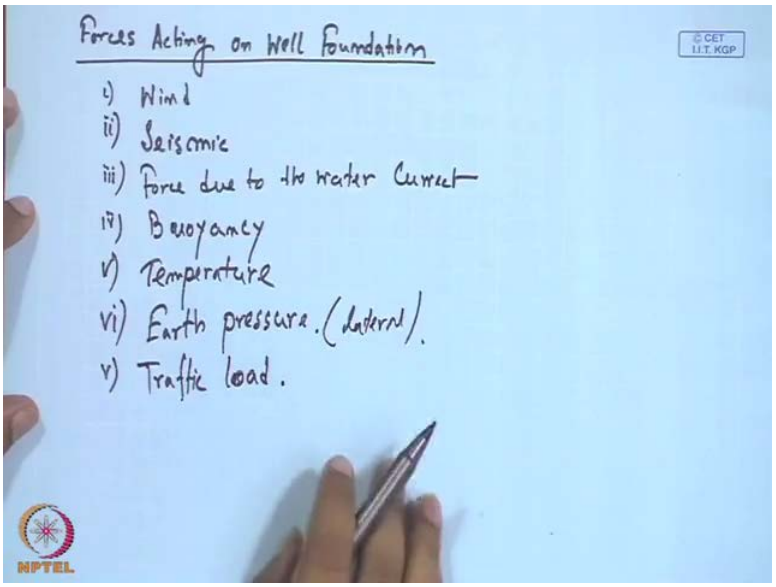
So, if I know that this b section and this n is the collected s p t value. And then we can determine, what would be the allowable load carrying capacity of the soil at the depth d below the scour level? Now and then we can use that whether the load which is coming on the soil is greater than q a or not. And then apply and then we have to apply the factor

allowable safety and then you have to check whether the load which is coming on the soil which is greater than of this load or not. Then if it is greater than you have to again redesigned this thing for the for that particular soil and that date. So, and this way we can determining what would be the depth of the foundation? We can determine the required depth of the well foundation. And at depth what would be the bearing capacity of the soil?

And then we have to check during the design, this b n capacity of the soil is good enough to resist the load which is coming from the structure and then now. So again, mentioned that you have to design these components very accurately because we have some different components of the well foundation. And then when we are constructing the well foundation there should be a lateral load which is coming from the in terms of water pressures for that means these things you have to consider during the design. Because this q way that I mentioned that is a bearing capacity, but when you design the total well foundation then you have to design some other components of load. That is the water pressure will come that may act during the like of this well so that in that state load.

Then the, those load, load that will come during the construction; during the lifetime of this well so that means you have to consider all these things during the design of the well. So that means this only the bearing capacity calculation that is not enough to design proper different components of the well. So that is the bearing capacity that will give whether fine this load which is coming on the soil which is capable this soil can take that load or not at that depth. So and depending upon the site conditions we have 2 then increase the load if it is not sufficient increase the depth of the well if the it is not sufficient to carry that load at that required depth. Now, the forces of different forces that is acting on that acting on the well foundations so that difference forces if all.

(Refer Slide Time: 46:05)

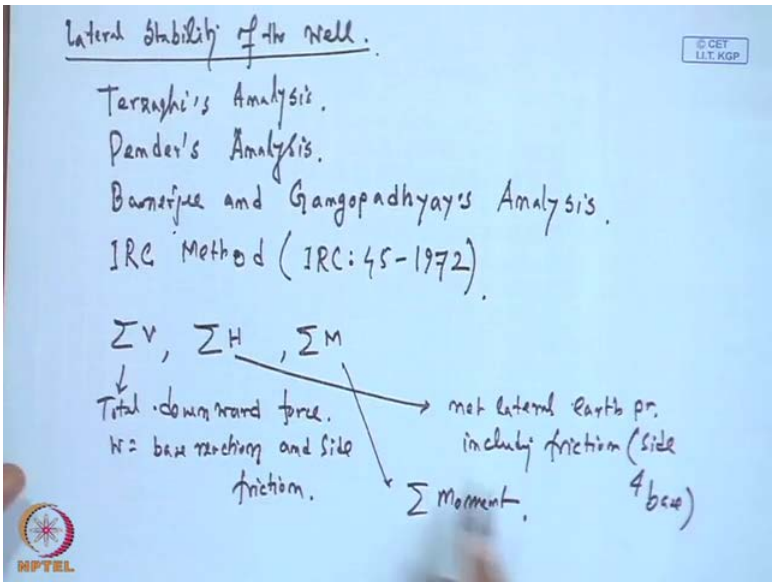


So, this forces includes that the wind force that act on the well foundation wind forces then the seismic force. Then forces due to the water current, current then the forces due to the buoyancy then force due to the temperature variation in the next, the force due to the earth pressure. So, these are the force is generally acting in well foundation and definitely the traffic force load that is acting on the well foundation in, in additional to that is it is in the. Then the 7 centrifugal force will also act into the well foundation. So, when you design this well foundation you have to consider all this forces which are acting on the well foundation during design. And this lateral earth pressure this earth pressure is basically the lateral earth pressure which is acting on the well foundation due to the soil surrounded by the well.

Now, when this all combination of force we have to apply and then based on then we can calculate what would be the net horizontal force that is acting on the well? What is the moment that is acting on the base of the well? Then what is the vertical or downward force that is acting on the well including the sellpite of the well? So, these force is we have to, to be considered during the design of a well foundation. Now, in discuss have also discuss about the dimension part then the depth part. And now this forces you have to consider during the design and now the design methodology that are available. So, that is basically there are few methods that is available. One is Terzequi method. So, another is first method for the design when we are talking about the design of a well foundation. Then we have talking about the, a lateral stability of the well so what how we can check

whether the well is stable and the lateral force or the combination of force or a force of moment whether there well is stable or not so, this lateral stability of this well.

(Refer Slide Time: 49:29)



Well we have to check whether this well is stable or not. Now, the different analysis are available that is for the Terzequi analysis. Then the Pender's analysis then Benerjee and Gangopadhyay's analysis and I R C also echomin one design or lateral stability check methodology and that is I R C 45, 1972. So, the by using these methods we can check whether the well which is laterally stable or not. And that among this methodology discussed about this I R C method and that will be discuss in the next class. Then how we can check the lateral stability of the well? How we can check then because this lateral stability are basically formed moment that is coming. So, that means the registry moment that should be greater than the moment which is acting on the well, base of the well. And an another check that the bearing capacity check that means the load which is acting or the stress which is acting on the soil, soil should will to carry that stress. So, that is the, we have to check whether that moment which is applied in the well that should be a counterbalance by the well foundation.

So, that means that is one check moment, check another one the that soil pressure that is sufficient the, the soil pressure which is coming on the soil so that is soil is sufficient to carry that load. And then we have to check another condition the way of horizontal force which is acting. So, that means the, that should be a counterbalance or resisting force we

have to that is sufficient to counterbalance that horizontal force. That means have to check whether horizontal force which is horizontal force checking how to check for the moment which is acting. And have check whether soil pressure acting on the base of the soil which is sufficient or not. So, when we design or we check all this things then after this checking of this well foundation you can say now this dimension we can provide for this particular conditions.

So, first we have to consider this load or combination of loads. And then based on that we consider what the net horizontal pressure our force, what is the moment net moment acting on the base of the well? And then based on that we have to consider the, what is the vertical force that is acting on the well? So, vertical force horizontal force and then the moment that is acting on the base those we have to calculate. And then we have to check whether this things soil can able to take thus vertical stress acting on the soil that is able to take on oil is able to take or not certain. That means the check that is we have to consider that for this purpose that what are the check that is the first check is if the summation of the vertical force. And the next one is summation of the horizontal force and the next one summation of the moment.

So, we have to check all these 3 things that means that this; this is the total down word or force that is including the base reaction and side friction. Then W H is the net lateral earth pressure including section that can be a side and base and net one in the summation of the moment including the lateral earth pressure and the friction side and the base. So, these are the force or that the 3 equilibrium condition sigma V vertical force summation of the horizontal force. And the summation of the moment that you have to check and according to that you have to check whether the well can a resist these horizontal force. And the soil can resist this vertical force or the stress which acting on the soil and the moment which is acting on the well.